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ENSEMBLE METHODS APPLIED TO HURRICANE TRACK AND INTENSITY FORECASTING

Mohan K. Ramamurthy*, Brian F. Jewett, and Heng Liu

Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign, Urbana, IL

1. INTRODUCTION

Hurricane track forecasting remains a significant and costly problem. The damage incurred by hurricane landfall is well known. Damage costs from hurricane Andrew (1992) reached $27 billion, and Floyd (1999) $6 billion. Tropical storm Allison brought over 30 inches of rain and $5 billion in damage to Houston, TX in 2001.

Beyond direct storm damage, an additional cost is associated with hurricane forecast track and timing errors as communities prepare for a landfall that does not occur, spending up to $3 million dollars *per square mile* of populated coastline when a watch or warning is issued (CNN, 1999). Clearly, improved track forecasting has many potential benefits to coastal communities.

Improvements in weather prediction models, coupled with rapid strides in our observing capability and advances in assimilation techniques, have led to improved tropical cyclone (TC) track guidance. However, there still exist many uncertainties in the dynamical prediction of TC tracks. The uncertainties stem from poor initialization of TC structure, intensity and location, approximations in model physics, and in the specification of the large-scale TC environment.

To account for these uncertainties, ensemble-forecasting techniques have been applied to TC track prediction. Ensembles composed of initial condition perturbations (Aberson et al. 1998), TC position, structure and environment (Zhang and Krishnamurti 1997) and multiple numerical models (Goerss 2000, Krishnamurti et al. 2001 and Aberson 2001) have been applied successfully to TC forecasting. In this study, we are exploring the relative importance of initial condition perturbations *as well as* model physics parameterizations in ensemble TC track forecasting.

2. METHODOLOGY

We are utilizing the Penn State / NCAR MM5V3 mesoscale model (Grell et al. 1995). Variations in model input data, physical processes and parameters will make up the ensemble set (Fig. 1). This approach will span the uncertainties important to TC prediction.

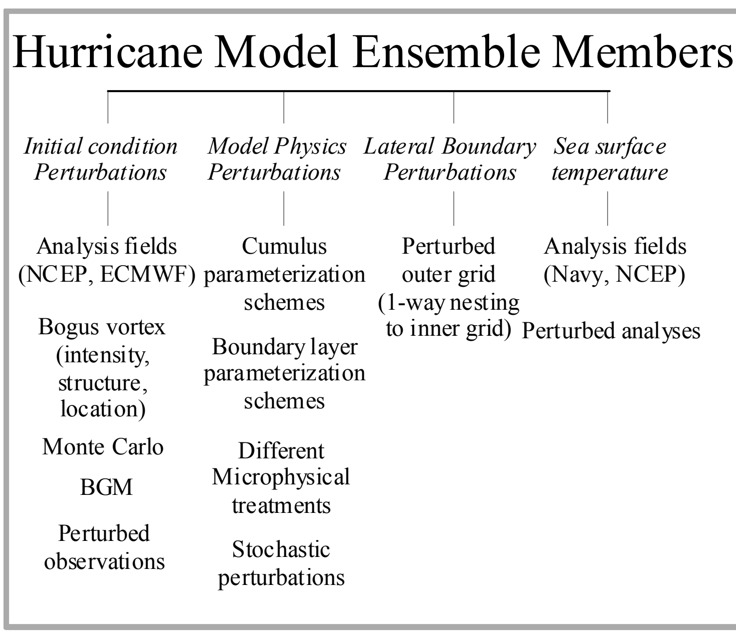

Fig. 1: Composition of the ensemble member set.

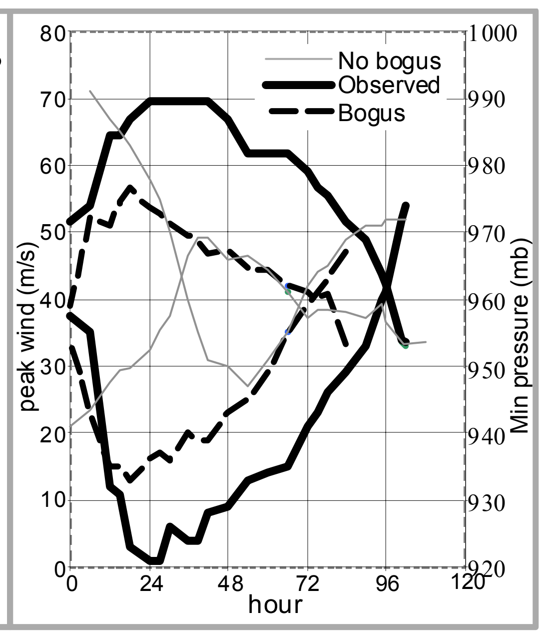

Fig. 2: Actual & modeled Floyd statistics.

*Corresponding author address: Mohan K. Ramamurthy, Department of Atmospheric Sciences, 111 Atmos Sci. Bldg., 105 S. Gregory St., Urbana, IL 61801. Email: mohan@atmos.uiuc.edu

MM5 offers several choices of physics, and TC evolution can be highly sensitive to these parameterizations (Davis et al., 2001). Three boundary layer methods (Blackadar, Burk-Thompson, and Hong-Pan), four Cumulus parameterization schemes (Anthes-Kuo, Betts-Miller, Kain-Fritsch, and Grell) and four microphysical approximations (Dudhia, Reisner II, Schultz and Goddard ice) will be used. Stochastic perturbations of key physics parameters will also contribute to the spread of the ensemble.

