NOAA Award Number: NA11OAR4310196
Recipient Name: The University of Rhode Island
Award Period: 08/01/2011 - 07/31/2013
Program Office: OAR Office of Weather and Air Quality (OWAQ)
Project Title: Improving the Operational Tropical Cyclone Models at NOAA/NCEP and Navy/FNMOC
PIs/PDs: Isaac Ginis and Morris Bender
Report Type: Progress Report (Year 2)
Reporting Period: 08/01/2012 - 01/31/2013

Work Accomplishments:

1. Leftover proposed tasks scheduled for Year 1 and proposed tasks scheduled for Year 2:
    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) *Improve vertical representations of the Loop Current and warm/cold eddies during the feature-based ocean model initialization procedure.*
    c) *Implement a unified GFDL/GFDN version control framework.*
    d) *Improve representations of initial conditions in the ocean model in all ocean basins.*
    e) *Implement wave coupling and sea spray effects.*
    f) *Implement improved radiation package, microphysics species advection, and increased vertical resolution.*

2. Tasks accomplished this period

Since the original writing of the Year 1 and Year 2 task lists, certain tasks have been prioritized more than others, and new, related tasks have been developed to suit the most pressing needs of NOAA/NCEP and Navy/FNMOC. Hence, the operational implementation of 1) wave coupling, 2) sea spray effects, 3) improved radiation, 4) microphysics species advection, and 5) increased vertical resolution have been postponed in favor of operational implementation of 1) increased horizontal resolution, 2) reduced gravity wave damping, 3) modified initiation of large-scale condensation, 4) improved vortex initialization, 5) improved PBL structure, and possibly 6) meso-SAS cumulus parameterization and 7) MPIPOM-TC. Below is a list of the tasks accomplished this period.

a) *Absolve the need for NHC to participate in the feature-based ocean model initialization.*

During the 2012 Atlantic hurricane season, it became clear that NHC did not always have the time or resources to regularly update the Loop Current and Loop Current eddy files associated with the feature-based ocean model initialization procedure, especially during potentially high-impact events when up-to-date versions of these files are most needed. Since the feature-based ocean model initialization procedure will still be used in the operational GFDL and HWRF coupled models in 2013, URI and GFDL are collaborating with EMC to create a regular update schedule for these files that will not require NHC's active participation. Hence, there is no longer a need for a graphical software package at NHC for viewing the depth of the 26°C isotherm after the feature-based ocean model initialization procedure.

b) Develop a brand new MPI version of POM-TC (MPIPOM-TC) for GFDL and GFDN.

URI's version of the Princeton Ocean Model (POM-TC) has been the ocean component of the operational GFDL coupled model since 2001. Some significant improvements to POM-TC have been made since then, including implementation of a feature-based ocean initialization for ocean coupling in the western Atlantic in both GFDL and GFDN (Falkovich et al. 2005; Yablonsky and Ginis 2008) and an NCODA-based initialization worldwide outside of the Atlantic in GFDN. However, no upgrades have been made to the ocean model resolution, and none of the community-based upgrades to POM have been incorporated into POM-TC since 1994. Indeed, since POM-TC runs on only one processor, future upgrades to the ocean model resolution are not computationally feasible. Hence, URI is now in the process of finalizing a major new effort to develop a new version of POM-TC (primarily under HFIP funding to improve HWRF, but with direct application to GFDL and GFDN); this version shall hereafter be known as MPIPOM-TC.

MPIPOM-TC incorporates many of the community-based upgrades to POM that have occurred between 1994 and 2012 by blending the community-based sbPOM (Jordi and Wang 2012) with the existing version of POM-TC (Yablonsky and Ginis 2008) (Fig. 1). Since it has MPI capabilities, MPIPOM-TC allows for higher spatial resolution and a larger domain size than POM-TC. In fact, one of the key improvements now included is the replacement of the two overlapping POM-TC domains in the Atlantic Ocean, each of which have ~1/6° horizontal grid spacing, with a single, new, transatlantic domain, which has ~1/12° horizontal grid spacing (Fig. 2). MPIPOM-TC is also very computationally efficient and scalable, and it has netCDF I/O.

