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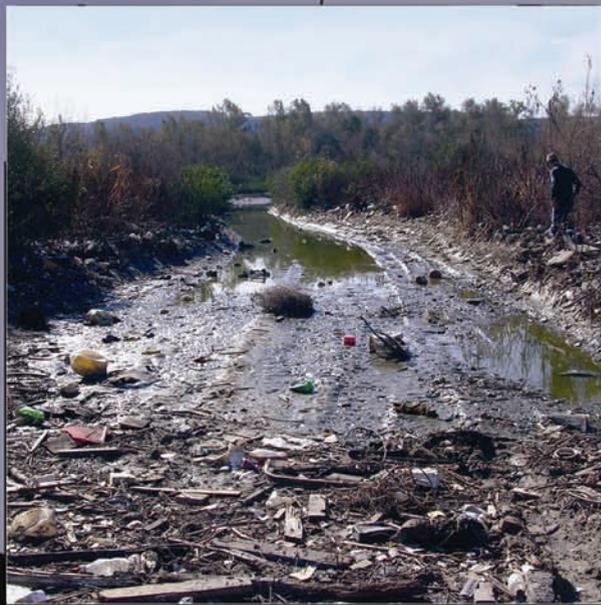
ENVIRONMENTAL MONITORING, REMOTE SENSING & POLLUTION CONTROL

Mapping Surface Currents Around U.S. Coasts

A Network of High-Frequency Radar for the Integrated Ocean Observing System

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Maps of ocean surface currents have been identified as crosscutting observational tools that aid a range of scientific and societal applications, including ecological studies, tracking the fate and transport of pollutants, oil spill response, assessment of beach water quality, search and rescue, maritime operations and tracking changes in ocean climate.

This broad range of uses has motivated local, state, regional and federal discussions directed toward the installation, development and operation of a network of surface-current mapping systems as part of the Integrated Ocean Observing System (IOOS).

While shore-based high-frequency (HF) radar techniques have matured in the last two decades to the point that systems are now routinely operated by the majority of U.S. oceanographic research organizations, only recently has attention been paid to the data management challenges facing this growing network.
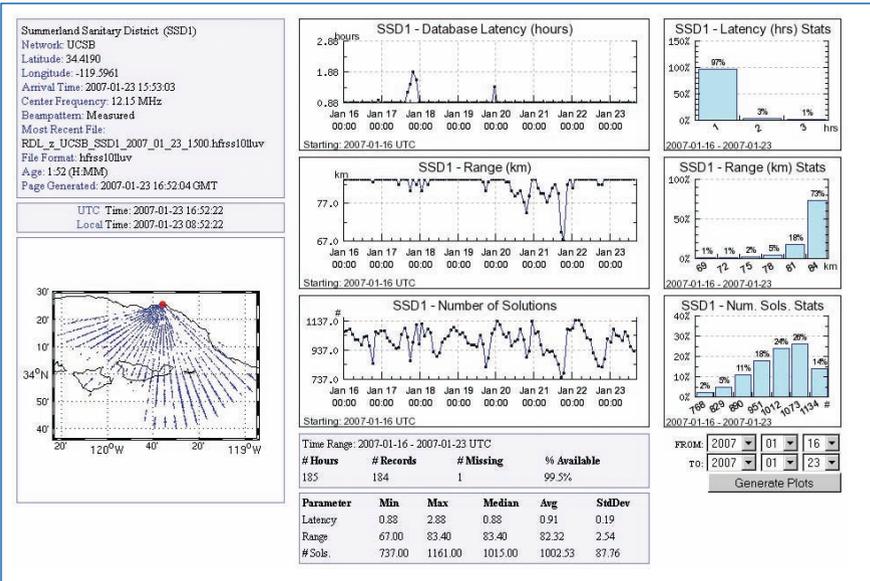
Central to the operational success of this large-scale network is a scalable data management, storage, access and delivery system. Prototype real-time data architecture, initially developed through funding from the National Science Foundation (NSF), is now being integrated by the Coastal Observing Research and Development Center (CORDC) at the Scripps Institution of Oceanography with existing

The overarching architecture of the national HF radar data management and communications system.

