Argonne NATIONAL LABORATORY

... for a brighter future

Advancing Emissions Quantification Techniques through the NASA AQAST Program

David Streets
Argonne National Laboratory

with contributions from:

AQAST team members: ***Greg Carmichael (U. Iowa), Ben de Foy (Saint Louis U.), Russ Dickerson (U. Maryland), Bryan Duncan (NASA/GSFC), David Edwards (NCAR), Daven Henze (U. Colorado), Daniel Jacob (Harvard U.), Yang Liu (Emory U.), Gabriele Pfister (NCAR)***

Other AQAST support: ***Marc Houyoux (US EPA), Nick Krotkov and Lok Lamsal (NASA/GSFC), Randall Martin (Dalhousie U.), Rob Pinder (US EPA)***

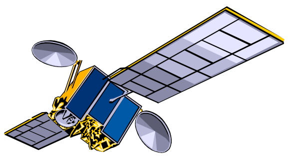
Other Argonne participants: ***Zifeng Lu, Siwen Wang, Qiang Zhang***

AQAST sponsors: ***John Haynes and Lawrence Friedl (NASA)***

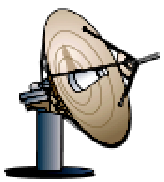
2012 U.S. EPA International Emission Inventory Conference
Tampa, FL
August 14-16, 2012

NASA Air Quality Applied Sciences Team (AQAST)

The AQAST goal is to transfer Earth Science knowledge to serve the needs of U.S. air quality management with focus on the use of NASA satellites, suborbital platforms, and models (Daniel J. Jacob, Harvard University, leader).



satellites



suborbital platforms

models

AQAST →

Air Quality Management Needs

- **Pollution monitoring**
- **Exposure assessment**
- **AQ forecasting**
- **Source attribution of events**
- **Quantifying and monitoring emissions**
- **Assessment of natural and international influences**
- **Understanding of transport, chemistry, aerosol processes**
- **Understanding of climate-AQ interactions**

(http://acmg.seas.harvard.edu/aqast/)

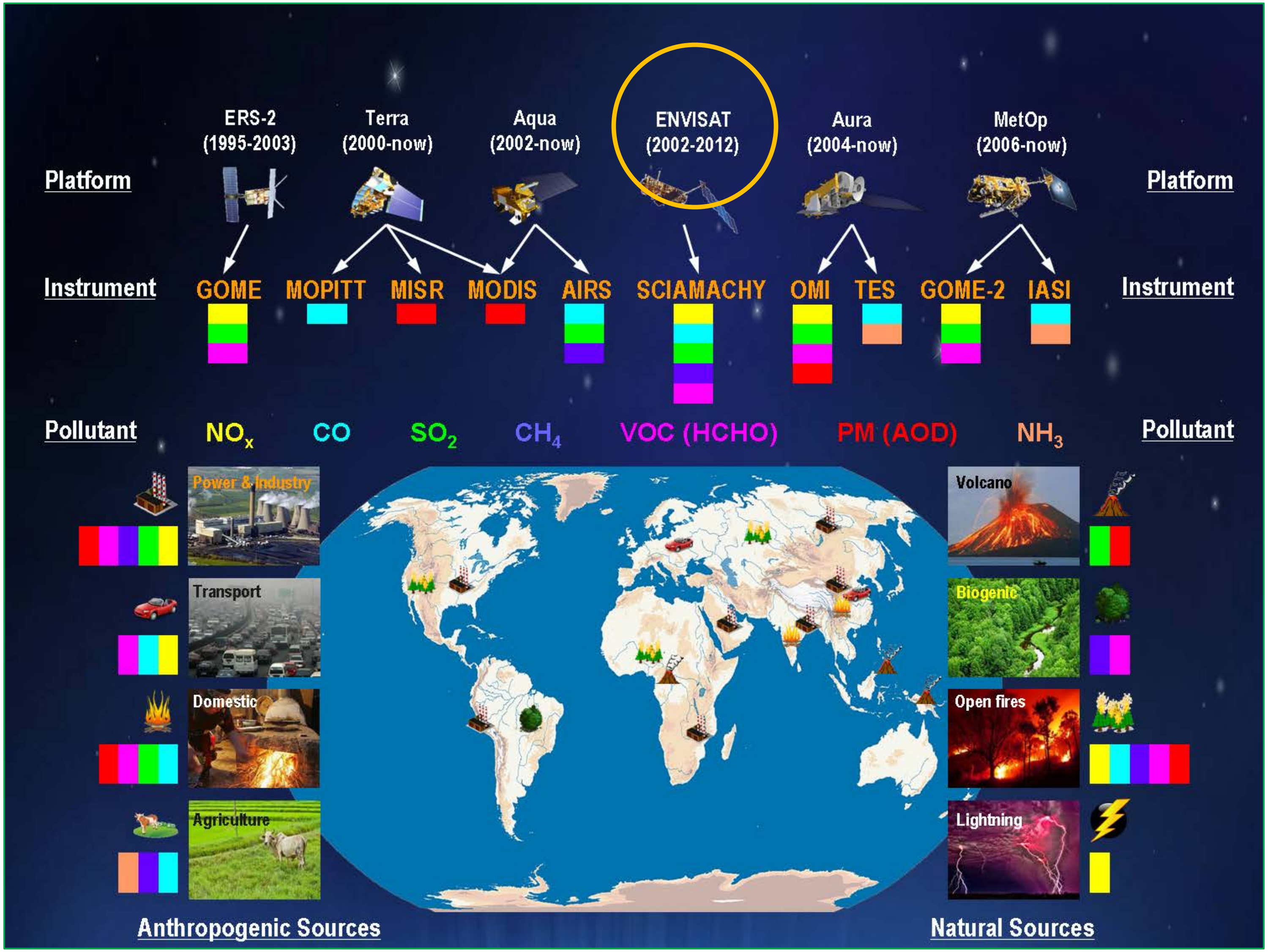
Objective: Assessment of the applicability of current worldwide studies of satellite retrievals and emissions estimation to U.S. air quality management

