"SAFETY AND EFFECTIVENESS OF OPERATIONS AT SEA"

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Abstract

GODAE's purpose is to provide an international coordinated development of operational oceanographic systems. As the ocean forecast systems progress, ocean forecast system performance is valued more heavily on the contributions it makes to activities such as safety, effectiveness and efficiency of sea going operations.

Herein we look at the applicability of the various ocean forecast systems in existence or in development to the improvement of safety and effectiveness of operations at sea. We focus on the applicability for both regional (shelf systems) and global forecast systems.

The paper reviews the requirements that ocean forecast systems need to possess for various safety applications at sea including: search and rescue drift calculations, oil drift calculation for containment-clean up, ice berg drift calculations, ice cover prediction and safety of offshore operations. Additionally a review of the decision tools used to make safety related decisions at sea is done along with their various oceanographic environmental input requirements. The need and mechanism for timely delivery of oceanographic information to various decision makers related to at sea safety and efficiency will be explored.

Introduction

Imagine you are lost at sea in a life raft with no GPS or ARGOS based tracking system. From your last mayday as you abandoned ship, personnel inside the search and rescue system (your countries Coast Guard or Meteorological Office) is busy calculating your potential drift and tasking search and rescue assets to come retrieve you. For this drift calculation task, reliable and accurate environmental forecasting is needed, in particular surface currents and surface winds. Additionally surface wave fields are also useful in that they can produce a component of surface drift called Stokes Drift which affects your displacement. Wave forecasts also help prepare the rescue crew.

Oceanographic current information related to safety is not only applicable to search and rescue where the information is used after an incident to retrieve a person in distress. Ocean current information is also important ahead of time to avoid distress or to make operations more efficient in time and fuel. Such applications include preventing ship

collisions with Ice Bergs, monitoring and towing icebergs close to important offshore installations, sea ice forecasting as well as ocean current forecasting for ship transit safety and efficiency.
A ocean forecast systems mature, their value will depend more heavily on enhancing applications such as safety, effectiveness and efficiency of sea going operations. In this paper we review the approach taken by various countries including Norway, France, Australia, Japan, United States of America and Canada in applying ocean forecast output to ensure a safe and efficient sea going operations. The objective of this paper is to highlight the current state of integration of ocean forecast systems into both search & rescue as well as safety and efficiency decisions at sea. We also elaborate on the various methodologies and the chain of operational institutional responsibilities in an incidence response where ocean current information is used.

The safety application need for ocean forecasting

Australia's extensive coastline ensures search and rescue is a frequent occurrence. The Australian Maritime Safety Authority (AMSA) is the national organisation responsible for the coordination of SAR activities and rely on a variety of systems to guide planning and conduct operations. Australia's territorial waters span a wide range of oceanic conditions: large continental shelf regions with large tidal currents; numerous narrow boundary currents; and open ocean geostrophic eddies, fronts and jets. The recent introduction of the first generation BLUElink operational ocean prediction system (Brassington et al., 2007) represents an opportunity to enhance the information available to the Australian Maritime Safety Organsation to conduct their operations.

In North America, Iceberg drift and Iceberg deterioration models are a safety necessity that require ocean model input. This is run by the International Ice Patrol (IIP) and the Canadian Ice Service. The USA has a Search and Rescue Optimal Planning System (SAROPS) that has been operational since early 2007 in all 51 United States Coast Guard Operational Centers. The Canadian Coast Guard runs simpler software for Search and Rescue Coordination called CANSARP (Canadian Search and Rescue Program) that has evolved for more than 20 years. Both systems use oceanographic model forecast input among other environmental parameters. Additionally sea surface temperature information is used in a survival model for predicting the duration that someone can remain alive at sea, which is important in search planning. In Canada ocean models are used for ship routing through ice. This allows the Coast Guard to plan in advance where to place it’s ships to ensure safe passage by Mariners through ice invested waters.

While there may be no ice in it’s coastal waters, France has three maritime traffic laden coastal areas: the English Channel/North Sea seaboard, the Atlantic seaboard and the Mediterranean seaboard. Roughly 45,000 ships pass every year through the English Channel and about 8,000 ship pass through Mediterranean French responsibility zones. In addition, France overseas territories in the Caribbean, the Pacific Ocean (French Polynesia, New Caledonia) and the Indian Ocean (Réunion, Mayotte). The French need for ocean forecast systems for improving safety and efficiency is thus global. Furthermore in France, commercial applications for safe and efficient ship routing have been developed and tested with industry.

In Japan, Search and Rescue Drift Prediction’s are in demand for the island nation with a strong fishing and sea based culture. An oil spill incident in 1997 provided motivation for better environmental forecast inputs and better drifts prediction methodologies. Drift prediction of ice Japan is done subjectively and awaiting to be coupled to the latest ocean forecast system

Safety and Efficiency Applications

Australia

Preliminary evaluations of both velocities and Lagrangian trajectories indicate that the Australian Ocean forecast system BLUElink on many occasions is able to capture the complex surface circulation in the Australian region. However, this is not true in all instances. In practice, a single bad forecast could be the one that was required. Understanding and explaining occurrences of drift forecast failure/error is necessary to build knowledge to advise search and rescue end users. One must note however that most oceanographic “surface” drifter’s are drogued at 15 m whereas search and rescue specific drifters deployed on scene by various coast guard agencies sample the top 1 m of the ocean which is more representative of search object drift. However coast guard specific drifters have generally short battery life and do not collect lots of data compared to longer lasting oceanography specific drogued buoys.

