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VERIFICATION OF SURFACE LAYER OZONE FORECASTS IN THE NOAA/EPA AIR QUALITY FORECAST SYSTEM IN DIFFERENT REGIONS UNDER DIFFERENT SYNOPTIC SCENARIOS

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1. INTRODUCTION

An air quality forecast (AQF) system has been established at NOAA/NCEP since 2003 as a collaborative effort of NOAA and EPA. The system is based on NCEP's Eta mesoscale meteorological model and EPA's CMAQ air quality model (Davidson et al, 2004). The vision behind this system is to provide national guidance for ozone, particulate matter and other pollutants with acceptable accuracy. As a first stage of the project, ozone concentrations have been predicted on a real-time basis since summer 2003 for the Northeast US. Based on the initial series of experiments, an updated version of the AQF system is set to operational status by the autumn of 2004. This paper discusses a detailed verification of the ozone forecasts for selected periods during summer 2004. Verification presented in this paper is done for the Northeast operational domain (Fig. 3). To create a capability for evaluating ozone, surface layer ozone concentrations from EPA AIRNOW measurements and CMAQ forecasts were incorporated into NCEP's Forecast Verification System (FVS) (Brill, 2004, DiMego et al, 2004). The AIRNOW network reports 1hr average and 8hr average surface ozone concentrations. Also, maximum values of these concentrations during the day can be derived. All these parameters are a subject for statistical evaluation. In this paper, however, only 1 hr average concentrations are verified. In FVS, the CMAQ predicted concentrations are interpolated to the observation points. Average statistics (e.g. bias, root mean square error, correlation, etc) are computed for the North East Coast, South East Coast, Mid-West, Gulf of Mexico and several other areas. Statistics for critical thresholds of ozone concentration are also computed.

2. EVALUATION OF OZONE FORECASTS IN DIFFERENT REGIONS

2.1 *July 27-30 2004*

The July 27-30 episode was chosen as one of the few intensive ozone periods during the summer of 2004. Figure 1a shows a cold frontal passage and northerly flow on July 29, 12Z UTC. Air behind the front is cold and dry, and ozone production in the early morning is small. Later in the day, increased solar radiation flux over a high-pressure area allows the photolysis process in the atmosphere to be more intensive and to produce more ozone. By 24 hours (Fig. 1b), the front becomes occluded, and the ozone peak moves to the northeast and remains in the high-pressure area. The CMAQ forecast of ozone concentrations over the Northeastern US domain is shown in Figure 2. The forecast started at 12Z UTC July 29, 2004 and the maximum values of ozone concentration appear at 21Z UTC (a 9 hour prediction). The most intense ozone area (over 105 ppb) is located along the coastal zone between New York and Boston, behind the cold front shown in Fig.1a.

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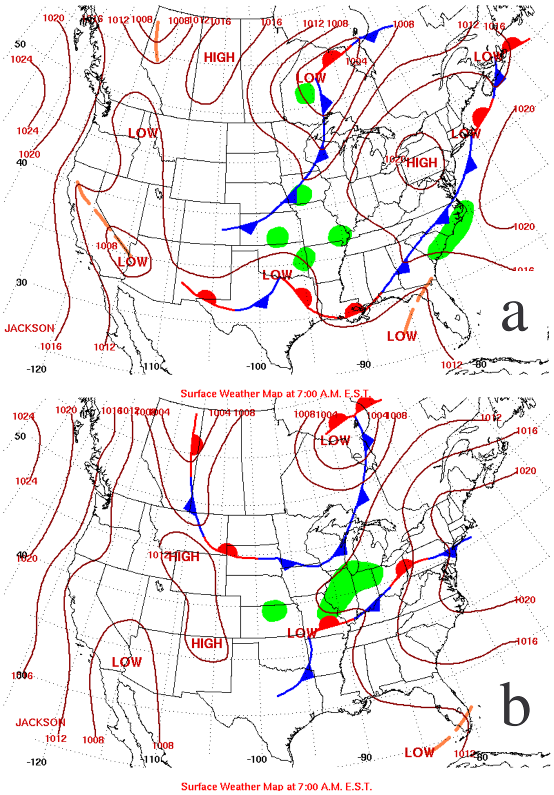