Issue: How can air quality managers make use of satellite retrievals to improve emission estimates, and what developments are needed to improve the usefulness of those retrievals?

Some potential applications in the U.S. (by no means exhaustive):

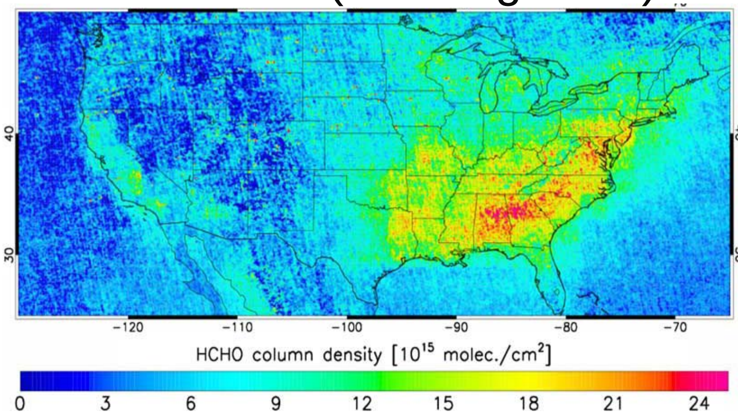
- **problematic industrial sources and industrial complexes**
- **power plant compliance**
- **uncertain area sources (including biogenic)**
- **verification of regional emission reductions**
- **quantification of atmospheric lifetimes**
- **quantification of uncertain Mexican and Canadian emissions**
- **coordinated use of multi-species retrievals, etc.**

The complexity of satellite platforms, instruments, pollutants, sources, and world regions. How to process the information?

