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A COMPARISON OF WRF FORECASTS MADE USING DIFFERING SOURCES FOR INITIAL AND BOUNDARY CONDITIONS

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1. INTRODUCTION

In South Florida, mesosacle weather features have a significant impact on day to day weather forecasts as they represent the primary forcing. Some of these features are: tropical waves, seas breezes, land breezes, thermal troughs, and outflow boundaries. The warm waters of the Gulf Stream also play an important role on the thermodynamic properties of the local air mass. Many of these features are not represented properly in the guidance from the National Centers for Environmental Prediction (NCEP) and therefore high resolution diagnostic as well as prognostic tools are necessary to support local forecasts. The advent of the Local Analysis and Prediction System (LAPS) at the Weather Service Forecast Offices (WFO) has provided the ability to ingest local data sets into locally controlled high resolution diagnostic analyses that capture and represent better some of these features.

This paper presents preliminary results of a study focusing on the impact of using the enhanced LAPS diagnostic analyses on the initialization of a locally run mesoscale model. The model used for the study is the WRF model. The study period ran from June 3, 2005 to July 31, 2005. The emphasis is during South Florida's convective season. Long term plans also include the incorporation of high resolution SST analyses into the initialization cycle to study their impact on the model's performance. This work is part of a COMET Partnership Project currently in effect between the University of Miami (UM) and WFO Miami.

The emphasis of this paper is to investigate the impact of incorporating high resolution analyses that assimilate non-traditional data sets into the model's initialization cycle.

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2. LOCAL ANALYSIS AND PREDICTION SYSTEM (LAPS)

LAPS became available to the WFO with the advent of AWIPS. As delivered in AWIPS, LAPS is a diagnostic tool only. It consists of high resolution three-dimensional analyses of the atmosphere using locally and centrally available meteorological observations. LAPS incorporates data from virtually every meteorological observation system onto a high-resolution grid centered on a domain of the users choosing. Data from local networks of surface observing systems, Doppler radars (only lowest level reflectivity along with precipitation estimates are used in the WFO LAPS), satellites, wind and temperature (RASS) profilers (404 and boundary-layer 915 MHz), as well as aircraft are incorporated into the analysis (Albers, 1995; Albers et al., 1996; Birkenheuer, 1999; McGinley, 2001; Schultz and Albers, 2001). At the Miami WFO, the analyses are produced every hour in a three-dimensional grid covering a 825 km west to east by 770 km north to south area centered around 25.6N and 80.9W. The horizontal resolution of the hourly LAPS surface analyses is 5 km with 39 vertical levels from 1000 mb to 50 mb at 25 mb intervals in the case of WFO Miami. The background field for the analyses is obtained from the AWIPS RUC 40 km 1 hour forecast. **Fig. 2** represents a summary of all the data sources LAPS is capable of assimilating into its three dimensional analyses, as well as those data sets used in the AWIPS LAPS running at WFO Miami. Data from both dedicated radars, Miami and Key West, are used in the analysis.

As it is evident in **Fig. 2**, not all data that LAPS is capable of ingesting is actually used operationally at the local WFO level. Despite the fact that LAPS is equipped with a Kalman filter (for quality control) it is not used operationally due to hardware limitations. Also, although the analysis is capable of ingesting VAD wind profiles and doppler radial veolicities, these are not used in the AWIPS LAPS due to the lack of access to the radar level II data in real time. As of AWIPS Operational Build 4.2, the analysis produces balanced temperature, humidity, height, and wind fields that can be used in combination with the cloud analysis to create initialization grids for the WRF. To improve the quality of the local analyses, the WFO in Miami has worked on incorporating additional local data networks into the analysis via the Local Data Acquisition and Distribution (LDAD) system, a component of AWIPS. This effort has led to a substantial increase in the amount of surface data going into the analyses. This data is quality controlled via the use of a blacklist.

