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Workshop Proceedings

Radar Technologies for Surface Current Mapping

St. Petersburg, Florida
March 14-16, 2004

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An ACT 2004 Workshop Report

A Workshop of Developers, Deliverers, and Users of Technologies for Monitoring Coastal Environments:

Radar Technologies for Surface Current Mapping

St. Petersburg, Florida
March 14-16, 2004

Sponsored by the Alliance for Coastal Technologies (ACT) and NOAA's Center for Coastal Ocean Research in the National Ocean Service.

Hosted by ACT Partner organization the University of South Florida (USF).

ACT is committed to develop an active partnership of technology developers, deliverers, and users within regional, state, and federal environmental management communities to establish a testbed for demonstrating, evaluating, and verifying innovative technologies in monitoring sensors, platforms, and software for use in coastal habitats.

Table of Contents

ACT WORKSHOP: RADAR TECHNOLOGIES FOR SURFACE CURRENT MAPPING

EXECUTIVE SUMMARY

The Alliance for Coastal Technologies (ACT) Workshop "Radar Technologies for Surface Current Mapping" was held in St. Petersburg, Florida, March 14th - 16th, 2004, sponsored by the University of South Florida College of Marine Science, an ACT partner institution, and the OceanUS Surface Current Mapping Initiative (see http://www.ocean.us/radarInitiative.jsp).

Surface currents are an identified high priority product for coastal ocean observing systems. Surface Current Mappers (SCMs) that broadcast and then observe back-scattered radio signals from the ocean's surface are now an operational technology that has been implemented in numerous locations worldwide. SCM technologies, using the same back-scattered radio signals, have also produced useful surface wave and vessel-tracking data in research applications. The workshop was designed to summarize existing radar technologies for surface current mapping (SCM) and address the impediments to their use in operational coastal ocean observing systems for the purpose of facilitating future technological advancements in these technologies. Participants were chosen to represent the research community, federal/state/local environmental managers, and industry representatives interested in the development and implementation of surface current radars for coastal ocean observation. The overall goal for the workshop was to explore present and future radar technologies as well as identify the steps necessary to incorporate them into an operational observing system. There was a strong focus on high frequency (HF) radar systems as these systems are in most widespread use today.

The general consensus attained SCM technologies to be effective in surface current measurement and useful in protecting the environment and saving lives. SCM technologies were suggested as being the most cost effective means for observing surface currents and that they have great potential for mapping surface waves. Obstacles to implementation of SCM as part of an operational observing system include restrictions on siting, radio frequency allocations, lack of human resources to operate SCM systems, and integration of data from multiple SCM operators. Recommendations include the identification and standardization of useful products from SCM observations, establishment of geographically distributed demonstration projects using multiple SCM technologies, establishing radar testbeds to evaluate and compare different SCM technologies, creation of a national frequency allocation policy, and education/training of SCM operators and technicians through workshops. It was recommended that work groups be established to attack the frequency allocation and siting issues. Development of a web Portal and/or list also was suggested in order to facilitate communication on SCM technologies for coastal ocean observing systems. Collaborative efforts between USF and OceanUS are underway in developing the basis for the web portal (http://act.marine.usf.edu/HFR.html).

ALLIANCE FOR COASTAL TECHNOLOGIES

There is widespread agreement that an Integrated Ocean Observing System (IOOS) is required to meet a wide range of the Nation's marine product and information service needs. There also is consensus that the successful implementation of the IOOS will require parallel efforts in instrument development and validation and improvements to technology so that promising new technology will be available to make the transition from research/development to operational status when needed. Thus, the Alliance for Coastal Technologies (ACT) was established as a NOAA-funded partnership of research institutions, state and regional resource managers, and private sector companies interested in developing and applying sensor and sensor platform technologies for monitoring and studying coastal systems. ACT has been designed to serve as:

- An unbiased, third-party testbed for evaluating new and developing coastal sensor and sensor platform technologies,
- A comprehensive data and information clearinghouse on coastal technologies, and
- A forum for capacity building through a series of annual workshops and seminars on specific technologies or topics.

The ACT workshops are designed to aid resource managers, coastal scientists, and private sector companies by identifying and discussing the current status, standardization, potential advancements, and obstacles in the development and use of new sensors and sensor platforms for monitoring, studying, and predicting the state of coastal waters. The workshop goals are to both help build consensus on the steps needed to develop and adopt useful tools while also facilitating the critical communications between the various groups of technology developers, manufacturers, and users.