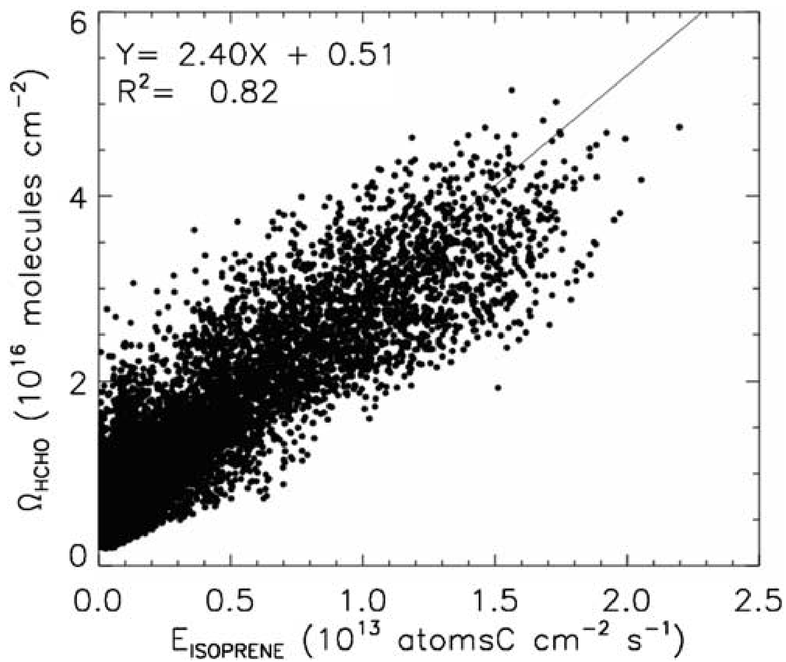


Past use of Ω_{HCHO} vs. $E_{isoprene}$ relationship over U.S. to constrain isoprene emission with OMI data (Jacob group)

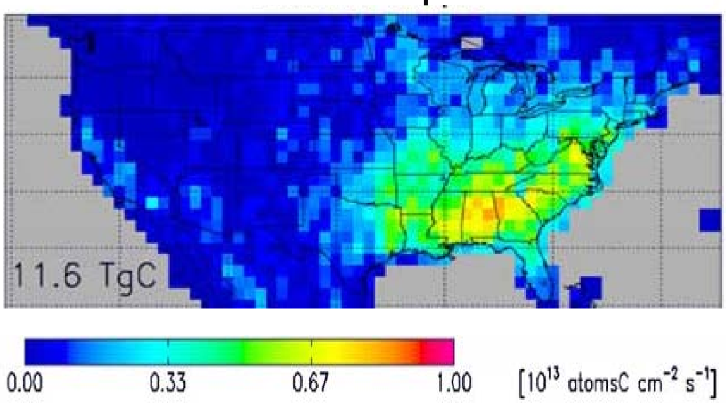
OMI HCHO (Jun-Aug 2006)



