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Project Title: Improving the Operational Tropical Cyclone Models at NOAA/NCEP and Navy/FNMOC
PIs/PDs: Isaac Ginis and Morris Bender
Report Type: Annual Report
Reporting Period: 04/01/2011 - 08/31/2012

Work Accomplishments:

1. Tasks scheduled for Year 1

   a) *Design and deliver a graphical software package to NHC for viewing the depth of the 26°C isotherm after the feature-based ocean model initialization procedure.*
   b) *Upgrade the ocean model domain configuration in the eastern Atlantic.*
   c) *Improve vertical representations of the Loop Current and warm/cold eddies during the feature-based ocean model initialization procedure.*
   d) *Implement a unified GFDL/GFDN version control framework.*
   e) *Upgrade the air-sea flux parameterization with full wind-wave-current interaction and sea-spray effects into the GFDL/GFDN models, evaluating its performance on an extensive set of real-world historical cases.*
   f) *Implement the new GFS cumulus parameterization and shallow convection schemes and the improved GFS PBL scheme into GFDL/GFDN.*

2. Tasks accomplished this period

We report here *only the tasks completed since 4/01/12*. The prior tasks are reported in our last semi-annual report, which covered the reporting period of 08/01/2011 – 03/31/2012.
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   a) *Design and deliver a graphical software package to NHC for viewing the depth of the 26°C isotherm after the feature-based ocean model initialization procedure.*

Development of the graphical package is in progress and active collaboration between URI and NHC (Eric Blake, in particular) to accomplish this task is ongoing. With regards to the feature-based ocean model initialization procedure, it became apparent during NHC's first 2012 attempt to update the LC/Ring files that both the altimetry-based maps and the executable file they used for this procedure were no longer available as they had been previously. Investigative work between URI and NHC (with assistance from Mark DeMaria at NESDIS) identified that the cause of the problem was the decommissioning of these operational products at NHC without the knowledge of URI and without an understanding at NHC of the ramifications of this decommissioning on the ability of NHC staff to update the LC/Ring files. Once the problem had been identified, URI worked diligently and efficiently with NHC to deliver the original source code, ensure that the program compiled and ran correctly, and provide an alternative source for the altimetry-based maps (namely the CCAR altimetry website) so that NHC staff could continue to update the LC/Ring files in real-time for the feature based ocean model initialization procedure that is crucial for the operational GFDL, GFDN, and HWRF models.