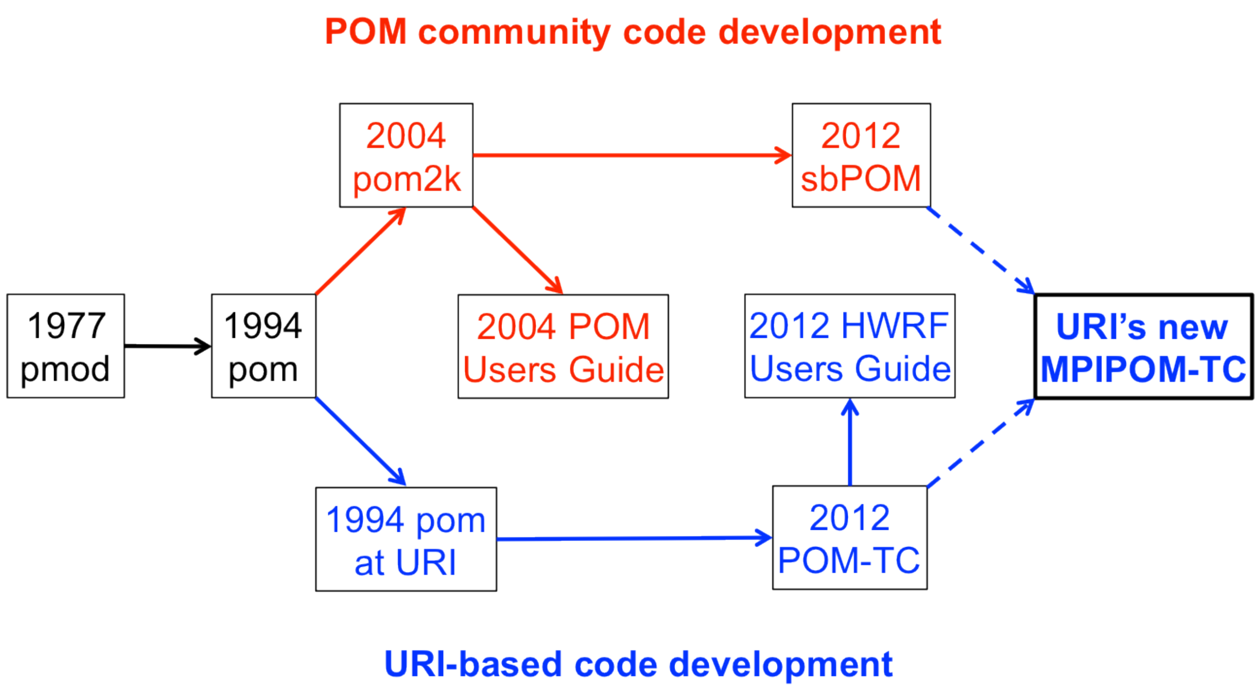

Fig. 1. *Schematic detailing the history of POM from its initial development at Princeton in 1977 to the version transferred to URI in 1994, which ultimately led to the 2012 version of POM-TC in GFDL, GFDN, and HWRF, and the subsequent merging of the 2012 POM-TC with the community-based 2012 sbPOM to form URI's new MPIPOM-TC.*

