Use of Remote Sensing Air Quality Information in Regional Scale Air Pollution Modeling: Current Use and Requirements

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Motivation

• Applications of regional AQ models are continuously being extended to address pollution phenomenon from local to hemispheric spatial scales over episodic to annual time scales.

• The need to represent interactions between physical and chemical processes at these disparate spatial and temporal scales requires use of observational data beyond traditional surface networks.
Use of Remote Sensing Information in Regional AQMs

• Evaluation/Verification of model results
  ▪ High spatial resolution over large geographic regions of remote sensing data is attractive

• Improve estimates of model parameters
  ▪ Location and effects of clouds (e.g., photolysis)
  ▪ Key meteorological parameters (e.g., PBL)
  ▪ Lateral Boundary conditions (LRT effects)
  ▪ Emissions (e.g., wildland fires, accountability)

• Chemical data assimilation
  ▪ Improving short-term air quality forecasts
  ▪ Identification of model deficiencies
Improving Key Meteorological Parameter Estimates
Impact of assimilation of Solar Radiation from GOES (7/31/1988; 1900z)

Surface Radiation (W/m²)
Large areas with reduced cloud effects

Ground Temperature (°K)
Up to 6 °K increase in surface temperature in affected areas

PBL Height (m)
Up to 1000m higher PBL in affected areas
Improving Model Parameter Estimates
Photolysis attenuation by clouds

- $J = J_{\text{clear}} \cdot f(\text{transmissivity, fraction})$

Model (MM5)

Satellite Derived (GOES)

Cloud Fraction

Transmissivity
Photolysis attenuation by clouds: CMAQ (contd.)

Base

Satellite Based

JNO₂ (s⁻¹)

Base

Satellite Based

Observed

21Z on 8/24/2000

Courtesy: A. Biazar, Univ. of Alabama
Photolysis attenuation by clouds: CMAQ (contd.)

Base Satellite Based

JNO$_2$ (s$^{-1}$)

Base Satellite Based Observed

21Z on 8/24/2000

Courtesy: A. Biazar, Univ. of Alabama
Photolysis attenuation by clouds (contd.)

Observed O3 vs Model Predictions
(South MISS., lon=-89.57, lat=30.23)

Ozone Concentration (ppb)
-40
-20
0
20
40
60
80
100
8/30/00 0:00 ... 8/31/00 18:00
Date/Time (GMT)

Observed O3
Model (cntrl)
Model (satcld)
(CNTRL-SATCLD)

Courtesy: A. Biazar, Univ. of Alabama
Improving Model Parameter Estimates
Wildfire Emission Specification in CMAQ

- Spatial allocation of emissions based on forest surrogates leads to unrealistic spatial distributions

- Reallocate NEI prescribed and wildfire emissions using MODIS Rapid Response Fire pixel count

⇒ Reallocation helps reduce bias and improves correlation in total carbon predictions
Evaluation of Modeled Spatial Distributions
NO$_2$ Columns: Summer 2004

On-going efforts:
- Test and Improve NO$_x$ Emission Inventories
- Accountability studies
  - Track impact of regulations on observed regional and local AQ over time using both model and observations

(Courtesy: R. Martin)
Evaluation of NO₂ Spatial Distributions (contd.)

**Comparable spatial distributions**

SCIAMACHY higher in rural areas
- higher regional background
- missing source (lightning), or
- chemistry \(\text{NO}_x \rightarrow \text{NO}_y\) too rapid

CMAQ higher downwind of urban areas
(e.g., Atlanta, St. Louis), Point sources
- Opposite trend compared to GEOS-CHEM
  (resolution/chemistry)
- air mass factor from GEOSCHEM (\(\text{NO}_x\) lifetime difference due to resolution)

**Similar discrepancies at surface**

Error at URBAN surface AIRS sites

Error at NONURBAN AIRS sites
Diagnosing Model Performance: Eta-CMAQ PM$_{2.5}$ Forecasts
July 16-22, 2004: Evidence of Effects of Long Range Transport Originating from Outside the Modeled Domain
Evolution of Model and Observed Aerosol Optical Depth

MODIS

Transport from outside the domain influences observed PM concentrations which are grossly under-predicted during this period

• Model picks up spatial signatures ahead of the front
• Under predictions behind the front (due to LBCs)
Further Evidence

7/13/04    7/14/04    7/15/04    7/16/04

Long Range Transport of Alaskan Plume

Distribution of measured carbonaceous aerosol at STN sites within domain
- Regional enhancement in TCM on July 17-20 suggests influence of wildfires on air masses advected into the domain

Can AOD assimilation improve model PM forecast?
MODIS AOD Assimilation: Impact on Surface PM$_{2.5}$ Model Performance

- Reduced Bias/Error
- Improved Correlation

**STN July 20, 04**

Domain median surface levels enhanced by 23 - 42% due to Alaskan fires on different days
Summary

• Air quality remote sensing data is useful for model evaluation and improvements
  ▪ What level of quantitative agreement is acceptable?
  ▪ Need for harmonization between assumptions used in retrieval and CTM process algorithms (e.g., AOD, NO2 columns) for more rigorous quantitative use

• Potential for use in chemical data assimilation
  ▪ Simultaneous information on multiple chemical species
  ▪ Use in air quality forecasting would require availability in near real-time

• Columnar distributions are a good starting point, but there is a need for better vertical resolution
  ▪ Discern between BL and FT
  ▪ Help improve FT predictions in regional AQMs
    • Linking with global models that assimilate satellite data
    • Direct assimilation in regional AQMs
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Reasonable model simulation of spatial and temporal variability in AOD is possible. Can AOD assimilation improve model PM forecasts?