# Hurricane Model Transitions to Operations at NCEP/EMC

Year One progress Report  August 1, 2005 – June 30, 2006

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The JHT project deals with the transition from the GFDL to the WRF model that is scheduled to become the next operational hurricane model in the 2007 tropical season. The first 6 month progress is indicated below in the August to February Timeline. The progress after February is discussed in the last part of the report. Progress in this project has also been reported in the JHT talks at the last IHC Conference and the 27th AMS Conference on Hurricanes.

Work Plan and Time Line
Year One:  August 1, 2005 – February 1, 2006

1) Continue to install, run and evaluate WRF prototype systems for 2005 hurricane season  with upgraded GFDL initial conditions. This system has both uniform resolution domain and one-way nesting.

An end-to-end, automated system of the NMM-WRF with the one-way moving nest initialized from real-time storm positions was run nearly for one full season in 2005, twice a day. Each forecast was run 5 days. The grib files from the GFDL forecast was used as an input to the NMM-WRFSI. The initial and boundary conditions along with the static, land surface data for the parent domain was obtained by running the WRFSI. The parent domain was set to about 60°x 60° at about 27-km-resolution and the one-way moving nest was set to a domain size of approximately 7°x 7° at 9 km resolution. The SAS convection, GFS surface, GFS boundary layer, NOAH-LSM scheme, Ferrier microphysics, GFDL radiation for the physics options were used. The aim here was to test the robustness of the one-way moving nest dynamics and algorithm related to the nest motion. There were very few failures noticed in the end to end system and each of the NMM-WRF runs (excluding the wrfsi initialization) for a five-day-forecast took about 50 minutes using 72 processors. Fig. 1, for instance, shows the position of the moving nest for one of the forecasts from Hurricane Wilma.

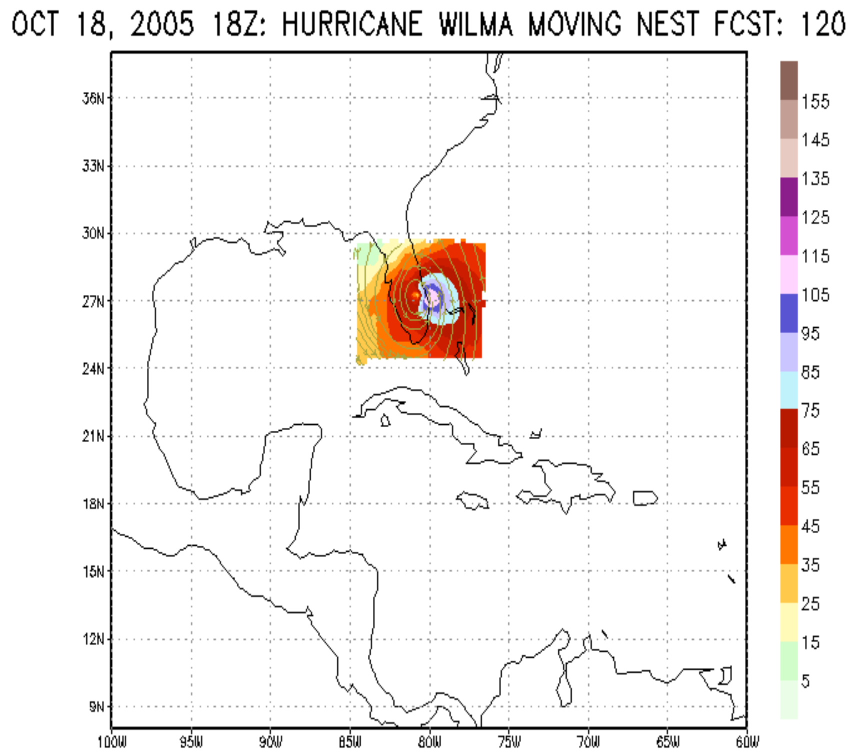


*Fig 1: semi-operational forecast* of *Hurricane Wilma, 2005.*

2) Compare 2005 HWRF prototype model runs with the GFDL operational/upgraded model. The GFDL upgraded model may include physics packages coded in WRF software framework to insure code integrity. The HWRF model will include changes to the 2005 HWRF prototype model with migration from GFS to GFDL physics for some physics processes.

The WRF physics codes have been assembled to provide a physically realistic, yet computationally efficient hurricane forecast model and forecast system. In transitioning to NCEP's next generational Hurricane WRF model, the benchmark physics will be the physics package presently used in the GFDL model. This physics package includes the Simplified Arakawa convective scheme and a Monin-Obukov surface scheme. These schemes will be compared to the present Global Forecasts System (GFS) parameterizations as well as with some other parameterizations deemed appropriate for meso-scale forecasting. One example of the difference between the GFDL and GFS model can be seen in Fig 2. Emphasis will be placed on the surface package presently used in the GFDL model and it's comparison with schemes that have separate surface roughness estimates for heat and momentum. This is especially important since intensity is known to be quite sensitive to these parameterizations and that hurricane maintenance can only be sustained through surface energy fluxes, especially that of moisture. On the other hand, surface friction has a retarding effect on hurricanes.

