ABSTRACT

Title of Document: INTERNATIONAL COOPERATION IN CLIMATE MONITORING VIA SATELLITE: INCENTIVES AND BARRIERS TO DATA SHARING

Mariel Michelle John Borowitz, Ph.D., 2013

Directed By: Professor John Steinbruner, School of Public Policy

Understanding and addressing climate change requires the collection of a significant amount of environmental data. Although satellites can best collect much of this data, it is not possible for one nation to collect all relevant climate data on its own, and there are currently gaps in relevant satellite data collection. Further, much of the data that is collected is not shared freely, but instead has barriers to access that limit its use for both scientific research and operational purposes. This research examined the development of data sharing policies to identify the barriers and incentives to international sharing of climate data collected by satellites. Quantitative analysis of satellite data-sharing policies for Earth observation data as well as case studies of domestic agencies in the U.S., Europe, and Japan, showed that limitations in data sharing are due to 1) a belief that data can efficiently be treated as a commodity, a viewpoint which conflicts with experience for nearly all climate data; 2) the lack of recognition of the normative justification for sharing climate data, though this norm

exists for weather data; and 3) insufficient agreement that international cooperation and data sharing are required to adequately monitor climate change. These limitations exist due to uncertainties about the nature of the market for climate data, the inadequate understanding of climate impacts and the ability to mitigate them, and an inadequate understanding of the requirements of climate science and operational activities. To address this situation, countries should adopt free and open policies, recognizing that social benefit is maximized when data is treated as a public good and freely shared, and that cost recovery and commercialization of scientific satellite data are not viable. Countries should also share climate data internationally because it has the potential to save lives and property, creating a moral requirement for sharing. Finally, countries should agree on a minimal set of climate data that must be shared to adequately monitor climate. This agreement should be institutionalized by World Meteorological Organization (WMO) resolution framework, similar to WMO Resolution 40, which addressed weather data sharing.

INTERNATIONAL COOPERATION IN CLIMATE MONITORING VIA SATELLITE: INCENTIVES AND BARRIERS TO DATA SHARING

By

Mariel Michelle John Borowitz

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Advisory Committee:
Professor John Steinbruner, Chair
Professor Nancy Gallagher
Professor Nathan Hultman
Professor Virginia Haufler
Dr. Colleen Hartman

Preface

I came to the topic of climate monitoring using satellites based on my previous experience in space policy and aerospace engineering. At the University of Maryland, I began working with the Center for International Security Studies. Individuals within this organization were focused primarily on traditional space security issues, such as dealing with space debris, but they were also interested in the security implications of climate change. I wasn't aware of much research being done in the area of satellites and climate change, so I began investigating the topic. In my initial background research, I found a significant amount of literature about the importance of satellite data sharing and efforts to encourage sharing, and I also found information about data not being shared. However, I discovered that there was a lack of information explaining how or why nations determine their data sharing policies, so I decided to focus my research on understanding this issue and filling this gap.

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There are many people who lent me their time and expertise in developing this dissertation, and I would like to recognize them here. I would like to thank my advisors and committee members who provided feedback and advice throughout the research and writing process. I would also like to thank all of those individuals that agreed to sit down for an interview; without the generous contribution of time and thought from these individuals, this work would not have been possible. Finally, I'd like to thank my family, particularly my husband, Jeff, for their support.

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Chapter 1: Introduction

Climate change is an important and complex phenomenon, and understanding and addressing it requires a great deal of data, including data related to many different variables collected over long time periods and large geographic areas. Satellites are particularly well suited to climate data collection because of their comprehensive global coverage and consistent methodology. International organizations have defined a set of essential climate variables that are largely dependent on satellites. However, a significant portion of this data is not being collected by any nation, and in many cases, even the data that is collected is restricted rather than freely shared, further diminishing the global capability to understand and address climate change. These limitations on data sharing exist despite the benefits of sharing data and the efforts of a number of international organizations over the past 30 years or more. In order to understand why this is the case, it's necessary to understand the most important incentives for and barriers to data sharing, i.e. which issues are most important to policy-makers developing data sharing policies?

To begin to answer this question, it is necessary to have an understanding of climate science and how satellites contribute to this field, as well as a clear understanding of the current state of climate-relevant satellite data collection and sharing. A detailed examination of existing theories and academic literature related to data sharing is used to define the breadth of potential data sharing policy determinants. Next, quantitative and qualitative analyses are brought to bear in providing insight into which of these theoretical arguments are most important in actual policy development. Finally, this analysis reveals that there are three primary determinants of data sharing policy: economic arguments, particularly whether data is seen as a public good or a commodity; normative arguments about the role of the government; and institutional arguments about the global nature of climate change and climate monitoring. However, uncertainty and lack of information about the economic, normative, and scientific costs and benefits of sharing climate-relevant data have made it difficult for nations to determine which policies are in their national interest, and have led to differing policies over time. Though experience has provided more information about these issues, leading many nations to increase data sharing, uncertainties in these three areas remain the largest barriers to data sharing.

The Need for Climate Data Collected by Satellites

The Intergovernmental Panel on Climate Change (IPCC), a body formed under UN auspices to provide an integrated, consensus-based view of climate change, stated in its 2007 Assessment Report, "warming of the climate system is unequivocal."[1] It based this statement on direct observations, including increases in global temperature in the air and ocean, increasing snow and ice melt, and rising sea levels. However, there is much that is still uncertain. For example, in the same report, the IPCC notes that fully determining the cause of climate change is complicated by short time scales and limited spatial coverage of current studies.[2] The National Aeronautics and Space

[1] *IPCC Fourth Assessment Report: Climate Change 2007: Synthesis Report Summary for Policymakers*. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html>.
[2] *IPCC Fourth Assessment Report: Climate Change 2007: Synthesis Report Summary for Policymakers*. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html>.

Administration (NASA) also identified a number of unresolved questions within climate science that require additional data and information. For example, the sun goes through an 11-year cycle, but data on this cycle has only been directly observed for about 30 years, and longer timescales are necessary to fully understand long-term changes. Similarly, aerosols, tiny particles in the atmosphere, have the potential to produce both warming and cooling effects on the climate system, depending on a number of specific characteristics of the particles and their location. More accurate observations of this phenomenon over time are important for fully understanding its role in climate change.[3]

Current understanding of the characteristics and dynamics of the climate system, as well as focused research on particular determinants of climate change, rely on a wide variety of observational data. Climate models are developed to take into account atmospheric, oceanic, and land-based aspects of the climate system, as well as interactions among these systems. These models are essential for providing insight into the causes of changes in the climate as well projecting future climate change, and they require a large number of long-duration, accurate measurements. Climate change has the potential to cause significant loss of life and property due to effects such as rising sea levels and increased floods, droughts, and severe weather. Building on studies of the climate system and model projections, other research and programs focus on identifying these climate impacts and developing mitigation and adaptation plans. These researchers also require high quality observational data.

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[3] "Uncertainties: Unresolved Questions about Earth's Climate." *Global Climate Change*. NASA, n.d. Web. 19 Mar. 2013. <http://climate.nasa.gov/uncertainties>.

Increasing the understanding of climate change processes, as well as the ability to forecast, mitigate, and adapt to future changes in climate, depend on a robust set of data. In response to a request from the IPCC, the Global Climate Observing System (GCOS) program defined a set of fifty "essential climate variables" that are required to support the work of the IPCC. This list of variables includes each aspect of the climate system, including the land, earth, and oceans.[4] In addition to collecting a large number of different variables, observations must also be made as comprehensively as possible on a global level with a degree of accuracy adequate to distinguish long-term climatic changes from short-term variability. Continuity of these measurements over long timescales of decades or more is also necessary in order to adequately address climate change.

Recognizing the growing importance of satellites in climate monitoring, GCOS released a supplemental report listing approximately twenty-five essential climate variables largely dependent on satellites.[5] Satellites provide the only way to directly measure solar irradiation, which is critical to understanding the Earth's energy balance, a fundamental area of climate science. Satellites' global coverage and unique vantage point allows them to collect data over the oceans, Arctic and Antarctic areas, and sparsely populated zones more comprehensively than can be achieved with any

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4 *The Second Report on the Adequacy of the Global Climate Observing Systems for Climate in Support of the UNFCCC. Rep. no. GCOS-82. Global Climate Observing System, Apr. 2003. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-82_2AR.pdf>.*

5 *Systematic Observation Requirements for Satellite-based Products for Climate Supplemental Details to the Satellite-based Component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC. Rep. no. GCOS-107. Global Climate Observing System, Sept. 2006. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf>.*

other method. In addition, satellites use a consistent method of monitoring over both space and time, which provides consistency difficult to ensure with other types of measurements. Maintaining this consistency over decades or more, however, often requires an overlap period between new and old satellite operations adequate to allow inter-calibration. Given the importance of consistency, it is also prudent to maintain redundant systems or back-up systems for essential climate variables.

Lack of Data Sharing

Many countries operate satellites collecting climate-relevant data, often through the efforts of their meteorological or space agencies. Generally, meteorological organizations collect data using operational weather satellites that are replaced on a regular basis, updating technologies and capabilities and that generally collect the same types of measurements over time. Space agencies tend to operate research satellites, which have much greater variability and focus on providing input to specific scientific questions rather than on providing continuous monitoring of the same variables over long time periods.

There are 35 nations or regional organizations involved in satellite Earth observations. Within this group, there are a small number of large contributors. The five countries with the largest Earth observation programs operate nearly 75 percent of the instruments; the top ten countries operate nearly 90%. However, many countries, including Chile, Malaysia, Morocco, and other non-traditional space nations, were involved in the development or operation of at least one satellite.

Despite this high level of involvement and significant activity, the climate monitoring system is inadequate. Less than half of the measurements needed to support the essential climate variables have been robustly collected during this time period, and 22 percent were not collected at all. Only about 40 percent of the instruments in the database are covered by policies that make data available without costs or restrictions, so the data availability situation is actually worse when data sharing policies are taken into account. Robust data is only available for about 36 percent of measurements needed, and no data is readily available for nearly a third of the relevant measurements. Restrictions on data sharing mean that not only is the international climate monitoring system inadequate, it is also suboptimal: some of the data that is collected is not fully contributing to understanding and addressing climate change.

Data sharing is necessary to ensure that data from all essential climate variables is available to the global community and for the work of groups like the IPCC. Because of the large number of variables to be collected and the high costs of building and operating satellite systems, it is not practical for any one country to attempt to collect all essential climate variables on its own. Even in the United States, which has the largest budget for Earth observations and operates significantly more Earth observation satellites than any other country, only about a third of relevant measurements are collected robustly. Another third of the measurements are not collected by the United States at all.

Sharing data also increases the efficiency of the global climate monitoring system as well as the efficiency of global climate research and operations. It allows countries to avoid redundant collection of data and to invest funds most efficiently to ensure all data is collected. Making the data widely available, through adequate sharing technology and open data sharing policies, also means it can be accessed by the greatest possible number of scientists, researchers, and other potential data users. This maximizes the quantity of climate-related research and operations undertaken and increases the speed with which climate-related advancements can be made. This increased understanding of climate processes as well as improved models and methods for forecasting, mitigating, and adapting to climate can provide global benefits. Furthermore, it seems particularly inefficient for governments to pay the millions to billions of dollars it takes to build and operate satellite systems, but then hold back on the relatively inexpensive step of maximizing use of the data through distribution systems and open data policies – the step in which returns on the investment on the system are actually realized.[6]

It is difficult to determine the exact benefits that would be generated due to marginal increases in data sharing, and there is a lack of consensus on prioritization of data collection and sharing beyond the definition of the essential climate variables. However, there are many anecdotes that illustrate the challenges of existing restrictions on data sharing.

[6] Personal interview.

Climate modelers face some of the largest challenges within the climate community. This is because climate models require many different types of data, often from many different sources. When one or more of these sources requires detailed applications for initial or continuing data access, this can slow the process of building or improving the model. If data cannot be accessed at all, this will likely make the model, and its results, less accurate than they could otherwise be. Restrictions on data re-distribution make it difficult for modelers to share their model or model results with others. In 2011, Jonathan Overpeck noted that about half of international environmental modeling groups were restricted from sharing digital climate model data beyond the research community because of intellectual property rights imposed by the government.[7] The same challenges that face the modeler also make it difficult for others to replicate and verify model results. Because they often work with fewer data sources at a time, these problems are generally less of a barrier for other, more focused research, though they certainly still play a role in slowing scientific progress overall. For example, high data costs or restrictions can lead researchers to abandon a particular research question or to carry out research using other, less expensive or less restrictive data that is less well suited for their purposes.[8]

There are multiple examples of individual researchers and organizations being unable to access data due to high costs or restrictions. For example, when prices were raised on European and Canadian climate-relevant data, the United States no longer

[7] Overpeck, Jonathan T., Gerald A. Meehl, Sandrine Bony, and David R. Easterling. "Climate Data Challenges in the 21st Century." *Science* 331.6018 (2011): 700-02. Web. 19 Mar. 2013. <http://www.sciencemag.org/content/331/6018/700.short>.
[8] Personal interview.

regularly accessed and used this data. Even within one government, high prices can prohibit use. When operation of the U.S. government-built Landsat satellite was turned over to a private company, data prices increased dramatically, and the National Oceanic and Atmospheric Administration (NOAA) restricted its own use. Even the lower prices charged for Landsat data when it had been returned to U.S. government control proved too high for use by the Department of Agriculture, which turned to less expensive Indian satellite data to fill the resulting gap in information. Though it minimized costs for the Department of Agriculture, this meant that the U.S. government as a whole was paying both for the Landsat system (and its data) as well as for similar Indian data.[9]

Many data sharing policies are written in such a way that data is provided for free for research use, but fees are charged when data is used for operational or commercial purposes. Though this may sound like a reasonable policy, it causes a number of challenges. For example, a group of countries collaborated in the development of a forest carbon tracking system, a tool that could be very useful for climate-related monitoring. Many space and meteorological organizations provided free satellite data to support research and development related to this system. The system was successfully developed and its usefulness was shown through a number of demonstration projects. With its usefulness proven, efforts were undertaken to maintain the forest carbon tracking system on an operational basis. However, this switch to an operational system, rather than a research program, meant that different data restrictions would apply. After the change, much of the data previously provided

[9] Personal interview.

for free would require relatively high prices be paid for access, putting the entire program in jeopardy. To many of those involved in this international endeavor, it seems that current policies penalize exactly those projects that turn out to be most successful.[10]

Similar challenges related to data-sharing restrictions are seen in the closely related area of natural disasters. There is significant international agreement that satellite data should be shared freely in the case of natural disasters; however, there are limitations on how this agreement is implemented. Some organizations, for example, will provide data for free, but maintain restrictions on redistribution of that data. In these cases, aid workers in the field may not be allowed to share images and other data products with colleagues from other organizations, and instead must direct colleagues to the original source of the data for access. This can be particularly challenging if information products are developed from multiple data sources.[11]

In addition, some data is only made freely available for a limited period of time after a natural disaster. After that period, the data or information must be returned or destroyed. This can result in a lack of available data for long-term recovery and rehabilitation, a period in the natural disaster cycle that often sees more death and difficulty than the initial disaster. Furthermore, no agreement exists to provide data in advance of a natural disaster, such as a hurricane, that has been forecasted. Some aid

[10] Personal interview.
[11] Personal interview.

workers cynically note that policies only ensure data is freely available while the disaster is still on the news.[12]

These anecdotes represent only a few examples of a widely recognized issue, and a number of international organizations have focused on the need to improve international data sharing. The World Meteorological Organization (WMO) was formed in 1950 with the goal of free and open international sharing of weather data, and satellite data was incorporated into system shortly after the technology was developed.[13] The Committee on Earth Observing Satellites (CEOS) was created in 1980 to promote international cooperation and data sharing with respect to Earth observing satellites, particularly research-oriented satellites.[14] The Global Climate Observing System (GCOS) program was initiated by the WMO in 1992 to identify needs and promote data sharing particularly related to climate.[15] In 2005, an intergovernmental agreement formed the Group on Earth Observations (GEO), a ministerial-level organization that included free and open data sharing as one of its founding principles.[16]

Despite the benefits of sharing data and the efforts of a number of international organizations over the past 30 years or more, some countries and agencies still restrict

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[12] Personal interview.
[13] "World Meteorological Organization Homepage." *World Meteorological Organization (WMO)*. N.p., n.d. Web. 19 Mar. 2013. <http://www.wmo.int/pages/index_en.html>.
[14] "CEOS Home." *Committee on Earth Observation Satellites*. N.p., n.d. Web. 19 Mar. 2013. <http://www.ceos.org/>.
[15] "GCOS: Index." *Global Climate Observing System*. N.p., n.d. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/>.
[16] "GEO Homepage." *Group on Earth Observations*. N.p., n.d. Web. 19 Mar. 2013. <http://www.earthobservations.org/index.shtml>.

access to data. In order to understand why this is the case, it's necessary to understand the incentives and barriers of data sharing, and which issues are most important to policy-makers choosing data sharing policies. What arguments, information, or concerns drive the development of data sharing policies?

To begin to answer this question, it is necessary to develop a more detailed understanding of the current state of climate-relevant satellite data collection and sharing. To do so, I created a dataset that includes all unclassified government satellites that operated at any time between 2000 and 2012. The database contains 186 satellites carrying a total of 483 instruments. As mentioned previously, this database reveals that less than half of the measurements needed to support the essential climate variables have been robustly collected between 2000 and 2012, and 22 percent were not collected at all. Taking into account restrictive data sharing policies, robust data is only available for about 36 percent of measurements needed, and no data is readily available for nearly a third of the relevant measurements.

Potential Incentives and Barriers to Data Sharing

There is a significant amount of literature related to data sharing, particularly with regard to geospatial data, which is often collected by the government. Authors in this area provide a wide range of arguments for and against climate change. Current thinking on the incentives and barriers to data sharing can generally be categorized into six theoretical areas: economic, normative, institutional, organizational, security, and political.

Those that focus on economic arguments debate the feasibility and relative efficiency of free data provision by the government compared to more market-based methods of data distribution. Harris recognizes the desire of countries to ensure a good return on their investment in Earth observation satellites, and notes that cost recovery can contribute to achieving this goal. Policies that include data sales can also help to stimulate a commercial Earth observation data market, though he notes that high prices could deter research users, in particular.[17] Uhlrich and Schröder argue that because data has increasing returns to use, economic and overall social benefits may be exponentially larger when data is made freely available.[18] Shaffer and Backlund also maintain that attempts at commercialization and cost recovery inhibit the distribution of data and potential economic growth and further contend that these restrictive policies are not feasible, providing evidence from U.S. satellite programs for which efforts at cost recovery and commercialization failed.[19]

For some, the normative aspects of data sharing are most salient. These debates often revolve around the ethical responsibilities of the government, particularly with regard to public safety and equity. In particular, it is widely recognized that the government has a responsibility to provide information in the event of severe weather or natural

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[17] Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.
[18] Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.
[19] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.

disasters, because this data can save lives and property.[20] With respect to equity, a common argument, made by Shaffer and others, is that citizens have already paid for the data through general taxation, and thus should not be excluded for data access by additional fees or restrictions.[21] Others, such as Onrud and Holland, argue that providing data for free to all users, including commercial entities, could be seen as an unfair subsidy to these groups at the expense of taxpayers, and that it is more equitable for those who use the data should to pay more than those who do not.[22]

Institutional arguments focus on the international aspects of data sharing, including the potential for mutual benefits among nations and the difficulties of collective action.[23] Organizational concerns focus on the dynamics within and among organizations that can affect decision-making, such as the views of upper-level managers or the professional culture.[24] Remote-sensing data can be used for both civil

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[20] *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
Ito, Atsuyo. "Issues in the Implementation of the International Charter on Space and Major Disasters." *Space Policy* 21.2 (n.d.): 141-49. Web.

[21] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.
Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.

[22] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.
Holland, William. "Copyright, Licensing and Cost Recovery for Geographic and Land Information Systems Data: A Legal, Economic and Policy Analysis." N.p., 1997. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/tempe/holland.html>.

[23] Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.
Bailey, G., D. Lauer, and D. Carneggie. "International Collaboration: The Cornerstone of Satellite Land Remote Sensing in the 21st Century." *Space Policy* 17.3 (n.d.): 161-69. Web.
Keohane, Robert O. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton, NJ: Princeton UP, 1984. Print.

[24] Harvey, F., and D. Tulloch. "Local-government Data Sharing: Evaluating the Foundations of Spatial Data Infrastructures." *International Journal of Geographical Information Science* 20.7 (2006): 743-68. Web.

and security purposes, so those focused on security issues attempt to detail the potential dangers of sharing remote sensing data and determine whether the benefits of sharing outweigh these concerns.[25] Some authors focus on the role of high-level policy-makers and the importance of the visibility of benefits of data distribution, arguing that benefits that are easier to measure, such as revenues, can be more convincing to policy-makers than less tangible benefits, such as research advancements.[26] Across these various debates, scholars provide a wide variety of potential arguments for and against data sharing, but they do not attempt to identify which of these arguments are most important in actual decision-making. Are policy-makers restricting data access due to economic goals, because of security concerns, or both equally? Do normative or organizational concerns have any effect on the policy-making process? This research attempts to address these questions.

Onsrud, Harlan. "Is Cost Recovery Worthwhile." Proc. of URISA 1995 Annual Conference Proceedings, Washington, DC. Urban and Regional Information Systems Association, 1995. Web.
Craig, William J. "White Knights of Spatial Data Infrastructure: The Role and Motivation of Key Individuals." *Journal of the Urban and Regional Information Systems Association* 16.2 (2005): 5-14. Web. 19 Mar. 2013.
<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.130.438&rep=rep1&type=pdf#page=5>.

[25] Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." Space Policy 22.4 (2006): 262-73. Web.
Salkin, Patricia A. "GIS in an Age of Homeland Security: Accessing Public Information to Ensure a Sustainable Environment." *William & Mary Environmental Law and Policy Review* 30.1 (n.d.): 55-94. Web.
Onsrud, Harlan. "Access to Geographic Information: Openness versus Security."*Http://www.spatial.maine.edu/~onsrud/pubs/OpennessVsSecurityPreprint.pdf*. N.p., n.d. Web. 19 Mar. 2013.

[26] Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.
Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.

Contribution of This Dissertation

There are many countries that operate climate-relevant satellites. However, the data collected by these satellites is shared in some cases and not others. Existing literature demonstrates that there are many potential factors that may affect a government agency's decision regarding whether or not to share their data. I posit that only a sub-set of the potential incentives and barriers to data sharing are actually meaningful determinants of data sharing policies. To understand which arguments are most important, I carry out both quantitative and case study analysis, building on the arguments posited in the existing literature.

Quantitative Model of Data Sharing

Using the database constructed to illuminate the current data sharing situation and the potential incentives and barriers to data sharing identified in the literature review, I carry out a quantitative analysis to determine the relationship between existing data sharing policies for each instrument and other observable characteristics related to the instrument, including technical or political characteristics. This is done using a probit regression model with proxies representing potential determinants of data sharing policies identified in the literature. This model shows that a number of specific arguments within the normative, institutional, organizational, and security areas are each correlated with data sharing policies, with statistically significant results all in the direction suggested by literature. These results provide some indication that the incentives and barriers suggested by the literature do play a role in determining data sharing policies. However, the proxies are only imperfectly able to capture the arguments discussed in the literature, and each proxy could potentially pick up other characteristics of instruments as well. Further, the analysis doesn't provide insight into how each of these issues affects policy development. Therefore, I build on this analysis by carrying out a series of case studies, examining how data sharing policies are developed in three countries with large climate-relevant satellite programs.

Domestic Agency-Level Comparative Case Studies

The domestic level case studies include the U.S. National Air and Space Administration (NASA), the U.S. National Oceanic and Atmospheric Administration (NOAA), the United States Geological Survey (USGS), the Japan Aerospace Exploration Agency (JAXA), Japan Meteorological Agency (JMA), the European Space Agency (ESA), and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). These three countries and regions – the United States, Europe, and Japan – were together responsible for approximately half of the unclassified government Earth observation instruments that operated between 2000 and 2012. The United States operated the largest portion (35 percent of instruments flown during this period), and Europe had a medium-sized program (12 percent), similar in size to the Earth observation program in Russia, China, and India. Japan's program is the smallest of the three cases chosen, with a 3 percent share of global Earth observation instruments operated in this period. Its program was similar in size to France and the Ukraine. Focusing on these three cases provides insight into policies that govern a large portion of relevant climate data while also providing some variation in program size. Developed through document analysis as well as semi-structured interviews with at least two individuals from each agency, these cases provide insight into the process of data sharing policy development as well as the motivations driving policy changes. The case studies demonstrate how data sharing policies in each of these organizations developed over time. They discuss internal discussions and arguments, and identify the primary determinants of policy development and policy change.

Across all seven cases there are a number of common trends. Most of the organizations began with informal data sharing, often with an international component, followed by efforts at cost recovery or commercialization that required restrictions on data sharing, which later gave way in favor of more open data sharing policies emphasizing data use. In all cases, economic, normative, and institutional arguments played a significant role in policy development. Economic arguments revolved around whether data should be treated as a public good or a commodity, and were informed over time by experience. In general, efforts at cost recovery and commercialization failed to generate significant revenues while free data policies led to significantly higher data use by both the research and commercial communities. Normative arguments about government's responsibility to act in the public interest were particularly salient within the weather community, where it is widely acknowledged that governments should share data that is needed to support forecasts that save lives and property. Governments also often make arguments about the proper role of government, either as a repository or a public trust, providing moral justification for their policies. Finally, arguments about the inherently global nature of weather play an important role in encouraging data sharing within the weather community, and all organizations examined share data according to the procedures of the World Meteorological Organization. Arguments about the need to share data in order to understand the climate system had less of an impact, though the importance of this issue is growing. Though all of the countries examined are also members of the Group on Earth Observations, they do not all fully comply with its data sharing principles.

These three cases demonstrate the role the economic, normative, and institutional arguments play in these three examples. They also illustrate that by giving different priorities to these various concerns and varying in their evaluation of the arguments, nations have implemented different policies at different times.

International Case Studies

The neoliberal institutional literature also suggests that international organizations can plan an important role in encouraging cooperation. Therefore, I look at two of the most active international organizations with regard to international sharing of data collected by Earth observation satellites. The World Meteorological Organization (WMO) and the Group on Earth Observations (GEO) both include international satellite data sharing as one if their primary goals. Almost every country in the world is a part of WMO, and more than 80 participate in GEO. Both organizations have developed data sharing principles. The discussions and viewpoints expressed by countries in developing these principles provide insight into the important incentives and barriers to data sharing on an international scale. Further, examination of these organizations can provide further insight into whether and how each organization actually affects the development of national data sharing policies.

Both organizations were formed based on the argument that particular issues, weather for WMO and a combination of societal issues in GEO, require international cooperation. This argument has been central to getting members to join the organization and to share data. However, within the WMO, for example, this argument only goes so far, providing a significant incentive to share data for official weather forecasting, but not necessarily for other uses. In GEO, this argument has been less effective, and data sharing is not uniform among members, even for official uses. Both organizations have also made a major contribution by providing a forum in which discussions of data sharing policies could take place. Nations have used these forums, particularly GEO, as a location in which to tout the benefits of data sharing policies that comply with the organization's principles. This has raised understanding and visibility of the effects of free and open data sharing policies. This increased understanding then informs policy making on the domestic agency level, and a trend towards increasingly open data sharing has been seen among GEO members.

Conclusions, Policy Implications, Future Research

Climate data is essential to understanding the climate system, but given the large quantities of data required, it isn't practical for any one nation to collect all of the relevant data on its own. Despite recognition of the need for international cooperation and a number of international organizations promoting data sharing, some data is shared and some is not. Current thinking on data sharing provides a wide range of potential incentives or barriers, but does not provide insight into which of these arguments is most important in policy-making. I used a comprehensive data set, quantitative analysis, and finally, a series of multi-level case studies, to better understand the process of data sharing policy development and the motivations driving policy changes.

Based on this analysis, I found issues in the economic, normative, and institutional realms are most important in determining data sharing policies. Limitations in data sharing are due to 1) a belief that data can efficiently be treated as a commodity, a viewpoint which conflicts with experience for nearly all climate data; 2) the lack of a normative justification for sharing climate data (though this norm exists for weather data), and 3) the lack of agreement that international cooperation and data sharing are required to adequately monitor climate change (again, this norm does exist for weather data). These limitations exist due to uncertainties about the nature of the market for climate data, the lack of understanding of climate impacts and the ability to mitigate them, and a lack of understanding of the requirements of climate science and operational activities.

To address these issues, countries should adopt free and open policies, recognizing that social benefit is maximized when data is treated as a public good and freely shared. Further, cost recovery and commercialization of scientific satellite data are not viable. Countries should share climate data internationally because it has the potential to save lives and property (similar to weather data), creating a moral requirement for sharing. Finally, countries should agree on a minimal set of climate data that must be shared to adequately monitor climate. This agreement should be institutionalized by a resolution within the WMO framework, similar to WMO Resolution 40, which addressed weather data sharing

Though experience with a variety of data sharing policies has greatly reduced these uncertainties, additional research could help to further improve understanding of data sharing policies. For example, quantitative analysis related to the Landsat system could provide a meaningful contribution to the empirical literature on the market for satellite data and the effects of various pricing and restriction policies. This system has gone through the most changes in terms of data pricing and number of users, and both have been well documented. This would be most effective if combined with data on the actual use of the data in terms of publications or products.

Chapter 2: Climate Science, Monitoring, and Data Sharing

In this chapter, I provide an explanation of the ways in which scientific research and operational activates related to climate change rely on observational data. I then look at existing efforts to define and prioritize these measurement needs and describe how satellites contribute to climate monitoring. Finally, I discuss the importance of sharing climate data collected by satellites and present evidence and anecdotes of the challenges posed to climate science activities by current data sharing restrictions.

2.1 Data are Essential to Climate Research and Operations

The scientific study of the climate system brings together the work of many different disciplines. Understanding the climate system requires an understanding of conditions and dynamics in the atmosphere, the oceans, and on land. It must incorporate information about the biosphere (plants and animals on the Earth) and the cryosphere (glaciers, land ice, and sea ice), and it requires an understanding of the interactions among each of these systems. The current scientific understanding of climate change is based on direct measurements, detailed analysis and research on specific climate dynamics, and complex models, all of which require a significant amount of data.

The Intergovernmental Panel on Climate Change (IPCC), a body formed under UN auspices to provide an integrated view of climate change, stated in its 2007 Assessment Report, “warming of the climate system is unequivocal.” They based this statement on direct observations, including increases in global temperature in the air and ocean, increasing snow and ice melt, and rising sea levels.[27] Direct measurements such as these are essential in describing and understanding the current state of the climate system.

Changes in climate are often relatively small and occur over long periods of time. Meanwhile, short-term changes in weather, for example, can be much larger. This is well illustrated by temperature changes. The global average temperature is estimated to have risen approximately one degree Celsius in the past one hundred years. By contrast, the temperature in one area may change by ten degrees Celsius or more in one day. The ability to determine small long-term changes despite these large short-term effects is based on the continuous collection of data at a high level of accuracy over long time periods. Surface temperature data have been collected using ground-based stations since the mid-19th century, and satellite measurements of surface temperature have been collected since the late 1970s. Organizations like the Hadley Center in the United Kingdom and the Goddard Institute for Space Studies in the United States collect and maintain these measurements, and analysts are able to show that the change in climate is beyond any errors in measurement or uncertainties from geographic variability.[28]

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[27] *IPCC Fourth Assessment Report: Climate Change 2007: Synthesis Report Summary for Policymakers*. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html>.

[28] "U.S. and Global Temperature." *Climate Change Indicators in the United States*. Environmental Protection Agency, 2012. Web. 19 Mar. 2013. <http://www.epa.gov/climatechange/science/recenttc.html>.

Climate change, on a basic level, is driven by an imbalance between the amount of energy reaching the Earth from the sun and the amount of energy radiated by the Earth back into space. Direct measurements of incoming solar radiation and outgoing radiation from the Earth, some of which can only be taken by satellites, help to determine the state of Earth's radiation balance. However, to understand climate change, it's also necessary to understand what is driving this imbalance. This is done by carrying out focused research and analysis on one or more direct measurements and the dynamics of the climate system.

An important distinction made by climate scientists is between forcings and feedbacks. Forcings are influences external to the climate system that can cause the climate system to change. Forcings include the buildup of greenhouse gases, injection of aerosols into the atmosphere by volcanic eruptions and human activity, changes in land cover, and changes in solar irradiance.

Direct measurements of concentrations of greenhouse gases in the atmosphere, such as carbon dioxide (CO_2) and methane (CH_4), show that concentrations of these gases have grown rapidly in the past century. Research on the effects of these increases combines this information with understandings of established scientific theory. For example, it is well known that some molecules, including carbon dioxide and methane, do not absorb radiation at the visible wavelengths emitted by the sun, but strongly absorb radiation at infrared wavelengths emitted by the Earth. Because of this, they trap radiation that may otherwise have left the Earth system, acting like a blanket and warming the Earth, leading to their designation as "greenhouse gases." Measurements of rising concentrations of greenhouse gases, research on the interaction of radiation and particular molecules, and scientific understanding of the greenhouse effect are combined to demonstrate the impact of these forcing factors.[29]

Additionally, different types of measurements and research are needed to test the implications of existing theories, potentially providing further confirmation. For example, if warming was caused by greenhouse gases, scientists would expect to see warming occurring equally for days and nights, since this effect would operate at all times. By contrast, if warming were caused by changes in solar irradiation, greater warming would be expected to occur during the day rather than at night. Measurements of changes in temperature during each of these periods shows that both days and nights have experienced warming, and the warming seen at night has been greater than the warming observed in the daytime.[30] Similar studies related to temperature distributions and changes within the upper and lower atmosphere provide similar results.[31]

Additional measurements and research are also required to provide greater insight into the causes of changes in forcing factors. For example, the understanding that increases in carbon dioxide are largely attributable to increases in fossil fuel use is

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[29] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: The Science of Global Warming and Our Energy Future*. New York: Columbia UP, 2009. Print.
[30] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: the Science of Global Warming and Our Energy Future*. New York, NY: Columbia UP, 2009. Print.
[31] "U.S. and Global Temperature." *Climate Change Indicators in the United States*. Environmental Protection Agency, 2012. Web. 19 Mar. 2013.
<http://www.epa.gov/climatechange/science/recenttc.html>.

based on a number of different measurements and studies. First, the amount of fossil fuels consumed by humans is fairly accurately measured, often at a national level, and these levels correlate closely to the increases of carbon dioxide in the atmosphere. This understanding is further supported by measurements of changing atmospheric concentrations of particular variants of carbon, called carbon isotopes. Fossil fuels contain carbon with high ratios of carbon-12 to carbon-13 compared to the carbon naturally occurring in the ocean and atmosphere. So, when these fossil fuels are burned, carbon dioxide with high ratios of carbon-12 to carbon-13 is released into the atmosphere and begins to build up there. Since systematic measurement began in 1977, there has been a steady increase in the carbon-12 to carbon-13 ratio in the atmosphere.[32]

Some other forcing factors are more complex and less well understood than greenhouse gases. For example, aerosols, tiny particles suspended in the air, can have different effects on the atmosphere depending on their composition. Some, like smoke particles and dust from dessert surfaces, having a cooling effect, while others, such as black carbon (soot), having a warming effect. The effect of aerosols is particularly difficult to study and understand because it is hard to measure on a global level with a high level of accuracy. Aerosols originate from point sources, like factories or wildfires, so their concentrations differ significantly from place to place.

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[32] *IPCC Fourth Assessment Report: Climate Change 2007: Chapter 2 Changes in Atmospheric Constituents and in Radiative Forcing. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf>.*

Further, they usually only remain in the atmosphere for a matter of days.[33] NASA identifies the effect of aerosols as a key uncertainty with regard to forcings that requires improved measurements.[34]

Similarly, uncertainties exist with respect to solar irradiance. Since 1978, solar irradiance has been monitored continuously by satellite, and the sun has displayed no statistically significant long-term change. The sun operates on an 11-year solar cycle during which the total irradiance changes approximately 0.15 percent. This change is too small and the cycles too short to have an appreciable influence on Earth's climate. However, it is possible that some temperature variation in the past 1000 years could be related to variations in solar irradiance, and NASA notes that the relatively short period for which direct measurements are available leads to significant uncertainty regarding the long-term dynamics of solar irradiance.[35]

Compared to forcings, feedbacks are often even more complex; a feedback is the result of a process that in turn influences the process itself, and it can have an amplifying (positive feedback) and/or dampening (negative feedback) effect on global warming. One of the commonly cited examples of feedbacks is ice cover. As warming from the buildup of atmospheric CO_2 causes sea ice to melt, there is less white ice to reflect solar energy, and a higher proportion of that energy gets absorbed

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[33] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: the Science of Global Warming and Our Energy Future*. New York, NY: Columbia UP, 2009. Print.
[34] "Uncertainties: Unresolved Questions about Earth's Climate." *Global Climate Change*. NASA, n.d. Web. 19 Mar. 2013. <http://climate.nasa.gov/uncertainties>.
[35] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: the Science of Global Warming and Our Energy Future*. New York, NY: Columbia UP, 2009. Print.
"Uncertainties: Unresolved Questions about Earth's Climate." *Global Climate Change*. NASA, n.d. Web. 19 Mar. 2013. <http://climate.nasa.gov/uncertainties>.

by the dark ocean, which enhances the warming, which then causes the ice to melt even faster. Because the change in albedo amplifies the warming, it is a positive feedback.[36]

Clouds represent an even more complex type of feedback than ice-cover, because they exert two competing influences: they reflect solar radiation back to space, but they also trap infrared radiation emitted from below. The formation of clouds depends on a number of other characteristics of the climate, such as water vapor concentrations, aerosols, and temperatures. In general, high clouds tend to be net warmers, whereas low clouds are net coolers. However, cloud feedback is considered the least certain of the feedbacks, because the interaction of clouds with the solar and terrestrial radiation depends on the total mass of the water, the size and shape of the droplets or particles, and the way they are distributed within the cloud. Improving scientific understanding of this feedback requires improved monitoring of each of these components. The IPCC identified cloud feedbacks as one of the highest research priorities; because of the large role of clouds in the climate system, even relatively small changes could result in speeding warming, slowing warming, or even reversing warming.[37]

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[36] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: the Science of Global Warming and Our Energy Future*. New York, NY: Columbia UP, 2009. Print.
[37] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: the Science of Global Warming and Our Energy Future*. New York, NY: Columbia UP, 2009. Print.
"Uncertainties: Unresolved Questions about Earth's Climate." *Global Climate Change*. NASA, n.d. Web. 19 Mar. 2013. <http://climate.nasa.gov/uncertainties>.

While the focused research described above usually requires a relatively small number of measurements regarding a particular forcing or feedback factor, climate models require data on a very wide range of factors. The most complex models, referred to as "general circulation models," take into account not only the dynamics within the atmosphere, oceans, or land, but also the interactions between them. These computer models combine data and measurements on a wide variety of factors with theories and equations describing the dynamics of the Earth system. Given these measurements and inputs, models are able to recreate climate conditions observed in real-life, such as seasonal cycles and atmospheric and oceanic circulation patterns. These models can be used both to confirm and improve understandings of the causes of climate change and to predict future changes in climate.[38]

For example, climate models reinforce the view that climate change is due to anthropogenic greenhouse gas emissions. Looking at the results of many different models, the IPCC found that when models were run with both anthropogenic and natural forcings, the simulations closely replicated the observed warming. But when they were run with only natural forcings - volcanic eruptions and variances in solar irradiance - the simulations displayed a significant and increasing deviation from the observed trend as of around 1960. To reproduce the actual warming experienced, the models required the input of anthropogenic forcings, specifically those due to greenhouse gases and aerosols.[39]

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[38] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: the Science of Global Warming and Our Energy Future*. New York, NY: Columbia UP, 2009. Print.
[39] *IPCC Fourth Assessment Report: Climate Change 2007: Climate Change 2007: Working Group I: The Physical Science Basis: Summary for Policymakers*. Rep. Intergovernmental Panel on Climate

Climate models are one of the most important sources for climate projections. Models estimate future warming of about 1.8 to 4.0 degrees Celsius, depending on future greenhouse gas emission levels, and provide a number of insights into likely future climate impacts.[40] While these models are very useful for projecting integrated global effects based on various scenarios, they have significantly less ability to accurately predict climate changes on smaller scales, such as the regional or national level. This is an issue, because these are the scales on which climate impacts must be understood in order to design and implement adaptation measures. Knowing that there will be more climate variability is important, but it is essential for policy makers or individuals to know, for example, whether their particular region is likely experience more droughts, floods, or both. One of the challenges for improving these models is the high computational requirement, but model development is also limited by a lack of accurate, long-duration measurements, many of which are best collected by satellites.[41]

Climate change is a global concern, rather than just a scientific interest, because of the potential for widespread, and in some cases devastating, impacts on individuals. Building on studies of the climate system and climate model results, a final area of

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Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spm.html>.

[40] *IPCC Fourth Assessment Report: Climate Change 2007: Climate Change 2007: Working Group I: The Physical Science Basis: Summary for Policymakers*. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spm.html>.

[41] National Research Council, *A National Strategy for Advancing Climate Modeling*, Washington, DC, 2012, http://www.nap.edu/openbook.php?record_id=13430&page=1 (accessed February 28, 2013).

climate science research focuses specifically on climate impacts and potential methods for mitigating or adapting to these effects. For example, rising sea levels have the potential to displace millions of people around the world and lead to billions of dollars in damage and loss of property. Changes in seasonal rainfall and snowmelt patterns, and increases in droughts and floods, can limit the ability of individuals to access sufficient safe drinking water and can lead to loss of agricultural productivity. These effects could lead to higher costs for food and water, and in poorer nations, may lead to increased starvation and death. Increased drought is also associated with an increase in the number and severity of forest fires, a trend already occurring in some areas.[42] Climate change is also associated with increased variability and severity of extreme weather. Though no one storm can be said to be caused by climate change, it does increase the likelihood of more severe storms in general. These storms lead to increased loss of life and property. Many of these effects, including rising sea levels and increased severity and numbers of droughts, floods, forest fires, and extreme weather events, can also lead to political instability and national security issues.[43]

2.2. Priorities for Climate Data: Essential Climate Variables

As illustrated above, accurate, long-term collection of climate data is essential to the study of climate change and to the many aspects of climate science. However,

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[42] Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: the Science of Global Warming and Our Energy Future*. New York, NY: Columbia UP, 2009. Print.

[43] "Effects: The Current and Future Consequences of Global Change." *Global Climate Change*. NASA, n.d. Web. 19 Mar. 2013. <http://climate.nasa.gov/effects>.

because there are so many variables of interest to climate scientists, it is necessary to prioritize some measurements over others.

In April 2003, the Global Climate Observing System (GCOS) group took the initiative to identify a fixed number of high priority climate observations. GCOS began by identifying the major issues of concern to the IPCC and the United Nations Framework Convention on Climate Change (UNFCCC) that would require collection of climate data. First, observations are needed to characterize the state of the global climate system and its variability. To do this, it is necessary to monitor both the natural and anthropogenic forcings and feedbacks on the climate system and identify the causes of climate change. Second, observations are essential for improving prediction of future global climate change, particularly at regional and national scales. Finally, the UNFCCC and IPCC require climate observations to assess risk and vulnerability, which allow improved impact assessment and inform efforts for adaptation.[44]

Focusing on these needs, GCOS developed a list of climate variables that would have a high impact and are currently feasible for global implementation. The list includes variables related to the atmosphere, oceans, and land, and each is referred to as an Essential Climate Variable (ECV). As GCOS has continued to examine and adapt to perceived global needs, the requirements for understanding the global climate system, improving prediction abilities, and assessing risk and vulnerabilities have remained

[44] *The Second Report on the Adequacy of the Global Climate Observing Systems for Climate in Support of the UNFCCC. Rep. no. GCOS-82. Global Climate Observing System, Apr. 2003. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-82_2AR.pdf>.*

central, and the list of approximately 50 variables has remained fairly consistent over time.[45]

Table 2.1 Essential Climate Variables

Domain	Essential Climate Variables[46]
Atmospheric (over land, sea, and ice)	**Surface**: Air temperature, Wind speed and direction, Water vapor, Pressure, Precipitation, Surface radiation budget. **Upper-air**: Temperature, Wind speed and direction, Water vapor, Cloud properties, Earth radiation budget (including solar irradiance). **Composition**: Carbon dioxide, Methane, and other long-lived greenhouse gases, Ozone and Aerosol, supported by their precursors
Ocean	**Surface**: Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean color, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton. **Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture

Table 2.1 provides a list of Essential Climate Variables (ECV) developed by the Global Climate Observation System group.

Although the identification of 50 high-priority variables is an important step forward in prioritizing some measurements over others, it is important to note that even within these confines, climate data collection is very complex. One reason for this is that the essential climate variables are defined at a relatively high level, such as the ECV "cloud properties," while actual measurements are very specific, looking for example at cloud height, location, or composition. Adequate collection of a single essential climate variable often requires collection of many types of specific measurements.

[45] *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*. Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.

[46] *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*. Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.

Furthermore, requirements and standards for climate data collection are generally much more demanding than those for other disciplines, such as weather. Data must be collected continuously over long time periods and large geographic areas, and a high level of accuracy is required in order to separate small climatic changes from larger short-term dynamics. These requirements make global climate data collection a larger, more complex, and more expensive undertaking than existing data collection efforts for other needs.

The GCOS climate monitoring principles, which accompany the essential climate variables, identify some of these standards and requirements. For example, the need for continuous, consistent data-collection means that the systems used to measure climate variables over time must either remain the same, or should have adequate overlap with new systems, allowing calibration of the measurements taken by each. Similarly, any changes in calibration, validation, or algorithms used to treat the data must be carefully assessed to understand the impact on the long-term dataset. It is particularly important, when working with climate data, that station operations and observing systems are maintained continuously, and do not experience gaps and interruptions in data collection. Data collection should be prioritized at stations with the longest existing historical records of collection, and new stations should be set up in data-poor regions, allowing for more complete global coverage. GCOS further emphasizes that these requirements need to be taken into account in the original planning for and funding of observation systems.[47]

2.3 Satellites Are Essential for Climate Data Collection

Historically, measurements relevant to climate have been taken using systems on or near the Earth, such as ground stations, weather balloons, water gauges, ocean buoys, and mobile stations on ships. However, since the 1970's, satellites have also been a very important contributor to global climate measurements.

Recognizing the increasing importance of satellite measurements, GCOS wrote a supplemental report addressing the systematic observation requirements for satellite-based products for climate. In this report, GCOS defined the ECVs largely dependent on satellite observations, as well as the type of satellite measurements required to produce these products.[48]

[47] *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*. Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.

[48] *Systematic Observation Requirements for Satellite-based Products for Climate Supplemental Details to the Satellite-based Component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC. Rep. no. GCOS-107. Global Climate Observing System, Sept. 2006. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf>.*

Table 2.2 Essential Climate Variables Largely Dependent on Satellites

Domain	Essential Climate Variables
Atmospheric (over land, sea, and ice)	Precipitation, Earth radiation budget (including solar irradiance), Upper-air temperature, Wind speed and direction, Water vapor, Cloud properties, Carbon dioxide, Ozone, Aerosol properties
Oceanic	Sea-surface temperature, Sea level, Sea ice, Ocean color (for biological activity), Sea state, Ocean salinity
Terrestrial	Lakes, Snow cover, Glaciers and ice caps, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Biomass, Fire disturbance, Soil moisture

Table 2.2 lists the Essential Climate Variables (ECV) that are largely dependent on satellites. These high-level variables are the most relevant of satellite data collection and sharing for climate.

Satellite measurements offer a number of advantages over ground-based measurements. One essential climate variable, the Earth Radiation Budget, can only be measured from space, because the interference from the atmosphere prohibits accurate measurements on the ground. This variable measures the overall balance between incoming energy from the sun and outgoing thermal and reflected energy from the Earth, and is one of the most basic elements for understanding climate change.[49]

Even for measurements that can also be collected on the ground, satellites offer unique benefits due to their ability to provide comprehensive global coverage. In fact, the Committee on Earth Observing Satellites argues, "only satellites provide the global coverage needed to observe and document global climate change." [50] Earth

[49] *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*. Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.

[50] *2010 Progress Report: Coordinated Response from Parties That Support Space Agencies Involved in Global Observations to the Needs Expressed in the Global Climate Observing System (GCOS) Implementation Plan of 2004*. Rep. Committee on Earth Observations, 2010. Web. 19 Mar. 2013. <http://www.ceos.org/images/CEOS-UNFCCC-2010.pdf>.

observation satellites are generally either in a polar orbit or a geosynchronous orbit. Polar-orbiting satellites travel in low, north-south orbits that take them over the poles, and allow them to monitor each point on the Earth approximately twice a day. Additional satellites in the same type of orbit can make it possible to monitor each point more than twice a day. Geosynchronous satellites are much farther away, orbiting in sync with the Earth's rotation. The great distance allows these satellites to view the entire disk of the Earth at one time, and the special orbit allows them to continuously monitor one area. Earth observation satellites in other orbits are rare, though they do exist. These satellites may be optimized to provide greater coverage of specific areas, such as the equatorial regions, which may be of particular interest to countries in these zones. [51]

Because of their comprehensive coverage, satellites are often the only source of adequate information on remote areas. For example, though ocean buoys provide important information, it is impossible to match satellites' spatial coverage of the oceans. Satellites are also particularly important for understanding the Arctic and Antarctic, where in situ measurements are sparse and difficult to obtain. Some of the most dramatic climate-related changes occurring at this time are related to ice and snow cover in the Arctic, and satellites provide the most complete understanding of these regions.

[51] *2010 Progress Report: Coordinated Response from Parties That Support Space Agencies Involved in Global Observations to the Needs Expressed in the Global Climate Observing System (GCOS) Implementation Plan of 2004*. Rep. Committee on Earth Observations, 2010. Web. 19 Mar. 2013. <http://www.ceos.org/images/CEOS-UNFCCC-2010.pdf>.

Another benefit of satellites is the use of the same measurement technique over the entire globe. Measurements taken on the ground are often done by different groups using different instruments and different methods, and these important differences are often not readily apparent. With satellites, scientists can be sure of the consistency of measurements taken in all regions, and this uniformity is a significant strength.[52] The unobtrusive nature of satellite measurements may also be important, as particular nations or regions may not be interested in or capable of fielding or monitoring in situ measurements.[53]

Though satellites have many capabilities, some of the essential climate variables can only be taken by systems located at or near the Earth. For example, satellites can monitor conditions on the surface of the ocean, but only deep-ocean surveys carried out by ships or buoys can take measurements below the surface.[54] Ground-based systems are also required for determining certain elements of groundwater and some aspects of biodiversity, which are not accessible via satellite.[55]

[52] *Strategic Plan for the U.S. Integrated Earth Observation System. Rep. Interagency Working Group on Earth Observations NSTC Committee on Environment and Natural Resources, 2005. Web. 19 Mar. 2013. <http://www.whitehouse.gov/sites/default/files/microsites/ostp/eocstrategic_plan.pdf>.*

[53] *Strategic Plan for the U.S. Integrated Earth Observation System. Rep. Interagency Working Group on Earth Observations NSTC Committee on Environment and Natural Resources, 2005. Web. 19 Mar. 2013. <http://www.whitehouse.gov/sites/default/files/microsites/ostp/eocstrategic_plan.pdf>.*

[54] *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*. Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.

[55] *The United States National Report on Systematic Observations for Climate for 2008: National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan*. Rep. Observations Working Group of the U.S. Climate Change Science Program (CCSP), Sept. 2008. Web. 19 Mar. 2013. <http://www.climatescience.gov/Library/UNFCCC-reporting-GCOS-Final.pdf>.

Even when the satellite data provide the primary source for observing an ECV, in situ observations are necessary for calibration and validation of satellite records.[56] The collection of both space- and earth-based measurements increases the confidence in both data sets. In fact, measuring the same variable with two different observing systems is sometimes the only way to minimize the adverse impacts of certain biases.[57]

Each type of system has important benefits as well as challenges, and satellite and non-satellite measurement systems need to be used in concert to take advantage of the unique benefits and challenges of each, such as the high spatial resolution and long histories of ground measurements and the comprehensive global coverage and consistency provided by satellites. However, as time goes on, the satellite measurements of climate change will increase in value and importance. Because long time series are essential to understanding the changing climate, each year that a satellite-based measurement continues to be collected in a well-calibrated and validated form, it becomes more valuable to the climate science community.[58] In fact, continuity may be more important than excellent accuracy (within limits), because a long-term trend can often be determined as long as the dataset has the required

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[56] *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*. Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.
[57] Karl, Thomas R., Vernon E. Derr, David R. Easterling, Chris K. Folland, David J. Hofmann, Sydney Levitus, Neville Nicholls, David E. Parker, and Gregory W. Withee. "Critical Issues for Long-term Climate Monitoring." *Climatic Change*31.2-4 (1995): 185-221. Web.
[58] *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)*. Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.

stability.[59] Given their unique advantages, growing capabilities, and increasing importance, it is important to ensure that there is adequate global climate monitoring via satellite.

2.4 The Current Global Monitoring System is Suboptimal Due to Lack of Sharing

Many countries operate Earth observing satellites, usually within their space agencies and meteorological agencies. However, even taking into account all of these systems, there are some ECVs that are not collected. Even the United States, which maintains the largest and most advanced Earth observing system in the world, would require unprecedented funding increases in order to collect all ECVs robustly. Furthermore, even when considering just the data that is collected, the global system is still suboptimal due to limitations on the sharing of data. Even though data may be collected, restrictions on data sharing significantly limit its availability to contribute to the ability to understand and address climate change.

Given that it is impractical for one country to collect all relevant data on its own, international data sharing is necessary in order to ensure adequate coverage of the essential climate variables, which represent the data required to support the work of the IPCC. Data sharing must occur to ensure an adequate understanding of global climate change and the ability to project and adapt to future changes in climate. Not

[59] *Systematic Observation Requirements for Satellite-based Products for Climate Supplemental Details to the Satellite-based Component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC.* Rep. no. GCOS-107. Global Climate Observing System, Sept. 2006. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf>.

only is data sharing the only effective way to ensure sufficient global climate monitoring, it increases the speed with which climate knowledge is obtained. The value of data is in its use. The more quickly and widely data is made available, the more scientists, researchers, citizens, policy-makers, and others can use it, resulting in increased understanding, new products, and better policy making.

Despite these benefits, there have been many reports of limitations on data sharing slowing scientific progress related to climate change. Climate modeling, in particular, requires input from many different sources, and progress has been slowed by difficulty in accessing data as well as restrictions on redistribution that limit sharing of models or model results. Data sharing restrictions that put greater restrictions on operational uses of data have been reported to create major barriers to projects attempting to move from research to operational status. This transition, which would ensure the long-term benefit of successful research or test projects, can be prohibitively expensive.

A number of international organizations have been created over the past 50 years or more with the goal of increasing international data sharing. The World Meteorological Organization (WMO) was formed in 1950 to facilitate worldwide exchange of weather data. The Committee on Earth Observing Satellites (CEOS) was formed in 1984 to promote international cooperation and data sharing related to all Earth observation satellites. The Group on Earth Observations (GEO), formed in 2005, encourages full and open sharing of all Earth observing data to address a number of global issues, including climate. However, despite the demonstrated need for data sharing, the negative effects of restrictions on sharing, and the efforts of numerous international organizations, there is still a significant amount of data that is not shared. This dissertation examines why data is shared in some cases and not others and aims to identify the primary determinants of data sharing policies for climate-relevant satellites.

Chapter 3: Characterizing Climate Data Collection and Sharing

To understand why data is shared in some cases and not others, it is first necessary to fully understand the current state of data collection and sharing; i.e., in which cases is data shared and in which cases is it not shared. In support of this goal, I created a dataset that includes all unclassified government satellites that operated at any time between 2000 and 2012. The dataset does not include commercial satellites, university satellites, or classified government satellites. 186 unclassified government satellites operated at some point during this period, carrying a total of 483 instruments.

The database includes technical characteristics, including the instruments on each satellite, the spatial resolution of those instruments, and the particular types of measurements each satellite can take. The ECVs are defined at a higher level of aggregation, and multiple specific types of measurements are required to adequately collect each ECV. Using this information, it was possible to map each instrument to the particular essential climate variables that it can support. The database also includes political characteristics, such as which country led development of the satellite, which other countries were involved in the program, and what the stated mission of the satellite was. Finally, it includes information about the data sharing policy applicable to each instrument, as of 2012.

This chapter provides an overview of the sources used to develop the dataset, and provides a few descriptive statistics that help to characterize the current global climate monitoring system. The data set is then used to highlight the gaps in the collection and sharing of data.

3.1 Global Climate Monitoring Satellite Database Sources

1) CEOS Mission, Instrument, and Measurement (MIM) Database

The primary dataset used in this research is the Committee on Earth Observing Systems (CEOS) Mission, Instrument, and Measurement Database, updated April 2012. The CEOS MIM database is updated annually based on a survey of CEOS member space agencies. The database provides data on the mission (satellite), instrument, and measurement level. The satellite-level table includes the agencies involved in the satellite, launch date, and end of life date. It also includes a description of the applications of the mission and the instruments on the mission. The MIM instrument table includes information about the general instrument type, its applications and measurements, and gives a variety of technical characteristics of the instrument, such as its waveband, spatial resolution, swath width, and accuracy. There were some instruments in the CEOS MIMS database that were not mapped to a detailed measurement. These mappings were added based on comparisons to similar types of instruments in the CEOS database that did have instrument to measurement mapping, and based on information from satellite mission websites. The measurement-level MIM table was not used.

2) CEOS Systems Database

The CEOS Systems Database Version 17, created January 18, 2012, traces the measurement types in the MIM database to the ECVs identified by GCOS. The mission data in the Systems Engineering Office (SEO) Systems Database is primarily based on the agency-provided ESA MIM Database content, but some “unofficial” updates have also been made to improve accuracy, and the connection of measurements to instruments and missions has not been reviewed by all agencies. Like the MIM database, the Systems Database includes tables on the mission, instrument, and measurement level. However, for the purposes of this research, it was only necessary to use the measurement-level data, which provides the measurement-ECV mapping. In cases where a measurement was not mapped to an ECV, I carried out additional research to identify the correct ECV mapping. Checks were also carried out to ensure that each of the nearly 150 types of measurements was consistently mapped to the same ECV(s). Satellites that did not contribute to the collection of at least one ECV were removed from the database.

3) Union of Concerned Scientists Satellite Database

The Union of Concerned Scientists Satellite Database, updated April 1, 2012, is a listing of the more than 900 operational satellites currently in orbit around Earth. The UCS database includes basic information about the satellites and their orbits. For the purposes of this research, the database was used primarily to verify the completeness and accuracy of the CEOS database. Comparison of the two databases revealed about 30 remote sensing and Earth observation satellites that are similar to those in the

CEOS database, but which were not already included in the CEOS database. A number of these came from non-traditional space-faring nations, such as Algeria and Egypt, and may have been excluded from the CEOS database because of the relatively small national space programs in these countries.

3) Satellite Program Websites

Though the CEOS databases include significant detail about satellites, instruments, and measurements, there are some additional variables that are relevant to research on determinants of data-sharing policies that are not available. This additional information was collected from each of the satellite program websites. These variables include: the lead country developing the satellite; the countries involved in the satellite program; the launch mass of each satellite; whether the satellite is civil, military, dual-use, commercial, or university-run; whether the satellite is for research or operational purposes, whether climate was part of the original purpose of the satellite mission; and the launch mass of the satellite. Satellite program websites were also used to collect all relevant information about satellites that were not included in the CEOS database. For example, on the instrument-level, information on spatial resolution was collected from the websites.

4) Existing Data-Sharing Policies and Websites

To document and analyze the extent of data sharing of satellite-collected climate data, information on the data sharing policies and procedures for each of the climate-relevant variables was collected from space agency website and data sharing websites. Data policies can vary in a number of ways, but for the purposes of the quantitative characterization, the primary focus was the cost of data access for research use and the restrictions on data access or use for research. Data policies can specify no cost, marginal cost, possible cost, or above marginal cost, and they can have no restrictions, some restrictions, or possible restrictions.

Marginal cost refers to the cost of fulfilling user requests, with no attempt to recover the costs of the satellite systems or ground infrastructure. Possible cost refers to situations in which a data policy that requires an application must be provided, often in response to a call for proposals, and the agency evaluates the application to determine whether data will be freely provided or whether a higher cost will be charged. Restrictions include limitations on access to the data based on user, planned use, or some other criteria. It can also include restrictions on redistribution of the data or other requirements, such as special reporting requirements. "Possible restrictions" refers to cases in which restrictions are waived under certain conditions, such as selection as part of a project team.

In some cases, it was impossible to find data or data policies online and attempts to contact data owners failed. When this occurred, the data policy was coded as "unknown." In terms of data sharing policies, unknown can be considered to be similar to "unavailable," but with a lower level of certainty. Data policies can also specify that data is not available to external researchers under any circumstances, and were then coded as "unavailable."

These two variables, cost and restrictions, were combined into one ordered data sharing variable with the following eight categories: 1) no cost and no restrictions, 2) no cost and some restrictions (on access, redistribution, or other requirements, such as reporting on use), 3) marginal cost and no restrictions, 4) marginal cost and some restrictions, 5) possible cost and possible restrictions, 6) above marginal cost and restrictions, 7) data is not made available (this is the case in which owners of the data explicitly state that it is not available to others), 8) data cannot be found or accessed.

Though data sharing policies are written at the national government agency level (e.g. NASA and NOAA each have a data sharing policy) data-sharing procedures are often defined on the instrument level. For example, NASA has one overall data policy, but data from one type of instrument on a particular satellite may not be shared at all, while data collected by other instruments on that same satellite is made freely available. Therefore, while decision-making and policy making occur on the agency level, the unit of observation for measuring and understanding data sharing is the instrument level. Also, for the purposes of this research, Europe is considered as one entity, or country. This is because the European Space Agency (ESA) and European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) each operate as one cohesive body, with decisions on data sharing made at this level.

It is important to note that within this database, the data sharing policy applicable to each instrument does not vary with time. It represents the data sharing policy for a given instrument in 2012, regardless of when the satellite was launched or when/if it has reached the end of its operational life. This is primarily due to the difficulty of collecting verifiable information on the changes in data-sharing policies over time. Though analyzing differences in data sharing policies across both time and instruments would be preferable, analyzing only differences in current policy across instruments is still useful for identifying whether there are observable patterns that can help explain why some data is currently shared (or restricted).

Deletions and Additions to the Dataset

To provide the most relevant data for examining the determinants of data sharing, the dataset was restricted in terms of time period and types of satellites included. These restrictions and their rationales are explained below.

Restrict Time Period

The time period examined in this research is restricted to the years between 2000 and 2012. Climate-relevant satellites were excluded only if they reached the end of their operational life before the year 2000 or if they had not yet been launched as of 2012. The time period begins in 2000, because by that time climate-relevant satellites had become more common as both remote sensing technologies improved and awareness of climate change issues increased. The 2012 cut off ensures that the dataset only includes satellites that have already been launched and have collected data. This is done because the data sharing policies related to existing data are well established and can be verified by examining the actual processes in place for accessing that data. In contrast, satellites planned for future launch do not always have data sharing policies in place, and even if they do, it is impossible to verify their implementation.

Remove commercial and university satellites

The commercial satellites and satellites owned by universities collecting climate-relevant data were removed from the database. This was done because the decision-making and policy-making process with regard to data sharing in these organizations is likely to be significantly different from that done by national governments. Including information on commercial and university data-sharing policies is not helpful in understanding the determinants of data sharing policies for governments.

The CEOS database does not include reconnaissance satellites, and no attempt was made to add these to the database. It is reasonable to keep these satellites out of the database, as these satellites are unlikely to be a primary target of international data sharing.

Remove satellites lost during launch failures

Satellites that were launched in the relevant time period but never became operational because of a failure on or immediately following the launch were removed from the database. Because no data was collected from these satellites, examining their data-sharing policies and procedures is not possible.

3.2 The State of Global Climate Monitoring via Satellite

The resulting dataset includes 186 satellites, carrying 483 instruments collectively. The set of 483 instruments includes duplicates of the same instrument flown on different satellites; only about 300 unique types of instruments were flown in this period. Each of the instruments is capable of collecting one or more types of measurements. The 186 satellites, with their 483 instruments, took 2775 types of measurements. Like the 483 instruments, these 2775 types of measurements are not unique; many satellites and instruments collected the same type of measurement. There are only about 150 unique types of measurements, all of which were identified and defined within the CEOS databases.

The number of satellites operating each year increased steadily from 2000 to 2012, with the number of satellites launched each year varying from about five to nearly twenty. More than 70% of satellites in this time period have expected lifespans of 10 years or less, and nearly 40% have a lifespan of 5 years or less.

This number of instruments operating each year has increased less rapidly than the number of satellites operating each year. This is due to a shift in focus from large satellites carrying many instruments to more specialized satellites, carrying fewer instruments. The majority of satellites in the database carry between one and three instruments.

Figure 3.1 Number of Satellites Operating Each Year

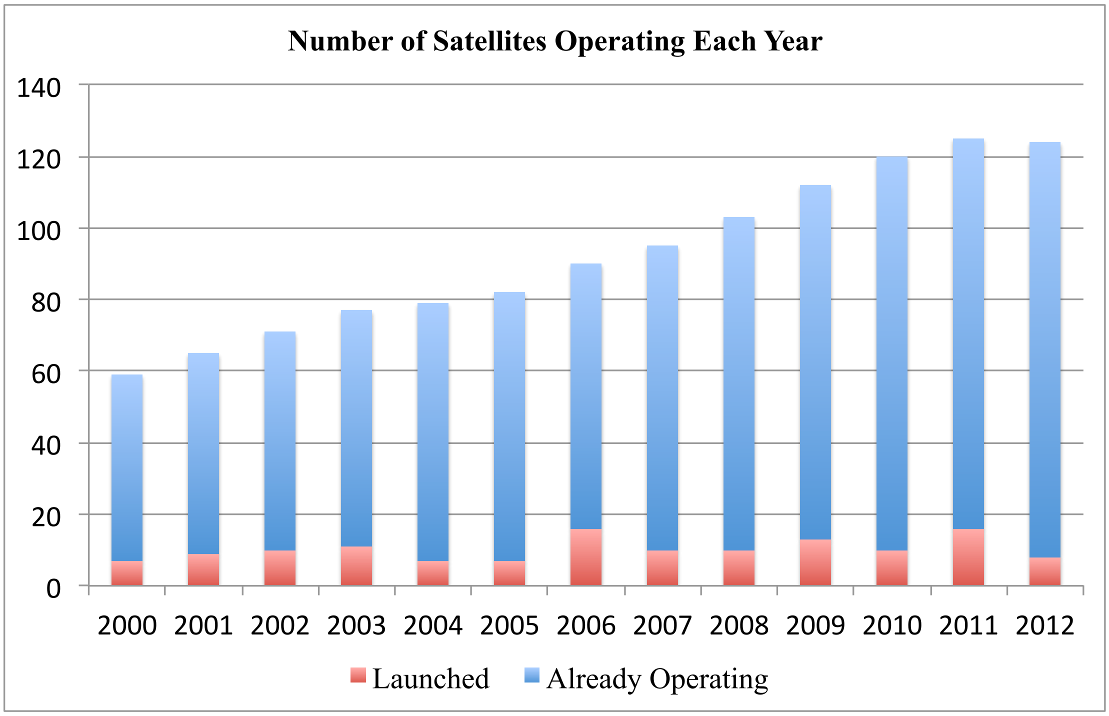

Figure 3.1 shows the total number of satellites that were operating each year. Satellites that were launched in that year are shown in red while satellites that were operating in that year, but launched previously, are shown in blue.

There are currently 35 countries that own or are involved in at least one Earth observing satellite relevant to climate. The United States has the largest number of climate-relevant satellites – nearly triple the number of any other nation. However, India, China, Europe, Russia, France, and Japan are also involved in significant numbers of climate-relevant satellites. When considering the number of instruments, rather than simply the number of satellites, in which each country is involved, the relative size of each program differs slightly, with Europe and Russia both moving ahead of India and China, for example, though the same six countries still lead data collection overall.

