Surface Circulation Radar Mapping in Alaskan Coastal Waters: Field Study Beaufort Sea and Cook Inlet

FY 2005

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LONG-TERM GOALS

Our primary goal with this project is to obtain spatial and temporal surface circulation fields for a portion of lower Cook Inlet and the central Beaufort Sea shelf in the vicinity of offshore oil production. These measurements will contribute to the baseline oceanography of two regions where few *in situ* current measurements have been made, and will therefore help to promote the general understanding of surface currents in these areas. These investigations will be an important undertaking for the Minerals Management Service (MMS) future efforts to model potential oil spills and for possible spill response and oil spill contingency planning. The data can also be used by MMS for model comparison and validation, for both hydrodynamic models as well as general circulation models. By disseminating the data over the internet in real-time, these data will assist professional users with a need for information for ship tracking and touring, coastal zone management, sediment transport, search and rescue operations, oil spill and other pollutant response.

OBJECTIVES

An important objective is to evaluate the sensitivity of the instruments to measure surface currents within mixed ice and open water conditions (limited fetch conditions), under periods of high fresh water outflow from the river systems, during the development of spring/summer shore leads, and during the fall freeze-up and the formation of landfast ice in the nearshore Beaufort Sea. Oil spill trajectory models typically derive their wind measurements from either coastal meteorological stations or from satellite derived barometric pressure fields. These data do not provide true surface current measurements in mixed ice and open water conditions when fetch is limited. HF Doppler radar would provide significantly more accurate surface current measurements under these fetch-limited conditions.

Once the data is acquired, objectives include:

- Assessing effects of sea ice concentration and extent on collection of surface current measurements from HF Doppler radar.
- Validating the HF Doppler radar surface current data measurement by comparing these data against the subsurface current measurements from the Acoustic Doppler Current Profilers (ADCPs).

- Comparing and contrasting wind measurements from MMS or other adjacent coastal meteorological stations against the HF radar surface current measurements.
- Developing a web site and ground capability to monitor system integrity and performance and providing near real-time dissemination of surface current field data, vector maps, and surface current animations.
- Providing detailed analysis of current and tidal variability and system response from the HF Doppler radar. Determining the dynamics and variability of surface current circulation. Including any sea ice, bathymetry, meteorological, ADCP, drifter, tidal, sea surface temperature or other important comparative data that has been collected within the study area.

APPROACH AND WORK PLAN

This study consists of two seasons of HF radar deployments in the Beaufort Sea and one year in Cook Inlet. In the Beaufort Sea we will deploy HF radar surface current mappers at two sites from June to October in 2005 and 2006. In October 2006, we will transport the two HF radar units to Cook Inlet where they will be deployed until November 2007. We will collect analyze, disseminate over the Internet, and archive surface current vector measurements. In the Beaufort Sea, data will be collected over a distance approximately 10-50 km from shore with a resolution of approximately 250 m to 3 km and will be used to resolve circulation patterns landward (inside) and seaward (outside) of any barrier islands (Figure 1). In Cook Inlet we will obtain quality controlled surface current vector measurements over a radial distance that is approximately 50-80 km from shore with a resolution of 1-3 km.

Scientific and technical personnel involved with the project from the University of Alaska Fairbanks (David Musgrave, Project Manager; Tom Weingartner, Oceanographer; Hank Statscewich, Technician; Rachel Potter, Deputy Program Manager; and Tony D'Aoust; Technician) and CODAR Ocean Sensors (Don Barrick, Brenda Lipa and Pete Lilleboe) are uniquely qualified and capable of fulfilling the goals and objectives of this study. Barrick, Lipa and Lilleboe are the founders of CODAR Ocean Sensors, the leader in HF ocean remote sensing radars. They are the pioneers who discovered and first applied HF radar to the mapping of ocean surface currents and wave monitoring, beginning 40 years ago. These individuals have over one hundred open-literature papers and hold ten patents on the subject of HF radar measurements. Musgrave, Statscewich, and D'Aoust will be responsible for the deployment of the HF radars. They have deployed HF radar systems for surface current mapping in Alaska since December 2002, as part of the Sea-Air-Land-Modeling-and-Observing Network (SALMON) Project under funding from NASA, NOAA, MMS, and the Prince William Sound Regional Citizens Advisory Council. Lastly, Potter will be involved in web design, real-time data acquisition and display, physical oceanographic data programming and analysis.