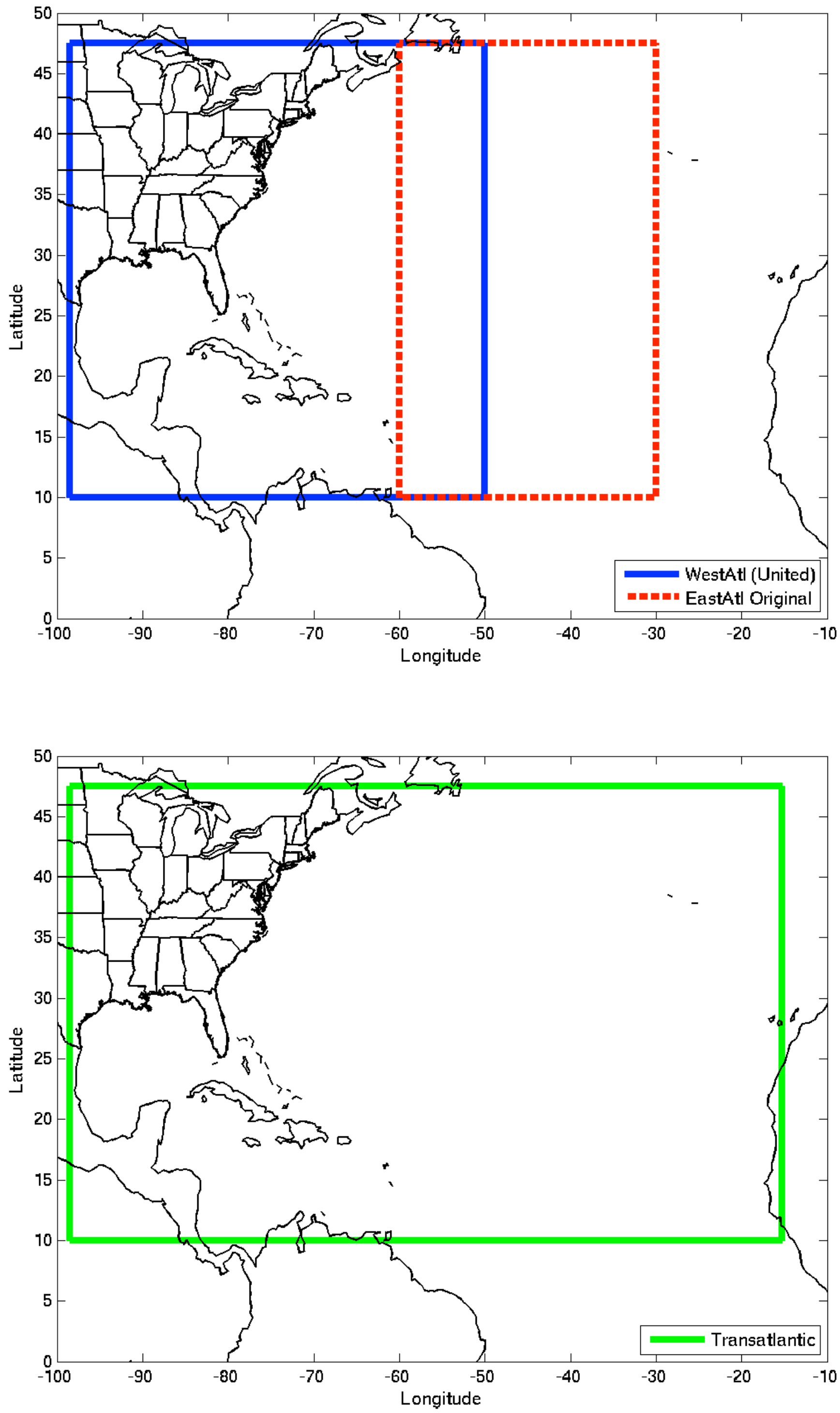

Fig. 2. *Overlapping United and East Atlantic POM-TC ocean domains (in the current operational GFDL and GFDN), each of which have ~1/6° horizontal grid spacing (upper panel), and the transatlantic MPIPOM-TC ocean domain, which has ~1/12° horizontal grid spacing (lower panel).*

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

As originally proposed, the Subversion (svn) software framework has now been incorporated into a newly unified GFDL/GFDN code system with version control, which will result in a more efficient transition to operations when improvements are to the model code and reduce the possibility of coding errors being introduced during future GFDL and GFDN implementations.

d) Develop new ocean initialization methodology

Currently, POM-TC utilizes different initialization procedures in different ocean basins in the GFDL and GFDN coupled systems, and the architecture of the POM-TC code varies from basin to basin to accommodate the various initialization procedures and grid specifications. URI has developed a new methodology to initialize a unified, basin-independent MPIPOM-TC code from different global real-time ocean products available at NOAA and the Navy. By separating the ocean initialization and grid specification module from the core MPIPOM-TC code, the initializations and grid specifications become a plug-and-play feature that facilitates simplified testing, evaluation, and operational implementation.

The implementation of the MPIPOM-TC in the operational GFDL and GFDN is a major proposed task in our pending JHT proposal and is scheduled for 2013-2014, pending positive test results. However, initial positive results indicate that it may be possible to implement the MPIPOM-TC in the Transatlantic and East Pacific basins (with feature-based initialization) into the 2013 operational GFDL model, at least one year ahead of schedule.

e) Improve representations of initial conditions in the ocean model in all ocean basins.