Figure 3.2 Number of Satellites per Country

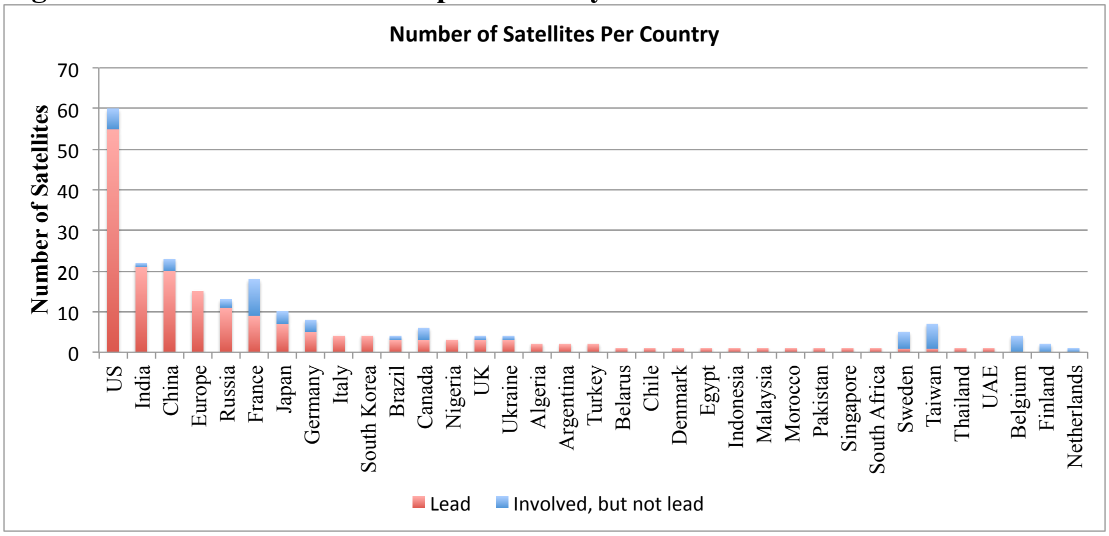

Figure 3.2 shows the number of satellites that each country operated in the period from 2000 to 2012. The portion of satellites for which the country was the lead developer or operator is shown in red. Satellites for which the country was involved, but did not take the lead, are shown in blue.

Figure 3.3 Portion of Satellites per Country (Lead Only)

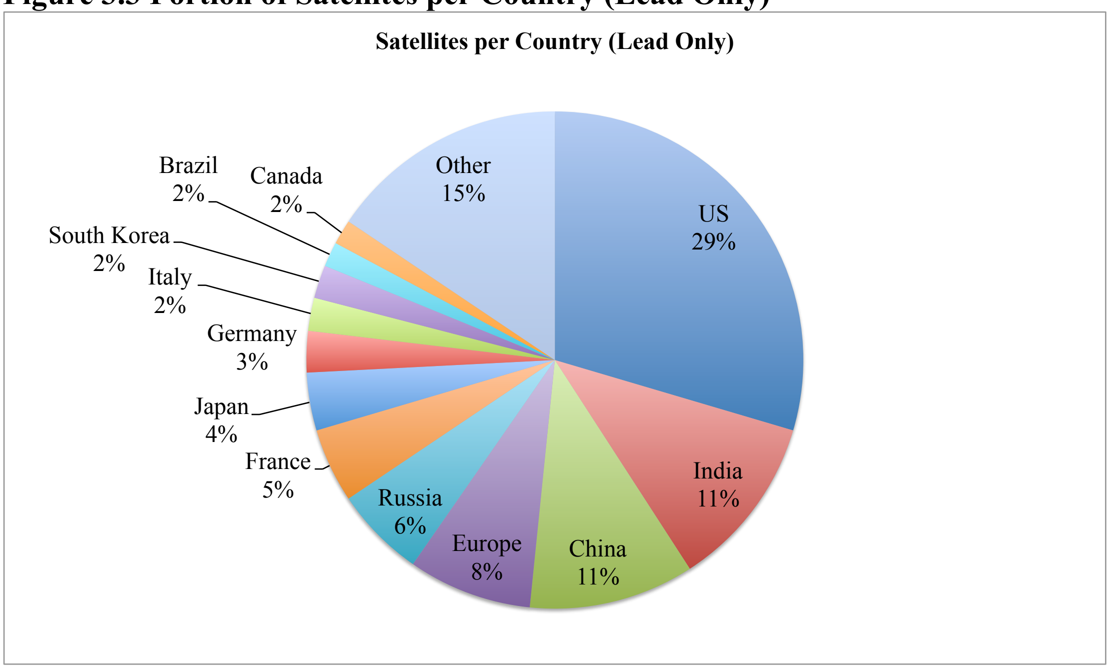

Figure 3.3 shows the portion of satellites for which each country was the lead out of the total 186 satellites that operated from 2000 to 2012. The United States led development or operation of nearly a third of satellites during this period, but India, China, Europe, Russia, and others also maintained large Earth observation satellite programs.

Figure 3.4 Number of Instruments per Country

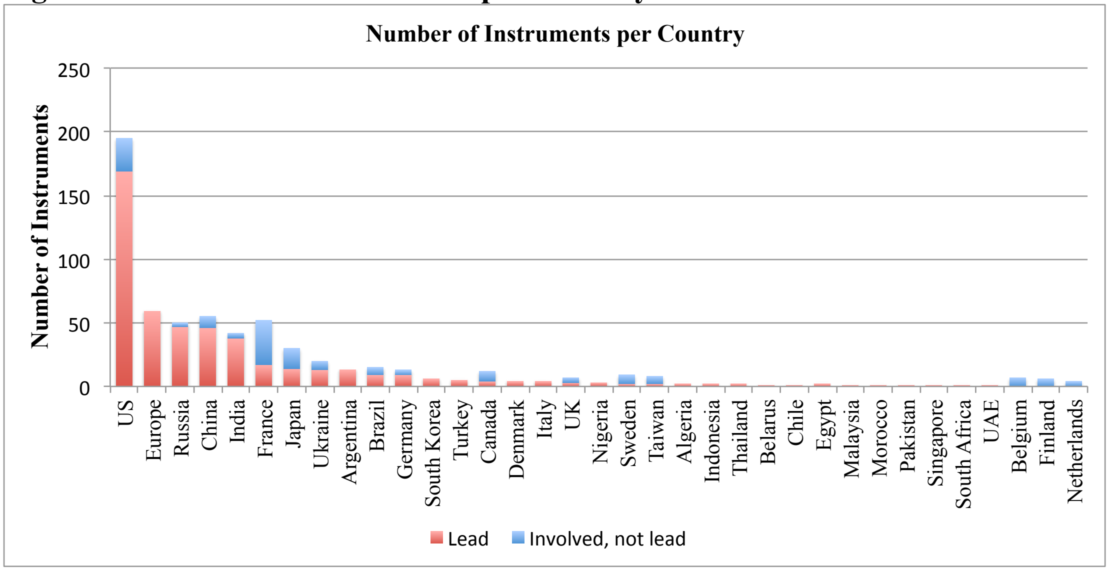

Figure 3.4 shows the number of instruments that each country operated in the period from 2000 to 2012. The portion of instruments for which the country was the lead developer or operator is shown in red. Instruments for which the country was involved, but did not take the lead, are shown in blue.

Figure 3.5 Portion of Instruments per Country (Lead Only)

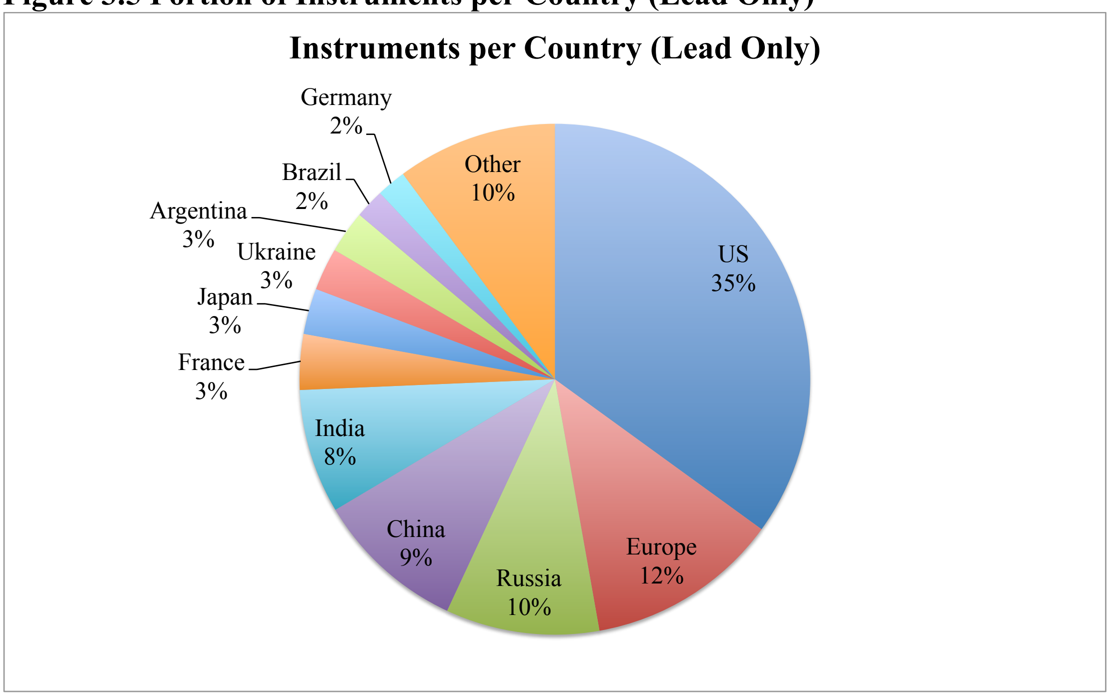

Figure 3.5 shows the portion of instruments for which each country was the lead out of the total 483 instruments that operated from 2000 to 2012. The United States led development or operation of more than a third of instruments during this period. India, China, Europe, and Russia follow.

<u>3.3 Gaps in Global Climate Satellite Data Collection and Sharing</u>

Data from about 40% of the 483 instruments that operated some time between 2000 and 2012 is available for free without any restrictions. Another 25% is available for free with some restrictions, usually on redistribution of the data. As noted earlier, even this relatively low level of restriction can pose a challenge, particularly for climate modeling projects, which require inputs from many different sources. Data from the remaining 35% of instruments is significantly more difficult to access.

Figure 3.6 Instrument Data Sharing, 2000-2012

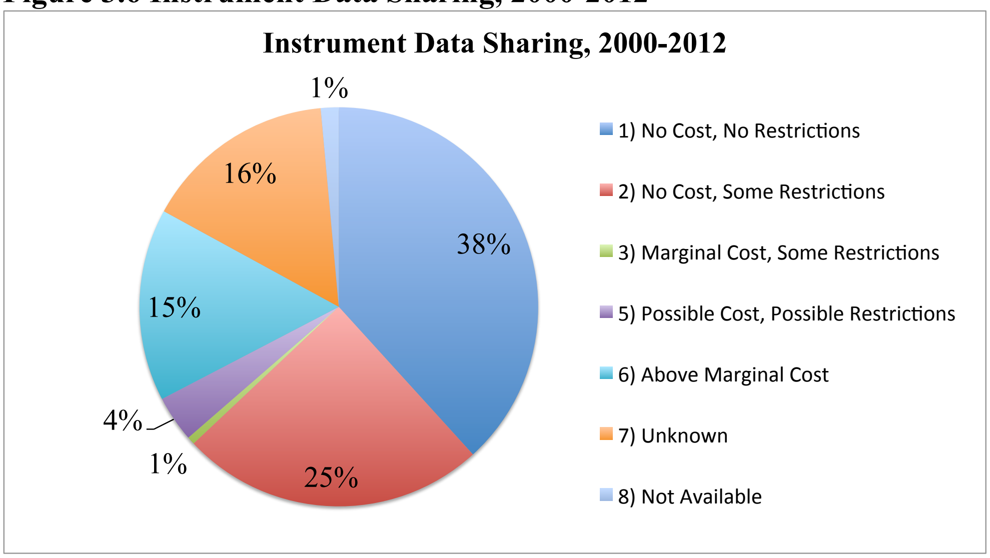

Figure 3.6 shows the data sharing policies that applied to the 483 instruments that operated at some time between 2000 and 2012. More than 60% of the data was not shared freely, i.e. data access was subject to either costs or restrictions.

However, each instrument collects a different number of unique measurement types and operates for a different period of time. Therefore, it is important to look at the number of instruments that collected each type of measurement and also have corresponding policies to make that data freely available. To distinguish between gaps due to lack of data collection and those due to lack of data sharing, both cases should be examined.

The areas of most concern are cases in which data is not available – either because there are no instruments collecting it or because access to data from instruments that do collect the measurement is limited by policies that involve costs or restrictions. Analysis of the dataset that takes into account the collection and sharing of detailed measurements over time shows that 22% of essential climate data is unavailable because it was not collected. However, restrictive data policies increase this percentage, and 31% of the data is not readily available to climate researchers when these policies are taken into account. Instances where data is not collected or not made freely available are shaded in red in the figures below.

Determining whether each measurement was collected in a way that actually meets these demanding requirements would require extensive analysis of satellite capabilities and potential for synergies between different instruments that is beyond the scope of this work. However, as a rule of thumb, only types of measurements that are available from more than five instruments operating concurrently are considered robustly collected or available. These cases are shaded in green in the figures below. When data collection is considered alone, 46% of essential climate data is robustly collected, but when restrictive data policies are taken into account, this falls to only 36% of the data that is robustly available.

In less extreme cases, data may be collected and shared, but only by a small number of instruments, shaded in yellow below. This is an issue because of the need within the climate community for data that is continuously collected, calibrated with other systems, and accurate, with global coverage provided on a regular and frequent basis. Ensuring continuity of measurements requires overlaps in systems and also benefits from some level of redundancy or back-up systems to ensure coverage in the case of satellite or instrument malfunctions. Intercalibration requires that systems operate concurrently for at least some period of time, and accuracy also tends to improve with the addition of multiple measuring systems. Though one polar satellite can often provide global coverage on its own, it only views each point on the Earth approximately twice a day; additional satellites are needed to improve temporal coverage.

Further, different instruments have different spatial resolutions and different capabilities in terms of differentiating among wavelengths. While they may all contribute to some extent to collection of an essential climate variable, any one instrument may not fully meet climate needs. The more instruments collect a given measurement, the greater the likelihood that these needs will be met by at least one instrument, or that needs can be met through re-analysis that creates integrated datasets based on multiple instruments. Confirming work with multiple datasets, or carrying out reanalysis also requires that this data be accessible, and not limited by restrictive data policies. Developing a new dataset through reanalysis of multiple sources is much less useful if one or more of those sources limit redistribution of the resulting product for use by others.

Two important points emerge from this analysis. First, the current climate monitoring system is inadequate – even including the efforts of every country, much of the data that we need to understand climate change is not collected robustly, or is not being collected at all. Second, restrictions on data sharing make the situation even worse. Lack of sharing means that we have a suboptimal system and are failing to benefit fully even from the data that is collected. The negative effects of restrictive data sharing policies are not only seen in the many anecdotal cases discussed earlier, but can also be shown quantitatively to have a meaningful impact on availability of essential climate data.

Figure 3.7 Measurements Collected vs. Measurements Collected and Shared, 2000-2012

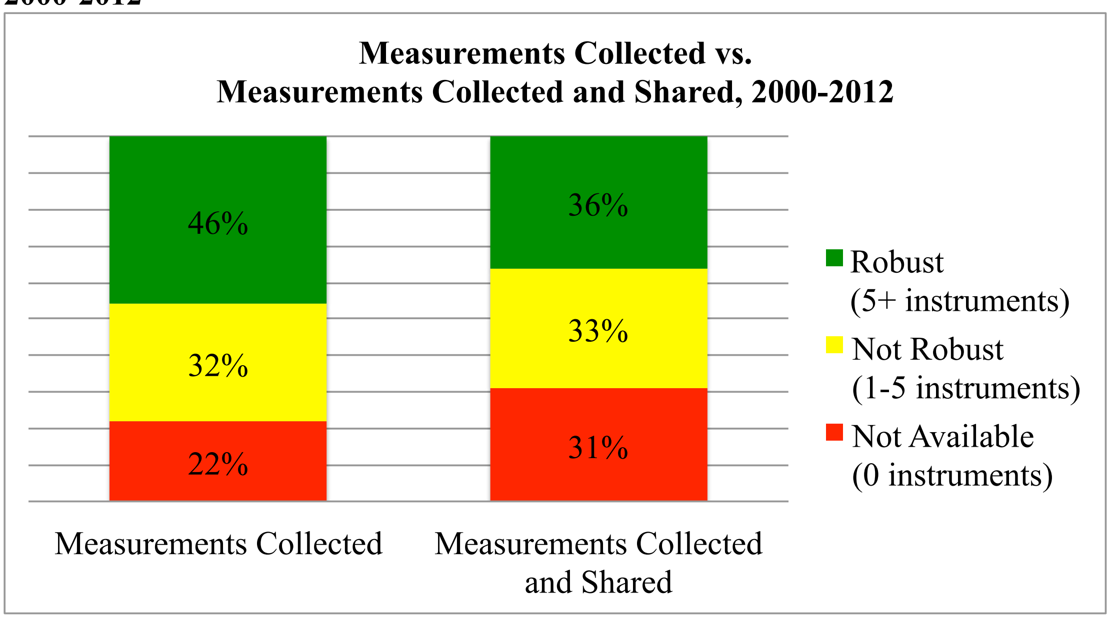

Figure 3.7 shows the proportion of measurement-years (including all detailed measurements needed to support the ECVs in the years 2000-2012) for which data was collected compared to the instances in which the data was both collected and shared. This chart shows that lack of sharing significantly decreases availability of data.

Table 3.1 Number of Instruments that Collected Each Measurement 2000-2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aerosol absorption optical depth (column/profile)	10	13	19	20	18	19	19	18	18	20	21	22	22
Aerosol effective radius (column/profile)	11	12	15	15	12	13	14	13	13	17	18	17	17
Aerosol Extinction / Backscatter (column/profile)	8	11	15	18	16	16	15	14	14	17	18	16	15
Aerosol optical depth (column/profile)	10	9	15	15	16	17	20	21	21	24	24	25	26
Atmospheric Chemistry - BrO (column/profile)	2	4	5	5	6	6	4	4	4	4	4	4	3
Atmospheric Chemistry - C2H2 (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - C2H6 (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - CFC-11 (column/profile)	0	0	2	3	3	3	3	3	3	3	3	3	3
Atmospheric Chemistry - CFC-12 (column/profile)	0	0	2	3	3	3	3	3	3	3	3	3	3
Atmospheric Chemistry - CH3Br (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - CH4 (column/profile)	5	5	9	9	11	11	9	9	9	10	10	10	11
Atmospheric Chemistry - ClO (column/profile)	0	1	1	1	2	2	2	2	2	2	2	2	2
Atmospheric Chemistry - ClONO2 (column/profile)	0	0	2	3	3	3	3	3	3	3	3	3	3
Atmospheric Chemistry - CO (column/profile)	1	2	5	5	7	7	8	8	8	8	8	8	9
Atmospheric Chemistry - CO2 (column/profile)	9	9	13	14	15	14	13	14	15	17	18	19	21
Atmospheric Chemistry - COS (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - HCFC-22 (column/profile	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - HCl (column/profile)	1	1	1	2	3	3	2	2	2	2	2	2	2
Atmospheric Chemistry - HDO (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - HNO3 (column/profile)	0	1	3	3	5	5	5	5	5	5	5	5	5
Atmospheric Chemistry - N2O (column/profile)	0	1	4	4	6	6	7	7	7	7	7	7	8
Atmospheric Chemistry - N2O5 (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - NO (column/profile)	1	1	2	3	3	3	2	3	3	3	3	3	3
Atmospheric Chemistry - NO2 (column/profile)	3	5	9	11	11	11	8	8	8	8	8	8	7
Atmospheric Chemistry - OClO (column/profile)	1	1	2	2	2	2	2	2	2	2	2	2	1
Atmospheric Chemistry - OH (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - PSC (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - SF6 (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - SO2 (column/profile)	1	1	2	2	3	3	3	3	3	3	3	3	2
Atmospheric pressure (over land surface)	0	0	0	0	0	0	0	0	0	0	0	3	3
Atmospheric pressure (over sea surface)	0	0	0	1	1	1	2	2	2	2	2	5	5
Atmospheric Specific Humidity (At Surface)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric specific humidity (column/profile)	53	55	69	68	68	67	68	67	72	75	81	87	89
Atmospheric stability index	5	6	8	8	7	8	8	7	7	8	9	10	10
Atmospheric temperature (at surface)	0	0	0	0	0	0	0	0	1	2	3	4	4
Atmospheric temperature (column/profile)	38	44	52	53	55	50	47	48	52	55	59	60	64
Bathymetry	3	2	3	3	3	3	3	4	4	4	4	4	3
Cloud base height	5	5	5	6	6	4	7	7	7	7	7	8	8
Cloud cover	24	24	29	29	26	26	30	30	29	32	33	36	35
Cloud drop size (at cloud top)	1	1	2	2	2	2	2	3	3	3	3	3	3
Cloud ice (column/profile)	1	1	1	1	1	1	3	3	3	3	3	3	3
Cloud ice content (at cloud top)	1	1	2	2	3	3	4	4	5	5	6	6	6
Cloud ice effective radius (column/profile)	0	0	0	0	0	0	1	1	1	1	1	1	1
Cloud imagery	20	20	24	23	22	24	28	27	29	32	34	37	37
Cloud liquid water (column/profile)	21	24	29	31	32	29	30	29	31	30	31	31	34
Cloud Mask	0	0	0	0	0	0	0	0	0	0	0	0	0
Cloud optical depth	1	1	4	5	4	4	6	6	6	6	6	6	6
Cloud top height	24	26	33	34	33	32	32	31	31	34	36	38	39
Cloud top temperature	18	18	23	23	20	20	19	18	19	21	24	25	25
Cloud type	22	24	32	34	34	36	37	39	43	45	49	52	52
Color dissolved organic matter (CDOM)	1	2	4	4	4	4	4	4	6	6	7	7	6

Diffuse attenuation coefficient (DAC)	1	1	2	2	2	2	2	2	2	2	2	2	2
Dominant wave direction	2	1	3	3	3	3	3	3	3	3	3	3	2
Dominant wave period	2	1	3	3	3	3	3	3	3	3	3	3	2
Downwelling long-wave radiation at the Earth sur	2	2	5	5	5	6	8	8	8	8	8	10	12
Downwelling short-wave radiation at the Earth su	5	5	7	7	7	8	9	9	9	10	10	11	12
Downwelling solar radiation at TOA	8	8	9	12	12	12	11	11	12	12	13	14	14
Earth surface albedo	39	43	47	53	54	60	64	66	73	75	77	79	74
Electron density profile	0	0	0	0	0	0	0	0	0	0	0	1	1
Fire area	21	23	24	24	23	23	24	24	24	28	28	32	33
Fire temperature	9	11	11	11	10	10	9	8	8	9	9	11	10
Fractionally absorbed PAR (FPAR)	8	9	13	15	16	17	18	18	19	20	20	22	22
Freezing Level Height	0	0	0	0	0	0	0	0	0	0	0	0	0
Geoid	3	4	6	6	6	6	6	6	8	9	10	9	8
Glacier cover	5	5	5	6	6	6	6	10	11	11	13	14	14
Glacier motion	3	2	4	4	4	4	5	9	10	10	12	12	10
Glacier topography	1	1	1	1	1	1	1	2	2	2	2	2	2
Gravity field	3	5	6	6	6	6	6	5	7	10	11	11	11
Gravity gradients	0	0	0	0	0	0	0	0	0	2	2	2	2
Height of the Top of the Planetary Boundary Layer	0	0	0	0	0	0	0	0	0	0	0	0	0
Height of tropopause	2	4	6	7	7	8	7	7	8	9	10	10	11
Ice sheet topography	0	0	1	1	1	1	1	1	1	1	1	1	1
Iceberg fractional cover	5	5	5	5	5	5	6	6	6	6	5	5	4
Iceberg height	5	5	5	5	5	5	6	6	6	6	5	5	4
Lake Surface Height	0	0	0	0	0	0	0	0	0	0	0	0	0
Land cover	10	11	13	14	14	14	15	18	20	22	23	27	26
Land surface imagery	44	48	55	59	62	68	72	76	85	88	92	96	92
Land surface temperature	29	31	40	42	41	44	45	43	48	53	58	64	66
Land surface topography	19	19	22	25	25	27	32	37	39	36	39	40	36
Leaf Area Index (LAI)	6	7	10	11	10	10	10	10	10	11	11	12	11
Lightning detection	2	2	2	2	2	2	2	2	2	2	2	3	3
Long-wave cloud emissivity	2	2	2	2	2	1	0	0	0	0	0	0	0
Long-wave Earth surface emissivity	7	7	13	13	13	14	16	16	17	17	17	18	19
Magnetic field (scalar)	8	8	9	9	11	10	11	10	10	11	11	10	10
Magnetic field (vector)	8	8	9	9	11	10	12	11	11	12	12	11	11
Melting Layer Depth in Clouds	0	0	0	0	0	0	0	0	0	0	0	0	0
Normalized Differential Vegetation Index (NDVI)	12	13	17	17	16	16	16	16	16	19	19	21	21
Ocean chlorophyll concentration	5	6	10	10	8	7	7	8	10	10	12	12	10
Ocean dynamic topography	10	12	12	11	12	12	12	9	13	13	13	13	13
Ocean imagery and water leaving radiance	32	32	35	31	32	33	35	34	36	37	40	41	38
Ocean salinity	0	0	0	0	0	0	0	0	0	1	1	3	3
Ocean surface currents (vector)	0	0	3	3	3	3	3	5	5	5	6	6	6
Ocean suspended sediment concentration	3	4	8	8	7	6	6	7	9	10	11	10	8
Oil spill cover	3	3	3	3	3	3	3	4	4	5	5	5	5
Outgoing long-wave radiation at Earth surface	2	2	4	4	4	4	5	5	5	5	5	7	8
Outgoing long-wave radiation at TOA	27	27	34	35	34	35	31	30	32	37	43	44	47
Outgoing short-wave radiation at TOA	5	5	7	7	7	8	8	8	9	9	10	13	15
Outgoing spectral radiance at TOA	0	0	0	1	1	1	1	1	1	1	1	1	1
Ozone profile	25	29	38	36	38	39	34	33	35	38	41	43	45
Permafrost	2	2	2	2	2	2	2	2	2	2	2	2	2
Photosynthetically Active Radiation (PAR)	2	3	6	6	6	6	6	6	7	7	7	7	6
Precipitation index (daily cumulative)	0	0	2	2	1	2	3	3	3	3	3	3	3
Precipitation Profile (liquid or solid)	4	4	5	5	5	6	8	8	8	9	9	11	13
Precipitation rate (liquid) at the surface	40	42	48	49	48	48	49	46	47	52	56	59	61
Precipitation rate (solid) at the surface	0	0	0	0	0	0	1	1	1	1	1	2	2
Sea level	3	5	7	7	7	7	7	6	11	11	12	13	12
Sea surface temperature	30	33	43	44	42	44	43	42	45	50	56	59	59
Sea-ice cover	35	36	43	38	39	40	41	43	46	51	54	57	55
Sea-ice sheet topography	11	9	10	10	11	11	12	12	11	11	12	11	9
Sea-ice surface temperature	2	2	2	2	2	2	2	2	2	2	2	3	3
Sea-ice thickness	21	22	18	13	16	17	16	14	15	17	18	16	15
Sea-ice type	5	3	5	5	5	5	7	11	12	13	15	16	14
Short-wave cloud reflectance	1	1	2	2	2	2	2	2	2	2	2	2	2
Short-wave Earth surface bi-directional reflectanc	13	13	18	18	19	22	24	23	25	26	26	26	25
Significant wave height	11	10	12	11	12	12	12	11	13	13	13	14	11

Snow Albedo	0	0	0	0	0	0	0	0	0	0	0	0	0
Snow cover	42	43	52	52	50	47	48	51	52	55	58	63	65
Snow Detection (mask)	0	0	0	0	0	0	0	0	0	0	0	0	0
Snow melting status (wet/dry)	0	0	0	0	0	0	1	1	1	1	1	1	0
Snow water equivalent	10	10	15	16	15	14	16	17	17	17	17	17	18
Soil moisture at the surface	14	12	19	20	19	18	22	23	24	26	27	28	29
Soil Moisture in the Roots Region	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil type	3	4	4	4	4	4	4	7	8	8	9	10	10
Surface Coherent Change Detection	1	1	1	1	1	1	1	2	2	2	2	2	2
Temperature of tropopause	10	10	13	14	14	13	10	10	12	12	14	14	15
Total electron content (TEC)	0	0	0	0	0	0	0	0	0	0	0	1	1
Vegetation Canopy (cover)	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetation Canopy (height)	0	0	0	0	0	0	0	0	0	1	1	1	1
Vegetation Cover	2	2	2	3	3	3	3	3	3	5	5	5	4
Vegetation type	28	28	37	42	42	44	46	51	55	56	57	59	56
Visibility	0	0	0	0	0	0	0	0	0	0	0	0	0
Volcanic ash	4	4	5	5	5	6	7	7	7	8	8	8	9
Water vapour imagery	0	0	0	0	0	1	2	2	2	2	2	3	3
Wave Directional Energy Frequency Spectrum	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind profile (horizontal)	17	16	19	21	19	21	20	19	18	19	21	21	19
Wind profile (vertical)	1	1	1	1	1	1	1	1	1	1	1	1	1
Wind speed over sea surface (horizontal)	14	15	23	24	23	22	22	22	24	25	26	32	33
Wind stress	0	0	0	0	0	0	0	0	0	0	0	1	1
Wind vector over land surface (horizontal)	0	0	0	0	0	0	0	0	0	0	0	1	1
Wind vector over sea surface (horizontal)	9	8	7	6	7	7	8	6	6	7	7	6	4

Table 3.2 provides a detailed view of the number of instruments that collected each of the detailed measurements that supports the Essential Climate Variables in each year from 2000 to 2012. Measurements that are collected robustly, by more than five instruments, are shown in green. Measurements that are not collected robustly are shaded in yellow, and data that are not collected by any instruments are shaded in red.

Table 3.2 Number of Instruments that Collected and is Shared Freely Without Restrictions Each Measurement 2000-2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aerosol absorption optical depth (column/profile)	8	9	13	13	11	12	11	10	10	12	13	14	13
Aerosol effective radius (column/profile)	8	9	12	12	10	11	11	10	10	12	13	13	12
Aerosol Extinction / Backscatter (column/profile)	5	6	8	9	8	8	8	7	7	8	9	8	7
Aerosol optical depth (column/profile)	5	5	8	8	9	10	11	12	12	13	13	15	15
Atmospheric Chemistry - BrO (column/profile)	1	1	1	1	2	2	1	1	1	1	1	1	1
Atmospheric Chemistry - C2H2 (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - C2H6 (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - CFC-11 (column/profile)	0	0	1	1	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - CFC-12 (column/profile)	0	0	1	1	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - CH3Br (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - CH4 (column/profile)	4	4	6	6	8	8	5	5	5	5	5	5	5
Atmospheric Chemistry - ClO (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - ClONO2 (column/profile)	0	0	1	1	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - CO (column/profile)	1	1	2	2	4	4	4	4	4	4	4	4	4
Atmospheric Chemistry - CO2 (column/profile)	9	9	11	11	12	11	8	9	9	10	10	11	11
Atmospheric Chemistry - COS (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - HCFC-22 (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - HCl (column/profile)	1	1	1	1	2	2	1	1	1	1	1	1	1
Atmospheric Chemistry - HDO (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - HNO3 (column/profile)	0	0	1	1	3	3	3	3	3	3	3	3	3
Atmospheric Chemistry - N2O (column/profile)	0	0	1	1	3	3	3	3	3	3	3	3	3
Atmospheric Chemistry - N2O5 (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - NO (column/profile)	1	1	1	1	1	1	0	1	1	1	1	1	1
Atmospheric Chemistry - NO2 (column/profile)	2	2	3	3	3	3	1	1	1	1	1	1	1
Atmospheric Chemistry - OClO (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - OH (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric Chemistry - PSC (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - SF6 (column/profile)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Chemistry - SO2 (column/profile)	0	0	0	0	1	1	1	1	1	1	1	1	1
Atmospheric pressure (over land surface)	0	0	0	0	0	0	0	0	0	0	0	3	3
Atmospheric pressure (over sea surface)	0	0	0	0	0	0	1	1	1	1	1	4	4
Atmospheric Specific Humidity (At Surface)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric specific humidity (column/profile)	35	37	48	49	48	46	44	43	45	48	49	53	53
Atmospheric stability index	5	6	7	7	6	6	6	5	5	6	7	7	6
Atmospheric temperature (at surface)	0	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric temperature (column/profile)	34	35	41	42	43	38	33	33	33	35	36	38	37
Bathymetry	0	0	0	0	0	0	0	0	0	0	0	0	0
Cloud base height	0	0	0	0	0	0	2	2	2	2	2	3	3
Cloud cover	10	11	15	15	13	14	16	16	16	18	19	20	19
Cloud drop size (at cloud top)	1	1	2	2	2	2	2	3	3	3	3	3	3
Cloud ice (column/profile)	1	1	1	1	1	1	3	3	3	3	3	3	3
Cloud ice content (at cloud top)	1	1	2	2	3	3	4	4	4	4	4	4	4
Cloud ice effective radius (column/profile)	0	0	0	0	0	0	1	1	1	1	1	1	1
Cloud imagery	13	14	16	16	15	16	18	17	17	19	20	21	20
Cloud liquid water (column/profile)	18	18	24	24	23	20	21	21	21	20	20	20	20
Cloud Mask	0	0	0	0	0	0	0	0	0	0	0	0	0
Cloud optical depth	1	1	3	4	3	3	5	5	5	5	5	5	5
Cloud top height	16	17	21	21	20	20	18	17	17	19	20	21	20
Cloud top temperature	12	13	17	17	15	14	11	10	10	12	13	13	12
Cloud type	6	6	11	14	14	17	18	18	18	19	19	19	19
Color dissolved organic matter (CDOM)	1	1	2	2	2	2	2	2	2	2	2	2	2

Diffuse attenuation coefficient (DAC)	1	1	2	2	2	2	2	2	2	2	2	2	2
Dominant wave direction	0	0	0	0	0	0	0	0	0	0	0	0	0
Dominant wave period	0	0	0	0	0	0	0	0	0	0	0	0	0
Downwelling long-wave radiation at the Earth surfa	2	2	4	4	4	4	5	5	5	5	5	6	6
Downwelling short-wave radiation at the Earth surf	5	5	7	7	7	8	8	8	8	9	9	10	10
Downwelling solar radiation at TOA	6	6	7	11	11	11	9	9	9	9	9	10	10
Earth surface albedo	10	10	13	14	13	14	14	14	14	15	15	16	16
Electron density profile	0	0	0	0	0	0	0	0	0	0	0	0	0
Fire area	16	17	19	19	18	18	16	15	15	17	18	21	20
Fire temperature	6	7	8	8	7	7	7	6	6	7	8	10	9
Fractionally absorbed PAR (FPAR)	7	7	9	9	9	10	10	10	10	11	11	11	11
Freezing Level Height	0	0	0	0	0	0	0	0	0	0	0	0	0
Geoid	0	2	2	2	2	2	2	2	4	4	4	4	4
Glacier cover	4	4	4	4	4	4	4	4	4	4	4	4	4
Glacier motion	0	0	0	0	0	0	0	0	0	0	0	0	0
Glacier topography	0	0	0	0	0	0	0	0	0	0	0	0	0
Gravity field	2	4	5	5	5	5	5	4	6	6	6	7	7
Gravity gradients	0	0	0	0	0	0	0	0	0	0	0	0	0
Height of the Top of the Planetary Boundary Layer	0	0	0	0	0	0	0	0	0	0	0	0	0
Height of tropopause	2	2	4	4	4	5	5	5	5	5	5	5	5
Ice sheet topography	0	0	0	0	0	0	0	0	0	0	0	0	0
Iceberg fractional cover	3	3	3	3	3	3	3	3	3	3	3	3	3
Iceberg height	3	3	3	3	3	3	3	3	3	3	3	3	3
Lake Surface Height	0	0	0	0	0	0	0	0	0	0	0	0	0
Land cover	5	5	6	6	6	6	6	6	6	6	6	7	7
Land surface imagery	9	9	12	13	12	13	13	13	13	14	14	15	15
Land surface temperature	22	24	31	32	31	33	31	29	29	33	35	38	36
Land surface topography	1	2	2	3	3	3	3	3	4	4	4	3	3
Leaf Area Index (LAI)	5	5	7	7	6	6	6	6	6	6	6	7	7
Lightning detection	1	1	1	1	1	1	1	1	1	1	1	2	2
Long-wave cloud emissivity	2	2	2	2	2	1	0	0	0	0	0	0	0
Long-wave Earth surface emissivity	6	6	12	12	12	13	13	13	13	13	13	14	14
Magnetic field (scalar)	5	5	6	7	7	6	7	7	7	7	7	7	7
Magnetic field (vector)	5	5	6	7	7	6	7	7	7	7	7	7	7
Melting Layer Depth in Clouds	0	0	0	0	0	0	0	0	0	0	0	0	0
Normalized Differential Vegetation Index (NDVI)	10	10	13	13	12	12	10	10	10	11	11	12	12
Ocean chlorophyll concentration	2	2	4	4	3	3	3	3	3	3	3	4	4
Ocean dynamic topography	3	6	7	7	7	7	7	4	8	8	8	8	8
Ocean imagery and water leaving radiance	12	13	16	16	14	15	15	14	14	16	17	18	17
Ocean salinity	0	0	0	0	0	0	0	0	0	0	0	2	2
Ocean surface currents (vector)	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocean suspended sediment concentration	2	2	4	4	3	3	3	3	3	3	3	3	3
Oil spill cover	2	2	2	2	2	2	2	2	2	2	2	2	2
Outgoing long-wave radiation at Earth surface	2	2	4	4	4	4	4	4	4	4	4	6	6
Outgoing long-wave radiation at TOA	23	24	30	32	31	31	23	22	22	26	27	28	27
Outgoing short-wave radiation at TOA	4	4	5	6	6	6	5	5	5	5	5	7	7
Outgoing spectral radiance at TOA	0	0	0	1	1	1	1	1	1	1	1	1	1
Ozone profile	19	20	25	25	27	27	21	20	20	23	24	25	24
Permafrost	2	2	2	2	2	2	2	2	2	2	2	2	2
Photosynthetically Active Radiation (PAR)	1	1	2	2	2	2	2	2	2	2	2	2	2
Precipitation index (daily cumulative)	0	0	2	2	1	2	3	3	3	3	3	3	3
Precipitation Profile (liquid or solid)	4	4	5	5	5	6	7	7	7	8	8	9	10
Precipitation rate (liquid) at the surface	30	32	39	41	38	37	36	34	34	38	40	42	41
Precipitation rate (solid) at the surface	0	0	0	0	0	0	1	1	1	1	1	2	2
Sea level	1	4	4	4	4	4	4	3	8	8	8	8	8
Sea surface temperature	20	22	29	30	27	29	27	25	25	29	31	33	32
Sea-ice cover	11	11	19	19	17	19	19	19	19	20	20	22	22
Sea-ice sheet topography	0	0	0	1	1	1	1	1	1	1	1	0	0
Sea-ice surface temperature	2	2	2	2	2	2	2	2	2	2	2	3	3
Sea-ice thickness	4	4	5	6	6	7	7	7	7	8	8	7	7
Sea-ice type	0	0	0	0	0	0	0	0	0	0	0	1	1
Short-wave cloud reflectance	1	1	2	2	2	2	2	2	2	2	2	2	2
Short-wave Earth surface bi-directional reflectance	6	6	9	9	8	9	9	9	9	10	10	10	10
Significant wave height	1	3	3	3	3	3	3	2	4	4	4	4	4

Snow Albedo	0	0	0	0	0	0	0	0	0	0	0	0	0
Snow cover	21	21	29	29	27	26	24	24	24	24	24	26	26
Snow Detection (mask)	0	0	0	0	0	0	0	0	0	0	0	0	0
Snow melting status (wet/dry)	0	0	0	0	0	0	0	0	0	0	0	0	0
Snow water equivalent	9	9	14	15	14	13	14	14	14	14	14	14	14
Soil moisture at the surface	8	8	13	14	13	12	13	13	13	13	13	14	15
Soil Moisture in the Roots Region	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil type	2	2	2	2	2	2	2	2	2	2	2	3	3
Surface Coherent Change Detection	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature of tropopause	10	10	13	13	13	12	8	8	8	8	8	8	8
Total electron content (TEC)	0	0	0	0	0	0	0	0	0	0	0	1	1
Vegetation Canopy (cover)	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetation Canopy (height)	0	0	0	0	0	0	0	0	0	0	0	0	0
Vegetation Cover	2	2	2	2	2	2	2	2	2	2	2	2	2
Vegetation type	8	8	10	10	9	9	9	9	9	9	9	10	10
Visibility	0	0	0	0	0	0	0	0	0	0	0	0	0
Volcanic ash	3	3	4	4	4	5	5	5	5	6	6	6	6
Water vapour imagery	0	0	0	0	0	1	2	2	2	2	2	3	3
Wave Directional Energy Frequency Spectrum	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind profile (horizontal)	9	10	12	13	12	13	12	11	11	12	13	13	12
Wind profile (vertical)	1	1	1	1	1	1	1	1	1	1	1	1	1
Wind speed over sea surface (horizontal)	9	10	14	14	13	12	12	11	12	12	12	15	16
Wind stress	0	0	0	0	0	0	0	0	0	0	0	1	1
Wind vector over land surface (horizontal)	0	0	0	0	0	0	0	0	0	0	0	1	1
Wind vector over sea surface (horizontal)	1	1	2	2	1	1	1	1	1	2	2	2	2

Table 3.2 provides a detailed view of the number of instruments that collected and for which data are shared (freely, without restrictions) for each of the detailed measurements that supports the Essential Climate Variables in each year from 2000 to 2012. Measurements that are robustly available, collected and shared by more than five instruments, are shown in green. Measurements that are not robustly available are shaded in yellow, and data that are not freely available from any instruments are shaded in red.

Chapter 4: Potential Incentives and Barriers to Data Sharing – Theory and Literature Review

The issue of data sharing has been debated in a broad range of fields, with unique issues and debates raised within disciplines of normative theory, economics, international relations, security theory, and organizational theory. Each of these disciplines provides important theoretical and experimental evidence and arguments related to data sharing. For the purpose of this research, I focus primarily on literature within these fields related to sharing publicly collected geospatial information, and particularly sharing of satellite remote sensing data, a specific type of geospatial information.

A common focus of the literature is in detailing arguments in support of or against various types of data sharing – most often comparing free and open data sharing with efforts to commercialize or privatize data. Some focus on conflicts between competing goals such as scientific inquiry and national security while others attempt to provide a more comprehensive lists of related issues, including benefits and drawbacks or incentives and disincentives of sharing data. There are a small number of articles that aim to provide empirical evidence to test current theories or prevailing thought.

In the following section, the ideas found in this literature are synthesized and discussed. Within each discipline, various arguments and open questions related to data sharing are debated while sharing common assumptions, values, or research focus. Therefore, this discussion is broken into a number of distinct theoretical groupings.

4.1 Normative Considerations

Normative literature focuses on identifying what is right and wrong. Normative issues are particularly important with regard to satellite data sharing. First, because data sharing can have impacts on the lives and well-being of individuals, its important to consider the potential for data sharing policies to help or harm others. If data is being used for policy-making, some argue that citizens should be given access to the data both to improve the quality of policy-making and to ensure government transparency and accountability. Finally, a large portion of scientific research data and geographic data is produced using public funding, and many articles examine the normative responsibilities of the government as a proper steward of that data, either by making it freely available to the citizens who have already paid for the data through taxation, or by acting as a public trust and selling the data to minimize the financial burden borne by citizens.

4.1.1 Public Safety

It is commonly accepted that the government should provide data and information that enhances public safety and leads to the protection of lives and property, and the need for environmental data to achieve these goals is well understood, particularly with respect to weather and natural disasters.[60] Almost all nations collect and freely share data and products related to extreme weather forecasts, such as hurricanes. To restrict access to this data is widely seen as immoral. The 1986 United Nations remote sensing principles specifically call out the need to disclose data promoting "protection of the Earth's natural environment" and "protection of mankind from natural disasters." For example, the 2000 International Charter on Space and Natural Disasters, which has gained wide acceptance and membership, represents a successful legal framework to ensure all states afflicted by disasters can benefit from space-based assets. When activated, all images of the natural disaster are provided free of charge from nations that are a part of the charter.[61] Numerous authors also call out the public interest in maximizing the use of environmental data and climate data, which can be achieved in part through free and open sharing.[62] However, the normative incentive to share data outside of the weather and natural disaster areas is less well developed.

4.1.2 Government Policy-Making, Transparency, and Accountability

Another ethical consideration is the special responsibility to share data or knowledge when it may be relevant to public policy. Access to data is important because analysis and research using the data can lead to improved policy making, and the government has an ethical responsibility to make the most well-informed and accurate decisions

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[60] *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
[61] Ito, Atsuyo. "Issues in the Implementation of the International Charter on Space and Major Disasters." *Space Policy* 21.2 (n.d.): 141-49. Web.
[62] Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.

possible.[63] Rajabifard and Williamson argue that the objective of data sharing must include the desire to stimulate better government and foster environmental sustainability.[64]

The National Research Council points out that without the ability to validate findings, it is possible that decisions or policies will be based on faulty conclusions. In addition to the potential harm to people and property that may be caused, these types of misguided actions are likely to lead to a reduction of public confidence in both the policy and research community.[65]

Further, many argue that an open government is a normatively better government, and that an informed citizenry is essential to democracy.[66] If government-collected data is used internally to make policy decisions that affect citizens, then citizens have a right

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[63] *Sharing Research Data*. Rep. National Research Council, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, 1985. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?isbn=030903499X>.

[64] Williamson, Ian P. "Spatial Data Infrastructures: An Incentive to Facilitate Spatial Data Sharing." By Abbas Rajabifard. Web. 19 Mar. 2013. <http://www.csdila.unimelb.edu.au/publication/misc/SDI_an_initative_to-facilitateSDI_GlobalEnvironmentalBook-SDI0Chapter6.pdf>.

[65] *Sharing Research Data*. Rep. National Research Council, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, 1985. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?isbn=030903499X>.

[66] Craig, William J. "White Knights of Spatial Data Infrastructure: The Role and Motivation of Key Individuals." *Journal of the Urban and Regional Information Systems Association* 16.2 (2005): 5-14. Web. 19 Mar. 2013. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.130.438&rep=rep1&type=pdf#page=5>.
Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.
Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.

to also view and analyze that data; data sharing is required to ensure government transparency and accountability. [67]

The use of geographic data to make city planning decisions, school bus routes, and emergency service plans all clearly have a personal effect on individuals, and access to this type of data is often provided through open records laws.[68] Though it may seem less personal, government actions related to climate change also affect the individuals within their own country and elsewhere, and many argue that it is necessary to facilitate access to this climate data as well.[69] Ensuring that government decisions on climate and other environmental issues are credible and in the public interest requires that citizens and scientists have access to the data to independently test and validate results.[70]

4.1.3 Equity and Fairness: Government as a Repository

It is commonly argued that government-collected data should be provided for free because the public has already paid for it through general taxation and shouldn't be

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[67] Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.
Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.

[68] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.
Onsrud, Harlan J. "Role of Law in Impeding and Facilitating the Sharing of Geographic Information." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

[69] Overpeck, Jonathan T., Gerald A. Meehl, Sandrine Bony, and David R. Easterling. "Climate Data Challenges in the 21st Century." *Science* 331.6018 (2011): 700-02. Web. 19 Mar. 2013. <http://www.sciencemag.org/content/331/6018/700.short>.

[70] *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

charged a second time.[71] The National Research Council also argues that "fair use" requires that scientific and educational communities have access to government-funded databases at no more than marginal cost.[72]

Shaffer and Backlund argue that this holds true regardless whether the data is to be used for personal, research, or commercial purposes. They ask, "If commercial housing developers want to understand earthquake risks and geological structure in an area, should they have to pay more for that understanding than a scientist who is publishing in a scientific journal?" [73] Uhrlich and Shroder further emphasize that when a fee is charged, the poorest and most disadvantaged individuals are the most likely to be unable to access data.[74] The policy of treating government as a repository is particularly compelling when free distribution of the data is likely to increase the well being of the community as a whole, or when many individuals in the general population have an interest in acquiring the data.[75]

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[71] "Free or Fee: The Governmental Data Ownership Debate: GITA White Paper." Geospatial Information & Technology Association, Aug. 2005. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/Courses/SIE525/FreeOrFee.pdf>.
Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.
Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.

[72] *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.

[73] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.

[74] Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.

[75] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.

4.1.4 Equity and Fairness: Government as a Public Trust

Some argue that rather than acting as a repository, it would be more equitable for government to act as a public trust. In this view, governments are custodians of databases for the general public, and they should try to set a price for the data that covers as much of the cost of gathering and maintaining the data as possible. Revenues can be used to offset the costs of government operations, relieving some of the pressure of general taxation.[76] Part of the argument for this model is that those who benefit most from the data should be paying a greater portion of its costs. In particular, if some users make a commercial gain from use of the data, they should contribute more to data production.[77]

The public trust model is most appropriate when there are only a few businesses or citizens that have the ability to take economic advantage of the information, due to the skills or information systems required, because in this case, freely shared government data would result primarily in private gain rather than public good.[78] Freely shared data in these cases may be seen as "unfairly subsidizing private profit at taxpayer expense."[79] There is ample evidence of this concern being salient, especially to policy-makers. Pira International reported that, "the concept of commercial companies being able to acquire, at very low cost, quantities of [public sector

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[76] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.
Commonwealth of Australia. Productivity Commission. *Cost Recovery by Government Agencies: Inquiry Report*. Melbourne: Productivity Commission, 2001. Print.
[77] Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.
[78] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.
[79] Holland, William. "Copyright, Licensing and Cost Recovery for Geographic and Land Information Systems Data: A Legal, Economic and Policy Analysis." N.p., 1997. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/tempe/holland.html>.

information] and resell it for a variety of unregulated purposes to make a profit, is one that policy makers in the EU find uncomfortable." In a paper examining the efforts of the city of Buena Vista, CA to develop a data access policy, King argues that if citizens believe the proper role of government is to act as public trust, then any "giveaway" of data could be seen as "dereliction of duty."[80]

Onrud points out a number of philosophical and practical problems with implementing a public trust for data. Historically, the idea of a public trust was meant to ensure that public resources would be protected from consumption by one generation so that they can be preserved for future generations. However, information can be provided to people now, and still be preserved, without deterioration, for future generations. A practical problem with operating a public trust is that it can be very difficult to estimate the actual number of private purchasers. Pricing that aims to fully recover costs is often quite high, making it more likely that inequities in ability to access the information will occur.[81]

4.1.5 Efficiency as a Normative Goal

It is a common assumption that efficiency is one of the goals of government, but it is important to also include this value in the context of normative discussions about the

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[80] King, John. "Problems in Public Access Policy for GIS Databases: An Economic Perspective." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. Print.

[81] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.

Onsrud, Harlan J. "Role of Law in Impeding and Facilitating the Sharing of Geographic Information." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

role of government. Richard Taupier, discussing geographic information and data access in Massachusetts, defines efficient organizations as those that aim to maximize social welfare and minimize costs. The most efficient activities are those where the social welfare to cost ratio is the greatest.[82] This normative goal is implicit in economic considerations, the topic of the following section.

4. 2 Economic Theory

Economic issues are discussed in the literature at great length, and are used more often than any other theoretical construct. Economic arguments revolve around whether data should be treated as a public good and made freely available or if it should be treated as a commodity and sold. At a basic level, it is well accepted that information is an impure public good, with properties congruent with both of these definitions, and economic theory suggests that it is possible to have an equally efficient system, i.e. one in which net social benefit is maximized, in which data is treated as a public good or in which data is treated as a commodity.

However, there are many differing opinions on the application of these theories to reality, and the extent to which various assumptions behind the theories are met. Many papers and arguments look at how these practical issues affect the relative efficiency of the two systems. These theoretical and practical arguments center

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[82] Taupier, Richard P. "Comments on the Economics of Geographic Information and Data Access in the Commonwealth of Massachusetts." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
OECD Principles and Guidelines for Access to Research Data from Public Funding. Rep. Organization for Economic Cooperation and Development, 2007. Web. 19 Mar. 2013. <http://www.oecd.org/sti/sci-tech/38500813.pdf>.

around the amount of data produced, the costs, and the benefits. The three arguments address 1) whether or not the government, on its own, is able or willing to produce an efficient amount of the good (i.e. an amount equal to total social benefit) and whether data sales or private sector involvement make it possible to come closer to efficient production levels, 2) whether a commercial entity is able to develop data collection and distribution systems at lower prices compared to the government, thus lowering costs, and 3) the extent to which various barriers, in terms of costs or licensing restrictions, actually lower the use of the data and therefore the benefits of the data. In a few cases, empirical evidence has been brought to bear on the economic issues related to data sharing, providing some insight into how these theories can best be applied.

Table 4.1 Economic Benefits and Drawbacks to Public Good vs. Commodity Models

	Amount Produced	Cost of Production	Benefits of Use
Public Good and Free Provision	May be too low if government underestimates social benefit, or has practical limitations to spending	Not affected by market incentives, government generally thought to be less efficient than industry	Free data maximizes data use and social benefit
Commodity and Data Sales	May be possible to produce greater amounts, due to combination of government and commercial investment	May produce data collection systems more efficiently (market incentives)	Barriers on data decrease use and social benefit, but amount depends on specific price/ restriction regime, and is unknown

Before looking at the differing views on the most efficient way to treat data, it is useful to look at the shared understanding of the economic characteristics of data. First, information is non-rival in consumption. This means that the use of the data by one person does not diminish the benefits received by all other consumers of the data. Further, if a good is non-rival, it follows that once it is provided, the marginal cost of another person's consuming it is zero.

Information is also non-excludable once it has been released to the public. However, individuals can be excluded if the data is not released or if it is covered by legal restrictions on its use such as copyrights and licensing agreements. This combination of traits makes information an impure public good and makes it possible to treat data either as a public good or a commodity.

Information also has a unique third trait: increasing returns to use. Kenneth Arrow addressed this in his landmark paper on "Allocation of Resources for Invention."[83] This reflects the idea that the value of data is in its use; the more people use the data and build on the information, the greater the value of that data. The output based on the use of this data increases the public welfare, often reaching far beyond those who actually work with it – for example, by increasing understanding of climate change or providing a greater variety of options in the market for specialized products and services. These positive externalities greatly increase the benefits of data. Furthermore, even after the data is given away, it is still retained by its original producer and can continue to be used.

[83] Arrow, Kenneth. "Economic Welfare and the Allocation of Resources for Invention." *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton UP, 1962. 609-26. Print.

Returns to Use: Economic Growth

A specific benefit of increasing returns to use is the overall effect on economic growth. This growth can stem from new discoveries and innovation, increased commercial activity, and improved efficiency in government or commercial sectors. It is a common belief that basic science research, which relies in part on fundamental facts and data, drives innovation and the creation of wealth around the world.[84] Information also helps to produce more products and increase effectiveness and efficiency.[85] Onsrud argues that in an information economy, the proven way to maintain a strong economy is by ensuring citizens and business have access to the data and knowledge they need to provide better information services and products to the nation and the world.[86] This important and unique aspect of information is often used in the literature as a justification for promoting the greatest possible dissemination of data.[87]

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[84] *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.
Barton, John H., and Keith E. Maskus. "Economic Perspectives on a Multilateral Agreement on Open Access to Basic Science and Technology." *SCRIPTed* (2004): n. pag. Print.

[85] Onsrud, Harlan. "The Tradgedy of the Information Commons." *Policy Issues in Modern Cartography* (1998): 141-58. Web.

[86] Onsrud, Harlan. "Access to Geographic Information: Openness versus Security."*Http://www.spatial.maine.edu/~onsrud/pubs/OpennessVsSecurityPreprint.pdf*. N.p., n.d. Web. 19 Mar. 2013.

[87] Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.
Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal* 3 (2004): 135-52. Web.

Returns to Use: More and Higher Quality Scientific Research

In addition to the general benefit of openly sharing data implied by increasing returns to use, access to data is necessary for the proper functioning of science.[88] The National Research Council's 1985 report on "Sharing Research Data," looked at these issues in detail. Availability of data reinforces open scientific inquiry and the openness of science. It allows verification, refutation, or refinement of original results, allowing scientists to check whether findings are robust to various assumptions and to replication of work with multiple data sets. This also reduces the incidence of faked and inaccurate results.[89]

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[88] Benowitz, Steve. "When Scientists Don't Share: Is Secrecy a Necessary Evil?" *Journal of the National Cancer Institute* 94.10 (2002): 712-13. Web. 19 Mar. 2013. <http://jnci.oxfordjournals.org/content/94/10/712.extract>.
Sharing Research Data. Rep. National Research Council, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, 1985. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?isbn=030903499X>.
Hedrick, Terry E. "Justifications for the Sharing of Social Science Data." *Law and Human Behavior* 12.2 (1988): 163-71. Print.
Marshall, Eliot. "The UPSIDE of Good Behavior: Make Your Data Freely Available."*Science* 299.5609 (2003): 990-91. Web.
Gardner, Daniel, Arthur W.Toga, Giorgio A. Ascoli, Ackson T. Beatty, James F. Brinkley, and Anders M. Dale. "Towards Effective and Rewarding Data Sharing." *Neuroinformatics* 1.3 (2003): 289-96. Print.
OECD Principles and Guidelines for Access to Research Data from Public Funding. Rep. Organization for Economic Cooperation and Development, 2007. Web. 19 Mar. 2013. <http://www.oecd.org/sti/sci-tech/38500813.pdf>.
Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.
Nelson, Bryn. "Data Sharing: Empty Archives." *Nature* 461.7261 (2009): 160-63. Print.
Schafer, Angela, and Heinz Pampel. *Baseline Report on Drivers and Barriers in Data Sharing*. Rep. Opportunities for Data Exchange, Seventh Framework Programme, 2011. Web. 19 Mar. 2013. <http://www.alliancepermanentaccess.org/wp-content/uploads/downloads/2011/11/ODE-WP3-DEL-0002-1_0_public_final.pdf>.
Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

[89] *Sharing Research Data*. Rep. National Research Council, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, 1985. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?isbn=030903499X>.

Access to data also allows exploration of new questions, which is important because often the full extent of alternative or future uses of data is unforeseen at the time of data production. It allows the creation of new data by joining multiple datasets together, and it encourages multiple perspectives. This may be particularly important for climate science, where multidisciplinary research is essential. Data use can even improve future data collection, as it allows scientists to develop knowledge about analytic techniques and research that may allow them to suggest improvements for future measurement and collection methods.[90]

Since economic efficiency requires maximizing the net social benefit of data, the most efficient method of producing and disseminating data will be determined by the costs of producing the systems and the benefits created by the use of data. Because data has increasing returns to use, social benefit is likely to be maximized when data distribution and use are maximized.[91] Within the economic literature, arguments

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[90] Hedrick, Terry E. "Justifications for the Sharing of Social Science Data." *Law and Human Behavior* 12.2 (1988): 163-71. Print.

[91] Taupier, Richard P. "Comments on the Economics of Geographic Information and Data Access in the Commonwealth of Massachusetts." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
Bits of Power: Issues in Global Access to Scientific Data. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.
Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.
Onsrud, Harlan Joseph., and Gerard Rushton. "Sharing Geographic Information: An Introduction." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
OECD Principles and Guidelines for Access to Research Data from Public Funding. Rep. Organization for Economic Cooperation and Development, 2007. Web. 19 Mar. 2013. <http://www.oecd.org/sti/sci-tech/38500813.pdf>.
Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.

focus on whether efficiency is maximized by treating data as a public good, with government production and free distribution, or by treating data as a commodity, with private or public production and sales of data.

4.2.1 Data as a Public Good and Free Data Distribution

Data can be viewed as a public good because it is non-rival in consumption and non-excludable once released to the public.[92] Furthermore, as mentioned above, the fact that information is non-rival implies that its marginal cost (the cost of one additional person consuming the data) is zero. This fact suggests that private provision will likely lead to efficiency problems. This is because if the marginal cost of providing the public good to another person is zero, the efficient price is zero. If an entrepreneur sets a price greater than zero in order to earn revenues, then some people who place a relatively low, but positive value on the good are inefficiently excluded.[93] Also, because data has positive externalities that are not captured by the market, for example advances in climate science that benefit everyone, the private sector is likely to under-produce this good. Therefore, as with other public goods, such as national

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Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.
Harris, Ray, and Nicola Olby. "European Perspectives on Trends in Public Sector Earth Observation Data Policies." *Space Policy* 16.1 (2000): 45-59. Web.

Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.
Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies." *International Journal of Geographical Information Science* 23.2 (2009): 195-212. Web.
[92] Mas-Colell, Andreu, Michael Dennis. Whinston, and Jerry R. Green. *Microeconomic Theory*. New York: Oxford UP, 1995. Print.
[93] Katz, Michael L., and Harvey S. Rosen. *Microeconomics*. Boston, MA: McGraw-Hill, 1998. Print.

defense, the implication is that net social benefit is maximized through government provision, i.e. data is produced most efficiently by the government.

Practical Considerations: Efficient Level of Production

It is important to note that despite its advantages over the private sector in this area, government data provision may still provide an inefficient amount of the good. As Paul Samuelson described in his 1954 publication, "The Pure Theory of Public Expenditure," determining the efficient provision would require summing each individual's marginal benefit from the production of the good to determine the marginal social benefit, and it is impossible to know these values in reality.[94]

Government provision of environmental data may be limited not only by difficulties in determining the true social benefits, but also by the capabilities of the government. There are a number of public goods for which the benefits of production are higher than the costs of production, but practical limitations in government funding make it unlikely that all of these projects would be funded to the full, economically efficient level. The government does not and cannot take on every project or program in which cost-benefit analysis is positive.

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[94] Samuelson, Paul A. "The Pure Theory of Public Expenditure." *Review of Economics and Statistics* 36.4 (1954): 387-89. Print.

Practical Considerations: Maximizing Data Use

The data sharing literature that focuses on the public good aspects of data advocates for government collection of data and distribution at zero cost.[95] This includes free access to the data for all possible uses, including operational, scientific, social, commercial, and political uses.[96] Given the fixed costs of data collection and dissemination systems, it is argued that free data provision leads to the greatest possible data use which in turn leads to maximization of social benefits, and is the most economically efficient outcome. Tulloch and Harvey put it simply, saying, "the more it is shared, the more it is used, and the greater becomes society's ability to

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[95] King, John. "Problems in Public Access Policy for GIS Databases: An Economic Perspective." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
Bits of Power: Issues in Global Access to Scientific Data. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.
Onsrud, Harlan. "The Tragedy of the Information Commons." *Policy Issues in Modern Cartography* (1998): 141-58. Web.
Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.
Barton, John H., and Keith E. Maskus. "Economic Perspectives on a Multilateral Agreement on Open Access to Basic Science and Technology." *SCRIPTed* (2004): n. pag. Print.
Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
Smith, L., and C. Doldirina. "Remote Sensing: A Case for Moving Space Data towards the Public Good." *Space Policy* 24.1 (2008): 22-32. Web.
Thomas, G. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.
Taupier, Richard P. "Comments on the Economics of Geographic Information and Data Access in the Commonwealth of Massachusetts." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
Johnston, S. "Public Good or Commercial Opportunity? Case Studies in Remote Sensing Commercialization." *Space Policy* 19.1 (2003): 23-31. Web.
[96] Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.
Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal*3 (2004): 135-52. Web.

evaluate and address the wide range of pressing problems to which such information may be applied."[97]

In theory, free provision of data without restrictions, a policy consistent only with government production of data, maximizes benefits by maximizing use of the data. Existing empirical research supports this theory. A 1999 report developed for the European Commission argued that the value-added sector, which uses data to create specialized information products to be sold, was much larger in the United States, where data was provided free, compared to Europe, where data policies were more restrictive. They argued that EU companies were at a serious disadvantage compared to their American counterparts, which benefit from the timely availability of public sector information.[98] The National Research Council notes that these value-added products benefit industries such as agriculture, transportation, fishing, mining, recreation, and weather.[99] There is also some empirical evidence that the returns to science are also considerable; the accelerated pace of discovery in genomics is often credited to action taken by that community to support the rapid and open sharing of data.[100]

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[97] Harvey, F., and D. Tulloch. "Local-government Data Sharing: Evaluating the Foundations of Spatial Data Infrastructures." *International Journal of Geographical Information Science* 20.7 (2006): 743-68. Web.

[98] *Public Sector Information: A Key Resource for Europe: Green Paper on Public Information in the Information Society*. Brussels: European Commission, 1998. Print.

[99] *Utilization of Operational Environmental Satellite Data: Ensuring Readiness for 2010 and Beyond*. Rep. National Research Council, Committee on Environmental Satellite Data Utilization, 2004. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=11187>.

[100] Rodriguez, Henry, Mike Snyder, and Mathias Uhlén. "Recommendations from the 2008 International Summit on Proteomics Data Release and Sharing Policy: The Amsterdam Principles." *Journal of Proteome Research* 8.7 (2009): 3689-692. Web.

Looking at the alternatives, it is likely that any cost imposed on the data will reduce the dissemination and the use of that data, thus reducing the overall social benefit. Part of the reason that government action is required to collect data is that while the value of the data to society as a whole is quite large, the value to any one user may be very small. By imposing even a nominal price on the data, the government may prevent scientists, companies, or other individuals from using the data to contribute to the public good. It is this reason that often leads authors to suggest that governments build the cost of data dissemination into the overall cost of the data collection project and ensure that data is disseminated without charge to all users.

Practical Considerations: Zero Marginal Cost

Part of the theoretical definition of a public good is that its marginal cost is zero. However, in reality the marginal cost of providing data to an addition user is unlikely to be zero and could in some cases be significant – for example, reaching thousands of dollars for one scene collected by a satellite.[101] Because multiple people within the government typically use data that the government collects, it is reasonable to assume that even without data sharing, the government develops the algorithms, meta data,

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Kaye, Jane, Catherine Heeney, Naomi Hawkins, Jantina De Vries, and Paula Boddington. "Data Sharing in Genomics — Re-shaping Scientific Practice."*Nature Reviews Genetics* 10.5 (2009): 331-35. Web.
"Prepublication Data Sharing." *Nature* 461.7261 (2009): 168-70. Web.
[101] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.
<http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.
Taupier, Richard P. "Comments on the Economics of Geographic Information and Data Access in the Commonwealth of Massachusetts." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.

and other documentation to make the data useful to others. It also must have some storage and access technology. However, if providing open access to the data is likely to greatly increase data requests, the government will need to invest in additional technology, for example, high capacity internet servers. It may also be important to provide additional documentation to make the data useful to people from other disciplines who may be less familiar with a particular type of data and how to use it. Efficient and user-friendly access portals may also need to be developed. All of these materials will need to be maintained over time.

However, charging an above-zero marginal cost is not as straightforward as it may seem, and poses a number of efficiency issues. For practical reasons, it is necessary that a fixed price be set. Charging each user the actual marginal cost of fulfilling their request would be unpredictable and somewhat arbitrary. For example, if the government has an efficient data sharing system set up that served the first 1,000 users, the actual marginal cost of serving the 1,001 user might be essentially zero. However, at some threshold, say 5,000 users, it may be necessary to upgrade the system. It would be absurd to expect that 5,000th user to pay the full costs of the system upgrade, even if it was truly the marginal cost of fulfilling his or her request.

Prices could be set at the average cost per user, but over-estimating or under-estimating the expected number of users, which depends significantly on the price that is set, could result in further inefficiencies. If the number of users is over-estimated, then the prices charged each user will be too low, and marginal costs will not be covered. If the number of users is under-estimated, each of these users will have been charged above marginal cost, leading to an inefficiently low use of the data.[102]

Finally, if the government decides to charge a fee for accessing data, the government will have to spend the time and develop the infrastructure necessary to assess the correct fee, accept payment, and manage the funds that are raised. This requires the development of a fee-accepting system.[103] Because marginal costs tend to be quite small, in some cases the cost of administering the fees may be larger than the fees collected.[104]

Even in 1962, Arrow noted that the cost of transmitting data is frequently very low. And many authors have noted that with the improvements and cost decreases in information technology that have occurred over time, and particularly with the growth of the internet, marginal costs of fulfilling user requests are smaller than ever.[105]

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102 Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.
<http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.

103 Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies." *International Journal of Geographical Information Science*23.2 (2009): 195-212. Web.

104 Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013.
<http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.

