Application of satellite observations to ozone attainment planning in Texas

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Project Team

RICE

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Funding: NASA (Earth Sciences for Decision-Making in Gulf of Mexico Region) ROSES grant (pending)
Project Objectives

• GOES cloud data to improve photolysis rates
• OMI NO$_2$ columns and other data to create top-down NO$_x$ inventory via inverse modeling
• CAMx-HDDM to assess how satellite-derived inputs influence ozone-precursor response in Texas SIP modeling episodes
  – Seek stakeholder input on how to target these analyses to inform decision-making
1. Photolysis Rates assimilated using GOES data
2. NOx Emissions inverted from OMI and TexAQS-II data
3. Model how revised inputs affect ozone responsiveness metrics
4. Provide results to TCEQ and stakeholders for upcoming attainment planning
Motivation: Misplacement of clouds by meteorology models

Figure 1. MM5 predicted and satellite observed cloud fields for (a) 24 August 2000, 2100 UT, and (b) 28 August, 1900 UT.

Pour-Biazar et al., JGR, 2007
Impacts on transmissivity & photolysis rates

Pour-Biazar et al., JGR, 2007

Figure 2. Cloud transmissivity and corresponding NO$_2$ photolysis rates for 24 August 2000 at 2100 UT from CMAQ_base and CMAQ_sat simulations at the surface (first model layer).
Motivation: Impact of satellite-based clouds on NOx & O3 concentrations

Figure 7. Largest differences in (a) NOx and (b) O3 between assimilation and control simulations (assim-control) for the entire period of study covering from 0000 UT, 24 August 2000, to 0000 UT, 1 September 2000.
Motivation: Influence of Photolysis Rates on Ozone-NOx Sensitivity

S(1) O₃ to NOx: Photolysis -30%

Contour: Ozone > 85 ppb
10am-6pm Local Time

June 21, 2005 10:00:00
Min = -0.007 at (32,31), Max = 0.015 at (11,22)

June 23, 2005 10:00:00
Min = -0.038 at (16,36), Max = 0.012 at (17,45)

S(1) O₃ to NOx: Photolysis +30%

Contour: Ozone > 85 ppb
10am-6pm Local Time

June 21, 2005 10:00:00
Min = -0.064 at (32,31), Max = 0.025 at (13,23)

June 23, 2005 10:00:00
Min = -0.035 at (18,34), Max = 0.023 at (11,39)

Fig. 5. Sensitivity of ozone to Houston anthropogenic NOₓ emissions, if the rate of all photolysis reactions is 30% smaller (L) or larger (R) than in base case, for June 21 (top) and June 23 (bottom). Contours show O₃ > 85 ppb in each case.

Cohan, Koo, and Yarwood, Atmospheric Environment (in press)
Motivation: Influence of NO\textsubscript{x} inventory on O\textsubscript{3} sensitivity to NO\textsubscript{x}

O\textsubscript{3} sens to NO\textsubscript{x} under a 50\% smaller NO\textsubscript{x} inventory

(c) S(1) Ozone to HGB ANO\textsubscript{x}, -50\% ANO\textsubscript{x}

[min= -0.000 at (31,5), max= 0.057 at (37,26)]

O\textsubscript{3} sens to NO\textsubscript{x} under a 50\% larger NO\textsubscript{x} inventory

(d) S(1) Ozone to HGB ANO\textsubscript{x}, +50\% ANO\textsubscript{x}

[min= -0.290 at (38,26), max= 0.036 at (38,34)]

Xiao et al., JGR (in revision)
Motivation: Influence of NO$_x$ inventory on O$_3$-precursor response

O$_3$ Sens to NO$_x$ as Function of Baseline ENO$_x$ (Harris County average, 9/1/2006, 3pm)

Xiao et al., JGR (in revision)
Approach: GOES-based photolysis rates

- Derive transmissivity fields based on GOES data (cloud albedo & cloud top pressure)
- Use original MM5-CAMx photolysis rates when satellite data unavailable
- Compute adjusted photolysis rates in CAMx-TUVRM
Limitations of satellite-based photolysis rates

• Missing data at some times/locations
• Inconsistency between photolysis rates and other cloud properties (wet deposition, cloud processing)
Approach: NOx inverse modeling

Baseline SIP modeling inputs from TCEQ

Photolysis rates assimilated using GOES data

CAMx-DDM model

Simulated NO & NO2 concentrations and their sensitivities to emissions

NO2 column densities (OMI satellite retrievals)

NOx observations (aircraft & surface monitors)

Kalman Filter Optimal Estimator

Updated Emission Inventory $E_{n+1}$

| $E_{n+1} - E_n$ | < $\delta$ ? |

Final Emission Inventory
Approach: NOx Inverse Modeling

• Similar to Napelenok et al (ACP, 2008) Kalman filter inversion, except:
  – Use data from newer, higher-resolution OMI instead of SCIAMACHY
  – Incorporate other observations (including TexAQS2 field campaign) into inversions
Challenges in NOx Inversions

- Poor model performance for upper tropospheric NO$_2$
  - Correcting for this influences results, esp. in rural areas
- How to "weight" different data sources
- How to define source regions and categories
- Comparing 3D gridded model results with satellite column pixels

Fig. 7. Vertical distribution of NO$_2$ concentrations observed by NASA INTEX DC-8 flights over the eastern United States compared to model predictions matched in space and time. Error bars

Napelenok et al, 2008
Assessing the impact of satellite-based inputs

- Plan to model Aug-Sept 2006 (HGB/TexAQS2) and June 2006 (DFW) episodes from TCEQ
- Run CAMx-HDDM with original and satellite-based inputs to compare concentrations and their sensitivities to emissions
- Model future year (2018) to explore impacts on relative reduction factors
Comments and Feedback

• How to define NO$_x$ source regions and categories?
• Control scenarios for sensitivity modeling?
• Suggested modifications or extensions?
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