As an alternative to the feature-based initialization in the Atlantic and the NCODA elsewhere, NCEP's Global HYCOM RTOFS and the Navy's Global HYCOM are being tested as ocean initial conditions in the GFDL/MPIPOM-TC (Fig. 3). By continuing to perform careful evaluation of various ocean initialization products in all ocean basins, it will be possible to ensure that MPIPOM-TC is initialized with the best product available for subsequent GFDL and GFDN operational implementations. In parallel, however, the feature-based ocean initialization procedure will continue to be improved in the Atlantic basin until an alternative initialization product is proven to have sufficient accuracy to render the feature-based initialization obsolete.

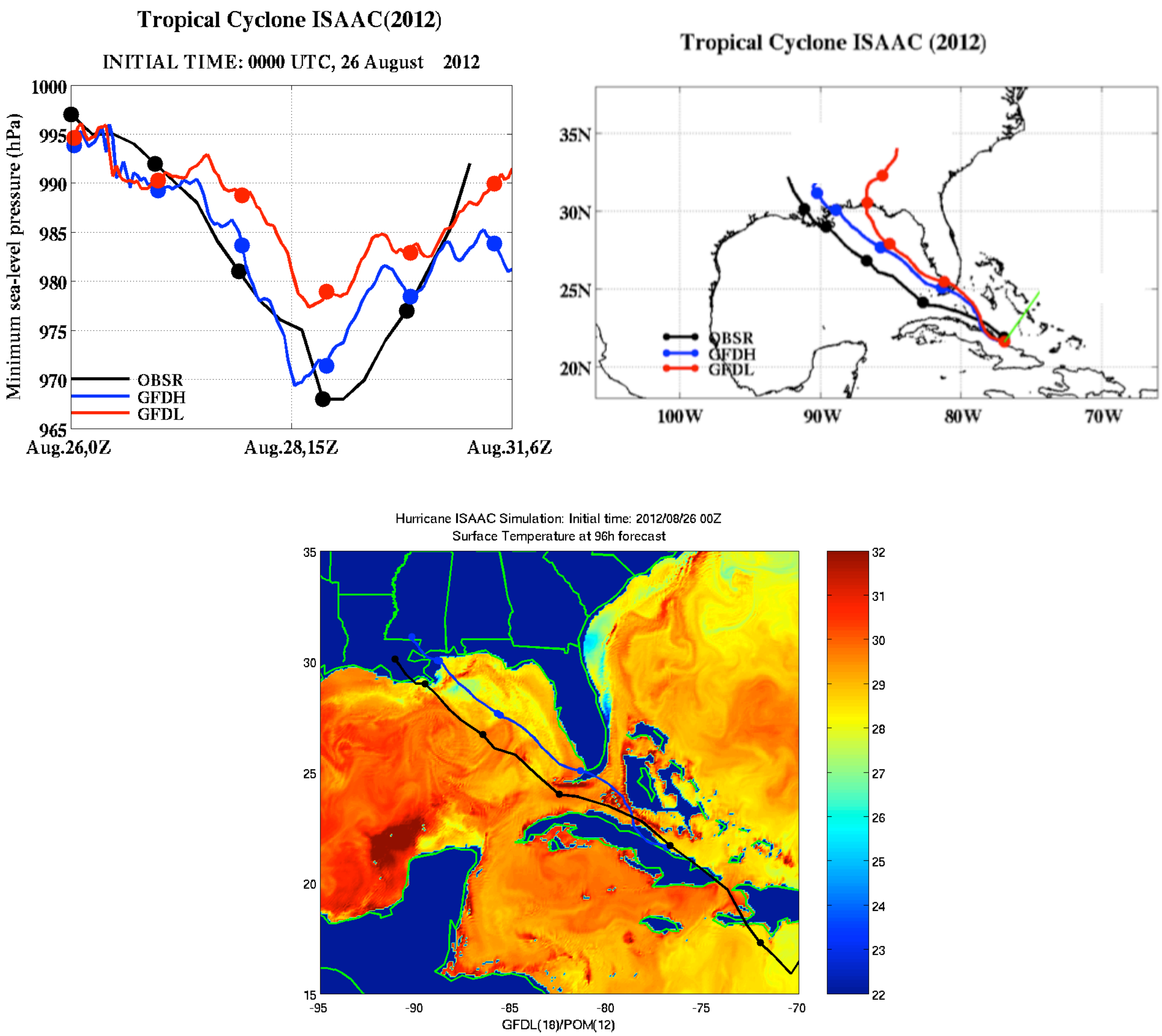

Fig. 3. *GFDL intensity (upper left) and track (upper right) forecasts of Hurricane Isaac (2012), initialized at 00 UTC on August 26, 2012, using either the operational GFDL/POM-TC system (GFDL, red) or the new high-res GFDL/MPIPOM-TC with Global HYCOM RTOFS ocean initialization (GFDH, blue), as compared to the observed intensity and track (OBSR, black). Sea surface temperature after 96-h of the GFDH simulation is shown in the lower panel.*

f) Implement increased GFDL/N horizontal resolution and improved physics/initialization.

