Evaluating CMAQ model's ability to capture satellite derived aerosol optical depth

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Introduction

This study compares aerosol optical depth (AOD) from the MODIS instrument with calculated AOD from the EPA Community Multiscale Air Quality Model. AOD is defined as the integration of the extinction coefficients with respect to height, from the bottom to the top of the atmosphere. In this way, it measures the amount of light scattered and absorbed by aerosols in the atmosphere.

AOD depends on the quantity of particles in the atmosphere, their vertical distribution, their size, and their chemical make-up. AOD may be calculated at a range of wavelengths, representing wavelength-dependent scattering and absorption. We will assess the sensitivity of these calculations in CMAQ to support improved model evaluation, and interpretation of AOD results to air quality. In particular, this project is part of the Regional Haze Tiger Team effort.

For this study, observed AOD is taken from the MODIS instrument on Terra. Data shown was calculated via the Dark Target algorithm [Martins et al., 2003]. All AOD was calculated at 550 nm. FlexAOD and CMAQ v5.2 are currently being currently being utilized to calculate AOD at user specified wavelengths.

Methods

A semi-empirical mass extinction method [Malm et al., 1994] was used to determine the extinction coefficients from model output. The coefficients were summed with each layer height, from bottom to top of the atmosphere.

$$AOD = \sum_{i=1}^{n} \sigma_{ext} \Delta Z$$

Data shown was from model output: July 2011, CMAQ version 5.0.1, CB05 chemical mechanism and the AERO6 aerosol mechanism.

How well does CMAQ capture AOD?

CMAQ Derived AOD *July 2011*

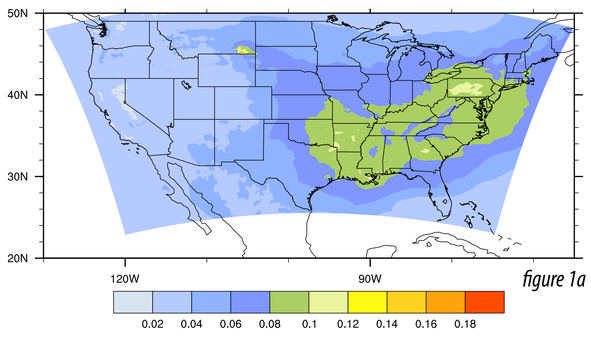

figure 1a

Satellite Observed AOD *July 2011*

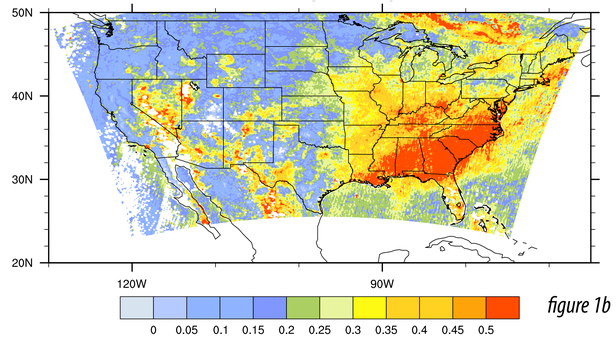

figure 1b

Pearson Correlation Coefficient *July 2011*

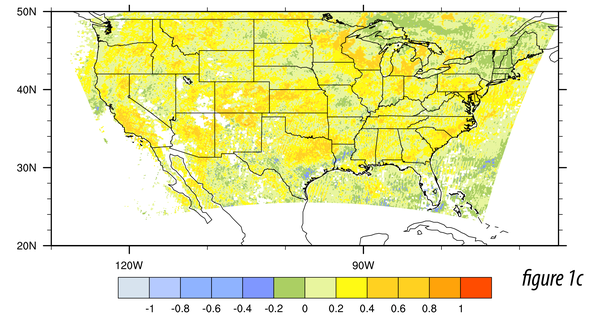

figure 1c

Model Bias *July 2011*

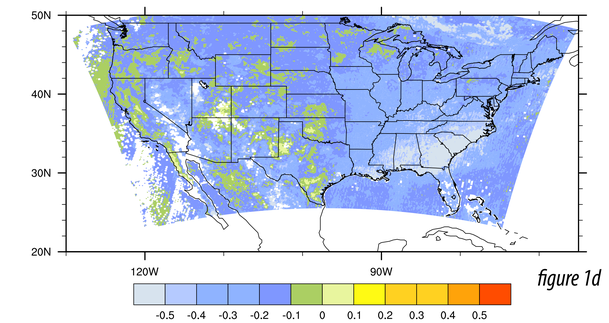

figure 1d

Figure 1: Maps showing AOD comparison between model and satellites for July 2011. a) CMAQ derived AOD via mass extinction method. b)Satellite observed AOD, MODIS instrument on Terra, Dark Target retrieval, c) Linear correlation coefficient between model and observed AOD, d) CMAQ AOD bias with respect to observed AOD.

Model underestimates AOD at 550 nm. The underestimation could be due to several factors:

- Method does not include certain aerosol species especially wind blown dust
- Errors in the calculation of AOD from CMAQ output
- Errors in satellite retrieval

CMAQ captures the spatial distribution of aerosols. This evident in figures 1c and 1d as well as the weak linear correlation.

Mean Correlation	Mean Bias	Mean Fractional Bias
0.32	-0.22	-1.05

The negative mean bias indicates the model under-predicts the observed AOD. This is affirmed in the mean fractional bias. The observed and predicted AOD show a positive weak correlation.

Next Steps

Model performance will be compared for June and August, 2011, at two additional wavelengths (440 nm and 660 nm) to assess variability in model performance. A CMAQ v5.2 run has been initialized for July 2011 to aide in AOD calculations. Version 5.2 of CMAQ adds several variables giving information on optical properties of aerosols. In addition, model aerosols will be compared with IMPROVE and AERONET data to assess whether the underestimation observed with the satellite data is consistent across other measurements. The Deep Blue retrieval algorithm will also be assesed.

Acknowledgments

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References

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Malm, W. C., Sisler, J. F., Huffman, D., Eldred, R. A. & Cahill, T. A. Spatial and Seasonal Trends in Particle Concentration and Optical Extinction in the United-States. J. Geophys. Res. 99, 1347–1370 (1994).

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