Hurricane Model Transitions to Operations at NCEP/EMC

Final Report (12/01/2009)

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Two year period from January 2007 – present

Statement of work and overall project status:

The primary task area was that of Hurricane WRF (Weather Research and Forecasting) model development and the integration of the WRF model into a complete forecast system. WRF physics codes were assembled to provide a physically realistic, yet computationally efficient hurricane forecast model. The fidelity of this system was compared with the operationally successful GFDL (Geophysical Fluid Dynamics Laboratory) nested system. Besides the model itself, post-processed output tools such as rainfall & wind swaths were developed and successfully tested and run operationally with few errors. Adjustments to the WRF system will be made to bring the WRF system up to and above the GFDL baseline standard.

This project helped in the successful implementation of HWRF into operations at NCEP and spanned the operational years of 2007-2009. Overall it appears that the HWRF system is nearly comparable with GFDL in track and intensity for short forecast periods of 1-3 days. However, there appears to be degradation in both track and intensity at longer forecast periods which was especially apparent in intensity for the relatively inactive 2009 Atlantic season (see figure below). Work will continue on this and other issues in the next JHT grant.

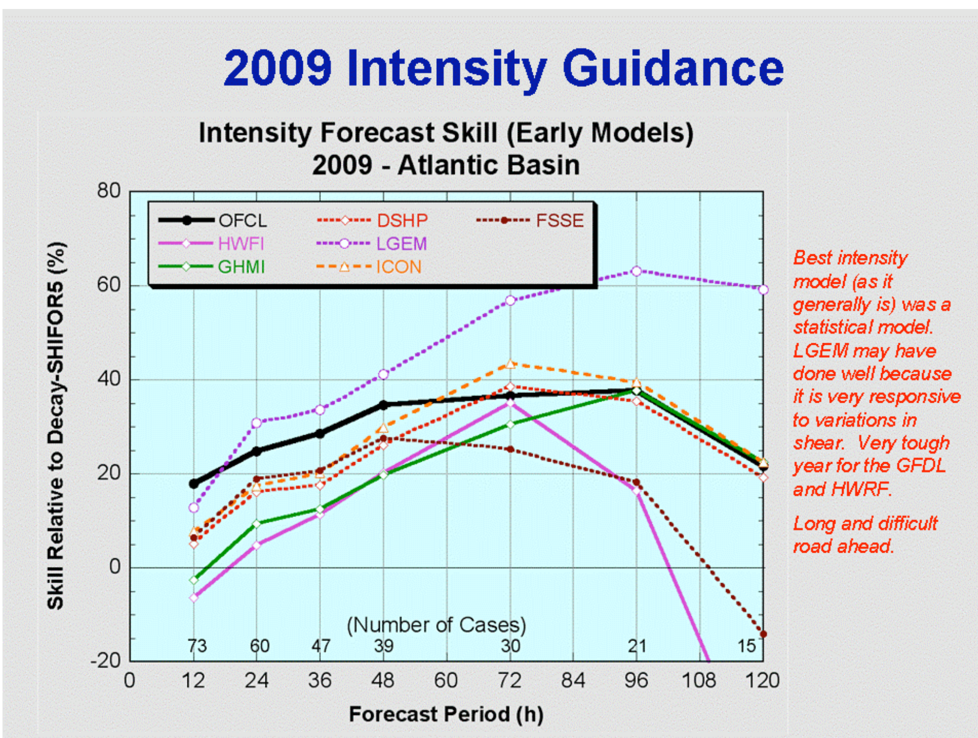

Figure 1. Intensity guidance of HWRF and other models for 2009. Note the degradation of HWRF beyond 72 hours.

