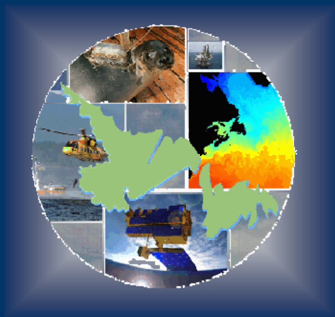

# CANADA-NEWFOUNDLAND OPERATIONAL OCEAN FORECASTING SYSTEM

November 20, 2007 / Volume I

**In this issue:**



## C-NOOFS PARTNERS

- MERCATOR-OCEAN
- MERSEA
- COMDA
- ISDM (formerly MEDS)
- GODAE
- CORIOLIS
- Canadian Coast Guard

## C-NOOFS FUNDING AGENCIES

- CANADIAN SPACE AGENCY
- NATIONAL SEARCH AND RESCUE SECRETARIAT
- DFO COMDA
- NATIONAL RESEARCH COUNCIL

## MEET THE C-NOOFS NAFC TEAM

**Dr. Fraser Davidson:**
**Research Scientist, Physical Oceanography**
Department of Fisheries and Oceans (DFO) research scientist at the Northwest Atlantic Fisheries Centre in St. John's, Newfoundland and Labrador.

**Andry William Ratsimandresy:**
**(NSERC) Visiting Scientist, Physical Oceanography**
DFO NSERC visiting scientist

**Adam Lundrigan:**
**Computer Systems Programmer, Physical Oceanography**
Responsible for the development of intranet applications for quality assurance and data management, as well as maintenance of the project's Linux and Solaris servers.

**Debbie Anne Power:**
**Computer Systems Programmer, Physical Oceanography**
Web master, computer programmer and project coordinator. Debbie specializes in web infrastructure, machine procurement and system operations.

**Jim Helbig: Research Scientist, Ocean Remote Sensing and Marine Optics**

**Ben Davis: A/Division Manager, Environmental Sciences**

## MEET THE C-NOOFS BIO/EC TEAM

- **Dan Wright: Research Scientist and Senior Modeller**
- **Youyu Lu : Research Scientist, Ocean and Ice Modelling**
- **Zeliang Wang: Scientist, Ocean Modelling**
- **Charles Hannah: Research Scientist and Project Coordinator**
- **Frederic Dupont: Research Scientist, Numerical Modelling**
- **Michael Dunphy: (Co-op Student now at University of Waterloo)**
- **Jie Sue: (NSERC) Visiting Scientist**

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## C-NOOFS PURPOSE

(By Fraser Davidson)

An operational oceanographic system provides a description of the ocean, past, present and/or future, in a routine manner to provide timely environmental inputs to ocean related decision making. The Canada-Newfoundland Ocean Forecasting System (C-NOOFS) is a quasi-operational ocean forecasting system that will provide information to the offshore oil industry, search and rescue operations, weather forecasting systems, and marine habitat management, among others. Relative to traditional numerical modelling in physical oceanography, operational ocean forecasting systems need to be robust and capable of running routinely and automatically while integrating available information and observations from a variety of sources.

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. Over the next three years, C-NOOFS will develop into a pre-operational end-to-end regional ocean forecasting system that uses data from other model inputs and from operations and disseminates a number of data products. One objective is for C-NOOFS to provide a test bed for the operational implementation of ocean modelling and data assimilation research projects currently underway within DFO and academia.

Interaction with other projects helps enhance knowledge on how to run an operational oceanographic system, how to validate the system (metrics), and how to apply the system to DFO activities ranging from Coast Guard Search and Rescue to Marine Environmental decision making.

While the end goal for C-NOOFS is broad, the focus is on developing a quasi-operational core marine service that will be ready to be run as a fully operational service by a 3rd party. A secondary goal is to motivate coordination and mutualism within DFO oceanographic research to ensure continued long term development, validation and improvement of ocean forecasting within Canada and Canadian participation in international ocean forecasting programs (i.e. Global Ocean Data Assimilation Experiment (GODAE), My Ocean).

