ABSTRACT

Title of Dissertation: ATMOSPHERIC MEDIA: COMPUTATION AND THE ENVIRONMENTAL IMAGINATION

Jeffrey Moro, Doctor of Philosophy, 2022

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Atmospheric media are techniques and technologies for the rationalization of air. They take many forms, from the meteorological media of weather maps and satellites, to the infrastructural media of ventilation and climate control, to the embodied media of the breath. This dissertation explores these atmospheric media as fundamental conduits for the cultural work of managing the air, and in turn, for managing climatological catastrophe. Through readings of diverse media objects, from electronic literature and science fiction to 3D printers to air conditioning in data centers, "Atmospheric Media: Computation and the Environmental Imagination" argues that scientists, artists, and laypeople alike have come to imagine the air as a computer, one that they might program as a way out of environmental crisis. Braiding interdisciplinary insights from environmental media studies, literary studies, and the digital humanities, this dissertation explores how computation smooths over atmospheric difference with the standardization of data, and in doing so, further imperils our shared skies.

ATMOSPHERIC MEDIA: COMPUTATION AND THE ENVIRONMENTAL IMAGINATION

by

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2022

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For Skye

Acknowledgements

There is a temptation always with acknowledgments to be exhaustive when such exhaustion is impossible. I cannot thank by name all those people, creatures, and things who supported me over the three years of writing this dissertation. I will forever be in their debt. Nevertheless, I will try.

Thanks are due first to my dissertation committee: Matthew G. Kirschenbaum, Kari Kraus, Kellie Robertson, Shannon Mattern, and Jason A. Farman. Collectively they have pushed this project in all the ways I needed it and in several ways I could have never expected. Singular thanks are due to Matt, as this dissertation's director, for his unwavering and indefatigable support from the very first email he sent me inviting me to join the University of Maryland. Thanks as well to those members of the UMD English department who have supported this dissertation in bits and pieces over the years, in particular Neil Fraistat, Christina Walter, and Edlie Wong, in whose classes I developed parts of what would eventually become this project. I wrote much of chapter four while in residence at the Maryland Institute for Technology in the Humanities (MITH) as their Winnemore Digital Humanities Dissertation Fellow in the fall of 2020, but my debt to the fine folks of MITH, in particular Trevor Muñoz, Ed Summers, Purdom Lindblad, Raffaele Viglianti, and Stephanie Sapienza, runs far deeper than that. Special thanks to my fellow graduate students in digital studies, in particular Kyle Bickoff, Setsuko Yokoyama, Andy Yeh, and the members of the Digital Studies Colloquium. I am also lucky to have benefitted from the support of many intellectual interlocutors outside the University of Maryland, especially those who have hosted this project in various forms in conference panels and edited it in publications: Jim Brown, Ben Mendelsohn, Sara Grossman, Salma Monani, Jean-Thomas Tremblay, Sarah Osment, Christina Gerhardt, Spencer Adams, Grant Wythoff, Miguel

Penabella, Amaru Tejada, and many others. Thanks as well to Preston Tobery of the John and Stella Graves Makerspace in the UMD McKeldin Library and the fine folks at Equinix's DC11 data center for allowing me to tour their spaces and to pester them with questions.

I would not have been able to imagine writing this dissertation, much less actually write it, without the support from past teachers, who I am proud now to be able to call colleagues. Marisa Parham has been a singular mentor and friend since I first worked with her at Five College Digital Humanities after undergrad; I am lucky to continue to learn from her and the whole team at AADHum and the Immersive Realities Labs for the Humanities to this day. Thanks as well to Andrew Johnston, without whose support I would have never thought a PhD possible. And to Miriam Posner, Roopika Risam, Alex Gil, John Drabinski, Lori Emerson, Jussi Parikka, Darren Wershler, Hsuan Hsu, Amanda Visconti, Daniel Greene, Lee Konstantinou, Élika Ortega, Dave Parisi, Jacqueline Wernimont, Mél Hogan, Andrew Ferguson, and Nicole Seymour, who at one point or another, whether they knew it or not, said something I needed to hear to keep me going.

And thanks to the many friends who have read me, listened to me, bitched with me, and cared for me over these three years: Travis Chi Wing Lau, Nick Silcox, Devin Daniels, Christopher Persaud, Tyler Morgenstern, Dennis Hogan, Ranjodh Dhaliwal, Thomas Pringle, Mitchell Wilson, Jake Byrne, Heather Froelich, Tamara Kneese, Kyle Yarusso, Nathaniel Brown, Kristian Robinson, Ezra Teboul, Rohan Mazumdar, Ryan Alawar, and uncountable others. Jenny Schollaert has been my intellectual rock and a dear friend. Henry Epp and Kelsey Rumley have been there since before the beginning. Thanks to my family on both sides of the aisle: my parents Rose and Neal; my brother and sister-in-law Jared and Alexa; and all the Simpsons, especially Susy, who I wish could have read this.

And to my wife, Skye Landgraf, I owe the greatest thanks. Every word of this dissertation bears the signature of her love and support. I am unconscionably lucky to spend my life with such a singular intellect and caring heart. This one is for us.

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Introduction

Atmospheric Media Theory

> the wind
> upon what point you find it
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> — "Instructions and Notes Very Necessary and Needful to Be Observed in the Purposed Voyage for Discovery of Cathay Eastwards," J.R. Carpenter

Atmospheric media are techniques and technologies for the rationalization of air. They take many forms, from the meteorological media of weather maps and satellites, to the infrastructural media of ventilation and climate control, to the embodied media of the inward and outward exchange of breath. Like the atmosphere itself, atmospheric media dilate in scale, operating both on the microscopic level of cellular respiration and the macroscopic level of that aerial envelope that makes life on Earth possible. They are media of understanding—of coming to grasp, on some impossible level, the inexhaustible totality of the air—but also media of control. For it is through atmospheric media that the human species manages the unfolding planetary crisis of anthropogenic climate change. Rising levels of atmospheric carbon prompt concomitant levels of atmospheric regulation. Increases in the frequency of severe weather events require innovations in meteorological mapping and prediction. In short, as the atmosphere grows out of control in the ricochets of industrial modernity, atmospheric media offer an apparent solution. Crucially, they do so through computation. While atmospheric media precede the invention of the digital computer, they nevertheless operate according to computational logics. Through atmospheric media, scientists, artists, and laypeople alike imagine the air as a computer, one that they might program as a way out of environmental crisis. However, atmospheres definitionally exceed attempts to capture them. Air leaks. Atmospheric media, like any medium, reproduce the cultural logics of their development and consequently intensify the very crises they claim to solve. Navigating this contradiction requires a reconsideration of the cultural dominance of computation as a conceptual model for understanding the atmosphere.

This dissertation explores atmospheric media as fundamental conduits for the cultural work of managing the air, and in turn, for managing climatological catastrophe. While the human species has engaged atmospheric media since time immemorial—rain rituals, astrological prediction, and weather diaries are all antique atmospheric media—this dissertation takes a special interest in the intersection of air and computation. Its archive is contemporary, stretching back as far as the late nineteenth century but clustering at the end of the twentieth and the beginning of the twenty-first centuries. It tracks atmospheric mediation across a diverse set of media objects, from creative works of electronic literature and science fiction, to media infrastructures of meteorological prediction and atmospheric management, to the data and code that enable the contemporary work of climate science. As such, this dissertation works at the interstices of the fields of digital media studies and the environmental humanities, participating alongside such scholars as Nicole Starosielski, Jussi Parikka, and Yuriko Furuhata, among many others, in a field-wide turn towards environmental media studies. Along the way, it braids together interdisciplinary insights from literary studies, media archaeology, critical code studies, and the digital humanities: a methodologically expansive scope that matches that of the atmosphere itself. Atmospheres are epistemologically complex in that they are averse to concrete definition yet touch all manners of working and living on this planet. "Atmospheric Media: Computation and the Environmental Imagination" demonstrates how computation negotiates these complexities, smoothing over atmospheric difference with the standardization of data. Furthermore, it is my hope that this dissertation will provide these diverse stakeholders with an alternative set of frameworks and logics beyond that of computation with which to understand our species' cultural relationship to the atmosphere. Ordering the air under the sign of data has brought our planet to the brink of destruction. In its own small way, this dissertation pushes back against the "naturalness" of such an order.

In what follows in this introduction, I offer preliminary context for this argument and situate it within the broader field of environmental media studies. I do so in three stages, loosely tracking this dissertation's title. I begin with a consideration of the keyword "atmosphere" within media studies generally and environmental media studies specifically. Atmosphere, I suggest, serves two functions for media studies: first, to augment conversations around media materiality that have otherwise focused on the "grounds" of mediation, such a silicon and rare earth minerals, with a reconsideration of aerial materialities; and second, to draw to environmental media studies' attention the capacities of atmospheres to organize affective and aesthetic qualities alongside material ones. I then address the specific role that computation plays in my dissertation as both a subject and method of analysis. In particular, I position computation as a media technique that organizes different kinds of atmospheric practices, some of which involve digital computers and others of which do not. Media techniques also function as a major structuring conceit of this dissertation, as each chapter will explore a specific atmospheric media technique: forecasting, conditioning, respiring, and modeling. I then turn to the phrase "the environmental imagination," which I define as media's two-fold capacity to capture atmospheres as data while also producing further cultural atmospheres. In this way, atmospheric media become structuring conceits that define the horizons of possibility for addressing the planetary-scale problem of climate change. Finally, I provide a map of the dissertation and a summary of each of its chapters.

The Atmospheres of Media Studies

At first glance, air and computers may seem unlikely bedfellows. While contemporary computing cultures are awash in aerial metaphors, of which "the cloud" is perhaps the most familiar, computers themselves seem solidly of the earth, all glass and metal and silicon. Yet air has been integral to computing's vision of itself since its earliest moments. In the 1830s, British inventor Charles Babbage sketched out two steam-powered devices that would become the ancestors of contemporary digital computers, the Difference Engine and the Analytical Engine. Although never completed, these machines inspired future elaborations by Ada Lovelace, Vannevar Bush, and other computing pioneers. Like other industrial technologies of its times, Babbage's Engines would have been steam-powered, with compressed air animating the manipulation of punch cards and arithmetic operations. Babbage was enraptured with steam. For him, steam meant new possibilities for the rationalization of production, the mobilization of human labor, and crucially, the extension of human control across the environment. In 1832, at the same time as he was designing his Engines, Babbage published a book called *On the Economy of Machinery and Manufacturers*. The book elaborates Babbage's observations on emerging factory processes and offers recommendations for their organizational refinement. Throughout, air offers new opportunities to extend labor beyond human capacity. "Where one portion of the workman's labor consists in the exertion of mere physical force," he writes, "it will soon occur to the manufacturer, that if that part were executed by steam-engine, the same man might, in the case of weaving, attend to two or more loops at once."[1] For Babbage, calculation is the natural end goal of industrial progress. Calculation, he writes, is that "higher science" in which lies total mastery over nature, from "the minutest atoms" to "the ethereal

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[1] Charles Babbage, *On the Economy of Machinery and Manufactures* (New York: August M. Kelley Publishers, 1832), 215.

fluid."[2] The irony is that even as Babbage extols the virtue of human control over the planet, he also records one of the earliest textual acknowledgments of climate change.[3] "The chemical changes" of steam power, Babbage writes, "are constantly increasing the atmosphere by large quantities of carbonic acid [carbon dioxide] and other gases noxious to human life."[4] He ultimately dismisses these concerns, assuming that nature, in its infinite mysteries, will solve the problem of carbon dioxide. Nearly two hundred years later, we have conclusively learned the answer: it will not.

I begin this story with Babbage to establish a genealogy for thinking about digital media in relation to the environment. It is a genealogy that media studies has become intensely interested in tracking over the first two decades of the twenty-first century. Media studies has of course long taken the natural world as a subject of consideration: early twentieth-century critics such as Lewis Mumford and Harold Innis, for example, wrote at length about the relationships between technology and environmental resources such as wood, minerals, and fish.[5] But in recent years, spurred by cross-pollination from diverse fields as the environmental sciences and the environmental humanities, to say nothing of the environmental justice movement more broadly, media studies has worked to develop what Nicole Starosielski calls an "environmental consciousness [in] the study of digital systems."[6] This work takes many forms, such as Starosielski's own work on undersea cables, Jussi Parikka's investigation of geology and media,

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[2] Babbage, 387.

[3] For further on Babbage's precognition of carbon dioxide, see the introduction to Andreas Malm, *Fossil Capital: The Rise of Steam of Power and the Roots of Global Warming* (London: Verso, 2016).

[4] Babbage, *On the Economy of Machinery and Manufactures*, 18.

[5] See Lewis Mumford, *Technics and Civilization* (New York and Burlingame: Harcourt, Brace & World, Inc., 1934) and Harold Adams Innis, *The Bias of Communication*, 2nd [rev.] ed (Toronto: University of Toronto Press, 2008).

[6] Nicole Starosielski, *The Undersea Network* (Durham and London: Duke University Press, 2015), 3.

Shannon Mattern's work on media materiality and urban infrastructure, Melody Jue's research on media and seawater, and John Durham Peters' elemental media philosophies.[7] It has spurred new scholarly journals, such as the *Journal of Environmental Media* and *Media + Environments*. These projects have taken a distinct interest in media's materiality, which they link to questions of environmental degradation and pollution. Scholars such as Mél Hogan and Sean Cubitt have forcefully demonstrated the inherent unsustainability of contemporary media practices, from the energy expenditures of data centers to the toxic pollution of media production.[8] Despite their shared environmental subject matter, these projects are heterogeneous in their archives and indeed conceptualizations of media studies. Some, such as Peters and Parikka, take more theoretical approaches; whereas others, such as Rahul Mukherjee's work on radiation in India and Jennifer Gabrys' study of environmental sensing technologies, pursue more sociological and ethnographic projects.[9] Across these projects, "the environment" offers a fruitful keyword with which to consider media's relationship not only to the planet, but also social and cultural practice, questions of racial and environmental justice, and media theory more broadly.

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[7] See Starosielski, *The Undersea Network*; Jussi Parikka, *A Geology of Media* (Minneapolis: University of Minnesota Press, 2015); Shannon Mattern, *Code and Clay, Data and Dirt: Five Thousand Years of Urban Media* (Minneapolis: University of Minnesota Press, 2017); Melody Jue, *Wild Blue Media: Thinking Through Seawater* (Durham and London: Duke University Press, 2020); and John Durham Peters, *The Marvelous Clouds: Toward a Philosophy of Elemental Media* (Chicago: University of Chicago Press, 2015). Other sources that have been touchstones for me in this field include John Durham Peters, *Speaking into the Air: A History of the Idea of Communication* (Chicago: University of Chicago Press, 1999) and Yuriko Furuhata, "Of Dragons and Geoengineering: Rethinking Elemental Media," *Media+Environment* 1, no. 1 (November 2019), https://doi.org/10.1525/001c.10797.

[8] See Mél Hogan, "Big Data Ecologies," *Ephemera* 18, no. 3 (2018): 631–57 and Sean Cubitt, *Finite Media: Environmental Implications of Digital Technologies* (Durham and London: Duke University Press, 2017).

[9] See Rahul Mukherjee, *Radiant Infrastructures: Media, Environment, and Cultures of Uncertainty* (Durham and London: Duke University Press, 2020) and Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet* (Minneapolis: University of Minnesota Press, 2016).

As a keyword, "atmosphere" draws together a range of humanistic approaches both within and beyond media studies. Meteorology and climate science are subjects of consideration in the history of science and science and technology studies, such as in Paul N. Edwards' work on computer modeling and climate data.[10] The concept has anchored recent work in anthropology and geography, where for scholars such as Derek P. McCormack and Tim Ingold, atmosphere encompasses a range of affective and political practices that construe space and the possibilities of navigating through it.[11] For McCormack in particular, thinking with atmospheres entails speculating across a wide range of theoretical and empirical research, as atmospheres otherwise "seem so vague and intangible as to evaporate, becoming inconsequential, while at other [times] they almost collapse under their own weight."[12] Literary studies has seen a profusion of recent work on atmosphere that bridges the world's environmental contexts to its parallel definition as a field of experience, related to literary concepts such as tone and mood. Hsuan L. Hsu, Jayne Elizabeth Lewis, and Jesse Oak Taylor, among others, engage literary histories that demonstrate the importance of environmental atmospheres to the development of aesthetic atmospheres.[13] Literary theorist Hans Ulrich Gumbrecht has linked atmosphere to the Heideggerian concept of *Stimmung*, loosely translated as "mood" or "attunement" to the

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[10] Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge: The MIT Press, 2010).

[11] See Derek P. McCormack, *Atmospheric Things: On the Allure of Elemental Envelopment* (Durham and London: Duke University Press, 2018); Tim Ingold, "The Eye of the Storm: Visual Perception and the Weather," *Visual Studies* 20, no. 2 (October 2005): 97–104, https://doi.org/10.1080/14725860500243953; and Peter Adey, *Air: Nature and Culture* (London: Reaktion, 2014).

[12] McCormack, *Atmospheric Things*, 195.

[13] See Hsuan L. Hsu, "Literary Atmospherics," *Literary Geographies* 3, no. 1 (June 2017): 1–5; Jesse Oak Taylor, *The Sky of Our Manufacture: The London Fog in British Fiction from Dickens to Woolf* (University of Virginia Press, 2016); and Jayne Elizabeth Lewis, *Air's Appearance: Literary Atmosphere in British Fiction, 1660-1794* (Chicago: University of Chicago Press, 2012).

aesthetic qualities of a given work of art.[14] Atmosphere in these aesthetic senses appears less frequently in media studies than in literary studies, and this dissertation in part seeks to bring these two senses into closer contact. Paul Roquet's work on ambient media is a notable exception. In his research on media as technologies of self-regulation in twentieth-century Japanese culture, Roquet lays much of the groundwork for this dissertation's approach to affective atmospheres within a media studies frame.[15]

Computation / Technique

Atmospheric media can take the form of discrete technologies, as is the case with Babbage's steam-powered Engines or the supercomputers that power modern meteorological models. But one of the arguments this dissertation advances is that atmospheric media are also techniques, or ways of doing things with technologies, to paraphrase media theorist Grant Wythoff.[16] Like environmental thinking, technique has become a recent topic of interest in contemporary media studies, where scholarship draws from diverse disciplinary foundations, from the sociological work of Marcel Mauss to the *Kulturtechniken* of German media theory. This intellectual diversity makes it tricky to pin down precisely what media scholars such as myself mean by technique. It might encompass the straightforward use of media technologies (how one operates a computer, for instance), but also the social and material infrastructures underpinning media (a topic that comes to the fore, for example, in my second chapter's focus on techniques for maintaining thermal equilibrium in data centers). For my dissertation, I extend

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[14] Hans Ulrich Gumbrecht, *Atmosphere, Mood, Stimmung: On a Hidden Potential of Literature*, trans. Erik Butler (Palo Alto: Stanford University Press, 2012), 1–22.

[15] Paul Roquet, *Ambient Media: Japanese Atmospheres of Self* (Minneapolis: University of Minnesota Press, 2016), 1–22.

[16] Grant Wythoff, "Extended Technique: New Scholarship on the Uses of Media," *Amodern* 9 (2020), https://amodern.net/article/amodern-9-techniques-technologies/.

Wythoff's definition that "techniques are interpretations of the world around us, arguments about the ways that things can and should be arranged."[17] Time and again, I suggest, computation functions as the underlying argumentative structure for how atmospheric media interpret and organize the world. By computation, I mean a type of calculation that relies on an underlying model or heuristic to guide its process, in essence, an algorithm. I locate computation broadly across this dissertation, whether in the procedural logics of electronic literature, the physical bits of 3D printing, or the style guides that dictate narrative possibilities in weather archives. As a technique, computation structures the "arguments," to return to Wythoff's definition, for the kinds of worlds atmospheric media call into being. The word "argument" is evocative for me in that it provides opportunity to consider counterarguments to how atmospheric media arrange the world. Thus, one way to describe this dissertation's research agenda is that it maps how computational media make arguments about how to arrange the air and what counterarguments are possible against such an arrangement.

In particular, this dissertation argues that technique has particular utility for the study of environmental media, and vice versa, that the study of technique is itself grounded in environmental thinking. Here I draw from John Durham Peters' insight that media "regulate traffic between nature and culture," both in the sense of information moving between the two, as well as how media determine the very categories of "nature" and "culture" more generally.[18] From Peters, I suggest that media are more than devices: they are interpretive frameworks for understanding and shaping the planet. As Jussi Parikka argues, "it is through and in media that

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[17] Wythoff.

[18] John Durham Peters, "Infrastructuralism: Media as Traffic Between Nature and Culture," in *Traffic*, ed. Marion Näser-Lather and Christof Neubert (Leiden: Brill, 2015), 32, https://doi.org/10.1163/9789004298774_003.

we *grasp earth* as an object for cognitive, practical, and affective relations."[19] I want to zero in on this "grasping earth," which I read as both "understanding" and "controlling." One of the conceptual moves this dissertation makes is that framing inquiry around technique allows for more dynamic oscillation across specific atmospheric media technologies, infrastructures, and practices. Take weather forecasting, a subject of my first chapter. Weather forecasting entails concrete media technologies such as satellites, computer programs, and environmental sensors. These technologies operate within a broader media infrastructure oriented around the recording, storage, and analysis of meteorological data, which includes hosts of activities from television broadcasting to data visualization to the preparation of formal climatological reports. And all of these technologies and practices influence practices of daily life under climate change and geopolitical attempts (or lack thereof) at its amelioration. By framing, as I do in my first chapter, my analysis around the media technique of forecasting, I make my central research question "how does computation function as a medium that translates across all these distinct yet interrelated practices?"

How, then, is the study of technique environmental? One answer emerges from German media theorist Bernhard Siegert's work on *Kulturtechniken*, or "cultural techniques," a strain of thinking around technique that is particularly influential to my project. The term originates in German agricultural practice in the nineteenth century, where it referred to what media theorist Geoffrey Winthrop-Young describes as "large-scale amelioration procedures such as irrigating and draining arable tracts of land, straightening river beds, or constructing water reservoirs."[20] These are projects that intervene directly into the earth itself. The term stayed largely confined to

[19] Parikka, *A Geology of Media*, 12, italics mine.

[20] Geoffrey Winthrop-Young, "Cultural Techniques: Preliminary Remarks," *Theory, Culture & Society* 30, no. 6 (November 2013): 2–3, https://doi.org/10.1177/0263276413500828.

agro-engineering communities throughout the twentieth century until media scholars appropriated it in the 1990s and 2000s.[21] At present, theories of cultural techniques extend and revise Friedrich Kittler's argument that media technologies constitute the *a priori* of culture[22] to hold that techniques—strategies, operations, patterns of use, and conceptual activities—generate cultural distinctions as such. To quote Siegert, "humans *as such* do not exist independently of cultural techniques of hominization, time *as such* does not exist independently of cultural techniques of time measurement, and space *as such* does not exist independently of cultural techniques of spatial control."[23] We can develop an example from the word's original sense: the presence of the abstract idea of "civilization" does not drive a town to straighten a riverbed; rather, the cultural techniques of agriculture have material impacts on the terrain that produce the categories of "town," "nature," "civilized," and "uncivilized." In the words of Cornelia Vismann, another prominent contributor to this tradition, "the agricultural tool determines the political act; and the operation itself produces the subject, who will then claim mastery over both the tool and the action associated with it."[24]

The advantage of thinking with technique is not to solve, once and for all, the chicken or egg question of from whence mediation arises. As Liam Cole Young has shown, cultural techniques share familiar resemblances with earlier arguments about technical media's role in

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[21] Here I am indebted to Liam Cole Young's excellent intellectual history of cultural techniques in Liam Cole Young, *List Cultures: Knowledge and Poetics from Mesopotamia to Buzzfeed* (Amsterdam: Amsterdam University Press, 2017), pp. 39–43.

[22] Friedrich A. Kittler, *Discourse Networks 1800/1900* (Palo Alto: Stanford UP, 1992).

[23] Bernhard Siegert, *Cultural Techniques: Grids, Filters, Doors, and Other Articulations of the Real*, trans. Geoffrey Winthrop-Young (New York: Fordham University Press, 2015), 9, italics in original.

[24] Cornelia Vismann, "Cultural Techniques and Sovereignty," *Theory, Culture & Society* 30, no. 6 (November 2013): 84, https://doi.org/10.1177/0263276413496851.

civilizational change.[25] We might also critique the term's interest in categorization and technological determinism, particularly its investment in the concepts of "nature" and "culture," which Donna Haraway has argued are best thought of as one term, "natureculture," inseparably bound and indissoluble.[26] Furthermore, recent strains of thinking in media studies have come to view mediation less as the province of individual devices and more as unfolding processes, what Richard Grusin has termed a kind of "radical mediation."[27] These processual approaches have had the advantage of multiplying the possible subjects of media studies, but run the risk, as the deconstructive turn did for the idea of the "text," of diluting "media" to the point where most *anything* could be viewed a medium. Technique is a potentially similar pitfall. What new insights, then, does technique bring environmental media studies? For my purposes, technique offers a compelling frame for thinking about practices of collecting, sorting, organizing, and processing atmospheric data. They open a window on atmospheric media such as weather forecasting as infrastructural techniques not only in the sense that they entail literal technical armatures—cables, satellites, buildings, legal support structures, the list goes on—but also as continual negotiations between humans, machines, and the planet. In this regard, techniques support an approach to media analysis suitable for ecosystem collapse, when these lines of negotiation falter.

The Environmental Imagination

As definitionally slippery as media are for media studies, so too is the environment for the environmental humanities. As literary critic Rob Nixon observes, the emergence of the

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[25] Young, *List Cultures*, 42.

[26] Donna Haraway, *Manifestly Haraway* (Minneapolis: University of Minnesota Press, 2016), 95.

[27] Richard Grusin, "Radical Mediation," *Critical Inquiry* 42, no. 1 (2015): 124–48.

environmental humanities in the Western academy in the 1990s reproduced many of the blind spots of the twentieth-century environmentalist movement, which imagined nature as something exterior to human culture.[28] The ensuing decades have seen many revisions and reconsiderations of this idea, such as Nixon's own work bringing postcolonialism to bear on environmental thinking, Nicole Seymour's feminist and queer environmentalism, and Joni Adamson and Salma Monani's indigenous environmentalism, to name but a few.[29] These scholars complicate the boundaries between nature and culture, proposing different kinds of continuities across categories too often imagined separate. Yet a definitional question remains: what is the environment, and what does it mean to study it specifically? Here, I am not trying to return to an earlier stage of environmental thinking, but rather to dwell on the question of how the concept of environment emerges in various discourses, and crucially, the role that media play in its emergence. This is the "environmental imagination" of this dissertation's subtitle, which I use to name the cultural and technical processes through which humans mediate their understanding of what "the environment" is and what possible relationships to it are. There are many different kinds of environmental imagination at work across history. The kind that Nixon critiques, for instance, is an imagination deeply embedded within Western notions of coloniality, civilization, and territorial dominance. This dissertation critiques one kind of environmental imagination in particular, which I view as dominant among contemporary Western practices of meteorology and climate science, and consequently among cultural formations that inherit from and respond to

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[28] Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge: Harvard University Press, 2011), 234.

[29] See Nicole Seymour, *Bad Environmentalism: Irony and Irreverence in the Ecological Age* (Minneapolis: University of Minnesota Press, 2018) and Joni Adamson and Salma Monani, eds., *Ecocriticism and Indigenous Studies: Conversations from Earth to Cosmos* (New York: Routledge, 2017).

those practices—namely, that of imagining the atmosphere as computational and thereby programmable.

The phrase "environmental imagination" has numerous critical predecessors for my project. Most notably, the phrase provides the title for eco-critic Lawrence Buell's landmark 1995 study of nature writing's relationship to the emergence of American culture. For Buell, the phrase refers specifically to a particular culture's relationship to the environment, and how such relationships are expressed in literary texts. Buell views the environmental crisis of the late twentieth century (which we have inherited and dramatically intensified in the twenty-first) as "a crisis of the imagination," the "pathologies" of which he locates in American literature, presupposing the United States as the locus of historical technological development and therefore anthropogenic climate change.[30] Eco-critic Ursula Heise uses the phrase in the subtitle to her 2008 monograph *Sense of Place and Sense of Planet*, which revises Buell's thesis on a global scale, attending to the production of ideas of "local" and "global" environments across environmentalist thought.[31] For my part, I am indebted to these and other applications of the phrase in the environmental humanities; however, my work in this dissertation is more focused on the media themselves that produce different structures for understanding the environment, more so than literary or aesthetic representations of the environment itself. In this regard, my use of the phrase is in part a kind of unconscious echo of Matthew G. Kirschenbaum's idea of the "forensic imagination," which appears in the subtitle to his 2008 monograph *Mechanisms*. For Kirschenbaum, the forensic imagination articulates new ways of engaging media, particularly

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[30] Lawrence Buell, *The Environmental Imagination : Thoreau, Nature Writing, and the Formation of American Culture* (Cambridge: Belknap Press of Harvard University Press, 1995), 2.

[31] Ursula K. Heise, *Sense of Place and Sense of Planet: The Environmental Imagination of the Global* (Oxford and New York: Oxford University Press, 2008).

storage media, that attend to their materiality as sites of inscription, wear, and use. He develops a forensic method, "where individualization, wear, . . . persistence over time, . . . and trace evidence collective name the behaviors and phenomena by which we construct legible records of what happened on the other side of present singularity."[32] My environmental imagination similarly turns to *how* media translate atmospheric phenomena into data, materiality, and cultural process, in turn concretizing the horizons of possibility for what atmospheres are or could be.

The environmental imagination, like many of the concepts in this dissertation, is a doubled movement. Media are tools we use to imagine a sense of the world, a sense which in turn circumscribes the limits of (certain kinds of) imagination. Throughout this dissertation, I use rhetorical figures inherited from cybernetics, particularly the feedback loop, to articulate this movement. As cybernetician Norbert Wiener observes, feedback loops are governance techniques: "when we desire a motion to follow a given pattern the difference between this pattern and the actually performed motion in used as a new input to cause the part regulated to move in such a way as to bring its motion closer to that given by the pattern."[33] This dissertation doesn't offer a strong technical argument for the existence of feedback loops across atmospheric media, although such feedback loops conceptually and materially recur across the chapters. Rather, the feedback loop serves as a model for how I argue the environmental imagination operates—and why it is so difficult to imagine beyond as a normative structure. The embeddedness of media in practices of scientific and cultural development strengthen such feedback loops, as the governance of the loop is reproduced across multiple levels of technical coordination. Sociologist and media theorist Jennifer Gabrys provides another way of thinking

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[32] Matthew G. Kirschenbaum, *Mechanisms: New Media and the Forensic Imagination* (Cambridge: The MIT Press, 2008), 251–52.

[33] Norbert Wiener, *Cybernetics, or Control and Communication in the Animal and the Machine*, 2nd ed., 10th print (Cambridge: The MIT Press, 2000), 6–7.

about this concept in her idea of the "becoming environmental of computation." In her study of environmental sensing technologies, Gabrys argues that such sensors do not simply capture information they find out in nature but are rather parts of complex systems of environmental attunement which in turn shape "new subjects of [environmental] experience."[34] These concepts are particularly salient for atmospheres, which resist concrete materialization and foreground affective and cultural attunement.

Over all these works, climate change looms. There is in all of them, including this dissertation, an urgent desire to intervene in some small way into a problem that threatens to destroy the possibility of life on this planet. During the years I have written this dissertation, the United Nations has published fifteen increasingly dire climate reports, which seem time and again to fall on the deaf ears of global leaders. Within such a geopolitical climate, it's easy to feel powerless. I am reminded of Kurt Vonnegut: "During the Vietnam war . . . every respectable artist in this country was against the war. It was like a laser beam. We were all aimed in the same direction. The power of this weapon turns out to be that of a custard pie dropped from a stepladder six feet high."[35] There is a similar desire on the part of literary and media critics to wish that we had the solutions to the world's problems, that we could stem the tide of environmental degradation, anti-democratic movements, and economic immiseration with our analyses of cultural objects. And in many, perhaps most ways, we can't. The world marches on. Yet—and here I have little but the strength of my own convictions and a desire to make my time on this planet of use to my species—I still believe in the power of critique to articulate the conscious and unconscious ways that the world operates, such that those critiques may be of use

[34] Gabrys, *Program Earth*, 267–68.

[35] David Hoppe, "Vonnegut at 80," *Alternet.org* (https://www.alternet.org/2003/01/vonnegut_at_80/, January 2003).

to those with the power to change them. The environmental imagination is a powerful ideological tool, but it is, like all ideologies, fungible. It is my hope that this dissertation contributes even in a microscopic way to revising hegemonic Western relationships to the environment, such that there may still be an environment left for our children.

The Chapters

Each of this dissertation's chapters takes as a structuring focus an atmospheric media technique. In order, they are forecasting, conditioning, respiring, and modeling. These techniques are not exhaustive, and we could imagine many other atmospheric media techniques. However, I have chosen these four for their topical and argumentative progression. They move from techniques of vision, perception, and anticipation (forecasting); to techniques of influence, modification, and feedback (conditioning); to techniques of embodiment, self-regulation, and survival (respiring); to techniques of virtualization, datafication, and construction (modeling). In other words, the arc of these chapters progresses from sensing atmospheres to controlling them. Computation, both in the sense of literal computing machines and more conceptual approaches, sutures these techniques. This progression also allows me to scope the dissertation along particular technical concepts. For instance, concepts from meteorology, a primary focus of the first chapter, support further work on atmospheric conditioning and modeling in subsequent chapters. Similarly, modeling recurs as a theme across the entire dissertation, and receives a full treatment in the final chapter, when the reader is more primed for its overtly technical focus. Methodologically, the chapters share a common denominator of environmental media studies, but each engages specific interdisciplinary approaches suitable to its subjects. Readers will note in the first chapter significant debts to literary studies, specifically the study of electronic literature; in the second chapter, science and technology studies; in the third chapter, media archaeology (and a return to literary criticism); and in the fourth chapter, the digital humanities. These are not siloed approaches, but rather an attempt to allow each chapter to inhabit an atmosphere of its own making.

The first chapter, "Imaginary Forecasts, or the Arts of Atmospheric Media," begins the dissertation with the technique of *forecasting*. In it, I explore the atmospheric media of meteorology through a series of close readings of works of media art that take meteorology's formal languages as points of creative departure. These works are contemporary, dating roughly over the past twenty years, and while multiple in their form and genre all have roots in the practice of electronic literature. They are poet and programmer J.R. Carpenter's 2018–20 interactive web project *This is a Picture of Wind*, book artist and digital humanist Johanna Drucker's 2005–10 speculative chapbook *Subjective Meteorology*, and textual artist Allison Parrish's 2015–19 Twitter bot *The Ephemerides*. I argue that these works' investment in computational techniques such as randomness, repetition, and procedural generation reflects both an attempt to aestheticize the practice of meteorology, as well as responds to meteorology's conceptual insufficiency in the face of ecological collapse and environmental devastation. Furthermore, I argue that these works engage a long media history to meteorology, as each artist connects contemporary computational meteorological practices to older media such as weather diaries, maps, and logs. Across all these works, forecasting functions as a speculative enterprise, one that is at once resolutely material and highly virtual. The virtuality of the forecasting—a conceptual paradox for meteorology itself—permits these artists to imagine models for capturing and processing weather data allied with forms other than digital computation; for instance, poetic verse or graphical juxtaposition.

The second chapter, "Air-conditioning the Internet: Temperature, Security, and the Myth of Sustainability," shifts to the technique of *conditioning*. Its subject is air conditioning, specifically the air conditioning that maintains thermal equilibrium in data centers. Through a case study of the multinational data center company Equinix, whose DC11 data center in Ashburn, VA I was able to tour in the spring of 2019, I argue that air conditioning is a fundamental technology without which the global infrastructure of the internet would collapse under its own heat. This chapter explores both theoretical relationships between computation and cooling as well as specific techniques, such as aisle containment and digital sensing, through which companies such as Equinix maintain stable temperatures in their data centers. More broadly, this chapter links these air conditioning practices to anxieties about the sustainability of cloud computing under the sign of climate change. I demonstrate how for data center companies such as Equinix, climate change is principally conceived as a security threat, against which air conditioning serves as a practice of spatial and thermal control. This control, so the narrative goes, is what allows data center companies to claim resilience in the face of climate change, even as those very same strategies of air conditioning contribute to global thermal collapse. This chapter is also where I develop further the cybernetic concepts of feedback that support my idea of the environmental imagination: conditioning is thus a broader conceptual framework for thinking about how media construe models of the atmosphere and then attempt to bring air in line with those models.

The third chapter, "Collective Tissue: Media Toxicity and Respiratory Temporality," moves from global infrastructures to the vulnerable human body through the technique of *respiring*. My interest here is in pollution and the environmental costs of atmospheric media as they register on the body. The primary subject of this chapter is 3D printing, which I engage media archaeologically, tracking the chemical materialities of its plastic filament, microprocessors, and cultural practice. I also take a detour to a science fiction story by author Ted Chiang titled "Exhalation" (2008), which concerns a race of humanoid robots that are powered by air as they face the prospect of their own entropic destruction. My goal in these heterogeneous readings is to argue that atmospheric media introduce new temporal relationships to the lived experience of media's toxicity, what the chapter terms "respiratory temporality." Breath, I argue, provides a model for understanding how atmospheric media engage cyclical and rhythmic temporalities, which in turn permit their particular kinds of pollution to insinuate themselves deeper into the body and into environments. Atmospheric media imperil the breath even as they rely on it to function. The arc of the chapter follows a breath near a 3D printer as it enters the nose, progresses to the lungs, and then lodges in the durational residue of the body. This arc allows me to engage sensory topics, in particular the role of smell as an undertheorized and atmospheric sense for doing environmental media studies. Finally, this chapter operates autotheoretically, as I reflect throughout on how my own body becomes involved as an environmental media studies researcher within the ecological operations of 3D printing.

The fourth and final chapter, "Machine Reading for Atmosphere: Modeling, Affect, and Weather Records," returns to the meteorological concerns of the first chapter through an analysis of the technique of *modeling*. It begins from an unresolved conceptual challenge posed in the first chapter: namely, how does the affective experience of severe weather enter official records? To answer this question, the chapter engages a case study of the *Storm Events Database*, a record of severe weather in the United States from 1950 the present day maintained by the National Oceanic and Atmospheric Administration (NOAA). Among its many data, the *Database* preserves narrative records of severe weather events, ranging in length from single sentences to hundreds of thousands of characters. To analyze these narratives, I turn to techniques from natural language processing termed "sentiment analysis," which attempt to articulate the presence and quality of emotion in a given text. Through a sustained engagement with these two subjects, the *Database* and sentiment analysis, I argue that these media, like all the atmospheric media I explore in this dissertation, share modeling as a common substrate. Modeling, I argue, is fundamentally a technique of interpretation; to create a sentiment analysis model suitable to interpreting the *Database* is then to make an epistemological argument about affect's relationship to textuality broadly and weather records specifically. As such, this chapter concludes the dissertation with a number of methodological developments grounded in the digital humanities, such as a critical code study of the source code of TextBlob, a particular sentiment analysis tool I use throughout the chapter; and an attempt to devise my own sentiment analysis model suitable to analyzing the *Database*, which I also reproduce in full in this dissertation's appendix.

I conclude the dissertation with a brief postscript on the political salience of atmospheric media, particularly as I have seen it unfold over my time writing this dissertation, which has been marked by the Trump administration, covid-19 pandemic, and a rapid increase in environmental instability and severe weather. Atmospheric media are not new concepts, but their study has, in my mind, never been so urgent as in the present moment. To this end, it is my hope that readers of this dissertation leave both with a renewed appreciation for the integral role of the air in computing cultures, and vice versa, the influence that computing has had over our species' relationship to the air. In a time where no breath can be taken for granted, we carry forward a great debt to future generations: to learn and to practice new ways of understanding and sustaining that beautiful, fragile envelope of the sky.

Chapter One

Imaginary Forecasts, or the Arts of Atmospheric Media

> No one understands weather anymore. You might as well look at shadows or listen to crickets!
> — From *Ponyo* (2008), directed by Hayao Miyazaki

Canadian poet and programmer J.R. Carpenter begins her 2020 poetry collection *This is a Picture of Wind* with a short cycle titled "The Beaufort Poems."[36] Each of these four concrete poems comprises thirteen words or phrases set in progressively larger font sizes as the reader works their way down the page (fig. 1). They are words evoking the experience of the wind and their sizes match their intensity. The first poem begins with "still" and finishes with "broken"; the fourth opens with "a lull" and climaxes in "a torment." These are poems of aerial crescendo, the wind rising and crashing over the page. Reading them aloud, I have the feeling of inhabiting a growing aerological intensity. In the third poem, successive fricatives in "flat / faint / flutter" test my breath control, while in the fourth, repeated gerunds ("a quickening / a freshening / a keening") collapse into the heap of the final undeclined "torment." In their final lines, "The Beaufort Poems" resolve into portraits of the wind's damaging effects on the physical world. "Broken," "violence," and "ruinous" make the wind's force visible in the wreckage it leaves behind. Carpenter writes in *Wind*'s acknowledgements that her work on the project began with her own experience of devastating windstorms in the southwest of England in the winter of 2014, where she lived at the time. That season was notably stormy, with repeated Atlantic cyclones hammering the vulnerable Cornish coast. The result was historic wind damage and substantial flooding. A team of meteorologists at Plymouth University, who conducted a 2016 study of that storm season, note that it tested U.K. scientists' and the government's abilities to predict and

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[36] J. R. Carpenter, *This Is a Picture of Wind* (Sheffield: Longbarrow Press, 2020), 27–33.

respond to severe weather, given that "the paucity of observational data collecting" due to the weather's unexpected severity "[required] modellers to extrapolate from less extreme conditions," contributing further to an unprepared disaster response.[37] Like a meteorological weather model, Carpenter's poetic project in "The Beaufort Poems" is one of representing the atmosphere in textual and informatic forms. There is a "paradox," Carpenter writes, "presented by attempts to evoke through the materiality of language a force such as wind which we can only perceive indirectly through its affect."[38] It is a fitting place to begin this dissertation's articulation of atmospheric media: how does a poet, or artist, or really any thinker interested in the sky's relationship to human culture, grasp the ungraspable wind?

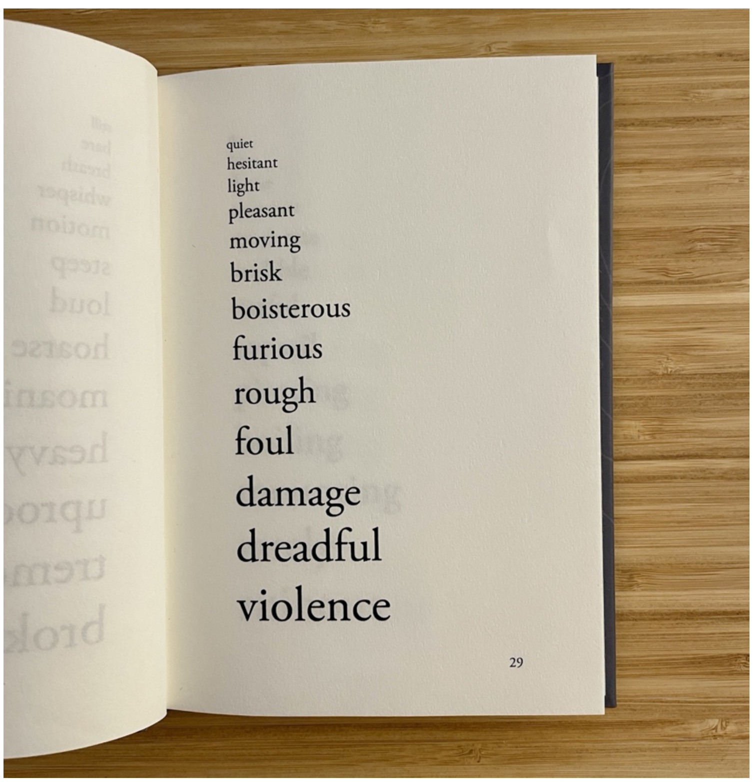

Figure 1. A page from "The Beaufort Poems," from This is a Picture of Wind *(2020) by J.R. Carpenter.*

[37] Gerd Masselink et al., "The Extreme 2013/2014 Winter Storms: Hydrodynamic Forcing and Coastal Response Along the Southwest Coast of England," *Earth Surface Processes and Landforms* 41, no. 3 (2016): 378–91, https://doi.org/10.1002/esp.3836.

[38] Carpenter, *This Is a Picture of Wind*, 124.

"The Beaufort Poems" take their name from the Beaufort scale, an invention of Francis Beaufort, a nineteenth-century hydrographer in the service of the British Royal Navy. Originally designed to help sailors estimate and record wind speed at sea, the scale has since been adapted to land use as well and remains a part of meteorologists' toolkits to this day. The Beaufort scale is an empirical metric, which means that instead of precise instrumental measurement it hinges on an individual's observation and judgment of the wind's effects. Like Carpenter's poems, it comprises thirteen classes from zero to twelve, with associated customary observations to aid classification. Class three, "gentle breeze: leaves and small twigs in constant motion; wind extended light flag"; class seven, "near gale: whole trees in motion; inconvenience felt when walking against the wind"; class twelve, "hurricane: devastation."[39] Beaufort invented his scale to solve what he saw as a crisis of disorganized data in the British Royal Navy. One officer's "strong breeze" might be another's "gale," making meaningful comparisons across time and space challenging.[40] Carpenter's poems remediate this scale, producing a poetic response to the scale's own attempts to "picture wind" with language and numbers. The Beaufort scale itself reads like a found poem, full of objects such as "dust" and "loose paper," twigs breaking off trees, and euphonious phrases like "fairly frequent white horses."[41] Carpenter preserves this attention to language, but also, through the piecewise increase of font size, its informational substrate. These are poems of data as much as words.