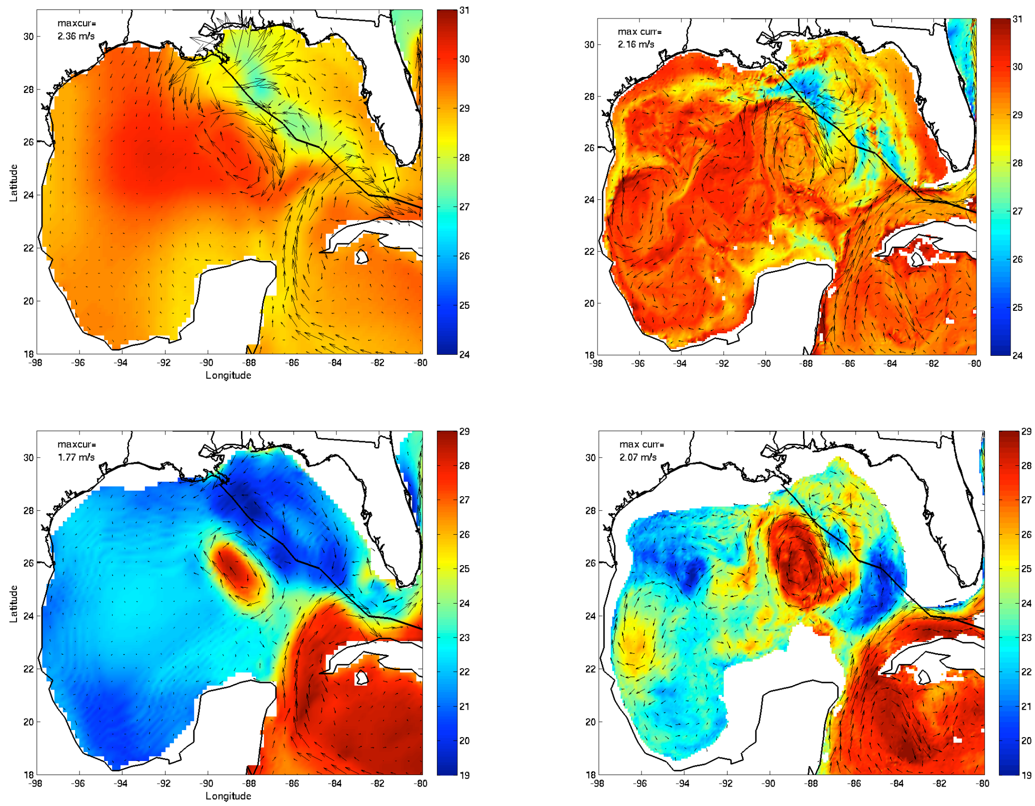

Figure 1. *Temperature (shaded in °C) and ocean current vectors at sea surface (top panels) and depth of 75 m (bottom panels) in the operational, feature-based POM (left panels) and in the HYCOM RTOFS-initialized POM (right panels) on August 28, 2012 00UTC during the passage of Hurricane Isaac in the Gulf of Mexico.*

b) *Improve vertical representations of the Loop Current and warm/cold eddies during the feature-based ocean model initialization procedure.*

Improved representation of the Loop Current and eddies in the feature-based initialization was tabled in favor of exploring alternative ocean initialization options (such as Global HYCOM RTOFS) as a potential replacement for the feature-based initialization. Currently, the Princeton Ocean Model (POM) used as the ocean component of the GFDL and GFDN coupled systems utilizes different initialization procedures in different ocean basins. It is recognized that the feature-based modeling procedure utilized in the Atlantic basin is subjective by design and has some technical and scientific limitations.

Therefore, we have developed a methodology to initialize POM from EMC's new Global HYCOM RTOFS, which began running operationally in real-time on 25 October 2011. This Global HYCOM RTOFS-initialization for POM is a possible alternative to the current feature-based ocean initialization in the Atlantic and also may be utilized in other ocean basins instead of the currently used NCODA. Testing and evaluation of this new system began during the 2012 hurricane season and may be implemented operationally in 2013 if results are favorable. Fig. 1 shows a comparison of the operational feature-based and Global HYCOM RTOFS-based ocean model initializations during Hurricane Isaac in the Gulf of Mexico.

If these alternative ocean initialization options do not ultimately provide increased skill over the feature-based initialization, then efforts will be refocused to improve the feature-based initialization to its fullest potential.

c) Implement a unified GFDL/GFDN version control framework.

It has been recognized that a unified GFDL/GFDN code system with version control will result in a more efficient transition to operations when improvements are made to one of the versions of the model. To accomplish this unification, we have incorporated the subversion (svn) software system at the URI computing cluster and are in the process of setting up the subversions at NCEP and FNMOC, to track future changes to all of the various components of the GFDL/GFDN forecast system. Subversion software is already being used successfully by the Developmental Testbed Center (DTC) to track changes to the HWRF version in the DTC repository, and we plan to build upon their expertise to accomplish a similar result with GFDL/GFDN. It is anticipated that this work will reduce the possibility of coding errors introduced during future implementations.