Australia's regional seas have not been well observed with particular deficiencies in the Tasman Sea, Great Australian Bight and North West Shelf (Summons et al., 2006). Adequately observing these regions does not occur through random drifters from other regions and thus requires specifically designed observational campaigns. The East Australian Current (EAC) and Tasman Sea experiment was designed to deploy drifting buoys into the EAC at a low cost and a high return (Brassington et al., 2007). This has been successfully achieved by the use of volunteer observing ships occupying the PX30 XBT line that transect the EAC at ~27S. In 2008 all six buoys deployed oberved the EAC and separated into the Tasman Sea to observe the frontal systems formed by the eddies in the region. Figure 1 shows four time snapshots of the BLUElink estimated sea level anomalies and associated surface currents together with the Lagrangian path traced by all available buoys in the region for a period of +/- 4days of the analysis shown. Successes include capturing a saddle point in Figure1b and the positions and structure of the front in Figure 1d. Failures include the fine scale eddy turbulent region in Figure 1a and the position of the separation of the EAC in Figure 1c. Regions where there is enhanced eddy-eddy interaction are highly nonlinear and lead to larger forecast error growth. However such interactions can be diagnosed and identified as regions of lower reliability. Analysis of the six buoys deployed in the 2008 campaign showed the position of the separation migrated southward and was consistently underestimated by the prediction system pointing to a bias in the ocean model.

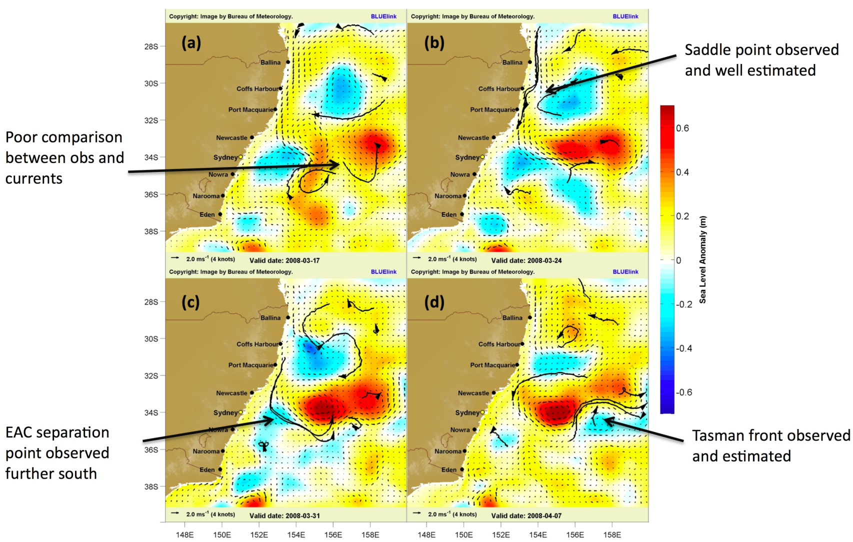


Figure 1: Lagrangian trajectories traced by surface drifting buoys in the Tasman Sea overlayed on estmated sea level anomalies and surface currents from BLUElink OceanMAPSv1.0b. Lagrangian trajectories are shown +/-4days to the ocean analysis dates (a) 17 Mar, (b) 24 Mar, (c) 31 Mar and (d) 7 Apr 2008.

The research and development of the BLUElink ocean prediction system has included the integration of an ocean reanalysis from 1992 to the present which corresponds to the period when the ocean was observed by satellite altimetry (Schiller et al., 2008). Among the many benefits of performing a reanalysis is the ability to quantify the statistical performance of the system against the historical archive of ocean observations. The reanalysis configuration is not identical to the operational prediction system, but nonetheless provides a guide to the expected prediction performance of the forecast system. Table 2 in Oke et al., (2008) shows the statistical comparison of BRAN2.1 with the drifting buoys in the Australian region divided into four quadrants. The performance can be summarised as RMSE|u| ~0.2 ms-1 over all four quadrants, the complex cross correlation is ~0.3 in the mid-latitudes with a directional error of ~20° and ~0.6 in the low latitudes with a directional error of ~5° . The reduction in performance in the mid-latitudes is consistent with the increase in eddy kinetic energy as shown in Figure 7 in Schiller et al., 2008. However, as shown in Figure 1 the statistical correlation is likely reduced by a smaller number of cases where the error has grown large and corresponds to ocean dynamics that is relatively less predictable.

In conjunction with the CSIRO and Australia's Bureau of Meteorology, the Asia-Pacific Applied Science Associates (APASA) have been incorporating the BLUElink ocean forecasting datasets into its operations. APASA is an organization of coastal engineers, marine scientists and oceanographers, based in Australia. APASA provides software and services to support ocean end users in the Australian and Asia-Pacific region, and in particular, for planning search and rescues and oil, gas and chemical spill predictions. APASA is closely affiliated with its parent company ASA based in the USA which develops and supports the trajectory models OILMAP, CHEMMAP and SARMAP. These softwares have been implemented in the USA to include NCEP atmospheric forecasts and the US Navy NCOM (Barron et al., 2006) ocean forecasts which are both global models and available as default options for APASA applications in Australia. APASA initiated a pilot project to help quantify the forecast model skill in predicting drogue trajectories to be used as guidance for employing BLUElink/NCOM forecasts into SAR operations and for oil spill predictions. The pilot project used the BLUElink OceanMAPSv1.0b forecast data and US Navy NCOM forecast data within trajectory models (OILMAP, CHEMMAP and SARMAP) and predicted the trajectories of ocean drifters over 5 day periods. A predicted trajectory example is plotted against the actual trajectory (see Figure 2a) and the maximum and average displacement over the 5 day period was calculated (see Figure 2b). This exercise was repeated for a number of 5 day periods with the same drifter buoy and for a number of buoys located in Australian waters during March 2008. The two notable kinks in the BLUElink trajectory in Figure 1 corresponds to the corrections introduced from the analysis cycle which is performed approximately every 3 days.