Carpenter's directive to "picture wind" is an apt summary of my project in this first chapter, which begins my study of atmospheric media with the deceptively simple question:

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[39] NOAA Storm Prediction Center, "Beaufort Wind Scale," *NOAA Storm Prediction Center* (https://www.spc.noaa.gov/faq/tornado/beaufort.html, No date.).

[40] For further reading on the media history of the Beaufort scale, see Etienne Turpin, "The Beaufort Scale of Wind Force: This Land of Forces," in *The Work of Wind: Land*, ed. Etienne Turpin and Christine Shaw (Berlin: K. Verlag, 2018), 9–26.

[41] NOAA Storm Prediction Center, "Beaufort Wind Scale."

"how do we see the wind?" This is a question taken up by diverse intellectual projects across human history, from ancient mythopoetics that imagined the wind as tumultuous gods, to the modern sciences of meteorology and atmospheric fluid dynamics, to creative artists such as Carpenter, and to anyone who has stood outside and asked themselves which way the wind was blowing and what that might augur for the weather to come. Throughout that history, humans have turned to media to assist the work of aerial perception, from objects such as weathervanes and balloons, to conceptual techniques such as the Beaufort scale, to the computational work of atmospheric modeling that powers the modern forecast. How to see, sense, understand, and predict the wind are questions for media studies as much as meteorology. They are particularly so for how they bear on culture, both historically and in our climatologically imperiled present. This chapter approaches these questions through a study of key works by contemporary artists who take the weather and its mediation as their subjects. In doing so, it articulates a formal language that undergirds these expressive attempts to picture the wind. I argue that these languages, which rely on computational techniques such as randomness, repetition, and procedural generation, are strategies through which these artists grapple with a mediated experience of the atmosphere. These questions come to the fore most prominently when these artists engage the work of forecasting the weather, a speculative project that has always combined elements of the arts and sciences.

This chapter's keyword for understanding atmospheric media is *forecast*. As both noun and verb, something meteorologists produce to predict tomorrow's weather and the act of prediction itself, forecasting is a shared formal framework and conceptual subject for the works I explore in this chapter. It is also a fitting place to begin an examination of how such works mediate atmospheres, whether as text, image, or computer models. In this chapter, as in this dissertation more generally, data function as conduits for these acts of mediation. Data are a shared interest of both the media arts and meteorology alike, providing fertile ground for poetic, graphical, and computational expression, as well as occasions to ask questions about how the collection and processing of atmospheric data construe our understanding of the environment. As media scholar Janine Randerson notes, the computational turn in contemporary meteorology has given artists access to the same tools and datasets as scientists, "diminish[ing]" the distance between the two practices.[42] For some, this might entail the direct use of weather data, as Carpenter does in her interactive web version of *Wind*. Others are inspired by the informatic languages of forecasting, as book artist and digital humanities scholar Johanna Drucker does in her experimental project *Subjective Meteorology* (2005–10), which I also discuss in this chapter. These artists share with their scientific counterpoints an interest in how to compute the sky: the technical mediation that occurs in the movement from atmospheric phenomenon, to data point, to weather model, to textual or graphical representation. In their hands, the forecast becomes a creative object. In a geohistorical moment when our experience of the atmosphere has perhaps never felt more immediate, bearing down on all aspects of living, that experience has also never been more *mediated*, processed through a range of technical activities. This is where our environmental imagination begins: in the forecast.

Meteorology, the study of atmospheric dynamics and weather forecasting, is itself entangled with media. John Durham Peters argues that even before the advent of recognizably modern meteorology, with its sensors and computers, humankind long looked for signs in the sky to communicate its tenor, such as clouds, stars, and migrating animals.[43] Medieval Europeans

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[42] Janine Randerson, *Weather as Medium: Toward a Meteorological Art* (Cambridge: The MIT Press, 2018), 44.

[43] Peters, *The Marvelous Clouds*, 165.

turned to the zodiac to determine long-term weather cycles, predicting decades in advance (although to rare success) droughts, floods, and famines. Historian of science Paul N. Edwards recounts how contemporary meteorology took shape on the battlefields of nineteenth-century Europe, where newly developed scientific methods of atmospheric fluid dynamics met military desires for more accurate forecasts.[44] In the crucible of continental combat, Edwards writes, physicists such as Vilhelm Bjerknes and Lewis Fry Richardson conceived of an atmosphere at war with itself through the endless battle of discontinuous and clashing "fronts" of hot and cold air. Advances in communications technologies such as telegraphs and unmanned balloons made capturing and transmitting atmospheric data possible on new scales, leading to the emergence of state-run meteorological services. Digital computation also addressed the problem of meteorology's mathematical complexity, allowing for fiendishly difficult forecasting equations to be solved before tomorrow's weather actually happened. One of the first tasks put to the supercomputer ENIAC in the 1950s was crunching data associated with weather simulation.[45] Without this proliferation of digital sensors, networked supercomputers, and technical interfaces, as Christian Anderson and Søren Bro Pold argue, meteorology would have no collective purchase on "the weather" as a discrete entity nor tools for its forecasting.[46]

The media of forecasting have in turn inspired artists who engage the cultural potentials for meteorological instrumentation. The three I have selected for this chapter—J.R. Carpenter, Johanna Drucker, and Allison Parrish—share in particular an affinity for the computation that undergirds contemporary forecasting. There are several qualities these artists share: all three are

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[44] Edwards, *A Vast Machine*, 90.

[45] Thomas Haigh, Mark Priestley, and Crispin Rope, *ENIAC in Action: Making and Remaking the Modern Computer* (Cambridge: The MIT Press, 2016), 214–20.

[46] Christian Ulrik Andersen and Søren Bro Pold, *The Metainterface: The Art of Platforms, Cities, and Clouds* (Cambridge: The MIT Press, 2018), 153–54.

actively working today, with the pieces I analyze dating back only to the 2010s, if not more recently; all three are allied to some degree with the field of electronic literature and have participated in annual conferences of the Electronic Literature Organization; and all three engage textual media to a substantial degree, particularly poetic alongside computational forms. Even still, like the atmosphere itself, none of their works that I examine are easily contained within formal and generic categories. Carpenter's *Wind* traverses formats, existing as a handmade chapbook, interactive website, published volume, and Twitter bot. Drucker's *Subjective Meteorology* takes the form of a series of conceptual artists books, drawings, and scholarly essays exploring the self-consciously impossible work of depicting personal mood through the formal languages of meteorology. And Parrish's *The Ephemerides* (2015–19) unspools procedurally generated poetry through a Twitter bot, imagining in turn the lonely consciousness of a satellite flung into deep space. These are projects neither exactly analog nor digital, but rather a blurring of the two. Furthermore, they are all ones that appropriate the techniques and technologies of meteorology in the service of imaginative work: weather diaries for days that never happened, impossible models, poetry from machines that can neither think nor speak as such yet structure humankind's capacity for both. These imaginative acts, I argue, are a kind of forecasting, one that maps together the arts and sciences of atmospheric media.

The works I discuss in this chapter are particularly well-suited in their technological hybridity to thematize a media history of forecasting that exceeds the emergence of digital computation as such. There is a media archaeological quality to these works as they reach across the decades, even millennia to propose continuities between recognizably modern forecasting and more unusual forms of proto-meteorology. Some propose genealogical continuities, as Carpenter does with her remediation of historical weather diaries in *Wind*. For Carpenter, the technique of observing and recording the weather at regular intervals interleaves with the automated work of wind speed sensors. Questions of subjectivity emerge: are those sensors more "impartial" than their human equivalents? Or do they encode new relations and potentialities in their technical regularity? Others incorporate techniques for encountering atmospheres from beyond meteorology alone. In Parrish's *The Ephemerides*, the techniques of procedurally generated poetry collide with traditional poetic forms such as Japanese *haiku* to imagine the impossible inner monologue of an interplanetary satellite. Procedural generation, a computational technique for creating text through purely automated means, becomes a technique through which to "voice" media technologies otherwise imagined unable to "speak." Paradoxically, these works also address how noisy atmospheric media can be: sensors that capture and transmit information constantly, that overflow systems and humans alike with ever-changing and ever-updating data, and that saturate the air with signals.

Over meteorology's history, forecasting has typically happened one of two ways. The first is that of historical extrapolation, in which weather patterns are assumed to be consistent and stable over time, and that past performance in effect will guarantee future results. In this approach, forecasting entails collecting historical data about a region's weather and making educated guesses based on those past patterns. Given atmospheric volatility, such predictions are not especially accurate. The second approach, now dominant in contemporary meteorology, relies on virtual computer models of atmospheres, out of which meteorologists derive probability statements for what the weather may be like, and when, and where. This approach has the advantage of being significantly more accurate, and as Andrew Blum notes, the reliability of the daily forecast has increased dramatically over the twentieth century with the advent of such computer models.[47] However, the reliance on modeling also presents meteorology with a fundamental paradox, one not dissimilar from Carpenter's: it is impossible to blanket the planet fully with the sensors required to afford a total picture of a single place's atmosphere at any given time, let alone throughout the planet. Meteorologists address this paradox by maintaining multiple different registers of computer models, some of which simulate the atmosphere from pure theory, some of which incorporate data from the physical world, and all of which scientists can address at a higher "resolution" than they can the actually existing planet. In short, contemporary meteorology's insights derive not only from observations of the world, but also—and even *more so*—from virtual models. These models are mathematical, epistemological, and political in equal measure, with different models making different assumptions about underlying theory and the interactions between phenomena. Through my analysis in this chapter, I frame forecasting's central paradox as fundamentally a question of mediation. How do data move from the "real" to the "virtual" world? Which phenomena make it into these models and which are left out?

This chapter proceeds in a series of close readings on how these works of media art thematize and interrogate the cultural and technological project of atmospheric forecasting. In the first, I explore Carpenter's *Wind* across its multiform media registers, with a particular focus on the interactive website version. I map how the project changes across media and how its investment in meteorological media forms such as the weather diary shifts in its movement from page to screen and back to the page. In particular, I attend to the role that computational randomness plays in Carpenter's project, arguing that randomness becomes a technique for imagining the wind where other scientific instrumentation fails. Questions of the forecast's basis

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[47] Andrew Blum, *The Weather Machine: A Journey Inside the Forecast* (New York: Ecco, 2019), 3.

in modeling and representation extend into my second section, on Drucker's *Subjective Meteorology*. Here my focus shifts from textual to graphical media: Drucker's work is a deliberately fanciful attempt to develop a pictorial system for mapping individual subjectivity by appropriating the formal languages of meteorology. In doing so, I argue, she reveals conceptual limits underpinning forecasting's relationship to data visualization, and charts new directions for the incorporation of subjectivity within meteorological modeling. Finally, I shift my attention to what lies beyond the atmosphere in outer space through a reading of Parrish's *The Ephemerides*. Here, I explore how Parrish's Twitter bot uses procedural generation to characterize satellites as data generators rather than simply data collectors. The virtuality of the forecast then begins not with the computer model, but rather in the very instant of atmospheric observation through technical means. I close the chapter with a summative meditation on forecasting as a keyword for thinking about atmospheric media and presage its development in subsequent chapters in this dissertation.

This is a Picture of Wind

"A strange pocket of calm" greets me when I load J.R. Carpenter's interactive website version of *This is a Picture of Wind* on my iPhone 12 (fig. 2). The phrase is soon replaced by "often overcast / smoke drifts," for Carpenter's "weather diary for smartphones," as she terms it, is as changeable as the breeze. The top of the screen displays a historic meteorological map of the southwest of England, around Plymouth, which was Carpenter's home during the writing of *Wind*. Plymouth and its winds burrow deep into this website-diary-poem, as wind speed velocity data drawn in semi-real time powers the random number generator that flips its phrases around. "Fine weather," "dreary hues," and "a sea of fallen leaves" pass by on my screen, as a small note in monospaced font tells me that the wind is blowing at 2.74 miles per hour. Below these data lie the bulk of the work itself: thirty-four short texts laid out in a calendar grid, month stacked over month, forming almost three years' worth of words. I am writing these sentences in October 2021 (it feels important when thinking about *Wind* to note my own situation, the time and space, the ground and sky) and the three texts that greet me are full of autumn. Phrases collide in clipped succession, periods interrupting what otherwise might scan as sentences: "Sea air. As such. Is not necessarily moister. In the middle of the day." Throughout, Carpenter eschews the sentence for the fragment, all the better to fit in the limited space of the grid. Or perhaps letting the wind rustle and blow sentences apart, scattering leaves murmuring as they fall from trees, better *pictures* the wind.

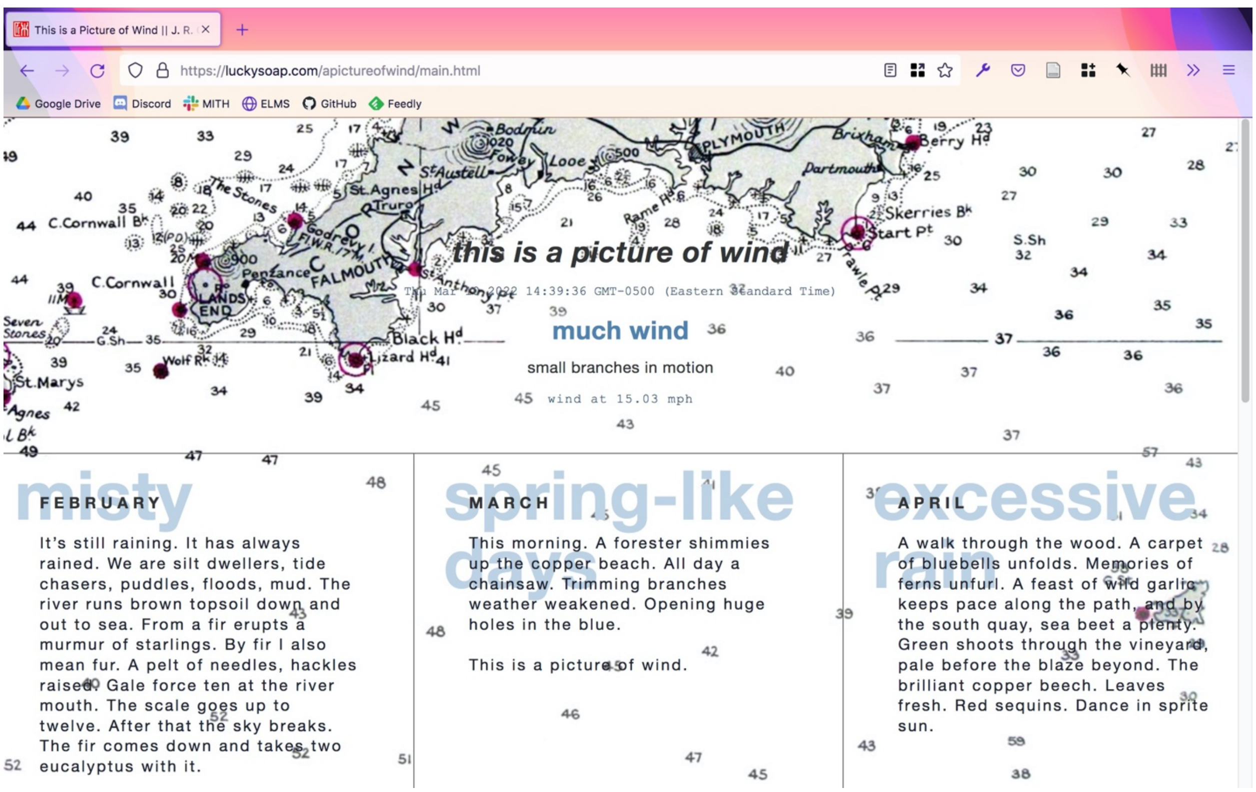

Figure 2. A screenshot of the website version of This is a Picture of Wind*, taken on the author's computer.*

I read Carpenter with the forecast on my mind. A writer and programmer, Canadian-born yet U.K.-based, committed maker of (deep breath) "maps, zines, books, poetry, short fiction, long fiction, non-fiction, and non-linear, intertextual, hypermedia, and computer-generated narratives," according to her official bio, Carpenter is a tricky artist to grasp—and I suspect she would prefer it that way. Her creative practice returns time and again to the natural world and humanity's media for navigating and making sense of it. Environmental media have become central to her more recent output, from *The Gathering Cloud* (2017), a website of hendecasyllabic verse and collage images on the materiality of cloud computing, to her first full-length poetry collection *An Ocean of Static* (2019), which uses the linguistic forms of computer programming to delve into cultures of ocean navigation. *Wind* similarly spans media. Originally conceived as a small zine circulated among friends (fig. 3), Carpenter expanded the project to a fully-fledged website in 2016 and has subsequently remediated the latter into a Twitter bot and physical volume. Much of the text is shared across versions and my primary analytical subject in this section is the website. But slippage between and across media—how texts render on page and screen—is core to her poetic project.

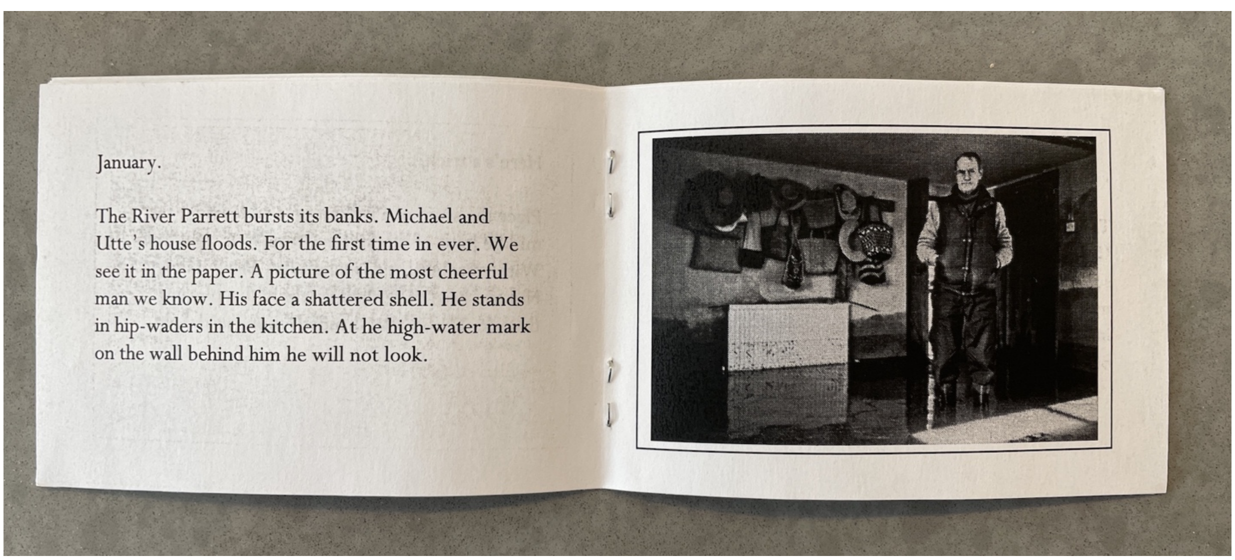

Figure 3. The original zine of This is a Picture of Wind*, reprinted in 2020. Author's copy.*

In her introduction to *Wind*'s print version, Johanna Drucker describes Carpenter's project as one of "realiz[ing] that the detailed observations essential to the construction of understanding grasp only part the inexhaustible phenomena."[48] Put another way: the wind evades its picturing. Carpenter's project in *Wind* is nothing less than exploring meteorology's fundamental informational paradox, that the complexity of atmospheric systems exceeds current human ability to record, analyze, and model it. Yet the drive to mediate the atmosphere still remains. On the one hand, *Wind* is a poetic mediation of the weather, grounded in a specific place, time, and medium. But on the other hand, it is a real-time weather diary itself, one that deploys live data streams to power the code of its operation. The weather diary is an ancient atmospheric medium, whose roots stretch back to regular celestial observations and omens recorded in Mesopotamian courts int he first millennium BCE.[49] From these astronomical and astrological roots, weather diaries became more systematic accounts of what we now regard as meteorological—rather than astrological—phenomena in the eighteenth and nineteenth centuries. *Wind* is a poetic project that shares this scientific impulse, and indeed much of its instrumentation, from wind sensors to the textual media of meteorological standardization such as grids and dates. In doing so, it proposes computational continuities across this long history of atmospheric media, locating in the textuality of the weather diary latent digital impulses that come to the fore in contemporary meteorology. In this section, I position *Wind* within this atmospheric media history, but I also investigate the computational techniques, in particular randomness, that Carpenter deploys as part of her larger investigation into meteorology's informational paradox. In randomness, which in fact powers *Wind* as much if not more than

[48] Johanna Drucker, "Dynamic Poetics: J.R. Carpenter's 'This Is a Picture of Wind,'" in *This Is a Picture of Wind* (Sheffield: Longbarrow Press, 2020), 11.

[49] Liba Taub, *Ancient Meteorology* (London: Routledge, 2003), 17.

actual meteorological data, Carpenter finds a computational and poetic analogue to the supposed ungraspability of the atmosphere.

Befitting an atmospheric medium, the genre conventions of weather diaries are far from fixed. Reading *Wind* provides us some guideposts. As with any diary, its observations are keyed to specific points in time, in this case, that of the month. They proceed chronologically forward in calendar time. Carpenter visually combines the forms of diary and calendar, suturing them through her choice of the grid as an organizational schema.[50] Her observations themselves tend not to run very long, focusing on a few regularly repeated pieces of information, such as cloud cover, precipitation, and wind speed. Complete sentences are scarce, contributing to the feeling of brief observations jotted off in the moment. There is, as with "The Beaufort Poems," a sense of taxonomical compression throughout *Wind*, with repeated images and environmental descriptors signaling both consistency and perhaps a knowing indulgence of cliché. Frost, snow, clear sky, lilacs, mists, excessive rains, sultry, mossy: the repeated images both ground the prose poems within a sense of bounded time and place but also within an organizational framework, as though Carpenter were developing her own private Beaufort scale for guiding her attention.[51] After all, experience only becomes data when mediated through form. The sentence fragment and vocabulary compression are textual techniques for such mediation. These techniques further remediate textual forms of weather recording, from the calendar to the fragment. They also engage a computational substrate underlying these textual forms, as if to say to the reader, "look, there were always data underneath, even on the page." Forecasting, even in fractured poetry, is a

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[50] For more on the grid as a technique of atmospheric mediation, see Jeffrey Moro, "Grid Techniques for a Planet in Crisis: The Infrastructures of Weather Prediction," *Amodern*, no. 9 (April 2020), https://amodern.net/article/grid-techniques/.

[51] This theme of atmospheric media's capacity to orient attention will be discussed in further depth in chapter four.

way of ordering the world and extrapolating predictions from it, a project it shares, in Carpenter's work, with language.

While the thirty-four monthly entries that comprise the bulk of *Wind* are fixed and unchanging, much of the rest of the work appears to shift in response to live weather data. Underneath the title ticks a clock of the current user's time in a monospaced font. Two phrases below shift in jerky rhythm, sometimes changing simultaneously and other times phasing against each other. Each grid square features a large, translucent phrase ("sleet," "clear," "a gale of wind by night") that shifts as well behind the fixed black text of the monthly entries. *Wind* is a web-based work and the bulk of its operations happen client-side, which is to say through scripts running in the user's browser rather than on a separate web server. This means that by using the web developer tools built into most modern browsers, one can read much of *Wind*'s code.[52] While the site's scaffolding is written in straightforward HTML and CSS, the majority of its computational work happens in Javascript. Viewing the work's page source provides insight into how Carpenter organizes and categorizes the phrases that flash across the screen. The two phrases underneath the time in the page's heading are tagged "randomThisMonthMessage" and "beaufortDescription," respectively. This means that the larger blue text comes from an array of possible phrases unique to each month of the year, varying the site not only with data but also time. One can read all of the possible monthly phrases in a Javascript file titled "month-messages-data.js," which comprises over eight hundred entries. A separate Javascript file, named "main.js," controls the selection of the phrases. As it turns out, these are chosen entirely at random, without regard for weather data, using a function aptly named "randomPicker." This is also true of the monthly phrases set behind each entry, which pull from the same list.

[52] I have done so using Firefox Developer Edition, version 94.0b3.

How then does live meteorological data factor into *Wind* if the majority of its phrases are chosen at random from a predetermined array of entries? The answer is in the two small phrases at the top of the page: the wind speed and "beaufortDescription." The code that selects the latter is located in a file named "library.js." Using a PHP script named "weather.php" (which is inaccessible to readers, as it is the lone piece that operates server- rather than client-side), Carpenter fetches wind speed data from 50.375456°N, 4.142656°W—the North Cross Roundabout in the center of Plymouth, U.K.[53] She then passes the integer through a function playfully named "beaufortify," which sorts the speed into one of thirteen categories corresponding to the Beaufort Scale. These categories match another file of phrase arrays named "beaufort-descriptions-data." As with the monthly phrases, Carpenter then pulls from pre-written arrays (around four hundred possible options) at random to populate "beaufortDescription." The Beaufort Scale thus becomes one more structuring technique for *Wind*, albeit one only legible at the level of source code. All told, a relatively small portion of *Wind* actually responds to live data, although the constantly regenerating phrases lend the impression otherwise. Its forecast is more a function of computational randomness than live wind speed.

Randomness is a tricky quality to ascribe to the weather. On the one hand, there are few systems less random than climatology, which proceeds through mathematical equations, rigorously recorded historical data, and exhaustive weather modeling to produce its predictions. Yet on the other hand, none of these media are capable of determining with precision what the weather tomorrow, or next week, or next year will hold. The "special climatology" of global

[53] Because PHP works server-side, it's impossible to know exactly which service Carpenter is using. My best guess, based on the names of the variables the script returns, is that she uses the Dark Sky weather API.

warming, to appropriate a phrase from philosopher Peter Sloterdijk,[54] suffuses daily meteorological experience with further randomness as once predictable patterns break down. Seen within this frame, *Wind*'s aleatory functions are not simply a clever programming trick, but rather a reflection of the experience of atmosphere under the sign of climate change. In *Wind*, there are three intelligences at work: Carpenter, who wrote the code and the fixed texts; the code itself, which sorts and displays her texts at random; and the wind sensor in Plymouth, which renders the environment into data. Together, these human and nonhuman intelligences produce imaginary forecasts, unfolding meteorological moments, none of which are "real" but all of which occupy a unified conceptual field of possibility. The juxtaposition of fixed and shifting text influences the meaning of both. Is an entry, for instance, set before "strong frost by day" or "clear"? Each entry prognosticates on the possibilities of the wind as much as represents a poetic impression of Carpenter's speaker as diarist. If the weather diary is an atmospheric medium of recording meteorological time, then we can call a medium of speculating meteorological time a *forecast*.

Carpenter's commitment to randomness varies across *Wind*'s remediations. In 2020, Carpenter released a print version of the project through Longbarrow Press, an independent English publisher. Here, she introduces new sets of formal categorizations for her texts beyond the tags of the website version. The volume comprises five main sections: "The Beaufort Poems," which remediate the data arrays in "beaufort-descriptions-data.js"; three main sections, titled "A Year at Tottenham," "A Year at Sissinghurst," and "A Year at Sharpham," respectively, which reprint the monthly entries from the website; and "The Month Arrays," which reprint "month-messages-data.js," with several omissions and additions. Notably, none of these places

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[54] Peter Sloterdijk, *Terror from the Air*, trans. Amy Patton and Steve Corcoran (Cambridge: Semiotext(e), 2009), 47.

are near Plymouth, although they are scattered about England more generally. This in turn destabilizes *Wind*'s sense of grounded geography. The print edition's appendix also sheds light on the textual sources for these monthly entries, which incorporate found language from a nineteenth-century treatise on meteorology, the writings of Vita Sackville-West (Virginia Woolf's lover), and a previous Twitter project by Carpenter titled @theriverdart. None of these pieces of information are strictly necessary for interpreting *Wind*'s website version, but taken together they constitute a significant refraction of its original project away from a quasi-individual diaristic feel and towards textual composite and collage. Yet paradoxically, titling each section "A Year at [Place]" *intensifies* the diaristic quality of the texts even as Carpenter's appendix destabilizes it. We cannot judge the print version by the standards of the electronic version, for they are two distinct projects. Nevertheless, they mark an intellectual progression on the part of Carpenter, as some aspects of the work—such as randomness—fall away, while others—such as point of view—become more central.

I first encountered *Wind* not in its website or print version, but rather as a Twitter bot, @apictureofwind, which Carpenter has been running since 2017. Every six hours, the bot tweets a series of cryptic phrases, modeled after the style of the web version's monthly entries:

> A low sun after some white cloud. The sound of a radio hangs over the foreseeable future. The river flat calm. #thisisapictureofwind (2:01 PM · Nov 12, 2021)
>
> The sky alive with scent. A sigh. Honeysuckle in bloom. The river running high. #thisisapictureofwind (8:01 AM · Nov 12, 2021)

> The sky a blank slate. Smoke rises vertically. Honeysuckle in need of attention. The river quicksilver. #thisisapictureofwind (2:01 AM · Nov 12, 2021)[55]

The source code to @apictureofwind is unavailable, but the metadata associated with each tweet indicates that Carpenter uses an interface named Cheap Bots Done Quick, which allows users to automate Twitter bots using a scripting language called Tracery. Bots powered by this service tend to function just as the main site of *Wind* does, with pre-written arrays of phrases populating fixed syntactical structures. Disarticulated from any chronological structure, @apictureofwind condenses *Wind* down to its most aleatory sense, spinning out (at the time of this writing) 5,408 different "pictures of wind." Taken together, these remediations complicate the function of weather data in a work that simultaneously relies on it as a poetic conceit yet eschews it for much of its operations. It forecasts from pure imagination rather than information. However, even that imagination seems to capture something essential about the experience of weather and indeed weather data: their constancy, repetition, and cyclical nature; but also their capacity of surprise and disturbance. Describing the weather instantiates it; indeed, it is the only way to see the weather *as* the weather. Each miniature forecast in *Wind* is a set of weathers that may have been and weathers that might yet be. Their virtuality is of no consequence. They are no less virtual, after all, than the records and forecasts of meteorology, which are shaped by manifold media techniques and technologies. These are pictures of wind, real or imagined, because what matters is the work of picturing.

[55] Links to these tweets, in order:
https://twitter.com/apictureofwind/status/1282026539224309761,
https://twitter.com/apictureofwind/status/14591442683295457300,
https://twitter.com/apictureofwind/status/1459053617856462850.

Subjective Meteorology

The pathetic fallacy, coined by Victorian literary and art critic John Ruskin, is an aesthetic conceit whereby a representation of the natural world in art reflects back the perception of human emotion onto a character or observer. For Ruskin, “an excited state of feelings . . . produce[s] in us a falseness in all our impressions of external things”: we might describe storm clouds as sullen or flowers laden with dew as weeping for lost lovers (to paraphrase Ruskin’s own analysis of Alfred, Lord Tennyson’s poem “Maud” [1855]).[56] While the modern sense of the word “fallacy” as flawed logical reasoning suggests that Ruskin is maligning this conceit, he is in fact observing neutrally how the definitionally “false” equivalence between human emotion and the natural world opens new avenues for the poetic expression of both. The pathetic fallacy, as a media technique of subjectivity, frames book artist and digital humanities scholar Johanna Drucker’s 2005–10 experimental project *Subjective Meteorology: Dynamics of Personal Weather*. In it, she devises a graphical system for the notation of subjective emotional experience modeled after the formal languages of meteorology. *Subjective Meteorology* comprises multiple editions of short, self-published artist’s books, alongside a critical essay on the project collected in Drucker’s 2009 book *SpecLab: Digital Aesthetics and Projects in Speculative Computing*. The artist’s book contain brief essays on the project’s conceptual and theoretical bases, descriptions of the system itself, “weather scenarios,” or drawings putting the system to use, further notations on individual graphical elements, and preliminary notes towards the translation of the drawings into an interactive digital program.[57] For Drucker, the descriptive, interpretive, and predictive

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[56] John Ruskin, *Modern Painters*, vol. 1 (New York: National Library Association, 1843). Accessed via https://www.gutenberg.org/files/29907/29907-h/29907-h.htm.

[57] I have tracked down two distinct versions of the *Subjective Meteorology* artist’s book, both published under Drucker’s independent Druckwerk imprint. The first, from 2005, is considerably shorter than the second, from 2010, although both contain much of the same

potential of meteorology, with its sensitivity to the complexity of atmospheric dynamics, provide metaphorical grounds for the concomitant mapping of emotion. "My fascination with [meteorology]," she writes, "is absolutely, firmly based in the belief that the subjective experience of daily life can only be described in such a system with all its exhaustive repleteness."[58]

Subjective Meteorology addresses two interrelated yet conceptually distinct audiences. First, it is by Drucker's own admission an artistic project, what she calls "an act of aesthetic provocation and a work of imagination."[59] On her website, Drucker sorts *Subjective Meteorology* not with her scholarly output, but rather alongside her over three dozen artist's books spanning a nearly fifty-year career in the medium. Nevertheless, *Subjective Meteorology* takes seriously aesthetics as a method of scholarly inquiry, in particular for the work's second audience, that of digital humanists. Drucker devised the project as part of her work with the Speculative Computing Laboratory, or SpecLab, an experimental digital humanities research group she cofounded at the University of Virginia in 2000 with Bethany Nowviskie and Jerome McGann. Speculative computing, Nowviskie writes, "is a computer science and software engineering practice that deliberately embraces inefficiency in order to foster what we might think of as a novel sort of intellectual responsiveness."[60] SpecLab, by consequence, was a site for digital humanities practices and projects that tested the nascent field's limits. Drucker's preliminary work on the drawings that would eventually become *Subjective Meteorology* began in a 2004

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material. Throughout I cite from the 2010 version unless there are materials that exist only in the 2005 version.

[58] Johanna Drucker, *Subjective Meteorology* (Los Angeles: Druckwerk, 2010), 13.

[59] Johanna Drucker, *SpecLab: Digital Aesthetics and Projects in Speculative Computing* (Chicago: University of Chicago Press, 2009), 99.

[60] Bethany Nowviskie, "Speculative Computing & the Centers to Come," *Bethany Nowviskie* (http://nowviskie.org/2014/speculative-computing/, November 2014).

residency at the Digital Cultures Institute at UC Santa Barbara.[61] This was a heady time for the digital humanities; for many, "digital" still carried the aura of difference, a set of alternatives to time-tested modes of scholarship, which might either enrich or threaten academic enterprise depending on one's personal inclination. It was also a time of intensive auto-theorization, as scholars such as N. Katherine Hayles, John Unsworth, and Willard McCarty wrestled with the definitional question of what, if anything, digital objects and methods brought to the humanities table.[62] Set against this intellectual lineage, *Subjective Meteorology* is Drucker's attempt to imagine new forms of knowledge production that exceed standard textual or mathematical forms of notation.

What does this look like in practice? *Subjective Meteorology*'s weather scenarios bear significant debts to weather maps and aerial diagrams. The first "Preliminary Scenario" (fig. 4) looks like an abstract cloud study, full of alternately curved and straight lines connoting atmospheric density. Drucker labels different sections of her "scenarios" with letters of the alphabet, corresponding to explanatory notes. Region A, a dramatic array of wisps punctuated by darker, almost violent irruptions in their center, corresponds to "interrupting irritants in a field that desires forward motion."[63] "Interruptions," Drucker defines, are "configured actions, events with a dynamic capability, probably ruptures."[64] If this reads as impossibly abstract, that's part of the game. Stripped of specifics, these interpretive notes are attempts to develop from first principles—namely that of the drawings themselves—a theory of subjective experience. Region

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[61] Drucker, *SpecLab*, 100.

[62] See N. Katherine Hayles, "Print Is Flat, Code Is Deep: The Importance of Media-Specific Analysis," *Poetics Today* 25, no. 1 (2004): 67–90; John Unsworth, "What Is Humanities Computing and What Is Not?" *Jahrbuch Für Computerphilologie* 4 (2002); and Willard McCarty, "Modelling," in *Humanities Computing* (London: Palgrave MacMillan, 2004), 20–72.

[63] Drucker, *Subjective Meteorology*, 31.

[64] Drucker, *Subjective Meteorology*, 28.

C, in the drawing's upper middle, corresponds to a "frustration storm," depicted by a flurry of short lines and patches with medium shading density, all resting above region D, "axes interrupting flow."[65] "Storm conditions," she proposes, "indicate cyclone disturbances . . . they can be small scale events, transformations, or bring about major state changes in a catastrophic mode."[66] Just as an atmospheric storm equalizes areas of high and low pressure through outbursts of wind, rain, and lighting, so too do emotional storms indicate phase shifts: disturbances and resolutions in psychic environments. There is a self-consciousness at work here for Drucker: "I am my own personal weather system," she writes, "even as I observe it."[67] How to mediate the storm, to achieve the fantastic view from above, is both a metaphorical and critical project.

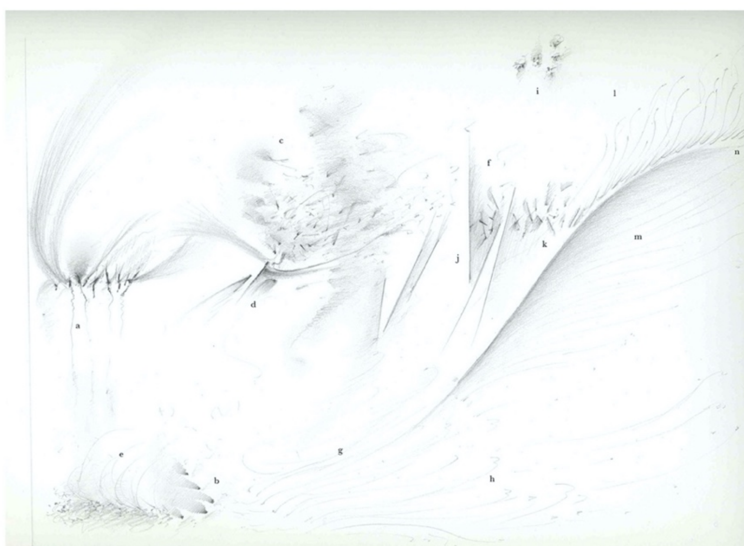

Figure 4. "Preliminary Scenario" from Subjective Meteorology.

[65] Drucker, *Subjective Meteorology*, 30–31.
[66] Drucker, *Subjective Meteorology*, 28.
[67] Drucker, *Subjective Meteorology*, 29.

My interest in *Subjective Meteorology*, like its audience, is two-fold. First, I see this project as a road not taken the in the development of the digital humanities, one that, like atmospheres do for media more generally, tests the limits of the field's investment in digitality. (This is, after all, a fully *analog* digital humanities project.) Second, I want to understand why Drucker seized upon weather out of all the possible metaphors for modeling complex systems, and what such an investment in meteorology means for how she theorizes knowledge production. Weather maps are one of our most familiar atmospheric media. They are integral to the modern project of imagining the weather as data. First developed on the battlefields of nineteenth-century Europe, the contemporary weather map that one glances at each morning is the outcome of a long chain of computational operations, from sensing satellites to cloud computing infrastructures, all together quantifying and visualizing planetary phenomena in the service of its forecast. To borrow an insight from Shannon Mattern, these technologies perceive the world as "code-space," a mesh of spatial and contextual data.[68] They are also, as Randerson argues, aesthetic objects in their own right, with generic expectations for how they go about the work of visualizing the weather.[69] Fixed cartographic projections, standardized color schema, and the regular tick-tock of radar visualization reflect both the computational processes underpinning such maps' production, as well as assumptions about what kinds of data make it onto the map at all—and what, in turn, gets left out. For all these maps' complexity, they are still incomplete representations of the weather. They *must* be, for that is meteorology's paradox. Nevertheless, Drucker's provocation still stands: that what subjective experience and atmospheric dynamics

[68] Shannon Mattern, "Mapping's Intelligent Agents," *Places Journal*, September 2017, https://doi.org/10.22269/170926.

[69] Randerson, *Weather as Medium*, 45.

share are *complexity* and *interaction*; and in turn, the techniques for modeling one might serve to inspire attempts to model the other.

Prior to her scenarios, Drucker provides a preliminary schema for her system, over which the figure of "atmosphere" looms large. Drucker defines atmosphere tautologically: "atmosphere is what is: All dynamic systems begin with a charged field that is highly specific and always contingent."[70] Atmosphere subsumes and comprises all activities that happen within it. When specificity emerges, it is only for a brief instant and in a particular locale, which quickly echoes out and dissipates into new structures. This is perhaps why her weather scenarios rely on visual clustering, rather than diffuse representations of total states. Throughout the project, and particularly in her discussion of atmosphere, Drucker eschews the possibility of causality. "Pay total attention to effects," she writes, and disregard any attempt at ascertaining from whence they come.[71] Atmosphere is autopoietic, "self-regulating," and "in constant flux."[72] There are nods to cybernetics here, as psychic atmospheres rely on negative feedback loops to maintain equilibrium.[73] Unrest emerges and resolves into a never-fixed base state. Nowhere is this concept more evident than in her development of atmospheric "conditions," here presaging the atmospheric media technique that structures my second chapter. Conditions are "always fluid and volatile, mutable and in flux, though they can stall and appear static, or even seem like givens . . . but they contribute as much instability to the atmosphere as equilibrium."[74] Examples

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[70] Drucker, *Subjective Meteorology*, 18.

[71] Drucker, *Subjective Meteorology*, 18.

[72] Drucker, *Subjective Meteorology*, 18.

[73] I address atmospheric media's investment in cybernetics in more depth in chapter two's discussion of air conditioning.

[74] Drucker, *Subjective Meteorology*, 20.

of such conditions include “stress, calm, determination, [and] anxiety.”[75] Like a slow drip of pitch, their apparent fixity is only an illusion.

Crucially, Drucker argues that atmospheres challenge traditional Western notions of representation. The practice of subjective meteorology, she writes, entails a conceptual shift away from “traditional” meteorology, which she sees as “partially grounded on classical physics and Euclidean geometry.”[76] Against these models—perhaps too of the *ground* for her atmospheric work—Drucker turns to “topological mathematics, quantum theory, and ’pataphysics.”[77] Of these three, pataphysics may be the most unfamiliar to a reader, yet I view it as the most crucial for Drucker’s project. Invented by French symbolist writer Alfred Jarry, ’pataphysics is a parodic quasi-intellectual pursuit into the “science of imaginary solutions.”[78] True to its avant-garde roots, it is nearly impossible to define and self-consciously useless in its applications—a perfect fit for a simultaneously serious and absurd project like Drucker’s. The art/science of subjective meteorology is pataphysical in that it exceeds metaphysics yet does so in a way that is legibly “scientific,” belonging equally to the realm of fancy and technics.[79] Part of Drucker’s pataphysical method is then to begin with the observation of specific effects, which in turn guide the description of always incomplete and ever mutable general principles. The drawings are the primary evidence upon which to base theoretical claims, rather than secondary visualizations of information. In this regard, *Subjective Meteorology* foreshadows Drucker’s more recent work on “non-representational” modeling. In a 2017 essay on the subject, she proposes that the dominant mode of contemporary data visualization presumes a “uni-

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[75] Drucker, *Subjective Meteorology*, 20.
[76] Drucker, *Subjective Meteorology*, 17.
[77] Drucker, *Subjective Meteorology*, 17.
[78] Andrew Hugill, *’Pataphysics: A Useless Guide* (Cambridge: The MIT Press, 2012).
[79] Drucker, *Subjective Meteorology*, 15.

directional" relationship between data and its visualization. "Data precede the display," she writes, "and the data are presumed to have some reliable representational relation to the phenomena from which they have been abstracted."[80] *Subjective Meteorology* offers the inverse. Data, or in this case an informational schema, emerge in tandem with their representation, each informing the latter in ways that are ultimately indissoluble.

The scenario for day three maps the progress and aftershock of an "unusual awareness of physical condition," which the notes hint indirectly as a prolonged headache (fig. 5). This is a more dynamic scene than her preliminary scenario, with sharp linear rises and falls, strong directionality, and a distinct use of negative space. The scenario's timeline reads left to right, although like a Duchamp portrait, multiple time scales collapse and converge. Region C denotes the "object under discussion," the headache, rising like a cumulonimbus out of the stratus cloud of "distant order" in Region G.[81] The headache folds the lines of force back on themselves, locking a kind of churning vortex between the order above it, the prevailing lines from the right, and the churn of motion underneath, which the notes suggest are Drucker's repeated attempts to work through the headache. When the headache breaks in region H, a marked phase shift occurs: the condition resolves and "lines of work and concentration" rocket from the bottom to the top-right of the image.[82] In this scenario, Drucker's language has become fully abstracted from its meteorological roots. One can sense correspondences in two realms. First, in the graphical qualities of the scenario, which continue to bear notable resemblance to meteorological maps, particularly in the lock-and-resolution of the headache. And second, in the scenario's conceptual underpinnings, which rely on images of lines of force and energy ruptures appropriated from

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[80] Johanna Drucker, "Non-Representational Approaches to Modeling Interpretation in a Graphical Environment," *Digital Scholarship in the Humanities*, 2017, 2.

[81] Drucker, *Subjective Meteorology*, 42–43.

[82] Drucker, *Subjective Meteorology*, 42–43.

atmospheric dynamics. Despite Drucker's insistence on the project's heterogeneous and quantum temporality, the flat page inheres much of meteorology's Newtonian dynamics. There is still a sense of time flowing linearly from left to right, catching up the psychic winds along the way.

