Performance of the National Air Quality Forecast Capability, Urban vs. Rural and Other Comparisons

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1. INTRODUCTION

In response to Congressional direction to the National Oceanic and Atmospheric Administration (NOAA) to build an operational air quality forecast capability, NOAA has been developing, testing, and implementing phased expansions of a National Air Quality Forecast Capability (NAQFC) since 2003. The capability is being built in partnership with the Environmental Protection Agency (EPA). The initial operational capability was implemented at the National Weather Service (NWS) in September 2004 (Otte et al. 2005), producing twice-daily forecasts of ground-level ozone across the northeastern United States. In the initial capability, the NWS/National Centers for Environmental Prediction (NCEP) North American Mesoscale (NAM) model was used to drive the Community Multi-scale Air Quality (CMAQ) model to produce next-day ozone predictions at 12-km grid resolution. The NAQFC has been expanded via a program of phased development and testing with implementations of ozone predictions over the entire eastern U.S. in 2005, and to the conterminous United States (CONUS) in 2007. Further goals for the NAQFC include providing quantitative predictions of fine Particulate Matter (PM2.5), which together with ozone is associated with almost all of the poor air quality episodes in the U.S. As a step toward building particulate matter prediction capabilities, NOAA has been testing a version of the CMAQ model that includes an aerosol prediction module. This module incorporates contributions to PM2.5 from the EPA's National Emissions Inventory.

MDL provided a performance evaluation of predicted surface ozone concentrations and fine aerosol concentrations against observations compiled by the EPA. The EPA provided urban/rural classifications and elevation information for 1,211 ozone observing sites and 716 aerosol sites over the CONUS. Our verification metrics included categorical analyses for Fraction Correct (FC), Threat Score (TS), Probability of Detection (POD), and False Alarm Ratio (FAR). For a more detailed discussion about two-by-two contingency table analyses, see Wilks (1995). We concentrated our analyses on the daily maxima of 8-h averaged ozone predictions or observations above the 76 ppb threshold and all daily maxima of 1-h average aerosol predictions or observations equal to or greater than a threshold of 35 ug/m^3 during a predefined 24-h period. For more information about the timing of our ozone performance metrics, see Gorline et al. (2006). In June 2008, the chemical mechanism for both ozone and aerosols was updated to CB05 (replacing CBIV) and the aerosol module was updated to AERO-4. Comparing predictions with CBIV and CB05 for the same year show that CB05 systematically increases over-prediction (not shown). For more information about CBIV and CB05, see Yarwood et al. (2005). For more information about the timing of our aerosol performance metrics and more details about the CMAQ aerosol module, see Gorline and Lee (2008).

MDL performed an urban vs. rural comparison of the NAM driven CMAQ experimental ozone predictions and developmental fine aerosol predictions, over the eastern United States. On some occasions developmental testing of the aerosol predictions was interrupted. Higher test priority for experimental ozone predictions resulted in fewer interruptions of daily predictions. Further information regarding differences in developmental and experimental test configurations is provided in McQueen et al. (2005). We compared performance at low vs. high elevation sites for both ozone and aerosols. We also compared performance for selected coastal sites in the northeastern U.S. compared to inland sites for ozone only. The sites for the eastern U.S. consisted of four of the six geographic regions in the CONUS. These six regions were used by MDL in previous years for regional comparisons. For this paper we included Lower Midwest (LM), Upper Midwest (UM), South East (SE), and North East (NE), and excluded the Pacific Coast (PC) and Rocky Mountains (RM). We compared categorical performance of next-day maximum 8-h average ozone predictions based on daily tests driven by the 1200 UTC NAM cycle. For developmental aerosol predictions, we compared categorical performance of next-day maximum 1-h

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average 0600 UTC cycle predictions. If an observation or model prediction for a station was missing, we excluded that station from our calculations.

2. PERFORMANCE OF 8-H OZONE AND 1-H AEROSOL PREDICTIONS, URBAN vs. RURAL

Figure 1 shows a map of ozone observing sites in the eastern U.S. The urban sites are red points and the rural sites are blue points. Also shown are the performance metrics of the daily maximum of 8-h ozone predictions for urban vs. rural sites, July 17-24, 2011. We chose this time period because the eastern U.S. was experiencing a heat wave that resulted in elevated levels of both surface ozone and aerosols. Comparing performance for ozone, the TS for rural sites was slightly higher (TS=0.191) than for urban sites (TS=0.141) but overall performance was similar. The TS is a good performance metric because it includes hits, false alarms, and misses. The POD is a good indicator of the detection rate but does not include false alarms. The POD for ozone was high in both urban (POD=0.966) and rural (POD=0.865) sites, slightly higher for urban sites.

