An Ice-Ocean Forecasting System for Eastern Canadian Waters

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An ice-ocean forecasting system for eastern Canadian waters has been developed to provide short-term forecasts of ice concentration, ice thickness, sea surface temperature and other oceanographic variables. In this paper, we describe the forecast model, forcing data, methods of data assimilation and operational procedure. The method by which to compute the forecast skills is outlined. As an example, April 2008 ice forecasts are evaluated by comparing the mean square errors of the forecast and the persistence.

INTRODUCTION

Knowledge of the present and future sea-ice conditions off Canada’s east coast is important for the operations of the offshore oil industry, marine shipping, fishing and weather forecasting. Timely and reliable ice forecasting requires accurate ice models. Ice models have been developed since the mid-1970s (Semtner, 1976). For the east coast of Canada, coupled ice-ocean models (Tang and Gui, 1996; Yao et al., 2000) were later developed and used to study the seasonal variation of ice cover and ice motion. These models were implemented in an ice-ocean forecasting system at the Bedford Institute of Oceanography (BIO). Improvements of the models and the forecasting system led to the development of the Canadian East Coast Ocean Model (CECOM) and a new forecasting system at BIO. The new system has been run operationally since 2007. Daily forecasts are provided to users in the offshore oil industry, sea-ice research institutes, and government agencies responsible for search-and-rescue operation and marine shipping. Forecast results in graphic forms are posted on the Internet accessible by the general public at the following: http://www.mar.dfo-mpo.gc.ca/science/ocean/icemodel/ice_ocean_forecast.html.

In this paper, we describe the forecast model and the BIO forecasting system, the methods of data assimilation for sea surface temperature and ice concentration, and the forecast schedule. The forecast skills are evaluated using ice data provided by the Canadian Ice Service (CIS).

MODEL DESCRIPTION

CECOM is a coupled ice-ocean model. The ocean component of the model is the latest version of the Princeton Ocean Model (Blumberg and Mellor, 1987). The ice component is a multi-category sea-ice model in which the internal ice stress is derived from the viscous plastic rheology of Hibler (1979), and ice thickness is characterized by a thickness distribution function from which ice concentration and mean ice thickness can be calculated. The thickness distribution satisfies a continuity equation which includes the mechanical distribution function representing the creation of open water and ridging of ice during deformation. The redistribution function in CECOM follows Hibler (1980), Thornrike et al. (1975) and Flato and Hibler (1995). Ten ice-thickness categories are implemented in CECOM with a maximum ice thickness of 5 m. Heat and salt fluxes at the ice-ocean interface are governed by the boundary processes discussed by Mellor and Kantha (1989). A full description of the ice model can be found in Yao et al. (2000) and Tang et al. (2008).

The model domain extends from northern Baffin Bay to the northern wall of the Gulf Stream, and from the St. Lawrence Estuary to 42°W (Fig. 1). The horizontal resolution is 0.1° × 0.1°. The grid is defined in a rotated spherical coordinate system. The equator of the rotated earth runs through the middle of the Labrador Sea in the north-south direction.

The vertical coordinate is the generalized s-coordinate. It allows both z and s levels in the vertical direction. In CECOM, the vertical levels are selected according to the bottom depth. The levels are scaled according to the thickness of the fixed upper layer or the varying lower layer. The total number of layers is 21. Monthly, climatological ocean temperature and salinity are used as the initial state and as open ocean boundary conditions. The monthly climatologies were obtained from an objective analysis of historical temperature and salinity data archived at BIO (Tang, 2007).

At open ocean boundaries, the flow relaxation scheme is applied. This requires a relaxation zone in which the interior solution relaxes to values prescribed by the exterior boundary; see the double lines in Fig. 1. For temperature and salinity, seasonal means interpolated to monthly values are prescribed. The normal component of the prescribed velocity is decomposed into baroclinic and barotropic components. The baroclinic is determined from geostrophy; the barotropic, from transports-based large-scale models and observations. Sea level is specified from the normal component of surface velocity by geostrophy.

INPUT DATA

Meteorological Data

Meteorological forcing is taken from the Canadian Meteorological Centre (CMC) Global Environmental Multiscale (GEM) model (Mailhot et al., 2006), which provides 48-h forecasts twice daily at 00:00 and 12:00 UTC, with fields output at 3-h intervals. The model uses a variable resolution grid over the entire globe, with a mesoscale 15-km horizontal-resolution window over NorthAmerica. Fields used in the forecasting system are 10-m winds, 2-m air and dew point temperatures, total cloud coverage,