GFDL and URI have now developed a high-resolution version of the GFDL and GFDN models. Pending final test results, it may be possible to implement this high-resolution version of the models into operations in 2013, at least one year ahead of schedule. In the new model configuration, the area of the innermost nest with highest resolution remains the same as the present version, but with an increased horizontal resolution from 1/12° to 1/18° grid spacing. This 1/18° grid spacing is the highest resolution physically justified for the GFDL model because it is hydrostatic. Several modifications to the model physics and initialization have been made to maximize the benefit of the increased resolution. These modifications include the reduction of the gravity wave damping term in the time differencing scheme (Kurihara et al. 1980), initiation of large-scale condensation at 100% humidity for inner nests, and improved specification of the maximum wind in the vortex initialization (which significantly reduces the initial negative wind bias). Results indicate a significantly improved storm structure for most storms (Fig. 4).

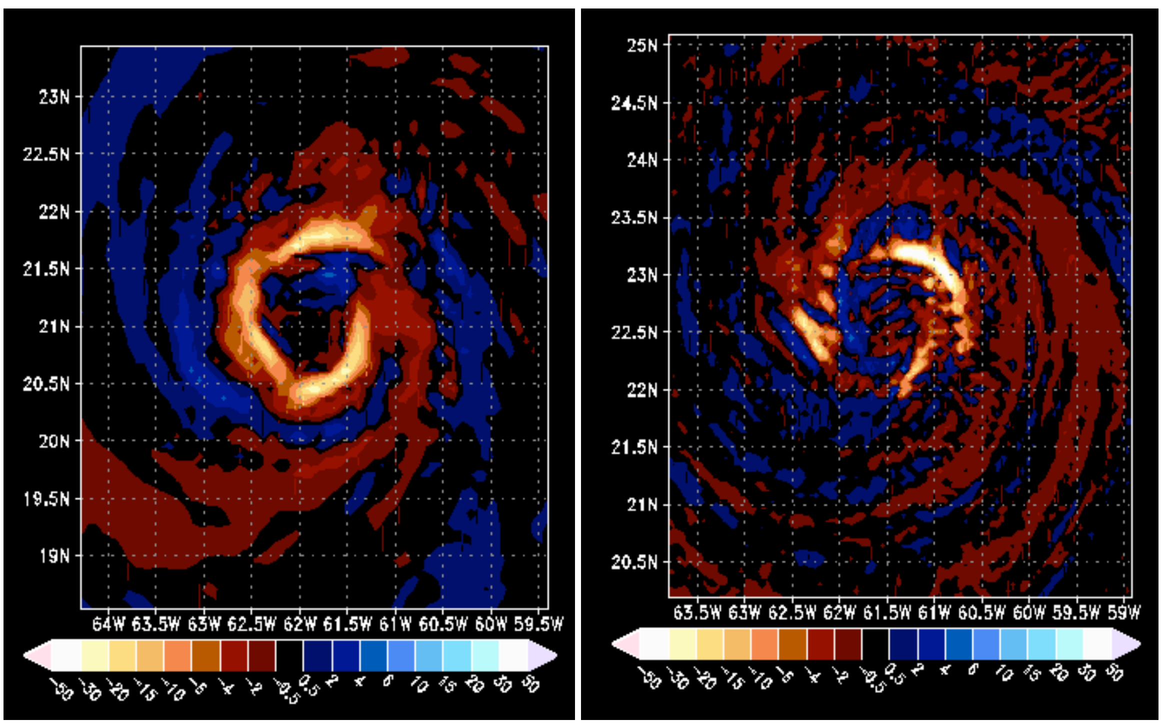

Fig. 4. *An example of significantly improved storm structure (500 hPa omega) from the current operational GFDL model simulation (left) to the high-resolution GFDL model simulation (right) of a 96-hour forecast of Hurricane Katia (initialized 00 UTC 01 Sept. 2011).*