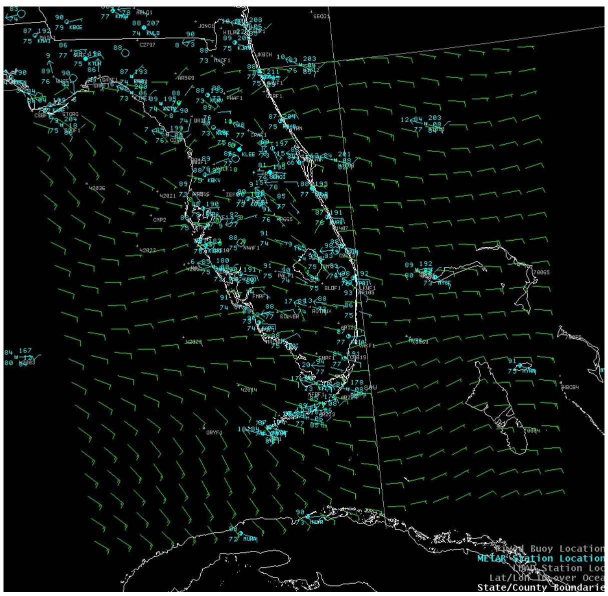

Figure 1: Domain of WFO Miami LAPS analyses.

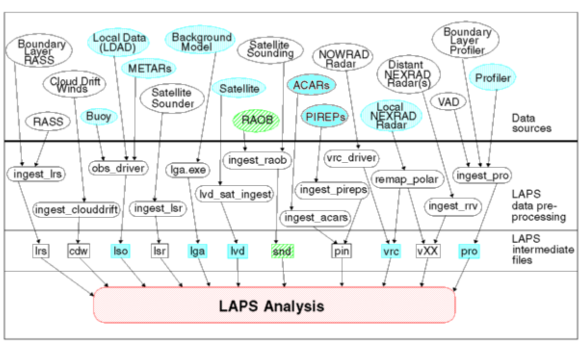

Figure 2: Schematic of Data Sources LAPS is capable of ingesting into its three dimensional hourly analyses. However, only those highlighted in blue and green are used in the operational LAPS analyses run at a typical WFO running AWIPS Operational Build 2.

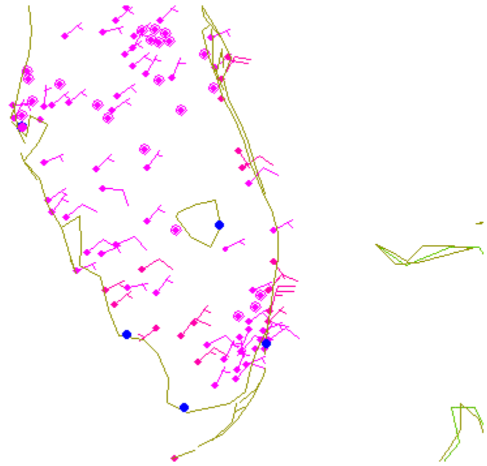

Figure 3a: Typical plot of surface Non-standard data networks (97 data points shown) ingested into AWIPS and the LAPS analyses at WFO Miami.

Figure 3b: Typical surface data availability across WFO Miami LAPS domain from standard data networks (METAR, Buoys, CMAN, Ships).

The predictive component of LAPS used for this experiment is the Weather Research and Forecast (WRF) model (Skamarock et al. 2001; Michalakes et al. 2001). The model is briefly described in the following section.

3. WRF MODEL CONFIGURATION

The model was run in one configuration. It is as follows:

- Start time 06Z and 18Z (2 runs daily)
- 18 hour simulation
- 121 x 121 horizontal grid points
- 31 vertical layers
- 5 km resolution
- Domain centered around 26.8N, 81.2W
- timestep: 20 seconds
- Microphysics: Purdue/Lin
- Longwave radiation: rrtm
- Shortwave radiation: Dudhia
- Surface layer: Monin-Obukhov
- Land surface: NOAH (5 soil layers)
- Boundary layer: YSU
- Cumulus: Kain-Fritsch
- Boundary Conditions: 12km NCEP NAM tiles

All model runs were performed on a cluster at the University of North Carolina at Charlotte. This cluster consisted of only two machines, each a Xeon dual-processor machine. In contrast to the work done in Welsh et al (2005), our project had more modest resources.