## Collaborative model development

(By Andry Ratsimandresy)

Northwest Atlantic Fisheries Centre (NAFC) scientists are responsible for implementing the A-Z operational ocean forecasting chain. With respect to the core numerical model Nucleus for European Modelling of the Ocean (NEMO), active collaboration with other research groups is and has been essential to improve, correct and update the NEMO code implementation. Such collaboration is performed through visits of Bedford Institute of Oceanography (BIO) scientists to NAFC and vice versa. Additional email correspondence and interaction has provided fruitful and active scientific exchange and improved the C-NOOFS experience immensely. Special thanks go to Dr. Dan Wright from BIO for his insatiable quest and direction for identifying the cause of identified model output oddities.

This section describes the effort undertaken to improve the ocean numerical model used in C-NOOFS. It mainly deals with the improvement in terms of numerical model/source code (Table 1). As such, the most recent collaboration with BIO and EC scientists has been the correction of the open boundary conditions which presented some anomalies following implementation earlier this year. Further corrections are under way but present results are significantly improved.

**Table 1 Configuration time line and run times of C-NOOFS system: Dec 2006-Nov 2007**

| | Dec 2006 | April 2007 | Aug 2007 | Oct 2007 | |
|---|---|---|---|---|---|
| **C-NOOFS version** | V0 | V0.1 | V1.beta.1 | V1.beta.2 | V1 |
| **Initial conditions** | Climatology | T S from MO | T S from MO | S T U V ssh from MO | S T U V ssh from MO |
| **Boundary conditions** | Closed | Closed | Open with prescribed S & T from MO | Open with prescribed S T U V ssh from MO | As V1.beta.2 + tides |
| **Computing resource** | 4-CPU shared memory | 4-CPU shared memory | 4-CPU shared memory | 16-core distributed memory | 16-core distributed memory |
| **Run time per model day** | 25 minutes | | | 6 minutes | |

Changes and updates to the NEMO based source code necessitate porting efforts to the C-NOOFS computational system with numerous result and consistency verifications. Output validation is ongoing and will be presented in a later newsletter release.

The very first objective for the development and implementation of C-NOOFS was to run a system quasi-operationally that can feed its input (initial conditions and open boundary conditions for S, T, U, V, and ssh) from Mercator Ocean's (MO) global system (Table 1: Version V1). With the key collaboration of scientists from BIO, EC, and NAFC, some issues have been solved when initializing the system to specific fields and prescribing open boundary conditions. The open boundary conditions are now based on a Flather-type condition with radiation. Some issues are still observed when looking at how the total energy of the system evolves in time and effort is now focused on correcting this.

## C-NOOFS Operational Infrastructure

(By Adam Lundrigan and Debbie Anne Power)

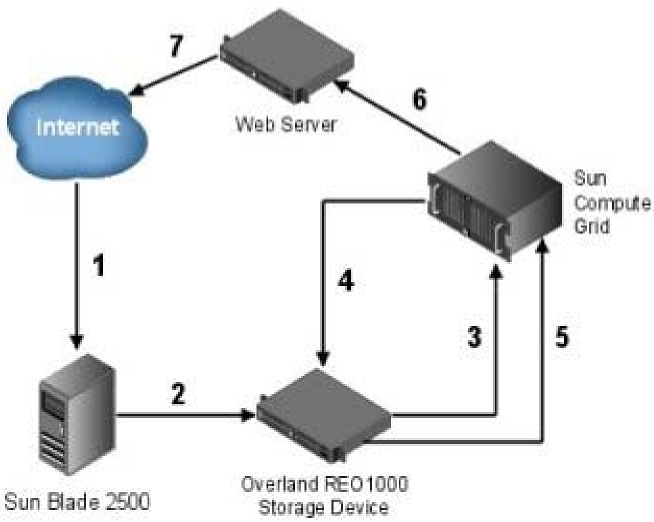
The C-NOOFS project employs ten separate UNIX- and Linux-based machines, all of which are located at the Northwest Atlantic Fisheries Centre in St. John's. Four Sun Fire x4100 M2s and a single Sun Fire x4200M2 are grouped into a 20-core compute grid via the Sun N1 Grid Engine software, and are interconnected using both gigabit Ethernet and 10-gigabit Infiniband switched fabric. The remaining machines play supporting roles for the grid, including post-processing, data storage, and web/FTP hosting.

