Enclosed is the JHT FINAL Report for:

A PROPOSAL FOR TRANSITION OF RESEARCH TO OPERATIONS:

Upgrades to the Operational GFDL Hurricane Prediction System

Morris A. Bender
Geophysical Fluid Dynamics Laboratory
P.O. Box 308, Forrestal Campus
Princeton, NJ, 08542

As reported in previous JHT summaries, major upgrades to the GFDL Hurricane Prediction System, made possible through JHT funding, have resulted in continuous improvements in the model's performance during the past several years. In 2003, the largest upgrade was made to the model physics since the GFDL model became operational in 1995. This new package was successfully implemented before the start of the hurricane season. In the two hurricane seasons since then, the GFDL model has had the lowest track errors of any model in both the Atlantic and East Pacific basins. The two year average track error at 72h was 156 nm in the Atlantic and 150 nm in the East Pacific, and the skill relative to CLIPER was 52% and 33%, respectively. In addition, the improved GFDL model has begun to show modest skill in intensity prediction in the last two years, with skill relative to SHIFOR averaging nearly 10% over the 5 day forecast period. This skill is roughly comparable to the statistical intensity prediction models (SHIPS and DECAY SHIPS).

In close collaboration with scientists at NCEP and URI (University of Rhode Island), a high resolution version of the GFDL model with an improved initialization package was developed during the past 2 years. After extensive testing demonstrated the superior capability of this model for both track and intensity prediction, the decision was made to implement it in May 2005 in conjunction with upgrades to the NCEP Global Forecast System (GFS). These major model improvements in both the GFDL and GFS forecast system were operationally possible due to the increased computer power at NCEP made available to operations in the Spring of 2005.

OUTLINE OF SPECIFIC IMPROVEMENTS MADE OPERATIONAL IN 2005

An important feature of the GFDL forecast system is that a realistic vortex structure is specified based on observed intensity and observed radial extent of gale force and 50 knots winds. This vortex is obtained using an axi-symmetric version of the forecast model, targeting the observed tangential component of the wind during a 60 h integration in order to obtain a model consistent vortex. During the past year the axi-symmetric model was upgraded with the identical physics used in the three-dimensional model. Following changes made in the targeting to the observed storm structure, this improved vortex initialization package was found to significantly decrease the spin-up and spin-down problem in the early part of the actual forecast. After extensive testing with other initialization changes (i.e., removal of the mass initialization and modification in the calculation of the storm size) this package was implemented operationally in 2005 together with the horizontal resolution upgrade.

A third nest with 1/12th degree resolution was added to increase the GFDL model resolution. Testing of this model upgrade was part of this JHT funded project. As mentioned previously, this model was developed in collaboration with scientists at the University of Rhode Island through a separate JHT project. When combined with the changes to the model initialization, the new forecast system clearly demonstrated significant reduction in the track error (~10% at 3-5 days) on selected storms from the previous 2 hurricanes seasons (*Fig. 1*). Improved forecasts of many of the landfalling cases from these past two seasons were also seen using this new model (*Fig. 2*).