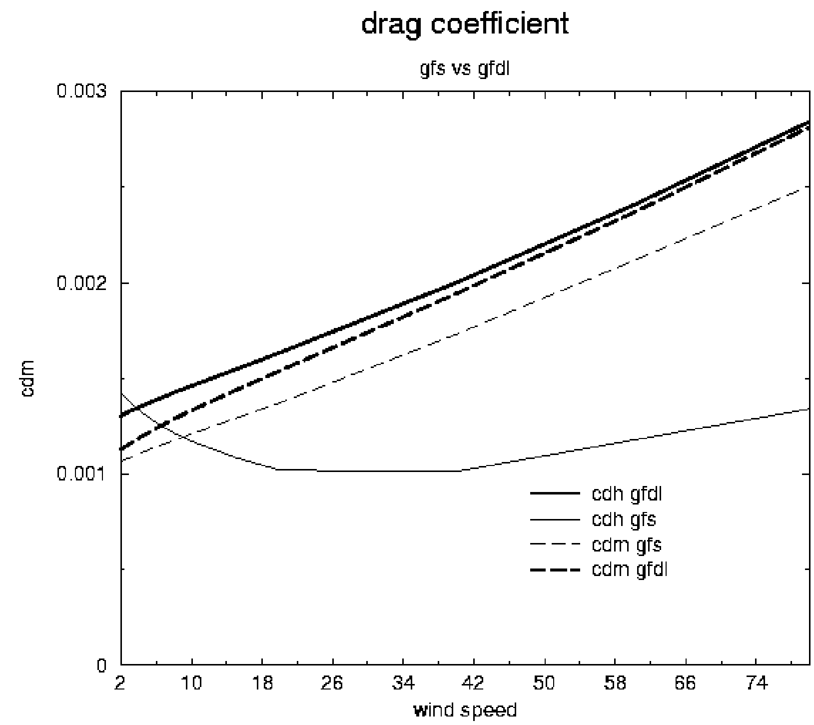


*Fig.2 Comparison of exchange coefficients of heat/moisture and momentum for the GFDL and GFS models.*

The surface exchange processes are still poorly understood and still under investigation. Recently, wave models and observations appear to indicate that the long used parameterizations that increase drag with wind speed may not apply under hurricane conditions. On the other hand, surface evaporation is complicated due to the effect of spray and the chaotic nature of the ocean interface under hurricane conditions.

HWRF Offline and model code comparisons indicate that surface evaporation in the GFDL model increases monotonically with wind speed while the GFS physics package increases evaporation at a lesser rate. Furthermore, the GFDL surface drag appears to be more dissipative even with a reduced coefficient.

3) Compare LSM characteristics including rainfall and runoff in HWRF with the GFDL model run.

A 3-day forecast for each of 25 historical landfall hurricanes was run for both slab (operational) and Noah LSM model couplings in the GFDL model. For the chosen cases, all hurricanes made landfall less than a day. The model results for hurricane track, intensity and (accumulated) precipitation over land were compared to the observations from the rain gauge data and the National Hurricane Center best track reanalysis. It was found (not shown) that the impact of the Noah LSM coupling on track and intensity are insignificant. For example, the track difference is smaller than 50 km for most of the cases. Appreciable differences are found in the precipitation particularly in local accumulation. The hurricane-Noah LSM coupled system in general improves the precipitation forecast (such as in total rainfall, equitable threat score and QPF bias score). An example is given in Fig. 3 for QPF bias score. Recently, the GFDL slab model was coded in the WRF framework for comparison with the NOAH LSM. An objective comparison of track, intensity and precipitation is ongoing in the HWRF system.

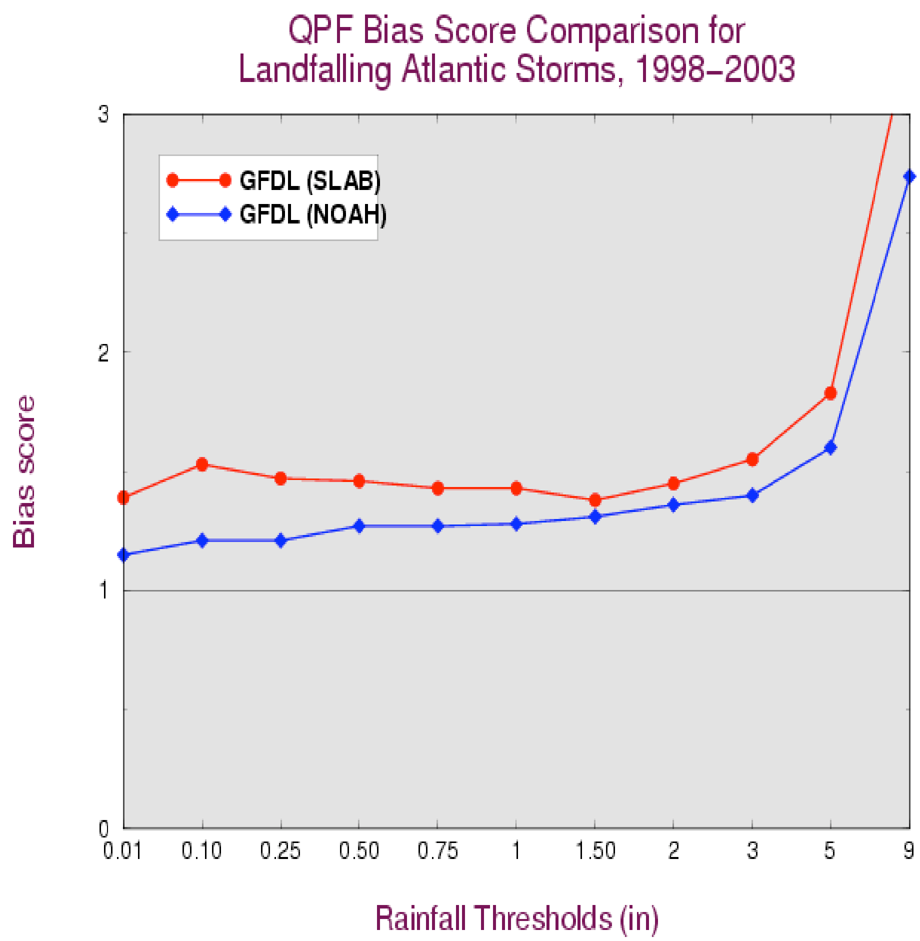


*Figure 3. Rainfall bias statistics for 25 historical landfall hurricanes over the Gulf ofMexico and western Atlantic basins from 1998 to 2003.*

Fig.4 presents a comparison of the sensitivity of the surface temperature using the NOAH LSM model and the more simple GFDL slab model in HWRF for a case of Dennis (2005). The effect of surface and convective parameterization on storm track and intensity are also being analyzed for a more complete suite of cases.