Figure 2 is a similar map for aerosols and performance metrics for the daily maximum of 1-h aerosols, urban vs. rural sites, July 17-24, 2011. Comparing performance for aerosols, the TS for urban and rural sites was very similar and the overall statistics were similar as well. The POD for both urban and rural aerosol sites was much lower than for ozone. For developmental aerosol predictions, there are strong seasonal bias changes, from under-prediction in the warm season, April to September, to over-prediction in the cool season, October to March. While these biases are consistent with missing source contributions (e.g. wildfires) in the summer months, additional complexity of the aerosol test predictions are contributing to large prediction errors, and are the subject of ongoing investigation. The consistent summer under-prediction in aerosols resulted in lower POD compared to the 8-h ozone predictions.

3. PERFORMANCE OF 8-H OZONE, INLAND vs. COASTAL SITES IN THE NORTH EAST

MDL compared inland vs. coastal sites in the North East (NE) region for ozone only. Figure 3 is a map of ozone observing sites in the northeastern U.S. The inland sites are red points and coastal sites are blue points. Also shown are the performance metrics of the daily maximum of 8-h ozone predictions for inland vs. coastal sites, July 17-24, 2011. The TS for coastal sites was significantly higher (more than two times higher) than the TS for inland sites. But we think that this result is because the coastal sites reported more ozone activity than the inland sites. For the 1-week test period the coastal sites reported 93 observations above the 76 ppb threshold while the inland sites reported 22 observed above the threshold. Figure 4 is a plot of TS vs. number of observations greater than 76 ppb, of the daily maximum of 8-h ozone predictions/observations over CONUS, for summer 2010 (red) and summer 2011 (blue). Figure 4 shows that the experimental CMAQ ozone model tends to perform better on active days than on less active days.

4. PERFORMANCE OF 8-H OZONE AND 1-H AEROSOL PREDICTIONS, LOW VS. HIGH ELEVATION

Figure 5 is a plot of daily maximum predictions/observations of 8-h average ozone vs. elevation, for the eastern U.S., July 17-24, 2011. Figure 5 also shows the contingency results for the 1-week period. Figure 6 is a plot of daily maximum predictions/observations of 1-h average aerosol vs. elevation, for the eastern U.S., July 17-24, 2011, and contingency results for the 1-week period. For the plots of predictions (red) and observations (green) vs. elevation, we used sites that contained non-zero values for elevation, 0.6 – 2,000 meters. For the contingency results, we used all sites in the EPA database with an elevation of zero meters as low elevation sites and all sites with an elevation greater than 250 meters as high elevation sites. The contingency results in Figure 5 for ozone are similar, TS=0.150, for low elevation sites, TS=0.152, for high elevation sites. The contingency results in Figure 6 for aerosols showed consistent under-prediction with better performance at low elevation sites (TS=0.129), compared to high elevation sites (TS=0.080). Comparing Figure 5 and Figure 6, the most interesting difference is that the predictions (red) mostly fall above the observations (green) in Figure 5, while the predictions fall below the observations in Figure 6, at all elevations. The ozone predictions falling above the observations indicate over-prediction and the aerosol predictions falling below the observations indicate under-prediction.

4. CONCLUSIONS

Beginning in 2008, experimental ozone predictions and developmental aerosol predictions were based on the newer CB05 mechanism and the aerosol module was updated to AERO-4. In summary, the urban vs. rural comparisons for both ozone and aerosols did not show much difference in the Threat Score (TS). We ran four different time periods, namely, two weeks, one month, and two months, but the longer time-period runs did not affect the results we found with the 1-week runs.

Plotting predictions/observation as a function of elevation, the most interesting result was that ozone showed over-prediction while aerosols showed under-prediction, which is what we would expect. The experimental ozone model tends to over-predict in the summer and the developmental aerosol model under-predicts in the summer. The only comparison that showed a clear difference was coastal vs. inland for ozone in the North East (NE) region. The TS was more than two times higher for the coastal sites but this was because the coastal sites were much more active than the inland sites. The NAM driven experimental CMAQ ozone model tends to perform better on active days than on less active days.

