Rapidly Deployable SeaSonde For Modeling Oil Spill Response

Helicopter-Deployable, High-Frequency Radar Unit Improves Operational Oil Drift Predictions in the Barents Sea

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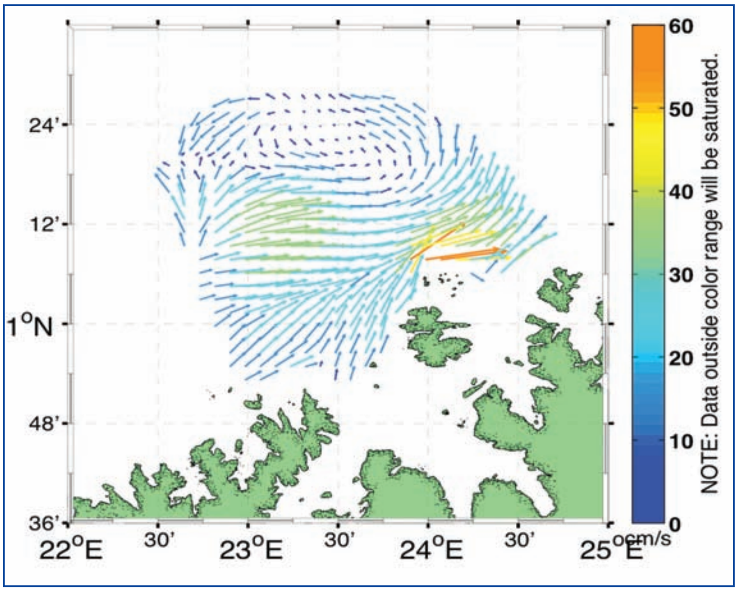
A rapid-response SeaSonde prototype is deployed at Tarhalsen, Norway.

Recent spill events such as the 2010 *Deepwater Horizon* accident in the Gulf of Mexico and the 2007 MV *COSCO Busan* collision in San Francisco Bay have highlighted the benefits and need for surface current mapping for response operations. CODAR Ocean Sensors' SeaSonde high-frequency radar networks, which provided maps of ocean currents during these events, consisted of permanently installed stations at sites in developed areas that were easily accessible by road with access to grid power and high-speed data links. Most of the SeaSondes operating around the world are located at such sites, and those that are not generally require weeks or months of planning alternative power and communications solutions. Much of the world's coastlines are at risk from the production and transport of oil, but high-frequency radar current maps only cover a fraction of them. Resolving this problem requires a mobile rapid-response capability.

The concept of mobile high-frequency radar systems is not a new one. In fact, it was one of the driving concepts behind the development of the compact Coastal Ocean Dynamics Radar system at NOAA in the 1970s and early 1980s. Others have since created their own customized mobile solutions using SeaSondes integrated into automobile trailers at both Texas A&M University and NOAA's Center for Operational Oceanographic Products and Services. These solutions, while innovative in their ability to quickly deploy equipment once on site and for their utilization of wireless communications and self-contained power sources, were still limited to coastal sites accessible by roads. Areas such as the Louisiana coast, the Mississippi Delta and along most of the coast of Norway, require a solution that can utilize a number of modes of transportation, including final positioning by helicopter.

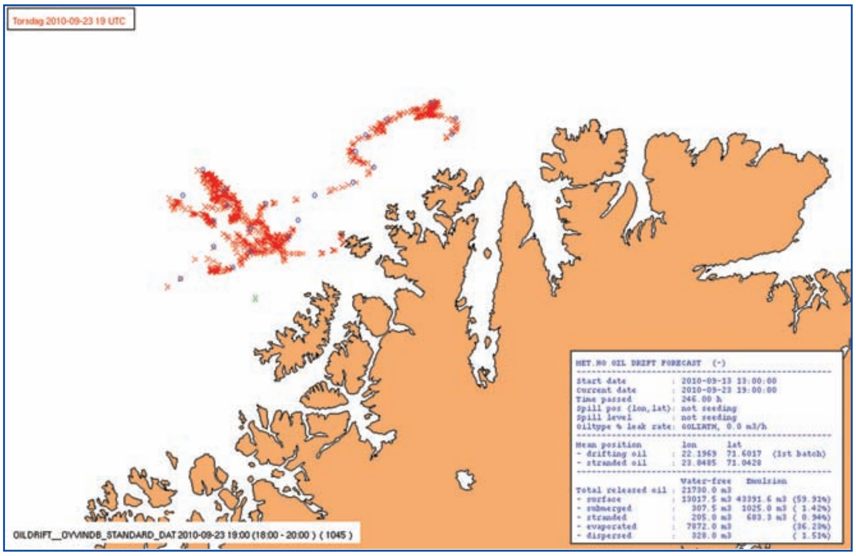
In 2009, on behalf of the companies operating on the Norway's continental shelf, the Norwegian Clean Seas Association for Operating Companies and the Norwegian Coastal Administration launched Oil Spill Response 2010, a multiyear development program for oil spill response technology. The goal of this program was to achieve significant improvements in providing continuous and effective oil spill response offshore and in coastal and shoreline areas during various weather, daylight and climatic conditions. In response to this call, CODARNOR AS, along with development partners CODAR Ocean Sensors, QUALITAS Remos (Madrid, Spain) and the Norwegian Meteorological Institute, developed a rapid-response SeaSonde for the rugged and remote Norwegian coastline.