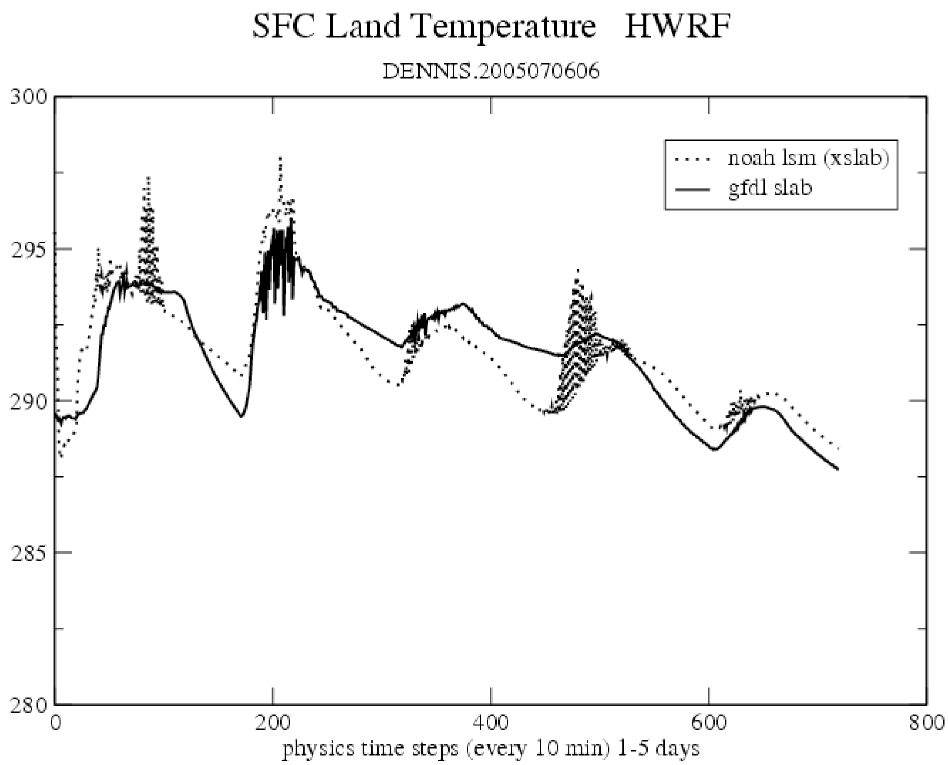


*Fig.4 Comparison between surface temperatures predicted using the NOAH LSM and the GFDL slab.*

4) Collaborate with EMC developers in the design, running and evaluation of the first moveable, 2-way nested version of HWRF. Also collaborate with university and NOAA components in running and evaluating different versions of EMC HWRF.

Two different approaches have been adopted in the design of a movable nested mesh, especially for hurricane forecasting. In one approach two non-overlapping adjacent meshes may be dynamically coupled when the time integration for the grid points near the mesh interface is performed on each side with the use of the information in the other mesh domain (e.g., Kurihara et al., 1979). A fairly easier method is to transfer meteorological information from a fine to a course mesh and vice versa over the region of coinciding grid points (e.g., Phillips and Shukla, 1973). The nested grid NMM-WRF modeling system is broadly based on the latter approach.
The two-way system is presently under development and it will be ready for parrllell testing for the 2006 year.
An active participation with Floridida State University has resulted in HWRF being run for a variety of spacial resolutions.

5) Compare developmental nested HWRF runs with the uniform resolution versions of HWRF.

One difference between GFDL and HWRF nested runs are that the uniform resolution parent grid is integrated throughout the parent domain so the comparison with the nested HWRF domain is more straight forward. For post-processing, software has been developed to combine the parent and nest domain into one fine resolution domaind for verification of tracks and intensity. Fig.5 indicates the design of parent and nest grid domains for HWRF in a 3 to 1 grid configuration.

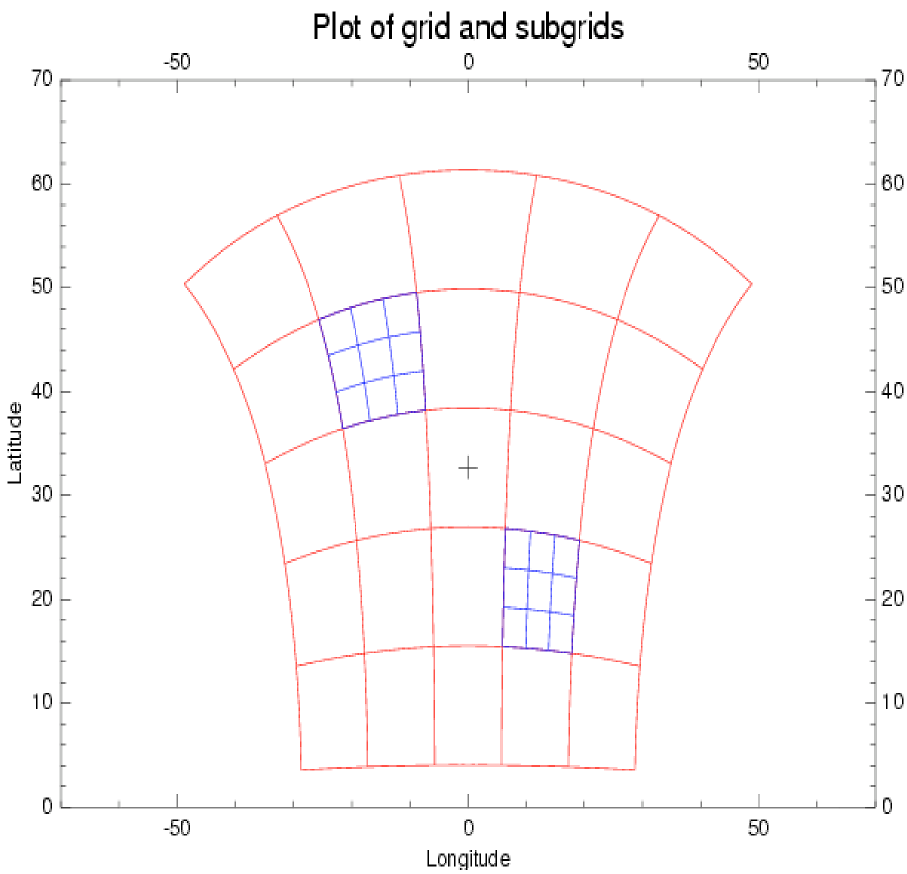


*Fig 5: The NMM telescopic nest as it appears on a true latitude-longitude coordinate system.*

Year Two: February 1, 2006 – June 30,2006

1) Compare developmental nested HWRF runs with the uniform nest version of HWRF.