The operational system run on these machines can be broken down into a seven-step process:

1. The input data used by the model in its forecast is downloaded from our global network of partners, including Environment Canada, Mercator Ocean, and Aviso.
2. The raw input files are pre-processed by a Sun Blade server, and placed on networked storage.
3. When the model run is invoked, input data is transferred from network storage to the master compute node.
4. Once the model has completed its run, the results of the run are transferred to our network storage for safe keeping, and post-processing of the data begins.
5. The distributed post-processing, running on our compute grid, retrieves the necessary model output from network storage, and uses Generic Mapping Tools (GMT) to produce a

visualization of the forecast data.

6. Forecast images created during post-processing are inserted into a relational database running on our public FTP server for display on our web site.
7. The general public may view images of the forecasts produced by the C-NOOFS operational system via the *C-NOOFS Forecast Viewer* at http://www.c-noofs.gc.ca/viewer

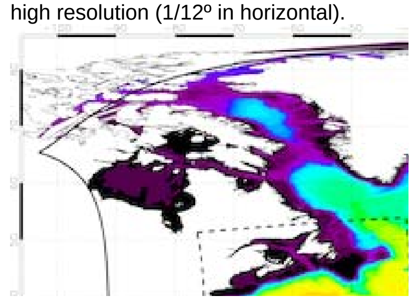



## Description and configuration of the C-NOOFS forecast system:

(By Andry Ratsimandresy)

An ocean forecast is carried out daily using the state-of-the-art numerical model NEMO used by numerous European and Canadian research centres. The implementation of the numerical model to DFO's domain of interest is actively carried by collaborating scientists from NAFC (DFO, Newfoundland and Labrador), BIO (DFO, Nova Scotia) and Environment Canada). The domain of interest is the northwestern part of the North Atlantic with the boundaries located at about 26ºN, 86ºN, 92ºW, and 27ºW for the northern, southern, western, and eastern boundaries, respectively (See Figure 1). This domain was chosen to cover all the major currents in the area, mainly the western part of the Subtropical Gyre and the Subpolar Gyre. Of special interest is the circulation in the shelf area off the eastern coast of Canada (Nova Scotia and Newfoundland and Labrador) and that around the Flemish Cap (dotted line in Figure 1). As of Nov. 2007, the north boundary is closed and. Hudson Bay is masked as land.

**Figure 1:** Domain of interest for C-NOOFS. The small domain off eastern Canada is a future implementation of high resolution (1/12º in horizontal).



The horizontal grid is based on the generic ORCA type mesh with a resolution of ¼º (at the equator). In this way, C-NOOFS can easily be nested within the Mercator-Ocean (MO) global operational system (PSY3) and make use of all the latter's characteristics. In the vertical, we consider 46 levels, with grid spacing ranging from 6 m at the surface to 250 m at depth.