105 Onsrud, Harlan Joseph., and Gerard Rushton. "Sharing Geographic Information: An Introduction." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
Felkner, John. "An Analysis of the Current State of International Remote Sensing Data Exchange and Transfer." *International Society for Photogrammetry and Remote Sensing (ISPRS)*. Proc. of XVIIIth ISPRS Congress, Vienna, Austria. N.p., July 1996. Web. 19 Mar. 2013.
<http://www.isprs.org/proceedings/XXXI/congress/part6/>.
Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.

Further, some point out that if the data is provided without restrictions on re-distribution, it is possible for users to share the data with others at no cost to the agency that originally developed the information.[106] Together, these arguments suggest that building the cost of dissemination into overall program costs and then providing data for free is more efficient than charging each user a small marginal cost.

4.2.2 Data as a Commodity and Data Sales

In theory, treating data as a commodity and selling it to at least some users above marginal cost can be equally efficient to treating data as a public good. This is achieved through perfect price discrimination, in which each user is charged based on his or her willingness to pay for the data. As long as the price is not above the individual's willingness to pay, each user will find the transaction beneficial, and data use will be maximized. Assuming the costs of data production and provision are not increased by this practice, overall social benefit will be maximized, and only the incidence of cost and benefits will change, with the data producer capturing more of the benefits and the consumer less. Further, if the private sector is involved in data sales, market incentives lead private industry to produce goods more efficiently than the government, reducing program costs.[107]

Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal*3 (2004): 135-52. Web.

[106] Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.

[107] Harris, Ray, and Nicola Olby. "European Perspectives on Trends in Public Sector Earth Observation Data Policies." *Space Policy* 16.1 (2000): 45-59. Web.

There are three primary models for data production and sales, all of which implement some type of price discrimination: government cost recovery, public-private

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Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
Dick, Steven J., and Roger D. Launius. "The Social and Economic Impact of Earth Observing Satellites." *Societal Impact of Spaceflight*. Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. N. pag. Print.
King, John. "Problems in Public Access Policy for GIS Databases: An Economic Perspective." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
Onsrud, Harlan J. "Role of Law in Impeding and Facilitating the Sharing of Geographic Information." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
Felkner, John. "An Analysis of the Current State of International Remote Sensing Data Exchange and Transfer." *International Society for Photogrammetry and Remote Sensing (ISPRS)*. Proc. of XVIIIth ISPRS Congress, Vienna, Austria. N.p., July 1996. Web. 19 Mar. 2013. <http://www.isprs.org/proceedings/XXXI/congress/part6/>.
Marshall, E. "Data Sharing: A Declining Ethic?" *Science* 248.4958 (1990): 952-57. Web.
Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.
Commercial Exploitation of Europe's Public Sector Information. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013. <http://ec.europa.eu/information_society/policy/psi/docs/pdfs/pira_study/2000_1558_en.pdf>.
Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.
United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.
Craglia, Max, and Ian Maser. "Access to Geographic Information: A European Perspective." *Journal of the Urban and Regional Information Systems Association*15.1 (2003): 51-60. Web. 19 Mar. 2013. <http://www.urisa.org/files/vol15apa1.pdf>.
Eisenberg, R. S. "Patents and Data-sharing in Public Science." *Industrial and Corporate Change* 15.6 (2006): 1013-031. Web.
Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies." *International Journal of Geographical Information Science*23.2 (2009): 195-212. Web.
Lutes, Charles D., Peter L. Hays, Vincent A. Manzo, Lisa M. Yambrick, and M. Elaine. Bunn. "Space Power and the Enviornment." *Toward a Theory of Spacepower: Selected Essays*. Washington, DC: National Defense UP, 2011. N. pag. Print.
Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age."*Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.
Goward, S. "Acquisition of Earth Science Remote Sensing Observations from Commercial Sources: Lessons Learned from the Space Imaging IKONOS Example." *Remote Sensing of Environment* 88.1-2 (2003): 209-19. Web.
Barton, John H., and Keith E. Maskus. "Economic Perspectives on a Multilateral Agreement on Open Access to Basic Science and Technology." *SCRIPTed* (2004): n. pag. Print.

partnerships, and commercial entities that sell to governments and other customers. Cost recovery refers to "a mechanism for pricing access to information in order to allay all or some of the costs incurred by the government agency holding the [information]."[108] The National Research Council defines commercialization in this area as the financial exploitation of government data and privatization as the transfer of government functions to the private sector.[109]

Furthermore, there is ample evidence that it is possible to sell data and information products successfully. Kenneth Arrow elaborates on information as a commodity in his 1962 paper on the "Allocation of Resources for Invention," noting, "information frequently has economic value, in the sense that anyone possessing the information can make greater profits than would otherwise be the case." He also notes that there is already a market for the sale of certain types of information, such as newspapers.[110] Environmental data in particular have numerous uses and can have high economic value in agriculture, mining, transportation, and numerous other areas.[111] The

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108 *Commercial Exploitation of Europe's Public Sector Information*. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013. <http://ec.europa.eu/information_society/policy/psi/docs/pdfs/pira_study/2000_1558_en.pdf>.

109 *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

110 Arrow, Kenneth. "Economic Welfare and the Allocation of Resources for Invention."*The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton UP, 1962. 609-26. Print.

111 Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age." *Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.
Dick, Steven J., and Roger D. Launius. "The Social and Economic Impact of Earth Observing Satellites." *Societal Impact of Spaceflight*. Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. N. pag. Print.

National Academy of Public Administration estimated that $3.56 trillion of U.S. economic activity was directly related to geographic information in 1998.[112]

Practical Considerations: Efficient Level of Production

In theory, the government should collect and provide data at a level consistent with the social benefit of that data. However, as mentioned earlier, this may not happen due to practical limitations on government spending. Building on this observation, one of the major benefits of treating data as a commodity is that private investment in data collection systems, either as part of a public-private partnership or a fully commercial venture, result in more data collection than would otherwise take place, bringing production closer to the economically efficient level. If private companies are providing additional data that the government could not afford to procure, this increases overall social benefit.[113]

Some suggest that this argument could be extended to government cost recovery. Limits on government spending and budgetary pressures are commonly cited as one of the reasons that governments turn to cost recovery, and the implication is that governments could not afford data collection at the same level without these

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[112] United States. *Value of Civil Imagery and Remote Sensing*. Federal Geographic Data Committee, Civil Imagery and Remote Sensing Task Force, 1 Oct. 2002. Web. 19 Mar. 2013. <http://www.fgdc.gov/participation/coordination-group/meeting-minutes/2002%20meeting%20minutes/may/cirs_report.pdf>.

[113] *Toward New Partnerships In Remote Sensing Government, the Private Sector, and Earth Science Research*. Rep. National Research Council, Steering Committee on Space Applications and Commercialization, 2002. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10500>.

measures.[114] However, empirical evidence shows that government cost recovery generates very little revenue, often just two or three percent of total project costs, and does not have a major impact on data collection capabilities.[115]

One reason to believe that commercial involvement leads to additional data collection is that government and commercial data producers focus on meeting the needs of different types of users. Governments are primarily interested in data with scientific or operational value, or data that will inform public-policy making. Commercial data providers are driven by potential revenues, which largely come from commercial data users in the agricultural, mining, oil, or other industries. Evidence suggests that the data needs of these users are quite different. [116] The National Research Council notes that commercial uses of data often involve high-resolution images taken of limited areas over limited times based on purchaser request. By contrast, environmental

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114 *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.
Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies." *International Journal of Geographical Information Science*23.2 (2009): 195-212. Web.
Benowitz, 2002) [When Scientists Don't Share - Is Secrecy a Necessary Evil, Journal of the National Cancer Institute]

115 Onsrud, Harlan. "Is Cost Recovery Worthwhile." Proc. of URISA 1995 Annual Conference Proceedings, Washington, DC. Urban and Regional Information Systems Association, 1995. Web.
Harris, R. "Current Policy Issues in Remote Sensing: Report by the International Policy Advisory Committee of ISPRS." *Space Policy* 19.4 (2003): 293-96. Web.
Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.

116 Birk, R. "Government Programs for Research and Operational Uses of Commercial Remote Sensing Data." *Remote Sensing of Environment* 88.1-2 (2003): 3-16. Web.
Goward, S. "Acquisition of Earth Science Remote Sensing Observations from Commercial Sources: Lessons Learned from the Space Imaging IKONOS Example." *Remote Sensing of Environment* 88.1-2 (2003): 209-19. Web.
Johnston, S. "Public Good or Commercial Opportunity? Case Studies in Remote Sensing Commercialization." *Space Policy* 19.1 (2003): 23-31. Web.

research requires consistent coverage over time and space and full disclosure of instrument specifications and calibration.[117]

With regard to satellite remote sensing, high-resolution data and synthetic aperture radar data seem to have the greatest value to private industry. Nearly all satellite remote sensing companies that develop and operate their own satellites specialize in one or both of these types of data. Medium and low-resolution satellite data has significantly less value on the commercial market. In 2001, NASA and the USGS consulted with the commercial remote sensing industry in developing a procurement approach for the follow-on to the Landsat-7 satellite, which collects medium-resolution imagery that has proven very valuable for scientific research. The industry argued the market was insufficient to support a private sector-only option.[118] If, as in this example, commercial industry is interested in providing data primarily of interest to commercial users while government is left to collect data whose primary value is scientific, the combination of commercial and government funding may lead to greater data provision than would otherwise occur.[119]

However, though there are many differences between commercial and scientific data needs, and certain data may be more useful for one group than the other, there are

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[117] *Toward New Partnerships In Remote Sensing Government, the Private Sector, and Earth Science Research*. Rep. National Research Council, Steering Committee on Space Applications and Commercialization, 2002. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10500>.
[118] Williamson, R. "Current US Remote Sensing Policies: Opportunities and Challenges."*Space Policy* 20.2 (2004): 109-16. Web.
[119] Harris, R. "Current Policy Issues in Remote Sensing: Report by the International Policy Advisory Committee of ISPRS." *Space Policy* 19.4 (2003): 293-96. Web.

also significant overlaps in data use.[120] For example, a program was carried out in which NASA bought some high-resolution remote sensing data from a commercial operator and provided it to scientists for evaluation and use. The scientists reported that the data was very valuable for research.[121] In another case, the SeaWIFS instrument, which provided sea color data of great interest to scientists, was developed as part of a public-private partnership. The private vendor owned and operated the satellite, selling the most up-to-date information, and then releasing data to the government for free distribution after a set period of time.[122]

Practical Considerations: Minimizing Production Costs

The second consideration in determining whether data should be treated as a public good and provided for free or treated as a commodity and sold is based on differences in the cost of production. Some argue that even government cost recovery is more efficient than free provision because funds from data sales reduce dependence on general taxation. However, this does not seem to have a meaningful effect, particularly because revenues from cost-recovery are so low in practice.[123] Instead,

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[120] Goward, S. "Acquisition of Earth Science Remote Sensing Observations from Commercial Sources: Lessons Learned from the Space Imaging IKONOS Example." *Remote Sensing of Environment* 88.1-2 (2003): 209-19. Web.

[121] *Toward New Partnerships In Remote Sensing Government, the Private Sector, and Earth Science Research*. Rep. National Research Council, Steering Committee on Space Applications and Commercialization, 2002. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10500>.

[122] *Toward New Partnerships In Remote Sensing Government, the Private Sector, and Earth Science Research*. Rep. National Research Council, Steering Committee on Space Applications and Commercialization, 2002. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10500>.

[123] Commonwealth of Australia. Productivity Commission. *Cost Recovery by Government Agencies: Inquiry Report*. Melbourne: Productivity Commission, 2001. Print.

the primary production efficiency benefits stem from the involvement of private industry.

Allowing information to be privatized can create incentives for innovation and efficiency. The U.S. patent system provides a good example. On the surface, it may seem that social benefit would be maximized by making all information regarding new ideas and inventions available to everyone right away. However, this would eliminate the incentive for individuals or companies to invent new products, since they would not be able to reap any of the benefits of their invention. Therefore, to create an incentive to do the research and work necessary to invent new products, governments grant patents on those inventions, allowing the company or individual to appropriate at least some of the financial benefits the new invention will enable.[124]

Similar logic lies behind an argument for legal protections for environmental data.[125] Granting companies the right to appropriate some of the benefits of their data collection creates the incentive necessary for the development of such a system. Further, in a commercial market, data producers have incentives to create systems that best meet customer needs and to develop these systems at the lowest cost possible. In this way, privatization incentivizes innovation and advancements in data

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[124] Onsrud, Harlan. "The Tradgedy of the Information Commons." *Policy Issues in Modern Cartography* (1998): 141-58. Web.
Eisenberg, R. S. "Patents and Data-sharing in Public Science." *Industrial and Corporate Change* 15.6 (2006): 1013-031. Web.
Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.

[125] Barton, John H., and Keith E. Maskus. "Economic Perspectives on a Multilateral Agreement on Open Access to Basic Science and Technology." *SCRIPTed* (2004): n. pag. Print.
Maurer, Stephen, Bernt Hugenholtz, and Harlan Onsrud. "Europe's Database Experiment." *Science* 294.5543 (2001): 789-90. Web.

collection technologies, resulting in more capable and/or less expensive data collection systems.[126] Advocates of privatization argue that the resulting improvements in cost and quality of data collection systems outweigh the reductions in data use caused by legal restrictions and higher access costs.[127] If the government purchases an open data license from a data collection company and then provides the data for free or at a low cost for certain types of users, for example, scientists and researchers, then commercial data collection simply represents an alternative procurement method of the government, and one in which costs are likely lower.

Unfortunately, the specific characteristics of remote sensing technology are likely to decrease the effectiveness of normal market incentives. Remote sensing satellites have high fixed costs and very low marginal costs, characteristics that lead to natural monopolies. When natural monopolies exist, a small number of firms are likely to dominate the market, other firms will be discouraged from entering, and prices will be inefficiently high. The lack of competition also reduces the incentive for innovation and cost reductions.[128]

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126 Williamson, Ian P. "Spatial Data Infrastructures: An Incentive to Facilitate Spatial Data Sharing." By Abbas Rajabifard. N.p.: n.p., n.d. N. pag. Web. 19 Mar. 2013. <http://www.csdila.unimelb.edu.au/publication/misc/SDI_an_initative_to-facilitateSDI_GlobalEnvironmentalBook-SDI0Chapter6.pdf>.

127 Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.

128 Commonwealth of Australia. Productivity Commission. *Cost Recovery by Government Agencies: Inquiry Report*. Melbourne: Productivity Commission, 2001. Print.
Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies." *International Journal of Geographical Information Science*23.2 (2009): 195-212. Web.
Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.
Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.

Practical Considerations: Maximizing Data Use

The notion that data sales can result in the same level of data use as free provision of data is based on the theory of perfect price discrimination. Of course, it is not possible in reality for a data distributer to know each potential user's willingness to pay.[129] Even approximating this practice by negotiating unique prices for each new customer would likely be prohibitively expensive, time-consuming, and inefficient.[130] Instead, price discrimination is usually implemented through a pricing policy that discriminates between a small number of groups. Government cost recovery and public-private partnerships often implement "tiered" policies, in which multiple pricing tiers are developed for different types of consumers.[131] The merits of such a policy are commonly discussed in the literature.[132]

Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

[129] King, John. "Problems in Public Access Policy for GIS Databases: An Economic Perspective." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

[130] Craglia, Max, and Ian Maser. "Access to Geographic Information: A European Perspective." *Journal of the Urban and Regional Information Systems Association*15.1 (2003): 51-60. Web. 19 Mar. 2013. <http://www.urisa.org/files/vol15apa1.pdf>.

[131] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.
Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.
Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.

[132] *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.
Green Paper, 1999) [Public sector information: A key resource for Europe
Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.
Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.

In cases where data is entirely privatized, with no government involvement, tiered policies are less common. However, price discrimination can still occur if the government purchases data licenses that allow it to make that data available to scientists or others at a lower cost. [133] Similarly, the government could provide funding directly to scientists for commercial data purchases. Both Harris and the National Research Council consider this scenario, arguing that if the cost of data was included in the grants researchers get from the government for their research programs, this would make it possible for scientists to access commercial data. In this method, the public good, data, is still being publicly funded, suggesting that the program would be efficient. It could even be considered superior, since the funding is now in the hands of the consumer of data and can be used as a kind of market signal.[134] However, the National Research Council concluded that this method of funding would have a number of disadvantages. First, while a data collection agency has the incentive and voice to request a stable level of funding from Congress, individual scientists are likely to have a harder time ensuring that overall funding

OECD Principles and Guidelines for Access to Research Data from Public Funding. Rep. Organization for Economic Cooperation and Development, 2007. Web. 19 Mar. 2013. <http://www.oecd.org/sti/sci-tech/38500813.pdf>.

[133] *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.

Public Sector Information: A Key Resource for Europe: Green Paper on Public Information in the Information Society. Brussels: European Commission, 1998. Print.

Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.

[134] Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.

Bits of Power: Issues in Global Access to Scientific Data. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.

remains the same. Smaller, individual grants are also more likely to be affected significantly by shortfalls in the national budget.[135]

Regardless of exactly how tiered policies are implemented, the data costs and legal restrictions required by this model will reduce data use, therefore reducing social benefits. Since the marginal cost of data provision is essentially zero, any individual whose willingness to pay is above zero but below the price set for their user group will be inefficiently excluded. The higher the prices, the less the data is shared, and the less it is used.[136] Additional inefficiencies occur when high prices drive others to build redundant systems, use inferior data, or not use the data at all.[137]

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135 *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.

136 *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.
(Benowitz, 2002) [When Scientists Don't Share - Is Secrecy a Necessary Evil, Journal of the National Cancer Institute]
Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies." *International Journal of Geographical Information Science*23.2 (2009): 195-212. Web.
Onsrud, Harlan. "The Tradgedy of the Information Commons." *Policy Issues in Modern Cartography* (1998): 141-58. Web.
Achache, José. "Open Access to Earth Observation From Space: Opportunity or Threat to Security?" ESA (European Space Agency). Speech.
Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.

137 *Commercial Exploitation of Europe's Public Sector Information*. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013. <http://ec.europa.eu/information_society/policy/psi/docs/pdfs/pira_study/2000_1558_en.pdf>.

A number of scholars suggest that scientists often get priced out of the market entirely.[138] As discussed earlier, free sharing of data within the scientific community is essential to the proper functioning of science, and intellectual property rights can particularly harm scientific progress through limits on redistribution.[139] Further, research, operational, and commercial uses are often treated differently in tiered policies. However, Harris argues that the transition from research to operations often is not clear; systems may have a mix of fully operational elements and pre-operational elements.[140] Overpeck noted that about half of international environmental modeling groups were restricted from sharing digital climate model data beyond the research community because of intellectual property rights imposed by governments.[141]

This effect extends to commercial users, who are often the primary target of efforts at cost-recovery or commercialization. The increase in cost means that only some interested firms will be able to utilize the data, and all firms for which the value of the data is above marginal cost but below the market price will be inefficiently excluded from the market. This results in a reduction in the size of the value-added sector

[138] Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.

[139] Maurer, Stephen, Bernt Hugenholtz, and Harlan Onsrud. "Europe's Database Experiment." *Science* 294.5543 (2001): 789-90. Web.

[140] Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.

[141] Overpeck, Jonathan T., Gerald A. Meehl, Sandrine Bony, and David R. Easterling. "Climate Data Challenges in the 21st Century." *Science* 331.6018 (2011): 700-02. Web. 19 Mar. 2013. <http://www.sciencemag.org/content/331/6018/700.short>.

overall, and a reduction in the variety and quality of products available for public consumption.[142]

There is evidence that this effect could be quite large. In fact, "Commercial Exploitation of Europe's Public Sector Information," released in 2000, included the surprising result that efforts at cost recovery may actually lead to a net financial loss to the government. According to the report, "although governments gain income from the commercial license fees, they lose the taxation and employment benefits from the higher volumes of commercial activity that would be generated by abandoning charges. We find that a conservative projection of a doubling of market size resulting from eliminating license fees would produce additional taxation revenues to more than offset the lost income from PSI charges [in Europe]." The doubling of market size was seen as conservative because while European and U.S. economies are of similar size, the United States' information market was estimated to be two to five times larger than Europe's.[143]

As described in the case of marginal cost pricing, the need to charge users a fee for data use is a transaction cost that adds to administration overhead, resulting in higher costs and inefficiency.[144] It also takes time, effort, and legal skill to draft a good

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[142] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.
[143] *Commercial Exploitation of Europe's Public Sector Information*. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013.
United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.
[144] Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.

contract or license. Lawyers may need to be consulted when dealing with particular user requests. Once contracts and licenses are involved, there is also the possibility of breach of contract lawsuits and other legal action.[145] Further, efforts at policing the policy, ensuring that data provided for research use is not used for commercial purposes, for example, would add additional costs.[146]

Consumers of data face transaction costs, as well, as they negotiate and abide by licensing agreements. Some argue that smaller companies may not have the legal resources to investigate and negotiate complex contracts or licensing regimes.[147] Scientists are likely to face even greater difficulties in dealing with these issues; they are less likely to have the time and resources to understand and maneuver legal barriers.[148] For environmental research, it is often necessary to use data from multiple sources. If scientists have to go through multiple different permissions processes, this process could be overly burdensome, even if the data is free, and could result in less research being done.[149]

The U.S. Landsat remote sensing satellite is often used as an example to demonstrate the detrimental effects of treating Earth observation data as a commodity. Wulder et

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Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.

[145] Onsrud, Harlan. "Is Cost Recovery Worthwhile." Proc. of URISA 1995 Annual Conference Proceedings, Washington, DC. Urban and Regional Information Systems Association, 1995. Web.

[146] Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.

[147] *Commercial Exploitation of Europe's Public Sector Information*. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013. <http://ec.europa.eu/information_society/policy/psi/docs/pdfs/pira_study/2000_1558_en.pdf>.

[148] Harris, Ray, and Roman Krawec. "Some Current International and National Earth Observation Data Policies." *Space Policy* 9.4 (1993): 273-85. Web.

[149] *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

al documents this case, explaining that in 2001, when Landsat images were sold at a price of $600 per scene, the Earth Resources Observation Science (EROS) Center provided about 25,000 images to users. When data was made free in 2008, use of the data rapidly increased; EROS provided approximately 2.5 million images in 2010. In addition to the increase in throughput, the paper also noted a rapid increase in scientific investigations and applications using Landsat, including widespread use by end users in a variety of disciplines. Though some of this increase is likely due to advancements in technical capability to analyze these types of datasets, it still provides a strong case that making data available for free, rather than charging a fee, will dramatically increase its use.[150]

Practical Considerations: Supporting Commercial Sector Development

As discussed above, commercial data provision can have a number of benefits, particularly in promoting innovation and lowering costs. Due to these benefits, it is commonly agreed that one of the proper roles of government is to help spur the development of new commercial industries.[151] While there might be short-term inefficiencies in subsidizing these industries, governments believe that there will be long-term economic benefits. However, some argue that there is no viable commercial market for commercial remote sensing data without the government,

[150] Wulder, Michael, Jeffrey Masek, Warren Cohen, Thomas Loveland, and Curtis Woodcock. "Opening the Archive: How Free Data Has Enabled the Science and Monitoring Promise of Landsat." *Remote Sensing of Environment* 122 (2012): 2-10. Web.
[151] Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.

even in the long run, and that by subsidizing these companies the government is only distorting the market and unnecessarily restricting data use.[152]

Practical Considerations: False Cost-Benefit Analysis

The discussion here focuses exclusively on economic efficiency defined as maximization of net social benefit. However, even policies that have similar net social benefits often differ in the incidence of costs and benefits. This can lead to certain policies looking more attractive to particular users.[153] For example, Harris and Olby point out that opinions on data pricing often differ between the data provider and the data user organizations, because users prefer to view the data as a public good (in which free data provision is the norm), while producers see it as a commodity (which results in data sales).[154]

The 2000 Pira Report warns that cost recovery may look like an obvious way for governments to improve efficiency by minimizing costs of creating public sector

[152] *Toward New Partnerships In Remote Sensing Government, the Private Sector, and Earth Science Research*. Rep. National Research Council, Steering Committee on Space Applications and Commercialization, 2002. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10500>.
Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.
Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.
Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.
[153] *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.
[154] Harris, Ray, and Nicola Olby. "European Perspectives on Trends in Public Sector Earth Observation Data Policies." *Space Policy* 16.1 (2000): 45-59. Web.

information and maximizing the value for the money directly. However, they point out that while government agencies may see a greater benefit within their agency from data sales, this may not be the best approach to maximizing economic value of public sector information to society as a whole.[155]

4.3 Institutional Theory

The application of economic theory is one of the most commonly discussed in the literature, but the importance of institutional theories, particularly related to the provision of global public goods and international cooperation is clear from the global nature of climate change. This section examines how these theories relate to international sharing of satellite data for climate, and how the related literature has built on these themes.

4.3.1 Global Public Goods

As discussed earlier, public goods are those that are non-excludable and non-rival in consumption. They often have externalities – results of an action that have effects outside of the transaction. We noted that data, which is a form of information or knowledge, has these attributes, and thus is a public good. It is interesting to note that climate change also meets these criteria, though it may be thought of more as a "public bad," as its effects are generally deleterious.

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[155] *Commercial Exploitation of Europe's Public Sector Information*. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013. <http://ec.europa.eu/information_society/policy/psi/docs/pdfs/pira_study/2000_1558_en.pdf>.

In 1999, the United Nations Development Program released a landmark publication entitled, "Global Public Goods: International Cooperation in the 21st Century." This collection of papers provided a definition of global public goods, noted the challenges often associated with their provision, and addressed specific subject areas where the theory applies – including both knowledge and climate change.[156]

The editors, Kaul, Gurnberg, and Stern, begin by defining global public goods, stating, "a pure global public good is marked by universality—that is, it benefits all countries, people and generations. An impure global public good would tend towards universality in that it would benefit more than one group of countries, and would not discriminate against any population segment or set of generations."[157]

It is widely recognized within the literature on data sharing that scientific data and climate change both have characteristics that make them inherently global issues.[158]

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156 Kaul, Inge, Isabelle Grunberg, and Marc A. Stern. "Defining Global Public Goods."*Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.
Heal, Geoffrey. "New Strategies for the Provision of Global Public Goods: Learning from International Environmental Challenges." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.
Stiglitz, Joseph. "Knowledge as a Global Public Good." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.
157 Kaul, Inge, Isabelle Grunberg, and Marc A. Stern. "Defining Global Public Goods."*Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.
158 Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal*3 (2004): 135-52. Web.
Bits of Power: Issues in Global Access to Scientific Data. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.
Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.
Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.
Landis, Robert. "Future of International Cooperation in Meteorological and Related Services." Proc. of American Meteorological Society 88th Annual Meeting, New Orleans, LA. N.p., Jan. 2008. Web. 20 Mar. 2013. <https://ams.confex.com/ams/88Annual/techprogram/programexpanded_452.htm>

The National Research Council explains, “Data in science are universal—they have the same validity for scientists everywhere.”[159] Harris mentions the intergenerational aspect of environmental data, stating that the value of the data may actually increase over time, thus benefiting future generations even more, particularly for climate change, which relies on long-term records.[160]

This definition has important implications. The efficient production of a public good requires that it be produced up to the point that the marginal cost equals the marginal social benefit, where the marginal social benefit is defined as the sum of all individual benefits. For a global public good, the definition is the same, but now the marginal social benefits should also include the sum of benefits from individuals in multiple nations and multiple generations. Nations rarely consider the benefits to citizens of other nations when determining how much of a good to produce. It seems to be even more rare for countries to consider the benefits to generations other than those currently living. Because they do not take into account these full benefits, global public goods generally suffer from under-provision.[161]

Felkner, John. "An Analysis of the Current State of International Remote Sensing Data Exchange and Transfer." *International Society for Photogrammetry and Remote Sensing (ISPRS)*. Proc. of XVIIIth ISPRS Congress, Vienna, Austria. N.p., July 1996. Web. 19 Mar. 2013. <http://www.isprs.org/proceedings/XXXI/congress/part6/>.
Achache, José. "Open Access to Earth Observation From Space: Opportunity or Threat to Security?" ESA (European Space Agency). Speech.

[159] *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.

[160] Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.

[161] Sandler, Todd. "Intergenerational Public Goods: Strategies, Efficiency and Institutions."*Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.

Kaul, Gurnberg, and Stern also present the important concept of final global public goods and intermediate global public goods. A final good is an outcome, such as a clean environment or the availability of knowledge. An intermediate public good contributes towards the provision of final public goods, though it may not have any intrinsic value on its own.[162] The case of international data sharing is interesting, because this may be seen as both a final good – it involves accessibility of knowledge – and as an intermediate good – it contributes to the ability to understand and address the issue of climate change. The authors note that the most important type of intermediate global public goods may be international regimes, for example, those that facilitate consultations and negotiations among parties.[163] A number of authors in the data sharing literature also note this important intermediate aspect of data, particularly in informing and enforcing international climate agreements.[164]

4.3.2 International Cooperation

The discussion of international regimes leads directly to the broader issues of international cooperation. One of the most important publications on this issue is Robert Keohane's 1984 work, After Hegemony. In this publication, Keohane suggests that international cooperation can occur, even among purely self-interested

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162 Kaul, Inge, Isabelle Grunberg, and Marc A. Stern. "Defining Global Public Goods."*Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.
163 Kaul, Inge, Isabelle Grunberg, and Marc A. Stern. "Defining Global Public Goods."*Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.
164 Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.
Achache, José. "Open Access to Earth Observation From Space: Opportunity or Threat to Security?" ESA (European Space Agency). Speech.
Williamson, Ian P. "Spatial Data Infrastructures: An Incentive to Facilitate Spatial Data Sharing." By Abbas Rajabifard. N.p.: n.p., n.d. N. pag. Web. 19 Mar. 2013.
<http://www.csdila.unimelb.edu.au/publication/misc/SDI_an_initative_to-facilitateSDI_GlobalEnvironmentalBook-SDI0Chapter6.pdf>.

states, when they can achieve mutual benefits by overcoming various impediments to cooperation. This type of situation can be modeled using the 'prisoner's dilemma' framework from game theory. If this game is played repeatedly, even a rational actor may choose cooperation. He argues that cooperation is particularly likely to occur within existing international regimes, because they help to reduce transaction costs among states – they allow a framework in which cooperation can take place. The repeated interactions allow states to build a reputation and to build mutual trust. Furthermore, he argues that rather than trying to exert resources to reconsider actions and decisions in each case of possible international cooperation, it may be even more beneficial for states to rely on existing rules and agreements and to benefit from existing international regimes. These regimes allow states to follow standard operating procedures or "rules of thumb."[165]

Keohane, along with Joseph Nye, expanded on this idea in their 1998 publication, "Power and Interdependence in the Information Age." They argued that despite the growth in global information communications technologies and transnational organizations, geographically defined states continue to structure politics in the information age. However, they note that power may depend less on material resources and more on the ability to remain credible to a public with many diverse sources of information.[166]

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[165] Keohane, Robert O. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton, NJ: Princeton UP, 1984. Print.
[166] Keohane, Robert O., and Joseph S. Nye, Jr. "Power and Interdependence in the Information Age." *Foreign Affairs* (1998): n. pag. Print.

The incentives and disincentives to engage in international cooperation identified in these landmark publications are also found in the literature on data sharing. As Keohane noted, to be incentivized to cooperate, self-interested nations must have mutual interests, because decisions are made based on rational decisions about the costs and benefits to the nation of engaging in cooperation. This condition is met when looking at international data sharing, particularly with regard to climate data. The global nature of both knowledge production and of climate change means that achieving domestic policy requires international cooperation.[167]

When data is shared internationally, it increases the use of the data and the production of knowledge, leading to an overall increase in the social benefit. This benefits not only the nation with whom the data is shared, but also the nation that made the data available. It allows that country to get a greater return on its investment in the data collection technology, and in that way, contributes to that nation's economic growth.[168] Sharing of data is simply more efficient. Since the data has international utility, data sharing can reduce costs by helping to avoid the need for redundant systems.[169]

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[167] Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.
Landis, Robert. "Future of International Cooperation in Meteorological and Related Services." Proc. of American Meteorological Society 88th Annual Meeting, New Orleans, LA. N.p., Jan. 2008. Web. 20 Mar. 2013. <https://ams.confex.com/ams/88Annual/techprogram/programexpanded_452.htm>.

[168] *Bits of Power: Issues in Global Access to Scientific Data*. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.
Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal*3 (2004): 135-52. Web.

[169] Nedović-Budić, Zorica, and Jeffrey K. Pinto. "Interorganizational GIS: Issues and Prospects." *The Annals of Regional Science* 33.2 (1999): 183-95. Web.

National governments are able to provide goods that have a high social benefit but relatively low individual benefits that would not otherwise be produced. Similarly, international cooperation can help to enable efficient provision of goods that individual nations value but have insufficient incentive to develop themselves.[170]

In the case of adequate monitoring of climate change, international cooperation is not only a more efficient method of achieving this goal, it may be the only way to do so. This is because the amount of funding needed to develop and operate all of the satellite systems needed to adequately monitor climate change would be well above the historical funding levels of any one country for this type of activity. With this type of challenge, international cooperation leads to more than efficiency – it leads to effectiveness. [171] Schafer notes that this may have been the crucial factor leading to

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Williamson, Ian P. "Spatial Data Infrastructures: An Incentive to Facilitate Spatial Data Sharing." By Abbas Rajabifard. N.p.: n.p., n.d. N. pag. Web. 19 Mar. 2013. <http://www.csdila.unimelb.edu.au/publication/misc/SDI_an_initative_to-facilitateSDI_GlobalEnvironmentalBook-SDI0Chapter6.pdf>.

[170] Bailey, G., D. Lauer, and D. Carneggie. "International Collaboration: The Cornerstone of Satellite Land Remote Sensing in the 21st Century." *Space Policy* 17.3 (n.d.): 161-69. Web.

[171] De Montluc, Bertrand. "The New International Political and Strategic Context for Space Policies." *Space Policy* 25.1 (2009): 20-28. Web.

Schafer, Angela, and Heinz Pampel. *Baseline Report on Drivers and Barriers in Data Sharing*. Rep. Opportunities for Data Exchange, Seventh Framework Programme, 2011. Web. 19 Mar. 2013. <http://www.alliancepermanentaccess.org/wp-content/uploads/downloads/2011/11/ODE-WP3-DEL-0002-1_0_public_final.pdf>.

Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal*3 (2004): 135-52. Web.

Felkner, John. "An Analysis of the Current State of International Remote Sensing Data Exchange and Transfer." *International Society for Photogrammetry and Remote Sensing (ISPRS)*. Proc. of XVIIIth ISPRS Congress, Vienna, Austria. N.p., July 1996. Web. 19 Mar. 2013. <http://www.isprs.org/proceedings/XXXI/congress/part6/>.

Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

international cooperation in weather monitoring in the end of the nineteenth century, noting, "Very early on, people learnt that it is most important to know the weather upwind in London to predict the next day's weather in Hamburg."[172] Fellous notes that even if environmental satellites could be developed by one nation, the in situ data needed to verify and calibrate these measurements requires international cooperation.[173]

Existing Data-Sharing Regimes

Robert Keohane argues that cooperation is particularly likely to occur within existing international regimes, because they help to reduce transaction costs among states – they allow a framework in which cooperation can take place. The repeated interactions allow states to build a reputation and to build mutual trust. Furthermore, he argues that rather than trying to exert resources to reconsider actions and decisions in each case of possible international cooperation, it may be even more beneficial for states to rely on existing rules and agreements and to benefit from existing international regimes. These regimes allow states to follow standard operating procedures or "rules of thumb."[174]

Withee, Gregory, Brent Smith, and Robert Masters. "The Prospects for Enhanced International Polar Orbiting Satellite Cooperation." *Space Policy* 17.2 (2001): 121-26. Web.
Fellous, Jean-Louis. "Towards a Global Climate Observing System." *Interdisciplinary Science Reviews* 33.1 (2008): 83-94. Web.

[172] Schafer, Angela, and Heinz Pampel. *Baseline Report on Drivers and Barriers in Data Sharing*. Rep. Opportunities for Data Exchange, Seventh Framework Programme, 2011. Web. 19 Mar. 2013. <http://www.alliancepermanentaccess.org/wp-content/uploads/downloads/2011/11/ODE-WP3-DEL-0002-1_0_public_final.pdf>.

[173] Fellous, Jean-Louis. "Towards a Global Climate Observing System." *Interdisciplinary Science Reviews* 33.1 (2008): 83-94. Web.

[174] Keohane, Robert O. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton, NJ: Princeton UP, 1984. Print.

Keohane's theory suggests that the existence of international organizations in which international agreements can be developed can be important for achieving long-term international cooperation. Landis notes that cooperation on the free international exchange of meteorological information, which is similar in many ways to climate data, has been taking place within the World Meteorological Organization for more than 100 years, and its continued operation is assumed by participating nations.[175] Moreover, this organization has the credibility that Keohane and Nye note as being essential to maintaining national power.[176] Withee notes that space-based Earth observation in particular has a long history of cooperation and free sharing of data.[177] That said, international sharing of all environmental data is not the norm, and the lack of an existing regime for this activity may make cooperation more difficult.[178] Furthermore, a history of wavering political and financial commitment to environmental monitoring on the part of some nations may make it more difficult to make credible international commitments.[179]

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175 Landis, Robert. "Future of International Cooperation in Meteorological and Related Services." Proc. of American Meteorological Society 88th Annual Meeting, New Orleans, LA. N.p., Jan. 2008. Web. 20 Mar. 2013. <https://ams.confex.com/ams/88Annual/techprogram/programexpanded_452.htm>. Schafer, Angela, and Heinz Pampel. *Baseline Report on Drivers and Barriers in Data Sharing*. Rep. Opportunities for Data Exchange, Seventh Framework Programme, 2011. Web. 19 Mar. 2013. <http://www.alliancepermanentaccess.org/wp-content/uploads/downloads/2011/11/ODE-WP3-DEL-0002-1_0_public_final.pdf>.

176 Ohlemacher, R. "The Earth Observation Summit: Heralding a New Era for International Cooperation." *Space Policy* 19.4 (2003): 277-81. Web.

177 Withee, Gregory, Brent Smith, and Robert Masters. "The Prospects for Enhanced International Polar Orbiting Satellite Cooperation." *Space Policy* 17.2 (2001): 121-26. Web.

178 Bailey, G., D. Lauer, and D. Carneggie. "International Collaboration: The Cornerstone of Satellite Land Remote Sensing in the 21st Century." *Space Policy* 17.3 (n.d.): 161-69. Web.

179 Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.

A related argument is that international cooperation can lead to more international coordination; the discussions and relationships necessary to facilitate data sharing may lead to further alliances.[180] The creation of standards necessary for sharing with one partner or within a narrow context may make more widespread sharing easier in the future.[181] International agreements on data sharing may make international coordination of data collection more likely, for example. Looking at it from another angle, if scientific data are not widely shared or easy to access internationally, that may impede the ability of scientists from different nations to work together or for scientists to develop transnational datasets more useful for global problems.[182]

4.4 Organizational Theory

Organizational theory has many similarities to international relations, though the unit of examination is now the organization or agency rather than the country as a whole. Like international relations, organizational theory suggests that sharing is more likely where there are superordinate goals – goals that both organizations hold, and that cannot be achieved without cooperation.[183] Efficiency and effectiveness are important

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[180] Nedović-Budić, Zorica, and Jeffrey K. Pinto. "Interorganizational GIS: Issues and Prospects." *The Annals of Regional Science* 33.2 (1999): 183-95. Web.

[181] GITA, 2005) [Free or Fee: The Governmental Data Ownership Debate]

[182] Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.

United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.

[183] Pinto, Jeffrey, and Harlan Onsrud. "Sharing Geographic Information Across Organizational Boundaries: A Research Framework." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 44-64. Print.

Nedović-Budić, Zorica, Jeffrey Pinto, and Lisa Warnecke. "GIS Database Development and Exchange: Interaction Mechanisms and Motivations." *Journal of the Urban and Regional Information Systems Association* 16.1 (2004): 15-29. Web.

benefits of sharing.[184] Just as existing regimes can make cooperation easier, the quality of existing relationships can be critical in successful data sharing among organizations.[185]

However, authors note that even when it seems that data sharing would be beneficial, it is often not done.[186] Organizational theory has a number of contributions distinct from the rational decision theory often used in economics and international relations that can help explain this paradox, based on intricacies of organizational structure and randomness as well as relationships between autonomy and power.[187]

4.4.1 Garbage Can Model

One of the most important models within organizational theory is the Garbage Can Model of Organizational Choice, developed by Cohen, March, and Olsen in 1972.

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184 Pinto, Jeffrey, and Harlan Onsrud. "Sharing Geographic Information Across Organizational Boundaries: A Research Framework." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 44-64. Print.
Nedović-Budić, Zorica, Jeffrey Pinto, and Lisa Warnecke. "GIS Database Development and Exchange: Interaction Mechanisms and Motivations." *Journal of the Urban and Regional Information Systems Association* 16.1 (2004): 15-29. Web.
185 Pinto, Jeffrey, and Harlan Onsrud. "Sharing Geographic Information Across Organizational Boundaries: A Research Framework." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 44-64. Print.
Nedović-Budić, Zorica, Jeffrey Pinto, and Lisa Warnecke. "GIS Database Development and Exchange: Interaction Mechanisms and Motivations." *Journal of the Urban and Regional Information Systems Association* 16.1 (2004): 15-29. Web.
186 Craig, William J. "Why We Can't Share Data: Institutional Inertia." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Print.
Meredith, Paul H. "Distributed GIS: If Its Time Is Now, Why Is It Resisted." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. 7-21. Print.
187 Onsrud, Harlan, and Gerard Rushton. "Sharing Geographic Information: An Introduction." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
Nedović-Budić, Zorica, and Jeffrey K. Pinto. "Interorganizational GIS: Issues and Prospects." *The Annals of Regional Science* 33.2 (1999): 183-95. Web.
Craglia, Max, and Ian Maser. "Access to Geographic Information: A European Perspective." *Journal of the Urban and Regional Information Systems Association*15.1 (2003): 51-60. Web. 19 Mar. 2013. <http://www.urisa.org/files/vol15apa1.pdf>.

Traditionally, it was imagined that an organization would identify a problem, come up with a logical set of choice alternatives, and then choose among them, maximizing based on their primary goals or objectives. The Garbage Can Model provides another, arguably more realistic, model of decision-making. They suggest that the preferences of organizations are often ill-defined or inconsistent, that trial and error is often utilized rather than a full understanding of the effect of new processes, and that the individuals working on a particular issue, as well as the amount of time they have to devote to it, change over time. Problems, solutions, attentive individuals, and decision-making opportunities all exist in tandem. Decision-making is a complex process in which the decision made, the time it takes, and the problem that is solved depend on the choices, problems, and solutions available at the time, as well as the other time demands on decision makers.[188]

These issues are commonly raised in the data-sharing literature. Meredith specifically references the garbage can theory in discussing the ambiguous environment in which data sharing decisions are made.[189] Taupier notes that agencies are not single-minded in their objectives, and often do not operate based on clear, consistent principles.[190] Azad and Wiggins note that the returns on investments in data sharing are often

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[188] Cohen, Michael D., James G. March, and Johan P. Olson. "A Garbage Can Model of Organizational Choice." *Administrative Science Quarterly* 17.1 (1972): n. pag. Web.
[189] Meredith, Paul H. "Distributed GIS: If Its Time Is Now, Why Is It Resisted." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. 7-21. Print.
Taupier, Richard P. "Comments on the Economics of Geographic Information and Data Access in the Commonwealth of Massachusetts." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.
[190] Taupier, Richard P. "Comments on the Economics of Geographic Information and Data Access in the Commonwealth of Massachusetts." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

unclear or intangible.[191] A specific example of conflicting goals is given by Harris, in reference to the United Kingdom's civil space agency. That agency's goals include helping to understand and protect the environment, opening up commercial and operational systems for the future, bringing in commercial returns, and generating uniquely valuable space science.[192]

While benefits for the government as a whole may be general improvements for the population, agencies often have a more narrow focus. The National Research Council suggests that agencies in the United States focus primarily on fulfilling their specific missions, which results in continued funding by Congress.[193] If data sharing is not seen as one of the agency's explicit goals, officials within the agency may fight the idea that it should be paid for out of its budget.[194]

Individual and organizational culture can also be important.[195] People within an organization are more likely to support data sharing if it is seen as important to senior management.[196] In fact, the attitudes or fundamental beliefs of those with authority

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[191] Azad, Bijan, and Lyna Wiggins. "Dynamics of Inter-Organizational Geographic Data Sharing: A Conceptual Framework for Research." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 22-43. Print.

[192] Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.

[193] *Resolving Conflicts Arising from the Privatization of Environmental Data*. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

[194] Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.

[195] Schafer, Angela, and Heinz Pampel. *Baseline Report on Drivers and Barriers in Data Sharing*. Rep. Opportunities for Data Exchange, Seventh Framework Programme, 2011. Web. 19 Mar. 2013. <http://www.alliancepermanentaccess.org/wp-content/uploads/downloads/2011/11/ODE-WP3-DEL-0002-1_0_public_final.pdf>.

[196] McDermott, Richard, and Carla O'Dell. "Overcoming Cultural Barriers to Sharing Knowledge." *Journal of Knowledge Management* 5.1 (2001): 76-85. Web.

over decision-making can be a very important factor in organizational action.[197] Data sharing can also be made easier in cases where individuals believe sharing is part of their professional culture.[198]

4.4.2 Autonomy, Power, and Budget

Another issue raised is the importance of autonomy. Agreeing to share data may reduce autonomy, for example, as international standards are adopted for data formatting or documentation.[199] Once a sharing regime is in place, the organization loses some of its freedom to act independently.[200] Creation of a data sharing system requires organizational change, including the creation of new tasks and structures.[201]

A related issue is that of power. Information is often a source of power, ownership, and control, and therefore sharing that data can affect power relationships.[202] Pinto and Onsrud argue that when agencies have few resources, they may have a desire to

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[197] Harvey, F., and D. Tulloch. "Local-government Data Sharing: Evaluating the Foundations of Spatial Data Infrastructures." *International Journal of Geographical Information Science* 20.7 (2006): 743-68. Web.
Onsrud, Harlan. "Is Cost Recovery Worthwhile." Proc. of URISA 1995 Annual Conference Proceedings, Washington, DC. Urban and Regional Information Systems Association, 1995. Web.
[198] Craig, William J. "White Knights of Spatial Data Infrastructure: The Role and Motivation of Key Individuals." *Journal of the Urban and Regional Information Systems Association* 16.2 (2005): 5-14. Web. 19 Mar. 2013.
<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.130.438&rep=rep1&type=pdf#page=5>.
[199] Azad, Bijan, and Lyna Wiggins. "Dynamics of Inter-Organizational Geographic Data Sharing: A Conceptual Framework for Research." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 22-43. Print.
[200] Azad, Bijan, and Lyna Wiggins. "Dynamics of Inter-Organizational Geographic Data Sharing: A Conceptual Framework for Research." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 22-43. Print.
[201] Nedović-Budić, Zorica, and Jeffrey K. Pinto. "Interorganizational GIS: Issues and Prospects." *The Annals of Regional Science* 33.2 (1999): 183-95. Web.
[202] Harvey, F., and D. Tulloch. "Local-government Data Sharing: Evaluating the Foundations of Spatial Data Infrastructures." *International Journal of Geographical Information Science* 20.7 (2006): 743-68. Web.

hoard those that they do have, including data. When organizations are less resource constrained, they may actually be more willing to share their data with other organizations. Pinto and Onsrud concluded that "perceived organizational munificence will have a positive and significant direct effect on geographic information exchange."[203]

4.5 Security Theory

National security is often seen as the foremost responsibility of nations. Therefore, it is not surprising that the potential security implications of international data sharing are an important and often-discussed issue in the literature. Even articles strongly supporting free and open data sharing often acknowledge that concern for national security is a legitimate reason to restrict access to data.[204] However, there are a number of issues that complicate the incorporation of concerns about national security into the design of a data sharing policy.

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203 Pinto, Jeffrey, and Harlan Onsrud. "Sharing Geographic Information Across Organizational Boundaries: A Research Framework." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 44-64. Print.

204 Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal*3 (2004): 135-52. Web.
"Free or Fee: The Governmental Data Ownership Debate: GITA White Paper." Geospatial Information & Technology Association, Aug. 2005. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/Courses/SIE525/FreeOrFee.pdf>.
Salkin, Patricia A. "GIS in an Age of Homeland Security: Accessing Public Information to Ensure a Sustainable Environment." *William & Mary Environmental Law and Policy Review* 30.1 (n.d.): 55-94. Web.
OECD Principles and Guidelines for Access to Research Data from Public Funding. Rep. Organization for Economic Cooperation and Development, 2007. Web. 19 Mar. 2013. <http://www.oecd.org/sti/sci-tech/38500813.pdf>.
Sharing Research Data. Rep. National Research Council, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, 1985. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?isbn=030903499X>.

4.5.1 Dual-Use Nature of Data

One of the fundamental difficulties in determining Earth observation data sharing policies is that a significant portion of the data, particularly high resolution and radar data, is dual-use – it has value for both civil and military purposes.[205] The implications for data access of each of these uses are diametrically opposed. If data can expose sensitive national security information, officials would prefer to not release the data at all. Data that is useful for civil purposes, including scientific research, is best utilized by distributing it to the greatest extent possible.[206]

One of the important considerations in determining whether data should be made freely available is whether it is more useful for offensive purposes or for defensive purposes. Terrorists might find maps of public utilities useful in planning an attack, but those same maps might be invaluable to citizens trying to plan a recovery after a national disaster.[207] Similarly, hydrological data are very important to understanding

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[205] Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.
Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.
De Montluc, Bertrand. "The New International Political and Strategic Context for Space Policies." *Space Policy* 25.1 (2009): 20-28. Web.
[206] Achache, José. "Open Access to Earth Observation From Space: Opportunity or Threat to Security?" ESA (European Space Agency). Speech.
Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.
United States. *Value of Civil Imagery and Remote Sensing*. Federal Geographic Data Committee, Civil Imagery and Remote Sensing Task Force, 1 Oct. 2002. Web. 19 Mar. 2013. <http://www.fgdc.gov/participation/coordination-group/meeting-minutes/2002%20meeting%20minutes/may/cirs_report.pdf>.
Lutes, Charles D., Peter L. Hays, Vincent A. Manzo, Lisa M. Yambrick, and M. Elaine. Bunn. "Space Power and the Enviornment." *Toward a Theory of Spacepower: Selected Essays*. Washington, DC: National Defense UP, 2011. N. pag. Print.
[207] Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.

environmental change, however, they are also seen to be of national strategic importance.[208]

Robert Jervis provided some insight into the importance of this issue in his 1978 article, “Cooperation Under the Security Dilemma.” He argued there are two variables crucial to determining the extent to which an increase in one state’s security decreases the security of others: whether defensive weapons and policies can be distinguished from offensive ones, and whether defense or offense has the advantage. Jervis argues that when it is possible to distinguish defensive weapons from offensive weapons, it is possible for a state to make itself more secure without making others less secure. When defense has the advantage over offense, then a large increase in the security in one state will result in only a marginal decrease in the security of others. In this case, countries can all enjoy a relatively high level of security. In the opposite case, where the disposition of weapons is indistinguishable and offense has the advantage, he suggests that the world will be doubly dangerous, and cooperation will be very difficult to achieve.[209]

The offensive uses of geospatial data were widely recognized after September eleventh. In the United States, many agencies removed previously available data out

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Craig, Brian. "Online Satellite and Aerial Images: Issues and Analysis." *North Dakota Law Review* 85 (2007): 547. Web.

[208] Schafer, Angela, and Heinz Pampel. *Baseline Report on Drivers and Barriers in Data Sharing*. Rep. Opportunities for Data Exchange, Seventh Framework Programme, 2011. Web. 19 Mar. 2013. <http://www.alliancepermanentaccess.org/wp-content/uploads/downloads/2011/11/ODE-WP3-DEL-0002-1_0_public_final.pdf>.

[209] Jervis, Robert. *Cooperation Under the Security Dilemma*. Los Angeles: Center for Arms Control and International Security, University of California, Los Angeles, 1977. Print.

of concern that it may have some value for terrorists.[210] However, others ask whether restricting public access to data may actually harm homeland security. Terrorists may not have significant difficulty identifying urban water supply sources, but widely available maps may be very valuable to local response teams and policy makers in the event of a disaster.[211]

Reconnaissance satellites are generally viewed as a stabilizing force. An increase in knowledge and certainty about the actions of other nations, for example, the ability to see any large-scale military mobilization almost immediately, reduces uncertainty about other nations' intentions.[212] However, the existence of commercial remote sensing satellites poses some unique challenges. In the past, the high-resolution imagery collected by reconnaissance satellites was limited to only a few nations with these capabilities. With commercial satellites, it is possible for any country to purchase imagery, and the location of tanks, troops, refugees, and natural resources can all be identified.[213] Asymmetric access to this imagery, driven by ability to pay, poses a number of challenges.[214] For example, a corporation could purchase data about a state and use the satellite data to learn more about a country's natural

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[210] Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
Salkin, Patricia A. "GIS in an Age of Homeland Security: Accessing Public Information to Ensure a Sustainable Environment." *William & Mary Environmental Law and Policy Review* 30.1 (n.d.): 55-94. Web.

[211] Onsrud, Harlan. "Access to Geographic Information: Openness versus Security."*Http://www.spatial.maine.edu/~onsrud/pubs/OpennessVsSecurityPreprint.pdf*. N.p., n.d. Web. 19 Mar. 2013.

[212] Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age." *Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.

[213] Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age." *Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.

[214] Lutes, Charles D., Peter L. Hays, Vincent A. Manzo, Lisa M. Yambrick, and M. Elaine. Bunn. "Space Power and the Enviornment." *Toward a Theory of Spacepower: Selected Essays*. Washington, DC: National Defense UP, 2011. N. pag. Print.

resources than the government itself may know. This knowledge could then be used to the company's advantage in negotiating contracts for resource extraction.[215] Furthermore, data can be misinterpreted, particularly by those not familiar with a particular technology.[216] On the other hand, benefits arise from the ability to easily share data collected by commercial satellites, for example with foreign coalition partners or domestic first responders, compared to that collected by reconnaissance satellites.[217]

Recognizing these issues, the U.S. Federal National Geographic Data Committee developed "guidelines for providing appropriate access to geospatial data in response to security concerns." They argued that decisions should be made based on three factors: risk to security, uniqueness of information, and net benefit of dissemination. In their view, data should only be safeguarded if it is sensitive, unique, and has security risks that outweigh the social benefits of dissemination.[218] A report done by the RAND corporation had similar conclusions, and added that attackers generally have a wide array of methods for obtaining information, and that publicly accessible geospatial information was generally not their primary source.[219]

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[215] Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age." *Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.
[216] Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.
[217] Birk, R. "Government Programs for Research and Operational Uses of Commercial Remote Sensing Data." *Remote Sensing of Environment* 88.1-2 (2003): 3-16. Web.
[218] United States. Federal Geographic Data Committee. *Guidelines for Providing Appropriate Access to Geospatial Data in Response to Security Concerns*. N.p., June 2005. Web.
[219] Salkin, Patricia A. "GIS in an Age of Homeland Security: Accessing Public Information to Ensure a Sustainable Environment." *William & Mary Environmental Law and Policy Review* 30.1 (n.d.): 55-94. Web.

Another important consideration in determining the effect of national security concerns on data sharing is the practical ability of nations to restrict access to the data. This is particularly relevant in the area of commercial remote sensing.[220] When this capability was first developed in the United States, the government imposed a restriction referred to as "shutter control," that allowed it to restrict the collection and/or sale of data when deemed necessary for national security or foreign policy reasons.[221] However, shutter control was never exercised, as the government seemed to prefer exclusive data buys, and in the Remote Sensing Policy of 2003, the shutter control option was no longer emphasized.[222] Similarly, over time, the U.S. government has relaxed or removed limits on the resolution of commercial remote sensing systems.[223] Part of this change was likely driven by the awareness that numerous commercial remote sensing companies were being developed in other countries where U.S. policies would not have an effect. Shutter control, or other efforts to limit satellite data, was simply not feasible.[224] As satellite remote sensing technology and information becomes increasingly accessible via international

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220 Bell, William S. *Commercial Eyes in Space: Implications for U.S. Military Operations in 2030*. N.p.: BiblioScholar, 2012. Print.

221 Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age." *Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.
Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.

222 Williamson, R. "Current US Remote Sensing Policies: Opportunities and Challenges." *Space Policy* 20.2 (2004): 109-16. Web.

223 Lutes, Charles D., Peter L. Hays, Vincent A. Manzo, Lisa M. Yambrick, and M. Elaine. Bunn. "Space Power and the Enviornment." *Toward a Theory of Spacepower: Selected Essays*. Washington, DC: National Defense UP, 2011. N. pag. Print.

224 Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age." *Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.
Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.
Lutes, Charles D., Peter L. Hays, Vincent A. Manzo, Lisa M. Yambrick, and M. Elaine. Bunn. "Space Power and the Enviornment." *Toward a Theory of Spacepower: Selected Essays*. Washington, DC: National Defense UP, 2011. N. pag. Print.

contractors and improved indigenous capabilities, efforts to restrict access to data from particular satellites become less effective.

4.6 Domestic Political Considerations

Data collection and sharing policies are reliant not only on the willingness of an organization to pursue data sharing, but also on the decisions of high-level bureaucrats or politicians to provide political and fiscal support for data sharing.[225] In particular, ensuring this political support generally requires that these agencies can show the value of their data.[226] The visibility of agency efforts and successes can play a significant role in agency funding.

Presenting revenues is a very straightforward way to present the value of agency activities and is generally well received. Joffe reported that even when revenues made up a very small proportion of overall costs of data collection and sharing, efforts at cost recovery were viewed positively by high-level decision-makers. However, he suggests that it is also possible to show the value of data collection and sharing by

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[225] Bailey, G., D. Lauer, and D. Carneggie. "International Collaboration: The Cornerstone of Satellite Land Remote Sensing in the 21st Century." *Space Policy* 17.3 (n.d.): 161-69. Web.
Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.

[226] United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.
Harvey, F., and D. Tulloch. "Local-government Data Sharing: Evaluating the Foundations of Spatial Data Infrastructures." *International Journal of Geographical Information Science* 20.7 (2006): 743-68. Web.
Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies." *International Journal of Geographical Information Science*23.2 (2009): 195-212. Web.

highlighting the extent to which the data is used and the benefits and revenue that are generated in society based on the use of the data.[227]

An important corollary to the importance of showing the value of the data produced by an agency is the importance of being able to track where data are being used. This is particularly true because the costs of making data available are concentrated while the benefits of data sharing are widely dispersed.[228] Organizations and agencies sharing geospatial data note the importance of getting credit for their activities as an incentive to greater data sharing.[229]

4.7 Contribution of this Research

As this review of theory and literature illustrates, there are a wide variety of arguments, from many different disciplinary areas, that apply to the issue of data sharing. However, this focus on arguments for and against data sharing is limited. It provides an understanding of the breadth of possible arguments that agencies may

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227 Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.

228 *Sharing Research Data*. Rep. National Research Council, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, 1985. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?isbn=030903499X>.

229 Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal*3 (2004): 135-52. Web.
Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.
OECD Principles and Guidelines for Access to Research Data from Public Funding. Rep. Organization for Economic Cooperation and Development, 2007. Web. 19 Mar. 2013. <http://www.oecd.org/sti/sci-tech/38500813.pdf>.
Harvey, F., and D. Tulloch. "Local-government Data Sharing: Evaluating the Foundations of Spatial Data Infrastructures." *International Journal of Geographical Information Science* 20.7 (2006): 743-68. Web.

marshal in developing their international data sharing policies, but it does not provide insight into the actual determinants of data sharing policies.

It is critical to understand how nations develop their data sharing policies, and what issues are determinants in this process in order to allow meaningful progress in future policy development. Rather than understanding why a nation *should* or *should not* share data, I am interested in why a nation *does* or *does not* share data, in the particular case of climate data collected by satellites. Do nations restrict access to data for economic reasons, security concerns, or both? Do they take into account normative issues in developing policies, or are these significantly less important than other concerns? Do organizational issues, such as the history and strategic focus of an agency affect the policy chosen? Understanding this issue makes it possible to better design future policy, based on the actual concerns of policy-makers.

I expect that the determinants of climate satellite data sharing policies will be a subset of the potential arguments provided in the literature, with some substantive arguments being much more important and more commonly cited by policy-makers than others. By determining whether this is in fact the case, and if so, which arguments are most important, I add an important new dimension to the existing literature on geospatial data sharing, providing insight specifically into the issues necessary for influencing and improving future policy.

Chapter 5: Econometric Analysis of Data Sharing

This section develops a quantitative model with the aim of determining the importance of the incentives and disincentives to international data sharing of climate-relevant data collected by satellites suggested by literature. The model will look at the relationship between data sharing policies applicable to each instrument in the database and other observable characteristics related to that instrument. The benefit of quantitative analysis is that it makes it possible to consider the relative roles of each of the theorized variables within a well-structured framework. However, there are also a number of drawbacks to using quantitative analysis to examine a largely qualitative question. In particular, each proxy variables imperfectly represents its associated theoretical incentive or disincentive and has the potential to pick up other characteristics related to the instrument. Specific concerns with each proxy variable are discussed later. Also, quantitative analysis can identify the correlation between incentives and data-sharing outcomes, but it cannot speak to the motivations or mechanisms behind these connections. Further, decision-making and policy-making are complex processes not easily modeled. For example, the choice to use an ordered probit rather than nested logit specification represents the belief that decision-makers examine the full range of data-sharing options available and choose among them, rather than choosing to share or not to share, and then deciding the degree of sharing. I believe this most accurately represents the reality of data-sharing decision making in most cases, though individual situations may vary. Due to these limitations of quantitative analysis, the results of this model are used only as a first look at the importance of the theoretical arguments. This is followed by qualitative analysis that further examines the barriers and incentives to data sharing and provides insight into the motivation for policy development and changes.

5.1 Methodology

This analysis uses an ordered probit model to test whether various proxies for data-sharing incentives or disincentives actually play a role in international data sharing. An ordered probit model is most appropriate, because it allows analysis of a discrete dependent variable that has multiple potential ordinal outcomes. In this case, the dependent variable represents the data sharing policy for a particular instrument, ranging from freely available with no restrictions to unavailable under all circumstances. Also, the probit model makes it possible to estimate the model using marginal effects, which allows a straightforward interpretation of the results. An appendix also includes the same models run using an ordinary least squares (OLS) regression model. Though OLS is not generally suited to analysis of discrete dependent variables, the estimates it provides have a straightforward interpretation. Also, the results from the OLS models for this analysis were similar to those in the probit model, demonstrating the robustness of results across model specifications.

This analysis will provide insight into which incentives or disincentives are most important in determining international data sharing in the case of climate-monitoring satellites. To look at these issues, three sets of regressions have been run. The first model includes all proxies, except for spatial resolution, as this variable is not available for all instruments and leads to a lower number of observations in the model. The second model is weighted by measurement and lifespan, to take into account the fact that some instruments may collect more measurements than others, and they operate for different periods of time. The third model repeats the unweighted analysis in the first model, but adds the spatial resolution variable.

These models are run at the instrument level. That means each unit of observation represents a particular instrument on a specific satellite. For example, if two satellites each carry two instruments, one of which uses the same technology, this would result in four unique observations in the dataset. This level of specificity is necessary, because it is the level on which data sharing varies. It is possible for one satellite to host many instruments, and data from one or more of these instruments may be shared freely while others are restricted. Because each of these instruments can be traced back to the satellite used to capture it, or the country that led development of the satellite, the instruments can also be linked to satellite characteristics, such as the civil or military designation, and to country-level characteristics, such as the size of the satellite program. These variables can then be used in the analysis.

5.2 Description of Variables Used

Dependent Variable: Data sharing

The dependent variable in these models represents the data sharing policy that applies to data collected by a specific instrument on a particular satellite. The variable can take eight values: 1) data is shared at no cost and with no restrictions, 2) data is available at no cost, but with some restrictions, 3) data is made available at marginal cost, but with no restrictions once the data is purchased, 4) data is made available at marginal cost, with some restrictions, 5) data is sometimes associated with above marginal cost and restrictions (due to application requirements), 6) data is available above marginal cost, 7) data access is unknown (which is essentially equivalent to being unavailable), and 8) data is not made available. The data-sharing variable does not vary with time. It represents the state of data-sharing policies for a given instrument in 2012, regardless of when the satellite was launched or when/if it has reached the end of its operational life.

Data from about half of the instruments considered in this research are shared freely, while data from the other half is made available with minor or major restrictions. Very few measurements are expressly made unavailable to researchers.

Figure 5.1 Number of Instruments in Each Data-Sharing Policy Category

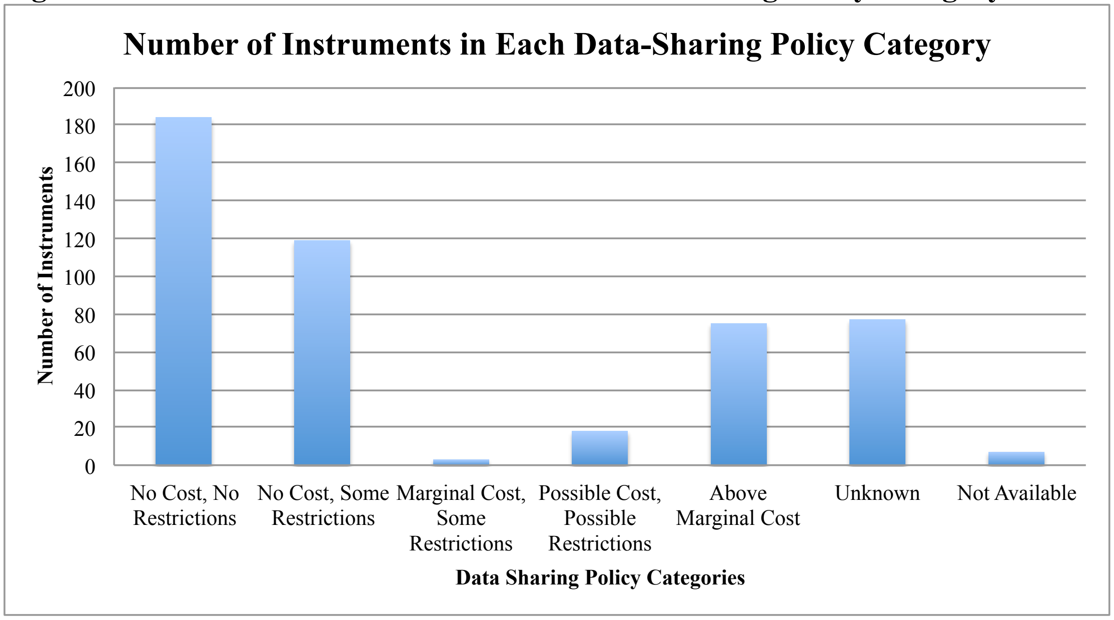

Figure 5.1 shows the number of instruments that fall into each of the data sharing policy categories used in the regression analysis.

Table 5.1 Dependent Variable Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Data Sharing	483	3.3	2.5	1	8

Table 5.1 shows some basic descriptive statistics for the dependent variable, data sharing.

Independent variables

Normative Theory

World Bank Voice and Accountability Index (Proxy for Government Transparency):

One of the theoretical determinants of data sharing policies is based on normative beliefs about the role of the government. In particular, normative theories suggested that data should be shared to enhance government transparency and to ensure fair access to citizens. Governments that highly value transparency would be expected to be more likely to provide citizens with easy access to data not limited by costs or other restrictions. However, measuring government transparency is difficult, and no one measure perfectly captures reality. This analysis makes use of the World Bank Voice and Accountability Index as a proxy variable. According to the World Bank, this variable "captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media."[230] Therefore, based on the earlier theoretical discussion, governments with a higher score on the voice and accountability index should be more likely to share data.