ACT Workshop Reports are summaries of the discussions that take place between participants during the workshops. The reports also emphasize advantages and limitations of current technologies while

ACT Headquarters is located at the UMCES Chesapeake Biological Laboratory and is staffed by a Director, Chief Scientist, and several support personnel. There are currently seven ACT Partner Institutions around the country with sensor technology expertise, and that represent a broad range of environmental conditions for testing. The ACT Stakeholder Council is comprised of resource managers and industry representatives who ensure that ACT focuses on service-oriented activities. Finally, a larger body of Alliance Members has been created to provide advice to ACT and will be kept abreast of ACT activities.

making recommendations for both ACT and the broader community on the steps needed for technology advancement in the particular topic area. Workshop organizers draft the individual reports with input from workshop participants.

ACT is committed to exploring the application of new technologies for monitoring coastal ecosystem and studying environmental stressors that are increasingly prevalent worldwide. For more information, please visit www.act-us.info.

WORKSHOP GOALS

The underlying goal of the ACT workshop on Radar Technologies for Surface Current Mapping was to explore present and future high frequency radar technologies for surface current measurement as well as identify the steps necessary to incorporate them into an operational coastal ocean observing system. Specifically, the participants were charged with the following tasks:

(1) To identify the present status and likely near-term advances in radar technologies for observation of ocean surface currents

(2) To identify impediments to the implementation of radar technologies as a component of an operational coastal ocean observing system

(3) To recommend specific, achievable actions to overcome these impediments

ORGANIZATION OF THE WORKSHOP

The workshop was convened March 14th - 16th, 2004, at the University of South Florida College of Marine Science in St. Petersburg, Florida. The workshop was sponsored by the OceanUS Surface Current Measurement Initiative (see http://www.ocean.us/radarInitiative.jsp) and the University of South Florida (USF) College of Marine Science, an ACT partner institution, in St. Petersburg, FL. The workshop organizing committee consisted of Jeff Paduan, Naval Postgraduate School (Chair), Larry Atkinson, OceanUS and Old Dominion University, Buzz Martin, Texas General Land Office, and Mark Luther, USF. Invited participants represented researchers, federal/state/regional environmental managers, and industrial representatives interested in the development and implementation of high frequency surface current radars. A list of participants is included at the end of the workshop proceedings.

Participants arrived the evening of Sunday, March 14th, 2004, and attended a dinner reception followed by a presentation summarizing the ACT organization provided by Mark Luther. On March 15th, Jeff Paduan presented an overview of the present status of SCM technologies. Then the participants divided into 3 groups to consider the impediments and make recommendations for concrete steps needed in order for radar technologies to be implemented as a component of an operational observing system. The workshop concluded at noon on March 16th, after a list of specific action items had been vetted and prioritized by the participants. The presentation and workshop-related notes can be accessed via the ACT web forum (http://act.marine.usf.edu/ACT_Workshops.html).

Participants broke into 3 groups for the morning session with each group consisting of either researchers, resource managers, or industrial representatives. Working group discussions focused on:

(1) Identifying key obstacles for implementing SCM technologies into operational observing systems.

(2) Recommend specific achievable actions needed to overcome these impediments and to make SCM technologies a component of operational observing systems.

After each group's summary of SCM technology impediments and recommendations from the morning session, participants reconvened in the afternoon where they were separated into three new groups. Each afternoon group contained a mixture of representatives from research, resource managers, or industrial sectors. Each group revisited the morning's discussions and organized the impediments and recommended actions into *Products, Hardware Issues, Partnerships, and Governance* categories with a priority ranking for each. The day closed with a summary from each breakout group.

Overview of Radar Technologies for Surface Current Mapping

Surface currents are an identified high priority product for coastal ocean observing systems. Surface Current Mappers (SCMs) that broadcast and then observe back-scattered radio signals from the ocean's surface are now an operational technology that has been implemented in numerous locations worldwide. SCM technologies, using the same back-scattered radio signals, have also produced useful surface wave and vessel-tracking data in research applications. A nested network of SCMs installed along the coast of the United States, and used in conjunction with other observations and data-assimilative forecast models, will address issues critical to the seven major goals of IOOS.

Most (but not all) commercially available SCM systems operate in the high frequency (HF) radio band. Such systems are variously called HF Radar, surface current radar, or CODAR (the dominant commercial system). CODAR or other commercial products, such as WERA (WavE Radar), could be used in any SCM implementation. Other short-range systems operate in the X-band of the radio spectrum while some systems utilize multiple frequency bands. This report focuses on systems operating in the HF band, as these systems are in most widespread use.