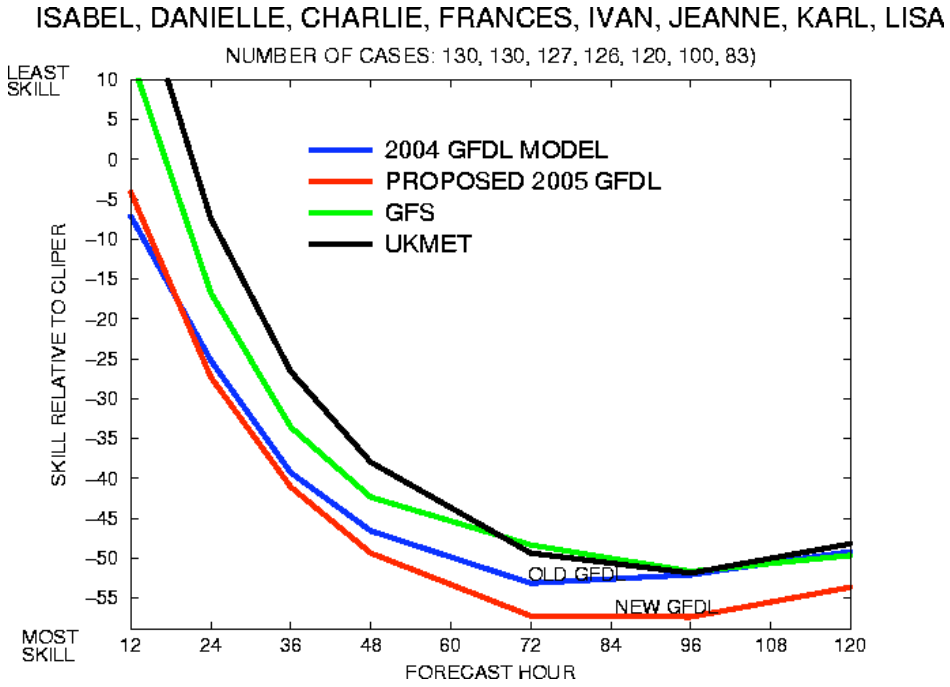

Fig. 1 Track verification for the 2004 and 2005 GFDL model compared to the GFS and UKMET models, for selected cases during the 2003 and 2004 hurricane seasons.

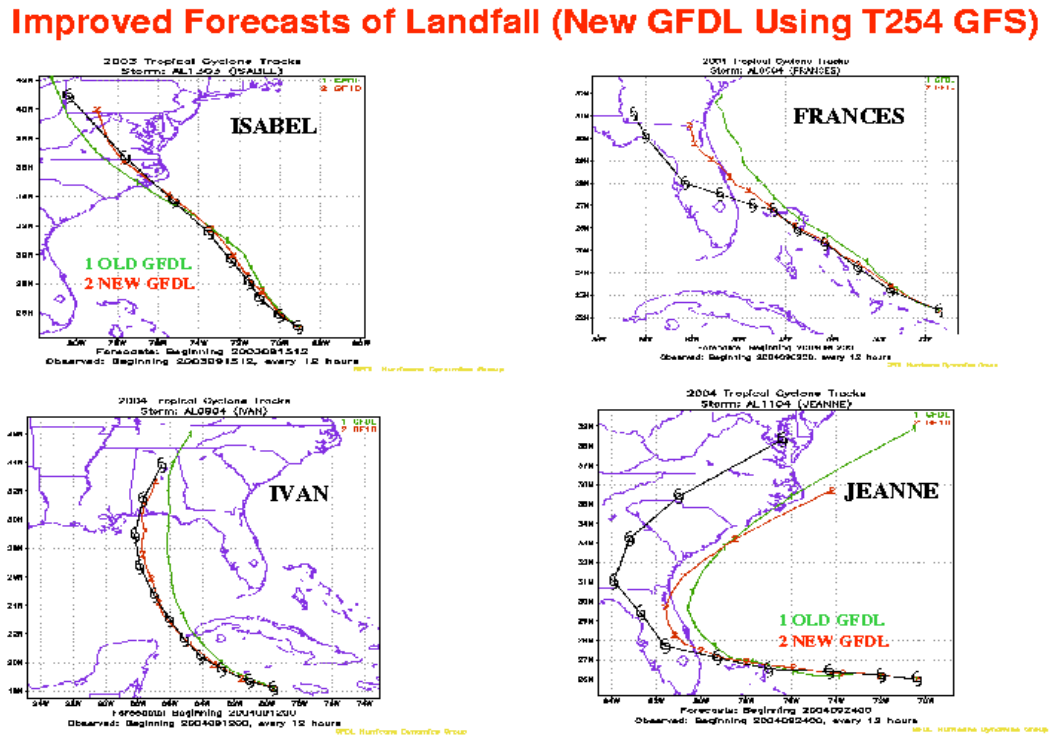

Fig 2. Forecast tracks from the 2004 (old) and 2005 (new) GFDL model for selected lanfalling cases using the T254 GFS analysis.

In addition, improved skill for intensity was also achieved particularly at 3-5 days (*Fig. 3*)