SeaSonde Objectives

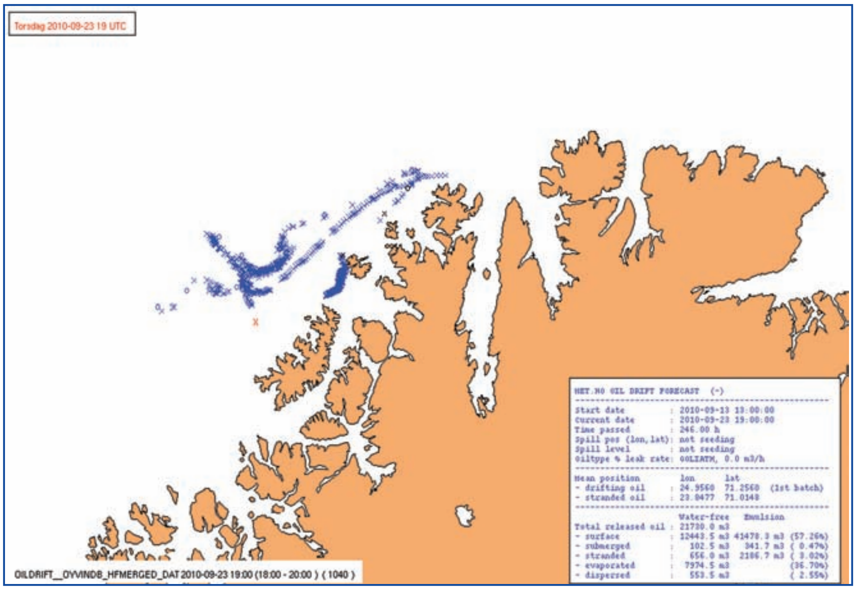
The objectives of this project were to develop a mobile SeaSonde high-frequency radar unit that can be rapidly deployed to the coast of Norway to aid in effective and efficient oil spill response. The project aimed to accomplish this through developing a data service that provides high-quality SeaSonde-derived 2D current fields to the Norwegian Meteorological Institute in near real time. This would be used for spill drift model input and operations planning while also demonstrating that these current fields can improve operational oil spill drift model results.

Adapting the commercial SeaSonde to a rapid-response system required outfitting it in a protective housing that is easily transportable by a number of methods, including helicopter. The mobile unit's shell was also required to be large enough to contain all equipment and tools, provide enough room for one person to sit comfortably, and be lightweight and compact.



Hardware Specifications

With this in mind, a shell was manufactured using a half-inch PVC foam core that was fiberglass-reinforced and polyester-laminated inside and out. The shell dimensions were 1.2 meters long by 1.2 meters wide and 1.5 meters high, mounted on skids that span a 1.2-by-two-meter area. For operating frequencies of 11 megahertz or higher, the unit uses a single transmit-receive antenna, which measures six to eight meters in total height with a four-meter-tall mast and whip antenna for the rest. For compactness during transport, the whip is quickly removable, and the mast was redesigned to be a two-piece hinged assembly that was mounted on the side of the shell. Once the rapid deployment unit is delivered, a single person can



(Top) Surface current fields reconstructed from open-boundary modal analysis. Note the existence of coastal tangent current.