HF radar systems operate between 3-30MHz, occupying wavelengths ranging from 10m to 100m. Lower frequency, longer wavelength systems have offshore ranges of up to 200 km. A Doppler radar transmits HF signals which propagate as electromagnetic groundwaves great distances over the conductive ocean's surface. Analogous to when light interacts with a diffraction grating, the waves scatter in numerous directions upon contact with surface gravity waves. Due to the effects of "Bragg scattering", a reflected signal will resonate with a surface gravity wavelength equal to ½ that of the transmitted wave. This received signal's frequency will be Doppler shifted because the velocities of the surface waves generally have components in the radial direction to the radar site (Figure 1). The above theory describes all HF radar systems. Where the HF radar systems differ, however, is in the various signal processing algorithms used to extract information on currents. Range typically is determined by converting the amount of time between a transmitted and received signal into distance. More advanced algorithms, such as frequency-modulated signals, facilitate extracting range information from signal processing. Two techniques to determine direction include "beam forming" and "direction-finding". The former utilizes linear "phased-arrays" of antennae, and is employed by the commercial OSCAR and WERA systems, while the latter one is based on loop antennae or compact arrays with much smaller footprints, and is employed by the commercial CODAR and also WERA systems (Figure 2).

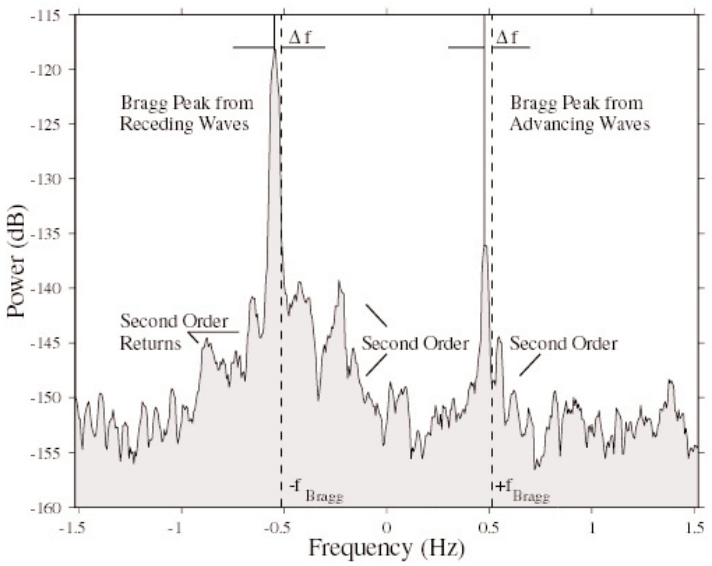

Figure 1. The cross-spectra return for a given received signal illustrates the theoretical Doppler shift. The current is calculated by measuring the Doppler frequency shift resulting from oscillatory ocean waves.

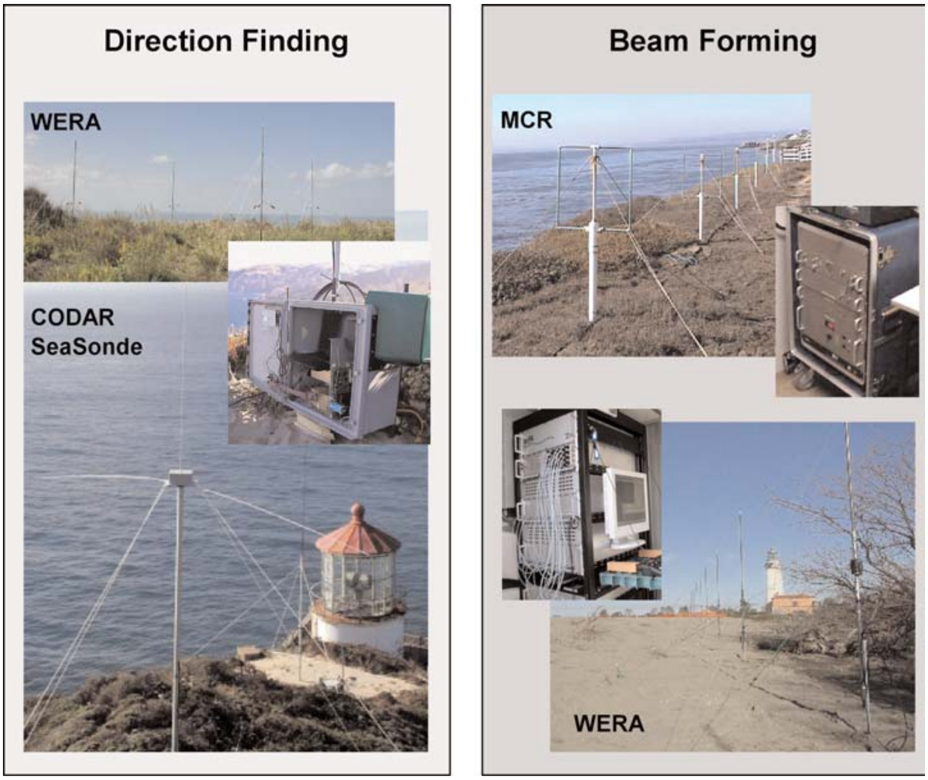

Figure 2. Examples of radar technologies, CODAR, WERA, and MCR?. Two different methods are used to determine the currents' positions: 1) Direction Finding (left panel) and 2) Beam Forming (right panel).