Figure 5.2 Number of Instruments in Each Voice and Accountability Index Range

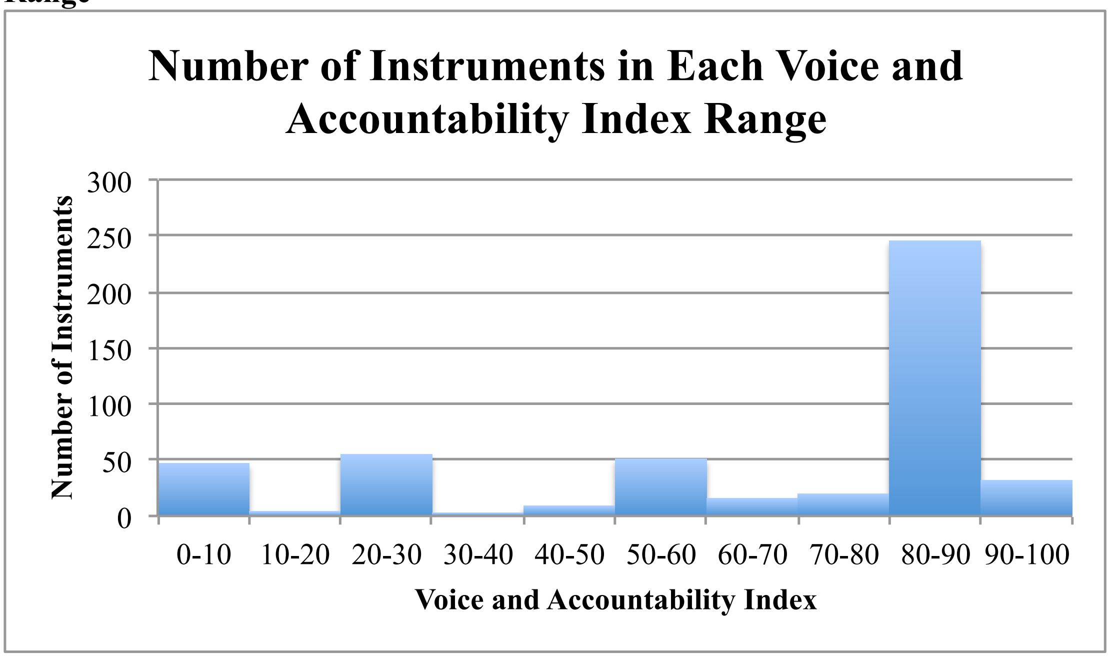

Figure 5.2 shows the number of instruments that fall into each Voice and Accountability Index range.

[230] "Governance & Anti-Corruption WGI 1996-2012 Interactive Home." *Governance & Anti-Corruption WGI 1996-2012 Interactive Home*. N.p., n.d. Web. 18 Oct. 2012. <http://info.worldbank.org/governance/wgi/index.asp>.

Figure 5.3 Mean Voice and Accountability Index in Each Data Sharing Category

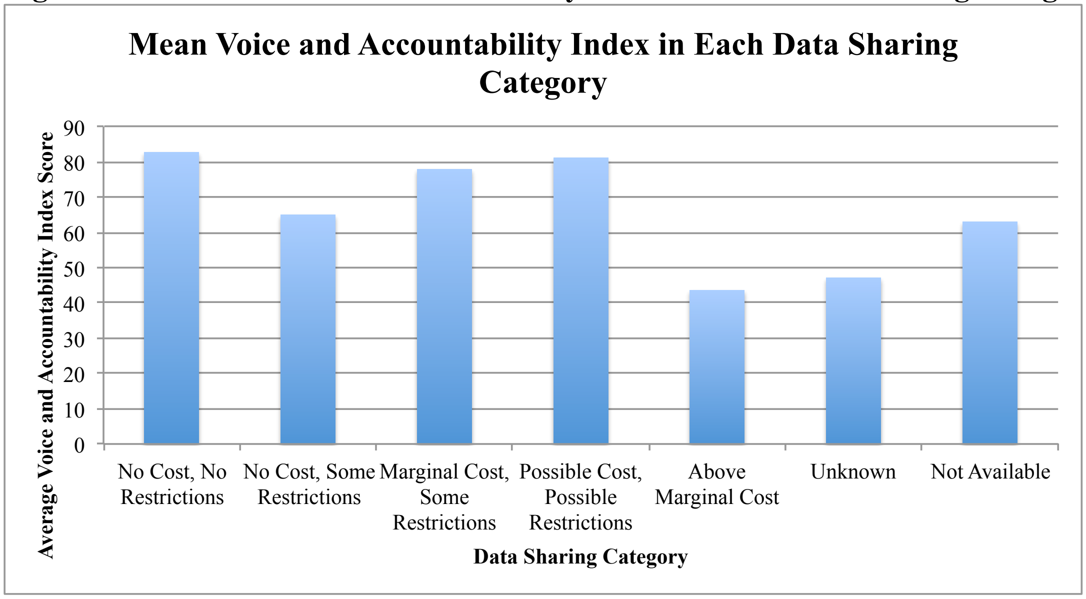

Figure 5.3 shows the mean Voice and Accountability Index score for each data-sharing category.

Economic

Spatial Resolution (Proxy for Commodity Value): Economic arguments for and against free and open data sharing relate to whether the data is viewed as a public good or a commodity. One of the reasons for viewing the data as a commodity is that it has some commodity value. Therefore, this effect, if important, would be expected to play a particularly large role in decision-making when the commercial value of the data is high. High spatial resolution imagery has proven to be of most value; this is the primary product of nearly every commercial remote sensing firm. Therefore, data from a higher resolution instrument (i.e. with a spatial resolution of a lower number of meters) should be less likely to be shared with countries not involved in the satellite.

Figure 5.4 Number of Instruments in Each Spatial Resolution Range

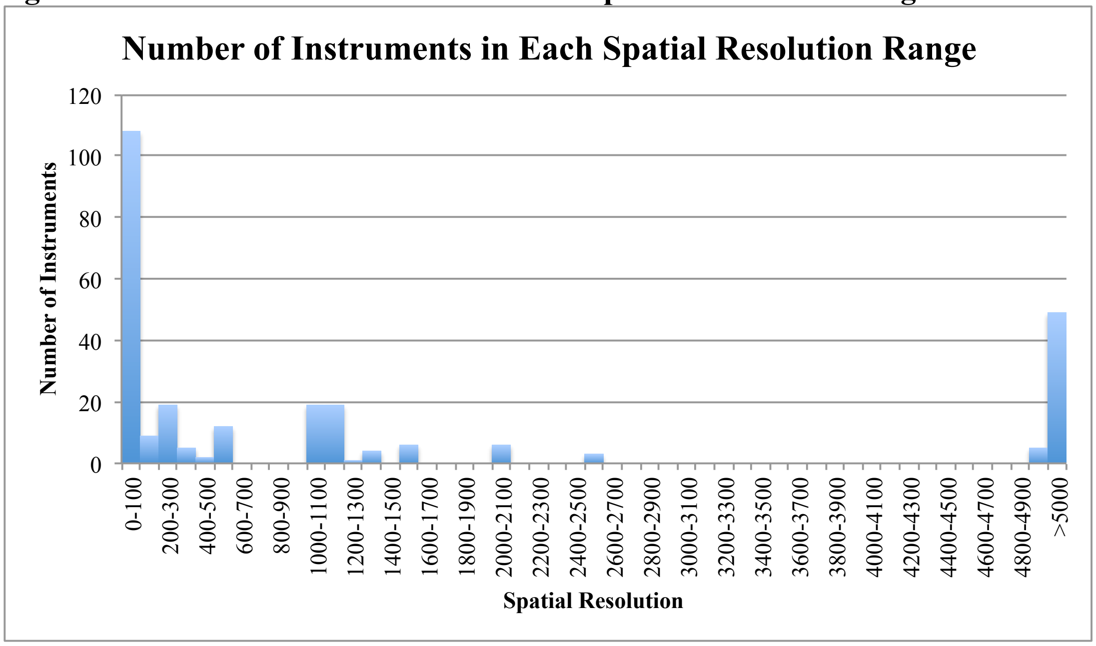

Figure 5.4 shows the number of instruments that fall into each spatial resolution range. Satellites are clustered in the relatively high-resolution ranges, though a large number of satellites have very low resolution as well.

Figure 5.5 Mean Spatial Resolution of Instruments in Each Data Sharing Category

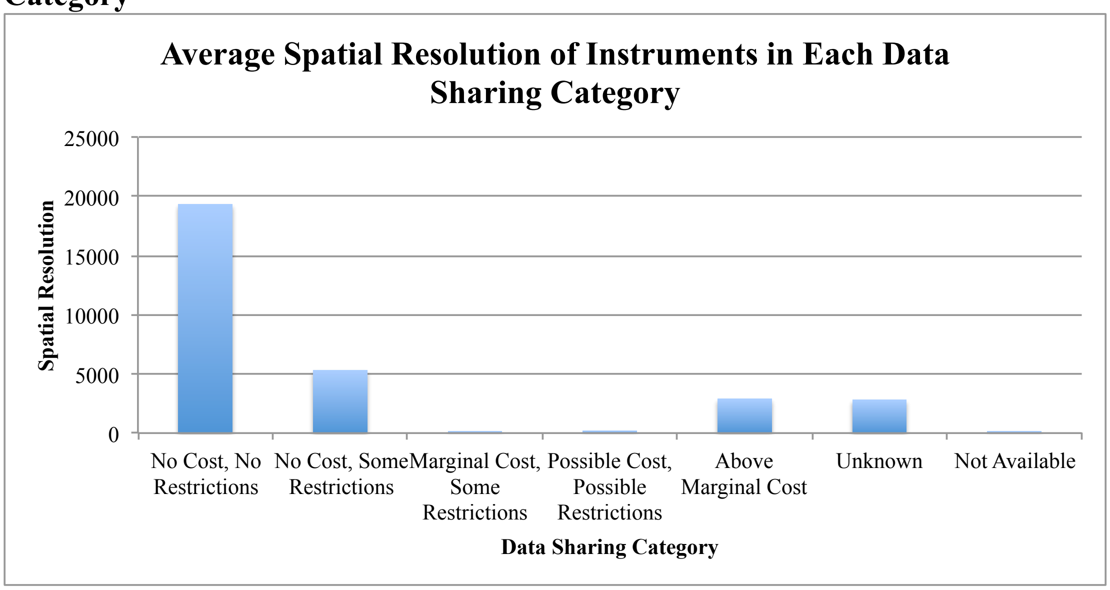

Figure 5.5 shows the mean spatial resolution of instruments falling into each of the data sharing categories.

International Relations

Number of Countries Involved (Proxy for Shared Interest): In the literature on international cooperation, it is noted that one of the most important factors for enabling cooperation is the recognition of a shared interest in the goal or outcome. In cases where more than one country was involved in the development of the satellite, there must have been some recognition that multiple countries would benefit from the information collected by such a satellite. Therefore, we would expect that data from instruments on satellites that were developed cooperatively would be more likely to be shared. One drawback to this proxy variable occurs in cases in which the cooperative agreement to create the satellite involved a barter that included access to the data as a component of the agreement. In those cases, data from satellites developed by more than one country may actually be less likely to be shared.

Figure 5.6 Number of Instruments on Satellites with Varying Levels of International Participation

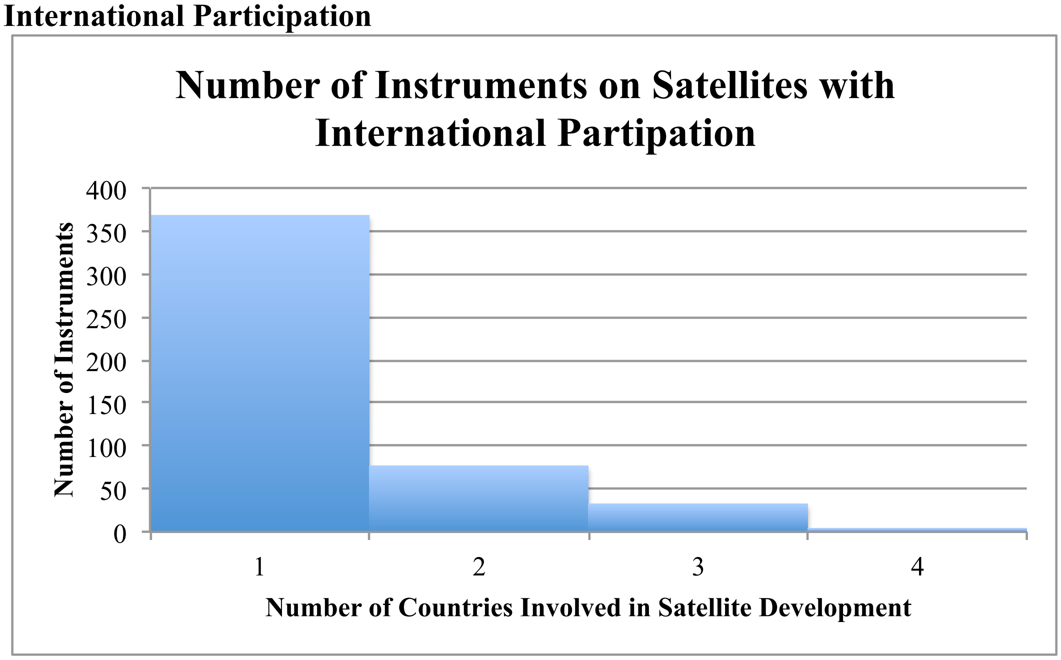

Figure 5.7 shows the number of instruments on satellites with varying levels on international participation (in terms of the number of countries involved in development and/or operation).

Figure 5.7 Mean Number of Countries Involved in Each Data Sharing Category

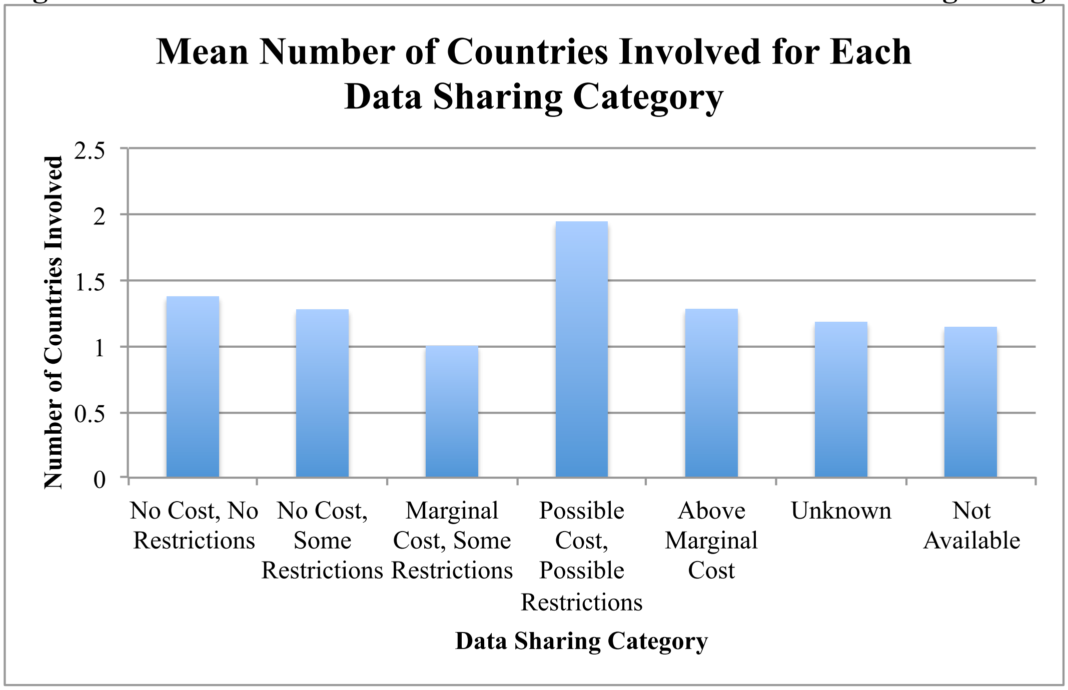

Figure 5.7 shows the mean number of countries involved for instruments in each of the data sharing categories.

International Participation Index (Proxy for Existing Institutions): A basic theory in international relations suggests that international cooperation will be easier to achieve if there are existing institutions in which countries are able to develop new agreements. Therefore, we would expect countries that are involved in a greater number of institutions that address data sharing issues to be more likely to share their data. This index gives a country a score of zero to four, with one point for participation of each of four groups: the Group on Earth Observations (GEO), the Committee on Earth Observation Satellites (CEOS), the Global Climate Observation System (GCOS) and the Coordination Group for Meteorological Satellites (CGMS). Theory would predict that higher scores on this index would be associated with greater data sharing. One concern with this index is that it is difficult to determine cause and effect. It may be that participating in more groups leads to more data sharing. However, it is also likely the case, at least to some extent, that an interest in data sharing would make a country more likely to join these groups.

Figure 5.8 Number of Countries Owned by Countries with each International Participation Index

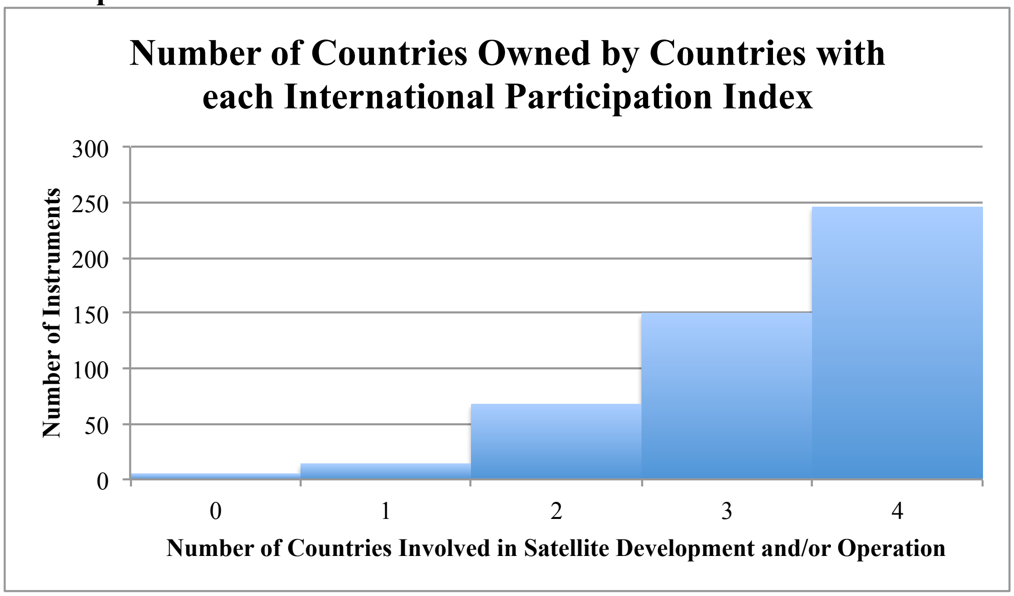

Figure 5.8 shows the number of instruments owned by countries undertaking various levels of international cooperation.

Figure 5.9 Mean International Participation Index in Each Data Sharing Category

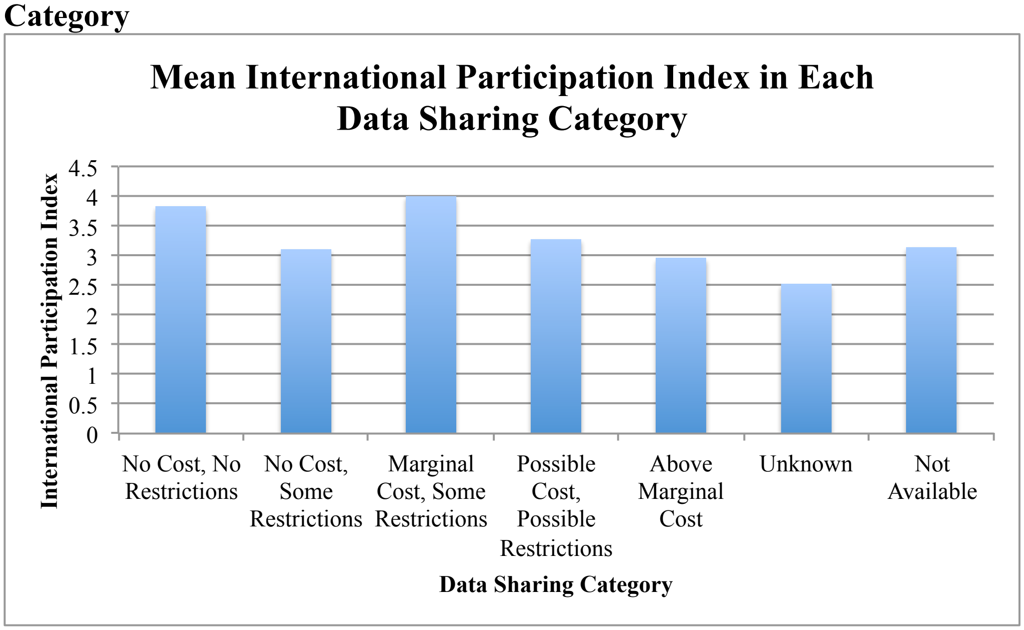

Figure 5.9 shows the mean international participation index for each data-sharing category.

Organizational Theory

National Portion of Global Earth Observation Satellites (Proxy for Program Resources): One of the potential determinants of data sharing discussed in the literature related to the desire for power and autonomy within organizations. The literature suggested that agencies that are smaller or have less resources are actually less likely to share data, because they feel a greater need to hold onto the power and autonomy that they can get from owning and controlling the data. It is difficult to get a reliable number for the budgets of all space and meteorological agencies, and even more difficult to determine the portion of that budget focused on Earth observation satellites and satellite data. Therefore, the proxy used here looks simply at the portion of the total global Earth observation satellites in which each country is involved (not just those for which it is the lead). This gives the relative size of the national program. Based on theory, we would expect those with relatively small programs to share less than those with relatively large programs.

Figure 5.10 Frequency Distribution of National Portion of Global Earth Observation Satellites

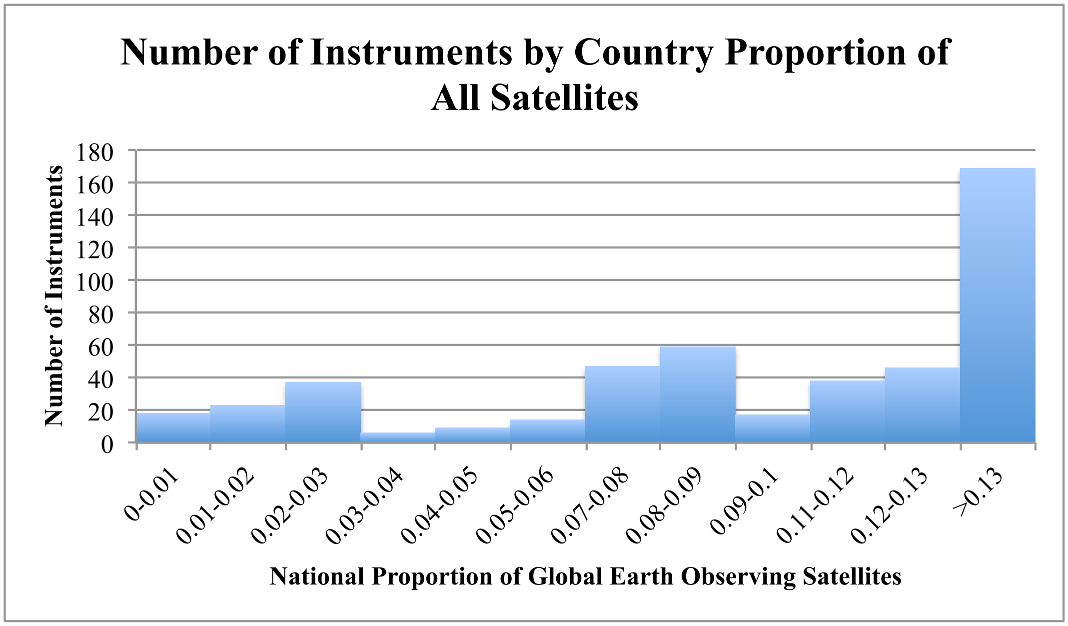

Figure 5.10 shows the number of instruments owned by countries based on the proportion of overall Earth observation satellites owned by that country.

Figure 5.11 Mean National Portion of Global Earth Observation Satellites in Each Data Sharing Category

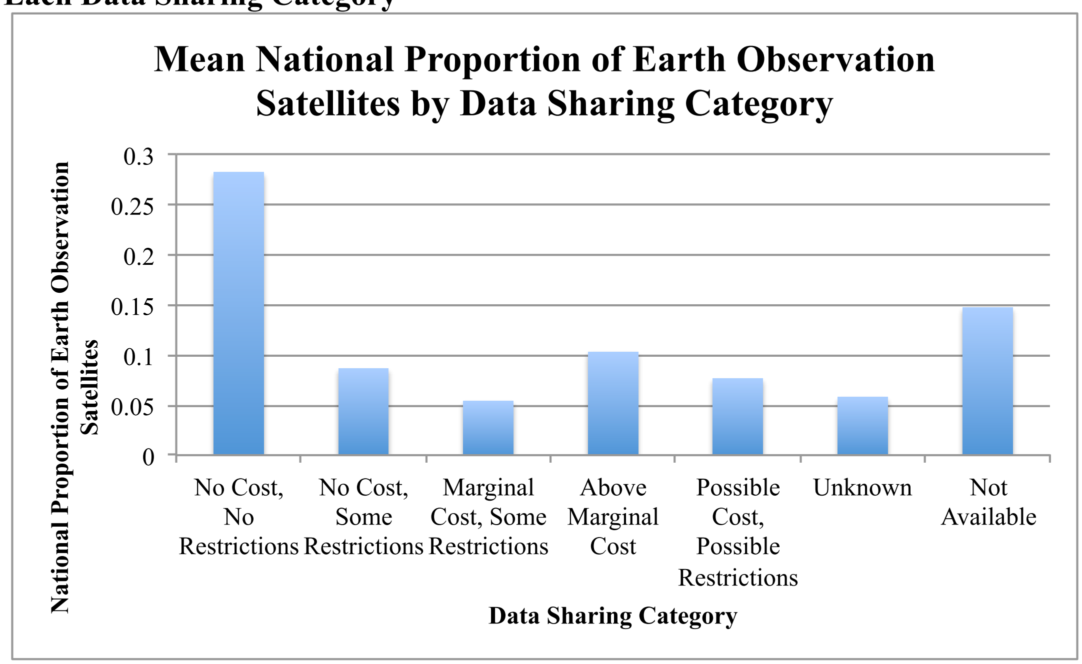

Figure 5.11 shows the mean national proportion of global Earth observation satellites for each data-sharing category.

Research or Operational Agency (Proxy for Professional Culture): Another potential organizational effect on data sharing is related to the view of data sharing in the professional culture. In the space community, there are two distinct types of organizations that develop and operate Earth observation satellites: research organizations and operational organizations. Research organizations, like NASA, focus primarily on satellites that aim to answer a specific research question. Operational organizations generally focus on observations that need to be taken indefinitely, with weather information as the most common example. Historically, there has been strong support for international sharing of operational weather data, particularly non-real time data, while research data is sometimes considered proprietary. Therefore, the theory would predict that operational organizations are more likely to share data.

Figure 5.12 Number of Instruments on Research vs. Operational Satellites

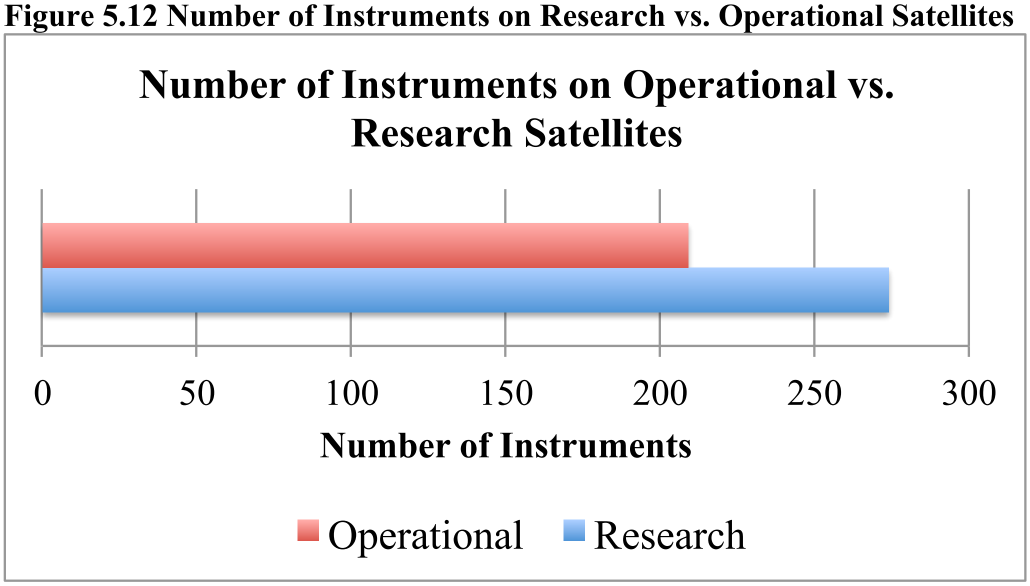

Figure 5.12 shows the number of instruments carried on operational satellites and the number carried on research satellites.

Figure 5.13 Portion of Instruments in Each Data Sharing Category that are Operational

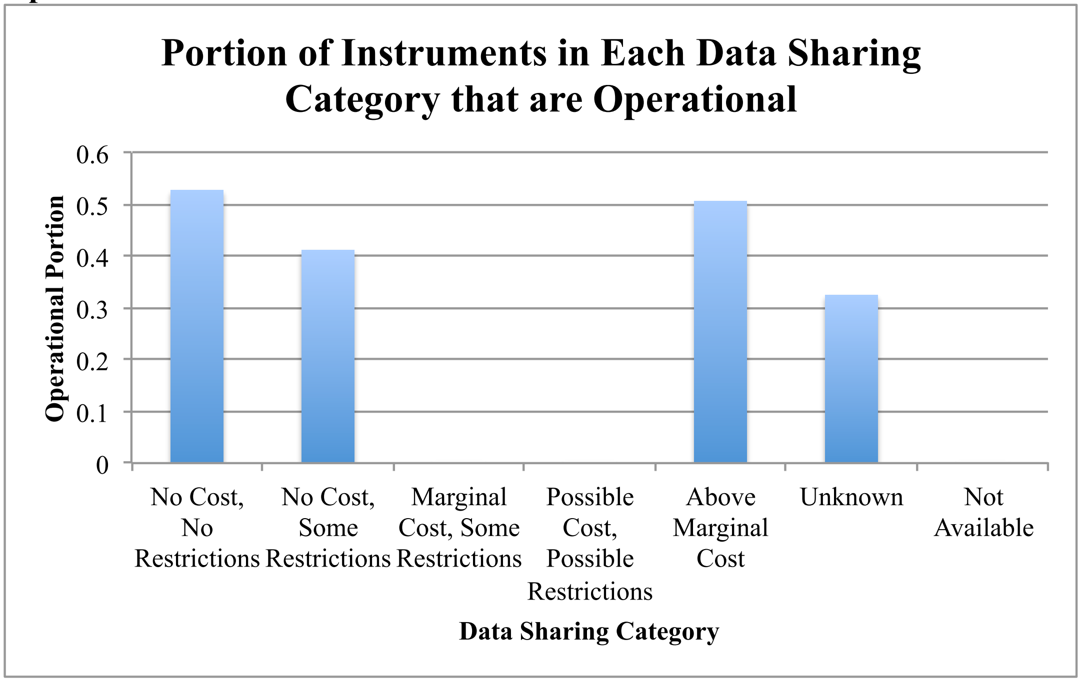

Figure 5.13 shows the portion of instruments in each data-sharing category that are operational.

Official Mission Includes Climate (Proxy for Agency Mission): Organizations frequently have conflicting goals and must base their actions not only on a strict cost benefit analysis, but also on their interpretation of their own mission. One potentially important consideration, therefore, is whether the satellite was specifically designed to include monitoring climate change as part of its mission. This proxy helps to illuminate whether data from satellites designed to monitor climate are more or less likely to be shared than data from satellites with other missions.

Figure 5.14 Number of Instruments that Have Climate in Mission

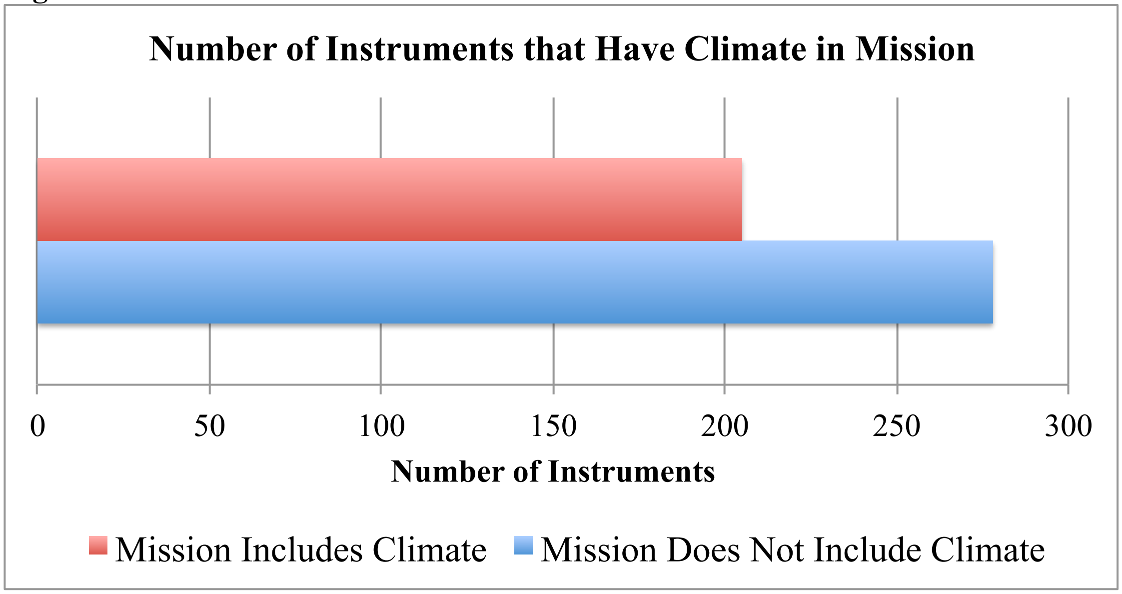

Figure 5.14 shows the number of instruments that are on satellites with climate as a portion of their mission, and the number of instruments on satellites that do not have climate as an explicit part of their mission.

Figure 5.15 Portion of Instruments in Each Data Sharing Category for which Climate is Part of the Mission

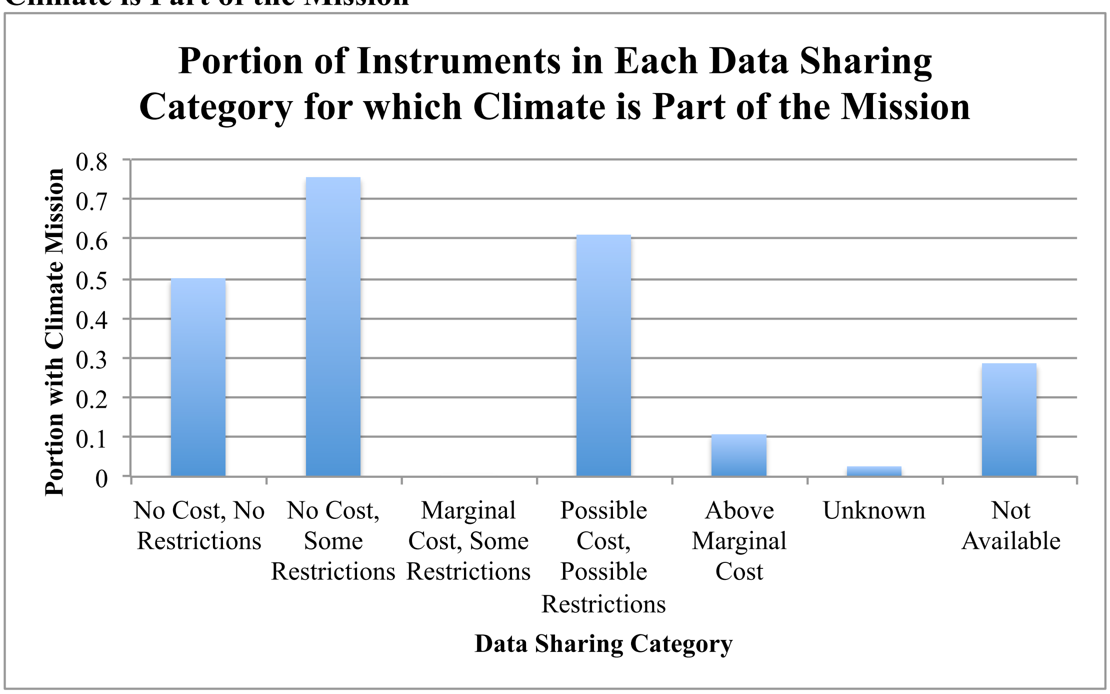

Figure 5.15 shows the portion of instruments in each data-sharing category that are on a satellite with a mission that includes climate.

Security

Military, Dual-Use, or Civil (Proxy for Security Concerns): It is clear that satellite remote sensing imagery has significant military value. This is evidenced by the large number of reconnaissance satellites operated by numerous countries around the world. However, those satellites are not included in this analysis. Therefore, the question is whether security concerns are a determinant in data sharing for unclassified government satellites. It is reasonable to expect that the satellites with the greatest national security value would be those developed and operated for the military or specifically designed for both civil and military use (dual-use). This dummy variable is one for satellites that are military or dual-use and zero for civil. Theory would suggest that military or dual-use satellites would be less likely to be shared.

Figure 5.16 Number of Instruments that are Military or Dual-Use vs. Civil

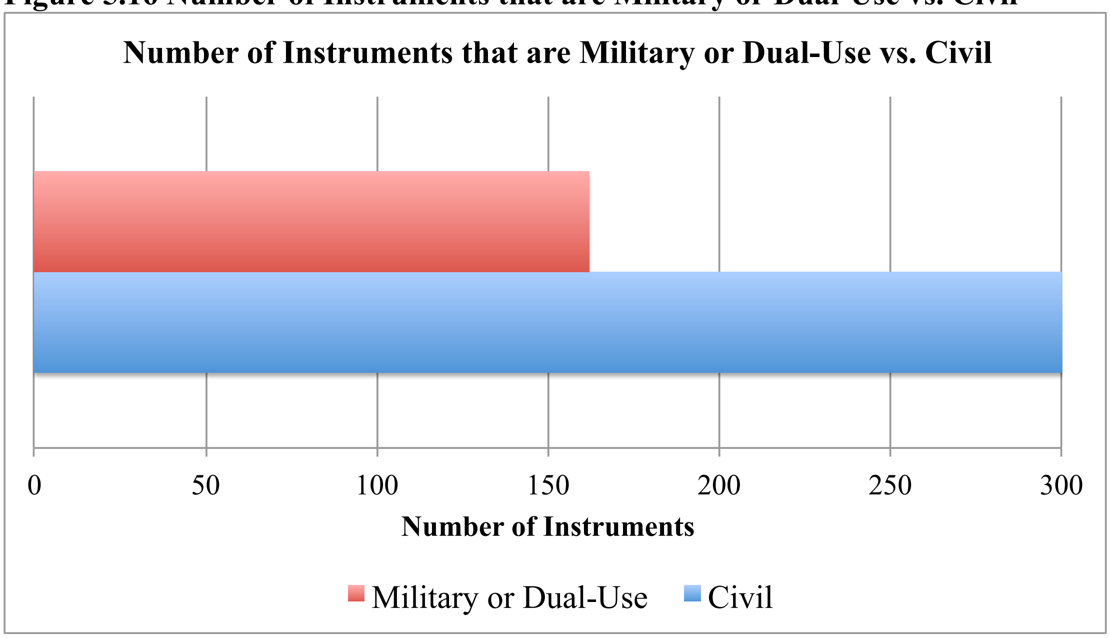

Figure 5.16 shows the number of instruments that are military or dual-use vs. Civil

Figure 5.17 Portion of Instruments on Military or Dual-Use Satellites in Each Data Sharing Category

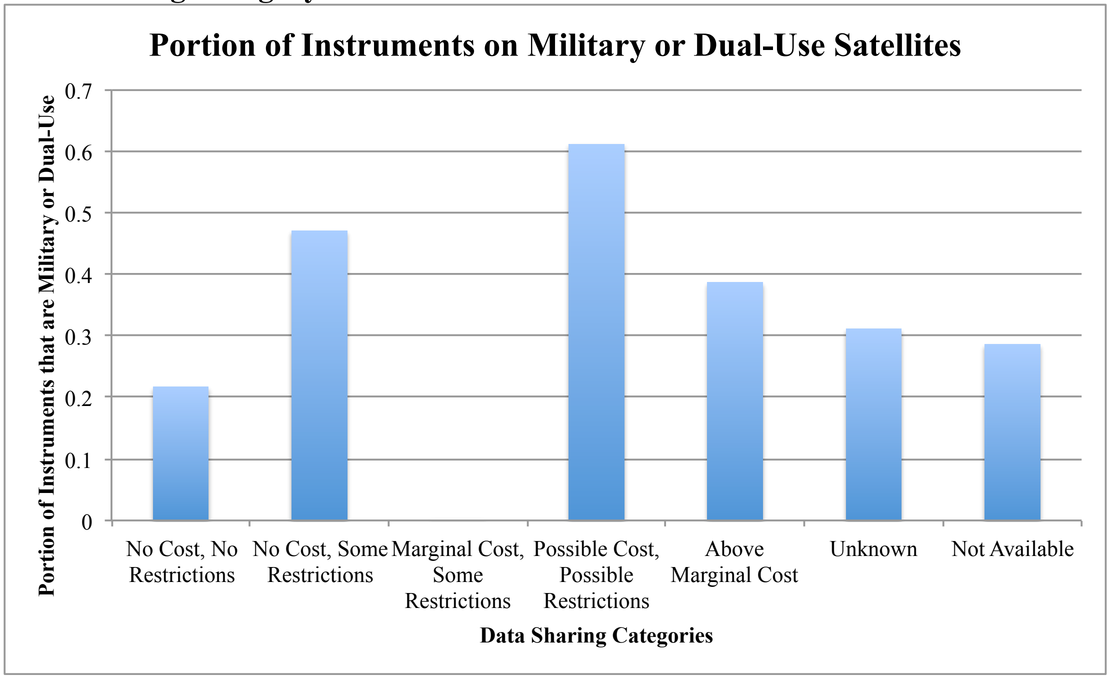

Figure 5.17 shows the portion of instruments in each data-sharing category that are on military of dual-use satellites.

Political

There were also arguments in the literature about the importance of political factors, particularly the importance of demonstrating the value of sharing Earth observing satellite data. The literature suggests that efforts to educate decision-makers about the value of data use and raise awareness about data-use metrics may be more difficult than raising awareness about revenues from data sales and the benefits of these revenues. However, no proxy variables were found that could represent this level of knowledge or understanding among members of national decision-making bodies.

Table 5.2 Independent Variable Descriptive Statistics

Variable	n	Mean	St. Dev.	Min	Max
Voice and Accountability	483	66.3	30	4.7	99.1
Spatial Resolution	267	7233 m	24,750 m	0.7 m	174,000 m
Number of Countries	483	1.3	0.6	1	4
International Participation Index	483	3.3	0.9	0	4
National Portion of Global EO Climate Satellites	483	0.159	0.124	0.005	0.323
Operational	483	0.43	0.50	0	1
Mission Includes Climate	483	.42	.49	0	1
Military or Dual-Use	483	.34	.47	0	1

Table 5.2 shows some basic descriptive statistics for the dependent variable, data sharing.

5.3 Results

Three groups of ordered probit models were run for this analysis. The first set is run without the spatial resolution variable, the second is weighted for number of measurements and lifespan, and the third is unweighted, but includes the spatial resolution variable. OLS specifications were also run, and are included in an appendix. The tables allow an analysis of which variables were statistically significant and in which direction they affect the results. Also, marginal effects are reported, rather than the coefficients, so it is possible to provide an interpretation of the magnitude of the relationship.

Table 5.3 Data Sharing, Ordered Probit, Marginal Effects

	No Cost, No Restrictions	No Cost, Some Restrictions	Marginal Cost, Some Restrictions	Possible Cost, Possible Restrictions	Above Marginal Cost	Unknown	Not Available
Voice and Accountability	0.00245**	-0.000355	-0.0000438	-0.000275*	-0.00117*	-0.000590*	-0.0000159
	(2.64)	(-1.48)	(-0.88)	(-2.16)	(-2.17)	(-2.06)	(-1.04)
Number of Countries Involved	0.0727	-0.0105	-0.00130	-0.00815	-0.0348	-0.0175	-0.000473
	(1.35)	(-0.85)	(-0.84)	(-1.33)	(-1.38)	(-1.33)	(-0.91)
International Participation Index	-0.0721	0.0104	0.00129	0.00808	0.0345	0.0173	0.000469
	(-1.24)	(0.81)	(0.90)	(1.09)	(1.29)	(1.23)	(0.86)
National Portion of Climate Satellites	3.481***	-0.504	-0.0622	-0.390**	-1.664***	-0.837***	-0.0226
	(6.89)	(-1.32)	(-1.01)	(-2.65)	(-5.10)	(-3.82)	(-1.22)
Operational	0.160*	-0.0232	-0.00286	-0.0179	-0.0765*	-0.0385*	-0.00104
	(2.42)	(-1.17)	(-0.94)	(-1.80)	(-2.51)	(-1.98)	(-0.98)
Mission Includes Climate	0.443***	-0.0642	-0.00792	-0.0496*	-0.212***	-0.107***	-0.00288
	(4.78)	(-1.26)	(-1.00)	(-2.55)	(-4.23)	(-3.38)	(-1.21)
Military or Dual-Use	-0.176**	0.0255	0.00314	0.0197	0.0840**	0.0423*	0.00114
	(-2.63)	(1.08)	(0.91)	(1.93)	(3.00)	(2.35)	(1.10)
N	483	483	483	483	483	483	483

Table 5.3 shows the marginal effects for each of the proxy variables across each of the data sharing categories.

Notes: These tables report marginal effects. T-statistics in parentheses.
*Denotes statistically significant at the 5 percent level
**Denotes statistically significant at the 1 percent level
***Denotes statistically significant at the 0.1 percent level
Sources: CEOS MIM Database, CEOS System Database, Union of Concerned Scientists Satellite Database, Satellite Mission Websites

Table 5.4 Data Sharing, Ordered Probit, Marginal Effects, Weighted by Number of Measurements and Lifespan

	No Cost, No Restrictions	No Cost, Some Restrictions	Marginal Cost, Some Restrictions	Possible Cost, Possible Restrictions	Above Marginal Cost	Unknown	Not Available
Voice and Accountability	0.00368* (2.15)	-0.00222* (-2.06)	-0.0000581 (-0.88)	-0.000511 (-1.46)	-0.000687 (-1.63)	-0.000200 (-1.53)	-0.00000276 (-0.74)
Number of Countries Involved	-0.0723 (-1.35)	0.0437 (1.37)	0.00114 (0.77)	0.0100 (1.08)	0.0135 (1.16)	0.00394 (1.10)	0.0000542 (0.69)
International Participation Index	-0.0233 (-0.29)	0.0141 (0.29)	0.000369 (0.29)	0.00324 (0.29)	0.00436 (0.30)	0.00127 (0.30)	0.0000175 (0.28)
National Portion of Climate Satellites	4.029*** (5.64)	-2.432** (-2.99)	-0.0636 (-1.00)	-0.559* (-2.43)	-0.752** (-3.22)	-0.219* (-2.15)	-0.00302 (-0.80)
Operational	0.0502 (0.62)	-0.0303 (-0.60)	-0.000793 (-0.54)	-0.00697 (-0.63)	-0.00936 (-0.62)	-0.00273 (-0.60)	-0.0000376 (-0.44)
Mission Includes Climate	0.280** (2.97)	-0.169* (-2.34)	-0.00442 (-0.95)	-0.0388* (-2.00)	-0.0522* (-2.21)	-0.0152 (-1.75)	-0.000210 (-0.77)
Military or Dual-Use	-0.216** (-3.23)	0.130** (2.58)	0.00341 (0.93)	0.0300* (2.12)	0.0403* (2.14)	0.0118 (1.65)	0.000162 (0.77)
N	483	483	483	483	483	483	483

Table 5.4 shows the marginal effects for each of the proxy variables across each of the data sharing categories. It is weighted by the number of measurements each instrument can take and by the lifespan of the instrument.

Notes: These tables report marginal effects. T-Statistics in parenthesis.
*Denotes statistically significant at the 5 percent level
**Denotes statistically significant at the 1 percent level
***Denotes statistically significant at the 0.1 percent level
Sources: CEOS MIM Database, CEOS System Database, Union of Concerned Scientists Satellite Database, Satellite Mission Websites

Table 5.5 Data Sharing, Ordered Probit, Marginal Effects, Including Spatial Resolution

	No Cost, No Restrictions	No Cost, Some Restrictions	Marginal Cost, Some Restrictions	Possible Cost, Possible Restrictions	Above Marginal Cost	Unknown	Not Available
Voice and Accountability	0.00179**	0.00107*	0.0000183	0.0000170	-0.00107*	-0.00175**	-0.0000751
	(2.77)	(2.46)	(1.05)	(0.37)	(-2.49)	(-2.75)	(-1.62)
Number of Countries Involved	0.00379	0.00226	0.0000388	0.0000360	-0.00226	-0.00370	-0.000159
	(0.13)	(0.13)	(0.13)	(0.12)	(-0.13)	(-0.13)	(-0.13)
International Participation Index	0.0383	0.0228	0.000391	0.000363	-0.0228	-0.0374	-0.00161
	(1.29)	(1.25)	(0.83)	(0.35)	(-1.26)	(-1.28)	(-1.12)
National Portion of Climate Satellites	1.333***	0.794***	0.0136	0.0127	-0.794***	-1.303***	-0.0559
	(4.40)	(3.72)	(1.15)	(0.37)	(-3.57)	(-4.79)	(-1.77)
Operational	0.0741	0.0442	0.000759	0.000704	-0.0442	-0.0725	-0.00311
	(1.83)	(1.73)	(0.97)	(0.36)	(-1.76)	(-1.81)	(-1.37)
Mission Includes Climate	0.257***	0.153***	0.00263	0.00244	-0.153***	-0.251***	-0.0108
	(5.22)	(3.76)	(1.12)	(0.37)	(-3.80)	(-5.24)	(-1.84)
Military or Dual-Use	-0.0811*	-0.0483*	-0.000830	-0.000770	0.0483*	0.0793*	0.00340
	(-2.14)	(-2.00)	(-1.04)	(-0.37)	(2.02)	(2.15)	(1.44)
Spatial Resolution	0.00000276	0.00000164	2.82e-08	2.62e-08	-0.00000164	-0.00000270	-0.00000011
	(1.91)	(1.93)	(1.06)	(0.38)	(-1.81)	(-2.01)	(-1.44)
N	267	267	267	267	267	267	267

Table 5.5 shows the marginal effects for each of the proxy variables across each of the data sharing categories. It includes the spatial resolution proxy variable.

Notes: These tables report marginal effects. T-Statistics in parenthesis.
*Denotes statistically significant at the 5 percent level
**Denotes statistically significant at the 1 percent level
***Denotes statistically significant at the 0.1 percent level
Sources: CEOS MIM Database, CEOS System Database, Union of Concerned Scientists Satellite Database, Satellite Mission Websites

Many of the proxy variables were statistically significant across multiple models. Countries with a higher score on the World Bank Accountability Index are more likely to share their data to a greater degree. Also, the larger the portion of global Earth observation satellites a nation was involved in, the more likely they were to share data more freely. When the climate was part of a satellite's official mission, the data from instruments on those satellites was more likely to be shared. If the satellite was specifically designated as military or dual use, sharing was less likely. The dummy variable representing operational or research status was only significant in the first model, but in that case, it was positive, indicating that data collected by satellites developed by operational agencies (generally meteorological agencies) is more likely to be shared. The results for the number of countries involved, the international participation index, and spatial resolution were not significant.

5.4 Discussion

The fact that the many of the proxy variables were statistically significant supports the idea that the theoretical arguments discussed in the literature do represent important incentives and disincentives to data sharing. Furthermore, each of the proxy variables that was statistically significant had an effect that matched the direction suggested by the literature.

As expected, the higher the score on the World Bank Accountability Index, the more likely a country was to share data more freely and openly. This suggests that valuing transparency is important as an incentive for sharing data.

The analysis also showed that countries that were involved in a larger portion of the overall global Earth observation satellites over this period were more likely to share their data. This agrees with the theory that having fewer resources essentially causes organizations to hoard the resources they do have, and makes them less likely to share their data.

The fact that climate was part of a satellite mission had a positive effect in terms of data sharing. This suggests that there is support for sharing of climate data, in particular.

If a satellite was designed for military or dual-use purposes, the data was less likely to be shared. This supports the theory that national security concerns are one of the disincentives to sharing satellite data.

Finally, though it was not significant in all cases, the effect of a satellite being considered operational, rather than research, did increase the likelihood that data would be shared. Again, this agrees with the theory that suggested the professional culture of sharing in meteorology (operational) agencies would make data from these organizations more likely to be shared overall.

These results provide some indication that the incentives and barriers suggested by the literature are playing a role in data sharing policies. However, the proxy variables have a limited ability to capture each theoretical argument, and the analysis doesn't provide insight into how each of these issues affects policy development. Therefore, the next section develops a series of case studies to investigate this issue more fully.

Chapter 6: Domestic Agency-Level Comparative Case Studies

The quantitative analysis in the previous chapter provided some indication of which barriers and incentives are important in international sharing of climate data collected by satellites. However, to further investigate the incentives and barriers to data sharing and the determinants of data sharing policy development and changes, I carry out a series of case studies on agencies that operate climate-relevant satellites in three nations with relatively large satellite Earth observation programs. The series will include a total of seven government agencies from the United States, Europe, and Japan: the U.S. National Aeronautics and Space Administration (NASA), the U.S. National Oceanographic and Atmospheric Association (NOAA), and the United States Geological Survey (USGS), the European Space Agency (ESA), the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), the Japan Aerospace Exploration Agency (JAXA), and the Japanese Meteorological Agency (JMA).

Table 6.1 Domestic Case Study Agency Statistics[231]

		Total Budget, 2012 (millions)	Earth Science Budget, 2012 (millions)	Number of climate-relevant satellites, 2000-2012
United States	NASA	$17,770.0	$1,760.5	19
	NOAA	$4,905.3	$1,878.0	17
	USGS	$1,068.0	$144.1	2
Europe	ESA	$5,090.0	$1,121.4	7
	EUMETSAT	$417.52	$417.52	8
Japan	JAXA	$2,180.0	$237.0	4
	JMA	$860		3

Table 6.1 shows a variety of descriptive statistics about the size of the agencies for which case studies were carried out.

There are 35 nations that were involved in the operation of at least one climate-relevant satellite between 2000 and 2012. These seven agencies were chosen because they come from three of the countries with the largest number of climate-relevant satellites, and they have some variation in their current data sharing policies. While Russian, Indian, and Chinese space and meteorological agencies also have a large number of relevant satellites and would be interesting cases, the major challenges of contacting and communicating with policy-makers in these countries were restrictive. France, Germany, and Italy also have large Earth observation programs, even independent of their contributions to the European agencies, but these were not chosen because of their close connection to the European cases already included.

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231 *The Space Report 2013: The Authoritative Guide to Global Space Activity*. Colorado Springs, CO: Space Foundation, 2013. Print.
United States. National Oceanic and Atmospheric Administration. *FY2013 Budget Summary: Introduction*. NOAA, n.d. Web. 28 Mar. 2013.
<http://www.corporateservices.noaa.gov/nbo/fy13_budget_highlights/introduction.pdf>.
United States. National Oceanic and Atmospheric Administration. National Environmental Satellite, Data, and Information Service. *NESDIS FY2013 Budget Highlights*. NOAA, n.d. Web. 28 Mar. 2013.
<http://www.corporateservices.noaa.gov/nbo/fy13_budget_highlights/NESDIS_FY13_One_Pager.pdf>.
United States. United States Geological Survey. *FY2013 Budget Highlights*. USGS, n.d. Web. 28 Mar. 2013. <http://www.doi.gov/budget/appropriations/2013/highlights/upload/BH051.pdf>.
Japan. Japan Meteorological Agency. *JMA Brochure*. N.p., 2012. Web. 28 Mar. 2013.
<http://www.jma.go.jp/jma/en/Activities/brochure201203.pdf>.

Countries with much smaller satellite programs generally have less impact on global data sharing issues, do not have official policies, and are more difficult to contact. However, analysis of a group of these smaller actors could provide insight into major differences from larger programs, and analysis of any of these additional groups of cases would be an interesting area for future research.

Government agencies are of great interest, because this is the level on which data-sharing policies are developed. Though an agency may choose different levels of restriction for data related to specific satellites or instruments, the data-sharing policy outlining these decisions is developed and approved for the agency as a whole. Therefore, examination of these agencies illuminates not only how data sharing policies developed and changed over time within each agency, but also why agencies changed their policies – the motivations for policy change. Similarities in the determinants of data sharing policies in these countries are used to identify incentives and barriers to data sharing that are likely operating in other countries as well. It is also possible to see the extent to which determinants vary by country, or type of agency (research or operational), type of satellite, and other theoretically important attributes.

The case studies included analysis of agency-level data sharing policies and related documents. They also build on interviews with at least two policy-makers at each agency who were involved in, or aware of, the development of the agency's data-sharing policies. In addition to describing the process of developing the data sharing policy, these interviews focused specifically on incentives and barriers to data sharing considered by the agency and the primary determinants in the final policy choice.

These case studies will show that all seven agencies had similar substantive concerns with regard to developing and choosing data sharing policies, in particular, concerns about economic efficiency, normative considerations related to responsibilities to share certain types of data as well as the proper role of government, and the importance of sharing data to address global challenges. However, their determinations on how to address these concerns differ both from agency to agency and also over time. Almost all agencies followed a similar pattern of development, moving from an informal policy of sharing to restrictive policies aimed at cost recovery or commercialization, and then towards a free and open sharing policy. However, even within each country, these steps often occurred at different times, for different lengths of time, and to greater and lesser extents for each agency.

6.1 United States

The United States has multiple agencies that operate Earth observing satellites, and as a whole, the United States has the largest Earth observing satellite system in the world, collecting data related to many essential climate variables. The two primary agencies of interest are the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA). Though the United States Geological Survey (USGS) only operates one series of Earth observation satellites, the Landsat series, it has also been an important player in data sharing issues. Also, it is important to note that although all three agencies are subject to many of the same government-wide policies and trends, they are located in different departments – NOAA is within the Department of Commerce, and USGS is in the Department of Interior. This means that they also report to, and have funding authorized by, different Congressional sub-committees. These differences help to explain the diversity in the data sharing policy drafts across these three U.S. agencies operating Earth observing satellites.

Table 6.2 Essential Climate Variable coverage with U.S.-led satellites only

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aerosol Properties	9	10	12	13	13	14	14	14	14	16	17	17	16
Aerosols	0	0	0	0	1	1	1	1	1	1	1	1	1
Albedo	7	7	9	9	9	10	10	10	10	11	11	11	11
Biomass	9	9	11	11	11	11	9	9	9	10	10	11	11
Carbon Dioxide, Methane, and Green	7	7	9	9	10	10	7	7	7	8	8	9	9
Cloud Properties	19	20	22	25	25	23	23	23	23	25	26	26	25
Earth Radiation Budget	15	16	18	19	18	18	15	14	14	16	17	18	17
FAPAR	6	6	8	8	8	9	9	9	9	10	10	10	10
Fire Disturbance	13	14	16	16	15	15	13	12	12	14	15	16	15
Glaciers and Ice Caps, and Ice Sheets	3	3	3	3	3	3	3	3	3	3	3	3	3
LAI	4	4	5	5	5	5	5	5	5	5	5	6	6
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0
Land Cover	15	17	19	20	20	20	18	17	18	20	21	20	19
Ocean Color	10	11	13	13	12	13	13	12	12	14	15	16	15
Ocean Currents	1	2	3	3	3	3	3	2	3	3	3	3	3
Ocean salinity	0	0	0	0	0	0	0	0	0	0	0	0	0
Ozone	13	14	16	16	16	16	12	11	11	13	14	15	14
Precipitation	15	16	18	19	18	16	16	15	15	17	18	19	18
Sea Ice	6	6	8	10	10	11	11	11	11	12	12	12	12
Sea Level	5	6	7	8	8	7	8	7	8	8	8	8	8
Sea State	1	2	2	2	2	2	2	1	2	2	2	2	2
Sea Surface Temperature	12	13	15	16	15	15	13	12	12	14	15	16	15
Snow Cover	14	14	16	18	18	16	15	15	15	16	16	17	17
Soil Moisture	9	9	12	14	14	13	14	14	14	14	14	15	15
Surface Temperature	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Wind Speed and Direction	10	11	13	14	14	13	13	12	13	12	12	13	13
Upper Air Temperature	17	18	20	21	21	19	22	22	22	24	25	26	25
Upper-air Wind	9	10	12	12	11	11	10	9	9	10	11	11	10
Water Vapour	19	21	23	25	25	23	27	26	27	29	30	31	30

Table 6.2 shows the number of instruments on U.S.-led satellites collecting each essential climate variable each year from 2000 to 2012.

6.1.1 National Aeronautics and Space Administration (NASA)

NASA Vision: To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind.[232]

Early Development and Unofficial Data Sharing

In 1958, the National Aeronautics and Space Act transformed the National Advisory Committee for Aeronautics into the National Aeronautics and Space Administration (NASA), creating a new civil agency. The act called for NASA to "provide for research into problems of flight within and outside the earth's atmosphere." This included developing satellites and the associated equipment.[233]

At that time, the Department of Defense had already been developing the first weather satellite, the Television Infrared Operational Satellite (TIROS), but it was handed off to NASA shortly after its formation. NASA developed a second series of meteorological satellites, the Nimbus satellite system, with the first three launches occurring in the 1960s. NASA continued launching Earth observing satellites, with six launches in the 1970s and another six in the 1980s.[234] Despite the focus on weather data collection, these satellites included technology demonstrations and new types of observing instruments.

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[232] "National Aeronautics and Space Administration." *NASA Index*. N.p., 7 Dec. 2012. Web. 28 Mar. 2013. <http://www.nasa.gov/about/index.html>.

[233] "National Aeronautics and Space Act of 1958 (Unamended)." *National Aeronautics and Space Act of 1958 (Unamended)*. N.p., n.d. Web. 30 Sept. 2012. <http://history.nasa.gov/spaceact.html>.

[234] "NASA - National Aeronautics and Space Administration." *NASA*. N.p., n.d. Web. 30 Sept. 2012. <http://www.nasa.gov/50th/50th_magazine/historyLetter.html>.

Throughout this period, NASA had no official data sharing policy. This was due in part to the technology demonstration focus of the program at that time; it was still a period where NASA was determining what Earth observing satellites could do and how they would be most useful. The number of scientists interested in investigating the potential of this new technology at such an early stage was relatively small and sharing was informal. In addition, the relatively small number of active satellites and the limitations of then contemporary data storage and sharing technologies were further limitations on widespread sharing.

However, as time progressed, these technology demonstrations proved that there was great potential to learn about the Earth using remote sensing satellites. During the late 1970s and early 1980s, awareness of global environmental issues, and climate change in particular, began to increase. In this period, NASA's observations and research concerning the ozone hole over Antarctica also provided it with experience and public recognition as a leader on environmental issues.[235] In 1973, NASA Administrator James Fletcher testified to Congress that NASA could be called an environmental agency, and that understanding the Earth and its environment may be NASA's essential task. In 1983, NASA created an Earth System Sciences Committee that worked with other government agencies to organize an initiative to study global change.[236]

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[235] Dick, Steven J., and Roger D. Launius. *Societal Impact of Spaceflight*. Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. Print.
[236] Launius, Roger D. "A Western Mormon in Washington, D.C.: James C. Fletcher, NASA, and the Final Frontier." *The Pacific Historical Review* 64.2 (1995): 217-41. Web. 28 Mar. 2013. <http://www.cumorah.org/libros/english/Science/A_Western_Mormon_in_Washington-James_C._Fletcher__NASA__and_the_Final_Frontier.pdf>.
Weart, Spencer R. *The Discovery of Global Warming*. Cambridge, MA: Harvard UP, 2003. Print.

Growth of Earth Science and the First Data Sharing Policy

With the value of Earth observing satellites proven, and NASA's role as a leader in Earth science established, NASA's ambitions grew. This began with planning of the "Mission to Planet Earth" in the early 1980s.[237] The centerpiece of this new mission was the "Earth Observing System," a comprehensive system of satellites, driven in part by the need for long-term, comprehensive observations to better understand the causes and effects of global change.[238] In 1986, the program plan included two very large and capable satellites with many sensors, to be launched by the early 2000s, and a series of smaller precursor missions in the 1990s. Total costs were projected to be $30 billion over 30 years, with $17 billion expected to be spent by 2000.[239]

When President George H. W. Bush entered office in 1989, he made global change the first "presidential priority" in science and technology, and named NASA's Earth Observation System the largest component. The program was officially adopted as a top priority in the newly formed interagency U.S. Global Change Research Program in 1990.[240] The increasing size and importance of the program was recognized within

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237 Edelson. *Mission to Planet Earth*. Washington, D.C.: National Academy, 1988. Print.

238 Stevens, William K. "NASA Plans a 'Mission to Planet Earth'" *The New York Times*. The New York Times, 25 July 1989. Web. 30 Sept. 2012. <http://www.nytimes.com/1989/07/25/science/nasa-plans-a-mission-to-planet-earth.html?pagewanted=all>.
Earth System Science Overview: A Program for Flobal Change. Washington, D.C.: National Aeronautics and Space Administration, 1986. *Google Books*. Web. 28 Mar. 2013. <http://books.google.com/books?id=KD4rAAAAYAAJ&printsec=frontcover&dq=%22OCLC14206395%22&as_brr=3&hl=&cd=1&source=gbs_api#v=onepage&q&f=false>.

239 Stevens, William K. "Huge Space Platforms Seen as Distorting Studies of Earth." *The New York Times*. N.p., 19 June 1990. Web. 28 Mar. 2013. <http://www.nytimes.com/1990/06/19/science/huge-space-platforms-seen-as-distorting-studies-of-earth.html?pagewanted=all>.

240 Dick, Steven J., and Roger D. Launius. "NASA and the Environment: Science in a Political Context." *Societal Impact of Spaceflight*. Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. 313-30. Web. 28 Mar. 2013. <http://history.nasa.gov/sp4801-chapter16.pdf>.

NASA. Starting in the 1990s and lasting over a decade, NASA's Earth Science office was moved out of the Space Sciences and Application area and elevated to a level equal to other major offices such as Spaceflight and Space Sciences.[241]

In the late 1980s and early 1990s, as plans for the Mission to Planet Earth and the Earth Observing System took form, NASA recognized the need to develop a plan to deal with the unprecedented amount of data that would be collected. The technical portion of this was the Earth Observation Satellite Data and Information System (EOSDIS), which would include data acquisition, archiving, and distribution centers. Along with these technical commitments, NASA began to examine its data sharing practices and develop a new, official data sharing policy.[242]

A number of NASA officials took the position that data should be shared openly and freely. They argued that data sharing was fundamental to science, the focus of their program, and that making data available to the greatest extent possible was the most efficient way to ensure more research gets done and more knowledge is produced. If each mission team, agency, or even country, kept its data to itself, progress on interdisciplinary and global issues like climate change would be very slow, if not impossible. Data from one instrument needs to be compared to others, gaps in data

[241] "NASA Organizational Charts." *NASA Organizational Charts*. N.p., n.d. Web. 30 Sept. 2012. <http://history.nasa.gov/orgcharts/printFriendly/orgcharts.html>.
[242] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy." *Space Policy* 6.1 (1990): 45-52. Web.

need to be filled in, and results need to be tested and re-tested. This type of science simply couldn't be done without sharing data and information.[243]

At this time, it was common for the principle investigators on a satellite program to be granted a period of exclusive use of the data, allowing them to be the first to review data and publish new findings. For example, the Upper Atmosphere Research Satellite (UARS) science team and principle investigators, a group of about 40 people, had two years of exclusive access to data collected by this mission after it launched in 1991.[244] As NASA officials developed the first official data sharing policy, they targeted the elimination of this practice as the first step in increasing data availability.[245] Eliminating this practice would help achieve the goal of maximizing data use and benefits.[246]

In March 1991, NASA released its Earth science data policy. This policy stated that data from NASA's Earth observation satellites would be made available free of charge and without any period of exclusive use "for use in Federally-funded research, development, and application programs and cooperative research programs." It noted that NOAA would have free access to all data with potential operational applications, and that data would also be available for free for educational and informational

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[243] Personal interviews. 2012. Adina Gillspie, Barbara Ryan, Bob Chen, Brent Smith, Michelle Hertzfeld, Brian Killough, Danielle Wood, Etienne Wood, Etienne Marcuz, Helen Wood, Ivan Petiteville, Jack Kaye, James Baker, Jerome Lafeuille, Jim Zimmerman, John Jones, Linda Moodie, Lulu Makapela, Martha Maiden, Norimitsu Kamimori, Paul Cournet, Silvia Castane, Peter Collohan, Simonetta Chelli, Tim Stryker, Bruce Quirk, Robert Doyle, Kazushi Kobata, and Tadayoshi Yahata.
[244] "EOSDIS FY2011 Annual Metrics Report." N.p., Feb. 2012. Web. 30 Sept. 2012. <http://earthdata.nasa.gov/sites/default/files/field/document/FY11AnnualReport.pdf>.
[245] Marshall, E. "Bringing NASA Down to Earth." *Science* 244.4910 (1989): 1248-251. Web.
[246] Personal interviews.

activities in the public interest and in keeping with any binding agreements with foreign or domestic institutions that establish a quid pro quo.[247]

However, it noted that, "Access terms will specify that such users will not engage in commercial applications of NASA-provided data without authorization."[248] This caveat was driven in large part by an interest on the part of Congress, as well as some within the agency, in selling Earth observation data. It was believed that this practice would lead to greater efficiency, decrease NASA budget requirements, and promote activity in the private sector.[249]

Just a few months after NASA's policy was announced, the "Bromley Principles" were released. Officially called the "Data Management for Global Change Research Policy Statements," these principles were developed within the U.S. Global Change Research Program, led by Presidential Science Advisor Allen Bromley. The principles were discussed and agreed to by thirteen government agencies, including NASA, NOAA, and USGS. The policy endorsed "full and open access" to data for global change research.[250]

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[247] United States. National Aeronautics and Space Administration. Office of Earth Science.*Directive NMI 8000.3 NASA Earth Science Program Data Program - Delegation of Authority*. N.p.: n.p., 1991. Print.