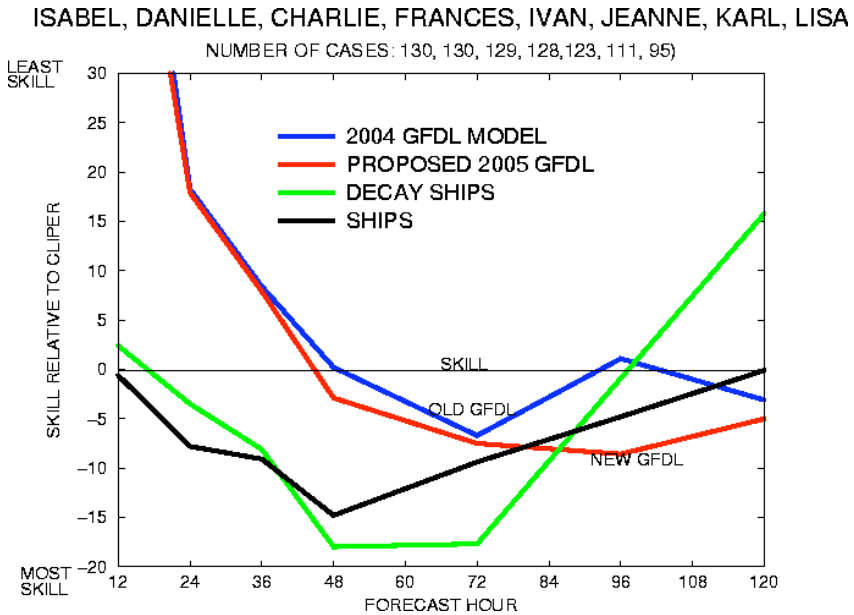

Fig. 3 Intensity verification for the 2004 (old) and 2005 (new) GFDL models for selected cases during the 2003 and 2004 hurricane seasons.

Another important physics upgrade funded by this JHT project involved an effort to import and evaluate micro-physics into the GFDL model. In collaboration with Robert Tuleya at NCEP, both the Lin and Ferrier micro-physics packages were added to the GFDL model during the past 2 years. In addition, a technique to spin up the micro-physics during the axi-symmetric vortex initialization was developed, although problems with it still remain to be resolved. Nevertheless, preliminary testing of both micro-physics packages have continued with encouraging results. Both micro-physics packages were successfully added into the high-resolution version of the GFDL model to enable testing to begin by the start of the 2005 hurricane season in near real time.

PRELIMINARY PERFORMANCE IN 2005

The 2005 Atlantic hurricane season so far has proven to be extremely active with seven named storms at the time of the preparation of this report. On this limited sample the upgraded GFDL model is continuing to show intensity skill that is comparable to the statistical models. A preliminary intensity verification on the storms through July 28th is presented in Fig. 4.

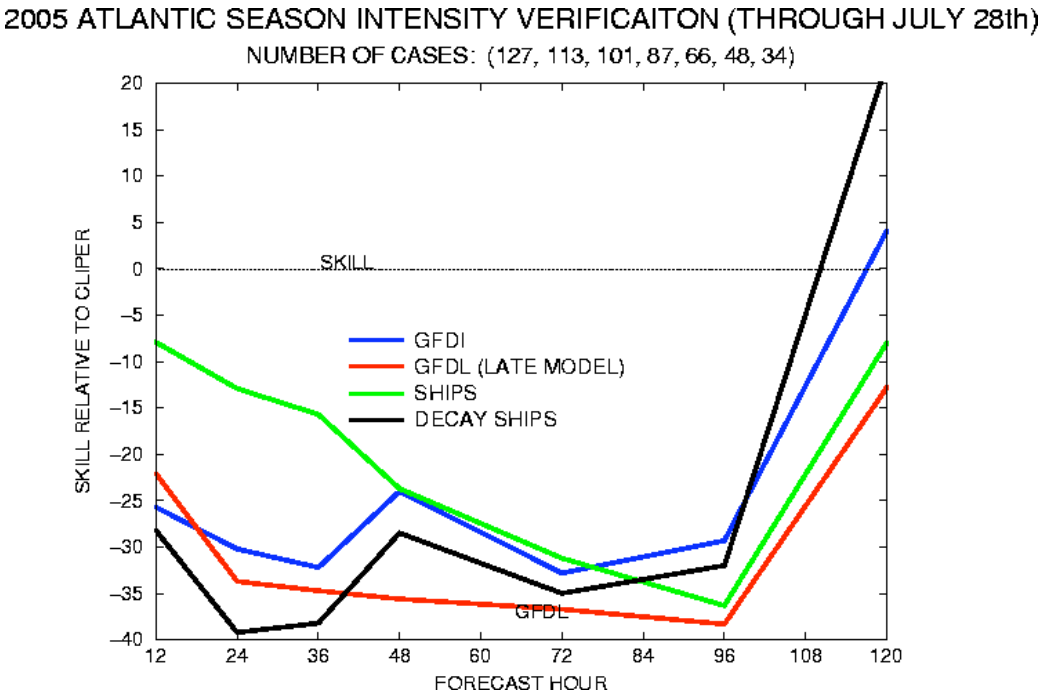

Fig. 4 Intensity verification for the operational GFDL model compared to the SHIPS and DECAY SHIPS statistical prediction models, for the 2005 hurricane season through July 28th, 2005.