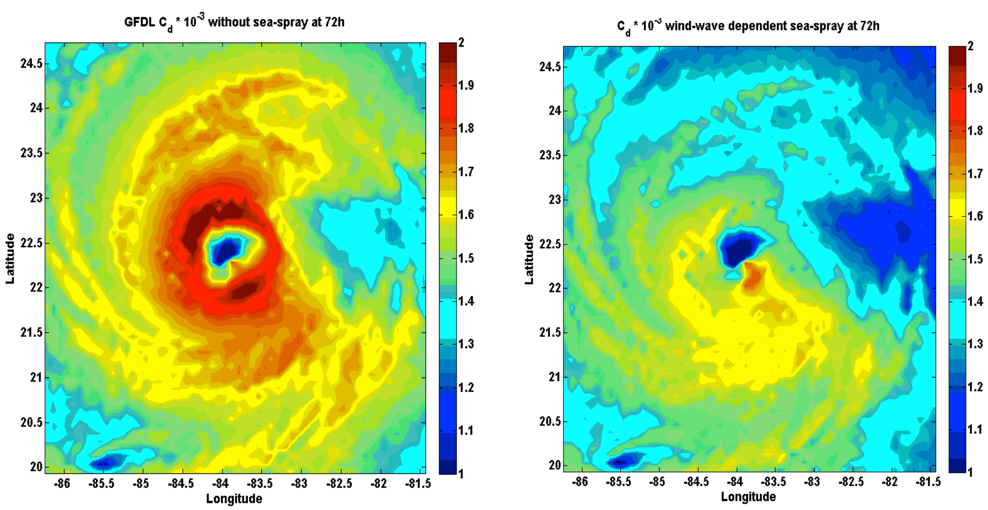

Figure 2. *Drag coefficient at 35-m height in the GFDL hurricane-wave-ocean coupled system without (left) and with (right) sea spray effects.*

d) Upgrade the air-sea flux parameterization with full wind-wave-current interaction and sea-spray effects into the GFDL/GFDN models, evaluating its performance on an extensive set of real-world historical cases

One of the Co-PIs (Isaac Ginis) has been leading a team of scientists from academia, the U.S. government, and the private sector, funded by HFIP/NOPP, to develop a unified air-sea interface module (ASIM) for fully coupled atmosphere-wave-ocean modeling systems. This module and associated physics packages are currently being implemented into the GFDL/GFDN hurricane-wave-ocean coupled system. These packages include the effects of wind-wave-current-sea spray interaction on the air-sea fluxes in high wind conditions.

We modified the MFLUX2 module in GFDL to include the sea-state dependent flux calculation capabilities. We also implemented two new wind stress calculation parameterizations, which were developed during the NOPP-funded projects, into WAVEWATCH following the guidelines in NOAA/EMC's "WAVEWATCH III development best practices". These parameterizations include 1) an updated URI wind stress calculation with a new tail parameterization and 2) the new University of Miami wind stress calculation.

We tested the new WAVEWATCH 4.04 version with different wind stress parameterizations, including the ST2 and ST4 physics packages. The results were compared with buoy and SRA data. Initial evaluation suggested that 4.04 would give lower significant wave height and spectra values compared to observations at most wavenumbers. These results were reported to EMC and discussed during the meeting at EMC on July 25, 2012. The evaluation of the new physics packages will continue in close collaboration with EMC.

We implemented the new ESRL sea-state dependent sea spray parameterization in the GFDL coupled hurricane-wave-ocean. In the implemented scheme, the mass-density effect of sea spray is considered as an additional modification to the stratification of the near-surface profiles of wind, temperature, and moisture in the marine surface boundary layer (MSBL) (Bao et at. 2011). The overall impact of sea-spray droplets on the mean profiles of wind, temperature, and moisture depends on the wind speed at the level of sea-spray generation. As the wind speed increases, the mean droplet size and the mass flux of sea-spray increase, rendering an increase of stability in the MSBL and the leveling-off of the surface drag. Sea spray also tends to increase the total air–sea sensible and latent heat fluxes at high winds. Our simulations with the GFDL hurricane-wave-ocean system with sea spray effects show significant impact of sea spray on the momentum and heat fluxes. An example of the drag coefficient with and without the sea spray effect is shown in Fig. 2.

3. Summary of 2012 physics upgrades and performance of GFDL model during the first half of the 2012 Atlantic hurricane season

The following is a list of the physics upgrades implemented into the operational GFDL model in 2012:

a) Implemented the GFS shallow convection scheme and made improvements to the current PBL scheme.

a) Incorporated communication of detrained micro-physics passed from the SAS convective scheme to the Ferrier micro-physics package.
b) Fixed a bug in the PBL scheme from the 2003 implementation.
c) Fixed a bug in the SAS convective scheme from the 2011 implementation.
d) Retuned the momentum mixing.
e) Improved the formulation of the surface exchange coefficients.
f) Evaluated the new GFS PBL scheme but rejected it for implementation due to degraded track performance.
g) Reduced the storm size and removed asymmetries in the vortex initialization.