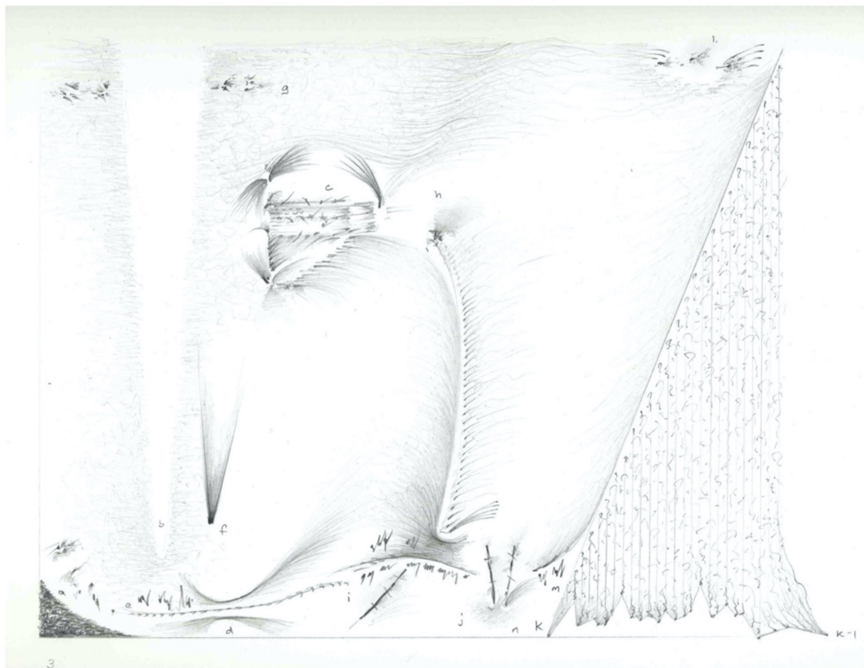

Figure 5. "Day Three" from Subjective Meteorology.

Subjective Meteorology fits curiously alongside other projects in the digital humanities in that it is not, at first blush, digital in the slightest. Drucker alludes across the project's documentation to the possibility of a digital version, although such a program has never emerged in the public eye.[83] How would such a project belong to the enterprise of "speculative computing"? Drucker herself is averse to providing a clear answer, although the project's roots in critiques of data visualization are fairly clear. I regard a more compelling answer as one that

[83] Drucker, *SpecLab*, 108.

Drucker herself perhaps did not anticipate at the time of the project's creation. *Subjective Meteorology* is a poetic experiment in the information modeling that supports the media of forecasting. It is digital in its conceptualization of psychic atmospheres, if not their implementation. This is a mode of thinking it inherits from meteorology, the languages of which reflect that field's core work of mediating the atmosphere as data for the purposes of modeling. There is a conceptual inheritance at work here that has material consequences for how Drucker imagines her system. *Subjective Meteorology* has no ontology (in the word's sense in information science, referring to a representational schema for defining subjects and relations). Her link across these domains of knowledge is mediation. Drucker explores this link in greater depth in her recent—and fairly idiosyncratic—volume, *The General Theory of Social Relativity* (2018). A spiritual sequel of sorts to *Subjective Meteorology*, the *General Theory* proposes modeling social dynamics as a kind of "quantum" and "atmospheric" system. Media are integral to producing these systems: they have "dynamic effects," she writes, "they draw us out, spread us thing, distribute us through their systems and capacities. Media are dynamic forces that engage us in a network of energy exchanges."[84] Here, media replace meteorology as a model of understanding social life. But I would contend that it's less about replacement and more another word for the same operation, that is, modeling (physical, emotional) experience by technical means.

Like Ruskin's pathetic fallacy, *Subjective Meteorology* hinges on a definitionally "false" equivalence between the natural world and human emotion. It develops a self-consciously pataphysical system in the service of imaginative exploration. It play-acts at formal logic as a way to undercut logic's claims; it calls itself digital with nary a byte in sight. But are not these

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[84] Johanna Drucker, *The General Theory of Social Relativity* (Canada: The Elephants, 2018), 39.

equivalences similar to those leaps of faith that forecasting asks of us? Accentuating these falsities opens up space for a greater critique of the system of forecasting more generally. What *would* forecasting look like, were we to admit emotional subjectivity alongside physical data? That meteorology provides the blueprint for an imaginative project such as this hints at the similar speculative work roiling through meteorology itself. This speculation goes beyond the simple falseness of, say, a forecast. Forecasts will sometimes be wrong: that is their job. Rather, it strikes at the heart of meteorology's attempts to mediate a world, to propose equivalences not between the natural world and emotion, but rather the natural world and information. Drucker views meteorology as providing the tools for the modeling of complex systems. Conversely, *Subjective Meteorology* echoes back a challenge to its atmospheric forebear: what do media include? And what do they omit?

The Ephemerides

Beyond the sky lies the dizzying vastness of space. Definitionally a non-atmosphere, holding nothing but itself, space nevertheless holds many of our most atmospheric media: rockets, satellites, and radio waves, to say nothing of the plenitude of celestial bodies that stud the screen of the sky. Outer space is that emptiness that exceeds forecasting's focus yet is the milieu for much of its contemporary practice. Weather satellites are technologies of meteorological capture, radio and televisual transmission, and geopolitics alike, as Lisa Parks writes.[85] The aerial views of weather forecasts would likewise be impossible without satellite imagery, such as that first afforded by balloons and later, as Caren Kaplan notes, by planes and

[85] Lisa Parks, *Cultures in Orbit: Satellites and the Televisual* (Durham and London: Duke University Press, 2005), 4.

satellites.[86] In this final close reading, I take the atmospheric media of forecasting satellites—their operations, their journeys into and beyond the atmosphere—as my focus. But I do so through a perhaps unusual text, that of a Twitter bot. *The Ephemerides* is a work of generative poetry hosted as bots on both Twitter and Tumblr. Conceived and designed in 2016 by artist Allison Parrish, *The Ephemerides* imagines what poetry a satellite would write as it rockets alone into the farthest reaches of space. The bot comprises two functions: first, it randomly chooses an image from NASA's OPUS database, which hosts publicly available space probe data; and second, it pairs the image with a computer-generated poem.[87] Unlike familiar color-corrected images of the outer planets, the images in *The Ephemerides* are raw transmissions from the satellites themselves. They are stark, monochromatic affairs, often in extreme close-up to celestial bodies, sometimes marked by glitched and transmission errors. The poems are similarly spare, formally reminiscent of Japanese haiku. They are lonely poems, cold poems.

Over its nearly four years in operation, *The Ephemerides* posted 6,793 poems to Twitter. Where one begins to read is a somewhat arbitrary endeavor. Computationally generated poetry poses a challenge to typical practices of close reading in that the "intelligence" behind the text is both human and nonhuman. Parrish sets the rules and a computer executes them. *The Ephemerides* is by necessity repetitive, as images, phrases, and syntax recur over the nearly seven thousand entries. Some make more "sense" than others, in that they obey familiar laws of English syntax more fluidly; others reveal in their glitchiness a computational substrate. But given Twitter's interface, the most logical place to begin is at the end, at the top of the bot's feed. On February 10th, 2019, the bot's final day in operation, it tweeted:

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[86] Caren Kaplan, *Aerial Aftermaths: Wartime from Above* (Durham and London: Duke University Press, 2018), 52–53.

[87] Allison Parrish, "The Ephemerides," *Decontextualize: Allison Parrish, Words and Projects*, August 2015, https://www.decontextualize.com/2015/08/the-ephemerides/.

The ice

was dangerous.

The air,

now, is

in contribution

an appropriate

subject

of consideration[88]

Figure 6. The image related to the 8:33 AM, Feb 10th, 2019 entry of The Ephemerides.

[88] Link to this tweet: https://twitter.com/the_ephemerides/status/1094590121742082048.

The poem comprises two sentences across two stanzas, each with their own elemental subject: the ice and the air. Elements, which Nicole Starosielski usefully glosses as the "constituent parts" and "substrates" of media,[89] loom large over contemporary environmental media studies. They may take the form of traditional Greek elements such as wind and water, non-Western elements such as the wood and metal of Chinese cosmology, geological minerals, or more fluid concepts such as the material and social composites of media infrastructures. From a satellite's perspective, ice and air are the defining elements of space travel. The former, a total quality of space's vast coldness as well as stray objects to avoid in planetary fly-bys; the latter, a metaphor for space itself, which has no air and yet is the attenuated extension of atmospheres. The dangerousness of ice for navigation is perhaps a given, while the air now being "in contribution" is a harder gloss. It's a moment of askew word choice and syntax, one in which the computer-generated quality of the poetry comes to the fore. But let's stay with the weirdness. The past tense of "the ice / *was* dangerous" (italics mine) reads like a ship's log. By contrast, "the air, / *now, is* / in contribution," the doubled insistence of the present tense, immediately contributing to something, perhaps the danger of the ice. The absence of punctuation at the end of the first stanza invites the reader to continue the sentence after a pause. The present contribution of the air to the danger of the ice makes it an "appropriate / subject / of consideration." Again, the poem confronts the reader with a parallelism, this time between "contribution" and "consideration." Both Latinate words, the infix (we might say element) *tribu* can mean either granting or bestowing. *Sidera*, by contrast, retains a more poetic meaning: constellations. After all, what is more fit for consideration and contemplation than the night sky?

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[89] Nicole Starosielski, "The Elements of Media Studies," *Media+Environment* 1, no. 1 (November 2019), https://doi.org/10.1525/001c.10780.

The accompanying image is, by contrast, neither icy nor aerial, but rather rocky. It depicts a small cosmological body, perhaps an asteroid or planetary satellite, illuminated from the lower left-hand corner. Its right-hand side sinks into the inky black. Striations on the body's surface guide the gaze into its center, providing the image a meditative quality. It is an invitation to consider, just as we are invited to consider the air. What has the satellite, through this poem and image, told us? I find the most meaning in its final turn to consideration, which I regard as the principal work of both generative poetry projects such as *The Ephemerides* as well as weather forecast modeling. Both are computer programs designed to rove over and algorithmically remediate data endlessly until someone pulls the plug. They are programs of study, exhausting a central question or concept through permutation. How to put words together and how to put atmospheres together are conjoined projects. The imaginative interiority of satellites, which support so much of our atmospheric media, deserves this consideration in turn, such that we as critics might come into closer contact with the computational nature of their operations.

By foregrounding this consideration, *The Ephemerides* shifts satellites' cultural function from that of information transmission to that of information generation. The former is a customary way of thinking about satellites; as Parks writes, "just as television has historically been misunderstood as the act of transmission, so, too, have satellites been described as mere relay towers in space."[90] Rather, she argues, satellites are active participants in the production of cultural discourses. The same is true, *The Ephemerides* suggests, of satellites' role in the data collection that undergirds forecasting. Satellites are replete with cameras and sensors. The *Cassini* probe, one of the main probes whose imagery *The Ephemerides* uses, hosted no fewer

[90] Parks, *Cultures in Orbit*, 11.

than four distinct spectrometers, alongside magnetometers, radar systems, and dust analyzers.[91] Following Jennifer Gabrys's work on computational environmental sensors,[92] I suggest that *The Ephemerides* reframes satellites as tools of information generation. Data aren't residual in the environment awaiting extraction and processing, constituted by the technical and cultural operations of media. For its utility in shifting media studies' attention away from unitary technologies and towards cultural processes, this critical move does make it difficult to discuss what that act of constitution entails. After all, media are not human. They have a sticky tendency, in the words of philosopher Graham Harman, to "withdraw" from view.[93] What *The Ephemerides* offers, then, is an imaginative route through a fundamentally intractable philosophical problem. What does forecasting look like from the perspective of a satellite? We can never answer this question in "reality," but through the kind of program of study offered to us by a generative poetry bot, we can arrive at at least one attempt at imaginative understanding.

Parrish summarizes the conceit behind *The Ephemerides* as one of poetic equivalence. "Both space probes and generative poetry programs venture into realms inhospitable to human survival," she writes, "and send back telemetry telling us what is found there. For space probes, that realm is outer space. For generative poetry programs, that realm is *nonsense*."[94] In *The Ephemerides*, this nonsense often takes the form of askew or ungrammatical word choices, as in the unexpected "contribution" in the poem above. At other times, the bot will produce grammatically complete sentences that are nevertheless seemingly opaque to reason, as in an entry from September 30th, 2016:

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[91] NASA, "Cassini Orbiter | Spacecraft," *NASA Solar System Exploration* (https://solarsystem.nasa.gov/missions/cassini/mission/spacecraft/cassini-orbiter, April 2019).
[92] Gabrys, *Program Earth*, 4.
[93] Graham Harman, *The Quadruple Object* (Winchester, U.K.: Zero Books, 2011), 21.
[94] Parrish, "The Ephemerides," italics in original.

Wind of each child

is not to be

gained in the torrid

zone from our

readers, sliding

with the coral.[95]

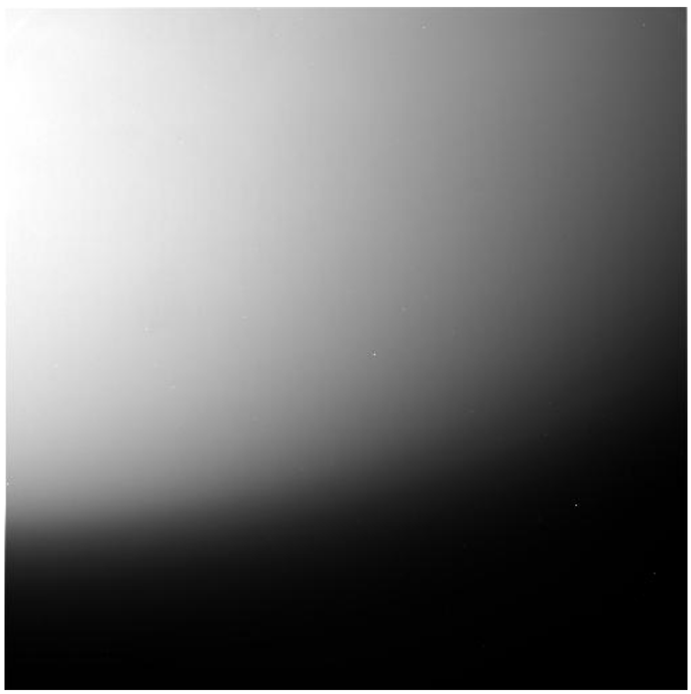

Figure 7. The image related to the 12:18 AM, Sep 30th 2016 entry of The Ephemerides.

Such a sentence is symptomatic of *The Ephemerides*' coding, which Parrish details briefly in a blog post. The source text comes from two freely available texts on Project Gutenberg: a 1920 book on astrology by the British Theosophist Walter Gorn Old (alias Sepharial), and Scottish children's book author and artist R.M. Ballantyne's *The Ocean and its Wonders* (1874), an informative book on oceanography and sea travel. Using a program named

[95] Link to this tweet: https://twitter.com/the_ephemerides/status/781890954391412736

Pattern,[96] Parrish parses these texts into lexical chunks and tags them grammatically. "To generate the poem," she writes, "the procedure selects a clause at random and then, for each constituent in the clause, replaces it at random with a constituent drawn from the entire corpus that shares the same part of speech or grammatical role."[97] The effect is to maintain the feeling of "grammaticality" while allowing for "strange juxtaposition[s]" between the source texts. Crucially, the code behind *The Ephemerides* does not understand, in a human sense, any of the words and phrases it processes. The same code could process any number of input texts and use any number of tagging schema to similar effect. This in turn highlights how its fundamental "strangeness," or alien distinction from human approaches to text, includes its operations as much as its outputs. "Nonsense" is a machine dialect, one that *The Ephemerides* affords us the opportunity to listen to and learn to speak.

The Ephemerides is as much as visual as a textual project. There is considerably less computational force behind the bot's selection of images: it simply pulls a random image from the OPUS database and pairs it with whatever poem it has generated. Parrish assures us that "there's no image recognition or other deep dream nonsense going on" in the juxtaposition of text and image; any meaning a reader derives is their own.[98] Nevertheless, the images echo the same kind of inhuman strangeness as do the poems. These are "raw" images, captured by and transmitted directly from the satellite along NASA's Deep Space Network (DSN), a collection of three massive radio antennae located in California, Spain, and Australia.[99] They have yet to

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[96] Pattern will play a larger role in my fourth chapter, where it forms the backbone of the sentiment analysis program TextBlob which I analyze in detail.

[97] Parrish, "The Ephemerides."

[98] Parrish, "The Ephemerides."

[99] NASA, "About the Deep Space Network | NASA," *NASA Space Communications* (https://www.nasa.gov/directorates/heo/scan/services/networks/deep_space_network/about, March 2020).

undergo any sort of post-processing to bring them more in line with what the public might expect space to look like. They are in black-and-white, rather than color, they feature visual glitches where the signal has been degraded over millions of miles, and they are often fragmented views, rather than full vistas. Cinema and media theorist Shane Denson argues that space photographs such as those featured in *The Ephemerides* are indicative of a broader shift in the sites and methods of image production after the emergence of the digital computer, what he terms "discorrelation." Discorrelation refers to how computer-generated or -assisted images no longer take as their baseline human spatial or temporal subjectivities, but rather introduce new kinds of machine and trans-human subjectivities alongside or instead of human ones.[100] Even the "raw" images in *The Ephemerides* are mediations of the electronic signals these probes generate and transmit. To see fully through a satellite's eyes is impossible, an impossibility that *The Ephemerides* maps for us and brings us close to, but definitionally never can comprehend.

A bot like *The Ephemerides* can theoretically run forever, provided sufficient computational resources. However, it halted operations in February 2019. This was through no decision of Parrish's. In the summer of 2018, Twitter changed its application developer process to make it considerably more difficult to produce bots such as *The Ephemerides*. Botmakers such as Parrish would need to undergo lengthy review processes for each bot they produce, and Twitter reserved the right to revoke permissions at any time.[101] Shortly after Twitter's announcement, Parrish tweeted that she "[did] not plan to take any proactive measures to keep [her] bots working on twitter," and has since shifted her botmaking output to open web platforms

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[100] Shane Denson, *Discorrelated Images* (Durham and London: Duke University Press, 2020), 21.

[101] Rob Dozier, "Twitter's New Developer Rules Might End One of Its Most Enjoyable Parts," *Slate*, August 2018, https://slate.com/technology/2018/08/twitters-new-developer-guidelines-might-end-fun-bot-accounts.html

such as Mastodon and RSS.[102] *The Ephemerides* is now a dead bot, up for as long as Twitter continues to allow it to exist. Many other bots have met similar fates; the internet is littered with projects that could have run longer were the tech platforms on which they ran actually interested in supporting insurgent artistic work. Yet this feels like the only appropriate fate for *The Ephemerides*. Satellites, after all, are impermanent technologies. In orbit, they eventually succumb to the free fall of gravity and burn up in the Earth's atmosphere. In deep space, they eventually fly so far away that their attenuated signals disappear from the DSN's views. Some, like the *Cassini* mission to Saturn, are intentionally destroyed so as to avoid extraterrestrial contamination.[103] Machine consciousness is as constrained by material resources as human consciousness, and with time and entropy all comes to darkness. The residue of text and image on Twitter speaks to the bot's necessarily temporary sojourn into realms beyond figuration, to make sense for a time of that which escapes human cognition.

"Ephemerides" is the plural of "ephemeris," an almanac or table that provides the trajectory of celestial bodies, whether natural or artificial. Astronomers have calculated ephemerides for thousands of years, with such tables forming the backbone of Babylonian timekeeping as far back as the first millennium BCE.[104] Ephemerides were also integral to ocean navigation, as the known position of stars and planets could allow sailors to triangulate their positions in a time before global position systems. They are media of forecasting the sky, of anticipating its motions and patterns and instantiating them in mathematical forms. In naming her

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[102] Allison Parrish, "fwiw, I do not plan to take any proactive measures to keep my bots working on twitter after this change, so enjoy them while you can I guess https://t.co/DbKkCc0fmF," Tweet, *@aparrish*, July 2018, https://twitter.com/aparrish/status/1021870104945012737.

[103] Paul Rincon, "Our Saturn Years," *BBC* (https://www.bbc.co.uk/news/resources/idt-sh/cassini_huygens_saturn, September 2017).

[104] F. Rochberg-Halton, "Between Observation and Theory in Babylonian Astronomical Texts," *Journal of Near Eastern Studies* 50, no. 2 (1991): 107–20.

bot *The Ephemerides*, Parrish gestures equally to these mathematical, celestial, and navigational procedures. The bot becomes a medium for their poetic concatenation. I have always found celestial data paradoxical in its simultaneously rigorous predictability yet inescapable vastness. Ephemerides, like eclipse calculations, can be made with reasonable certainty centuries into the future. Yet as Parrish's project intuits, space's unknowability still presents feelings of uncanniness, even ghostliness, within otherwise concrete data—to say nothing of the tenuousness with which space probes conduct their operations. Here, multiple techniques of forecasting converge: astronomical prediction, poetic conceit, computational intelligence, and environmental sense-making.

Forecasting Media

Close reading the atmospheric investments of a suite of creative media projects, from electronic literature to experiments in the digital humanities to Twitter bots, this chapter began my study of atmospheric media with an inquiry into media techniques and technologies of seeing and predicting the air. I have demonstrated a shared problem across both scientific meteorology and the atmospheric media arts, that of an informational paradox whereby atmospheres always exceed attempts to mediate them, whether textually, visually, or informatically. Atmospheric media extend Jorge Luis Borges's familiar metaphor of the map and the territory into the sky. Any attempt to grapple with atmospheres and atmospheric media begins with this fundamental question, which I have argued is principally one of mediation. *Forecasting*, the media technique around which I have organized this chapter, is therefore an attempt to resolve this paradox through further mediation. Forecasting fills in the gaps in the map, such that it might usefully reflect back onto the territory. For the artists I have explored in this chapter specifically, forecasting offers them an opportunity to imagine new social and cultural practices for relating to and understanding the weather in climatologically tenuous times. Climate change is not an explicit subject of any of these works, with the exception perhaps of Carpenter's *Wind*, yet looms over all of them to some degree. For Carpenter, it is the motivation to picture wind; for Drucker, a social milieu that demands new ways of relating to other humans; for Parrish, a memento mori. In these works, forecasting serves as the first step for conjuring forth virtual atmospheres of their own.

I have also in this chapter begun the work of mapping parallels and connections across different domains of atmospheric knowledges, in this case, meteorology and the creative arts. I do so in an effort to demonstrate how mediation operates as an undercurrent which brings together otherwise distinct cultural and epistemological atmospheric practices. In the case of forecasting, these connections bring to the fore in particular how fragile our current meteorological landscape truly is. While the twentieth century has seen a dramatic improvement in the quality and reliability of weather forecasts thanks to digital media technologies such as computer modeling and climatological sensors, these improvements are further imperiled by political, cultural, and technological constraints, to say nothing of how such technical improvements paradoxically come at the cost of the very environments they seek to map and predict. One project the creative works I analyze in this chapter undertook was to see contemporary weather forecasting within a long media history, as contiguous with older media practices such as weather diaries, maps, and aerial instrumentation. This long media history serves as a reminder that our contemporary meteorological landscape is not the result of a narrow teleology but rather a series of choices, conscious and unconscious, made through the long arc of cultural history. These are choices we could choose to make otherwise, as Drucker reminds us in her challenge to think about encoding qualities such as emotion and subjectivity within meteorological systems. And indeed, we may *need* to choose otherwise if we are to continue living on this planet.

It's possible to imagine a different version of this chapter, one grounded in the meteorological sciences rather than the creative arts. Such a chapter might look at the physical media of meteorology themselves: the diaries, balloons, satellites, and computer models that encompass historical and contemporary forecasting. To a certain extent, these projects have already been undertaken in by such writers as Edwards and Blum.[105] But I chose instead to focus on the creative arts of atmospheric media for how they foreground the cultural work of imagining atmospheres. Doubled meanings run throughout this dissertation and forecasting is no exception. On the one hand, I have explored meteorological forecasting; on the other hand, I have tried to take forecasting more expansively to encompass practices of imagination, prediction, and modeling (the latter will reappear in more length in the final chapter of this dissertation). One of the major themes of this dissertation is that atmospheres do not simply appear from nothing, but rather must be created through mediation. The creative projects with which I began this dissertation are atmospheric media in the sense that they take atmospheres as their primary subject, but more importantly in that they *create* atmospheres through their operations. This is why digital concepts such as interactivity, randomness, and procedural generation are vital to these works and other such works in this dissertation more broadly. They are also projects that definitionally resist completion, preferring to unfold atmospherically in permutation.

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[105] See Edwards, *A Vast Machine* and Blum, *The Weather Machine*.

Looking forward, subsequent chapters build on this chapter's articulation of forecasting as a fundamental operation of atmospheric media. This chapter has been unique in my dissertation for its focus on the creative arts; remaining chapters will take more infrastructural, theoretical, and technical focuses. Yet these artists will remain a touchstone throughout for how their work articulates that doubled sense of atmospheric mediation, whereby the lines between media and environment blur. In particular, the central media theoretical questions underlying forecasting recur throughout this project. Indeed, the media techniques that structure my remaining chapters—conditioning, respiring, and modeling—might be thought of as varieties of the central species of forecasting. Underneath all these techniques runs computation, which this chapter has sought to decouple from strictly digital computing technologies in order to view it more expansively as a way of mediating the world. Ultimately, it is this sense of forecasting as mediation that I carry forward in this dissertation.

Chapter Two

Air-conditioning the Internet: Temperature, Security, and the Myth of Sustainability

> Well—if catastrophe struck, and the HVAC broke down, it'd be about twenty minutes to total heat death.
> — An anonymous employee at Equinix's DC11 data center

A click—and a dull roar interrupts the silence; or else white noise present at the edge of perception. Perhaps legible as a *thing*, balanced on the edge of an apartment windowsill; or else insinuated into a building's architecture, testified by vents and the occasional duct. But in the great or small roar, heat becomes cool, humid becomes dry, and the air jumps into motion (unless it is strangely still). Few technologies are as emblematic of modernity as air conditioning. From its invention in the 1890s, air conditioning has promised new forms of atmospheric comfort and thermal standardization. Finally, "room temperature," a measurement so ingrained as a standard (68°F or 20°C) that its very definition was the first set by the International Organization for Standardization, could be precisely *that*.[106] No longer would human beings—at least wealthy Western ones—suffer at the hands of heat waves and crippling humidity. Yet air conditioning also carries connotations of weakness, even malice. Author Henry Miller titled his scathing 1945 portrait of post-war America *The Air-Conditioned Nightmare*, a testament to what

[106] Specifically, ISO 1 sets a "standard reference temperature" of 20°C so as to standardize the measurement of objects' geometrical and dimensional properties. 20°C also has the virtue of being an integer on both the Celsius and Fahrenheit scales. The ISO formally adopted ISO 1 in 1951. Fifteen years later, another professional organization that will feature prominently in this chapter's story, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) published Standard 55, their recommendations for "indoor climate regulation." This standard was explicitly calibrated against a particular kind of human body—a forty-year-old man—wearing a particular kind of clothing—a men's business suit. Standard 55 has become the essential reference point for setting temperatures in office buildings, leading to the familiar (and correct) accusations that such buildings are set far too cold for women's bodies and typical garments. For more, see Anthony Lydgate, "Is Your Thermostat Sexist?" *The New Yorker* (https://www.newyorker.com/tech/annals-of-technology/is-your-thermostat-sexist, August 2015).

he saw as the nation's banal depravity. Ruby Dee's character Mother Sister in Spike Lee's classic 1989 heatwave film *Do the Right Thing* refuses to buy an air conditioner, which she sees as a youthful indulgence. "Don't like them," she says, "a fan will do." Common wisdom warns against sleeping with air conditioners on, lest sleepers suffer dehydration or respiratory illness. And all these creature comforts and health impacts pale in the face of air conditioning's environmental impact, which is responsible from everything from increased global energy consumption to ozone depletion. Air conditioning is responsible for a dramatic shift in the condition of modern life itself.

Air conditioning is atmospheric: it envelops modernity. Life without it, although the norm just fifty years ago, may be scarcely imaginable for many. Air conditioning has emerged as a necessity for a range of global industries, from agriculture to microprocessor manufacturing. As rising global temperatures demands new scales of personal and industrial cooling, air conditioning proliferates apace. A 2018 report by the International Energy Agency estimates that air conditioning for human comfort alone contributes to about ten percent of the world's electricity consumption.[107] The United States and Japan lead the pack, but air conditioning costs in some of the world's most densely populated and rapidly warming places, such as south Asia and sub-Saharan Africa, are set to skyrocket over the next thirty years.[108] With rising global incomes, air conditioners shed their stereotype as unaffordable luxuries; with rising temperatures, they become biological necessities. It took China just fifteen years for air conditioner penetration (a measure of HVAC units per dwelling) in its urban areas to rise from

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[107] International Energy Agency, "The Future of Cooling Analysis" (International Energy Agency, May 2018).

[108] Marlyne Sahakian, *Keeping Cool in Southeast Asia: Energy Consumption and Urban Air-Conditioning* (London: Palgrave Macmillan, 2014).

just a few percent to well over a hundred percent.[109] Other high-density, high-temperature countries, such as Brazil and India, are on similar tracks. Air conditioning may even have to move out of doors. The oil-rich nation of Qatar, one of the hottest places on Earth, has begun experiments in cooling the air in public spaces from soccer stadiums to outdoor markets, in an effort to make living in unbearable heat more viable.[110]

Digital media require stable atmospheres as well, a task made all the more challenging by the sheer amount of heat they emit. Electricity coursing through computers encounters resistance, which transforms energy into heat, much like the friction of rubbing one's hands together. Cooling has been a computing concern since the medium's inception. Early room-sized computers could make do with a building's HVAC, but smaller contemporary computers fold cooling within the mechanism itself. Techniques include the quintessential (although rapidly disappearing) laptop fan, elaborate water-circulation systems, and the passive cooling of mobile devices, which route heat through their plastic or metal chassis.[111] Alone, a single computer is a potent heat source. At the scale of cloud computing, which connects countless millions of servers, personal devices, and networking equipment, heat compounds exponentially. In data centers, which collocate servers and function as vital nodes in the physical infrastructure of the

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[109] Nihar Shah et al., "Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning" (Ernest Orland Lawrence Berkeley National Laboratory, 2015).

[110] Stephen Mufson, "Facing Unbearable Heat, Qatar Has Begun to Air-Condition the Outdoors," *Washington Post* (https://www.washingtonpost.com/graphics/2019/world/climate-environment/climate-change-qatar-air-conditioning-outdoors/, October 2019).

[111] Steve Jobs famously insisted that the first Macintosh ship without a cooling fan in an effort to reduce the noise. After three years of users complaining about hardware failures due to overheating, Apple included a fan in the 1987 Macintosh SE, which it advertised as having fifteen years of operating capacity. (It probably helped that Jobs had been fired from Apple in 1985.) See Ian Bogost, "I Wrote This on a 30-Year-Old Computer," *The Atlantic* (https://www.theatlantic.com/technology/archive/2019/06/why-30-year-old-macintosh-works-better-todays/591154/, June 2019) and Jerry Borrell, "SE Close-up," *Macworld*, May 1987, 115–17.

internet, cooling alone can account for up to forty percent of the energy bill.[112] Given that data centers consume upwards of two percent of the world's electricity,[113] this makes air-conditioning the internet no trivial matter. Without stable air conditioning, data centers can rapidly slip into "thermal runaway," where heat builds on heat toward an inevitable failure point. Just as an overheating laptop can grow sluggish or even damaged, so too can data centers lose valuable components to thermal runaway. While the time to failure varies between data centers, even the most capable can reach heat death in mere minutes.[114] The internet's existence requires its ongoing air-conditioning.

This chapter is about the total heat death that awaits the cloud, and the atmospheric media technologies those who manage the internet use to delay it, although they can never eliminate it entirely. As a subject for environmental media studies, air conditioning encompasses far more than whirring compressors, blowing fans, and rattling ducts. For data centers, technology companies, and computer users alike, air conditioning names the comprehensive, ongoing technical management of the air in the service of keeping data alive. By alive, I mean active, accessible, capable of fluid motion, and able to drive the hundreds of millions of human and nonhuman micro-decisions that constitute the contemporary internet.[115] Air conditioning drives this project. It is through air conditioning's atmospheric mediation, both within and beyond the

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[112] Nicola Jones, "How to Stop Data Centres from Gobbling up the World's Electricity," *Nature* 561, no. 7722 (September 2018): 163–66, https://doi.org/10.1038/d41586-018-06610-y.

[113] Fred Pearce, "Energy Hogs: Can World's Huge Data Centers Be Made More Efficient?" *Yale E360* (https://e360.yale.edu/features/energy-hogs-can-huge-data-centers-be-made-more-efficient, April 2019).

[114] Active Power, "White Paper 105: Data Center Thermal Runaway," 2015, http://powertechniquesinc.com/wp-content/uploads/2015/08/Active-Power-WP-105-Data-Center-Thermal-Runaway.pdf

[115] In this definition I draw from Sarah Kember and Joanna Zylinska's work on the "vitality" of media. See Sarah Kember and Joanna Zylinska, *Life After New Media: Mediation as a Vital Process* (Cambridge: The MIT Press, 2012).

walls of data centers, that the internet can function at its present planetary scale. Moreover, air conditioning is a vertically integrated enterprise that connects individual computers to cooling infrastructures to global concepts of the internet's "sustainability." In an age of constant anxiety over data's ongoing security, climate change has emerged as the threat that supersedes all others. Can data centers—and thus the internet itself—withstand rising sea levels, natural disasters, and a warming planet, even as they undoubtedly contribute to the prevalence of these conditions through their own emissions? These climate anxieties, which in this chapter I trace across the marketing, grey literature, and legal filings of data center companies, index how air conditioning has become a frontier on which data centers imagine a newly environmental security. Through the air's conditioning, media technologies shape a cultural imaginary of the environment as a computer itself. If the planet is a computer, this logic suggests, then the solutions to its environmental imperilment must also be computational. Critiquing this logic is this chapter's project.

As with "forecasting" in my previous chapter, I offer "conditioning" as a keyword and atmospheric media technique that structures my inquiry in this chapter. In particular, I propose conditioning as a theoretical keyword for media studies that links the field's long-standing interests in the cultural effects of global technological systems to related projects within the environmental humanities. From the Latin *condiciōn-em*, attested in some form or another in English since the 1300s, "condition" has for most of its existence referred to legal contexts, as stipulations or terms that must be satisfied for the fulfillment of a contract. However, in the industrial late 19th century, "to condition," as a verb rather than a noun, gained traction in commerce and agriculture. There, conditioning meant testing the quality of goods, particularly textiles, as well as the processes through which materials were brought to particular conditions. It is in this latter sense that we “condition” the air.[116] If “forecasting” names how atmospheric media describe and predict the air, then “conditioning” names how such media manipulate and act upon it. By placing “condition” in its verb sense, I draw attention to how media give rise to multiple overlapping “conditions” (in the nominal sense) that constitute our contemporary media-environmental landscape. As such, my study of air-conditioning the internet proposes two major interventions—the first for media studies as a field and the second for the environmental humanities. For media studies, I propose that the framework of “conditioning” more accurately articulates the ongoing work atmospheric media perform on the environment to bring it in line with forecasted models. Conversely, for the environmental humanities, “conditioning” demonstrates the absolute necessity of bringing media studies to bear on its enterprise, as digital media are one of the—if not *the*—primary actors of contemporary environmental transformations. In short, “conditioning” draws together these two fields as one.

The idea of “conditions” has percolated in critical theory for over sixty years. From Hannah Arendt’s foundational 1958 work of political theory *The Human Condition* sprang a whole host of theoretical “conditions” seeking to describe something about contemporary life. The phrase “the X condition” saw a rapid increase following Jean-François Lyotard’s 1979 essay on techno-science *The Postmodern Condition*: one can find scholarly work on “the neoliberal condition,” the “premodern condition,” and the “cosmopolitan condition,” just to name a few.[117]

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[116] It is also from these industrial contexts that “conditioning” acquires its newest sense in the twentieth century in the field of psychology: “to condition” in the sense of training a reflexive response in an individual. For all this etymological legerdemain, I draw from the *Oxford English Dictionary*, 1989 edition.

[117] For this rash of conditions, see: Hannah Arendt, *The Human Condition*, 2nd ed (Chicago: University of Chicago Press, 1998); Jean-François Lyotard, *The Postmodern Condition: A Report on Knowledge* (Minneapolis: University of Minnesota Press, 1984); Maurizio Lazzarato, *The Making of the Indebted Man*, trans. Joshua David Jordan (Cambridge: Semiotext(e), 2012); Bruce Holsinger, *The Premodern Condition* (Chicago: University of

In 1991, literary critic Jerome McGann articulated a "textual condition," a world of material textuality very different from that articulated by his deconstructionist forebears. In McGann's textual condition, "time, space, and physicality are not emblems of a fall from grace, but the bounding conditions which turn gracefulness abounding."[118] In other words, our present (in 1991) condition is one of text's materialization, distinct from earlier conditions in which texts were thought removed from messy qualities like materiality. While scholars have spoken of these various "conditions" over the past decades, the word itself has fallen out of fashion of sorts. A Google n-gram search for "the postmodern condition," by far one of the more popular references, shows a peak in 1997, after which it experiences a rapid decline. Perhaps in the twenty-first century it became gauche to propose, as these phrases seem to, totalizing descriptions of the essential qualities of a particular socio-historical moment. For this is the central rhetorical move of "condition theory": to proclaim that humanity now exists under the imprimatur of a particular condition, which the theorist them limns.

That the "condition" of these earlier theorists is intended in the word's nominal rather than verbal sense is not incidental. Condition theory may describe grand conditions, or even more plural, partial, and overlapping conditions, but rarely addresses "conditioning" in its verbal sense. For my purposes, I set "conditioning" alongside a host of other key gerunds in media studies that organize understandings of *what media do*. Terms such as "processing," "rendering," "curating," and "networking" attempt to map technical processes onto the domain of culture. For instance, Noah Wardrip-Fruin uses the phrase "expressive processing" explicitly to link the

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Chicago Press, 2005); and Ulrich Beck, "The Cosmopolitan Condition: Why Methodological Nationalism Fails," *Theory, Culture & Society* 24, no. 7–8 (December 2007): 286–90, https://doi.org/10.1177/02632764070240072505.

[118] Jerome McGann, *The Textual Condition* (Palo Alto: Princeton UP, 1991), 9.

electrical churn of computers in operation to "what [such] processes express in their design."[119] In this regard, speaking of "conditioning" shifts our attention from specific technologies of conditioning (although they certainly feature in this chapter's analysis) and toward describing techniques of conditioning, which traverse cultural and media forms. This is part of my dissertation's broader project of proposing such techniques as core to how atmospheric media mediate. In an essay on logistics (another such key word for contemporary media studies), Matthew Hockenberry summarizes this shift artfully: "Not, for example, the container, but . . . *containment*. Not the assembly line, I argue here, but *assembly*."[120] By offering "conditioning" as such a technique, I am asking what media do to brining cultural and environmental conditions in line with different models, whether models of temperature, security, or cultural development.

Air conditioning technologies are explicitly ones of regulation and influence, what Nicole Starosielski terms "standardization."[121] At their most sophisticated, they are digital media in their own rights, dedicated to capturing and processing information as much as controlling aerial conditions. Individual consumers may recognize these tendencies in internet of things (IoT) devices such as the Google Nest thermostat or Bluetooth-enabled AC window units. But digital media's embeddedness into HVAC is best ascertained at the scale of a data center, the primary subject of this chapter's analysis. Data centers rely on distributed arrays of temperature and humidity sensors to detect aerial conditions and respond to failure points. Wireless sensor networks (WSNs) allow data centers to monitor temperature continuously and shift cooling

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[119] Noah Wardrip-Fruin, *Expressive Processing: Digital Fictions, Computer Games, and Software Studies* (Cambridge: The MIT Press, 2009), 4–5.

[120] Matthew Hockenberry, "Techniques of Assembly: Logistical Media and the (Supply) Chaîne Opératoire," *Amodern* 9 (2020), italics in original.

[121] Nicole Starosielski, "Thermocultures of Geological Media," *Cultural Politics* 12, no. 3 (November 2016): pp. 302, https://doi.org/10.1215/17432197-3648858.

energy in real time.[122] Data from these networks power thermal models with which data centers simulate increased energy loads and natural disasters. Data centers can run WSNs on the servers themselves, but more often deploy "out-of-band" networks, or separate computing devices that run in parallel to the center's main servers. The result is a secondary computing network devoted exclusively to temperature sensing and control. The proliferation of sensors throughout data centers recalls Jennifer Gabrys's concept of the "becoming environmental of computation."[123] For Gabrys, the centrality of digital sensors to contemporary environmental science betrays how computing has itself become environmental, not just in its miniaturization and proliferation, but as the primary medium for documenting and understanding environments themselves. WSNs allow data center companies to picture their buildings as artificial environments. I suggest that we might take Gabrys's analysis one step further, to articulate how computing becoming environmental then requires its inverse: that the environment become computational. WSNs are just one atmospheric media of many through which data centers condition the air itself as data, something they can manipulate and calibrate just as they would servers.

Conditioning the air as data gives rises to the cultural imaginary of the data center as an impregnable fortress, over which data center companies have total control. But air, as this dissertation argues, always finds a way to leak. This might be in the form of pollution and emissions, which often form the crux of the environmental study of data centers.[124] For my part in this chapter, I build on this foundational work, which has done much over the past decade to demonstrate how the data center industry is environmentally damaging. Yet just as air leaks out

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[122] Samee U. Khan and Albert Y. Zomaya, eds., *Handbook on Data Centers* (New York, NY: Springer New York, 2015), https://doi.org/10.1007/978-1-4939-2092-1.

[123] Gabrys, *Program Earth*, 267.

[124] See Hogan, "Big Data Ecologies", Allison Carruth, "The Digital Cloud and the Micropolitics of Energy," *Public Culture* 26, no. 2 (73) (May 2014): 339–64, https://doi.org/10.1215/08992363-2392093, and Cubitt, *Finite Media*.

of the data center, so too does it leak in. Anxieties about natural disasters, runaway global warming, and geopolitical conflict as a result of climate change proliferate the data center industry. Many of the world's largest data center companies, such as CenturyLink, Equinix, and NTT Industries, explicitly indicate in their investor reports how climate change poses fundamental threats to their business. Data center companies respond to these risks in turn by construing their buildings as hermetic spaces, safely removed from danger, even going so far as to retreat geographically to the imagined "safe" spaces of the Arctic or the ocean floor. Data security becomes atmospheric both in that tracking and monitoring technologies pervade data centers, as well as in that the air itself becomes a threat to data's stability. Whether bodies or buildings, atmospheric media are defined by permeable and ever-shifting boundaries. The data center industry's intense obsession with environmental security is then best understood as an attempt to assert boundaries on those atmospheric media that continually flout them.

Paradoxically, some data center companies have responded to the dangers of climate change by pairing increased security with unprecedented integrations into their local environments. Media studies is not alone in noting the internet's environmental costs; the data center industry has made a concerted effort in recent years to grapple with its unsustainability. In particular, the multinational data center company Equinix, which I use as a case study throughout this chapter, has in recent years pivoted its branding toward sustainability, touting its centers' use of renewable energy. As Mél Hogan notes, much of the tech industry's attempts to "partner with nature" on sustainability ventures end up unconsciously reproducing colonial logics of exploitation and domination, "unwittingly serv[ing] to encourage consumption" rather than conservation.[125] "Sustainability" is more a marketing trick than a material practice. However,

[125] Hogan, "Big Data Ecologies," 631.

Equinix's turn toward sustainability isn't just a marketing strategy: its sustainability and investor reports make clear that environmental sustainability takes on real urgency given the frame of climate change as a security risk. Throughout this chapter, I remain relentlessly critical of the concept of "sustainability" as it manifests in the data center industry. Yet I also try to take these companies at their word, however partial, that they are attempting to pivot towards environmentally "friendly" practices. The challenge, I suggest, is that contemporary concepts of sustainability, particularly as practiced in the tech industry, are themselves construed from the get-go to justify partial and insufficient practices. A truly sustainable internet would need to look very different from the internet we currently have. The question is whether or not it is possible to transform our current infrastructures without ripping them out from the root.

I have structured this chapter in three sections and a coda. In the first, I offer a media theoretical approach to air conditioning as a technology, tracing the relationships between HVAC and computing from the late nineteenth century to the present day. This section also develops the concept of "conditioning" by reading through the cybernetic media theory of Marshall McLuhan. Through my engagement with McLuhan, I argue that data centers use HVAC to condition the air not just to a certain temperature, but also as data. In my second section, I ask what effect this conditioning has on the data center industry more broadly, particularly in light of the existential threats posed by climate change. In this moment of climate crisis, the data center industry (much like nation-states) takes refuge in increased security. Conditioning the air as data allows the data center industry to construe climate change as first and foremost a data security threat, transforming a crisis to which it is a fundamental contributor and framing it as something it is uniquely prepared to counter. However, in my third section, I demonstrate how fragile this alliance between sustainability and security really is. The legal and technical strategies through which data centers imagine their own sustainability are fundamentally designed to allow the image of sustainability to propagate at the expense of its material practice. But what else can the industry do? The internet, as currently constituted, is bound to overheat. No amount of air conditioning can prevent this. This chapter's coda, like that of the other chapters, returns to the central keyword of conditioning. I link the work atmospheric media do to condition air to the project of forecasting outlined in my previous chapter, as well as look forward to how conditioning anticipates a concern of my next chapter: that of the place of the vulnerable human body amidst atmospheric media.

