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THE HF RADAR NATIONAL SERVER AND ARCHITECTURE PROJECT

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1. INTRODUCTION

High Frequency (HF) Radar is a mature technology capable of giving maps of ocean surface current at varying resolutions and distances from coastal installations of equipment. Evidence of the maturity is that many academic institutions have invested in the concept by purchasing commercial-off-the-shelf equipment and installed in areas of their research interests. Further evidence is the significant investment by the State of California to cover their entire coastline with HF Radar, the Coastal Ocean Currents Monitoring Program (COCMP). This has resulted in a loose collection of some 90 to 100 installations (and growing) all around the U.S. which collectively represents a relatively unharnessed national capability.

However, this capability suffers from two critical shortfalls: operational status (systems largely run in research mode by academic institutions) and significant gaps in coverage where no regional academic, state or other entity have made an investment.

The HF Radar National Server and Architecture project is a NOAA-led, academic-leveraged effort to lay the foundation for an eventual Integrated Ocean Observing System (IOOS) "Backbone" network by demonstrating and increasing the utility of the existing installations. Two major objectives are being addressed. First, the creation of a national Data Management and Communications (DMAC) architecture and accompanying information technology infrastructure which will provide for the optimal utilization of all the various HF Radar data in real time. Second, the critical prerequisite of establishing real-time quality control (QC) algorithms is being developed so that confidence in the national "grid" of values can be assured.

The server and architecture effort heavily leverages the California effort led by Scripps Institution of Oceanography which requires a robust data system to accompany the fielding of radars. The QC effort leverages the experience of many academic institutions which have years of experience with HF Radar data in the research environment.

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2. ESTABLISHING A NATIONAL HF RADAR DATA ARCHITECTURE AND INFRASTRUCTURE

The nature of HF Radar presents challenges to the timely integration and distribution of HF Radar data. The development of radial vectors of current requires an integration time of one to three hours depending on frequency and range, and these resultant vectors must be communicated rapidly to a processor capable of combining with nearby radial solutions to produce a total vector. By establishing a robust national framework, information from adjacent radars which might even be fielded by different entities can be combined to improve data quality and coverage. The process brings automatic standardization to the total vector development, and provides for the most logical point to apply many of the emerging quality control techniques. It is imperative that the system be scalable to accommodate the growth of new installations, up to the point of a comprehensive national system.

The underlying information technology of this effort has roots in the seismic community which has even greater challenges of combining data from disparate sensors in a real-time environment. Antelope, an integrated collection of programs for real-time data processing from Boulder Real Time Technologies, is used at the core of the network architecture. The real-time system is built around large, flexible, non-volatile object ring buffers (ORBs). Datascope, a relational database, provides a bridge between real-time processing at the ORB level and long-term storage to a local database. Terrill, et.al, 2006, contains details of the information technology used in the project.

The fundamental "on-ramp" into the architecture for an HF Radar site is the **portal**. Data from portals are forwarded to **nodes**, where the bulk of necessary processing to produce the total vectors takes place. The total vectors produced through this process are designed to be the best possible solution available in real time. Thus, the fundamental data product of the project is the Real Time Vector (RTV).

The architecture currently contains three nodes: a west coast node at Scripps which would otherwise be needed to handle the growing California initiative data, an east coast node at Rutgers University, and NOAA's national user-access node located at the National Data Buoy Center (NDBC) on the Gulf of Mexico (Figure 1.). During 2007, approximately 5 portals will be

