

Evaluation of a Regional Air Pollution Model with Satellite Measurements

Krish Vijayaraghavan^{1a}, Yang Zhang², Hilary E. Snell^{1b}, and Jian-Ping Huang²

¹Atmospheric & Environmental Research, Inc., ^aSan Ramon, CA and ^bLexington, MA

² North Carolina State University, Raleigh, NC

1. Model Description

- The Community Multiscale Air Quality Model (CMAQ) is a 3-D Eulerian chemistry transport model developed by the U.S. EPA.
- CMAQ is applied to simulate tropospheric O₃, CO, NO, NO₂, VOC and other gases, as well as particulate matter.
- Modeling period and domain
 - ▶ 2001
 - ▶ North America
 - ▶ Horizontal grid resolution of 36 km
 - ▶ 14 vertical levels up to the tropopause

2. Objective

A preliminary evaluation of CMAQ results using ground-based measurements has been conducted earlier (Zhang et al., 2006). Here, we present an evaluation of CMAQ predictions against satellite data.

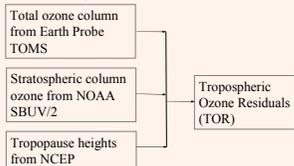
3. Parameters evaluated

Tropospheric column of
O₃
NO₂
CO
HCHO
Aerosol optical depth

4. Satellite Data Overview

a. Ozone

- ▶ Tropospheric ozone residuals estimated by Dr. Fishman, NASA (Fishman et al., 2003).
- ▶ 1 x 1.25 degree resolution



b. NO₂

- ▶ Tropospheric NO₂ columns estimated by Dr. Richter (Univ. Bremen) using data from the GOME instrument on the ERS-2 satellite
- ▶ 0.5 x 0.5 degree resolution
- ▶ Uncertainty of about a factor of two (Richter and Burrows, 2002)

c. CO

- ▶ Tropospheric CO columns from the MOPITT instrument (Edwards et al., 2004) on EOS Terra
- ▶ 1 x 1 degree resolution
- ▶ Bias mean, standard deviation based on aircraft profiles (Emmons et al., 2004)
 - 4.9 ± 10.8% (before May 2001)
 - 0.5 ± 12.1% (from Aug 2001)

d. HCHO

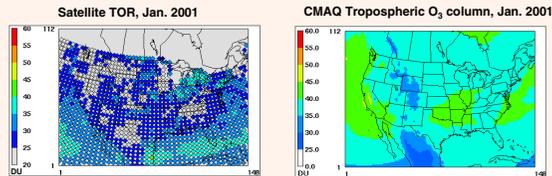
- ▶ Tropospheric HCHO columns estimated by the Tropospheric Emission Monitoring Internet Service (TEMIS, European Space Agency) using data from the GOME instrument on the ERS-2 satellite
- ▶ 320 km x 40 km resolution

e. Aerosol Optical Depth (AOD)

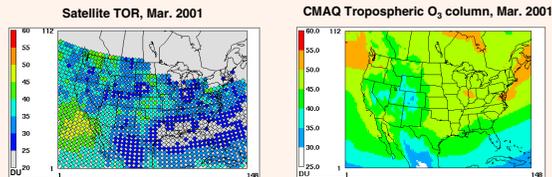
- ▶ AOD from MODIS on Terra
- ▶ 1 x 1 degree resolution
- ▶ Uncertainty (Remer et al., 2005)
 - $\Delta\tau = \pm 0.05 \pm 0.15\tau$ over land
 - $\Delta\tau = \pm 0.03 \pm 0.05\tau$ over water

5. Ozone Column

Monthly averages of CMAQ tropospheric ozone columns (in Dobson units) are compared with the TOR derived from TOMS/SBUV data.



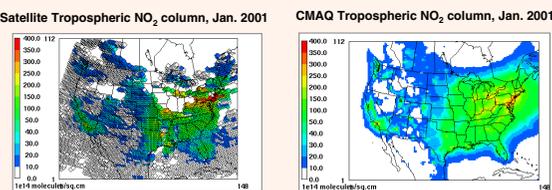
Mean TOR = 30.1, Mean CMAQ = 38.3, NMB = 27%, NME = 28%, Corr. Coeff. = -0.02



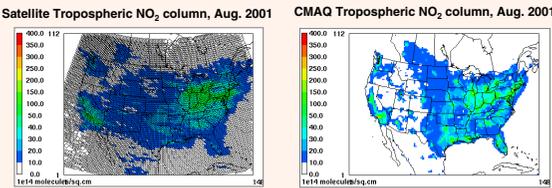
Mean TOR = 33.3, Mean CMAQ = 42.5, NMB = 28%, NME = 29%, Corr. Coeff. = 0.08

6. NO₂ Column

Monthly averages of CMAQ tropospheric NO₂ columns are compared with the tropospheric columns estimated from ERS/GOME data.



