Application of satellite observations to ozone attainment planning in Texas: Update on NASA project

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Project Team

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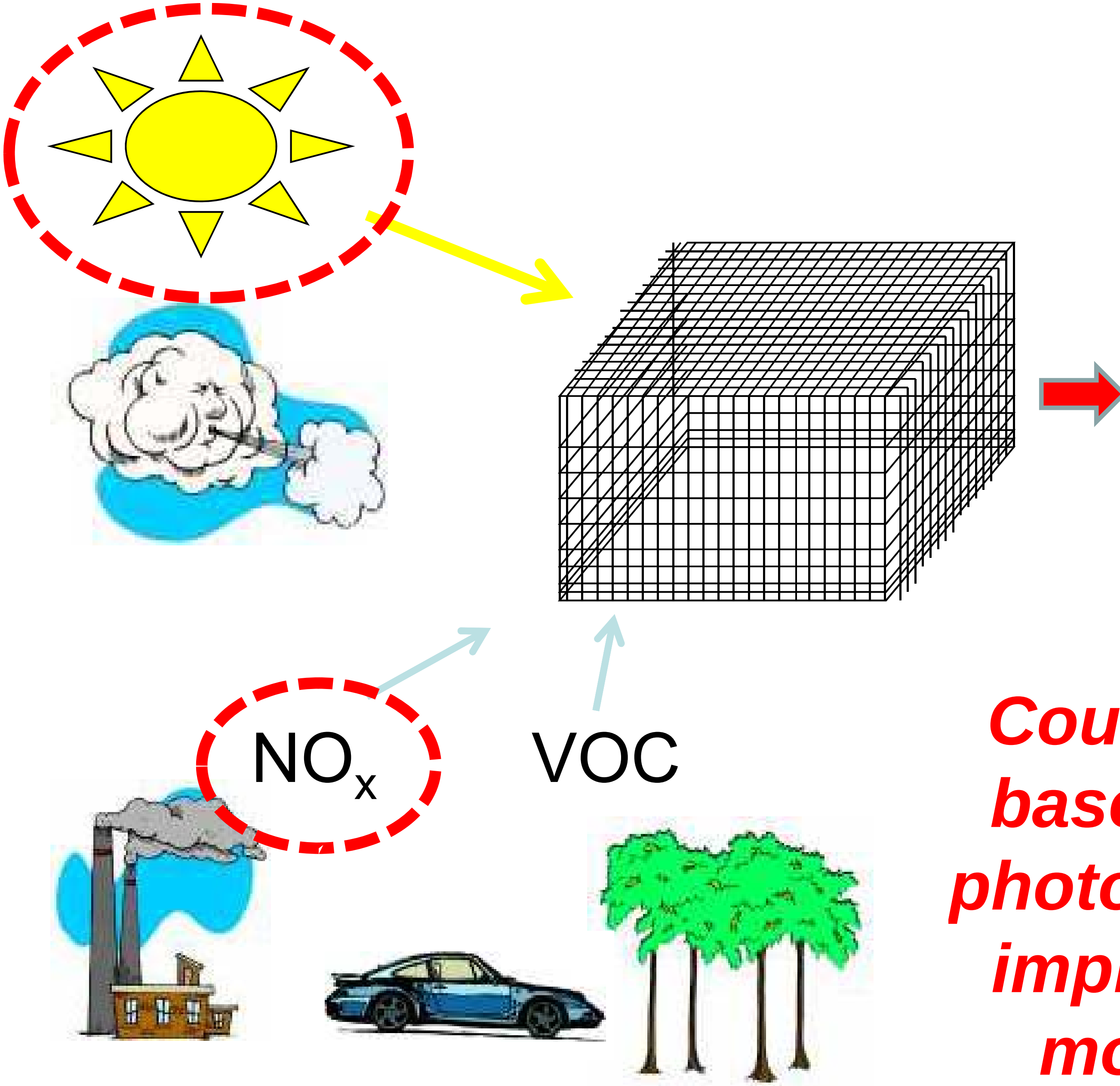
Ozone Photochemical Modeling



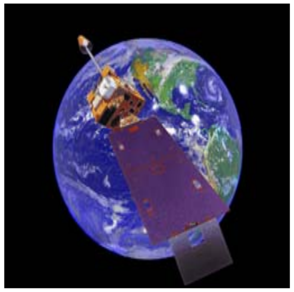
Ozone and its sensitivity to ΔEmissions

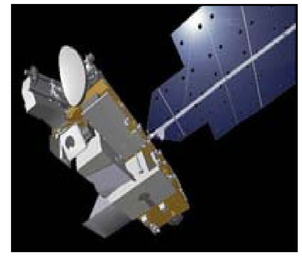
Could satellite-based NO_x and photolysis inputs improve ozone modeling??