A Media Theory of Air Conditioning

In the first season of the 2010s techno-thriller television show *Mr. Robot*, protagonist Elliot (Rami Malek) plans a hack of an impenetrable data storage facility named Steel Mountain. He uses an unlikely strategy: exploit its climate-control system. Elliot has fallen in with a motley team of anarcho-insurrectionists calling themselves "fsociety," whose stated aim is the erasure of all debts via the destruction of their records, starting with those held by the mysterious company E Corp. Steel Mountain (based on the real-life information management company Iron Mountain) stores E Corp's debt records on magnetic tape locked in vaults hundreds of feet underground. How to reach and destroy them? Elliot's plan is ingeniously simple: turn up the heat. He socially engineers his way into Steel Mountain by posing as a reclusive tech billionaire, and then plants a small circuit board (a Raspberry Pi, in one of its earliest media appearances) behind a thermostat. Through this board, fsociety can access a backdoor to Steel Mountain's intranet and control the building's WSN and climate-control systems. "Iron oxide and mag tape sticks to polyurethane with a binder," Elliot says to his fsociety colleagues in a miniature media archaeology lesson, “and if HVAC conditions surpass the ceiling of ninety-five degrees, polyurethane adhesive mollifies and tape data is unreadable.”[126] In other words, if it gets hot, the tape will melt. Ultimately, Elliot’s hack goes unfulfilled. The show’s twists and turns abandon the Steel Mountain plot in favor of more global hacking efforts.[127] But *Mr. Robot*’s realistic portrayal of the importance of air conditioning to the transmission and long-term storage of data stands out among film and television shows for whom data centers are more like shiny stock photos than actually existing facilities. Moreover, the show understands the most important aspect of air-conditioning the internet: how fragile it is as an enterprise.

Air conditioning plays a foundational role in the history of computing. From the clanking ducts of the room-sized computers of the 1940s to Steel Mountain’s digital feedback systems, HVAC is as important to computing as silicon and electricity. In this section, I trace this history and argue for air conditioning’s centrality to how we think about and interact with computers. In particular, I suggest that air conditioning conditions digital media in two primary respects. First, HVAC gives rises to conditions of environmental enclosure. Just as cloud computing distributes computation by dislocating it from an individual’s computer, only to recentralize it elsewhere in the data center, so too does the internet’s HVAC distribute and recentralize thermal energy. The cloud alienates users from their computers’ environmental impacts, promising to seal those impacts away safely in the data center’s hermetic vault. Second, HVAC conditions the internet’s

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[126] Nisha Ganatra, “Eps1.3_da3m0ns.Mp4,” *Mr. Robot* (USA Network, July 2015).

[127] The Steel Mountain hack is based in part on the Stuxnet worm, a cyberweapon believed responsible for crippling much of Iran’s nuclear weapons capabilities in the late 2000s. Stuxnet, jointly developed as a theoretical weapon by the US and Israeli military, targets physical control systems responsible for maintaining the integrity of nuclear materials processing. Briefly, the worm causes fast-spinning centrifuges to overheat and break down, thereby damaging valuable equipment. The Stuxnet worm was formally uncovered in 2010 and is often considered one of the more sophisticated cyberweapons to emerge from the War on Terror—and is a potent reminder that often the easiest (and only) way to destroy digital media is by exploiting its physical materiality.

users into imagining that computing can be done under environmentally sustainable conditions, when in fact this is almost impossible. Air conditioning is fundamentally imagined as a technology of "comfort," albeit one that in data centers prioritizes the comfort of machines over humans. Nevertheless, I argue that air conditioning is so culturally ingrained as technology that makes things easier that it becomes impossible to acknowledge when it makes things worse—or gives cover for other things getting worse. Air conditioning is a technology that claims to maintain stable conditions in times of (thermal, cultural) chaos. As such, it works to limit the possibility of its users imagining a truly sustainable internet.

While our species has tried to keep cool throughout its history, from wet reeds hung in windows to ice shipped transnationally, recognizably modern air conditioning emerged in the industrial milieu of the early 20th century.[128] Like calculus, air conditioning developed in a variety of places at roughly the same time. The honor of the first air conditioner often goes to American engineer Willis Carrier. In 1902, Carrier submitted a design for an early humidity and temperature control system to the Sackett-Wilhelms Lithographing and Publishing Company in Brooklyn. Over the subsequent four years, Carrier refined his designs, ultimately receiving a patent in 1906 for "an efficient practical apparatus of simple construction," which used a filtration mechanism built into a folding baffle to "thoroughly separate all solid impurities, floating particles, and noxious materials from the air either with or without altering its

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[128] Cultural and historical work on air conditioning is fairly limited. The "gold standard" for scholarship is Gail Cooper's 1998 *Air-conditioning America: Engineers and the Controlled Environment, 1900–1960*, which locates air conditioning within early 20th century tensions between engineers and the public about who should have the final say over a building's internal climate. Salvatore Basile's 2014 *Cool: How Air Conditioning Changed Everything* takes a more pop-history approach but provides a useful historical overview of air conditioning's emergence and proliferation. Marsha Ackermann's 2002 *Cool Comfort: America's Romance with Air Conditioning* takes a similar tack. More recently, Daniel Barber's 2020 *Modern Architecture and Climate: Design Before Air Conditioning* takes a deep dive into architectural techniques that preceded the proliferation of forced-air cooling.

temperature or humidity."[129] From its earliest moments, air conditioning was about more than just hot and cold. It was nothing less than the production of an artificial interior climate, what a 1921 *Scientific American* article on the emerging technology artfully calls "mechanical weather."[130] That this mechanical weather was first intended for media manufacturing is integral to air conditioning's history. Working at roughly the same time as Carrier, but in the American South, textile mill engineer Stuart Cramer pioneered a humidity control system designed to keep mill air damp, which was known to improve yarn's workability. The phrase "air conditioning," often attributed to Carrier's patents, is in fact an appropriation from Cramer, who coined it in a 1906 speech to the National Cotton Manufacturer Association. He derived the phrase from "yarn conditioning," the earlier process for treating yarn with moisture.[131] Before air conditioning trudged toward the miniaturization and efficiency that would make it suitable for homes, it was a fundamental driver of industrialization. As it turns out, we air-conditioned media long before we air-conditioned people.

Contemporary architectural and engineering perspectives on air conditioning often center human comfort. "Thermal comfort is not a luxury," write architects Oliver Klein and Jörg Schlenger, "it is an important criterion for being able to use a building fully for its intended purpose."[132] The popularization of air conditioning in the mid-twentieth century United States hinged on the idea that humans (at least, those able to afford it) deserved standardized interior climates. In 1959, E.C. Thom, a scientist with the United States Weather Bureau, devised what he called the "discomfort index," a forerunner of the contemporary heat index. Thom combined heat and humidity measures for cities across the United States into a linear metric for classifying

[129] Willis H. Carrier, Apparatus for treating air, US808897A, issued January 1906.
[130] Cited in Starosielski, "Thermocultures of Geological Media," pp. 302.
[131] Cooper, *Air-Conditioning America*, 19.
[132] Oliver Klein and Jörg Schlenger, *Room Conditioning* (Basel: Birkhäuser, 2008), 10.

perceived atmospheric discomfort.[133] As a metric, Thom's index has no particular calibration or training to account for psycho-physical variations in what people regard as "comfortable." Rather, it seems to have invented a certain kind of discomfort. Historian of the American south Raymond Arsenault credits Thom's index, which became popular in forecasts across the United States by the mid-1960s, with turning "what had once simply been a 'hot day' . . . into a menacing aberration."[134] Thom's index is by no means solely responsible for the popularization of air conditioning, but its role as an atmospheric media technique points to shifting cultural senses of how certain populations, particularly in the industrialized West, began to regard temperature in the twentieth century. Air conditioning rushes in to relieve humans of these newly "uncomfortable" climates. As Carrier's and Cramer's industrial systems demonstrate, not all air conditioning was intended for human comfort. Historian Gail Cooper notes that "the oldest conflict over atmospheric standards was the one between labor and management . . . atmospheric conditions required for efficient [materials] processing did not necessarily promote workers' health or comfort."[135] This is as true of digital media as text or textiles. Air conditioning's history is one of tensions between what it takes to keep machines "comfortable" versus what that comfort means for the humans who work with, alongside, and under those machines.

For the earliest computers, cooling was a constant reminder of the fragility of their operations. The room-sized ENIAC, built in the 1940s and popularly considered one of the first digital computers, had elaborate air intake and steam control valves to ensure it stayed at safe operating temperatures. Nevertheless, it was plagued by HVAC breakdowns. Once, as Thomas

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[133] E. C. Thom, "The Discomfort Index," *Weatherwise* 12, no. 2 (April 1959): 59, https://doi.org/10.1080/00431672.1959.9926960.

[134] Raymond Arsenault, "The End of the Long Hot Summer: The Air Conditioner and Southern Culture," *The Journal of Southern History* 50, no. 4 (November 1984): 615, https://doi.org/10.2307/2208474.

[135] Cooper, *Air-Conditioning America*, 52.

Haigh, Mark Priestly, and Crispin Rope describe in their history of ENIAC, "a number of tubes were damaged when part [of the computer] shut down automatically after internal temperatures hit 120 F because a set screw on an air intake hadn't been properly tightened."[136] Overheating wasn't the only atmospheric problem ENIAC's engineers had to face. In the mid-Atlantic climate of Aberdeen, Maryland, where ENIAC was first developed, its paper punch cards had a habit of growing soggy and unusable in the humidity.[137] Later supercomputers fell prey to similar problems. The Cray-1, an influential supercomputer developed by Seymour Cray in the 1970s, had an unusually baroque cooling system, composed of liquid Freon running throughout the machine's circular body. The Cray-1's cooling systems were so innovative—and elaborate—that they represent the sole patents that Cray sought on the machine. Given that air conditioning was still an architectural novelty in the mid-twentieth century, these room-sized computers often became air conditioning units themselves. ENIAC's engineers in Aberdeen would often roll their desks into one of the computer's nine rooms to escape the summer climate.[138] Room-sized computers, ancestors of today's data centers, transformed interior climates to their mechanical needs.

Contemporary users rarely encounter computers on the scale of ENIAC or Cray-1. Computers nowadays are smaller, more energy-efficient, and with the advent of cloud computing, off-load much of their work to data centers across the globe. While there's no single strategy for cooling a data center, many companies have defined best practices over the past few decades, as centers have become more common and in demand worldwide. Despite the popular imaginary of data centers as icy "meat lockers," many contemporary data centers run closer to

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[136] Haigh, Priestley, and Rope, *ENIAC in Action*, 82.
[137] Haigh, Priestley, and Rope, *ENIAC in Action*, 214.
[138] Haigh, Priestley, and Rope, *ENIAC in Action*, 214.

room temperature than one might expect. It's true that in the 1990s and early 2000s data centers often kept their temperatures quite low—as low as 55°F/13°C. But data centers have risen their temperatures in recent years, as companies seek to balance cooling requirements with energy efficiency. This shift comes in no small part due to an influential 2011 American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) white paper, which recommends that data centers be kept between 65°F/18°C and 81°F/27°C and at 60% relative humidity.[139] That being said, many data centers, particularly older ones, still run at substantially colder temperatures as a hedge against costly equipment failure.[140] Just as smaller personal computers use fans to cool their processors, so too do data centers rely primarily on forced-air cooling. The cooling capacity of a typical computer room air conditioner, or CRAC, exceeds a home unit by several orders of magnitude.[141] CRAC energy consumption is so substantial that it can even outpace that of the servers themselves, reaching around 40% of a typical data center's energy load, and up to even 60% in certain conditions.[142] From an energy perspective, it makes more sense to say that data centers' top priority is keeping servers cool than keeping them connected.

Despite these energy costs, data centers can make back efficiency through their architectural design, which can optimize for cooling in ways that few domestic spaces can afford.

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139 ASHRAE TC9.9, "Data Center Power Equipment Thermal Guidelines and Best Practices" (ASHRAE, 2015), 11.

140 Kevin Heslin, "A Look at Data Center Cooling Technologies," *Uptime Institute Blog*, July 2015, https://journal.uptimeinstitute.com/a-look-at-data-center-cooling-technologies/.

141 John Niemann, Kevin Brown, and Victor Avelar, "Impact of Hot and Cold Aisle Containment on Data Center Temperature and Efficiency" (Schneider Electric, 2011).

142 Jiacheng Ni and Xuelian Bai, "A Review of Air Conditioning Energy Performance in Data Centers," *Renewable and Sustainable Energy Reviews* 67 (January 2017): 625, https://doi.org/10.1016/j.rser.2016.09.050.

One of the most popular techniques is "aisle containment."[143] In aisle containment systems (fig. 8), data centers position their server racks in long aisles, with the fans on the backs of the racks facing each other, producing alternating aisles of hot air (coming off the servers) and cold air (pumped in from CRACs in the floor or ceiling).[144] The data center then walls off either the hot or cold aisles with doors or hanging plastic sheets and allows the conversely cold or hot air to proliferate throughout the data center. For energy efficiency, hot-aisle containment is far and away the superior option. It allows the ambient cold air to reduce overall energy costs and makes working temperatures a bit more bearable for those humans who work among the racks. However, cold-aisle containment is often cheaper to implement and easier to retrofit onto smaller server rooms or older data centers. In either approach, containment becomes one of the data center industry's great dreams and necessary fictions. The data center *contains*, both in that it houses the very matter of the internet itself, as well as in that it demarcates it. It bounds the internet in a building outside town, where it becomes a safe reserve, neither polluting nor overrunning its boundaries.

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[143] My colleague Kyle Bickoff first alerted me to aisle containment through his work on digital containment logics. See Kyle Bickoff, "Digital Containerization: A History of Information Storage Containers for Programmable Media," MITH Digital Dialogue (MITH, April 2019), https://archive.mith.umd.edu/mith-2020/dialogues/dd-spring-2019-kyle-bickoff/.

[144] Niemann, Brown, and Avelar, "White Paper 135."

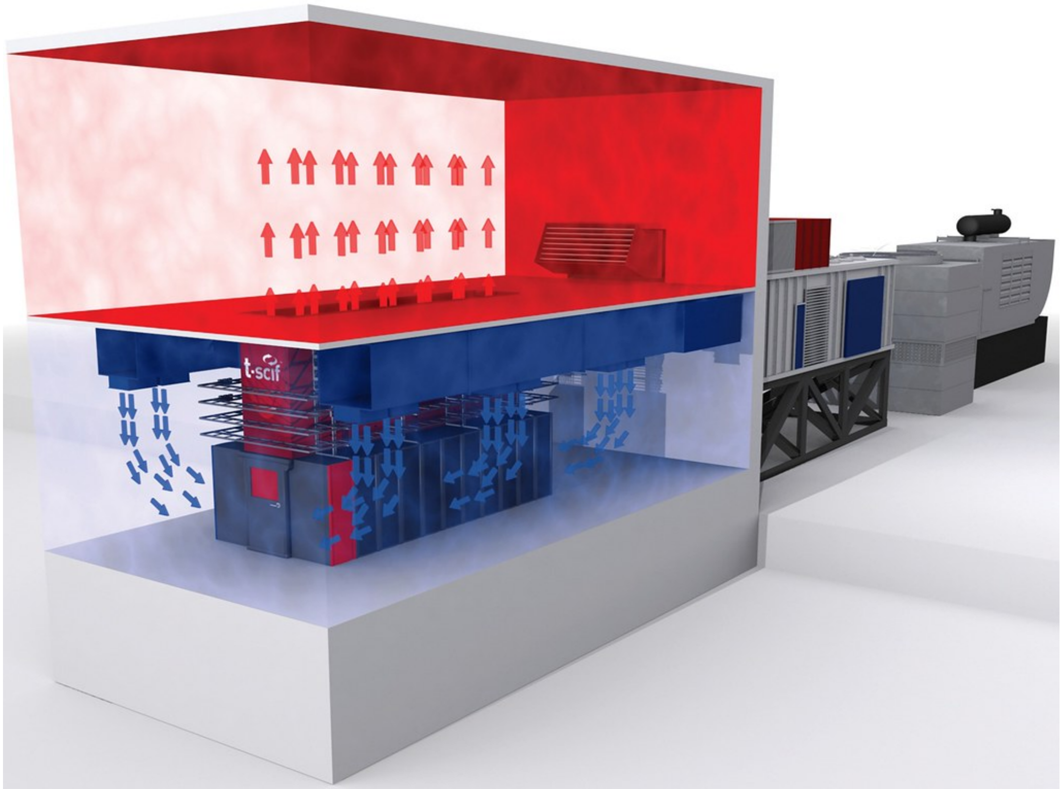

Figure 8. A diagram of aisle containment. https://www.flickr.com/photos/traftery/6976003747.

Through aisle containment, the data center industry cultivates formal distinctions between "hot" and "cold" air that recalls similar projects in media theory. As Nicole Starosielski notes, temperature appears in many of the foundational texts of media studies.[145] Wolfgang Ernst suggests that temperature first became a concern of media in Claude Shannon's 1949 "The Mathematical Theory of Communication," which appropriates the concept of entropy from thermodynamics.[146] Our contemporary moment has only made these entanglements between media and temperature more explicit. Temperature is embodied in haptic media[147] and the

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[145] Starosielski, "Thermocultures of Geological Media," 294.

[146] Wolfgang Ernst, "Fourier('s) Analysis: 'Sonic' Heat Conduction and Its Cold Calculation," *International Journal of Communication* 8 (2014): 2535.

[147] David Parisi, *Archaeologies of Touch: Interfacing with Haptics from Electricity to Computing* (Minneapolis: University of Minnesota Press, 2018).

thermal imagery of drone warfare.[148] Through the ongoing covid-19 pandemic, temperature checks have become a commonplace technique through which to verify one's possible infectious status.

Perhaps no media scholar is more associated with the concepts of hot and cool than Marshall McLuhan. In his influential 1964 book *Understanding Media: The Extensions of Man*, McLuhan proposes his durable—if inscrutable—argument that all media are either "hot" or "cool." For McLuhan, hot and cool have less to do with literal temperature and more with what he terms a medium's "definition" and "participation."[149] A hot medium such as radio is "high definition," filled in with information, yet does not allow the user to participate beyond tuning the dial. A cool medium like a cartoon, conversely, is "low definition," sketched in suggestions, requiring the reader to fill in the medium's gaps. The cloud computing practiced in DC11 complicates McLuhan's heuristic in that it is simultaneously awash in information yet demands constant participation from its users to contribute more. Yet McLuhan takes care to note that a medium's "temperature" is never absolute, but rather shifts "in constant interplay with other media."[150] Rather than determining whether the cloud is hot or cool along McLuhan's admittedly constrained axis, I suggest instead that media scholars understand the cloud as a field of temperature differentials, hotter in some places and cooler in others. This is what allows the cloud, and computation more generally, to function atmospherically. The unevenness of the cloud's literal and affective temperatures enables the flexibility with which it absorbs and reproduces the characteristics of other media formats. Here, I'm wary of how I'm pushing

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[148] Lisa Parks, "Drones, Infrared Imagery, and Body Heat," *International Journal of Communication* 8 (2014): 2518–21.

[149] Marshall McLuhan, *Understanding Media: The Extensions of Man*, 1st MIT Press ed (Cambridge: The MIT Press, 1964), 22–23.

[150] McLuhan, *Understanding Media*, 26.

McLuhan's admittedly vague definitions of hot and cool past the metaphorical and toward the thermodynamic. But as Dylan Mulvin and Jonathan Sterne suggest, this might be a latent tendency in McLuhan's own theory, given how his "blend of systems theory and temperature metaphors makes sense: a climate is a calibrated system, and 'equilibrium' in that system is all too fragile."[151] Indicative of McLuhan's investment in cybernetics, this homeostatic equilibrium influences how contemporary scholars such as Starosielski approach temperature as a medium of standardization. Without the precise calibration of thermal energy, media can all too easily (and quite literally) melt down.

The connection between McLuhan's interest in thermal equilibrium and my concept of conditioning is best articulated in another, less-cited concept from *Understanding Media*: that of the "break boundary." A break boundary, McLuhan suggests, is a point at which a medium moves so far in a particular direction along the hot/cool axis that it "overheats" (his thermodynamics get messy here) and must course-correct in the opposite direction. McLuhan describes this break violently: "the stepping-up of speed from the mechanical to the instant electric form reverses explosion into implosion."[152] Break boundaries are Pandora's boxes that once opened can never close again. Crucially, McLuhan does not offer break boundaries as mere points of no return in media history, but rather as limiting factors upon media's own tendency to grow exponentially. Break boundaries are techniques of negative feedback. The data center industry's architectural obsession with temperature and reliance on air conditioning then betrays literal and figurative break boundaries. In the literal sense, a data center must mitigate against the overheating that would disrupt its systems' operations. But in the figurative sense, architectural

[151] Dylan Mulvin and Jonathan Sterne, "Media, Hot and Cold Introduction: Temperature Is a Media Problem," *International Journal of Communication* 8 (2014): 2497.

[152] McLuhan, *Understanding Media*, 35.

techniques such as aisle containment betray how the tech industry is negotiating an oncoming climatic break boundary, as the drive toward cloud computing multiplies the demand for data centers worldwide, and thus the possibility of overheating servers. This is a moment with historical precedent, as McLuhan notes when he describes the industrial developments of the late nineteenth century as "[heating] up the mechanical and dissociative procedures of technical fragmentation."[153] Air conditioning might mitigate against a "break" for now, but on a global scale everything leaks. As Finn Brunton observes, "the Earth's thermal system—atmosphere, hydrosphere, cryosphere, lithosphere, biosphere—is the terminal heat sink," a technical term for the part of a computer that safely collects thermal energy away from vulnerable components.[154] The work of conditioning delays but never resolves this reality.

"Air conditioning" then names the technical and cultural processes through which the management of the air delays the latent tendency of media technologies to destroy themselves. As such, air conditioning is not just a bulky object mounted in a window keeping one cool. Rather, air conditioning is a cultural orientation toward the air itself, which views it as fungible, malleable, and capable of bending to an individual's will. This is why air conditioning has always been a technology of the upper classes, who have cultivated the inner sense that what they think the air should be like matters more than what the air is like. The cruel irony of their selfishness is that it has made air conditioning nigh mandatory for those who cannot escape the oppressive atmospheric conditions that air conditioning in turn fuels. In the age of climate change, the old, poor, and sick now require air conditioning as a fact of life, not as momentary comfort. The rise of cloud computing has only intensified these tendencies. Computing media

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[153] McLuhan, *Understanding Media*, 39.

[154] Finn Brunton, "Heat Exchanges," in *The MoneyLab Reader: An Intervention in Digital Economy*, ed. Geert Lovink, Nathan Tkacz, and Patricia de Vries (Amsterdam: Institute of Network Cultures, 2015), 168.

require air conditioning to operate, yet also are driving forces of the cultural work of conditioning the air.

Air Under Lockdown

Nestled in an office park in Ashburn, Virginia, the multinational company Equinix's DC11 data center blends into its surroundings. Decked in steel-slab grey, windows tinted opaque, with subtle yet persistent fencing on all sides, this data center (more properly a "peering point," as DC11 focuses more on the transmission of data rather than its long-term storage) fades easily into anonymity. It shares this with its town. Ashburn sits thirty miles west of Washington, D.C., where the nation's urban capital frays into suburban fragments, distinguished mostly by the progress of their construction projects. Here, everything is anonymous. As Tung-Hui Hu writes, data centers' "insatiable demand for water and power explains why [many] are built in out-of-the-way locations" at a remove from urban cores.[155] Ashburn has long been central to the cloud's infrastructure, a jewel in what Paul Ceruzzi calls the "Internet Alley," the geographical locations from which "the internet is managed and governed."[156] Among the historical factors leading both to Ashburn's anonymity and its outsized role in the internet's history, perhaps none is more foundational than its proximity to the defense industry. As Equinix notes on its website for its D.C. market, Ashburn is both a "strategic communications hub for the eastern United States" and "an ideal colocation site for agencies and companies subject to government regulations and compliance."[157] Of Equinix's fifteen D.C.-area data centers, ten are in Ashburn. Ashburn in turn

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[155] Tung-Hui Hu, *A Prehistory of the Cloud* (Cambridge: The MIT Press, 2015), 79.

[156] Paul E. Ceruzzi, *Internet Alley: High Technology in Tysons Corner, 1945-2005* (Cambridge: The MIT Press, 2008), 135.

[157] Equinix, "About Equinix," *Equinix* (https://www.equinix.com/about/, Accessed 8 Oct 2019).

has more data centers concentrated in it than anywhere else on Earth: 13.5 million square feet, with another 4.5 million in development as of 2019.[158] About three-quarters of the world's internet traffic, at some point, passes through this suburb. Perhaps more than anywhere else, here in Ashburn data must operate under conditions of total security.

Figure 9. A Google Streetview of DC11. Equinix strictly forbids photography inside the data center.

Data security has become an environmental concern. Under the ever-present threat of climate catastrophe, air conditioning has become integral to the internet's physical and digital security. In turn, security entails the unprecedented conditioning of aerial space and its transformation into data. This story has two parts, in that it is both about the technologies data centers such as DC11 use to lock themselves down in the event of climatological disaster, as well as the cultural narratives through which data center companies such as Equinix imagine climate

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[158] Loudon County, "Data Centers," *Loudoun County Economic Development, VA*, 2019.

change as a data security issue. These narratives, which I trace through DC11's physical design, Equinix's investor reports, and data center industry best practices, construe an internet at war with the environment—a war that Equinix seeks to persuade its customers that it alone can win. This martial approach is consonant with tech companies' broader project of establishing themselves as sovereign agents, what Benjamin Bratton describes as the desire to become entities capable of mustering the geopolitical force traditionally reserved for nation-states.[159] The environment becomes an important ideological frontier for an industry obsessed with speed, security, and just-in-time content delivery. The question then is for whom does the cloud operate as an agent of security and for whom does it demand vulnerability? How does the tech industry condition air, data, and space to justify these narratives of martial dominance? Answering these questions reveals how the internet produces highly differentiated aerial conditions, in which some populations have access to secure atmospheres by forcing vulnerable ones upon others.

DC11 is one of Equinix's "IBX" data centers, designed specifically for business applications—although its security features seem more in line with bank vaults. (Given that Equinix counts retail banks, credit card processors, and stock exchanges among its clients, this comparison might be more than superficial.) Equinix has patented its security system, which tracks employees, clients, and visitors alike across multiple levels of gated security, replete with cameras and biometric hand scanners.[160] These security measures ramp up exponentially as individuals move from outside the building, to a manned security desk, to the main body of the

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[159] Benjamin H. Bratton, *The Stack: On Software and Sovereignty*, Software Studies (Cambridge: The MIT Press, 2015), 341.

[160] Albert M. Avery IV, Jay Steven Adelson, and Derrald Curtis Vogt, United States Patent: 6971029 - Multi-ringed internet co-location facility security system and method, 6971029, issued November 2005.

data center, onto the floor with the servers, and finally into the server cages themselves.[161] Throughout, individuals pass through "man-traps," small antechambers in which one door will not open without both being shut, a precaution both against intruders and as firebreaks. On a tour I took of DC11 in the spring of 2019, guides elaborated even more baroque security measures available for those willing to pay, from 24/7 armed guards to infrared trip wires. After touring a similar Equinix data center in 2012, journalist Andrew Blum described these measures as "cyberiffic," designed as much to awe potential clients as to guarantee actual security.[162] These measures certainly aim for dramatic overkill, but more to the point, as Equinix describes in its patent, they allow the data center access to unprecedented levels of information about the movements of individuals inside its walls. Equinix proposes a security system driven by a "wide area network," or WAN, which materially resembles the WSNs that control its air conditioning systems. The point of both is to condition the data center's entire material holdings, from air to people, as information.

Not that there are ever that many people in a data center at any given time. While data center companies often trumpet new construction projects as valuable job creators for the surrounding areas—and consequently reaping governmental subsidies—these promises fail to deliver. While typical corporate headquarters, similar in scope and footprint to a data center, generally employ between two hundred and a thousand people on site, data centers often employ fewer than thirty, even as low as the single digits.[163] Moreover, data centers rarely handle the

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[161] Equinix, "IBX Data Center Physical Security | Equinix Videos," *Equinix* (https://www.equinix.com/resources/videos/ibx-data-center-physical-security/, September 2011).

[162] Andrew Blum, *Tubes: A Journey to the Center of the Internet* (New York: HarperCollins, 2012), 94.

[163] Alison Denisco Raymone, "Why Data Centers Fail to Bring New Jobs to Small Towns," *TechRepublic* (https://www.techrepublic.com/article/why-data-centers-fail-to-bring-new-jobs-to-small-towns/, September 2016).

day-to-day management of individual servers themselves, leaving that work instead to the clients, who either provide their own employees to work on site or hire contractors. Walking through DC11 was then an eerie experience, given the near total absence of people. The few I saw were clients and contractors of clients—overwhelmingly men, the enterprise version of the cable guy. Data centers are deeply depopulated, physically and financially. This depopulation bears out in the stories I tell in this chapter, which have as their putative protagonists buildings and corporations rather than individual human beings. Yet I take this absence not as a justification to ignore those rare-but-still-present humans who work alongside the server racks, but rather to draw attention to how data centers deliberately sideline humans in favor of machines. This bears out in their air conditioning apparatuses, which exist solely for the comfort of machines, with humans as afterthoughts. DC11's security apparatus is similar in that it operates primarily by removing the human as much as possible from the equation.

Alongside DC11's physical security features primarily targeting rogue individuals, Equinix has grown more sensitive in recent years to security threats posed by nonhuman forces, which would render their centers inoperable rather than steal information. Climate change poses a range of threats to data center integrity, from sea level rise threatening coastal infrastructure to natural disasters such as hurricanes or tornadoes damaging networking equipment.[164] In its 2019 10-K (a formal report that U.S. companies must file annually with the Securities and Exchange Commission), Equinix explicitly notes that climate change poses an existential threat to its operations. In its 10-K, it writes that "the frequency and intensity of severe weather events are reportedly increasing locally and regionally as part of broader climate changes . . . [posing] long-

[164] Ramakrishnan Durairajan, Carol Barford, and Paul Barford, "Lights Out: Climate Change Risk to Internet Infrastructure," in *Proceedings of the Applied Networking Research Workshop* (Montreal QC Canada: ACM, 2018), 9–15, https://doi.org/10.1145/3232755.3232775.

term risks of physical impacts to our business."[165] It notes that pressures to address climate change emerge not only from the environment itself, but also from clients and investors, for whom climate change presents a significant point of anxiety. Natural disasters pose a threat to energy infrastructures as well as individual buildings. "Each new [data center] requires access to significant quantities of electricity," Equinix writes, "limitations on generation, transmission and distribution [due to climate change] may limit our ability to obtain sufficient power capacity."[166] In a 2018 annual report on "corporate sustainability" to its investors, Equinix states that "[it] will prioritize responsible energy usage and high standards of safety, and commit to protecting against external threats such as climate change and data security."[167] Climate change and data security join together under the rubric of "external threats" against which Equinix must predict, plan, and protect.

Like the rest of humanity, Equinix has few tools available to stem rising tides and catastrophic storms. When it builds new data centers in vulnerable areas, it can do so with increased levels of architectural resiliency, but that doesn't help existing data centers. As such, Equinix's most powerful tool for climate security is more abstract: that of redundancy. By maintaining multiple backup systems for power, cooling, and data, Equinix hedges its risks such that if a data center is damaged or taken offline, other systems can fluidly step in to fill its place. These approaches are standardized across the industry through what it terms an "N" approach. For example, DC11 operates on an "N+1" redundancy model for its power and "N+2" for

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[165] Equinix, "SEC Form 10-K," February 2020.
[166] Equinix, "SEC Form 10-K."
[167] Equinix, "Corporate Sustainability Report | Equinix Green Data Centers," *Equinix* (https://www.equinix.com/resources/infopapers/corporate-sustainability-report/, 2018), 4.

cooling.[168] This means that onsite, it has everything to maintain its operations, plus minimal backup to support one or two components failing—say, a single CRAC or generator. This contrasts with "2N" approaches, which maintain an entire parallel backup network for critical infrastructure.[169] N+1 systems carry more risks but are cheaper to implement. As for the data themselves, they are not necessarily made redundant in the way power, cooling, and other physical infrastructures are. Data redundancy is the responsibility of the client rather than the data center, indicative of precisely how disinterested companies such as Equinix are in the content of their holdings. All that matters is the infrastructure.

Equinix's collapsing of climate change and securitization takes on explicit military parallels. The United States military, particularly under the Obama administration, has repeatedly cited climate change as a potential threat to national security.[170] For example, in November 2013, the Defense Department released a report concerning the melting Arctic Ocean, which it argued presents new opportunities for trade routes and resource extraction, control over which may lead to international disputes.[171] Equinix has anticipated these developments. It trumpets its Arctic data centers as potential entry points for new trans-oceanic cables capable of bypassing Asia's land routes in favor of more direct submarine connections between Europe and Japan. Seen through this perspective, DC11's bunker-style security has more in architectural common with northern Virginia's military bases than its high-tech offices. An Equinix internal reporting

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[168] Equinix, "DC11 Site Specs," 2019, https://equinix.app.box.com/embed/s/c1eyt2q09jsi981x2cbq2053mgycqwr7.

[169] J. Steman, "Data Center Redundancy: N+1, 2n, 2(N+1) or 3n2 (Distributed)," *Colocation Amsterdam | Datacenter.com - Amsterdam, Dallas, Luxembourg, Singapore Data Center Facilities*, December 2018, https://datacenter.com/news_and_insight/data-center-redundancy-2plus1-2n-distributed-redundancy/.

[170] US Department of Defense, "Quadrennial Defense Review Report" (US Department of Defense, February 2010).

[171] US Department of Defense, "Arctic Strategy" (US Department of Defense, November 2013).

document[172] makes brief reference to a data center named "DC97," which deviates from the naming structure of its other fifteen D.C.-area locations. DC97 is located in a "SCIF," or sensitive compartmented information facility, a deliberately secured location designed for the handling of classified materials. (Perhaps the best-known SCIF is the White House's Situation Room.) Notably, this makes DC97 exempt from sustainable energy reporting requirements. Political theorist Jairus Grove has argued that war has become the primary ordering principle of a society in the throes of a climate crisis: "[war] presents itself as an ordering principle or form of ecology . . . while also undermining the image of the world as one ruled by laws of a singular transcendental order."[173] Presented with the disorder of climatological catastrophe, Equinix and its peers offer clients the feeling of order through security. Cloud computing's desire for security through enclosure is emblematic of this doubled movement, wherein the very strategies that guarantee thermal order produce further climatological disorder.

Air conditioning drives the maintenance of the security state thanks in no small part to the laws of thermodynamics, in which thermal energy dissipates by going elsewhere. Data centers are that elsewhere. In turn, they give rise to other elsewheres: surrounding areas that absorb their thermal and atmospheric pollution. To borrow from Giorgio Agamben, data centers are thermal states of exception, where the upper classes transfer their computing energy, and where it pollutes in turn. For Agamben, a state of exception is a "threshold, or a zone of indifference" established by a state, in which normal rules of engagement (say, concerning the legality of torture) are suspended.[174] Like illegal CIA black sites, data centers as thermal states of

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[172] Equinix, "IBX Data Center Physical Security | Equinix Videos."

[173] Jairus Victor Grove, *Savage Ecology: War and Geopolitics at the End of the World* (Durham and London: Duke University Press, 2019), 65.

[174] Giorgio Agamben, *State of Exception* (Chicago: University of Chicago Press, 2005), 23.

exception must operate under conditions of secrecy. The cloud exists such that computer users in the West never need confront the material costs of their own computing, all the while drawing computing further under the control of corporate actors. Key to Agamben's concept is that the maintenance of states of exception characterize, indeed define, sovereign power. However, with rare (usually military) exception, states do not control cloud infrastructures. Private tech companies do. This shift is emblematic of what Bratton terms "platform sovereignty," or the tendency of modern tech companies to assume functions originally exclusive to the state. In building vast global infrastructures that contribute to climate change—whose entire function is to launder energy from the West elsewhere—tech companies have assumed the sovereign power to wield pollution. This is air under lockdown, in which the air of the wealthy stays pure while the air of others grows hotter, dirtier, and more untenable.

DC11 becomes a site of acute thermodynamics, as server heat multiplies server heat. For Equinix, securitization fuels the air's ongoing conditioning. Imagining the air as data enables its unprecedented surveillance. In a way, DC11's vision of a bunker-style security, in which air's movements are tightly controlled, runs counter to recent tendencies in security studies, which as Lisa Parks[175] and Peter Adey[176] have each noted, trend toward forms of atmospheric dispersal rather than traditional models of centralization. This is what Adey calls "security atmospheres": the security of millions of location-tracking smart phones triangulating individuals in real time rather than the classic closed-circuit camera. Security is "atmospherically distributed" and

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[175] Lisa Parks, *Rethinking Media Coverage: Vertical Mediation and the War on Terror* (London: Routledge, 2018).

[176] Peter Adey, "Security Atmospheres or the Crystallisation of Worlds," *Environment and Planning D: Society and Space* 32, no. 5 (October 2014): 834–51, https://doi.org/10.1068/d21312.

"immersive."[177] However, I would suggest that DC11 represents the physical incarnation of the paradox at the heart of cloud computing, namely that our digital systems are not disaggregated, but rather displaced. Our ubiquitous devices are now little but terminals accessing computers elsewhere. Proliferating the cloud entails centralizing the data center, as servers' thermal requirements are so specific as to be onerous if further decentralized. Dispersed, immersive, atmospheric security in one location requires centralized, locked-down security in another. These atmospheres are definitionally uneven. DC11 is simply one of many extrusions of a globally distributed security atmosphere.

This unevenness is core to my concept of atmospheric media. It's an unevenness we can read in the literal gaseous and thermal fields that data centers condition. But it's also an unevenness in the very act of defining data centers as atmospheric media. It may make more sense to say that data centers are the engines—even quite literally heat engines, as my previous section suggests—of the atmospheric media of cloud computing, which is itself constantly shifting energies across material and affective fields. Another way to frame the work that data centers such as DC11 do to condition the air is to note how they function as horizons of possibility for what shape cloud computing can take. Infrastructures have enormous inertia. They are not easily revised or replaced. Once embedded within culture, they can resonate their effects for decades, if not centuries. In my next section, I turn to what effect this inertia has on the possibility of imagining a truly sustainable internet, if such a thing can even exist. Though imagined as indeterminate, shifting, and illusive, atmospheric media are extraordinarily persistent. They linger. This lingering emerges from conditions set by prior media and condition the possibilities of future media in turn.

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177 Adey, 835.

Unsustainable Conditions

Data centers are prodigious consumers of environmental resources, from the land they stand on, to the water they use for power, to the electricity they draw to stay online twenty-four hours a day, seven days a week, three hundred and sixty-five days a year.[178] Much of this energy drives cooling,[179] the requirements for which are so substantial that the data center industry is now even exploring ways to suborn the climate itself as a passive HVAC system. Asta Vondereau notes that the far northern reaches of the planet have become attractive new sites for data center construction.[180] Arctic countries have seen a rapid data center boom, buoyed by permanently cold temperatures (for now) and governmental subsidies on electricity.[181] Microsoft has even gone so far as to test a data center at the bottom of the ocean near the Orkney Islands, where the cold water functions as the ultimate in passive cooling.[182] Equinix touts a number of its data centers as integrated directly into their local environments. The company's TR1 site in Toronto cools servers with water drawn from the depths of Lake Ontario, while AM3 in Amsterdam uses "free air cooling," or harnessing local winds to blow cool air in from the outside.[183] As Mél Hogan writes, such projects have grown common in a tech industry that "has

[178] Hogan, "Big Data Ecologies," 632.

[179] Pearce, "Energy Hogs."

[180] Asta Vonderau, "Storing Data, Infrastructuring the Air: Thermocultures of the Cloud," *Culture Machine* 18 (2019), https://culturemachine.net/vol-18-the-nature-of-data-centers/storing-data/

[181] Alix Johnson, "Emplacing Data Within Imperial Histories: Imagining Iceland as Data Centers' 'Natural' Home," *Culture Machine* 18 (April 2019), https://culturemachine.net/vol-18-the-nature-of-data-centers/emplacing-data/

[182] John Roach, "Under the Sea, Microsoft Tests a Datacenter That's Quick to Deploy, Could Provide Internet Connectivity for Years," *Microsoft Press Releases* (https://news.microsoft.com/features/under-the-sea-microsoft-tests-a-datacenter-thats-quick-to-deploy-could-provide-internet-connectivity-for-years/, June 2018).

[183] Equinix Editors, "Stay Cool, Equinix. Data Center Temperatures Always a Priority, Hot Weather or Not." *Equinix* (https://blog.equinix.com/blog/2014/07/10/stay-cool-equinix-data-center-temperatures-always-a-priority-hot-weather-or-not/, July 2014).

mandated itself to be responsible and to manage natural resources sustainably, premised on the logic of natural balance."[184] However, Hogan notes that these projects inevitably reproduce settler colonial logics of resource extraction. "Sustainability" becomes exploitation.

Sustainability is one of the keywords of our time. While "sustainable" (from the Old French *soutenir*: to bear, withstand, and endure) dates to the seventeenth century in English, the noun form "sustainability," in the sense of maintaining environments, is considerably more recent, emerging only in the mid-twentieth century. The concept itself is older than the word: after all, indigenous approaches to sustainable agriculture date back thousands of years. However, the word "sustainability" has taken on a specific set of meanings in the twenty-first century. When deployed by corporations, NGOs, and governments, "sustainability" names a theoretical harmony between capitalism and the environment, such that both might continue in their current form indefinitely. In this sense, "sustainability" emerges from concepts developed by seventeenth-century German accountant and mining manager Hans Carl von Carlowitz, whose treatise *Silvicultura Oeconomica* lays out principles that undergird the practice of sustainable forestry to this day.[185] Carlowitz's "sustainability" [*Nachhaltigkeit*] argues that foresters should take active roles in the planning, maintenance, and long-term management of forests, taking care to cut down only those trees that they can replenish the following season. This essential principle—that sustainability demands the human technical management of natural systems—informs the tech industry's embrace of the concept. However, I argue that the data center industry's embrace of sustainability, however well-intentioned, functions as a smokescreen for the internet's unsustainable conditioning. The technologies of air conditioning

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[184] Hogan, "Big Data Ecologies," 634–35.

[185] Seppo Vehkamäki, "The Concept of Sustainability in Modern Times," in *Sustainable Use of Renewable Natural Resources from Principles to Practices*, ed. Anneli Jalkanen and Pekka Nygren, 2005, 13.

and cultural logics of aerial security I have elaborated in earlier sections are key to the data center industry's business model, which operates through land enclosure and rent extraction. The "sustainability" granted through creative HVAC practices has become a cottage industry of financial instruments that launder capitalism rather than address its material contradictions. I argue that these instruments operate through digital logics: they are technologies that transform the "sustainable" qualities of things (like renewable wind energy) into abstract concepts (like financial instruments). I close the section by asking what conditions the "sustainable" internet actually sustains—and if there are possible avenues out of its thermodynamic catch-22.

The irony of media studies' recent love affair with data centers is that data centers are themselves profoundly disinterested in the data they host and transmit. Daniel Greene notes that Equinix and its peers and first and foremost landlords.[186] Like Swiss banks and the state of Delaware, data center companies not only don't care what's on their servers, but they also actively don't want to know. What Equinix sells isn't data or even servers (clients provide and maintain both), but rather life-support systems: air conditioning, back-up generators, and physical proximity to other servers. This arrangement bears out in Equinix's legal status. In 2015, Equinix converted itself from a standard c-corporation to a real estate investment trust, or REIT.[187] An REIT is a tax-advantaged legal organization for firms who hold a substantial portion of their assets in and generate profits from real estate. REITs are legally obligated to pass on at least ninety percent of their profits to shareholders in the form of dividends, but as a consequence don't pay any income taxes themselves. While the corporate tax cuts of the Trump administration's 2018 Tax Cuts and Jobs Act have limited the attractiveness of REIT conversion

[186] Dan Greene, "Landlords of the Internet," 2019.

[187] Equinix, "Equinix Board of Directors Approves REIT Conversion | Equinix, Inc." *Equinix: Investor Relations* (http://investor.equinix.com/news-releases/news-release-details/equinix-board-directors-approves-reit-conversion, December 2014).

in recent years, Equinix is still one of many data center companies that have made the jump. From a shareholder perspective, REITs hedge the risks of corporate investing against the theoretical stability of the real estate market. As Greene notes, this legal status means that Equinix has more in common with apartment buildings, storage unit companies, and malls than tech companies like Amazon or Google. It's in the business of enclosing space. Data is an afterthought.

At the same time as Equinix pursued its REIT conversion in 2015, it also joined over a hundred other companies in joining the American Business Act on Climate pledge. This Obama-era program, designed in concert with the COP-21 Paris Agreement, encouraged companies to set voluntary sustainability goals. As part of its pledge, Equinix has promised a range of sustainability ventures, most notably plans to operate one hundred percent of its data centers using renewable energy, and to build all new data centers in accordance with LEED Silver Standards, the second of four levels of a sustainable design certification program developed by the non-profit U.S. Green Building Council. (One can begin to see levels of integration with the non-profit industrial complex emerge.) While Equinix's sustainability ventures are no doubt commendable, the voluntary nature of these programs makes it all too easy for businesses to set goals that fall short of the transformative change the climate crisis requires, or to defer goals if their implementation grows too costly or inconvenient. Critiquing the voluntary nature of the Paris Agreement, Amitav Ghosh writes that "[its rhetoric aims] to create yet another neo-liberal frontier where corporations, entrepreneurs and public officials will be able to join forces in enriching each other."[188] In the intervening five years since its climate pledge, Equinix has positioned itself as the "green alternative" to its peers, building its brand on sustainability. Yet

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[188] Amitav Ghosh, *The Great Derangement: Climate Change and the Unthinkable* (Chicago: University of Chicago Press, 2016), 156.

these sustainability ventures stand in stark contrast to a business model predicated on land enclosure—to say nothing of redoubled commitments to maximizing shareholder value. Equinix's "green" programs operate from the fundamental premise that its business can continue to grow on a planet with finite resources.

