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APPLICATIONS OF GODAE OCEAN CURRENT FORECASTS TO SEARCH AND RESCUE AND SHIP ROUTING

Courtesy of Fisheries and Oceans Canada

ABSTRACT. As GODAE ocean forecast systems progress, their contributions toward improving the safety and efficiency of operations at sea will increase. In this article, we review present uses of GODAE ocean forecast systems for various safety applications at sea, including search and rescue drift calculations, iceberg drift calculations, ice cover prediction, and safety of offshore operations. Additionally, we review how various countries presently use safety and decision support tools that incorporate ocean current forecasts.

INTRODUCTION

A person or object lost at sea without propulsion is subject to drift from ocean currents, wave action, and direct wind action. To locate such a drifting target, timely, reliable, and accurate environmental forecasting is needed regarding surface currents and surface winds. An aim within the GODAE OceanView program is to ensure that the ocean forecast systems developed will both improve prediction of search target location and provide useful environmental ocean information for increasing the effectiveness of the search operation.

Ocean and ice forecast and hindcast systems can also contribute proactively to safety at sea. Advance knowledge of strong currents enables routing of ships to maximize transit speed. Likewise, use of ice-free routing greatly improves transit speed and safety. Sea surface temperatures from ocean forecasts provide estimated survival times at sea, permitting coast guards to optimize vessel coverage in the event of an emergency. Prediction of iceberg tracks in the vicinity of offshore oil installations permits mitigation activities to reduce the risk of collision with expensive infrastructure.

In this article, we review the national safety needs of several GODAE member countries and examine approaches taken to apply ocean forecast information to meet these needs. The underlying motivation is that a data assimilative ocean analysis and subsequent forecast performs better than climatology for predicting where a search object will drift next.

NATIONAL SAFETY NEEDS AND GODAE SYSTEMS IN USE

For most countries, an objective is to create strong links between at-sea operational decision makers and the best available validated ocean forecast/hindcast information. The approach adapts to geographical, demographic, and strategic needs. For example:

1. In Japan, an island nation with a strong fishing and sea-based culture, search and rescue (SAR) drift predictions are in great demand.
2. Australia, Canada, and the United States have extensive coastlines with large areas of ocean to search, complicated by a large variety of oceanographic features, including ocean tidal regimes, eddies, fronts, and jets.
3. In Canada, icebergs and pack ice occur on the east coast of the country but not on the west coast.
4. France needs to provide search coverage locally for three maritime traffic-laden coastlines, and globally for overseas territories.
5. Norway has a long, indented coastline where high-resolution current data is required to predict drift trajectories.

GODAE systems are already in use by various national coast guard agencies. For instance:

1. The recently introduced first-generation GODAE BLUElink> operational ocean prediction system (Brassington et al., 2007a) enhances information available to the Australian Maritime Safety Authority (AMSA) for conducting its operations. Australia's Bureau of Meteorology and Asia-Pacific Applied Science Associates (APASA) also incorporate BLUElink> ocean forecasting data sets into safety operations. AMSA coordinates SAR activities and receives ocean current information from BLUElink>.
2. The US Coast Guard (USCG) relies primarily on output products from data assimilative regional and global models, including the global Navy Coastal Ocean Model (NCOM; Barron et al., 2006) and the National Oceanic and Atmospheric Administration (NOAA) North Atlantic HYbrid Coordinate Ocean Model (HYCOM).
3. The Canadian Coast Guard makes use of the Mercator forecasting system for the North Atlantic, the Canada-Newfoundland Operational Oceanography Forecast System (C-NOOFS; a coupled atmosphere-ocean-ice forecasting system) for the Gulf of St. Lawrence, and a non-data-assimilative forecast system for the eastern seaboard.
4. In Japan, the Japan Meteorological Agency (JMA) is now using its new operational Multivariate Ocean Variational Estimation (MOVE) forecast system (Usui et al., 2006).
5. The Joint Rescue Coordination Centers of Norway employ the operational ocean forecast system of the Norwegian Meteorological Institute (met.no), whose SAR forecast system covers the Norwegian, North, and Barents seas at 4-km and 1.5-km resolution.
6. Météo-France applies model output from the MyOcean/GODAE forecasting centers, which include Mercator (global, North Atlantic, Mediterranean Sea), Forecast Ocean Assimilation Model (FOAM; global, North Atlantic), and Towards an Operational Prediction system for the North Atlantic European coastal Zones (TOPAZ; Arctic Ocean).