GEOS-Chem relationship between HCHO column and isoprene emission



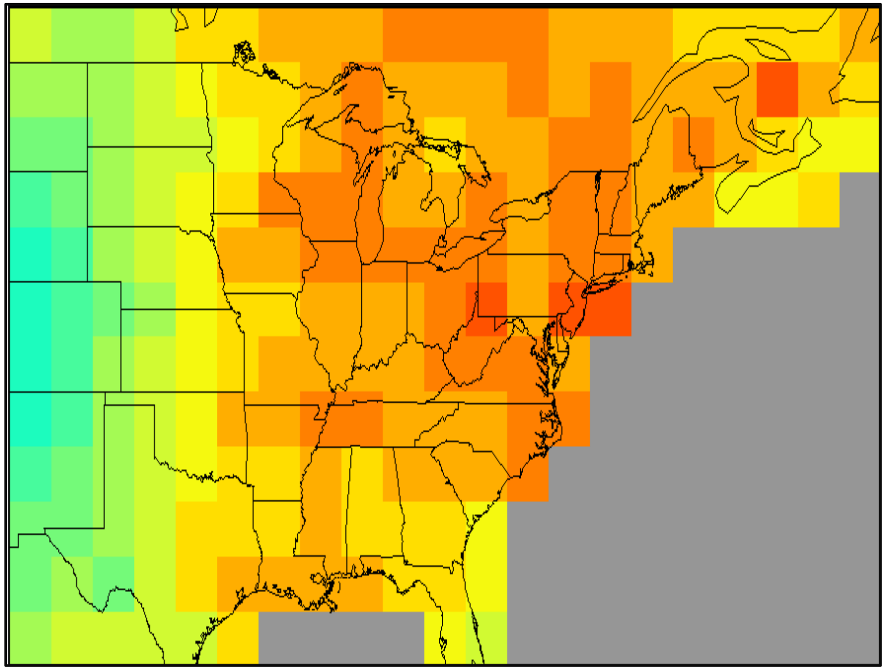
OMI-constrained isoprene emission



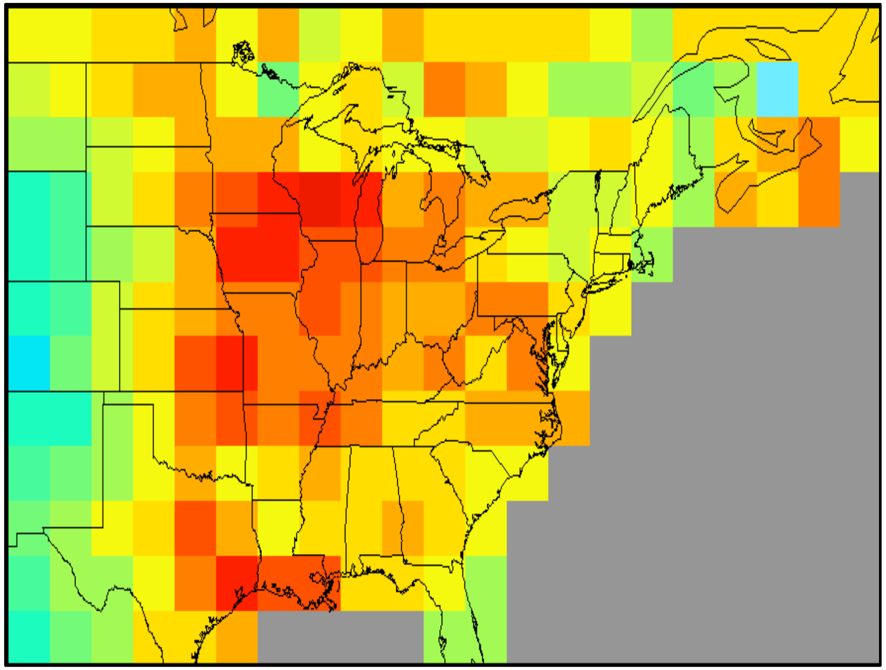
Millet et al., JGR, 2008

SCIAMACHY satellite data identify potential errors in current U.S. methane emission inventories (Jacob group)

GEOS-Chem modeled column-average CH_4, 1 July - 15 August 2004, using EDGAR v4



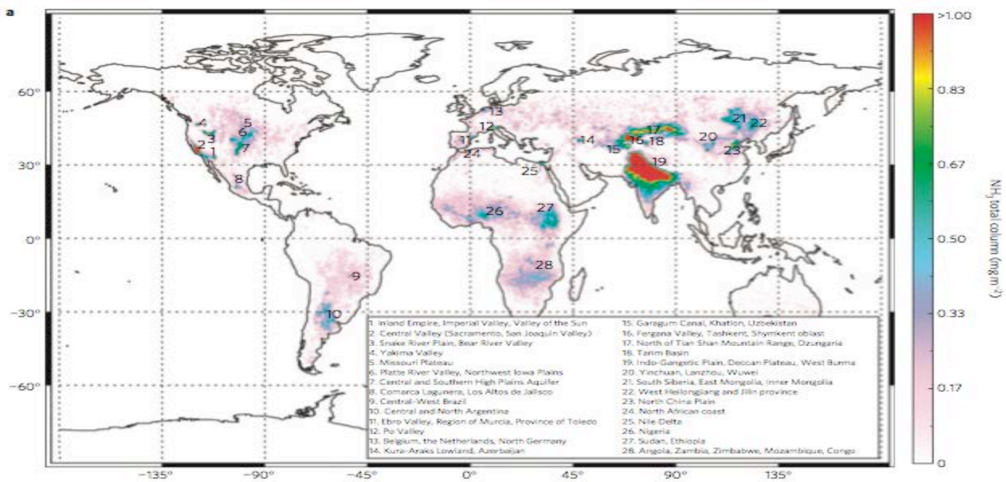
SCIAMACHY column-average CH_4, 1 July - 15 August 2004



SCIAMACHY data suggest higher-than-expected emissions from oil and gas industry, agriculture

