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Analysis of MM5 Simulations based on three PBL schemes over the eastern US for August 6 to 16, 2002

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Introduction: In a prior report[1] dated December 8, 2003, a comparison was performed between meteorological measurements and the simulated MM5 fields for August 6 to 16, 2002 based upon 3 approaches to the PBL. In this report, we provide the comparison with TDL and CASTNet measurements.

Purpose: The intent of this exercise was to investigate the response of three PBL schemes and develop a recommendation for the use of a PBL method for developing meteorological fields for the May through September of 2002, in support of air quality modeling work.

Approach: In this study, Prof. Dalin Zhang of University of Maryland, applied 3 PBL schemes for the August 6 to 16, 2002, a period in which the OTR experienced high ozone as well as particulate levels. The three schemes were (a) modified Blackadar [BL], (b) the Pleim-Xiu scheme with the soil module [PX], and (c) modified Blackadar with soil module [SSIB]. The simulated meteorological fields were compared to the measurements from TDL (NWS) and CASTNet.

Model setup: The MM5 model setup is similar to the earlier exercise of developing meteorological fields for July 1997, with the first level at 10 m. The projection for this exercise was that recommended by the RPOs, and has a spatial resolution of 12 km (see Figure 1)

Analysis: The basic approach used is to compare domain-wide averaged measurements and predictions for surface temperature, wind speed and direction, and where available with humidity. While the CASTNet sites are more representative of rural areas, the TDL are reflective of urban/suburban settings. There are 47 CASTNet and about 600 NWS sites in the TDL data set over the modeling domain.

TDL data and MM5 simulations:

Average wind speed and direction (see Figures 2a through 2c)

[1] Hao, W., Ku, M., and Sistla, G. (2002) 'Preliminary analysis of MM5 simulations for the August 6 to 17, 2002 – A status report', NYSDEC, Albany, NY 12233

Overall, the 3 PBL schemes provide good agreement with the observed average wind direction . In terms of wind speed:
BL: Under prediction of daytime maximum wind speed, but agreement with nighttime low windspeed
P-X: Systematic under prediction during daytime and over prediction in the nighttime
SSIB: Under prediction during daytime with phase lag, the predicted maximum occurring latter than the measured maximum

Temperature (see Figures 3a through 3c)

BL: Good agreement throughout the episode days
P-X: Initial over prediction of temperature minimum, and under prediction of daytime maximum
SSIB: Over prediction of daytime maximum

Humidity (see Figures 4a through 4c)

BL: While the general trend is captured during the episode, there is poor agreement between the observed and predicted diurnal patterns, with the observation showing a double peak versus one peak based on predictions.
P-X: The model yields the observed daily double peak, but with underprediction and a phase lag.

CASTNet data and MM5 simulations:

Average wind speed and direction (see Figures 5a through 5c)

All 3 PBL approaches provide good agreement with the observed average wind direction. In terms of wind speed:

BL: Wind speed over prediction during the daytime, a feature that differs from the TDL results, but good agreement with nighttime minimum
P-X: Wind speed over prediction, for both day- and nighttime hours.
SSIB: Wind speed over prediction at the start and end of the episode, and exhibiting a phase-lag of 1 to 2 hours

Average Temperature (see Figures 6a through 6c)

BL: Overall good agreement
P-X: Systematic under prediction during daytime and over prediction in the nighttime with phase lag
SSIB: Over prediction during the daytime, but good agreement during nighttime

Average Humidity

There were no data to perform this comparison, as mixing ratio cannot be estimated due to lack of station pressure.

Spatial distribution of correlation between TDL data and MM5 simulations

Wind Speed (see Figures 7a through 7c)
BL: The correlation levels are generally in the 0.7 or higher range over most portions of the domain, with lower values mainly confined to the southeastern and western parts of the domain.
P-X: The correlation levels are slightly lower compared to BL, with more stations exhibiting a correlation level of less than 0.6 in the Southeastern portion of the domain.
SSIB: The correlation levels are similar to P-X, but with increased number of stations exhibiting correlation levels less than 0.6 over the domain

Temperature (see Figures 8a through 8c)
BL: The correlation levels are generally higher (>0.97) over the northeastern portions of the domain, with the remainder of the domain exhibiting correlation levels in the range of 0.94 to 0.96
P-X: Overall the correlation levels are slightly lower than BL
SSIB: Similar to P-X, with correlation levels in the 0.95 throughout the domain

Humidity (see Figures 9a through 9c)
BL: The correlation levels over the northeast are generally higher than the rest of the domain, although most portions of the domain report correlation of 0.70 or higher
P-X: The correlation levels are comparable or slightly better than BLK
SSIB: The correlation levels are comparatively lower than the other two over the northeastern portions of the domain

Discussion and conclusions

On an overall basis, it appears that the BL scheme exhibits a better correspondence to the measured data than the other two schemes. The exception being the poor capture of the observed diurnal pattern of humidity in the case of the BL scheme. While the P-X scheme shows a better correspondence with the observed diurnal pattern for humidity, it fails to perform well for wind speed and temperature. Further work is needed to improve the performance of these methods. An examination of other studies in which the P-X scheme was applied suggests the predictive performance is similar to this study.

Other comparisons of model to observed or measured parameters such as cloud cover, precipitation, and upper air soundings/profiler network are under examination to provide a comprehensive evaluation of the meteorological model. Also, the use of the model simulated fields in air quality model and comparison to pollutant fields is also in progress.

