13D.6 Test of the new GFDL hurricane-land coupled system for landfalling tropical cyclones

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1.INTRODUCTION

The tropical cyclone prediction system at the National Centers of Environmental prediction (NCEP) is currently coupled with a slab land model which only predicts land surface temperature with other land conditions, such as the land moisture and heat capacity, fixed. The use of fixed land moisture and heat capacity may cause the land surface temperature prediction and thus the surface thermodynamic processes to be significantly biased where the changes of these conditions are large. In addition, the current prediction system uses the land wetness condition derived from its surface vegetation while the land surface wetness in reality is largely dependent on precipitation, which has large temporal and spatial variability. These deficiencies of the operational system may limit the predictive skills of the prediction system for landfalling hurricanes. This paper describes the newly implemented hurricane-land coupled system and shows the preliminary results from its test mainly for the 2003 season.

2. MODEL DECRIPTION

The hurricane model is the operational Geophysical Fluid Dynamics Laboratory (GFDL) movable mesh model. Specifically, it is the version for the 2003 hurricane season. The major upgrade for this version is that cumulus convection scheme and surface boundary layer physics are replaced by those of the NCEP Global Forecast System (GFS) .

The land surface model for the newly coupled system is the comprehensive Noah land surface model, which is presently used in NCEP's regional Eta model (Ek et al., 2003) and North American Land Data Assimilation System, NLDAS (Mitchell et al., 2004). The Noah land model currently uses four soil layers: 10 cm, 30cm, 60cm, and 100cm. The root zone extends through the first three or all four layers depending on the vegetation class. Vertical diffusion, latent heating from soil freezing/thawing and heat fluxes at top and bottom of the soil column are the physics in the soil thermodynamic equation. Vertical diffusion, hydraulic conductivity (including bottom drainage), surface infiltration of water, surface evaporation and transpiration by canopy roots are all responsible for the moisture changes in the soil column. The surface evaporation and surface infiltration of precipitation are influenced by the vegetation canopy. The atmospheric inputs for the land surface model (LSM) include the downward surface shortwave and longwave radiation, precipitation, surface wind, pressure, air temperature and humidity. The LSM outputs for the atmospheric model are the surface evaporation (latent heat flux), sensible heat flux, land-surface skin temperature (upward longwave radiation), and albedo (upward shortwave radiation).

Currently, the system does not have its own hurricane-land coupled initialization. The initial land surface conditions used in the hurricane system mainly comes from the Eta-based 4-D Data Assimilation System (EDAS), while the GFS land conditions are used for the area outside the EDAS domain. In the near-future, initial land states from the NLDAS will be tested for the CONUS portion of the model domain. A technique similar to that in the hurricane-ocean coupling is used for the coupling between the movable mesh hurricane model and the land surface. Readers interested in details may see the full documentation (see the relevant website listed at the end).

3. PRELIMINARY RESULTS

The new hurricane-land coupled system was used for investigation of landfalling tropical cyclones of the last season (namely, landfalling tropical cyclones Bill, Claudette and Isabel). A few cases for the 2002 season were also investigated. Comparison was made to the results with the slab LSM. For simplicity, the ocean coupling was not used in our experiments for such a comparison. In fact, we did compare the slab model results with the operational forecast (with ocean coupling) and found that the impacts of ocean coupling on the near- and after-landfall tropical cyclones, which are focused for our investigation, are very small.