HF radar data networks through a joint development program administered and managed by the National Data Buoy Center (NDBC) and the National Ocean Service (NOS), with oversight provided by the National Oceanic and Atmospheric Administration's (NOAA) IOOS program office.
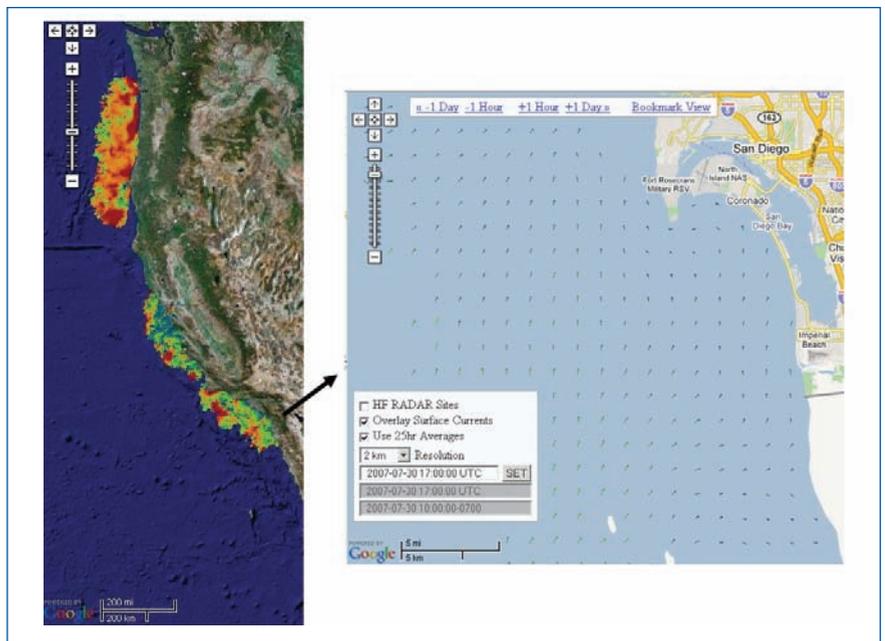
This joint university-NOAA partnership is focused on defining and meeting the expressed needs for an information technology architecture supporting a national HF radar network (HFRNet) of surface-current mapping data systems.

Surface-current velocity measurements collected by HF radar benefit from aggregation and the integrated processing of data from geographically distributed sites. The network of

Summerland Sanitary District (SSD1)
Network: UCSB
Latitude: 34.4190
Longitude: -119.5961
Arrival Time: 2007-01-23 15:53:03
Center Frequency: 12.15 MHz
Beampattern: Measured
Most Recent File:
RDL_z_UCSB_SSD1_2007_01_23_1500.hfrss10lluv
File Format: hfrss10lluv
Age: 1:52 (H:MM)
Page Generated: 2007-01-23 16:52:04 GMT

UTC Time: 2007-01-23 16:52:22
Local Time: 2007-01-23 08:52:22

SSD1 - Database Latency (hours)

SSD1 - Latency (hrs) Stats

SSD1 - Range (km)

SSD1 - Range (km) Stats

SSD1 - Number of Solutions

SSD1 - Num. Sols. Stats

FROM: 2007 / 01 / 16
TO: 2007 / 01 / 23
Generate Plots

Time Range: 2007-01-16 - 2007-01-23 UTC

# Hours	# Records	# Missing	% Available
185	184	1	99.5%

Parameter	Min	Max	Median	Avg	StdDev
Latency	0.88	2.88	0.88	0.91	0.19
Range	67.00	83.40	83.40	82.32	2.54
#Sols.	737.00	1161.00	1015.00	1002.53	87.76

HFRNet Architecture

From a broad perspective, the HFR-Net is comprised of two building blocks—portals and nodes—each representing server computers enabled with the real-time code and serving distinct roles.

Portals serve as point-of-entry machines by acquiring and serving radial data from any number of HF radar sites. Nodes serve as data concentrators by collecting radial data from any number of portals (or nodes). This design minimizes data requests through sometimes unstable network connections to individual sites by serving data through portals while maintaining a high degree of network flexibility through selective data collection at nodes.

(Above) Near-real-time radial diagnostic web site for a University of California, Santa Barbara radar installed at Summerland Sanitary District facility. Site diagnostics are available to operators.

(Right) A real-time vector map for the West Coast. Maps are also available for Alaska, the Gulf of Mexico and the Eastern Seaboard.

HF RADAR Sites
Overlay Surface Currents
Use 25hr Averages
2 km Resolution
2007-07-30 17:00:00 UTC   SET
2007-07-30 17:00:00 UTC
2007-07-30 10:00:00-0700

surface-current mapping systems is characterized by a tiered structure that extends from the individual field installations to regional operations maintaining multiple sites and further on to aggregation sites obtaining data from all regions.

The data-system development effort focuses on building robust data communications from remote field locations for ingestion into the data system via data portals. Portals are computer systems enabled with the Boulder Real Time Technologies (Boulder, Colorado) Antelope real-time system, allowing the acquisition, transfer, buffering and delivery of data. Once surface-current data is within this architecture, it is buffered and transported through object-ring buffers, a set of code that is specific to real-time data delivery. Each portal is designed to interact with any number of data repositories (nodes), which collect data from any number of regional portals.

A data system built around the concept of a distributed network provides redundancy by allowing multiple locations to house data while addressing throttling issues during high-usage periods. Aggregation of surface-current data across regional associations enables integrated total-vector processing on large-scale national grids.

The distributed network is envisioned to enable national surface-current data grids to be configured for ingestion by tools, such as U.S. Coast Guard search-and-rescue models, ocean circulation models, ecosystem management, public health and water-quality warning systems, and third-party data providers, delivering value-added products.

In this article, details and an update of the HFRNet architecture and total-vector processing are presented, along with prototype and semi-operational applications.