**Figure 2:** Schematic view of the model simulation for C-NOOFS.

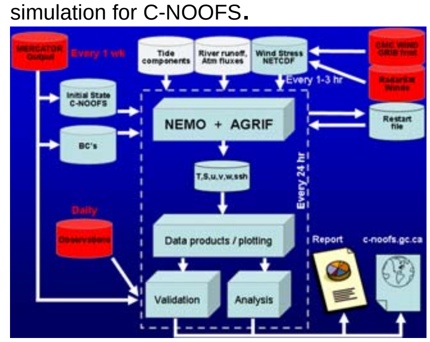



Figure 2 gives a schematic view of the modelling part of C-NOOFS. It consists of various components. First, there is the ocean simulation part where NEMO is run and the post-processed results are stored. Second, the model gets its initial conditions, forcing fields, and validation fields from various centres including DFO. The result is compared with different types of data for validation and then made available to users through world web access. At the surface, C-NOOFS is forced by wind stress computed from the wind field output of the Canadian Meteorological Centre (CMC) weather forecast. Our centre currently receives two sets of 6-day forecasts of wind from CMC every day. Along the eastern and the southern boundaries, salinity, temperature, sea surface height, and the horizontal components of the model velocity field are restored to prescribed daily values from MO forecast output. DFO receives 18 days of data (7 reanalysis, 1 analysis, and 10 forecasts) from MO every week. The present version of the model does not include ice model. In fact, C-NOOFS presently relies on MO results for the ice. Future versions of the system will consider the simulation of ice (generation and drift). For each run, the simulation is initialized with salinity, temperature, sea surface height, and the two components of the horizontal velocity fields obtained from MO. Data for validation include in-situ measurements regularly carried out by DFO, in-situ and remotely sensed measurements provided by international partners (Coriolis, Marine Environment and Security for the European Area (MERSEA), AVISO, etc…), and model outputs such as MO and others in the area.

The C-NOOFS system is run once a day early in the morning so that forecast results are available by beginning of business (9 am). The system is run forward for 6 days with 1 day of analysis and 5 days of forecast. This was chosen because of the period of forecast data that CMC can provide.

The result is stored every 6 hours with the possibility of more frequent outputs when needed and data storage provisions are in place.

## Validation

(By Andry Ratsimandresy and Fraser Davidson)

To improve C-NOOFS system performance, results are validated with observed data and the source code is consequently improved and updated. Results are compared to DFO Atlantic Zone Modelling Program (AZMP) surveys primarily, as well as with output results from other ocean models (for the time being; only MO results are considered).

For comparison, we consider different parameters such as temperature (T), salinity (S), current velocity (U and V), sea surface height (ssh), total kinetic energy (TKE), and more. The distribution of those parameters at various levels as well as along specific sections are studied and compared. We have developed and implemented some validation routines and methodologies in order to consistently repeat comparisons that permit knowledge of the system's improvements over time. Analysis of these comparisons is provided below. Various hindcasts have been run for earlier dates to cover the period when in-situ measurements were available.

DFO makes regular in-situ measurements of physical, chemical, and biological parameters along fixed transects every year (Figure 3). For our validation exercises, we use data from various transects, namely Southeast Grand Banks, Flemish Cap, Bonavista, Funk Island, White Bay, and Seal Island. As an example, Figure 4 illustrates the distribution of temperature along the July 2005 occupation of the Flemish Cap transect across the Grand Banks and the Flemish Pass. The panels illustrate the observed distribution, the MO simulated distribution (upper right panel), the C-NOOFS simulated distribution when initialized with temperature and salinity fields from climatology (lower right panel), and the C-NOOFS simulated distribution when initialized again with temperature and salinity fields but from MO. The model outputs and the in-situ measurements show similar structure. MO output and C-NOOFS output initialized with MO data tend to have a slightly warmer water column. When C-NOOFS is initialized with climatology, the model gives a much warmer result (3-4ºC warmer).

One of the problems we found when initializing the model with only S and T fields is that the Gulf Stream was hardly reproduced. This seems to come from the fact that the whole system starts from rest and could not reach any real ocean state by the time the forecast run is finished (currently one week). A more realistic initial condition considers initializing a number of parameter fields such as S, T, U, V, and ssh to be fed into the model. The result of such improvement in the physics has shown an appreciable improvement to the circulation (figures not shown).