The hardware influenced other decisions about our WRF configuration. The first decision was to run the WRF model at 5km resolution. This was done because the LAPS analyses were available at 5km and NWS gridded forecasts are issued at 5km resolution. Given the hardware in place, in order to produce output in a timely manner, we chose a domain of 120 by 120 horizontal grid cells, with 31 vertical levels. This allowed an 18 hour run to be completed in about 3 and ½ hours. Thus, our 06Z and 18Z runs were available at about 8 AM and 8 PM local time, and thus available for updates to the forecast packages issued around 10AM and 10PM.

The number of gridpoints allowed the modeling of the peninsula and the offshore waters to a distance to include the forecast areas of WFO Miami, Key West, and Melbourne. In addition, the west and east model boundaries were sufficiently far away from Florida to prevent the boundaries from causing problems. See figure 4 for our model domain.

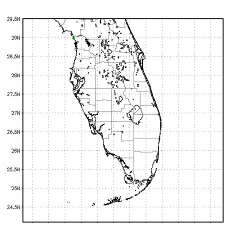

Figure 4: Model domain for WRF simulations.

4. IMPACT OF LAPS ON PRECIPITATION

An example of the impact of using LAPS to initialize the WRF model is shown for the 18Z initialization on June 6, 2005. Figure 5 shows the base reflectivity from the Melbourne, FL, and Key West, FL radar sites at approximately 18Z. At this time, there were strong reflectivity values in southern Florida as well as off the central Florida coast. An accurate representation of the initial conditions at this time should include some representation of this convection.

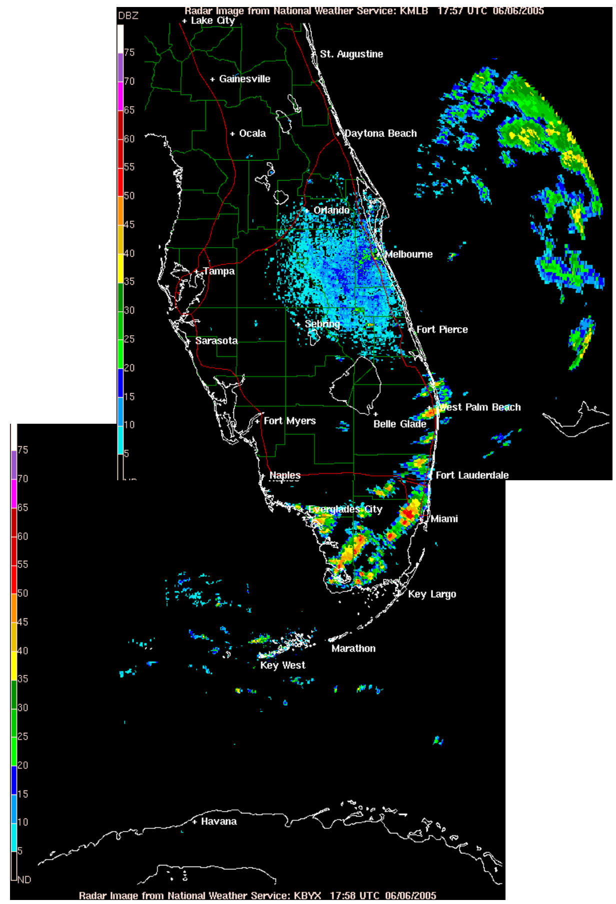

Figure 5 – Base reflectivity from the Key West and Melbourne, FL radar sites. (Courtesy http://www.srh.weather.gov/mfl/newpage/radar.html)

The initial conditions for 700 mb relative humidity are shown in figure 6. The top panel shows the initial conditions when the NAM tiles are used to initialize WRF, the bottom panel when LAPS is used to initialize WRF. The signal of the convection is quite evident in the LAPS produced initial conditions, with relative humidity values in excess of 90% in the south Florida locations where convection was evident. In contrast, the NAM produced initial conditions do not have this feature.