SCM networks currently require transmit and receive antennae at each site. Direction-finding implementations have a small number of antennae placed ten's of meters apart and look both directions along a beach. Phased-array designs utilize more widely spaced antennae (~100m) and look in one direction along a beach. Ideal locations for both types of systems are shoreward of open beaches. Because of the compact footprint, direction finding systems are convenient to deploy on headlands or in heavily populated areas where space is premium. The basic measurements provided by all systems are maps of radial currents. Vector currents are available for the region of overlapping coverage from two or more individual sites. For non-redundant coverage of a large coastal region, sites must be spaced about every 100km along the coast, assuming offshore ranges of 100-180km (Figure 3).

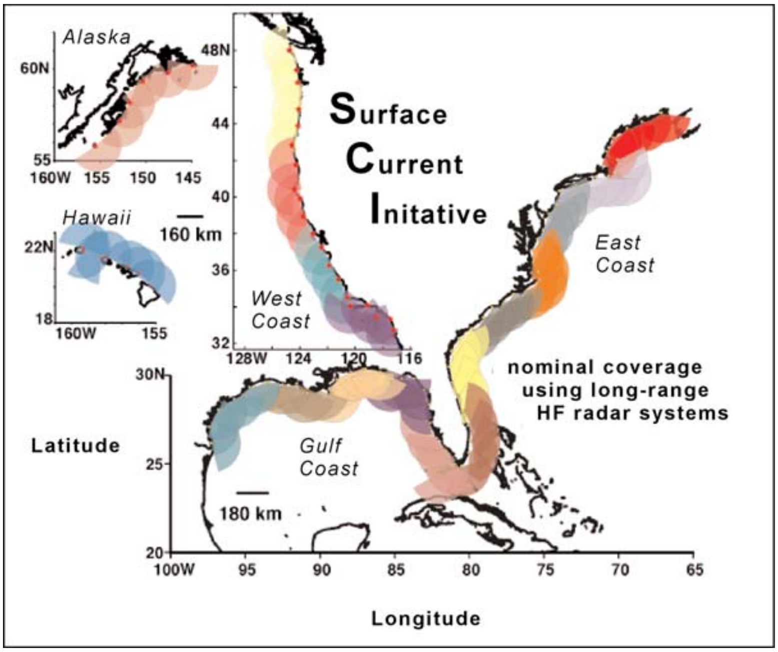

Figure 3. Surface current mapping coverage from a 93-site long-range HF radar network. Color coding is intended to illustrate the nominal distribution of local SCM operating "nodes". The networks in Hawaii, Alaska, and other U.S. territories require continuing assessment. The coverage depicted for Hawaii and Alaska is for example only.

Over forty individual SCM systems are presently operated in US EEZ waters by research institutions. Many systems are long-range, as described above, while others are more regional-scale (30-60 km), higher resolution systems. Examples from the types of products available from these systems are provided on-line, http://act.marine.usf.edu/docs/RadarWorkshop/RadarReportAppendix.pdf.

Working Group Reports

The following is a synthesis of the working group reports, including identification of impediments to further development and recommended actions.

SURFACE CURRENT MAPPING TECHNOLOGICAL IMPEDIMENTS

1. Products

Identification

Mostly, HF radar system products are closely aligned with the framework for a national backbone SCM network proposed for the IOOS. HF radar systems are capable of generating several different products. They span a range from mapping scales of highest resolution, lowest range implementations to lower resolution, long-range systems. SCM technologies are used to identify surface current fields (tidal, etc.), from which trajectories of passive bodies can be computed, waves and wave heights, and atlas products of current and wave statistics. Operational products, such as NOWCOAST, have been developed for currents and waves. Examples that serve the public include real-time velocities (U and V components), trajectories for search and rescue or hazardous material spill mitigation, wave observations, and short term forecasts of current and wave conditions.

Development

SCM technology is developmental and more needs to be done to further its application. Uncertainties in measurements of surface currents and waves need to be identified in the form of confidence limits or errors. Further work is also required to refine vessel detection and tracking capabilities of HF radar systems. Subsurface currents and bathymetry, directional wave information, and winds are examples of developmental applications. Trial support, perhaps by USCG SAR & NOAA HAZMAT, is needed to explore these applications and is especially desired for currents.

A regional focus needs to be identified within SCM technologies. Available products vary in format and are not yet provided through a central location. Expanded products should be developed in coordination with users. Furthermore, formats for sharing and/or comparing SCM data across regions and systems need to be established. A product-developer's working group would augment development of shared standard analysis and display software. When developing products, users and/or stakeholders need to be involved. Central quality control, archiving, and product distribution needs to be established.