These results are preliminary. We have a validated test bed in place and if funding permits, a more comprehensive test plan for urban vs. rural, high vs. low elevation, and other comparisons could be pursued. One idea for improvement in the urban vs. rural comparisons is to remove rural sites that are too close to urban areas. Urban contamination from some rural sites may have affected our results. We were expecting higher surface ozone at rural sites, especially downwind of urban areas, and this increase could (in theory) be detected in the performance metrics. Further work is needed to perform these comparisons for all six regions, especially for the Pacific Coast (PC) region. Coastal ozone photochemistry can be explored further by expanding the inland vs. coastal comparisons to include the entire U.S. East coast. For aerosols, it would be good to perform these comparisons for winter vs. summer. This is a good first test and the meta-data will be useful to the NAQFC implementation team.

5. ACKNOWLEDGMENTS

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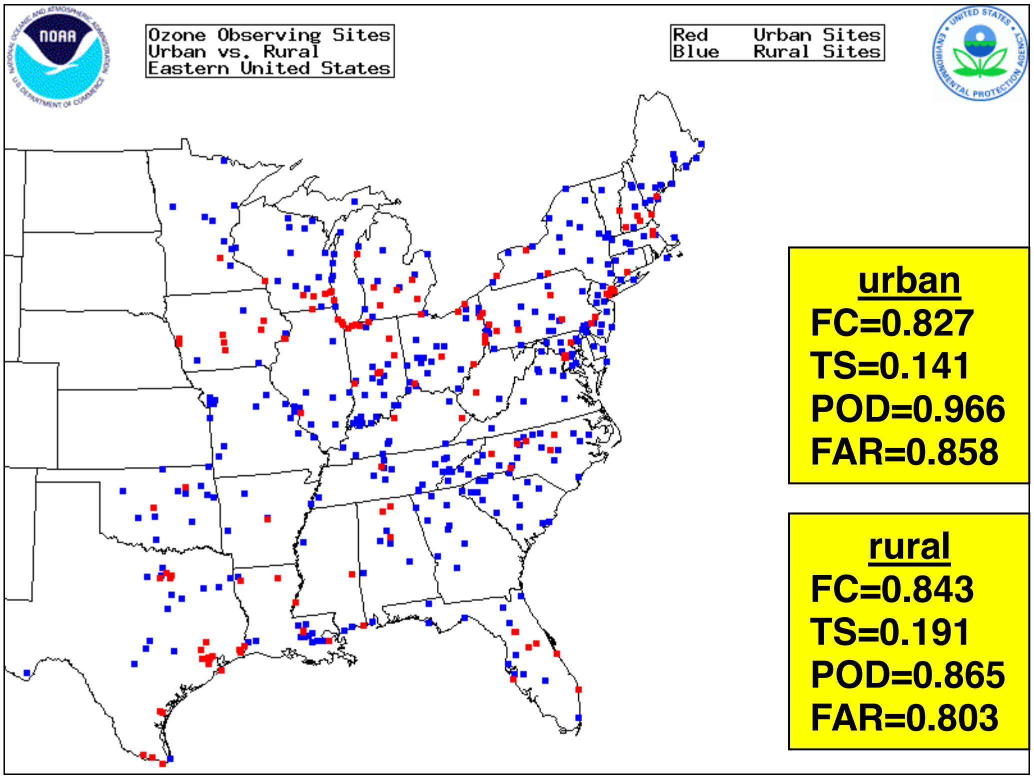

Fig. 1. Contingency results, daily maximum of 8-h ozone, urban (red) vs. rural (blue) sites, Eastern United States, July 17-24, 2011.