[248] United States. National Aeronautics and Space Administration. Office of Earth Science.*Directive NMI 8000.3 NASA Earth Science Program Data Program - Delegation of Authority*. N.p.: n.p., 1991. Print.

[249] Personal interviews.
Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.

[250] "USGCRP Policy Statements on Data Management for Global Change Resesarch."*USGCRP Policy Statements on Data Management for Global Change Resesarch*. N.p., n.d. Web. 30 Sept. 2012. <http://www.gcrio.org/USGCRP/DataPolicy.html>.

Similar to the NASA policy, this policy stated, “Full and open sharing of the full suite of global data sets for all global change researchers is a fundamental objective.” It specified, “Data should be provided at the lowest possible cost to global change researchers in the interest of full and open access to data. This cost should, as a first principle, be no more than the marginal cost of filling a specific user request. Agencies should act to streamline administrative arrangements for exchanging data among researchers.” It also noted that agencies should develop plans for commercial access to global change databases, but did not address any specific procedures or costs related to this access.[251]

NASA’s Data Sharing Policy Update

In the early 1990s, NASA’s plans for the Earth Observing System were scaled back, largely due to budget pressures. The program had already been redesigned to include six smaller satellites, rather than two very large ones, and in 1991, Congress directed NASA to cap spending at $11 billion by 2000, approximately two-thirds the amount originally projected.

In 1992, Dan Goldin became NASA Administrator and implemented his “faster, better, cheaper” initiative for the agency; the Earth Observing System did not meet his criteria.[252] As budget pressures increased, interest within the government in data

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[251] "USGCRP Policy Statements on Data Management for Global Change Resesarch."*USGCRP Policy Statements on Data Management for Global Change Resesarch*. N.p., n.d. Web. 30 Sept. 2012. <http://www.gcrio.org/USGCRP/DataPolicy.html>.

[252] Dick, Steven J., and Roger D. Launius. "NASA and the Environment: Science in a Political Context." *Societal Impact of Spaceflight.* Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. 313-30. Web. 28 Mar. 2013. <http://history.nasa.gov/sp4801-chapter16.pdf>.

sales continued. Despite the restriction on commercial use included in NASA's policy, a Government Accountability Office Report released in June 1992 criticized NASA for not going far enough in engaging the commercial sector. In particular, it noted that NASA did not sufficiently consider commercial needs in developing plans for satellite systems, and did not have clear plans in place for access to data by commercial entities.[253]

President Clinton entered office in 1992, but environmental priorities were focused more on carbon dioxide reductions and other mitigation actions rather than long-term observations. The administration also prioritized deficit reduction, and by 1995, the Earth Observing System was cut to $6.8 billion, a third of the original projected amount. The reduced program included numerous small satellites and three medium-sized "flag-ship" missions: Aqua, Aura, and Terra, focusing on water, atmosphere, and land respectively.[254] Despite these cutbacks, the Earth Observing System would be the most comprehensive national Earth observing system ever undertaken. To deal with all of the data being collected, NASA developed the Earth Observation System Data and Information System (EOSDIS). EOSDIS would help to ensure that all of the data was collected, managed, and made quickly available.[255]

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[253] United States. General Accounting Office. *GAO/IMTEC-92-44 Questions Remain About U.S. Commercial Access*. N.p.: n.p., 1992. Print.

[254] Dick, Steven J., and Roger D. Launius. "NASA and the Environment: Science in a Political Context." *Societal Impact of Spaceflight*. Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. 313-30. Web. 28 Mar. 2013. <http://history.nasa.gov/sp4801-chapter16.pdf>.

[255] "Wired 1.06: Mission To Planet Earth." *Wired.com*. Conde Nast Digital, n.d. Web. 30 Sept. 2012. <http://www.wired.com/wired/archive/1.06/mission.earth.html>.

NASA's data policy was set to expire at the end of 1998, and as that time grew near, NASA's data policy was examined and discussed. There was still a group within the government that believed commercialization of satellites and satellite data, whenever possible, would be the most efficient action. There was some support for marginal cost pricing, and a sense that this would be the most economically efficient method, allowing NASA to get some returns based on data use. However, others in the Earth Science program believed the best way to achieve NASA's mission was by providing data free of charge without any restrictions.[256] They argued that any costs or restrictions on the data, even those necessary to distinguish between research and commercial uses, would decrease data dissemination and use.[257]

In addition to the view that it was the most efficient way to achieve its mission, a number of individuals within NASA espoused the view that data sharing was a moral obligation – it was just the right thing to do. They argue that NASA is not, and should not be, in the business of trying to make money.[258] They explained that taxpayers had already paid for development and operation of the system and should not be required to pay again to access the data.[259]

Individuals in NASA's Earth Science office also felt that charging for data just didn't make economic sense. Why spend a billion dollars developing and launching a

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[256] Personal interviews.
[257] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy." *Space Policy* 6.1 (1990): 45-52. Web.
[258] Personal interviews.
[259] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy." *Space Policy* 6.1 (1990): 45-52. Web.

satellite and then nickel-and-dime the users by charging for data? There were complaints that charging meant that some NASA employees would need to spend their time accepting payments and making bank runs, all for a monetary benefit that was very small compared to the cost of the satellite.[260] Even if $100,000 was made from selling satellite data at marginal cost, that revenue would reflect only one tenth of one percent of the cost of a billion-dollar satellite like Terra, Aqua, or Aura.[261] This small benefit was not believed to be worth the effort on the part of NASA nor was it worth the disincentive to data use that it created for potential users.[262] They also pointed to the experience of the Landsat system, which had recently been returned to government control after a failed effort to commercialize the system.[263] Advocates for a fully open data policy argued that open access would generate more revenue and contribute more to economic growth than cost recovery by increasing activity in the value-added sector, which would create new products and businesses.[264]

One of the primary arguments of the group advocating for free and open sharing came from a government-wide policy originally released in 1985 that had recently been revised.[265] The 1994 revision of the Office of Management and Budget (OMB) circular A-130 on the management of federal information resources emphasized the

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[260] Personal interviews.

[261] "Terra: Flagship of the Earth Observing System." *Press Kit*. NASA, Nov. 1999. Web. 30 Sept. 2012. <http://www.nasa.gov/pdf/156293main_terra_press_kit.pdf>.
"Aura Press Kit." *Press Kit*. NASA, July 2004. Web. 30 Sept. 2012. <http://www.nasa.gov/pdf/60914main_AuraPressKit6-30.pdf>.
"Aqua." *Press Kit*. NASA, 2002. Web. 30 Sept. 2012. < http://www.nasa.gov/pdf/151543main_aqua_presskit.pdf >.

[262] Personal interviews.

[263] Personal interviews.

[264] Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy." *Space Policy* 6.1 (1990): 45-52. Web.

[265] Personal interviews.

need for improved public access to government information. This document also stated that agencies must “set user charges for information dissemination products at a level sufficient to recover the cost of dissemination but no higher.”[266]

NASA advocates of free and open data sharing emphasized an exception to this requirement that allowed data to be provided without any cost to the user. This portion of OMB Circular A-130 stated that costs could be waived, “where the agency plans to establish user charges at less than cost of dissemination because of a determination that higher charges would constitute a significant barrier to properly performing the agency's functions, including reaching members of the public whom the agency has a responsibility to inform.”[267]

NASA officials argued that NASA’s mission of promoting research and increased understanding of the Earth required disseminating the data as widely as possible, and

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[266] "Circular No. A-130 Revised." *The White House*. N.p., n.d. Web. 30 Sept. 2012. <http://www.whitehouse.gov/omb/circulars_a130_a130trans4>.
"OMB Announces New A-130 Circular." *Seclists*. N.p., 28 June 1993. Web. 28 Mar. 2013. <http://seclists.org/interesting-people/1993/Jun/83>.
"FOIA Update: Agencies Place Increasing Emphasis on Affirmative Information Disclosure." *FOIA Update: Agencies Place Increasing Emphasis on Affirmative Information Disclosure*. United States Department of Justice, 1995. Web. 28 Mar. 2013. <http://www.justice.gov/oip/foia_updates/Vol_XVI_1/PAGE1.htm>.
Weiss, Peter. "Revisions to OMB Circular No. A-130: Management of Federal Information Resources." U.S. Office of Management and Budget. Washington, DC. 30 Oct. 1994. Web. 28 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/tempe/weiss.html>.

[267] "Circular No. A-130 Revised." *The White House*. N.p., n.d. Web. 30 Sept. 2012. <http://www.whitehouse.gov/omb/circulars_a130_a130trans4>.
"OMB Announces New A-130 Circular." *Seclists*. N.p., 28 June 1993. Web. 28 Mar. 2013. <http://seclists.org/interesting-people/1993/Jun/83>.
"FOIA Update: Agencies Place Increasing Emphasis on Affirmative Information Disclosure." *FOIA Update: Agencies Place Increasing Emphasis on Affirmative Information Disclosure*. United States Department of Justice, 1995. Web. 28 Mar. 2013. <http://www.justice.gov/oip/foia_updates/Vol_XVI_1/PAGE1.htm>.
Weiss, Peter. "Revisions to OMB Circular No. A-130: Management of Federal Information Resources." U.S. Office of Management and Budget. Washington, DC. 30 Oct. 1994. Web. 28 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/tempe/weiss.html>.

even marginal cost could be a barrier to access. This was particularly true if marginal cost was interpreted, as it was in the case of some agencies, to include the man-hours required to fulfill requests and the infrastructure costs of maintaining archiving systems, in addition to costs of media and mailing.[268]

Arguments for free and open data sharing won out, and NASA's 1998 policy, which is still in place as of 2012, "promotes the full and open sharing of all data with the research and applications communities, private industry, academia, and the general public." The policy notes that the greater the availability of data, the more quickly and effectively it can be utilized for science and applications that benefit the general public. It explains that NASA collects and archives data in order to promote scientific research and thus acts to maximize access to data. NASA's 1998 data policy includes full and open data sharing from all Earth observing satellites as soon as data becomes available, continuing the stipulation that no period of exclusive access to NASA Earth Science data will be provided. The policy states that all data users will be treated equally, and that data will only be restricted when it is obtained from international systems and restriction is required under a memorandum of understanding.[269]

Difficulties for Earth Science and Data Policy Stability

By the end of the 1990s, NASA had launched more than ten satellites associated with the Earth Observing System, including the flagship Terra satellite. In 2002, NASA's

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[268] Personal Interviews.
[269] "Data & Information Policy - NASA Science." *Data & Information Policy - NASA Science*. N.p., n.d. Web. 30 Sept. 2012. <http://science.nasa.gov/earth-science/earth-science-data/data-information-policy/>.

mission was updated, reflecting the importance of its Earth science mission. The new mission was: "To understand and protect our home planet; To explore the Universe and search for life; To inspire the next generation of explorers …as only NASA can."[270] Aqua was launched the same year, and Aura two years later.[271]

Figure 6.1 NASA Total Budget and Earth Science Budget Over Time

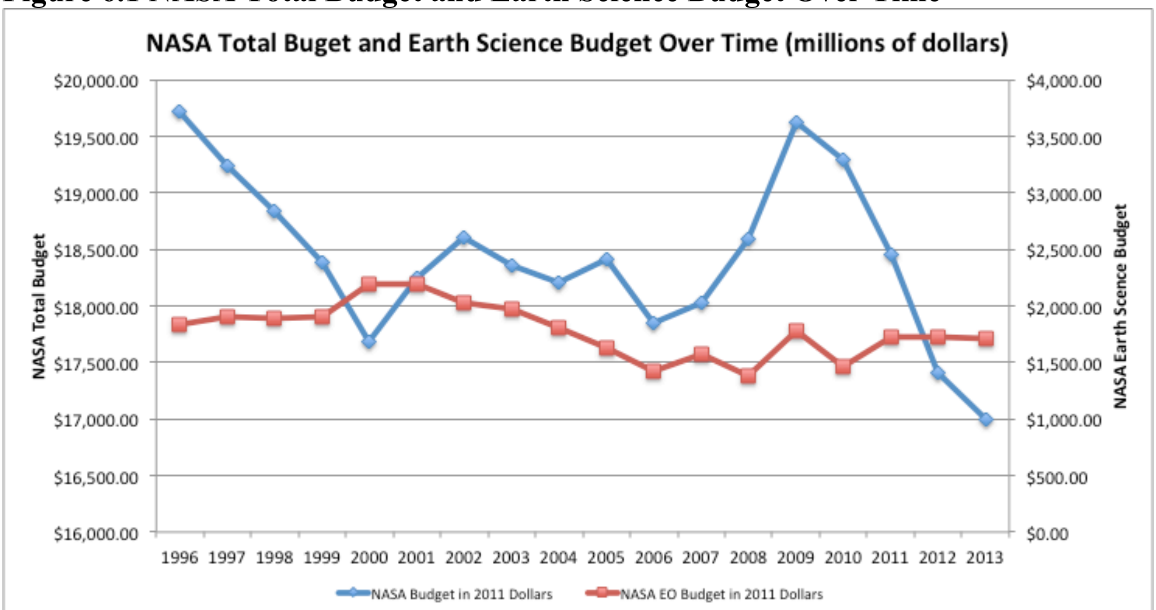

Figure 6.2 shows NASA's total budget and its Earth Science Budget from 1996 to 2013. Note that classification of the Earth Observation program within NASA budget changed over this time period.

However, as development of the flagship Earth Observing System systems came to a close, NASA Earth Science saw its budget steadily decrease. In 2005, President George W. Bush announced a new vision for space exploration, shifting the priorities

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[270] "Administrator Unveils Future NASA Vision and a Renewed Journey of Learning." N.p., 12 Apr. 2002. Web. 30 Sept. 2012. <http://www.nasa.gov/home/hqnews/2002/02-066.txt>.
[271] "NASA's Earth Observing System." *NASA's Earth Observing System*. N.p., n.d. Web. 28 Mar. 2013. <http://eospso.gsfc.nasa.gov/eos_homepage/mission_profiles/show_mission_list.php?id=20>.

of the agency.[272] The Earth Science office within NASA was combined with the office focused on studies of the Sun, creating the Earth-Sun System "theme," and this group was moved within the Science Mission Directorate. At the same time, the agency's mission was amended again, removing the portion about understanding and protecting the home planet. NASA's new mission was "to pioneer the future in space exploration, scientific discovery, and aeronautics research."[273]

A 2005 interim report by the National Research Council stated that this change in priorities put NASA's ability to fulfill its obligations in jeopardy, particular with regard to efforts related to climate change. The report argued that mission cancellations, scale-backs, and reductions in budget had put the U.S. system of environmental satellites "at risk of collapse."[274] The National Research Council's final report, released in 2007, reported that concerns had greatly increased, as additional missions had been canceled in the intervening two years.[275] By 2010, NASA's Earth observation budget was more than thirty percent below its 2000 budget in real dollars.[276]

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272 Revkin, Andrew C. "NASA's Goals Delete Mention Of Home Planet." *The New York Times*. The New York Times, 22 July 2006. Web. 30 Sept. 2012. <http://www.nytimes.com/2006/07/22/science/22nasa.html>.

273 "NASA Strategic Plan 2006." N.p., 2005. Web. 30 Sept. 2012. <http://www.nasa.gov/pdf/142303main_2006_NASA_Strategic_Plan_sm.pdf>.

274 Anthes, Richard A., Berrien Moore, and Arthur Charo. *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation*. Washington, DC: National Academies, 2005. Web. 28 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=11281>.

275 *Earth Science and Applications from Space: National Imperatives for the next Decade and beyond*. Washington, DC: National Academies, 2007. Web. 28 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=11820>.

276 *Earth Science and Applications from Space: National Imperatives for the next Decade and beyond*. Washington, DC: National Academies, 2007. Web. 28 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=11820>.

In July 2010, NASA outlined plans for a "climate-centric architecture for Earth observations and applications from space," supported by the Obama Administration. As part of this initiative, NASA Earth Science was expected to receive $10.3 billion from FY 2011 to 2015, returning it to 2000 levels.[277] The full increase to approximately $2 billion annually has not occurred, but NASA Earth Science did get an eighteen percent increase in the 2011 budget, bringing it to approximately $1.7 billion. Levels are now expected to remain constant at this level throughout the decade.[278] Despite these increases, a 2012 report by the National Research Council argued that programs were being developed at a slower pace than expected and that the program was still at risk of collapse. The report argued that U.S. Earth observing instruments in space by 2020 could be as little as 25 percent of the current number.[279]

Since the release of its updated policy in 1998, the Earth Science program has experienced numerous ups and downs, but its data sharing policy has not changed. Despite the strong support within NASA for free and open data, it is not immune to arguments for restricting data, particularly in attempts to recover costs. Though these occasionally come from newcomers to the agency, they are generally seen as external pressures, most commonly from those whose primary concerns have to do with the

277 United States. National Aeronautics and Space Administration. *Responding to the Challenge of Climate and Environmental Change*. N.p.: n.p., 2010. Web. 28 Mar. 2013. <http://science.nasa.gov/media/medialibrary/2010/07/01/Climate_Architecture_Final.pdf>.
278 United States. National Aeronautics and Space Administration. *NASA FY2013 President's Budget Request Summary*. N.p., n.d. Web. 28 Mar. 2013. <http://www.nasa.gov/pdf/632697main_NASA_FY13_Budget_Summary-508.pdf>.
279 *Earth Science and Applications from Space: A Midterm Assessment of NASA's Implementation of the Decadal Survey*. Washington, DC: National Academies, 2012. Web. 28 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=13405>.

national budget. When budgets are tight, members of Congress and others look for ways to save, and selling data often appears to them to be a good option.

However, NASA officials are adamant about the success of NASA's current policy and the need to keep data freely available. The agency collects metrics on data use and data users, providing evidence of the effectiveness of the policy. Officials argue that open data sharing remains central to NASA's mission as a research agency. NASA officials have also made a conscious effort to promote the policy not only internally, but also internationally, particularly in the multilateral Group on Earth Observations. In part, this allows NASA to take a leadership role in the international arena, which is viewed positively domestically. Being a leader also allowed NASA to develop a data policy that would provide mutual benefit if adopted by other countries. NASA's success in distributing large volumes of data, supported by the careful collection of metrics, and the United States' relatively large value-added sector are both pointed to as success stories, illustrating the benefits of NASA's policy.[280]

Overall, the NASA argument seems to be based primarily on a moral and economic argument that Earth observation data should not be subject to any restrictions, and should be shared to the greatest extent possible to bring the greatest benefit to the public. This is almost always combined with the argument that it isn't possible to have commercialization or cost-recovery with respect to scientific data, anyway, and that evidence has shown that commercialization of scientific Earth observing

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[280] "Concerns Over NASA's Basic Research Funding Strategy." *Earth Observing System*. N.p., July 1996. Web. 30 Sept. 2012. <http://www.gao.gov/assets/230/223043.pdf>.

satellites is impossible, and cost-recovery does not offer meaningful monetary returns. The primary barrier to free and open data sharing is seen as coming from external actors driven by larger government budgetary concerns.

NASA officials' views on data sharing in the case where commercialization is possible pose an interesting issue. The United States is home to DigitalGlobe (which recently combined with rival GeoEye), a company that sells high-resolution remote sensing satellite imagery. DigitalGlobe's primary customer is the U.S. government, particularly the military and intelligence agencies. NASA officials acknowledge that in addition to its commercial value, the data sold by DigitalGlobe (and other commercial remote sensing firms) also has fairly significant scientific value. For example, it can be used to understand boundary conditions for environmental modeling or to look at surface features such as water pools on ice that are not visible using other types of satellite data. An experimental data buy of similar high-resolution commercial remote sensing data by NASA in 1999 demonstrated that this type of data was useful to scientific researchers.[281] However, the costs of commercial data are generally prohibitively high for most researchers, and, unsurprisingly, research use of the data is low relative to use of freely available data.

In general, NASA officials didn't seem to feel strongly that the sale of commercially collected data was an issue. It did not raise the type of moral or economic arguments given in defense of making other scientifically relevant data available. This raises the

[281] Goward, S. "Acquisition of Earth Science Remote Sensing Observations from Commercial Sources: Lessons Learned from the Space Imaging IKONOS Example." *Remote Sensing of Environment* 88.1-2 (2003): 209-19. Print.

question of how practical arguments about the feasibility of cost recovery or commercialization affect NASA policy-making. With respect to the scientific data that they collect, NASA officials feel strongly that as few restrictions as possible should be put on the data. In the case that commercialization is possible, as with high-resolution imagery, NASA does not get involved, leaving action to the private sector.

Of course, NASA does not have the authority to prohibit commercial remote sensing firms from operating, nor can it compel them to make their data freely available to research users or others. Further, commercial activity is generally viewed as positive in the United States, so it is likely that if NASA attempted to develop a high-resolution imagery satellite that would provide data for free in the pursuit of science, thus undermining the business case of the commercial remote sensing industry, this program would not be approved by Congress. This knowledge might prohibit NASA from even attempting such an activity. NASA officials argue that high resolution is not a priority right now, and therefore NASA would not choose to develop a high-resolution imaging satellite, regardless commercial activity. However, accuracy can be very important for climate studies, and it is possible that as research advances, this type of data will become a priority. Until that point is reached, it is not possible to know for sure how NASA and other decision-makers would respond.

NASA has been a leader in both development and operation of Earth observation satellites and in the development of free and open data policies. Beginning very early in its program, NASA moved towards fewer and fewer restrictions on the data, removing exclusive-use periods and discrimination among types of users, and rejecting even marginal cost fees. Now it has the most open data access policy in the world. NOAA, though operating in the same political environment and referencing many of the same initiatives, policies, and reviews, followed a somewhat different path. Unofficial sharing at NOAA was followed by sustained efforts at cost recovery, though ultimately, a free and open data sharing policy was adapted.

6.1.2 National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Data and Information Service (NESDIS)

The NESDIS vision is to be the world's most comprehensive source and recognized authority for satellite products, environmental information, and official assessments of the environment in support of societal and economic decisions.[282]

Worldwide Data Sharing in Early Years

The ability to improve understanding of weather phenomena and to improve weather forecasting was one of the first clear beneficial applications of Earth observation satellites. In May 1961, President Kennedy announced in a speech before a Joint Session of Congress that 75 million dollars would be devoted to developing a satellite system for worldwide weather observation as quickly as possible.[283] By 1965, NASA

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282 United States. National Oceanic and Atmospheric Administration. National Environmental Satellite, Data, and Information Service. *NOAA Satellite and Information Service*. N.p., n.d. Web. 28 Mar. 2013. <http://www.nesdis.noaa.gov/pdf/NESDIS.pdf>.

283 "Excerpt from an Address Before a Joint Session of Congress." Address. Joint Session of Congress. Washington, DC. 25 May 1961. *John F. Kennedy Presidential Library and Museum*. Web. 28 Mar. 2013. <http://www.jfklibrary.org/Asset-Viewer/xzw1gaeeTES6khED14P1Iw.aspx>.

(NOAA NESDIS had not yet been created) had launched ten weather satellites, and the Weather Bureau was using them in operational weather monitoring.[284]

Worldwide sharing of weather data was commonplace even before the invention of weather satellites, and when weather satellites were developed this practice continued.[285] Broadcasts from early U.S. weather satellites were made available to any ground station in line of sight without restrictions on collection and use or any requirement to pre-notify the United States.[286] Over the lifetime of third Television Infrared Observation Satellite (TIROS 3), launched in 1961, "approximately thirty countries conducted intensified observational programs to coincide with the passage of the satellite overhead."[287] A 1962 report related to the Nimbus meteorological satellite system, another series of research and technology demonstration satellites, noted that data from the system would be distributed via facsimile, radio, and teletypewriter. It specifically stated that, "distribution will be made to users in the United States and abroad, it being understood that all data are freely available to the world community."[288]

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284 "Polar-orbiting Satellites: The First Launched." *POES History*. NOAA, 29 Sept. 2011. Web. 28 Mar. 2013. <http://www.oso.noaa.gov/history/first-launched.htm>.

285 United States. Department of Commerce. Weather Bureau. *National Operational Meteorological Satellite System*. Washington, DC: n.p., 1962. *National Operational Meteorological Satellite System*. Web. 28 Mar. 2013. <http://docs.lib.noaa.gov/rescue/TIROS/TL798M4N371962.pdf>.

286 United States. National Oceanic and Atmospheric Administration. Satellite and Information Service. *History of the NOAA Satellite Program*. By Gary Davis. N.p.: n.p., 2011. *History of the NOAA Satellite Program*. Web. 28 Mar. 2013. <http://www.osd.noaa.gov/download/JRS012504-GD.pdf>.

287 United States. Department of Commerce. Weather Bureau. *National Operational Meteorological Satellite System*. Washington, DC: n.p., 1962. *National Operational Meteorological Satellite System*. Web. 28 Mar. 2013. <http://docs.lib.noaa.gov/rescue/TIROS/TL798M4N371962.pdf>.

288 United States. Department of Commerce. Weather Bureau. *National Operational Meteorological Satellite System*. Washington, DC: n.p., 1962. *National Operational Meteorological*

This early decision to share data stemmed from both self-interest and accepted moral obligation. Weather is an interconnected, global phenomenon, and adequate forecasting requires cooperation with others. It is in each country's interest to participate in a system that encourages international sharing of meteorological data, ensuring that data relevant for its own needs is provided. Secondly, weather can be dangerous, and life-saving weather forecasts rely on international data sharing. It is generally accepted that data and information should be shared if they can significantly contribution to improving health or safety.

By the mid 1960s, the Weather Bureau began financing meteorological satellite development jointly with NASA, as the program transitioned from a technology demonstration program to fully operational program.[289] NASA developed the first geostationary satellite in 1966, allowing continuous monitoring of weather over the United States, a key operational need.[290]

In 1970, President Nixon created the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce, which also houses the

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Satellite System. Web. 28 Mar. 2013.
<http://docs.lib.noaa.gov/rescue/TIROS/TL798M4N371962.pdf>.
United States. National Oceanic and Atmospheric Administration. Satellite and Information Service. *History of the NOAA Satellite Program*. By Gary Davis. N.p.: n.p., 2011. *History of the NOAA Satellite Program*. Web. 28 Mar. 2013. <http://www.osd.noaa.gov/download/JRS012504-GD.pdf>.

[289] "Polar-orbiting Satellites: The First Launched." *POES History*. NOAA, 29 Sept. 2011. Web. 28 Mar. 2013. <http://www.oso.noaa.gov/history/first-launched.htm>.

[290] "Applications Technology Satellite (ATS)." *NASA*. N.p., 22 Jan. 2010. Web. 28 Mar. 2013. <http://www.nasa.gov/centers/goddard/missions/ats.html>.
United States. National Oceanic and Atmospheric Administration. Satellite and Information Service. *History of the NOAA Satellite Program*. By Gary Davis. N.p.: n.p., 2011. *History of the NOAA Satellite Program*. Web. 28 Mar. 2013. <http://www.osd.noaa.gov/download/JRS012504-GD.pdf>.

National Weather Service (formerly the Weather Bureau).[291] NOAA took over responsibility for developing and operating the weather satellite program, though NASA still built and launched the satellites. Accordingly, after 1970, each polar orbiting meteorological satellite launched successfully was given a NOAA designation. NOAA 1 through 5 were launched between 1970 and 1976.[292] Also known as the Polar-orbiting Operational Environmental Satellites (POES), this series has had multiple upgrades throughout its history. By 2010, 19 polar-orbiting satellites had been successfully launched.[293] The first Geostationary Operational Environmental Satellite (GOES) was launched in 1975, followed by 15 additional successful GOES satellite launches by 2010.[294] NOAA contributed to international data sharing systems developed within the World Meteorological Organization and generally made data freely available to other countries. Though NOAA did not have a formal data policy in place for access by individuals, it became common to charge a small fee to recover the cost of fulfilling a data request (copying and shipping, for example).[295]

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291 "Reorganization Plan 4 of 1970." *NOAA Central Library*. N.p., n.d. Web. 28 Mar. 2013. <http://www.lib.noaa.gov/noaainfo/heritage/ReorganizationPlan4.html>.
"NOAA Legacy." *NOAA History*. N.p., 8 June 2006. Web. 28 Mar. 2013. <http://www.history.noaa.gov/noaa.html>.

292 Wells, Helen T., Susan H. Whiteley, and Carrie E. Karegeannes. "Satellites." *Origins of NASA Names*. Washington, D.C.: Scientific and Technical Information Office, National Aeronautics and Space Administration, 1976. N. pag. *NASA History Office*. Web. 28 Mar. 2013. <http://history.nasa.gov/SP-4402/ch2.htm>.

293 "POES Spacecraft Status Main Page." *Polar-orbiting Operational Environmental Satellites*. NOAA, 11 Mar. 2013. Web. 28 Mar. 2013. <http://www.oso.noaa.gov/poesstatus/>.

294 "The Geostationary Operational Environmental Satellites: GOES-P." *Current Missions*. NASA, 28 Feb. 2013. Web. 28 Mar. 2013. <http://www.nasa.gov/mission_pages/GOES-P/main/index.html>.

295 Landis, Robert. *The Road to Resolution 40 and Beyond: Part I Data Exchange*. Working paper. American Meteorological Society, 4 June 2008. Web. 28 Mar. 2013. <http://www.ametsoc.org/atmospolicy/documents/PartIDataExchange.pdf>.

Cost Recovery Efforts Begin

As the capabilities of meteorological satellites increased, along with the quality and quantity of data, there was broad recognition that meteorological satellite data had significant value. In particular, data that was not directly related to traditional weather warnings or forecasts clearly had value outside the meteorological industry and did not fit as neatly into the old model of data sharing, which emphasized only meteorological uses of the data. As seen in the NASA case study, pressure to restrict access to data through fees and agreements came from outside the agency. Recognition of the value of this data combined with tightening budgets and growing belief in the efficiency of commercialization and privatization, led Congress to pass a law in 1988 authorizing the Secretary of Commerce to assess fees for access to environmental data archived by NOAA NESDIS.[296] This law was reinforced by the Omnibus Budget Reconciliation Act of 1990, which also included plans for increased government revenues based on the "fair" increases in fees and services offered by NOAA.[297] In accordance with this new law, NOAA developed a schedule of fees for its environmental data and products that were above the marginal cost of fulfilling user requests.

Despite this move towards data sales, NOAA remained committed to free and open exchange of meteorological data, an activity that was still seen as essential to

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296 S. 2209, 100 Cong., U.S. G.P.O. (1988) (enacted). Print.
National Aeronautics and Space Administration Authorization Act, Fiscal Year 1989
"15 USC § 1534 - Assessment of Fees for Access to Environmental Data." *Legal Information Institute*. Cornell University Law School, n.d. Web. 29 Mar. 2013.
<http://www.law.cornell.edu/uscode/text/15/1534>.

297 H.R. 5835, 101 Cong. (1990) (enacted). Print.Omnibus Budget Reconciliation Act of 1990, Sec. 10201 National Oceanic and Atmospheric Administration User Fees

understanding the weather, an inherently global system.[298] The difficulty of balancing these two contradictory goals is seen in the elaboration of NOAA policy at the time. In 1991, NOAA and the Privatization Branch of the Office of Management and Budget (OMB) jointly developed a policy statement, "The National Weather Service (NWS) and Private Weather Industry: A Public-Private Partnership." It promoted the concept of a public-private partnership with respect to weather services, including data sales, and also emphasized "the need to protect the free and open international exchange of data."[299] NOAA also participated in the U.S. Global Change Research Program to develop the Bromley Principles, released in 1991, which advocated for free and open sharing of data relevant to global change research, even though this policy was not being implemented within NOAA at the time.[300]

Interests in the ethical responsibilities of the government to collect and share data and information that saves lives also remained central. Addressing concerns raised during a public comment period for its policy, NOAA and OMB stated that the National Weather Service would remain the single official voice for issuing weather warnings. They also noted that the National Weather Service would ensure the continued collection and sharing of information needed for the protection of life and property,

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298 Personal Interviews.

299 United States. NOAA. *Policy Statement on the Weather Service/Private Sector Roles*. N.p.: n.p., 1991. *Industrial Meteorology*. National Weather Service. Web. 29 Mar. 2013. <http://www.nws.noaa.gov/im/fedreg.htm>.

300 United States. Executive Office of the President. Office of Science and Technology Policy. *Data Management for Global Change Research Policy Statements*. By Allan Bromley. N.p.: n.p., 1991. *U.S. Global Change Research Information Office*. Web. 28 Mar. 2013. <http://www.gcrio.org/USGCRP/DataPolicy.html>.

even if some data collection was contracted out to the private sector.[301] The 1992 Land Remote Sensing Act went further, expressly prohibiting any attempts at commercialization of the weather satellite program, at that time or in the future.[302]

Also in the early 1990s, the United States was engaged in a debate on commercialization and data sharing within the World Meteorological Organization (WMO). Despite the recent law requiring NOAA to recover costs by selling its data at "fair" prices, within the WMO, the U.S. representatives advocated for continued free and open sharing of weather data without restrictions. The U.S. provided the primary counterpoint to European desires to put into place a data sharing policy in which some data would be restricted and sold to commercial entities to allow cost recovery for National Meteorological Services.[303] Perhaps not surprisingly, the United States was not successful in maintaining the norm of free and open international data exchange. In 1995, the WMO passed Resolution 40, which formalized the practice of restricting access to some data to allow commercial sales.[304]

On the technical side, NOAA continued efforts to improve data access. NOAA NESDIS developed the Satellite Active Archive (later known as the CLASS system)

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301 United States. NOAA. *Policy Statement on the Weather Service/Private Sector Roles*. N.p.: n.p., 1991. *Industrial Meteorology*. National Weather Service. Web. 29 Mar. 2013. <http://www.nws.noaa.gov/im/fedreg.htm>.

302 "United States Code Title 15 Chapter 82 Land Remote Sensing Policy." *Landsat Program*. NASA, 21 Oct. 1999. Web. 29 Mar. 2013. <http://geo.arc.nasa.gov/sge/landsat/15USCch82.html>.

303 Landis, Robert. *The Road to Resolution 40 and Beyond: Part I & II Data Exchange*. Working paper. American Meteorological Society, 4 June 2008. Web. 28 Mar. 2013. <http://www.ametsoc.org/atmospolicy/documents/PartIDataExchange.pdf>.

304 World Meteorological Society. *Resolution 40 (Cg-XII)*. WMO, n.d. Web. 28 Mar. 2013. <http://www.wmo.int/pages/about/Resolution40_en.html>.

in 1995, originally to allow users to access data from the Advanced Very High Resolution Radiometer (AVHRR) satellite instrument via the internet.[305] Additional data was added to this archive over time, and the number of online users requesting access to this data grew dramatically throughout the late 1990s.[306]

This increase in data access came with a cost. In a 1997 issue of the Federal Register, NOAA stated that it would recover the cost of disseminating its data and information, including the cost of a required upgrade in data handling capabilities, though fees on the user community, consistent with OMB Circular A-130. However, it also stated that because NOAA is responsible for promoting research and education, which would be hindered by additional fees, prices would not be increased for other Governmental entities, universities, nonprofit organizations, and depository libraries.[307] This essentially implemented a two-tier pricing policy for NOAA data, though it was not specifically called out as such.[308]

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305 Singer, Ken, Dave Terril, Jack Kelly, and Cathy Nichols. "Building a COTS Archive for Satellite Data." Proc. of 4th NASA Goddard Conference on Mass Storage Systems and Technologies, College Park, MD. N.p., n.d. Web. 28 Mar. 2013. <http://storageconference.org/1995/C1_2.PDF>.
306 United States. NOAA. NESDIS. *The Nation's Environmental Data Treasures at Risk : Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. By Allen Hittelman and Ida Hakkarinen. Silver Spring, MD: National Oceanic and Atmospheric Administration, 2001. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/pdf/letter.pdf>.
307 United States. *Federal Register*. 88th ed. Vol. 62. N.p.: n.p., 1997. *Schedule of Fees for Access to NOAA Environmental Data and Information and Products Derived Therefrom*. Web. 29 Mar. 2013. <http://www.gpo.gov/fdsys/pkg/FR-1997-05-07/pdf/97-11789.pdf>.
Anthes, Richard. "The President's Corner: The International Exchange of Data." UCAR Quarterly 18 (1994): n. pag. University Corporation for Atmospheric Research. Web. 29 Mar. 2013. <http://www.ucar.edu/communications/quarterly/winter94/pres.html>.
Bretherton, Francis. *On the Full and Open Exchange of Scientific Data*. Washington D.C.: National Research Council, Committee on Geophysical and Environmental Data, 1995. Web. 29 Mar. 2013. <http://www.nap.edu/readingroom.php?book=exch&page=preface.html>.
308 United States. NOAA. NESDIS. *The Nation's Environmental Data Treasures at Risk: Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. By Allen Hittelman and Ida Hakkarinen. Silver Spring, MD: National Oceanic and Atmospheric Administration, 2001. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/pdf/letter.pdf>.

Decline of Cost Recovery and Return of Free Data Exchange

While NASA officials had only made the argument in theory, NOAA officials were able to point to experience in arguing that efforts at cost recovery had not been successful. Even at their highest levels, in 1996, revenue from data sales were only about 0.2% of NOAA's budget for the year.[309] As more data was made available online, many users were charged little or no fee, reflecting the low marginal cost. This led to an increasing number of requests for data, but decreasing revenues.[310]

Common frustrations related to NOAA's data policy were addressed in a 2001 NOAA report, "The Nation's Environmental Data: Treasures at Risk." The report noted that archiving and disseminating environmental data were central to NOAA's mission, and lamented that guidelines provided by OMB Circular A-130 were flexible enough to allow greatly varying interpretations. The report argued that though NOAA had been mandated to collect user fees to offset the costs of data services, anticipated increases in revenues never materialized and had actually decreased. It stated that NOAA was nearing a situation in which it would be more expensive to carry out a program attempting cost recovery than it would be to simply provide data for free. It

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[309] United States. NOAA. NESDIS. *NOAA Environmental Data: Foundation for Earth Observations and Data Management System*. By Allen Eustis and David J. Vercelli. Washington, D.C.: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, 2003. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/foundations.shtml>.

[310] United States. NOAA. NESDIS. *The Nation's Environmental Data Treasures at Risk : Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. By Allen Hittelman and Ida Hakkarinen. Silver Spring, MD: National Oceanic and Atmospheric Administration, 2001. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/pdf/letter.pdf>.

United States. NOAA. NESDIS. *NOAA Environmental Data: Foundation for Earth Observations and Data Management System*. By Allen Eustis and David J. Vercelli. Washington, D.C.: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, 2003. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/foundations.shtml>.

also stated that cost-recovery policies had alienated some users, particularly in the research community, reducing data use. They noted that there was no uniform policy guiding the use and re-use of NOAA environmental data, and that data for which NOAA was charging were being distributed for free by a number of websites, including those of other Federal government agencies.[311]

Arguments related to the ineffectiveness of cost recovery efforts were paired with arguments about the efficiency of free data policies in encouraging data use and maximizing benefits.[312] The same 2001 NOAA report stated, "The accessibility of data is key to the value of data. A data set has no value if no one knows it exists, if it is on a media or in a format that makes it unusable, or if the cost associated with being given access to the data is higher than the user can afford to pay."[313] A 2003 follow-up report expands on this, noting that ensuring the widest possible use of government-collected weather data improves warning systems vital to public safety, is essential for the academic sector, and leads to growth of a healthy value-added meteorological industry.[314] Both reports also emphasized the global nature of both weather and climate, harkening back to one of the earliest arguments for free and

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311 United States. NOAA. NESDIS. *The Nation's Environmental Data Treasures at Risk: Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. By Allen Hittelman and Ida Hakkarinen. Silver Spring, MD: National Oceanic and Atmospheric Administration, 2001. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/pdf/letter.pdf>.

312 Personal Interviews.

313 United States. NOAA. NESDIS. *The Nation's Environmental Data Treasures at Risk: Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. By Allen Hittelman and Ida Hakkarinen. Silver Spring, MD: National Oceanic and Atmospheric Administration, 2001. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/pdf/letter.pdf>.
Fair Weather: Effective Partnerships in Weather and Climate Services. Washington (D.C.): National Academies, 2003. Web. 29 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10610>.

314 *Fair Weather: Effective Partnerships in Weather and Climate Services*. Washington (D.C.): National Academies, 2003. Web. 29 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10610>.

open data sharing.[315] Based on these arguments, NOAA data policies continued to open up throughout the 2000s.

In 2003, NOAA's leader at the time, Admiral Conrad Lautenbacher, initiated the first Global Earth Observation Summit, which involved ministerial-level representation from several dozen of world's nations and expressly promoted the need for international cooperation and data sharing.[316] It was believed that high-level government involvement in a data-sharing regime would be necessary to ensure that efforts at free and open data sharing had the support of upper-level decision-makers that might otherwise be focused on budget alone.[317]

In 2005, NOAA's Private-Public Partnership Policy was updated. The new policy stated that it was based on "the premise that government information is a valuable national resource, and the economic benefits to society are maximized when government information is available in a timely and equitable manner to all."[318] NOAA's 2006 Policy on Partnerships in the Provision of Environmental Information states that "NOAA will carry out activities that contribute to its mission, including…

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[315] United States. NOAA. NESDIS. *The Nation's Environmental Data Treasures at Risk : Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. By Allen Hittelman and Ida Hakkarinen. Silver Spring, MD: National Oceanic and Atmospheric Administration, 2001. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/pdf/letter.pdf>.
United States. NOAA. NESDIS. *NOAA Environmental Data: Foundation for Earth Observations and Data Management System*. By Allen Eustis and David J. Vercelli. Washington, D.C.: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, 2003. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/foundations.shtml>.

[316] United States. NOAA. NESDIS. *NOAA Environmental Data: Foundation for Earth Observations and Data Management System*. By Allen Eustis and David J. Vercelli. Washington, D.C.: U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, 2003. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/foundations.shtml>.

[317] Personal Interviews.

[318] "Policy on Partnerships in the Provision of Environmental Information." *NOAA*. N.p., n.d. Web. 29 Mar. 2013. <http://www.noaa.gov/partnershippolicy/fairwxpolicy.html>.

providing open and unrestricted access to publicly-funded observations, analyses, model results, forecasts, and related information products in a timely manner and at the lowest possible cost to users." It also includes a clause specifically regarding interactions with other entities: "The nation benefits from government information disseminated both by Federal agencies and by diverse nonfederal parties, including commercial and not-for-profit entities. NOAA recognizes cooperation, not competition, with private sector and academic and research entities best serves the public interest and best meets the varied needs of specific individuals, organizations, and economic entities."[319]

The NOAA National Data Centers Free Data Distribution Policy of March 2009 further elaborated on this policy, listing 11 groups, such as other NOAA offices and the U.S. Congress, and circumstances, such as existing data agreements or natural disasters, for which free data distribution is allowed. Of course, this meant that in some cases, data was not provided for free. In accordance with U.S. legal code, the policy stated that data would be provided free of charge to "Federal, State, and local government agencies, to universities, and to other nonprofit institutions at the cost of reproduction and transmission, if such data, information, and products are to be used for research and not for commercial purposes."[320]

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319 "Policy on Partnerships in the Provision of Environmental Information." *NOAA*. N.p., n.d. Web. 29 Mar. 2013. <http://www.noaa.gov/partnershippolicy/>.
United States. NOAA. NOAA Policy on Partnerships in the Provision of Environmental Information. N.p.: n.p., 2006. Web. 29 Mar. 2013.
<http://www.noaa.gov/partnershippolicy/FinalClarifiedPolicy011906.pdf>.

320 United States. NOAA. *National Data Centers Free Data Distribution Policy*. N.p.: n.p., 2009. Web. 29 Mar. 2013. <http://www.ncdc.noaa.gov/oa/nndc/freedata.pdf>.

In 2011, NOAA released a new data access and distribution policy that applied to satellite data and products made available within 1-2 hours of initial observation (near real-time). The policy, which is still the most current as of January 2013, notes, "NESDIS recognizes the need for full and open exchange of environmental satellite data, metadata and products, as provided for by relevant international and national laws and policies, agreements, organizational policies and the availability of resources." It states that one of the preferred methods to distribute NESDIS satellite data and products was through "publicly available distribution services such as the Global Telecommunication System (GTS), NOAA satellite direct broadcast services, public Internet websites, and the NOAA Data Centers, including the Comprehensive Large Array data Stewardship System (CLASS)."[321]

The CLASS website provides further information. The website distributes data from all NOAA POES and GOES satellites and from all DOD DMSP satellites, and the data from newly launched satellites are made available as soon as they are declared operational. Users can download this data freely, though they are requested to limit data sets ordered to less than 500 per day. If very large data sets are needed, CLASS can be contacted to arrange an offline data option, though these requests are subject to review due to the time and labor required to fill them. Orders on media rather than online can also be made, though there is a fee ($25 per unit for CDs, $100 per unit for

[321] United States. NOAA. NESDIS. *Policy on Access and Distribution of Environmental Satellite Data and Products*. N.p.: n.p., n.d. Web. 29 Mar. 2013. <http://www.ospo.noaa.gov/Organization/About/access.html>.

magnetic tapes, plus shipping and handling). The website does not mention any restrictions on data use.[322]

However, the 2011 NOAA policy on data access and distribution does not apply to archive products, such as climate data records, which require reprocessing of long-term temporal data and are thus not deemed operational. These are held at the NESDIS data centers.[323] The NOAA National Data Centers (NNDC) Online Data Access Policy states, "Due to various Federal Laws and Regulations, NNDC is required to charge for some of its online data to recover the cost of data dissemination. This includes hardware and personnel costs incurred by each Data Center. Charges are required for most domains (e.g., .com, .org, .net). All online data are now free for all .gov, .edu, .k12, .mil, .us, and a few other specific domains."[324] The authorization to assess user fees for access to environmental information is provided to NOAA NESDIS under 15 U.S. Code 1534. The Federal Register includes a full schedule of fees for access to NOAA environmental data effective in 2013, including numerous satellite data products. However, these fees relate primarily to non-digital or processed products.[325] In practice, almost all climate-relevant data collected by NOAA satellites is available to all users at no cost.

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322 "CLASS FAQs." Comprehensive Large Array-data Stewardship System. NOAA, n.d. Web. 29 Mar. 2013. <https://www.class.ncdc.noaa.gov/notification/faq.htm>.

323 United States. NOAA. NESDIS. *Policy on Access and Distribution of Environmental Satellite Data and Products*. N.p.: n.p., n.d. Web. 29 Mar. 2013. <http://www.ospo.noaa.gov/Organization/About/access.html>.

324 "NOAA National Data Centers Online Data Access Policy." *National Climate Data Center*. NOAA, 20 Aug. 2008. Web. 29 Mar. 2013. <http://www.ncdc.noaa.gov/oa/nndc/freeaccess.html>.

325 United States. Federal Register. N.p.: n.p., 2012. Schedule of Fees for Access to NOAA Environmental Data, Information, and Related Products and Services. Web. <Schedule of Fees for Access to NOAA Environmental Data, Information, and Related Products and Services>.

Within NOAA, there were four major incentives and one major barrier to data sharing. Two of these incentives stemmed from NOAA's history as a weather agency. First, was an awareness of the global nature of meteorology, and later, climate change. There was recognition that these global environmental challenges required global cooperation and data sharing. Secondly, there was an ethical argument made that sharing weather data was in the public interest – an argument that is particularly strong when dealing with extreme weather and natural disasters. Finally, a belief that efficiency would be maximized by encouraging maximum use of the data via low costs and easy access policies, also drove efforts to make NOAA satellite data freely available. The primary barrier to these efforts was a contrasting view of environmental data as a commodity, and a desire by high-level decision-makers concerned with budget issues to attempt cost recovery through data sales, particularly to commercial entities. The final incentive for free and open data sharing was a practical rebuttal to the cost-recovery argument, stating that cost-recovery simply wasn't possible to any meaningful degree.

While NASA never truly made an attempt at cost recovery, NOAA made significant attempts to recover costs for over a decade. USGS went even further than NOAA, at one point attempting to fully privatize its Earth observing satellite system. However, like NOAA, USGS found that efforts to sell data from Earth observing satellites were not fruitful, and certainly not viable as a fully private venture. Though it took more time, officials at USGS eventually used the same arguments regarding efficiency, ethical responsibility, and the importance of addressing global challenges to support the move to a fully free and open data policy.

6.1.3 United States Geological Survey (USGS) and Landsat

The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.[326]

The United States Geological Survey (USGS) is a science organization, established in 1879, whose mission includes "providing reliable scientific information to describe and understand the Earth." USGS has been involved in the Landsat series of satellites since the beginning of the program and is currently the lead agency for the Landsat program, including data archiving and distribution. However, this was not always the case: Landsat has at various times been operated by different agencies and even companies. This case study, therefore, will focus primarily on the development of the Landsat system and changes in its policy, rather than exclusively on USGS as an Earth science agency.

The emphasis on Landsat is important. Though the Landsat series includes only seven medium-resolution imaging satellites, it is one of the most important cases of changing data sharing policy. The series has provided a continuous set of data for 40

[326] "About USGS." *United States Geological Survey*. N.p., n.d. Web. 29 Mar. 2013. <http://www.usgs.gov/aboutusgs/>.

years, including data that is essential for understanding land use change and data that can be combined with other information for a multitude of uses. Throughout its complicated history, Landsat ownership and data access policies and prices have changed numerous times, providing a natural experiment on the effect of these policies on data use. This has made it one of the most commonly cited examples in discussions of the effect of various data sharing policies.[327]

International Cooperation and Unofficial Sharing in Early Years

In a speech before the United Nations in 1969, Richard Nixon announced that the United States would be developing the first "Earth resource survey satellites," an activity that was considered sensitive at the time. However, Nixon emphasized the peaceful nature of these efforts, stating, "this program will be dedicated to producing information not only for the United States, but also for the world community."[328]

The first satellite in the Landsat series was developed by NASA in 1972 and was originally named the Earth Resources Technology Satellite (ERTS). Landsat 2 followed in 1975 and Landsat 3 in 1978. NASA maintained responsibility for operating the system through the 1970s, though the USGS was responsible for archiving data and creating products and useable images.[329] Throughout this period,

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327 "Landsat: A Global Land-Observing Program." *Fact Sheet*. USGS, Mar. 2003. Web. 29 Mar. 2013. <http://egsc.usgs.gov/isb/pubs/factsheets/fs02303.html>.

328 Nixon, Richard. "Address Before the 24th Session of the General Assembly of the United Nations." Address. 24th Session of the General Assembly of the United Nations. New York, NY. 18 Sept. 1969. *American Presidency Project*. Web. 29 Mar. 2013. <http://www.presidency.ucsb.edu/ws/index.php?pid=2236>.

329 "Landsat: A Global Land-Observing Program." *Fact Sheet*. USGS, Mar. 2003. Web. 29 Mar. 2013. <http://egsc.usgs.gov/isb/pubs/factsheets/fs02303.html>.

NASA also made efforts to encourage use of this data, providing research grants and training to universities and other organizations.[330] In accordance with President Nixon's vision for the program, international ground stations were put in place to directly receive Landsat data. Landsat data could also be ordered through the Earth Resources Observations Systems (EROS) Data Center for the cost of reproduction and distribution ($200 per scene), though NASA generally made data available for free on an unofficial basis.[331]

Though the Landsat program had so far been successful at NASA, the continuity desired for Landsat was more like that in weather satellite programs than in the one-satellite research programs favored by NASA. In 1980, control of the Landsat program was turned over to NOAA, which had been successful in running the operational weather satellite program. However, the White House directive transferring control of the program also specified that its goal was "the eventual

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Williamson, Ray A. "The Landsat Legacy: Remote Sensing Policy and the Development of Commercial Remote Sensing." *Photogrammetric Engineering & Remote Sensing* 63.7 (1997): 877-85. Web.

330 Williamson, Ray A. "The Landsat Legacy: Remote Sensing Policy and the Development of Commercial Remote Sensing." *Photogrammetric Engineering & Remote Sensing* 63.7 (1997): 877-85. Web.
United States. General Accounting Office. *Landsat's Role in an Earth Resources Information System*. Washington: U.S. General Accounting Office, 1977. Web. 29 Mar. 2013. <http://gao.justia.com/department-of-commerce/1977/6/landsat-s-role-in-an-earth-resources-information-system-psad-77-58/PSAD-77-58-full-report.pdf>.
"Landsat Program Chronology." *NASA*. N.p., 4 Nov. 1998. Web. 29 Mar. 2013. <http://geo.arc.nasa.gov/sge/landsat/lpchron.html>.

331 Williamson, Ray A. "The Landsat Legacy: Remote Sensing Policy and the Development of Commercial Remote Sensing." *Photogrammetric Engineering & Remote Sensing* 63.7 (1997): 877-85. Web.

operation by the private sector of civil land remote sensing activities."[332] Landsat 4 and 5 were launched in 1982 and 1984, respectively.[333]

Though the international data receiving stations stayed in place, and could still access Landsat data for free, the Landsat data policy changed shortly after this move to NOAA. Once again driven by desires by high-level policy makers for cost recovery, Congress mandated that Landsat costs should be recovered through data sales, and prices rose to $650 per scene. This price was raised again in 1983, bringing prices closer to those expected to prevail when Landsat was commercialized. Both of these changes were associated with decreases in the amount of data distributed. Data sales were estimated at between two and nine million dollars, a quarter of which were sales of data to other U.S. government agencies. Again, even at their highest levels, revenues were less than one percent of system costs.[334]

Privatization of Landsat

Despite the inability of NOAA to generate significant revenues from Landsat data sales, plans went ahead to privatize the system, following a belief, particularly in the

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332 United States. Department of Commerce. *NOAA Upgrades Satellite Division, Changes Name*. By William J. Brennan. Rockville, MD: n.p., 1980. *NOAA*. Web. 29 Mar. 2013. <http://docs.lib.noaa.gov/rescue/TIROS_johnson/NESS%20Highlighted.pdf>.
United States. Executive Office of the President. *Civil Operational Remote Sensing*. N.p.: n.p., 1979. Jimmy Carter Presidential Library. Web. 29 Mar. 2013. <http://www.jimmycarterlibrary.gov/documents/pddirectives/pd54.pdf>.

333 "Landsat 3." *Landsat Science*. NASA, 21 Mar. 2013. Web. 29 Mar. 2013. <http://landsat.gsfc.nasa.gov/about/L3_td.html>.

334 Baker, David. "Remote Future for Third World Satellite Data." *New Scientist* 22 Oct. 1987: 48-51. Web. 29 Mar. 2013. <http://books.google.com/books?id=nCLWnFozM6EC&lpg=PA51&ots=YlR2ZJ75Fl&dq=Landsat%205%20development%20cost%20million&pg=PA3#v=onepage&q=Landsat%205%20development%20cost%20million&f=false>.

Reagan Administration, that transition of government functions to the private sector would improve efficiency. This action met little resistance, as Landsat's unique mission, which required a continuous series of satellites that didn't fit the NASA mold, and the programs focus on land, which didn't fit NOAA's focus on weather, meant that Landsat had no clear home agency advocating to retain control of the satellite. The Land Remote Sensing Commercialization Act of 1984 mandated that operation and data marketing of civil land remote-sensing systems, including Landsat, should be transitioned to private industry. It noted that unenhanced data must be made available on a non-discriminatory basis, and that collection of data must be continued for at least six years.[335] In 1985, the Earth Observation Satellite Company (EOSAT) signed a contract with NOAA to take responsibility for operation and data marketing and sales for Landsat 4 and 5, while NOAA continued to control the data receiving stations on the ground. Under the contract, EOSAT was also responsible for developing Landsat 6 and 7, for which the government would provide a total of $250 million in subsidies over five years.[336]

The requirement to provide non-discriminatory access to data was designed to ensure a level playing field for value-added services. However, it was also interpreted to mean that EOSAT must charge the same price to all users. Therefore, both research and commercial users suddenly faced prices of thousands of dollars per scene.

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335 H.R. 5155, 98 Cong. (1984) (enacted). Print. Land Remote-Sensing Commercialization Act of 1984

336 United States. Cong. Senate. Committee on Commerce, Science and Transportation.*Landsat Amendments Act of 1995*. 104th Cong., 1st sess. S. Rept. 104-81. Washington, DC: U.S. Government Printing Office, 1995. Web. 30 Mar. 2013. <http://www.gpo.gov/fdsys/pkg/CRPT-104srpt81/pdf/CRPT-104srpt81.pdf>.

EOSAT saw revenues increase slowly from 1986 to 1990.[337] At the same time, the number of orders dropped from 35,000 in 1984 to about 8,000 in 1990.[338] By 1995, EOSAT was reported to have made $80 million dollars.[339] This was approximately double the cost of operating the Landsat system, but only about five percent of the costs of building and launching Landsat 4 and 5 (which had been paid for by the government).[340] Also, as a result of high prices, some government entities, including NOAA, were no longer able to afford Landsat images.[341] Some expressed frustration with the model, in which the government paid for development of the system and operation of the ground systems, but EOSAT sold the data and retained the revenue. As one government scientist put it, "We [the U.S. government] have the worst of all possible worlds: we are both spending the money and making sure we get nothing out of it."[342]

Though EOSAT's contract included $250 million in government subsidies, EOSAT received only $27.5 million in 1986 and $5 million in 1987. In 1988, a new contract

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337 Williamson, Ray A. "The Landsat Legacy: Remote Sensing Policy and the Development of Commercial Remote Sensing." *Photogrammetric Engineering & Remote Sensing* 63.7 (1997): 877-85. Web.

338 United States. Cong. Senate. Committee on Commerce, Science and Transportation.*Landsat Amendments Act of 1995*. 104th Cong., 1st sess. S. Rept. 104-81. Washington, DC: U.S. Government Printing Office, 1995. Web. 30 Mar. 2013. <http://www.gpo.gov/fdsys/pkg/CRPT-104srpt81/pdf/CRPT-104srpt81.pdf>.

339 "Commerce Defers to Court on Eosat Decision." *Washington Technology*. N.p., 12 Jan. 1995. Web. 30 Mar. 2013. <http://washingtontechnology.com/articles/1995/01/12/commerce-defers-to-court-on-eosat-decision.aspx>.

340 Baker, David. "Remote Future for Third World Satellite Data." *New Scientist* 22 Oct. 1987: 48-51. Web. 29 Mar. 2013. <http://books.google.com/books?id=nCLWnFozM6EC&lpg=PA51&ots=YlR2ZJ75Fl&dq=Landsat%205%20development%20cost%20million&pg=PA3#v=onepage&q=Landsat%205%20development%20cost%20million&f=false>.

341 Personal Interviews.

342 Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy."*Space Policy* 6.1 (1990): 45-52. Web.

stipulated that the U.S. Government would provide a one-time payment of $220 million for hardware development, and EOSAT would only be responsible for the development of one satellite, Landsat-6. Meanwhile, NOAA found that it did not have sufficient funds to continue to operate the Landsat ground stations, and shut down data collection operations for a few months in 1988.[343]

Development of Landsat-6 was slow, revenues for EOSAT remained relatively low, and budget shortfalls led NOAA to announce in March 1989 that it planned to shutdown Landsat 4 and 5. In response, a presidential statement in June 1989 announced the provision of emergency funding for continued operations and noted, "It has become increasingly evident that commercializing the entire Landsat program would not be feasible until at least the end of the century."[344] With a subsidy from the U.S. government, and in collaboration with NASA, Landsat 6 was scheduled for launch in 1993. After a nearly decade-long hiatus in Landsat launches, both Landsat 4 and 5 were operating beyond their design lives. Unfortunately, Landsat-6 suffered a failure that prevented it from reaching the correct orbit.[345]

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[343] Vedda, James A. *U.S. National Security and Economic Interests in Remote Sensing: The Evolution of Civil and Commercial Policy*. Rep. no. TOR-2009(3601)-8539. N.p.: Aerospace Corporation, 2009. Web. 30 Mar. 2013. <http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB404/docs/27-new.pdf>.

[344] "Statement by Press Secretary Fitzwater on Landsat Satellite Program Funding." Address. 1 Jan. 1985. *George Bush Presidential Library and Museum*. Web. 30 Mar. 2013. <http://bushlibrary.tamu.edu/research/public_papers.php?id=481&year=1989&month=6>.

[345] NOAA. *Landsat 6 Failure Attributed to Ruptured Manifold*. N.p., 10 Mar. 1995. Web. 30 Mar. 2013. <http://landsat.gsfc.nasa.gov/pdf_archive/NOAA_landsat6.pdf>.

Return to Government Control

The Land Remote Sensing Commercialization Act of 1992 returned the Landsat program to government management, noting, "Full commercialization of the Landsat program cannot be achieved within the foreseeable future." Despite wide recognition of the complete failure of the Landsat privatization effort, the Act also stated, "commercialization of land remote sensing should remain a long-term goal of United States policy."[346] Congress maintained its desire to raise revenues and increase efficiency through data sales, even in the face of evidence that this was not productive. Contrary to this long-term goal, the Land Remote Sensing Act of 1992 also recognized, "the cost of Landsat data has impeded the use of such data for scientific purposes," and required that EOSAT, which continued to market and distribute Landsat 4 and 5 data until 2001, transition to a practice in which data were made available at no more than the cost of fulfilling user requests.[347]

In 1996, Landsat 4 and 5 data was priced at $4400 per scene for the public and a maximum of $2500 per scene for the U.S. government and affiliated users (such as researchers with government grants) for non-commercial purposes. Archived data was available to government users for $425 per scene. Also, once the government purchased data, it could be copied and distributed without restriction to other U.S.

[346] H.R. 6133, 102nd Cong. (1992) (enacted). Print. Land Remote Sensing Policy Act of 1992
[347] "United States Code Title 15 Chapter 82 Land Remote Sensing Policy." *Landsat Program*. NASA, 21 Oct. 1999. Web. 29 Mar. 2013.
<http://geo.arc.nasa.gov/sge/landsat/15USCch82.html>.
"Landsat 5." *Landsat Science*. N.p., n.d. Web. 30 Mar. 2013.
<http://landsat.gsfc.nasa.gov/about/landsat5.html>.

government and affiliated users for non-commercial purposes.[348] In 1997, the U.S. government released prices for Landsat 7 data, which would go into effect after the satellite was launched in 1999. The stated objective was to provide data at the lowest possible cost, and the cost per scene was set at approximately $500.[349] While data access did increase as prices decreased, revenues remained low relative to the costs of the program.

In 2000, the Clinton Administration developed a Landsat Remote Sensing Strategy, which dictated that USGS take responsibility for the Landsat program and ensure continuation of Landsat-type data collection beyond Landsat-7.[350] Shortly after Landsat was transitioned to its new home agency, USGS officials began to advocate a move from cost recovery (with scenes priced at a few hundred dollars a scene) to free and unrestricted data sharing.[351] USGS officials argued that making data freely available would increase data use and result in greater benefits for society. Like NASA, they argued that since the systems had been developed at taxpayer expense, all taxpayers should have equal access. Finally, they pointed to OMB Circular A-130,

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348 "Current Status and Summary of Agreement Between Landsat Program Management and EOSAT Corporation on Cost and Reproduction Rights for Landsat 4/5 Thematic Mapper Data." *Landsat Program*. NASA, 11 Apr. 1994. Web. 30 Mar. 2013. <http://geo.arc.nasa.gov/sge/landsat/apr11.html>.

349 U.S. Geological Survey. *Landsat 7 Data Prices Announced*. N.p., 31 Oct. 1997. Web. 30 Mar. 2013. <http://web.archive.org/web/19980120090116/http://edcwww.cr.usgs.gov/programs/landsat7price.html>.

350 United States. Executive Office of the President. *Presidential Decision Directive NSTC-3*. N.p.: n.p., 1994. Web. 30 Mar. 2013. <http://landsat.usgs.gov/documents/PDD_PDF.pdf>.
United States. Executive Office of the President. *Landsat Remote Sensing Strategy (Amendment to 1994 Directive)*. N.p.: n.p., 2000. Web. <http://landsat.usgs.gov/documents/PDD_PDF.pdf>.

351 Personal Interviews.

arguing that it required data be provided at the marginal cost of fulfilling user requests, which should be zero when data is accessed online.[352]

There was some internal resistance to the change; even with revenues from data sales at less than one percent of the USGS budget, some USGS professionals as well as those in Congress, were loath to make changes that would make USGS about ten million dollars poorer. Commercial remote sensing companies, such as GeoEye and DigitalGlobe, argued that it would harm their business. There were also still arguments that cost recovery by the government was an economically efficient practice.

However, proponents of a free and open policy were persistent in advocating a change. They argued that data sales were inefficient, with a large portion of sales just representing transfers of funds within the government, through purchases by other agencies or to scientists with government funding. They argued that the private sector would benefit from free and open data, leading to greater value-added applications. They pointed out that even at the lower prices developed after commercialization, the U.S. Department of Agriculture had stopped buying Landsat data, instead purchasing similar data at a lower price from India.

A key event spurring the move to a free and open data policy ties back to the earliest days of Landsat and the existence of international ground stations around the world. During an official visit, USGS officials found that Brazil, which operated one of these

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ground stations, was distributing Landsat data online. USGS officials argued that if Brazil could afford to set up an online distribution system for Landsat data, then the United States should do so as well. Once provided online, the marginal cost would be essentially zero. Finally, advocates got high-level buy-in from Secretary of Interior Bob Kempthorn to make the policy change.[353]

Looking to emphasize both the importance of international data sharing as well as to promote its own activities as widely as possible, USGS announced at the 2008 Group on Earth Observations Plenary that all Landsat data would be made available for download at no cost.[354] The 2008 Landsat Data Distribution Policy stated that data would be provided to all users at no more than the cost of fulfilling user requests, which would not include the capital costs of satellites or ground systems. For data provided online, the cost would be zero. It also stated that there would be no delay between data reception, processing, and distribution, ensuring products would be provided in a timely and dependable manner.[355]

The USGS argues that Landsat data are now considered a public good "similar to GPS and weather data." USGS also noted that moving to free online distribution led to savings through the elimination of the billing and accounting system that had previously been required. As use of Landsat data has steadily increased, it has

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353 Personal Interviews.
354 Group on Earth Observations. *GEO Announces Free and Unrestricted Access to Full Landsat Archive*. N.p., 20 Nov. 2008. Web. 30 Mar. 2013. <http://www.earthobservations.org/documents/pressreleases/pr_0811_bucharest_landsat.pdf>.
355 United States. USGS. *Landsat Data Distribution Policy*. N.p., n.d. Web.

become easy to demonstrate the value of this data for research, government, and commercial users, strengthening the case for continuing to provide free and open access to data.[356] Even commercial remote sensing companies reported benefits, noting that customers were using Landsat data to identify particular areas for which higher-resolution was needed, and then turning to the commercial sector for this data.[357] Following the transition to the free data policy, distribution of Landsat images has grown rapidly, from 25,000 scenes sold per year before the policy was implemented to 25,000 scenes accessed in a single day in 2012. In total, nearly ten million scenes have been distributed.[358] The increase was particularly large for scientific and educational users, and data has been delivered to 186 countries.[359]

The central role of economic determinants in the development of Landsat data policy is clear. On one side, originating from the presidential administration and legislative levels, was a view of the data as a commodity, and a desire to reduce government expenditures and increase efficiency through cost-recovery efforts or complete privatization. Counter to this position was an argument, generally coming from the agency and the scientific community, that data should be provided on a free and open basis to ensure the greatest possible utilization of the data, particularly for research. However, unlike the cases of NASA and NOAA, the Landsat program essentially

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356 "Fees and Landsat Data Products." *USGS Land Remote Sensing Program*. N.p., n.d. Web. 30 Mar. 2013. <http://remotesensing.usgs.gov/landsat_fees.php>.
357 Personal Interviews.
358 "Landsat Project Statistics." *Landsat Project Statistics*. N.p., n.d. Web. 30 Mar. 2013. <http://landsat.usgs.gov/Landsat_Project_Statistics.php>.
USGS. *Over 9 Million Downloads for Free Landsat Data. United Nations Office for Outer Space Affairs*. N.p., 12 Sept. 2012. Web. 30 Mar. 2013. <http://www.un-spider.org/about-us/news/en/6182/2012-09-12t080000/usgs-over-9-million-downloads-free-landsat-data>.
359 Parcher, Jean. "Benefits of Open Availability of Landsat Data." CEOS Plenary 2012. N.p., n.d. Web.

went through a trial and error process to arrive at a final policy. In the end, however, the dramatic increase in data use as Landsat moved from commercial sales to cost recovery and finally to free and open data sharing have proven to be one of the most striking examples of the benefits of open policies.