Figure 2a MM5 Simulation - UMD BLK & TDL - Aug 6 01Z to Aug 17 00Z 2002

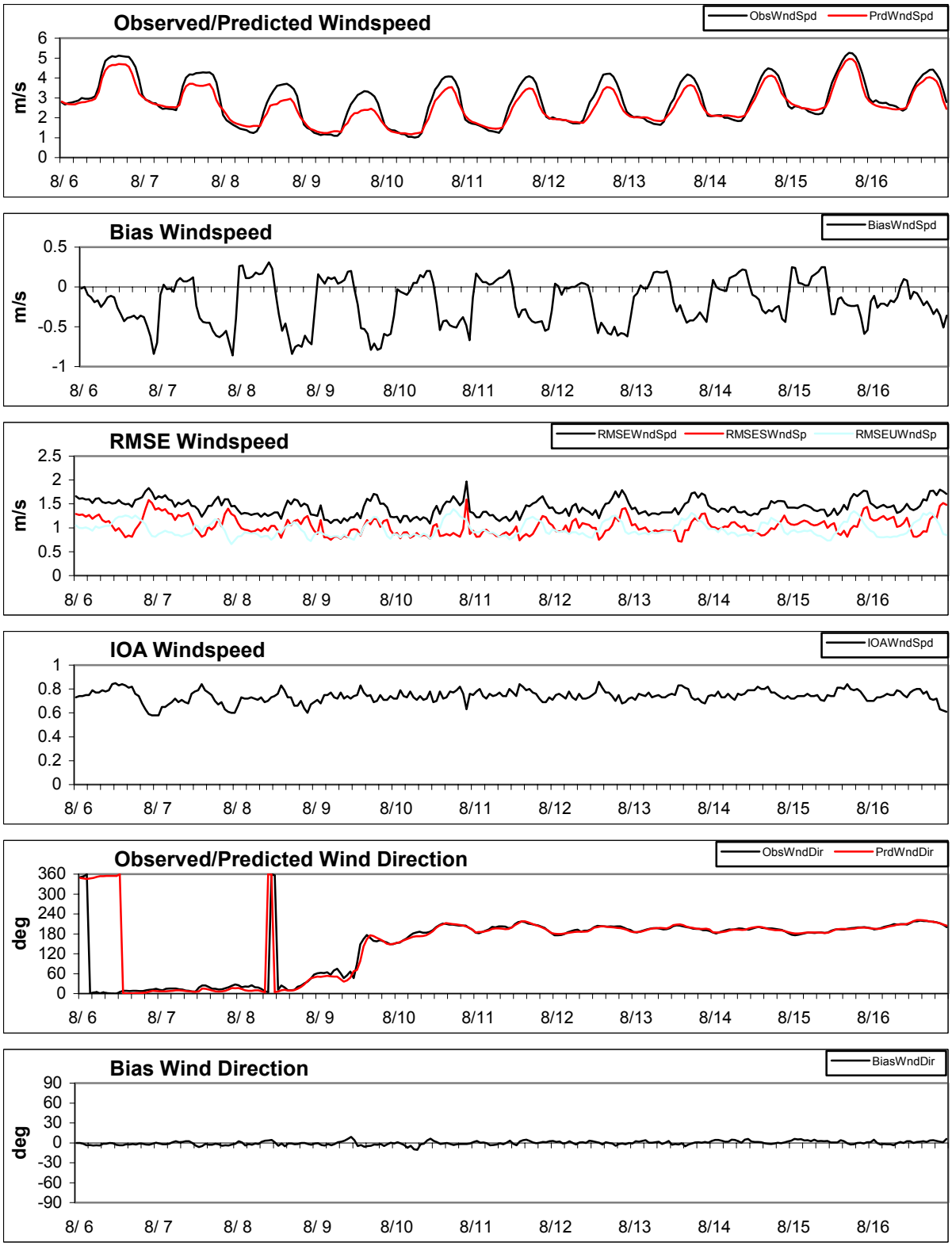

Figure 2b MM5 Simulation - UMD PX & TDL Aug 06 01Z to Aug 17 00Z 2002

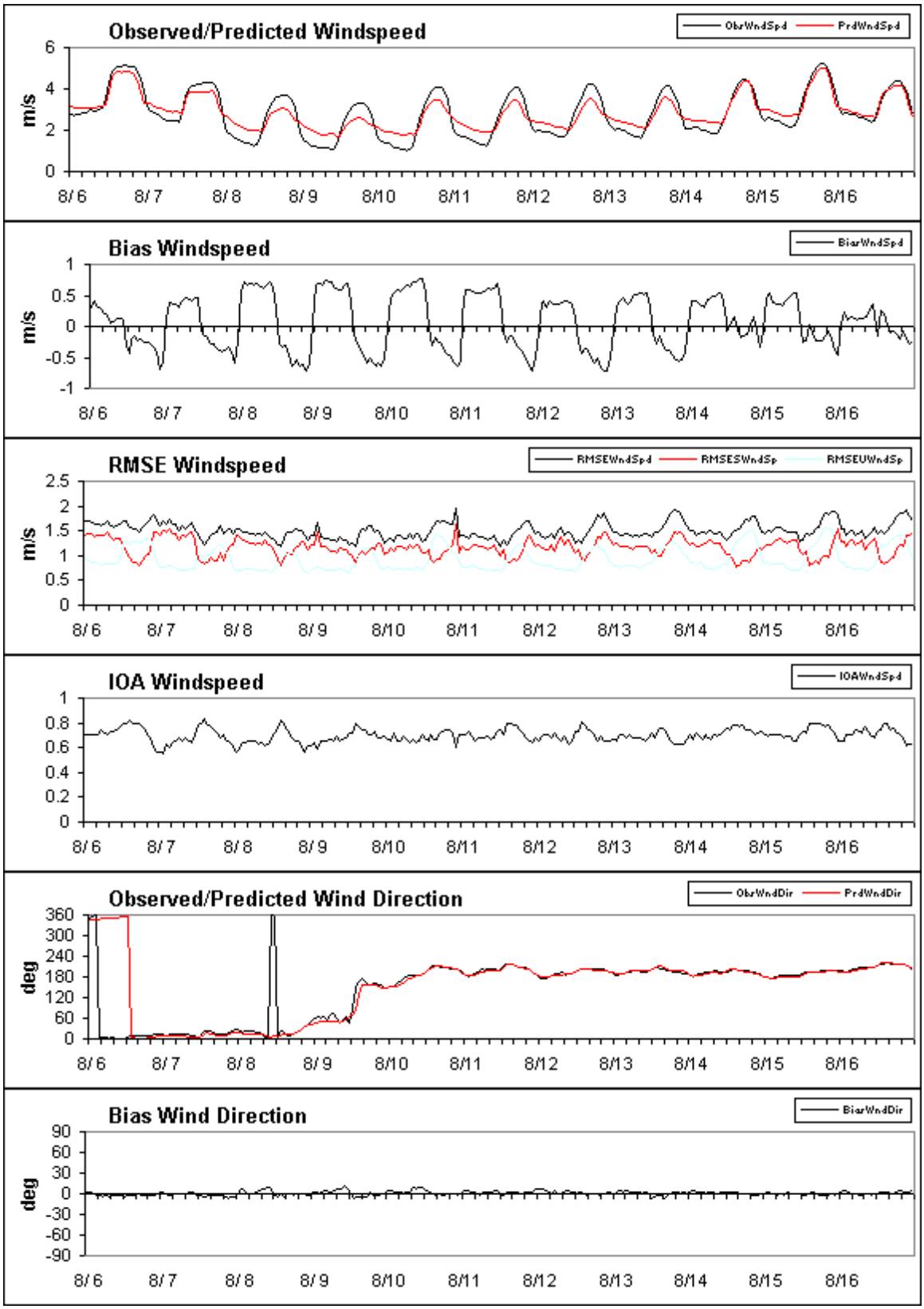

Figure 2c MM5 Simulation - UMD SSIB & TDL Aug 06 01Z to Aug 17 00Z 2002

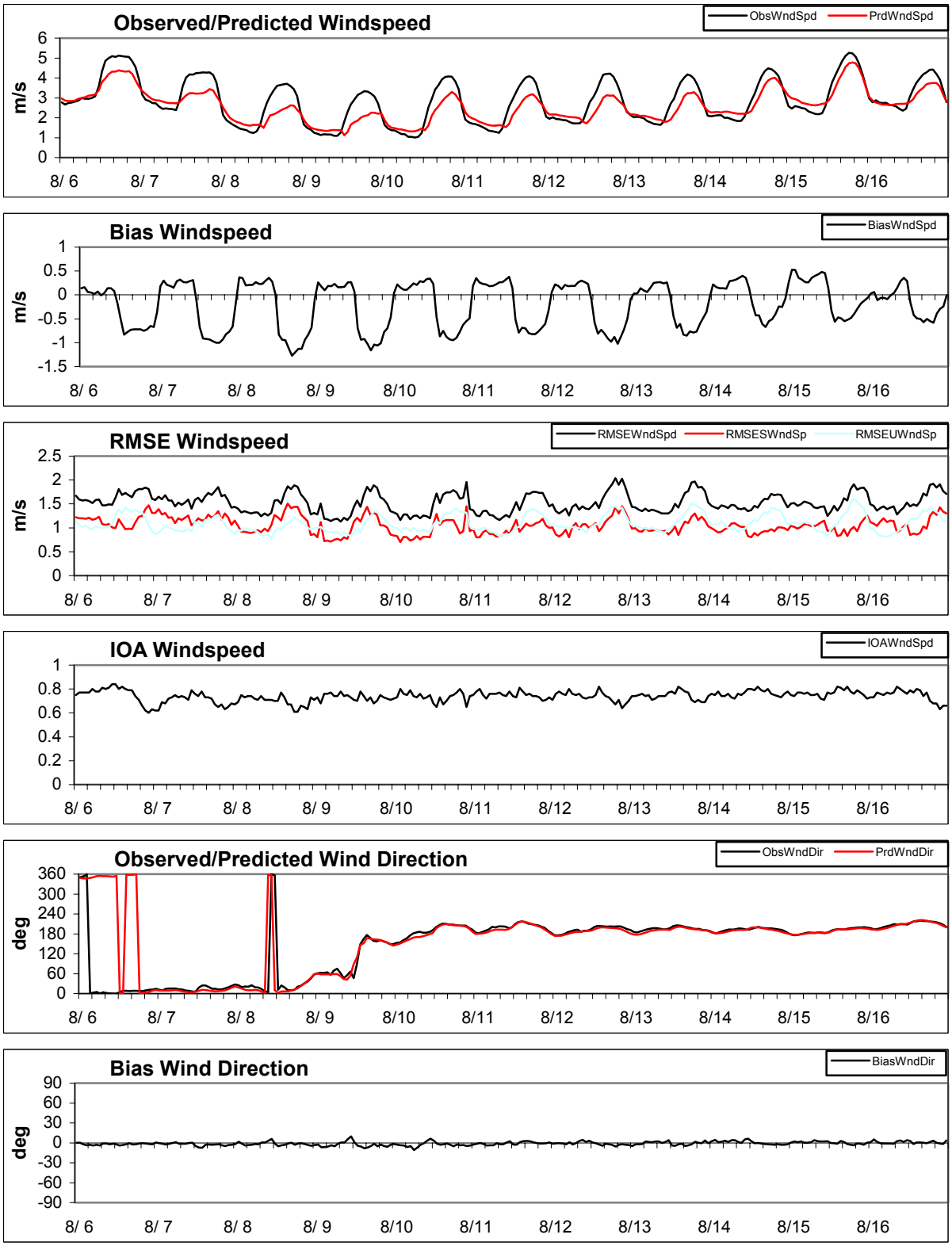