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*

Approach





1. Photolysis Rates assimilated using GOES data

2. NO_x 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

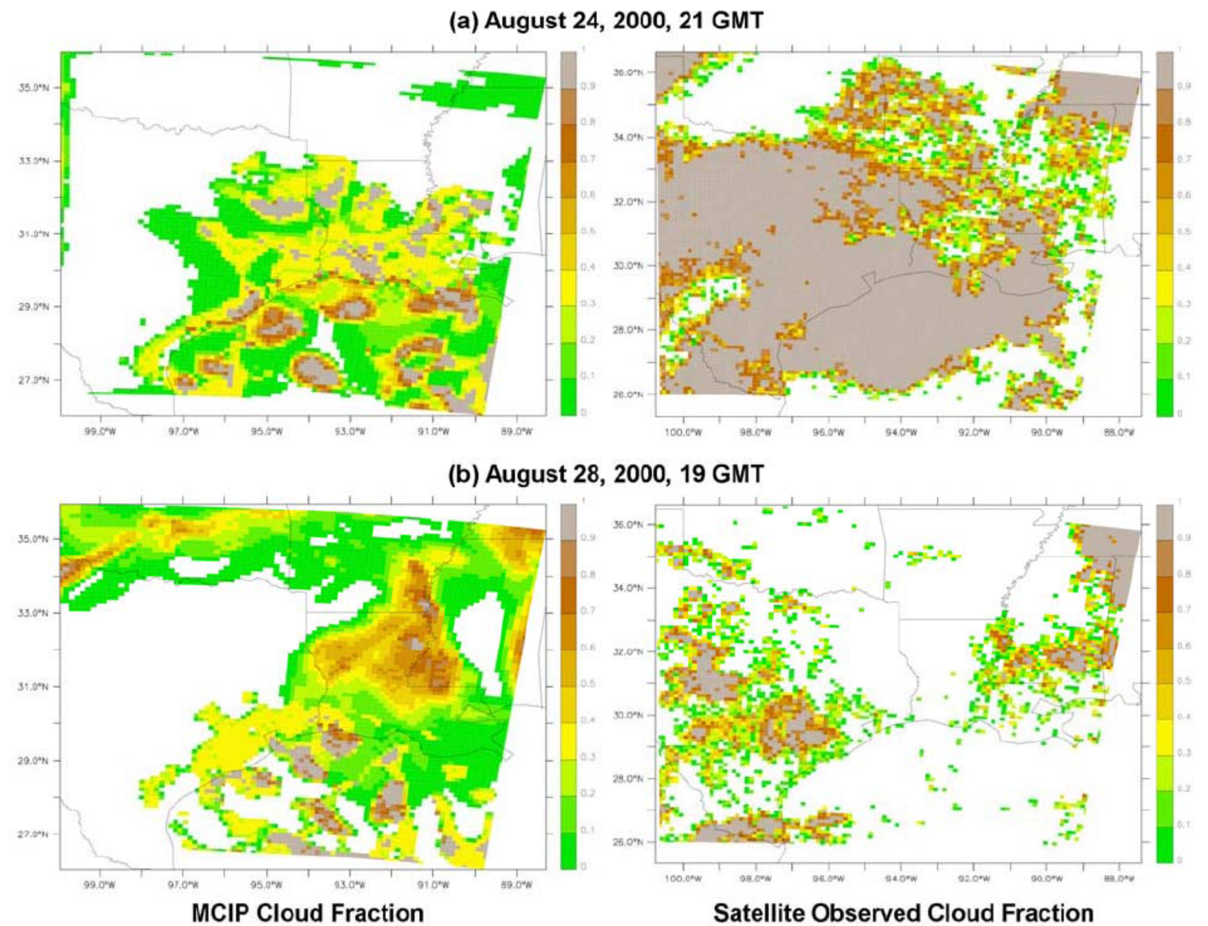


Figure 1. MM5 predicted and satellite observed cloud fields for (a) 24 August 2000, 2100 UT, and (b) 28 August, 1900 UT.

Pour-Biazar et al., JGR, 2007

Motivation: Impact of satellite-based clouds on NOx & O3 concentrations

NOx Concentrations | Ozone Concentrations

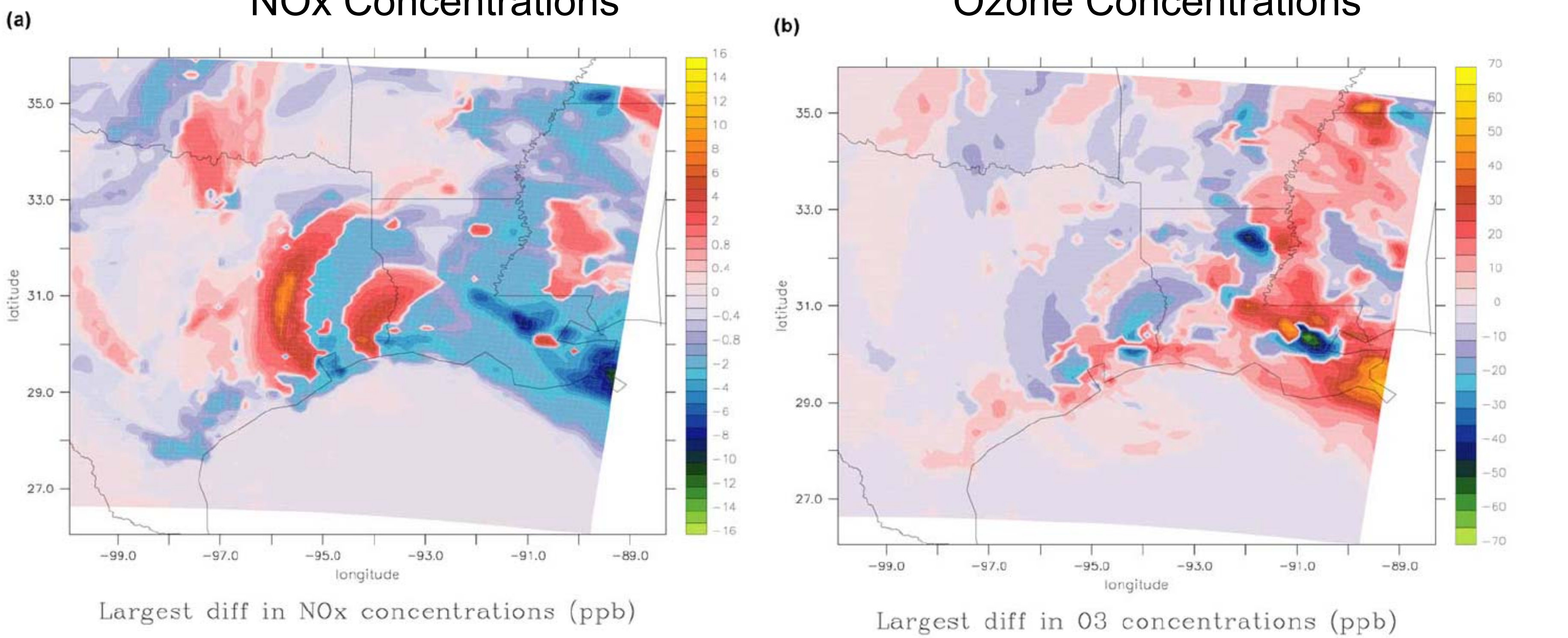


Figure 7. Largest differences in (a) NO_x and (b) O_3 between assimilation and control simulations (assim-control) for the entire period of study covering from 0000 UT, 24 August 2000, to 0000 UT, 1 September 2000.