6.2 Europe

Within Europe, many countries have their own space agencies, and some, particularly France, Germany, and Italy, operate multiple national Earth observation satellites. However, the majority of European Earth observation activities are coordinated through the European Space Agency (ESA). For meteorological satellites, efforts are coordinated by the European Organization for Exploitation of Meteorological Satellites (EUMETSAT). Though the context for decisions within ESA and EUMETSAT were significantly different than those at NASA, the major trends are familiar: informal data sharing as technology is developed and refined, efforts at cost recovery once the value of the data has been recognized, followed by a move to increasingly free and open data policies when efforts at cost recovery prove ineffective at raising revenues and detrimental to data use.

Table 6.3 Essential Climate Variable coverage with European-led satellites only

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aerosol Properties	2	2	3	3	3	3	4	4	4	4	4	4	4
Aerosols	1	1	2	2	2	2	2	2	2	2	2	2	1
Albedo	2	2	4	4	4	5	6	6	6	6	6	6	7
Biomass	0	1	1	1	1	1	2	2	2	2	2	2	3
Carbon Dioxide, Methane, and Green	0	0	1	1	1	1	2	2	2	2	2	2	3
Cloud Properties	5	4	6	6	6	7	8	8	7	7	7	7	7
Earth Radiation Budget	1	1	2	2	2	3	4	4	4	4	4	4	5
FAPAR	0	1	2	2	2	2	3	3	3	3	3	3	4
Fire Disturbance	0	0	0	0	0	0	1	1	1	1	1	1	2
Glaciers and Ice Caps, and Ice Sheets	2	1	2	2	2	2	2	2	2	2	2	2	1
LAI	0	1	1	1	1	1	1	1	1	1	1	1	1
Lakes	2	1	2	2	2	2	2	2	2	2	2	2	1
Land Cover	2	2	4	4	4	5	6	6	6	6	7	7	8
Ocean Color	2	2	3	3	3	3	4	4	4	4	4	4	4
Ocean Currents	2	1	2	2	2	2	2	2	2	2	2	2	1
Ocean salinity	0	0	0	0	0	0	0	0	0	1	1	1	1
Ozone	2	1	3	3	3	4	5	5	5	5	5	5	6
Precipitation	4	3	4	4	4	5	6	6	5	5	5	5	6
Sea Ice	2	1	2	2	2	2	3	3	3	3	4	4	4
Sea Level	2	1	2	2	2	2	2	2	2	3	4	4	3
Sea State	2	1	2	2	2	2	2	2	2	2	2	2	1
Sea Surface Temperature	5	4	6	6	6	7	8	8	7	7	7	7	7
Snow Cover	2	1	2	2	2	2	3	3	3	3	3	3	3
Soil Moisture	2	2	3	3	3	3	4	4	4	5	5	5	5
Surface Temperature	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Wind Speed and Direction	2	1	2	2	2	2	3	3	3	3	3	3	3
Upper Air Temperature	1	1	2	2	2	2	3	3	3	3	3	3	4
Upper-air Wind	3	3	4	4	4	5	5	5	4	4	4	4	4
Water Vapour	5	4	6	6	6	7	8	8	7	7	7	7	7

Table 6.3 shows the number of instruments on U.S.-led satellites collecting each essential climate variable each year from 2000 to 2012.

6.2.1 European Space Agency (ESA)

ESA's purpose shall be to provide for, and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems[360].

[360] "ESA's Purpose." *European Space Agency*. N.p., n.d. Web. 30 Mar. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/ESA_s_Purpose>.

International Cooperation and Unofficial Sharing in Early Years

The predecessor of ESA, the European Space Research Organization (ESRO), was created in 1962 as a joint European space organization focused on developing spacecraft. In 1978, ESA was created by combining ESRO with its counterpart, the European Launch Development Organization (ELDO), which focused on developing a launch system.[361] Because ESA is an international organization, its decision-making body is made up of representatives from each member state. Since its creation, membership has doubled, reaching 20 nations by 2012. Funding arrangements are also unique, with each ESA member required to provide funding to ESA's mandatory program relative to its gross domestic product (GDP). This covers ESA's general budget and science program, including technology development, as well as studies on future activities.[362] The Earth Observation program is considered an optional program, in which individual members can choose the level of their financial contribution.[363]

Europe's earliest Earth observation activities began in the 1970s with data acquisition from international satellites at the Center for Earth Observation in Italy. This center then helped European researchers access data from other countries' satellites,

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361 Europe. European Space Agency. *Convention for the Establishment of a European Space Agency & ESA Council.* Netherlands: ESA Publications Division, 2003. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/docs/SP1271En_final.pdf>.
362 "About ESA: Funding." *European Space Agency*. N.p., n.d. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/Funding>.
363 "ESA Mandatory and Optional Scientific Programmes." *Department for Business, Innovation & Skills*. United Kingdom Space Agency, n.d. Web. 01 Apr. 2013. <http://www.bis.gov.uk/ukspaceagency/what-we-do/exploring-the-universe/how-we-deliver/esa-programmes>.

including Landsat.[364] The first Earth observation satellite developed by Europe was Meteosat-1, a geosynchronous meteorological satellite, launched in 1977.[365] Throughout the late 1970s and early 1980s, ESA continued to focus on technology development related to weather applications. However, like NASA, ESA eventually handed off these activities to a meteorological agency.[366] ESA then turned to larger satellites focused on scientific data collection.

In 1991, ESA launched the Earth Resource Satellite-1 (ERS-1), followed by ERS-2 in 1995. Both were large, complex satellites carrying multiple instruments, including synthetic aperture radars that allowed them to take measurements of the Earth regardless of cloud cover.[367] In the late 1980s and early 1990s, as ESA was developing these satellites, it signed bilateral memorandums of understanding concerning access to the data for foreign users with the United States, Japan, India, and other nations.[368] This international sharing was consistent with existing official and unofficial practices of exchanging data from scientific satellites, particularly through the installation of ground stations in other nations. ESA officials also noted

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364 "History of Europe in Space." *European Space Agency*. N.p., 24 June 2010. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/History_of_Europe_in_space>. Bruzzi, Stefano. Speech. The Living Planet. Stockholm. 11 Mar. 2009. Web. 1 Apr. 2013. <http://www.snsb.se/Global/Fj%C3%A4rranalysanv%C3%A4ndare/Fj%C3%A4rranalysdagarna%20presentationer/2B_Stefano_Bruzzi_ESA_EO_programme.pdf>.

365 "50 Years of Earth Observation." *European Space Agency*. N.p., n.d. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/50_years_of_Earth_Observation>.

366 "Observing the Earth: A Brief History of Meteosat." *European Space Agency*. N.p., n.d. Web. 01 Apr. 2013. <http://www.esa.int/Our_Activities/Observing_the_Earth/Meteosat_Second_Generation/A_brief_history_of_Meteosat>.

367 "Earthnet Online." *Earth Resource Satellite*. European Space Agency, n.d. Web. 01 Apr. 2013. <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/ers>.

368 United Nations. *International Agreements and Other Available Legal Documents Relevant to Space-related Activites*. Vienna: n.p., 1999. *International Agreements and Other Legal Documents Relevant to Space-related Activities*. Web. 1 Apr. 2013. <http://www.oosa.unvienna.org/pdf/spacelaw/intlagree.pdf>.

that sharing data would help to illuminate potential uses or the data, demonstrating its value.[369]

ESA developed principles related to provision of ERS data, noting that ESA retained ownership of the data and that fair prices would eventually be phased in, consistent with the economic value of the data. However, it stated that prices could be waived for particular types of users, particularly those working with ESA on scientific research.[370] Though the satellites were developed primarily to address scientific questions, hopes were high that cost recovery would also be possible. Some member states had already demonstrated an interest in cost recovery and commercialization efforts within their own programs, particularly the SPOT program in France. A belief in the value and efficiency of cost recovery was expressed within ESA, and with some of the largest and most advanced satellites of their time, member states had reason to believe that data would have a high value.[371]

Cost Recovery Begins

ESA's third large Earth observation satellite, Envisat, launched in 2002, was the largest civilian Earth observation satellite ever built. Like the ERS satellite, it carried a synthetic aperture radar as well as many other instruments.[372] In 1998, in preparation for the upcoming launch, ESA approved an official Envisat data policy

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369 Harris, Ray, and Roman Krawec. "Some Current International and National Earth Observation Data Policies." *Space Policy* 9.4 (1993): 273-85. Web.

370 Harris, Ray, and Roman Krawec. "Some Current International and National Earth Observation Data Policies." *Space Policy* 9.4 (1993): 273-85. Web.

371 Personal Interviews.

372 "Earthnet Online." *Instruments*. European Space Agency, n.d. Web. 01 Apr. 2013. <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments>.

whose objectives included maximizing beneficial use of Envisat data and balancing development of science, public utility, and commercial applications. With this policy, ESA laid out the plan to commercialize Envisat, charging market prices (set by data distributers) for access to the data by foreign, operational, and commercial users. Only those chosen by ESA to work on ESA-approved research projects would have the opportunity to access the data for free. The policy did this by establishing two tiers, or categories, based on how data would be used.

Category one included ESA internal use, research and applications in support of mission objectives, and research in preparation for future operational use. All other uses, including operational and commercial use of the data, fell under category two.[373] Researchers wishing to be certified as a category one user were required to go through a peer-review process developed by the ESA Earth Observation Program Board. Approved users were then required to report on and publish any findings and to present results in a symposia organized by ESA. In general, data for category one uses was to be provided at or near the cost of reproduction. This price could be waived for projects chosen in response to a specific Announcement of Opportunity from ESA.[374]

ESA planned to distribute data to approved category one users itself at or near the cost of reproduction, while allowing distributing entities to set prices and distribute

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[373] Europe. European Space Agency. *European Space Agency Earth Observation Programme Board Envisat Data Policy*. Paris: n.p., 1998. Web.
[374] Europe. European Space Agency. *European Space Agency Earth Observation Programme Board Envisat Data Policy*. Paris: n.p., 1998. Web.

data to category 2 users. ESA would provide data access to these approved distributers at or near the cost of reproduction. Foreign stations (similar to those operated by the United States and others for the ERS satellites) would be subject to an access fee for the right to receive high rate data from Envisat. Only ESA member states would not be subject to this fee.[375] The data policy noted that the creation of a revenue stream for ESA was of less importance than other objectives. However, there was hope that implementation of the policy would "lead to a sustainable market led by user demand" and would "create the conditions for the private sector to invest in new products and services."[376] In 2000, the same policy was applied to the ERS satellites.[377]

Cost Recovery is Largely Abandoned for Full and Open Sharing

Unfortunately for ESA, these hopes did not turn into reality. The policy led to a significant decrease in international data sharing between ESA and other nations, particularly the United States, ending the precedent set with ERS.[378] A commercial market for ESA's satellite data did not materialize, and ESA did not see significant returns from its cost recovery efforts. Further, a report commissioned by the European Union showed that the value-added sector for geospatial information in Europe was

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375 Europe. European Space Agency. *European Space Agency Earth Observation Programme Board Envisat Data Policy*. Paris: n.p., 1998. Web.
376 Europe. European Space Agency. *European Space Agency Earth Observation Programme Board Envisat Data Policy*. Paris: n.p., 1998. Web.
377 Europe. European Space Agency. Earth Observation Programme Board. *Earth Explorer Data Policy: Update for GOCE and SMOS*. Paris: n.p., 2006. Web. 1 Apr. 2013. <https://earth.esa.int/pi/esa?type=file&ts=1173801698591&table=aotarget&cmd=image&id=1420>.
378 Personal Interviews.

significantly smaller than that in the United States, suggesting that restricted access to data was leading to less commercial activity rather than more.[379]

Following the 2002 launch of Envisat, ESA embarked on its Living Planet Program, which focused on developing smaller and more focused missions, referred to as Earth Explorer Missions, which could be launched more frequently. Interest in climate change was growing, and many of the scientific focus areas for the Living Planet Program directly related to the work of the International Panel on Climate Change (IPCC).[380] The first mission of the Living Planet Program, Cryosat, was launched in 2005, but never entered orbit due to an error with the launch vehicle. However, this mission was followed by two additional Living Planet Program missions successfully launched in 2009: the Gravity field and Ocean Circulation Explorer (GOCE) and the Soil Moisture Ocean Salinity (SMOS) satellite. Cryosat-2, which specialized in measurements of ice cover and thickness, launched in 2010.[381] As each of these satellites was launched, ESA's existing tiered policy was applied to the data. However, as the years wore on and revenues did not increase, ESA members

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379 *Commercial Exploitation of Europe's Public Sector Information*. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013. <http://ec.europa.eu/information_society/policy/psi/docs/pdfs/pira_study/2000_1558_en.pdf>.

380 Europe. European Space Agency. Earth Science Division. *The Science and Research Elements of ESA's Living Planet Programme*. Netherlands: ESA Publications Division, 1998. Web. 1 Apr. 2013. <http://due.esrin.esa.int/stse/files/document/SP-1227.pdf>.

381 "CryoSat." *Earthnet Online*. European Space Agency, n.d. Web. 01 Apr. 2013. <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat>.
Europe. European Space Agency. Earth Observation Mission Science Division. *The Changing Earth - New Scientific Challenges for ESA's Living Planet Programme.* Netherlands: ESA Publications Division, 2006. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/docs/SP-1304.pdf>.

recognized that a commercial market in scientific satellite data was not viable, and began to consider opening the data policy.[382]

Also pushing for more openness was an emphasis by ESA on the importance of maximizing data use rather than agency revenues. ESA officials felt that the value of satellite programs could be better demonstrated by showing the many ways in which data could be used, rather than by demonstrating relatively small financial revenue. Europe was also becoming more interested in the issue of climate change, aiming to be a world leader on this issue. It was felt that progress on scientific and operational projects related to climate change could proceed more quickly if data was freely available.[383]

The 2008 announcement at GEO that Landsat data would be made freely available provided a clear demonstration of willingness of other nations to abandon efforts at cost recovery in favor of full and open sharing, and this made an impression on decision-makers in Europe. Initial results from Landsat also suggested that transitioning to a free and open dataset could lead to large increases in data use.[384] At the 2008 ESA Ministerial Conference, Earth observation was confirmed as one of ESA's largest programs, and a climate change initiative was endorsed.[385] Earth

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382 Personal Interviews.
383 Personal Interviews.
384 Personal Interviews.
385 Bruzzi, Stefano. Speech. The Living Planet. Stockholm. 11 Mar. 2009. Web. 1 Apr. 2013. <http://www.snsb.se/Global/Fj%C3%A4rranalysanv%C3%A4ndare/Fj%C3%A4rranalysdagarna%20presentationer/2B_Stefano_Bruzzi_ESA_EO_programme.pdf>.

observation continued to be a priority for ESA; in 2010, it became the highest-funded domain within the ESA budget, overtaking spending on launchers.[386]

In 2009, the European Space Agency developed joint principles regarding data from the Sentinel satellites, which were being developed to support the European Union Global Monitoring for Environment and Security (GMES) program. The principles stated that anyone could access Sentinel data, with no distinction made between public, commercial, and scientific use or between European and non-European users. Data would be provided free of charge online following a user registration process and the acceptance of "generic" terms and conditions.

Reflecting the growing emphasis within Europe on the value of open data policies to scientific research and the development of the commercial value-added sector, the policy objectives included "promoting the use and sharing of GMES information and data," "strengthening Earth observation markets in Europe, in particular the downstream sector," and "supporting the European research communities." The policy referenced the Global Earth Observation System of Systems (GEOSS) Data Sharing Principles as part of the legal and programmatic framework for the policy.[387] Dissemination would be limited only in exceptional, security related cases.[388]

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386 Europe. European Space Agency. *ESA Budget for 2009*. N.p., n.d. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/docs/corporate/ESA_2009_Budgetsweb.pdf>.
Europe. European Space Agency. *ESA Budget for 2010*. N.p., n.d. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/multimedia/DG/ESA_2010_Budget.pdf>.
"ESA Budget for 2013." *Funding*. European Space Agency, 7 Feb. 2013. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/Funding>.

387 Europe. European Space Agency. Earth Observation Programme Board. *Joint Principles for a GMES Sentinel Data Policy*. Paris: n.p., 2009. Web. 15 Apr. 2013. <http://www.d-gmes.de/sites/default/files/dokumente/sentinel_data_policy_ESAPB-EO_2009_98_REV1.pdf>.

In 2010, building on the consensus regarding the Sentinel data policy, ESA updated the policy regarding its existing satellites, this time distinguishing by the type of data rather than the type of data use. The European Space Agency Earth Observation Data Policy was approved in 2010 and applied to data from all ESA Missions, including ERS-1, ERS-2, Envisat, GOCE, SMOS, and Cryosat, as well as future Earth Explorer missions. The policy defines two groups of datasets: the free dataset and the restrained dataset. Data from both types of datasets are provided free of charge, and only user registration is needed to access the free dataset. For the restrained dataset, users must provide a project proposal. For all data, onward distribution requires special permission from ESA.[389]

The policy also stated, "ESA will pursue its effort for enlarging the quantity of data available within the free dataset."[390] The restricted dataset includes SAR data from ERS and Envisat missions as well as requests for very large volume datasets. Part of the reason for the restriction is technical: the SAR instrument can be operated in different modes that do not fit all user requirements, so data is only processed and

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"Sentinel Data Policy and Access to Data." Lecture. Workshop on GMES Data and Information Policy. Brussels. 12 Jan. 2012. *European Space Agency*. Web. 15 Apr. 2013. <http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=7149>.

388 Riedlinger, Torsten. "GMES Data and Information Policy." Lecture. Global Monitoring for Environment and Security. Rome. 7 May 2012. European Commission. Web. 15 Apr. 2013. <http://www.earthobservations.net/documents/meetings/201205_gepw6/geo_wp_in_gmes_data_policy_riedlinger.pdf>.

389 "Revised ESA Earth Observation Data Policy." *Earthnet Online*. ESA, n.d. Web. 15 Apr. 2013. <https://earth.esa.int/web/guest/missions/content?p_r_p_564233524_assetIdentifier=revised-esa-earth-observation-data-policy-7098>.

390 "Revised ESA Earth Observation Data Policy." *Earthnet Online*. ESA, n.d. Web. 15 Apr. 2013. <https://earth.esa.int/web/guest/missions/content?p_r_p_564233524_assetIdentifier=revised-esa-earth-observation-data-policy-7098>.

made available in response to specific requests. Access to SAR data for research purposes requires the submission of a project proposal. If accepted, access to a specified quota of data is provided for free.[391]

However, ESA has not completely given up its efforts at cost recovery. For non-research users, or those that do not have an accepted project proposal, the SAR data is priced at market levels by data distributers, which pay ESA programming and/or production fees. Requests made through these distributing entities (generally for operational or commercial uses) have higher priority than requests made through the submission of a project proposal.[392]

Although ESA and EUMETSAT are both governed by member nations from Europe, the concerns of members differed. EUMETSAT, which focused on the collection and distribution of weather data, was especially concerned with international data sharing for weather forecasting. However, like ESA, when member states expressed an interest in commercializing data sales and attempting to recover costs from the activities of their National Meteorological Agencies, EUMETSAT followed suit, attempting to balance these two goals. Eventually, commercialization efforts proved to be largely fruitless, and EUMETSAT began to loosen policy restrictions with the aim of increasing the size of its data user community.

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391 Europe. European Space Agency. *Revised ESA Data Policy for ERS, Envisat and Earth Explorer Missions (Simplified Version)*. N.p.: n.p., 2010. Web. 15 Apr. 2013. <https://earth.esa.int/pi/docs/doc/download/revised_ESA_data_policy.pdf>.
392 Europe. European Space Agency. *Revised ESA Data Policy for ERS, Envisat and Earth Explorer Missions (Simplified Version)*. N.p.: n.p., 2010. Web. 15 Apr. 2013. <https://earth.esa.int/pi/docs/doc/download/revised_ESA_data_policy.pdf>.

6.2.2 European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)

The vision of EUMETSAT is to be the leading user-governed operational agency for European Earth observation satellite programs that are consistent with the objectives of its Convention. In this area EUMETSAT will be a trusted global partner of the provision of satellite data from geostationary and low-earth orbits.

International Sharing of Weather Data

In 1981, the same year that ESA launched Meteosat-2, an intergovernmental group agreed that a European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) should be created to ensure continuity of a meteorological satellite system in Europe. In 1986, the EUMETSAT Convention entered into force with 16 members, though this would grow to 26 members and 5 participating states by 2012.[393] EUMETSAT's decision-making body was made up of representatives of the national meteorological services (NMSs), and the organization's activities were funded through contributions by member states based on Gross Domestic Income.

Under the convention, EUMETSAT's primary objective was to "establish, maintain, and exploit European systems of operational meteorological satellites, taking into account as far as possible the recommendations of the World Meteorological

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393 "Funding." EUMETSAT, n.d. Web. 15 Apr. 2013. <http://www.eumetsat.int/Home/Main/AboutEUMETSAT/WhoWeAre/Funding/index.htm?l=en>.

Organization."[394] The Convention did not explicitly mention data sharing, though it did note that participation in the WMO and cooperation "in conformity with meteorological tradition" with member and non-member states were important to the organization. EUMETSAT signed numerous bilateral data exchange agreements with countries including Russia, China, India, Korea, and Japan, ensuring direct access to EUMETSAT data in return for similar access to their data.[395]

Thus, in its earliest days of operation, EUMETSAT engaged in extensive data sharing, both on a bilateral basis and within the WMO. However, EUMETSAT's status as a voluntary international organization posed special challenges. In particular, members felt that there needed to be some way to ensure that countries contributing to the system received special benefits. Otherwise, other countries, European countries in particular, could get all the benefits from EUMETSAT without paying any of the costs.[396] Therefore, a 1988 resolution on "EUMETSAT Principles on Distribution and Charging" distinguished between requirements for data access for EUMETSAT member states and all others. Non-member states could acquire data by getting permission from EUMETSAT and would be charged a fee, though in some cases, data was available through bi-lateral agreements.[397] As additional resolutions continued to amend and add to EUMETSAT's data policy over the next few years,

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394 Europe. EUMETSAT. *Convention for the Establishment of a European Organization for the Exploitation of Meteorological Satellites*. N.p.: n.p., 1986. Web. 15 Apr. 2013.
395 Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.
396 Castañer, Silvia. "Access to EUMETSAT Data." Lecture. Workshop on GMES Data and Information Policy. Brussels. 12 Jan. 2012. Web. 15 Apr. 2013. <http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=7145>.
397 "European Meteorological Satellite Organisation." NASA, n.d. Web. 15 Apr. 2013. <http://gcmd.nasa.gov/KeywordSearch/Supplementals.do?Portal=amd>.

the distinction between member and non-member states remained central, and was made possible through the use of licenses restricting use and redistribution.[398]

In 1989, Meteosat-4 was launched as the first satellite funded by EUMETSAT, and was followed by Meteosat-5 though 10 over the next two decades.[399] Beginning with Meteosat-4, EUMETSAT was in charge of collecting user requirements and jointly defining future satellite missions with ESA. While ESA continued to development and procure the satellites, once launched, responsibility for satellite operations and user relations belonged to EUMETSAT.[400]

In the early 1990s, there was increasing pressure on national meteorological agencies to recover some of the costs of their activities, and data was seen as a valuable asset well suited to this use.[401] Many countries' NMSs began selling both data and commercial products. Just as had been seen in the United States, Europeans made normative arguments on fair data access based on the fact that satellites were built using taxpayer funds; however, the conclusion of the argument was the opposite of NASA's. Europe argued that data are owned by all citizens, not just those interested in exploiting them, and, therefore, it is best for the government to get a return on the

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398 "EUMETSAT." *ECSL News: Bulletin of the European Center for Space Law* 7 (1991): n. pag. Web. 15 Apr. 2013. <http://www.esa.int/esapub/ecsl/ecsl7.pdf>.
399 Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.
400 Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.
401 "EUMETSAT." *ECSL News: Bulletin of the European Center for Space Law* 7 (1991): n. pag. Web. 15 Apr. 2013. <http://www.esa.int/esapub/ecsl/ecsl7.pdf>.
Europe. EUMETSAT. *Meteosat Second Generation Image Data Dissemination Service*. Vol. 1.2. N.p.: n.p., 2003. Web. 15 Apr. 2013.
<ftp://ftp.dartcom.co.uk/pub/manuals/legacy/EUMETSAT%20TD08.pdf>.

public investment through data sales.[402] As NMSs' interest in commercial activities grew, private industry was also looking into the possibility of using satellite data to produce new commercial products.[403]

The overlapping commercial interests of these private companies and the NMSs led to arguments among countries and between countries and commercial entities. Some countries argued that if data were made freely available to companies that use it to develop value added products, then those companies would be unfairly benefiting from the system without making a contribution. The NMSs argued that this unfair competition would prevent them from achieving cost recovery goals.[404] Companies argued that data costs went too far in the other direction, with some NMSs pricing raw data at higher rates than their own value-added products, making it impossible for private companies to enter the value-added market.[405]

In addition to arguments about commercialization, EUMETSAT recognized the importance of research using meteorological data, both to improve forecast ability and the quality of meteorological products, as well as to carry out research related to global climate change.[406] It also needed to continue international data sharing within the WMO, consistent with its charter. EUMETSAT balanced these preferences by

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[402] Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.
[403] Europe. EUMETSAT. *EUMESAT Data Policy*. N.p.: n.p., 2012. Web. 24 May 2013.
[404] Europe. EUMETSAT. *Meteosat Second Generation Image Data Dissemination Service*. Vol. 1.2. N.p.: n.p., 2003. Web. 15 Apr. 2013. <ftp://ftp.dartcom.co.uk/pub/manuals/legacy/EUMETSAT%20TD08.pdf>.
[405] Personal Interviews.
[406] Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.

developing a data sharing policy that differentiated by particular data, user and type of use.

The policy called for a continuation of open data sharing with NMSs in other countries, with the stipulation that data would be provided only for their official use, and should not be further distributed. Commercial data users would be required to pay an access fee for certain data. EUMETSAT members would have free access to all data, but their commercial value-added branches would have to pay the same price as other commercial users, ensuring a level playing field. Archived and near-real time data could be accessed for free for research use, although it could not be redistributed. This policy, though complex, ensured maximum benefit to EUMETSAT members for official meteorological use, allowed for commercialization of some data, but also continued to contribute some data to the international community on free and open basis and support the research and educational community.[407]

As EUMETSAT developed its own policy, it also helped to shape complementary data sharing principles within the WMO. EUMETSAT and its member states advocated for a tiered policy within WMO, in which access to some data could be restricted to allow commercial activities. This policy was put into place in WMO Resolution 40.[408]

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[407] Europe. EUMETSAT. *EUMESAT Data Policy*. N.p.: n.p., 2012. Web. 24 May 2013.
[408] Europe. EUMETSAT. *EUMESAT Data Policy*. N.p.: n.p., 2012. Web. 24 May 2013.

From Commercialization to a More Open Policy

However, as with other environmental satellite data, EUMETSAT and its member states found that revenue generation from data sales was low. Over time, EUMETSAT's policy has retained its complexity, differentiating by users, uses, and types of data, but the amount of data made freely available has increased. As of 2012, the only data not made freely available is near-real time Meteosat data, and even this is made freely available to less developed countries and in times of emergency.[409] However, despite change in fees and accessibility, licensing restrictions have largely remained the same. EUMETSAT has emphasized its ownership of the data, preferring that users access data directly from its servers and not from a third party that may or may not highlight the EUMETSAT contribution.[410] This also allows EUMETSAT to track use through registration, providing another way to measure value of the data and maintain a close connection to the user community.[411]

In 2006, EUMETSAT launched its first polar-orbiting weather satellite, Metop-A, followed by Metop-B in 2012. Both of these satellites were part of an agreement with the United States to develop an International Joint Polar System (IJPS) in which the U.S. and Europe developed polar-orbiting weather satellites in complementary orbits. As part of the agreement, all data from these satellites was made freely available.[412]

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[409] "Alain Ratier, Director-General, EUMETSAT." *Research Media Ltd*. N.p., 29 Aug. 2011. Web. 15 Apr. 2013. <http://www.research-europe.com/index.php/2011/08/alain-ratier-director-general-eumetsat/>.
[410] Europe. EUMETSAT. *Convention for the Establishment of a European Organization for the Exploitation of Meteorological Satellites*. N.p.: n.p., 1986. Web. 15 Apr. 2013.
[411] Personal Interviews.
[412] Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.

The Jason-2 satellite, which was also developed in partnership with the United States, launched in 2008.[413] Jason data is also freely available to all.[414]

From its founding, EUMETSAT highly valued international cooperation as part of the international meteorological community. However, early in its development, there was pressure to take advantage of the value of meteorological data to recover some costs. As time passed and revenues failed to grow, efforts to recover costs through data sales lessened, and more data was made freely available. Like ESA, a small amount of data is still sold, and restrictions on data use and redistribution still exist.[415]

Japan, which has a smaller satellite program than the USA or Europe, maintains greater restrictions on its data, similar to the early European data sharing policies. However, it has not followed Europe's move to free and open access, still hoping to recover some costs and spur commercial remote sensing activities in Japan.

6.3 Japan

There are only two agencies within Japan that operate satellites, the Japan Aerospace Exploration Agency (JAXA), which focuses primarily on research satellites, and the Japan Meteorological Agency (JMA), which runs the operational meteorological satellite program.

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413 Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.
414 Europe. EUMETSAT. *EUMESAT Data Policy*. N.p.: n.p., 2012. Web. 24 May 2013.
415 Castañer, Silvia. "Access to EUMETSAT Data." Lecture. Workshop on GMES Data and Information Policy. Brussels. 12 Jan. 2012. Web. 15 Apr. 2013. <http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=7145>.

Table 6.4 Essential Climate Variable coverage with Japanese-led satellites only

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Aerosol Properties	0	0	1	1	0	0	0	0	0	0	0	0	0
Aerosols	0	0	0	0	0	0	0	0	0	0	0	0	0
Albedo	0	0	1	1	0	0	1	1	1	1	1	1	0
Biomass	0	0	1	1	0	0	1	1	1	1	1	1	0
Carbon Dioxide, Methane, and Green	0	0	1	1	0	0	0	0	0	1	1	1	1
Cloud Properties	1	1	2	2	1	2	2	2	2	3	3	3	3
Earth Radiation Budget	0	0	0	0	0	0	0	0	0	0	0	0	0
FAPAR	0	0	1	1	0	0	0	0	0	0	0	0	0
Fire Disturbance	0	0	0	0	0	0	1	1	1	1	1	1	0
Glaciers and Ice Caps, and Ice Sheets	0	0	0	0	0	0	1	1	1	1	1	1	0
LAI	0	0	1	1	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0
Land Cover	0	0	1	1	0	0	1	1	1	1	1	1	0
Ocean Color	0	0	1	1	0	0	1	1	1	1	1	1	0
Ocean Currents	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocean salinity	0	0	0	0	0	0	0	0	0	0	0	0	0
Ozone	0	0	1	1	0	0	0	0	0	0	0	0	0
Precipitation	1	1	2	2	1	2	2	2	2	2	2	2	3
Sea Ice	0	0	1	1	0	0	1	1	1	1	1	1	0
Sea Level	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea State	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea Surface Temperature	1	1	2	2	1	2	2	2	2	2	2	2	3
Snow Cover	0	0	1	1	0	0	1	1	1	1	1	1	0
Soil Moisture	0	0	1	1	0	0	1	1	1	1	1	1	1
Surface Temperature	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Wind Speed and Direction	0	0	1	1	0	0	1	1	1	1	1	1	1
Upper Air Temperature	0	0	1	1	0	0	0	0	0	0	0	0	0
Upper-air Wind	1	1	1	1	1	2	2	2	2	2	2	2	2
Water Vapour	1	1	2	2	1	2	2	2	2	2	2	2	3

Table 6.4 shows the number of instruments on U.S.-led satellites collecting each essential climate variable each year from 2000 to 2012.

6.3.1 Japan Aerospace Exploration Agency (JAXA)

The National Space Development Agency of Japan (NASDA), the forerunner of the JAXA, was established in 1969 under the Ministry for Science and Technology.[416] Like NASA and ESA, JAXA's first Earth observation satellite was an experimental meteorological satellite, the Geostationary Meteorological Satellite-1 (GMS-1). NASDA's Earth Observation Center was created in 1978. This center acted as a data

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[416] "United Nations Office for Outer Space Affairs." *Law Concerning The National Space Development Agency Of Japan*. N.p., n.d. Web. 24 May 2013. <http://www.unoosa.org/oosa/en/SpaceLaw/national/japan/nasda_1969E.html>. "National Space Development Agency of Japan (NASDA) History." *NASDA History*. JAXA, n.d. Web. 24 May 2013. <http://www.jaxa.jp/about/history/nasda/index_e.html>. Berner, Steven. *Japan's Space Program: A Fork in the Road?* Rep. Rand, 2005. Web. 24 May 2013. <http://www.rand.org/content/dam/rand/pubs/technical_reports/2005/RAND_TR184.pdf>.

reception hub for data from the U.S. Landsat 3 satellite.[417] The marine Observation Satellite Mission (MOS-1) was launched in 1987 to observe ocean phenomena. Like NASA and ESA, efforts carried out in the 1970s and 1980s were focused on technology development and satellites were considered experimental. No official data sharing policy was in place, and data was provided on an informal basis.

The 1990s saw three additional Earth observation satellite launches: the Japanese Earth Resources Satellite (JERS-1) in 1992, the Advanced Earth Observing Satellite (ADEOS) in 1996, and the Tropical Rainfall Measuring Mission (TRMM), a join mission with NASA, in 1997. Corresponding with the launch of JERS-1 in 1992, NASDA implemented a two-tier policy that distinguished between research users and general-purpose users. Research users could access data at the cost of reproduction with the requirement that they report on their research to JAXA. Other users could access data through private data distributers, which received data from JAXA at a relatively low cost and were free to determine their own prices for users. This policy was also applied to ADEOS and ADEOS-II data.[418] NASA was the lead agency for TRMM, so data were made freely available in accordance with NASA's data policy.[419]

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417 "History of JAXA's Earth Observations." JAXA, n.d. Web. 24 May 2013. <http://www.jaxa.jp/article/special/disaster/sat_e.html>.
418 Personal Interviews.
419 "TRMM." *Tropical Rainfall Measurement Mission*. NASA, n.d. Web. 24 May 2013. <http://trmm.gsfc.nasa.gov/data_dir/data.html>.
"Aqua Project Science." *Aqua*. NASA, n.d. Web. 24 May 2013. <http://aqua.nasa.gov/science/images_data.php>.

As in the United States and Europe, this policy was driven by a desire to balance the promotion of research with cost recovery and spurring the development of the commercial sector. In support of its policy, JAXA officials also expressed a belief that publicly-funded data are best held in a "public trust." They argue that restricting access to data is necessary to properly control and protect Earth observation data as the property of the nation, including charging users, particularly commercial entities, a fee to access data.[420]

In 1995, Japan established the Earth Observation Research Center, specifically aimed at data processing, analyzing, and archiving.[421] A revision of the Fundamental Policy of Japan's Space Activities in 1996 emphasized the importance of Earth Observation and Earth Science as a priority area for development, and stated that NASDA would expand the scope of utilization of Earth observation technology. International cooperation was a key aspect of this plan, which stated, "In addition to these endeavors, we will establish a global Earth observation system through international consultation and coordination. This system seeks a harmonious integration of observing satellites from various countries."[422] However, in 1997, NASDA experienced significant funding cuts, forcing it to scale back plans for Earth observation satellites under development.[423]

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420 Personal Interviews.
421 *Earth Observations Research Center*. Rep. JAXA, n.d. Web. 24 May 2013. <http://www.eorc.jaxa.jp/en/about/jaxa_eorc_pamphlet.pdf>.
422 Japan. JAXA. N.p.: n.p., 1996. *Fundamental Policy of Japan's Space Activities*. JAXA. Web. 24 May 2013. <http://warp.ndl.go.jp/info:ndljp/pid/286794/www.mext.go.jp/english/kaihatu/aerosp01.htm>.
423 Triendl, Robert. "Japan Tightens Focus in Space Research." *Nature* 388 (1997): n. pag. Web. 24 May 2013.

In 2001, as part of a larger government reorganization, NASDA was moved to the Ministry of Education, Culture, Sports, Science, and Technology (MEXT). Following that move, both the Aqua Satellite, another joint project, this time with the United States and Brazil, and the ADEOS-II satellite were launched in 2002. A year later, in 2003, NASDA changed its name to JAXA. At the same time, JAXA updated its data policy slightly, noting that researchers could now access data for free online, though redistribution was restricted. General users were still required to purchase data from distributing entities.[424]

In 2005, JAXA released a long-term planning document, "JAXA 2025." JAXA's priorities under this vision included ensuring utilization of aerospace technologies, particularly systems that can help in management of natural disasters and protection of the global environment.[425] The Greenhouse Gases Observing Satellite (GOSAT), launched in 2009, and the Global Change Observation Mission-Water (GCOM-W1), launched in 2012, were both aimed specifically at climate-related issues.[426]

In 2008, Japan passed the "Basic Space Law," removing legal barriers to conducting military space activities, emphasizing interest in dual-use technology, and expressly

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424 "Data Distribution Service." *Earth Observations Research Center*. JAXA, n.d. Web. 24 May 2013. https://data.gosat.nies.go.jp/GosatUserInterfaceGateway/guig/GuigPage/open.do
425 Japan. JAXA. *JAXA Vision 2025*. N.p.: n.p., 2005. Web. 24 May 2013. <http://www.jaxa.jp/about/2025/pdf/jaxa_vision_e.pdf>.
426 "History of JAXA's Earth Observations." JAXA, n.d. Web. 24 May 2013. <http://www.jaxa.jp/article/special/disaster/sat_e.html>.

supporting commercialization efforts, particularly in the launch industry.[427] In the "Basic Space Plan" that followed the new law in 2009, JAXA stated that utilization of space assets, rather than just research and development, was essential. JAXA's new plan included a focus on the environment, as well as an intent to provide data that could help in disaster monitoring and in addressing global warming. . It also notes that thought needed to be given to value-added possibilities, and concluded that Japan needed a standard data policy for provision of satellite data.[428]

In 2012, Japan restructured its government, placing JAXA under the joint control of Ministry of Education, Culture, Sports, Science, and Technology (MEXT) and the Ministry of Economy, Trade, and Industry (METI).[429] METI has shown an interest in new programs, such as dual-use Earth observation and has expressed an interest in working more closely with the commercial sector.[430] A new data policy is currently being developed, and is expected to differentiate between types of data. In particular, efforts will be made to sell high-resolution imaging data.[431]

The desire to promote the growth of domestic industry seems to be the greatest incentive for efforts at data sales and cost-recovery within Japan. This motive has only gained strength as JAXA has come under the joint control of the Ministry of

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[427] Aoki, Setsuko. "The National Space Law of Japan: Basic Space Law and the Space Activities Act in the Making." 1 Dec. 2011. Web. 24 May 2013. <http://www.iislweb.org/docs/2011_galloway/Aoki.pdf>.
[428] Personal Interviews.
[429] Personal Interviews.
[430] Kallender-Umezu, Paul. "Japan Passes Law Permitting Military Space Development."*Defense News*. N.p., 22 June 2012. Web. 24 May 2013. <http://www.defensenews.com/article/20120622/DEFREG03/306220001/Japan-Passes-Law-Permitting-Military-Space-Development>.
[431] Personal Interviews.

Economy, Trade, and Industry. However, there has been very little information made available about the success of past efforts in generating revenue, and a robust commercial industry has not yet developed. In contrast to its relatively restrictive data policy, JAXA policy has emphasized the importance of data utilization, and the need to balance extensive data use with efforts at commercialization. On numerous occasions, JAXA has emphasized the importance of international cooperation and data sharing.[432] Japan was one of the leaders in developing the Group on Earth Observations (GEO), a global organization that seeks to increase free and open sharing of environmental data.[433]

This contradiction was acknowledged somewhat in a statement by Osamu Ochiai, Associated Senior Administrator of the Satellite Applications and Promotion Center, highlighted on JAXA's website. Ochiai stated: "JAXA wants to continue to contribute to GEO in the future… If you want people to use new data in a wide range of areas, first of all, you have to make it easy - to lower the barriers to entry. The data provider needs to provide support to the users. I think this is true for any kind of service. Unfortunately, in my personal opinion, I think JAXA's satellite data hasn't yet reached a stage where it is widely utilized. By making our Earth observation data

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[432] "Fundamental Policy of Japan's Space Activities." JAXA, 24 Jan. 1996. Web. 24 May 2013. <http://www.jaxa.jp/library/space_law/chapter_4/4-1-1-4/index_e.html>.
Japan. JAXA. Strategic Headquarters for Space Policy. N.p., 2 June 2009. Web. 24 May 2013. <http://www.kantei.go.jp/jp/singi/utyuu/basic_plan.pdf>.
[433] Koizumi, Junichiro. "Welcome Remarks by Prime Minister Junichiro Koizumi at the Earth Observation Summit II." Speech. Earth Observation Summit II. 25 Apr. 2004. Web. 24 May 2013. <http://warp.ndl.go.jp/info:ndljp/pid/286794/www.mext.go.jp/english/kaihatu/earth/pdf/koizumi_e.pdf>.
Hayashi, Kumiko. "Statement of the Japanese Government at the 2010 GEO Ministerial Summit in Beijing." Speech. GEOSS Ministerial Summit. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_Japan_statement.pdf>.

freely available and encouraging its use, I think we can make it the international standard not just for GEO but for broader use as well."[434] Despite this sentiment, current discussions about new policy development suggest that efforts to engage the commercial sector will continue, and restrictions on data use will not be loosened.

Despite interests in promoting data utilization, climate research, and international cooperation, JAXA policies have remained relatively restrictive since 1992. A strong interest in cost recovery and commercialization drive this policy and seem likely to continue to play a large role in the future. Though JAXA's policy has seen very little change over time, the data policy of the Japan Meteorological Agency (JMA) is even less developed. JMA participates in WMO, exchanging data in accordance with Resolution 40, and also provides access to some imagery online via a data distributer. Perhaps because JMA has only operated satellites since 2005, there is very little evidence that satellite data sharing outside of WMO has been given much consideration.

6.3.2 Japan Meteorological Agency (JMA)

JAXA (NASDA) developed the first meteorological satellites for Japan, starting with the Geostationary Meteorological Satellite (GMS-1), also known as a Himawari satellite, in 1977. From early in the program's development, the potential for operational meteorological use was clearly recognized by JMA. Efforts were made to coordinate development of Japan's meteorological satellites with the standards of

[434] "JAXA's Earth Observation Satellite Highly Praised Worldwide." JAXA, n.d. Web. 24 May 2013. <http://www.jaxa.jp/article/special/geo/ochiai_e.html>.

those developed in Europe and the United States to ensure interoperability.[435] With a total of seven satellites launched since the beginning of the program, JMA maintains one operational geostationary satellite covering East Asia and the Western Pacific as well as one spare satellite in orbit.[436]

JMA has been a member of WMO since its founding, and shares satellite data with other NMSs within this structure, following WMO data sharing principles.[437] It also has a number of multilateral and bilateral agreements for data sharing.[438] In 1994, the Japan Meteorological Business Support Center (JMBSC) was created "to support and enhance the activities of weather business and efforts towards prevention/ mitigation of natural hazards by authorities concerned." One of the services it provides is distribution of meteorological data, products, and information in real time and non-real time to user communities at a marginal cost approved by JMA.[439] Archived GMS data can also be purchased through JMBSC.[440] In 2008, JMA also made its satellite imagery freely available on the internet in jpeg format, stating that this was done to ensure access to MTSAT imagery for many users in the public.[441] JMA also explained that more extensive online HRIT, JPEG, and other satellite data are

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435 Sekiguchi, Yoshiro. "JMA Memo." Letter to Dr. David S. Johnson, NOAA. 6 Feb. 1978. N.p.: n.p., n.d. N. pag. Web. 24 May 2013.
436 "Outline of the Multi-functional Transport Satellite (MTSAT) Series." *About MTSAT Series*. JMA, 31 Mar. 2008. Web. 12 Feb. 2013.
437 "For NMHSs." *Meteorological Satellites - Japan Meteorological Agency*. JMA, n.d. Web. 24 May 2013. <http://www.jma.go.jp/jma/jma-eng/satellite/ds.html>.
438 "International Cooperation." *Japan Meteorological Agency*. JMA, n.d. Web. 24 May 2013. <http://www.jma.go.jp/jma/en/Activities/intcorp.html>.
439 *Japan Meteorological Business Support Center*. JMBSC, 27 July 2009. Web. 24 May 2013. <http://www.jmbsc.or.jp/english/index-e.pdf>.
440 "Data Archives." Meteorological Satellite Center of JMA, 4 Mar. 2009. Web. 24 May 2013. <http://mscweb.kishou.go.jp/product/library/data/index.htm>.
Japan Meteorological Business Support Center. JMBSC, 27 July 2009. Web. 24 May 2013. <http://www.jmbsc.or.jp/english/index-e.pdf>.
441 Future Plan of Japanese Meteorological Satellite Program (presentation)

available only to NMSs due to limitations of JMA's server capacity and network bandwidth.[442]

JMA has one of the most restrictive policies of all, sharing data on an official level within the WMO, making a minimal set of images available online, and giving responsibility for all other data distribution to a commercial entity, where a fee is required for access. However, further action, whether to promote data use by researchers or others or to make greater efforts at cost recovery, does not seem imminent.

6.4 Domestic Agency-Level Comparative Case Study Discussion

Each of the seven organizations examined in this chapter followed a slightly different path in the development of their data policy, though there were a number of similarities in both actions and motivations. There was a common starting place, as each agency began without an official data sharing policy at the outset, generally engaging in informal data sharing in the early days of satellite Earth observation. From there, almost every agency made some attempt to benefit from the value of the data being collected. This led to efforts at cost recovery, commercialization, or even privatization that lasted for different periods of time for each agency. Following efforts, or at least consideration of, cost recovery, two U.S. agencies, NASA and USGS, moved gradually to completely free and open data policies. NOAA went through a similar transition, though it retains the ability to sell its data. ESA and

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[442] Tsunomura, Satoru. "Current Status and Future Plan of Japanese Meteorological Satellite Program." Lecture. Japan Meteorological Agency. Web.

EUMETSAT also retain slightly tighter control, using licensing that restricts redistribution and retaining some capability for satellite data sales. JAXA and JMA have both retained cost recovery efforts to the greatest extent among the seven cases, with JAXA charging market prices to commercial users only, while JMA charges a fee to all users for all but the most basic data.

Figure 6.2 Data Sharing Policies Over Time in Seven Agencies

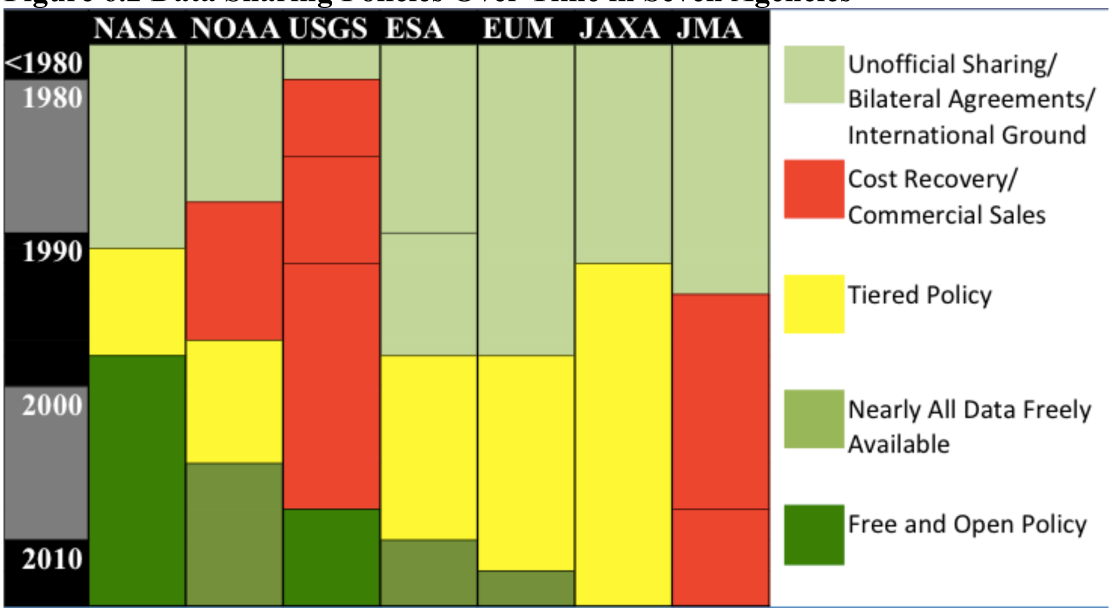

Figure 6.2 shows how the data sharing policies changed over time in the seven agencies for which case studies were carried out.

As all of these policies developed over time, there were three arguments central to the discussions. Most important were economic arguments about whether it would be more efficient and beneficial to the country to treat data as a public good and make it freely available or treat it as a commodity and sell it. Normative arguments also played an important, though limited, role in weather data in particular. It was generally agreed that access to some weather information is required on moral grounds, and thus, distribution of this type of data was not subject to restriction based on economic arguments. With this exception, however, ethical arguments were generally secondary to economic arguments, with public good views supported by a belief that the public had the right to access the data for free, and commodity views supported by a belief that the government has a responsibility to protect the public's investment and secure a return for general taxpayers whenever possible. Finally, the international aspect of satellite Earth observation and the global nature of some of the issues it can address also played an important role in policy development. In the meteorological agencies, NOAA, EUMETSAT, and JMA, in particular, international cooperation at some level was always seen as an imperative, with no consideration of stopping international data sharing altogether. For the science-focused agencies, this was less accepted, though the increasing importance of climate change as a global issue has raised its significance.

Within each case study, there were two primary groups involved in data sharing policy development – agency officials and legislative or executive officials with responsibility for the agency budget, and the interests of these two groups determined the substantive issues that carry the most weight. Agencies are concerned with accomplishing their mission, which often requires sharing data to maximize research, inform the public, or understand what they recognize is an inherently global issue. As experts in these areas, they also have a better understanding of the difficult-to-quantify benefits of data use. Non-agency officials concerned primarily with budget issues prioritize efficiency and cost reduction. They are often not experts in satellite or geospatial data, and are less likely to be aware of, or understand, the value of difficult-to-quantify benefits of data use. Economic arguments are driven largely by the interests and positions of these two groups. Normative and institutional arguments are of interest to both groups, but differences of opinion on their application are based on the character of the data, specifically whether the data is used for weather or climate purposes.

Economic arguments were the most important determinant of policy development across all seven agencies. Both agency and budgeting officials are concerned with economic efficiency, and both have an incentive to accomplish as much as possible with the budget provided. Budgeting officials have a further interest in decreasing overall costs and reducing the budget, if possible. Because of its unique characteristics, satellite data can be viewed as either a public good or a commodity, and depending on the assumptions made or limitations faced in reality, either view could potentially be more efficient or more beneficial for a nation. The position taken on this theoretical question is aligned with the primary interests of each group of officials.

Agency officials generally support the view of data as a public good and push for free provision of data. These agency officials hone in on the fact that the value of the data comes from its use, particularly in areas such as research and education. Providing data for free maximizes data use for a given mission cost, resulting in the greatest possible amount of research carried out and greatest overall social benefit. This is a logical position for agency officials, as it prioritizes their ability to best achieve their agency's mission of supporting research and increasing understanding of climate issues, given the resources provided. Budgeting officials did recognize the value and importance of data use, but rather than focusing exclusively on these benefits, they prioritized the importance of overall efficiency and of cost reductions, reflecting their primary interest in government-wide budget issues.

The positions and interests of these two decision-making groups drove the development of early data sharing policy. Across these case studies, data from early satellites was shared, often informally. This demonstrated the value and quality of the data collected by each agency's space assets, including the potential for commercial applications using the data. Once this commercial value was clear, debates about whether and how data sharing policies should best capture the value of data took place. In general, agency officials supported a policy that would continue free data sharing, while budgeting officials supported efforts at data sales that would lead to cost recovery, commercialization, or privatization.

Early in Earth observation satellite program development, in the 1980s and 1990s, there were a number of key uncertainties that favored the budgeting official position. First, it was known that there were potential commercial uses of data for mining, agriculture, fishing, and other areas, and it was not yet known whether there was sufficient interest to support a commercial remote sensing sector. If efforts to sell data could help to spur a vibrant commercial satellite remote sensing sector, these activities could be largely removed from the government budget, and satellite data collection would benefit from all of the inherent efficiencies of a competitive market system. Even a system that was not commercially viable could at least be a source of cost recovery, alleviating pressure on government budgets. Second, the elasticity of demand for satellite data was unknown. If elasticity was low (demand was inelastic), then commercial or cost recovery models could operate without significantly reducing data use, because the same number of individuals (research, commercial, or otherwise) would purchase the data regardless of the price. Finally, the potential uses of data, including particular research findings, operational, and commercial uses were not fully known, and the benefits of these potential findings and products were difficult to quantify. For example, data use for research leads to a nebulous "better understanding" of climate, while the benefit of revenues generated from data sales is an easy-to-understand monetary amount.

Given the structure of these arguments and these key uncertainties, it is not surprising that most agencies at least attempted to sell data. While a free data policy would only continue the status quo, data sales had the potential to reduce costs for the government through cost recovery or to spur the development of a private remote sensing sector. Further, these easy to understand cost reductions could potentially be captured without significantly decreasing data use, if demand proved to be inelastic. The high hopes for efforts at data sales were seen in the actions and statements of many agencies. In the United States, it was hoped that commercialization of the Landsat system would result in a new commercial remote sensing market, ensuring sustainable data collection over time and encouraging technical innovation, both of which would benefit all users. In ESA, it was further argued that if data could be sold efficiently, it would be possible to gauge the true value of the data and ensure that development of the most valuable types of systems were continued. Both NOAA and EUMETSAT believed that sales of some weather data would provide revenues that could increase the sustainability of government meteorological agencies.

In all three countries, data sales by the government were seen as initial steps in the development of a commercial sector, including both a commercial industry in raw data collection and sales as well as growth of a value added sector. Although policies were developed with these commercial goals in mind, they often included compromises that at least partially accommodated the position of agency officials, who were focused on maximizing data use, particularly for research. In combination with data sales, many programs provided special arrangements for the research community, sometimes providing free data in response to specific announcements of opportunity, or more broadly through implementation of a two-tiered data policy in which access for research use was free. NASA officials were most effective at making the agency case, arguing that research was central to their mission, and that the primary value of the data they collected lay in scientific use. Though they did implement a two-tiered policy for a short period, requiring authorization for commercial use, they never fully engaged in commercial data sales.

Within approximately ten years of putting restrictive cost recovery and commercialization policies in place, most agencies had removed these policies. This occurred largely because the efforts had failed; ESA, NOAA, USGS, and EUMETSAT all reported that revenues had represented only a small fraction of system costs. Many of the key uncertainties that existed in the early Earth-observing satellite development period were now much better understood. Most importantly, experience had shown across many examples that there is not a viable commercial market for the sale of most satellite remote sensing data; the primary value of this data lies in its use for research and operational projects in the public interest. By continuing data collection programs, rather than canceling them, governments implicitly acknowledged that this data was valuable and its collection was the proper role of government. However, for data with the greatest commercial value and potential for sales, many nations continue to support commercialization and cost recovery. This is seen in the sale of high-resolution data in the U.S. private sector, licensed by the U.S. government, and ESA's sales of synthetic aperture radar data. Both the United States and Europe refrain from developing government-owned high-resolution satellites that could potentially compete with the private sector. JAXA's expected policy change also reflects recognition of the limitations of the commercial market for certain types of data as they move from a policy that charges based on user to instead only charging for high-resolution data.

As cost recovery and commercialization ventures failed, governments began to open data sharing policies. Experiences in cost recovery and the eventual adoption of free data policies made it increasingly evident that demand for remote sensing data was highly elastic. Landsat provides the most striking demonstration of this characteristic. When the initial decision to commercialize Landsat was made, data that had previously been freely available was sold at a relatively small cost. These costs were then raised in anticipation of transfer to the public sector, and raised again, dramatically, when control of satellite data sales was given to a private company. Each of these price increases was associated with a significant decrease in data use. When Landsat data was made completely free in 2008, use of the data skyrocketed. ESA and EUMETSAT also found that attempts to commercialize data resulted in relatively low data use, and the high elasticity of demand was not limited to research users. Studies showed that the value added sector for publicly collected geospatial information was much smaller in Europe than in the United States, a trend that was correlated with data pricing policies.

Information learned about the remote sensing satellite data market through trial-and-error weakened the argument of budget officials and gave strength to agency officials' argument. In recent years, most agencies, particularly in the United States and to a lesser extent in Europe, have moved from a view of data as a commodity to treatment of satellite data as a public good. The emphasis at NASA, NOAA, USGS, ESA, and EUMETSAT is largely in reaching as many users as possible and progress is shown in increasing numbers of users, data downloads, and related publications, rather than in revenues.

The second important determinant identified in the case studies was ethical arguments. Most often, ethical arguments are made in terms of the fairest way to distribute data and are closely related to economic arguments. When agencies argue that data should be treated as a public good, they support this by stating that the public has the right to access data for free, because they have already paid for it once through taxation. This argument has been made on many occasions by NASA officials arguing for free data access policies. When data is viewed as a commodity, agencies argue that the satellite data is an important national asset that should be protected by the government; the government is viewed as a public trust for the data. It is also argued that those who use the data, particularly companies that process and re-sell it for a profit, benefit more from the system, and therefore should be responsible for contributing more to the system. These revenues then benefit taxpayers equally, by improving government capabilities or reducing reliance on general taxation. These arguments have been common in both Europe and Japan in support of their cost-recovery efforts. Though these arguments do not seem to be the primary determinants, they have an important role in justifying policies. Almost every agency makes a point of providing not only an economic argument, but also a moral rationale for its proposed actions.

Though the most commonly mentioned ethical arguments seem to simply be used to support economic arguments, the most interesting cases are those few in which normative arguments about moral responsibilities outweigh economic arguments. This is particularly visible in efforts to sell weather data compared to other environmental satellite data. There is an accepted belief that the provision of weather information, particularly extreme weather forecasts and warnings, must be carried out by the government. While some raw weather data or weather products may be sold, it is understood that certain weather data must be available to the government, and that data and derived products must be provided freely to the public. For example, no government supports charging a price for hurricane warnings, and no government is willing to risk having data relevant to hurricane warnings be subject to the changes and developments in the commercial market. This was made most explicit in the United States when the Satellite Remote Sensing Commercialization Act of 1984 called specifically for commercialization of government remote sensing systems, particularly Landsat, but also specifically forbade efforts to commercialize weather satellite systems. Though it was not codified in law, collection and distribution of weather data and information was similarly protected in Europe and Japan. EUMETSAT also demonstrates the importance of this argument by making special exceptions to its data sharing restrictions to ensure that data was shared “for official use” by other meteorological agencies.

The effectiveness of these arguments with respect to weather data but not climate data is surprising, since the structure of the two phenomena have so many similarities. The moral obligation to provide weather data is based primarily on the fact that weather causes loss of life and significant damage to property, and that satellite data can be used to increase understanding of weather events and develop forecasts that save lives and property. However, climate change also has impacts with the potential to cause significant loss of life and significant damage to property, and satellite data can be used to better understand and forecast future climate change. The difference in moral obligation stems from the understanding and strength of the link between the phenomenon and damage as well as the link between increased understanding or improved forecasting for the phenomenon and prevention of damage.

In the case of weather, the link between extreme weather and loss of life and property is very clear. A hurricane or flood occurs and individuals are killed and homes and businesses are destroyed. The link between forecasting and prevention of loss of life and property damage is also clear. If a hurricane's path and intensity is accurately forecast a few days in advance, individuals can be evacuated, windows can be boarded up; fewer people die and less property damage occurs.

These links are less clear for climate, in part because understanding of climate change and climate impacts is relatively new and rapidly evolving. (The Intergovernmental Panel on Climate Change was formed only 25 years ago, compared to the International Meteorological Organization, which was formed more than 125 years ago.) Scientists argue that climate change leads to changes in temperature patterns that can affect timing of monsoons or other seasonal events, or likely incidence and severity of floods or droughts. When these events happen at unexpected times or in unexpected places they can lead to loss of life, damage to property, and decreases in agricultural production. However, these connections are not well understood by the public or by many decision-makers. Other climate impacts are even more difficult to connect directly and immediately to loss of life and property. Climate change leads to an increase in the likelihood of extreme weather events, but isn't the cause of any particular extreme weather event. Climate change leads to rising sea levels, which cause erosion and other problems and eventually could lead to loss of property, mass migration, and conflict, but sea level rise happens gradually over long time periods and the precise effect on life and property is hard to determine. The link between increased understanding of climate or climate forecasting and the protection of life and property is also less clear than in the case of weather. Individuals, including policy-makers, often have a poor sense of what a climate forecasting system would entail and what its benefit would be. Existing operational forecasting systems that build on climate data, like NASA's Famine Early Warning System and Drought Monitoring System are often not very visible to the public. The extent to which these systems actually lead to protection of life and property is even more opaque.

This difference in the public understanding of links between climate change and damage as well as climate change forecasting and prevention of damage weakens the moral argument for sharing climate data. As scientific and public understanding of climate change improves, climate impacts become more visible, and use of climate forecasting systems increases, it is likely that this normative argument will become more important.

Finally, arguments about the international structure of the problem are central to the development of data sharing policies. This has been most clearly visible in the weather community, where the need for international cooperation has been recognized since before satellites existed. In fact, the argument for international cooperation was likely stronger when only in-situ data could be collected, since many more stations were needed to get adequate coverage and countries could not access the territory of others to take measurements on the ground without permission. When meteorological satellites were developed, it was possible for one country to collect weather data over another country without permission, but practical limitations due to the high costs of satellite systems and ongoing need for in-situ data still prevented any one nation from collecting all relevant weather data on its own. Weather satellite data was incorporated into the well-established tradition of international meteorological data sharing.

All three meteorological agencies, NOAA, EUMETSAT, and JMA, have been members of WMO since very early in their existence. As soon as they began satellite activities, these efforts were coordinated within WMO. Even during debates about the merits of cost recovery and commercialization, it was never suggested that international cooperation and data sharing should be discontinued. Efforts to sell data were always balanced with the need to share data internationally. This occurred through the identification of "essential" meteorological data, which would always be shared, an agreement that all three agencies signed on to as part of WMO Resolution 40. Both EUMETSAT and JMA, while restricting some data, make special exceptions for providing data to national meteorological agencies for their official use.

For other agencies, including NASA, USGS, ESA, and JAXA, international cooperation was traditionally less of an imperative. International data sharing did occur, but for different reasons. In early U.S. Earth observation activities, for example, efforts were made to share data to meet high-level foreign policy goals, demonstrating the peaceful nature of the space program. Other countries shared data early on to encourage development of new uses and to help establish its value. Within many of the agencies, it was felt that international data sharing was beneficial for science, driving much of the informal data sharing that occurred in the 1970s and 80s. However, when these considerations had to be balanced against the potential benefits of cost recovery, the economic determinant largely won out, at least temporarily, and international cooperation decreased. An example of this was seen in ESA when efforts at cost recovery began with the Envisat program, including costs for foreign data users, reversing a decade-long tradition of free data sharing with other countries.

Part of the explanation for the difference of treatment of weather and climate data is that climate change is a relatively new phenomenon compared to weather. Scientists and political officials from different countries are still not in full agreement on what data needs to be collected to understand climate and whether it is necessary to collect some or all of this data on an operational basis, i.e. consistent, ongoing collection. However, the complex international nature of climate change is gaining more recognition, and this is beginning to have an impact on data policies. All seven agencies mention climate change research as an important goal of their organization and note that efforts to address this problem require international cooperation. Climate monitoring and other climate services are starting to be incorporated into the activities of National Weather Services (NWSs), and the view that climate variables need to be monitored on a consistent and ongoing basis, similar to weather data, is becoming more common.

Further, international organizations have made important contributions to building consensus on the need for climate data. For example, many nations recognize the Essential Climate Variables developed by the Global Climate Observation System, providing a starting point in building international agreement on a clearly defined set of data required for understanding and addressing climate change. The large variety of variables that are considered "essential" has also given strength to the argument that international cooperation will be required to adequately monitor climate change, as it would be prohibitively expensive for one nation to collect all of the relevant data on its own. Almost all nations involved in climate monitoring using satellites are members of international organizations, particularly GEO and WMO, that call attention to the current state of international data sharing and promote mechanisms to build on existing data sharing, activities that help push countries to share data more freely.

Chapter 7: International-Level Comparative Case Study

The second set of case studies, presented here, examines two international organizations that specialize in activities that use data collected by Earth observing satellites and facilitate international data sharing: the Group on Earth Observations (GEO) and the World Meteorological Organization (WMO). Founded in 1950, the WMO coordinates international cooperation related to weather, and counts almost every country in the world as a member. One of its primary goals is encouraging and facilitating the international exchange of weather and climate data, including that collected by satellites. GEO, founded in 2005, has an even broader aim, with efforts to coordinate all international Earth observation efforts to support a number of applications, including climate, weather, natural disasters, health, and others. Encouraging free and open international data sharing is one of its primary goals.

These organizations do not develop or operate satellites of their own. Instead, both have a coordinating role, bringing together representatives from countries or agencies with relevant space-assets and facilitating international cooperation. Both organizations have developed principles related to international satellite data sharing, and development of these principles involved lengthy international debates. These debates provide insight into the incentives and barriers of data sharing and the primary arguments or positions of various countries. The methods and level of success in achieving international data sharing among members also varies between the two organizations. Examination of these organizations also helps to illuminate how and to what extent the existence of these international organizations actually affects the development of satellite data sharing policies.

As with the domestic case studies, this analysis is based on document analysis and semi-structured interviews with at least two individuals from each international organization. Documentation reveals each organization's development process, and particularly the evolution of its data-sharing practices and principles. Interviews provide additional insight into this development process and the internal debates that took place within each organization.

These case studies show that both organizations have played an important role in maintaining and encouraging international data sharing from climate-relevant satellites. The WMO, with its long history and relatively narrow focus on meteorology, has been more successful in ensuring international data sharing in this area. This stems largely from international agreement on the importance of sharing data that is needed to save lives and property as well as the inherently international nature of weather monitoring, which cannot be achieved by any nation on its own. The greatest level of success involves cooperation on an official level between national meteorological agencies. Broader data sharing has been less of a focus, and less has been achieved in this area. GEO, by contrast, is focused especially on encouraging the free and open exchange of data for all users. While they have not fully succeeded in getting members to adopt this principle, significant progress has been made, with a number of members making their data more freely available.

Evidence suggests that discussions regarding the economic efficiency of data sharing and ethical responsibilities to share data have been effective. The visibility provided by the organization, both in highlighting the contributions of countries that share data as well as bringing to light restrictions that still exist, has provided greater incentive to increase data exchange. It has also facilitated the sharing of information about changes in member nations' policies, as well as the impact these changes had. Arguments regarding the inherently global nature of climate monitoring and of many substantive issues in which data was needed were critical to encouraging countries to join the organization.

