# A Local WRF Downscaling of the Global Ensemble Forecast System Members using Modest Computer Resources

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## Abstract

The Global Ensemble Forecast System (GEFS) produces 21 global forecasts during each 6-hour forecast cycle. The variability among the members may give the forecaster an estimate of some of the uncertainty in the forecast. However, examining the 6-hour global forecast output may not give a satisfactory picture of the likely forecast uncertainty on the local scale. This poster describes a system that uses the Weather Research and Forecast (WRF) model to effectively downscale the GEFS members over a small region. The system produces local ensemble forecasts of hourly temperatures, winds, and precipitation through the 144-hour period of the GEFS using very modest computing resources. The data and model processing are described and examples of a forecast are given. Surface verification statistics over a 6-month period for selected stations over the United States are given.


## Data and model processing—twice daily forecasts

- GRIB data covering the region of interest from the 21 GEFS members (control + 20 perturbation members) are downloaded and processed through the WRF Preprocessing System (WPS).
- A 144-hour WRF simulation covering the area of interest is performed using each GEFS ensemble forecast member as the initial and boundary conditions.
- WRF data is post-processed using the UPP (Unified Post Processor). The surface data elements (winds, temperature, dew points, precipitation) are extracted from the forecast data files.
- Data are plotted graphically and are posted between 6 and 10 hours if the GEFS initial time.

## Data processing for verification

- Gridded surface data elements from the WRF ensemble members are archived.
- Surface data from the Meteorological Assimilation Data Ingest System (MADIS) are acquired and archived.
- Data from WRF and MADIS are joined using the Model Evaluation Tools (MET). Regional and statistical statistics are generated.

## WRF Domain and configuration

- ARW version 3.4.1
- 100x93 points, 20 km resolution
- Cumulus physics: BMJ
- Microphysics: WSM3
- PBL scheme: MYJ
- Surface physics: MYJ
- Land surface physics: Noah
- Short-wave radiation: Dudia
- Long—wave radiation: RRTM
- Adaptive time step
- No nudging
- GEFS members are the initial and boundary conditions.

## Model and processing software versions

- Environmental Modeling System (EMS), version 3.4.1 (WRF and associated pre-and post-processing)
- Model Evaluation Tools (MET), version 4.1
- Meteorological Assimilation Data Ingest System (MADIS) for observational data

## Computer system

Processor: Single Intel Core™ i7-4770, OS sees 4 virtual processors
Memory: 24 GB (hardware) 8 GB (OS)
Operating System: CentOS 6.5, running as virtual machine under Windows 8.

## Typical Timeline (0000 UTC GEFS cycle)

0715: Begin download of first GEFS member and start first WRF job
0745: Second job begins after first. Each job requires about 25-30 minutes
0945: After sixth member complete, generate preliminary graphics
1245: After twelfth member complete, generate updated graphics
1530: After all 21 members complete, generate final graphics and archive data.

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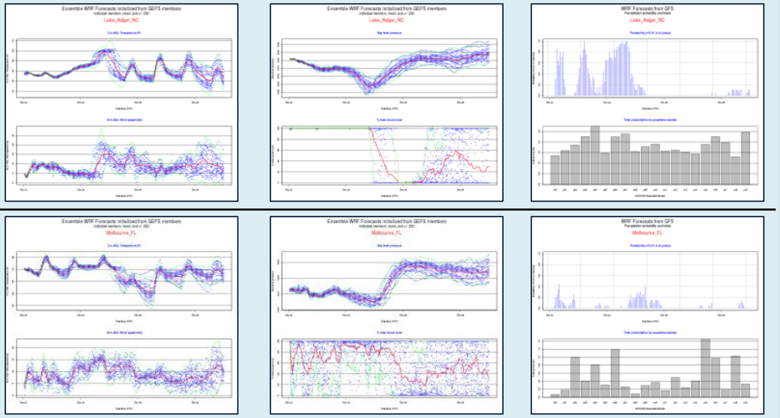
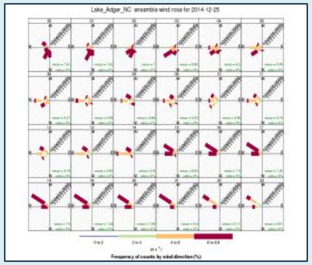
## Example of forecast products

Below are examples of the forecasts that are generated by the system. These forecasts were generated from the 0000 UTC 22 December 2014 cycle. Forecasts through 168 hours for two locations (Melbourne, Florida, and Lake Adger, North Carolina) are shown. The dots on each plot are hourly forecasts by one ensemble member. The red line is the mean of the ensemble members by time.