The next step of improvement consisted in setting open boundary conditions along the east and south limit of the domain by prescribing the values to specific MO fields. First, the boundaries were set to the same values as the initial conditions for the whole period of simulation, second we started to consider open boundary conditions which evolve in time. The later can be performed using the daily forecast fields obtained from MO. Figure 5 shows the geographical distribution of surface velocity fields from the MO run, C-NOOFS run with complete MO variable initialization and open boundaries fixed to the initial fields (middle left panel), and a similar initialized C-NOOFS run with daily varying open boundaries prescribed daily (lower left panel). Also shown are the differences between C-NOOFS result and the corresponding MO output (right set of panels). The result presented comes from day +7 (2007-09-16) after the initialization on 2007-09-09. One can observe that C-NOOFS runs show the same structure as the MO run with the Gulf Stream now relatively well represented in C-NOOFS. In general differences in the velocity are relatively small for the open ocean. C-NOOFS tends to provide a slightly faster surface velocity around the Gulf Stream and slightly slower velocity in the Labrador Basin. The more striking differences are observed along the western coast of Greenland for both C-NOOFS cases and along the boundaries for open boundary cases. At the time of writing, all efforts are being focused on investigating these anomalies in order to achieve C-NOOFS runs that best reproduce the MO result.

A final note on the present analysis is that the result obtained with C-NOOFS is very similar to the corresponding prescribed ocean states (Initial conditions and boundary conditions). At the present time, our performance in reproducing the in-situ observation depends a great deal on the input data we use to initialize our model.

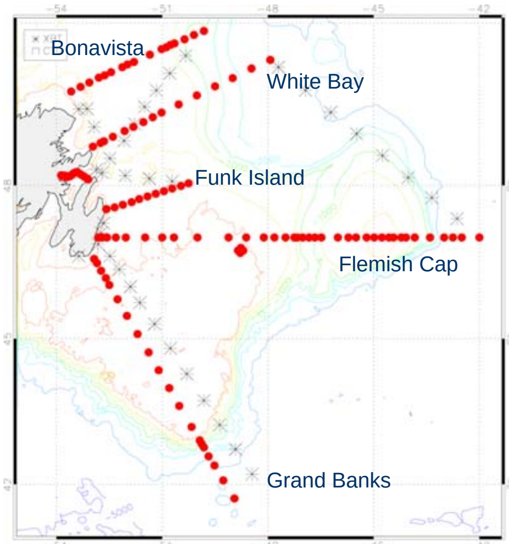



**Figure 3:** Sample fixed transects along which AZMP in-situ measurements were performed during April 2007 oceanographic cruise