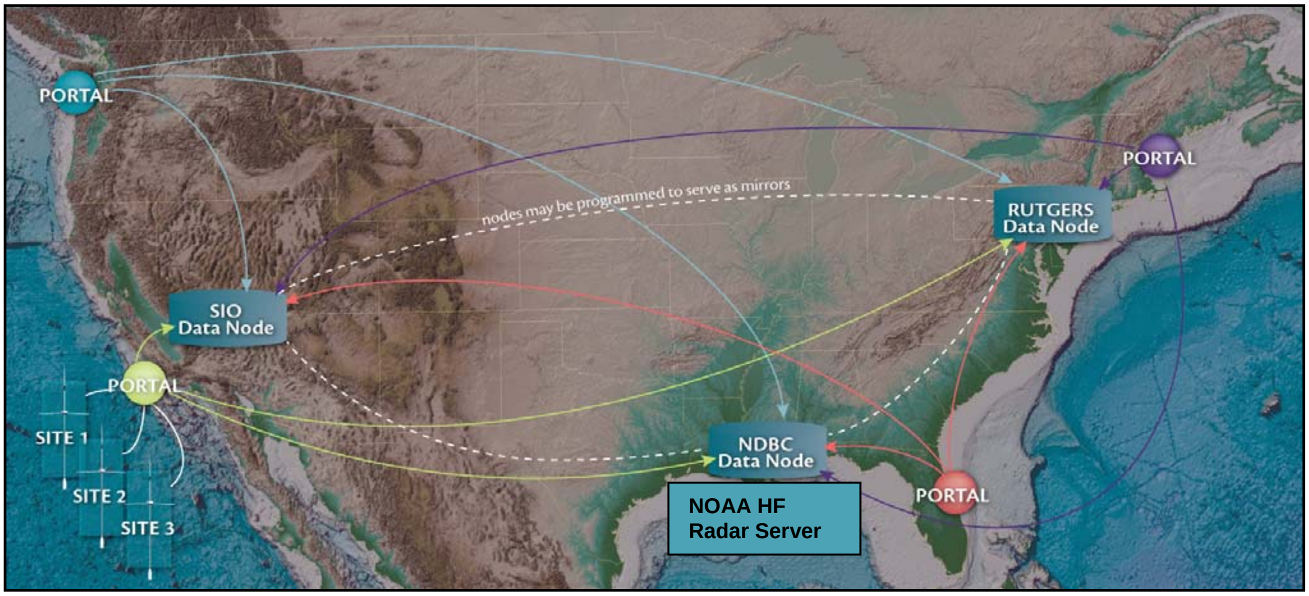


FIG 1. The overarching architecture of the national HF Radar data management and communications system. (Portal locations are conceptual, and do not represent actual installation locations).

installed in a distributed fashion around the continental coastal U.S.

A significant contribution of this project has been the development of a national HF Radar grid, on which RTVs are populated in the nodes. This grid, nominally 1 km, provides for variable resolution corresponding to the resolutions available in typical HF Radar installations with higher resolution inshore.

3. NOAA'S NATIONAL HF RADAR SERVER

Taking advantage of the node located at NDBC, NOAA has established a server and web presence designed to be the primary real-time user access point in the architecture. Through this server NOAA will make available all RTV data in the national system. Although the architecture is technically one of peer-equivalence at the node level, the presence of nodes at Scripps and at Rutgers University on the east coast effectively provide a robust backup capability with geographic diversity. The Scripps site will also contain the metadata and diagnostic data which is of interest to researchers and those seeking to reprocess data in a post-time mode.

The NOAA server is accessible from the primary NDBC site at www.ndbc.noaa.gov through several different links including one available to users viewing an individual observing station and then desiring to view currents in the vicinity. The user may be presented with a map of the continental United States showing all locations of the most recent hour having data (Figure 2). The user may then select a region from the drop-down menu or "rubber-band" an area of interest, or choose a pre-defined area. The Java ™ applet allows a continuum of zoom, and allows the user to scroll back and forth in time (Figure 3). This is particularly important in that the long range radar integration times are longer and data may not appear in the most recent hour.

Figures 4 and 5 show that the mouse pointer hovering over a data point gives either a detailed view of the most current data or a time series of the past 12 hours. The user may also select to overlay IOOS buoy and coastal station positions, and can hover over the position to view comparison data.

At this writing, the server is limited to graphic products. As the quality control being developed in this project matures, it will be applied in the node architecture. At this point, data products will be made available from the server.

4. QUALITY CONTROL AND STANDARDS DEVELOPMENT

The quality control procedures being developed for the network take advantage of the extensive knowledge-base accumulated over many years by the HF Radar research community. In addition to the sharing of insight and information inherent in most research communities, HF Radar investigators throughout the world have held annual meetings to exchange detailed algorithmic designs and software. The most widely used HF Radar in the United States is the Codar Ocean Systems SeaSonde, often referred to as, simply, CODAR. Since more than 90% of the HF Radars are CODARs, most of the QC efforts focus on them. The project funded efforts in quality control are still underway at this writing and full reports will be available by early 2007.

The algorithms for HF Radar quality control can be loosely grouped into three levels of the data: 1) radial velocities, 2) total vector velocities and 3) hardware diagnostics.