HOW CURRENT DATA ARE USED IN SEARCH AND RESCUE

A common feature in all search and rescue applications of GODAE ocean forecasting systems is the dissemination of ocean model output through a central data server. Here, we include a few examples. In the United States, an environmental data server routinely pre-processes ocean model outputs from various forecast systems to provide a common interface for 1-m-depth surface currents. JMA pushes output from its MOVE system to the Japan Coast Guard (JCG) Headquarters servers. JCG subsequently blends into the ocean current forecast output several observational data sets, including vessel acoustic Doppler current profiler (ADCP) data, satellite altimeter data, sea surface temperature data, and high-frequency (HF) radar data. This modified model output is then transferred daily to a central drift prediction server from which 11 coast guard regions can run drift simulations remotely. In Canada, ocean model output is centralized at the Canadian Coast Guard College and then pushed out to all Search and Rescue Centers where Search Coordinators run drift prediction software on local servers.

The Norwegian "Leeway" search model is described below as a typical drift prediction model. It computes the net motion of a range of search and rescue objects using:

1. A database of wind drag effect coefficients (i.e., leeway) on the object (see Allen, 2005)
2. Prognostic forcing fields of 10-m winds
3. Near-surface current vectors from the operational suite of forecast models provided by the Norwegian Meteorological Institute (see Breivik and Allen, 2008; Hackett et al., 2006)

The measure of how much wind directly pushes an object floating at the surface of the water is determined by leeway coefficients obtained from field trials. A Monte Carlo technique generates an ensemble of drifts that account for uncertainties in forcing fields (wind and current), leeway drift properties, and the initial position of the search object. The ensemble yields an estimate of the time-evolving probability density function of the search object's location, and its envelope defines the search area. Comparison with older drift methods using uniform circular expansion of search domain shows ensemble methods to provide a smaller search area with high-resolution forcing fields. The Norwegian model is capable of reading the global self-consistent hierarchical high-resolution shoreline (GSHHS) database (see Wessel and Smith, 1996) to determine when particles are stranded onshore. The model software is open source and publicly available under the GNU public licence (a project of the Free Software Foundation—GNU is a recursive acronym for GNU's Not Unix).

In contrast, the French drift calculation program MOTHY uses ocean model current data from a single depth (at the base of the Ekman Layer) obtained from an ensemble of available GODAE ocean forecasting systems. The effect of wind and tides on ocean currents is calculated separately. In France, the SAR coordinator references a Météo-France visualization and data service Web site linked to an on-call duty forecaster. The system is operated on demand at the Marine Rescue Coordination Centers.

The USCG search and rescue controllers run a software system entitled the Search and Rescue Optimal Planning System (SAROPS) to retrieve the top 1-m average or the top model layer (if thicker than one meter) of the ocean model currents. In Canada, Search and Rescue Centers run their own search and rescue software, the Canadian Search and Rescue Planning Program (CANSARP), also using ocean currents approximating the top 1 m of the ocean.

VALIDATION

For SAR purposes, output from GODAE ocean forecasts is best validated against observed surface drifter tracks as this best approximates drift of search objects. Two categories of drifters are used. Coast guard agencies use Surface Self-Locating Datum Marker Buoys (SLDMBs), which represent movement in the top 1 m of the water column. They are usually deployed on arrival at a search scene and are designed to last 5–25 days. These buoys are used by search coordinators to assess in near-real-time predicted ocean model surface drift accuracy on scene. The SLDMB tracks can also be used as a proxy for currents. The second drifter category is World Ocean Circulation Experiment (WOCE)-type drifters drogued at 10–15-m depth and deployed for scientific missions. WOCE

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drifters provide long drift tracks of a year or more.