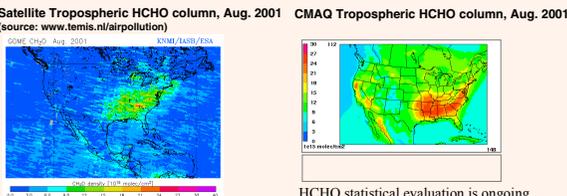
Mean Obs. = 27.8, Mean CMAQ = 33.9, NMB = 22%, NME = 58%, Corr. Coeff. = 0.79



Mean Obs. = 12.4, Mean CMAQ = 11.5, NMB = -7%, NME = 43%, Corr. Coeff. = 0.73

9. HCHO Column

Monthly averages of CMAQ tropospheric HCHO columns are compared with the tropospheric columns estimated from ERS/GOME data.



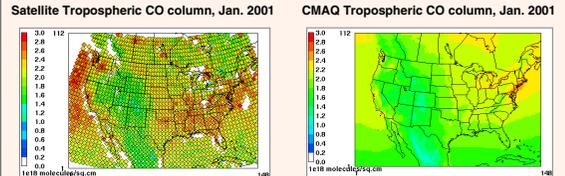
HCHO statistical evaluation is ongoing.

References

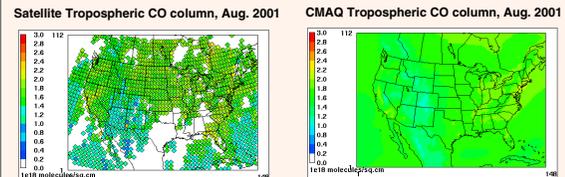
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7. CO Column

Monthly averages of CMAQ tropospheric CO columns are compared with EOS/MOPITT data.



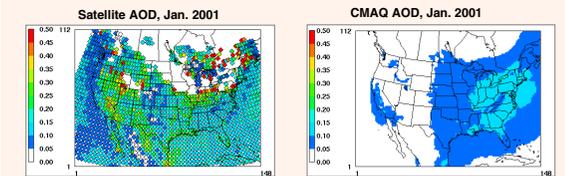
Mean Obs. = 2.1, Mean CMAQ = 1.8, NMB = -16%, NME = 17%, Corr. Coeff. = 0.62



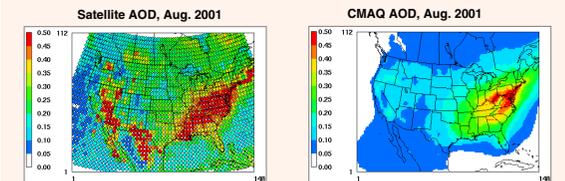
Mean Obs. = 1.7, Mean CMAQ = 1.6, NMB = -6%, NME = 19%, Corr. Coeff. = -0.05

8. Aerosol Optical Depth (AOD)

AOD calculated from CMAQ particulate matter following Chameides et al. 2002. $AOD = f(SO_4, NO_3, OC, BC, RH)$. Monthly CMAQ averages of AOD (up to the tropopause) are compared with the MODIS AOD data. We assume that the stratospheric component of the MODIS AOD column is negligible.



Mean Obs. = 0.17, Mean CMAQ = 0.06, NMB = -65%, NME = 67%, Corr. Coeff. = 0.06



Mean Obs. = 0.25, Mean CMAQ = 0.12, NMB = -53%, NME = 59%, Corr. Coeff. = 0.42

10. Conclusions

- CMAQ simulates the observed increase in tropospheric O₃ column from winter to spring. However, there are significant differences between CMAQ predictions and satellite-TOR in some regions; for example, the model overpredicts in the Northeast.
- CMAQ reproduces well the spatial and seasonal variations in the NO₂ column. The magnitude of differences between model and satellite estimates lies within the uncertainty in satellite estimates.
- Model performance is also good for CO in summer.
- The model exhibits a strong negative bias for AOD. Possible reasons include underprediction of biomass fires in summer in the western U.S., lack of treatment of sea-salt and long-range transport of dust, and uncertainties in emissions of OC and BC.
- Differences between simulated values and satellite data may arise due to uncertainties in model inputs and/or satellite estimates.

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- Dr. Andreas Richter, University of Bremen, Germany, for providing GOME NO₂ data
- NASA DAAC – for providing MODIS aerosol optical depths
- NCAR, NASA – for providing MOPITT CO data
- TEMIS: <http://www.temis.nl/airpollution/no2.html> - GOME HCHO

Further information
Please contact
krish@aer.com