Figure 3a MM5 Simulation - UMD BL & TDL Aug 6 01Z to Aug 17 00Z 2002

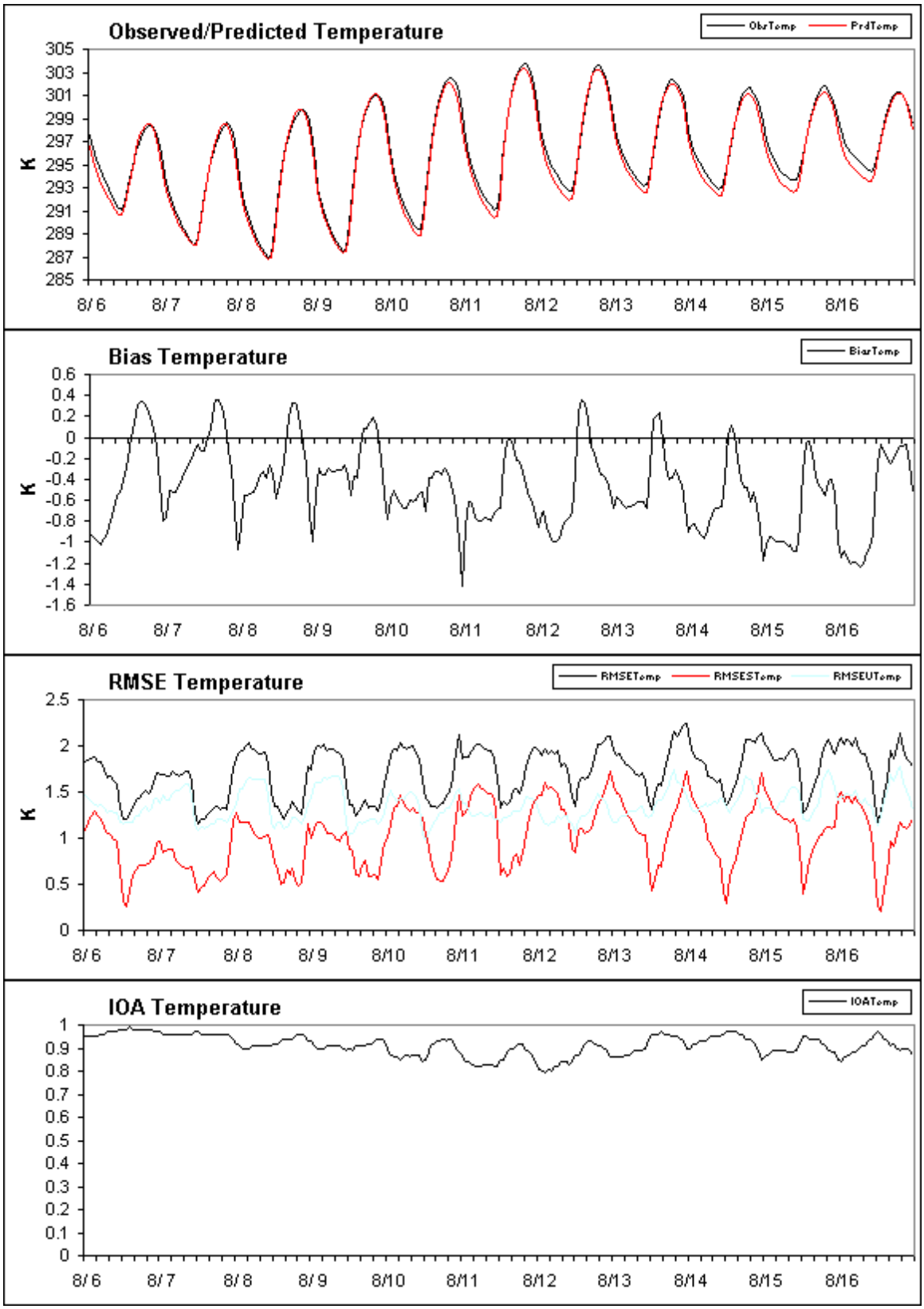

Figure 3b MM5 Simulation - UMD PX & TDL Aug 06 01Z to Aug 17 00Z 2002

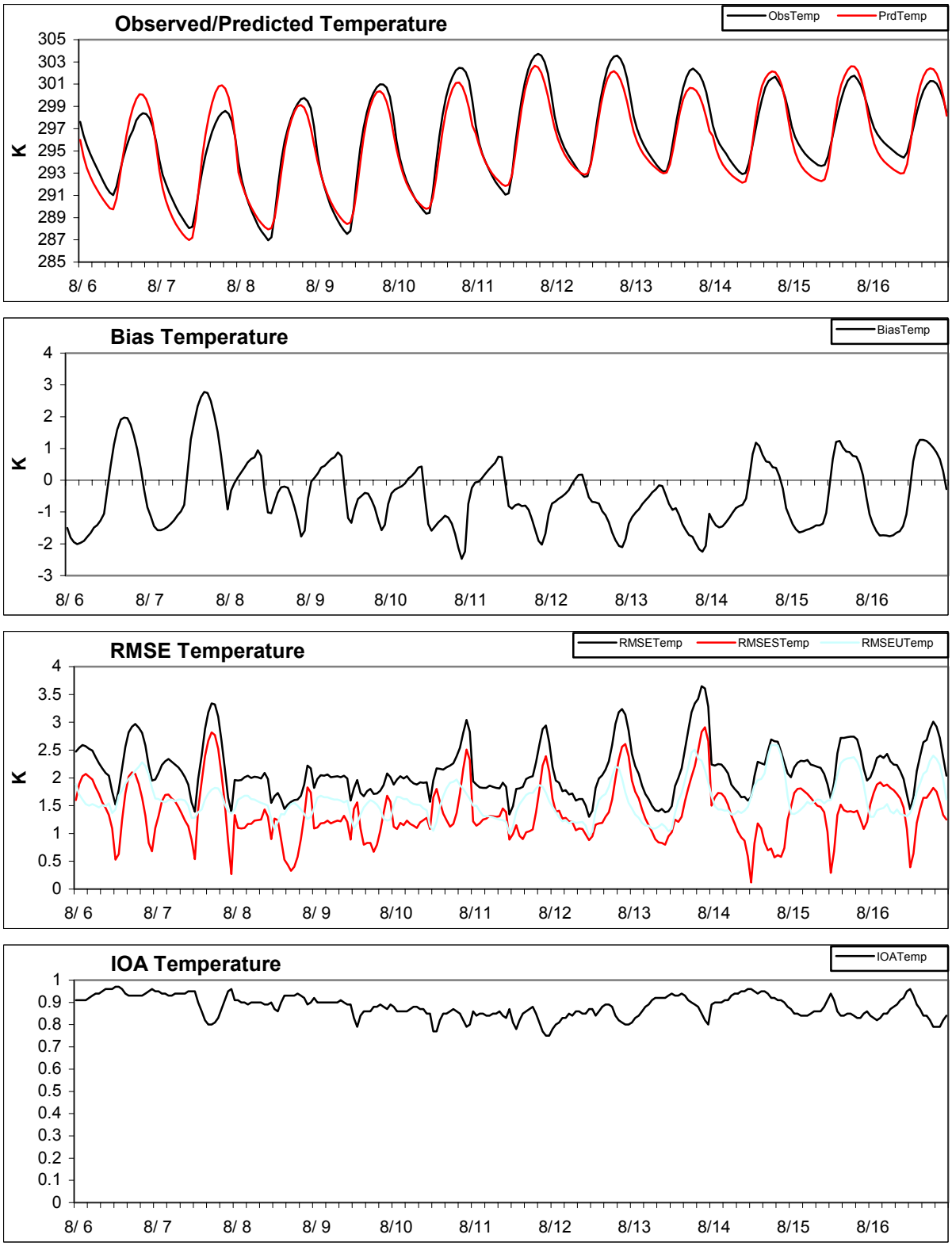

Figure 3c MM5 Simulation - UMD SSIB & TDL Aug 06 01Z to Aug 17 00Z 2002

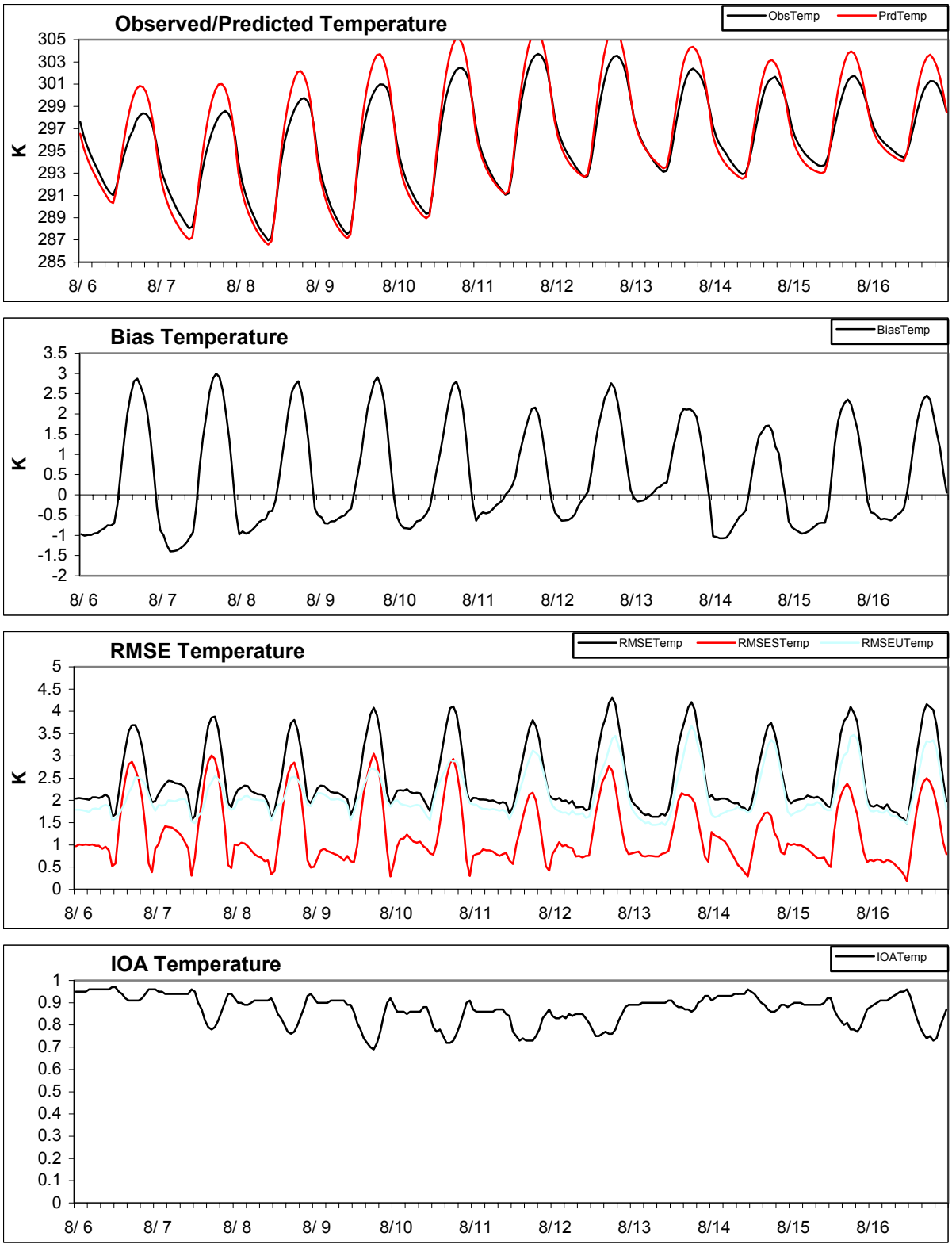