Our preliminary results indicate that the impacts of Noah land surface coupling are generally small on landfalling storm track and intensity depending on the formulation of the surface exchange coefficients while the land surface temperature and soil moisture may be considerably different from those with the slab model. However, the precipitation differences are more pronounced, implying the relative importance of land coupling in predicting inland rainfall and flooding. Fig. 1 shows a Claudette case for 2-day accumulated precipitation. It is apparent that the local precipitation around the storm track is reduced with the Noah LSM

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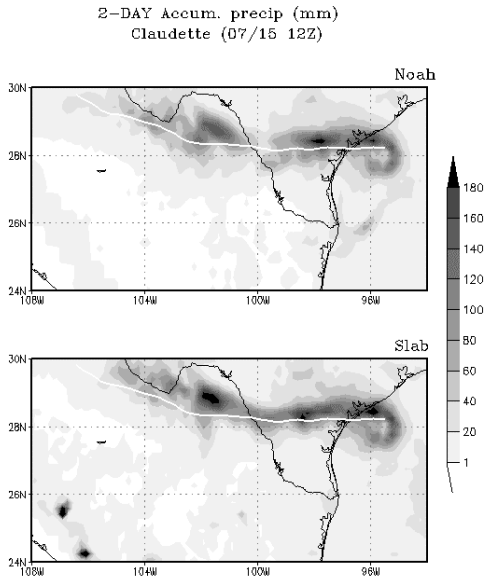

Figure 1. 2-day accumulated precipitation predicted by the hurricane model coupled with the Noah and slab land surface models for the case of Claudette (12Z, 07/15/2003). The white line is the storm track.

coupling. Further calculation shows that the 2-day averaged reduction of maximum local precipitation for every 6 hours is over 20% with the maximum reduction near 40%. It is also seen that the spurious rainfall near the lower left corner in the slab LSM case is not produced with the Noah LSM. This implies a rainfall improvement in the overall environment with the use of the Noah LSM. It is worth of pointing out that the results from all landfalling cases in the Atlantic ocean and Gulf Mexico basin for the 2003 season are quite consistent regarding the above features.

4. DISCUSSION AND FUTURE

The use of a comprehensive LSM in the GFDL hurricane model aims to better represent the land surface processes in the hurricane system due to the deficiencies in the current system with an over-simplified land scheme. It is well known that in general, landfall decay is dominated by rapid reduction of surface evaporation due to the shortage of land surface water and the small surface heat capacity. Therefore, significant impact on such decaying hurricanes may not be expected from any reasonable changes in the land surface scheme although surface thermodynamic states can be very different.

The study of this paper aims to investigate whether and in what aspects a comprehensive LSM can make an impact that cannot be ignored for accurate hurricane prediction near and after landfall. It was found that the thermodynamic exchanges over land with the Noah LSM may appreciably change the hurricane-induced precipitation in the current system. Some differences may result from using different slab models depending on their treatments of the physics and the (both fixed and changeable) variables. Thus, our current results come from the wholesale differences between the slab land model that is presently used in the operational system and the Noah LSM using initial land states from the assimilation systems of the other NCEP forecast models.

Investigation of all recent-year landfall cases by using Noah LSM initial land states from the NCEP North American Land Data Assimilation System, which is forced with observed precipitation, is an ongoing project, as is further case analysis. Another important issue is the verification of landfall precipitation, which is currently being conducted. Some of the results on the landfall will be presented.

5. REFERENCE

Ek, M. B., K. E. Mitchell, Y. Lin, E. Rogers, P. Grunmann, V. Koren, G. Gayno, and J. D. Tarpley (2003), Implementation of Noah land surface model advances in the National Centers for Environmental Prediction operational mesoscale Eta model, J. Geophys. Res., 108(D22), 8851, doi:10.1029/2002JD003296.

Mitchell, K. E., et al. (2004), The multi-institution North American Land Data Assimilation System (NLDAS): Utilizing multiple GCIP products and partners in a continental distributed hydrological modeling system, J. Geophys. Res., 109, in press, doi:10.1029/2003JD003823.

6. RELEVANT WEBSITES

On the GFDL hurricane model upgrades:
http://www.emc.ncep.noaa.gov/gfdl_2003_upgrades.pdf
On the description of the Noah LSM:
http://www.emc.ncep.noaa.gov/mmb/gcp/noahlsm/README_2.2.doc
On the hurricane-land coupled model:
http://wwwt.emc.ncep.noaa.gov/mmb/hurri-land/landfall_2003.html