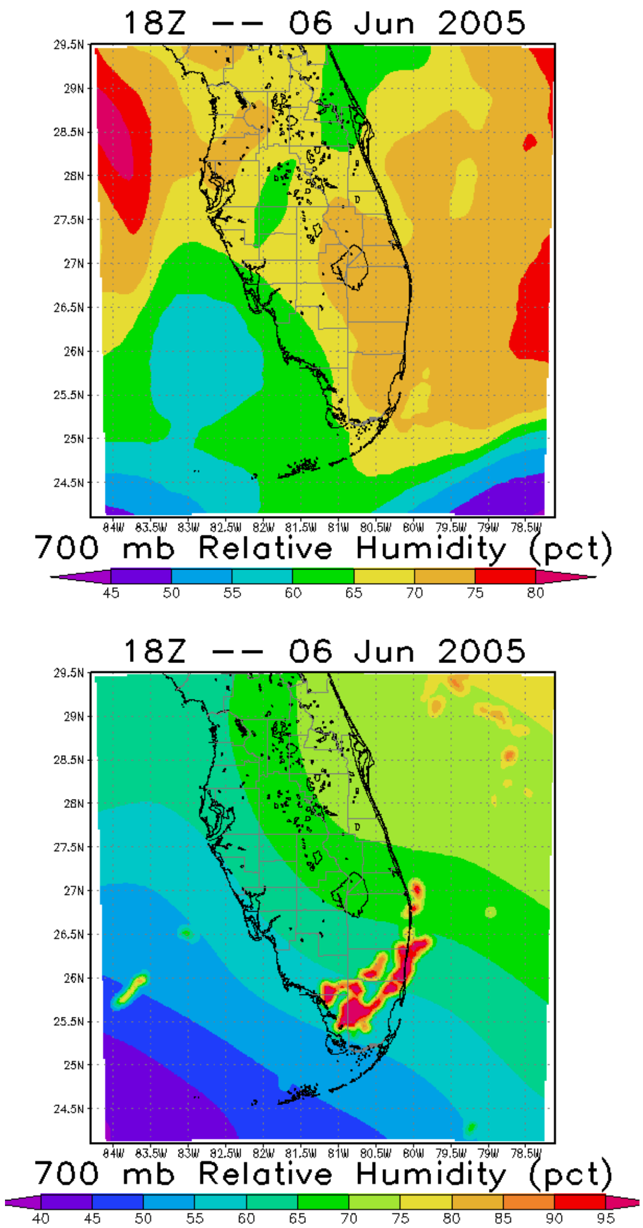

Figure 6 – 700mb Relative Humidity at the analysis time (18Z) for two WRF simulations. Top panel initialized using NAM output, bottom panel using LAPS.

The resulting precipitation forecasts from these two sets of initial conditions is quite different. During the first hour of the forecasts, the amount of precipitation generated in South Florida from the LAPS initialized WRF forecast is roughly consistent with the radar imagery. In contrast, the WRF run initialized with NAM tiles has no precipitation during the first hour.