Accomplishments:

Year One: September 2007 –through August 2008

1. *Test and evaluate present physics packages that are installed in the HWRF system and tune for performance skill in track and intensity. Check for physical deficiencies compared to the 2006 GFDL hurricane model. Investigate the role of cloud-radiation feedback in the determination of storm track and intensity. Compare with GFDL and other models. (EMC-1,EMC-2,TPC-1)* The project has extensively studied the surface flux parameterization routines of HWRF and other models. Tuleya has worked with others in checking the integrity of the surface flux parameterization. This may lead to a revised surface flux formulation for the upcoming 2010 season. Tuleya found a small inconsistency in the GFDL system and pointed it out to the GFDL caretakers. Tuleya has worked with others in evaluating the difference in low-level wind distribution of HWRF vs GFDL. Apparently, HWRF horizontal diffusion has to be reduced to give a wind distribution similar to GFDL. This issue is still unresolved. Tuleya has pointed out the scientific basis of both the GFDL & HWRF horizontal diffusion. A minor HWRF bug was discovered in the operational version in that the HWRF diffusion coefficient is a function of turbulent eddy kinetic energy which is calculated in the Meollor-Yamada options which is no longer called in th NMM physics package.
2. *Continue to contribute to the implementation of the HWRF into an efficient operational system which timely produces the products necessary for operational hurricane prediction. Test and evaluate the initialization, model, and post-processing steps. (EMC-1,TPC-4).* One big issue found in the 2007 HWRF version was the erroneous sea level pressure noise that occurs in the HWRF output. That problem was solved in a hydrostatically consistent fashion by accounting for changing of the nested topography during mesh movement. That solution was described earlier in the project.

3. *Collaborate with EMC developers in the continued improvement of the forecast/analysis portion of the system which specifies the initial condition of the storm. Collaborate with EMC developers in the evaluation of the coupled HWRF-ocean system.* Tuleya understands the differences and similarities between the GFDL and HWRF initialization systems and has made input into changes in the HWRF system. Tuleya has recently worked with EMC initialization developer, QingFu Liu, in making modifications in the system to reduce the cyclogenic bias of the system. Tuleya has also worked in advising the in-house EMC ocean group and the URI ocean group in interfacing their ocean and wave coupling systems to the atmospheric component of HWRF.

4. *Investigate the skill of the HWRF system in forecasting rainfall using hurricane-specific validation techniques. This may be done in collaboration with other NOAA investigators.* Code has been ported for the validation of hurricane specific rainfall. This is an outgrowth of an earlier project where the skill of the GFDL and GFS hurricane rainfall was evaluated. The skill of the HWRF rainfall prediction will be evaluated with the subsequent study involving the implementation of the NOAH LSM into the HWRF system (see below).

5. *Investigate the impact of the NOAH LSM(land surface model) on the prediction of the distribution of low level surface winds and rainfall amounts and the overall decay rate upon landfall. This will be contrasted with the simpler one-layer GFDL slab model which is presently used in both the benchmark HWRF and operational GFDL hurricane models. (EMC-2,EMC-3,TPC-7)* Some preliminary experiments have been performed where the rainfall amount appear more realistic. Additional benefit is that the LSM can be coupled to a river routing model. Some recent results are shown below where track forecasts for Fay and Hanna were improved.