Equinix must resolve this contradiction: how simultaneously to sustain a business model predicated on environmental enclosure alongside a brand predicated on environmental sustainability? Returning to its 2018 corporate sustainability report (subtitle: "Connecting with Purpose") provides an answer. In it, Equinix touts a "long-term goal of 100% clean and renewable energy across [its] global portfolio."[189] It claims to have reached this goal for its United States market, having "purchased 1 megawatt hour (MWh) of renewable energy products for every 1 MWh consumed."[190] This investment only represents the energy that Equinix draws from the power grid. It doesn't account for its data centers' varied emissions, which Equinix acknowledges encompass "diesel generators used for back-up power [and] on-site natural gas," as well as emissions generated by tertiary business practices, such as employee travel. For these, it's still "gathering data."[191] This is not to suggest that Equinix is actively dissembling in its corporate sustainability report. Rather, Equinix's strategies for defining and reporting its sustainability are in line with broader industry practices that are more interested in producing the image of sustainability rather than its actual material conditions. This is evident in the scope of its sustainability report, which touches not only on the environment but also the company's social impact and governance structure. Equinix's environmental commitments actually only encompass about three pages in the forty-page report. Other sections detail Equinix's

[189] Equinix, "Corporate Sustainability Report | Equinix Green Data Centers," 7.
[190] Equinix, 8.
[191] Equinix, 8.

commitments to gender equity (a whopping 11% of its nine-member board are "women and minorities"), its programs for hiring military veterans, and commitments to client privacy. Nowhere in this document are the fears expressed in its 10-K about climate change's devastating possible impacts on its business. Rather, sustainability functions as an affective branding technique, designed to soothe anxious investors and clients that not only can Equinix make them money—it can do so in a way that makes everyone feel good about the enterprise.

Just as air conditioning promises the sustainable operations of individual servers, so too does wind undergird Equinix's claims of corporate sustainability. In a separate investor document, Equinix claims that its DC11 center achieved 100% renewable energy coverage in 2017 and 2018 from wind power.[192] But does this mean that the electricity flowing through its servers and powering its HVAC actually came from wind turbines? The answer, it turns out, is "probably not." One of the challenges for determining renewable energy use for the purposes of reporting is that once electricity reaches the power grid, it's impossible to determine its original source. Equinix simply cannot verify that the electrons in its data centers came from any one place in particular. However, the energy industry has developed a number of different legal and financial instruments through which businesses such as Equinix can "tag" and thus verify renewable energy usage. Equinix verifies DC11's wind power through an instrument called the renewable energy certificate, or REC. An REC is an abstract commodity corresponding to the intangible environmental benefits of one megawatt-hour of renewable energy. Crucially, these benefits are distinct from the actual energy itself—the bare materiality of electrons flowing through cables. By buying an REC from a renewable energy provider, Equinix can claim legal ownership of that energy's "renewableness" without actually using the energy itself. Indeed,

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[192] Equinix, "Equinix International Business Exchange Sustainability Quick Reference Guide" (Equinix, August 2019).

Equinix can do so without even being on the same electrical grid as the wind turbines whose intangible environmental benefits it has purchased. In this way, energy providers can use the sale of RECs as a parallel income stream. As the bearer of the REC, Equinix has the legal right to proclaim that its data centers are "covered" by however many thousands of turbines it takes to generate the same amount of energy as it uses for its data centers.

The REC conditions through decomposition. It cleaves a megawatt-hour of renewable energy into composite parts. RECs emerge from a cultural desire to make energy do something that it materially cannot—that is, to speak as data. In the electrical grid, metadescriptive qualities such as "point of origin" and "sustainability" dissolve into an unintelligible slurry. The REC retrojects information onto energy, tagging it as though it were an entry in a relational database. Even with the best of intentions, the REC and the reporting structures it seeks to satisfy produce an easily manipulable system, where meeting metrics becomes the point of the exercise rather than an actual commitment to renewable energy use. This is what economists call "Goodhart's Law," named after economist Charles Goodhart quoting anthropologist Marilyn Strathern: "when a measure becomes a target, it ceases to be a good measure." In the introduction to their 2013 edited collection *"Raw Data" is an Oxymoron*, Lisa Gitelman and Virginia Jackson contend that "data need to be imagined *as data* to exist and function as such."[193] RECs and climate pledges alike are symptomatic of this imaginative project. Imagining energy as data necessitates rhetorical sleights of hand: hence the careful emphasis in Equinix's reports that DC11 is not using wind power but is rather covered by wind power. Coverage appropriates a legal right to the concept of sustainability and applies it to energy that may or may not be sustainable. These are techniques of datafication. Environmental matter becomes abstract

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[193] Lisa Gitelman and Virginia Jackson, eds., *"Raw Data" Is an Oxymoron* (Cambridge: The MIT Press, 2013), 3, italics in original.

quantities and qualities, only further obscuring the materiality at hand. Like "the cloud," "sustainability" becomes disaggregated, unbundled, spread fluidly across the land in accordance with market logics.

In the conclusion to her 2016 book *Exposed: Environmental Politics and Pleasures in Posthuman Times*, environmental humanist Stacey Alaimo reflects on how contemporary corporate discourses of sustainability function as updates to early twentieth century concepts of "conservation," themselves based in "a tendency to render the lively world as a storehouse of supplies for the elite."[194] Sustainability smoothly fits in with capitalism's desire for unchecked expansion and disarticulates environmentalism from its "tree-hugger" reputation in the 1970s and 1980s, providing in its place "a more technocratic, apolitical domain . . . more palatable for academic institutions, governments, and businesses."[195] Against what she sees as the anthropocentric rhetoric of sustainability, Alaimo offers the by-now familiar theoretical figures of entanglement, mattering, and co-constitution: we must come to see the world through a feminist new materialist lens that might reckon with uneven ethical and material obligations between humanity and the world that sustains us. I agree with Alaimo's critique and am sympathetic to her counterprogram. However, I disagree with her contention that corporate sustainability discourses were ever anthropocentric to begin with. This chapter's analysis of air-conditioning the internet has demonstrated the dizzying range of nonhuman activity that preserves the concept of sustainability, from the server networks that surveil temperature, to the HVAC units themselves, to the financial instruments that ensconce the cloud within market logics. These are networks that, by virtue of their digitality, are intensely sensitive to

[194] Stacy Alaimo, *Exposed: Environmental Politics and Pleasures in Posthuman Times* (Minneapolis: University of Minnesota Press, 2016), 169.

[195] Alaimo, 171.

entanglement and co-constitution. Indeed, I would suggest that digital media understand entanglement better than any human theorist might. Just think what happens when small failures cascade into massively broken systems.

The internet, in its current configuration, is an intensely unsustainable enterprise. That may be okay; we may not want to sustain it. By "unsustainable," I mean first that it is not possible to meaningfully alter its core technologies on the global scale at which it operates, at least with the political will currently available to our species. Second, I mean that it is impossible to practice the contemporary infinite growth drive of capitalism on a planet with finite resources. Data center companies grow by buying and enclosing more land. This will become exhausted soon enough, to say nothing of the energy circulations that make such enclosure untenable. There seem to be two avenues available out of this mess. The first is a techno-solutionist avenue, similar to that proposed by the now defunct Paris Agreement. We must put our faith in untested and unproved technologies that we hope will allow us to continue what we are doing indefinitely. The second is the revolutionary avenue, in which the foundations of our enterprise are untenable, and we must seek new foundations. These approaches are perhaps not mutually exclusive. Holly Jean Buck's recent work on geoengineering, for instance, provides a rhetorical space for imagining techno-environmental projects that center decolonial and critical race perspectives, rather than simply the unchecked maw of capitalism.[196] Along similar lines, work in digital humanities on minimal computing imagines digital infrastructures that run on the principles of small and slow, rather than big and fast.[197] I am reminded of an evocative project by *Low Tech Magazine* to run a solar-powered version of their website, which sometimes goes off-line when it

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[196] Holly Jean Buck, *After Geoengineering: Climate Tragedy, Repair, and Restoration* (London: Verso, 2019).

[197] GO::DH Minimal Computing Working Group, "Minimal Computing" (https://go-dh.github.io/mincomp/, February 2017).

gets cloudy in Barcelona (where the server runs).[198] If we are to move past conditions of (un)sustainability to meet the challenges of preserving what is good about the internet in the face of its own self-obliteration, our solutions may end up looking more like *Low Tech Magazine* than sophisticated HVAC: an internet based on partiality, contingency, and brokenness, but for which those are virtues and not design flaws.

Conditioning Media

Since I began work on this chapter in the spring of 2019, HVAC has become an even more pressing concern for modern living in no small part due to the ongoing covid-19 pandemic. While our collective understanding of the disease's transmission vectors continues to evolve, one aspect has become startlingly clear: adequate ventilation is among the strongest prophylaxes we have available against the virus. As the CDC notes, and as the past two years have made obvious to us all, SARS-CoV-2 (the virus that causes covid-19) "spread[s] between people more readily indoors than outdoors" due to limited air flow.[199] Outdoors, "even a light wind can rapidly reduce concentrations," mitigating both risk of disease and the severity of cases should one be infected. In such conditions, proper HVAC is a must. However, as with too many aspects of life during pandemic, access to adequate air flow is unevenly distributed along existing lines of inequity. Returning to in-person educational instruction has laid these questions bare: whose institutions have ensured up-to-date HVAC? Who gets to teach in rooms with windows? Do those windows even open properly? The tensions of air conditioning engineering between the ability of individuals to open windows to exterior environments and the desire for fully

[198] See: https://solar.lowtechmagazine.com/about.html.

[199] CDC, "Ventilation in Buildings," *Centers for Disease Control and Prevention* (https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation.html, June 2021).

controlled interior climates have returned with a vengeance. Air conditioning has produced variegated conditions for life itself.

Whereas my first chapter began this dissertation with a study of creative atmospheric media texts, this chapter has turned to atmospheric media technologies: namely, air conditioning and the internet. Through formal, technical, and theoretical analyses of data center HVAC practices, this chapter has demonstrated the inextricability of these two technologies. The internet materially depends on massive expenditures of energy for cooling and humidity control, without which it could not function at all. But more crucially, as I have argued throughout this chapter, both air conditioning and the internet extend a project of technical standardization over the planet itself. For the data center industry, this comes to the fore in its obsession with security. In order to put air under lockdown (another metaphor that takes on new salience amidst pandemic living), the data center industry employs media techniques of surveillance, segmentation, and computational control. Above all these practices, climate change looms. I am reminded of science fiction novelist Octavia Butler's prescience in her 1993 post-apocalypse novel *Parable of the Sower* that climate collapse is also the rise of the gated community. By conditioning the internet's air, we also set the conditions for its further function and possibility. Under current conditions, an internet without air conditioning is impossible. Producing new conditions begins with understanding this atmospheric media project, but also involves substantial transformations in the political, material, and juridical realities of the internet itself.

For my dissertation more broadly, this chapter's focus on conditioning operates as a hinge between my previous chapter's discussion of forecasting and my subsequent keywords in my next two chapters, respiring and modeling. In the previous chapter, I began my discussion of atmospheric media with definitional questions: what are atmospheric media and how do they picture and predict aerial environments? From that definitional beginning, this chapter has explored what atmospheric media *do* to environments in order to maintain those pictures and predictions. Whereas the previous chapter took a unidirectional approach to atmospheric mediation—the media mediate something found *sui generis* in the environment, even as they then produce alternative and imaginative versions of those environments—this chapter has taken a bidirectional approach, engaging atmospheric mediation that moves between media and environments in more fluid fashions. This is most evident in this chapter's theoretical and historical interest in air conditioning's relationship to cybernetics. The media figure of the feedback loop has been important to this chapter's analysis and will become even more so in subsequent chapters as questions of embodiment and affect come more to the fore. The human body, which the data center industry deliberately expunges from its atmospheric media models, makes these questions all the more urgent. I am reminded of German philosopher Peter Sloterdijk's claim that "air conditioning, in the literal sense, will establish itself as the main space-political theme of the coming era," in that surviving climatological catastrophe will depend, for a time, on who has access to stable atmospheres and who is left out in the heat.[200]

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[200] Peter Sloterdijk, *Globes*, trans. Wieland Hoband (Cambridge: Semiotext(e), 2014), 961.

Chapter Three

Collective Tissue: Media Toxicity and Respiratory Temporality

> We are talking epidemiology here, not metaphor.
> — Carolyn Steedman, *Dust*

The 3D printer hums. I watch its nozzle dart over its heated bed, threading fine plastic like spider's silk. We're alone in this small conference room together. I acquired this machine, a cheap Monoprice Maker Select, for a research project with some colleagues at my home institution of the University of Maryland. We set out to learn everything we could about this single machine, from where its circuit boards were printed to the online communities that emerged around it.[201] We cracked it open and never quite got around to putting it all the way back together. It's now in a sorry state. The filament no longer sticks to the heated bed and the cooling fan dangles off the back: I've fired it up for one last hurrah. The Maker Select doesn't have a ventilation hood, which means that the air in this conference room has long since filled up with the hazy vapor of melted plastic. I recall an internet review of this particular plastic filament that suggested it smells like toasted cake when heated and extruded.[202] Against my better judgment, I lean in close to the nozzle to catch a whiff. It's an acrid yet sweet smell, and my head fills with a brief plasticene rush—no toasted cake for sure. I turn to the circuit board's enclosure and feel the heat coming off it. A small breeze tickles my hand, misdirected from the broken fan. As I inhale and exhale, I notice my throat burning a little. Suddenly, I catch a sharp and urgent smell. The circuitry has overheated and started to burn the vinyl table underneath. I

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[201] This research was sponsored by a grant from the Rutgers-Camden Archive of Digital Ephemera (R-CADE), which hosts a yearly symposium. For my contribution to this project, see https://jeffreymoro.com/research/2017/rcade/.

[202] Kerry Stevenson, "The Smells of 3d Printing," *Fabbaloo* (https://www.fabbaloo.com/blog/2013/8/13/the-smells-of-3d-printing.html, August 2013).

flip the "off" switch and unplug the printer from the wall for good measure, hoping that no one who walks in later notices the reek of scorched plastic hanging in the air.

Atmospheric media surround and suffuse us. By breathing in the 3D printer's fumes, I invite its plastic toxicity into my flesh. As a mediating circuit between the human body and its surrounding environments, breath has long figured in media theory. Walter Benjamin's notion of "aura" is first apprehended through breath, for instance. In the second version of his essay "The Work of Art in the Age of Its Technological Reproducibility" (1935) he writes: "to follow with the eye—while resting on a summer afternoon—a mountain range on the horizon or a branch that casts its shadow on the beholder is to breathe the aura of those mountains, of that branch."[203] For Benjamin, breath mediates the visual perception of a phenomenon into embodied experience. The word "aura," which Benjamin uses in the essay's original German, is Latin and Greek for "breath" and "breeze," respectively. The auratic quality of an object is its innate quintessence, its breath or life force. However, the respiratory aura I encounter in the 3D printer is a far cry from Benjamin's mountains. What I apprehend is not sublimity but rather the stench of poison. Breath is life only when sustained and the contemporary media landscape is itself filled with hostile atmospheres. The literal breath of we human animals, it seems, may not survive the great cosmic exhalation of carbon dioxide into the planet's atmosphere. Choked lungs testify to the material costs of technological development. Atmospheric media have arrived at our bodies' doorstep to claim their ecological debt.

Whereas my previous chapters have discussed atmospheric media in terms of the air that surrounds us, such as the media of weather forecasting or the controlled climates of air

[203] Walter Benjamin, *The Work of Art in the Age of Its Technological Reproducibility, and Other Writings on Media*, ed. Michael William Jennings et al. (Cambridge: Belknap Press of Harvard University Press, 2008), 23.

conditioning, this chapter turns to atmospheric media's capacity to suffuse the human body. My keyword in this chapter is *respiring*, the successive and sustained action of breathing air in and out of the lungs. As John Durham Peters argues, respiration is simultaneously awash with mediation through such technologies as assisted breathing apparatuses and quantified breathing sensors, yet often thought "removed from technical devices" by virtue of being considered "pure and natural."[204] Furthermore, as Jean-Thomas Tremblay argues, technological modernity impacts the breath of different populations in different ways, stratifying its deleterious effects along existing lines of racial, gender, and economic inequality.[205] My project in this chapter thereby uses respiration to index atmospheric media's environmental consequences in relationship to the human bodies such media penetrate. In particular, I argue that atmospheric media introduce new temporal relationships to the lived experience of media's toxicity, what I call "respiratory temporality." These rhythmic and cyclical temporal relationships echo that of the breath, allowing media toxicity to ingrain itself within our cultures and bodies. The spatialized feedback loops between media and environment I have mapped in previous chapters now take on temporal dimensions, as atmospheric media lodge an enduring chemical materiality within the humans who make, use, and dispose of them. 3D printing serves as my primary subject of analysis throughout his chapter, although my discussion extends beyond the printer's plastic to encompass its broader computer architecture and cultures of use. (There is also, late in the chapter, a brief foray into science fiction.) Together, I propose that it is atmospheric media's cyclical and rhythmic temporality, best ascertained in the breath, that makes its environmental effects so pervasive.

[204] John Durham Peters, "The Media of Breathing," in *Atmospheres of Breathing*, ed. Lenart Škof and Petri Berndtson (SUNY Press, 2018), 179.

[205] Jean-Thomas Tremblay, "Feminist Breathing," *Differences* 30, no. 3 (December 2019): 97, https://doi.org/10.1215/10407391-7974016.

Breathing in the 3D printer's fumes reveals the biochemical dimensions of atmospheric media. While not one of the five classical Aristotelian senses, breath is nevertheless a sensory phenomenon just like vision and hearing. We feel a tightness in our chests around smoke and our noses prickle at a stench. But respiration is more durational than other senses. While a smell might linger in the nose for a few minutes, breath collects chemical matter and secrets it away in the body's hidden recesses for days, years, even lifetimes. In his research on media and geology, Jussi Parikka employs what he calls a "syndrome per metal" chart, which illustrates the biological effects of common metals used in media production. Cadmium "accumulates, for instance, in the kidneys" and barium "causes brain swelling, muscle weakness, and damage to the heart, liver, and spleen."[206] These biochemical effects transform computer hardware into "hardwork," Parikka's neologism for the unconscious and nonconsensual labor that the media manufacturing industry extracts from its workers. This is an argument familiar to feminist and queer theory, which have both long charted the instability of bodily boundaries. Instead, as Mel Y. Chen argues, such questions as where media end and the body begin "become particularly complex when taking into account the various mixings, hybridizations, and impurities that accompany contemporary bodily forms."[207] While complex, multicellular life has always been an assemblage of microorganisms and semi-animate biochemical matter, atmospheric media introduce new dimensions to this impurity. Following Stacey Alaimo's work on multiple chemical sensitivity disorder, respiration blurs boundaries not just between bodies and media, but also bodies and the environment. This provides, Alaimo writes, "a potential site from which to

[206] Parikka, *A Geology of Media*, 95.

[207] Mel Y. Chen, *Animacies: Biopolitics, Racial Mattering, and Queer Affect* (Durham and London: Duke University Press, 2012), 193.

reconceptualize human materialities as coextensive with the rest of the world."[208] There is no way to breathe without altering one's material constitution. Breathing in media, we also breathe out, leaving material traces in the world.

In turning in this chapter to atmospheric media's pollution and toxicity, I am self-consciously orienting my attention to those qualities of media that might otherwise be thought peripheral to media technologies themselves. My subjects in this chapter are gases, fumes, and particulate matter alongside computer chips and 3D printers. In this shift, I track what I see as a kind of phase change in contemporary environmental media studies, as scholars' attention moves from solid media objects—think the computer, the television, the book, or the vinyl record—toward fluid and gaseous materialities. Here, thinkers such as Jennifer Gabrys, Richard Grusin, and Bernard Stiegler have marshaled strains of process philosophy and new materialism toward the notion that media are unfolding relations rather than stable objects.[209] In this model, there is little in the world that is not some form of mediation, exploding the potential subject matters of media studies. For my part, I have been influenced throughout this dissertation by these lines of thinking, particularly in how I describe atmospheric mediation as a feedback loop across humans, technologies, and environments. Nevertheless, I am grounded in this chapter in toxic *things*. The reek of ink pouring off a printing factory and the ozone of a misfiring circuit board have material effects on the world that we must as scholars track. The atmospheric mediation I trace in respiration is thus not a free-floating relation, but rather a specific and uneven allocation of toxic materiality.

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[208] Stacy Alaimo, *Bodily Natures: Science, Environment, and the Material Self* (Bloomington: Indiana University Press, 2010), 136.

[209] See Jennifer Gabrys, "Becoming Planetary," *E-Flux* (https://www.e-flux.com/architecture/accumulation/217051/becoming-planetary/, 2019), Grusin, "Radical Mediation", and Bernard Stiegler, *The Neganthropocene*, trans. Daniel Ross (London: Open Humanities Press, 2018).

For my part, I locate the effects of this toxic materiality in what I call in this chapter *respiratory temporality*: the durational, cyclical, and rhythmic experience of media toxicity, which echoes from a single breath out to generations of breathing. Media theorists have long explored how technologies constitute and influence human senses of time; in this dissertation I have explored the temporality of weather forecasting, for instance, through such technologies as diaries and calendars. In this regard, breath is no different. The rhythm of breathing influences bodily function and mood, and the availability of air is the availability of life. To import a metaphor from computing: breath clocks life. By introducing toxic impurities to the body, media influence this respiratory temporality. Conversely, respiration's cyclical nature allows for media to exert outsized durational influence on bodies over time, echoing environmental humanities scholar Rob Nixon's concept of "slow violence."[210] For Nixon, environmental disaster is particularly difficult to countenance given how it unfolds over long timescales, which can stretch decades, lifetimes, even civilizations. The duration of environmental violence is also a convenient way for polluters to evade responsibility for their actions. By the time a poison takes root, a polluting company may have transferred ownership or dissolved entirely. The rhythm of respiratory temporality is thus a useful vantage point from which to investigate how atmospheric media recast notions of time and space. The durational scale of environmental catastrophe meets the breath's microtemporality. Furthermore, I use respiratory temporality as a way to interrogate contemporary environmental media studies' investment in the rhetorical and geological figure of the Anthropocene. Rather than a discrete periodization in geological history, I argue for thinking about our contemporary ecological moment as one of overlapping and intersecting temporalities: the time of the breath, the time of the machine, and the time of the planet.

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[210] Nixon, *Slow Violence and the Environmentalism of the Poor*, 47.

Computing has long served as a default answer to nearly every social and material problem our species has faced since we developed it, what critic Evgeny Morozov has pithily termed "technosolutionism." 3D printing, as a symbol of a contemporary techno-social vanguard, is no exception. It's "maker" culture, Silicon Valley, and the promise of well-paying STEM jobs. 3D printing recalls science fictional technologies of easy abundance, such as Star Trek's replicator. In this way, the 3D printer concretizes what Shirin Vossoughi, Paula K. Hooper, and Meg Escudé describe as the "distinctly economic" discourse of the contemporary "maker" movement.[211] While Star Trek's replicator was a fantasy of post-scarcity, the 3D printer intensifies the capitalist order. No wonder then that 3D printers are becoming more common in libraries, universities, and community centers, where they can function as tools to train individuals into the fantasy of capitalism's infinite growth. It's a fantasy that rings hollow on a planet whose resources the human species is rapidly exhausting. Throughout this chapter, I use the figure of breath's exhaustion to link the material effects of atmospheric media toxicity to its cultural experience. How do technologies such as 3D printing exhaust the breath even as they attempt to shore up its further possibility? What resolutions are possible to resolve the seemingly inherent tendency of computing to exhaust individual—and planetary—breath? In this regard, this chapter extends the questions I explored in my previous chapter on air conditioning. In both chapters, atmospheric media are tasked with solving problems of their own making, a tendency which further extends their material and social pervasion. In exhaustion, I ask in this chapter what happens when atmospheric media can no longer sustain their immanent contradictions.

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[211] Shirin Vossoughi, Paula K. Hooper, and Meg Escudé, "Making Through the Lens of Culture and Power: Toward Transformative Visions for Educational Equity," *Harvard Educational Review* 86, no. 2 (June 2016): 207, https://doi.org/10.17763/0017-8055.86.2.206.

This chapter follows a breath through the body from the moment of its initial sensation, through its entry into the lungs, and finally into the durational experience of lingering in the body. The first section, titled "Nose," explores the role of smell in 3D printing and atmospheric media more generally. Smell is an under-theorized sense in media studies, with connotations of bodily excess, imprecision, and disease. Drawing on sensory studies and the environmental humanities, this section proposes smell as a powerful interpretive tool for 3D printing, in particular for how it links technological materiality to embodied experience. The second section, titled "Lungs," follows the breath deeper into the body to map the experience of media toxicity. Drawing further on scholars such as Chen and Alaimo, I explore the role that pollution and toxicity play in contemporary environmental media studies. I also trace the material uses of toxicity and impurity in the development of the transistor architecture that undergirds 3D printing and digital computation more generally. Digital communication, I suggest, is impossible without the strategic application of materialities poisonous to the human body, with consequences for those tasked with creating, using, and disposing of digital media. The third section, titled "Time (A Parable)," takes a somewhat unusual turn in the chapter away from 3D printing to a close reading of a short science fiction story titled "Exhalation" (2008) by Ted Chiang. Through reading this story, which narrates the apocalyptic decline of a species of air-powered robots, I connect the material and cultural questions of the previous sections to themes of respiratory exhaustion and decay. Media's toxicity exhausts the breath and short-circuits its temporality. The chapter's closing articulates respiration as a key technique of atmospheric mediation, one that brings those techniques of previous chapters to the level of the human body and its vulnerability within technological systems.

Nose

Is it safe to breathe 3D printer fumes? The question is relative, as I can hardly think of any gas classified as a fume that's "safe" to breathe. Having left the smell of acrid singe behind in the conference room to continue airing out, I decide that my first stop in the quest to answer the question should be the internet, long-time source of knowledge for bad ideas that you probably shouldn't put into practice. Trawling on the social media and news aggregation website reddit, I discover a number of 3D printer users who have worried about their newest toy's fumes for much longer than I have:

- "I live in an apartment and can only have my printer in my bedroom with bad air conditioning."
- "I'm thinking about placing the 3d printer in my home office, where I spend 90% of my waking hours. I work at home. So I'll always be there, right next to the printer"
- "The problem is we live in a small apartment and there is no place that is further than about 10-15m that I can put it and no well ventilated spot."[212]

I begin to develop a mental image of these 3D printer users, who are not too dissimilar from myself. They are new to the hobby, live in a small apartment or house with limited space, are excited to try out their new toy, yet are anxious about the long-term effects of respiring the printer's vapors. They are able to afford some new tech—but not a two-bedroom apartment. More experienced users chime in with their own fume remediation techniques. These range from

[212] Links to these posts, in order: https://web.archive.org/web/20190418125634/https://www.reddit.com/r/3Dprinting/comments/7pjr5o/abs_fumes_in_bedroom/, https://web.archive.org/web/20190418125747/https://www.reddit.com/r/3Dprinting/comments/a3719s/whats_the_consensus_on_printing_and_fumes_these/, https://web.archive.org/web/20190418125837/https://www.reddit.com/r/3Dprinting/comments/bazn71/harmful_fumes/.

expensive, purpose-built enclosures complete with HEPA filters to more ad hoc structures such as air conditioner filters glued to IKEA side tables. I look up the price for one of the most top-of-the-line air filtration systems for 3D printers, designed by a company inexplicably named "BOFA." Its prices were "please enquire with our marketing department," indicative perhaps of how little thought the printing ventilation industry has given the home hobbyist. Time and again, the posters come back to smell as a sign of 3D printing's ambiguous danger. Some think they're no worse than lighting a candle, while others worry about asthma attacks and disgruntled neighbors. No one seems to know whether or not the fumes are a problem: "I believe right now [the fumes] will kill you," one user writes, "[but] ask again in a couple of weeks and we will probably be safe around them."[213] The nose, it seems, doesn't always know.

This section takes a sharp inhale through the nose to explore the odors of 3D printing. In doing so, I engage smell as a respiratory technique for interpreting atmospheric media more generally, one that is uncommonly deployed in digital media studies yet that I argue helps critics link questions of sensation, respiration, and affect to the study of media. Alongside taste, smell stands apart from hearing, vision, and touch as a chemical sense, one that entails matter entering the body and binding with chemical receptors to produce sensation. As literary historian Hsuan Hsu observes, Western thought has long denigrated smell, associating it with "passive reception, physical permeability, corporeal excess, involuntary responses, and disease transmission."[214] Unlike sight and hearing, which can hold subjects at a respectable distance, smell is unsuitably intimate for intellectual work or aesthetic enjoyment. This section inverts this narrative, asking

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[213] Link: https://web.archive.org/web/20190418130417/https://www.reddit.com/r/3Dprinting/comments/a3719s/whats_the_consensus_on_printing_and_fumes_these/eb3wess/?utm_source=share&utm_medium=web2x.

[214] Hsuan L. Hsu, "Naturalist Smellscapes and Environmental Justice," *American Literature* 88, no. 4 (December 2016): 790, https://doi.org/10.1215/00029831-3711126.

how odor's intimacy functions as a signaling mechanism within 3D printing cultures, one that indexes an atmosphere of anxiety that permeates the enterprise. Despite 3D printer users' best efforts to ameliorate the hobby's foul odors, whether by ventilation or choice of printing material, the ambiguous danger remains. Furthermore, I suggest that incorporating smell into environmental media studies' analytical toolkit helps focalize attention on its specific materialities—in the case of 3D printing, plastic. Following pollution studies scholar Max Liboiron's work on the material and cultural specificity of plastics,[215] I trace in this section the role particular filaments play in 3D printing cultures, their material histories, and the signaling function of their odors. Ultimately, I argue that attempts to deodorize 3D printing can erase the symptom of smell but never the cause of plastic, in turn disabling a sense that has much to tell us about the perception of media toxicity.

In its basic biochemical operation, the sensation of smell begins with molecules of matter binding with sensory receptors in the nasal cavity. Through this binding process, these receptors mediate chemical information into electrical stimuli, which then travel to the olfactory bulb, a branch of the brain dedicated to odor processing.[216] In biochemistry, these external molecules are "odorants" and the process of their sensation "olfaction." Olfaction parses information about odorants and assimilates them into discrete odors in the brain. Like insects and the flowers they pollinate, olfactory receptors and odorants are unique matches, each of the former corresponding

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[215] Max Liboiron, "There's No Such Thing as Plastic. Only Plastics. Here's Why That Matters." *CLEAR*, May 2019, https://civiclaboratory.nl/2019/05/14/theres-no-such-thing-as-plastic-only-plastics-heres-why-that-matters/

[216] I. Gaillard, S. Rouquier, and D. Giorgi, "Olfactory Receptors," *Cellular and Molecular Life Sciences CMLS* 61, no. 4 (February 2004): 456–57, https://doi.org/10.1007/s00018-003-3273-7.

to a specific chemical in the latter.[217] Habitually, we think of the human sense of smell as paling in comparison to our fellow animals, part and parcel of the idea of smell as a "base" or animalistic sense. However, recent research further mapping the human olfactory system indicates that we deeply underestimate our own sensory acuity.[218] In fact, the range of different kinds of olfactory receptors in the human nose—and as such, the range of chemicals we can theoretically sense—actually outnumbers the receptors for vision or taste by several orders of magnitude. Moreover, unlike other senses, smell has a unique neurological pathway to the brain. While vision, hearing, taste, and touch are processed post-sensation in the thalamus, smell travels directly to the olfactory bulb. There it undergoes a significant amount of information processing before it reaches the rest of the brain.[219] By virtue of its position at the front of the brain, the olfactory bulb has a direct line to the hippocampus and prefrontal cortex, systems known to scientists as integral to memory recording and processing. Smell then may be our most *immediate* of our mediating senses.

The denigration of smell has long roots in the Western philosophical tradition. As far back as Aristotle, thinkers have held smell at arm's length. In *De Anima*, Aristotle writes that "smell and its object are much less easy to determine" than sight or sound, given that "our power

[217] We owe our understanding of these processes to the work of Richard Axel and Linda B. Buck, recipients of the 2004 Nobel Prize in medicine for their work identifying and mapping the existence of olfactory receptors in rats—a testament also to how recent our biochemical knowledge of smell actually is. See Linda Buck and Richard Axel, "A Novel Multigene Family May Encode Odorant Receptors: A Molecular Basis for Odor Recognition," *Cell* 65, no. 1 (April 1991): 175–87, https://doi.org/10.1016/0092-8674(91)90418-X.

[218] C. Bushdid et al., "Humans Can Discriminate More Than 1 Trillion Olfactory Stimuli," *Science (New York, N.Y.)* 343, no. 6177 (March 2014): 1370–72, https://doi.org/10.1126/science.1249168.

[219] Laura U. Marks, *Touch: Sensuous Theory and Multisensory Media* (Minneapolis: University of Minnesota Press, 2002), 119–20.

of smell is less discriminating and in general inferior to that of many species of animals."[220] Kant disparaged smell as well, calling it "ungrateful," "most dispensable," and apt "to pick up more objects of aversion than of pleasure."[221] Eighteenth-century Europe saw the rise of the "miasma theory" of disease, which held smell as the primary vector for disease transmission.[222] In their influential 1994 book *Aroma: The Cultural History of Smell*, sensory studies scholars Constance Classen, David Howes, and Anthony Synoff characterize Western modernity as operating under an "olfactory silence."[223] Even as miasma theory gave way to germ theories of disease in the nineteenth and twentieth centuries, odors remained repellent concepts, surviving only in "sentimental and sensuous" applications such as perfumery.[224] This is not to say that smell vanished entirely from public and private life, but rather that the range of acceptable smells and the proper sites for their sensation have winnowed dramatically over the centuries. We are pleased to smell fresh bread emanating from a bakery and displeased to smell sewage on a hot day. In particular, the thought of smelling digital media is something thought faintly ridiculous, as evidenced by Google's 2013 April Fool's Day announcement of "Google Nose Beta," an innovative (and nonexistent) platform for the digital transmission of smells.[225] 3D printing interrupts this olfactory silence by reintroducing to computing alien sensations.

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[220] *DA* 2.9 421a7–11

[221] Kant, Immanuel, *Anthropology from a Pragmatic Point of View*, edited by Robert B. Louden and Manfred Kuehn (Cambridge: Cambridge University Press, 2006) 50–51.

[222] One of the first works in the canon of "smell studies," French historian Alain Corbin's 1982 *The Foul and the Fragrant: Odors and the French Social Imagination* treats the emergence and consequences of miasma theory in depth. See Alain Corbin, *The Foul and the Fragrant: Odor and the French Social Imagination* (Oxford: Berg, 1986).

[223] Constance Classen, David Howes, and Anthony Synnott, *Aroma: The Cultural History of Smell* (London: Routledge, 1994), 161.

[224] Classen, Howes, and Synnott, *Aroma*, 7.

[225] Google, "Introducing Google Nose," March 2013, https://archive.google.com/nose/.

The odor of a 3D printer has little to do with the machine itself and everything to do with the material one feeds into it. In 3D printing parlance, this material is called "filament," named for its extruded shape. Dozens of different filaments exist, each with its own affordances and drawbacks—and odors. As such, many hobbyists mitigate fumes by consciously choosing those filaments that emit fewer bad smells, and so the reasoning goes, fewer toxic vapors. Two materials in particular dominate the hobbyist market: acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). It's these two materials that users most often contrast, not only in terms of their quality for finished prints, but also in terms of the vapors they emit in production.

ABS is a petroleum-based plastic that is among the most commonly used in the consumer appliance market more generally. Its sturdiness and resistance to wear make it useful for children's toys (LEGO bricks, most famously, are ABS), as well as for computer keyboard caps and video game console enclosures. If you are reading these sentences in an office, chances are there is ABS under your fingertips or within arm's reach right now. ABS has several material characteristics that make it well-suited to 3D printing. It becomes pliant under heat yet cools quickly into a solid shape; it does so at a low glass transition temperature of 105°C, which means it doesn't require dangerously high temperatures to become malleable; and it responds well to later machining, which makes it easy to smooth out imperfections. However, true to its name, ABS releases a chemical called styrene when heated. In high concentrations, styrene has a strong plasticky smell that can induce dizziness and headaches. Current research indicates that it is a potent carcinogen in humans.[226] Many 3D printing enthusiast sites recommend avoiding ABS entirely, particularly in domestic settings, despite its long association with 3D printing as a

[226] Parham Azimi et al., "Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments," *Environmental Science & Technology* 50, no. 3 (February 2016): 1260–68, https://doi.org/10.1021/acs.est.5b04983.

practice. Moreover, while ABS's thermoplastic characteristics make it highly recyclable, its manufacture still depends on practices of petroleum extraction and processing. Its recyclability is also limited to melting ABS products down into further ABS products. Once consigned to a landfill, ABS refuses to biodegrade.

Enter PLA. Unlike petroleum-derived ABS, PLA is a "bioplastic," produced from renewable plant or animal material. In PLA's case, this is any kind of plant starch. Exactly which starch depends on where the PLA is manufactured. While production in the United States focuses on corn,[227] other regions deploy different staple crops, such as cassava in southeast Asia.[228] As such, PLA's production reflects local geographic, cultural, and even culinary specificities, even as those specificities are themselves erased in the polymerization process. PLA boasts many advantages over ABS for 3D printing: it's less tricky to use, as unlike ABS it doesn't warp during the cooling stages; it doesn't involve petroleum extraction; and crucially, due to its chemical composition, it doesn't stink up the room in use. Filament manufacturers and 3D printing users alike tout PLA as an "odorless" filament, which is why I chose PLA for the Maker Select. In fact, enthusiasts often describe PLA's smell as sweet or pleasant, reminiscent of toasted corn syrup. Given PLA's sensory and material advantages over ABS, it's no surprise that it's the filament of choice for many home hobbyists. PLA's lack of smell, non-petroleum sourcing, and biodegradability all contribute to the sense that PLA is "safer" or more "eco-

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[227] Elizabeth Royte, "Corn Plastic to the Rescue," *Smithsonian Magazine*, August 2006, https://www.smithsonianmag.com/science-nature/corn-plastic-to-the-rescue-126404720/

[228] Abdul Ghofar, Shingo Ogawa, and Takao Kokugan, "Production of L-lactic Acid from Fresh Cassava Roots Slurried with Tofu Liquid Waste by Streptococcus Bovis," *Journal of Bioscience and Bioengineering* 100, no. 6 (December 2005): 606–12, https://doi.org/10.1263/jbb.100.606.

friendly" than ABS.[229] However, this sense of safety may be more theoretical than actual. PLA's odors are undoubtedly less offensive to human noses than those of ABS, but that doesn't mean that PLA emits no vapor in heating and extrusion. One of the few environmental engineering studies to address 3D printing emissions finds that PLA still emits vaporous lactide, albeit in lower quantities than ABS emits styrene.[230] Unlike styrene, lactide is not currently known to be harmful to humans. That hasn't stopped some forum users from posting with complaints they imagine to be related to PLA fumes, from sinus irritation[231] to shortness of breath.[232] While far from a medical study, these brief examples illustrate the difficulty of speaking with precision about fumes' effects on different bodies and the anxiety that can pervade even putatively "safe" printing.

On a material level, PLA and ABS are equally "natural," in that they both derive from organic material. However, PLA's reliance on corn does not exempt it from systems of industrial production that themselves have deleterious environmental impacts, from corn's excessive water usage to its over-reliance on fertilizer compared with other staple crops.[233] PLA's biodegradability may also be overstated. Composting PLA requires temperatures of around 140°F/60°C and the introduction of special microbes—conditions far beyond what a 3D printing

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[229] Link: https://web.archive.org/web/20190423155250/https://www.reddit.com/r/3Dprinting/comments/araxzs/question_about_the_safety_of_3d_printing/.

[230] Azimi et al., "Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments."

[231] Link: https://web.archive.org/web/20190423160729/https://www.reddit.com/r/3Dprinting/comments/65oh2x/how_toxic_are_pla_fumes_exactly/dgc3uvk/?utm_source=share&utm_medium=web2x.

[232] Link: https://3dprinting.stackexchange.com/a/8565/.

[233] Jeremy Hobson, "The Environmental Risks Of Corn Production," *WBUR* (https://www.wbur.org/hereandnow/2014/06/11/corn-environmental-risks, June 11th 2014).

hobbyist can reproduce in a backyard composting pile.[234] These same material characteristics that make PLA theoretically biodegradable also make it difficult to recycle, as it requires a lower melting point than other forms of plastic, and as such can disrupt operations at recycling plants. PLA's main affordance then is less in its material constitution and more in how it assists in managing the anxieties of pollution and toxicity that dog 3D printing. As an "eco-friendly" material, PLA transforms environmental thinking into consumer choice. Vin Nardizzi critiques the affective "friendliness" of environmentalist discourse as providing cover for wealthy Western subjects, who produce the lion's share of global pollution and waste. "In making these consumer 'decisions,'" he writes, "we also pay a duty for assuaging guilt and for wanting not to make matters any worse."[235] Such "friendliness" extends beyond PLA's marketing and into its vapors, which in their sensory inoffensiveness offer enthusiasts the imaginary ability to print without consequences and to produce without externalities. The absence of smell, when compared with ABS's styrene stink, also provides a rhetorical route outside of what Stephanie LeMenager terms "petroleum culture," or the centrality of oil and its flows through media objects and discourses to the constitution of a specifically American twentieth-century capitalist modernity.[236] When printing with ABS, strong odors produce subjects in thrall to petro-capitalism: headaches and shortness of breath attest to a poison at the heart of the very industrial manufacturing that made America its fortunes. PLA, by contrast, claims to escape petroleum cultures, substituting harmful styrene with (supposedly) harmless lactide. But this escape from petroleum is not an escape from the broader systems of plastic proliferation and industrial manufacturing enabled by petroleum.

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[234] Royte, "Corn Plastic to the Rescue."

[235] Vin Nardizzi, "Environ," in *Veer Ecology: A Companion for Environmental Thinking*, ed. Jeffrey Jerome Cohen and Lowell Duckert (Minneapolis: University of Minnesota Press, 2017), 192.

[236] Stephanie LeMenager, *Living Oil: Petroleum Culture in the American Century* (Oxford: Oxford University Press, 2014), 6.

Ultimately, the stench of ABS and the fragrance of PLA are imperfect signifiers for either immediate or durational toxicity. While smell can function as a warning system of sorts, a sign that something is off in the room, it cannot capture with certainty the bodily risks of 3D printing. Rather, I view smell as an indication of those qualities to printing that exceed digital abstraction, that is, its messy materiality. 3D printers, after all, are not futuristic "clean" technologies; they are miniaturized versions of industrial extrusion printing practiced across the globe. Odors are also a way that 3D printing produce atmospheres of their own through the pervasion of sensory experiences that its users can control to varying degrees but never quite escape. The sensations that go hand in hand with respiration are mercurial, but nevertheless point to how atmospheric media involve bodies in their operations, even involuntarily.

Lungs

"We moved into this room expressly for the ventilation. That the layout made it easier to show off all our tech was an added bonus." I'm meeting with Preston Tobery, coordinator of maker technologies at the John and Stella Graves Makerspace in the McKeldin Library at the University of Maryland. We're on the second floor, with eight-foot-tall windows looking down on the campus below. Almost a dozen 3D printers whir around us, alongside tinker toys, VR headsets, and a pack of students who have made the makerspace their temporary home. I've asked Tobery to tell me about the makerspace's institutional history and the techniques he uses to mitigate fumes. The makerspace's original location, he tells me, was in a room down the hall at the corner of the building, barely a quarter of the size of the room we're in now. Even with far fewer printers, it filled up with fumes fast. Tobery tells me he was able to relocate the makerspace to this larger room by a stroke of bad luck: soon after the university installed air handlers, a kind of industrial-strength air conditioner focused on filtration, a massive storm swept through and flooded the room—right through the air handlers themselves. Eight months later, Tobery negotiated this new space. He shows me a recent study completed by the university's Department of Environmental Safety, Sustainability, and Risk, evaluating the emissions in the makerspace. The study found that styrene levels—one of the primary carcinogenic vapors of 3D printing—were "significantly below OSHA Permissible Exposure Levels," clocking in at a mere 0.03 parts per million. Styrene's regulatory limit is 100ppm. Unconsciously, I take a deep breath. I feel as though the study has finally given me permission to do so.

Technological vanguard or oversized glue gun? The threat of media toxicity lingers over 3D printing even as the example of the John and Stella Graves Makerspace demonstrates that it's possible to ameliorate fumes—at least at the point of use. Up and down 3D printing's archaeological chain, the question gets thornier. 3D printing's environmental impacts are well attested: the technology draws more electrical power than other forms of manufacturing and its reliance on plastic runs up against the same issues of mass over-production that have dogged Western consumer culture for a century.[237] Still, 3D printing holds real promise for many industries. In medicine, for instance, printed joints and limbs can provide expert levels of tailoring to an individual's body. It's that same body that is vulnerable to the unknown and unknowable particles that 3D printers pump into the atmosphere. And yet, 3D printing is an alluring, even entrancing practice. When I sit with the printer, I feel as though I am in the presence of an alien consciousness, one that understands how to rip apart the concept of an object and reassemble it before my eyes, layer by layer, physical bit by physical bit. The 3D

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[237] Reid Lifset, "3d Printing and Industrial Ecology," *Journal of Industrial Ecology* 21, no. S1 (2017): S6–8, https://doi.org/10.1111/jiec.12669.

printer's toxicity is *intoxicating*. In a world where the future seems ever more banal in its horrors, the 3D printer feels like a small concession to the promise of computers as labor-saving rather than labor-multiplying. This chapter section follows the breath down into the lungs to explore this intoxicating potential of media toxicity: how atmospheric media are both environmentally damaging and culturally compelling, and how the body becomes a site for playing out this tension.