Figure 4a MM5 Simulation - UMD BL & TDL Aug 6 01Z to Aug 17 00Z 2002

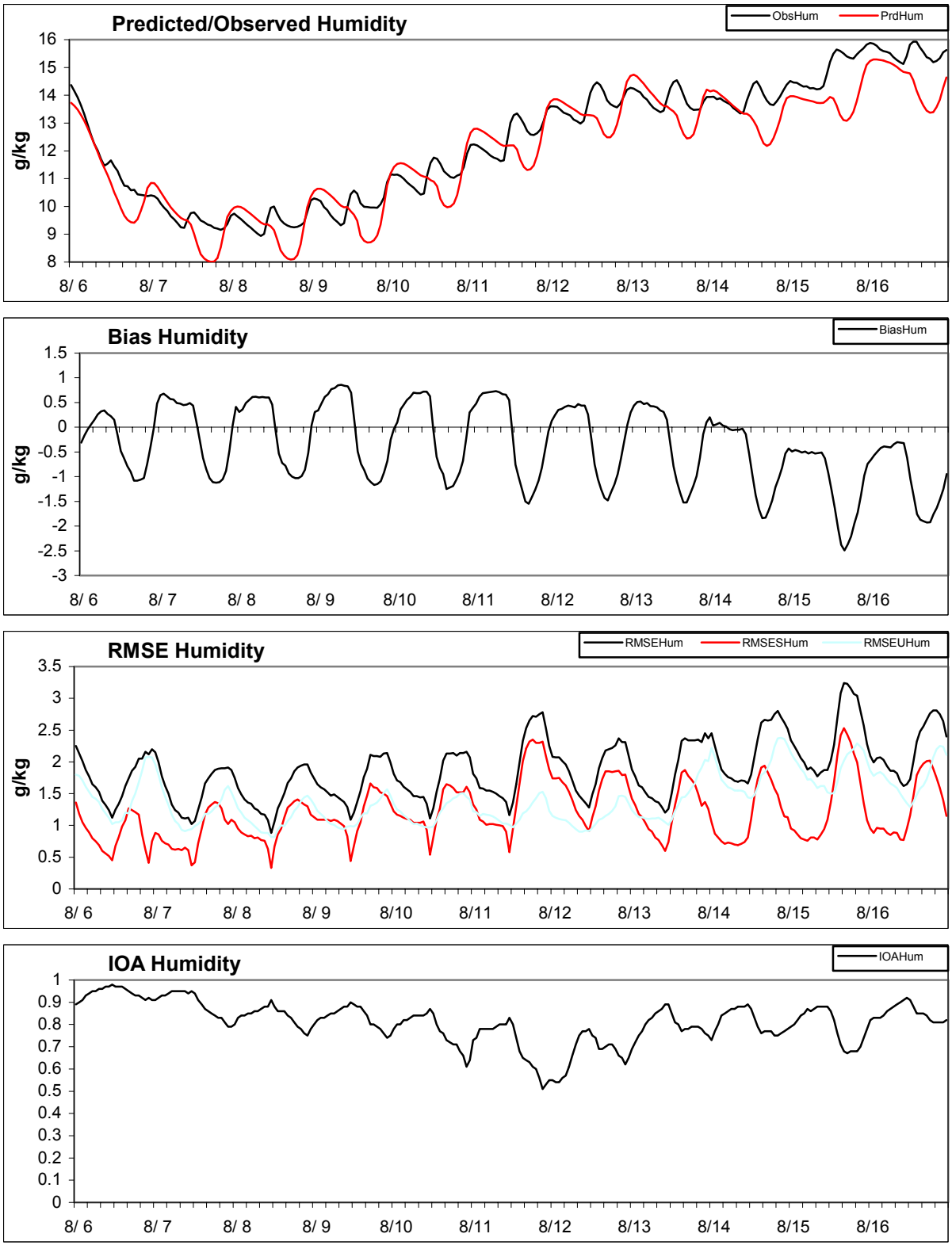

Figure 4b MM5 Simulation - UMD PX Aug 06 01Z to Aug 17 00Z

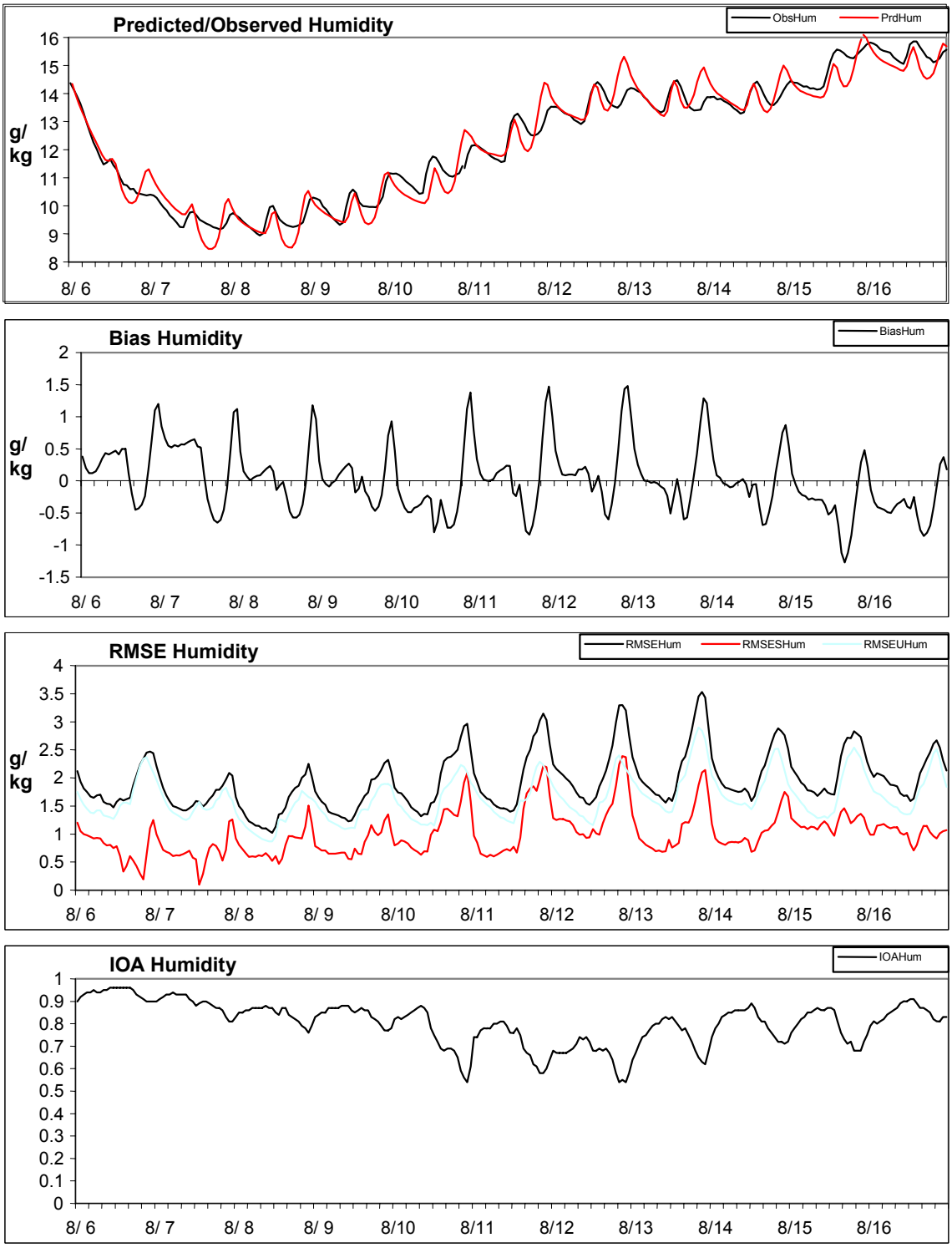

Figure 4c MM5 Simulation - UMD SSIB & TDL Aug 06 01Z to Aug 17 00Z 2002

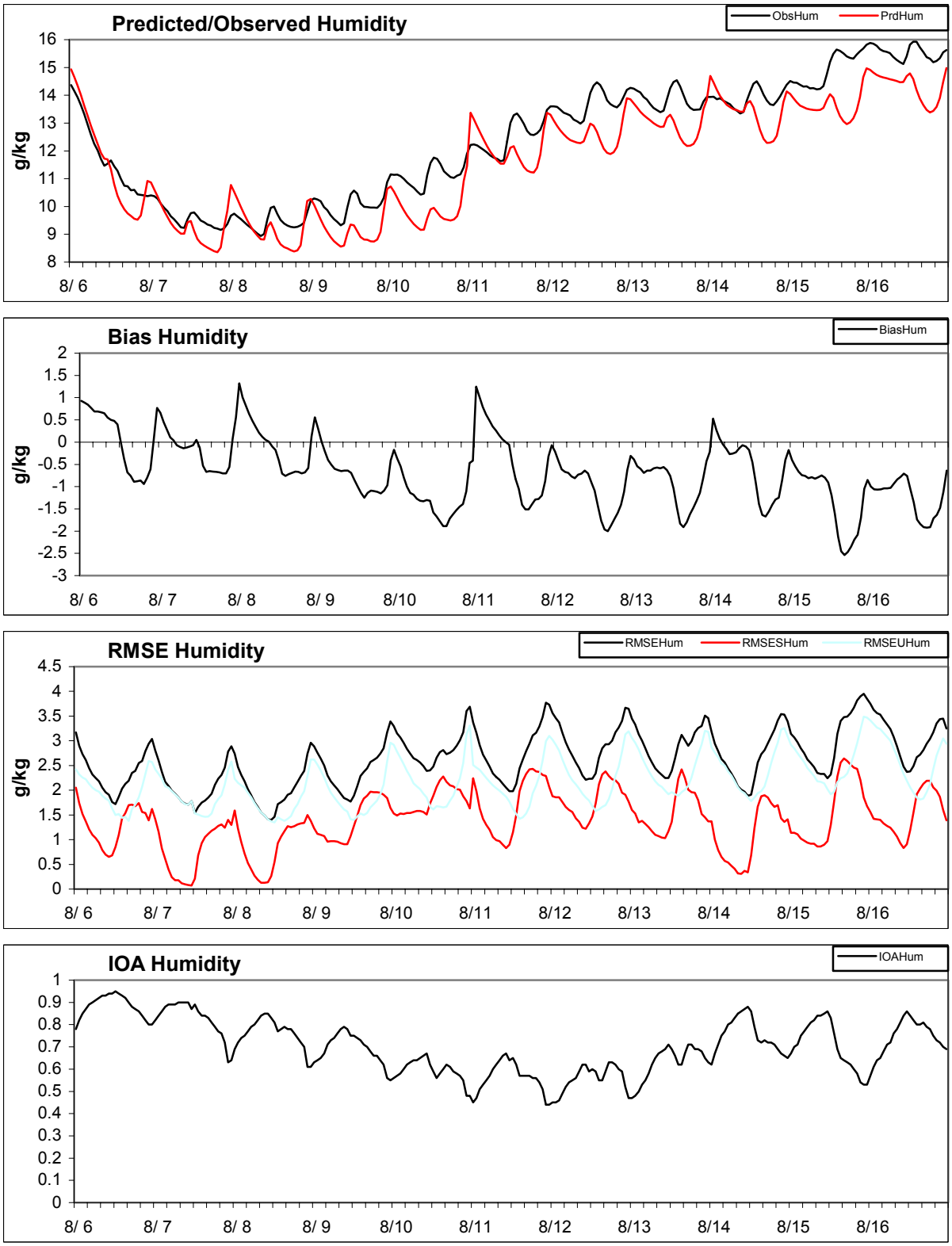

Figure 5a MM5 UMD - BL & CASTNet Aug 6 01Z to Aug 17 00Z 2002