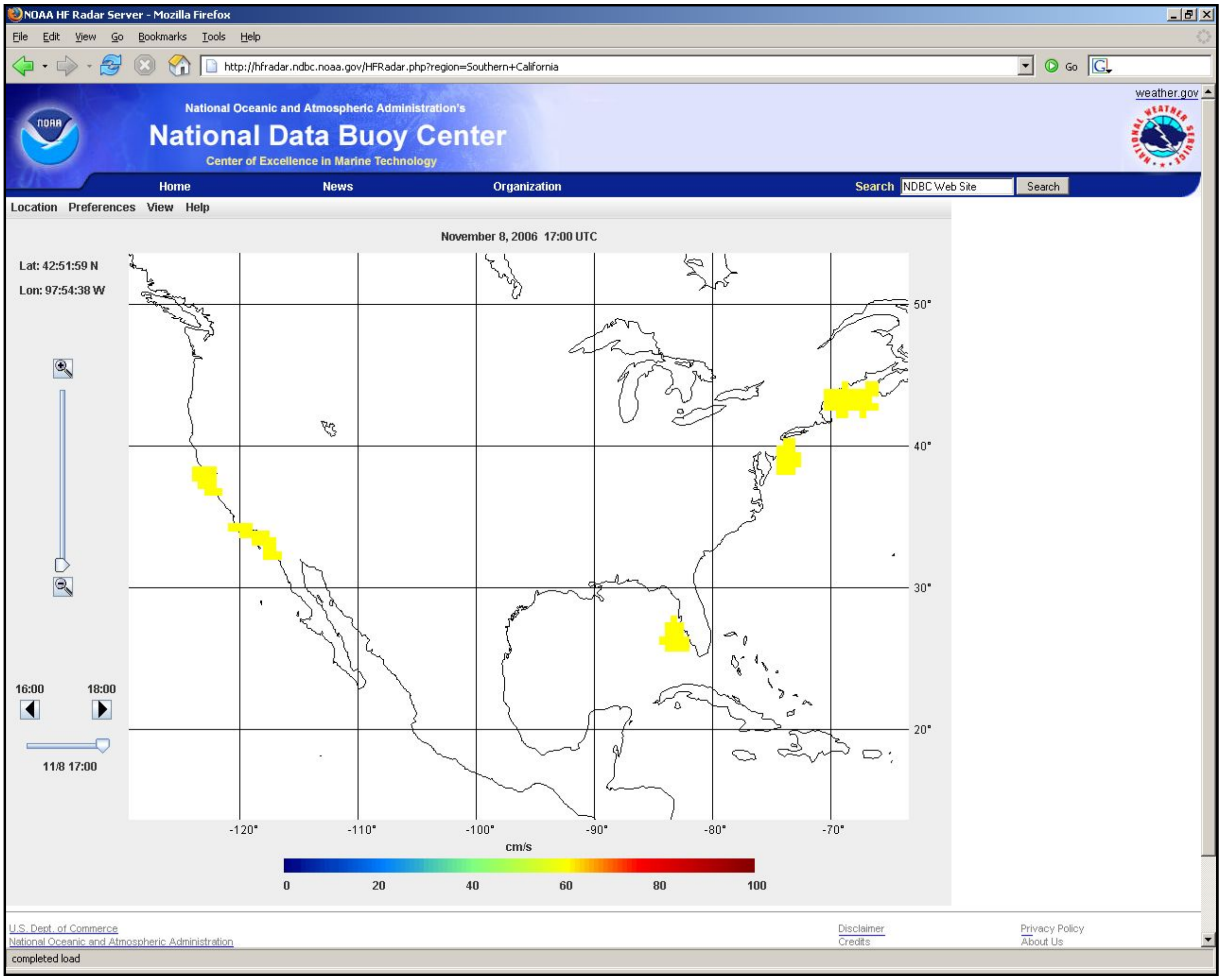


FIG 2. The NOAA HF Radar National Server screen capture showing all regions where data is available in near real time at 17Z on 6 November, 2006.

4.1 Radial Velocity

Most of the QC methods involve the use of *in situ* current measurements as a determination of accuracy. However, some of the most promising ideas use, for example, radar-to-radar comparisons which should have equal and opposite velocity magnitudes under typical conditions. Some of the topics under consideration are: effects of signal-to-noise ratio on accuracy; correlation of wind speed and wave height with error.

For direction-finding systems, such as the SeaSonde, an algorithm is used to determine the angle of arrival of the measured Doppler velocity. The algorithm currently in use is a form of the Multiple Signal Classification (MUSIC) algorithm. The parameters that affect the behavior of this algorithm are being investigated in order to obtain some knowledge of the occurrence of anomalous radial velocities.