"Toxicity" is in the air of environmental media studies. Media technologies at the scale of the industrial present depend on chemical processes that are their themselves biologically toxic or that produce toxic by-products. Silver nitrate film decomposes with age, releasing combustible fumes. Digital computers rely on rare earth minerals that are environmentally and financially costly to extract. Books don't get off the hook either: paper bleaching and ink production both contribute to industrial run-off and water pollution. Across interdisciplinary fields such as discard and maintenance studies, media theorists, anthropologists, sociologists, and historians of technology have turned their attention to media's capacity to poison. As Chen notes, "toxicity" has also become a shorthand for cultural atmospheres: our political discourses are toxic; our food is toxic; and our interpersonal dynamics are toxic.[238] Within digital media studies specifically, this emphasis on toxicity has produced a kind of chemical consciousness. Buoyed by a renewed materialism drawn from the media archaeological turn of the 2000s, the field has taken an interest in mapping the deleterious environmental effects of media's development. Media are Silicon Valley's twenty-three Superfund sites.[239] They are Bitcoin's energy consumption[240] and

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[238] Chen, *Animacies*, 190.

[239] Evelyn Nieves, "The Superfund Sites of Silicon Valley," *The New York Times*, March 2018.

the afterlives of rare earth mining's radioactive waste.[241] Anxieties around media's toxic afterlives have moved from the environment to the body, which has itself become a kind of environment. Sean Cubitt writes that "in Zambia's vast copper pits . . . the use of explosives and drills produces silica dust that attacks the lungs, while nearby smelters release large quantities of sulfur dioxide, which falls as acid rain."[242] Environmental pollution is no longer thought exterior to the human body. It is urgently inside us.

While the 3D printer's plastic presents the most obvious locus of its media toxicity, that toxicity extends to nearly all aspects of its operations, including even its computer chips. Digital media's capacity to mediate relies as much on chemical processes as it does electrical ones. This is perhaps clearest in the example of doping, the primary technique through which computer chip manufacturers assemble microprocessors. In its pure state, silicon's electrical conductivity varies with temperature. At low temperatures, it's a poor conductor; at high temperatures, a better one. In order to standardize silicon's electrical conductivity, and thus make it appropriate to use as a semiconductor, microprocessor manufacturing "dopes" the silicon by introducing trace impurities. These impurities shift silicon's conductive potential. The primary technique for doping is called vapor-phase epitaxy. This involves exposing silicon to chemical gases for hours at a time in order to build up a thin film of impurity. Doped silicon comes in two different varieties, depending on the gas used. Phosphorus and arsenic gas produce n-type silicon, which is negatively charged and permits the free passage of electrons. Boron and gallium gas, conversely, produce p-type silicon: positively charged, which traps electrons. Together, n- and p-

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[240] Timothy B. Lee, "New Study Quantifies Bitcoin's Ludicrous Energy Consumption," *Ars Technica* (https://arstechnica.com/tech-policy/2018/05/new-study-quantifies-bitcoins-ludicrous-energy-consumption/, May 2018).

[241] Tim Maughan, "The Dystopian Lake Filled by the World's Tech Lust," *BBC* (http://www.bbc.com/future/story/20150402-the-worst-place-on-earth, April 2015).

[242] Cubitt, *Finite Media*, 70.

type silicon form the basis of a diode, the fundamental technology of modern electronics which permits the flow of electricity in one direction but not the other. In effect, contemporary digital computing is impossible without industrial processes reliant on materials toxic to biological life.

Poisoning sand with toxic vapor is thus the foundation of all modern computing architecture.[243] Combinations of doped silicon are integral to the metal oxide semiconductor field effect transistor, or MOSFET, the most widely used kind of transistor in contemporary electrical and computing media. The MOSFET is so widely used that, according to historian of computer David Brock, it ranks as the most manufactured object in human history: over thirteen sextillion MOSFET transistors have been manufactured since its invention in 1959.[244] The irony then is that even as computer chips depend on impurity in order to function, they must also be manufactured under exacting conditions designed to prevent further impurities. In such "clean rooms," manufacturers carefully filter and recirculate air to remove the dust that would contaminate the chips. However, these rooms are anything but "clean" for the human beings who work in them, who are constantly exposed to chemical fumes. As journalist Susan Q. Stranahan writes, these workers, particularly in Silicon Valley, tend to be women and ethnic minorities, who suffer disproportionate rates of cancer, aneurysms, and birth defects, possibly as a result of the chemicals required to dope and manufacture silicon microprocessors.[245] From etching glass surfaces to doping transistors, computer manufacturing relies on toxic gas—and more to the

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[243] As the Twitter account @computerfact puts it: "computers think using etchings in poisoned sand and measure time using vibrating crystals so if you were looking for magic you found it." (https://twitter.com/computerfact/status/722931893256065024).

[244] David Laws, "13 Sextillion & Counting: The Long & Winding Road to the Most Frequently Manufactured Human Artifact in History," *Computer History Museum* (https://computerhistory.org/blog/13-sextillion-counting-the-long-winding-road-to-the-most-frequently-manufactured-human-artifact-in-history/, April 2018).

[245] Susan Q. Stranahan, "The Clean Room's Dirty Secret," *Mother Jones* (http://www.motherjones.com/politics/2002/03/clean-rooms-dirty-secret, March/April 2002).

point, relies on human labor put in the crossfires of and made to suffer the after-effects of such gas. All digital media are thus atmospheric in their reliance on minerals turned into vapor.

Nevertheless, we desire communication, even when it comes with environmental, bodily, and moral hazard. That these hazards are foundational to the very possibility of digital communication makes the problem even thornier. Wendy Hui Kyong Chun has argued that wireless networking relies on what she calls "leakage": computers in networking modes constantly broadcast information packets to all other computers in range, which in turn accept all packets and surreptitiously delete "those not directly addressed to [them]."[246] "Even seemingly sealed," she writes, "our computers constantly leak: they write to read, read to write, erase to keep going."[247] The same, I argue, is true of media's atmospheric chemistry. 3D printing makes this explicit with its vapors, but even seemingly hermetic devices like smartphones and laptops rely on or eventually, consigned to the trash heap, become toxic externalities. Odors and fumes might be foreign to many Western users of digital media. But these phenomena are exquisitely, even violently familiar to those who manufacture computers. There is an irony then in how 3D printing reintroduces media manufacturing to the tech-forward Western subject, for whom fumes become a curiosity rather than an occupational hazard.

One helpful philosophical tool for thinking about the tension between media's material toxicity and its cultural intoxication is the concept of the pharmakon, which has received various developments in both literary and media theory. Its classic exegesis is in Jacques Derrida's 1981 essay "Plato's Pharmacy," an extended deconstruction of the word pharmakon as it appears in Plato's *Phaedrus*. In ancient Greek, pharmakon means both "poison" and "remedy." Derrida

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[246] Wendy Hui Kyong Chun, *Updating to Remain the Same: Habitual New Media* (Cambridge: The MIT Press, 2016), 51.

[247] Chun, *Updating to Remain the Same*, 52.

applies these dual definitions to the technology of writing. Writing is poison in that it destroys oral memory, and it is remedy in that it provides new methods for inscription. The pharmakon exceeds binaristic thinking, in turn opening up space for the free play of signifiers.[248] Philosopher Bernard Stiegler extends Derrida's exegesis beyond writing to encompass media technologies more generally. For Stiegler, all technology oscillates "pharmacologically" between poison and remedy.[249] The twenty-first century, Stiegler argues, has only accelerated the speed with which ambiguously dangerous pharmaka appear for our adoption or disavowal.[250] The 3D printer is then in many ways a classic pharmakon in the mode of Derrida or Stiegler. Its profusion of plastics and fumes literally poisons ecosystems and bodies alike. Yet we also speak of the 3D printer with delight and wonder. 3D printers anchor such spaces as campus makerspaces precisely because they are attention-grabbing and fascinating. They change the energy of a room. In this regard, 3D printers are atmospheric media both in that they produce literal gases as well as command affective space.

Poison or remedy. N-type or P-type. The binary is hard to shake. I am left with the lungs. Many of 3D printing's respiratory effects are frustratingly speculative, which make them all the harder to study, understand, and ameliorate. What few environmental engineering studies that do exist on these topics circulate online like samizdat, offering snatches of knowledge to substantiate a range of claims about 3D printing's toxicity. The forum users I have returned to throughout this chapter rely on these studies to help themselves answer that lingering unanswerable question: is this thing I love going to hurt me? This relation of cruel optimism, to

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[248] Jacques Derrida, *Dissemination*, trans. Barbara Johnson (London: Athlone Press, 1981), 103.

[249] Bernard Stiegler, *What Makes Life Worth Living: On Pharmacology*, trans. Daniel Ross (Cambridge: Polity Press, 2013), 37–39.

[250] Stiegler, *What Makes Life Worth Living*, 55.

follow literary theorist Lauren Berlant,[251] is made all the more challenging given these studies' ambiguity on what the toxic components of 3D printing vapors actually are. Azimi et al. note that the true danger of 3D printing may not be in its vapors, but rather the ultrafine dust particles sloughed off in operation.[252] These particles are less than 0.1 nanometers in length, which allows them to pass through the lungs and into the bloodstream with ease. Their small size also means they can evade current scientific instrumentation, leaving us with the paradox that while we can detect that these particles exist, we can't actually say with certainty what they are.[253] Without advances in instrumentation and longitudinal study, we'll never be able to say for certain whether or not those harsh odors evince respiratory risks. Of course, this doesn't matter much for those clean room workers who bear the full brunt of atmospheric media's toxicity, for whom heightened cancer risks testify in ways that scientific instrumentation cannot. Concepts like the pharmakon can provide us a theory of media's risk and reward, but the body is the final screen upon which the drama plays.

Breath's vulnerability lingers in the flesh. After passing into the bloodstream, these fine industrial dusts collect over a lifetime. In this way, media's materiality insinuates the body into its mechanisms. Carolyn Steedman offers a potent example in her 2002 book *Dust: The Archive and Cultural History*. In it, she literalizes Derrida's concept of "archive fever" through an analysis of anthrax spores in parchment production and parchment's later deterioration in the

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[251] Lauren Berlant, *Cruel Optimism* (Durham and London: Duke University Press, 2011).

[252] Azimi et al., "Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments."

[253] See Tracy L. Zontek et al., "An Exposure Assessment of Desktop 3d Printing," *Journal of Chemical Health and Safety* 24, no. 2 (March 2017): 15–25, https://doi.org/10.1016/j.jchas.2016.05.008 and Qian Zhang et al., "Characterization of Particle Emissions from Consumer Fused Deposition Modeling 3d Printers," *Aerosol Science and Technology* 51, no. 11 (November 2017): 1275–86, https://doi.org/10.1080/02786826.2017.1342029.

bowels of physical archives. These spores produce an archive-borne illness in the form of meningitis.[254] For Steedman, the dust of book history lodges in the archivist's and academic's bodies, leaving a medical trace. "In its modern nosology," she writes, "meningitis bears strict comparison [with] the sedentary, airless, and fevered scholarly life."[255] In a similar study on dust, art historian Joseph Amato writes of "silicosis," a catch-all for diseases caused by dust inhalation, as "industries—from mining, quarrying, and grinding to clothmaking and grain farming—release into the air fine toxic dusts, molds, and fungi that causes respiratory diseases and over time can bring the strongest workers to a wheezing halt."[256] With the twentieth and twenty-first centuries' technological proliferation, occupational illnesses that were once the concern of factories and mills, localized industrial spaces, are now projected across the planet. Dusts are "air pollution, acid rain, and radioactive fallout."[257] They are the lingering fumes of a makerspace, lodged in our lungs. 3D printing has no disease correlate as archives do meningitis or clothmaking silicosis. What it does have, by contrast, is a set of related *feelings*: risk, uncertainty, terror, excitement, and desire. This is another dimension to atmospheric media, that is, its capacity to marshal sensory and emotional phenomena into a coherent, albeit definitionally inarticulable, field of experience. Breath is a vital—both in the sense of its importance and its embodiment—link between these two senses of atmosphere.

Time (A Parable)

But now, I want to tell you a story:

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[254] Carolyn Steedman, *Dust: The Archive and Cultural History* (New Brunswick: Rutgers University Press, 2002), 22–29.

[255] Steedman, *Dust*, 28.

[256] Joseph Amato, *Dust: A History of the Small and Invisible* (Berkeley: University of California Press, 2000), 129.

[257] Amato, *Dust*, 130.

In Ted Chiang's 2008 science fiction short story "Exhalation," anthologized in his 2019 collection of the same name, breath mediates the end of the world. The story tells of a mechanical species powered by air, "which others call argon."[258] Each day, members of this species consume two aluminum lungs full of air, and each day they fill them back up from an immense reservoir hidden under the ground. Their universe has many towns and districts but is bounded at its edges by a "solid chromium wall that extends from the ground up into the infinite sky."[259] One day, a traditional new year's ceremony which always takes exactly one hour—timed to the species' mechanical precision—runs a few minutes long. This is surprising. The news spreads, and they discover that the ceremony ran long all across their universe. The clocks themselves seem to work correctly; time itself seems to have slowed. The narrator, an anatomist, suspects that the truth resides in the species's brains. To solve this mystery, he performs an auto-dissection with an apparatus of his own design. Just as the nature of consciousness has eluded us organic humans, so too has it for Chiang's automata. Some believe their minds are inscribed on countless tiny gold foil leaves in their brains. Others suspect that the flow of air operates other hidden yet more subtle recording media. During his auto-dissection, the narrator discovers the truth: consciousness is not inscribed in the brain, but rather constituted by the flow of air *through* the brain as it forms and reforms electrical connections with infinite plasticity. From this revelation, the narrator deduces that time itself is not slowing down, but rather that the force of air through the brain is slowing, in turn impairing cognition. That this is happening uniformly across their universe then implies that the infinitely high chromium walls must in fact "curve

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[258] Ted Chiang, "Exhalation," in *Exhalation: Stories* (New York: Alfred A. Knopf, 2019), 37.

[259] Chiang, "Exhalation," 39.

inward to form a dome," bounding the universe like a bell jar.[260] The second law of thermodynamics: entropy increases in a closed system, smoothing it over until there are no areas of differential pressure. Every action, though, and motion increases the universe's entropy, "hasten[ing] the arrival of that fatal equilibrium," that is, death.[261] At "Exhalation"'s end, we discover that the story itself is a postmortem message from after the end of entropy, when some other life form—us, the readers—breaks through the chromium wall. "Exhalation" remains as a record of the worlds that mechanical species made with the air and time remaining to them.

My discussion of respiration has so far emphasized its chemical dimensions. Breath is an avenue of vulnerability through which bodies become integrated into circuits of atmospheric mediation, with potentially deleterious results. In this section, I want to turn to breath's temporality. Media toxicity remakes our relationship to time, with consequences for how we approach its amelioration—if such amelioration is even possible. As I discussed in the previous section, 3D printing's respiratory effects are frustratingly speculative, unknowable without new kinds of scientific instrumentation and durational study. It is in the spirit of this speculative dimension to atmospheric media's durational toxicity that I shift my attention in this section to "Exhalation," a work of speculative fiction. Like many of Chiang's stories, "Exhalation" explores the extended cultural consequences of a scientific concept, in this case entropy. Through the physical principles of thermodynamics, breath enacts a tragic irony in a world system. The work of sustaining a particular kind of life makes further life impossible. I read "Exhalation" as an archive of media theoretical possibility, as Chiang knits together problems of technology, mediation, consciousness, embodiment, temporality, and the environment. Breath is the crux of these concepts, in particular through their relationship to time. "Exhalation" suggests

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[260] Chiang, "Exhalation," 50.
[261] Chiang, "Exhalation," 50.

that time's measurement and perception, long interests of media studies, have become urgently environmental. We can apprehend these environmental temporalities through respiration, which operates not linearly but rather recursively, traversing scale in its rhythm and repetition. In this way, we can think of media toxicity as a set of temporal relations inherent to how media make sense of the world, as inescapable as the gallium gas doping a MOSFET chip.

"Exhalation" stages two different kinds of time, that of interior perception and that of exterior accounting. On the one hand, time is the embodied sense that one moment follows the next. On the other hand, time is the accounting of theoretically impartial technologies, themselves calibrated against physical phenomena. When the story's horologists inspect the clocks throughout their universe, they find no imperfection or error: "the turret clocks were all found to have resumed keeping perfect time."[262] The present perfect tense effaces the moment of disjuncture as an eddy in the flow of time. That the story's world is wholly mechanical, from the mechanical bodies and minds of its central species to the clocks, air pumps, and engines they have built to fill their world, permits Chiang to analogize fluidly across these two senses of time. The story's drama derives from the narrator's discovery that these two senses, which putatively share a material substrate, have become uncalibrated. The substrate, the narrator discovers, is not *matter* in and of itself, but rather the *difference across matter*. "This is why, at the beginning of this engraving [the narrative]," the narrator writes,

> I said that air is not the source of life. Air can neither be created nor destroyed; the total amount of air in the universe remains constant, and if air were all that we needed to live, we would never die. But in truth the source of life is *a difference of air pressure*, the flow

[262] Chiang, "Exhalation," 39–40.

> of air from spaces where it is thick to those where it is thin. . . . We are not really consuming air at all.[263]

As matter, air cannot be exhausted. Rather, the species's actions exhaust difference, increase randomness, and thereby eliminate mechanical action. At face value, we might take "Exhalation" as a conservable, perhaps even nihilistic fable. However, in its articulation of feedback loops across machine, life, and environment, we find a cautionary tale about human involvement in our own world system.

At first glance, Chiang's approach to time comports with some foundational models in media studies, for which time is a side-effect of its technologization. For early twentieth-century critic Harold Innis for instance, a particular civilization's available recording media determine available relationships to time.[264] A paper-based civilization, for instance, may favor synchronicity across great distance, facilitating by the speed of paper's circulation, whereas a stone-based civilization would be more diachronic, favoring static media that span larger swathes of time. Innis's ideas form the basis of later media-archaeological approaches to time, particularly for digital media. For Wolfgang Ernst, digital media are "time-critical," in that they depend on precise timing in order to function at all.[265] Digital time is measured by quartz crystals marking out ticks of UNIX time, which reckons the beginning of history from Thursday, January 1st, 1970, when atmospheric carbon measured only 325ppm. While Ernst argues that digital media have abolished Innis's earlier emphases on distinctions between storage and transfer—that is, between the medium and its action of conveyance—he nevertheless reproduces Innis's main argument that media are integral to the manufacture of time more generally. In his 2016

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[263] Chiang, "Exhalation," 50, italics in original.
[264] Innis, *The Bias of Communication*, 33, 62.
[265] Wolfgang Ernst, *Digital Memory and the Archive*, ed. Jussi Parikka (Minneapolis: University of Minnesota Press, 2013), 100.

Chronopoetics, Ernst distinguishes between "hard" and "soft" time, or the time imposed on machines by physics and the time invented by machines in their operations.[266] "As the technical implementation of mathematics," he writes, "the computer is not simply a symbol-processing machine; rather, its radical time-critical modes of operation also make it a complex time machine."[267] Time reduces to technical materiality. While the hard time of physics continues outside the media object, our apprehension of that time is ineluctably bound to the stability of soft, machine-generated time.

However, "Exhalation" complicates these approaches with its environmental consciousness. The story begins with reductions in air pressure slowing down the mechanical species's cognition and thus their lived experience of time. Their clocks, which operate by non-aerial means, march forward. Yet the ultimate consequence of maximum entropy, the narrator writes, is "the end of pressure, the end of motive power, the end of thought."[268] Entropy will come for the clocks as well. Clearly a neat division between hard and soft time, between human and mechanical time cannot hold. To resolve this contradiction, I turn to the role breath plays in this story. Breath articulates the interdependence of temporal mediation with environmental phenomena, collapsing distinctions between mediation "outside" the device and mediation "inside" the device. Breath is critical as a theoretical model for media's circulation and rhythmic repetition. Ernst's and Innis's media archaeological models explicitly restrict their purview to those kinds of time that emerge from technical media. In focusing on the breath, I want to follow a critical trail that understands temporal mediation, indeed mediation more generally, as a function of constant negotiation. Crucially, human technical involvement in the climate system

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[266] Wolfgang Ernst, *Chronopoetics: The Temporal Being and Operativity of Technological Media* (London and New York: Rowman & Littlefield International, 2016), 63.
[267] Ernst, *Chronopoetics*, 64.
[268] Chiang, "Exhalation," 53.

has made speaking of a "hard" time outside the bounds of mediation impossible. Time, as "Exhalation" teaches us, is a difference of pressure: meaning only as relation.

I'm far from alone in suggesting alternatives to these models of media temporality. In her 2014 book *In the Meantime: Temporality and Cultural Politics*, Sarah Sharma classifies these models as ones obsessed with "speed." In these models, she suggests, media accelerate temporality and collapse space, drawing cultures closer together and obliterating the time spent waiting for messages to transmit. Culture grows faster and faster, with deleterious effects for sociality and the possibility of a public sphere. Sharma argues that these models offer too simple an analysis of media temporality. In their place, she "offers an approach to time that is about the micropolitics of temporal coordination and social control between multiple temporalities."[269] Her subject is "synchronicity," and the constant cultural work it takes to negotiate otherwise differentiated microtemporalities—to move from slow to fast, from fast to slow, to keep different senses of time *in time* with each other. One's relationship to time, much like one's relationship to the environment, is bound to political positions.

It's also bound to the body. John Durham Peters argues that the human body itself is a temporal medium, one that carefully calibrates a dizzying multiplicity of time scales. The geophysical "pulse" of day and night "seems at some level to be built into living things" through circadian rhythms.[270] The human body features multiple time-keeping systems, waves of hormonal and neurological functions that wax and wane not only during the day, but across decades. Citing neurologist David Eagleman, Peters notes that there is in fact no part of the brain that operates as a master clock; rather, the work of maintaining these distinct temporal systems is

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[269] Sarah Sharma, *In the Meantime: Temporality and Cultural Politics* (Durham and London: Duke University Press, 2014), 7.

[270] Peters, *The Marvelous Clouds*, 178.

distributed across the human organism.[271] Seen through this frame, the unconscious rhythm is breath is only one part of a complex media system of temporality that constantly calibrates and recalibrates. I want to take rhythm forward in my analysis here. Shintaro Miyazaki argues that rhythm has always been a central if under-recognized aspect of algorithmic culture. Rhythm, which he defines as "an elementary movement of matter, bodies, and signals, which oscillates in-between the discrete and the continuous, between the symbolic and the real, between digital and analogue," supersedes the notion of the "clock" or the "pulse," which fail to account for the constant negotiation between states of matter characteristic to digital media.[272] These are similar to claims I have made about atmospheres throughout this chapter: atmospheric media, particularly through respiration, is characterized by the coordination of manifold systems (what my previous chapter termed "conditioning") that move fluidly across analog and digital. Rhythm names the active work of synchronizing disparate moments of mediation into the gestalt of atmospheric media. It follows then that we might characterize the drama of "Exhalation," and perhaps our current climate crisis, as a disarticulation of rhythm.

As word of the narrator's discovery spreads throughout "Exhalation"'s universe, so too does panic about the new possibility of death. For a few pages, the story becomes an overt allegory for human responses to climate change. "Many called for the strict curtailment of activities in order to minimize the thickening of our atmosphere," the narrator writes, "accusations of wasted air escalated into furious brawls."[273] A quasi-religious sect called the Reversalists gains popularity, "dedicat[ing] themselves to the goal of reversing the equalization

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[271] Peters, *The Marvelous Clouds*, 180.

[272] Shintaro Miyazaki, "Algorhythmics: Understanding Micro-Temporality in Computational Cultures," *Computational Culture*, September 2012, http://computationalculture.net/algorhythmics-understanding-micro-temporality-in-computational-cultures/.

[273] Chiang, "Exhalation," 51.

of pressure."[274] In a parody of geoengineering, the Reversalists construct an engine that compresses air, thereby increasing overall air pressure. "Alas," the narrator observes, "the engine itself was powered by air from the reservoir . . . It did not reverse the process of equalization but, like everything else in the world, exacerbated it."[275] Faced with the impossibility of preventing atmospheric degradation, "anatomists and mechanics [began to] design replacements for our cerebral regulators, capable of gradually increase the air pressure within our brains," paralleling transhuman adaptations to inhospitable climates.[276] All comes to naught. They are incapable of contravening the laws of physics. The narrator closes the story speculating on a possible future when some intrepid explorer breaches the chromium wall and turns the closed system into an open one. "It cheers me to imagine that the air that once powered me could power others," the narrator writes, "[though] I do not delude myself into thinking this would be a way for me to live again, because I am not that air, I am the pattern that it assumed, temporarily."[277]

In their introduction to their 2017 edited collection *Anthropocene Reading: Literary History in Geologic Times*, Tobias Menely and Jesse Oak Taylor propose a "stratigraphic" approach to literary studies. Just as the Anthropocene has complicated the geological work of stratigraphy, or the geo-historical legibility of lithic layers in the planet's crust, so too has it complicated literary study by demanding global scale, trans-disciplinary understanding, and novel approaches to temporality.[278] A similar tension has emerged in media studies, which has undergone its own historical turn over the past decades. In particular, the media-archaeological turn of the early twenty-first century, while correctly critiqued for privileging hermetic

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[274] Chiang, "Exhalation," 52.
[275] Chiang, "Exhalation," 52.
[276] Chiang, "Exhalation," 53.
[277] Chiang, "Exhalation," 55.
[278] Tobias Menely and Jesse Oak Taylor, eds., *Anthropocene Reading: Literary History in Geologic Times* (State College: Penn State University Press, 2017).

technologies over cultural contexts,[279] has enlivened understands of how media develop haphazardly over time, and how roads not taken in media history can elucidate current media cultures. Like literary studies, media studies encodes a stratigraphic model of temporality. Pasts accrete over each other, which scholars unearth with careful analysis, often involving the physical deconstruction of technologies themselves. "Exhalation" suggests that the lithic approach may not be the only—or the best—strategy available for media studies in the Anthropocene. The breath does not truck with lithic layers, because from its atmospheric perspective no such layers exist. Mediation is the work of constant temporal regulation: regulation against the material substrates of timekeeping, the geophysical procession of planetary rhythm, the biological and affective experience of time passing. It is also atmospheric, in the sense that the past's accretion is spread fluidly *throughout*, not buried *underneath*. What new rhythms will emerge in these environments?

The temporality of "Exhalation"'s conclusion provides a provisional answer. Its last paragraphs offer a "valediction," as the narrator directly addresses the reader-as-explorer. "Does the same fate that befell me await you?" they ask.[280] While much of Chiang's story is in the past tense, here at the end it inhabits an imagined future, addressing the reader in the imperative mood: "Visualize all these the next time you look at the frozen world around you, and it will become, in your minds, animated and vital again."[281] This is the temporality of speculation, which Chiang offers as a mode of thinking with ecological collapse that neither takes the collapse as a given nor naively believes that it can be forestalled. There is an end, and there is that which comes after the end. The after-the-end is a space of mournful possibility: "Our

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[279] Here I am thinking with Shannon Mattern's critique of the implicitly masculine discourses of media archaeology. See Mattern, *Code and Clay, Data and Dirt* pp. xv.

[280] Chiang, "Exhalation," 56.

[281] Chiang, "Exhalation," 56.

universe might have slid into equilibrium emitting nothing more than a quiet hiss. The fact that it spawned such plenitude is a miracle, one that is matched only by your universe giving rise to you."[282] To think with breath is to mediate time, for oneself but also for others. It's to mediate the possibility of the next breath to come, to coordinate and connect across a host of natural and cultural systems. In climate crisis, we know beyond a shadow of a doubt that our industrial media are breath-ending. The challenge "Exhalation" leaves us with is to refashion them as breath-sustaining.

Respiring Media

The trick about breath is what goes in does not come out. Alveoli, dendritic sacs in the lungs, collect oxygen and exchange it for carbon dioxide, the fuel and waste of cells respiring at microscopic scale. Breath mediates in the word's fundamental sense. In an unfolding ecological catastrophe and the ongoing afterlife of an acute respiratory pandemic, we now face the question: what do media make *us*?

In this chapter, I have argued that breath offers a model for analyzing how media entwine human bodies into their atmospheres. In an inhale, we become storage media, collective tissue recording trace transcriptions. Two decades of environmental media materialism have taught us what media are made of: rare earth metals exhumed in Inner Mongolia; aluminum refined from Australian bauxite; all fated to the e-waste trash dumps littering the global South. Breath maps this circuit's expansion. The mediated logics of its imperilment, as Tremblay forcefully argues, "[are] as much a phenomenological statement as a historical and cultural one."[283] When standing near a 3D printer, each breath lodges the fine dust of progress deeper in the body. Of course, this

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[282] Chiang, "Exhalation," 57.
[283] Tremblay, "Feminist Breathing," 97.

is a new media relation only for some. Karl Marx wrote of the "mephitic" atmospheres of cotton mills;[284] Steedman of anthrax spores. Without unwitting flesh, there are no media. There is a temporality, then, to this vulnerability. Over time, the printer's metal body will rust, its rubber wiring degrade, and its silicon chips tarnish. Some of its plastics may biodegrade if we're lucky. Others, effectively immortal, may linger in sea and air, blood and cells. Even if the early twenty-first century thrill of 3D printing wears off and we resign the technology, like so many before it, to the dust heap of technical gimmickry, our planet—and ourselves—bear its signature. These are interlocking respiratory temporalities of birth and decay, mediation piling on itself. Breath teaches us to hold onto simultaneity: a circle, a cycle, a somatic rhythm that requires attention and sustaining care.

Like Chiang's automata, atmospheric media invigorate and exhaust. Throughout this chapter, I have mapped this pharmacological contrast, which I have argued is inherent to the capacity for atmospheric media to mediate. In my previous chapter, I levied a critique against the concept of sustainable media: "sustainability," I argued, reflects a set of capitalist logics whereby media are called upon to solve the problems they create, obviating the possibility of thinking differently about solutions to their deleterious environmental effects. This is a critique I carried forward in this chapter along more media theoretical lines. I am wary, as I come closer to the end of this project, of it reading as definitionally fatalistic. If poison is inherent to mediation, what solution could there possibly be? It's true, as Chiang reminds us, that with enough time all comes to stillness. But in the meantime, there is still work to be done in ameliorating those toxic atmospheres digital cultures have created and interrogating possibilities for avoiding them in the future. This chapter has been one of critique, but it is also one, I think, of hope. Looking forward,

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[284] Karl Marx, *Capital*, trans. Ben Fowkes, vol. 1 (New York: Penguin Classics, 1976), 612.

my dissertation's final chapter returns to some of the more familiar sites of its earlier chapters in its focus on weather data and software studies. What I carry forward from this chapter, however, is attention to how atmospheric media involve embodied, emotional, and affective experience into their enterprise. To respire media is to *feel* media, and those feelings are ones that we can track and analyze even if in provisional and unexpected ways.

Chapter Four

Machine Reading for Atmosphere: Modeling, Affect, and Weather Records

```
<sentiment language="en" version="1.3" author="Tom De Smedt,
Walter Daelemans" license="PDDL">
    ...
    <word form="atmospheric" cornetto_synset_id="n_a-502696"
wordnet_id="a-02831736" pos="JJ" sense="relating to or located in
the atmosphere" polarity="0.0" subjectivity="0.0" intensity="1.0"
confidence="0.9" />"
    ...
</sentiment>
```

— from `en.sentiment.xml`[285] in the TextBlob code base

From 1959 to the present day, the National Oceanic and Atmospheric Administration (NOAA) of the United State has published *Storm Data and Unusual Weather Phenomena*, a monthly report detailing all severe and otherwise extraordinary weather events recorded throughout the country (fig. 10). Blending quantitative data on storms' paths, severity, and damage to life and property with qualitative accounts of the storms themselves, *Storm Data* not only provides an official record of severe weather in the United States but also serves as a valuable resource for researchers and businesses alike. The publication has undergone significant revisions over its nearly seventy-year history, during which its scope and content have shifted dramatically. While originally *Storm Data* reported a narrow selection of weather events, mostly focused on strong winds, the contemporary publication encompasses fifty-five distinct types of severe weather from blizzards to wildfires to seiches (a kind of rare standing wave in a body of water). *Storm Data* collects its information from a range of sources, including the National Weather Service's (NWS) own forecasts, eyewitness testimony, law enforcement, and local media reports. In 1993, NOAA employees began recording *Storm Data* as digital media, first as

[285] Throughout this chapter, computer code, including the names of code files, will be rendered in monospaced font.

unformatted text files, and then, beginning in 1996, in database programs.[286] This database grew over the subsequent years and became a standalone resource in its own right: the *Storm Events Database*. The *Storm Events Database* now serves as the basis for publications of *Storm Data*. Furthermore, it has the advantage of being searchable through a web portal on NOAA's website and downloadable as a series of comma-separated value (.csv) files, which make the *Database* available for computational address and analysis (fig. 11).[287]

Storm Data and Unusual Weather Phenomena

July 2018

Location	Date	Time Local/ Standard	Path Length (Miles)	Path Width (Yards)	Number of Persons Killed	Number of Persons Injured	Estimated Damage Property	Estimated Damage Crops	Character of Storm
KENTUCKY, Eastern									
Magoffin County									
Seitz	04	1944EST			0	0			Thunderstorm Wind (52EG)
	An NWS Employee observed several trees downed along Kentucky Highway 378 in and around Seitz. Note: The estimated wind gust of 52 knots is equivalent to 60 mph.								
Breathitt County									
1 NNE (JKL)Carroll Arpt Ja	04	1946EST			0	0	0.00K	0.00K	Thunderstorm Wind (50EG)
	NWS Employees observed a large tree blown down on Kentucky Highway 2436 near the Jackson NWS office. A cluster of strong to severe thunderstorms moved west/southwest from West Virginia into portions of northeast and east Kentucky this evening. Due to the high amount of moisture and subsequent instability in place, the downdraft portion of one of these storms produced winds of up to 85 mph as it collapsed over Paintsville. This resulted in substantial damage in Paintsville, including half of a roof being removed from an office building along with the steeple of a church being blown off. A couple of residential buildings were also damaged from falling trees. Note: The estimated wind gust of 50 knots is equivalent to 58 mph.								
Powell County									
1 WNW Stanton Arpt	05	1759EST 1800EST			0	0			Thunderstorm Wind (51EG)
	A trained spotter and a local media outlet reported trees down from Maple Street in Stanton south to Mountain Parkway. Note: The estimated wind gust of 51 knots is equivalent to 59 mph.								

Figure 10. An example page from the July 2018 print edition of Storm Data.

[286] See https://www.ncdc.noaa.gov/stormevents/versions.jsp.

[287] Much of this chapter pursues its argumentation through computer code. For ease of reading and accessibility to non-programmers, I have excerpted this code in the body of the chapter and included the full code in Appendix A. Throughout, I use a parenthetical convention to mark specific moments that correspond to code in the appendix: **(code 0a)**, in which the number corresponds to the chapter section, beginning with 0, and the letter to the example within the section. The appendix is also available in an interactive code notebook at https://colab.research.google.com/drive/1pXSrphMMiSJ0wXVq3VwuKZ2NLQL3Lgcb?usp=sharing.

```
[ ] df
```

	BEGIN_YEARMONTH	BEGIN_DAY	BEGIN_TIME	END_YEARMONTH	END_DAY	END_TIME	EPISODE_ID	EVENT_ID	STATE	STATE_FIPS	YEAR
0	195004	28	1445	195004	28	1445	NaN	10096222	OKLAHOMA	40.0	1950
1	195004	29	1530	195004	29	1530	NaN	10120412	TEXAS	48.0	1950
2	195007	5	1800	195007	5	1800	NaN	10104927	PENNSYLVANIA	42.0	1950
3	195007	5	1830	195007	5	1830	NaN	10104928	PENNSYLVANIA	42.0	1950
4	195007	24	1440	195007	24	1440	NaN	10104929	PENNSYLVANIA	42.0	1950
...	...	...	...	...	...	...	...	...	...	...	...
54887	202106	13	1430	202106	13	1630	160145.0	968778	KENTUCKY	21.0	2021
54888	202106	13	1430	202106	13	1630	160145.0	968781	KENTUCKY	21.0	2021
54889	202106	13	1530	202106	13	1730	160145.0	968782	KENTUCKY	21.0	2021
54890	202106	12	2230	202106	12	2230	159367.0	963844	OKLAHOMA	40.0	2021
54891	202106	13	29	202106	13	29	159368.0	963851	TEXAS	48.0	2021

1718273 rows × 51 columns

Figure 11. Accessing the Storm Events Database using the `pandas` *data science tool.* ***(code 0a).***

Accessing the *Database* is one thing; understanding it is another. With nearly 1.7 million entries, the *Database* is simultaneously dizzyingly large and usefully compact: too comprehensive to sit down and read in a single or even several sittings, yet small enough to address with even rudimentary computational tools.[288] More challenging to analyze, however, are the qualitative narratives that accompany most of the entries. These narratives range in length from single sentences to thousands of characters and vary widely in content and tone. Some are impersonal descriptions of single events, while others paint more dramatic portraits of storms unfolding over many days and hundreds of square miles. Controlling for duplicate narratives (as related weather events can share narrative entries), there are more than 750,000 unique narratives

[288] When downloaded, the full *Database* runs about 250 MB, the size of a standard definition television episode.

in the *Database*. As environmental media studies scholar Sara Grossman notes, records such as these are integral resources for scholars interested in the intersections of data culture and climate change: how scholars recognize climate change through the slow accretion of decades of data, yes, but also where such data reside, how they are managed and preserved, and to what uses they are put.[289] These records are testaments to the lived experience of severe weather, even as they often eschew the evocative registers of literary description for the formal, stolid tone of governmental documents. Furthermore, they are narratives written by individual workers, whose choices about what details to include and how to depict them ramify through the records. Given the *Database*'s importance to the historical, cultural, and meteorological understanding of severe weather in the United States, these narratives in turn offer an opportunity to interrogate the relationships between weather as experience and weather as data. In short: how do emotion, affect, and lived experience enter the *Database*? How does the affective experience of severe weather get recorded and effaced in this resource? And what analytical techniques can scholars of environmental media use to make sense of such databases, given their centrality to our interpretive enterprise?

Whether in the arts, history, or the daily forecast, severe weather is one of humanity's most affectively charged experienced. From biblical floods to Shakespearean storms to the living memory of disasters such as Hurricane Katrina, severe weather catalyzes fear and wonder in equal measure. As such events grow more common under anthropogenic climate change, so too does the urgency of understanding affective and emotional responses to them with the same attention paid to the number of lives lost and the value of property destroyed. These are questions that media studies is particularly suited to answer, given how mediated severe weather

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[289] Sarah J. Grossman, "Archiving Weather Data," *Process: A Blog for American History*, May 2017, http://www.processhistory.org/archiving-weather-data/

is now, experienced not just as howling storms bearing down on houses but also as televisual alerts, satellite transmissions, radar maps, and records such as the *Database*. As Grossman argues, while these media enable the unprecedented visualization and analysis of severe weather, the "galactic view" they offer can serve to efface the ground-level networks, connections, and experiences that are equally vital to understanding severe weather's human impact.[290] The all-encompassing, atmospheric picture that data seems to offer—a variety of what Caren Kaplan has termed the "view from above"[291]— is always partial, fragmented, and politicized. The *Database* offers a fruitfully complex opportunity to examine these tensions, given how it lies somewhere between data and narrative, legible to the techniques of data science and the humanities while remaining opaque in key ways to both.

This final chapter in my dissertation pursues a cultural and technical study of affect in the *Storm Events Database*, exploring both affect's place in official meteorological records as well as computational techniques for interpreting affect in such records given their formal resistance to literary techniques such as close reading. As such, this chapter concludes my dissertation with a keyword that has run through its entire enterprise: *modeling*. All of the atmospheric media I have explored thus far have in some way contributed to a broader project of modeling environments through mediation, from the modeling underpinning weather forecasting, to the climate control models that HVAC feeds back into, to the spatial and temporal models disrupted by media toxicity. Here, I position modeling as an atmospheric media technique of interpretation. To understand the environment, whether as a scientist or a humanist, is to model it. Following work on artificial intelligence, digital textuality, and affect by scholars such as computer scientist

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[290] Sara J. Grossman, "Ugly Data in the Age of Weather Satellites," *American Literature* 88, no. 4 (December 2016): 823, https://doi.org/10.1215/00029831-3711138.

[291] Kaplan, *Aerial Aftermaths*, 10.

Oren Etzioni[292] and media theorist N. Katherine Hayles,[293] I practice in this chapter what I term "machine reading for atmosphere,"[294] the process of using computational tools alongside more familiar strategies of close reading to understand how the *Database* models relationships between affect and environment.

I have made computational techniques for textual analysis core to this chapter for two reasons. First, the *Database*'s scale makes it impractical to "read" in a traditional fashion. Following work in the digital humanities on topics such as distant reading and topic modeling, I use techniques drawn from data science to help navigate "galactic" and "ground-scale" views of the *Database*.[295] Second, I am interested in what the computational address of affect, itself a long-standing research program in computer science, offers the cultural study of atmospheric media. As such, this chapter pursues a parallel methodological research project on the place of

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[292] Oren Etzioni, Michele Banko, and Michael J. Cafarella, "Machine Reading," *American Association for Artifical Intelligence*, 2006.

[293] N. Katherine Hayles, "Human and Machine Cultures of Reading: A Cognitive-Assemblage Approach," *PMLA* 133, no. 5 (2018): 1225–42.

[294] My use of "machine reading" is also an echo and inversion of Matthew Kirschenbaum's use of the same phrase in his monograph *Mechanisms: New Media and the Forensic Imagination*. For Kirschenbaum, machine reading is a reading practice that takes the machine, in his case the hard drive, as the primary text. For my purposes, I frame machine reading as reading *by* machine. See Kirschenbaum, *Mechanisms*, pp. 19.

[295] While I have worked for much of my scholarly career under the auspices of the digital humanities, I am a reluctant practitioner of what literary scholar Nan Z. Da has termed, somewhat pejoratively, "computational literary studies," that is, approaches to textual analysis grounded in computational statistics. I am not a trained statistician, nor am I fully convinced by the arguments for or against such analytical techniques, which I view more as proxies for political disagreements about the continued status of literary studies within the neoliberal university. My interest in computational techniques in this chapter is less in their capacity to substantiate specific claims about the texts under analysis and more in their function as pointer mechanisms to direct my critical attention toward qualities otherwise alien to me as a human reader. As I discuss throughout this chapter, I view the principal value of computational methods to humanities research their capacity to make our methods strange again, such that we might inhabit the inhuman perspective of the machine, even briefly. See Nan Z. Da, "The Computational Case Against Computational Literary Studies," *Critical Inquiry* 45, no. 3 (March 2019): 601–39, https://doi.org/10.1086/702594.

digital tools in environmental media studies. For the *Database* specifically, I argue that machine reading reveals how its formal logics efface critical attempts to make affective experience legible. More broadly, I suggest that the *Database* operates as a limit test for the computational address of affect, revealing the insufficiency of the field's own presumptions about how textual narratives function as data. What the *Database* and the computational tools I explore in this chapter share is an atmospheric model of understanding the relationship between data, textuality, and affect, one that does not distinguish between them and indeed presumes fluid interchangeability across all three categories.

Affect and computation have long entangled. Early in the first volume of his magnum opus *Affect, Imagery, Consciousness*, published in 1962, psychologist and affect theorist Silvan Tomkins links the study of affect to a perhaps unusual parallel field: the study of artificial intelligence. Unlike many of his contemporaries in the computer sciences (who he scorns as "temperamentally unsuited to create and nurture mechanisms" capable of true judgment),[296] Tomkins argues that the capacity for computational intelligence depends on an "affect system." The affect system is a theoretically discrete neurobiological system that mediates external stimuli into physical and emotional experience. Tomkins's classic example is that of asphyxiation: the stimulus of constricted breath activates the specific affective channel of "fear," which an individual then mediates, based on their own lived experience, into a range of emotional reactions. In this model, affect is a "system" organized around specific "programs," which activate "rewarding and punishing characteristics," in essence, a feedback mechanism.[297] In their 1995 essay introducing Tomkins's affect theory to literary studies, "Shame in the Cybernetic

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[296] Silvan S. Tomkins, *Affect Imagery Consciousness: The Complete Edition* (New York: Springer Pub, 2008), 65.

[297] Tomkins, *Affect Imagery Consciousness*, 66.

Fold: Reading Silvan Tomkins," Eve Kosofsky Sedgwick and Adam Frank position his work within the cybernetic milieu of post-'45 America. Affect theory emerges, they argue, within intellectual frameworks of systems theory, "fold[ing]" across the technological and the biological, the digital and the analog.[298] For Sedgwick and Frank, Tomkins's work reorients literary theory toward richer considerations of interdisciplinarity and "the dynamics of consensus formation" across fields.[299] But more to the point, and for my discussion in this chapter, they point toward affect's explicitly computational intellectual history. Addressing affect as information—as data—that circulates within and fine-tunes cognitive systems, whether human or machine, is thus a lineage that begins not with digital media, but rather with affect's emergence as a concept more generally.