Pour-Biazar et al., JGR, 2007

Motivation: Influence of Photolysis Rates on Ozone-NOx Sensitivity

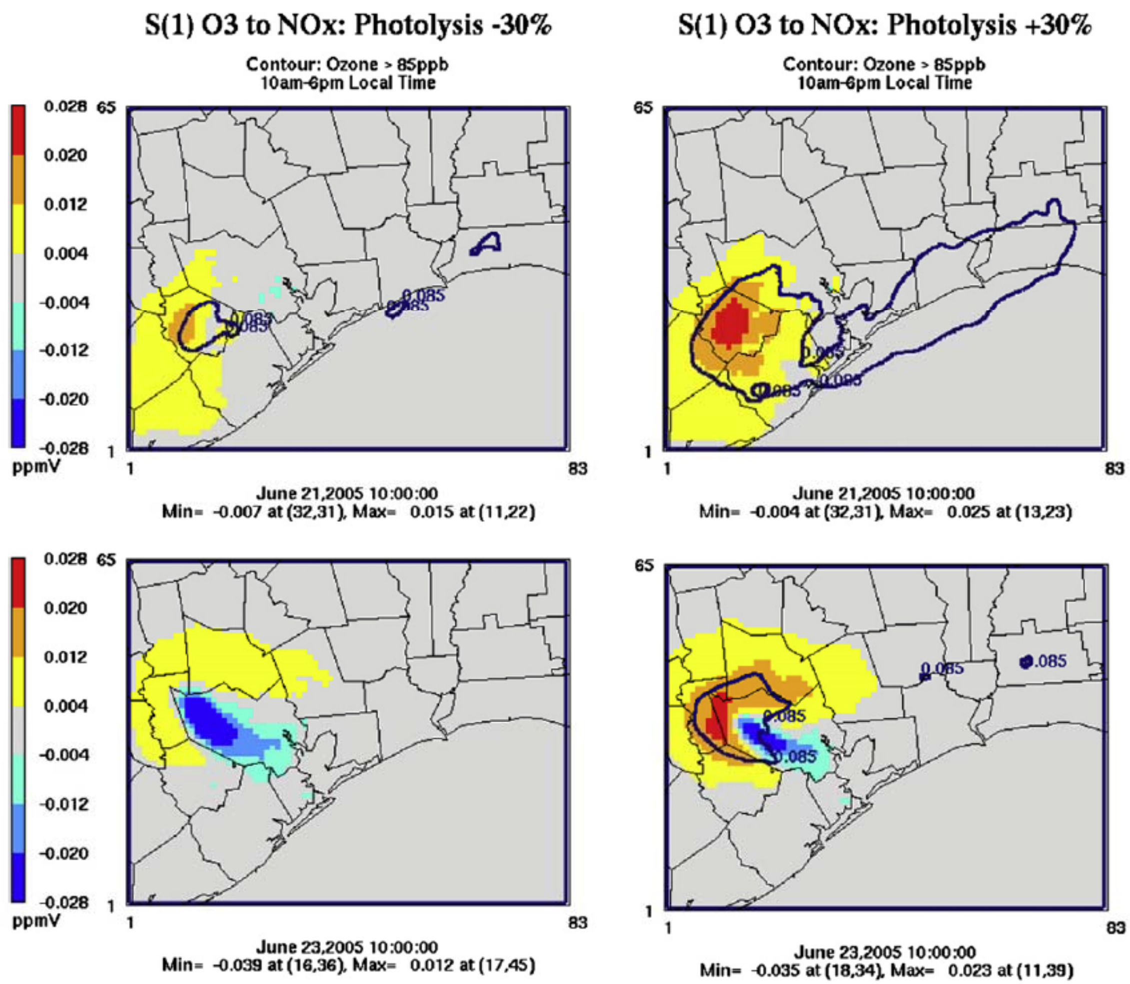


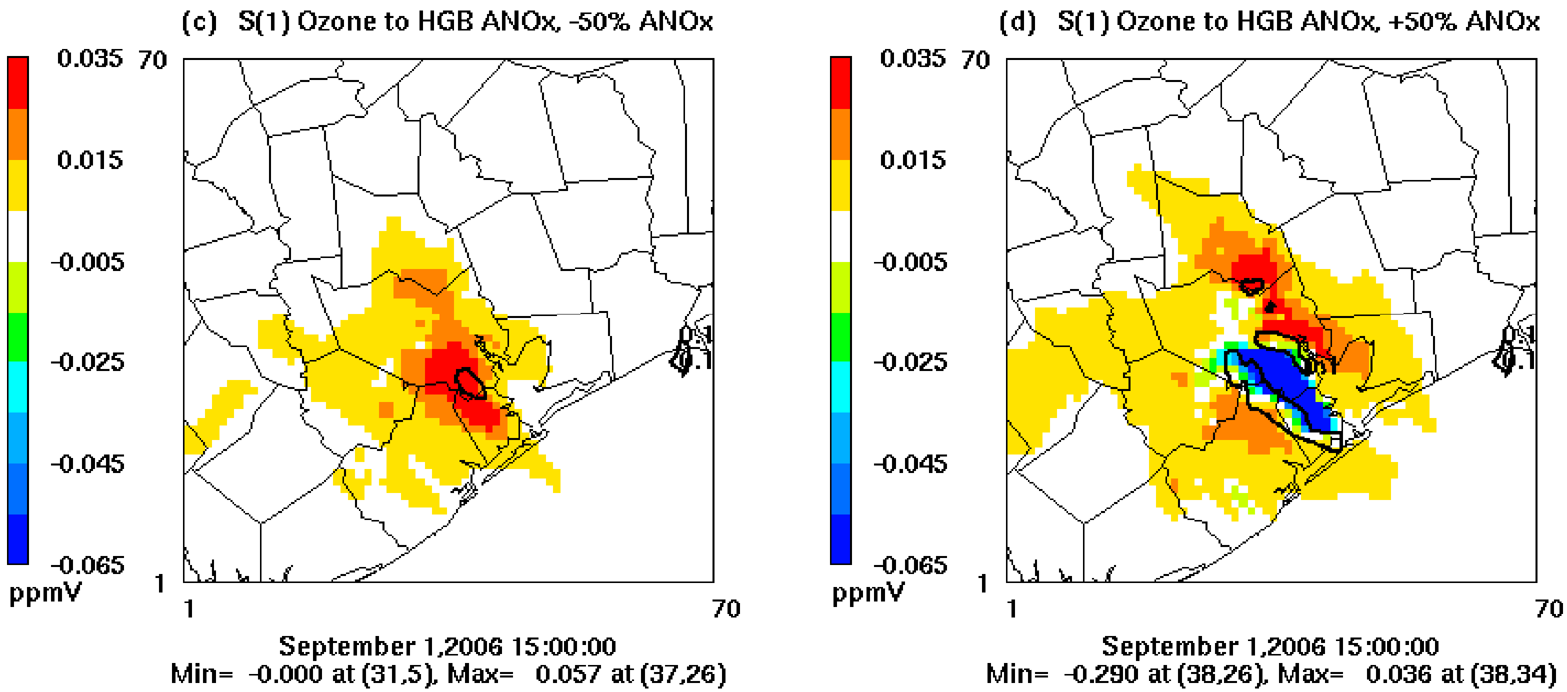
Fig. 5. Sensitivity of ozone to Houston anthropogenic NO_x emissions, if the rate of all photolysis reactions is 30% smaller (L) or larger (R) than in base case, for