An ocean forecasting system for the east coast of Canada

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1. Introduction

The ocean off Canada's Atlantic coast is a region of vital economic importance to Canada. On the Grand Banks and Scotian Shelf, two oil and gas fields have been in production since the mid-1990's. Several seaports along the coast are the destinations of marine shipping and sightseeing cruises from the U.S. and Europe. The area is a pathway to the Great Lakes through the St. Lawrence Seaway. Fisheries are a major industry of the region. To plan and maintain safe offshore operations and to respond to emergencies, reliable forecasts of marine conditions are needed. To meet this requirement, an ocean forecasting system has been developed at Bedford Institute of Oceanography (BIO) to provide daily forecasts of surface currents, waves, tides and sea-ice in the coastal waters of eastern Canada including the Labrador Shelf, N.E. Newfoundland Shelf and the Grand Banks.

2. Forecast models

The BIO Ice-Ocean Forecast System implements three separate models - a coupled multi-category ice model and the Princeton Ocean Model, a Grand Banks tide model and a spectral wave model. The ice/ocean model covers the entire Labrador Sea and its surrounding shelves (Yao et al., 2000). Sea-ice is coupled to POM using the coupling scheme of Mellor and Kantha (1989). For the ocean model, three-dimensional mean temperature and salinity fields for each season are constructed from an objective analysis of historical data archived at BIO using an iterative difference-correction methods with topography-dependent radii of influence on a 1/6 by 1/6 degree grid. At the open boundaries, temperature and salinity are prescribed using the seasonal data set. In the interior, there is no constraint on the temperature and salinity fields. Sea surface elevation at the open boundaries is specified in such a way that the resulting volume transports are consistent with observation. In particular, 35 Sv is used for the volume transport into the Labrador Sea south of Greenland. Fig. 1 shows the vertically averaged mean current field for summer. The main feature of the circulation includes a cyclonic circulation in the northern Labrador Sea, the Labrador Current along the shelf edge of the continental shelf, weak mean currents on the Grand Banks, and the topography following North Atlantic Current.

The tidal constants used to compute tidal elevation and tidal currents are generated from the three-dimensional tide model of Han (1996). The model covers the Grand Banks, and includes the major semidiurnal (M2 , S2 , N2) and diurnal (K1 , O1) tides. Tidal elevations are specified at the open boundary on the basis of Petrie's (1987) model output and satellite altimetric measurements. The model results are validated with available water level and current data from coastal tide gauge and offshore bottom pressure gauge stations, and moored current meters.

The wave model used in the forecast is a spectral wave model (Komen, 1984). The model domain covers a large part of the North Atlantic, approximately 20ºN to 65ºN, 80ºW to 20ºW. Sea-ice areas are treated as land if the ice concentration and thickness are greater than 70% and 0.10m respectively. Work is underway to replace the spectral wave model by a more advanced wave model, SWAN, which includes shallow water effects, reflection at the coast and other processes.

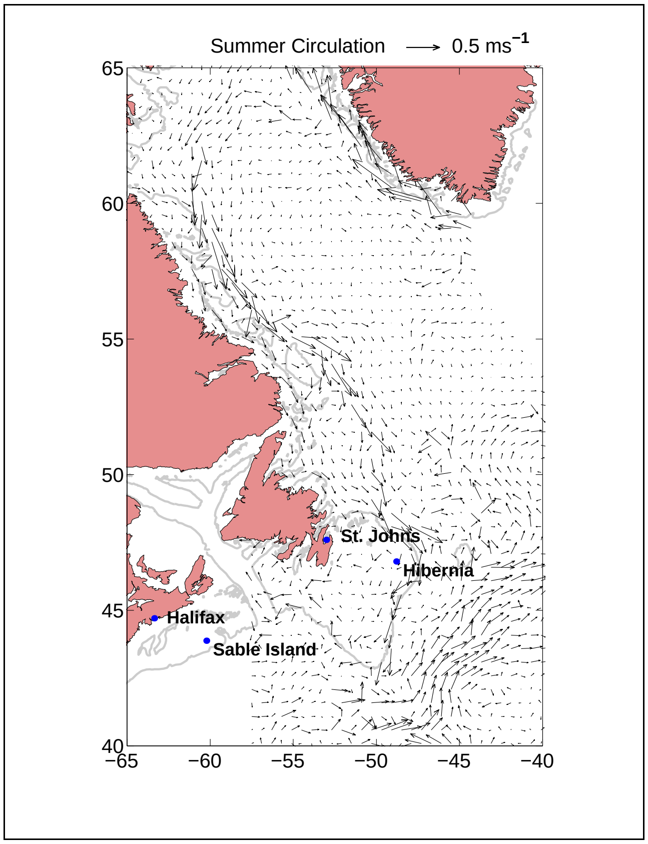

Fig.1 Vertically averaged mean current for summer. Hibernia and Sable Island are the sites for offshore oil and gas production. The grey line is the 200-m isobath.

3. Forcing fields

The forcing fields were calculated and interpolated to the model grid and time steps from six-hourly forecast meteorological parameters provided by Canadian Meteorological Service. The parameters include wind speed and direction, sea level pressure, air temperature, dewpoint temperature, precipitation and cloud cover. Short-wave and long-wave radiations are calculated from standard formulas. For wave, sea level and current forecasts, the most important forcings are winds.