Part of the challenge that affect poses any study, whether humanistic or scientific, is its aversion to concrete definition. The word has a range of etymologies, all of which resolve through one route or another to the Latin *afficere*, meaning to act upon or to cause influence, particularly with regards to disease. This root definition informs affect's distinct yet interrelated usages in the field of philosophy and psychology, where it is perhaps more fully conceptually developed. In philosophy, affect names a core concept in a strain of continental thought that runs roughly from Baruch Spinoza through Henri Bergson and to Gilles Deleuze and his contemporaries. Deleuzian philosopher Brian Massumi glosses affect within this tradition as "a prepersonal intensity corresponding to the passage from one experiential state of the body to another," in other words, a material, cultural, or psychic force that shifts both the body's

[298] Eve Kosofsky Sedgwick and Adam Frank, "Shame in the Cybernetic Fold: Reading Silvan Tomkins," *Critical Inquiry* 21, no. 2 (January 1995): 13, https://doi.org/10.1086/448761.
[299] Sedgwick and Frank, "Shame in the Cybernetic Fold," 2.

experience and its capacity *to* experience.[300] It's in this sense that contemporary critical theorists have articulated an "affective turn" in humanistic thought, what Gregory Seigworth and Melissa Gregg define as "means of inquiry invented to account for the relational capacities that belong to the doings of bodies."[301] In psychology, by contrast, affect is a more concretely defined concept. Inchoate in the works of Freud and Lacan, affect emergences in Tomkins's writing as a neurobiological system, what Tomkins scholar Donald Nathanson terms "the biological portion of emotion."[302] That these genealogies are rarely discretized in contemporary affect theory makes it all the more challenging to fix as an object of study. Conversely, affect then operates as a site that shades together discourses across a range of disciplines.

Another way to articulate the contrast between these genealogies is through the concepts of analog and digital. In its philosophical tradition, affect theory is almost overwhelmingly analog. Affect inhabits the spaces between bodies, things, and systems; it functions through "folds" and "shimmers"; it traces liminal and grey spaces. In one representative passage from her 2010 monograph *Vibrant Matter: A Political Ecology of Things*, political theorist Jane Bennett describes an encounter with trash on a Baltimore street as "shimmer[ing] and spark[ing] . . . a contingent tableau that they formed with each other, with the street, with the weather that morning, with me."[303] This is a thoroughly analog image. By contrast, psychological affect takes on shades of the digital. Tomkins's affect theory is perhaps most famous for his insistence that

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[300] Brian Massumi, "Notes on the Translation and Acknowledgements," in *A Thousand Plateaus: Capitalism and Schizophrenia* (Minneapolis: University of Minnesota Press, 1987), xvi–xix xvi.

[301] Melissa Gregg and Gregory J. Seigworth, *The Affect Theory Reader* (Durham and London: Duke University Press, 2010), 9.

[302] Donald L. Nathanson, *Shame and Pride: Affect, Sex, and the Birth of the Self* (New York: W.W. Norton & Company, 1994), 49.

[303] Jane Bennett, *Vibrant Matter: A Political Ecology of Things* (Durham and London: Duke University Press, 2010), 5.

all possible human affects be sortable into a discrete number of possibilities: distress-anguish, interest-excitement, enjoyment-joy, surprise-startle, anger-rage, fear-terror, shame-humiliation, disgust, and dissmell. (Each binary names an emergent affect that gives way to its more intense version; "dissmell" is a Tomkins neologism for "avoidance.") Numerical, quantifiable: this is a digital model.[304] For my part in this chapter, I am interested in affect's capacity to slip between analog and digital, which I have argued throughout this dissertation is a quality definitional to atmospheric media. Unsurprisingly, the latter digital models of affect have proven more influential in computer science than the former analog philosophical models. There, Tomkins's models serve as the basis for a suite of technologies and research areas into emotion's computational analysis.

Take, for instance, the following Python code, which applies one such program, called TextBlob, to a random entry from the *Database* **(code 0b)**.

```
from textblob import TextBlob

for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=1):
  print(x)
  print(TextBlob(x).sentiment.polarity)

output:
An area of low pressure moved from eastern New York into New England
Monday night. Rapidly moving thunderstorms associated with this system
resulted in a transport down to the surface of strong upper level
winds. In Barre, Vermont, numerous trees were uprooted.  Some
structural damage was reported. Power lines were blown down with a
number of residents without power.
0.049368686868686854
```

[304] In distinguishing between "analog" and "digital" philosophies, I draw from Alexander Galloway's recent development of a similar schema, which he has mapped most recently in a series of blog posts on his personal website. See Alexander R. Galloway, "How to Spot an Analog Philosopher," *Alexander R. Galloway*, December 2019, http://cultureandcommunication.org/galloway/how-to-spot-an-analog-philosopher and Alexander R. Galloway, "How to Spot a Digital Philosopher," *Alexander R. Galloway*, October 2019, http://cultureandcommunication.org/galloway/how-to-spot-a-digital-philosopher.

Computer science calls what this code has executed "sentiment analysis." To translate these lines into natural language: I have tasked TextBlob with determining the *polarity* of this weather narrative. Expressed on a scale from +1.0 to –1.0, polarity describes a text's inherent emotional positivity or negativity. TextBlob assigns this narrative a polarity score of ~+0.05, indicating slight positivity. Also known as "opinion mining," sentiment analysis is a fast-growing subfield of natural language processing, itself an interdisciplinary field of research into the computational address of spoken or written human languages.[305] Sentiment analysis draws explicitly on affective schema such as Tomkins's. For instance, the Human-Machine Interaction Network on Emotion (HUMAINE), a European human-computer interaction research group, proposed in 2006 the Emotion Annotation and Representation Language (EARL), an .xml-based markup language for quantifying emotions in computational research. EARL specifies forty-eight distinct emotions, grouped into larger schema such as "positive thoughts" or "negative and passive."[306] Such projects are examples of what computer scientist Bing Liu describes as the work of "know[ing] how such feelings are expressed in natural langauge and how they can be recognized [computationally]."[307] From a humanities perspective, this work might seem suspect, even folly. Cultural critics such as Frank Pasquale have blasted the field of "affective computing" in no uncertain terms as effectively snake oil, technical operations that claim to provide empirical answers but instead launder bias, prejudice, and discrimination.[308] I am alert to these critiques, and throughout this chapter question sentiment analysis' capacity to deliver empirical truths

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[305] Bing Liu, *Sentiment Analysis: Mining Opinions, Sentiments, and Emotions* (New York, NY: Cambridge University Press, 2015) xi.

[306] HUMAINE, "HUMAINE Emotion Annotation and Representation Language (EARL) Emotion-Research.net" (https://web.archive.org/web/20080411092724/http://emotion-research.net/projects/humaine/earl, April 2008).

[307] Liu, *Sentiment Analysis*, 36.

[308] Frank Pasquale, "More Than a Feeling," *Real Life* (https://reallifemag.com/more-than-a-feeling/, October 2020).

about texts. Instead, I am interested in how sentiment analysis itself understands affect as linguistically coded and digitally expressible. In short, I use sentiment analysis to understand how computer science mediates epistemological models of the relationships between language and emotion—models that I argue are influential on resources such as the *Database* and which provide blueprints for new kinds of models for doing environmental media studies.

Moreover, I am intrigued by the critical potential of putting narrative weather data in conversation with sentiment analysis, such that the tool, imperfect though it may be, might orient environmental media studies towards questions of modeling. From the perspective of natural language processing, sentiment analysis is a two-step project. First, it develops a statistical model of the relationships between language and emotion based on lexical characteristics. Second, it trains a computer program to recognize these relationships with minimal human supervision. These relationships are formal rather than contextual, based on features like lexical repetition and word proximity rather than any understanding of "content" itself. Hayles argues that machine reading "proceeds by making myriad connections between the same words in different contexts and by comparing and contrasting words with other words."[309] Sentiment analysis effectively reflects back a model of language, datafied. This datafication process mirrors similar ones I have discussed throughout this dissertation, from the data of forecasting to the informatics of HVAC. The ongoing work of capturing, recording, and processing the weather in the *Database* is yet another example of a cultural drive to mediate the atmosphere as information. In a way, sentiment analysis is another such example, albeit one concerned with the aesthetic rather than environmental sense of the word "atmosphere."

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[309] Hayles, "Human and Machine Cultures of Reading," 1226.

I begin my analysis with a "data biography" of the *Storm Events Database*. Drawn from the work of data scientist Heather Krause and developed further by Lauren Klein and Catherine D'Ignazio, the "data biography" is a genre of writing about data that restores the cultural and historical contexts of their production, which are all too often effaced from the final datasets. I track the *Database*'s migration through a variety of analog and digital platforms from the 1950s to the present day, mapping the official policies that have guided its recording. In this section, I also use TextBlob to perform a preliminary sentiment analysis of the *Database*, out of which I explore tensions between the machine's capacity to read for affect and my own instincts as a human reader. These tensions undergird the chapter's second section, which turns its attention fully to TextBlob. Using techniques drawn from critical code studies and software studies, I engage a close reading of TextBlob's source code to investigate how the program construes relationships between affect and textuality. I suggest that TextBlob reflects a broader project in sentiment analysis of imagining affect as discrete and encoded within individual words—in short, as data. I demonstrate how TextBlob's underlying statistical model, itself adapted from several other natural language processing programs, is insufficient to capture the nuances of the *Database*. This insufficiency guides my final section, in which I use an experimental feature in TextBlob to develop my own model for assigning Tomkins's affective schema to the *Database*. While TextBlob returns mixed results, I argue that the process of attempting to develop such a model parallels the same kinds of technical and epistemological models that power the *Database* and computational weather prediction more generally. I conclude the chapter with a reflection on the role modeling plays as a keyword both for this chapter and for my dissertation more generally.

A Data Biography of the Storm Events Database

On September 3rd, 2020, at 4:45 PM, the Sligo Creek, located a few hundred feet from my old apartment in Takoma Park, Maryland, rapidly rose over six feet and flooded a nearby road. I know this from the *Storm Events Database*, which records eight such floods on the creek in 2020 alone. The *Database* links this particular flood to thirteen other simultaneous floods in Maryland, all of which share the same root cause of "a disturbance (the remnant of convection from the day before over the Tennessee River Valley) [which] triggered a few supercells and line segments from eastern West Virginia into the Washington/Baltimore metro areas." As the flood's entry indicates, it caused no deaths, injuries, or property damage, just a minor inconvenience for any drivers who found themselves on Sligo Creek Parkway that Thursday afternoon. Entries in the *Database* have up to two recorded narratives: an "episode narrative," which describes an overarching weather event that can instigate multiple individual entries, and an "event narrative," often much shorter, which narrativizes a single entry. The September 3rd flood has both. They read:

> EPISODE NARRATIVE: A disturbance (the remnant of convection from the day before over the Tennessee River Valley) triggered a few supercells and line segments from eastern West Virginia into the Washington/Baltimore metro areas. This lead to some isolated instances of flooding in parts of MD.
>
> EVENT NARRATIVE: The water level rapidly rose above flood stage of 5.5 feet within 40 minutes. The water level crested at 6.14 feet at 5:10 PM EST. Sligo Creek Parkway was flooded near the gauge location just north of Maple Avenue.

According to NWS Instruction 10-1605, the official governmental directive guiding NOAA and NWS employees in maintaining *Storm Data*, episode narratives should "describe the entire episode in a general fashion, and briefly describe the synoptic meteorology associated with the episode,"[310] in other words, summarize the basic atmospheric conditions that produced the event in question. The event narrative, conversely, "describes the significance or impact of an event within an episode," with a particular focus on the event's quantitative impact on life and property. Every entry must have an episode narrative, but the inclusion of event narratives are left to the discretion of the data preparer. The distinctions between the two categories are evident in the September 3rd flood's entries: the episode narrative, shared with the other thirteen related floods, narrativizes the atmospheric disturbances that produced them; the event narrative focuses on the creek itself, with attention to the numerical quantities of water level rise over time. Together, these narratives remediate data as sentences. Their style is clipped, each running a few hundred characters. Their subjects are the storms themselves, their origin points, tracks, and after-effects. There's little in them not already attested in the metadata, from the cause ("Heavy Rain") to the location ("1N TAKOMA PARK"). Even the report source is depersonalized: it's a rive gauge I've walked by a number of times on strolls around my neighborhood (fig. 13). To encounter this event in the database is then to navigate the gulf between my own memory of this weather and its mediation as data.

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[310] K James and C Woods, "Storm Data Preparation" (National Weather Service, July 2018), 15, https://www.nws.noaa.gov/directives/sym/pd01016005curr.pdf.

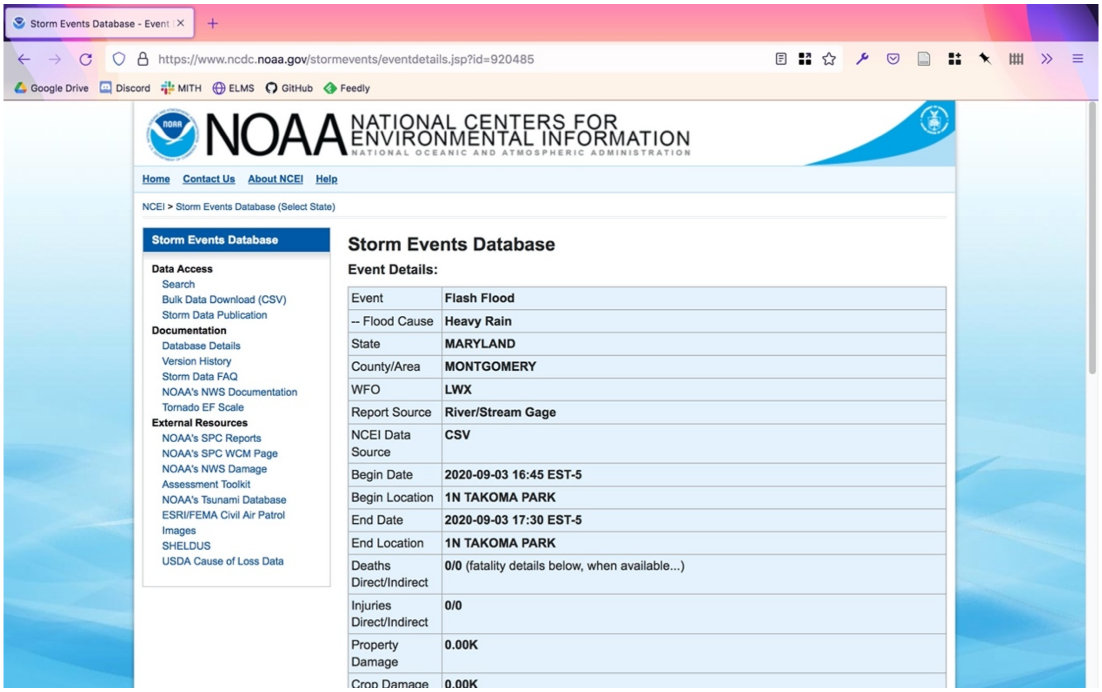

Figure 12. The Sligo Creek Flood's entry in the Storm Events Database, *https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=920485*.

Figure 13. The river gauge near my old apartment in Takoma Park, Maryland.

This section undertakes a "data biography" of the *Storm Events Database*. Coined by data scientist Heather Krause, a data biography is a pedagogical and analytical tool for restoring social and cultural context to datasets prior to their use.[311] Bare datasets cannot tell the stories of their creation, maintenance, and circulation; as digital media scholars Lauren Klein and Catherine D'Ignazio write, "the bottom line for numbers is that they cannot speak for themselves."[312] Data biographies are thereby a strategy through which media studies scholars can critique the form and use of such datasets. Moreover, they are a strategy that allows scholars to traverse multiple scales of reading a dataset, from the close reading of a single entry (as I pursue in the paragraphs above) to the macroanalysis of a dataset as a whole. As the *Database*'s website attests, its "data collection and processing procedures" have shifted over its seventy-year history, from changes in the kinds of weather events recorded, to the media of their processing, to the formal guidance given to individuals tasked with data collection and entry. Documenting these shifts restores historical context to a dataset that is in fact anything but cohesive. As I explore in this section, the *Database* is in fact a deeply inconsistent record of weather, reflecting social and technical specificities that change over its history. Attempts to smooth over these inconsistencies, I suggest, contribute to the flattening of its narratives' affect. By combining the close attention of media studies with the statistical techniques of data science, I map the *Database*'s ambivalence to the affective experience of weather. The *Database* flattens out affect in aggregate, even as individual outliers offer extreme portraits of weather's capacity for death and devastation. Despite the *Database*'s obsessive interest in human death, it narrativizes events from the

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[311] Heather Krause, "Data Biographies: Getting to Know Your Data," *Global Investigative Journalism Network* (https://gijn.org/2017/03/27/data-biographies-getting-to-know-your-data/, March 2017).

[312] Catherine D'Ignazio and Lauren F. Klein, *Data Feminism* (Cambridge: The MIT Press, 2020), 171.

perspective of weather itself, which it imagines as impartial and toneless. Conversely, applying machine reading techniques to the *Database* reveals the inherent strangeness of how computers make such affective determinations.

When the NWS began printing *Storm Data* in 1959, it didn't have the full scope that it has today. Originally, and until the mid-1990s, *Storm Data* only tracked a limited range of atmospheric disturbances, focused mostly on thunderstorms, tornadoes, and hail. With the 1995 publication of Instruction 10-1605, *Storm Data* expanded its scope to fifty-five different event types (fig. 14), incorporating oceanic and terrestrial severe weather. At the same time, the National Climatic Data Center (NCDC), then the largest weather archive in the United States, began implementing digital database technologies for its collection and processing work.[313] As part of a 1997 project to produce a digital resource for matching entries in *Storm Data* to corresponding radar maps, an NCDC employee named Richard Cram spun up a team to create the earliest version of what is now the *Database*. Cram's team had to work across many different media types, from mid-century tornado records stored in raw text files, to then-current entries in *Storm Data* stored in a database program named Borland Paradox, to archival hard copies of the publication itself. The digital version of the *Database* went online in 1998 and immediately became one of the NCDC's most popular resources. The site underwent four major upgrades between its 1998 launch and the present day, each time porting data forward from previous database technologies, each time producing new challenges to standardization. Infamously, early versions of Paradox allowed employees to input event types in a free text box, resulting in over 900 distinct types recorded in the *Database*. Furthermore, there are still many data fields that

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[313] This history draws from an anonymously authored document about the *Database* recorded as a .docx file on its official website, located at http://www1.ncdc.noaa.gov/pub/data/swdi/stormevents/The-History-of-the-Storm-Events-Database.docx.

haven't survived the transition from physical to digital media. This is particularly stark for the episode and event narratives. While there are narratives for entries as far back as 1959, these haven't been inputted into the .csv versions of the *Database* due to the sheer labor required. Only narratives from 1996 on—the beginning of the transition to digital media—appear in the .csv versions I use throughout this chapter.

NWSI 10-1605 July 16, 2018

Heavy Snow event, or a new, all-time, 4-hour rainfall record value can appear in the event narrative of a Flash Flood event.

2.1.1 Storm Data Event Table

Event Name	Designator	Event Name	Designator
Astronomical Low Tide	Z	Lightning	C
Avalanche	Z	Marine Dense Fog	M
Blizzard	Z	Marine Hail	M
Coastal Flood	Z	Marine Heavy Freezing Spray	M
Cold/Wind Chill	Z	Marine High Wind	M
Debris Flow	C	Marine Hurricane/Typhoon	M
Dense Fog	Z	Marine Lightning	M
Dense Smoke	Z	Marine Strong Wind	M
Drought	Z	Marine Thunderstorm Wind	M
Dust Devil	C	Marine Tropical Depression	M
Dust Storm	Z	Marine Tropical Storm	M
Excessive Heat	Z	Rip Current	Z
Extreme Cold/Wind Chill	Z	Seiche	Z
Flash Flood	C	Sleet	Z
Flood	C	Sneaker Wave	Z
Frost/Freeze	Z	Storm Surge/Tide	Z
Funnel Cloud	C	Strong Wind	Z
Freezing Fog	Z	Thunderstorm Wind	C
Hail	C	Tornado	C
Heat	Z	Tropical Depression	Z
Heavy Rain	C	Tropical Storm	Z
Heavy Snow	Z	Tsunami	Z
High Surf	Z	Volcanic Ash	Z
High Wind	Z	Waterspout	M
Hurricane (Typhoon)	Z	Wildfire	Z
Ice Storm	Z	Winter Storm	Z
Lake-Effect Snow	Z	Winter Weather	Z
Lakeshore Flood	Z		

Legend: There are three designators: C - County/Parish; Z - Zone; and M – Marine Zone.

Figure 14. The event types as currently listed in Instruction 10-1605.

Given the *Database*'s scale, paratexts such as Instruction 10-1605 are crucial to writing its data biography. In its current iteration, the directive runs nineteen pages with a substantial eighty-eight-page index describing the criteria for classifying each of the fifty-five possible event types in detail. Classification and edge cases are the document's bread and butter, from determining when storms begin and end to how they traverse territorial boundaries. In one memorable instance, it defines how many fatalities to count if a storm kills a pregnant person (the answer is one).[314] Time and again, the document addresses death and damage. *Storm Data* is an example of what media studies scholar Jacqueline Wernimont has termed "quantum media," or media technologies invested in counting, particularly the injured and the dead.[315] It exists within a lineage of weather records, burial registers, mortality bills, and actuarial tables, all media technologies of accounting lost lives. Instruction 10-1605's primary defining imperative for whether a weather event should be included at all is that it be of "sufficient intensity to cause loss of life, significant property damage, and/or disruption to commerce."[316] No wonder then that one of the *Database*'s major audiences is the insurance industry, which uses its data to calculate rates for weather-based policies.

Instructions on preparing textual narratives take up a scant two pages of the directive. It mandates a concise style, albeit takes special care to enjoin data preparers to use complete sentences rather than fragments and phrases.[317] While every entry requires an episode narrative, the directive only mandates event narratives if the event in question "cause[s] injury, fatality, or

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[314] James and Woods, "Storm Data Preparation," 10.

[315] Jacqueline Wernimont, *Numbered Lives: Life and Death in Quantum Media*, Media Origins (Cambridge: The MIT Press, 2018), 22–23.

[316] James and Woods, "Storm Data Preparation," 4.

[317] James and Woods, "Storm Data Preparation," 17.

property/crop damage."[318] Death rules the database. However, the embodied specifics of human death rarely enter the frame. One exception is lightning strikes, where the directive notes that "it is highly desirable to include in the event narrative, the age, gender, location, and weather conditions at the time of occurrence, if known or determinable," due to such data being used to compile separate published statistics.[319] The narrative guidelines mandate keeping the emphasis on storms themselves as both grammatical and topical agents. These formal constraints, in turn, condition how sentiment analysis programs might interpret the entries. In figures 15 and 16, I've passed the entirety of the *Database*'s episode narratives,[320] as available in .csv files, through TextBlob's default sentiment analysis implementation, a function titled `Pattern_Analyzer`. For figure 15, I then wrote a function to display mean polarity scores per year,[321] as a loose way to take a snapshot of the *Database* as a whole as well as noting any shifts in sentiment across time **(code 1a)**. The graph shows a nearly flat line at +0.0, indicating that on the whole, the *Database* trends towards the flat concision mandated in Instruction 10-1605.

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[318] James and Woods, "Storm Data Preparation," 15.

[319] James and Woods, "Storm Data Preparation," 17.

[320] I opted for episode rather than event narratives primarily for the former's relative complexity compared to the latter. Event narratives also tend to be much shorter compared to episode narratives, and for reasons that I explore in depth in my second data story, are therefore more likely to return null sentiment scores.

[321] This function also drops any entry that returns a score of 0.0. The reason why, as I explore in more depth in the next section, is that such a score in TextBlob more often than not means that none of the words in the narrative corresponded to TextBlob's predefined polarity lexicon; in effect, there were no data with which TextBlob could make an affective determination. As these scores are therefore not meaningful, and can pull the range of these graphs towards 0.0 unnecessarily, I have opted for removing them.

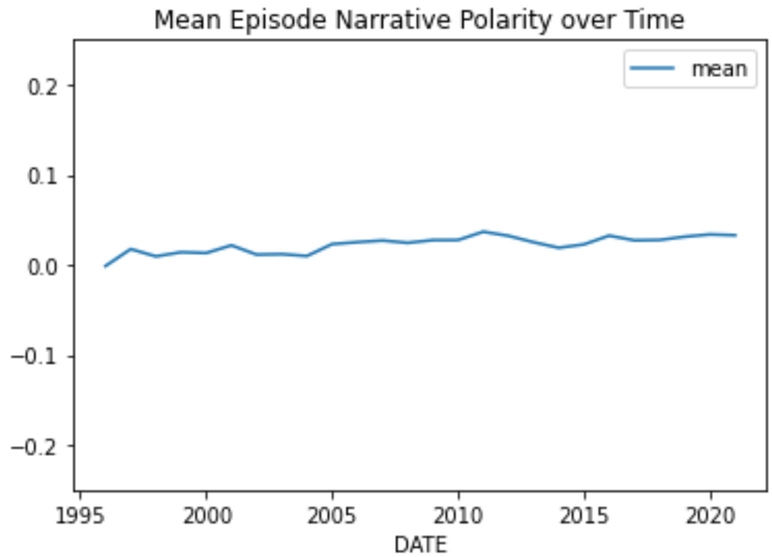

Figure 15. Mean episode narrative polarity over time.

Despite this overall trend toward neutrality, there are still entries with notable polarity scores in either direction. Figure 16 shows a scatterplot of every entry's polarity in the *Database* from 1996 to the present day. It's a frankly bewildering graph, as the points themselves are often too small to see but for clouds of their clustering. While the majority of entries all between -0.5 and +0.5, we can still see indications of sentiment across the full polarity range.

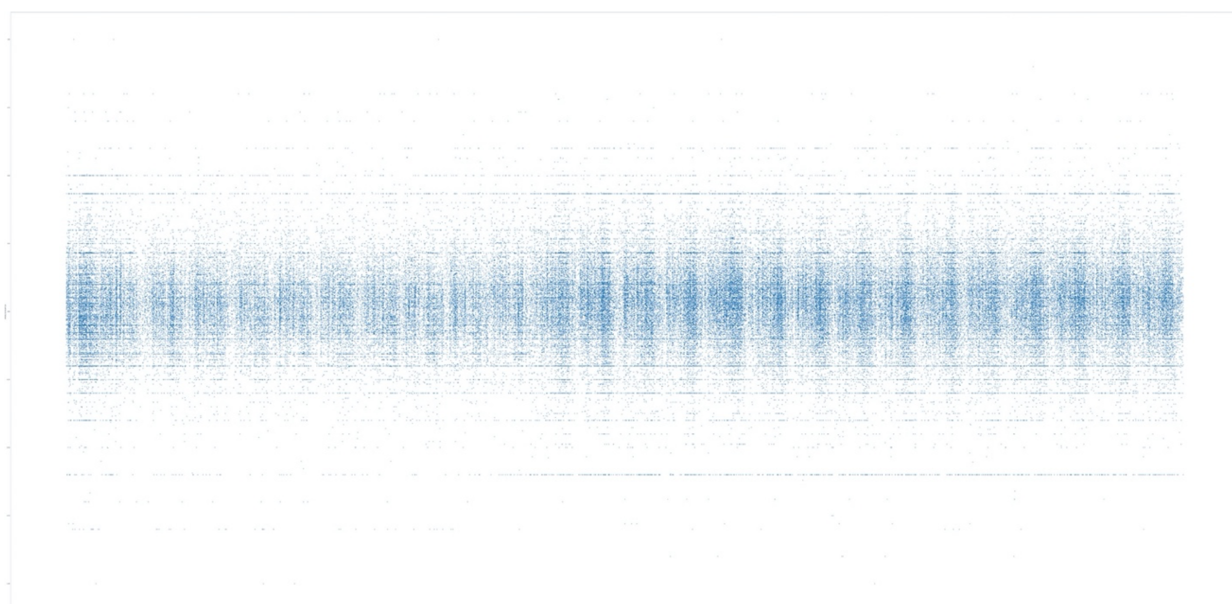

Figure 16. Total episode narrative polarity.

What do these extremely positive and extremely negative entries actually look like? TextBlob assigns five entries polarity scores greater than or equal to +0.9 and eleven entries scores less than or equal to –0.9, which I've reproduced here **(code 1b)**:

POSITIVE NARRATIVES:

- Up to twelve inches of snow fell in the northwest mountains. The greatest amount reported of 12 inches was in parts of Yellowstone National Park.
- Snow accumulated 5 to 12 inches, curtailing travel and closing some schools for a day. The greatest amount of 12 inches was reported southwest of Luverne.
- Lightning strikes caused power outages in Dover, Jackson and Manchester Townships. About 1,000 homes and businesses lost power with the greatest concentration in Holiday City. In Jackson Township, about 20 passengers were stuck on a roller coaster at Six Flags after power was lost.
- Some impressive ice jamming on the Yellowstone River brought substantial flooding to Prairie and Dawson Counties.
- A severe thunderstorm clipped northern Tripp County, with quarter sized hail west of Ideal.

NEGATIVE NARRATIVES:

- Sherriff reported lightning struck a house, shocking three people inside. They recovered.
- A thunderstorm crossed Chautauqua county downing trees and power lines. The worst hit area was in the town of Gerry and the surrounding area. In some cases, the falling trees caused damage to structures and automobiles.
- Rainfall of between 2 and 3 inches fell over the eastern part of Burnet County just after midnight, with up to 5 inches in some locations. The worst flash flooding was in the Marble Falls area, where police barricaded roads until just before sunrise.
- Frigid temperatures combined with upslope flow over eastern Kentucky terrain, and a wave of energy aloft brought widespread snow showers to eastern Kentucky on January 4th.
- Arctic air spilled south across the region on 2/9/11. Northeast winds of 30-40 mph combined with frigid temperatures to produce wind chill values of -15 to -20 degrees Fahrenheit.
- Frigid air settled over the area resulting in wind chill temperatures from 40 below to 55 below zero.
- Cheyenne County remained in Severe (D2) Drought in October, with the worst conditions south of Highway 40.
- A arctic air mass produced frigid temperatures, with nighttime lows from -20 to -35 degrees. Combined with wind speeds of 15 to 25 mph, equivalent wind chill temperatures of -25 to -50 were observed.
- A arctic air mass produced frigid temperatures, with nighttime lows from -20 to -30 degrees. Combined with wind speeds of 10 to 25 mph, equivalent wind chill temperatures of -25 to -45 degrees were observed.

- Frigid Canadian air slammed into Kansas on January 6th, dropping wind chill values to around 30 degrees below zero.
- A frigid air mass settled over the Northern Plains, with morning lows on the 25th ranging from 10 below to 25 below zero. On the morning of the 26th, temperatures ranged from 15 below to 30 below zero. Winds throughout the period ranged from 5 to 15 mph, which resulted in wind chill values from 40 below to 45 below zero at times.

Readers expecting intensely positive or negative entries may be disappointed by these selections, which seem otherwise to accord with the *Database*'s flat affect. Why, out of all of the entries in the *Database*, would TextBlob assign extreme scores to these ones in particular? The negative scoring selections may provide some clues, given that they paint at times quite strong portraits of the weather's violence. There are some notable verb choices: lightning "shocked" three people in a house; a cold front "spilled south" and "slammed" into a region; trees fell, power lines downed, police barricaded roads. Sentiment analysis programs cannot understand context; all they have available to them are formal linguistic relationships, defined variously depending on the program in question. Given this reliance on formal structures, individually strong verbs may "overpower" the polarity scores after a fashion, resulting in these strong outliers. This insight helps elucidate the positive entries, which by contrast, seem far more out of place, even erroneous. A thousand homes losing power does not strike me as a positive feeling. However, individual word choices may skew the scores yet again. "Impressive" ice, "greatest" amounts, and even the place name of "Ideal" in Tripp County might have triggered positive polarity scores, despite them being out of context. Computer scientist Oren Etzioni defines a computer's ability to "understand" text as "the formation of a coherent set of beliefs based on a textual corpus and a background theory."[322] What is "coherent" for me as a human reader and what is "coherent" for a machine will necessarily diverge, even as sentiment analysis research seeks to close that gap as much as

[322] Etzioni, Banko, and Cafarella, "Machine Reading," 1.

possible. In this brief moment, we have caught a glimpse of the machine's underlying beliefs, corpus, and theory.

Taken purely as an exercise in determining textual affect, sentiment analysis, at least in its off-the-shelf implementation in TextBlob, has clear flaws. However, I am struck by the technology's capacity for indicating formal relationships in the *Database* that align with, but occasionally diverge from affect as a concept. In other words, this brief experiment reveals competing epistemological models of affect: that of computer science and that of my sense as a reader. How might sentiment analysis then help scholars understand the shape these textual narratives take and how they function within the broader interpretive model of the *Database* specifically and databases more generally? One critical tool for understanding commonalities and divergences across these models is that of form. Form is an under-theorized keyword in environmental media studies. In environmental literary studies, form mostly enters the frame through discussions of generic forms, such as the cli-fi novel or dystopian film. Media studies, by contrast, prefers the languages of materiality and infrastructures. But in passing the *Database* through TextBlob, I note how necessary the languages of form are for understanding what is happening in it on both computational and interpretive levels. Narrative itself, as literary scholar Caroline Levine reminds us, is a form, one that she contends "best captures the experience of colliding forms."[323] Narrative is a meta-form. This is an apt way to describe Instruction 10-1605's guidance to treat narrative as a way of remediating—we might say *reforming*—quantitative data. In this way, these narratives echo back hosts of discrete structures and data points, collapsing into grammar the otherwise overwhelming profusion of information assigned to each weather event. Narrative becomes a set of formal relations for encountering weather data

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[323] Caroline Levine, *Forms: Whole, Rhythm, Hierarchy, Network* (Princeton: Princeton University Press, 2015), 19.

in new ways—a model. The linguistic relationships across these narratives are yet another kind of weather data, a metadata produced in the *Database*'s production: unintentional perhaps, but no less vital to the study of severe weather's datafication.

A Critical Code Study of TextBlob

File: en/sentiments.py[324]
Programming language: Python
Developed: 2013–Present day
Principal author: Steven Loria
Platform: Cross-platform (Windows, macOS, Linux)
Libraries used: NLTK
Source file: https://github.com/sloria/TextBlob/blob/dev/textblob/en/sentiments.py
Interoperating files: `base.py`, `sentiments.py`, `_text.py`, `en/__init__.py`, `en/en-sentiment.xml`

***

```
# -*- coding: utf-8 -*-
"""Sentiment analysis implementations.

.. versionadded:: 0.5.0
"""
from __future__ import absolute_import
from collections import namedtuple

import nltk

from textblob.en import sentiment as pattern_sentiment
from textblob.tokenizers import word_tokenize
from textblob.decorators import requires_nltk_corpus
from textblob.base import BaseSentimentAnalyzer, DISCRETE, CONTINUOUS


class PatternAnalyzer(BaseSentimentAnalyzer):
    """Sentiment analyzer that uses the same implementation as the
    pattern library. Returns results as a named tuple of the form:
```

[324] The structure of this section follows a model for doing critical code studies developed by the Critical Code Studies Working Group, led by Mark Marino. Such readings begin with metadata about the code under analysis, quote the code in full, annotate it, and then provide an analysis.

```
    ``Sentiment(polarity, subjectivity, [assessments])``

    where [assessments] is a list of the assessed tokens and their
    polarity and subjectivity scores
    """
    kind = CONTINUOUS
    # This is only here for backwards-compatibility.
    # The return type is actually determined upon calling analyze()
    RETURN_TYPE = namedtuple('Sentiment', ['polarity', 'subjectivity'])

    def analyze(self, text, keep_assessments=False):
        """Return the sentiment as a named tuple of the form:
        ``Sentiment(polarity, subjectivity, [assessments])``.
        """
        #: Return type declaration
        if keep_assessments:
            Sentiment = namedtuple('Sentiment', ['polarity', 'subjectivity',
'assessments'])
            assessments = pattern_sentiment(text).assessments
            polarity, subjectivity = pattern_sentiment(text)
            return Sentiment(polarity, subjectivity, assessments)

        else:
            Sentiment = namedtuple('Sentiment', ['polarity', 'subjectivity'])
            return Sentiment(*pattern_sentiment(text))


def defaultfeatureextractor(words):
    """Default feature extractor for the NaiveBayesAnalyzer."""
    return dict(((word, True) for word in words))


class NaiveBayesAnalyzer(BaseSentimentAnalyzer):
    """Naive Bayes analyzer that is trained on a dataset of movie reviews.
    Returns results as a named tuple of the form:
    ``Sentiment(classification, ppos, pneg)``

    :param callable featureextractor: Function that returns a dictionary of
        features, given a list of words.
    """

    kind = DISCRETE
    #: Return type declaration
    RETURNTYPE = namedtuple('Sentiment', ['classification', 'p_pos',
'p_neg'])

    def __init__(self, feature_extractor=_default_feature_extractor):
        super(NaiveBayesAnalyzer, self).__init__()
        self._classifier = None
```

```
        self.feature_extractor = feature_extractor

    @requires_nltk_corpus
    def train(self):
        """Train the Naïve Bayes classifier on the movie review corpus."""
        super(NaiveBayesAnalyzer, self).train()
        neg_ids = nltk.corpus.movie_reviews.fileids('neg')
        pos_ids = nltk.corpus.movie_reviews.fileids('pos')
        neg_feats = [(self.feature_extractor(
            nltk.corpus.movie_reviews.words(fileids=[f])), 'neg') for f in
neg_ids]
        pos_feats = [(self.feature_extractor(
            nltk.corpus.movie_reviews.words(fileids=[f])), 'pos') for f in
pos_ids]
        train_data = neg_feats + pos_feats
        self._classifier =
nltk.classify.NaiveBayesClassifier.train(train_data)

    def analyze(self, text):
        """Return the sentiment as a named tuple of the form:
        ``Sentiment(classification, p_pos, p_neg)``
        """
        # Lazily train the classifier
        super(NaiveBayesAnalyzer, self).analyze(text)
        tokens = word_tokenize(text, include_punc=False)
        filtered = (t.lower() for t in tokens if len(t) >= 3)
        feats = self.feature_extractor(filtered)
        prob_dist = self._classifier.prob_classify(feats)
        return self.RETURN_TYPE(
            classification=prob_dist.max(),
            p_pos=prob_dist.prob('pos'),
            p_neg=prob_dist.prob("neg")
        )
```

***

Annotations

1–4: Comments in code orient programmers and readers alike to the functions contained within a file, as well as to its development and publication history. Loria added sentiment analysis to TextBlob in version 0.5.0, published on 10 August 2013. According to the changelog on GitHub, where TextBlob's code is hosted, `en/sentiments.py` was most recently updated on 2 December 2017.

5–13: Python programs customarily include dependencies, or external programs which files require in order to operate, as "imports" at the beginning of code. Notably, line 8 imports NLTK; line 10 imports a function called `sentiment` from the file `en/__init__.py`, a lightly revised version of Pattern's sentiment analysis implementation; and line 13 imports wrapper functions that define the basic form of both `PatternAnalyzer` and `NaiveBayesAnalyzer`.

16: The remainder of `en/sentiments.py` defines two Python classes, one for each implementation. Loria begins with `PatternAnalyzer`.

28: Loria includes an if/else function in `PatternAnalyzer` to handle whether the user wants optionally to return "assessments," or the major lexical criteria upon which the function determines a sentence's polarity.

36, 41: In both the if and else parts of this function, the actual work of computing polarity occurs in `pattern_sentiment(text)`, which applies Pattern's sentiment analysis function, imported in line 10, to the given input text. While not included directly in `en/sentiments.py`, this function averages together assigned polarity scores drawn from a lexicon file.

44: In preparation for `NaiveBayesAnalyzer`, Loria includes a brief definition of a feature extractor. In NLP, a feature extractor parses input for major "features," or statistically significant lexical data.

50: `NaiveBayesAnalyzer` uses machine learning functions to train its analysis on a dataset of movie reviews included as an example corpus in the NLTK code base. This corpus comprises two hundred movie reviews, half tagged positive and half tagged negative, assembled in 2004 by computer scientists Bo Pang and Lillian Lee as a tool for sentiment analysis projects. The corpus and its associated research papers are available at https://www.cs.cornell.edu/people/pabo/movie-review-data/. These reviews are imported in line 12.

61: Defines a subsequent feature extractor using the form previously defined in line 44.

66: Indicates that this function requires the user to download the NLTK corpus to their computer in order to run.

67–77: `NaiveBayesAnalyzer` comprises two major functions: a training and an analysis function. This first training function identifies which reviews in the Pang and Lee corpus are tagged positive or negative; extracts key textual features from each; combines them into a single variable named `train_data`; and then uses NLTK's built-in algorithms to train a classifier.

79–93: These lines define `NaiveBayesAnalyzer`'s analysis function, where the sentiment analysis work actually happens. Lines 85–87 break down the text into individual features, which are then classified using a probability distribution function in line 88. Lines 89–92 print the results to the command line using the schema defined in line 52.

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In the previous section, I engaged a machine reading of the *Storm Events Database* using a natural language processing (NLP) tool called TextBlob. Developed from 2013 to the present day by software engineer Steven Loria, TextBlob is a Python library that provides simple, off-the-shelf tools for NLP tasks such as part-of-speech tagging, classification, and sentiment analysis. One of many freely available NLP tools, TextBlob is commonly used for classroom instruction and preliminary research, particularly in the digital humanities. These affordances have made it a practical tool for my machine readings in this chapter. Moreover, TextBlob's relative architectural simplicity, while a barrier to more sophisticated readings, make it ideal for a critical study of sentiment analysis technologies. This data story shifts my attention briefly away from weather data and toward technologies for detecting and quantifying affective, rather than meteorological atmospheres. I pursue a critical code study of TextBlob's sentiment analysis functions, asking how the tool parses, interprets, and assigns polarity scores to the *Database*. Media scholar Mark C. Marino defines critical code studies (CCS) as "an approach to code studies that applies critical hermeneutics to the interpretation of computer code, program architecture, and documentation within a sociohistorical context."[325] Marino has developed the approach in concert with members of the CCS Working Group, an online community of practitioners, over much of the past decade. CCS emphasizes code's textuality, arguing that the "traditional" critical approaches of the humanities have much to add to conversations around code's historical, social, and cultural work. I apply CCS principles to one specific file in TextBlob's code base, the 97-line file `en/sentiments.py`[326] quoted and annotated in full above. `en/sentiments.py` features two distinct sentiment analysis implementations, the default `Pattern_Analyzer`, which I employed in the previous section; and `NaiveBayesAnalyzer`, a more computationally sophisticated but processor-intensive implementation that uses machine

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[325] Mark C. Marino, *Critical Code Studies: Initial Methods* (Cambridge: The MIT Press, 2020), 39.

[326] I include the leading `en/` to distinguish from another file in the TextBlob code base named `sentiments.py`.

learning techniques. Crucially, `en/sentiments.py` does not contain the analytical functions that compute polarity in itself. Rather, it serves as a wrapper file, drawing together code from a range of sources both within and beyond the TextBlob code base.

Through this section's close reading of `en/sentiments.py`, I advance two intertwined claims about TextBlob and sentiment analysis more generally. First, I map TextBlob's reliance on a complex web of dependencies. From a technical perspective, `en/sentiments.py` does little computational lifting of its own. Instead, it draws together prior work from a range of other Python tools and datasets, in particular the libraries Pattern and NLTK.[327] While such dependencies are far from unusual in computer code (a program without dependencies would perhaps be *more* unusual), TextBlob's dependencies are notable for how they transmit conceptual as well as technical operations. Through its citational relationships with Pattern and NLTK, TextBlob inherits their mathematical models of the relationship between language and affect, which in turn influence its capacity to interpret the *Database*. Analyzing these models supports this section's second claim: that TextBlob and sentiment analysis more generally imagine affect as programmatically latent in the smallest particles of language, which they then strive to make available for extraction and computation. TextBlob envisions affect as discrete and encoded within individual words, in short, as *data*. Whether or not TextBlob is empirically successful at identifying affect—if indeed affect is computationally identifiable at all—is then secondary to the conceptual project of making affect appear programmatically legible through computational techniques.

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[327] For the code base of Pattern, see Tom De Smedt and Walter Daelemans, "Pattern" (Computational Linguistics Research Group, April 2021). For NLTK, see Steven Bird, Edward Loper, and Ewan Klein, *Natural Language Processing with Python* (O'Reilly Media, 2009).

Loria describes TextBlob as a "library for processing textual data."[328] Before it can compute relationships *across* such data, it must first mediate textual input *into* data. Many core NLP tasks concern themselves with reducing complex textual inputs into smaller lexical units, which computers can more easily process and compare statistically. One such technique, deployed in `en/sentiments.py`, is called "tokenization." In NLP, a token refers to an arbitrary unit of lexical information. A program may tokenize a paragraph into sentences, a sentence into words, a word into syllables, or a syllable into letters, depending on the researchers' questions and interests.[329] Programs can further reduce related words (for instance, different inflections of the same verb) through computational processes such as stemming (removing affixes and suffixes) and lemmatization (removing inflectional endings, e.g., "-ly" for adverbs). TextBlob's operative level of tokenization is that of individual words. Line 11 in `en/sentiments.py` imports a tokenization function from elsewhere in the code base, itself lightly adapted from and wrapping a related function in NLTK. Line 85 demonstrates this function in action, applying `word_tokenize` to the input text, making it subsequently available for further filtering and feature extraction.

The decision to tokenize at the level of words has two consequences for TextBlob's sentiment analysis. First, it renders word order irrelevant. For example, `PatternAnalyzer` assigns Noam Chomsky's famously meaningless sentence "Colorless green ideas sleep furiously" a –0.2 polarity score, indicating slight negativity. (Perhaps the sentence may not be as meaningless as Chomsky suggests, at least where affect is concerned!) Rearranging the sentence to "Green ideas colorless furiously sleep," similarly meaningless but syntactically invalid,

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[328] Steven Loria, "TextBlob: Simplified Text Processing: TextBlob 0.16.0 Documentation" (https://textblob.readthedocs.io/en/dev/, 2020).

[329] Christopher D. Manning, Prabhakar Raghavan, and Hinrich Schütze, *Introduction to Information Retrieval* (Cambridge University Press, 2008).

returns the same score **(code 2a)**. This entails a second consequence: namely, that TextBlob inheres affective meaning *within* single words, stripped bare of syntactical context and morphological derivation. A programming choice perhaps designed to lower the computational load thus produces a cognitive and conceptual model. Furthermore, TextBlob imagines the affect within these words as mathematically fixed, capable of adding to or subtracting from the affect of other words, but not changing based on other linguistic characteristics.