7.1 World Meteorological Organization (WMO)

The vision of WMO is to provide world leadership in expertise and international cooperation in weather, climate, hydrology and water resources and related environmental issues and thereby contribute to the safety and well-being of people throughout the world and to the economic benefit of all nations.[443]

The WMO is a specialized agency of the United Nations, promoting international cooperation to enable operational weather, climate, and hydrology activities. As part of this effort, WMO facilitates the free and unrestricted exchange of data and information and contributes to policy development on this issue.[444] As of January

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[443] "WMO's Desired Outcomes, Strategies and Associated Goals." *WMO's Vision*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/vision_en.html>.

[444] "WMO in Brief." *About Us*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/index_en.html>.

2013, WMO had 191 members, including countries and territories. Representatives from each of these members come together every four years as part of the World Meteorological Congress to determine long-term policies and plans, to approve expenditures, and to elect the 37-member WMO Executive Council and other leaders. The Executive Council members are all directors of their respective national meteorological or hydrological services. They meet at least once a year to implement the programs approved by the congress. A permanent Secretariat is based in Geneva, Switzerland, and works to carry out regular WMO activities.[445] The WMO carries out its work through about 20 scientific and technical programs, including the World Weather Watch, the WMO Space Program, and the World Climate Program (WCP), which includes the Global Climate Observing System (GCOS).[446]

Early Sharing of Weather Satellite Data within WMO

For hundreds of years, it has been clear that information about weather in one country could be used to anticipate weather soon to occur in another. International exchange of weather data on a useful timescale became possible with the invention of the telegraph in the mid-1800s.[447] In 1873, meteorologists around the world formed the International Meteorological Organization (IMO) to coordinate and facilitate data sharing.[448]

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[445] "WMO in Brief." *About Us*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/index_en.html>.
[446] "WMO in Brief." *About Us*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/index_en.html>.
[447] *Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.
[448] "IMO: The Origin of WMO." *WMO 50*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/wmo50/e/wmo/history_pages/origin_e.html>.

The World Meteorological Organization was founded in 1950 with 31 member countries, replacing the non-governmental IMO with an official inter-governmental organization under the auspices of the United Nations.[449] The WMO charter, written in 1947, listed one of the purposes of the organization, "To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information."[450] As capabilities in numerical modeling, forecasting, and monitoring improved in the early years of the program, and as the WMO's production of information and products multiplied and improved accordingly, the international exchange of data only became more important.[451]

The potential for satellites to contribute to international meteorology was recognized within WMO very early on, and in 1959, a resolution was passed to "encourage the

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"The Beginnings of WMO (1950s-1960s)." *History*. World Meteorological Organization, n.d. Web. 24 May 2013.
<http://www.wmo.int/pages/about/wmo50/e/wmo/history_pages/beginning_e.html>.
United Nations. World Meteorological Organization. *Convention of the World Meteorological Organization*. N.p.: n.p., n.d. Web. 24 May 2013.
<http://www.eco.gov.az/hidromet/umumdunya%20meteorologiya.pdf>.

449 "IMO: The Origin of WMO." *WMO 50*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/wmo50/e/wmo/history_pages/origin_e.html>.
"The Beginnings of WMO (1950s-1960s)." *History*. World Meteorological Organization, n.d. Web. 24 May 2013.
<http://www.wmo.int/pages/about/wmo50/e/wmo/history_pages/beginning_e.html>.
United Nations. World Meteorological Organization. *Convention of the World Meteorological Organization*. N.p.: n.p., n.d. Web. 24 May 2013.
<http://www.eco.gov.az/hidromet/umumdunya%20meteorologiya.pdf>.

450 United Nations. World Meteorological Organization. *Convention of the World Meteorological Organization*. N.p.: n.p., n.d. Web. 24 May 2013.
<http://www.eco.gov.az/hidromet/umumdunya%20meteorologiya.pdf>.

451 *Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013.
<http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.

development of meteorological satellites as a means of providing data."[452] The first WMO report on meteorological satellites was jointly developed by representatives from the US and USSR, illustrating the extent of international consensus on the importance of sharing meteorological data, despite the fact that this data was and is important for military operations. As weather satellites were launched, the resulting data was shared freely with all nations, and special effort was put into designing communications systems that could disseminate data to all WMO Members on a timely basis.[453]

These activities had a high level of political visibility and support; in 1961, the UN General Assembly passed a resolution noting the progress in meteorological satellites and "the world-wide benefits to be derived from international cooperation in weather research and analysis." The resolution called for the WMO to draft a report on organizational and financial achievements to advance the state of atmospheric science and technology to provide better understanding of weather and climate and to further develop existing weather forecasting capabilities.[454]

The resulting report laid out plans for the World Weather Watch (WWW) system - a coordinated worldwide system for collecting and sharing weather information and

[452] Rasmussen, James R. "Historical Development of the World Weather Watch." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/themes/oceans/www_en.html>.

[453] Davies, Arthur. *Forty Years of Progress and Achievement: A Historical Review of WMO*. Rep. no. 721. Geneva: n.p., 1990. World Meteorological Organization. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_721.pdf>.

[454] United Nations. *1721 (XVI). International Co-operation in the Peaceful Uses of Outer Space*. N.p.: n.p., 1961. United Nations Office for Outer Space Affairs. Web. 24 May 2013. <http://www.oosa.unvienna.org/oosa/SpaceLaw/gares/html/gares_16_1721.html>.

products. The WWW included a Global Observing System made up of national observational networks, both in-situ and satellite, global centers for processing data, and telecommunications technologies to allow rapid exchange of information. The ultimate aim of the Global Observing System was to create "an integrated system which would provide all the observational data required for operational and research purposes by the most economical means."[455]

In 1962, the UN General Assembly referenced the report, calling on the WMO to further develop its plan to strengthen meteorological services and research. In response, the World Weather Watch system was officially established by the Fourth World Meteorological Congress in 1963.[456] The General Assembly again recognized and encouraged these efforts in a resolution specifically calling on Member States to participate in the establishment of the World Weather Watch.[457] This consistent high-level interest and support was referenced as a critical component in the initial success

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455 *Annual Report of the World Meteorological Organization. Rep. no. 241 RP. 80. Geneva: n.p., 1968. WMO. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_241_en.pdf>.*
Rasmussen, James R. "Historical Development of the World Weather Watch." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/themes/oceans/www_en.html>.

456 United Nations. *1721 (XVI). International Co-operation in the Peaceful Uses of Outer Space*. N.p.: n.p., 1961. United Nations Office for Outer Space Affairs. Web. 24 May 2013. <http://www.oosa.unvienna.org/oosa/SpaceLaw/gares/html/gares_16_1721.html>.
"The Beginnings of WMO (1950s-1960s)." *History*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/wmo50/e/wmo/history_pages/beginning_e.html>.
Rasmussen, James R. "Historical Development of the World Weather Watch." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/themes/oceans/www_en.html>.

457 United Nations. *1721 (XVI). International Co-operation in the Peaceful Uses of Outer Space*. N.p.: n.p., 1961. United Nations Office for Outer Space Affairs. Web. 24 May 2013. <http://www.oosa.unvienna.org/oosa/SpaceLaw/gares/html/gares_16_1721.html>.

of the WWW and also reflects the extent to which leaders recognized the benefits of international cooperation in meteorology.[458]

WMO had been engaged in observation and research related to climate since its creation, but increasing interest led it to hold the first World Climate Conference (WCC-1) in 1979, with participants from 53 countries and 24 international organizations.[459] They concluded that understanding and forecasting of climate change needed to be improved and proposed improving the acquisition and availability of climatic data. The WMO created the World Climate Program to address these needs.[460] In 1988, WMO and UNEP, partners in the World Climate Program, proposed the establishment of the Intergovernmental Panel on Climate Change (IPCC), which would provide an assessment of scientific knowledge related to climate change.[461]

Resolution 40: Formalizing Some Data Sharing and Allowing Restrictions

For more than forty years, the practice of free and open international exchange of meteorological data had operated within WMO. However, in the late 1980s, facing

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458 *Annual Report of the World Meteorological Organization*. Rep. no. 241 RP. 80. Geneva: n.p., 1968. WMO. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_241_en.pdf>.

459 Zillman, John W. "A History of Climate Activities." *WMO Bulletin* 58.3 (2009): n. pag. Web. 24 May 2013. <http://www.wmo.int/pages/publications/bulletin_en/archive/58_3_en/58_3_zillman_en.html>.

460 World Meteorological Organization. *Declaration of the World Climate Conference*. N.p.: n.p., n.d. Web. 24 May 2013. <http://www.dgvn.de/fileadmin/user_upload/DOKUMENTE/WCC-3/Declaration_WCC1.pdf>.

461 Zillman, John W. "A History of Climate Activities." *WMO Bulletin* 58.3 (2009): n. pag. Web. 24 May 2013. <http://www.wmo.int/pages/publications/bulletin_en/archive/58_3_en/58_3_zillman_en.html>.

tightening budgets and high-level political pressure, a number of National Meteorological Agencies within Europe were considering undertaking commercial activities to help recover agency costs. It was clear these activities would conflict with existing norms of free data sharing. The issue of data exchange and commercial activities was raised at the Tenth World Meteorological Congress in 1987, and the Congress determined that the issue needed careful consideration. In the meantime, it released a resolution stating that "the principle of free and unrestricted exchange of meteorological data between National Meteorological Services should be maintained."[462]

This situation continued to evolve over the next four years. National Meteorological Services in Europe wanted to recover costs by selling value-added products, but argued that companies able to access data for free had an unfair competitive advantage over NMSs that bore the costs of developing and operating data collection systems. Some developing countries worried that commercial companies from developed countries with access to free data and advanced technology would undermine their official national meteorological systems. Some NMSs responded by considering restrictions on data distribution or charges for commercial users wishing to access data.[463] In 1991, the Eleventh World Meteorological Congress recognized that "Commercial meteorological activities (have) the potential to undermine the free

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[462] *Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.
[463] Personal Interviews.

exchange of meteorological data and products between National Meteorological Services."[464]

The WMO formed a working group to study the issue of commercialization and to examine how to reinforce the principle of free and unrestricted international sharing of data.[465] Until the 1990s, meteorological data had been freely shared internationally for almost 100 years, even though no formal policy or legally binding commitment to do so existed. The United States and some other nations argued for continued free and open exchange of meteorological data. However, it was clear that tradition would no longer be sufficient to ensure that this practice continued. Europe was the primary proponent of restrictions on data sharing. Europe was not convinced by arguments about the efficiency of open data sharing and emphasized that not all data needed to be made freely available; some data was more applicable to particular regions or to some commercial purposes and could be restricted.[466] WMO is a consensus organization, and therefore a compromise was developed that would address the desire to formalize the tradition of free and open data sharing while still establishing the right of nations to restrict data in order to engage in commercial activities. The

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464 *Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.

465 *Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.

466 Personal Interviews.

result was Resolution 40, agreed to by the Twelfth World Meteorological Congress in 1995.[467]

The resolution protected free and open data sharing for a specified set of data, requiring that this "essential data" remain freely available. Agencies were encouraged, but not required, to share their "non-essential" datasets freely as well. It was expected that "non-essential" data, though restricted for commercial uses, would still be available for the official uses of national meteorological agencies within WMO. Essentially, WMO ensured continued free and open international exchange of data by formalizing the allowable exceptions to this practice. This explains the somewhat contradictory wording, in which WMO "urges members to strengthen their commitment to free and unrestricted exchange of meteorological and related data and products [and to] increase the volume of data and products exchanged," but also notes that "WMO Members may be justified in placing conditions on their re-export for commercial purposes outside of the receiving country… for reasons such as national laws or cost of production."[468] In 1999, a similar policy was put in place for hydrological data.[469]

It may seem that the resolution simply reflected the most conservative national perspectives with respect to data sharing, with Europe essentially just being granted

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467 *Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.

468 "Resolution 40 (Cg-XII)." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/Resolution40_en.html>.

469 "Resolution 25 (Cg-XIII)." World Meteorological Organization, n.d. Web. 24 May 2013. < http://www.wmo.int/pages/about/Resolution25_en.html>.

"permission" for what they already intended to do. However, the policy ensured that this one concession, this particular limitation on free and open data sharing, would be well defined and limited in scope. The resolution prevented individual nations from deciding on an ad hoc basis which data sets would be shared when. It ensured stability by getting agreement that the most important data would continue to be made freely available, regardless of future developments, and that other data would remain available for official use within the WMO. Resolution 40 even includes guidance to Members on appropriate actions in the case of non-compliance. For example, Annex 2 notes that when restrictions on non-essential data are not honored, "the originating NMS may take appropriate actions including denial of access to these additional data and products to the receiving Member."[470]

In addition to formalizing the principle of free and unrestricted international sharing of essential meteorological data, there was some hope that the new policy would actually increase data sharing. If countries were able to generate commercial revenues from the sale of meteorological information and products, this could act as an incentive for the collection of a greater amount of "non-essential" data. Though the re-export of this data was restricted, its sharing within the WMO for official purposes as well as research and education use was still expected, and therefore, the WMO could still benefit from its collection.[471]

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[470] "Annex II to Resolution 40." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/AnnexIItoRes40_en.html>.

[471] *Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice*. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.

While discussion of international sharing of weather data was underway, the WMO also continued its research and efforts related to climate. The IPCC's First Assessment Report was released in 1990 and discussed at the Second World Climate Conference (WCC-2) later that year. One of the key recommendations of WCC-2 was the establishment of the Global Climate Observing System, which occurred in 1992.[472] GCOS was based on the WMO Global Observing System, and was to be made up of climate relevant components of existing observing systems. The observations coordinated by GCOS would support the World Climate Program, the Intergovernmental Panel on Climate Change (IPCC), and the newly formed United Nations Framework Convention on Climate Change (UNFCCC). In 2003, WMO participated in the newly formed ad hoc Group on Earth Observations (the pre-curser to the permanent GEO organization), eventually taking a lead or participating role in social benefit areas related to weather, water, climate, and disasters.[473]

The WMO Global Framework for Climate Services (GFCS) program, created as a result of the third World Climate Conference (WCC-3) in 2011, noted the importance of improving sharing of global climate data. It argued that efforts were needed to overcome significant restrictions on sharing and barriers to accessing climate data, and it includes promoting free and open exchange of climate and observational data

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472 Zillman, John W. "A History of Climate Activities." *WMO Bulletin* 58.3 (2009): n. pag. Web. 24 May 2013. <http://www.wmo.int/pages/publications/bulletin_en/archive/58_3_en/58_3_zillman_en.html>.

473 *Fourteenth World Meteorological Congress: Abridged Final Report with Resolutions*. Rep. Geneva: n.p., 2003. World Meteorological Organization. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_960_en.pdf>.
Mohr, Tillmann. "The Global Satellite Observing System: A Success Story." *WMO Bulletin* 59.1 (2010): n. pag. Web. 24 May 2013. <http://www.wmo.int/pages/publications/bulletin_en/archive/59_1_en/59_1_mohr_en.html>.

as one of its eight principles. The GFCS proposes working through international deliberative mechanisms within WMO to reach agreement on essential climate data and products that should be shared in support of the protection of life and property, following the approach taken for meteorological data in Resolution 40.[474]

Officially, the World Meteorological Organization does encourage nations to "strengthen their commitment to the free and unrestricted exchange of meteorological and related data and products [and to] increase the volume of data and products exchanged to meet the needs of WMO Programs."[475] But overall, the impact of the World Meteorological Organization is mixed. In one sense, the decisions of the WMO have a significant impact on the policies of its members, which include almost every nation in the world, because they are considered binding by members and even lay out some sanctions for non-compliance. Agencies do change their policies to comply with World Meteorological Organization resolutions. However, because of the consensus nature of the organization, this coercive ability is only used to a very limited extent with respect to data sharing. Furthermore, organizations like the national space agencies have not historically been active within the WMO, and generally were not considered in the creation of data-sharing policies. These organizations often collect research or experimental data, and generally do not collect data that falls within the "essential data" category, and thus the WMO data principles have little effect on these agencies' data sharing policies.

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474 *Climate Knowledge for Action: A Global Framework for Climate Serves - Empowering the Most Vulnerable. Rep. no. 1065. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/hlt-gfcs/downloads/HLT_book_full.pdf>.*

475 "Resolution 40 (Cg-XII)." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/Resolution40_en.html>.

7.2 Group on Earth Observations (GEO)

The vision for GEOSS is to realize a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations and information.[476]

The Group on Earth Observations is a voluntary intergovernmental organization that aims to build a Global Earth Observation System of Systems (GEOSS). GEOSS would connect existing and planned observing systems around the world, encouraging internationally coordinated efforts in terms of data collection and technical standards. A key element is enabling access to data collected from the thousands of instruments around the world. To do this, one of GEO's aims is to coordinate data sharing policies and practices among members.[477]

As of 2012, GEO had 88 government members, as well as the European Union, and 67 other intergovernmental, international, and regional organizations involved in Earth observation issues. Members meet each year on the senior or ministerial level, and a standing executive committee consisting of 14 representatives from different regions remains in place throughout the year. Approximately every three years, GEO

[476] "Index." *GEO*. Group on Earth Observations, n.d. Web. 24 May 2013. <http://www.earthobservations.org/index.shtml>.
[477] "Index." *GEO*. Group on Earth Observations, n.d. Web. 24 May 2013. <http://www.earthobservations.org/index.shtml>.

holds a Ministerial Summit, which brings together ministerial-level representatives from Member states to reaffirm GEO efforts. [478]

The efforts to create GEOSS are centered on five crosscutting areas: architecture, data management, capacity building, science and technology, and user engagement, as well as nine societal benefit areas: disasters, health, energy, water, weather, ecosystems, agriculture, biodiversity, and climate. Within the climate group, GEO advocates for sustained and coordinated climate observing systems, with the goal of improving the ability of governments to understand and adapt to the impacts of climate change.[479] Efforts in this area are coordinated through the Global Climate Observing System (GCOS). The Committee on Earth Observing Systems (CEOS) is the coordinator of the satellite component of GCOS, as well as the space-based component of other GEO efforts. Both GCOS and CEOS are active in coordinating system development and in promoting full and open data sharing.[480]

International Recognition of the Need for Data Sharing and Precursors to GEO

To fully understand the history of GEO, particularly its space and climate related components, it's necessary to start almost two decades before GEO was even proposed, with the G7 Summit in 1982, which established a working group on remote sensing from space. In 1984, this working group became the Committee on Earth

[478] "About GEO." *GEO*. Group on Earth Observations, n.d. Web. 24 May 2013. <http://www.earthobservations.org/about_geo.shtml>.
[479] "Climate." *GEO*. Group on Earth Observations, n.d. Web. 24 May 2013. <http://www.earthobservations.org/geoss_cl.shtml>.
[480] "CEOS Home." *CEOS*. Committee on Earth Observing Satellites, n.d. Web. 24 May 2013. <http://www.ceos.org/>.
"News." *GCOS: Index*. Global Climate Observing System, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/prog/gcos/>.

Observing Satellites (CEOS), a permanent intergovernmental organization created to coordinate international civil Earth observing satellite missions, including planning, development, and interoperability of satellite missions and their related data.[481]

Another important organization was spurred from the Intergovernmental Panel on Climate Change (IPCC) First Assessment Report, released in 1990. The IPCC report noted the need for systematic long-term observations of the Earth system, including increased accuracy and coverage, and enhancement of both satellite-based and surface-based climate measurements. At the World Climate Conference held in the same year, this point was discussed, and it was determined that monitoring and research of climate would need to be strengthened. In early 1992, the Global Climate Observing System (GCOS) was created to meet the observational need for the World Climate Research Program, the Intergovernmental Panel on Climate Change, and the United Nations Framework Convention on Climate Change.[482] Shortly after its creation, GCOS became an associate member of CEOS.[483]

Also in 1992, the United Kingdom hosted a Conference on Space and the Environment in preparation for the United Nations Conference on Environment and Development (UNCED), also known as the Rio Earth Summit, which was to take place later that year. Based on this conference, CEOS put together a document for

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481 "Earth Observation Handbook." *CEOS*. Committee on Earth Observing Satellites, n.d. Web. 24 May 2013. <http://www.eohandbook.com/eohb2012/annexes.html>.
482 *20 Years in Service for Climate Operations*. Rep. Global Climate Observing System, 2012. Web. 24 May 2013. <http://www.wmo.int/pages/prog/gcos/Publications/GCOS_book_20years.pdf>.
483 "Members." *CEOS*. Committee on Earth Observing Satellites, n.d. Web. 24 May 2013. <http://www.ceos.org/index.php?option=com_content>.

presentation at the Rio Earth Summit on "The Relevance of Satellite Missions for Study of the Global Environment," which listed existing and anticipated satellite missions and their contributions to a variety of research areas.[484]

In 1992, as the benefits of Earth observation satellites were getting greater recognition at these international events, CEOS developed its *Satellite Data Exchange Principles for Global Change Data*. The document noted that many CEOS members were involved in global change research and that satellite systems required major investments. They also noted that these systems produced data with significant value, and called for maximizing use through an exchange mechanism among CEOS members, non-discriminatory access to data for non-CEOS members, and a goal of providing data at a price primarily reflecting the cost of filling the user request. It also stated that programs should have no period of exclusive data use, with data released no more than 3 months after the start of data acquisition.[485]

Two years later, CEOS developed *Data Principles for Operational Environmental Data*. Again recognizing both the high costs of satellite systems as well as the benefits of wide data use, CEOS proposed developing compatible policies for data provision for the public benefit. The principles stated that real time and archived data for operational environmental use for the public benefit should be provided "on time scales compatible with user benefit." They called for the provision of meta-data, the

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[484] Dundee, R.A. Vaughan. "Review of The Relevance of Satellite Missions to the Study of the Global Environment by CEOS." *Remote Sensing* 14.7 (1993): n. pag. Web. 24 May 2013.
[485] *CEOS Satellite Data Exchange Principles for Global Change Data*. Rep. N.p.: n.p., 1995. CEOS Yearbook. Web. 24 May 2013.

use of common international standards, and establishment of "appropriate data provision mechanisms." They also stated that there should be no period of exclusive use, except for that needed to provide data validation.[486]

In 1995, GCOS developed its Climate Monitoring Principles, which also dealt with data provision.[487] While acknowledging that GCOS member nations have their own policies regarding data exchange, as well as the fact that the principles were not legally binding, GCOS noted that GCOS contributors "have responsibilities in adopting" the principles. The principles called for "full and open sharing and exchange of GCOS-relevant data and products… at the lowest possible cost" as a fundamental objective. It called for information to be made widely available as soon as it became broadly useful for GCOS purposes, particularly for data and projects that have initial periods of exclusive use. The principles also dealt with more technical issues of data archiving, provision of algorithms and meta-data, and development and adherence to international data standards.[488]

The importance of global Earth observations were recognized at the highest levels once again at the World Summit on Sustainable Development (WSSD) in 2002 and the G-8 conference in 2003. At the WSSD, NOAA Administrator Conrad Lautenbacher called for a global observing system for climate, a challenge that would

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[486] *1998 CEOS Consolidated Report: Appendix D - Data Exchange Principles*. Rep. N.p.: n.p., 1998. Print.
[487] *20 Years in Service for Climate Operations*. Rep. Global Climate Observing System, 2012. Web. 24 May 2013. <http://www.wmo.int/pages/prog/gcos/Publications/GCOS_book_20years.pdf>.
[488] *Data and Information Management Plan: Version 1.0.* Rep. no. GCOS-13. N.p.: n.p., 1995. Global Climate Observing System. Web. 24 May 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-13.pdf>.

require close international cooperation.[489] Jose Achache, the head of ESA Earth Observations as well as Chairman of CEOS at the time, also made a statement at the WSSD arguing, “there is no sustainable development without adequate information about the state of the Earth and its environment.” He also promoted the efforts of CEOS and encouraged cooperation with respect to satellites.[490]

The WSSD Implementation Plan included numerous mentions of the need for international cooperation on Earth observations and specifically called out the need to develop systems to allow the active exchange of Earth observation data.[491] Building on this, the G-8 meeting held in Evian, France, in 2003 developed three priorities involving science and technology, one of which was strengthening international cooperation on global observation, including minimizing data gaps and promoting data sharing.[492] There was recognition that adequate monitoring of the Earth could not be accomplished by one nation, and that the benefits of these activities extended beyond national borders.[493]

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489 National Oceanic and Atmospheric Administration. Public Affairs. *NOAA Administrator Promotes Role of Global Observations to Sustainable Development at WSSD*. N.p., 30 Aug. 2002. Web. 24 May 2013.
<http://www.publicaffairs.noaa.gov/releases2002/aug02/noaa02109.html>.

490 "Statement by Prof. Jose Achache." Speech. World Summit for Sustainable Development. Johannesburg. 30 Aug. 2002. United Nations. Web. 24 May 2013.
<http://www.un.org/events/wssd/statements/ceosE.htm>.

491 *World Summit on Sustainable Development: Plan of Implementation*. Rep. N.p., n.d. Web. 24 May 2013.
<http://www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.htm>.

492 "Science and Technology for Sustainable Development - A G8 Action Plan." *Evian Summit 2003*. N.p., n.d. Web. 24 May 2013.
<http://www.g8.fr/evian/english/navigation/2003_g8_summit/summit_documents/science_and_technology_for_sustainable_development_-_a_g8_action_plan.html>.

493 "NOAA Participates in U.S.-Hosted Earth Observation Systems Summit: Nations Join Together to Take Pulse of Planet Earth." *NOAA Magazine Online*. N.p., 27 Aug. 2003. Web. 24 May 2013.
<http://www.magazine.noaa.gov/stories/mag107.htm>.

Creation of GEO and Data Sharing Principles

A large part of the impetus for creating GEO was the recognition that international cooperation was required for adequate global Earth observation; it was a challenge that no country could meet on its own. Following shortly after high-level recognition of the need for international cooperation on Earth observations at the World Summit on Sustainable Development (WSSD) and G8 Summit, the United States hosted the first Earth Observation Summit in Washington, DC in 2003. This one-day summit brought together ministerial-level representatives from 35 developing and developed countries as well as key international organizations, including CEOS and GCOS.

The goal of the event was to raise awareness of the need for international cooperation on environmental monitoring among high-level decision makers and ensure a sustained level of cooperation and investment for the future.[494] Participants in the summit developed a declaration that affirmed the need for global information about the Earth. They called for improved strategies for data collection and the minimization of data gaps, stating that a system was needed to ensure "Full and open exchange of observations with minimum time delay and minimum costs, recognizing relevant international instruments and national policies and legislation."[495] The declaration also created an ad hoc Group on Earth Observations (GEO) to develop a 10-year Implementation Plan.[496]

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494 "NOAA Participates in U.S.-Hosted Earth Observation Systems Summit: Nations Join Together to Take Pulse of Planet Earth." *NOAA Magazine Online*. N.p., 27 Aug. 2003. Web. 24 May 2013. <http://www.magazine.noaa.gov/stories/mag107.htm>.

495 *Declaration of the Earth Observation Summit. Rep. N.p., 2003. Web. 24 May 2013. <http://www.earthobservations.org/documents/eos_i/Declaration-final%207-31-03.pdf>.*

496 *Declaration of the Earth Observation Summit. Rep. N.p., 2003. Web. 24 May 2013. <http://www.earthobservations.org/documents/eos_i/Declaration-final%207-31-03.pdf>.*

The second Earth Observation Summit, held in Tokyo, Japan in 2004, adopted the Framework for the 10-year Implementation Plan, which specifically laid out plans for the Global Earth Observation System of Systems (GEOSS).[497] The Framework document recognized the many ongoing efforts in terms of international cooperation on global monitoring, including the World Meteorological Organization, which it noted was the most advanced in its promotion of international collaboration.[498] However, the document noted that despite these efforts, progress was limited by lack of access to data, large spatial and temporal gaps in data sets, lack of interoperability, inadequate user involvement, and other challenges.

To address these issues, they proposed the establishment of GEOSS, which would be a comprehensive, coordinated, and sustainable system of systems. GEOSS was to address observation, data processing, data exchange, and data dissemination. The term "system of systems" was chosen because it made clear the large scale of this global effort, and it reassured members that there would not be one "command center" with control over all Earth observations – there would be many national system contributions to a coordinated international system.[499]

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[497] *Communique of the Second Earth Observation Summit*. Rep. N.p., 25 Apr. 2004. Web. 24 May 2013. <http://www.earthobservations.org/documents/eos_ii/EOS%20II%20Communique.pdf>.
[498] *From Observation to Action— Achieving Comprehensive, Coordinated, and Sustained Earth Observations for the Benefit of Humankind Framework for a 10-Year Implementation Plan*. Rep. N.p., 25 Apr. 2004. Web. 24 May 2013. <http://www.earthobservations.org/documents/Framework%20Doc%20Final.pdf>.
[499] Lautenbacher, Conrad. *The Global Earth Observation System*. Rep. Marshall Institute, 12 Oct. 2004. Web. 24 May 2013. <http://www.marshall.org/article.php?id=269>.

Speaking at an event in Washington, DC in 2004, NOAA Administrator Lautenbacher noted data policy as one of the four big challenges for GEOSS implementation, along with integration, data management, and engaging developing countries. He asked, "How do we get free and openly traded data passed from one nation to another?" He acknowledged the challenges posed by the different business models in each country, including efforts at cost recovery and systems in which agencies purchase data from other agencies within the same government. However, he pointed to the example of the World Meteorological Organization (WMO), which is successful in sharing weather data on a free and open basis.[500]

Just as WMO focuses on weather, GEO participants felt that it was important to focus on the specific benefits of a global observing system, rather than just the technologies. They identified nine societal benefit areas to which global observations would contribute. This also made it possible to emphasize areas of mutual interest and concern, such as natural and man-made disasters. Admiral Lautenbacher noted that "even enemies will help each other in these situations," due to the ethical responsibility to share data when it can save lives. Lautenbacher also emphasized the considerable economic benefits associated with greater understanding of Earth systems and better prediction of weather, extreme events, and other societal benefit areas. [501]

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[500] Lautenbacher, Conrad. *The Global Earth Observation System*. Rep. Marshall Institute, 12 Oct. 2004. Web. 24 May 2013. <http://www.marshall.org/article.php?id=269>.
[501] Lautenbacher, Conrad. *The Global Earth Observation System*. Rep. Marshall Institute, 12 Oct. 2004. Web. 24 May 2013. <http://www.marshall.org/article.php?id=269>.

The third Earth Observation Summit was hosted by the European Union in 2005. By this time, participation in the summit had grown to nearly 60 nations. The resolution established GEO as a permanent body rather than an ad hoc group and endorsed the 10-Year Implementation Plan for GEOSS.[502] Among other things, this plan laid out the GEOSS data-sharing principles, which included "full and open exchange of data" within GEOSS, with recognition of relevant international instruments and national policies. It stated that all shared data would be made available "with minimum time delay and at minimum cost." It also noted that GEOSS would encourage providing data free of charge or at the marginal cost of reproduction for research and education uses.[503] Every country and organization that joined GEO endorsed the 10-Year Plan and these data sharing policies with it. However, the plan is not legally binding, and compliance with the principles is done under the "best effort" of member nations.

In mid-2005, high-level backing continued, as the G8 heads of state once again announced their support for international cooperation on global Earth observations, specifically calling out the GEOSS 10-Year Implementation Plan in the Gleneagles Plan of Action. They noted that national implementation of GEOSS would move forward, and efforts to further develop the Global Climate Observing System (GCOS), especially for the benefit of developing nations, would be supported.[504] At

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502 Resolution of the Third Earth Observation Summit. Rep. N.p., 16 Feb. 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/eos_iii/Third%20Summit%20Resolution.pdf>.

503 *The Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan*. Rep. GEO, 16 Feb. 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/10-Year%20Implementation%20Plan.pdf>.

504 *Gleneagles Plan of Action*. Rep. G-8 Summit, 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/resolutions/G-8%20Plan%20of%20Action%20Cites%20GEOSS.pdf>.

the 2007 G-8 meeting in Germany, the Summit Declaration stated, "We will continue to exercise leadership in the development of the Global Earth Observation System of Systems (GEOSS)."[505]

Data Sharing Implementation in GEOSS

It was recognized that further effort would be needed to implement and refine the data sharing policies that had been included in the GEOSS Implementation Plan. In 2006, the Group on Earth Observations established a task focused on "furthering the practical applications of the agreed GEOSS data sharing principles" and established a data principles task force. A special workshop was organized by the Committee on Data for Science and Technology (CODATA) of the International Council for Scientific Unions (ICSU) to exchange ideas related to this task.[506] Workshop participants emphasized the need to develop incentives for compliance, rather than enforcement mechanisms, and to give credit to data providers. They felt that peer pressure could be effective in promoting sharing. They argued that in cases where restrictions are in place, the costs and benefits should be reviewed carefully and suggested that more work be done to demonstrate the value of open access data.[507]

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[505] *Growth and Responsibility in the Growth Economy: Summit Declaration*. Rep. G8 Summit 2007, 7 June 2007. Web. 24 May 2013. <http://www.iea.org/IEAnews/0607/Summit_Declaration.pdf>.

[506] *2006 General Report on GEOSS Progress*. Rep. GEO, Nov. 2006. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iii/16-2006_General_Report_on_GEOSS_Progress.pdf>.
GEO 2007-2009 Work Plan: Toward Convergence. Rep. N.p., n.d. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iii/11-2007-2009_Work_Plan.v3.pdf>.

[507] *Furthering the Practical Application of the Agreed GEOSS Data Sharing Principles*. Rep. GEO, 22 Oct. 2006. Web. 24 May 2013. <http://www.codata.org/GEOSS/DA-06-01MeetingBeijingOct2006review.pdf>.

The fourth Earth Observation Summit took place in Cape Town, South Africa in late 2007, bringing together 72 GEO Members and 46 Participating Organizations. This summit recognized GEO's first Report on Progress, which issued a "call to action" on four areas, including data sharing.[508] Participants argued that to fully realize the benefits of GEOSS, it was imperative to support the GEO principle of free and open exchange of data.[509] Many of the Members and Participating Organizations also emphasized the importance of climate change and stressed the global nature of that and other GEOSS challenges.[510]

Differences in opinion on data sharing policies came to light when discussing the specifics of official GEO data sharing statements. In drafting the Cape Town Declaration for approval at the Ministerial Summit, France suggested deleting a paragraph that discussed advancing the implementation of data sharing principles, but a number of other countries, including Australia, Brazil, Canada, China, India, and Japan, opposed this change, and highlighted the importance of open data access.

During the Ministerial Summit, many nations also mentioned the importance of data sharing and highlighted their own efforts in this area. The European Commission noted that data sharing was one of the greatest challenges for the future of GEOSS,

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508 *Report on Progress 2007*. Rep. GEO, 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/MS2_The%20GEO%20Report%20on%20Progress.pdf>.
509 *Report on Progress 2007*. Rep. GEO, 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/MS2_The%20GEO%20Report%20on%20Progress.pdf>.
510 "GEO Ministerial Statements and Speeches." *GEO*. N.p., n.d. Web. 24 May 2013. <http://www.earthobservations.org/pr_speeches.shtml>.

and highlighted its own efforts at increasing data sharing in Europe.[511] Egypt noted that reducing costs for satellite images was one of the keys to ensuring developing nations benefit from GEOSS.[512] Finland stated that it endorses the GEOSS Data Sharing Principles and had already decided to share environmental data owned by its national Environmental Administration free of charge.[513] Germany noted that it provides TerraSAR radar satellite data free of charge for scientific use, and Japan stated that it was "pursuing an open data policy."[514] One of the efforts highlighted at this event, and mentioned by numerous members and participating organizations in speeches, was the decision to provide the China-Brazil Environmental Resource Satellite data to users in China, South America, and Africa on a free and open basis.[515]

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511 Potocnik, Janez. "Earth Observations for Sustainable Growth and Development." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_european_commision_statement.pdf>.

512 "Egypt Statement." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_egypt_statement.pdf>.

513 "EO Summit IV Statement by Finland." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_finland_statement.pdf>.

514 *GEO-IV Report*. Rep. GEO, 19 Nov. 2008. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_v/03_GEO-IV%20report.pdf>.

515 *100 Steps to GEOSS (Annex)*. Rep. GEO, 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/2007_%20Annex%20of%20Early%20Achievements%20to%20the%20Report%20on%20Progress.pdf>.
"Statement of Dr. Tsehaie Woldai, Principal Delegate of the African Association of Remote Sensing of the Environment (AARSE)." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_aarse_statement.pdf>.
"Statement by Brazil." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_brazil_statement.pdf>.
Potocnik, Janez. "Earth Observations for Sustainable Growth and Development." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_european_commision_statement.pdf>.

G8 leaders continued to voice their support for GEOSS, specifically mentioning it in the 2008 Declaration on Environment with respect to climate and sustainable development, and the 2009 Declaration of Responsible Leadership for a Sustainable Future.[516] The 2008 statement noted, "To respond to the growing demand for Earth observation data, we will accelerate efforts within the Global Earth Observation System of Systems (GEOSS), which builds on the work of UN specialized agencies and programs, in priority areas, inter alia, climate change and water resources management, by strengthening observation, prediction and data sharing."

At the 2008 Plenary, CODATA presented a white paper on the GEOSS Data Sharing Principles. The White Paper outlined existing policies, laid out some of the rationales for widely sharing data, and identified some of the legal and policy exceptions to data sharing.[517] GEO created a Data Sharing Task Force to look at these issues in depth and consider how they could be put into practice. The resulting *Data Sharing Principles Implementation Guidelines* were presented at the 2009 Plenary. The guidelines defined "full and open access" to mean data made available "with

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"Keynote Address by the Minister of Science and Technology." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_south_africa_statement.pdf>.

516 *G8 Hokkaido Toyako Summit Leaders Declaration*. Rep. N.p., 8 July 2008. Web. 24 May 2013. <http://www.mofa.go.jp/policy/economy/summit/2008/doc/doc080714__en.html>.
http *Responsible Leadership for a Sustainable Future*. Rep. G8, n.d. Web. 24 May 2013. <http://www.g8italia2009.it/static/G8_Allegato/G8_Declaration_08_07_09_final,0.pdf>.

517 *White Paper on the GEOSS Data Sharing Principles*. Rep. CODATA, 27 Sept. 2008. Web. 24 May 2013. <http://www.earthobservations.org/documents/dsp/Draft%20White%20Paper%20for%20GEOSS%20Data%20Sharing%20Policies_27Sept08.pdf>.

minimum time delay and with as few restrictions as possible, on a nondiscriminatory basis, at minimum cost for no more than the cost of reproduction and distribution."[518]

The guidelines also argue that governments should remove restrictions on redistribution and reuse, an issue that is essential in order for data to achieve maximum results. The report states, "The cost of data needs to be free, or as low as possible for the widest possible range of users." The guidelines argue for expanding provision of free data to not only research and educational users, but also to developing countries. They also note that research and educational categories should be based on use of the data, not the affiliation of the user. The guidelines strongly suggest that governments collect impact metrics regarding the use of their data.[519]

In discussing these guidelines, a number of Participating Organizations, including CEOS and GCOS, emphasized that data is a global public good and also that the value of data for capacity building was a key element. The United States and ESA supported the document, but, others, such as France and Canada, asked for changes or clarifications, particularly for countries that did not adhere to the data sharing policies, but still wanted to contribute. Japan questioned wording that aimed to

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[518] *Implementation Guidelines for the GEOSS Data Sharing Principles*. Rep. no. Doc. 7. GEO, 17 Nov. 2009. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vi/07_Implementation%20Guidelines%20for%20the%20GEOSS%20Data%20Sharing%20Principles%20Rev2.pdf>.

[519] *Implementation Guidelines for the GEOSS Data Sharing Principles*. Rep. no. Doc. 7. GEO, 17 Nov. 2009. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vi/07_Implementation%20Guidelines%20for%20the%20GEOSS%20Data%20Sharing%20Principles%20Rev2.pdf>.

encourage removal of restrictions on reuse or redistribution. Australia suggested that GEO should encourage charging for data to allow cost recovery.[520]

The GEO Plenary met in 2008 and 2009. Once again, countries highlighted their activities in support of GEO, including with respect to data sharing. The United States announced that all Landsat data would be made freely available online to all users.[521] The EC noted that it was developing GMES data-sharing policies consistent with the GEO data-sharing principles of full and open access. ESA stated that its Earth explorer missions would adopt the same policy. Brazil reported on the widening of free data provision from CBERS, and China noted again that its weather satellite data would be universally available free of charge. EUMETSAT took the opportunity to announce its new data sharing policy, which made all archived data available freely online. Participants noted that promotion of the benefits of full and open access to GEOSS data would help to engage providers and users.[522]

As these and earlier statements show, one of GEO's largest contributions is as a forum for discussion of data sharing policies. This forum provides an opportunity to exchange information on concrete benefits of various data sharing policies, and it allows nations to make political arguments and exert peer pressure. For example, the United States announced at a GEO meeting that Landsat data would be made freely

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[520] *Report of GEO-VI*. Rep. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/04_Report%20of%20GEO-VI.pdf>.

[521] Williams, Michael. "GEO Announces Free And Unrestricted Access To Full Landsat Archive." *EarthZine*. N.p., 2 Dec. 2008. Web. 24 May 2013. <http://www.earthzine.org/2008/12/02/geo-announces-free-and-unrestricted-access-to-full-landsat-archive/>.

[522] *Report on GEO-V*. Rep. no. Doc. 4. GEO, 17 Nov. 2009. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vi/04_GEO-V%20Report.pdf>.

available online to all users. After this policy was implemented, Landsat distributed as many scenes in one month as had previously been distributed over an entire year. GEO provided a forum in which this dramatic demonstration of user demand for freely available data could be presented to those developing data sharing policies in other nations, and it had a significant impact. The Landsat example is frequently referenced as a concrete argument in favor of moving to free and open data sharing policies. Nations share information on data use, growth of the value-added sector, and other economic benefits of open data policies.

Data Sharing Innovations: Data Democracy and Data-CORE

The 2010 GEO Plenary, GEO-VII, marked the halfway point in GEOSS implementation. The mid-term evaluation report noted that a large number of survey respondents identified the GEOSS data sharing principles as both the most important accomplishment of GEOSS to date and as one of the major challenges still facing GEOSS. It was felt that GEO had facilitated discussion and some consensus on a historically contentious issue, but also that the discussion needed to be transitioned to action.[523]

The concept of the GOESS Data Collection of Open Resources for Everyone (the GEOSS Data-CORE) was introduced at the 2010 Plenary. While all data is welcome within GEOSS, the CORE includes only data that fully adhere to the GEOSS data sharing principles of full and open access. This makes freely available data easier for

[523] *Mid-Term Evaluation of GEOSS Implementation*. Rep. no. Doc. 6. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/06_Mid-Term%20Evaluation%20of%20GEOSS%20Implementation%20Rev1.pdf>.

users to find and also provides special recognition for data providers that follow the GEO principles.[524] The plenary also endorsed the idea of Data Democracy, originally developed within CEOS, which emphasized data sharing and capacity building specifically with respect to developing countries.[525] The GEOSS Data Sharing Action Plan laid out specific actions to implement the data sharing principles.[526]

The GEOSS Data-CORE is one example of an innovative idea developed within GEO that helps to clearly identify the state of data sharing and to make concrete arguments related to data sharing outcomes. With the Data-CORE, it is possible to clearly see which nations or agencies comply with the GEOSS Data Sharing Principles and which do not. This makes it easier to exert peer pressure, political, and economic arguments to effect non-compliant data sharing policies. The existence of the Data-CORE also works as a demonstration project to show the benefits of easily accessible, freely available data.

Responding to these new concepts, many countries continued to voice their support for data sharing, including the establishment of the Data-CORE and the concept of data democracy, with the United States and South Africa as particularly strong advocates. Other countries continued to be sensitive to wording that reflected poorly

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524 *GEOSS Data Sharing Action Plan*. Rep. no. Doc. 7 Rev. 2. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/07_GEOSS%20Data%20Sharing%20Action%20Plan%20Rev2.pdf>.

525 *GEO 2012-2015 Work Plan Development Process and Schedule*. Rep. no. Doc. 10. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/10_GEO%202012-2015%20Work%20Plan%20Development%20Process%20and%20Schedule.pdf>.

526 *GEOSS Data Sharing Action Plan*. Rep. no. Doc. 7 Rev. 2. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/07_GEOSS%20Data%20Sharing%20Action%20Plan%20Rev2.pdf>.

on more restrictive national policies. For example, the European Space Agency (ESA) suggested that the word “conditions” should be used rather than “restrictions,” because it has a more positive connotation, and argued that it is reasonable to view prices as a condition rather than a restriction.[527] This highlights the issues that even some very active GEO members, like Japan and India, did not made substantial changes in their data sharing policies that would increase access to data, instead attempting to broaden the data sharing principles or emphasizing the “best efforts” aspect of the agreements.

Data democracy emphasizes normative arguments, attempting to get agreement on increased free data sharing in particular cases. Brazil and other developing nations have been particularly vocal about the concept of Data Democracy, which encourages data-sharing and capacity building specifically for developing nations. Groups within GEO have also chipped away at restrictive data sharing policies by arguing for, and getting, exceptions to data restrictions with respect to particular societal benefit areas, like disasters, or particular projects, like forest carbon monitoring.

The GEOSS Data-CORE and Data Democracy concepts were endorsed at the 2010 GEO Ministerial Summit that followed the GEO-VII Plenary. The importance of data sharing was again highlighted at the summit, with multiple countries calling out the issue in their statements. Estonia noted that full and open exchange of data was one of

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[527] *GEOSS Data Sharing Action Plan*. Rep. no. Doc. 7 Rev. 2. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/07_GEOSS%20Data%20Sharing%20Action%20Plan%20Rev2.pdf>.

the biggest achievements of GEO and had caused a complete change in philosophy.[528] The European Commission called the adoption of the Data Sharing Action Plan “the beginning of a new era of international cooperation in Earth observation,” and reminded members of the policy of open access for GMES data.[529] ESA noted that it had put in place a new policy of free and open access to its data, including past ERS, Envisat, and Earth Explorer missions.[530] The United States emphasized the need for international cooperation on data collection and access and noted its continued support for the promotion of the GEOSS Data Sharing Principles.[531]

Many participants in GEO noted a change in data sharing norms that has taken place over time. Whereas countries used to ask, “Why should I share my data?” countries now focus on “Why can’t this data be shared?” This change in focus – from an assumption of restrictions to an assumption of openness – is even written into the

[528] "Estonia Statement." Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_Estonia_statement.pdf>.

[529] "European Commission Statement: "Observe, Share, Inform"" Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_European%20Commission_statement_english.pdf>.

[530] "Statements by Head of Participating Organizations." Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_ESA_statement.pdf>.

[531] "Statements from The Netherlands." Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_Netherlands_statement.pdf>.
"United States Remarks to the GEO 2010 Ministerial." Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_USA_statement.pdf>.

Data Sharing Action Plan approved that year, which encouraged nations to examine restrictions on each dataset to clearly define the justifications for these restrictions.[532]

The 2011 GEO Plenary, GEO-VIII, focused on implementing the GEOSS Data-CORE concept. An official evaluation of the Architecture and Data Management activities found that the GEOSS architecture was still limited by restrictive data policies. They concluded that implementation of the Data Sharing Action Plan would be crucial for the group to meet its goals by 2015.[533] The 2012-2015 work plan called for maximizing the number of data sets available within the GEOSS Data-CORE, developing metrics to show the impact of open data, and encouraging countries to identify specific institutional, legal, and technical barriers to full and open exchange of data.[534]

The ultimate goal of GEO with respect to data sharing is to have all countries in full compliance with the GEOSS Data Sharing Principles. This would involve full and open access to all Earth observation data at no cost for all users. Data would be easily discoverable, accessible, and usable for all needs. Clearly, GEO has not yet fully achieved this goal – there is a significant amount of Earth observation data for which access is restricted or that is not available at all.

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532 *GEOSS Data Sharing Action Plan*. Rep. no. Doc. 7 Rev. 2. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/07_GEOSS%20Data%20Sharing%20Action%20Plan%20Rev2.pdf>.
533 *Second Evaluation of GEOSS Implementation*. Rep. no. Doc. 6. GEO, 16 Nov. 2011. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo-viii/06(Rev1)_Second%20Evaluation%20of%20GEOSS%20Implementation%20(ADM).pdf>.
534 *GEO 2012-2015 Work Plan Development Process and Schedule*. Rep. no. Doc. 10. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/10_GEO%202012-2015%20Work%20Plan%20Development%20Process%20and%20Schedule.pdf>.

It is clear that countries do not change their policies just because “GEO said so.” GEO is an intergovernmental, consensus-based organization, based on voluntary “best efforts” of members. The vast majority of GEOSS costs are borne by members or participating organizations through their own actions, rather than through a central fund controlled by GEO. This voluntary structure means that GEO cannot and does not force members to change their data sharing policies. However, GEO did act as a forum in which economic arguments, normative arguments, and the inherently global nature of climate change and Earth observations were widely discussed.

It is not clear that GEO will ever be able achieve free and open data sharing of all global Earth observation data. There may always be countries that do not see the benefits of contributing, and are not willing to make the necessary investments to do so. The desire to benefit from economically valuable data and the desire to control data access and distribution are unlikely to ever completely disappear, and could even see a resurgence, depending on larger economic and political trends. However, GEO has had a meaningful effect on national data sharing policies through wide and growing participation, promotion of high-level recognition of the importance of international cooperation on global Earth observations, and as a forum for both economic and normative arguments. Innovative ideas, such as the GEOSS Data-CORE, provide concrete steps to further encourage data sharing. Continued efforts within GEO, building on these strengths, are likely to continue to have a meaningful impact on data sharing policies.

7.3 International Case Study Discussion

These two case studies show that international organizations have a major role to play in encouraging international data sharing. However, due to their different histories, focus, and organization, WMO and GEO affect data policies in different ways and have unique methods in which they could drive future climate data sharing. WMO has a long established history of international data sharing and an established sharing system. Its focus on operational monitoring and has the ability to make resolutions that are considered binding by members. These characteristics make it best able to institutionalize official data sharing among members for a minimal set of "essential data." It has accomplished this goal for weather, and has great potential to apply similar methods to institutionalize official operational climate monitoring. GEO is a relatively new organization, with a smaller, but growing membership that includes operational and research organizations. Its strength lies in its ability to bring together individuals with the ability to affect national data sharing policies, and its commitment to maintaining pressure on members to adopt free and open data sharing policies for all environmental data. Though its policies and principles are not considered binding, it has had, and continues to have, an important effect on national data sharing policies. It has done this by developing systems, such as the GEO Data-CORE that make compliance with its free and open data sharing principles easy to monitor, and providing a forum in which compliant countries can gain recognition and praise and non-compliant countries can be visibly called-out on their non-compliance. This visibility, combined with forums in which information about data sharing mechanisms and benefits can be shared and discussed, exerts meaningful peer pressure on members. Although compliance with its principles is not as universal as compliance with WMO resolutions, GEO has a greater ability to extend data sharing beyond "essential" data to all relevant environmental data.

Both the World Meteorological Organization and the Group on Earth Observations were created due to recognition of the need for international cooperation on global issues, including meteorological and other environmental challenges. Both organizations have had consistently high levels of political visibility and support for their programs. This support has played a major role in encouraging progress on organizational goals and has ensured that decisions made in these organizations would be implemented by members. The focus of the organizations is on the benefits to society of international cooperation in weather, climate, disasters, or other areas, rather than on a particular technology or more abstract desires for international engagement. Both identified specific needs for data and information and emphasized that it would be impossible for any one country to address these issues on its own. These factors, which illustrate the importance and benefits of the organizations, have been effective in attracting members.

International data sharing was and is a very prominent issue in both organizations, and is seen as fundamental to achieving each organization's goals. However, the World Meteorological Organization and the Group on Earth Observations have taken different tactics in addressing the issue of data sharing. The WMO was built on an existing tradition of free and open data sharing for weather, encouraging and building this capability as meteorological technology and techniques improved over time. However, the most important action of the WMO in this area was its successful attempt to formalize adherence to this tradition when it was endangered by growing interest in commercial activities. The WMO was able to do this by emphasizing the importance of international data sharing to the shared goal of accurate global weather forecasting and negotiations among member states about which data was essential to achieving this goal. The WMO had a major impact on national data sharing policies because members consider its resolutions binding. Before the resolution was passed, interest in cost recovery and commercialization had led to uncoordinated decisions by individual nations to restrict international sharing of some types of data. After the resolution, there was agreement by all nations on which data may or may not be restricted. Despite this important achievement, the effect on WMO data principles are limited, because they address only a minimal set of "essential" data, and they do not play an important role for agencies that were not traditionally involved in meteorological activities, such as space research agencies.

Though each of its programs emphasize specific data needs or encourage further sharing, WMO has not yet taken major action, on the level of that undertaken for Resolution 40, to increase data sharing or address climate data in particular. However, the WMO has already begun to work more closely with space agencies that collect climate data, and the WMO Global Framework for Climate Services program has proposed developing a data policy similar to Resolution 40 specifically aimed at climate data. If the WMO moved forward to identify a set of “essential” climate data to be collected and shared on an operational basis, this could have a similar impact to WMO Resolution 40, institutionalizing at least some level of free and open international data sharing. Beyond identifying and getting consensus on which data must be shared, WMO would represent a mature international system in which climate data could be exchanged – WMO could provide not just the what, but the how. While there is great potential for WMO to make a meaningful impact on international climate data sharing policies, getting consensus on climate data sharing would not be easy, as there is less precedent for sharing this type of data, and the WMO would likely need to engage non-traditional members, such as space agencies, to fully take advantage of all available data sources.

GEO, by contrast, has no coercive effect on national data sharing policies, and adherence to its data sharing principles is only expected on a “best effort” level by members. However, unlike the WMO, efforts to increase international data sharing have remained at the forefront of GEO activities, resulting in policy innovations, such as the GEO Data-CORE, that increase visibility of nations that do or do not comply with GEO’s data sharing policies. This visibility increases the prestige for nations that do comply. It also raises awareness of data availability, which likely increases data use and overall benefit. USGS’s decision to announce its open data sharing policy for Landsat at a GEO Summit was based on the fact that this forum was highly visible and filled with international representatives who would recognize the significance of such an announcement. Without this opportunity, awareness of the policy change and its importance would likely have been much lower, the United States would have received less prestige benefit, use of Landsat data may have been lower, and the United States would have had less potential to affect other nations' policies. GEOs efforts to increase visibility also increase the penalty, in terms of prestige, for nations that do not comply with its principles. Japan, for example, takes a leadership role in many GEO activities, but is repeatedly called out for not adopting a free and open data sharing policy.

GEO acts as an important forum in which political arguments are made, peer pressure is exerted, and impacts of existing data sharing policies are demonstrated and discussed. These discussions and demonstrations have played an important role in convincing nations to open their data sharing policies. GEO is still a relatively new organization, and it is not yet clear the extent to which it will be able to fully achieve its goals. However, GEO is currently the most important international organization in terms of actively addressing global data sharing issues and driving change in national climate-relevant satellite data sharing policies.

Overall, these case studies show that international organizations have a major role to play in encouraging global data sharing. Both organizations help to generate consensus that climate data that must be shared internationally. WMO's strength lies in its ability to institutionalize data sharing for at least a sub-set of data it deems essential and to provide a technical and organizational framework for data exchange to take place. Through these mechanisms, it plays a very important role in maintaining international sharing of weather data, as WMO members ensure their policies comply with WMO resolutions. As climate monitoring becomes increasingly important to the National Weather Services that make up its core membership, and as it continues to engage space agencies that collect climate data, the WMO has the potential to have an important role in institutionalizing international data sharing of climate data, as well. GEO's primary contribution is in keeping the issue of international environmental data sharing visible at high levels of government, providing prestige and benefits to those who share data freely, and consistently pressing nations that do not adopt free and open policies to do so. GEO also helps to distribute information about the benefits of data sharing and the effects of existing international data sharing policies, which can be used in internal domestic policy-making discussions.

Chapter 8: Conclusions and Policy Implications

This dissertation began with an assertion that there was a need for climate data that could not be met by one nation on its own, but that some data is shared while other data isn't; data sharing is not consistent. Current thinking on data sharing policy provided a large number of potential arguments for and against data sharing, but did not provide insight into which of these arguments are most important in developing data sharing policies, particularly in the case of climate satellites. This research examined the process of satellite data sharing policy development to add this important new dimension, identifying which issues were most important in determining data sharing policies within space and meteorological agencies, why these particular issues were important, and what implications this has for future policy-making. I used a comprehensive data set, quantitative analysis, and finally, a set of multi-level case studies to develop a model of policy making for Earth observation data. The model shows that data sharing policies are driven by debates among government agency and budget representatives regarding the most efficient, morally defensible, and effective data sharing practices. Policy-making has historically taken place despite a number of key uncertainties, which greatly influenced the development of early policies. Data-sharing policies have been informed by experience over time, reducing uncertainties and changing the strength of arguments within each area as well as the relative importance of each substantive issue.

Economic arguments, particularly whether the data is seen as a public good or a commodity, play the greatest role in Earth observation satellite data sharing policies. Agency officials support treatment of data as a public good and free and open data sharing. For a given level of expenditure, this policy maximizes data use, allowing agencies to achieve their mission of promoting research or operational activities to the greatest extent possible. Budgeting officials support data sales, emphasizing the importance of lowering costs and minimizing budget outlays. Once an agency has established that its satellite data is dependable, useful, and has potential commercial value, budgeting officials have an interest in promoting cost recovery or commercialization policies that could reduce costs to the government and increase overall efficiency. In cases where the size of the commercial market for data is large, commercialization will likely be successful and bring the efficiency benefits associated with a competitive market. If demand is highly inelastic, then these polices can be put in place without significantly decreasing data use and related benefits. With inelastic demand, cost recovery could lead to decreased costs without loss of benefits, even if a fully commercial venture was not viable.

If the size of the commercial market and elasticity of demand for satellite data was unknown, as it was for early systems in the 1980s and 1990s, the budgeting officials' argument is particularly strong – it has the potential for lowering costs without lowering benefits, while free data policies can only continue the status quo, with no potential for savings. This led to the adoption of cost recovery or commercialization policies in almost all early government Earth observation satellite programs.

However, these efforts failed in almost all cases, demonstrating both that a commercial market for satellite data is not viable for most climate relevant data and that elasticity of demand is actually quite high – even small increases in cost lead to significant reductions in data use. In cases where commercial data sales may still be possible, particularly for high resolution and synthetic aperture radar data, policies supporting data sales are often continued. Therefore, a rule of thumb for data sharing policies is that if the data can be sold, it will be sold – free data sharing policies are generally only put in place when data sales have proven impossible.

Normative arguments about the fairness of data sharing policies are most often used to justify economic arguments. Agencies that see data as a commodity back up their policies with an argument that the government should act as a public trust. Agencies that argue for a public good view of data say that the public has already paid for the data and shouldn't be forced to pay again. This normative argument is almost always given, so though it may not drive policy, it is seen as an important component in defending a policy.

In very specific cases, normative arguments can trump economic arguments; this is primarily seen in the case of the weather, due to the clear connection between extreme weather events and loss of life and property as well as the ability for accurate monitoring and forecasts to reduce loss of life and property. These arguments are weaker with regard to climate data, largely because the links between climate change and loss of life and property as well as climate data and reduction of these losses is less well understood, particularly by decision-makers. However, understanding of climate impacts and benefits of climate knowledge and forecasting are increasing, and this trend will strengthen these arguments over time.

Finally, the global nature of climate change and environmental monitoring plays an important role in encouraging data sharing. The need for international cooperation to effectively address global issues was the primary determinant for the creation of international organizations focused on data sharing – particularly the WMO and GEO. This argument is particularly strong within the weather community. Even when a restriction of data sharing was discussed, it was always mutually agreed within the WMO that some international sharing would continue. Countries argued about which data should be shared, not whether or not all data should be shared. This was less true with respect to climate data for a number of reasons. First, climate is a relatively new phenomenon, without the nearly 150-year history of sharing seen in the international weather community. Further, the needs for climate, in terms of both the types of data needed as well as requirements for consistent, ongoing monitoring are less well defined than those for weather.

Table 8.1 Summaries of Determinants of Data Sharing Policy, Key Uncertainties, and Policy Implications

	Economic	Normative	Institutional
Agency Officials	Free data maximizes use and therefore benefit (though hard to quantify) Best way to achieve mission	Climate data sharing saves lives and property (argument strong with respect to weather data, weaker for climate data)	International cooperation required to address the issue (argument strong with respect to weather data, weaker for climate data)
Legislative and Budget Officials	Cost recovery or commercial system could reduce costs, and/or create revenue (quantifiable benefit) May not have substantial effect on data use		
Key Uncertainties	Is there a commercial market for satellite data? What is the elasticity of demand? What are the benefits of data use?	Link between climate impacts and loss of life/ property Link between climate data and adaptation/ mitigation of impacts (e.g. lives saved)	How much data is required? Which data must be shared? How can/ should it be shared and used (no history)?
Conclusions / Findings	Evidence and experience suggests that for almost all climate data, there is no commercial market, and elasticity is very high There are a multitude of valuable data uses	Advances in climate science are making the link between climate change and its impacts more clear, operational uses of climate data need to be further developed	Int. orgs have helped to show that it is not possible for one country to collect all climate data on its own, international cooperation is required
Policy Implications	It is most efficient for governments to treat data as a public good and make it freely available	Climate data should be shared because of its ability to contribute to saving lives and property	WMO should develop a resolution on climate data sharing GEO should continue efforts to increase data sharing

Figure 8.1 summarizes the determinants of data sharing policies across agencies, the key uncertainties that affect each area, and the policy implication in each area.

However, international organizations such as GCOS have helped to increase international agreement on climate data collection requirements. Also, NMSs, which make up WMO membership, have become increasingly interested in operational climate monitoring, and WMO has engaged with space agencies collecting climate data. WMO has the potential to be an important facilitator of climate data sharing in the future. GEO has contributed to increasing international data sharing primarily by putting consistent pressure on both meteorological and space agencies to increase data sharing. Though its policies and principles are not considered binding, GEO ensures that national data sharing policies remain visible, praising nations that provide data freely and calling attention to those that do not.

Policy Implications

This research identified the driving themes of data-sharing policy development – the three areas on which countries base their decision-making – as economic, normative, and institutional concerns. It is important to also tie this finding to the challenge that motivated this research – the prospects of improving the global ability to adequately monitor climate change.

Economic considerations were determined to be one of the most important determinants of current data sharing policies, particularly as a barrier to free and open sharing. All experience and evidence up to this point has suggested that there is no viable commercial market for most climate-relevant satellite data, and elasticity of demand is very high. Therefore, the best information available suggests that governments should treating climate data collected by satellites as a public good and adopting free and open data sharing policies, as this will maximize economic efficiency.

Despite past experience, there is still some uncertainty about the costs and benefits of various data sharing policies, and nations have often continued efforts at cost recovery or commercialization in cases where data is at least partially commercially viable, for example for high resolution imagery and synthetic aperture radar data. Given widespread government preferences for supporting commercial efforts whenever possible, governments should aim to identify opportunities for maximizing data use, particularly for research and educational use, within the constraints of commercial or public-private regimes for data sales. Further, arguments about the economic efficiency of free and open data policies could be strengthened through analysis of the costs and benefits of particular policies. To do this, governments should seek to better track users, downloads, and resulting publications or products, and they should support research on economic impacts of various data sharing policies.

Secondly, I found that normative arguments played a role in both the weather and climate communities, but were given higher priority in the weather community. Given the similarities in the structure of these two issues, normative and institutional arguments made in the weather community should be applied to climate data. The ability of climate data to contribute to the preservation of life and property should be clarified and presented to the public and to government decision-makers. Building on this understanding, governments should increase international climate data sharing, at least for official use, due to the moral requirement to share data that has the potential to reduce loss of life and property.

Finally, requirements and organizational systems for international exchange of weather data are much better developed than those for climate, as seen within the WMO system. However, the need for international cooperation to adequately monitor climate is similar to that for weather. Therefore, the WMO should specifically address the issue of climate data sharing by developing a resolution on the issue modeled after Resolution 40, as has been proposed by the WMO Global Framework for Climate Services. This would institutionalize international collection and sharing of at least a minimal set of essential climate data. Further, GEO should maintain its efforts to encourage data sharing by continuing to raise the visibility of both compliant and non-compliant national data sharing policies, and providing a forum for understanding the benefits of free and open data sharing policies.

Future Research

Carrying out this research has illuminated numerous questions and potential future research areas. One of the greatest needs in this area is for increased evidence of the economic effects of various data sharing policies. The U.S. Landsat Program is one of the best candidates for beginning this type of research. The Landsat Program has continuously operated medium-resolution land remote sensing satellites for forty years, and has gone through many changes in both data pricing and number of users.

Both these price changes and the number of users, as well as revenue, are well documented. This analysis would be most effective if combined with data on the actual use of the data in terms of publications or products derived from Landsat data. An analysis of the relationship between Landsat data sharing policies and data use or outputs could provide important insight into the effects of data sharing policies. This research could take into account other variables, such as increasing permeation of the Internet and computer processing power. This analysis would help to provide evidence of the economic impacts of changes in data sharing policies, tying back to my first policy implication.

The analysis here showed that though economic arguments are important, there tends to be a rule of thumb that if it is possible to sell the data commercially, it will be sold. However, many of the existing commercial remote sensing entities are public-private partnerships that rely on public investment in satellite development or private companies that rely on the government as an anchor tenant. Research that looked at the various models currently in place for commercial remote sensing could help to illuminate the extent to which these activities are viable in the long-run, how they may evolve, and how data use that serves the public interest could best be achieved within these models. Case studies could focus on companies such as Digital Globe, Rapid-eye Canada, Astrium Services, and DMCii. Assuming that the rule of thumb will remain over time, a better understanding of commercial models for remote sensing sales could help to identify potential compromises or partnerships that would increase the amount of data available for climate research or operations. For example, government open-license data buys, sharing of archived data, or sharing of degraded data could all offer potential improvements on the current situation amenable to both commercial entities and other users.

Similarly, as identified by the second policy implication above, there is a need to look systematically at the structural similarities between weather and climate and the data needed for each of these areas. This would help to identify in more detail why meteorological data sharing is widely accepted and implemented as a normative and institutional imperative, while climate data sharing is not. Demonstrating similarities between the two may help to encourage increased commitments to climate data sharing, bringing this activity up to the level of meteorological data sharing. Differences in the two areas can help to illuminate the reasons for current differences in data sharing as well as special challenges that may need to be addressed in order to encourage climate data sharing in the future.

While this research has focused on data sharing policies in countries with the largest Earth observation programs, expansion to other nations could be beneficial as well. For example, a case study on Chinese data sharing policy would be quite interesting, as this is an area where China is relatively open and transparent, sharing a significant amount of data. India, by contrast, operates important climate-relevant satellites, but is uncharacteristically opaque, significantly restricting access to their environmental satellite data. In India's case, this seems to stem from security concerns, a determinant that is rare among countries with regard to unclassified Earth-observing satellites. A better understanding of this concern may illuminate whether this determinant is likely to remain important in India, gain strength elsewhere, or become less important over time. Though this analysis included Europe as a whole, analysis of individual European countries would improve overall understanding of the data sharing policy-making process. In particular, France engages in a number of unique public-private partnerships that involve satellite development and data sales that could provide insight into government views on commercialization.

Another interesting set of cases would focus on the contribution of developing nations, which often own only one or two relatively simple Earth observation satellites. A number of developing countries, led by Brazil, are very vocal within GEO about the ethical responsibility of countries to share data for the benefit of developing nations. However, as a whole, developing nations are generally less likely to make their data freely available. These countries face different structural challenges than the countries examined in this research, particularly in their economic constraints or their ability to contribute to an international observing system. They may also be learning from the policies and actions of other countries. Case studies focused specifically on data sharing policies in these countries could provide insight into these diverse policy-making considerations.

It was noted early on that international cooperation on climate monitoring would require international coordination in terms of data collection as well as cooperation in sharing the data that is collected. This research focused on the latter, but the former is also of great importance. Because of the level of investment required, it is impractical for one country to collect all relevant climate data. Improved international cooperation in this area could not only lead to elimination of climate monitoring gaps, but could also provide budgetary savings as a more efficient global system eliminates unnecessary collection overlaps. Given budgetary concerns following the global financial crisis, particularly in the United States, this potential for savings may be an important factor driving future cooperation.