At present BLUElink data is only available as a daily average effectively filtering the currents due to inertial oscillations and has a vertical resolution of 10m over the top 200m. NCOM is available as a 6hrly product which is interpolated to 1hr and has a vertical resolution of 1m for the top cell which leads to significant inertial oscillation responses. The drogue of the surface drifting buoy has an operating depth of 15+/-7m and compares well with the forecast trajectory from BLUElink. The sensitivity of Lagrangian trajectories to both sampling frequency and vertical resolution are critical areas to optimise and guide the servicing of ocean prediction at the Bureau of Meteorology.

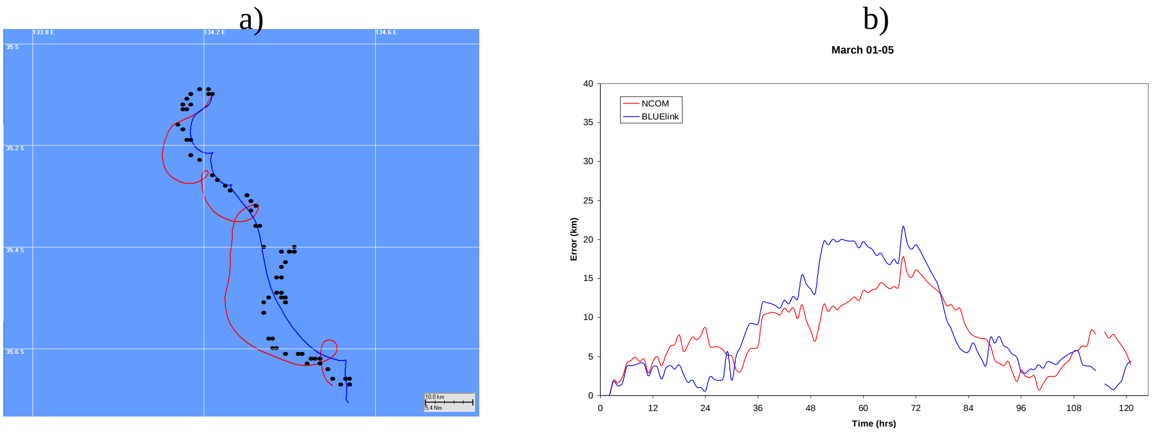


Figure 2: (a) Computed and observed (Black Dots) Drifter tracks for Buoy 16512 in the Great Australian Bight. The NCOM predicted trajectory is in red and the BLUElink predicted trajectory in blue. Drift dates are March 1st - 5th 2008 (b) Spatial error in kilometres from part a) for iNCOM (red line) and BLUElink (blue line) predicted trajectories.

The analysis of BLUElink forecasts for SAR and related applications is an ongoing activity. Analyses to date of the first generation BLUElink prediction system have provided very encouraging and competitive results. BLUElink2 a follow-on project will introduce an upgrade to the current operational system in late 2008/early 2009 to improve the initialisation and atmospheric fluxes which has been demonstrated in trials to improve the skill of surface currents. BLUElink2 will also implement a new prediction system in 2010 that will include a number of major modification including a larger region of eddy-resolving resolution and enhanced vertical resolution. Forecast data products are also expected to increase in temporal sampling to accommodate short range applications such as SAR.

United States Search and Rescue Applications

SAROPS relies primarily on regional and global model output products. Real-time data assimilating ocean models presently used by SAROPS include: US Navy's global NCOM; NOAA North Atlantic HYCOM model RTOFS; NOAA NOS five Great Lakes models and four PORTS models. Tidal current products are also available to SAROPS: ADCIRC for east and west coasts of the USA, and tidal current models for six coastal / harbor regions. SAROPS also has access to two historical static sea current files: the Mariano ship drift seasonal currents and the Florida Current files for the Florida Straits region.

Surface current fields from HF radar are available to SAROPS. Twenty-four hour statistical forecasts based upon the HF radar current provide the necessary forecasted capabilities for SAROPS users along the continental shelf from Cape Hatteras to Cape Cod.

The USCG surface and air assets deploy Self-Locating Datum Marker Buoys (SLDMBs) in response to SAR cases. SLDMBs are CODE/Davis surface drifters that report 30-minute GPS positions via the Argos System and last up to 30 days. The SAR controllers use SLDMBs in real time to assess ocean model surface drift accuracy and choose which model performs best for the given incident. If several SLDMBs are deployed during a SAR case, SAROPS can provide an objective analysis surface current field from the drifter tracks.

The wind fields used by SAROPS include NOAA's Global Forecast System (GFS), North America Mesocsale Model (NAM), the National Digital Forecast Database (NDFD), and the Great Lakes forecasts; and the US Navy's NOGAPS winds.

SAROPS is run by United States Coast Guard Search and Rescue (SAR) controllers. The software is distributed and available to other countries coast guard organizations. The first half of SAROPS is the SAR scenario set up and drift trajectory model which requires ocean forecasts. The second half of SAROPS is the resource allocation portion, which also requires environmental parameters to characterize searching effectiveness. After a scenario or set of scenarios are created by the SAROPS user, an Area of Interest is created around the outside bounds of the scenarios accounting for 3 knots of drift in all directions over the period of the scenarios. The AOI is easily adjustable by the controller to either extend or limit its extend. The AOI defines the latitude - longitude box for that SAROPS run. SAROPS then makes request to an Environmental Data Server (EDS) for sea surface currents and surface winds products for latitude - longitude time cubes defined by the AOI and SAR scenario time line. The EDS has already pre-accessed a number of model now and forecasted sea surface current and winds products, archived those products, aggregates in both time and space the necessary fields requested and provides to SAROPS in a single common format the data fields.