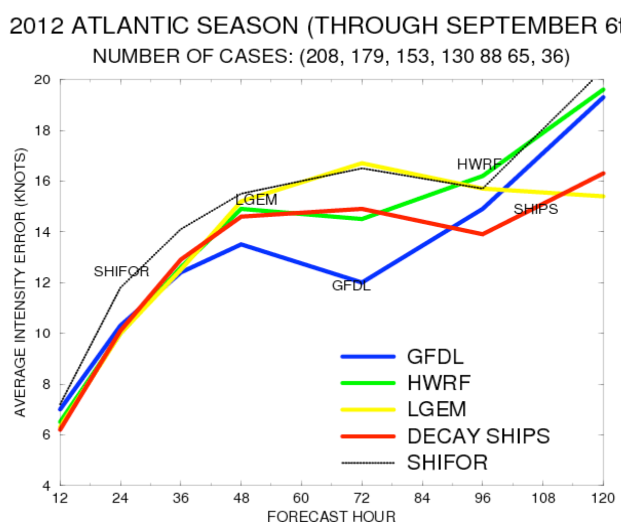

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Figure 3. *Intensity errors (knots) for the operational GFDL model (blue), compared to HWRF (green), LGEM (yellow), Decay SHIPS (red) and SHIFOR (dotted black) for all forecasts in the Atlantic basin through September 6th, 12z.*

The implemented physics upgrades in the operational GFDL model have resulted in significantly improved intensity prediction (*Fig. 3, 4 and 5*). Overall, the upgraded model for the first half of the Atlantic hurricane season has the smallest intensity errors of all other operational guidance, in the critical 36h-72h time periods. The model so far is exhibiting skill relative to SHIFOR at all forecast time periods ranging from 3% to 27%. For Hurricane Isaac, which was a significant US landfalling event, the upgraded GFDL model intensity performance was particularly impressive (*Fig. 4, Fig. 5a*), beating all other available operational guidance for all forecast time periods except day 5, which may have been negatively impacted by large landfall errors. The model also showed skillful performance for Hurricane Leslie (*Fig. 5b*). It appears that much of the improved performance of the upgraded model is due to a reduced positive bias, which has been prevalent in the operational GFDL model in previous years, limiting its reliability as a useful intensity model. For the first half of the Atlantic season, the average bias is about -2.1 knots.