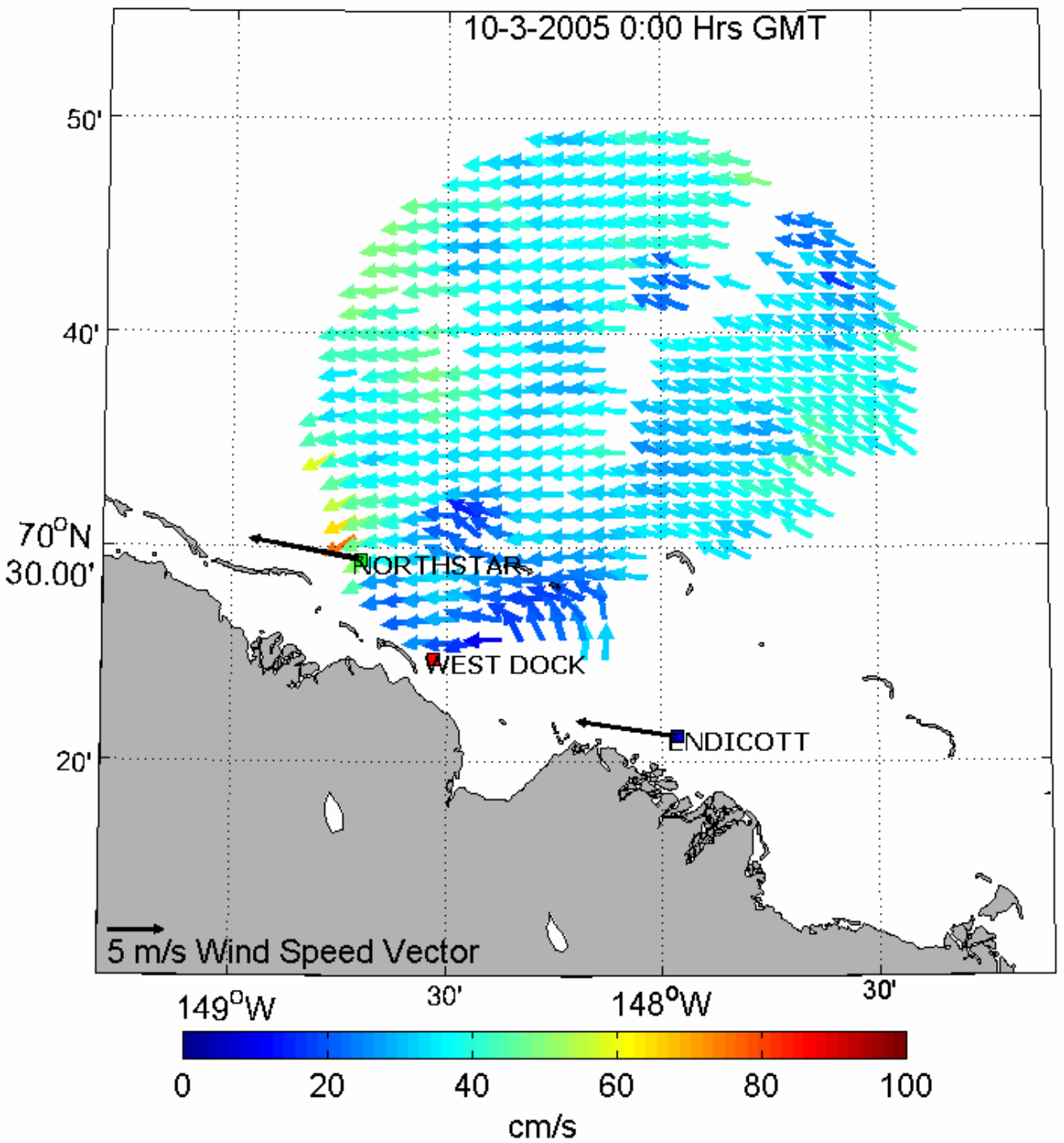

Figure 1. A map of the surface currents for 00:00 GMT on October 3, 2005, in the Beaufort Sea, which lies offshore of Prudhoe Bay, Alaska. This map shows the location of the West Dock and Endicott Island locations from which HF radar data were collected. The surface currents are given by the arrows that are color coded by magnitude. Wind vectors from meteorological stations at North Star and Endicott are given by the black arrows and the magnitude is given by the scale in the lower right.

WORK COMPLETED

Within fiscal year 2005, our work consisted of:

1. Site visit to Beaufort Sea in anticipation of a June 2005 deployment.
2. Acquiring, testing, and shipping a HF Radar system to Prudhoe Bay, Alaska, in April 2005.
3. Deploying, installing, calibrating, and maintaining the HF Radar system in Beaufort Sea from June through October 2005, when it was be demobilized for the winter.
4. Developing and maintaining a web site where real-time surface current data will be displayed
5. Compiling and submitting a Bibliographic Database of HF Radar resources.

We deployed and fine tuned two HF radar systems that can be switched between 12 and 24 MHz, at West Dock and Endicott Islands. An example of the data collected is shown in Figure 1, which shows the domain of coverage operating at 12 MHz. The use of two different frequencies permits us to tune the radars depending on environmental conditions: when the fetch is small then we expect the wave field to have more energy in shorter waves, which can be detected with the 24 MHz radar. When the fetch is larger, presumably under no ice conditions, the energy would be shifted to longer waves, which can be detected with the 12 MHz radar that has a longer range (Figure 2). This is the first attempt to use a switchable dual frequency system in an operational setting.