Forecasts using the ocean model current (middle) predicted that oil released from the green "X" in September 2010 would stay well off the coast, drifting mostly northward and, to a smaller extent, near land. However, the high-frequency, radar-blended currents (bottom) indicate that oil released from the same location (the red "X") would have drifted closer to the island coasts, representing more of a threat. As the images illustrate, if the location and scale of features are not captured well, the predicted drift of objects on the surface can be quite different from reality.

completely assemble and erect the antenna in about 10 minutes.

Power was supplied via redundant, off-the-shelf, two-kilowatt Honda generators with uninterruptible power supply backup and power conditioning. The prototype unit required 400 watts of continuous power, but a new transmit module design has since brought this number down to about 200 watts. Communications for data transfer were provided by the Ice.net CDMA 450-megahertz cellular service available along the Norwegian coast, and a redundant satellite communications system will be available in production models.

Rapid Data Products

While designing hardware for rapid-response deployments is important, perhaps more important is devising a plan for how to provide data products to operators and responders. Spatial gaps or shadows in surface-current coverage due to coastline geometry, radio interference, nearfield antenna distortions, etc., can often be present in real-time, high-frequency current maps. Moreover, when using a conventional local combination of radial data to obtain surface current data, it is not possible to have currents close to the coast where radial vectors from the two stations are almost parallel due to purely geometrical considerations. To overcome these difficulties, project participants have implemented and tested, in a real-time configuration, a robust and well-established method based on open-boundary modal analysis (OMA) to fill spatial gaps and expand the data to the coast.

OMA relies on the decomposition of the total velocity field as a sum of divergence-free and irrotational modes as well as modes describing flow through the open boundary. The radial data from the high-frequency radar stations are then fitted to an optimal linear combination of these modes through the minimization of a cost function. The modes depend exclusively on the domain selected, and the definition of the closed and open boundaries are computed only once and do not change in time. In addition to filling gaps and the baseline region, radial data from a single site can be used to reproduce an entire total vector field when data from another site are unavailable. Updated 2D current vector maps can be available with temporal resolutions of 10 to 60 minutes and delays due to data transfer and OMA processing of 10 to 20 minutes.

"The rapid SeaSonde deployment unit operated at Tarhalsen unmanned and uninterrupted, providing continuous data for more than two weeks with only one visit for inspection and refueling."

On their own, quality-controlled 2D vector maps available in near real time provide vessel pilots information on the currents in the area they are working. A real added value, however, would come from using the data to improve spill predictions and, therefore, being able to plan positioning and utilization with much more efficacy. This is specifically one of the goals of this effort.

The operational oil spill model was developed and is operated by the Norwegian Meteorological Institute. The ocean model component is a modified Princeton Ocean Model. The spill model requires wind fields, wave fields and current fields. These data are collected from the operational forecast model suite. Drift predictions are based on ocean, wind and wave model outputs and the characteristics of the type of oil spilled. The currents produced by the ocean model that are closest to the coast are generally the most suspect.

Numerous efforts have shown that model outputs can be vastly improved by assimilating high-frequency radar maps. Full assimilation techniques, however, can take months or years to establish in a given region. This kind of time is not available after a spill, and the added benefits may be short-lived in places like the Norwegian coast, where a strong coastal current can quickly advect away the improved model currents. Instead, a technique was developed whereby current predictions derived from high-frequency radar are blended with model output currents using a weighting function dependent on range from the radar. During an actual spill event, the resultant currents and drift simulations would be provided to those in command of the response efforts.

Prototype Deployment in Norway

In order to fully test the prototype unit, a deployment was planned along the coast of Finnmark, the northernmost county in Norway. Finnmark provided the remote and rugged conditions in which a rapid deployable unit should operate, and it is also an important area for present and future development of offshore energy. Additionally, the Norwegian Clean Seas Association for Operating Companies has an operations center located near Hammerfest, Norway, within the Polarbase AS (Rypefjord, Norway) facility that provided a strategic staging area. With the Snøhvit gas field already in the production stage and the Goliat oil field, located approximately 60 kilometers offshore, scheduled to begin production drilling in late 2012, there is a need for coastal current monitoring in this region, both for drilling operations as well as spill preparedness and response.

In order to cover an area that would be most useful to operations for the Goliat field, the SeaSondes used an operating frequency in the 13-megahertz band, which typically gives a 70- to 90-kilometer range, depending on sea conditions and the local radio environment. Based on satellite images and coastline databases, two sites were chosen ahead of time: Fruholmen and Tarhalsen.