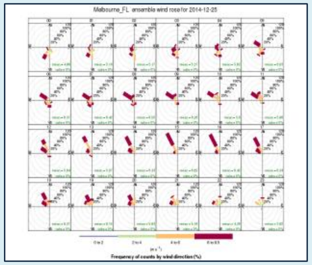
| | Temperature (°F) Wind speed (kt) | Sea level Pressure (hPa) Cloudiness (%) | Ensemble PoP Total 168-hr precip. by member |
|---|---|---|---|
| Lake Adger, NC | | | |
| Melbourne, FL | | | |





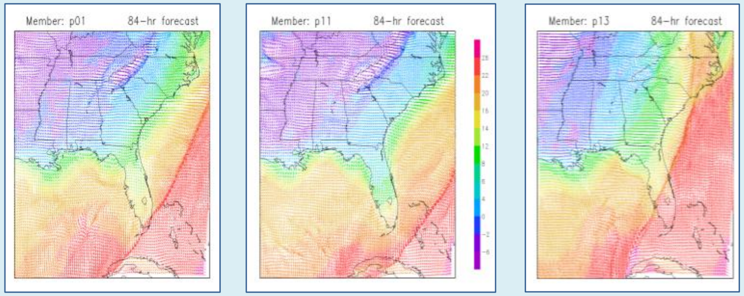
### Ensemble wind rose

Hourly wind rose plots for 25 Dec 2014 (72- through 95-hour forecasts). The length of the stems denote how many of the ensemble members predicted winds from the given direction and speed. Many short stems in a particular hour's plot suggest a higher spread in the ensemble wind forecasts.



### WRF surface wind and temperatures by member

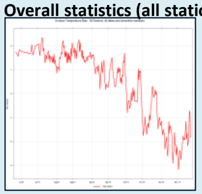
The maps below show the 10 m AGL wind vectors colored by the 2 m AGL temperature (°C) for the 84-hour forecast. Note the difference in speed of the cold front passing off the east. The *p13* member also shows very different winds and temperatures over far western North Carolina.



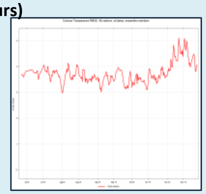

## Sample surface verification statistics

Surface wind, temperature, dew point, and precipitation were extracted from each of the WRF ensemble members' forecasts and archived. Using the MET tools, the model forecasts were matched with surface observations from the MADIS database. Below are sample statistics for one station, Melbourne, Florida (KMLB). These and other plots for 28 other stations over the southeastern United States can be found at the URL *http://www.steve-weather.com/ams-2015* (QR code above).

### Overall statistics (all stations, all dates, all forecast hours)



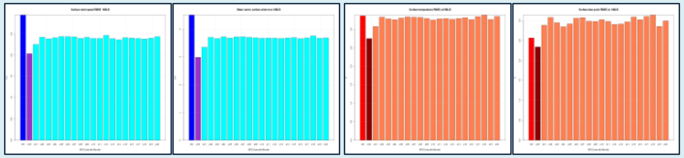
Temperature bias (left) and temperature RMSE (right) by model initialization time. Note how the temperature bias changes sign between June and November. The RMSE increased during the last month of the data period.

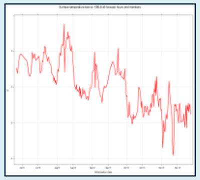


### Ensemble mean *vs.* ensemble member: Overall KMLB statistics by member

Left bar (*c00*) is the GEFS control member. The next bar represents the mean of the other GEFS control members. The remaining bars are the statistics for the individual members.

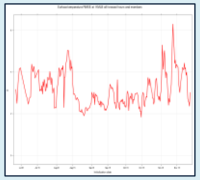
Sfc wind speed RMSE | Sfc vector wind error | Sfc temperature RMSE | Sfc dew point RMSE





### Overall surface temperature statistics

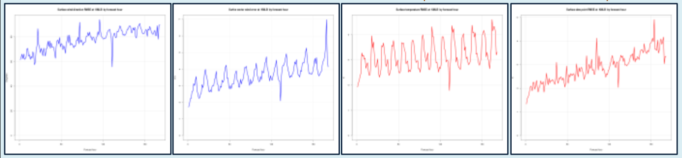
KMLB surface temperature bias (left) and RMSE (right). As with the overall domain statistics above, the temperature bias switched sign between summer and autumn. The RMSE was lower in the early autumn, but increased as winter approached.



### Wind and temperature errors by forecast hour

As is expected, the errors in temperature and winds gradually increase as the forecasts progress from their initial time and also show diurnal variability.

Surface wind direction RMSE | Surface vector wind error | Surface temperature RMSE | Surface dew point RMSE



### Summary and Future work

This work shows how detailed local ensemble forecasts can be produced based on the GEFS. The entire system runs on a single Intel i7-class computer and produces operational forecasts twice a day. The change in spread of the ensemble forecasts can be easily discerned from the local forecast graphics. Some possible further developments of this work include:

- Verification of the ensemble precipitation forecasts.
- Moving the calculations into the "cloud." Each of the WRF forecasts could be run as a separate process, greatly speeding the generation of the forecasts.
- Investigating the "spread-skill" relationship of the forecasts.