Considerable progress has been made on the development of the 2-way, moving grid nested grid system for HWRF. This system has been shown to be quite robust. The nested system is patterned after the overall WRF Software nested framework and is quite different from the GFDL system where intergration is not performed over any overlapping grids. HWRF integrates over the entire domain of all the grids. For practical reasons, the HWRF system is restricted to coincidene grid points and a grid ratio of 3 to 1.

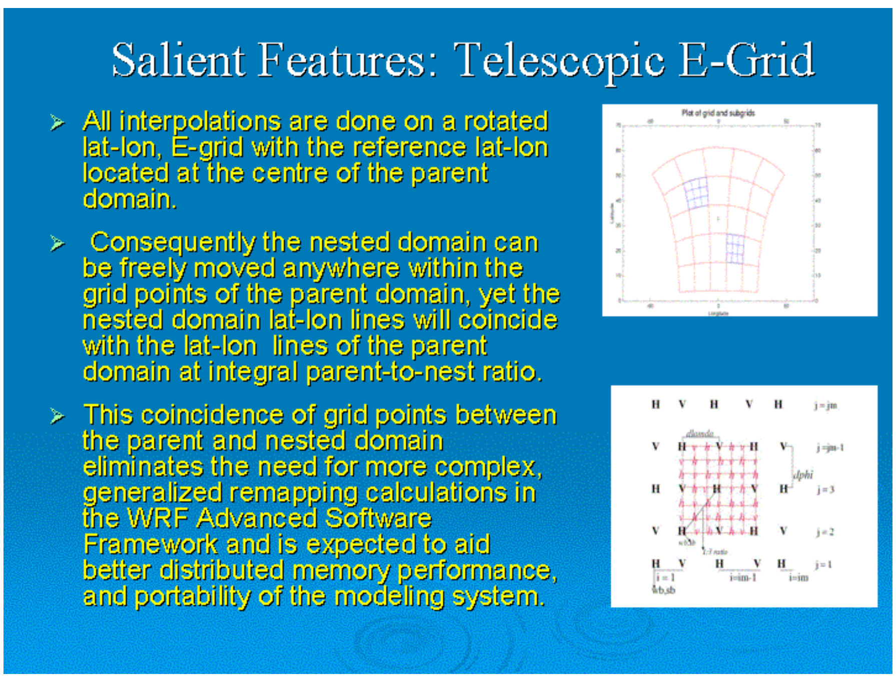


*Fig.6 Some feature of the HWRF nested grid system*

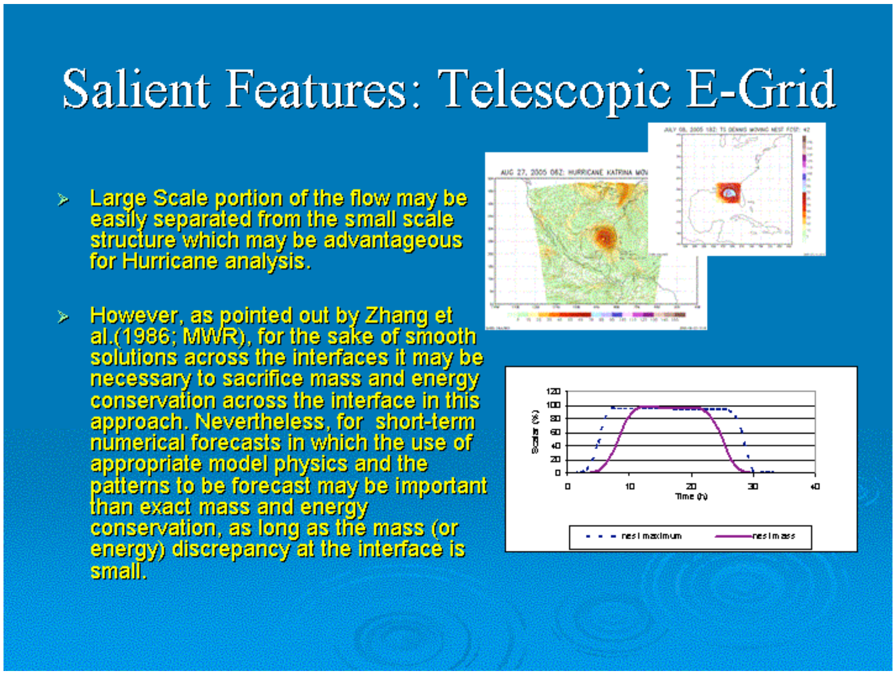


*Fig.7 Some additional feature of the HWRF system. A typical domain Configuration is shown for HWRF.*

During the 2005 season, the one-way HWRF system had some problems in forecasting particular cases. One such case was an early forecast (pre-Florida landfall) of Katrina. Some of these forecasts had a pre-mature northward turn in the NE Gulf.

