Hurricane Transition to Operations at NCEP/EMC - GFDL hurricane model

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I. Introduction

This is a new proposal based on the suggestion of the JHT SC committee dated 26 April 2002. The scientific rationale closely follows the previous submission under the same title except we have eliminated the collaboration with Penn St. under this initiative. We have elaborated on the work plan for Bob Tuleya which is distinctive from work being carried out by GFDL (by Morris Bender) and addressed other questions raised by the committee.

This proposal is a request for **second year** funding through the USWRP supported JHT for Bob Tuleya who is retiring from GFDL as a civil servant in the next month or so. With sufficient funding provided by this proposal, Bob Tuleya will become a contract employee as of July 1, 2002 at EMC to work on needed GFDL physics upgrades for the upcoming 2003 hurricane season. Details of this work are given in Section 2a.

We also request support for Weixing Shen, a contractor at EMC who is working on implementing the NOAH land surface model into the GFDL hurricane prediction system. Details of this work are given in Section 2b.

Section 3 describes NCEP's accomplishments in meeting our FY01-02 funded obligations and provides information regarding previously funded JHT work.

2. Advancement to the NCEP/EMC hurricane modeling effort

a. GFDL physics model upgrades

For the 2001 season, in the Atlantic basin, an ocean model was coupled with the GFDL model and some upgrades were made to the vertical diffusion of the model to give more reasonable wind profiles near the eyewall region. The bogusing scheme was also adjusted to reduce the overly cyclogenic nature of the first few hours of integration. In the meantime the NCEP global analysis and forecast system was upgraded in both resolution and physics. Since 1995, the global forecast system has been upgraded from T128L18 (100km) to T170L42 (75km.). In 2002, a further upgrade to T254L64 (55km.) is planned. Additionally, considerable changes have also been made to the convective parameterization and an explicit forecast of cloud water has been added. In view of the considerable progress and improvement in the global model tropical forecasts including the tropical storm forecasts; the GFDL system must be improved to take advantage of the global improvements. A redesign of the GFDL model with 2 grids: the outer-most grid resolution having ½ ° with the inner grid having a resolution of 1/6 ° will be implemented in the 2002 hurricane season. In this sense, the GFDL model will be more compatible with the global model at its lateral boundaries and be less subject to spurious spin-up and spin-down at the initial stages of integration.

The present proposal, however, will concentrate on upgrades to the GFDL model physics to have them conform to the current state of the art global model physics. These upgrades are necessary to establish the GFDL model as a state of the art hurricane forecast model, particularly since no major physics upgrades have been implemented in this model since it became operational. It is anticipated that these upgrades will produce more realistic simulations of the hurricane and its environment. Additionally, work is proposed on coupling the GFDL model with a land surface model to better represent the surface processes for landfalling storms. This is an important step forward to improve precipitation forecasts to address the inland flooding problem. These advancements are necessary to establish the GFDL model as a benchmark from which to evaluate all future advanced model implementations.

The four principal tasks that will be carried out by Tuleya are outlined below. Each task will require 30% effort by Tuleya, except Task (3) for which he will provide guidance at 10% effort. A decision to work on task five this year will be left to results obtained in the other upgrades.

Defined Tasks

1. TASK: Test and prepare for FY03 implementation the AVN Simplified Arakawa-Schubert convective parameterization scheme (SAS) (Pan, 1989) into the GFDL model: The present convective scheme (Kurihara) is known to be overly cyclogenic resulting in over-intensification especially in sheared environment.
ANTICIPATED RESULT: Improved intensity forecasts as well as some track improvement because of superior forecast of environmental winds. The SAS scheme should be superior in simulating the role of wind shear in modifying the heating and momentum fluxes in areas of convection.

2. TASK: Implement AVN boundary layer parameterization scheme (Hong and Pan, 1996) into the GFDL model: The present scheme(Mellor-Yamada 2.5) has shown some ability to simulate the hurricane boundary layer wind profile with its prediction of turbulent kinetic energy. Nevertheless, it is still a "local" scheme which is dependent for the most part on local vertical gradients.
ANTICIPATED RESULT: The AVN scheme is more penetrative and more explicitly predicts the height of the PBL. It has been shown to be quite compatible with the AVN convective scheme. A more superior track and intensity forecast is anticipated when Tasks 1 & 2 are incorporated together.

RESULT FOR TASKS 1&2: Task 1 & 2 resulted in the operational implementation of the GFS SAS and PBL schemes into the GFDL operational model for the 2003 season. Based on the parallel tests that were made for the 2001 and 2002 seasons, substantial improvements in track forecasts and a significant reduction in intensity bias are anticipated.