With the sea surface currents and surface (10-meter) wind field retrieved and in a common NetCDF format, the simulator portion of SAROPS uses a 20-minute time step to calculate the drift displacements for each SAROPS thousand particles. During the scenario set-up, the user selects 1 to 4 SAR drift objects for which SAROPS has the downwind and crosswind leeway rate equations from Allen (2005) plus 19 new additional categories. SAROPS assigns randomly a spread of leeway equations for leeway category, so that each particle is moved by its own unique set of leeway equations based upon the underlining quality of the leeway data and whether the selected category is broad or narrowly defined. At each time step the nearest 3 current and wind points are inversely weighted by distance and used to estimate the drift for that particle. The sea current data points are used directly and wind are used via the leeway equations. Simple random flight models of dispersion are applied to the wind and current fields. However, these dispersion models have simple high or low parameters for open ocean or continental shelf conditions.

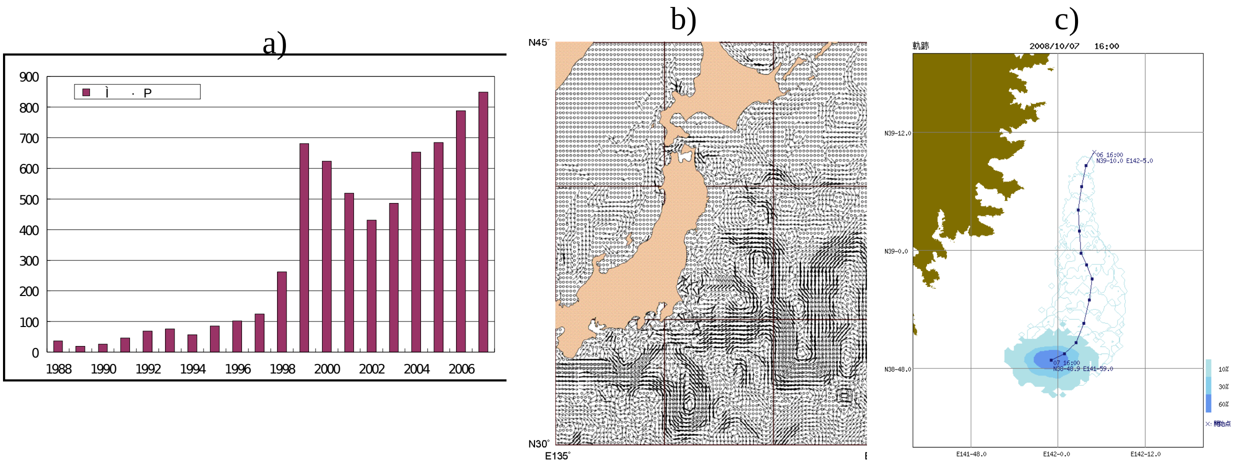
For drift prediction he US Coast Guard makes use of top 1m of model or the upper model layer (if thicker than 1m). Additionally 10 M wind speeds are used. For determining searching effectiveness of the search plan a variety of parameters are needed: Surface visibility, Sea state, Cloud ceiling and wind speed. For determining survivability of a person in distress, Sea Surface Temperature is required, Sea State as well as humidity.

Drift Prediction in Japan

In Japan, the Coast Guard (JCG) is divided into eleven geographic regions to facilitate operations. The drift predictions for search and rescue and for the oil spill responses are carried out at the eleven Regional Coast Guard Headquarters, but through a central server in Coast Guard Tokyo headquarters. Large volumes of oil covered Japanese coastlines from the 1997 Nakhodka tanker accident in the Sea of Japan, triggered significant opportunities for surface drift prediction by the Regional C.G. Headquarters (RCGHs) as evidenced in Figure 3a. Figure 3a shows the number of drift simulations undertaken by RCGHs for all of Japan with a noticeable increase following 1997 and featuring 850 drift prediction events for 2007. Japanese Coast Guard developed its drift prediction system in 2000. Surface drift calculations have as environmental inputs; tidal current, ocean current, and wind-driven current. And, the leeway drifts are also calculated by wind data. A Monte Carlo technique is employed to generate an ensemble for the various uncertainties.

The Japanese Meteorological Agency (JMA) pushes the ocean current analysis of its assimilation system, Multivariate Ocean Variational Estimation system (MOVE) to Japanese Coast Guard Headquarter servers (Kaneko et al., 2008).. JCG Headquarter in Tokyo subsequently tunes the ocean current forecast from JMA using observed vessel ADCP data, satellite altimeter data, sea surface temperature data, HF radar data etc. Because most search and rescue cases occur near the coast, modifications at near-shore area are carried out carefully. An example of modified ocean current filed is shown in Figure 3b. Coast Guard modified ocean current data are updated and transferred daily to a central Drift Prediction Server, to which the 11 Regional Coast Guard Headquarters access to calculate drift scenarios.

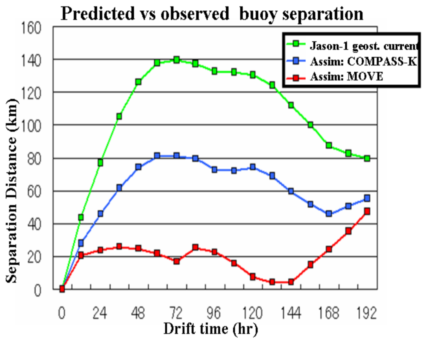
Figure 3: a) Annual total number of drift prediction carried out by the Japanese Coast Guard. b) Example of ocean model current field on the east part of Japan for October 5, 2008 modified by the Japanese Coast Guard with observations near the coast. c) A Japanese Coast Guard example of Surface Drift Calculation output for a Life Raft. The symbol X denotes the starting point of



When a distress situation occurs at sea, the coast guard operators access the Drift Prediction Server and input the required parameters, such as, the specifications of objects, the initial position and time, etc. Leeway drift is calculated from wind speed. Stokes drift is not taken into account and to some extent, accounted already in the Leeway drift. Figure 3c is a surface drift calculation example for a life raft. The area of the drifting object is generated using a Monte Carlo technique. When the RCGHs obtained current and/or wind data observed by patrol vessels or drifting buoys within the distress area, the operators are able to input this new environmental data and recalculate the trajectories of the drifting objects. The search areas are decided based on the result of drift predictions.