Fig.1: Weather maps for 12Z July 29, 2004 (a) and 12Z July 30, 2004 (b)

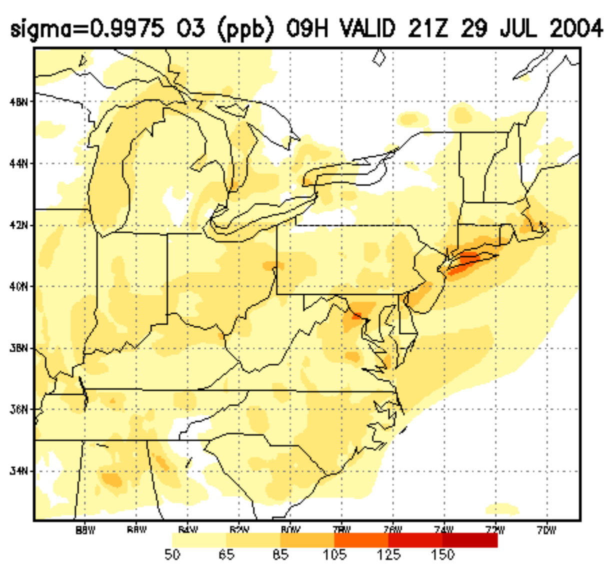


Fig.2: CMAQ 1hr average (backward) ozone concentration (ppb) for 12Z + 9hr forecast (Valid 21Z UTC July 29, 2004)

The ozone forecasts for the July 27-30 period were evaluated using the FVS system at NCEP. Figure 3 shows the regions in which verification at NCEP is being done. Figure 4 shows the bias error and correlation coefficient for the selected regions. Both bias and correlation coefficients are averaged by forecast hour, and only forecasts with starting times of 12 Z are verified. As we can see in Figure 4a, the bias has a relatively large range over the forecast domain, but for all sub-domains it is positive, indicating a model over-prediction. The largest bias is associated with the North-East (NEC), South-East (SEC) and Appalachian (APL) areas, but for this period mean ozone concentrations were also highest for these regions. The highest daytime correlations (Fig. 4b) are shown over the NEC region, despite the large daytime bias. For the first 12 hours of the forecast, the NEC, SEC and APL regions have almost the same bias, but mean concentrations were decreasing from north to south for the July 27-30 period, which is reflected in the highest daytime correlations of about 0.7 for NEC, 0.4 for APL, and 0.3 for SEC. On the other hand, the Midwest (MDW) area demonstrates the worst (about 0.1) daytime correlations despite having low biases. During the daytime, the model seems to predict better in areas with higher ozone concentrations, despite the relatively large biases.

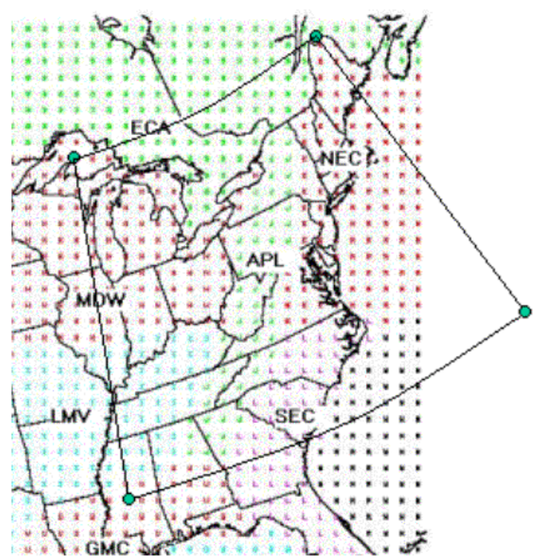


Fig.3: Sub-regions for Forecast Verification System at NCEP and NE operational domain position.