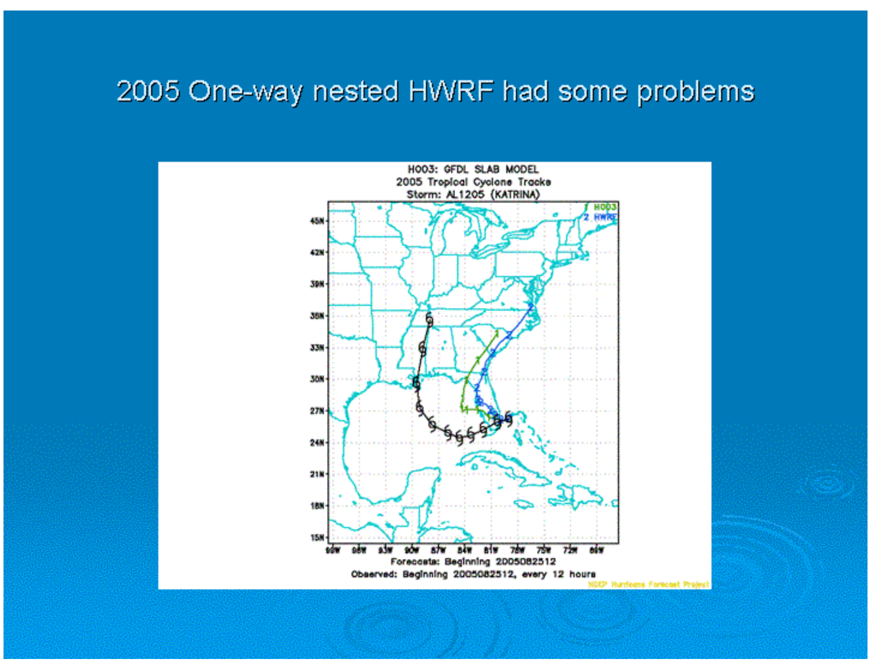


*Fig.8. HWRF run in one-way nest mode.*

When the 2-way nested grid was implemented, some cases exhibited dramatic improvement. The 2-way scheme involves the dynamic feedback of the fine scale nest back to the coarse mesh. A particular case of improvement was that of Katrina. Fig. 9 displays a track much improved but still showing an northward and eastward bias.

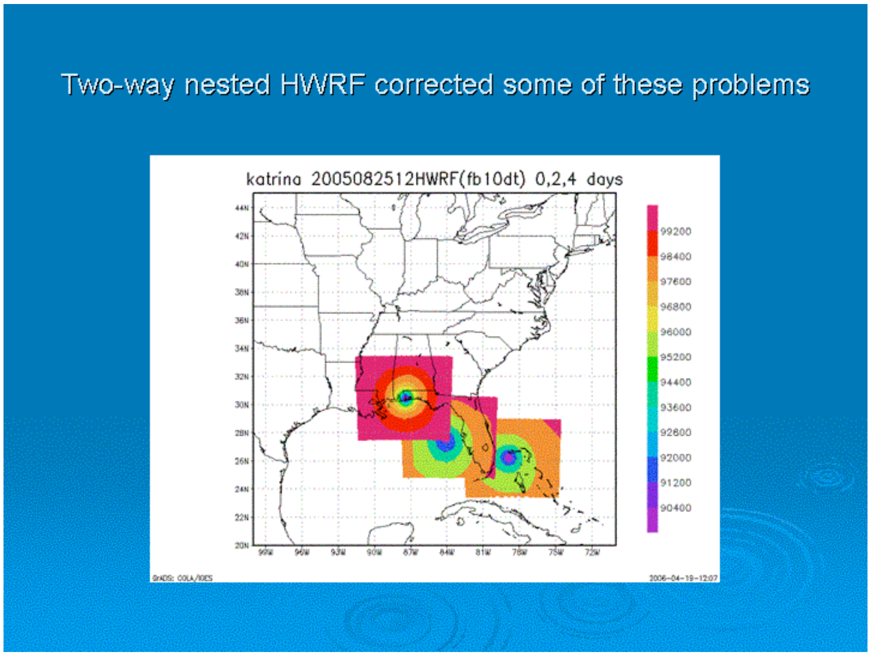


*Fig. 9 HWRF forecast of Katrina run in 2-way mode.*

2) Collaborate with EMC and university personnel in the development and integration of ocean and wave model components into the HWRF forecast system.

The ocean group at EMC is working on the ocean coupling component of HWRF. This includes both the ocean initialization and the software neccesary to couple the HYCOM model with the atmospheric component of HWRF. Gopalakrishnan and Tuleya have discussed the ocean coupling interface from the atmospheric prospective and compared it with what is done in the GFDL model. URI is working closely with EMC in designing the ocean initialization and the ocean coupling interface from the oceanic prospective. The interface involves the exchange of enthalpy, momentum, and radiative fluxes from atmosphere to ocean and the prediction of SST by the ocean. In addition, Tuleya has worked with the URI and GFDL on the coding of the surface flux parameterization of the surface wave effects on roughness which is presently in the GFDL operational model.

3) Continue to evaluate the physics and dynamics packages in HWRF that give the best skill in track and intensity compared with the GFDL benchmark. The baseline physics of HWRF will be the GFDL physics package.

Several GFDL physics packages have been implemented into the software WRF framework. This basically involves the development of GFDL physics software modules which mimic the physics processes of the GFDL model. One of the most important packages coded and implemented was that of the surface flux package that was distinct from the GFS package which was run for the bulk of the 2005 season. For some specific cases this makes a dramatic improvement (Fig.10). Another improvement was that of calling the phyiscs at a more frequent interval. This made a dramatic improvement in some cases of Katrina which were quite sensitive to subtle changes (Fig. 11). The GFDL model routinely calls physics packages every time step. WRF physics packages are routinely called less frequently.