Preliminary evaluations of both velocities and drift trajectories indicate that the Australian ocean forecast system BLUElink> is often able to capture the complex surface circulation in the Australian region. The East Australian Current (EAC) and Tasman Sea Experiment deployed drifting buoys into the EAC (Brassington et al., 2007b). Successes include capturing observed saddle points, which occur between eddies, and frontal structures. Failures include not reproducing trajectories in some fine-scale eddy turbulent regions and the position of the EAC separation. A BLUElink> reanalysis from 1992 to the present (Schiller et al., 2008) permitted Oke et al. (2008) to identify a root mean square (RMS) error with drifter observed velocities of about 0.2 m s^{-1} with a direction error of 20° at mid latitudes for the BLUElink> velocities versus drifter velocities. At low latitudes, the error decreases with decreasing eddy kinetic energy (Schiller et al., 2008).

Figure 1 shows an example of a comparison of various estimated current fields by JMA for the East China Sea. The MOVE assimilation-prediction system with a 0.1° grid is a significant improvement over the older Japanese COMPASS-K forecast system using a 0.25° grid.

Thorough validations of model drift against observed drift using data from a year or more are required to provide reliable statistical information about drift prediction error in ocean models. Barron et al. (2007) conducted one such global study for a period of one year. Their comparison of observed versus modeled drift in 29 global subdomains showed that a high-resolution (1/32°) data assimilative ocean forecast system reduced RMS errors compared to using either climatological currents or persistence. Here, persistence refers to computing drifter location after 24 hours from the initial drifter position and initial observed drift velocity at the beginning of the 24-hour drift period. Barron et al. (2007) showed one-day drift RMS errors ranging between 10 and 22 km of separation, which is similar to values seen in Figure 1 for the MOVE example after 24 hours of drift.

FUTURE NEEDS AND APPLICATIONS

For search and rescue drift applications, the greatest need is for short-term drift forecasts covering up to two days. After this time period, drift prediction error is so great that the predicted search area containing the target is too large to search effectively. Most standard global ocean model output is issued as daily averages (e.g., the MyOcean project). There is a need, however, for hourly output of surface currents to better resolve surface drift contributions from oscillatory currents such as tidal and inertial currents stemming from sudden