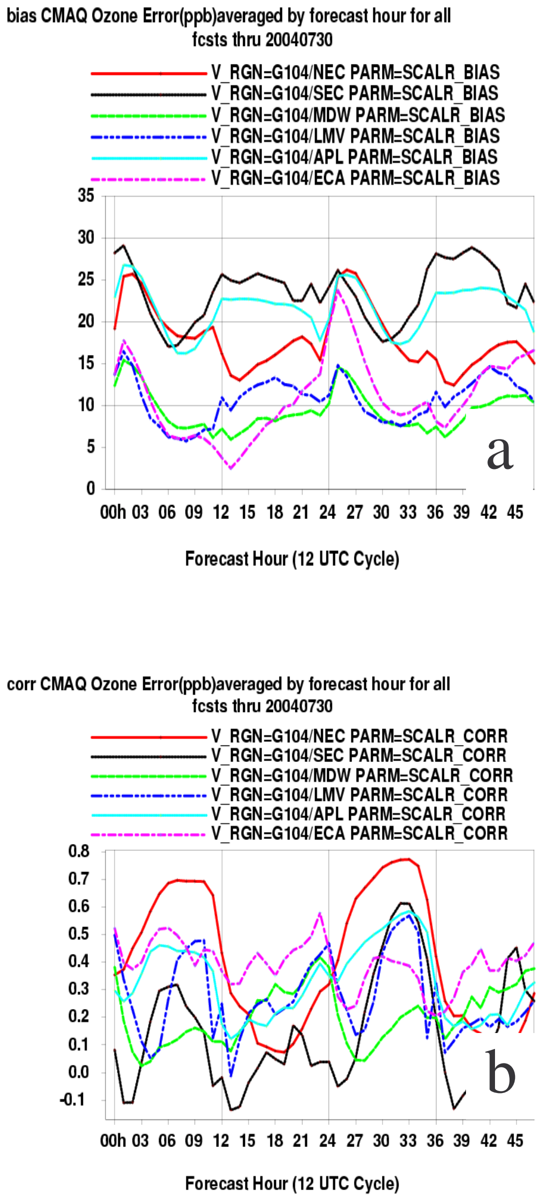


Fig.4: CMAQ ozone bias (a) and correlation (b) averaged by forecast hour for July 27-30, 2004

The AQF model was also evaluated for different forecast hours and for different regions by computing statistics for critical ozone concentration thresholds. Figures 5 and 6 show the probability of detection for threshold values of 50, 65, 85, 105, 125 and 150 ppb. Probability of detection is defined as *H/O*, where *O* is the number of observed points above a threshold, and *H* is the number of correctly forecasted points ('hits'). The July 27-30 period was one of relatively few intense episodes during the summer of 2004; there were just a few observations above 85 ppb, and almost nothing above 105 ppb. It is clearly seen from the forecast hour statistics (Fig. 5) that the model predicts differently for daytime and nighttime. For values above 50 ppb, the probability of detection is about 0.8-0.9 in the daytime, whereas, at night it is only about 0.3-0.4. Figure 6 shows only one forecast hour, the 6h forecast, but for different regions. The best areas during this period were NEC and APL, both above 0.9 for the 65 ppb threshold. The probability of detection above 65 ppb drops significantly for the other regions.

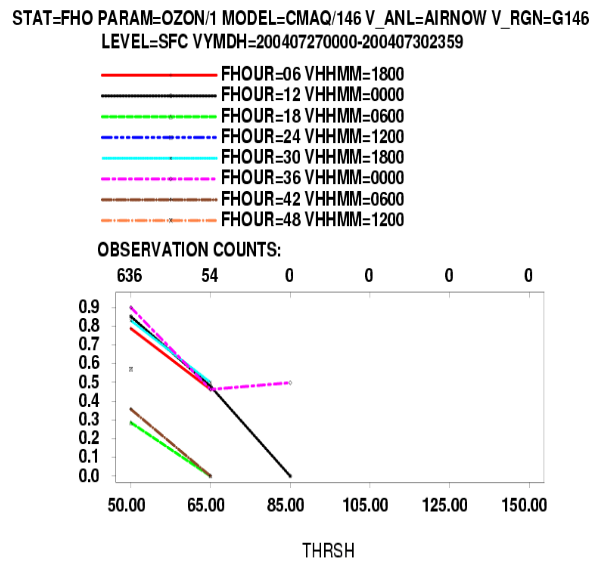


Fig.5: CMAQ ozone probability of detection for different forecast hours, July 27-30, 2004. Observations counts are shown for the first trace.