In addition, the track forecast skill has improved, particularly for certain storms, as illustrated in the Hurricane Nadine (2012) comparisons in Fig. 5. Intensity bias statistics from the 2010, 2011, and 2012 Atlantic Hurricane seasons, as well as intensity and track errors from the combined 2010-2012 seasons, are shown in Fig. 6; these results indicate a significantly reduced intensity bias for all three seasons at most time periods. With the additional physics upgrades currently being evaluated (e.g., improved PBL, MPIPOM-TC, it is anticipated the final upgraded model configuration will demonstrate additional reduction in track and intensity error.

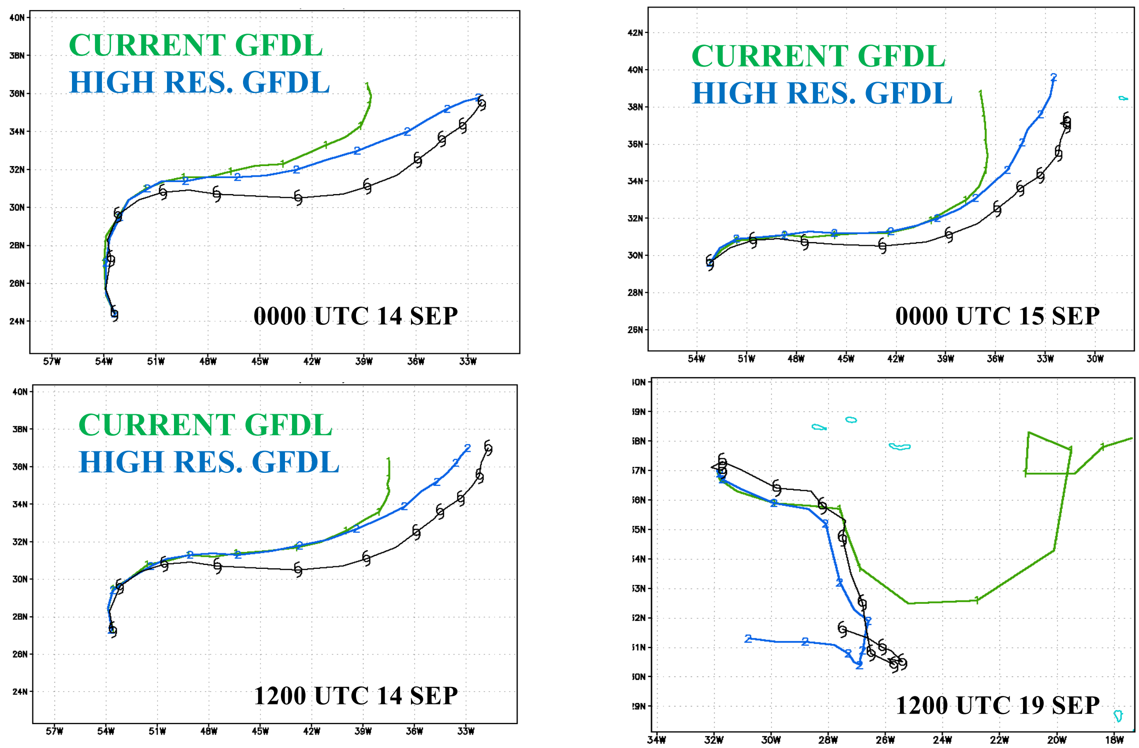

Fig. 5. *GFDL simulated tracks for Hurricane Nadine (2012) at four initial times. Each panel includes current operational GFDL (green), high-resolution GFDL (blue), and observed (black).*

