Downscaling Example:

Canada-Newfoundland Operational Ocean Forecasting System (C-NOOFS) : Boundary Condition Validation and Operational System

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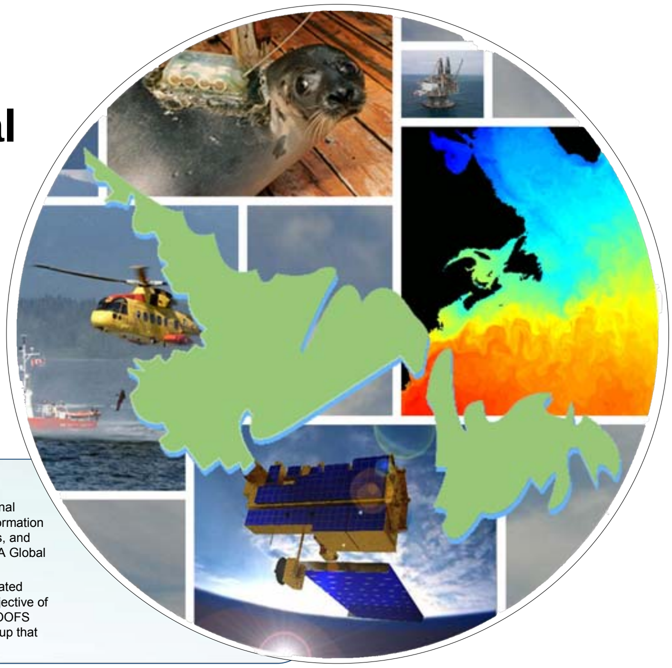

The objectives of C-NOOFS

C-NOOFS is a quasi-operational ocean forecasting system development whose primary objective is to build a core, regional, operational oceanographic capacity to provide information to various end users in Atlantic Canada. End user activities in need of better ocean information include in particular: search and rescue operations, ship navigation through ice, the offshore oil industry, weather forecasting systems, and marine habitat management, amongst others, for the North West Atlantic. It is also the Canadian example for downscaling of MERSEA Global products to the regional level.

Relative to traditional numerical modeling in physical oceanography, operational ocean forecasting systems need to be robust, automated and routinely producing ocean state information while integrating available information/observations from a variety of sources. The objective of C-NOOFS is to ensure that a third party, such as Environment Canada, can undertake 24/7 operation levels of service using the C-NOOFS ocean forecast system. The end goal for the project is to have a coupled ice ocean forecasting system for the North West Atlantic set up that will provide Marine end users with complete environmental information for making better at sea decisions.

Validation and tune up

The code development, validation, and tune up tasks are carried out in collaboration with scientists from other DFO institutions and MERSEA participants (Mercator-Ocean, LMC-IMAG…).

DFO carries out tri-annual oceanographic cruise transects as part of it's Atlantic Zonal Monitoring Program (AZMP). A long term data base of physical and biological ocean properties (S, T,O2 etc…) is maintained providing validation opportunity of C-NOOFS output. Fig. 1 is a map showing the different transects carried out in November 2007. Fig. 2 - 4 illustrate temperature and salinity fields from different sources (Observation, Mercator-Ocean, C-NOOFS) for the Flemish Cap transect on 20071123. Comparison shows model output warmer and saltier than the observation.

Fig. 1: Different transects where ocean data collection was carried out during the 200711 oceanographic cruise.

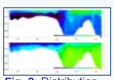

Fig. 2: Distribution of temperature (upper panel) and salinity (lower panel) along the Flemish Cap transect on 20071123 from the AZMP observation

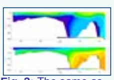

Fig. 3: The same as Fig. 2 but from PSY3V1R1 Mercator-Ocean system. The fields come from the 20071121 run.

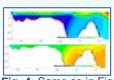

Fig. 4: Same as in Fig. 2 but from C-NOOFS system after 12 h of simulation on 20071123.