The issue of how to turn HF radar data into information brings about a larger issue of establishing a data management program (for further information see Governance section of this document). A data pipeline extending from providers to users is currently lacking but is necessary in order to take this very promising technology to operational status. Expert personnel must be involved in data acquisition, processing, archiving, and interpretation. Standards need to be integrated into QA/QC of the data, specifically addressing variable coverage between time stamps, time trials, and verification tests. Formats for sharing and/or comparing HF radar data need to be established across regions and systems. A product-developer working group could be established to augment development of shared standard analysis and display software. Error assessment processes are needed to quantify product dependence, real-time physics, instrument error, and data assimilation errors. Experienced personnel should assist with assimilating (and interpreting) statistical/dynamical data into models. The user community, as opposed to manufactures, should perform validations tests. Performance metrics must go beyond root mean square differences between systems. Addressing differing needs for differing applications will decrease redundancy and costs in operating a data management program - building a more effective data pipeline (Table 1).

Table 1. Manager perspectives on SCM needs and its applications.

Concerns	Time Scale	More Than Surface	Data Interpolation
Oil Spills	-24h; +days/wks	typically 90%	Y %accuracy
HABs	variable; R-T; days-mos.	typically	Y %accuracy
Navigation	-4h; +6h; R-T	6min	N
Rip Currents: Swim safety	R-T	N	N-now; Y-prediction
SAR	-2wks; +24hr	N	N; vector accuracy
Bacteria: Sewage Spills	nRT-72hr	N	Y-prediction
River Discharge Plumes	nRT-72hr	Y	Y-prediction
Severe Weather EMT	depends; R-T, >6min	Y	Y
Fish Survival Recovery	RT-mos; - & +	Y	Y
Larval Invasive spp.	RT-mos; - & +	Y	Y
Erosion Coastal Mnmt.	yearly to event; RT; historical	Y	Y
Fisherman Concerns			
Offshore Oil & gas activities	-7days;+14days	Y	Y

2. Hardware Issues

Products from SCM systems derive from the intrinsic capabilities of the hardware and from continuing improvement of algorithms (software). Improvement of the accuracy and the characterization of the system performance must be ongoing activities.

Siting

Finding and gaining access to potential sites pose both short and long term difficulties inhibiting the implementation of HF radar on a national and regional level. The permitting process requires cooperation from multiple governing agencies on the federal, state, and local levels, including but not limited to: USCG, NPS, FAA, NOAA, BLM, USN, USAF, US Army Corps of Engineers, state/city/county agencies, native entities, private sector and individuals, and non-governmental operations. Instead of viewing these governing agencies as roadblocks, collaborations among agencies should be encouraged. For example, lighthouses could be used as HF radar sites if US Coast Guard headquarters made this a priority. Other examples of potential sites include state parks, coastal NPDES discharges and lakes, and offshore transmission sites (bistatic configurations). Products produced from HF radar data should be explained to the above mentioned governing agencies, emphasizing the utility of the SCM products, although some benefits may not be obvious now. Insurance and liability must be taken into account when inquiring about siting permissions. Additionally, visual impacts may cause denial or delay in obtaining permits (antenna and ancillary equip.; solar cells, generators, etc.). Therefore, the physical installation, including electronics housings, should be aesthetically pleasing. Academia and/or Small Business Research Initiative (SBRI) should be targeted to explore alternative technologies to lower power consumptions and expand data telemetry options for remote installations. Radio frequency safety education materials should be supplied to the governing agencies, academia, and SBRI, explaining the operating principles of HF radar to avoid fears of human health impacts from radio frequency energy.

Frequency Allocation

The frequency band useful for surface current mapping operations is constrained by oceanic wavelengths. As the number of oceanographic surface current mapping systems increases there will be increasing competition for frequency allocations in the limited part of the electromagnetic spectrum available for these observations. Consequently, competition will be increased between surface current mapping systems and other users of the HF band. Some entity, perhaps NOAA, should coordinate a working group to contend with frequency allocation issues. Currently, if any primary user operating in the band (or influenced by operations in the band) complains, the surface current mapping system operator must immediately shut down or shift frequencies. An inventory should be maintained of frequency band availability and location to enable efficient use of frequencies. Furthermore, frequency surveys at SCM system sites should be conducted for use in establishing frequency requests. Professional assistance, both legal and radio frequency, should be considered in order to obtain this effort. FCC and IRAC (international counterpart) rules and regulations should be tracked by an action committee, including multiple Federal and international partners, minimizing frequency conflicts with waveform design, addressing both hardware and software concerns. Contact officials within the National Weather Service (NWS) to seek advice based on recent successful experiences obtaining dedicated frequency allocations for NexRAD weather radar systems. Although it may take years, dedicated bands in the 4-5mHz range, with primary licenses, need to be obtained. This issue may involve cooperation among government, businesses and international advocacy. Hardware solutions must be sought that allow several surface current mapping systems to share exactly the same operating frequency, for example, GPS-based precise timing. Specifically, for a given frequency allocation, increasing GPS precise time usage and other technologies would allow for multiple surface current mapping installations. Letters of support from the main users would facilitate permissions regarding frequency allocations.