4.2 Total Vector Velocity

Total vectors are nominally computed using the radial velocities from two or more sites which are nearly orthogonal. In practice, the sites may not be orthogonal. Also, an area is defined over which many

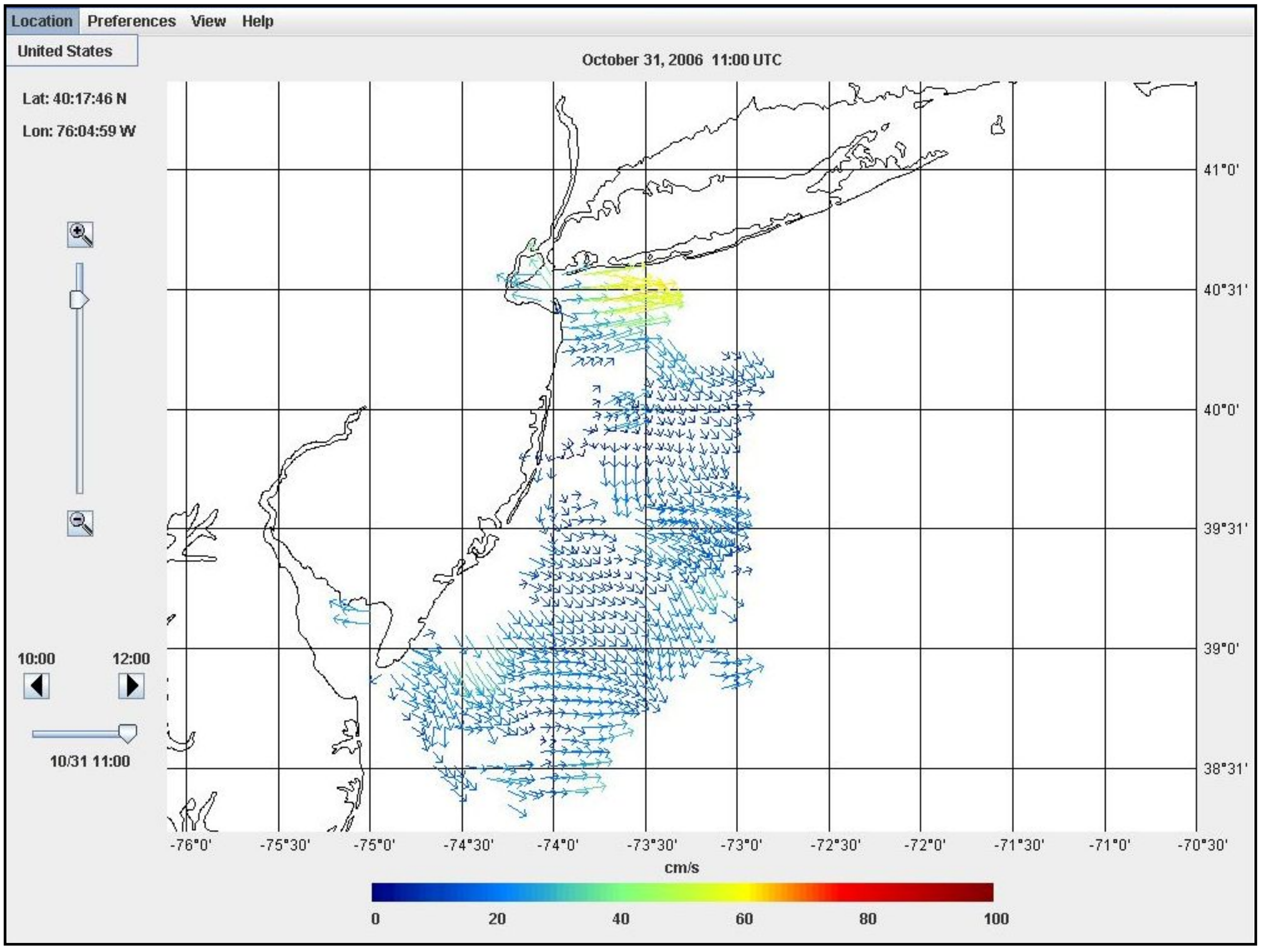


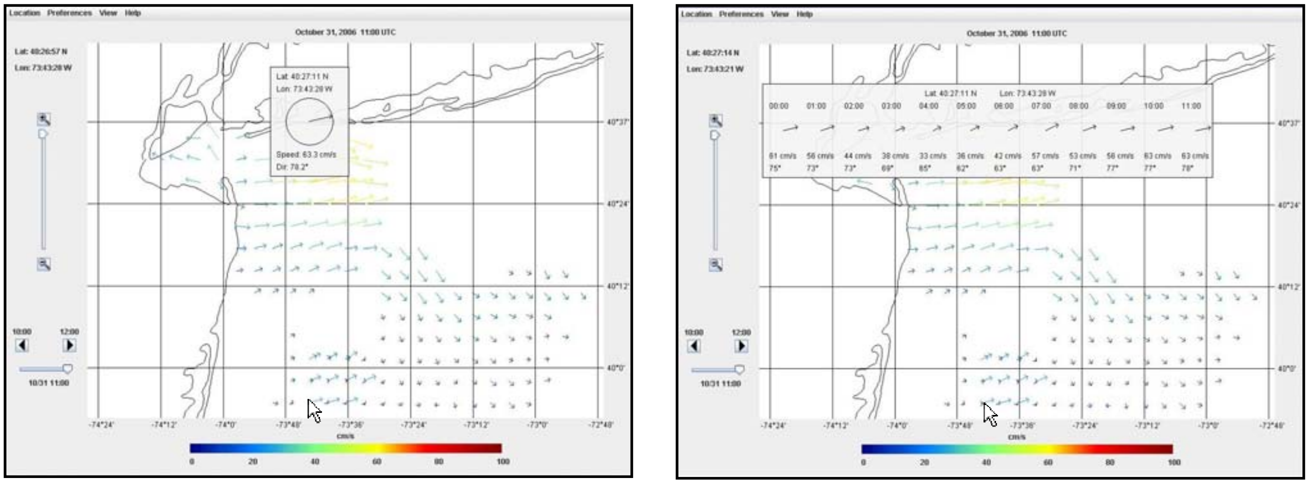
FIG 3. Zoomed image showing data in the middle Atlantic region (radars operated by Rutgers University). Note buttons and slider for moving forward and backward in time. Velocity scale is user adjustable.

radial velocities from each site are used to create a single total vector on some sort of regular grid. Clearly, there are many ways to combine the radial velocities. Several of the combining techniques are under investigation including spatial averaging area, weighting according to range, and least-squares techniques.

4.3 Hardware Diagnostics

Recently, the CODAR SeaSonde has been equipped with sensors to report and record numerous operating parameters of the radar. A few examples are transmitter temperature, voltage standing wave ratio, forward and reflected power, among many others. A number of these parameters will be investigated with respect to coverage extent, comparison with nearby radars, and radar downtime.

In addition to fully exploiting the current HF Radar resources, the project will define the Integrated Ocean Observing System (IOOS) Data Management and Communications (DMAC) standards which will be required to expand the system to a federal backbone capability. This will include the definition and development of long-term DMAC-compliant archive. The QC effort has also been actively engaged in the QARTOD (Quality Assurance of Real-Time Oceanographic Data) process, a community-led quality effort now embraced by IOOS.