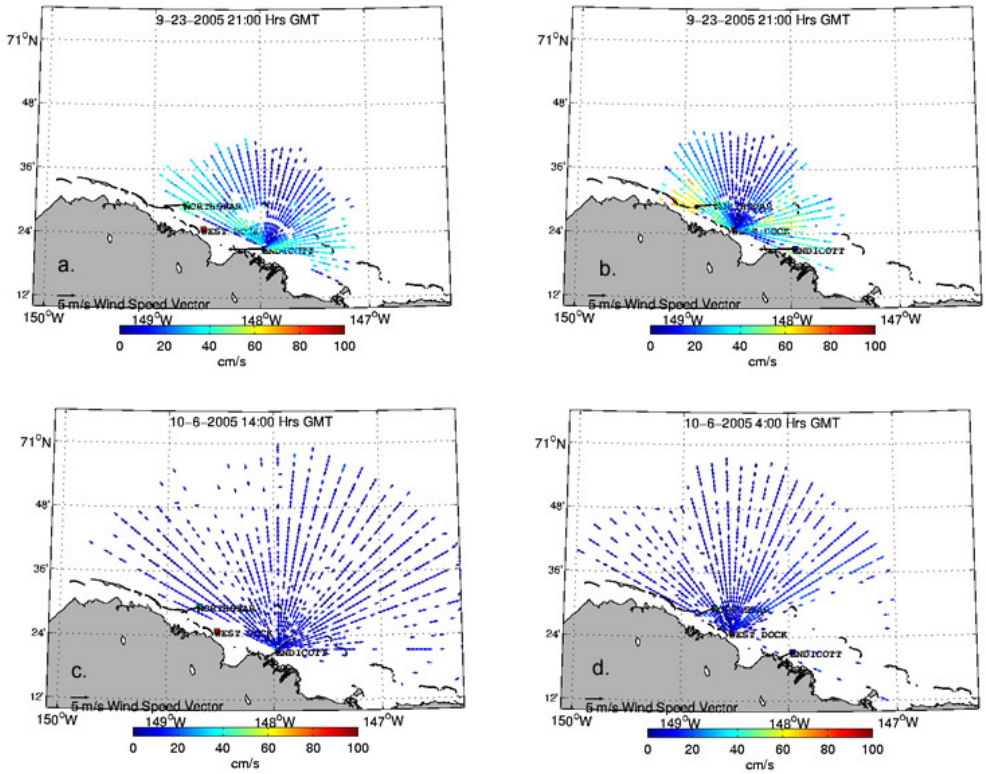

Figure 2. Maps of the radial surface currents from systems at West Dock (right panels) and Endicott Island (left panels. (Radial velocities are from each site are added vectorally to give the total two dimensional velocity vectors as shown in Figure 1). The upper panels are from September 23 and the lower panels are from October 6, when the system was operating at 24 MHz and 12 MHz at those times, respectively. The 24 MHz system has half the range (30 km) of the 12 MHz systems.

We had several issues that required troubleshooting due to the new switchable system, issues of power supply, and antenna patterns (Figure 3). We were able to collect two dimensional velocity vectors from August 22 to

October10.