Performance
In order to promote optimal performance, coordination is needed nationally and internationally. Multiple data communications at remote stations (data transfer & control) ought to be designed efficiently, avoiding redundancy. Consistency and validation checks between radars and other current measurements should be implemented into the HF radar system designs. Equipment will need to be maintained regularly, including recalibrations. Staffing standards for data flow of QA/QC is essential in order to provide reliable performance - automate where possible and develop interference canceling techniques. Idea sharing between remote site operations must be encouraged.

NEXT STEPS FOR SURFACE CURRENT MAPPING TECHNOLOGIES

Data from all HF radar systems are similar, as are the requirements for installing and maintaining the instruments. Hence, establishing a systematic network for data management represents one component of IOOS in which centralized coordination and training will be beneficial. HF radar system installation, in particular will benefit if the following actions are promoted by each of the IOOS organizing bodies. First, high level support for frequency allocation and siting issues must be established (as discussed in SCM Impediment section of this document). Secondly, assistance must be obtained in developing a governance model (explained below). Thirdly, funding for targeted research studies to improve all aspects of model data assimilation is needed. This coordination would bring together a liaison of HF radar users and modelers to publish known technical applications as well as outline future challenges. Fourthly, funding for SCM pilot or pre-operational projects could be considered a precursor to pre-operational and operational systems (see Pilot Study below).

1. Governance Issues
A national organization is essential in order to promote and oversee a backbone network of surface current observations derived from SCM systems. The horizontal resolution, overall coverage, funding pathways, and implementation phasing priorities will be determined through the community feedback process. Currently, university research groups operate SCM system networks. In the next phase of development, expansion is likely to occur under the auspices of Regional Associations (RA's). A nation-wide coordinating body is recommended to be established at the earliest stage.

Coordinating Bodies
The coordination and optimal use of a wide-ranging network of SCM systems will benefit from a common structure for governance. Particularly, the systems, by definition, will be spread across regions and institutions, including federal government laboratories, state government offices, and academic institutions. The proposed governance structure will draw from each of these components to provide a single governing board. Coordinating bodies encompassing four levels

(1-4) termed sites/nodes, central hub, regional center, and national governance respectively, will provide a clear pathway in data transformation (Figure 4). This organizational structure will be based on distributed nodes operated by regional associations or other entities feeding into central hub(s) for standardized products overseen by a national board of directors.

