Surface Current Mapping via Land Based CODAR in Cook Inlet, Alaska

Hank Statscewich, Dave Musgrave, and Tony D'Aoust
Institute of Marine Science, University of Alaska Fairbanks, Fairbanks, AK

Introduction

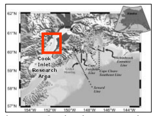


Figure 1: Cook Inlet Research Area.

In early December of 2002, The Salmon Project began operating new High Frequency (HF) Radar instrumentation which has provided unprecedented coverage of sea surface currents in Alaskan waters. These instruments are manufactured by CODAR (Coastal Ocean Dynamic Applications Radar) Ocean Sensors in Los Altos, California. The systems have ultimately been slated for operation at remote sites in Prince William Sound and Kodiak Island, but due to the technical complexities associated with maintaining and monitoring these systems at remote locations, prototype power and telemetry systems are being developed and deployed in Cook Inlet. The funding for these systems is being provided by grants awarded by The National Aeronautical and Space Administration (NASA) and The National Oceanic and Atmospheric Administration (NOAA).

How does it work?

A single CODAR site consists of two antennas and computer equipment necessary for transmitting, receiving and processing radio signals. One antenna (Figure 2) transmits a radio wave out across the ocean surface. The power of this transmitted signal is only 40 watts. Therefore this antenna behaves like a household lamp with a 40 watt light bulb. Unlike radio stations that only transmit a signal, CODAR uses the second antenna (Figure 3) to listen for and measure the received signal, so that the part of the transmitted signal that is reflected back toward the site by the ocean waves can be recorded and processed. It is this returned signal that is used to measure the moving ocean surface. These antennas are separated by about 30 meters. The computer equipment consists of a Macintosh laptop computer, responsible for processing the incoming signal, a transmitter and a receiver (Figure 4).


Figure 2: CODAR transmit antenna.


Figure 3: CODAR receive antenna.

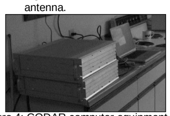


Figure 4: CODAR computer equipment.

What is CODAR?

CODAR is a High Frequency (HF) radar system that remotely measures ocean surface currents. The system allows one to get a complete map of ocean currents (Figure 8) on an hourly basis without stepping foot aboard a boat or deploying an expensive array of current meters. Each map has a range of about 50-70 kilometers (about 35 miles) from the coast with a measurement every 1.5 kilometers (0.9 miles). The SALMON Project CODAR system, currently deployed in Cook Inlet, is the only operational HF-Radar system of its kind in Alaska. It consists of two remote sites, located in Kenai and Kasilof, and a central site at the Institute of Marine Science in Fairbanks, Alaska.

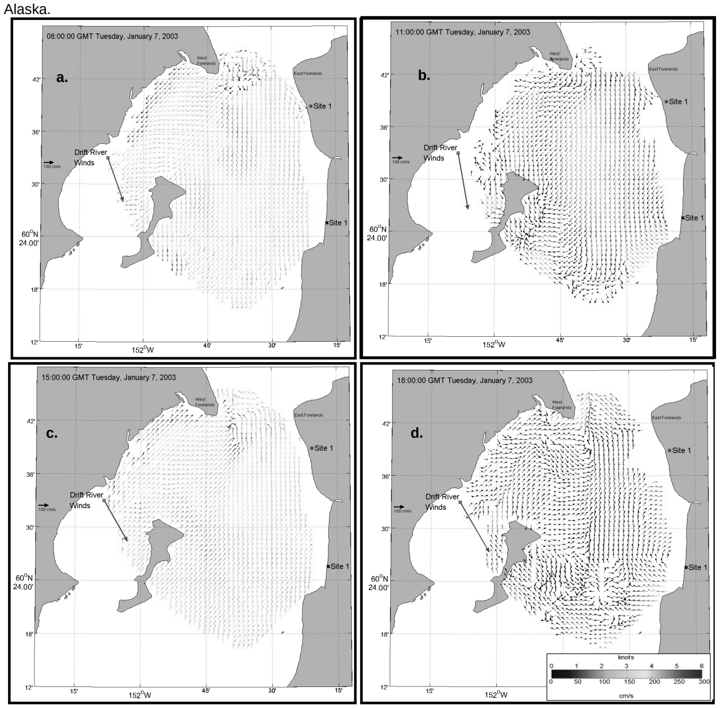


Figure 8: Total current maps collected from the Cook Inlet CODAR system on January 7, 2002 at four stages of the tide: (a) Ebb, (b) Slack Low, (c) Flood, and (d) Slack High. The inset in (d) is the velocity color key for all maps. The meteorological station at the Drift River Terminal is operated by the National Data Buoy Center.