4. Forecast runs and display of outputs

All forecasts start at 1200 UTC for a maximum period of 48 hours. The ocean model is run continuously. The temperature and salinity fields are constrained by the fixed boundary conditions. During winter where sea-ice is present, ice concentration and thickness are updated every day at -24 hours forecast time with the daily digital ice maps provided by Canadian Ice Service. The wave model is started from rest daily at -24 hours to calculate initial conditions for the 48 hour forecast.

Selected model outputs from the forecast runs are plotted and displayed at the website: http://www.mar.dfo-mpo.gc.ca/science/ocean/icemodel/ice_ocean_forecast.html. These includes

(a) Time series of water level at St. John's, Newfoundland and Hibernia oil production site on the Grand Banks (see Fig.1 for location). The water level is the sum of tidal elevation and sea surface elevation calculated from POM relative to the seasonal mean.
(b) Maps of significant wave height, wave direction and period at 0, 6, 12, 18, 24, 30, 36, 42, 48 hours.
(c) Animation of wave fields for the 48-hr forecast period.

(d) Time series of significant wave height at Halifax, Sable Island, St. John's, and Hibernia.
(e) Trajectories of surface currents over the Grand Banks in the 48-hr forecast period. The surface currents are represented by the sum of currents from POM averaged over the top 10 meters, and tidal currents from the tide model.
(f) Maps of sea-ice concentration and thickness at 0, 12, 24, 36, 48 hours.
(g) Animation of seasonal ice concentration and thickness using ice fields at 0 and 12 hours from the beginning of the ice season.

Figs. 2 and 3 are examples showing the wave fields and surface drift trajectories on the Grand Banks.

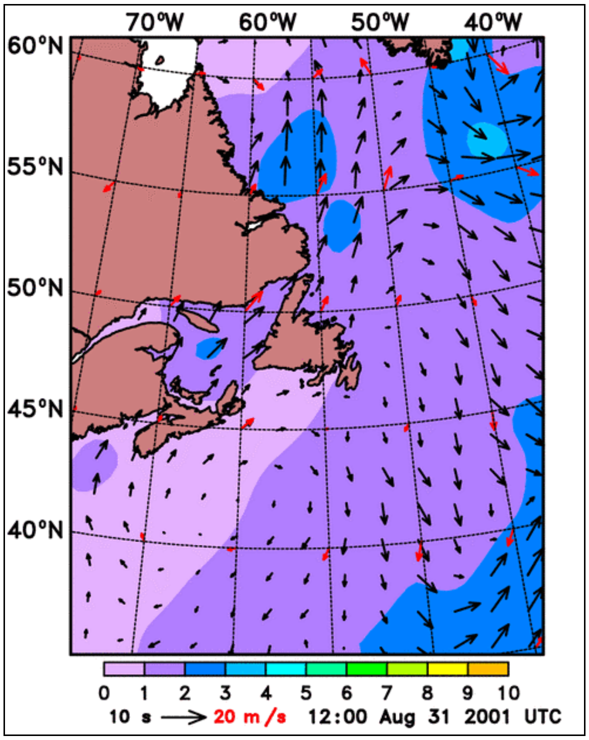

Fig.2 Significant wave height (color coded), wave direction and period (black arrows) for the northwestern North Atlantic at 1200 UTC, August 31, 2001. The red arrows indicate surface wind.

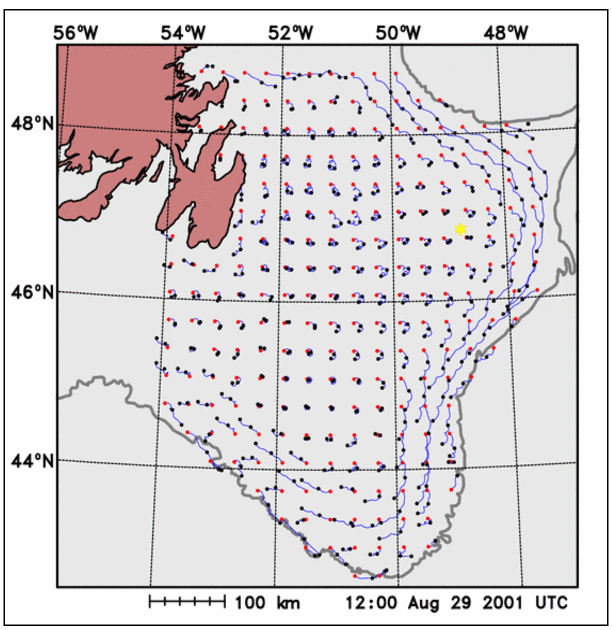

Fig. 3 Trajectories of surface drift on the Grand Banks for 1200 UTC, August 29, 2001. The grey line indicates the 1000-m isobath.

5. Concluding remarks

The forecast system and models described above are being improved and upgraded on a continuing basis. Two areas that need special attention are surface currents and data assimilation. Surface currents are represented by vertically averaged horizontal currents in the top 10 m. This is necessitated by the fact that POM does not have the first grid point at the ocean surface. In the top meters of the ocean, the effects of surface waves become important. The surface waves induce a Stoke drift, and modify the momentum transfer from the atmosphere to the ocean by wave growth and dissipation. Accurate modeling of surface currents must take the wave effects and vertical structure of the current into consideration.

Data assimilation can correct model errors by making use of real-time or recent data. In the Labrador Sea, the main current system is the Labrador Current, which is topography-steered and hence relatively stable except in the upper water column where the current is affected by winds. It is therefore anticipated that data assimilation is less effective in correcting model errors than it is for an unstable current system such as the Gulf Stream and the Kuroshio.

Acknowledgements

This research is supported by the Program for Energy Research and Development.

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