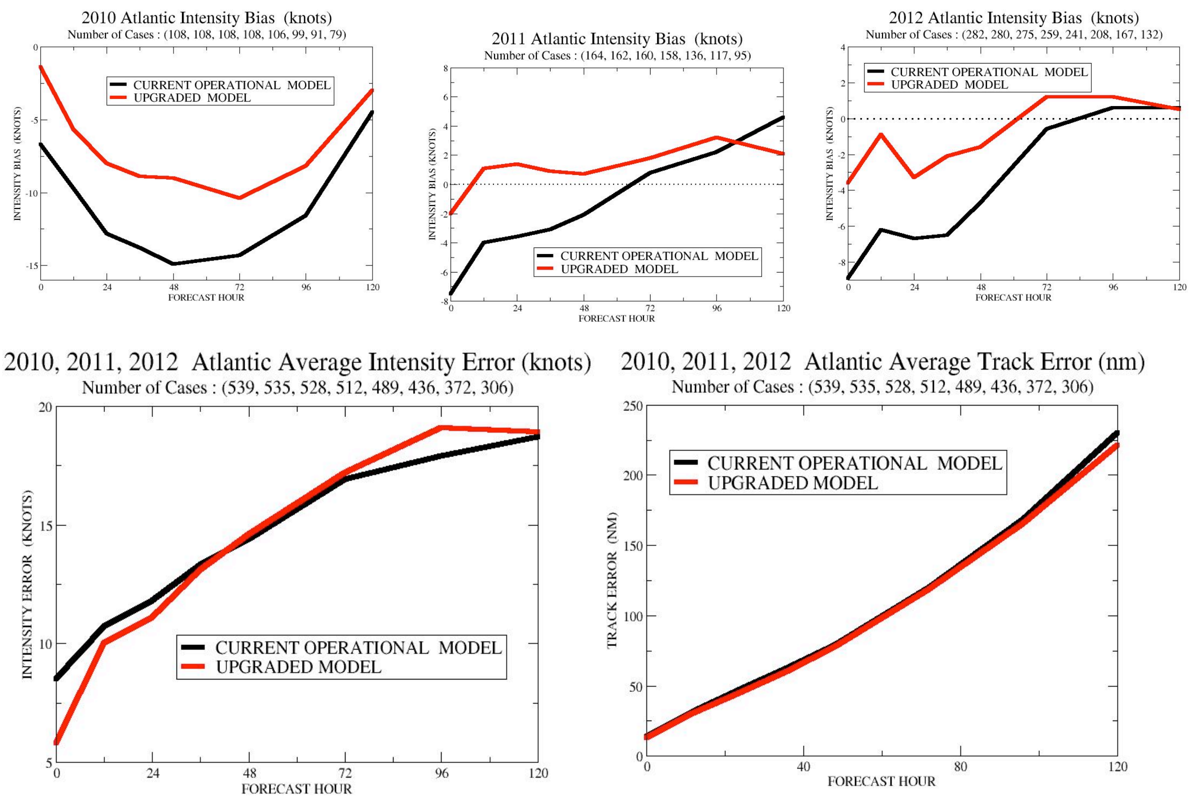

Fig. 6. *Current (black) and upgraded (red) GFDL* intensity bias statistics from the 2010 (upper left), 2011 (upper middle), and 2012 (upper right) Atlantic Hurricane seasons, as well as intensity (lower left) and track (lower right) errors from the combined 2010-2012 seasons.

References:

Falkovich, A., I. Ginis, and S. Lord, 2005: Ocean data assimilation and initialization procedure for the Coupled GFDL/URI Hurricane Prediction System. *J. Atmos. Oceanic Technol.,* **22,** 1918–1932.

Kurihara, Y., and M. A. Bender, 1980: Use of a movable nested-mesh model for tracking a small vortex. *Mon. Wea. Rev.,* **108,** 1792-1809.

Jordi, A., and D.-P. Wang, 2012: sbPOM: A parallel implementation of Princeton Ocean Model. *Environmental Modelling & Software*, **39,** 58-61. doi:10.1016/j.envsoft.2012.05.013

Yablonsky, R. M., and I. Ginis, 2008: Improving the ocean initialization of coupled hurricane-ocean models using feature-based data assimilation. *Mon. Wea. Rev.,* **136,** 2592-2607.