Throughout HFRNet's development, the designers considered variations in radial file formats (some historical due to legacy issues) so that information can be extracted in a consistent and controlled manner by downstream processing, and the system is compatible with legacy installations. File formats fall into two broad categories known as range bin and LatLonUV (LLUV). In addition, data interpreters have been written to allow ingestion of data from two commercially available HF radar systems: the Seasonde, built by Codar Ocean Sensors (Palo Alto, California), and the WERA, from Helzel MessTechnik (Kaltenkirchen, Germany).

Once files are ingested and made available on a portal, it is up to the node(s) to retrieve packets and unpack

them into the local database. When packets of interest arrive on the source, they are copied reliably (without modification) and sent immediately to the destination, where they are unpacked. Since data transfer within the Antelope framework is accomplished via this throttled-packet method, load-on portals can be reduced, or network traffic to the nodes can be distributed.

HFRNet was initiated at Scripps with a single portal and node and four radar sites in December 2003. It has since grown to proto-operational status, with over one million radial files ingested at press time and data reporting from 90 radar sites operated by 22 different organizations. Considering that an hour of HF radar operation generally results in over 1,000 individual radial velocity solutions, the data system is now managing over order (10^9) discrete radial velocity data points. Seven portals have been deployed around the country to date, with nodes in operation presently at Rutgers, Scripps and the National Data Buoy Center. The Scripps node is now used for regular production of radial diagnostics, in use by HF radar site operators around the country. The network has proven to be stable and robust through network outages, power failures and system upgrades.

Under normal circumstances, radial files are often available at the node within minutes of being produced at the remote sites.

RTV Production

Coastal grids have been developed around the United States to integrate radial data for near-real-time total-vector (RTV) production on a nation-wide scale.

Due to the large spatial extent of the nation's coast (distances up to 3,000 kilometers) and the relatively high resolution of the data (one to six kilometers), careful consideration had to be given to the pros and cons of various grid-generation methodologies.

Nominal one-kilometer grids—based on equidistant cylindrical projections—were developed for the West, East and Gulf coasts, extending 300 kilometers offshore. Grid points falling over land or within 0.5 kilometers are removed using polygons produced from the World Vector Shoreline database, available through the National Geophysical Data Center. The resulting grid has variable resolution in longitude that increases pole-ward, but constant resolution in latitude. In return for sacrificing constant resolution and equal area, orthogonality is gained in addition to a grid with simple construction and interpolation. The grid is geoid-independent, since it is based on constant latitude and longitude spacing.

A MATLAB HF radar processing library, produced by MathWorks (Natick, Massachusetts) and in use by the radar community, was adopted and modified for the real-time processing of the radial data. Because HF radar processing continues to be an active area of research, this environment provides a robust platform for operational processing, as well as the flexibility needed to develop new products and processing techniques. Modifications include optimization for large national grids and for integration with HFRNet and the relational database residing on nodes.

Total vectors are processed at four resolutions along the East, West and Gulf coasts and the Gulf of Alaska to accommodate for the range of resolutions in radial data. Systems greater than approximately 40, 24, 13 and five megahertz contribute to totals on the 0.5, one, two and six-kilometer grids, respectively. These hourly total vectors form the basis for further product development. Twenty-five-hour averages, representing a tidally-removed current product, are also in real-time production for both grids at all four grid resolutions.

Current HFRNet Applications
Web-Accessible Radial Diagnostics. The first application of the HFRNet was to develop an online radial diagnostic utility for use by HF radar operators. This system allows the radar operator to track the performance of an individual radar site.
RTV Interactive Web Interface. This interface is a prototype online interactive site for hourly and 25-hour-averaged RTVs produced on a national scale. RTVs are presently processed and released on an hourly basis for the waters of the West, East and Gulf coasts and the Gulf of Alaska. A Google (Mountain View, California) mapping interface was developed by Scripps to provide a user-friendly data access system for geospatial data and has been adopted for operational use by the Central and Northern California Ocean Observing System and the Southern California Coastal Ocean Observing System through funding from the California state-funded Coastal Ocean Currents Monitoring Program.

Trajectories
Tools have been developed that interface the data system and provide updated trajectories to track ocean transport pathways. A common application of this tool is the use of tracking plumes from river flows and other near-shore discharges to indicate probabilities of impaired water quality on California beaches.

For the past two years, health officers from the San Diego, California, Department of Environmental Health have used these real-time trajectories to aid in minimizing public health risks from flows leaving the Tijuana River.

Maturing these tools for broad areas of coastline will aid water-quality managers. Similarly, the use of these tools for predicting the transport of surface oil slicks has been evaluated by both California's Office of Spill Prevention and Response and NOAA's Coastal Response Research Center.

Conclusions
Investment in the data architecture for a large-scale network of HF radar is solving one of the many challenges of operating and maintaining a national, distributed environmental observation system, which lends itself to expansion to other areas of the world. The effort presently provides information to a broad span of user levels, ranging from the individual HF radar site operators through to end user applications requiring updated surface velocity measurements.

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