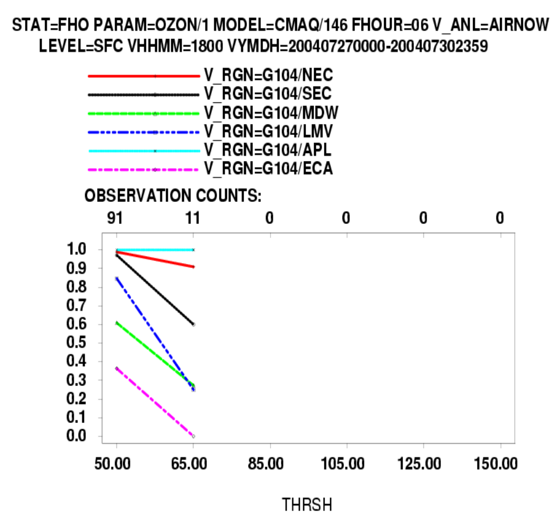
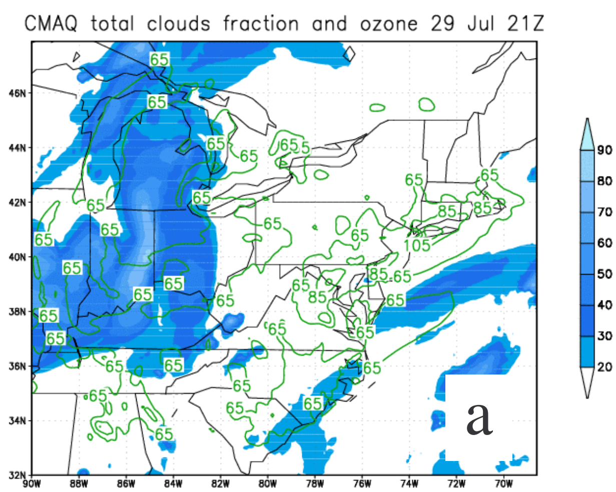


Fig.6: CMAQ ozone probability of detection for different sub-regions, July 27-30, 2004. Observations counts are shown for the first trace.

For further understanding of possible sources for the AQF errors, coupling issues between meteorological and chemical models could be investigated. As an example of existing differences, cloud coverage for both models is demonstrated. Figure 7 illustrates the total cloud fraction used in the meteorological and chemical models. CMAQ computes cloud cover from Eta relative humidity profiles and not directly from Eta cloud microphysics predictions. Cloud cover is primarily used in CMAQ to estimate incoming short-wave radiation, driving chemical photolysis (Byun and Ching, 1999). Less cloud cover is diagnosed by CMAQ (Fig.7a) than is predicted by Eta (Fig. 7b). Relative to Eta, CMAQ predicts more short-wave radiation and photolytic activity, suggesting that use of Eta's predicted cloud cover directly in CMAQ might reduce the ozone overprediction bias. Cloud coverage and related radiation fields are among the hardest meteorological parameters to predict, and both Eta and CMAQ clouds are subjects for further evaluation against observations.