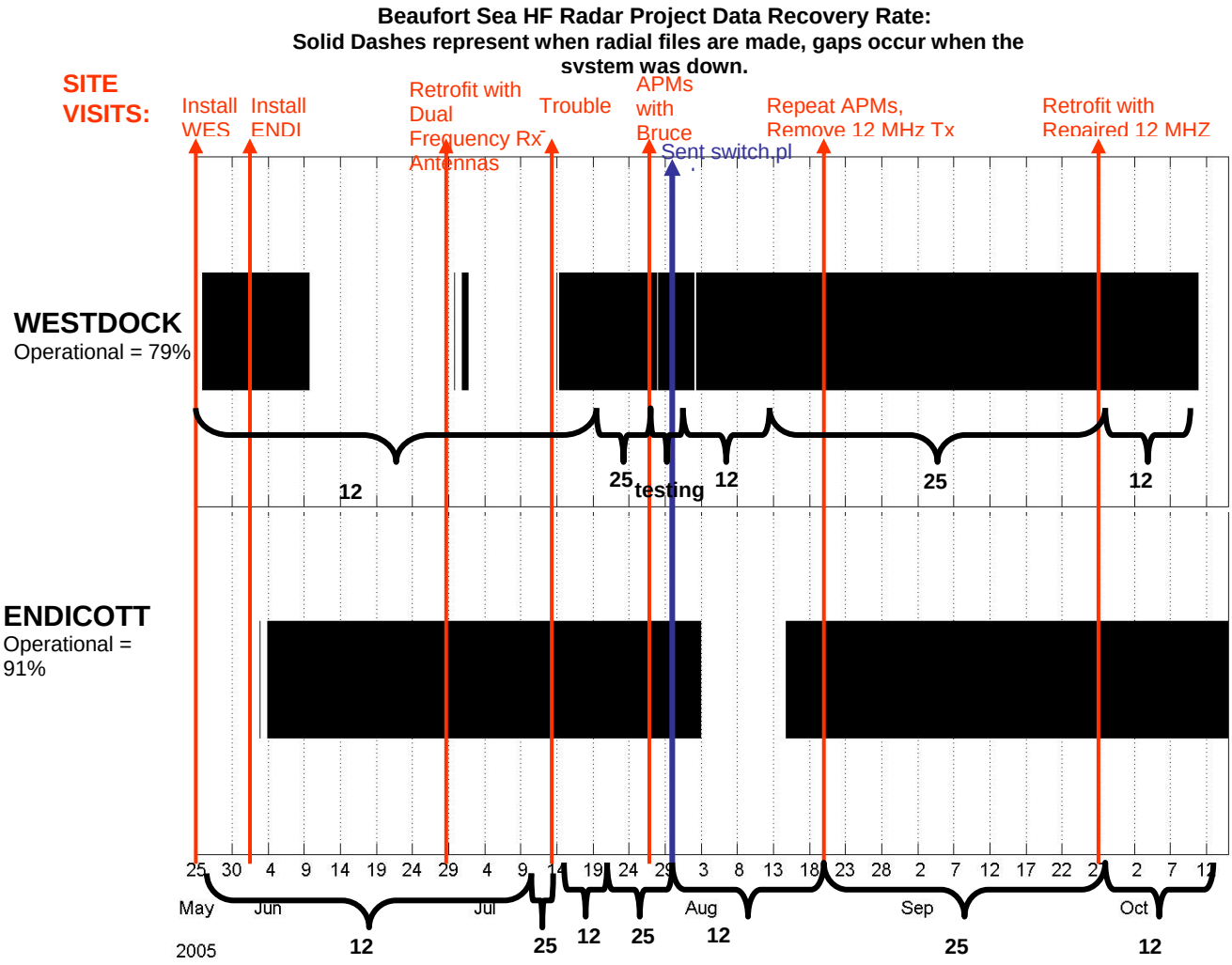

Figure 3. Timeline of operations in Beaufort Sea. The operational frequency is given below the curly brackets for each site. Both sites must be operating to give two dimensional velocity vectors. This