Tuleya coded the GFS boundary layer scheme directly into the GFDL model and worked closely with GFDL in evaluating the performance of both the GFS SAS convective and PBL schemes. Tuleya presented the joint results of the GFDL and EMC efforts in developing the GFDL2003 system at the March IHC meeting at the JHT session. These results showed that for 2001, the track error was reduced ~15%for day 2-3 in both the ATL and EPAC basins. For 2002 in the ATL, track improvements in the 3-5 day forecasts ranged from 8% at day 3 to ~35% at day 5. Tuleya also made comparisons with other pertinent parameterizations schemes such as Emanuel and Kurihara convective schemes and the Mellor-Yamada 2.5 boundary layer scheme.

3. TASK: Provide guidance on the implementation of the NOAH land surface model into the GFDL: While surface processes are quite important in landfalling tropical storms, presently the GFDL model utilizes a simple one level slab model over land. The NOAH model has been recently introduced into the ETA/EDAS modelling system.
ANTICIPATED RESULT: These processes will impact surface energy fluxes and stresses and local wind patterns that should improve precipitation and wind patterns. A side benefit of the NOAH model is the ability to do stream routing for flood prediction as well.

RESULT FOR TASK 3: Weixing Shen has successfully integrated the NOAH land surface model into the GFDL using two distinct methods. He has originally coded the LSM as a module of the GFDL atmospheric model. This involved coding the LSM in a nested mesh configuration. The 2nd method involves coded the NOAH LSM as a separate component model similar to what is done for the GFDL/URI POM ocean coupled system. This has the advantage that model develop can be done in either system (atmospheric or land model) more independently. In this case the NOAH LSM has been implemented utilizing uniform fine resolution. Shen successfully implemented this version of the model and has run cases from this past season including Lili and Isidore. Preliminary results indicate that intensity impacts are rather small although dependent on formulations of surface exchange coefficients. Precipitation differences are more pronounced and show the importance of coupling to the land model to address the inland rainfall and flooding problem.

Plans call for testing the joint GFDL/NOAH model for both significant historical cases such as Floyd and for cases of this upcoming hurricane season. In additions EMC has initiated a plan to feed the run-off results of the GFDL/NOAH model into a state-of-the-art stream routing model.

Also, part of the land coupling is to deal with the initial data particularly the initial land surface data. The present hurricane-land model uses GFS and Eta assimilations as well as some other fixed (global) land surface property data so that it can be served for semi-operational runs. Shen is currently extending its capability to use the NLDAS data for historical cases. The virtue of this data set is that it is better assimilated and has land data from 1996 to the present with unchanged
configuration (domain and resolution) , which also includes the forcing (i.e., precipitation) and many diagnostic outputs for verification. With respect to surface fluxes, the surface flux scheme used in the Eta model is also used as an option in the hurricane model. Preliminary results indicate that much more work is needed regarding the way to attain surface exchange coefficients and impact of these on landfalling hurricanes.

4. TASK: Upgrade vertical resolution to 42 levels to make it compatible with the AVN: . It is highly likely that to obtain full benefits of the other physics packages, improved resolution will be required. In the past few years, some sensitivity experiments were run with high vertical resolution but there was some degradation in track and intensity using the present GFDL physics packages. This will require further investigation with the upgraded physics.

RESULT FOR TASK 4: EMC together with GFDL implemented the 42 levels into the GFDL modeling system that will be used in the 2003 season. It was clearly shown that the SAS scheme was superior to the Emanuel scheme in track performance and did not suffer from overdevelopment bias which plagued the original Kurihara scheme.

5. TASK: Presently both GFDL and the GFS utilize a Monin-Obukhov framework in the surface layer although there are some differences in detail. Surface layer and its interface with surface fluxes is a critical issue in tropical development and maintenance. Also, the GFS and GFDL radiation package differs primarily in short wave formulation and how clouds are treated. Upgrading these packages may be worthwhile however, this implementation is dependent on the results obtained above. At present, it is not clear how an upgrade in the radiation package will complement the above changes.

RESULT FOR TASK 5: Several other changes were made for the GFDL operational that were a result of substantial improvement in track and a significant reduction in intensity bias. Tuleya worked with GFDL to recalculate the pressure gradient using virtual temperature. This was coded by Tuleya several years ago but with limited success. With the new implementation the reformulation of this term proved to have an unanticipated positive impact of forecasting both track and intensity when integrated with the new GFS physics. Also implemented was the use of pressure interpolation of the wind fields in the GFDL preprocessing step. This led to some small but significant changes over mountain areas.

The surface layer and radiation part of this task was delayed to this upcoming year. We simply did not have the time to look into this important issue and would like to continue that effort over the coming year.

For further details on the GFDL 2003 implementation, see:

http://www.emc.ncep.noaa.gov/gfdl_2003_upgrades.pdf