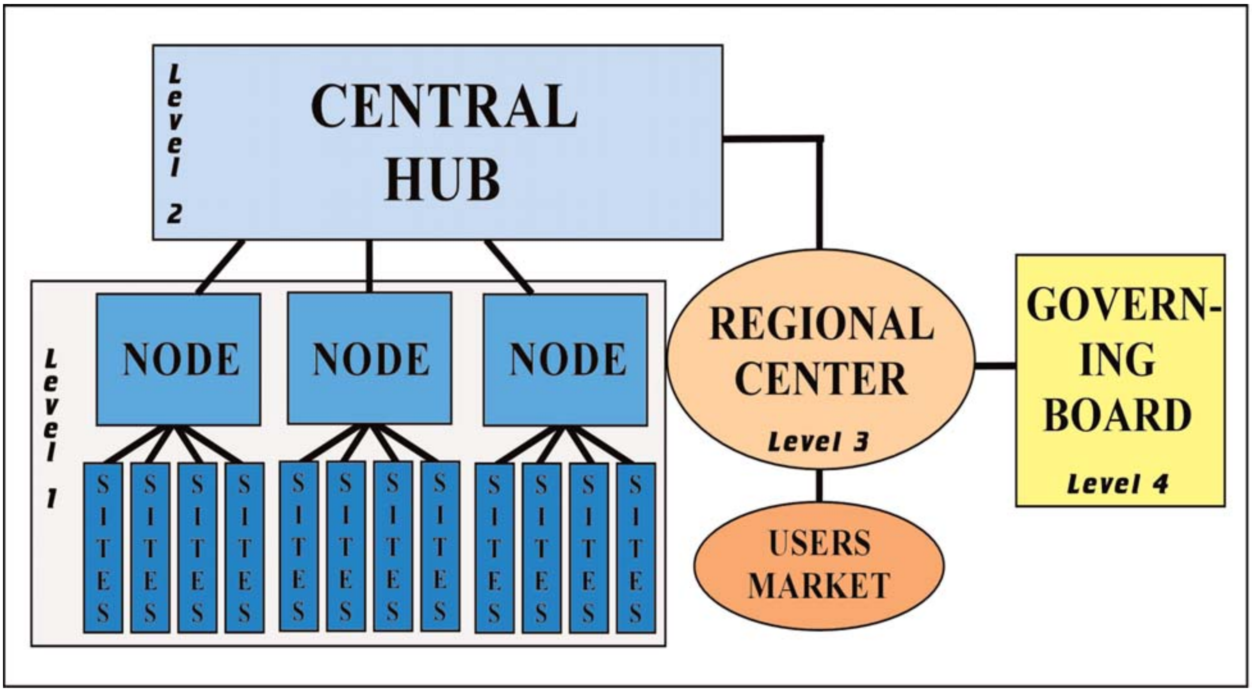

Figure 4. The SCM Initiative governance networking system.

Nodes (level 1), with sites, responsibilities will be localized. The term site refers to a single HF radar installation and the term node is used to designate the collection of sites operated by a group. Technicians at these levels will maintain and monitor altimeter, range, and spectrum continuously. The primary objective will be to meet data criteria through some level of processing radial currents, waves, and winds. Standards, as defined by the central hub, will be applied to radar output format, metadata, processing, and overall QA/QC processes. Staff at these levels will be required to have substantial web-based education and provide interactive type of data use design. Thus, these skills will facilitate outreach capabilities that could be further encouraged via RA's.

At the 2nd level, the central hub will establish HF radar data requirements and standards tailored to meet the user market's needs as well as ensuring data regulations for future applications. The term central hub refers to a central office designed to retrieve data from each site, via the local SCM node. Staff will communicate with the user and research communities to identify the desired product(s) and be responsible for the development and distribution of these products. Moreover, current maps, trajectories, operational products, statistical information, dynamic models, etc. will be regionally tailored as specified by the users. HF radar data and finished products will be archived. The central hub, per region, may virtually act as one system, but physically compose of seven.

By soliciting input from the users for system designs, desired products, etc., the regional center, level 3, will serve as a link between the users and HF radar data output. This center corresponds directly with a national board of directors (level 4), who will provide oversight governance at a federal level. The governing board will oversee standard product specifications, data exchange formats, and error characterization standards required for the common data backbone. They will recommend algorithm standards and upgrades based on research results as they become available. The same SCM and data will also be available to the local operators and regional observing systems, whom may have additional products tailored to the region. The governing board also will recommend and oversee the personnel structure, HF radar system design, and performance criteria for backbone network operations.

2. Costs

Many people want to use SCM technologies agree the resulting products will be useful on numerous fronts, but few can afford it. Costs of a system are an issue, running approximately $150K per antennae site. Annual operating costs are about $32K per antennae site. Training technicians takes about 2 years for independence status. Network cost estimates, including ranges, are provided in Table 2. The largest uncertainties are related to the total number of sites to be established and the operating costs associated with the most remote locations. Note these funds would provide processed and quality controlled radial currents from each site posted to a central processing site, standard, real-time vector current products would also be available.

Table 2. Cost estimates for a nation-wide SCM network based on long-range HF radar units (SCMI report 14 February 2004).

Initial Set-up

Hardware Costs/Site	Installation Costs/Site*	Number of Sites**	Total Costs
$110,000 to $150,000	$40,000 to $70,000	100 to 200	$15M to $44M

Annual Operating Costs

Node/CH Salaries***	Node/CH Maintenance	Node/CH Costs	Total Costs
$220,000 to $300,000	$30,000	$250,000 to $330,000	$5.3M to $13.5M

*Includes personnel time required scouting an dpreparing field locations.

**Depends on the density in Hawaii, Alaska, and US territories, in addition to the desired redundancy nationwide.

***Based on 5 sites/nodes requiring 2 technicians/node; A single central hub is budgeted at costs similar to a single node.

3. Partnerships

HF radar data sharing protocols and trained technicians created by a long-range backbone network will greatly reduce the marginal costs associated with adding additional, higher-resolution HF radar systems in specific regions. Governance provided over SCM technologies will aid in cooperating with industry, academic research, and government, without impeding political and/or corporate participation (see Governance section of document). In advancing this technology to operational status, the HF radar community needs to collaborate and coordinate a pilot study providing a concrete description of what technology and/or product is to be achieved.

Federal, State, and Local

Process to build Federal, State, and local partnerships within the radar community will result in showing coast-wide integration of HF radar data providers. Additionally, local use of SCM would be encouraged by providing funds, approximately $100K, for local use applications of SCM outputs. This type of local partnering could occur with coastal managers, for example, by identifying strategies to prevent oiling of popular white sandy beaches. Establishing liaisons with the nearshore community will be essential since much of it is considered local.