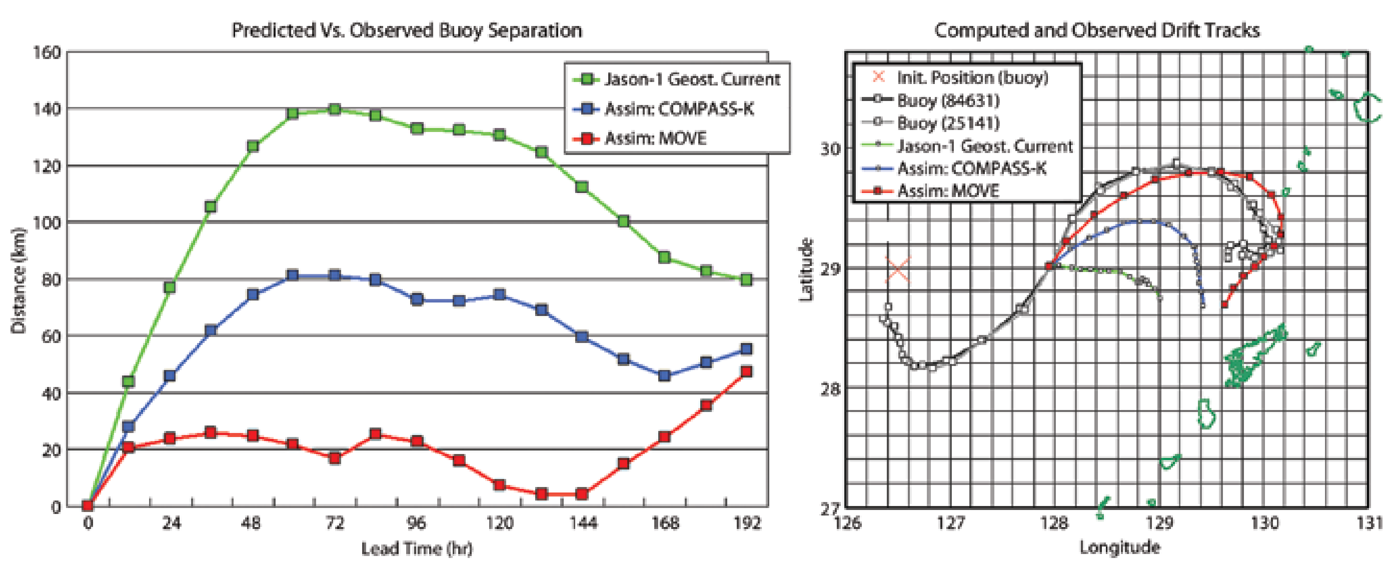

Figure 1. (left) Separation error over time between computed and observed drift using buoy 84631. (right) Drifter tracks are shown in grey and black with computed drift using Jason altimetry in green, COMPASS-K (1/4° resolution; Kamachi et al., 2004) forecast system in blue, and MOVE/MRI.COM-WNP (1/10° resolution; Usui et al, 2006) in red. The impacts of the assimilation result on the current field are substantial (Kaneko et al., 2009).

wind impulses and Earth's rotation. The sensitivity of drift trajectories to both sampling frequency and vertical resolution is critical for optimizing and guiding the servicing of ocean prediction to coast guards. Reducing the RMS error of short-term drift projections is important. Indeed, a decrease in the RMS error of one-day drift by a factor of two (from, say, 20 km to 10 km), decreases the search area by a factor of four (from, say, 1200 km^2 to 300 km^2). Such reduction in uncertainty has a huge impact on search effectiveness. Additionally, refining SAR object categories (i.e., behavior with respect to winds and currents) through field campaigns is an ongoing international effort. To take advantage of the results, it is necessary to agree on standards for the exchange of field data to ensure that the results can be used in the various operational SAR software systems. Common quantitative validation procedures are required to test GODAE product applicability for SAR applications. The differences between near-surface drifters and drifters drogued at 15 m need to be quantified using both in situ experiments and model simulations.

The trend for developing coupled atmosphere-ocean-ice forecasting systems such as the Gulf of St. Lawrence model run by the Canadian Meteorological Centre (Pellerin et al., 2004) will help with drift prediction by better resolving surface processes and winds over the ocean. Such coupled systems also improve the prediction capability for pack ice forecasting. Canada is looking to expand the system to cover the Northwest Atlantic and provide the Canadian Coast Guard with surface information on currents, winds, waves, ice distribution, and visibility from a single unified forecast system.

Ocean forecast systems are also used for operational forecasts for drifting ships as well as real-time risk analysis for ships along planned routes (Eide et al., 2007). Prior to the availability of GODAE systems, vessel captains used historical information on monthly averaged surface currents from pilot charts. The arrival of GODAE ocean forecast systems provides captains better information for choosing optimum routes.

Transitory events such as eddy activity in the Loop Current in the Gulf of Mexico (Figure 2) are not seen in climatological charts. Figure 2 demonstrates how forecasting such large-scale eddies can benefit ship routing. Proper use of forecast currents can reduce transit times by one to two hours per day, lowering fuel consumption by as much as 8%. In France, Collecte Localisation Satellite (CLS) uses near-real-time forecast surface current output calculated to provide a "best-current" route. It is an optimal compromise between favorable currents along route and total route distance. Two major maritime companies successfully tested these techniques at the beginning of 2008 and demonstrated improved ship fuel savings.