During the 2005 hurricane season, the version of the GFDL model using the Ferrier micro-physics will be run in parallel for cases in both the Atlantic and East Pacific. In this new version of the model, one additional change being tested involves an improved surface roughness formulation that was developed by scientists at URI using output from the WAVEWATCH 3 model. This effort was also funded by a separate JHT project (PI Isaac Ginis). So far, this model

is exhibiting improvements in the intensity prediction in some of the highly sheared cases where the GFDL model still tended to have a large positive intensity bias. One example is shown in Fig. 5, for Tropical Storm Franklin.

As this model continues to be run in parallel for the remainder of the hurricane season, additional tuning of some of the micro-physics variables are anticipated. Evaluation of the results is being carried out in close collaboration with NCEP scientists, particularly Brad Ferrier and Robert Tuleya. Operational implementation of these major physics upgrades is planned for the 2006 hurricane season if the results continue to be positive. However, an effort will be necessary to optimize some of the code in order to meet the timing requirements for operations.

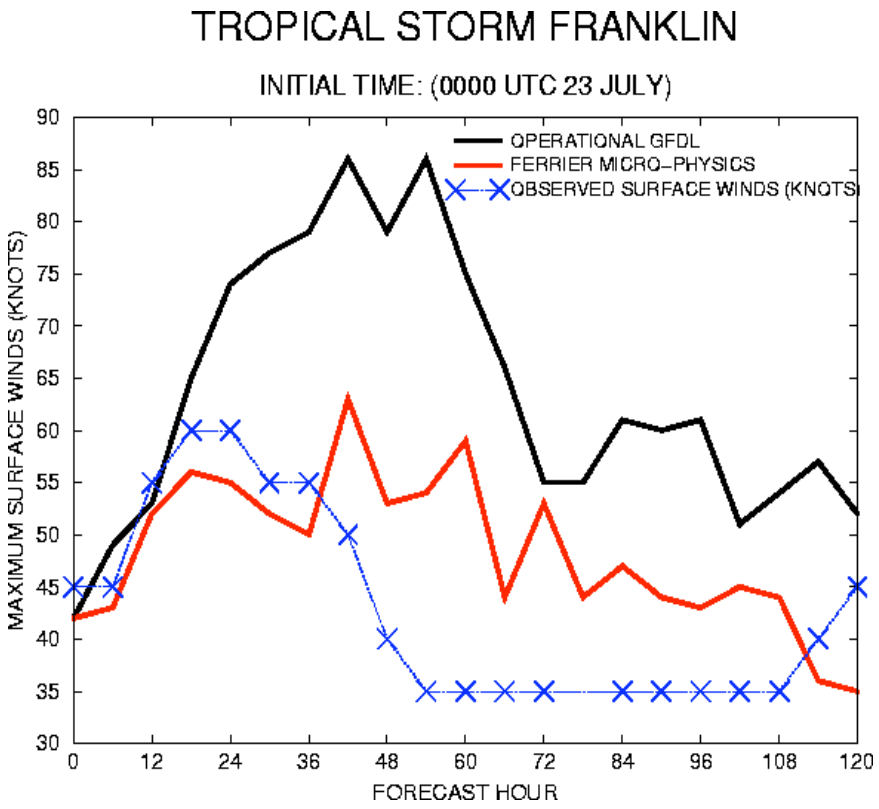

Fig. 5 Time series of maximum surface winds (knots) for the forecast of Tropical Storm Franklin starting at 000 UTC 23 July, for the operational GFDL model (black line) and a version of the GFDL model (red line) with the Ferrier micro-physics and an improved roughness length formulation.

Finally, most of the changes in the GFDL model initialization were also imported into the US Navy's version of the model (GFDN). Following testing of these changes at FLEET, the improved package demonstrated statistically significant reduction in track error and was made operational by the Navy in June 2005. The high-resolution code was also recently imported to FLEET although computer limitations make it impossible to be implemented operationally in 2005. Nevertheless, this version of the model will be tested in parallel for selected cases during the summer 2005, with possible operational implementation at FLEET in 2006 if additional computer resources are made available and results are positive.