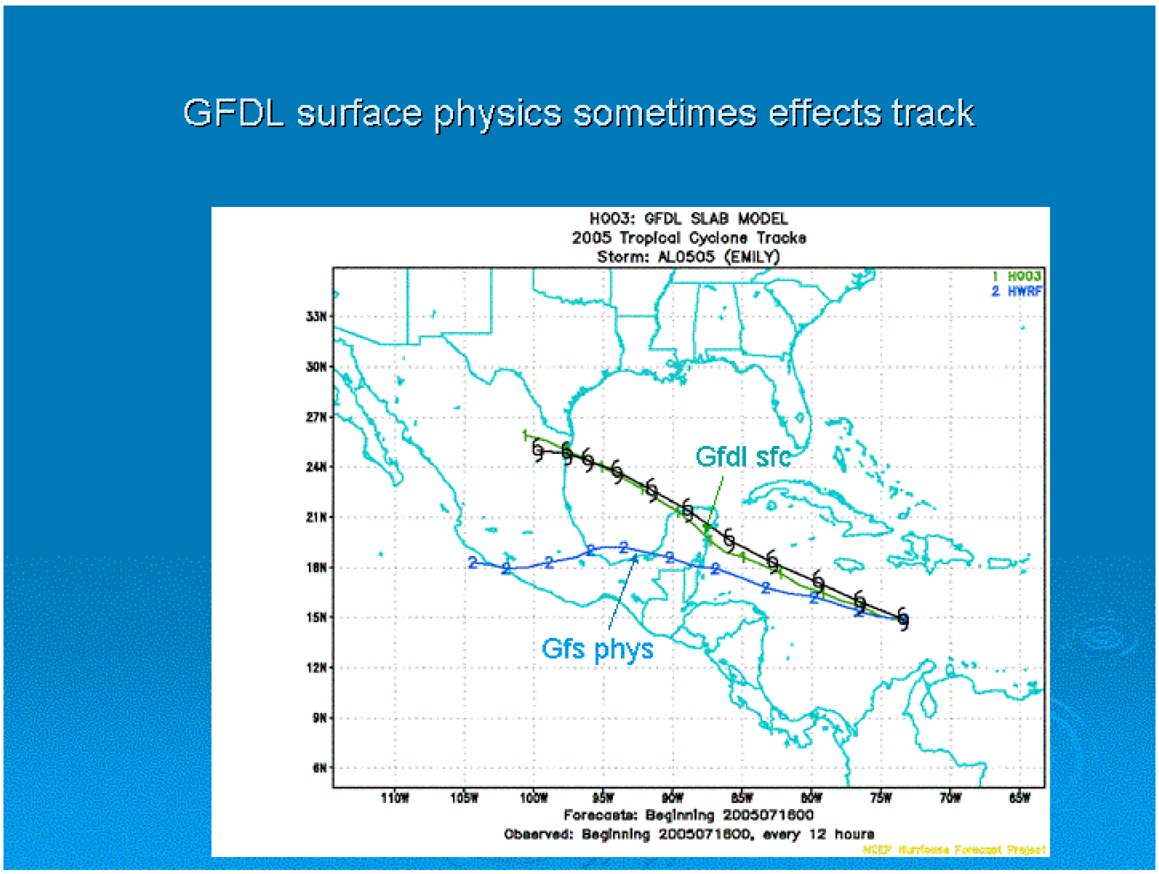


*Fig.10 HWRF tracks of Emily showing the sensitivity of surface flux parameterization.*

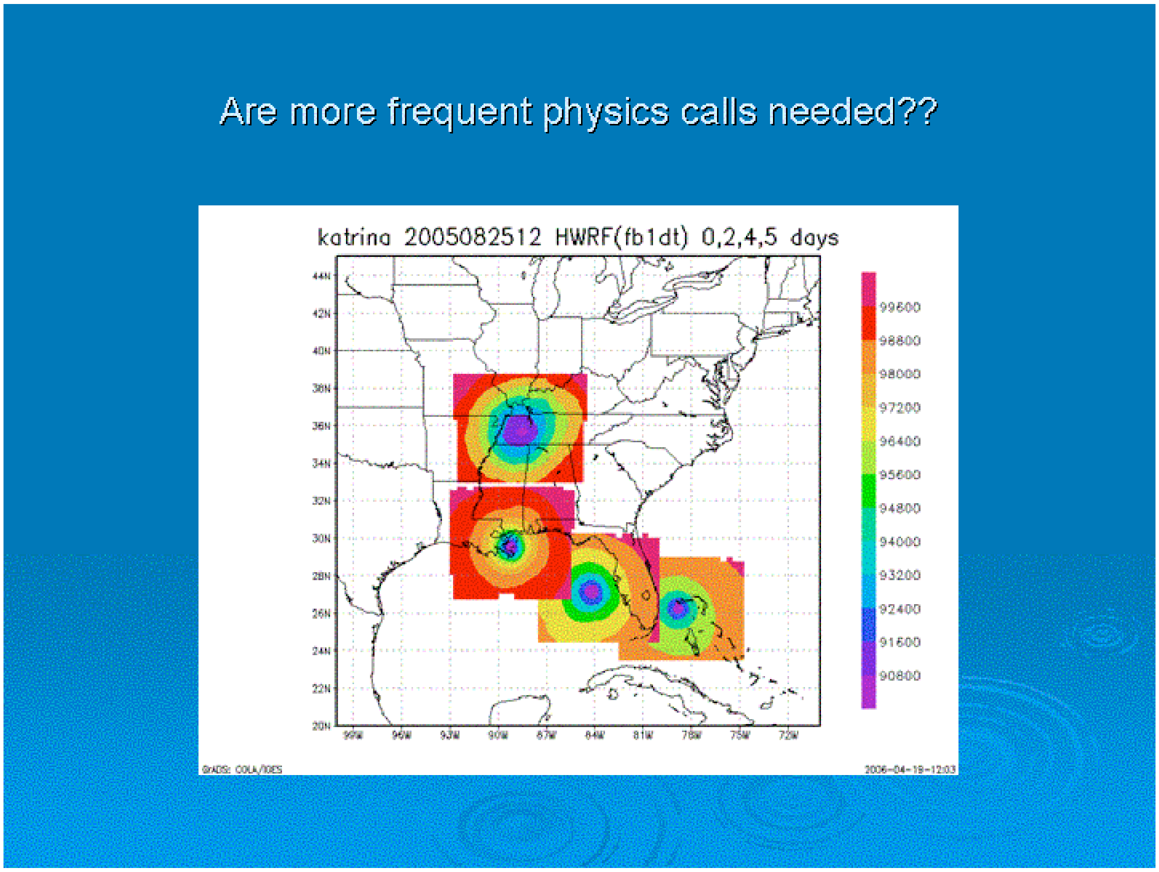


*Fig. 11. In this HWRF forecast, the physics packages of convection and bounday layer and surface exchanges were done every time step of the grids. Compare with Fig.9.*

4) Run both the nested and uniform resolution versions of HWRF in parallel for the 2006 hurricane season.