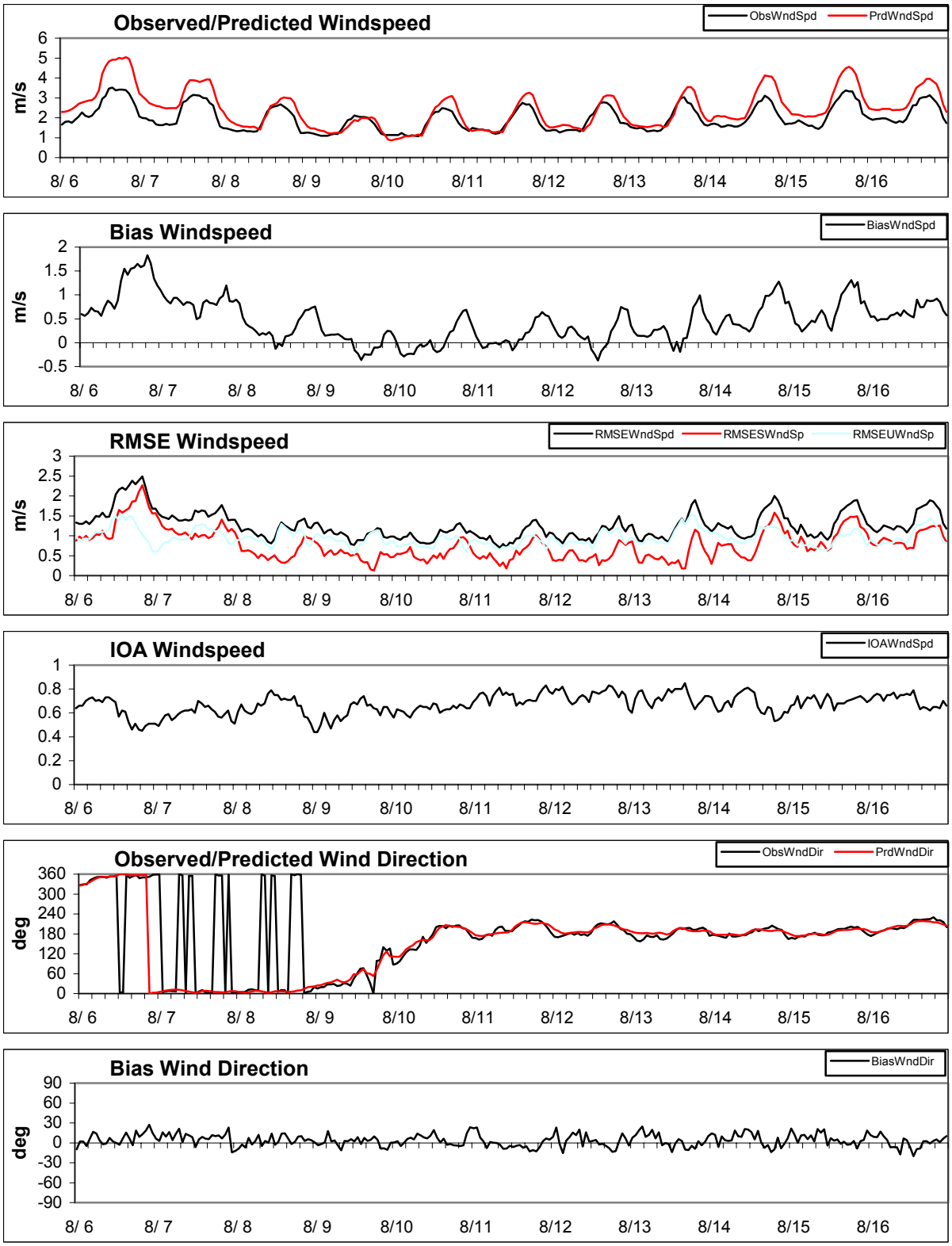

Figure 5b MM5 - UMD PX & CASTNet Aug 06 01Z to Aug 17 00Z 2002

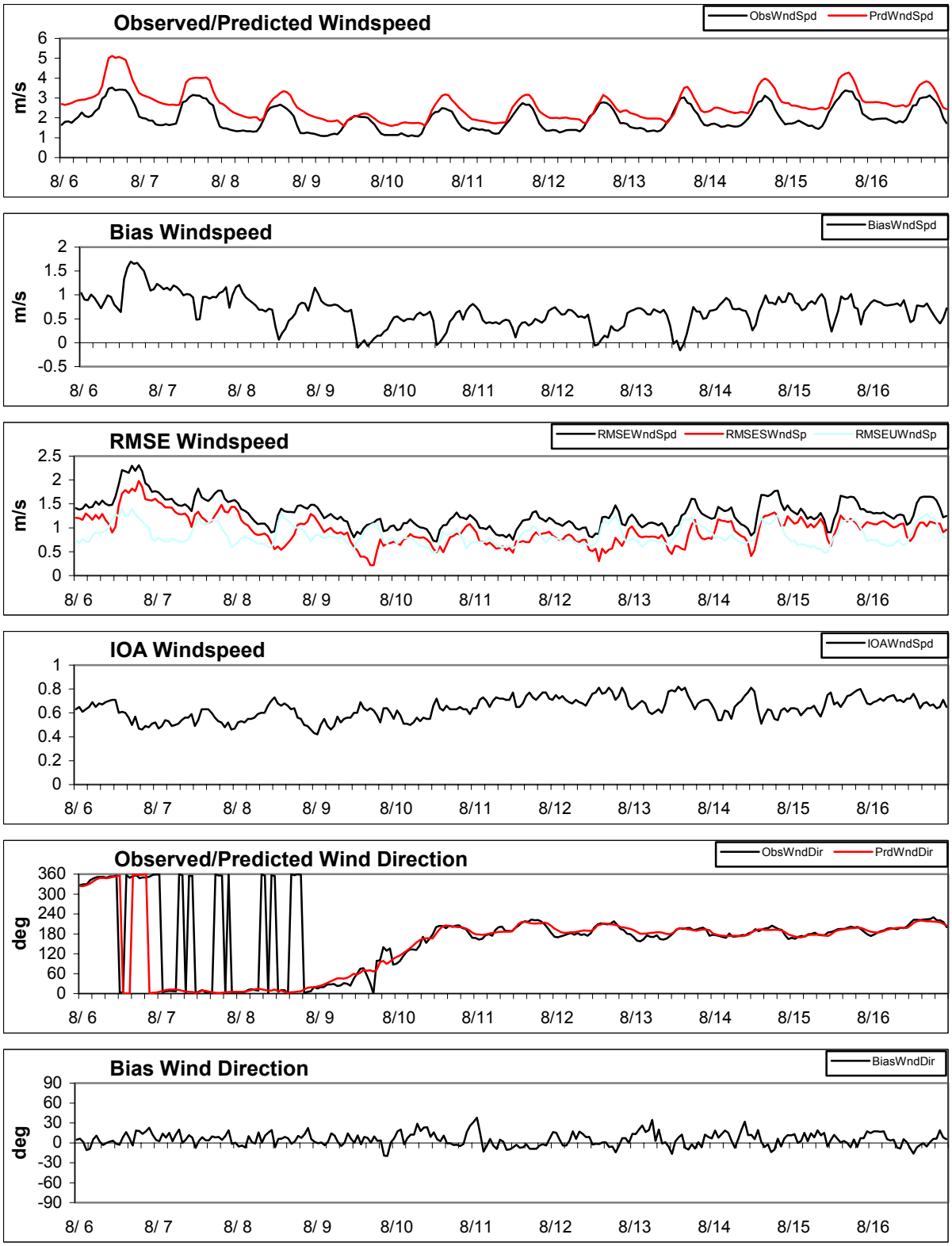

Figure 5c MM5 - UMD SSIB & CASTNet Aug 06 01Z to Aug 17 00Z 2002

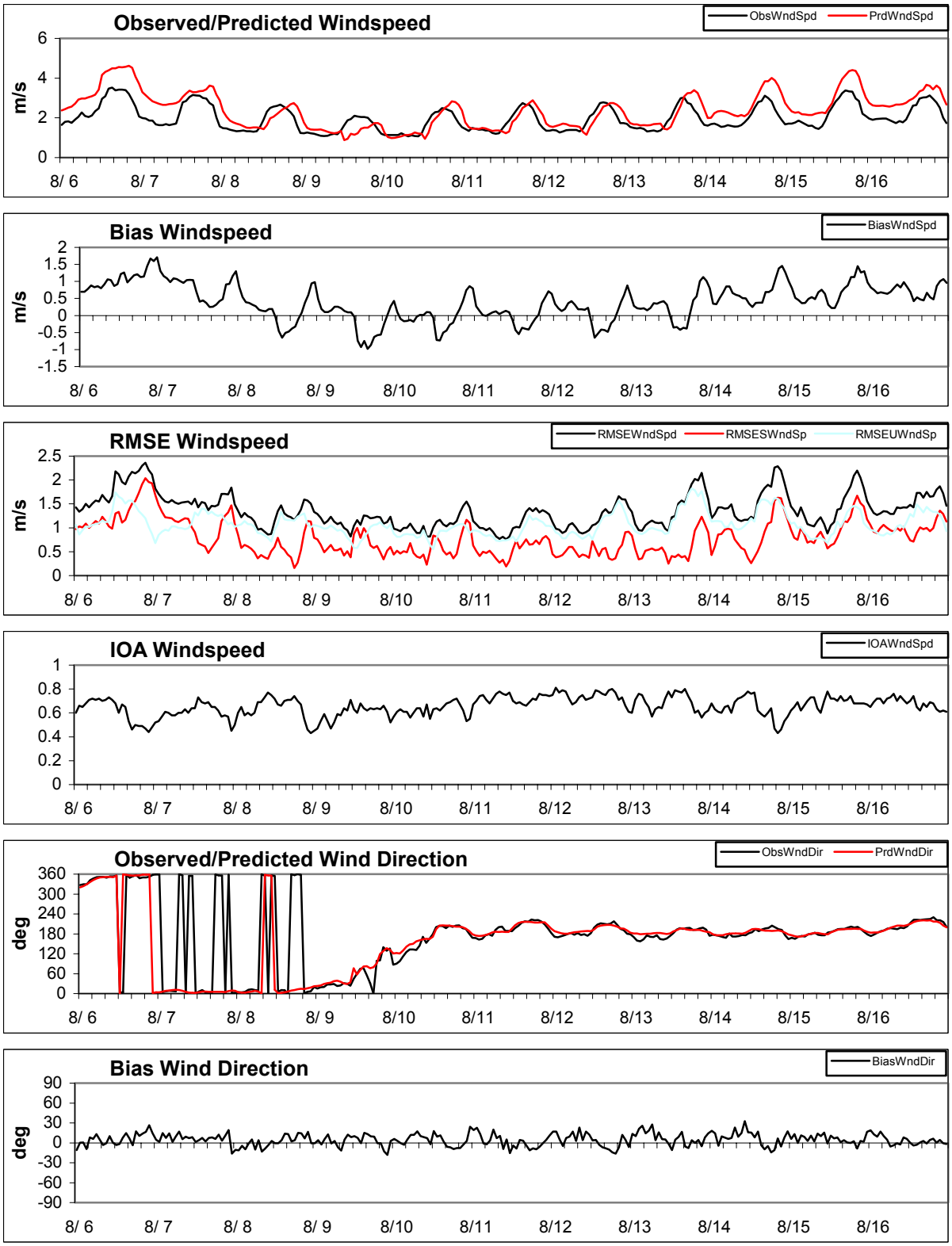

Figure 6a MM5 - UMD BL & CASTNet Aug 6 01Z to Aug 17 00Z 2002