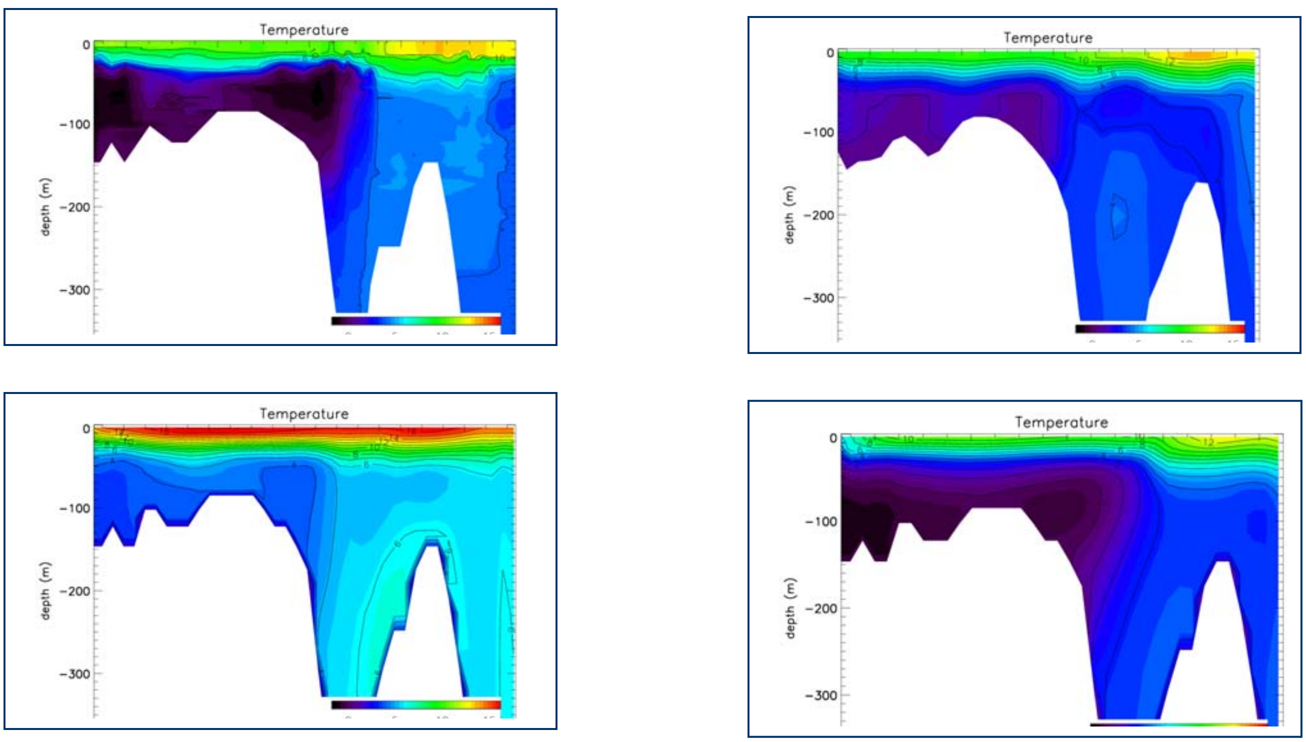
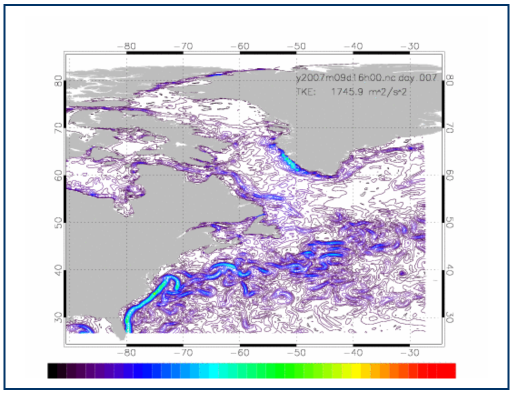
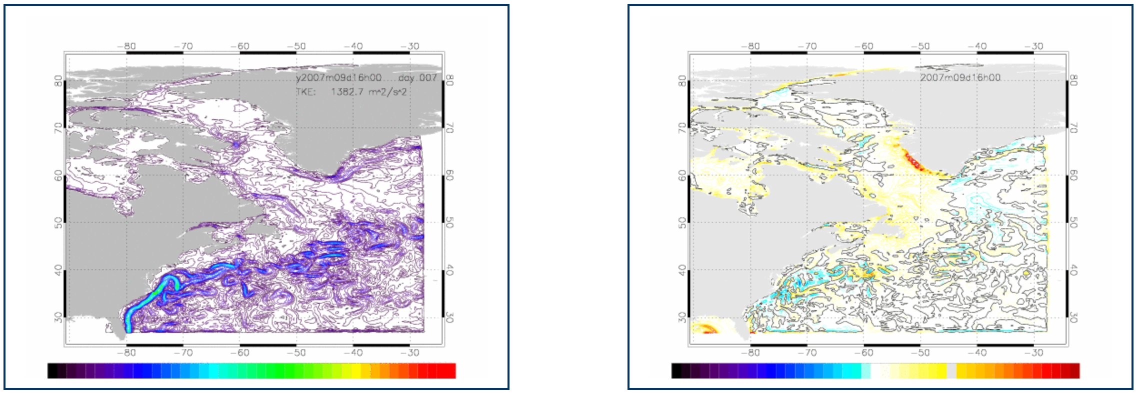



**Figure 4:** Temperature distribution on July 2005 as given by AZMP observation (upper left panel), by MO PSY1V2 run (upper right panel), by C-NOOFS run initialized with climatology data (lower left panel), and by C-NOOFS run initialized with MO data.