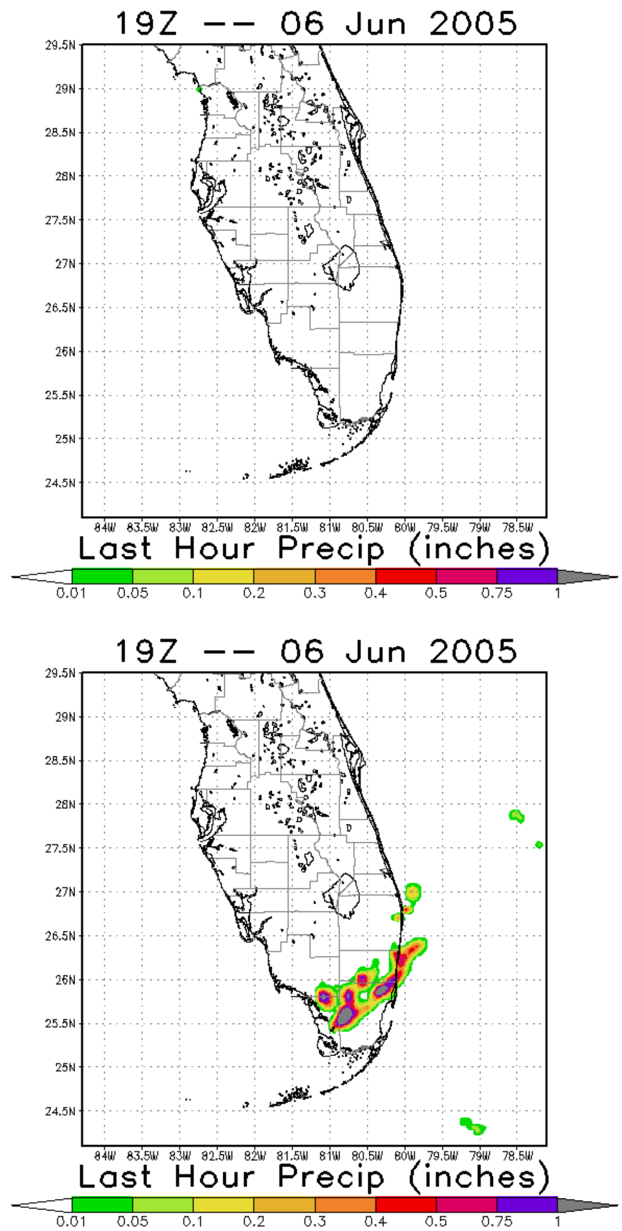

Figure 7 – Precipitation for the first hour of two WRF simulations. Top panel initialized using NAM output, bottom panel using LAPS.

5. SENSITIVITY STUDY

Given that the temperature fields are an agent to drive the wind fields, and the wind fields contribute to the location of precipitation, a sensitivity study of the 2-meter temperatures was performed.

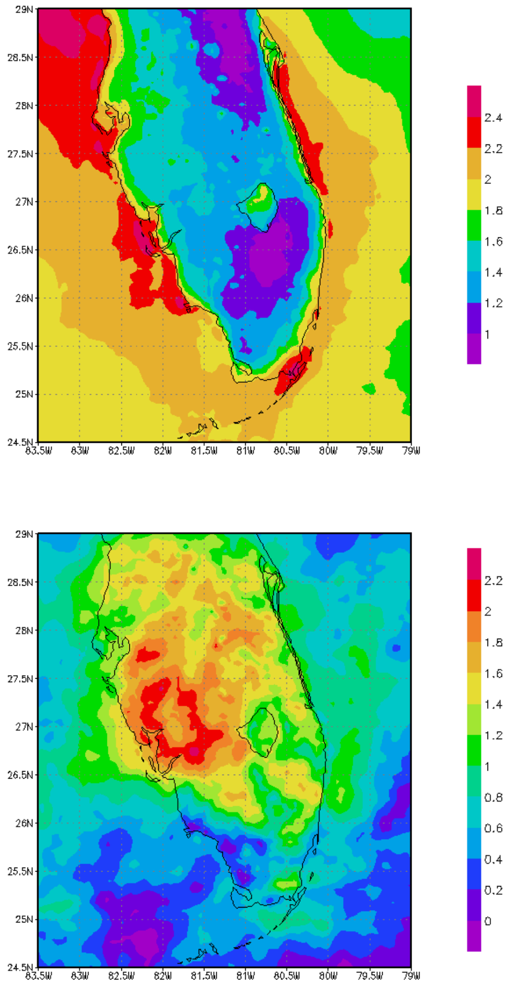

Figure 8 – The average difference between LAPS initialized WRF runs and NAM initialized WRF runs at 1-hour into the forecast (top panel) and 9-hours into the forecast (bottom panel). Initialization time is 06Z

Figure 8 shows the difference between the WRF forecasts initialized with NAM tiles and WRF forecasts initialized using WRF 1 hour and 9 hours into the forecast. These images are for 06Z initialized WRF runs. At 1-hour into the forecast, there is a clear signal that in all locations, the NAM initialized forecasts are warmer than the LAPS initialized forecasts. In addition, temperatures over water are noticeably warmer. As the forecast unfolds, this trend reverses, and by 15Z, it is a pocket over west-central Florida where the NAM initialized WRF forecasts are most different.