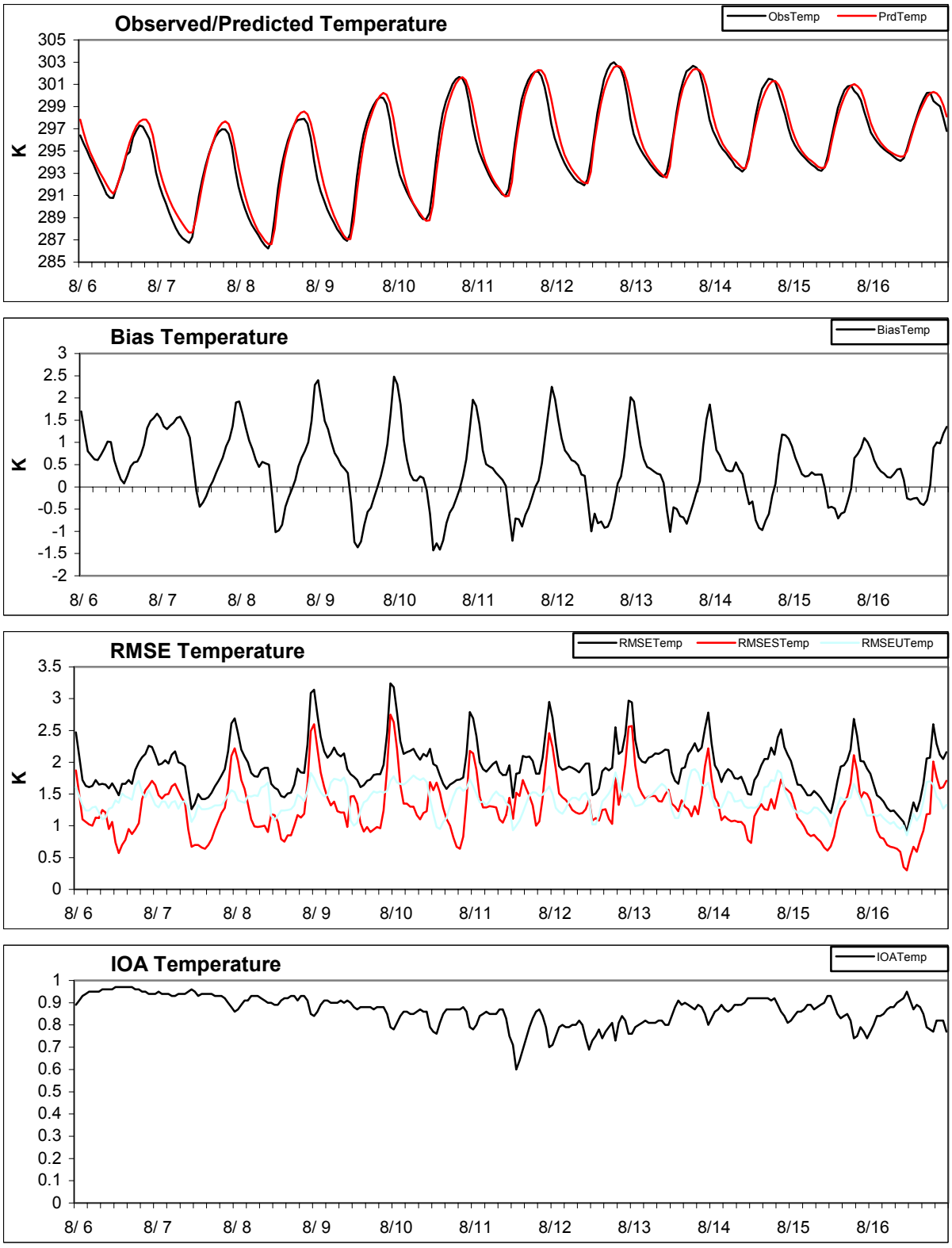

Figure 6b MM5 - UMD PX & CASTNet Aug 06 01Z to Aug 17 00Z 2002

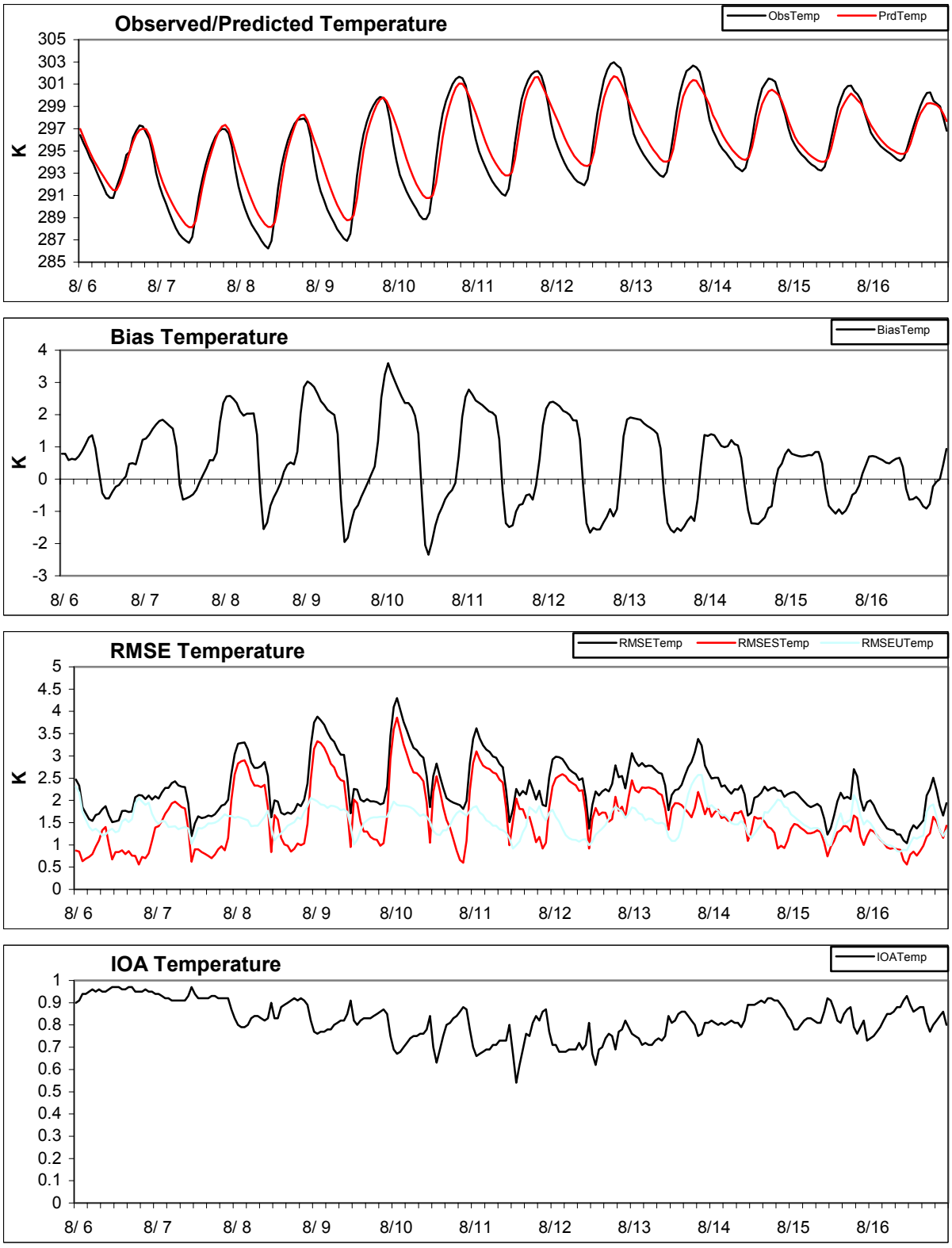

Figure 6c MM5 - UMD SSIB & CASTNet Aug 06 01Z to Aug 17 00Z 2002

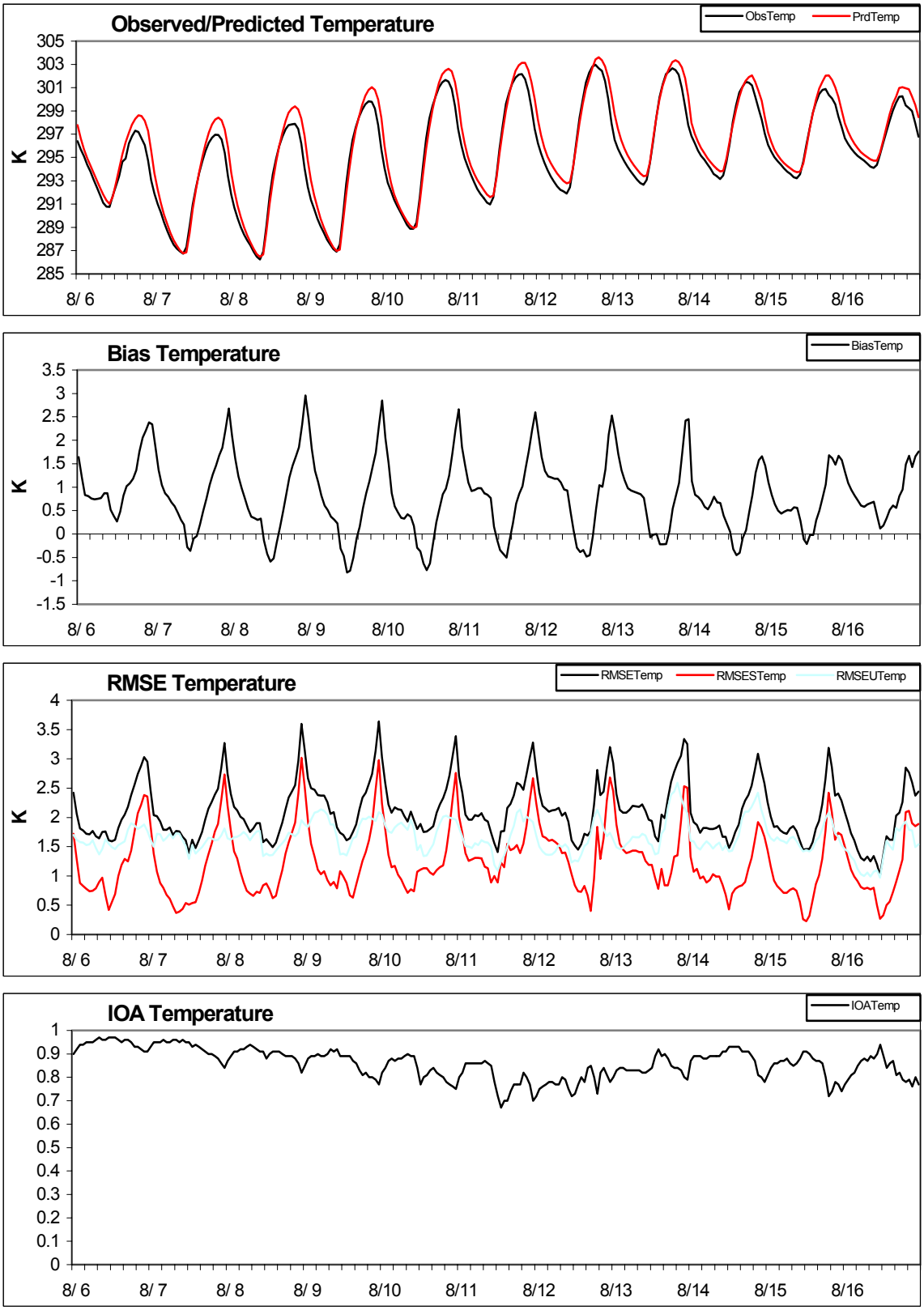

Figure 7a Spatial Correlation – Wind speed – BL & TDL

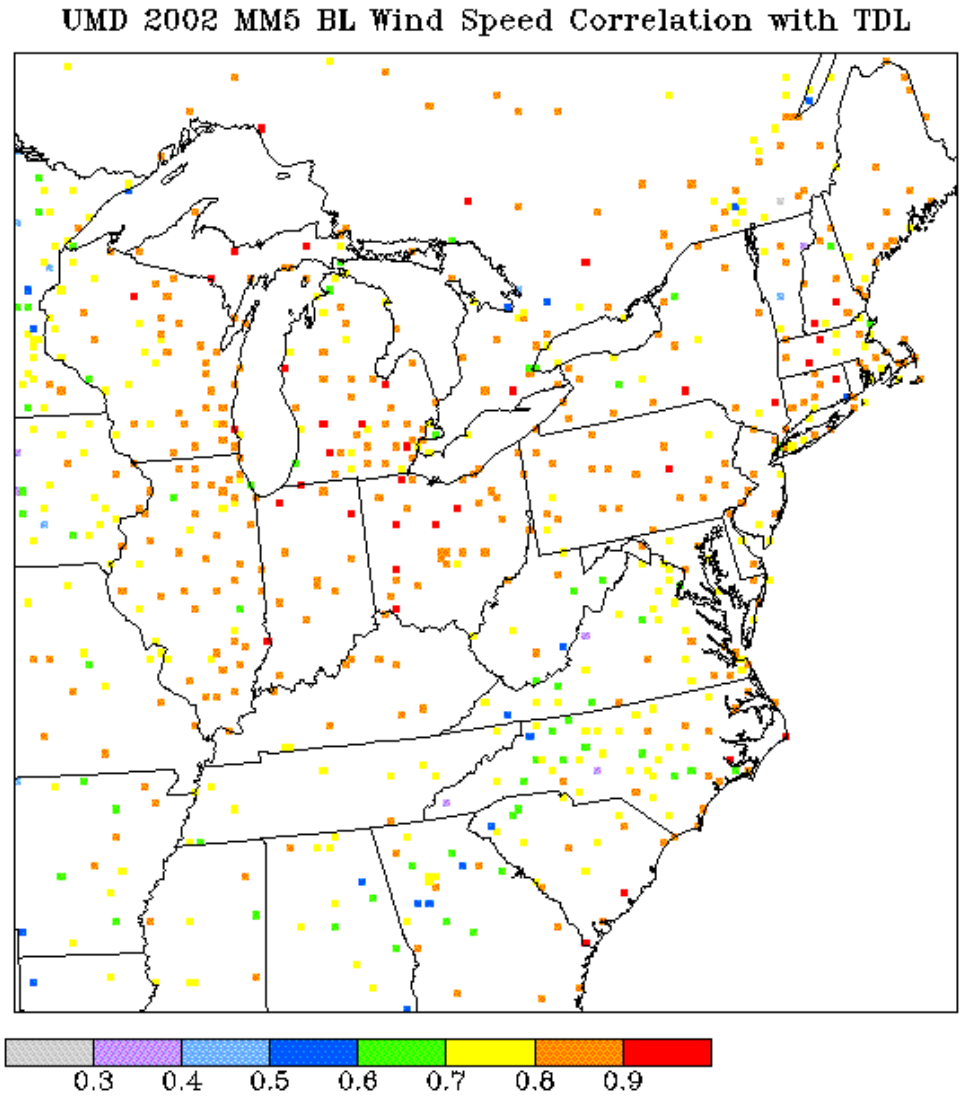