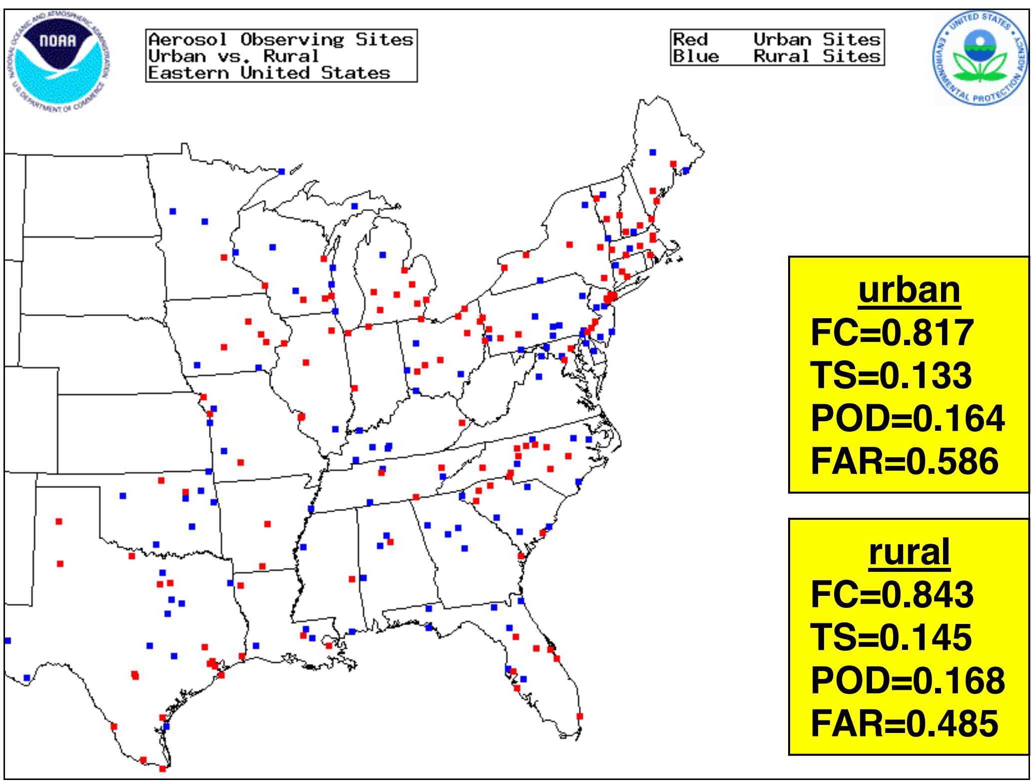

Fig. 2. Contingency results, daily maximum of 1-h aerosols, urban (red) vs. rural (blue) sites, eastern United States, July 17-24, 2011.

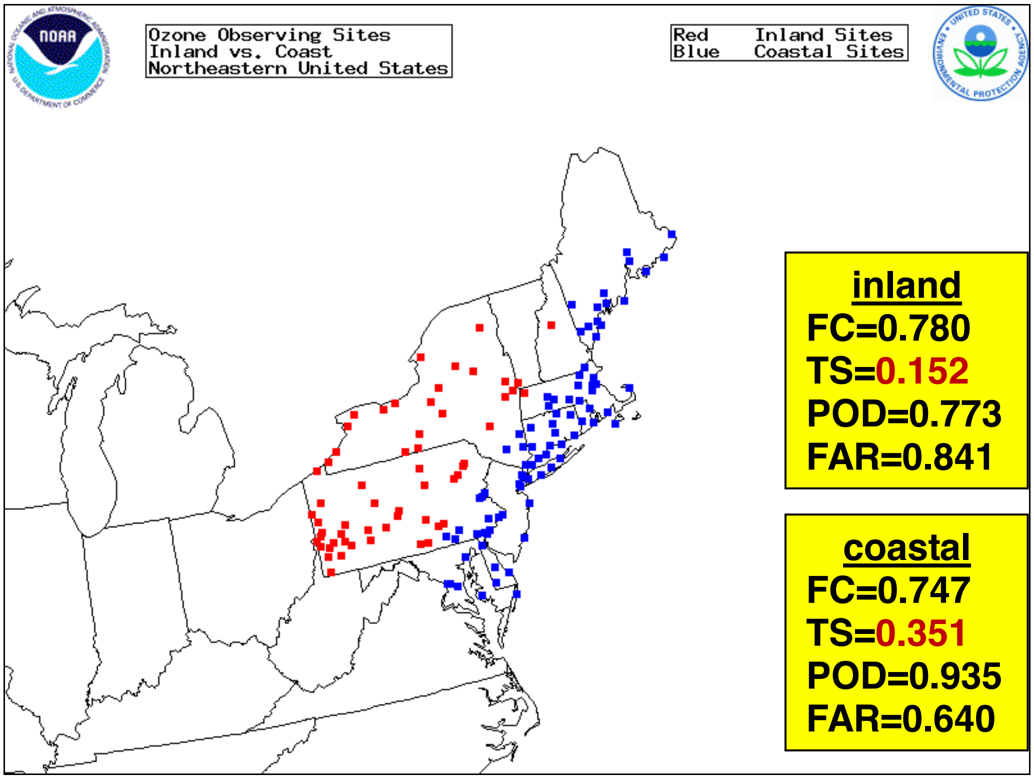

Fig. 3. Contingency results, daily maximum of 8-h ozone, inland (red) vs. coastal (blue) sites, northeastern United States, July 17-24, 2011.