HWRF will be run in two main modes for the 2006 season. The first will be similar to last year with GFDL initial conditions, but with more GFDL physics packages including surface fluxes and GFDL SAS. The second mode will be with the HWRF regional analysis system. Fig.13 belows shows the comparison between HWRF and GFDL for the 1$^{st}$ case of the 2006 season. It appears that HWRF was deficient in the 1-2 day period. This is presently being investigated. HWRF shows superiority at 12h and at day 3 and 4, but there are very few cases at the long time periods. Continuous parallel runs are planned. Runs with the new regional analysis system are also being run. It is anticipated that coupled-ocean experiments will commence during the Atlantic tropical season.

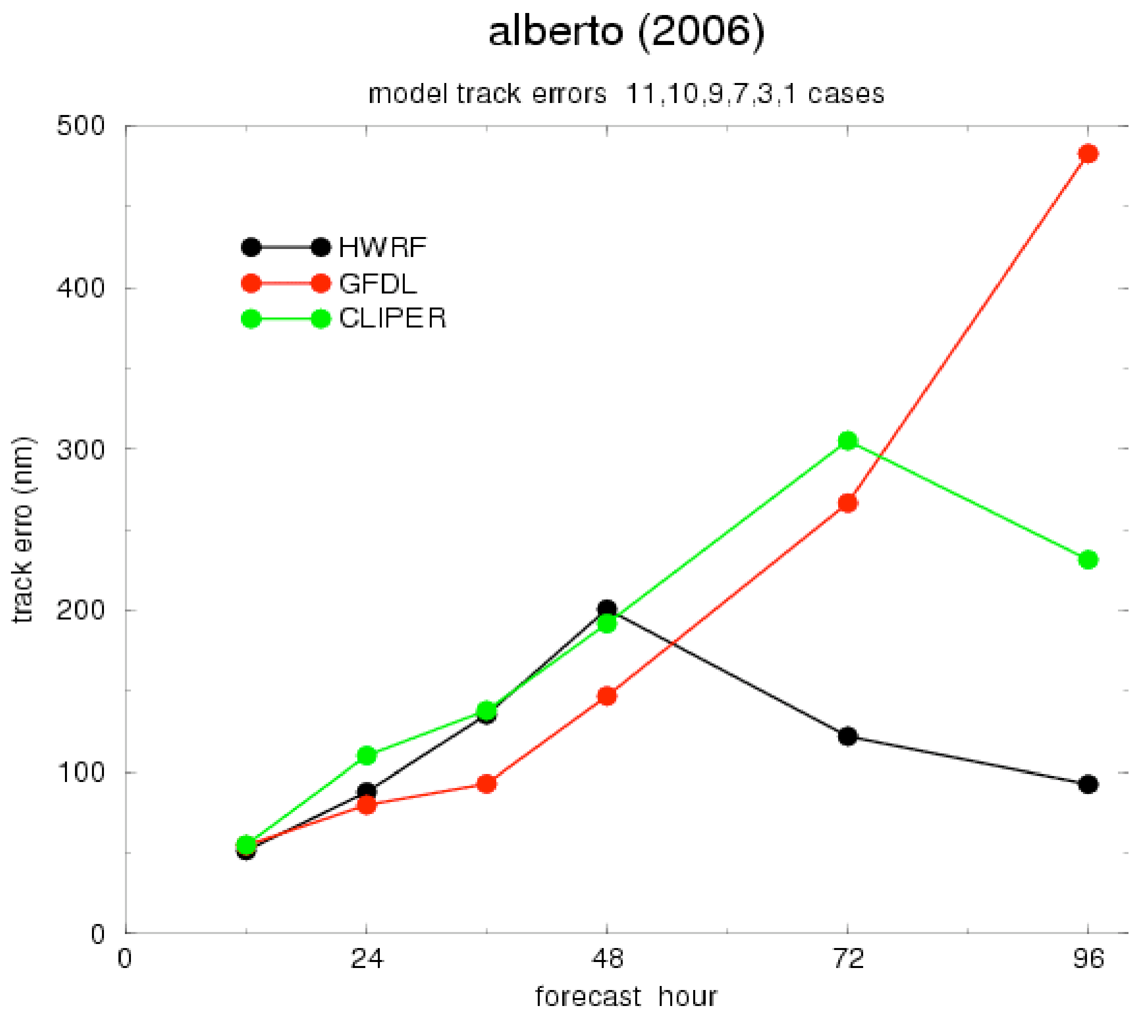


*Fig. 12. Comparison of HWRF with the GFDL for Alberto(2006).*

5) Continue to collaborate with university and NOAA components in running and evaluating different versions of EMC HWRF.

EMC personnel funded by JHT participated in several WRF NMM workshops in which the nested grid system of NMM core was introduced to the WRF community. Universities that have implemented the NMM WRF core (HWRF) include FSU, University of Maryland, and University of Southern Alabama. Other universities and government organizations have shown interest. JHT funded personnel have helped develop a work plan for collabaration with USA.

6) Continue to compare the HWRF results with the operational GFDL benchmark.This will involve continued collaboration with GFDL model developers.

Another task underway in HWRF is to implement the same changes made in the 2006 GFDL system to the 2006 HWRF system. As mentioned before, the GFDL system has now changed their surface momentum and enthalpy flux formulation to take into account the now generally accepted fact that surface roughness is reduced at high wind speeds. This is shown in Fig.13.  Notice how the effective exchange coefficient for momentum(drag) has been considerably reduced at high wind speed in the 2006 GFDL implementation. One of the issues is how to handle the enthalpy fluxes since they may or may not be influenced by the momemtum roughness.Another task underway is to run HWRF software packages in the GFDL model to test for code integrity. EMC SAIC personnel are working with GFDL and URI personnel in this area.