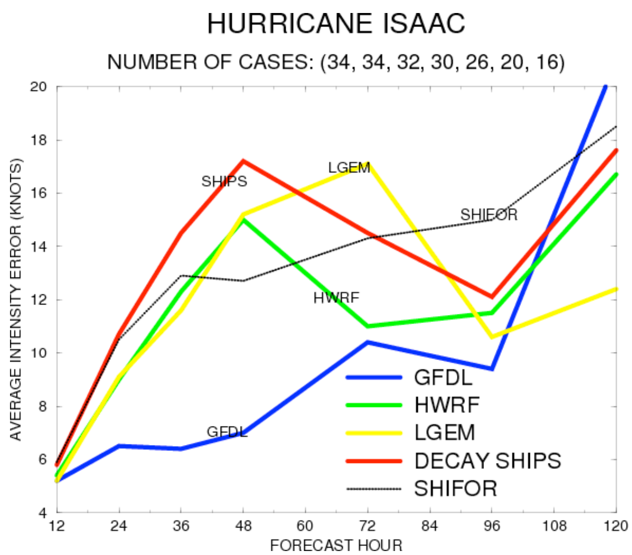

Figure 4. *The same as Fig. 3, but for Hurricane Isaac.*

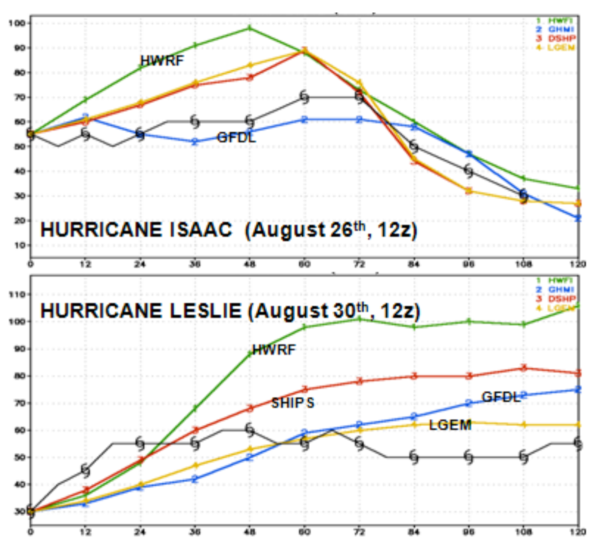

Figure 5. *Time series of forecasted maximum surface winds (knots) for one sample forecast of Hurricane Isaac (top, starting on August 26*th*, 12z) and one forecast of Hurricane Leslie (bottom, starting on August 30*th *12z), for the operational GFDL model (blue), HWRF (green) LGEM (yellow), Decay Ships (red) and observed (black).*

4. The 2012 upgrades of the GFDN model at FNMOC

One of the major upgrades transitioned to the operational GFDN model included the replacement of 1-D ocean coupling with 3-D ocean coupling in the North and South Indian Ocean and Southern Pacific Ocean. Similar to the Atlantic, Eastern Pacific, and Western Pacific, the Princeton Ocean Model (POM) with 1/6 degree horizontal grid spacing is used for the 3-D ocean coupling in these other basins. Other upgrades included passing of the detrained microphysics from the SAS scheme to the Ferrier microphysics scheme and removal of asymmetries in the vortex initialization. During theses upgrades implementation, it was noticed that the GFDN tracks were occasionally displaying erroneous motion, prompting the URI and GFDL scientists to carefully evaluate all of the source code. This evaluation resulted in a major bug being uncovered in the operational GFDN system. This bug was caused by FNMOC personnel when a critical line of computer code in one of the Optimum Interpolation routines was accidently removed during the transition of the model to a new computer system. The bug fix was implemented operationally prior to the beginning of the 2012 hurricane season. The details of all these upgrades are provided in our semi-annual report.

Not all of the upgrades implemented into the GFDL model in 2012 have been transitioned operationally into the GFDN model yet. These remaining GFDL upgrades, however, have been imported into the GFDN system and are currently being tested in the various ocean basins for operational implementation in late-Fall 2012. Fig. 6 shows an example of the new upgraded GFDN forecast for Typhoon Haikui (2012) in the western Pacific.

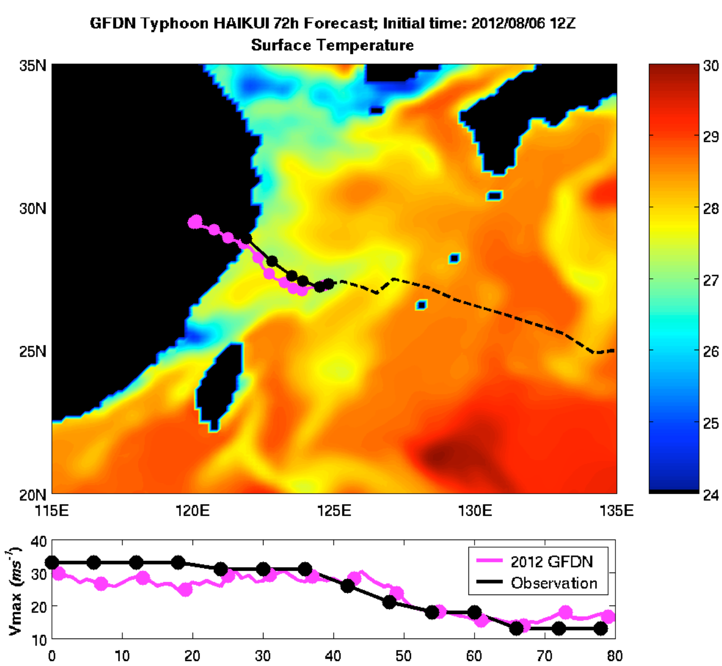

Figure 6*. Sea surface temperature (shaded in °C) and ocean current vectors at 72h (top) and maximum wind forecast (bottom) by the upgraded GFDN model initialized 2012/08/06 12 Z.*