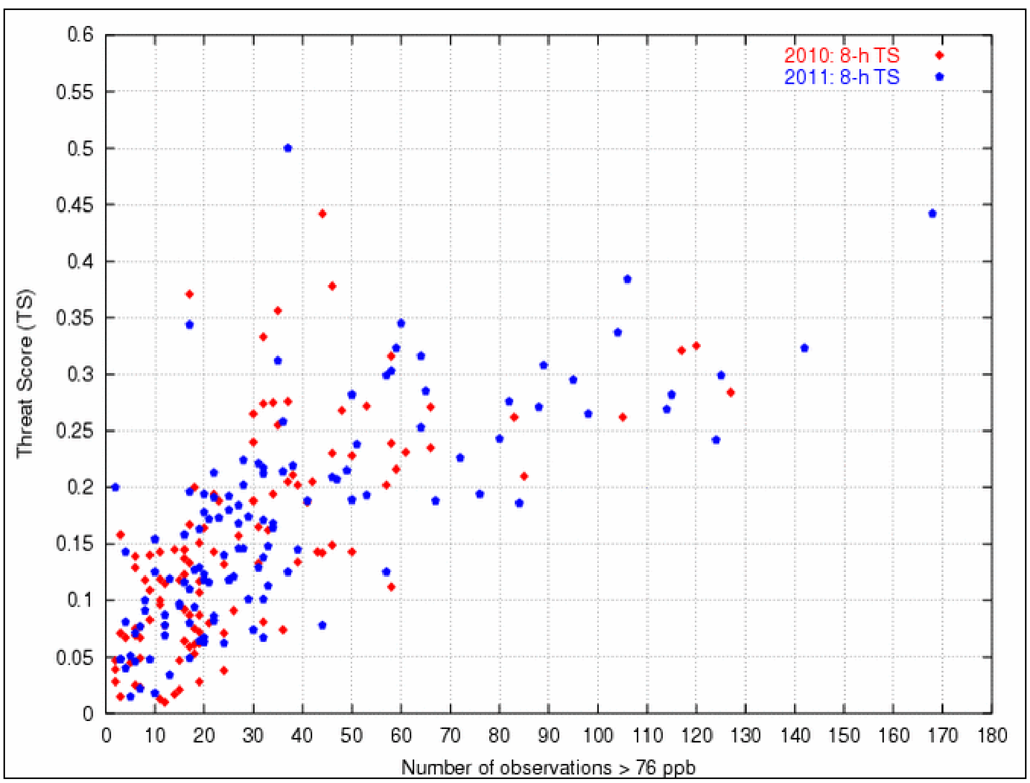

Fig. 4. Threat Score vs. number of observations > threshold, daily maximum 8-h ozone, CONUS, summer 2010 (red) and summer 2011 (blue).