June 21 (top) and June 23 (bottom). Contours show $O_3 > 85$ ppb in each case.

Cohan, Koo, and Yarwood, Atmospheric Environment 2010

Motivation: Influence of NO_x inventory on O3 sensitivity to NOx

O3 sens to NOx under a 50% smaller NOx inventory

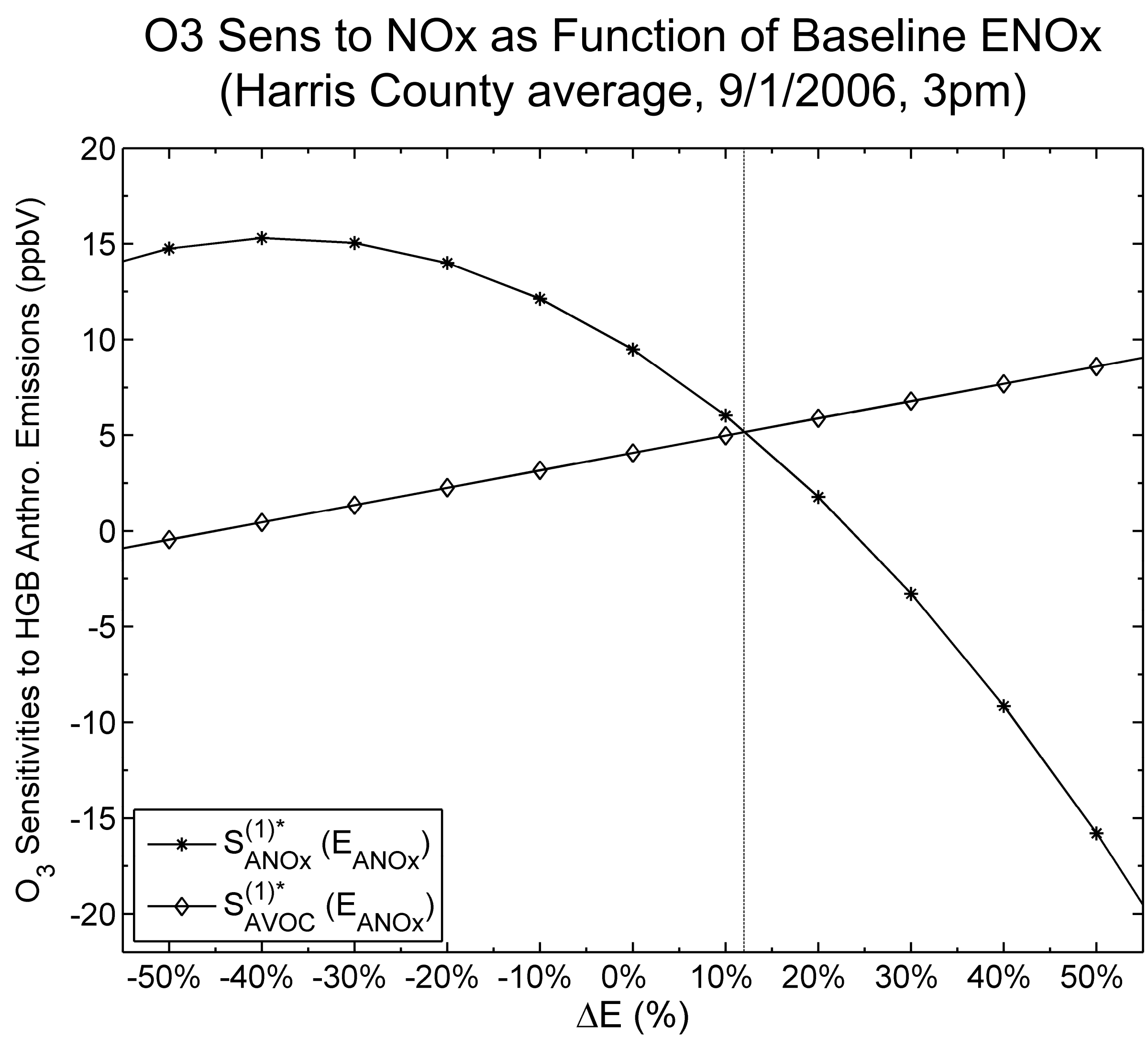
O3 sens to NOx under a 50% larger NOx inventory