Models

Partnerships could be encouraged through RA's via pilot grants and thus, facilitate transferring SCM technologies to local end users - they want involvement. Models, such as Ocean Circulation, can foster partnerships between industry, academia/research, and users. Several partnership models currently operating include National Data Buoy Center (NDBC) and Tampa Bay Physical Oceanographic Real-Time Systems (PORTS). Partnership models provide ties to product and consequently, liability issues will need to be addressed by federal agencies.

Education

More partnerships can be established through existing outreach education programs, such as SeaGrant and COSEE, as well as local communication with K-12 teachers. Edifying techniques, ranging from games and coloring books to classes and workshops, could be tailored to anyone, state and/or local, that is interested in HF radar data. Education outreach implies one-way communication; however, it needs to be two-way occurring at the design level.

User and Industry Collaborations

Once the user market is defined, communication is needed between the user and industry. The SBIR and STTR can facilitate lacing information between the two groups by providing partnership insight and funding for SCM technology. For example, the industry and users could collaborate in order to coordinate a pilot study providing a concrete description of what technology and/or product is to be achieved.

4. Pilot Study

A large-scale pilot study can begin immediately given the large number of research efforts already underway using HF radar units. Furthermore, this study could cover a significant fraction of the proposed national implementation plan. Significant refers to include several "nodes" demonstrating the challenges involved data exchange and reliability. A pilot study utilizing multiple nodes should include a central hub to coordinate data flow and provide a single point user interface. This study could be based in regions with large numbers of existing HF radar installations; operators would have to agree to the data sharing and exchange (and reliability) specifications of the national system in the exchange for operations funding. Later implementations could take place with new hardware, possibly NOAA-owned (or another agency), and contracted out to other node operations around the country. This cooperation will "return" the existing systems back to the pilot study operators for other uses or for resolution enhancements.

Workshop Recommendations

At the close of the workshop, the participants constructed a list of recommendations that would facilitate advances of high frequency surface current radar for coastal ocean observing systems. These recommendations were prioritized in order of importance by vote of all participants, with each participant having 5 votes to cast. There was a general consensus that HF radar technologies are effective in surface current measurement and are useful in protecting the environment and saving lives. It was agreed that HF radar technologies are the most cost effective means for observing surface currents and that they have great potential for mapping surface waves. Obstacles to implementation of HF radar as part of an operational observing system include restrictions on siting, radio frequency allocations, lack of human resources to operate HF radar systems, and integration of data from multiple HF radar operators. Recommended vision and action items needed to further radar technologies are prioritized according to the number of votes received for each item provided by the participants as follows:

General Recommendations:

- Identify useful and standard products, ranging from mapping scales of high to low resolution.
- Launch simultaneous and geographically diversified demonstration projects that implement multiple technologies and stress education-outreach.
- Establish radar testbeds, comparing and evaluating different radar technologies.
- Create national frequency policy action addressing frequency bands, rules and regulations, hardware and software concerns dedicated to surface current mapping systems.
- Conduct a workshop educating operators and technicians on the methodologies utilized to incorporate HF radar technologies into an operational observing system. Perpetuate workshop as an on-going effort, continuously educating next generation of HF Radar operators and users. (This has been done. The first annual meeting of the Radiowave Operators Working Group (ROWG) will be held in January 31st 2005 to February 4, 2005 aboard the "Majesty of the Seas.")

- o Establish working groups where managing siting issues is the key focus. Responsibilities include finding and gaining access to potential sites and cooperating with multiple governing agencies stemming from the federal, state, and local levels.
- o Embark on a regional large-scaled pilot study, integrating existing HF radar systems to demonstrate the challenges involved in data exchange and reliability.

Recommendations Specific to ACT:

- o Development of a web Portal and/or list also was suggested in order to facilitate communication on HFR technologies for coastal ocean observing systems. The basis for this web portal has been initiated through collaborative efforts of USF and OceanUS (http://act.marine.usf.edu/HFR.html).
- o Provide information for resource managers specifically on HF to X band describing the limitations as well as the applications.

ACKNOWLEDGMENTS

ACT would like to thank the following people for their assistance in conduct of this workshop: Sherryl Gilbert and Lauren Wetzell provided logistical support for all aspects of the workshop. Vembu Subramanian, Kriten Sopkin, and Amanda Linville assisted with audio-visual needs and daily operations of the program. Howard Rutherford of the Pier Aquarium arranged the Monday evening reception and dinner. Lauren Wetzell transcribed the video and audio tapes of the discussions and constructed the initial draft of the workshop report. Portions of this report were excerpted from the OceanUS document on the Surface Current Mapping Initiative (http://www.ocean.us/radarInitiative.jsp). Descriptions of HF radar principles were obtained from Sage Lichtenwalner, University of South Florida, and The South Central California CODAR Project (http://www.icess.ucsb.edu/iog/codar_science.htm, UCSB Principal investigators, L. Washburn, S. Gaines, and B. Gaylord).

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