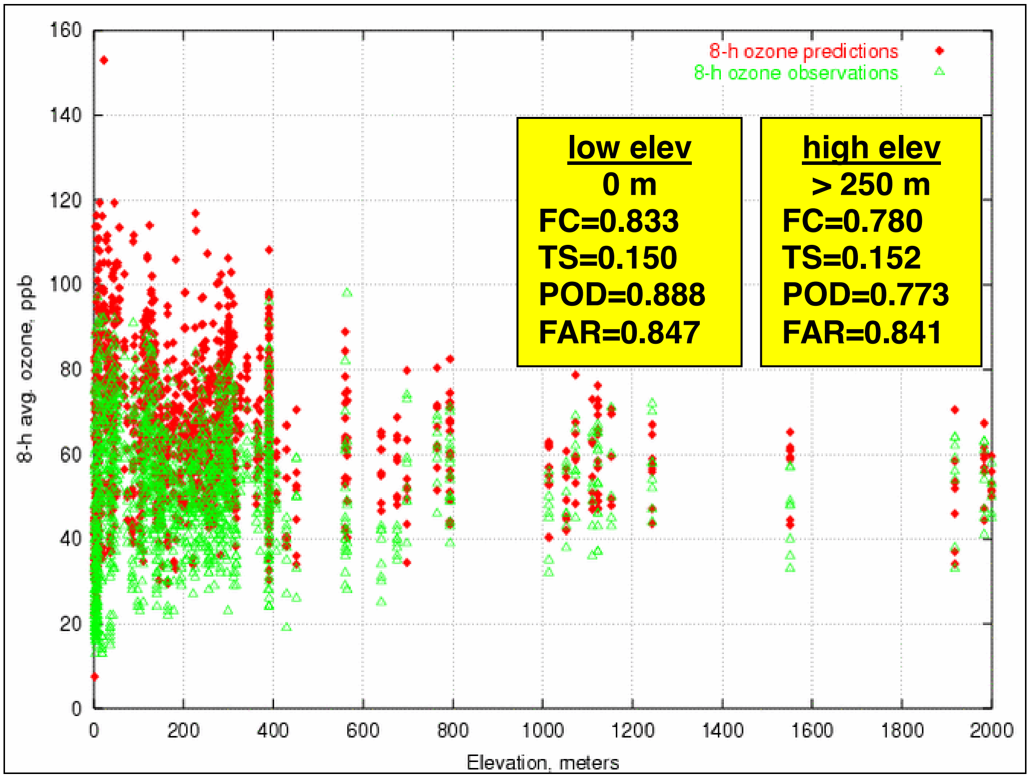

Fig. 5. Contingency results, daily maximum predictions/observations, 8-h average ozone vs. elevation, eastern United States, July 17-24, 2011.

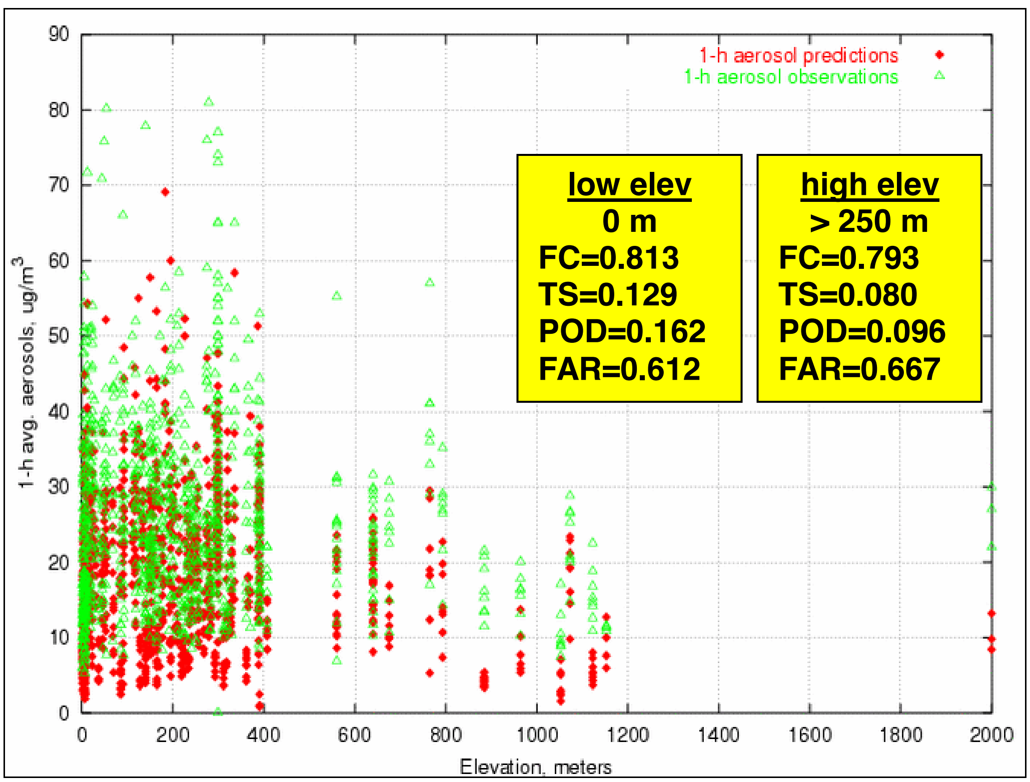

Fig. 6 Contingency results, daily maximum predictions/observations, 1-h average aerosols vs. elevation, eastern United States, July 17-24, 2011.