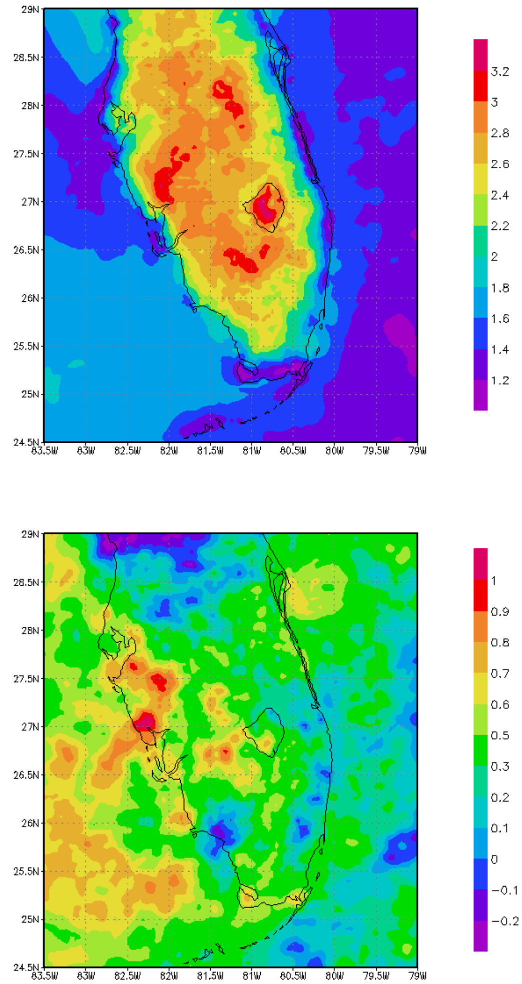

Figure 9 – The same as figure 7, but for 18Z initialized WRF runs.

Figure 9 shows the same information as figure 8, but for 18Z initialized WRF runs. Again, the NAM initialized WRF runs are warmer than the LAPS initialized runs, but in contrast to the 06Z runs, it is over the land where the NAM initialized runs are most different. Also in contrast to the 06Z initialized WRF runs, there is less cohesion of the differences between the NAM and LAPS initialize runs 9 hours into the forecasts.

Figure 10 shows the mean difference and the root mean squared difference between the NAM and WRF initialized forecasts for both 06Z (top) and 18Z (bottom) initial times. Clearly, the differences between the forecasts decrease as lead time increases, and the influence of the initial conditions wanes and the influence of boundary conditions and model physics increases.

Though the differences between NAM initialized and WRF initialized forecasts are roughly the same 1-hour into the forecast for both 06Z and 18Z initialized forecasts, the differences approach zero faster for the 18Z initialized forecasts than for the 06Z initialized forecasts.

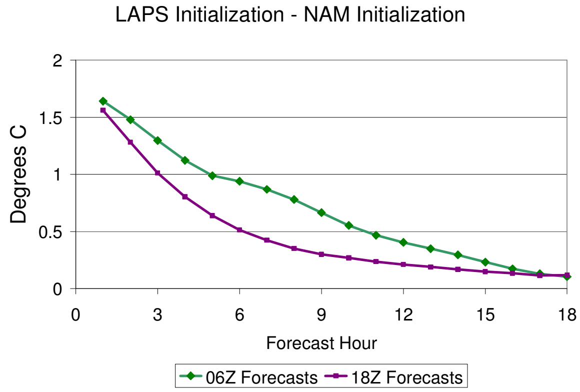

Figure 10 – Average difference between WRF simulations initialized with LAPS and those initialized with NAM tiles as a function of forecast hour. Green line (top) is for 06Z initial time forecasts, purple line (bottom) is for 18Z initialized forecasts.

Of greater significance is which of the two forecasts was more accurate. In general, 06Z initialized using LAPS were had more accurate temperature forecasts, while for 18Z initialized forecasts, it was the NAM initialized forecasts which were more accurate. Results are shown in figure 11. Of particular significance is that for the 06Z initial time runs, those runs initialized from LAPS were more accurate in the critical time from 12Z to 21Z, when convection is most common across Florida. To be more accurate at this critical time is valuable.

