Experiences With a Twice-Daily Ensemble of Regional WRF-ARW Model Simulations Across the Southeast US

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Background

Ensemble modeling methods have been shown to provide superior forecast skill to single-member model forecasts (e.g. HPC 2009). Numerous forecast centers regularly execute one or more forms of ensemble forecasts for real-time or research purposes, whether using perturbed initial atmospheric states (e.g. NCEP GEFS. ECMWF EPS); different models, resolution, and physics packages (e.g. NCEP SREF); or perturbations of parameters within model physics packages (e.g. Hacker et al. 2008).

Since 2006, we have produced once-daily WRF-ARW forecasts across the eastern US. With additional computing resources becoming available to us in early 2008, we decided to experiment with a real-time, twice-daily four-member ensemble system across the region. Since then, we have increased to five and now eight members with extremely promising results.

The results presented here highlight but three of the many examples where interrogating regional ensemble output has proven useful for improving regional temperature and precipitation forecasts.

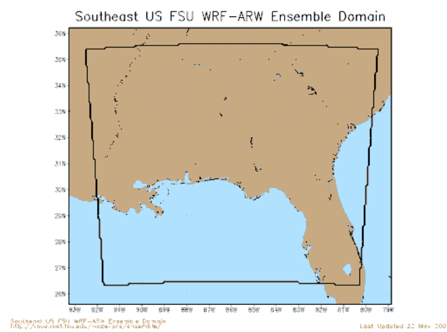


Figure 1: Southeast US FSU WRF-ARW Ensemble model domain, covering 1.26 million km^2 across the region.

Methodology and Setup

- Model Package: WRF-ARW V3.0.1.1 (to be WRF V3.1 early fall)
- Forecasts: 36 hr in length, run at 0600 and 1800 UTC daily
- Number of Ensemble Members: Eight (see below)
- Domain: 80x70x31 (dx=15 km), centered near Geneva, AL (Figure 1, left)
- Hardware: 15-18 CPUs, each 2.4GHz+ Intel Xeon processors with 1-2 GB RAM per CPU
- Runtime: Approximately 4 hours from start to finish (could be sped up with code optimizations in NAM grib2 data conversion and post-processing)
- Output available in real-time on the website above using GrADS 2.0a5.

The eight members of the Southeast US FSU-WJHG WRF-ARW Ensemble are formulated based upon three sets of variations...

- Initial/boundary conditions: NAM vs. GFS
- Cumulus parameterizations: Kain-Fristch (KF) vs. Betts-Miller-Janjic (BMJ)
- PBL parameterizations: Yonsei Univ. (YSU) vs. Mellor-Yamada-Janjic (MYJ)

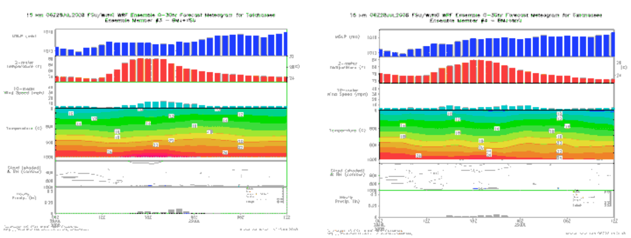


Figure 2: 36 hr meteograms for Tallahassee, FL (KTLH) from the GFS-initialized BMJ+YSU ensemble member (left) and BMJ+MYJ ensemble member (right). Note the 4-6 F difference in surface temperature at peak heating (verification: 91 F).

Examples and Experiences

Here, we present three case studies from real-time forecasts using the Southeast US FSU-WJHG WRF-ARW modeling system...

1. Impacts of boundary layer parameterization schemes upon localized near-surface temperature forecasts (left)
2. Impacts of cumulus parameterization schemes upon precipitation, instability, and temperature forecasts across the region (right)
3. The utility of ensemble-based forecast products for extreme regional weather events, as exemplified with heavy rainfalls from Tropical Storm Fay in August 2008 (below)

These studies highlight but a few of the weather phenomena that the ensemble forecast system has successfully been used to predict. Other regional phenomena captured by the ensemble forecast system include summer sea breeze events; the 10 April 2009 southeast US severe weather outbreak; and the recent heavy rainfall event across the Florida peninsula.

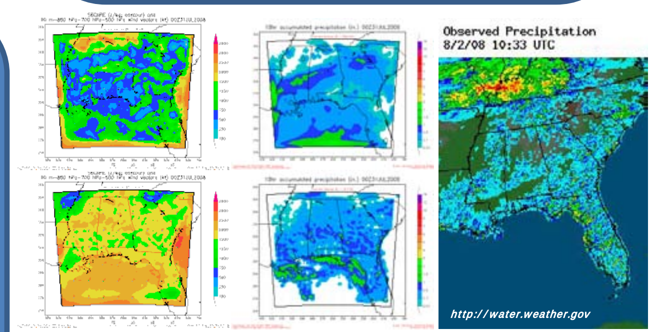


Figure 3: Effects of the BMJ (top) and KF (bottom) convective schemes upon instability (left) and precipitation forecasts (center; verification at right).

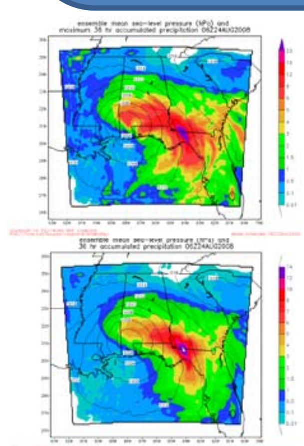
Applications

Knowledge of what causes forecast variations from the various schemes employed in the ensemble has proven very useful toward interrogating its output...

- PBL schemes: differences in how they handle mixing processes lead to differences within and atop the PBL, influencing temperature and moisture profiles within the PBL.
- Convective schemes: differences in how they perform convective adjustment within the atmosphere lead to differences in how tropospheric temperature and moisture profiles evolve.

Full technical descriptions of these differences and more may be found on the ensemble system webpage.

What still remains to be quantified, though, are how the differing initial conditions as well as the non-linearity of the physical system influence model forecasts. Ensemble mean products have proven useful in reducing any biases that may arise from these factors.



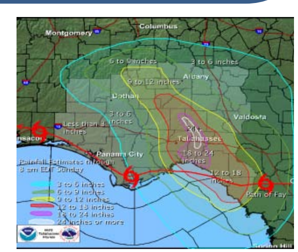


Figure 4: ensemble mean forecast (left), ensemble maximum forecast (right), and observed precipitation amounts (top, from NWS WFO Tallahassee, FL) from Tropical Storm Fay during 22-24 August 2008.

Acknowledgments and References

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Scripts used to execute the model in real-time are available upon e-mail request.

Hacker, J. et al., 2008: Building ensembles by varying parameters: an exploration of parameter ranges. Presentation given at the 8th WRF Users' Worhsop, NCAR, Boulder, CO, 23-27 June 2008.

HPC, cited 2009: NOAA NWS NCEP Ensemble Training Page. [Available online at http://www.hpc.ncep.noaa.gov/ensembletraining/].