Figure 7b Spatial Correlation – Wind Speed – P-X & TDL

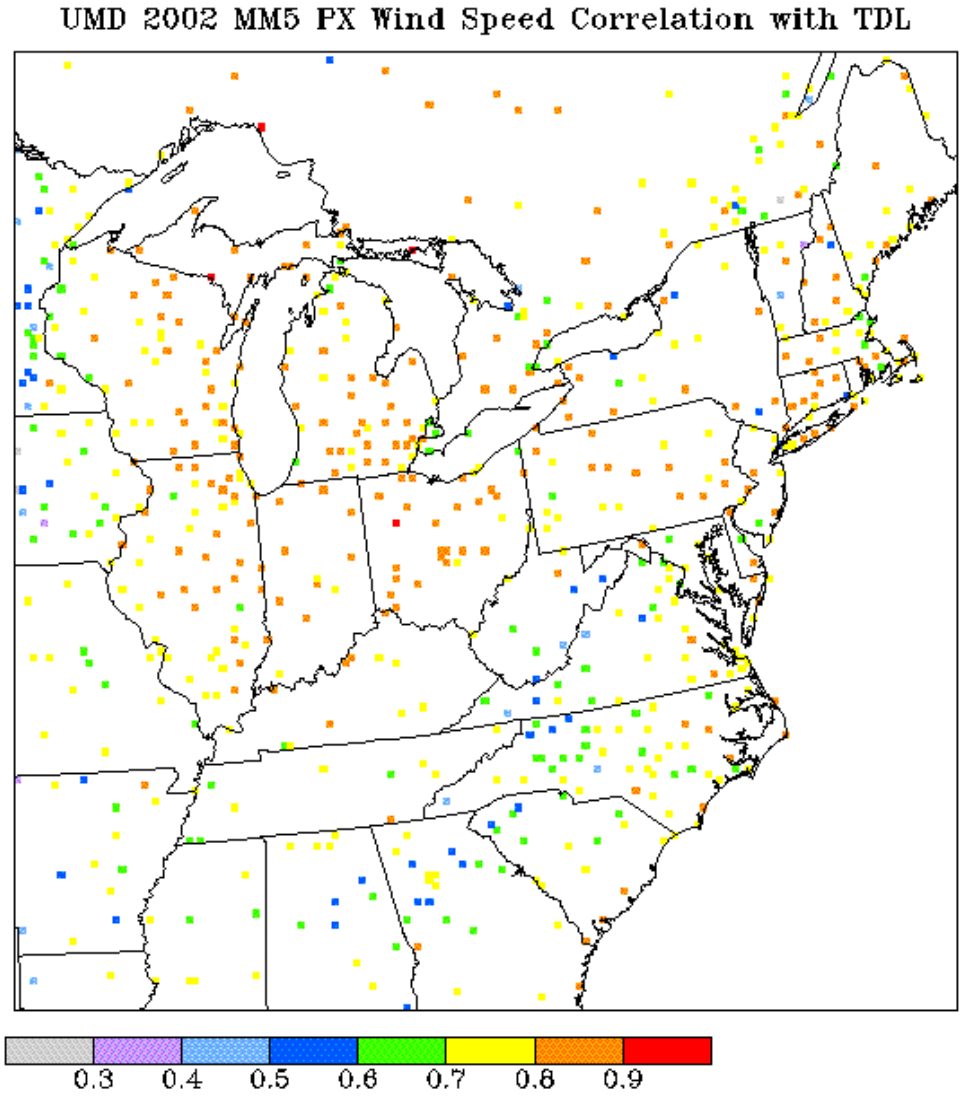

Figure 7c Spatial Correlation – Wind Speed SSIB & TDL

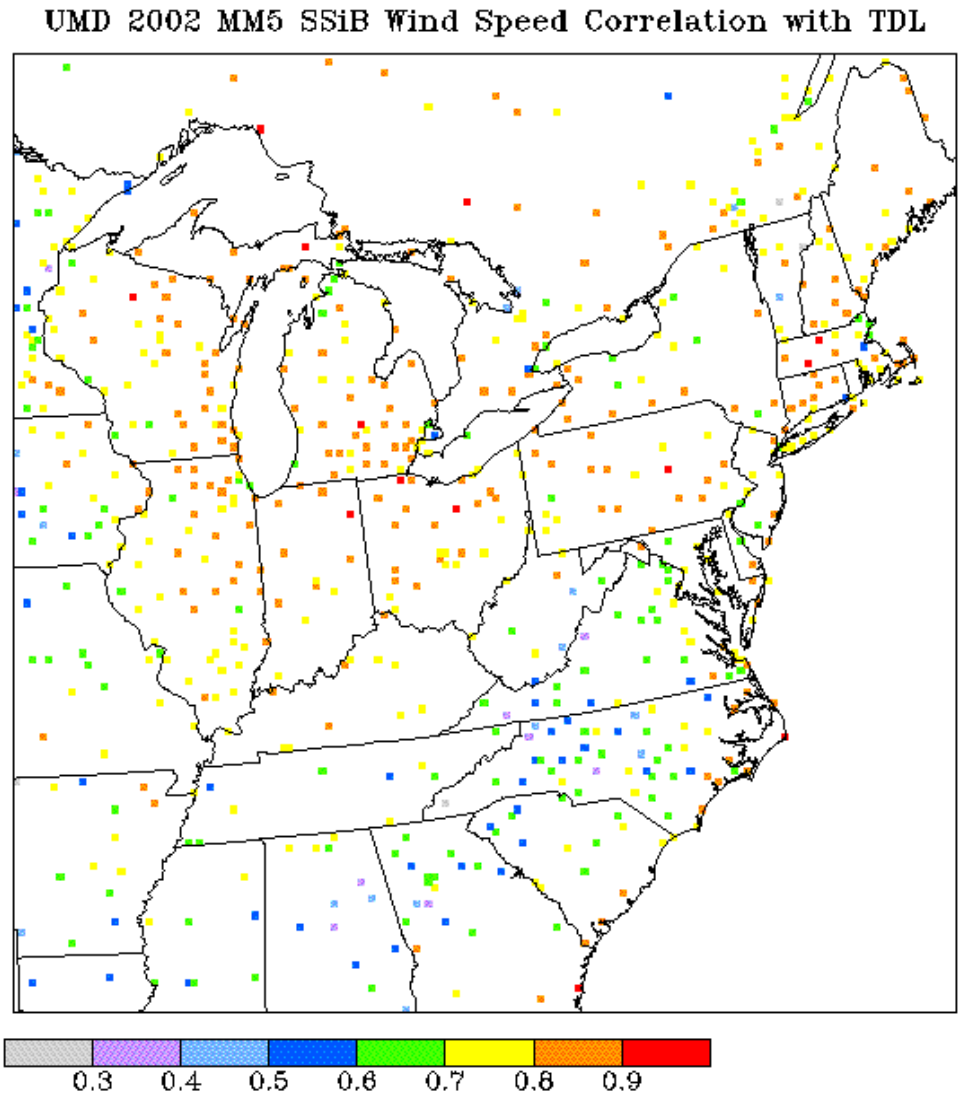

Figure 8a Spatial Correlation – Temperature – BL & TDL

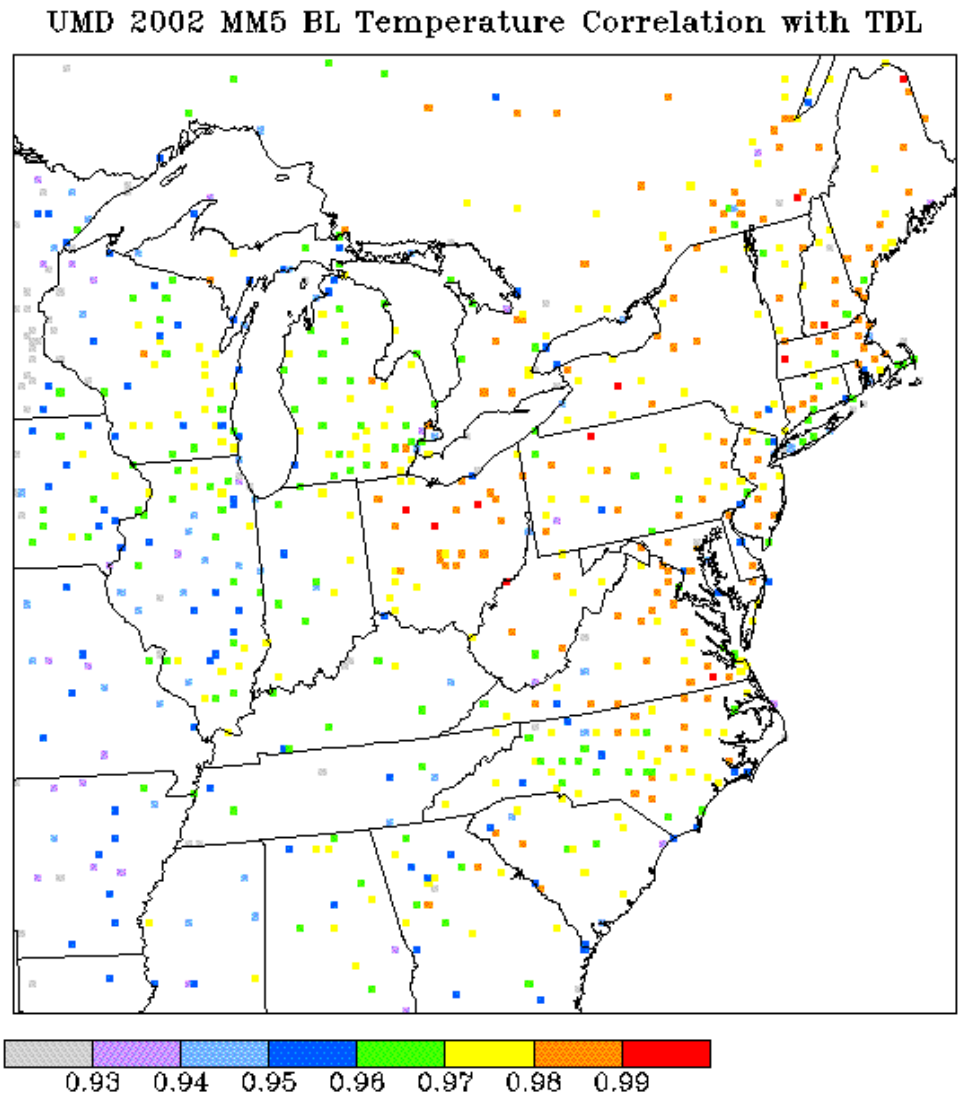

Figure 8b Spatial Correlation – Temperature – PX & TDL

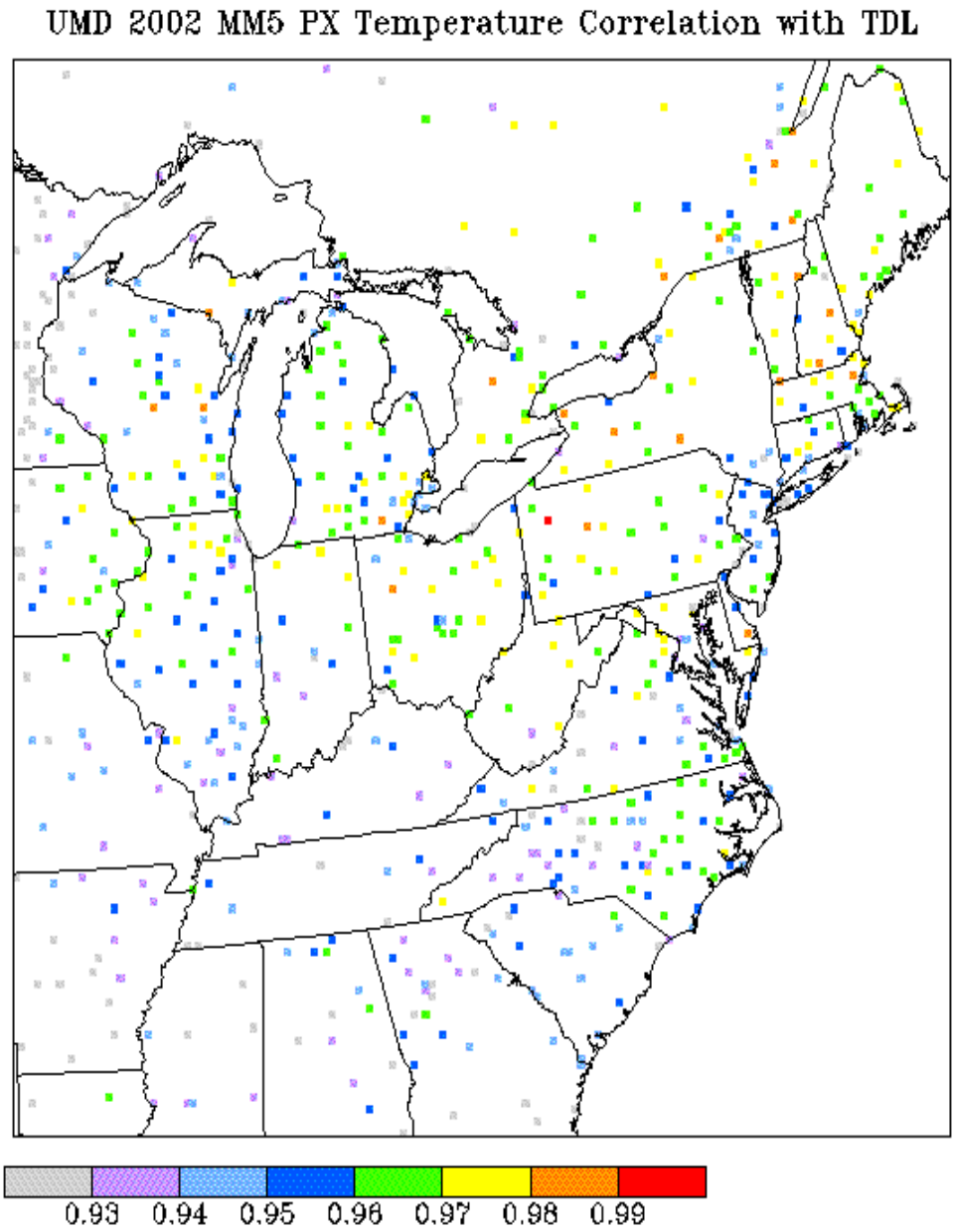