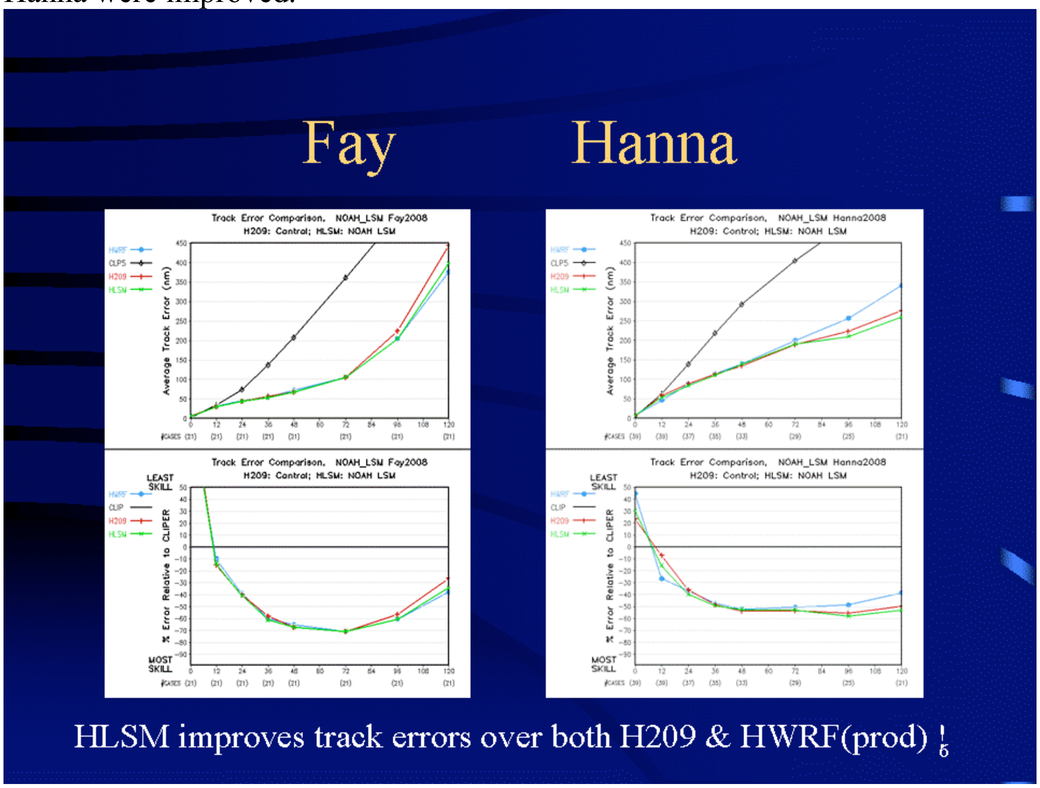

Figure 2. HWRF with the Noah LSM (HLSM) indicating improved track forecasts for Fay(2008) and Hanna(2008).

Accomplishments
Year Two: September 2008 to present

1. *Continue to evaluate the physics and dynamics packages in HWRF which lead to improvements over/above the 2007-2008 HWRF system.* One nagging problem noticed was the unrealistic land surface temperatures predicted during the 2008 tropical season in HWRF. This was an especially taxing problem in that most diagnostics failed to indicate the extent of the problem. It was discovered that this was a sporadic problem involving the radiative surface fluxes that were sporadically set to zero in the nest domain when the nest domain was moved. It was discovered that this could be resolved by calling radiation for the nest domain at frequent (9min) constant intervals. This problem lead to spurious tracks near/at landfall in some cases of Gustav and Fay. Nevertheless, the fix to call radiation at regular intervals was not implemented in the 2009 season because of the overly cyclogenic behavior of the bundled H209 package. Recent experiments have concentrated on reducing the initialized vortex moisture over land similar to that of the GFDL model (see figure below).

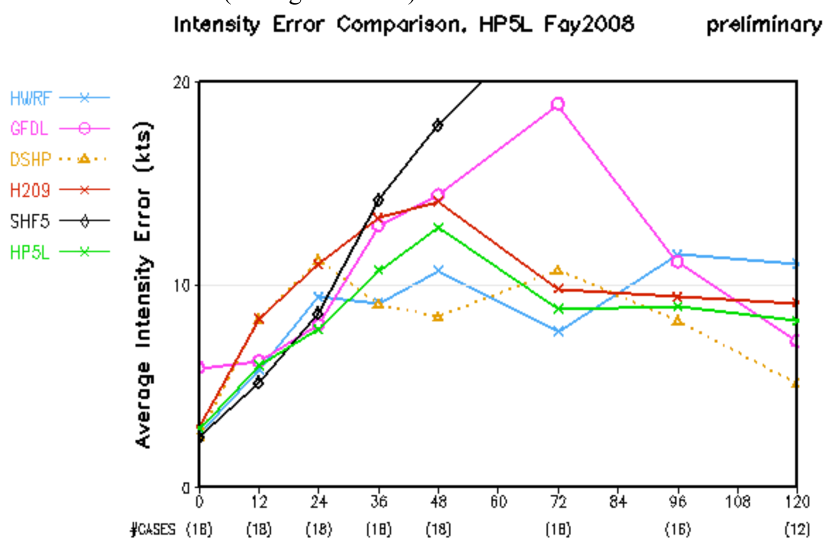

Figure 3. Decrease of HWRF H209 intensity error by reduction of initial vortex moisture over land (HP5L).

