Development of CARICOOS ROMS Ocean-Shelf Model

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LONG-TERM GOALS

The long term goals of this project is to provide accurate surface and vertical column currents for the region of Puerto Rico and the U.S. Virgin Islands. These will be used to provide not only ocean current forecasts, but also to study the ocean dynamics at the interface of deep and shelf water in this region. Processes of particular interest include mesoscale and submesoscale eddies and regional jets, and the interaction of these features with the steep shelf South of Puerto Rico. In the future the CARICOOS ROMS model will provide boundary conditions to the CARICOOS FVCOM model.

MILESTONES / OBJECTIVES

- An initial thorough sensitivity test of boundary conditions, wind forcing, horizontal momentum mixing (eddy viscosity), and prescription of surface and bottom stresses was succesfully conducted. A combination of these parameters resulted in a more stable ROMS model, which begins to recreate eddy-like features that are observed in HFR. In addition spurious and long-period oscillations were eliminated.
- A detailed look into the comparison of AMSEAS and HFR currents showed very poor performance of AMSEAS, at many times with currents in the reverse direction than observed. This led to compare the *monthly means* of AMSEAS and HFR current fields, which showed dramatic differences going from large differences in the speed and direction of regional jets, and opposite rotation on eddy features as well as ficticious eddies or missing representation of observed eddies.
- This discovery brought into attention the dominance of AMSEAS in the ROMS model error. As such, graduate student conducted a comparison of AMSEAS, NASA OSCAR, and HFR currents to determine their errors in the area of the ROMS model. The results indicate that OSCAR has good agreement with the HFR observations, while AMSEAS performs poorly. This corroborated that AMSEAS is the main driver of the ROMS error. As such the search for an alternative to use as boundary conditions was initiated.
- A new operational and validation framework was designed and implemented.

WORK COMPLETED

- Atmospheric forcing changed to CARICOOS WRF 2KM, hourly. Included atmospheric pressure which was not being used before. Wind stress formulation changed to Foreman and Emeis (JPO,2010) for wind speeds over 8 m/s. For light winds under 8 m/s formulation by Wu (JGR,1981) is used. Completely rewrote code to read and process the WRF files and compute stresses.

- Wind stress is now applied as a body force over the top 5 sigma layers. Bottom friction is now applied as a body force over the bottom 3 sigma layers. This was crucial in the successful generation of eddy features along the West and South coasts, which were also observed in HFR. This was not taken into account previously.

- Harmonic eddy viscosity of 50 m2/s and biharmonic eddy viscosity of 10000 m4/s are now used. This used to be zero, both.

- At the model boundaries now 2D nudging (horizontal) is used for the three-dimsensional currents being ingested from NCOM AMSEAS. An inflow nudging timescale of 1 day and outflow nudging timescale of 360 days are used at the boundaries. Prior to this 1D nudging was used, effectively eliminating the parallel component of currents from entering or exiting the domain, thus causing loss of information at the boundaries.

- Created new Python scripts to generate atmospheric forcing files, call Matlab/GMT scripts that generate ROMS/HFR vector time series figures, send figures to S3 bucket, and rename ROMS output files to the required THREDDS naming convention for easy aggregation.

- All relevant Matlab codes were re-designed as functions. This allows to easily call them from Python and in the future will allow to easily run Matlab preprocessing functions as independent subprocesses in parallel, which will result in faster execution times.

- New Matlab functions were created to generate contours for operational and non-operational figures. These functions were designed in a way that it is possible to call them independently as subprocesses through Python. For example X amount of figure domains can be independently called into X processes to be executed in parallel from Python, allowing faster execution times.

- Organization of output directories was designed in such a way that it is now transparent to call the figure generation functions regardless of the duration of the run in a given folder, amount of files, time intervals, etc. Everything is taken care for automatically and everything is able to be uploaded into the S3 bucket. Functions traverse a given folder and subfolders, read files, find out domains and times information automatically.

- All initial conditions, boundary conditions, atmospheric forcing files were re-designed in a way that it is now transparent to do operational and non-operational runs, regardless if it is one day, a month, years. Extraction of AMSEAS values is based on the THREDDS aggregation. Multi-year runs for validation, extended spin up, and stabilization of vertical column will begin soon in Stampede supercomputer.

- Execution time of operational version is approximately 1.77 simulation days per wallclock hour in Magueyes desktop, running on 16 threads using OpenMP. Works with either Intel or GCC compilers. Three day forecast runs on 1.70 hours.

MAJOR OUTCOMES

- A new, robust operational framework has been completed. The framework simplifies archiving, validation, and distribution of the model results, and it works transparently regardless over both operational and non-operational runs. This provides an added

value in respect to easy distribution of any model simulation through the THREDDS server.

- The detailed comparison of AMSEAS and HFR currents was a turning point in the determination that AMSEAS was the main driver of error in ROMS, and that the discrepancies were so large that the contamination of ROMS was irreversible. Comparison of current means at various time scales (monthly, weekly) showed that AMSEAS was and is consistently providing incorrect solutions which at some points are opposite of the observed. Thus it was determined that AMSEAS should not be used anymore as boundary conditions.
- ROMS showed a noticeable sensitivity to how the surface and bottom stresses are prescribed, indicating that there is a fine balance between these two stresses which is important for our region. In particular bottom stress was a key into generating eddy like features in the vincinity of the shelf South of Puerto Rico.

RELATED PROJECTS

A significant effort was put into making the ROMS operational and validation framework as dependent as possible on the CARICOOS THREDDS server. In this way we make a better use of our own resources, monitor them constantly, and can evaluate it from the viewpoint of our scientific users.

WORK PLAN FOR UPCOMING PERFORMANCE PERIOD (June 1 2017 – Nov 30 2017)

- Conduct a comparison of NCEP RTOFS ocean currents with HFR to determine suitability of using these currents at boundary conditions for ROMS. Preliminary comparisons show a better agreement of RTOFS currents with HFR than NCOM AMSEAS, which at times provides reverse currens than observed severely affecting the ROMS solution.
- Based on RTOFS and HFR comparison, implement RTOFS as the new boundary condition for ROMS.
- Increase domain size and do a redistribution of the vertical levels. The need to prescribe surface and bottom stresses as body forces is an indication that vertical level distribution is not optimum (too thin levels).
- Automate model statistics and include depths in THREDDS output for easy visualization through ERDDAP.
- Do a multi-year simulation to asses effect of spinup and inclusion of climatologies into the ROMS model.
- Determine the effect of interval of boundary condition update. For example, if we get a better ROMS solution by updating boundary conditions every 6, 12, 18, etc. hours. Also low pass filtering of boundary condition time series might be necessary if using longer intervals.

PUBLICATIONS & PRODUCTS

Poducts:

ROMS is in stagin mode and available at:
http://staging.caricoos.org/currents/forecast/ROMS/PRVI/Currents

Publications:

W. Silva-Araya, F. Santiago-Collazo, J. Gonzalez-Lopez, J. Maldonado-Maldonado. Flooding effects combining storm surge and surface runoff during Hurricane Georges on the Eastern coast of Puerto Rico. To be submitted to *Journal of Hydrology* by July 2017.

Presentations:

J. Gonzalez-Lopez, Giovanni Seijo, Luis Pomales, Miguel Solano, Carlos Garcia-Moreno, Colin Evans, Julio Morell, Miguel Canals, Jorge Capella. Incorporating HF-Radar and Lagrangian Drifters into a Coastal and Mesoscale Model Validation Framework in the Eastern Caribbean Sea. AMS Annual Meeting. January 2017. Seattle, WA.