Model initialization includes use of first-guess fields (e.g. NCEP or ECMWF) as a basis for an analysis incorporating rawinsonde and specialized observations where available. Ensembles will be constructed by varying SST and first-guess grids and via perturbations to the observations (Hamill et al. 2000) or grid values (Monte Carlo, Breeding of Growing Modes - BGM) in a systematic way.

The above initial condition perturbations address the hurricane environment rather than the tropical cyclone structure. Ensembles are also being developed through implementation of a synthetic vortex. Specification of and modifications to the TC vortex address ambiguity in vortex location, structure and intensity and allow the ensemble to incorporate these uncertainties. Preliminary synthetic vortex simulations of Floyd (Fig. 2) resulted in a far more intense cyclone, with much less spin-up time required.

3. RESULTS FOR HURRICANE FLOYD

As part of the development of ensembles of model physics and initial condition perturbations, simulations have been carried out for hurricanes Opal (1995), Georges (1998), and Floyd (1999). We are assessing the impact of initial grids, data assimilation and the use of operational, dropsonde and satellite wind observations on the forecast track of Floyd.

In Fig. 3, the bold grey line represents the actual track of Floyd. All MM5 simulations based on operational datasets keep the storm offshore, with some alteration in track depending on the first-guess analysis used. However, when the MM5 simulation is used as a first guess and an analysis performed utilizing the extensive dropsonde data collected during Floyd, the track is altered much farther to the west. The best use of this data and of implementing observation and analysis perturbations in hurricane track forecasting is currently being investigated. Results will be presented at the Conference.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

Aberson, S. D., 1998: Five-Day tropical cyclone track forecasts in the north Atlantic basin. *Wea. Forecasting*, **13**, 1005–1015.

___, 2001: The ensemble of tropical cyclone track forecasting models in the north Atlantic basin (1976–2000). *Bull. Amer. Meteor. Soc.*, **82**, 1895–1904.

CNN, 1999: “Where hurricane watches and warnings come from.” <europe.cnn.com/WEATHER/9908/27/hurricane.prediction/>

Davis, C. A., J. G. Powers, and L. F. Bosart, 2001: Track and intensity prediction of tropical cyclone Diana (1984): Sensitivity to MM5 physical parameterizations. *11th PSU/NCAR MM5 Users' Workshop*, Boulder, CO.

Goerss, J. S., 2000: Tropical cyclone track forecasts using an ensemble of dynamical models. *Mon. Wea. Rev.*, **128**, 1187–1193.

Hamill, T. M., C. Snyder, and R. E. Morss, 2000: A comparison of probabilistic forecasts from bred, singular vector, and perturbed observation ensembles. *Mon. Wea. Rev.*, **128**, 1835-1851.

Krishnamurti, T. N., Sajani Surendran, D. W. Shin, Ricardo J. Correa-Torres, T. S. V. Vijaya Kumar, Eric Williford, Chris Kummerow, Robert F. Adler, Joanne Simpson, Ramesh Kakar, William S. Olson, F. Joseph Turk, 2001: Real-time multianalysis–multimodel super-ensemble forecasts of precipitation using TRMM and SSM/I Products. *Mon. Wea. Rev.*, **129**, 2861–2883.

Zhang, Z., and T. N. Krishnamurti, 1997: Ensemble forecasting of hurricane tracks. *Bull. Amer. Meteor. Soc.,* **78**, 2785–2795.

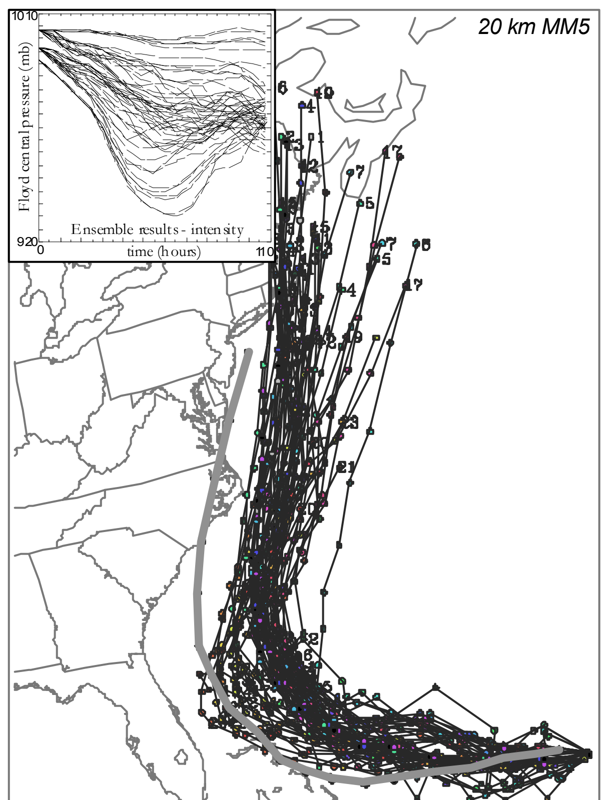

Fig. 3: Simulated Floyd track and intensity (inset).