There are two options for current input on drift; a geostrophic current field derived from satellite altimetry and the latest data assimilative ocean model output from the Japanese Meteorological Agency. In general for drift prediction, the Japanese Coast Guard operates the prediction with the lead time of 2 to 3 days. The Japanese Meteorological Agency performs the prediction with the lead time from 3 days to 1 week.

The effects of various current fields on SAR drift prediction are shown in Figures 4a,b. Sensitivity of the current fields if shown from satellite derived geostrophic current, the old operational ocean assimilation system COMPASS-K (0.25 deg resolution, Kamachi et al. (2004)) and the new operational ocean assimilation system MOVE/MRI.COM-WNP (0.1 deg. Resolution, Usui et al., 2006) to observed buoy drift position (Kaneko et al., 2008). Significant improvements from the assimilation system MOVE are evidenced by Figure 7.



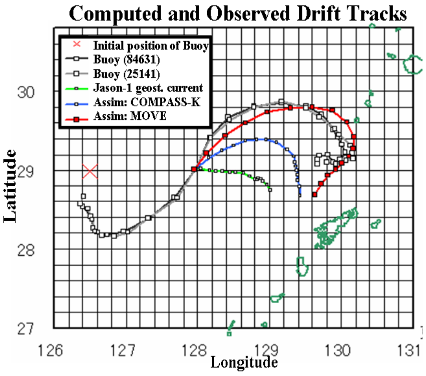


Figure 4: Computed error comparison (left) and drift track (right) for surface buoy drift computed from; 1. satellite altimeter derived geostrophic currents (green), 2. former operational ocean assimilation system COMPASS-K (0.25 deg resolution, Kamachi et al. (2004)) in blue and 3. the new Japanese operational ocean assimilation system MOVE/MRI.COM-WNP (0.1 deg. Resolution, Usui et al., 2006) to observation buoy position (Kaneko et al., 2008). The impacts of the assimilation result (current field) are very large.

The eddy resolving model reproduces strong eddies which impact trajectory drift prediction. The Japanese Meteorological Agency has started to examine ensemble prediction with the assimilation output. The prediction of ice cover prediction is done by a subjective method. The Japanese Meteorological Agency started examining use of output of the ocean assimilation system MOVE/MRI.COM-WNP by the Japanese Coast Guard for search and rescue applications. Now in the operational model, satellite observed (geostrophic) current is adopted. Near future JMA will adopt assimilation/prediction result current.

FRANCE

Surface Drift Calculations for search objects and marine pollution

The French response to accidental marine pollution is organized by the Polmar Instruction, applicable to discharges of any substance likely to damage the marine environment. The structure in charge of operations comprises representatives of all the Government Departments concerned and appropriate technical bodies, in particular Cedre (Centre for Documentation, Research and Experimentation on accidental water pollution) and Meteo-France. Meteo-France is in charge of met ocean support and slick and object drift predictions. The oil spill forecast system has been developed by combining the oil chemistry expertise at Cedre with the weather and ocean forecasting and modelling expertise at Météo-France into a robust operational service maintained by Météo-France.
The drift forecast system consists of three components: an object/oil spill model, geophysical forcing data and a user interface. At the core is the object/oil spill drift model MOTHY, which calculates the drift of floating objects or oil spill. Geophysical forcing data are perhaps the most decisive component of the system. The user interface consists of an on-call duty forecaster, available 24/7/365, and a web service, with which a user may visualize a forecast run, as well as download data. The system is operated on demands of Cedre for support of the oil spill fighting operations and on demands of the Marine Rescue Coordination Centres for support of the search and rescue operations. About 500 interventions each year are conducted with an average response time under 30 minutes.

The Meteo-France drift prediction system results over many years' shows that the most critical component for drift forecast skill is the accuracy of the applied ocean current model. Since prognostic ocean models are less mature (and accurate) than atmospheric models, a major effort has been put into obtaining the best possible current data. In the MERSEA Integrated, Meteo-France has investigated the benefits of applying global to basin scale ocean model data from the

MERSEA forecasting centres. Several of the MERSEA forecasting systems are major components of GODAE: Mercator (global, North Atlantic, Mediterranean sea), FOAM (global, North Atlantic), TOPAZ (Arctic Ocean), MFS (Mediterranean Sea). The implementation consists of a multi-source forcing data pre-processor that facilitates access to ocean model data sets from MERSEA and other providers. This approach has a number of advantages: it allows a global service, when combined with global atmospheric from ARPEGE/IFS models; it allows a "mini-ensemble" of forecasts when several data sets cover the area in question; the same pre-processor may be used to force similar drift models for floating objects and ships, and allow consistent coupling of the drift models (e.g., oil spill from a drifting tanker). Access to external data is either by secured copy or routine ftp delivery.

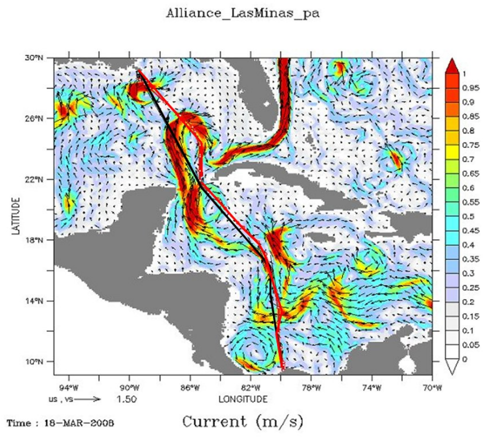
MOTHY only uses ocean model data from a single depth – typically at the base of the Ekman layer – in the place of a climatological background current, and calculates the main drift component from the wind and tide data. It parameterizes the upper ocean drift from wind speed using a sophisticated Ekman type scheme.