CODAR Applications

- Safe and efficient navigation and marine operations
- Efficient hazardous spill trajectory prediction and clean up
- Monitoring, predicting and mitigating coastal hazards
- Military operations
- Education
- Scientific research
- Search and rescue

The Future of CODAR in Alaska

The future of the CODAR in Alaska involves plans to increase the present number of operational systems and deploy the currently operating system in remote locations. To accomplish this, several sources of funding are currently being pursued for support of new systems. Areas highlighted for future CODAR deployments include: Bering Strait, Prudhoe Bay, Shelikof Strait, the Northern Gulf of Alaska and Bristol Bay (Figure 9). One more CODAR deployment will take place in 2003 in Kachemak Bay. This system will have the capability to operate at two frequencies thereby extending coverage to 200 km. The Cook Inlet site will be relocated to Prince William Sound this summer (Figure 10) and fully outfitted with a renewable power source with generator backup (Figure 11). We expect that real time currents from the Sound will be available by July 2003.

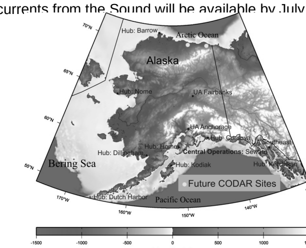


Figure 9: Map of Alaska showing possible locations for future CODAR deployments.

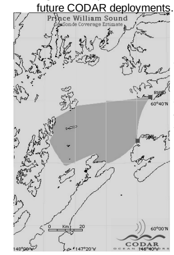


Figure 10: Map of Prince William Sound showing the locations for the two remote CODAR sites as well as the area over which total surface currents will be measured for this system.

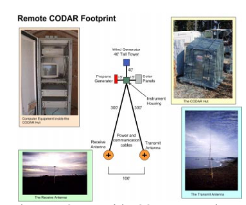


Figure 11: Cartoon of the CODAR remote layout.

How are ocean currents measured from land?

The CODAR system in Cook Inlet measures surface currents by transmitting electromagnetic waves of 12 MHz (25 m wavelength) which travel along the sea surface by ground wave propagation. The radar signal will return directly to its source only when the radar signal scatters off a wave that is exactly half the transmitted signal wavelength, AND that wave is traveling in a radial path either directly away from or towards the radar (Figure 5). The scattered radar electromagnetic waves add coherently resulting in a strong return of energy at a very precise wavelength (Figure 6). This is known as the Bragg principle, and the phenomenon 'Bragg scattering'. At the frequencies used in Cook Inlet, the periods of these Bragg scattering short ocean waves are between 2 and 3 seconds. What makes HF RADAR particularly useful for current mapping is that the ocean waves associated with HF wavelengths are always present. At this point, three facts about the Bragg wave are known: its wavelength, period, and travel direction. Because we know the wavelength of the wave, we also know its speed very precisely from the deep water dispersion relation. The returning signal exhibits a Doppler-frequency shift. In the absence of ocean currents, the Doppler frequency shift would always arrive at a known position in the frequency spectrum (Figure 6), but the observed Doppler-frequency shift does not always match up exactly with the theoretical wave speed. The first order Doppler-frequency shift includes the theoretical speed of the wave PLUS the influence of the underlying ocean current on the wave velocity in a radial path (away from or towards the radar). The effective depth of the ocean current influence on these waves depends upon the wave's period or length. The current influencing the Bragg waves falls within the upper meter of the water column. So, once the known, theoretical wave speed is subtracted from the Doppler information, a radial velocity component of surface current is determined (Figure 7). By looking at the same patch of water using radars located at two or more different viewing angles, the surface current radial velocity components can be summed to determine the total surface current velocity vector (Figure 8).

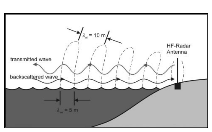


Figure 5: Cartoon illustrating the principles of Bragg scattering.

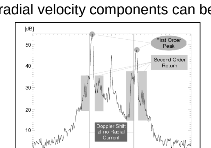


Figure 6: An example of a Doppler spectrum measured by an HF RADAR system. The first order Bragg lines show 50 dB signal to noise ratio and the second order reflections (used for wave height determination) can clearly be seen.

Figure 7: Typical radial current map collected hourly by a remote site in Cook Inlet.

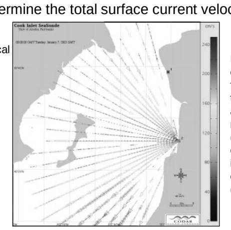
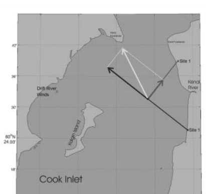


Figure 8: A remote site can only measure how fast the water is moving toward or away from the antennas. The net movement of the water (shown in yellow) can only be determined using information collected from each of the two sites (shown in blue and red).



Acknowledgements

Support provided by NASA, NOAA, The Alaska State Troopers Wildlife Protection Unit, the Cook Inlet Regional Citizens Advisory Council and the Great State of Alaska. Special thanks to Susan Saupe, Steve Okkonen, Josh Kohut, Mike Crowley, Rachel Potter, Keith Carney and the Staff at CODAR Ocean Sensors, INC.

Find out about this project and more on the web: http://www.salmonproject.org