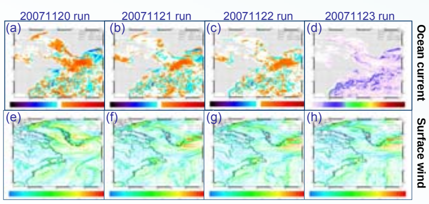

Fig. 6: (Upper panel) C-NOOFS current field, for 20071123, at 10 m as given by different forecast runs. (a), (b), (c) show the differences between the forecast runs and the analysis for 20071120, 20071121, and 20071122 runs, respectively; red color means the forecast shows faster current speed than the analysis. (d) is the 20071123 analysis run.
(Lower panel) The same but for the surface wind fields used to force the ocean model. In this case, (e), (f), (g) show the distribution of surface wind speed for forecast 20071120, 20071121, and 20071122 runs, respectively. (h) is the 20071123 analysis run.

The following section focuses on forecast system performance and errors which need to be understood.

1) Does the model differ from the forcing fields used as initial and boundary conditions (Fig. 5): TKE of the Mercator Ocean PSY3V1R1 increases in increments while that of NWA decreases monotonically. PSY3 runs contain assimilation (SSH) whereas NWA does not. Additionally C-NOOFS uses daily produced Environment Canada forecast winds as opposed to ECMWF weekly generated forecast winds… However Fig. 5 does indicate that data assimilation within C-NOOFS would help maintain realistic energy levels within the domain.

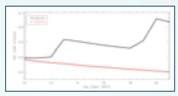

Fig. 5: TKE computed as Σhv^2 for the whole NWA domain region from Mercator-Ocean PSY3V1R1 (black line) and C-NOOFS (red line) systems for the period of 20070910 to 20070921.

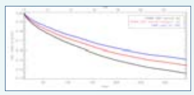

Fig. 7: TKE computed as Σhv^2 for a sub-region RNWA from different test runs for the period of 20070910 to 20070924. Run cases are: NWA used as initial conditions and boundary conditions (blue line), RNWA where only the tangential velocity is prescribed along the OBC (black line), and RNWA with corrected OBC where both normal and tangential velocity is prescribed (red line).

2) Figure 6a-d shows the current fields at 10 m from the C-NOOFS for the 23rd of November. Panels (a), (b), (c) respectively show how the 3-, 2- and 1-day forecasted currents for Nov. 23rd differ from the analysis of Nov. 23rd in Panel (d). The forecasted current field looks more and more similar to the analysis as the forecast run shortens.

Predicting surface currents in C-NOOFS is important for search and rescue drift determination. Slight changes or errors in the wind field can have an impact on predicted surface currents. Figure 6e-h shows the analysis of Environment Canada prescribed surface winds in panel (h) with panels (e), (f), and (g) showing analysis and forecast for the 3-, 2- and 1-day forecast of Nov. 23rd. Thus, it is important to run regional ocean forecast system on at least a daily basis to ensure as best surface current accuracy as possible. Errors and variability in the wind forecast impact the model surface currents (Figure 6a-d).

3) An additional investigated source of error in the C-NOOFS forecast system was the 1-way nested boundary conditions. A smaller domain was chosen within C-NOOFS called RNWA for Regional North West Atlantic domain. Boundary conditions for this come from the C-NOOFS NWA domain (Figure 8).

This permits controlling
_ the exact characteristics of the runs from which the boundary conditions are extracted,
_ the frequency to which the boundary conditions are prescribed, and also
_ the frequency of comparison.
This is more difficult to accomplish with the fixed output from PSY3 which also differs through its addition of data assimilation.

The comparison 1-way nesting in the sub-domain RNWA is performed with both simulations run freely with similar initial conditions and without any wind forcing at the surface.

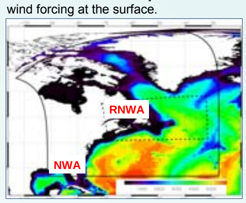

Fig. 8: Map of the C-NOOFS NWA (North West Atlantic) domain and the embedded RNWA (Regional NWA) domain used to study the OBC issues.

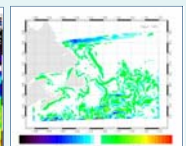

Fig. 9: Map showing the differences in current speed between the NWA run and the RNWA run with both normal and tangential velocity prescribed.

One of the main corrections lately implemented in the boundary conditions is the additional prescription of tangential velocity fields as part of the prescribed data along the open boundaries. Fig. 7 shows how the TKE gets improved as the two components of the velocity are prescribed. Fig. 9 illustrates an example of differences in the velocity fields at 10 m after 6 days of run.