Figure 8c Spatial Correlation – Temperature SSIB & TDL

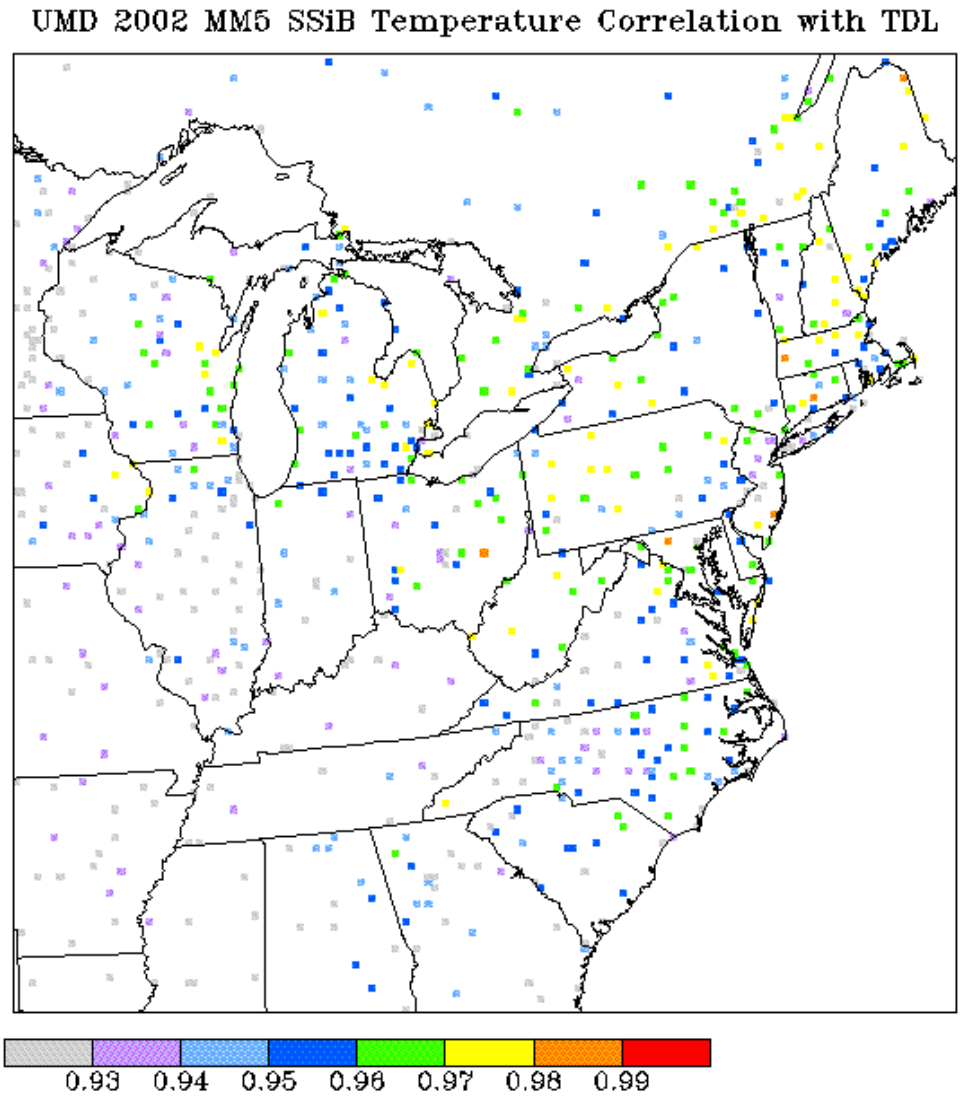

Figure 9a Spatial Correlation - Humidity BL & TDL

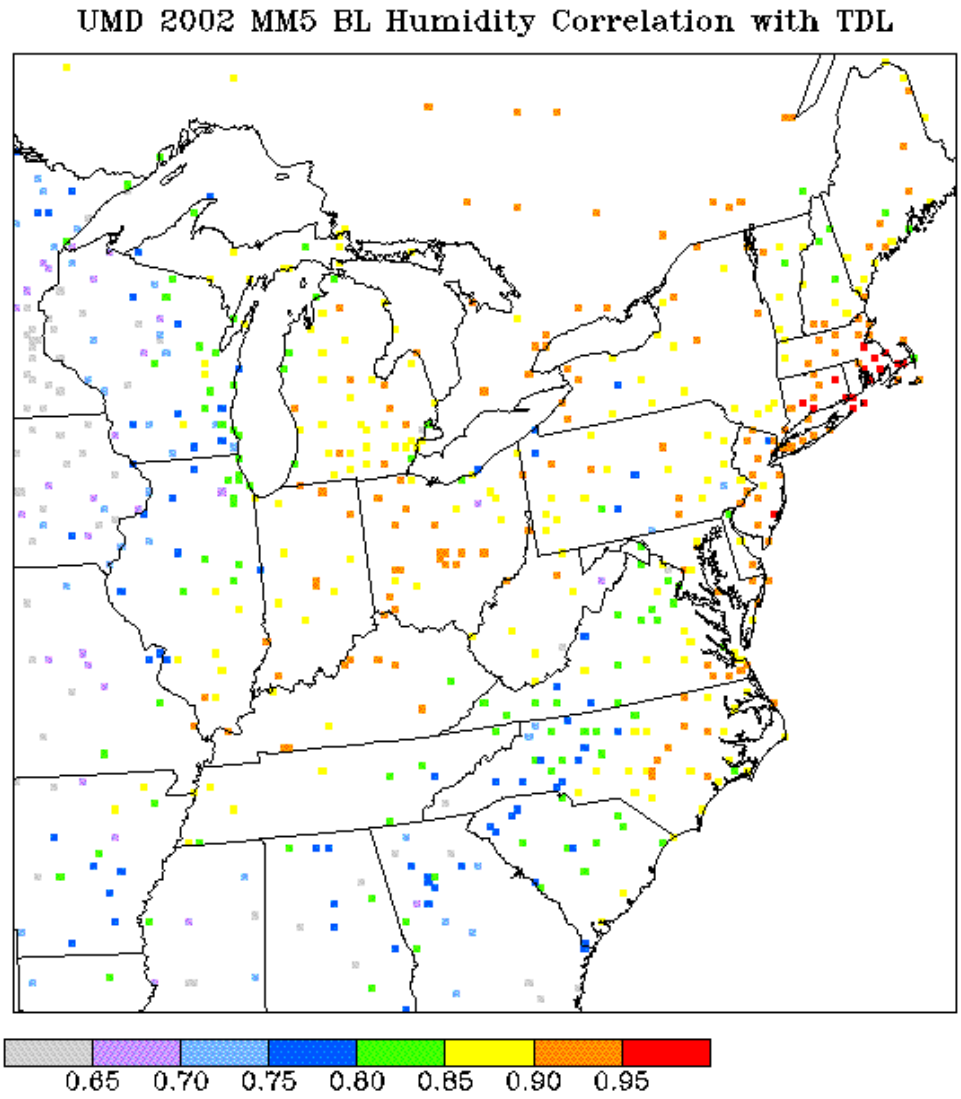

Figure 9b Spatial Correlation – Humidity PX & TDL

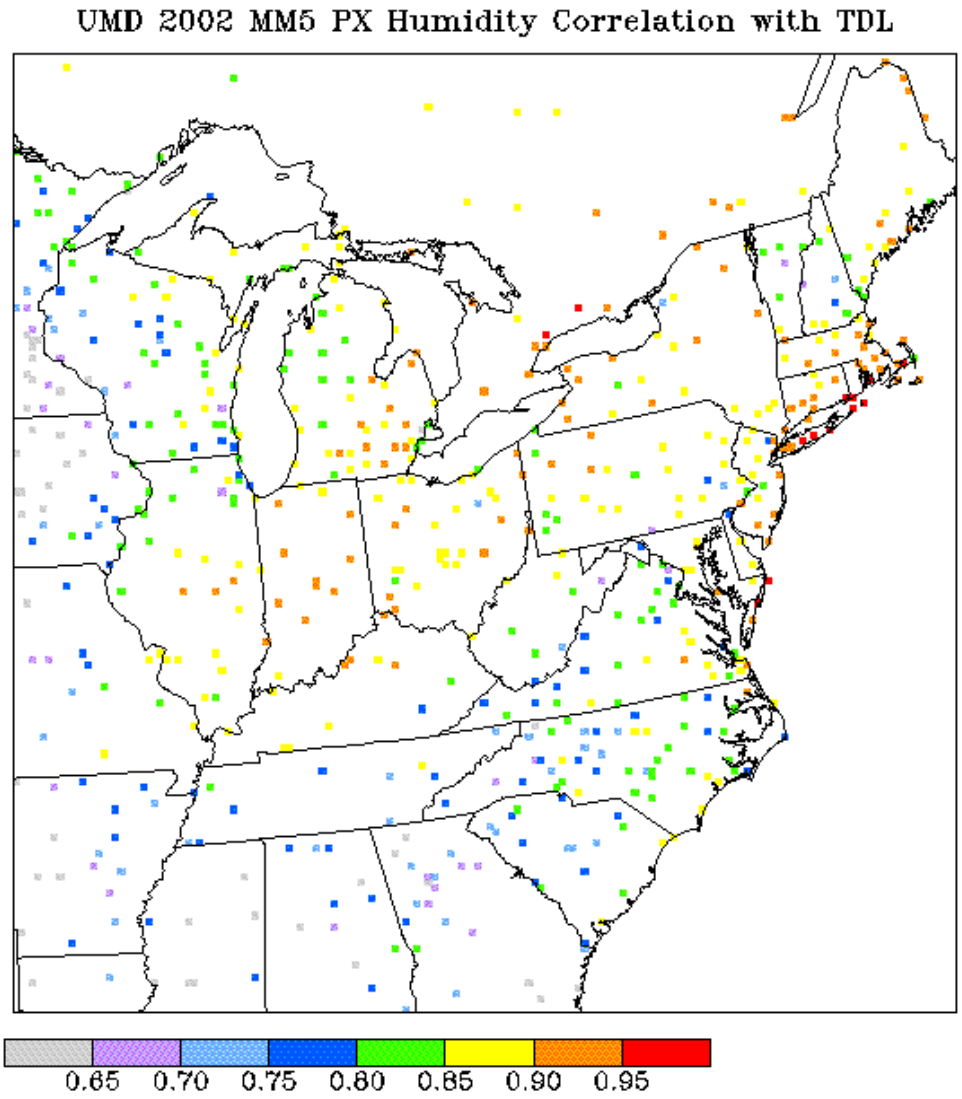

Figure 9c Spatial Correlation – Humidity SSIB & TDL