RICE

Xiao et al., JGR 2010

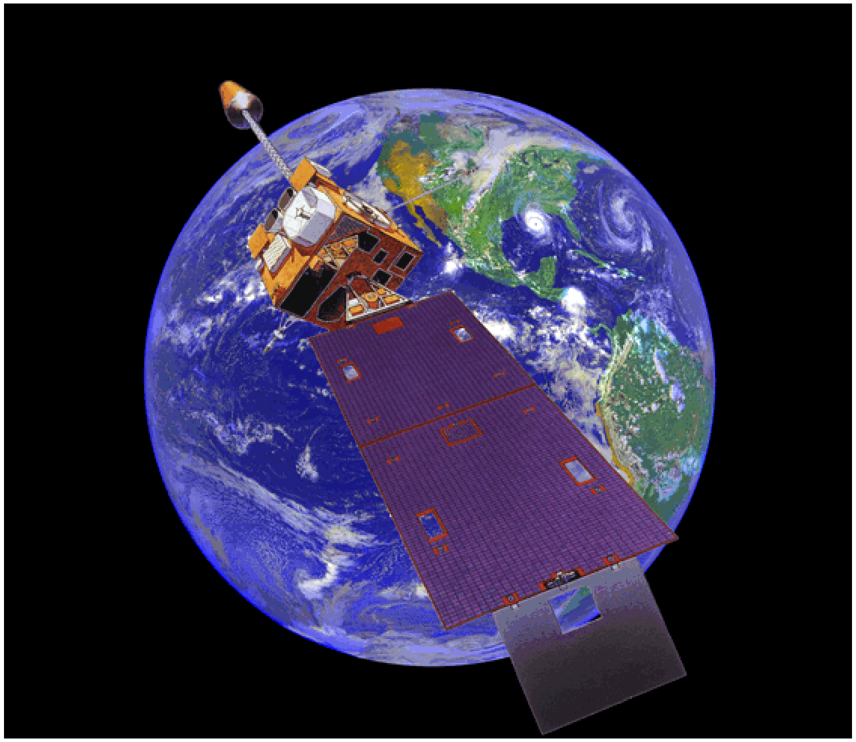
Motivation: Influence of NO_x inventory on O3-precursor response



Xiao et al., JGR 2010

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



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GOES-based photolysis rates in CAMx

GOES-CAMx INTERFACE

Cloud transmissivity (calculated from satellite retrieved cloud albedo), cloud top pressure, and cloud fraction are prepared for input to MM5CAMx

$$tr_{cld} = 1. - (alb_{cld} + abs_{cld})$$

MODIFIED MM5CAMx

GOES retrievals replaces MM5 cloud information being passed to CAMx. Cloud fraction, transmissivity, cloud base and top heights are used to calculate cloud transmissivity to be passed to CAMx.

READINP in CAMx

In subroutine READINP, clear sky photolysis rates will be adjusted for cloud cover based on GOES cloud fraction and cloud transmissivity information.

$$J_{below} = J_{clear}\left[1 + cfrac(1.6tr\cos(\theta) - 1)\right]$$
$$J_{above} = J_{clear}\left[1 + cfrac((1 - tr)\cos(\theta))\right]$$

Interpolated in between.