Summary: discrepancies were found between the forecast field and its forcing fields. DFO has introduced some improvement in the prescription of the OBC. This has led to the forecast result better representing the forcing fields. However, further investigation is needed to correct the remaining differences. Data assimilation is also necessary to achieve better results.

Public access to ocean forecast

http://www.c-noofs.gc.ca/ or http://www.sopoc-tn.gc.ca/

The web site is developed to give quick access of the ocean forecast to any user. It also provides all the information concerning C-NOOFS and its development.

Users can view the ocean state using the "**Forecast Viewer**" page (Fig. 10):

The C-NOOFS operational ocean model runs each night at 3:45AM, and requires approximately two hours to fully complete. This run time can be broken down into distinct components:

Figure 10: Forecast Viewer page

Production Chart

Weekly download of MERCATOR PSY 3 boundary/initialisation data.

Daily Model Runs

1. Download of Coriolis Observation Data
2. Download of Environment Canada wind/atmospheric files
3. 6 day forecast runs 30 min
4. DIMG to NetCDF file conversion: 16 min
5. Image Generation: 83 min
   21 images per day of simulation per language (French & English) for a total of 126 images.

Total Forecast System Run Time = 2 hours

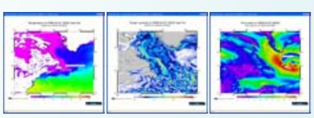

Figure 11: Example of forecast result on April 22, 2008

The C-NOOFS website displays a thumbnail of the surface temperature, ocean current and winds for the current day on the home page.

Applications currently in development to use C-NOOFS output data

C-NOOFS is designed so that forecast data can be used for different applications. The following is a short description of a couple of these applications that are developed within the same research group:

_ Application to **aquaculture industry and invasive species research and management**. For that downscaling to shore area is carried out using the FVCOM model and DEPOMOD software. (Fig. 12).

Figure 12: Downscaling of C-NOOFS for aquaculture.

_ **CANSARP**: C-NOOFS facilitates interaction between ocean data providers (such as Mercator-Ocean or C-NOOFS itself) and Canadian Coast Guard to provide the latter ocean current data for search and rescue. A scientific version has been developed which allows inclusion and quality assessment of new physics and new dataset into the software package (Fig. 13).MERCATOR/MERSEA provides weekly surface current data for Canadian Coast Guard.

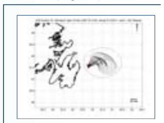

Figure 13: Computed path followed by a "body" in the water obtained from feeding the CANSARP simulator with wind data from CMC together with surface currents computed by the C-NOOFS. The blue line shows the real path of a life raft released off St. John's, NL and the red line the computed path.

Acknowledgments

C-NOOFS is a Centre for Ocean Model Development and Application (COMDA - a DFO Centre of Expertise) project that dovetails with other efforts within Environment Canada (EC) and DFO. It focuses on the Canadian Atlantic Region from Cape Hatteras (US) to the northern end of Baffin Bay.

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Pêches et Océans Canada Fisheries and Oceans Canada
Environnement Canada Environment Canada
Canadian Forces
MERCATOR
MERSEA

C-NOOFS next steps

C-NOOFS is looking within 2 years to run operationally at Environment Canada in a Coupled Ocean Atmosphere system including ice at 1/12th of a degree resolution with limited zoom areas for 1/36th of a degree resolution. This coupled system will be driven at the boundaries by global systems including MyOcean ocean and ice boundary conditions as well as ECMWF/EC-CMC wind forecasts initialization conditions. The following stepping stones will take place:

For Sept 1 2008: LIM 3 ice model within NEMO code will be turned on
Prototype pre-operational system will move from ¼ degree to 1/12th a degree resolution
Validation systems and visualization tools from MERSEA work packages will be implemented
DODS data protocols will be implemented

For Sept 1 2009: Regional data assimilation system will be coupled to C-NOOFS
Coupling with Atmosphere model using Oasis and GOSSIP coupling solutions will be implemented
Pre-op runs will take place for the 2009/2010 ice season on Environment Canada computers