Fruholmen is a small, rocky island near the convergence of the Norwegian and Barents seas and is home to a lighthouse and navigational beacons. The lighthouse is no longer manned, but with AC grid power and existing buildings, it made an ideal site for a standard SeaSonde unit. Tarhalsen, a rocky point of land at the northwestern tip of the Sørøya Island, is uninhabited with no power or shelter. Delivering equipment to Tarhalsen requires a helicopter, and power must be self-generated and quiet due to the presence of a sizable bird nesting area.

The equipment located at Fruholmen was delivered by boat ahead of time and installed in less than a day. The rapid deployment unit was scheduled for delivery and installation by a Eurocopter AS350 B3 in September

2010, but the deployment had to be aborted when thick fog rolled in, quickly covering the entire outer coastline of Sørøya.

With the unit placed about eight kilometers away at the village of Akkarfjord, Norway, on the inner side of Sørøya, it was easy to take advantage of a weather window that opened up about 36 hours later. Two hours after summoning the helicopter, the unit was on site, and data collection began an hour after arrival. It was a reminder that in places like northern Norway, rapid deployment considerations can have as much to do with local weather as it does with site accessibility.

Both sites transmitted radial current data (polar projections of the current field) to servers in California and Spain hourly. Surface current vector fields were then created on two-by-two-kilometer grid by using the traditional least squares radial combination method performed by CODAR Combine software as well as OMA methods included in PORTUS by QUALITAS Remos. The OMA maps covered more area, including patches with poor geometry between the two sites and some patches only covered by one radar, as well as being free of any gaps. Quality-controlled OMA fields were then passed to the Norwegian Meteorological Institute for blending into regional ocean models as described above. The rapid deployment unit operated at Tarhalsen unmanned and uninterrupted, providing continuous data for more than two weeks with only one visit for inspection and refueling.

High-frequency radar currents from the nine-day experiment in September 2010, during which both radars operated, were blended with ocean model current fields to produce a continuous gridded data set. Two sets of simulations were performed where oil was released from point sources throughout the high-frequency observation period. The first set of simulations used model-only surface current fields while the second set of simulations used blended ocean current fields. In the simulations, when oil was released within the high-frequency coverage, it remained either close to shore or strands to a much higher degree than in the model-only simulations.

The oil drift simulations clearly indicate that the high-frequency currents show a persistently stronger alongshore current than what the model displays. The improvements to the drift tracks provided by the high-frequency radar data are significant and would provide improved information to decision-makers during an actual spill response.

SeaSonde Pilot Program, Next Steps

As a continuation of this project, CODARNOR AS has been asked to provide a two-year pilot service to the Norwegian Clean Seas Association for Operating Companies that includes three mobile SeaSonde units deployed at different locations along the coast of Norway. The objective of this pilot service will be to deliver real-time, high-quality surface current data as input to the Norwegian Meteorological Institute operationally run oil spill trajectory model. This will make it possible to further improve the oil spill trajectory predictions.

Within this pilot service, the mobile unit can be made even more compact, with the development of a foundation and base plate that makes it easy to install on a wide variety of ground surfaces both for the shelter tie downs and in case the antenna has to be mounted away from the shelter. Kits will also be developed to provide a more robust power generator system and a redundant communication system. All of this will be designed for deployment from a small helicopter.

A short-term prediction system able to make surface current forecasts of the next six to 12 hours of surface currents will be implemented. This will be based on the OMA already developed in the project. This will run in real time with suitable displays, e.g., movie loops of forecasted current trajectories and user-selectable future displays.

This will be a service offered worldwide from CODARNOR AS, in cooperation with its partners QUALITAS Remos, CODAR Ocean Sensors and the Norwegian Meteorological Institute.

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Dr. Anton G. Kjelaas is a special advisor to the Research Council of Norway on development of new offshore technology. As president and owner of CODARNOR AS, he has been focusing on new applications for seasoned high-frequency radar along the coasts of Norway. A pioneer in the development of microwave radars for ocean wave measurements in Norway, Kjelaas has more than 25 years of experience working within the oil industry.

Chad Whelan has been technical projects manager and lead field engineer for CODAR Ocean Sensors since 2001, both planning and managing development projects and experiments related to the SeaSonde high-frequency radar. He has more than 17 years of experience working with developmental and commercial high-frequency radar systems for ocean monitoring.