Lat: 40:27:11 N
Lon: 73:43:28 W
Speed: 63.3 cm/s
Dir: 78.2°

Lat: 40:27:11 N Lon: 73:43:28 W

00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00
61 cm/s	56 cm/s	44 cm/s	38 cm/s	33 cm/s	36 cm/s	42 cm/s	57 cm/s	53 cm/s	56 cm/s	63 cm/s	63 cm/s
75°	73°	73°	69°	65°	62°	63°	63°	71°	77°	77°	78°

FIGs 4 and 5. When user's mouse pointer "hovers" over a data point, a pop-up of detailed information about the data appears. The user may also select to view a series of the last 12 hours observations when hovering.

5. SUMMARY

This project attempts to advance the utilization of existing HF Radar resources through the addition of a robust data management and communications architecture and the single-point delivery of data on a national basis. This is intended also to provide a demonstration of the capability of HF Radar technology to address the need for surface current information. As the project's quality control initiatives are implemented, it is expected that HF Radar product development will occur that will further demonstrate and increase capability. The groundwork will thus be laid for a national decision on the implementation of a robust, operational HF Radar system as a major component of the IOOS.

6. REFERENCES

Terrill, E., M. Otero, L. Hazard, D. Conlee, J. Harlan, J. Kohut, P. Reuter, T. Cook, T. Harris, and K. Lindquist, 2006: Data management and real-time distribution for HF Radar national network. MTS/IEEE Oceans 2006, Boston, Paper 060331-220.

An excellent online reference containing an introduction to the principles of HF Radar can be found on the Rutgers University Coastal Ocean Observation Lab (RU COOL) website: http://marine.rutgers.edu/cool