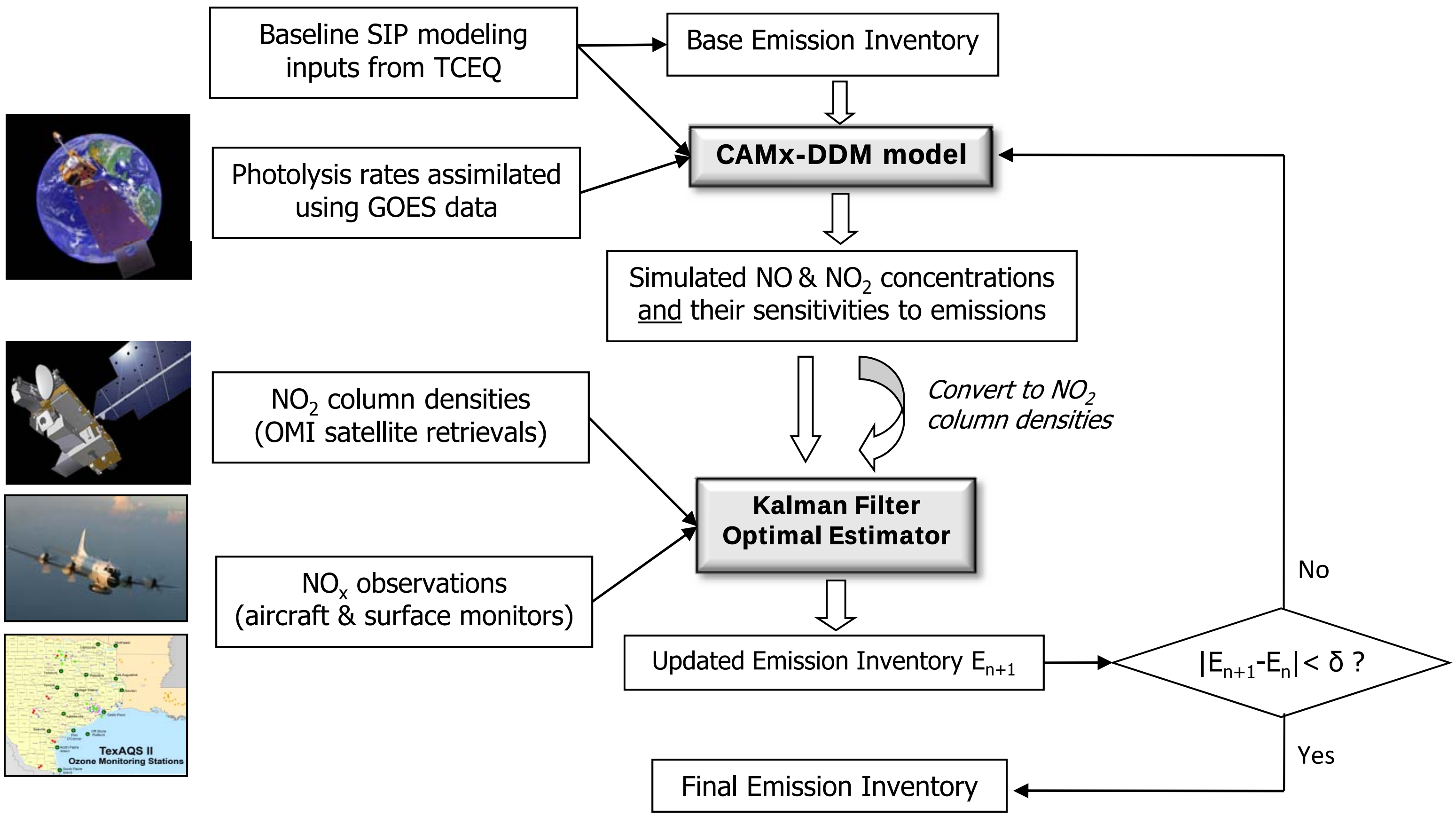
Cloud Base According to Lifting Condensation Level

$$T_c = B / \ln\left[\frac{A\varepsilon}{wp_0}\left(\frac{T_0}{T_c}\right)^{1/k}\right]$$

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

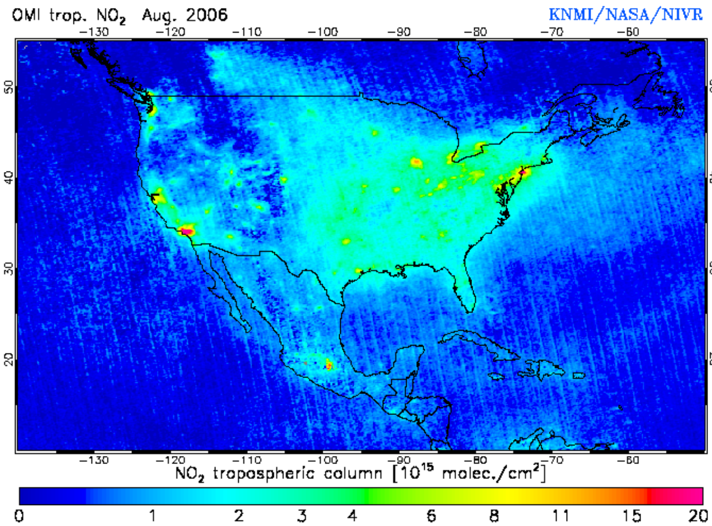


Approach: NOx Inverse Modeling

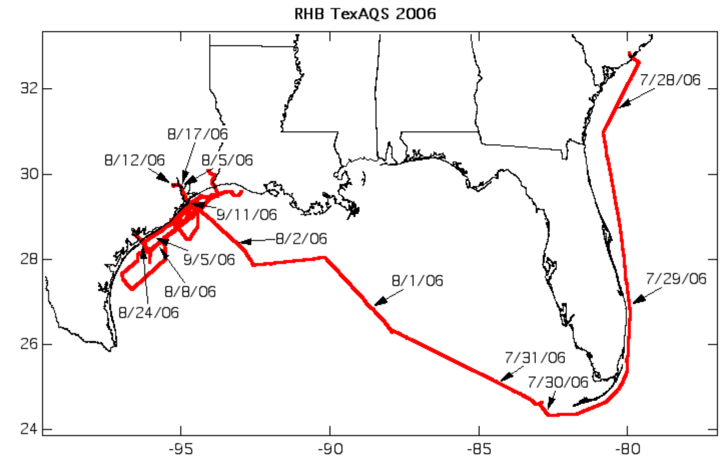
- Similar to Napelenok et al (ACP, 2008) Kalman filter inversion, except:
  - Use data from newer, higher-resolution OMI instead of SCIAMACHY
  - Incorporate other observations (including TexAQS2 field campaign) into inversions