Safer and Efficient Ship Operations

While surface drift calculations are important in determining responses to environmental mishaps as well as accidents at sea with drifting survivors, ocean forecast are also starting to play a role in making operations at sea more efficient and safer.

Prior to the availability of GODAE systems, vessel captains used pilot charts that contained historical information on monthly averaged surface currents from which to choose an efficient sea route. These pilot charts were created more than 30 years ago based on ship board observations providing sparse and inaccurate data. With the arrival of GODAE ocean forecast systems, with data assimilation from satellite altimeters, oceanographers have the needed expertise to help sea captains better choose their routes based on real-time analysis of ocean currents.

a)



b)

Figure 5: a) Ship routing overlaid over the MERCATOR-OCEAN current forecast for the 15th of March 2008. The black line represents the initial proposed route of a cargo ship from North to South through the Gulf of Mexico by the shipping company. This initial ship route opposes strong currents (black line). The red line is the route recommended by CLS (in red) taking full advantage of the MERCATOR-OCEAN current forecast to ensure that ship travel is with strong currents rather than against strong currents. The ship captain thus saved 5 hours out of the 100 hour trip, thus saving 5% in fuel and ship time. b) "The Bro Catherine" with 45,000 deadweight tonnage, an example of a ship that participated in testing the use of MERCATOR-OCEAN ocean forecasts currents through value added CLS decision systems. This vessel serves Brostrom AB's chemical tanker shipping operations

Choosing optimal along currents paths, allows vessels to either increase speed with no additional engine power or to reduce engine power while still maintaining speed and respecting required time of arrival and docking time slots. Proper use of real time analysis currents can permit a sea captain to reduce transit times by 1-2 hours per day leading to efficient fuel consumption with up to 8% savings in fuel. Over the course of year, 8% fuel savings can be a substantial contribution to a shipping company's bottom line as well as a benefit to the environment.

In France, Collecte Localisation Satellite (CLS) uses real-time surface current data calculated from both satellite observations (CLS SURCOUF product) or based on forecasted model current data (using the MERCATOR-Ocean ocean forecast output) to calculate the "best-current" route, or the quickest route to reach the arrival port, for a given ETD (Estimated Time of Departure), vessel calm weather speed and departure port. Current speed is taken into account for the calculation of the average vessel speed along the route. The route takes advantage of real-time ocean currents as well as the extra distance associated with the route. The "best-current" route is therefore the best compromise between favorable currents and distance.

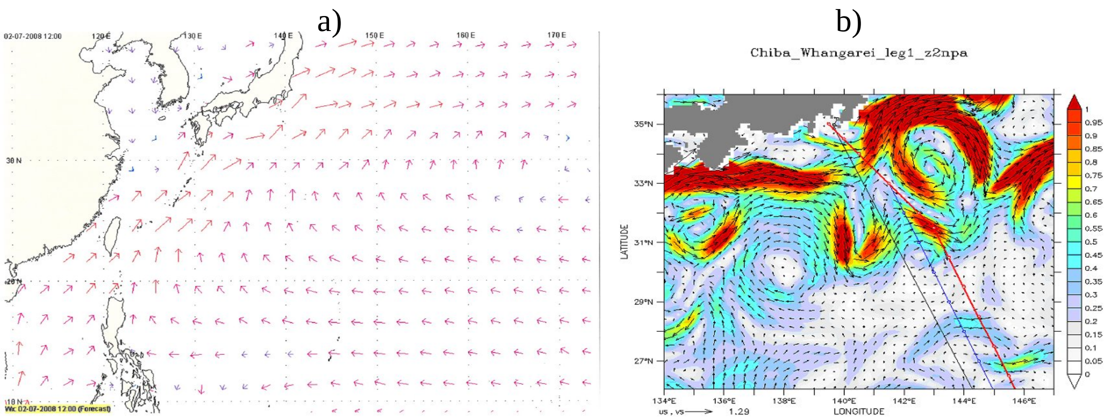


Figure 6: a) Climatological pilot chart based on historical observations for the Chiba (Japan) to Whangarei (New Zealand) route. This is the primary tool used by captains when selecting a route. b) Real-time ocean surface currents forecast by MERCATOR-OCEAN along the Chiba to Whangarei route. Ship is traveling North to South with initial route in black, and recommended route (following strong along track currents) in red. We note the presence of eddies in the real time analysis versus the "climatological" pilot chart.

These innovative techniques have been successfully tested with two major maritime companies at the beginning of 2008. Scientists and engineers at CLS worked with vessel captains to study and qualify the benefits of using ocean observation products for marine transportation. Together they validated a best fuel economy routing approach for marine transportation, based on real-time, high quality, ocean current data. On every route monitored during this test phase, when the vessel followed the recommended route there bye navigating on advantageous currents, significant reductions in transit times were posted. Concomitantly this implied considerable reductions in ship fuel consumption.

CANADA

The Canadian Coast Guard is responsible for coordinating all search and rescue activities over water. Additionally coast guard looks at anticipating safety problems at sea particularly related to ice and iceberg conditions. Environmental information is thus vital for Coast Guard to conduct it's safety and search and rescue operations. Oil spill drift in Canada is a responsibility of Environment Canada while coast guard is responsible for the environmental response to an oil spill.