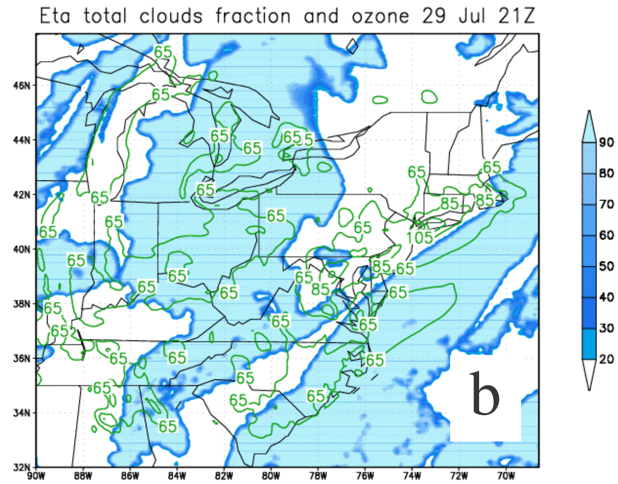
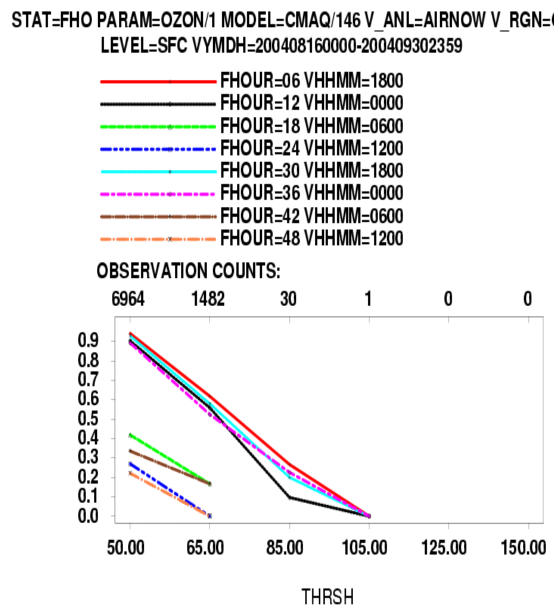


Fig.7: Total cloud fraction (%) 12Z + 9hr forecast (Valid 21Z UTC July 29, 2004) for CMAQ (a), Eta (b).

2.2 ***August-September 2004***

As a further verification of model forecasts, the threshold statistics were computed for the extended period of August 16 – September 30. Figure 8a shows that, similar to the July 27-30 period, the probability of detection is much higher for the daytime forecast, about 0.9 for the values above 50 ppb and about 0.6 for the 65 ppb threshold. At night, even for the 50 ppb threshold, the probability of detection is not more than 0.4. In the regional statistics (Fig. 8b), on the other hand, the August-September period demonstrates more consistency between sub-regions than the short July 27-30 episode. All sub-regions have a probability of detection of about 0.9 for the 50 ppb threshold and 0.5-0.7 for the 65 ppb threshold. One possible explanation for this fact is that the model prediction accuracy is related more to the synoptic conditions than to the model constant fields like land use or vegetation.



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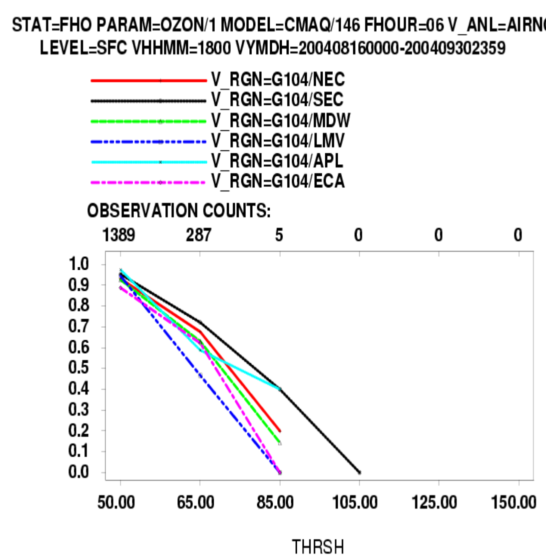

b

Fig.8: CMAQ ozone probability of detection for different forecast hours (a) and for different sub-regions (b), August 16 – September 30, 2004. Observations counts are shown for the first trace.

3. SUMMARY

Verification of the CMAQ model forecasts for one of the high ozone episodes during the summer of 2004 has been done. Different types of statistics have been computed using the NCEP's Forecast Verification System. Despite the over-prediction of ozone concentrations over the whole domain, the forecasts demonstrate different accuracies in different regions and for different forecast hours. The most accurate forecasts appear to be over the Northeast coast for the daytime, in high-pressure areas under a clear sky. In the extended period, the differences between regions are relatively small but larger differences are seen between the day and night predictions. Future work will explore a tighter coupling of the radiation and cloud models within the meteorology and chemistry models.

4. ACKNOWLEDGEMENTS AND DISCLAIMER

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