3-D measurements of air pollutants

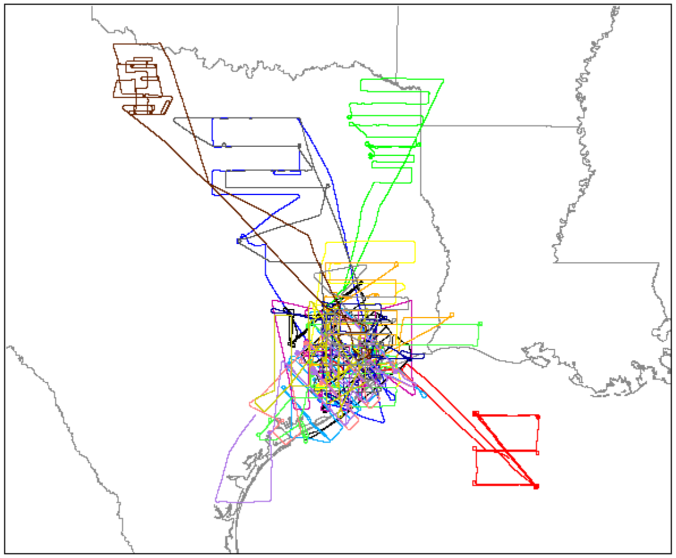
OMI satellite



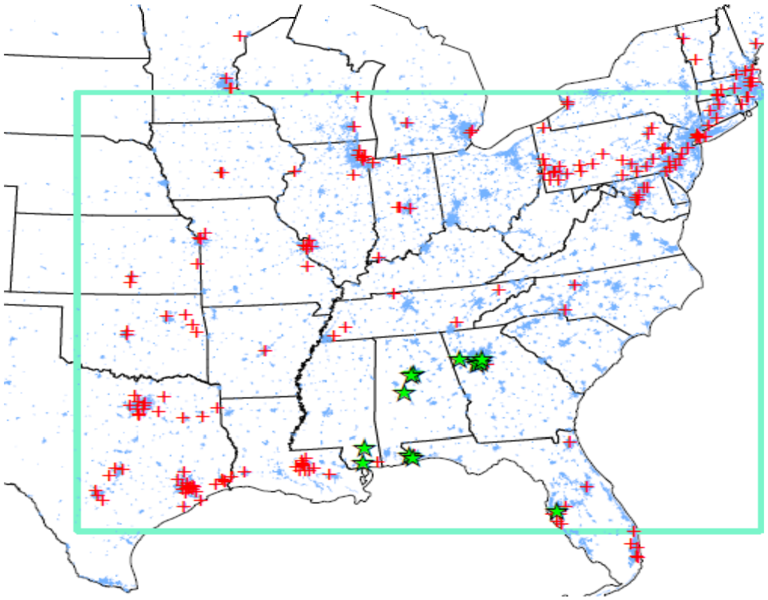
NOAA R/V vessel



NOAA P-3 aircraft

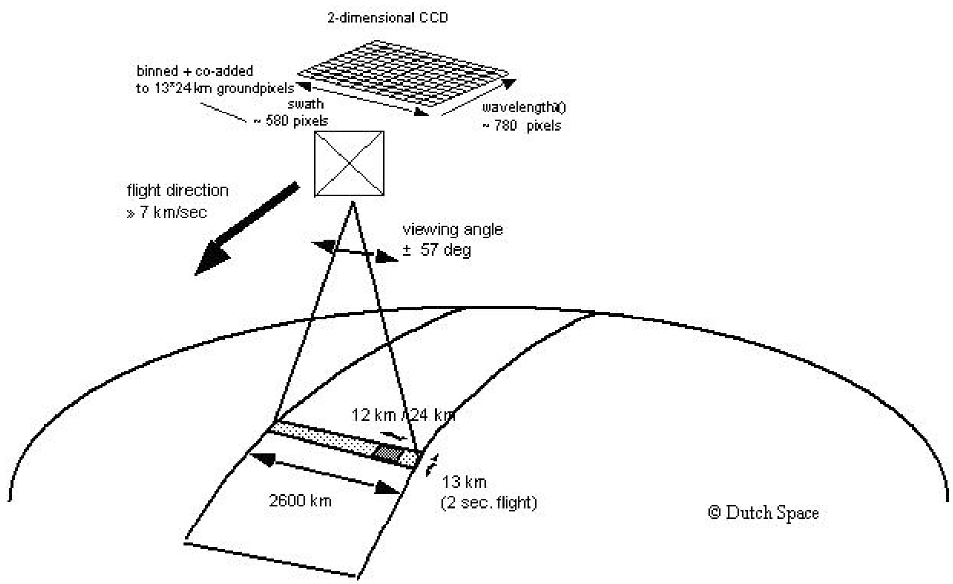


NO_2 monitors



Ozone Monitoring Instrument (OMI)

- NO_2 spectral range (405-465 nm)
- Over-pass time: 13:45 local time (North America)
- Daily global coverage
- Spatial resolution: 13km × 24km (nadir-view point)
- Products: OMI_DP, OMI_ST, OMI_DP_GC (Lamsal et al., 2010, JGR)



Source: OMI Guide 2009

Challenges in NOx Inversions

- How to "weight" different data sources
- How to define source regions and categories
  - Invert emissions in every cell?
  - Retain spatial patterns of bottom-up inventory?
- Comparing 3D gridded model results with satellite column pixels
- Poor model performance in upper troposphere
  - See next slide

Challenge: Upper Tropospheric NO_x

- Poor model performance for upper tropospheric NO_2
  - Important in rural areas
- Will use Lightning Detection Network data with Kaynak et al. scheme for lightning NO
  - Places NO where cloud-to-ground flashes observed
  - Scales to include cloud-to-cloud
  - Vertical profile from Pickering
- CB-6 may address CB05 NO_x chemistry problems noted by Henderson et al (2010)