Currently the Canadian Coast Guard uses it's developed software CANSARP to produce a search plan for tasking assets such as planes, helicopters, ships to search in a prescribed manner. The Search and Rescue coordinator runs the drift scenarios on a work station next to his/her coordinator's desk. CANSARP has been adapted to read in netcdf for ocean current products and grib wind files for Atmospheric products. The inputs used by CANSARP are: surface currents, wind, observed drift tracks and observed wind. Other information is also obtained such as target information from sea surface temperature, Radar Sat Satellites, and ancillary data such as significant wave height and observations regarding fog. However these later data are not used in CANSARP, but in other supporting decisions tools for maritime situational awareness and survival calculation tools.

Currently the drift theory used in CANSARP stems from post second world war theory that has been computerized. The MIN-MAX method for drift essentially adds the components of wind driven currents, non wind driven currents and wind drag (Leeway) onto target drift. Since wind effects on an object can vary, several different angles of Leeway drift due to wind are accounted for. Diffusion in the MIN MAX method is assumed homogeneous, and as the particle drifts, the search area increases in a circular fashion. The search area comprises of all regions encompassed by the several different runs (Figure 7a). Figure 7 shows the MIN-MAX validation on 1 drifter of the Newfoundland coast. The red line is the mean computed drift from the various runs. The blue line represents the observed buoy track. The impact of running with high resolution winds and in-situ analysis of surface currents versus climatology currents is evidenced in Figure 7.

Canadian Coast guard is currently enhancing CANSARP to use a random walk Monte Carlo method that can take in horizontal shear in ocean forecast systems and produce potential drift distributions that are representative of what's observed.

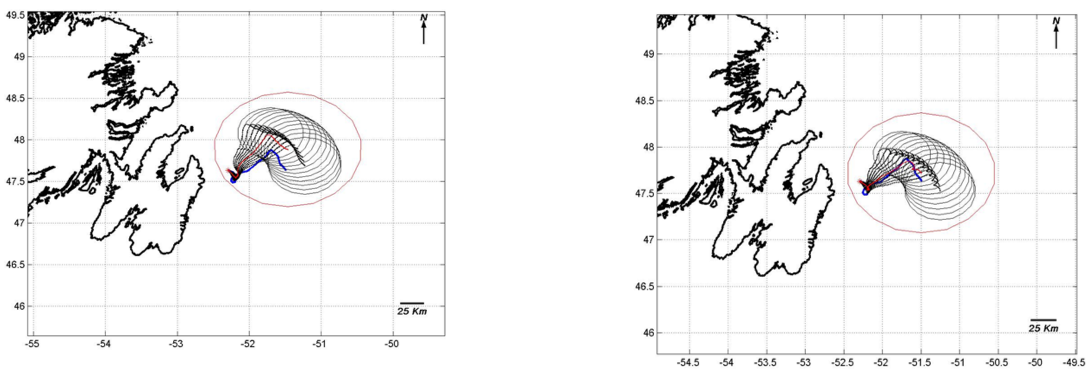


Figure 7: Min-Max CANSARP simulations for Eastern Newfoundland with climatology (a) , and (b) with daily forced regional forecast system downscaled from MERCATOR-OCEAN global model output. Blue line is buoy drift and red line is computed mean drift from MIN-MAX method. Red circle shows "designated search area.

Current research for the Canadian Coast Guard is in the development validation methodologies and software to use a data base of observed drifters compared to computed drift derived from reanalysis projects. This will provide a quantitative validation of the ability of GODAE global and regional forecasts to provide useful environmental inputs for search and rescue.

The Canadian Coast Guard also aims to anticipate issues arising from Marine Traffic through at times in-hospitable waters. On the east coast of Canada, a primary concern is the prediction of iceberg drift and pack ice. The most advanced system currently in Canada for applications for ship routing using operational ocean and ice model output, is the system for the Gulf of St. Lawrence

Global Observatory, a joint effort of Environment Canada and DFO. Here short term forecasts are initialized with ice distribution obtained from satellite derived ice analysis at the Canadian Ice Service. The model then forecasts ocean and ice conditions over a three day period. Maps of forecast ice distribution allow the coast guard to plan for the best and most efficient ship route. Coast Guard ice breaking services then manage safety along the prescribed "ice free" route.

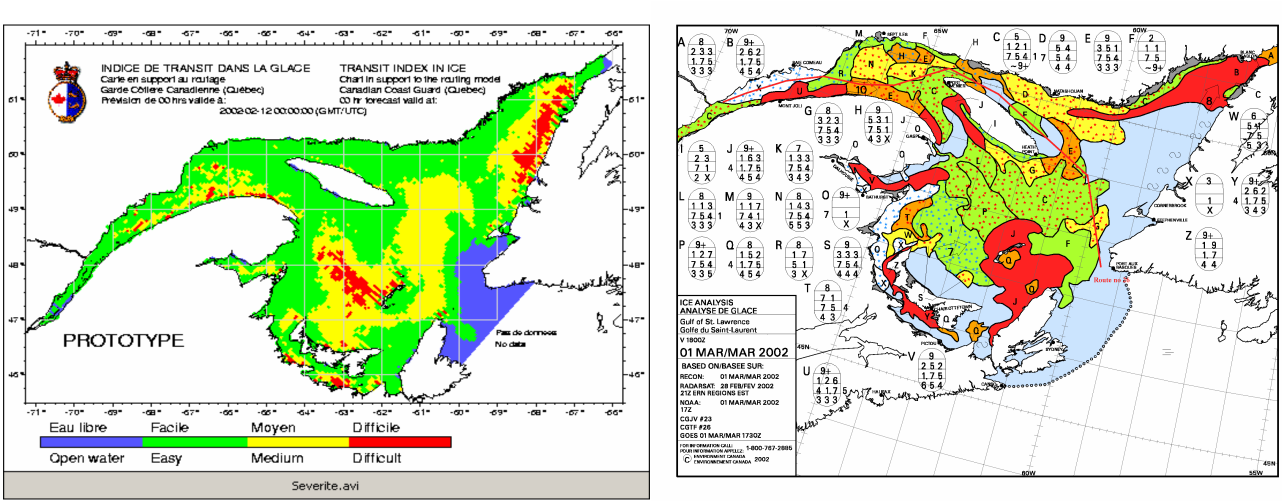


Figure 8 a) Ship passage effort index forecast from the Canadian Gulf of St. Laurence coupled Atmosphere Ocean and Ice forecast system for predicting transit times through the Gulf of St. Lawrence during the ice season. b) Canadian Ice service analysis chart with optimal ship route in red.