Understanding how nations decide which and how many climate-relevant satellites to build, and particularly the extent to which they currently coordinate with other nations in doing so, would be essential to eventually developing a complete global climate monitoring system. There is evidence that some countries, for example Argentina, look specifically to develop satellites that collect data no other nation is collecting, ensuring that other nations will value their contribution to the international system, even if it only consists of a small number of satellites.[535] Other nations seem to focus on collecting only the data that is of greatest importance to their own country. In addition to looking at motivations for these different policies, it would be useful to examine existing methods of cooperation in data collection, whether in joint satellite development, coordinated satellite constellations, or other cooperative models, to determine the most effective methods.

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535 "Speech by Argentinian Representative." 22nd United Nations/International Astronautical Federation Workshop on "Space Technologies Applied to the Needs of Humanity: Experience from Cases in the Mediterranean Area" Naples. 30 Sept. 2012. Speech.

Bibliography

100 Steps to GEOSS (Annex). Rep. GEO, 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/2007_%20Annex%20of%20Early%20Achievements%20to%20the%20Report%20on%20Progress.pdf>.

"15 USC § 1534 - Assessment of Fees for Access to Environmental Data." *Legal Information Institute*. Cornell University Law School, n.d. Web. 29 Mar. 2013. <http://www.law.cornell.edu/uscode/text/15/1534>.

1998 CEOS Consolidated Report: Appendix D - Data Exchange Principles. Rep. N.p.: n.p., 1998. Print.

20 Years in Service for Climate Operations. Rep. Global Climate Observing System, 2012. Web. 24 May 2013. <http://www.wmo.int/pages/prog/gcos/Publications/GCOS_book_20years.pdf>.

2006 General Report on GEOSS Progress. Rep. GEO, Nov. 2006. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iii/16-2006_General_Report_on_GEOSS_Progress.pdf>.

2010 Progress Report: Coordinated Response from Parties That Support Space Agencies Involved in Global Observations to the Needs Expressed in the Global Climate Observing System (GCOS) Implementation Plan of 2004. Rep. Committee on Earth Observations, 2010. Web. 19 Mar. 2013. <http://www.ceos.org/images/CEOS-UNFCCC-2010.pdf>.

"50 Years of Earth Observation." *European Space Agency*. N.p., n.d. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/50_years_of_Earth_Observation>.

"About ESA: Funding." *European Space Agency*. N.p., n.d. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/Funding>.

"About GEO." *GEO*. Group on Earth Observations, n.d. Web. 24 May 2013. <http://www.earthobservations.org/about_geo.shtml>.

"About USGS." *United States Geological Survey*. N.p., n.d. Web. 29 Mar. 2013. <http://www.usgs.gov/aboutusgs/>.

Achache, José. "Open Access to Earth Observation From Space: Opportunity or Threat to Security?" ESA (European Space Agency). Speech.

"Alain Ratier, Director-General, EUMETSAT." *Research Media Ltd*. N.p., 29 Aug. 2011. Web. 15 Apr. 2013. <http://www.research-europe.com/index.php/2011/08/alain-ratier-director-general-eumetsat/>.

"Annex II to Resolution 40." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/AnnexIItoRes40_en.html>.

Annual Report of the World Meteorological Organization. Rep. no. 241 RP. 80. Geneva: n.p., 1968. WMO. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_241_en.pdf>.

Anthes, Richard A., Berrien Moore, and Arthur Charo. *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation*. Washington, DC: National Academies, 2005. Web. 28 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=11281>.

Anthes, Richard. "The President's Corner: The International Exchange of Data." *UCAR Quarterly* 18 (1994): n. pag. University Corporation for Atmospheric Research. Web. 29 Mar. 2013. <http://www.ucar.edu/communications/quarterly/winter94/pres.html>.

Aoki, Setsuko. "The National Space Law of Japan: Basic Space Law and the Space Activities Act in the Making." 1 Dec. 2011. Web. 24 May 2013. <http://www.iislweb.org/docs/2011_galloway/Aoki.pdf>.

"Applications Technology Satellite (ATS)." *NASA*. N.p., 22 Jan. 2010. Web. 28 Mar. 2013. <http://www.nasa.gov/centers/goddard/missions/ats.html>.

"Aqua Project Science." *Aqua*. NASA, n.d. Web. 24 May 2013. <http://aqua.nasa.gov/science/images_data.php>.

Arrow, Kenneth. "Economic Welfare and the Allocation of Resources for Invention." *The Rate and Direction of Inventive Activity: Economic and Social Factors*. Princeton: Princeton UP, 1962. 609-26. Print.

Arzberger, P., P. Schroeder, A. Beaulieu, G. Bowker, K. Casey, L. Laaksonen, D. Moorman, P. Uhlir, and P. Wouters. "Promoting Access to Public Research Data for Scientific, Economic, and Social Development." *Data Science Journal* 3 (2004): 135-52. Web.

Azad, Bijan, and Lyna Wiggins. "Dynamics of Inter-Organizational Geographic Data Sharing: A Conceptual Framework for Research." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 22-43. Print.

Bailey, G., D. Lauer, and D. Carneggie. "International Collaboration: The Cornerstone of Satellite Land Remote Sensing in the 21st Century." *Space Policy* 17.3 (n.d.): 161-69. Web.

Baker, David. "Remote Future for Third World Satellite Data." *New Scientist* 22 Oct. 1987: 48-51. Web. 29 Mar. 2013. <http://books.google.com/books?id=nCLWnFozM6EC&lpg=PA51&ots=YlR2ZJ75Fl&dq=Landsat%205%20development%20cost%20million&pg=PA3#v=onepage&q=Landsat%205%20development%20cost%20million&f=false>.

Barton, John H., and Keith E. Maskus. "Economic Perspectives on a Multilateral Agreement on Open Access to Basic Science and Technology." *SCRIPTed* (2004): n. pag. Print.

"The Beginnings of WMO (1950s-1960s)." *History*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/wmo50/e/wmo/history_pages/beginning_e.html>.

Bell, William S. *Commercial Eyes in Space: Implications for U.S. Military Operations in 2030*. N.p.: BiblioScholar, 2012. Print.

Benowitz, Steve. "When Scientists Don't Share: Is Secrecy a Necessary Evil?" *Journal of the National Cancer Institute* 94.10 (2002): 712-13. Web. 19 Mar. 2013. <http://jnci.oxfordjournals.org/content/94/10/712.extract>.

Berner, Steven. *Japan's Space Program: A Fork in the Road?* Rep. Rand, 2005. Web. 24 May 2013. <http://www.rand.org/content/dam/rand/pubs/technical_reports/2005/RAND_TR184.pdf>.

Birk, R. "Government Programs for Research and Operational Uses of Commercial Remote Sensing Data. *"Remote Sensing of Environment* 88.1-2 (2003): 3-16. Web.

Bits of Power: Issues in Global Access to Scientific Data. Rep. National Research Council, Committee on Issues in the Transborder Flow of Scientific Data, 1997. Web. 19 Mar. 2013. <http://books.nap.edu/catalog.php?record_id=5504>.

Bretherton, Francis. *On the Full and Open Exchange of Scientific Data*. Washington D.C.: National Research Council, Committee on Geophysical and Environmental Data, 1995. Web. 29 Mar. 2013. <http://www.nap.edu/readingroom.php?book=exch&page=preface.html>.

Bruzzi, Stefano. Speech. The Living Planet. Stockholm. 11 Mar. 2009. Web. 1 Apr. 2013. <http://www.snsb.se/Global/Fj%C3%A4rranalysanv%C3%A4ndare/Fj%C3%A4rranalysdagarna%20presentationer/2B_Stefano_Bruzzi_ESA_EO_programme.pdf>.

Castañer, Silvia. "Access to EUMETSAT Data." Lecture. Workshop on GMES Data and Information Policy. Brussels. 12 Jan. 2012. Web. 15 Apr. 2013. <http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=7145>.

"CEOS Home." *CEOS*. Committee on Earth Observing Satellites, n.d. Web. 24 May 2013. <http://www.ceos.org/>.

"CEOS Home." *Committee on Earth Observation Satellites*. N.p., n.d. Web. 19 Mar. 2013. <http://www.ceos.org/>.

CEOS Satellite Data Exchange Principles for Global Change Data. Rep. N.p.: n.p., 1995. CEOS Yearbook. Web. 24 May 2013.

"CLASS FAQs." *Comprehensive Large Array-data Stewardship System*. NOAA, n.d. Web. 29 Mar. 2013. <https://www.class.ncdc.noaa.gov/notification/faq.htm>.

"Climate." *GEO*. Group on Earth Observations, n.d. Web. 24 May 2013. <http://www.earthobservations.org/geoss_cl.shtml>.

Climate Knowledge for Action: A Global Framework for Climate Serves - Empowering the Most Vulnerable. Rep. no. 1065. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/hlt-gfcs/downloads/HLT_book_full.pdf>.

Cohen, Michael D., James G. March, and Johan P. Olson. "A Garbage Can Model of Organizational Choice."*Administrative Science Quarterly* 17.1 (1972): n. pag. Web.

"Commerce Defers to Court on Eosat Decision." *Washington Technology*. N.p., 12 Jan. 1995. Web. 30 Mar. 2013. <http://washingtontechnology.com/articles/1995/01/12/commerce-defers-to-court-on-eosat-decision.aspx>.

Commercial Exploitation of Europe's Public Sector Information. Rep. Pira International, 20 Sept. 2000. Web. 19 Mar. 2013. <http://ec.europa.eu/information_society/policy/psi/docs/pdfs/pira_study/2000_1558_en.pdf>.

Commonwealth of Australia. Productivity Commission. *Cost Recovery by Government Agencies: Inquiry Report*. Melbourne: Productivity Commission, 2001. Print.

Communique of the Second Earth Observation Summit. Rep. N.p., 25 Apr. 2004. Web. 24 May 2013. <http://www.earthobservations.org/documents/eos_ii/EOS%20II%20Communique.pdf>.

Craglia, M., and I. Maser. "Access to Geographic Information: A European Perspective." Proc. of ESF-NSF Workshop on Access to Geographic Information and Participatory Approaches Using Geographic Information, Spoleto, Italy. N.p.: n.p., 2001. N. pag. Print.

Craglia, Max, and Ian Maser. "Access to Geographic Information: A European Perspective." *Journal of the Urban and Regional Information Systems Association* 15.1 (2003): 51-60. Web. 19 Mar. 2013. <http://www.urisa.org/files/vol15apa1.pdf>.

Craig, Brian. "Online Satellite and Aerial Images: Issues and Analysis." *North Dakota Law Review* 85 (2007): 547. Web.

Craig, William J. "White Knights of Spatial Data Infrastructure: The Role and Motivation of Key Individuals."*Journal of the Urban and Regional Information Systems Association* 16.2 (2005): 5-14. Web. 19 Mar. 2013. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.130.438&rep=rep1&type=pdf#page=5>.

Craig, William J. "Why We Can't Share Data: Institutional Inertia." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Print.

"CryoSat." *Earthnet Online*. European Space Agency, n.d. Web. 01 Apr. 2013. <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat>.

"Current Status and Summary of Agreement Between Landsat Program Management and EOSAT Corporation on Cost and Reproduction Rights for Landsat 4/5 Thematic Mapper Data." *Landsat Program*. NASA, 11 Apr. 1994. Web. 30 Mar. 2013. <http://geo.arc.nasa.gov/sge/landsat/apr11.html>.

Data and Information Management Plan: Version 1.0. Rep. no. GCOS-13. N.p.: n.p., 1995. Global Climate Observing System. Web. 24 May 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-13.pdf>.

"Data Archives." Meteorological Satellite Center of JMA, 4 Mar. 2009. Web. 24 May 2013. <http://mscweb.kishou.go.jp/product/library/data/index.htm>.

"Data Distribution Service." *Earth Observations Research Center*. JAXA, n.d. Web. 24 May 2013.

Davies, Arthur. *Forty Years of Progress and Achievement: A Historical Review of WMO*. Rep. no. 721. Geneva: n.p., 1990. World Meteorological Organization. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_721.pdf>.

De Montluc, Bertrand. "The New International Political and Strategic Context for Space Policies." *Space Policy* 25.1 (2009): 20-28. Web.

Declaration of the Earth Observation Summit. Rep. N.p., 2003. Web. 24 May 2013. <http://www.earthobservations.org/documents/eos_i/Declaration-final%207-31-03.pdf>.

Dick, Steven J., and Roger D. Launius. "NASA and the Environment: Science in a Political Context." *Societal Impact of Spaceflight*. Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. 313-30. Web. 28 Mar. 2013. <http://history.nasa.gov/sp4801-chapter16.pdf>.

Dick, Steven J., and Roger D. Launius. "The Social and Economic Impact of Earth Observing Satellites."*Societal Impact of Spaceflight*. Washington, DC: National Aeronautics and Space Administration, Office of External Relations, History Division, 2007. N. pag. Print.

Dundee, R.A. Vaughan. "Review of The Relevance of Satellite Missions to the Study of the Global Environment by CEOS." *Remote Sensing* 14.7 (1993): n. pag. Web. 24 May 2013.

"Earth Observation Handbook." *CEOS*. Committee on Earth Observing Satellites, n.d. Web. 24 May 2013. <http://www.eohandbook.com/eohb2012/annexes.html>.

Earth Observations Research Center. Rep. JAXA, n.d. Web. 24 May 2013. <http://www.eorc.jaxa.jp/en/about/jaxa_eorc_pamphlet.pdf>.

Earth Science and Applications from Space: A Midterm Assessment of NASA's Implementation of the Decadal Survey. Washington, DC: National Academies, 2012. Web. 28 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=13405>.

Earth Science and Applications from Space: National Imperatives for the next Decade and beyond. Washington, DC: National Academies, 2007. Web. 28 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=11820>.

Earth System Science Overview: A Program for Flobal Change. Washington, D.C.: National Aeronautics and Space Administration, 1986. *Google Books*. Web. 28 Mar. 2013. <http://books.google.com/books?id=KD4rAAAAYAAJ&printsec=frontcover&dq=%22OCLC14206395%22&as_brr=3&hl=&cd=1&source=gbs_api#v=onepage&q&f=false>.

"Earthnet Online." *Earth Resource Satellite*. European Space Agency, n.d. Web. 01 Apr. 2013. <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/ers>.

"Earthnet Online." *Instruments*. European Space Agency, n.d. Web. 01 Apr. 2013. <https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments>.

"Effects: The Current and Future Consequences of Global Change." *Global Climate Change*. NASA, n.d. Web. 19 Mar. 2013. <http://climate.nasa.gov/effects>.

"Egypt Statement." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_egypt_statement.pdf>.

Eisenberg, R. S. "Patents and Data-sharing in Public Science." *Industrial and Corporate Change* 15.6 (2006): 1013-031. Web.

Eisenberg, R. S. "Patents and Data-sharing in Public Science." *Industrial and Corporate Change* 15.6 (2006): 1013-031. Web.

"EO Summit IV Statement by Finland." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_finland_statement.pdf>.

"ESA Budget for 2013." *Funding*. European Space Agency, 7 Feb. 2013. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/Funding>.

"ESA Mandatory and Optional Scientific Programmes." *Department for Business, Innovation & Skills*. United Kingdom Space Agency, n.d. Web. 01 Apr. 2013. <http://www.bis.gov.uk/ukspaceagency/what-we-do/exploring-the-universe/how-we-deliver/esa-programmes>.

"ESA's Purpose." *European Space Agency*. N.p., n.d. Web. 30 Mar. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/ESA_s_Purpose>.

"Estonia Statement." Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_Estonia_statement.pdf>.

"EUMETSAT." *ECSL News: Bulletin of the European Center for Space Law* 7 (1991): n. pag. Web. 15 Apr. 2013. <http://www.esa.int/esapub/ecsl/ecsl7.pdf>.

Europe. EUMETSAT. *Convention for the Establishment of a European Organization for the Exploitation of Meteorological Satellites*. N.p.: n.p., 1986. Web. 15 Apr. 2013.

Europe. EUMETSAT. *EUMESAT Data Policy*. N.p.: n.p., 2012. Web. 24 May 2013.

Europe. EUMETSAT. *EUMETSAT 25 Years*. Darmstadt: EUMETSAT, 2011. Web. 15 Apr. 2013. <http://www.eumetsat.int/groups/cps/documents/document/pdf_br_history-book.pdf>.

Europe. EUMETSAT. *Meteosat Second Generation Image Data Dissemination Service*. Vol. 1.2. N.p.: n.p., 2003. Web. 15 Apr. 2013. <ftp://ftp.dartcom.co.uk/pub/manuals/legacy/EUMETSAT%20TD08.pdf>.

Europe. European Space Agency. *Convention for the Establishment of a European Space Agency & ESA Council*. Netherlands: ESA Publications Division, 2003. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/docs/SP1271En_final.pdf>.

Europe. European Space Agency. Earth Observation Mission Science Division. *The Changing Earth - New Scientific Challenges for ESA's Living Planet Programme*. Netherlands: ESA Publications Division, 2006. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/docs/SP-1304.pdf>.

Europe. European Space Agency. Earth Observation Programme Board. *Earth Explorer Data Policy: Update for GOCE and SMOS*. Paris: n.p., 2006. Web. 1 Apr. 2013. <https://earth.esa.int/pi/esa?type=file&ts=1173801698591&table=aotarget&cmd=image&id=1420>.

Europe. European Space Agency. Earth Observation Programme Board. *Joint Principles for a GMES Sentinel Data Policy*. Paris: n.p., 2009. Web. 15 Apr. 2013. <http://www.d-gmes.de/sites/default/files/dokumente/sentinel_data_policy_ESAPB-EO_2009_98_REV1.pdf>.

Europe. European Space Agency. Earth Science Division. *The Science and Research Elements of ESA's Living Planet Programme*. Netherlands: ESA Publications Division, 1998. Web. 1 Apr. 2013. <http://due.esrin.esa.int/stse/files/document/SP-1227.pdf>.

Europe. European Space Agency. *ESA Budget for 2009*. N.p., n.d. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/docs/corporate/ESA_2009_Budgetsweb.pdf>.

Europe. European Space Agency. *ESA Budget for 2010*. N.p., n.d. Web. 1 Apr. 2013. <http://esamultimedia.esa.int/multimedia/DG/ESA_2010_Budget.pdf>.

Europe. European Space Agency. *European Space Agency Earth Observation Programme Board Envisat Data Policy*. Paris: n.p., 1998. Web.

Europe. European Space Agency. *Revised ESA Data Policy for ERS, Envisat and Earth Explorer Missions (Simplified Version)*. N.p.: n.p., 2010. Web. 15 Apr. 2013. <https://earth.esa.int/pi/docs/doc/download/revised_ESA_data_policy.pdf>.

"European Commission Statement: "Observe, Share, Inform"" Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_European%20Commission_statement_english.pdf>.

"European Meteorological Satellite Organisation." NASA, n.d. Web. 15 Apr. 2013. <http://gcmd.nasa.gov/KeywordSearch/Supplementals.do?Portal=amd>.

"Excerpt from an Address Before a Joint Session of Congress." Address. Joint Session of Congress. Washington, DC. 25 May 1961. *John F. Kennedy Presidential Library and Museum*. Web. 28 Mar. 2013. <http://www.jfklibrary.org/Asset-Viewer/xzw1gaeeTES6khED14P1Iw.aspx>.

Exchanging Meteorological Data Guidelines on Relationships in Commercial Meteorological Activities: WMO Policy and Practice. Rep. no. 837. Geneva: n.p., 1996. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_837_en.pdf>.

Fair Weather: Effective Partnerships in Weather and Climate Services. Washington (D.C.): National Academies, 2003. Web. 29 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10610>.

"Fees and Landsat Data Products." *USGS Land Remote Sensing Program*. N.p., n.d. Web. 30 Mar. 2013. <http://remotesensing.usgs.gov/landsat_fees.php>.

Felkner, John. "An Analysis of the Current State of International Remote Sensing Data Exchange and Transfer." *International Society for Photogrammetry and Remote Sensing (ISPRS)*. Proc. of XVIIIth ISPRS Congress, Vienna, Austria. N.p., July 1996. Web. 19 Mar. 2013. <http://www.isprs.org/proceedings/XXXI/congress/part6/>.

Fellous, Jean-Louis. "Towards a Global Climate Observing System." *Interdisciplinary Science Reviews* 33.1 (2008): 83-94. Web.

Florini, Ann, and Yahya Dehqanzada. "Commercial Satellite Imagery Comes of Age." *Issues in Science and Technology* (1999): n. pag. Web. 19 Mar. 2013. <http://www.issues.org/16.1/florini.htm>.

"FOIA Update: Agencies Place Increasing Emphasis on Affirmative Information Disclosure." *FOIA Update: Agencies Place Increasing Emphasis on Affirmative Information Disclosure*. United States Department of Justice, 1995. Web. 28 Mar. 2013. <http://www.justice.gov/oip/foia_updates/Vol_XVI_1/PAGE1.htm>.

"For NMHSs." *Meteorological Satellites - Japan Meteorological Agency*. JMA, n.d. Web. 24 May 2013. <http://www.jma.go.jp/jma/jma-eng/satellite/ds.html>.

Fourteenth World Meteorological Congress: Abridged Final Report with Resolutions. Rep. Geneva: n.p., 2003. World Meteorological Organization. Web. 24 May 2013. <http://library.wmo.int/pmb_ged/wmo_960_en.pdf>.

"Free or Fee: The Governmental Data Ownership Debate: GITA White Paper." Geospatial Information & Technology Association, Aug. 2005. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/Courses/SIE525/FreeOrFee.pdf>.

From Observation to Action— Achieving Comprehensive, Coordinated, and Sustained Earth Observations for the Benefit of Humankind Framework for a 10-Year Implementation Plan. Rep. N.p., 25 Apr. 2004. Web. 24 May 2013. <http://www.earthobservations.org/documents/Framework%20Doc%20Final.pdf>.

"Fundamental Policy of Japan's Space Activities." JAXA, 24 Jan. 1996. Web. 24 May 2013. <http://www.jaxa.jp/library/space_law/chapter_4/4-1-1-4/index_e.html>.

"Funding." EUMETSAT, n.d. Web. 15 Apr. 2013. <http://www.eumetsat.int/Home/Main/AboutEUMETSAT/WhoWeAre/Funding/index.htm?l=en>.

Furthering the Practical Application of the Agreed GEOSS Data Sharing Principles. Rep. GEO, 22 Oct. 2006. Web. 24 May 2013. <http://www.codata.org/GEOSS/DA-06-01MeetingBeijingOct2006review.pdf>.

G8 Hokkaido Toyako Summit Leaders Declaration. Rep. N.p., 8 July 2008. Web. 24 May 2013. <http://www.mofa.go.jp/policy/economy/summit/2008/doc/doc080714__en.html>.

Gardner, Daniel, Arthur W.Toga, Giorgio A. Ascoli, Ackson T. Beatty, James F. Brinkley, and Anders M. Dale. "Towards Effective and Rewarding Data Sharing." *Neuroinformatics* 1.3 (2003): 289-96. Print.

"GCOS: Index." *Global Climate Observing System*. N.p., n.d. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/>.

GEO 2007-2009 Work Plan: Toward Convergence. Rep. N.p., n.d. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iii/11-2007-2009_Work_Plan.v3.pdf>.

GEO 2012-2015 Work Plan Development Process and Schedule. Rep. no. Doc. 10. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/10_GEO%202012-2015%20Work%20Plan%20Development%20Process%20and%20Schedule.pdf>.

"GEO Homepage." *Group on Earth Observations*. N.p., n.d. Web. 19 Mar. 2013. <http://www.earthobservations.org/index.shtml>.

"GEO Ministerial Statements and Speeches." *GEO*. N.p., n.d. Web. 24 May 2013. <http://www.earthobservations.org/pr_speeches.shtml>.

GEO-IV Report. Rep. GEO, 19 Nov. 2008. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_v/03_GEO-IV%20report.pdf>.

GEOSS Data Sharing Action Plan. Rep. no. Doc. 7 Rev. 2. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/07_GEOSS%20Data%20Sharing%20Action%20Plan%20Rev2.pdf>.

"The Geostationary Operational Environmental Satellites: GOES-P." *Current Missions*. NASA, 28 Feb. 2013. Web. 28 Mar. 2013. <http://www.nasa.gov/mission_pages/GOES-P/main/index.html>.

Gleneagles Plan of Action. Rep. G-8 Summit, 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/resolutions/G-8%20Plan%20of%20Action%20Cites%20GEOSS.pdf>.

The Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan. Rep. GEO, 16 Feb. 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/10-Year%20Implementation%20Plan.pdf>.

Goward, S. "Acquisition of Earth Science Remote Sensing Observations from Commercial Sources: Lessons Learned from the Space Imaging IKONOS Example." *Remote Sensing of Environment* 88.1-2 (2003): 209-19. Web.

Group on Earth Observations. *GEO Announces Free and Unrestricted Access to Full Landsat Archive*. N.p., 20 Nov. 2008. Web. 30 Mar. 2013. <http://www.earthobservations.org/documents/pressreleases/pr_0811_bucharest_landsat.pdf>.

Growth and Responsibility in the Growth Economy: Summit Declaration. Rep. G8 Summit 2007, 7 June 2007. Web. 24 May 2013. <http://www.iea.org/IEAnews/0607/Summit_Declaration.pdf>.

Harris, R. "Current Policy Issues in Remote Sensing: Report by the International Policy Advisory Committee of ISPRS." *Space Policy* 19.4 (2003): 293-96. Web.

Harris, R. "Current Policy Issues in Remote Sensing: Report by the International Policy Advisory Committee of ISPRS." *Space Policy* 19.4 (2003): 293-96. Web.

Harris, R. "Earth Observation Data Policy and Europe." *Space Policy* 17.1 (2001): 55-60. Web.

Harris, R. "Earth Observation Data Pricing Policy." *Space Policy* 9.4 (1993): 299-318. Print.

Harris, R. "Global Monitoring for Environment and Security: Data Policy Considerations." *Space Policy* 19.4 (2003): 265-76. Web.

Harris, Ray, and Nicola Olby. "European Perspectives on Trends in Public Sector Earth Observation Data Policies." *Space Policy* 16.1 (2000): 45-59. Web.

Harris, Ray, and Roman Krawec. "Some Current International and National Earth Observation Data Policies."*Space Policy* 9.4 (1993): 273-85. Web.

Harris, Ray, and Roman Krawec. "Some Current International and National Earth Observation Data Policies."*Space Policy* 9.4 (1993): 273-85. Web.

Harvey, F., and D. Tulloch. "Local-government Data Sharing: Evaluating the Foundations of Spatial Data Infrastructures." *International Journal of Geographical Information Science* 20.7 (2006): 743-68. Web.

Hayashi, Kumiko. "Statement of the Japanese Government at the 2010 GEO Ministerial Summit in Beijing." Speech. GEOSS Ministerial Summit. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_Japan_statement.pdf>.

Heal, Geoffrey. "New Strategies for the Provision of Global Public Goods: Learning from International Environmental Challenges." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.

Hedrick, Terry E. "Justifications for the Sharing of Social Science Data." *Law and Human Behavior* 12.2 (1988): 163-71. Print.

"History of Europe in Space." *European Space Agency*. N.p., 24 June 2010. Web. 01 Apr. 2013. <http://www.esa.int/About_Us/Welcome_to_ESA/ESA_history/History_of_Europe_in_space>.

"History of JAXA's Earth Observations." JAXA, n.d. Web. 24 May 2013. <http://www.jaxa.jp/article/special/disaster/sat_e.html>.

Holland, William. "Copyright, Licensing and Cost Recovery for Geographic and Land Information Systems Data: A Legal, Economic and Policy Analysis." N.p., 1997. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/tempe/holland.html>.

H.R. 5155, 98 Cong. (1984) (enacted). Print.

Land Remote-Sensing Commercialization Act of 1984

H.R. 5835, 101 Cong. (1990) (enacted). Print.

Omnibus Budget Reconciliation Act of 1990, Sec. 10201 National Oceanic and Atmospheric Administration User Fees

H.R. 6133, 102nd Cong. (1992) (enacted). Print.

Land Remote Sensing Policy Act of 1992

"IMO: The Origin of WMO." *WMO 50*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/wmo50/e/wmo/history_pages/origin_e.html>.

Implementation Guidelines for the GEOSS Data Sharing Principles. Rep. no. Doc. 7. GEO, 17 Nov. 2009. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vi/07_Implementation%20Guidelines%20for%20the%20GEOSS%20Data%20Sharing%20Principles%20Rev2.pdf>.

Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update). Rep. no. GCOS-138. Global Climate Observing System, Aug. 2010. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>.

"Index." *GEO*. Group on Earth Observations, n.d. Web. 24 May 2013. <http://www.earthobservations.org/index.shtml>.

"International Cooperation." *Japan Meteorological Agency*. JMA, n.d. Web. 24 May 2013. <http://www.jma.go.jp/jma/en/Activities/intcorp.html>.

IPCC Fourth Assessment Report: Climate Change 2007: Chapter 2 Changes in Atmospheric Constituents and in Radiative Forcing. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf>.

IPCC Fourth Assessment Report: Climate Change 2007: Climate Change 2007: Working Group I: The Physical Science Basis: Summary for Policymakers. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spm.html>.

IPCC Fourth Assessment Report: Climate Change 2007: Synthesis Report Summary for Policymakers. Rep. Intergovernmental Panel on Climate Change (IPCC), 2007. Web. 19 Mar. 2013. <http://www.ipcc.ch/publications_and_data/ar4/syr/en/spms1.html>.

Ito, Atsuyo. "Issues in the Implementation of the International Charter on Space and Major Disasters." *Space Policy* 21.2 (n.d.): 141-49. Web.

Japan. Japan Meteorological Agency. *JMA Brochure*. N.p., 2012. Web. 28 Mar. 2013. <http://www.jma.go.jp/jma/en/Activities/brochure201203.pdf>.

Japan. JAXA. *JAXA Vision 2025*. N.p.: n.p., 2005. Web. 24 May 2013. <http://www.jaxa.jp/about/2025/pdf/jaxa_vision_e.pdf>.

Japan. JAXA. N.p.: n.p., 1996. *Fundamental Policy of Japan's Space Activities*. JAXA. Web. 24 May 2013. <http://warp.ndl.go.jp/info:ndljp/pid/286794/www.mext.go.jp/english/kaihatu/aerosp01.htm>.

Japan. JAXA. Strategic Headquarters for Space Policy. N.p., 2 June 2009. Web. 24 May 2013. <http://www.kantei.go.jp/jp/singi/utyuu/basic_plan.pdf>.

Japan Meteorological Business Support Center. JMBSC, 27 July 2009. Web. 24 May 2013. <http://www.jmbsc.or.jp/english/index-e.pdf>.

"JAXA's Earth Observation Satellite Highly Praised Worldwide." JAXA, n.d. Web. 24 May 2013. <http://www.jaxa.jp/article/special/geo/ochiai_e.html>.

Jervis, Robert. *Cooperation Under the Security Dilemma*. Los Angeles: Center for Arms Control and International Security, University of California, Los Angeles, 1977. Print.

Joffe, Bruce. "Ten Ways to Support GIS Without Selling Data." *Journal of the Urban and Regional Information Systems Association* 16.2 (n.d.): 27-33. Web.

Johnston, S. "Public Good or Commercial Opportunity? Case Studies in Remote Sensing Commercialization."*Space Policy* 19.1 (2003): 23-31. Web.

Kallender-Umezu, Paul. "Japan Passes Law Permitting Military Space Development." *Defense News*. N.p., 22 June 2012. Web. 24 May 2013. <http://www.defensenews.com/article/20120622/DEFREG03/306220001/Japan-Passes-Law-Permitting-Military-Space-Development>.

Karl, Thomas R., Vernon E. Derr, David R. Easterling, Chris K. Folland, David J. Hofmann, Sydney Levitus, Neville Nicholls, David E. Parker, and Gregory W. Withee. "Critical Issues for Long-term Climate Monitoring." *Climatic Change* 31.2-4 (1995): 185-221. Web.

Katz, Michael L., and Harvey S. Rosen. *Microeconomics*. Boston, MA: McGraw-Hill, 1998. Print.

Kaul, Inge, Isabelle Grunberg, and Marc A. Stern. "Defining Global Public Goods." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.

Kaye, Jane, Catherine Heeney, Naomi Hawkins, Jantina De Vries, and Paula Boddington. "Data Sharing in Genomics — Re-shaping Scientific Practice." *Nature Reviews Genetics* 10.5 (2009): 331-35. Web.

Keohane, Robert O. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton, NJ: Princeton UP, 1984. Print.

Keohane, Robert O., and Joseph S. Nye, Jr. "Power and Interdependence in the Information Age." *Foreign Affairs* (1998): n. pag. Print.

"Keynote Address by the Minister of Science and Technology." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_south_africa_statement.pdf>.

King, John. "Problems in Public Access Policy for GIS Databases: An Economic Perspective." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

Koizumi, Junichiro. "Welcome Remarks by Prime Minister Junichiro Koizumi at the Earth Observation Summit II." Speech. Earth Observation Summit II. 25 Apr. 2004. Web. 24 May 2013. <http://warp.ndl.go.jp/info:ndljp/pid/286794/www.mext.go.jp/english/kaihatu/earth/pdf/koizumi_e.pdf>.

Landis, Robert. "Future of International Cooperation in Meteorological and Related Services." Proc. of American Meteorological Society 88th Annual Meeting, New Orleans, LA. N.p., Jan. 2008. Web. 20 Mar. 2013. <https://ams.confex.com/ams/88Annual/techprogram/programexpanded_452.htm>.

Landis, Robert. *The Road to Resolution 40 and Beyond: Part I Data Exchange*. Working paper. American Meteorological Society, 4 June 2008. Web. 28 Mar. 2013. <http://www.ametsoc.org/atmospolicy/documents/PartIDataExchange.pdf>.

"Landsat 3." *Landsat Science*. NASA, 21 Mar. 2013. Web. 29 Mar. 2013. <http://landsat.gsfc.nasa.gov/about/L3_td.html>.

"Landsat 5." *Landsat Science*. N.p., n.d. Web. 30 Mar. 2013. <http://landsat.gsfc.nasa.gov/about/landsat5.html>.

"Landsat: A Global Land-Observing Program." *Fact Sheet*. USGS, Mar. 2003. Web. 29 Mar. 2013. <http://egsc.usgs.gov/isb/pubs/factsheets/fs02303.html>.

"Landsat Program Chronology." *NASA*. N.p., 4 Nov. 1998. Web. 29 Mar. 2013. <http://geo.arc.nasa.gov/sge/landsat/lpchron.html>.

"Landsat Project Statistics." *Landsat Project Statistics*. N.p., n.d. Web. 30 Mar. 2013. <http://landsat.usgs.gov/Landsat_Project_Statistics.php>.

Launius, Roger D. "A Western Mormon in Washington, D.C.: James C. Fletcher, NASA, and the Final Frontier." *The Pacific Historical Review* 64.2 (1995): 217-41. Web. 28 Mar. 2013. <http://www.cumorah.org/libros/english/Science/A_Western_Mormon_in_Washington-James_C._Fletcher__NASA__and_the_Final_Frontier.pdf>.

Lautenbacher, Conrad. *The Global Earth Observation System*. Rep. Marshall Institute, 12 Oct. 2004. Web. 24 May 2013. <http://www.marshall.org/article.php?id=269>.

Lutes, Charles D., Peter L. Hays, Vincent A. Manzo, Lisa M. Yambrick, and M. Elaine. Bunn. "Space Power and the Enviornment." *Toward a Theory of Spacepower: Selected Essays*. Washington, DC: National Defense UP, 2011. N. pag. Print.

Marshall, E. "Data Sharing: A Declining Ethic?" *Science* 248.4958 (1990): 952-57. Web.

Marshall, Eliot. "The UPSIDE of Good Behavior: Make Your Data Freely Available." *Science* 299.5609 (2003): 990-91. Web.

Mas-Colell, Andreu, Michael Dennis. Whinston, and Jerry R. Green. *Microeconomic Theory*. New York: Oxford UP, 1995. Print.

Mathez, Edmond A., and Jason E. Smerdon. *Climate Change: The Science of Global Warming and Our Energy Future*. New York: Columbia UP, 2009. Print.

Maurer, Stephen, Bernt Hugenholtz, and Harlan Onsrud. "Europe's Database Experiment." *Science* 294.5543 (2001): 789-90. Web.

McDermott, Richard, and Carla O'Dell. "Overcoming Cultural Barriers to Sharing Knowledge." *Journal of Knowledge Management* 5.1 (2001): 76-85. Web.

"Members." *CEOS*. Committee on Earth Observing Satellites, n.d. Web. 24 May 2013. <http://www.ceos.org/index.php?option=com_content>.

Meredith, Paul H. "Distributed GIS: If Its Time Is Now, Why Is It Resisted." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. 7-21. Print.

Mid-Term Evaluation of GEOSS Implementation. Rep. no. Doc. 6. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/06_Mid-Term%20Evaluation%20of%20GEOSS%20Implementation%20Rev1.pdf>.

Mohr, Tillmann. "The Global Satellite Observing System: A Success Story." *WMO Bulletin* 59.1 (2010): n. pag. Web. 24 May 2013. <http://www.wmo.int/pages/publications/bulletin_en/archive/59_1_en/59_1_mohr_en.html>.

"NASA's Earth Observing System." *NASA's Earth Observing System*. N.p., n.d. Web. 28 Mar. 2013. <http://eospso.gsfc.nasa.gov/eos_homepage/mission_profiles/show_mission_list.php?id=20>.

"National Aeronautics and Space Administration." *NASA Index*. N.p., 7 Dec. 2012. Web. 28 Mar. 2013. <http://www.nasa.gov/about/index.html>.

National Oceanic and Atmospheric Administration. Public Affairs. *NOAA Administrator Promotes Role of Global Observations to Sustainable Development at WSSD*. N.p., 30 Aug. 2002. Web. 24 May 2013. <http://www.publicaffairs.noaa.gov/releases2002/aug02/noaa02109.html>.

"National Space Development Agency of Japan (NASDA) History." *NASDA History*. JAXA, n.d. Web. 24 May 2013. <http://www.jaxa.jp/about/history/nasda/index_e.html>.

A National Strategy for Advancing Climate Modeling. Rep. National Research Council Board on Atmospheric Sciences and Climate, 2012. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?record_id=13430&page=1>.

Nedović-Budić, Zorica, Jeffrey Pinto, and Lisa Warnecke. "GIS Database Development and Exchange: Interaction Mechanisms and Motivations." *Journal of the Urban and Regional Information Systems Association* 16.1 (2004): 15-29. Web.

Nedović-Budić, Zorica, and Jeffrey K. Pinto. "Interorganizational GIS: Issues and Prospects." *The Annals of Regional Science* 33.2 (1999): 183-95. Web.

Nelson, Bryn. "Data Sharing: Empty Archives." *Nature* 461.7261 (2009): 160-63. Print.

"News." *GCOS: Index*. Global Climate Observing System, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/prog/gcos/>.

Nixon, Richard. "Address Before the 24th Session of the General Assembly of the United Nations." Address. 24th Session of the General Assembly of the United Nations. New York, NY. 18 Sept. 1969. *American Presidency Project*. Web. 29 Mar. 2013. <http://www.presidency.ucsb.edu/ws/index.php?pid=2236>.

NOAA. *Landsat 6 Failure Attributed to Ruptured Manifold*. N.p., 10 Mar. 1995. Web. 30 Mar. 2013. <http://landsat.gsfc.nasa.gov/pdf_archive/NOAA_landsat6.pdf>.

"NOAA Legacy." *NOAA History*. N.p., 8 June 2006. Web. 28 Mar. 2013. <http://www.history.noaa.gov/noaa.html>.

"NOAA National Data Centers Online Data Access Policy." *National Climate Data Center*. NOAA, 20 Aug. 2008. Web. 29 Mar. 2013. <http://www.ncdc.noaa.gov/oa/nndc/freeaccess.html>.

"NOAA Participates in U.S.-Hosted Earth Observation Systems Summit: Nations Join Together to Take Pulse of Planet Earth." *NOAA Magazine Online*. N.p., 27 Aug. 2003. Web. 24 May 2013. <http://www.magazine.noaa.gov/stories/mag107.htm>.

Nye Jr, Joseph S. "The American National Interest and Global Public Goods." *International Affairs* 78.2 (2002): 233-44. Web. 24 May 2013.

"Observing the Earth: A Brief History of Meteosat." *European Space Agency*. N.p., n.d. Web. 01 Apr. 2013. <http://www.esa.int/Our_Activities/Observing_the_Earth/Meteosat_Second_Generation/A_brief_history_of_Meteosat>.

OECD Principles and Guidelines for Access to Research Data from Public Funding. Rep. Organization for Economic Cooperation and Development, 2007. Web. 19 Mar. 2013. <http://www.oecd.org/sti/sci-tech/38500813.pdf>.

Ohlemacher, R. "The Earth Observation Summit: Heralding a New Era for International Cooperation." *Space Policy* 19.4 (2003): 277-81. Web.

"OMB Announces New A-130 Circular." *Seclists*. N.p., 28 June 1993. Web. 28 Mar. 2013. <http://seclists.org/interesting-people/1993/Jun/83>.

Onsrud, Harlan. "Access to Geographic Information: Openness versus Security."*Http://www.spatial.maine.edu/~onsrud/pubs/OpennessVsSecurityPreprint.pdf*. N.p., n.d. Web. 19 Mar. 2013.

Onsrud, Harlan, and Gerard Rushton. "Sharing Geographic Information: An Introduction." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

Onsrud, Harlan. "Is Cost Recovery Worthwhile." Proc. of URISA 1995 Annual Conference Proceedings, Washington, DC. Urban and Regional Information Systems Association, 1995. Web.

Onsrud, Harlan J. "Role of Law in Impeding and Facilitating the Sharing of Geographic Information." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

Onsrud, Harlan. "The Tragedy of the Information Commons." *Policy Issues in Modern Cartography* (1998): 141-58. Web.

Onsrud, Harold J. "In Support of Cost Recovery for Publicly Held Geographic Information." *Cost Recovery for GIS*. N.p., 1992. Web. 19 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/pubs/Cost_Recovery_for_GIS.html>.

"Outline of the Multi-functional Transport Satellite (MTSAT) Series." *About MTSAT Series*. JMA, 31 Mar. 2008. Web. 12 Feb. 2013.

Overpeck, Jonathan T., Gerald A. Meehl, Sandrine Bony, and David R. Easterling. "Climate Data Challenges in the 21st Century." *Science* 331.6018 (2011): 700-02. Web. 19 Mar. 2013. <http://www.sciencemag.org/content/331/6018/700.short>.

Parcher, Jean. "Benefits of Open Availability of Landsat Data." Proc. of CEOS Plenary 2012. N.p., n.d. Web.

Personal interview. 2012. Adina Gillspie, Barbara Ryan, Bob Chen, Brent Smith, Michelle Hertzfeld, Brian Killough, Danielle Wood, Etienne Wood, Etienne Marcuz, Helen Wood, Ivan Petiteville, Jack Kaye, James Baker, Jerome Lafeuille, Jim Zimmerman, John Jones, Linda Moodie, Lulu Makapela, Martha Maiden, Norimitsu Kamimori, Paul Cournet, Silvia Castane, Peter Collohan, Simonetta Chelli, Tim Stryker, Bruce Quirk, Robert Doyle, Kazushi Kobata, and Tadayoshi Yahata.

Pinto, Jeffrey, and Harlan Onsrud. "Sharing Geographic Information Across Organizational Boundaries: A Research Framework." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Print.

Pinto, Jeffrey, and Harlan Onsrud. "Sharing Geographic Information Across Organizational Boundaries: A Research Framework." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. 44-64. Print.

"POES Spacecraft Status Main Page." *Polar-orbiting Operational Environmental Satellites*. NOAA, 11 Mar. 2013. Web. 28 Mar. 2013. <http://www.oso.noaa.gov/poesstatus/>.

"Polar-orbiting Satellites: The First Launched." *POES History*. NOAA, 29 Sept. 2011. Web. 28 Mar. 2013. <http://www.oso.noaa.gov/history/first-launched.htm>.

"Policy on Partnerships in the Provision of Environmental Information." *NOAA*. N.p., n.d. Web. 29 Mar. 2013. <http://www.noaa.gov/partnershippolicy/fairwxpolicy.html>.

"Policy on Partnerships in the Provision of Environmental Information." *NOAA*. N.p., n.d. Web. 29 Mar. 2013. <http://www.noaa.gov/partnershippolicy/>.

Potocnik, Janez. "Earth Observations for Sustainable Growth and Development." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_european_commision_statement.pdf>.

"Prepublication Data Sharing." *Nature* 461.7261 (2009): 168-70. Web.

Public Sector Information: A Key Resource for Europe: Green Paper on Public Information in the Information Society. Brussels: European Commission, 1998. Print.

Rao, M., and K. Sridharamurthi. "Keeping up with Remote Sensing and GI Advances—Policy and Legal Perspectives." *Space Policy* 22.4 (2006): 262-73. Web.

Rasmussen, James R. "Historical Development of the World Weather Watch." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/themes/oceans/www_en.html>.

"Reorganization Plan 4 of 1970." *NOAA Central Library*. N.p., n.d. Web. 28 Mar. 2013. <http://www.lib.noaa.gov/noaainfo/heritage/ReorganizationPlan4.html>.

Report of GEO-VI. Rep. GEO, 3 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vii/04_Report%20of%20GEO-VI.pdf>.

Report on GEO-V. Rep. no. Doc. 4. GEO, 17 Nov. 2009. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_vi/04_GEO-V%20Report.pdf>.

Report on Progress 2007. Rep. GEO, 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/MS2_The%20GEO%20Report%20on%20Progress.pdf>.

"Resolution 25 (Cg-XIII)." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/Resolution25_en.html>.

"Resolution 40 (Cg-XII)." World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/Resolution40_en.html>.

Resolution of the Third Earth Observation Summit. Rep. N.p., 16 Feb. 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/eos_iii/Third%20Summit%20Resolution.pdf>.

Resolving Conflicts Arising from the Privatization of Environmental Data. Rep. National Research Council, Committee on Geophysical and Environmental Data, 2001. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10237>.

Responsible Leadership for a Sustainable Future. Rep. G8, n.d. Web. 24 May 2013. <http://www.g8italia2009.it/static/G8_Allegato/G8_Declaration_08_07_09_final,0.pdf>.

"Revised ESA Earth Observation Data Policy." *Earthnet Online*. ESA, n.d. Web. 15 Apr. 2013. <https://earth.esa.int/web/guest/missions/content?p_r_p_564233524_assetIdentifier=revised-esa-earth-observation-data-policy-7098>.

Riedlinger, Torsten. "GMES Data and Information Policy." Lecture. Global Monitoring for Environment and Security. Rome. 7 May 2012. European Commission. Web. 15 Apr. 2013. <http://www.earthobservations.net/documents/meetings/201205_gepw6/geo_wp_in_gmes_data_policy_riedlinger.pdf>.

Rodriguez, Henry, Mike Snyder, and Mathias Uhlén. "Recommendations from the 2008 International Summit on Proteomics Data Release and Sharing Policy: The Amsterdam Principles." *Journal of Proteome Research* 8.7 (2009): 3689-692. Web.

S. 2209, 100 Cong., U.S. G.P.O. (1988) (enacted). Print.

National Aeronautics and Space Administration Authorization Act, Fiscal Year 1989

Salkin, Patricia A. "GIS in an Age of Homeland Security: Accessing Public Information to Ensure a Sustainable Environment." *William & Mary Environmental Law and Policy Review* 30.1 (n.d.): 55-94. Web.

Samuelson, Paul A. "The Pure Theory of Public Expenditure." *Review of Economics and Statistics* 36.4 (1954): 387-89. Print.

Sandler, Todd. "Intergenerational Public Goods: Strategies, Efficiency and Institutions." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.

Schafer, Angela, and Heinz Pampel. *Baseline Report on Drivers and Barriers in Data Sharing*. Rep. Opportunities for Data Exchange, Seventh Framework Programme, 2011. Web. 19 Mar. 2013. <http://www.alliancepermanentaccess.org/wp-content/uploads/downloads/2011/11/ODE-WP3-DEL-0002-1_0_public_final.pdf>.

"Science and Technology for Sustainable Development - A G8 Action Plan." *Evian Summit 2003*. N.p., n.d. Web. 24 May 2013. <http://www.g8.fr/evian/english/navigation/2003_g8_summit/summit_documents/science_and_technology_for_sustainable_development_-_a_g8_action_plan.html>.

Second Evaluation of GEOSS Implementation. Rep. no. Doc. 6. GEO, 16 Nov. 2011. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo-

viii/06(Rev1)_Second%20Evaluation%20of%20GEOSS%20Implementation%20(ADM).pdf>.

The Second Report on the Adequacy of the Global Climate Observing Systems for Climate in Support of the UNFCCC. Rep. no. GCOS-82. Global Climate Observing System, Apr. 2003. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-82_2AR.pdf>.

Sekiguchi, Yoshiro. "JMA Memo." Letter to Dr. David S. Johnson, NOAA. 6 Feb. 1978. N.p.: n.p., n.d. N. pag. Web. 24 May 2013.

"Sentinel Data Policy and Access to Data." Lecture. Workshop on GMES Data and Information Policy. Brussels. 12 Jan. 2012. *European Space Agency*. Web. 15 Apr. 2013. <http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=7149>.

Shaffer, L., and P. Backlund. "Towards a Coherent Remote Sensing Data Policy." *Space Policy* 6.1 (1990): 45-52. Web.

Sharing Research Data. Rep. National Research Council, Committee on National Statistics, Commission on Behavioral and Social Sciences and Education, 1985. Web. 19 Mar. 2013. <http://www.nap.edu/openbook.php?isbn=030903499X>.

Singer, Ken, Dave Terril, Jack Kelly, and Cathy Nichols. "Building a COTS Archive for Satellite Data." Proc. of 4th NASA Goddard Conference on Mass Storage Systems and Technologies, College Park, MD. N.p., n.d. Web. 28 Mar. 2013. <http://storageconference.org/1995/C1_2.PDF>.

Smith, L., and C. Doldirina. "Remote Sensing: A Case for Moving Space Data towards the Public Good."*Space Policy* 24.1 (2008): 22-32. Web.

The Space Report 2013: The Authoritative Guide to Global Space Activity. Colorado Springs, CO: Space Foundation, 2013. Print.

"Speech by Argentinian Representative." 22nd United Nations/International Astronautical Federation Workshop on "Space Technologies Applied to the Needs of Humanity: Experience from Cases in the Mediterranean Area" Naples. 30 Sept. 2012. Speech.

"Statement by Brazil." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_brazil_statement.pdf>.

"Statement by Press Secretary Fitzwater on Landsat Satellite Program Funding." Address. 1 Jan. 1985. *George Bush Presidential Library and Museum*. Web. 30 Mar. 2013. <http://bushlibrary.tamu.edu/research/public_papers.php?id=481&year=1989&month=6>.

"Statement by Prof. Jose Achache." Speech. World Summit for Sustainable Development. Johannesburg. 30 Aug. 2002. United Nations. Web. 24 May 2013. <http://www.un.org/events/wssd/statements/ceosE.htm>.

"Statement of Dr. Tsehaie Woldai, Principal Delegate of the African Association of Remote Sensing of the Environment (AARSE)." Speech. Fourth GEO Ministerial Summit. Cape Town. 30 Nov. 2007. Web. 24 May 2013. <http://www.earthobservations.org/documents/geo_iv/ctms_aarse_statement.pdf>.

"Statements by Head of Participating Organizations." Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2005. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_ESA_statement.pdf>.

"Statements from The Netherlands." Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_Netherlands_statement.pdf>.

Stevens, William K. "Huge Space Platforms Seen as Distorting Studies of Earth." *The New York Times*. N.p., 19 June 1990. Web. 28 Mar. 2013. <http://www.nytimes.com/1990/06/19/science/huge-space-platforms-seen-as-distorting-studies-of-earth.html?pagewanted=all>.

Stiglitz, Joseph. "Knowledge as a Global Public Good." *Global Public Goods: International Cooperation in the 21st Century*. New York: Oxford UP, 1999. N. pag. Web.

Strategic Plan for the U.S. Integrated Earth Observation System. Rep. Interagency Working Group on Earth Observations NSTC Committee on Environment and Natural Resources, 2005. Web. 19 Mar. 2013. <http://www.whitehouse.gov/sites/default/files/microsites/ostp/eocstrategic_plan.pdf>.

Systematic Observation Requirements for Satellite-based Products for Climate Supplemental Details to the Satellite-based Component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC. Rep. no. GCOS-107. Global Climate Observing System, Sept. 2006. Web. 19 Mar. 2013. <http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf>.

Taupier, Richard P. "Comments on the Economics of Geographic Information and Data Access in the Commonwealth of Massachusetts." *Sharing Geographic Information*. New Brunswick, NJ: Center for Urban Policy Research, 1995. N. pag. Print.

Thomas, G. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.

Thomas, Gerald B., James P. Lester, and Willy Z. Sadeh. "International Cooperation in Remote Sensing for Global Change Research: Political and Economic Considerations." *Space Policy* 11.2 (1995): 131-41. Web.

Toward New Partnerships In Remote Sensing Government, the Private Sector, and Earth Science Research. Rep. National Research Council, Steering Committee on Space

Applications and Commercialization, 2002. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=10500>.

Triendl, Robert. "Japan Tightens Focus in Space Research." *Nature* 388 (1997): n. pag. Web. 24 May 2013.

"TRMM." *Tropical Rainfall Measurement Mission*. NASA, n.d. Web. 24 May 2013. <http://trmm.gsfc.nasa.gov/data_dir/data.html>.

Tsunomura, Satoru. "￼Current Status and Future Plan of Japanese Meteorological Satellite Program ￼." Lecture. Japan Meteorological Agency. Web.

Uhlir, Paul F., and Peter Schröder. "Open Data for Global Science." *Data Science Journal* 6 (2007): OD36-D53. Web.

"Uncertainties: Unresolved Questions about Earth's Climate." *Global Climate Change*. NASA, n.d. Web. 19 Mar. 2013. <http://climate.nasa.gov/uncertainties>.

United Nations. *1721 (XVI). International Co-operation in the Peaceful Uses of Outer Space*. N.p.: n.p., 1961. United Nations Office for Outer Space Affairs. Web. 24 May 2013. <http://www.oosa.unvienna.org/oosa/SpaceLaw/gares/html/gares_16_1721.html>.

United Nations. *International Agreements and Other Available Legal Documents Relevant to Space-related Activites*. Vienna: n.p., 1999. *International Agreements and Other Legal Documents Relevant to Space-related Activities*. Web. 1 Apr. 2013. <http://www.oosa.unvienna.org/pdf/spacelaw/intlagree.pdf>.

"United Nations Office for Outer Space Affairs." *Law Concerning The National Space Development Agency Of Japan*. N.p., n.d. Web. 24 May 2013. <http://www.unoosa.org/oosa/en/SpaceLaw/national/japan/nasda_1969E.html>.

United Nations. World Meteorological Organization. *Convention of the World Meteorological Organization*. N.p.: n.p., n.d. Web. 24 May 2013. <http://www.eco.gov.az/hidromet/umumdunya%20meteorologiya.pdf>.

"United States Code Title 15 Chapter 82 Land Remote Sensing Policy." *Landsat Program*. NASA, 21 Oct. 1999. Web. 29 Mar. 2013. <http://geo.arc.nasa.gov/sge/landsat/15USCch82.html>.

United States. Cong. Senate. Committee on Commerce, Science and Transportation. *Landsat Amendments Act of 1995*. 104th Cong., 1st sess. S. Rept. 104-81. Washington, DC: U.S. Government Printing Office, 1995. Web. 30 Mar. 2013. <http://www.gpo.gov/fdsys/pkg/CRPT-104srpt81/pdf/CRPT-104srpt81.pdf>.

United States. Department of Commerce. *NOAA Upgrades Satellite Division, Changes Name*. By William J. Brennan. Rockville, MD: n.p., 1980. *NOAA*. Web. 29 Mar. 2013. <http://docs.lib.noaa.gov/rescue/TIROS_johnson/NESS%20Highlighted.pdf>.

United States. Department of Commerce. Weather Bureau. *National Operational Meteorological Satellite System*. Washington, DC: n.p., 1962. *National Operational*

Meteorological Satellite System. Web. 28 Mar. 2013. <http://docs.lib.noaa.gov/rescue/TIROS/TL798M4N371962.pdf>.

United States. Executive Office of the President. *Civil Operational Remote Sensing*. N.p.: n.p., 1979. Jimmy Carter Presidential Library. Web. 29 Mar. 2013. <http://www.jimmycarterlibrary.gov/documents/pddirectives/pd54.pdf>.

United States. Executive Office of the President. *Landsat Remote Sensing Strategy (Amendment to 1994 Directive)*. N.p.: n.p., 2000. Web. <http://landsat.usgs.gov/documents/PDD_PDF.pdf>.

United States. Executive Office of the President. Office of Science and Technology Policy. *Data Management for Global Change Research Policy Statements*. By Allan Bromley. N.p.: n.p., 1991. *U.S. Global Change Research Information Office*. Web. 28 Mar. 2013. <http://www.gcrio.org/USGCRP/DataPolicy.html>.

United States. Executive Office of the President. *Presidential Decision Directive NSTC-3*. N.p.: n.p., 1994. Web. 30 Mar. 2013. <http://landsat.usgs.gov/documents/PDD_PDF.pdf>.

United States. Federal Geographic Data Committee. *Guidelines for Providing Appropriate Access to Geospatial Data in Response to Security Concerns*. N.p., June 2005. Web.

United States. *Federal Register*. 88th ed. Vol. 62. N.p.: n.p., 1997. *Schedule of Fees for Access to NOAA Environmental Data and Information and Products Derived Therefrom*. Web. 29 Mar. 2013. <http://www.gpo.gov/fdsys/pkg/FR-1997-05-07/pdf/97-11789.pdf>.

United States. *Federal Register*. N.p.: n.p., 2012. *Schedule of Fees for Access to NOAA Environmental Data, Information, and Related Products and Services*. Web. <Schedule of Fees for Access to NOAA Environmental Data, Information, and Related Products and Services>.

United States. General Accounting Office. *GAO/IMTEC-92-44 Questions Remain About U.S. Commercial Access*. N.p.: n.p., 1992. Print.

United States. General Accounting Office. *Landsat's Role in an Earth Resources Information System*. Washington: U.S. General Accounting Office, 1977. Web. 29 Mar. 2013. <http://gao.justia.com/department-of-commerce/1977/6/landsat-s-role-in-an-earth-resources-information-system-psad-77-58/PSAD-77-58-full-report.pdf>.

United States. National Aeronautics and Space Administration. *NASA FY2013 President's Budget Request Summary*. N.p., n.d. Web. 28 Mar. 2013. <http://www.nasa.gov/pdf/632697main_NASA_FY13_Budget_Summary-508.pdf>.

United States. National Aeronautics and Space Administration. Office of Earth Science. *Directive NMI 8000.3 NASA Earth Science Program Data Program - Delegation of Authority*. N.p.: n.p., 1991. Print.

United States. National Aeronautics and Space Administration. *Responding to the Challenge of Climate and Environmental Change*. N.p.: n.p., 2010. Web. 28 Mar. 2013. <http://science.nasa.gov/media/medialibrary/2010/07/01/Climate_Architecture_Final.pdf>.

United States. National Oceanic and Atmospheric Administration. *FY2013 Budget Summary: Introduction*. NOAA, n.d. Web. 28 Mar. 2013. <http://www.corporateservices.noaa.gov/nbo/fy13_budget_highlights/introduction.pdf>.

United States. National Oceanic and Atmospheric Administration. National Environmental Satellite, Data, and Information Service. *NESDIS FY2013 Budget Highlights*. NOAA, n.d. Web. 28 Mar. 2013. <http://www.corporateservices.noaa.gov/nbo/fy13_budget_highlights/NESDIS_FY13_One_Pager.pdf>.

United States. National Oceanic and Atmospheric Administration. National Environmental Satellite, Data, and Information Service. *NOAA Satellite and Information Service*. N.p., n.d. Web. 28 Mar. 2013. <http://www.nesdis.noaa.gov/pdf/NESDIS.pdf>.

United States. National Oceanic and Atmospheric Administration. National Weather Service. *Borders in Cyberspace: Conflicting Public Sector Information Policies and Their Economic Impacts*. By Peter Weiss. NOAA, Feb. 2002. Web. 19 Mar. 2013. <http://www.nws.noaa.gov/sp/Borders_report.pdf>.

United States. National Oceanic and Atmospheric Administration. Satellite and Information Service. *History of the NOAA Satellite Program*. By Gary Davis. N.p.: n.p., 2011. *History of the NOAA Satellite Program*. Web. 28 Mar. 2013. <http://www.osd.noaa.gov/download/JRS012504-GD.pdf>.

The United States National Report on Systematic Observations for Climate for 2008: National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan. Rep. Observations Working Group of the U.S. Climate Change Science Program (CCSP), Sept. 2008. Web. 19 Mar. 2013. <http://www.climatescience.gov/Library/UNFCCC-reporting-GCOS-Final.pdf>.

United States. NOAA. *National Data Centers Free Data Distribution Policy*. N.p.: n.p., 2009. Web. 29 Mar. 2013. <http://www.ncdc.noaa.gov/oa/nndc/freedata.pdf>.

United States. NOAA. NESDIS. *The Nation's Environmental Data Treasures at Risk : Report to Congress on the Status and Challenges for NOAA's Environmental Data Systems*. By Allen Hittelman and Ida Hakkarinen. Silver Spring, MD: National Oceanic and Atmospheric Administration, 2001. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/pdf/letter.pdf>.

United States. NOAA. NESDIS. *NOAA Environmental Data: Foundation for Earth Observations and Data Management System*. By Allen Eustis and David J. Vercelli. Washington, D.C.: U.S. Dept. of Commerce, National Oceanic and Atmospheric

Administration, 2003. Web. 28 Mar. 2013. <http://www.ngdc.noaa.gov/noaa_pubs/foundations.shtml>.

United States. NOAA. NESDIS. *Policy on Access and Distribution of Environmental Satellite Data and Products*. N.p.: n.p., n.d. Web. 29 Mar. 2013. <http://www.ospo.noaa.gov/Organization/About/access.html>.

United States. NOAA. *NOAA Policy on Partnerships in the Provision of Environmental Information*. N.p.: n.p., 2006. Web. 29 Mar. 2013. <http://www.noaa.gov/partnershippolicy/FinalClarifiedPolicy011906.pdf>.

United States. NOAA. *Policy Statement on the Weather Service/Private Sector Roles*. N.p.: n.p., 1991.*Industrial Meteorology*. National Weather Service. Web. 29 Mar. 2013. <http://www.nws.noaa.gov/im/fedreg.htm>.

"United States Remarks to the GEO 2010 Ministerial." Speech. Fifth GEO Ministerial Summit. Beijing. 5 Nov. 2010. Web. 24 May 2013. <http://www.earthobservations.org/documents/ministerial/beijing/statements/bms_USA_statement.pdf>.

United States. United States Geological Survey. *FY2013 Budget Highlights*. USGS, n.d. Web. 28 Mar. 2013. <http://www.doi.gov/budget/appropriations/2013/highlights/upload/BH051.pdf>.

United States. USGS. *Landsat Data Distribution Policy*. N.p., n.d. Web.

United States. *Value of Civil Imagery and Remote Sensing*. Federal Geographic Data Committee, Civil Imagery and Remote Sensing Task Force, 1 Oct. 2002. Web. 19 Mar. 2013. <http://www.fgdc.gov/participation/coordination-group/meeting-minutes/2002%20meeting%20minutes/may/cirs_report.pdf>.

"U.S. and Global Temperature." *Climate Change Indicators in the United States*. Environmental Protection Agency, 2012. Web. 19 Mar. 2013. <http://www.epa.gov/climatechange/science/recenttc.html>.

U.S. Geological Survey. *Landsat 7 Data Prices Announced*. N.p., 31 Oct. 1997. Web. 30 Mar. 2013. <http://web.archive.org/web/19980120090116/http://edcwww.cr.usgs.gov/programs/landsat7price.html>.

USGS. *Over 9 Million Downloads for Free Landsat Data*. *United Nations Office for Outer Space Affairs*. N.p., 12 Sept. 2012. Web. 30 Mar. 2013. <http://www.un-spider.org/about-us/news/en/6182/2012-09-12t080000/usgs-over-9-million-downloads-free-landsat-data>.

Utilization of Operational Environmental Satellite Data: Ensuring Readiness for 2010 and Beyond. Rep. National Research Council, Committee on Environmental Satellite Data Utilization, 2004. Web. 19 Mar. 2013. <http://www.nap.edu/catalog.php?record_id=11187>.

Van Loenen, B. "Developing Geographic Information Infrastructures: The Role of Access Policies."*International Journal of Geographical Information Science* 23.2 (2009): 195-212. Web.

Vedda, James A. *U.S. National Security and Economic Interests in Remote Sensing: The Evolution of Civil and Commercial Policy*. Rep. no. TOR-2009(3601)-8539. N.p.: Aerospace Corporation, 2009. Web. 30 Mar. 2013. <http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB404/docs/27-new.pdf>.

Weiss, Peter. "Revisions to OMB Circular No. A-130: Management of Federal Information Resources." U.S. Office of Management and Budget. Washington, DC. 30 Oct. 1994. Web. 28 Mar. 2013. <http://www.spatial.maine.edu/~onsrud/tempe/weiss.html>.

Wells, Helen T., Susan H. Whiteley, and Carrie E. Karegeannes. "Satellites." *Origins of NASA Names*. Washington, D.C.: Scientific and Technical Information Office, National Aeronautics and Space Administration, 1976. N. pag. *NASA History Office*. Web. 28 Mar. 2013. <http://history.nasa.gov/SP-4402/ch2.htm>.

White Paper on the GEOSS Data Sharing Principles. Rep. CODATA, 27 Sept. 2008. Web. 24 May 2013. <http://www.earthobservations.org/documents/dsp/Draft%20White%20Paper%20for%20GEOSS%20Data%20Sharing%20Policies_27Sept08.pdf>.

Williams, Michael. "GEO Announces Free And Unrestricted Access To Full Landsat Archive." *EarthZine*. N.p., 2 Dec. 2008. Web. 24 May 2013. <http://www.earthzine.org/2008/12/02/geo-announces-free-and-unrestricted-access-to-full-landsat-archive/>.

Williamson, Ian P. "Spatial Data Infrastructures: An Incentive to Facilitate Spatial Data Sharing." By Abbas Rajabifard. N.p.: n.p., n.d. N. pag. Web. 19 Mar. 2013. <http://www.csdila.unimelb.edu.au/publication/misc/SDI_an_initative_to-facilitateSDI_GlobalEnvironmentalBook-SDI0Chapter6.pdf>.

Williamson, R. "Current US Remote Sensing Policies: Opportunities and Challenges." *Space Policy* 20.2 (2004): 109-16. Web.

Williamson, Ray A. "The Landsat Legacy: Remote Sensing Policy and the Development of Commercial Remote Sensing." *Photogrammetric Engineering & Remote Sensing* 63.7 (1997): 877-85. Web.

Withee, Gregory, Brent Smith, and Robert Masters. "The Prospects for Enhanced International Polar Orbiting Satellite Cooperation." *Space Policy* 17.2 (2001): 121-26. Web.

"WMO in Brief." *About Us*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/index_en.html>.

"WMO’s Desired Outcomes, Strategies and Associated Goals." *WMO's Vision*. World Meteorological Organization, n.d. Web. 24 May 2013. <http://www.wmo.int/pages/about/vision_en.html>.

World Meteorological Organization. *Declaration of the World Climate Conference*. N.p.: n.p., n.d. Web. 24 May 2013. <http://www.dgvn.de/fileadmin/user_upload/DOKUMENTE/WCC-3/Declaration_WCC1.pdf>.

"World Meteorological Organization Homepage." *World Meteorological Organization (WMO)*. N.p., n.d. Web. 19 Mar. 2013. <http://www.wmo.int/pages/index_en.html>.

World Meteorological Society. *Resolution 40 (Cg-XII)*. WMO, n.d. Web. 28 Mar. 2013. <http://www.wmo.int/pages/about/Resolution40_en.html>.

World Summit on Sustainable Development: Plan of Implementation. Rep. N.p., n.d. Web. 24 May 2013. <http://www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.htm>.

Wulder, Michael, Jeffrey Masek, Warren Cohen, Thomas Loveland, and Curtis Woodcock. "Opening the Archive: How Free Data Has Enabled the Science and Monitoring Promise of Landsat." *Remote Sensing of Environment* 122 (2012): 2-10. Web.

Zillman, John W. "A History of Climate Activities." *WMO Bulletin* 58.3 (2009): n. pag. Web. 24 May 2013. <http://www.wmo.int/pages/publications/bulletin_en/archive/58_3_en/58_3_zillman_en.html>.