Due to the nested dependencies and imported functions in `en/sentiments.py`, it's difficult to see where and how TextBlob defines these eternal affective constants. For `PatternAnalyzer`, the process of assigning and computing polarity scores happens with the terse invocation of `pattern_sentiment(text)`, a function imported into rather than defined within this file. We can follow this function along a chain of interoperable files to `en-sentiment.xml`, a lexicon file containing 2,918 individual words with associated polarity scores. Entries follow a standardized format:

```
<sentiment language="en" version="1.3" author="Tom De Smedt, Walter
Daelemans" license="PDDL">
    ...
    <word form="airheaded" cornetto_synset_id="n_a-507793"
wordnet_id="a-02120828" pos="JJ" sense="lacking seriousness"
polarity="0.5" subjectivity="1.0" intensity="1.0" confidence="0.8" />
    <word form="alarming" cornetto_synset_id="n_a-527099"
wordnet_id="a-00193015" pos="JJ" sense="frightening because of an
awareness of danger" polarity="-0.1" subjectivity="0.6" intensity="1.0"
confidence="0.8" />
    <word form="alas" wordnet_id="" pos="UH" polarity="-0.4"
subjectivity="1.0" intensity="1.0" confidence="0.8" />
    ...
</sentiment>
```

Just as Loria imports the Pattern library's algorithmic functionality, so too does he re-use De Smedt and Daelemans's lexicon. In their 2012 paper introducing Pattern, De Smedt and Daelemans describe using the web scraping tool to produce this lexicon itself: "We mined online

Dutch book reviews and extracted the 1,000 most frequent adjectives. These were manually annotated with positivity, negativity, and subjectivity scores," a task they repeated with a number of European languages, including English.[330] "Manual annotation" means exactly what it sounds like: De Smedt and Daelemans hand-tagged (or computationally inferred, for words with related senses and meanings) words with polarity scores. These scores came from their own critical judgment rather than any computational process. While this practice may raise red flags to an audience of humanistic critics—it seems an excellent way to encode a whole range of unattested biases and subjectivities into the program, for one—it's a standard approach in NLP. The Pang and Lee movie review corpus that powers `NaiveBayesAnalyzer` uses a similar approach, beginning with human subjective evaluation of reviews in order to build a baseline for machine comparison.[331] While programmers often document such development processes in code comments and research papers, these innate subjectivities get effaced in the movement from data to code. In offering a putatively "objective" snapshot of textual affect, TextBlob contributes to this pattern.

While `PatternAnalyzer` uses simple averaging to compute its scores, `NaiveBayesAnalyzer` deploys machine learning techniques. True to its name, it uses a naïve Bayes algorithm to assign probabilistic (rather than definitive) polarity scores. But what does this algorithm entail? Named after Reverend Thomas Bayes, an eighteenth-century English mathematician, a Bayesian algorithm is one based off of Bayes' Theorem, which offers a relatively simple statistical model for predicting the likelihood of an event happening given

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[330] Tom De Smedt and Walter Daelemans, "Pattern for Python," *Journal of Machine Learning Research* 13 (2012): 2065.

[331] Bo Pang and Lillian Lee, "Seeing Stars: Exploiting Class Relationships for Sentiment Categorization with Respect to Rating Scales," in *Proceedings of the 43rd Annual Meeting on Association for Computational Linguistics - ACL '05* (Ann Arbor, Michigan: Association for Computational Linguistics, 2005), 2, https://doi.org/10.3115/1219840.1219855.

various kinds of prior knowledge about such an event. A Bayesian algorithm is "naïve" when it presumes that all units of information are discrete and have no other statistically meaningful relationships: for example, when one computes a sentence's polarity scores based off of individual words alone, regardless of syntactical context. Even given `NaiveBayesAnalyzer`'s putative sophistication when compared to `PatternAnalyzer`, they share many of the same conceptual underpinnings. Both decompose inputs into individual words, in doing so obviating finer points of lexical and syntactical relation. I make this observation not to dismiss the projects of either; sentiment analysis is an extraordinarily taxing operation, both at the level of conceptual development and machine operations. The task demands simplification, compression, and abstraction. However, I suggest that programs such as TextBlob could do more, from a user perspective, to flag the necessarily subjective models that underpin their analysis. Doing so may undercut sentiment analysis's claims to objective utility, but by contrast would name more clearly what the technology actually does: namely, develop (imperfect, partial, but potentially useful) models of critical judgment.

Given that TextBlob provides two distinct sentiment analysis implementations, it allows users the opportunity to see how these different statistical models diverge. The following code runs another random *Database* entry through both `PatternAnalyzer` and `NaiveBayesAnalyzer` **(code 2b)**:

```
for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=5):
  print("PatternAnalyzer:")
  print(x)
  print(TextBlob(x).sentiment.polarity)

for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=5):
  print("NaiveBayesAnalyzer:")
  print(x)
  print(TextBlob(x, analyzer=NaiveBayesAnalyzer()).sentiment)
```

```
output:
PatternAnalyzer:
Southwest winds associated with a trough of low pressure led to a rip
current along the South Carolina coast.
0.0
NaiveBayesAnalyzer:
Southwest winds associated with a trough of low pressure led to a rip
current along the South Carolina coast.
Sentiment(classification='neg', p_pos=0.435910961474572,
p_neg=0.564089038525427)
```

Here, the limitations of the model become clear. While `PatternAnalyzer` appears to compute the sentence as perfectly neutral, in fact the score of 0.0 indicates that none of its constituent words had positive or negative polarity scores assigned in De Smedt and Daelemans' lexicon. (The only two words to appear are "low" and "current," each with 0.0 scores.) `NaiveBayesAnalyzer` fares better, returning a roughly negative classification. However, as a human reader, I will admit that its numerical assessment gives me pause, given how ultimately inscrutable its logics are. Whereas `PatternAnalyzer`'s reliance on a lexicon file makes its assessments transparent, if insufficient, `NaiveBayesAnalyzer` cloaks its logics within the black box of machine learning. We know from `en/sentiments.py` that it trains its model on movie reviews, a textual form sharply distinct from the *Database*'s severe weather narratives. Many off-the-shelf sentiment analysis tools rely on similar affectively charged forms, from online reviews to social media posts. While these are undoubtedly easier for human researchers to manually tag than dispassionate weather narratives, they raise in turn the question of their suitability to textual forms that aren't so affectively charged and that don't operate in the more casual registers of online speech. Once again, TextBlob returns results that reflect more about the tool itself than the texts it analyzes. This is why, from my position as a critic trained in media studies, I am skeptical that these functions can do what they claim. I root this skepticism not in any particular valorization of human judgment, but rather in my analysis of its computational models, which strike me as too radically simplified and partial to address affect's multivariate complexity. However, I am intrigued by sentiment analysis's capacities to model different forms of critical judgment, and in doing so remove them from an exclusively human context.

`en/sentiments.py` provides a brief, if telling glimpse into the conceptual assumptions substantiating sentiment analysis and NLP: that language is fundamentally reducible to mathematical information; that statistical techniques can construe meaningful relationships across this information; and that these mathematical relationships can translate fluidly back into the register of language. In addressing affect specifically, `en/sentiments.py` participates in what Patricia Ticineto Clough, Karen Gregory, Benjamin Haber, and R. Joshua Scannell have called the "datalogical turn," or "how the algorithms that parse big data are an intensification of . . . [an] unconscious drive to empiricism, positivism and scientism."[332] I contend that there is a fundamental slippage between what sentiment analysis claims to do and what it actually does. `en/sentiment.py`'s contrasting implementations demonstrate the fundamental importance of modeling to sentiment analysis's enterprise. While NLP research understandably focuses on improving the accuracy of such underlying models, my interest as a humanistic critic in technologies such as TextBlob is not with their potential (and I would argue, always deferred) capacity to determine empirically a text's affect, but rather with the imperfect, variable, and broken qualities that emerge from experiments with them. As digital humanists, we have an obligation to surface the cultural work such technologies perform before adopting them into our enterprise. In the case of sentiment analysis, this entails acknowledging how the technology's epistemological assumptions conflict with those underpinning, say, media studies. To work with

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[332] Svitlana Matviyenko, "On Governance, Blackboxing, Measure, Body, Affect, and Apps: A Conversation with Patricia Ticineto Clough and Alexander R. Galloway," *The Fibreculture Journal*, no. 25 (2015): 23.

sentiment analysis is to foreground the contingency of one's own assumptions about otherwise stable concepts like "text," "word," "mood," or "judgment." The final section of this chapter takes this provocation as its starting point, asking how we might produce a sentiment analysis model more suitable to the *Database*, and in turn what attempting to do so teaches us about the formal relationship between environmental media and computational affect.

A Model for All Seasons

Throughout this dissertation, I have asked questions about how digital technologies mediate atmospheres, and in doing so, produce atmospheres themselves. Time and again, these questions have taken on epistemological dimensions, as I have interrogated how media encode different cultural, historical, and informatic assumptions about what "atmospheres" even are. I have used various keywords to name and to analyze these epistemological functions, from forecasting to conditioning to respiring. Here, at the end of my dissertation, I have turned to modeling. The story goes something like this: atmospheres elude concrete apprehension, even as they surround, structure, and support all manners of living on this planet. Computer models cut through this elusiveness, providing stable if imperfect subjects for analysis. We find models at the heart of all our atmospheric media: models for weather prediction; models for HVAC systems; models of respiration and circulation. This chapter has addressed models for interpreting emotion and affect. My analysis in the previous two sections revealed multiple layers of modeling at work in my sentiment analysis of the *Storm Events Database*. Sentiment analysis relies on models of the relationship between textuality and affect; indeed, even before programmers can produce such computational models, they must begin from the epistemological presumption that such relationships are able to be modeled in the first place. Behind the

Database lies a data model, a set of conceptual decisions about how its data relate to each other and how they are structured. These models, as my data biography of the *Database* demonstrated, do not align perfectly. Each carry with them assumptions about relational form unique to the circumstances of its intellectual and material production. Put another way: meteorologists model differently from computer scientists, who model differently from literary theorists, who model differently from digital humanists. These are not stable intellectual categories and there is slippage—productive slippage, even—between them. This is not a novel claim, but I state it plainly here as a prelude to the project of this final section, which is an exercise in negotiating these epistemological limits.

My project in this section is to develop a sentiment analysis model more suited to the formal specificities of the *Database* than the general-purpose models included in TextBlob, which I have demonstrated are rife with false positives and technical limitations. Doing so, I argue, requires me as a critic to redefine the very conceptual project of sentiment analysis, such that I can name more plainly what it actually does as a technology: namely, to function as a classifier trained on arbitrary data. In this section, I recast sentiment analysis as a model of my own idiosyncratic critical judgment rather than an "objective" measure of affective quality. In order to achieve this, I use an experimental feature in TextBlob that allows users to create their own Naïve Bayesian classifier based on custom training data. This experiment thus has two objectives: first, to document the process of building, training, and testing this model; and second, to situate this work of affective model-building within the critical frameworks of digital humanities and media studies. It's my hope that both of these projects serve readers interested not only in my critique of modeling in atmospheric media, but also pedagogically for those interested in applying such modeling technologies to their own scholarly practice. As such, this section features significantly more code than previous sections; reference to the interactive code appendix may be useful to some readers. My inclusion of significant passages of code also serves a methodological function. One of the recurring “debates” in the digital humanities is how much, if at all, its practitioners should deploy code as argumentation in their work. This debate has taken on many forms over the past decades, from Bethany Nowviskie’s memorable takedown of the “hack vs. yack” dichotomy,[333] to Annette Vee’s useful troubling of “learn to code” initiatives.[334] I am not advancing a didactic claim in this chapter for whether or not digital humanists *should* code—rather, I attempt to demonstrate what an argument that in my estimation relies both on hacking (code) and yacking (writing) might look like.

As a topic of consideration in the digital humanities, modeling is decidedly old-fashioned. The word hearkens back to an earlier period of the field’s development, around the turn of the millennium, when scholars such as Willard McCarty used modeling as a theoretical hinge by which to connect the digital humanities to prior traditions of humanistic scholarship across fields as various as textual editing and information science. A model, McCarty writes, is “a representation of something for the purposes of study, or a design for realizing something new,” a doubled definition that gestures towards modeling’s capacity both to capture existing relations as well as produce speculative ones.[335] Such models might take the form of documents encoded in TEI for the purpose of scholarly archives, models for relational databases, or even narrative fiction itself in its capacity to encapsulate human relations and activities. “Modeling” thus has a tendency to function like “media,” in that it simultaneously invites rigorous

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[333] Bethany Nowviskie, “On the Origin of ‘Hack’ and ‘Yack’,” in *Debates in the Digital Humanities* (Minneapolis: University of Minnesota Press, 2016).

[334] Annette Vee, *Coding Literacy: How Computer Programming Is Changing Writing* (Cambridge: The MIT Press, 2017).

[335] McCarty, “Modelling,” 24.

theorization while evading concrete specificity. For my purposes in this chapter, I turn to this "modeling moment" in the digital humanities both to situate my work within a longer history of the field more generally, as well as to put further pressure on modeling's relationship to data. As Julia Flanders and Fotis Jannidis note, the formal abstraction required of modeling necessarily lies in tension with the messy realities of information capture.[336] This is a tension familiar to this dissertation—I think, for instance, of Allison Parrish's invocation of similar messiness in the information capture of space satellites in *The Ephemerides*. For my part, I avoid resolving this messiness, choosing instead to produce definitionally imperfect models that ask more questions than they resolve answers.

The code for my classifier is as follows **(code 3a)**:

```
from textblob.classifiers import NaiveBayesClassifier
from sklearn.model_selection import train_test_split

dfAffects = pandas.read_csv("/content/drive/My
Drive/dissertation/sentiment-analysis/data/dfNOAASample_200_2021-01-
15_CODED.csv")

dfAffectsTrain, dfAffectsTest = train_test_split(dfAffects,
test_size=0.2)

varAffectsTrain = []
varAffectsTest = []

for index, row in dfAffectsTrain.iterrows():
  varAffectsTrain += [(((row['EPISODE_NARRATIVE'])), (row['AFFECT']))]

for index, row in dfAffectsTest.iterrows():
  varAffectsTest += [(((row['EPISODE_NARRATIVE'])), (row['AFFECT']))]

clAffects = NaiveBayesClassifier(varAffectsTrain)

for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=1):
# "random_state" fixes the output as the same every time; remove it to
```

[336] Julia Flanders and Fotis Jannidis, "Data Modeling," in *A New Companion to Digital Humanities*, ed. Susan Schreibman, Ray Siemens, and John Unsworth (London: Wiley-Blackwell, 2016), 229–37.

```
get a truly random entry
  print(x)
  print("affect: " + clAffects.classify(x))
```

```
output:
The combination of a strong high pressure system exiting off the coast
and a strong cold front approaching from the west caused damaging
southeast wind gusts, estimated at least 58 mph.  (A spotter from
Harrison in Hudson County reported a wind gust to 55 mph.)High winds
downed numerous tree limbs, trees, wires, and power lines.  Some of
these fell on and damaged cars.  A driver in Carlstadt (Bergen County)
was treated for injuries after a tree fell on his parked car.  During
the peak, Public Service Electric and Gas Co. reported more than 70,000
customers without power across the area.  Damage was widespread across
the area.Selected peak wind gusts measured by ASOSs at Newark,
Caldwell, and Teterboro Airports were all 53 mph.

affect: interest-excitement
```

I'll gloss this code in natural language. The first question I needed to ask myself when building this classifier was what, precisely, was I classifying? The polarity functions I have used in other chapter sections sort input texts on a positive-negative binary. I could recreate these functions with different training data, but I had already demonstrated how polarity is an insufficient concept for thinking about the affect present in the *Database*. Furthermore, I wanted to build a classifier that captured, if briefly, some aspect of my own judgment. I could attempt objectivity through similar techniques as the TextBlob training data: get together a group of volunteers to sort episode narratives themselves and then combine the scores. But such an approach felt beyond my limitations as a statistician and critic. I decided instead to lean hard into subjectivity. I pulled a random selection of two hundred episode narratives from the *Database* and sorted them, based on my own imperfect intuition, into Silvan Tomkins' nine affective categories: distress-anguish, interest-excitement, enjoyment-joy, surprise-startle, anger-rage, fear-terror, shame-humiliation, disgust, and dissmell. I imported that data into the dataframe `dfAffects` in line 4. I then split that dataframe into two separate dataframes, one for training the classifier and one for testing the classifier. This is a standard procedure in data science that allows researchers to test the quality of their classifier; typically, one uses an 80/20 split between training and testing data. I have done so here. Lines 8 through 15 pass the episode narratives and my affective determinations into python arrays that TextBlob can read. The actual training happens in line 17: a single line and TextBlob builds its classifier using a Naive Bayes algorithm imported from NLTK. Lines 19 through 22 demonstrate the classifier in action, returning a random episode narrative from the deduplicated *Database* and printing its resultant affect.

TextBlob provides a built-in testing function that we can apply to the classifier, judging it against the testing data **(code 3b)**:

```
clAffects.accuracy(varAffectsTest)
```

```
output:
0.5
```

As we can see, this is not a high score at all—effectively a coin flip. There are numerous variables at play in the classifier's accuracy, from the salience of the initial training data, to its suitability to TextBlob's particular algorithms, to the quality of those algorithms themselves. Two hundred entries may not be enough upon which to base the classifier: my own judgment in sorting entries inconsistent. Those looking for a model that performs accurately based on the epistemologies of data science would do well to base the production of their training data after the best practices of data science. I wanted my model to achieve different ends: to teach me about what it was like to ask a machine to mimic my brain.

Like any theory, a model approaches its data asymptotically, encompassing some aspects and omitting others for the sake of productive generalization. There are, as I see it, two critical approaches to the necessary role of generalization in modeling. Neither are preferential and we can pursue both simultaneously. The first, characteristic of data science, is to work to close the asymptote: to bring the model as close to the conditions of "reality" as possible, whether through the accumulation of more data or the refinement of statistical techniques. The second, characteristic of media studies, takes the lack as a given and explores its *why*. An attractive proposition, no doubt, yet one that runs into problems of machine reading's technical opacity. How did TextBlob make the decisions it made about how to translate my classifications into an automatic procedure? The program provides a useful feature whereby it prints the "informative features" that drive its classifiers. Informative features are probability statements derived from the statistical analysis of the training data with which TextBlob then sorts inputs into categories. Here are the top twenty-five most informative features for `clAffects` **(code 3c)**:

```
clAffects.show_informative_features(25)

Most Informative Features
      contains(roadways) = True           enjoym : intere =     22.0 : 1.0
         contains(minor) = True           enjoym : intere =     22.0 : 1.0
          contains(30th) = True           enjoym : intere =     22.0 : 1.0
      contains(injuries) = True           enjoym : intere =     22.0 : 1.0
            contains(No) = True           enjoym : intere =     22.0 : 1.0
        contains(stream) = True           enjoym : intere =     22.0 : 1.0
      contains(drainage) = True           enjoym : intere =     22.0 : 1.0
  contains(temperatures) = True           anger- : surpri =     18.3 : 1.0
          contains(form) = True           enjoym : surpri =     18.3 : 1.0
         contains(crops) = True           anger- : intere =     15.7 : 1.0
           contains(had) = True           anger- : intere =     15.7 : 1.0
           contains(old) = True           anger- : intere =     15.7 : 1.0
          contains(Lake) = True           anger- : intere =     15.7 : 1.0
        contains(winter) = True           anger- : intere =     15.7 : 1.0
      contains(included) = True           anger- : intere =     15.7 : 1.0
     contains(Lightning) = True           fear-t : surpri =     15.3 : 1.0
          contains(near) = True           anger- : surpri =     14.1 : 1.0
     contains(overnight) = True           enjoym : intere =     13.2 : 1.0
         contains(light) = True           enjoym : intere =     13.2 : 1.0
        contains(totals) = True           anger- : surpri =     13.1 : 1.0
        contains(struck) = True           fear-t : distre =     11.3 : 1.0
  contains(east-central) = True           fear-t : intere =     11.0 : 1.0
        contains(downed) = True           fear-t : intere =     11.0 : 1.0
     contains(destroyed) = True           fear-t : intere =     11.0 : 1.0
         contains(lines) = True           fear-t : intere =     11.0 : 1.0
```

These entries are abbreviated given the space of the command line, where these programs run, but we might gloss the first one in natural language as "if an input contains the word 'roadways,' it is twenty-two times more likely to belong in the 'enjoyment-joy' category than the 'interest-excitement' category." Some of these probability statements are more legible to me as a human reader than others. That the word "destroyed" indicates fear-terror eleven times more than interest-excitement makes sense. Others become apparent to me when I think about my own experience classifying the training data. For example, that the word "old" indicates a tendency toward anger-rage comports with my own outrage in reading narratives about elderly victims of severe weather. Many other entries baffle me. Why would "overnight" or "light" so strongly indicate enjoyment-joy? Other words seem impossible to derive affective meaning from at all, particularly functional words like "30th," "No," and "had." I think here of Jonathan Hope and Michael Witmore's observation that digital reading is fundamentally "banal": "as readers," they write, "we tend to ignore the ubiquitous gloop," their evocative turn of phrase for the boring bits of sentences that literary critics tend not to invest with too much meaning, such as articles and conjunctions.[337] For TextBlob, all language is gloop, equally full of "meaning" from a machinic perspective. Even if TextBlob were to return from its testing function a 100% accuracy rating, it would be deriving its observations from entirely different features than I consciously or unconsciously used in making the initial classifications itself. I am faced, in this classifier, with a machine version of my judgment that bears surface resemblances yet rests on alien logic.

Another way to examine the contrast between my training data and its remediation as a classifier is in graphing the occurrence of different kinds of affective categories in both datasets.

---

[337] Jonathan Hope and Michael Witmore, "The Hundredth Psalm to the Tune of 'Green Sleeves': Digital Approaches to Shakespeare's Language of Genre," *Shakespeare Quarterly* 61, no. 3 (2010): 361.

Below are two graphs: the first, the affects that `clAffects` returns for a random 5000-entry slice of the *Database*;[338] the second, the affects I manually classified in the training data **(code 3d)**:

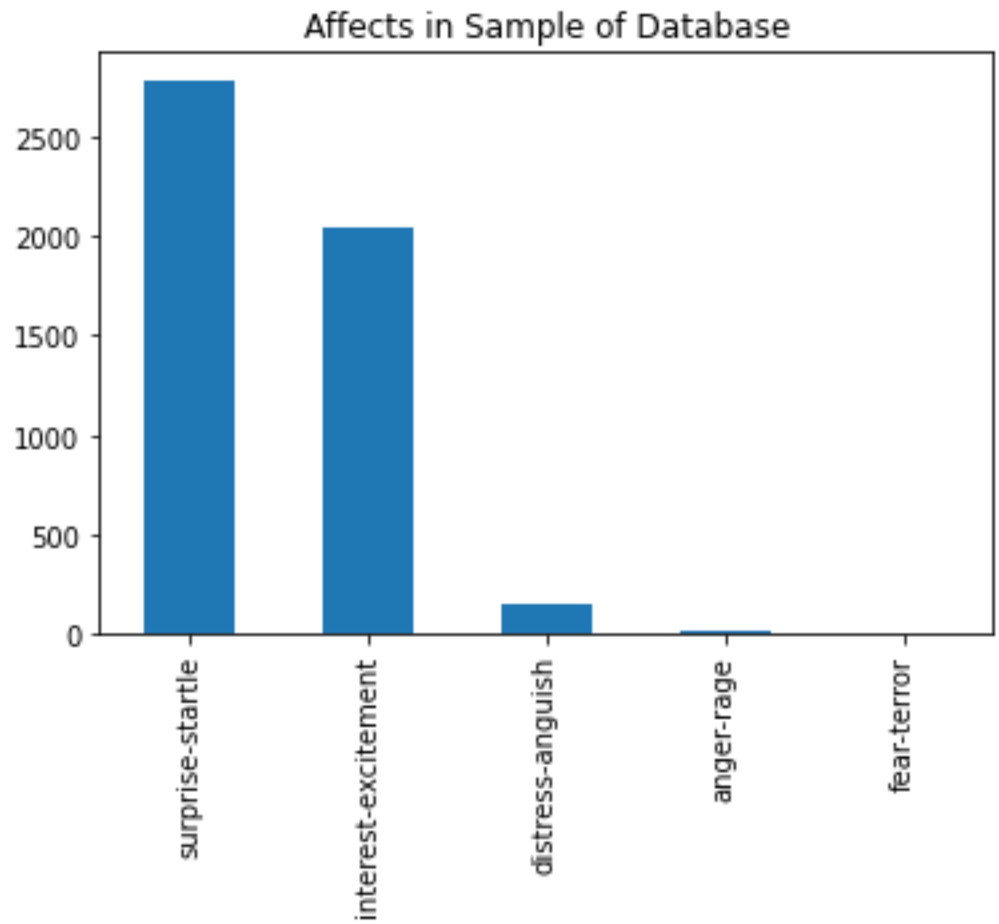

Figure 17. Affects as determined by `clAffects` *in a sample of the* Database*.*

[338] Naive Bayes algorithms take significantly longer to run than TextBlob's default sentiment analysis classifier, so I opted for a random sample rather than iterating across the entire *Database*.

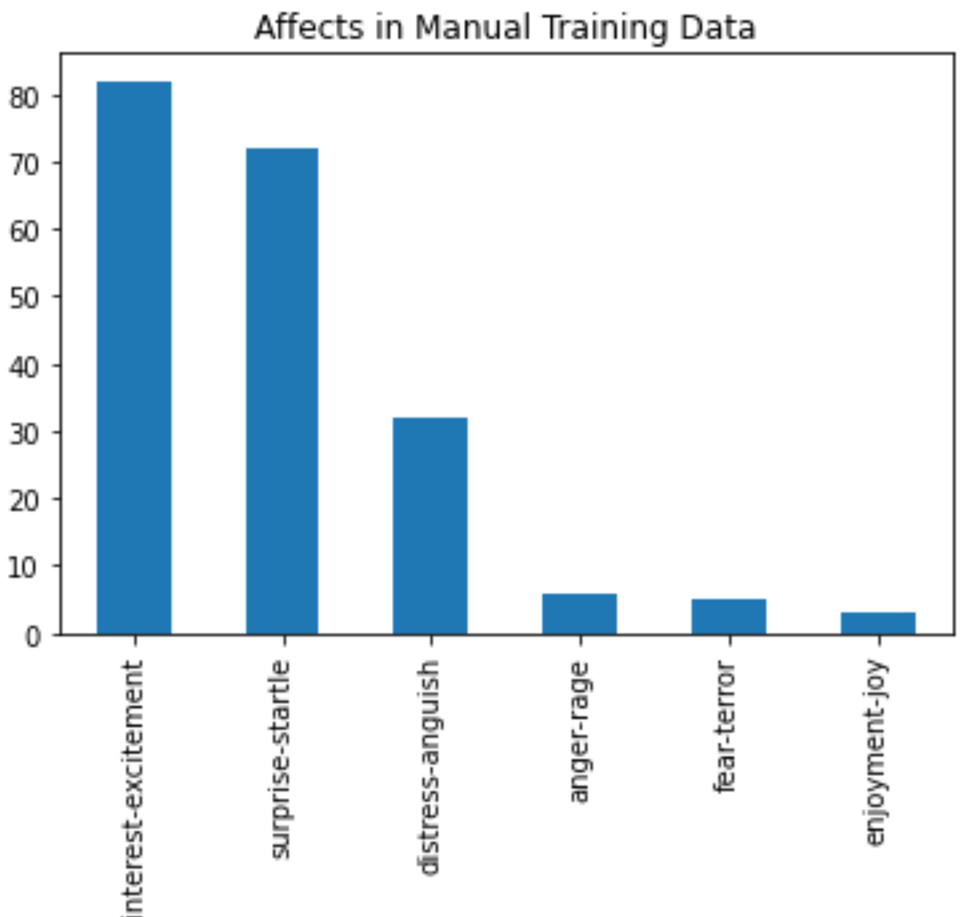

Figure 18. Affects in the manual training data.

As we can see from figure 18, I coded the majority of the training data either interest-excitement or surprise-startle, with a smaller trail of distress-anguish, anger-rage, fear-terror, and enjoyment-joy. Unsurprisingly, the data in figure 17 reflect this distribution: the biases of the training data appear, more or less, in the implementation of the classifier. Fascinatingly however, `clAffects` inverts interest-excitement and surprise-startle, finding measurably more of the latter than the former in the *Database*. I cannot account for this shift at this time; there are no clearly informative features that TextBlob returns that indicate such a preference for surprise-startle over interest-excitement, or indeed over any other affects. I am left once again with a brief encounter with a machine consciousness that I cannot fully understand yet seems to understand something about my critical judgment that I never thought to consider. Ultimately, I regard this experiment with sentiment analyzing the *Database* as an illustration of the challenges of atmospheric modeling and an object lesson in the definitional elusiveness of atmospheric media more generally. Time and again throughout this chapter, the *Database* has defied my attempts to derive a concrete theory of its affect. At each stage of its composition, it has been designed to remove human perspectives from its equation, leaving its readers instead with the bare "facts" of severe weather. Meeting its computational nature with computational tools has seemingly only multiplied the problem, producing the feeling that this putatively human document is in fact the product of a kind of machine logic from inception to implementation. This is, as I have discussed throughout this dissertation, one of the dominant effects of atmospheric mediation: to recast the atmosphere in all its inarticulable complexity as analogous to a digital computer, with rules humans can understand and manipulate. What this experiment has taught me, however, is that some of those rules may yet still be beyond our articulation: systems of atmospheric complexity continue to exceed our capacity to grasp them. It's easy to look back on the experiments of this chapter and see them as a record of struggle against a definitionally impossible problem. I prefer instead to view them as an alternative pathway to analyzing atmospheric media, one that takes such media's evasion, complexity, and downright *weirdness* as givens rather than roadblocks. Understanding atmospheres is then less a project of pinning them onto digital terms and more one of allowing their complexity to redefine our fundamental precepts as scholars of media studies.

Modeling Media

Like much of this dissertation, this chapter has pursued a two-fold project. On the one hand, it has explored the *Storm Events Database* as a cultural and meteorological resource, one that joins numerous similar governmental and scientific projects across the globe in the broader work of casting the environment as data. In particular, it has explored the *Database*'s inclusion of qualitative weather data in the form of its event and episode narratives, using them as jumping-off points for thinking about the production of weather narratives more generally and the work such narratives do in discourses dominated by numerical data. How do such narratives contribute to our understanding of the crisis of climate change, given the otherwise privileged place of numbers—rising atmospheric carbon, rising sea levels, rising temperatures? I've argued throughout this chapter that the *Database*'s qualitative narratives still reflect the primacy of numbers within such discourses, given that they are crafted deliberately to remediate numerical data rather than center affective experience. Affect is flattened out of the *Database* at nearly every level, even down to the grammatical. On the other hand, this chapter has taken the question of affect as an analytical and methodological question for the study of atmospheric media. In order to read affect in a resource as complex as the *Database*, I have turned to the computational methods of sentiment analysis in tandem with more familiar literary strategies of close reading. I have also taken these technologies as subjects of analysis themselves, given their capacity to both interpret and to construe models of atmosphere in the word's affective sense. I have found these technologies lacking in some respects and useful in others. As tools for determining affect, they are unsuited to much of the *Database*. But as tools of modeling critical judgment, they join other such tools in the digital humanities as distant reading and topic modeling as sites for further exploration and creative reimagining on the part of scholars attuned to the definitional weirdness of machine interpretation.

Throughout this chapter, I have been wary of ascribing to sentiment analysis too much—or even *any*—explanatory power. To return to TextBlob's polarity scores, even the most rudimentary media studies analysis pokes holes in its enterprise. In exploring how TextBlob calculates such scores, I have troubled some of the underlying epistemological assumptions undergirding machine reading—that affect is latent in texts, that we can surface affect through an analysis of relational grammar, and that affective qualities can be coded along digital binaries. Throughout, I have resisted making normative claims about the analytical capacities of data science as a field: its methods and archives are its own, and I have tried to meet them in the spirit of interdisciplinary generosity. Ultimately, I have tried instead to tell a story in this chapter about the necessity of interdisciplinary conversation to the analysis of atmospheric media. The stories I have told in this chapter have environmental data at their cores, but they also have been about the cultural and technical processes of producing, interpreting, and manipulating data themselves. They're about the role that data play *as media*—as cultural and material forms that sit in the middle of experience and interpretation. They're stories about collisions between epistemologies, and how affect's parallel critical development in the humanities and sciences is actually one of intellectual cross-hatching and conceptual migration. Ultimately, I both embrace and critique modeling as a practice for interpreting atmospheric media. While I abjure the very possibility of designing objective models for extracting emotion from the *Database*, I remain interested in modeling's gaps, slippages, blind spots, and curious moments of unexpected insight. Modeling is a tool for atmospheric understanding, but it cannot be a tool for atmospheric mastery.

Postscript

Don't walk away in silence
— Joy Division, "Atmosphere"

On the morning of September 1st, 2019, Donald Trump, then President of the United States, tweeted a warning about Hurricane Dorian, which was a few days out from making landfall in on Florida's eastern coast.[339] In it, he claimed that along with Florida, many other states would be impacted by the hurricane, including Alabama. There was just one problem: Dorian was not forecasted to hit Alabama. The Birmingham National Weather Service quickly tweeted a correction, but in the days that followed, the Trump White House, in its typical fashion, chose to double down on the President's error rather than admit it. On September 4th, Trump broadcasted an update on Dorian from the Oval Office in which he showed an outdated NWS weather map of the hurricane's track with a curious addition. It appeared that someone had drawn a thin black line at the end of the storms' track such that it might include Alabama alongside Florida. A media circus ensued. "The ordeal," journalist Emily Stewart wrote in *Vox*, "highlights the president's penchant for lying and his refusal to let even the most trivial items go."[340] Weather journalist Dennis Mersereau pointed out on Twitter that falsifying an NWS forecast, as the president appeared to have done, violates U.S. law.[341] In this way, the Dorian debacle demonstrates the political function of atmospheric media and how easily bad actors such

[339] Trump's Twitter account is currently suspended. The original tweet is available at https://web.archive.org/web/20190905010758/https://twitter.com/realDonaldTrump/status/1168174613827899393?s=20.

[340] Emily Stewart, "The Incredibly Absurd Trump/CNN SharpieGate Feud, Explained," *Vox* (https://www.vox.com/policy-and-politics/2019/9/6/20851971/trump-hurricane-dorian-alabama-sharpie-cnn-media, September 2019).

[341] Dennis Mersereau, "It is a violation of federal law to falsify a National Weather Service forecast and pass it off as official, as President Trump did here. 18 U.S. Code § 2074: https://law.cornell.edu/uscode/text/18/2074 https://t.co/TnIuvZRJoS," Tweet, @*wxdam*, September 2019, https://twitter.com/wxdam/status/1169309514669199361.

as Trump can manipulate them to their own ends. While a weather map drawn over with sharpie might appear faintly ridiculous, even absurd, these events are a synecdoche for the highly politicized place of atmospheric media in a climatologically imperiled world.

I have written this dissertation in what some might call "interesting times." I began graduate school on the eve of the Trump administration, which worked swiftly to pull out of the Paris Agreement, a landmark global climate change accord. A year into work on the project itself, the world shut down amidst the covid-19 pandemic, which focalized many of the concepts about which I had already spent a year thinking: the imperilment of breath, the necessity of ventilation, and the globally unequal distribution of viable atmospheres. Throughout it all, temperatures have steadily risen and pollution continues unabated. To think and write about atmospheric media these three years has been an object lesson in confronting some of the most urgent problems facing our species today, from environmental degradation, to the intensification of anti-democratic movements, and to the role of technology in exacerbating these trends. Throughout this dissertation, I have tried to keep these current events in mind but not directly in the center of the frame. They are still too freshly unfolding for me to theorize them the way I might a literary text or media object. Nevertheless, it is my hope that readers of this dissertation leave with an understanding of how atmospheric media affect many different registers of life on this planet beyond strictly the environmental. Atmospheric media organize space and construct perceptions of time. They determine how long we can live, and what kinds of lives some get to live at the expense of others' lives. They structure the horizons by which governments, scientists, artists, and laypeople alike can understand the skies above them and the air around them. If this dissertation has had multiple conceptual and methodological centers, it is because atmospheric media are nothing if not resolutely expansive.

In its heterogeneity, "Atmospheric Media: Computation and the Environmental Imagination" has attempted as well to model an approach to environmental media studies suitable both to the study of atmospheres as well as within the contested space of media studies today. Like most humanities disciplines, media studies in the Anglophone university system has seen decades of underfunding and neoliberalization by state legislatures and university administrators who see it at best as a pathway to careers in marketing and at worst an unnecessary thorn in the side of engineering programs. In a way, this dissertation has been a celebration of media studies' particular capacity to marshal interdisciplinary knowledges around core cultural and technical concepts. In the first chapter, I used literary criticism to engage a close reading of media arts interested in weather forecasting, arguing that forecasting is a media technique for imagining the atmosphere. In the second, I drew on science and technology studies as well as media theory to explore the vital role of air conditioning in keeping the internet functioning—and for substantiating data center companies' claims that they can save the planet from environmental destruction. The third chapter merged a media archaeology of 3D printing with further close readings of science fiction in its project to understand how atmospheric media imperil the human breath and recast relationships to time. And the fourth took a turn toward the digital humanities in its data biography of an official governmental storm database and computational techniques for identifying affect and emotion within it. All of these approaches get at something different about the relationship between computers and the air, but they share a fundamental substrate of *mediation*.

The imagination is a curious, flexible thing; the environmental imagination all the more so. It is challenging to re-imagine one's relationship to the air, but it is fundamentally a possible task. This dissertation has mapped what I view as a dominant environmental imagination in contemporary Western culture, that of understanding the air as a computer. But it is only one such environmental imagination among many. Further work must chart in more detail those alternatives and the work happening on the ground to bring them from the margins of techno-culture and to the center. The stakes of this continued work are nothing less than the viability of human life on this planet.

September 2018 (405.65 ppm)
– April 2022 (420.01 ppm)

Appendix A: Code for "Machine Reading"

This appendix contains the executable code that powers the data analysis in chapter four, "Machine Reading for Atmosphere: Modeling, Affect, and Weather Records." Readers will find the chapter's code reproduced here, alongside other snippets that augment the code's functioning but that I have omitted from the chapter for ease of reading. This appendix is a modified version of a Google CoLab notebook, available at https://colab.research.google.com/drive/1pXSrphMMiSJ0wXVq3VwuKZ2NLQL3Lgcb?usp=sharing, which is interactive and should be regarded as the authoritative version of this appendix. This code is also available as a Python file stored at https://jeffreymoro.com/files/c4-appendix-data.zip.

I have organized this appendix following the chapter's basic structure. I have also flagged in both the chapter and the appendix moments that correspond with each other using the following convention: **(code 0a)**. The number corresponds with the chapter section, beginning with 0. The letter corresponds with the example within the individual section.

***

0. Introduction

0a. Imports external functions, initializes preliminary variables, and sets up the *Storm Events Database* as a `pandas` dataframe.

```
!pip install --quiet requests-html pandas tqdm

import pandas
import requests_html
from tqdm import tqdm

http = requests_html.HTMLSession()
url = 'https://www1.ncdc.noaa.gov/pub/data/swdi/stormevents/csvfiles/'
resp = http.get(url)

df = pandas.DataFrame()
for link in tqdm(resp.html.find('a')):
```

```
  if 'StormEvents_details-ftp_v1.0' in link.attrs['href']:
    csv_url = url + link.attrs['href']
    df = pandas.concat([df, pandas.read_csv(csv_url)])

# Displays the *Storm Events Database* dataframe.

df
```

0b. Selects a random entry from the *Database* and applies TextBlob's default polarity analysis program to it.

```
# Remove empty and duplicate episode narrative entries from the Database

dfDeDup = df.drop_duplicates(subset=['EPISODE_NARRATIVE'])
dfDeDup = dfDeDup.dropna(subset=['EPISODE_NARRATIVE','EVENT_TYPE'])
dfDeDup = dfDeDup.iloc[1:]

# Select random entry and apply polarity analysis to it.

from textblob import TextBlob

for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=1):
# "random_state" fixes the output as the same every time; remove it to get a
truly random entry
  print(x)
  print(TextBlob(x).sentiment.polarity)
```

1. A Data Biography of the Storm Events Database

1a. Applies TextBlob's default sentiment analysis implementation to the *Database* and returns charts of mean polarity over time and a full scatterplot of polarity.

```
# Produce a useable date-time column as an x-axis for the charts.

dfDeDup['DATE'] = dfDeDup['BEGIN_YEARMONTH'].apply(str) +
dfDeDup['BEGIN_DAY'].apply(str)
dfDeDup['DATE'] = pandas.to_datetime(dfDeDup['DATE'], format='%Y%m%d')

# Produce a function that walks through the dataframe and applies TextBlob's
# sentiment analysis implementation to each entry in turn.

def tbPolarity_PA(s):
    if type(s) == str:
        return TextBlob(s).sentiment.polarity
    else:
        return None
```

```
dfDeDup['EPISODE_TB_POLARITY_PA'] =
dfDeDup['EPISODE_NARRATIVE'].apply(tbPolarity_PA)

# Removes null scores for more effective visualization.

dfDeDup_filtered = dfDeDup[dfDeDup['EPISODE_TB_POLARITY_PA'] != 0]
dfDeDup_filtered

# Produce a graph of mean episode narrative polarity over time.

import matplotlib.pyplot as plt

p =
dfDeDup_filtered['EPISODE_TB_POLARITY_PA'].groupby(dfDeDup_filtered['DATE'].d
t.year).agg({'mean'}).plot(title="Mean Episode Narrative Polarity over Time")
p.set_ybound(-.25,.25)

# Produce a scatterplot of every episode narrative's polarity in the
Database.

dfDeDup_filtered.plot.scatter(x = 'DATE', y = 'EPISODE_TB_POLARITY_PA',
figsize=(200,100))
```

1b. Isolate extremely positive and extremely negative entries and print them to the console.

```
maxPositive = dfDeDup_filtered['EPISODE_TB_POLARITY_PA'] >= 0.9
df_maxPositive = dfDeDup_filtered[maxPositive]

maxNegative = dfDeDup_filtered['EPISODE_TB_POLARITY_PA'] <= -0.9
df_maxNegative = dfDeDup_filtered[maxNegative]

print("POSITIVE NARRATIVES:")
for x in df_maxPositive["EPISODE_NARRATIVE"]:
  print(x)

print("\n")

print("Negative NARRATIVES:")
for x in df_maxNegative["EPISODE_NARRATIVE"]:
  print(x)
```

2. A Critical Code Study of TextBlob

2a. Demonstrates the irrelevance of word order to `PatternAnalyzer`.

```
from textblob import TextBlob

chomsky = TextBlob("Colorless green ideas sleep furiously.")

chomsky.sentiment.polarity

rechomsky = TextBlob("Green ideas colorless furiously sleep.")

rechomsky.sentiment.polarity
```

2b. Runs another random *Database* entry through both `PatternAnalzyer` and `NaiveBayesAnalyzer`.

```
## Required import programs for NaiveBayesAnalyzer

from textblob.sentiments import NaiveBayesAnalyzer
import nltk
nltk.download('movie_reviews')
nltk.download('punkt')

for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=6):
  print("PatternAnalyzer:")
  print(x)
  print(TextBlob(x).sentiment.polarity)

for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=6):
  print("NaiveBayesAnalyzer:")
  print(x)
  print(TextBlob(x, analyzer=NaiveBayesAnalyzer()).sentiment)
```

3. A Model for All Seasons

3a. Demonstrates a proof of concept of TextBlob's modeling capacities by building a classifier based on affective training data.

```
from textblob.classifiers import NaiveBayesClassifier
from sklearn.model_selection import train_test_split

from google.colab import drive
drive.mount('/content/drive')

dfAffects = pandas.read_csv("/content/drive/My Drive/dissertation/sentiment-
analysis/data/dfNOAASample_200_2021-01-15_CODED.csv")

dfAffectsTrain, dfAffectsTest = train_test_split(dfAffects, test_size=0.2)
```

```
varAffectsTrain = []
varAffectsTest = []

for index, row in dfAffectsTrain.iterrows():
  varAffectsTrain += [(((row['EPISODE_NARRATIVE'])), (row['AFFECT']))]

for index, row in dfAffectsTest.iterrows():
  varAffectsTest += [(((row['EPISODE_NARRATIVE'])), (row['AFFECT']))]

clAffects = NaiveBayesClassifier(varAffectsTrain)

for x in dfDeDup["EPISODE_NARRATIVE"].sample(n=1, random_state=1):
# "random_state" fixes the output as the same every time; remove it to get a
truly random entry
  print(x)
  print("affect: " + clAffects.classify(x))
```

3b. Displays informative features for `clAffects`.

```
clAffects.show_informative_features(10)
```

3c. Graphs the occurrence of various affects in the *Database*. Naive Bayes algorithms take significantly longer to run than TextBlob's default classifier, so I am running this on a random sample of 5000 entries.

```
dfSample = dfDeDup.sample(n=5000, random_state=1)

def tomkinsfy(s):
  if type(s) == str:
    return clAffects.classify(s)
  else:
    return None

dfSample['AFFECT'] = dfSample['EPISODE_NARRATIVE'].apply(tomkinsfy)

dfSample['AFFECT'].value_counts().head(25).plot(kind='bar', title='Affects in
Sample of Database')

dfAffects['AFFECT'].value_counts().head(25).plot(kind='bar', title='Affects
in Manual Training Data')
```

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