## MERCATOR




## C-NOOFS




## C-NOOFS

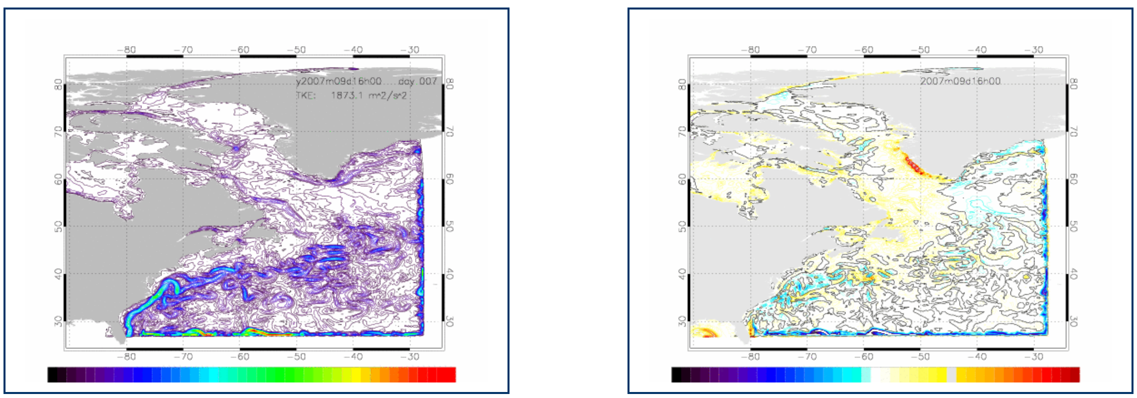



**Figure 5:** Geographical distribution of surface velocity (left panels) for day +7. Upper panel is from MO output, middle panel from C-NOOFS with open boundary conditions constant for the whole period of run, and lower panel C-NOOFS with open boundary conditions which change every day. Both C-NOOFS runs were initialized with MO S, T, U, V, and ssh fields on 2007-09-09. Right panels illustrate the corresponding differences with MO output.

## Anatomy of a Model Run

(By Adam Lundrigan)

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 three distinct components:

1. **Forecast Time**: The forecast system performs a single day of analysis, and two days of forecast, in approximately 20 minutes.

2. **Conversion Time**: Once the model has completed its forecast, the output is converted from DIMG into NetCDF, and moved to networked storage. This stage is completed in approximately 16 minutes, depending upon network congestion.

3. **Image Generation**: The generation of forecast visualizations for the C-NOOFS web site is by far the most time consuming component of the forecast system. It generates 21 images per language per day of simulation, for a total of 126 images, and requires 83 minutes to complete.

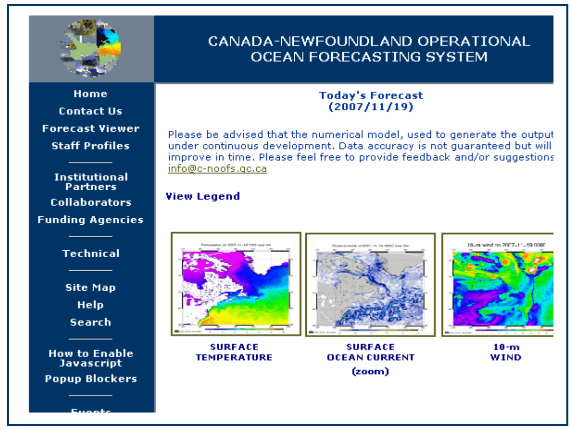
As seen in the above figures, nearly 68% of the total model run time is spent creating images for the C-NOOFS website. This is due to the use of Generic Mapping Tools (GMT), which uses Encapsulated Postscript as its native graphics format, which adds a costly EPS to PNG conversion step into the image generation chain. We are currently experimenting with using IDL in lieu of GMT, which we hope will provide a much needed boost in the efficiency of our plotting routines.

As of Tuesday, November 20th, 2007 the C-NOOFS operational ocean model will commence six-day runs – one analysis and five forecast - which will double the time required to perform a forecast to approximately four hours.