The work in progress is to expand on the Gulf of St. Lawrence operational oceanography systems to create a data assimilative coupled ocean ice and atmosphere forecast system for Eastern Canadian waters that is nested within a global ocean forecast system. The east coast forecast system will then provide surface parameters for search and rescue (wind, surface currents, SST) drift and survival calculations. Additionally the system will permit better prediction of parameters such as fog and ice cover that are useful in managing marine activities including search and rescue.

CONCLUSIONS

A common theme in this study has been the centralizing of ocean environmental data for the agencies responsible for conducting search and rescue exercises. The specifics of providing delivery of environmental data to search and rescue units vary. However, central to all national efforts is a need for: standard software tools for exploiting better environmental forecasts, a national protocol for using environmental inputs for safety purposes, a national approach for collecting, archiving and disseminating the environmental information required to conduct these operations.

The United States Coast Guard uses an Environmental Data Server (EDS). The EDS downloads the environmental inputs and archives the nowcast/analysis fields, storing the most recent forecasted fields at the USCG's Operational Systems Center in Martinsburg West-Virginia. Environmental data is accessed by XML request from the SAROPS user system which defines the zone and time period for which the environmental data is needed. Thus only the data required is aggregated and returned in NetCDF format to the end user.

By contrast in Canada the all environmental data is pushed to a Central Coast Guard server at the Canadian Coast Guard College in Sydney Nova Scotia. All this data is then delivered to individual CANSARP work stations at the various Search and Rescue Centers in Canada. All data is thus duplicated on all CANSARP work stations in Canada. Furthermore, Japan's method is interesting as the actual drift calculations are performed in a central computing facility in Tokyo, yet run by search and rescue coordinators across the country. All data is thus located in the same facility where the search scenarios and drift calculations are run.

In France, the environmental inputs are stored in Meteo-France database. They include all Meteo-France/ECMWF models and routine deliveries by ftp (MFS) or secured copy (MERCATOR). These data are updated twice to four times daily to yield up to 120-hour forecasts. In addition, analysis fields for the past nineteen days are retained in a fast archive so that events starting up to nineteen days in the past may be readily simulated.

Within the last two year's Canadian Coast Guard is adding output from the MERCATOR-OCEAN north Atlantic model output to it's CANSARP development prototypes. A desire is to have oceanographic information spanning near shore shelf areas to global coverage for helping other countries with distress incidents is also present.

Using operational oceanography systems for drift prediction purposes indicates various ocean model outputs show large differences in the predicted current fields. The often large discrepancies between the predicted currents in the open ocean reflects the fact that the current field is dominated by unstable mesoscale dynamics (eddies, meanders); these processes are difficult to predict, yet they have an enormous impact on individual observed drift. Nearer the coast, the presence of land and the continental slope tends to align mean currents along isobaths which is easily replicated in numerical ocean models. However in coastal areas, length scales of eddies and instabilities diminish due to the shallow water effect complicating assimilation of data. The most accurate results are obtained when applying currents from a local, fine-scale ocean model nested in basin-scale forecast system. The increase in resolution refines the positioning of the mesoscale eddies where the current are more intense and narrow. Assimilation in these regional systems is provided they improve the surface drift fields through assimilation. Desired improvements include the assimilation of observed drifters in the area, assimilation of ground based HF radar system currents and of course better high frequency atmospheric wind fields.

Desired improvements for search and rescue also include how the environmental inputs are processed into a search tool or decision making tool. What is apparent is that for the use of drift prediction, all environmental inputs should be bench marked using standard protocols and data sets to provide a skill score for search and rescue purposes of the ocean forecast system for instance and for the drift methodology. The use of long duration global and regional reanalysis runs are required for benchmarking the ocean forecast systems, atmospheric forecast systems etc… to access all collected historical data on observed drift for validation. These reanalysis studies for search and rescue validation also help understand geographical distribution of observed model/data error. Additionally this error information can be used to correct computed drift from the forecast system, particularly with the use of Monte Carlo techniques. The United States Coast Guard is looking at improving it's random flight dispersion model.

Drift validation with observed drifters also will help validate new drift methodologies as the research matures. With the complexity ocean prediction systems it is likely that a trained forecaster will be essential to help interpret the information in real-time. Various applications for safety and efficiency at sea are emerging. It is important that there continue to be good exchanges of experiences between experienced oceanographers and end users such as the coast guards of the world, shipping companies and oil companies to optimize at sea operations from both a safety and efficiency perspective.

Herein we have reviewed a few of many applications where data assimilative ocean forecasts are used for gaining efficiency in marine operations. We have also reviewed some of the search and rescue needs and applications for various coast guard agencies in the world. The trend towards using better ocean GODAE/OceanView analysis must continue as this will help save fuel, increase efficiency and safety. It is important that these improvements in operational efficiency and safety be documented and highlighted as these applications will increase in importance for validating the utility of GODAE/Oceanview ocean forecast systems. Increased efficiency such as in routing also increases safety as more precise knowledge of the ocean leads to better decisions which is most appreciated under potentially dangerous circumstances.

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