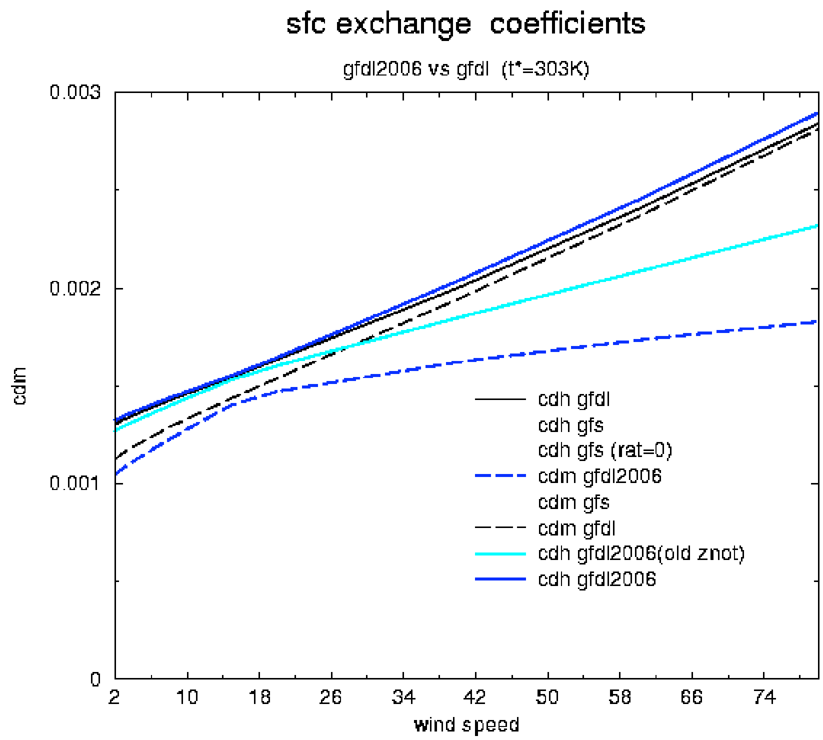


*Fig. 13.  Exchange coefficients of momentum(dashed) and enthalpy(solid) are shown for the 2005 (black) and the 2006(colored) versions of the GFDL model.*

7) Determine the feasibility of running operationally a Hurricane WRF forecast system for the 2007 season.

This year is critical in the evaluation of the HWRF model. It is anticipated that in addition to the work described, other experiments will be made to tune the HWRF system for both track and intensity forecasts. Looking back much work has been accomplished, but the bottom line goal is for improvement over the GFDL system. That goal has not yet been accomplished but steps have been made toward that goal.

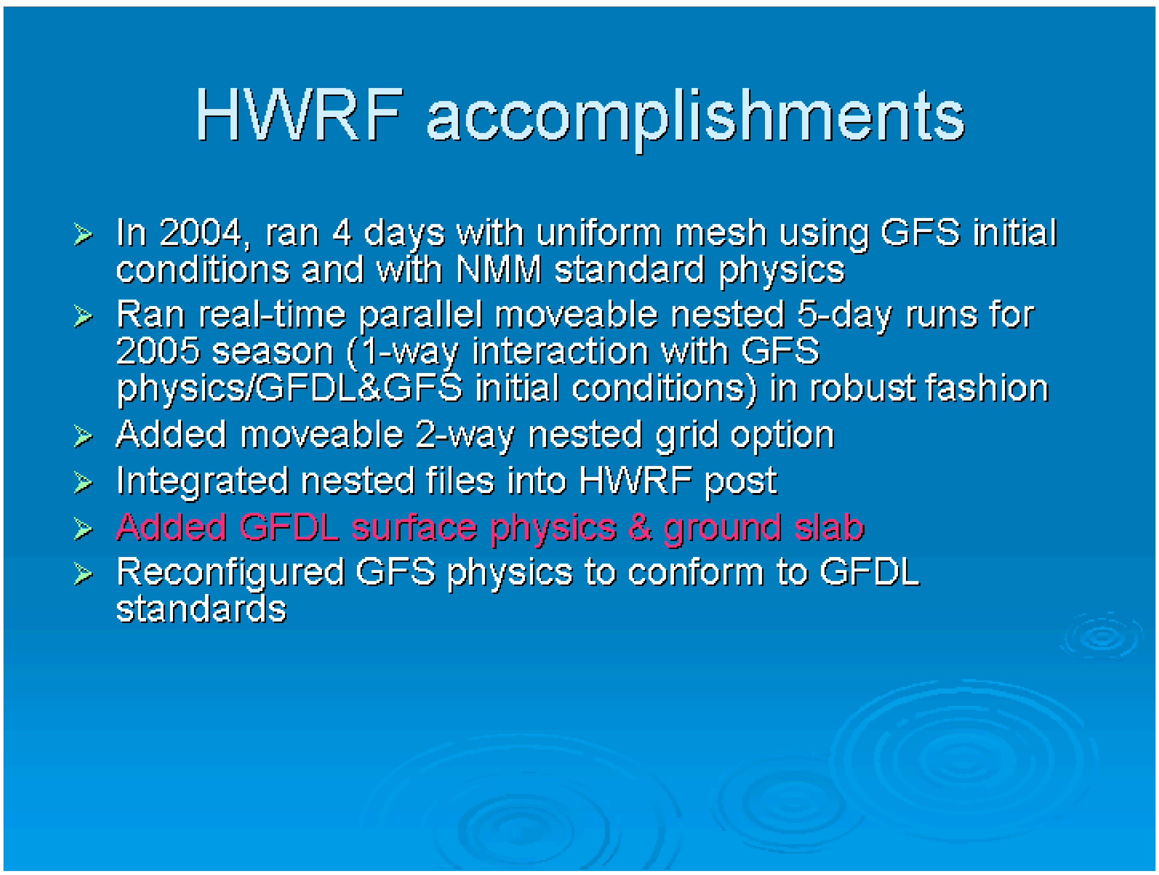


*Fig.14. JHT sponsored progress on operational implementation of HWRF.*