## C-NOOFS WEBSITE

(By Debbie Power)

**English version [www.c-noofs.gc.ca](http://www.c-noofs.gc.ca)**
**French version [www.sopoc-tn.gc.ca](http://www.sopoc-tn.gc.ca)**




The CNOOFS website displays a thumbnail of the surface temperature, ocean current and winds for the current day on the home page. The user can click on a graphic to enlarge the display.

The site also gives information on C-NOOFS Partners, Collaborators, Funding Agencies and staff profiles.

The “Contact Us” page has a link for viewers to supply feedback to the C-NOOFS team.

There is also a “Technical” page which details the technical aspects of the C-NOOFS project.

An “Events” link in the side bar navigation displays a photo gallery of events C-NOOFS has arranged or participated in.

There are other links on the web site in conformance with the government CLF 1.0 standards. These links are for the following pages: Help, Search, Canada Site, Site Map, and DFO National.

The “Forecast Viewer” page displays Wind, Surface Temperature, and Ocean Current information for the current date by default but allows the user to view this information for other dates as well.

The link for the “Forecast Viewer” displays the interface shown below:


**Brief Tutorial:**

The forecast viewer displays options to view the forecast for the current day, and +1 Day up to +5 Day by default.

The user can view a different date by clicking on the Calendar on the forecast viewer. It is possible to view images for past dates but not for future dates when using the calendar. When the user clicks on the calendar object the screen below is displayed:


Choose the date(s) to generate images for (they will be highlighted in blue) and then click the x on the top right hand corner to close the calendar.

To narrow the amount of images returned use the filtering criteria in the “Search for a Forecast …” section.

To view any image click on the icon.

This website is written in PHP and utilizes Javascript and a MySQL backend database. It conforms to government web standards CLF 1.0 and will be upgraded this year to conform to CLF 2.0. It also conforms to XHTML 1.0 Strict W3C web standards.

## C-NOOFS Forecast Viewer

(By Adam Lundrigan)

Visualization of the forecast generated by the C-NOOFS operational system is the responsibility of the C-NOOFS Forecast Viewer. This system is broken down into two distinct components: image generation and hosting, and the web user interface.

### Image Generation and Hosting

When the nightly model run of the C-NOOFS forecast system completes, it signals the post-processing subsystem to begin its work. It does this by creating a series of job files, each describing a unique combination of the forecasted date and water depth. A daemon running on the post-processing machine detects these job files, and begins processing them five at a time in parallel.

Each job started by the daemon loads model data relating to the specified combination of forecasted date and water depth and produces eight EPS images - Temperature, Salinity, and two Ocean Currents in both official languages. Each of these images is submitted to a conversion program utilizing the Sun N1 Grid Engine to be converted into a web-friendly PNG format, and then inserted into a relational database for later use.

### Web User Interface

Access to the images stored in the forecast viewer's relational database is granted via a web-based user interface. The interface is built entirely using JavaScript, and uses components from the open-source JavaScript library *Yahoo! User Interface (YUI)*. In addition, it relies heavily on AJAX to prune the list of available images based upon the criteria the user selects.

The forecast viewer operates by using AJAX to exchange XML messages with a specially-built web service, which returns the metadata tied to each image which fits within the pruning criteria selected by the user. When the user changes the selected pruning criteria, an AJAX request is sent to the web service, and the results table is updated "on the fly" as results are returned – all behind the scenes, and without having to reload the entire page from scratch.

The web user interface can be accessed by visiting http://www.c-noofs.gc.ca/viewer (English) or http://www.sopoc-tn.gc.ca/viewer (French).

## Acronyms used in this newsletter

Canada-Newfoundland Ocean Forecasting System (C-NOOFS)
Centre for Ocean Model Development and Application (COMDA)
Global Ocean Data Assimilation Experiment (GODAE)
Northwest Atlantic Fisheries Centre (NAFC)
Nucleus for European Modelling of the Ocean (NEMO)
Mercator Ocean (MO)
Generic Mapping Tools (GMT)
Canadian Meteorological Centre (CMC)
Marine Environment and Security for the European Area (MERSEA)
Atlantic Zone Modelling Program (AZMP)