A further investigation of the results showed that for 18Z initial time forecasts, 2-meter temperature forecast for griboxes over land were noticeably worse for those forecast initialized from LAPS. In contrast, for gridboxes over the water, WRF forecasts initialized using LAPS analysis were in general better or as good as forecasts initialized from NAM. However, after about 12 hours into the forecast, the impact of the initial conditions had waned and the forecasts were of similar quality, yet in error by about 0.5 degrees Celsius. In future work, we will investigate the impact using high resolution Sea Surface Temperature data on WRF forecasts.

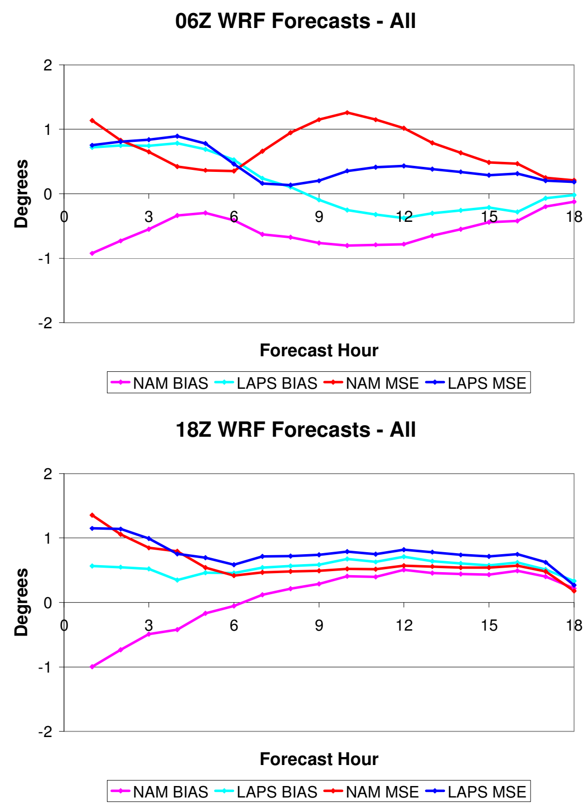

Figure 11 – Bias and Mean Squared error for WRF forecasts initialized from LAPS analyses (red and pink lines) and from NAM analyses (light blue and dark blue lines).

7. REFERENCES

Albers, S., 1995: The LAPS wind analysis. *Wea. Forecasting*, 10, 342-352.

Albers, S., J. McGinley, D. Birkenheuer, and J. Smart, 1996: The Local Analysis and Prediction System (LAPS): Analyses of clouds, precipitation, and temperature. *Wea. Forecasting*, 11, 273-287.

Birkenheuer, D., 1999: The effect of using digital satellite imagery in the LAPS moisture analysis. *Wea. Forecasting,* **14**, 782-788.

McGinley, J.A., 2001: Toward a surface data continuum: Use of the Kalman filter to create a continuous, quality controlled surface data set. *Preprints, 18th Conf. on Weather Analysis and Forecasting*, Ft. Lauderdale, FL, Amer. Meteor. Soc.

Michalakes, J., Chen S., Dudhia J., Hart L., Klemp J., Middlecoff J., and Skamarock W., 2001: Development of a next generation regional weather research and forecast model. Developments in Teracomputing: *Proceedings of the Ninth ECMWF Workshop on the Use of High Performance Computing in Meteorology*, W. Zwieflhofer and N. Kreitz, Eds., World Scientific, 269–276.

Schultz, P. and S. Albers, 2001: The use of three-dimensional analyses of cloud attributes for diabatic initialization of mesoscale models. *Preprints, 14th Conf. on Numerical Weather Prediction*, Ft. Lauderdale, FL, Amer. Meteor. Soc.

Skamarock, W. C., Klemp J. B., and Dudhia J., 2001: Prototypes for the WRF (Weather Research and Forecasting) model. Preprints, *Ninth Conf. on Mesoscale Processes, Fort Lauderdale, FL, Amer. Meteor. Soc., J11–J15*.

Welsh, P. T., Lambert, J. D., and Bogenschutz, 2005: NWP with the Weather Research And Forecast Model and Local Data Siimilation as a Prelude to “Neighborhood Weather”. Preprints, *21st Conference on Weather Analysis and Forecasting/17th Conference on Numerical Weather Prediction, Washington, D. C., Amer. Meteor. Soc., 10A.3.*