occurred consistently from August 22 to October 10.

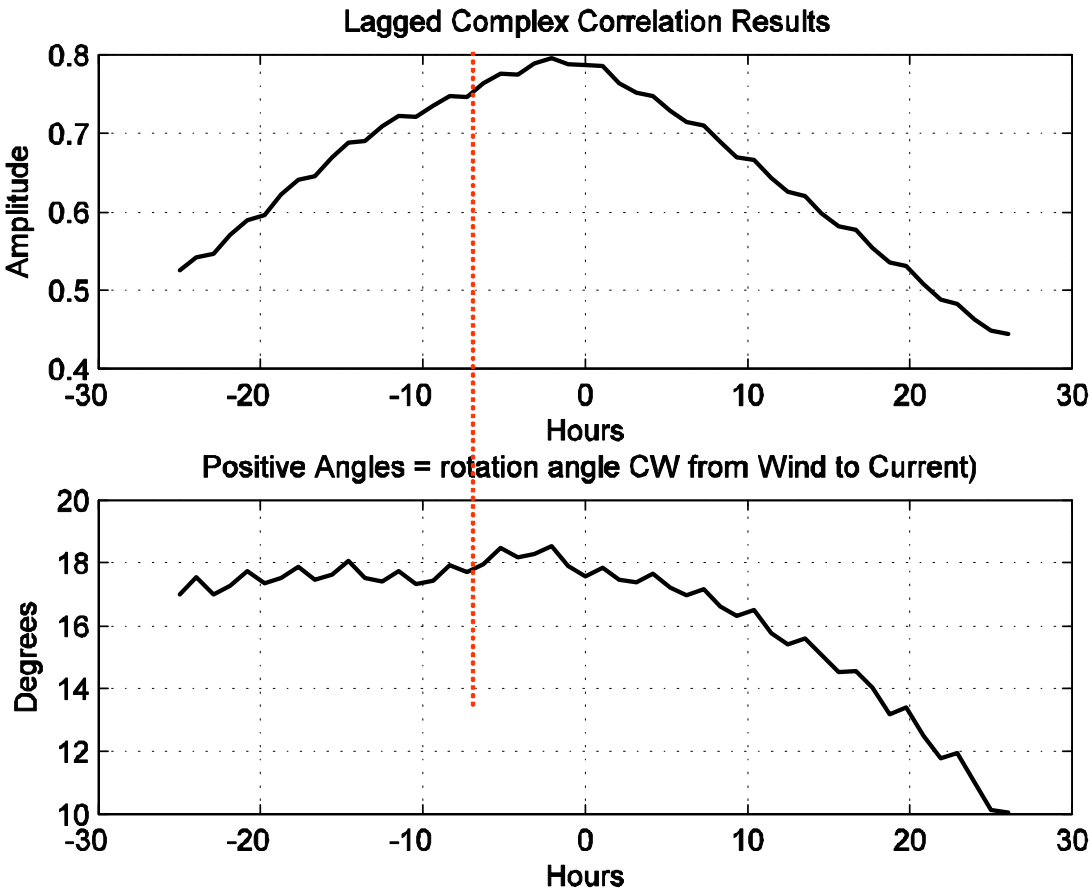

Figure 4. Lagged complex correlation between winds at Endicott Island and surface velocity at a point just outside the barrier islands.