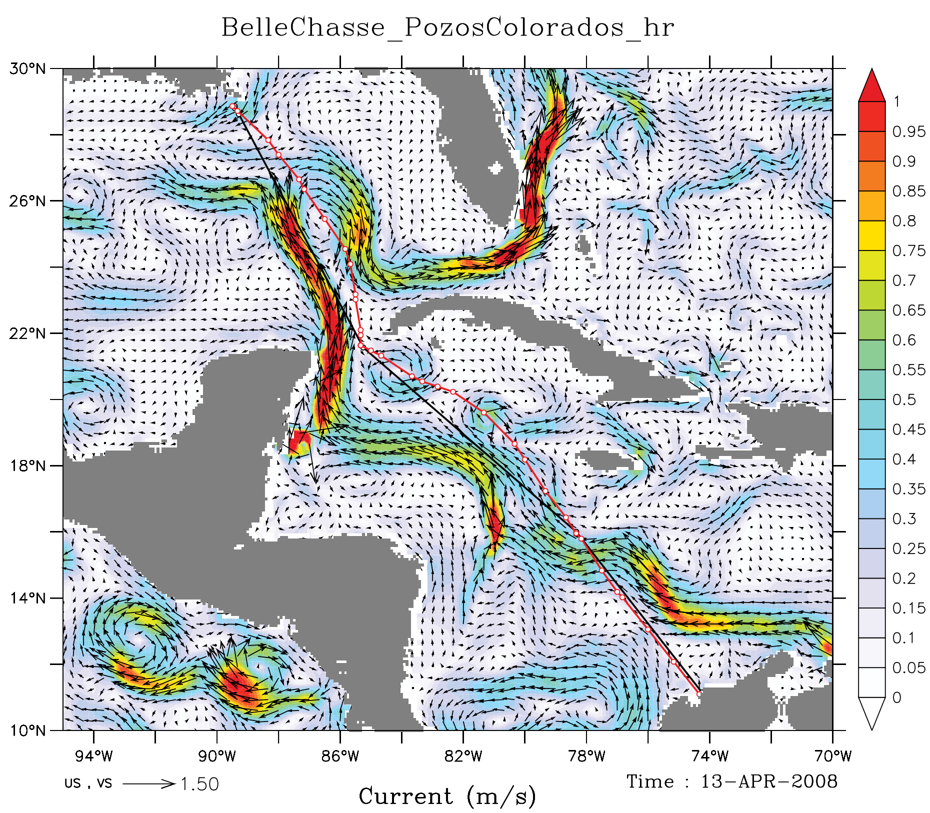

Figure 2. Ship routing laid over the Mercator current forecast for March 15, 2008. The black line represents the initial proposed north-to-south route of a cargo ship through the Gulf of Mexico by the shipping company. This initial ship route opposes strong currents. The recommended route (red line) takes advantage of strong, along-route forecasted currents, potentially shaving five hours off the 100-hour trip.

CONCLUSION

National frameworks exist for centralizing ocean environmental data for the agencies responsible for conducting SAR exercises. In Canada, all environmental data on the central server are additionally pushed to SAR coordination centers for local access. In most cases, coast guards modify the forecasted current fields based on their local experience and/or on-scene, in situ observations.

A common desire is to have oceanographic information with both coastal and global coverage. Standardized output will help coordinate search and rescue software approaches among various countries. Hourly surface current outputs from ocean forecast systems are required to better represent oscillatory motions such as tides. Furthermore, maps of error or ocean-model uncertainty would be useful within SAR decision-support software.

Comparisons of observed drifter tracks against forecasted drift are needed for a variety of drift objects, including drogued and undrogued buoys. In particular, the accuracy of one- or two-day drift forecasts needs to be understood and compared across different forecast systems. Model drift accuracy prediction by geographic domains is important as this error information can be used to correct known computed drift biases. Ongoing drift validation with various types of drifters, from GPS-tracked icebergs to ocean surface drifters, will help validate and provide confidence and experience in using ocean forecast output for safety and rescue drift applications.

Exchanges between oceanographers and end users, including coast guard agencies and industry, will help tune development and delivery of ocean forecast system output and improve end user applications of these forecasts. The trend toward using improved GODAE OceanView analyses will continue as this will help save fuel, increase efficiency, and improve safety.

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