2. *Investigate the feasibility of higher resolution HWRF. (EMC-1)* The HWRF group has made advances in developing a high resolution version of the production version of HWRF. The first task was to be able to split up the 5 day integration into separate 12h-24h forecasts chained together. This was a challenging task for a 2-nest system to allow WRF restart options and obtain identical answers. More recently, the system has been upgraded to double the resolution (4.5km inner nest) with ocean coupling included. A high resolution case of hurricane Rita was run with an apparent increase in skill in both track and intensity. Tuleya has worked with Zack Zhang of EMC on this task. More recently this task has been assigned to a HFIP-hired EMC employee. Many cases were run this past summer but there were some issues getting the system to run successfully on the Vapor computer system. The results appear worse than the HWRF operational but probably because of interruption of the cycling procedure and ocean coupling.

3. *Investigate the skill of the HWRF system in forecasting landfall: the overall decay rate as well as the distribution of winds. (EMC-2,EMC-3,TPC-7)* Tuleya has performed some preliminary comparisons of the filling rates at landfall between the simple landfall decay model of Kaplan and DeMaria and the HWRF and GFDL operational models. These were presented at the diagnostic workshop at NHC. To make this comparison, Tuleya has coded the decay model to calculate the filling rates at landfall along both the GFDL and HWRF track(see figure below). Tuleya anticipates more investigation into this behavior when investigating the implementation of the NOAH LSM into the operational HWRF in the next JHT project.

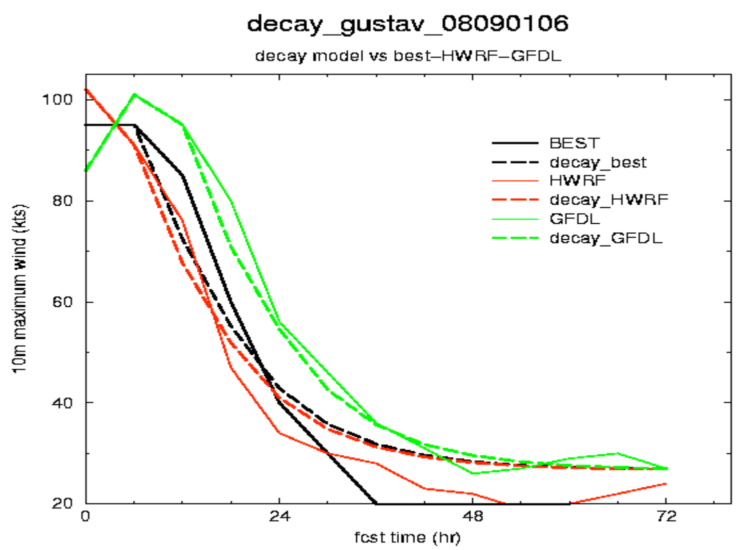

Figure 4. Intensity forecast of landfall of Gustav using operational HWRF & GFDL wind forecasts vs landfall decay model using operational HWRF & GFDL initial intensity at landfall and forecast tracks.

4. *Collaborate with EMC and universities in the further development of the interface of the ocean and wave components into the HWRF system.* Tuleya wrote up the scientific physics documentation for the upcoming Hurricane workshop at the Development Test Bed Center. Tuleya has collaborated with the URI group on the technical details in wave coupling with the surface flux computations in the HWRF atmospheric model. This involves the use of two roughness lengths used in the HWRF model. The system has to be changed to export both roughness lengths to the solver level where the coupling is done with both the ocean and wave models.
5. *New model-derived forecast tools such as wind and precipitation swaths and meteo-grams will be attempted.*
   The focus of this issue has been to improve the wind and precipitation swaths by increasing the time frequency of the output. This will make the output graphs smoother. More frequent output of maximum winds are now available at hourly frequency. Examples of this model output have been presently at the IHC meetings. One remaining issue is the representativeness of the temporal output and how it compares with observations. There have been several discussions concerning this in HFIP meetings.