Initial results indicate that the winds drive the circulation (Figure 4). The complex correlation amplitude between the winds and the surface velocity at one point in the domain (just outside the barrier islands) is a maximum (accounting for 80% of the variance) when the surface velocity lags the winds by 2 hours. The surface currents are rotated 18° clockwise from the winds at a two hour lag.

IMPACT AND APPLICATIONS

Economic Development

The Beaufort Sea borders the Arctic coastal plain and is very important to MMS, in part because of its potential for offshore oil gas production. The adjacent North Slope coastal plain region produces over 20% of the United States oil from mostly onshore State of Alaska oil fields. Offshore, oil is produced from Northstar Production Island, a joint state/federal production unit. This oil is transported to shore via a subseabed pipeline where it is connected to the larger Prudhoe Bay pipeline infrastructure.

Over the past 25 years, HF Doppler radar has been developed and improved so that detailed, gridded, two-dimensional maps of surface current circulation can be recoded in real time. Currents would play a

critical role in the transport and fate of spilled oil. Current meters provide data at specific points and not at the water surface, where most oil would be transported. HF Doppler radar provides a measured equivalent of a gridded circulation model and can be used as input to validate and to assimilate into oil spill trajectory models.

Electromagnetic remote sensing of ocean currents from the shoreline out to sea provides a complete mapping capability and has become the most cost-effective solution operationally for coastal current measurements.

Quality of Life

These data will assist professional users with a need for information for coastal zone management, sediment transport, search and rescue operations, oil spill and other pollutant response. Also, subsistence hunting is very important social activity for the Native population that resides along the Arctic coastal plain. Subsistence hunters hunt the bowhead whale, polar bear, ringed seal, fish, etc. which are found within the waters and on top of the ice in the Beaufort Sea. They could benefit from knowledge of the surface currents.

Science Education and Communication

There is a limited amount of information to resolve the spatial and temporal surface currents circulation patterns in the Beaufort Sea and Cook Inlet. The sites where current meters have been placed, in either area, have not resolved the complexity of the surface currents. Our present knowledge of surface currents is limited and can be improved. Time series observations of surface current measurements over extensive regions are essential for understanding ocean circulation dynamics. High Frequency (HF) Doppler radar systems are ideal for accomplishing this task.
The tidal range measured in Cook Inlet is one of the largest in the world, and the short season of open water conditions in the Beaufort Sea is followed by a period of growth and seaward spread of landfast ice, followed by pack ice incursion, ice ridging, opening and closing of leads, spring overflooding, opening of the shoreline leads, and melting of the land fast ice which leads to the short open water season. HF Doppler radar will provide important new information on the changing surface current measurements within these unique and dynamic environments.

TRANSITIONS

Economic Development

These investigations will be an important undertaking for the Minerals Management Service (MMS) future efforts to model potential oil spills and for possible spill response and oil spill contingency planning.

Quality of Life

By disseminating the data over the internet in real-time, these data will assist professional users with a need for information for ship tracking and touring, coastal zone management, sediment transport, search and rescue operations, oil spill and other pollutant response.

Science Education and Communication

The data can be used by MMS for model comparison and validation, for both hydrodynamic models as well as general ocean circulation models.

RELATED PROJECTS

A similar study is being conducted in Prince William Sound, Alaska, by the same University of Alaska Fairbanks research group. The HF Radar system provides insight on the circulation of Prince William Sound and information on the tidal currents in the region (http://halibut.ims.uaf.edu:8000/~salmon/CODAR/CODAR.html).