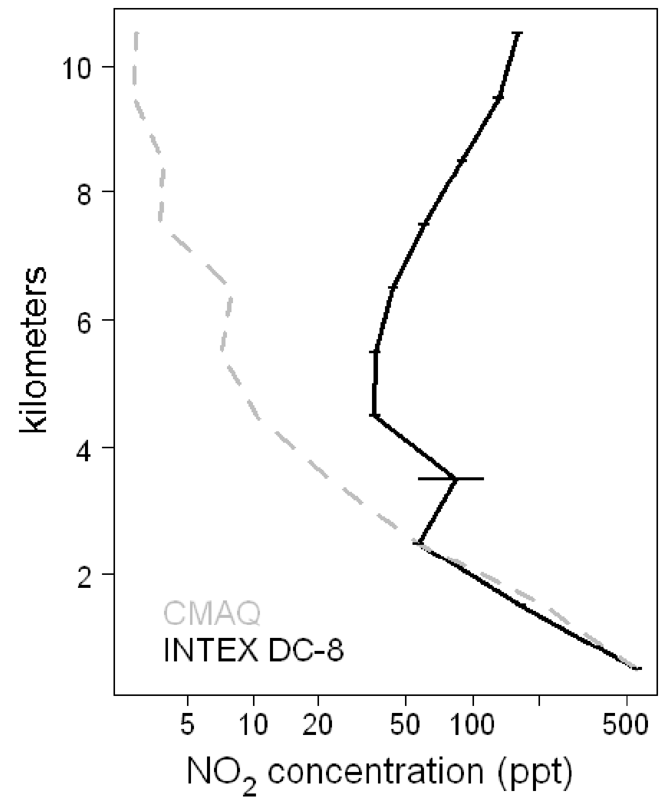


Fig. 7. Vertical distribution of NO_2 concentrations observed by NASA INTEX DC-8 flights over the eastern United States compared to model predictions matched in space and time. Error bars

Napelenok et al, 2008

RICE

Assessing the impact of satellite-based inputs

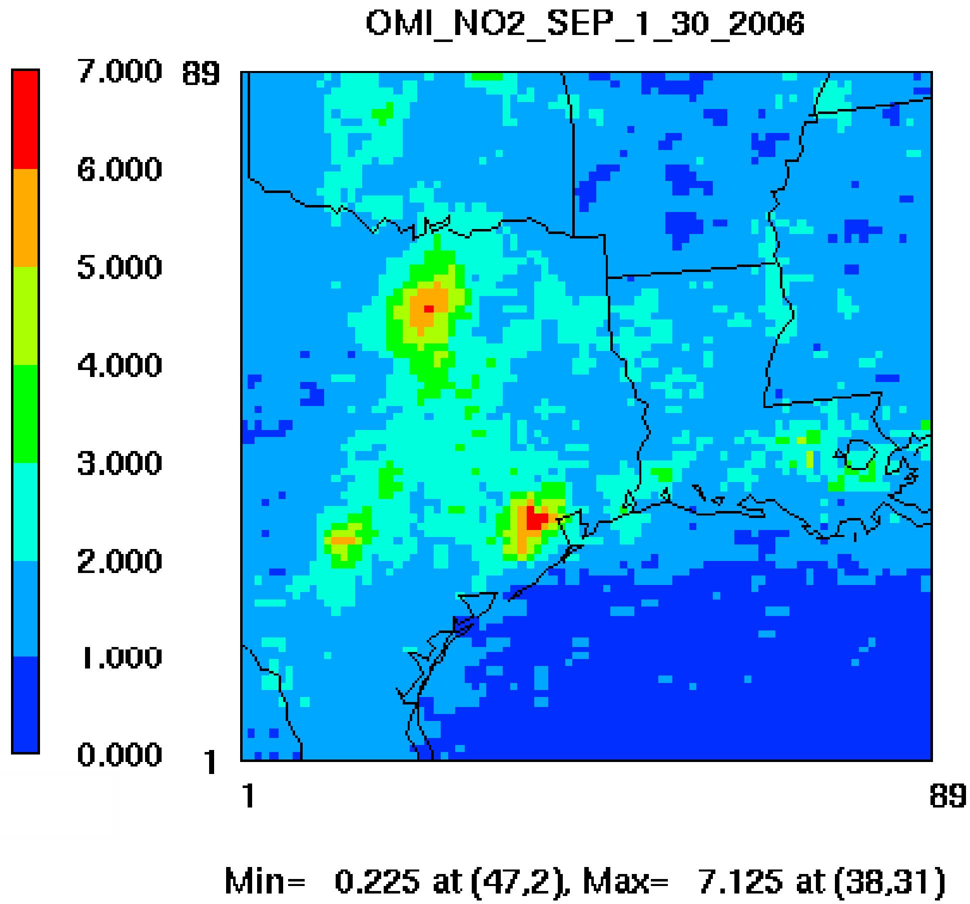
- Run CAMx-HDDM with original and satellite-based inputs to compare O_3 concentrations & sensitivities to emissions in TCEQ episodes
  - August-September 2006 for HGB/TexAQS2
  - June 2006 for DFW
- Model future year (2018) to explore impacts on relative reduction factors

Progress to Date

- Obtained both episodes from TCEQ
- Validated CAMx results on Rice system
  - Updated to CAMx v. 5.20; awaiting v. 5.30
  - Working on 3-D CAMx-HDDM outputs
- Obtained DOMINO-GC OMI NO_2 data from Dalhousie U. (L. Lamsal & R. Martin)
  - Mapped onto CAMx domain
  - Scattering weights to compare CAMx vs. OMI
- Obtained Lightning Detection Network data

RICE

DOMINO-GC data mapped onto TCEQ 12-km domain



September 2006 average
Units: 10^{15} molecules/cm^2

Linkage to Texas AQRP Grant

- "Factors influencing ozone-precursor response in Texas attainment modeling"
  - Grant to Rice U. (PI D. Cohan) and ENVIRON (B. Koo and G. Yarwood), 10/2010 – 8/2011
  - Will consider various structural and parametric uncertainties in same CAMx SIP episodes
    - Alternate inputs: Satellite-based photolysis rates and inverse NO_x, along with alternate boundary conditions, biogenic VOC, and % changes in parameters
    - Bayesian approaches will use observations to assess the relative likelihood of each case
    - Probability distribution of O3-emissions sensitivities

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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