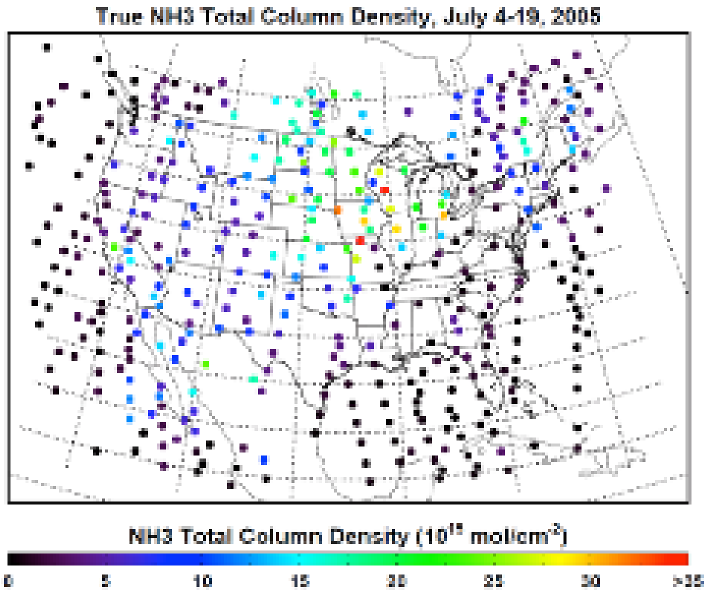
Wecht and Jacob, unpublished, 2012

Remote sensing of NH_3 by IASI and TES (Henze, Pinder)



IASI: daily global coverage

Clarisse et al., Nat. Geosci., 2009;
Clarisse et al., JGR, 2010



TES: "covers" the globe in 16 days; 5 km x 8 km footprint; more sparse but more precise than IASI

Beer et al., GRL, 2008; Clarisse et al., JGR, 2010;
Pinder et al., GRL, 2011; Shephard et al., ACP, 2011

Application of satellite observations for timely updates to NO_x emission inventories (Martin group)

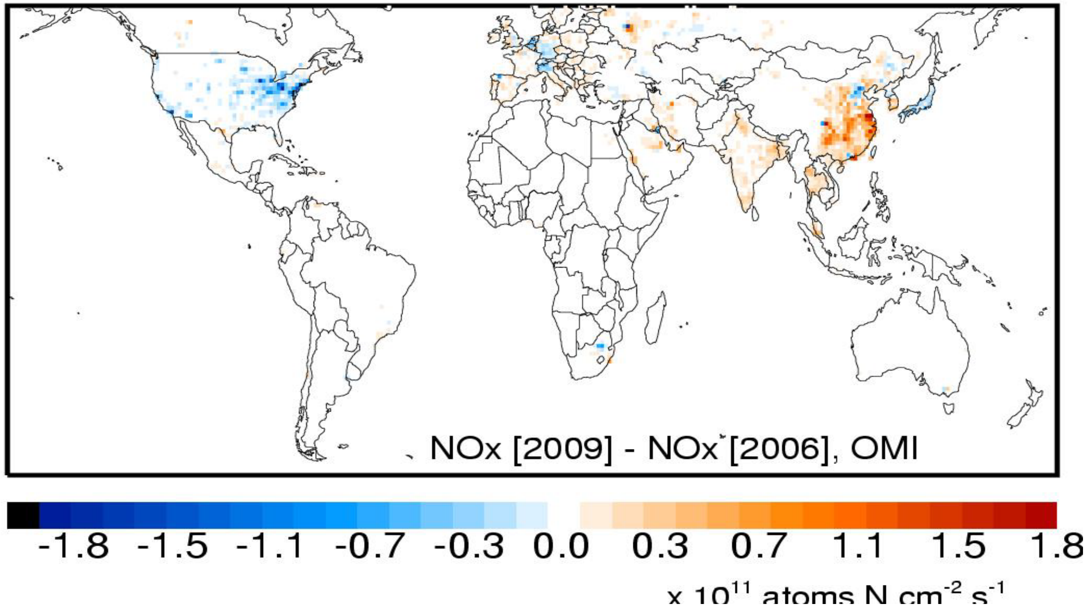
Use CTM to calculate local sensitivity of changes in trace-gas column to changes in emissions

Fractional Change in Emissions

$$\Delta E = \beta \quad \Delta\Omega$$

Fractional Change in Trace-Gas Column

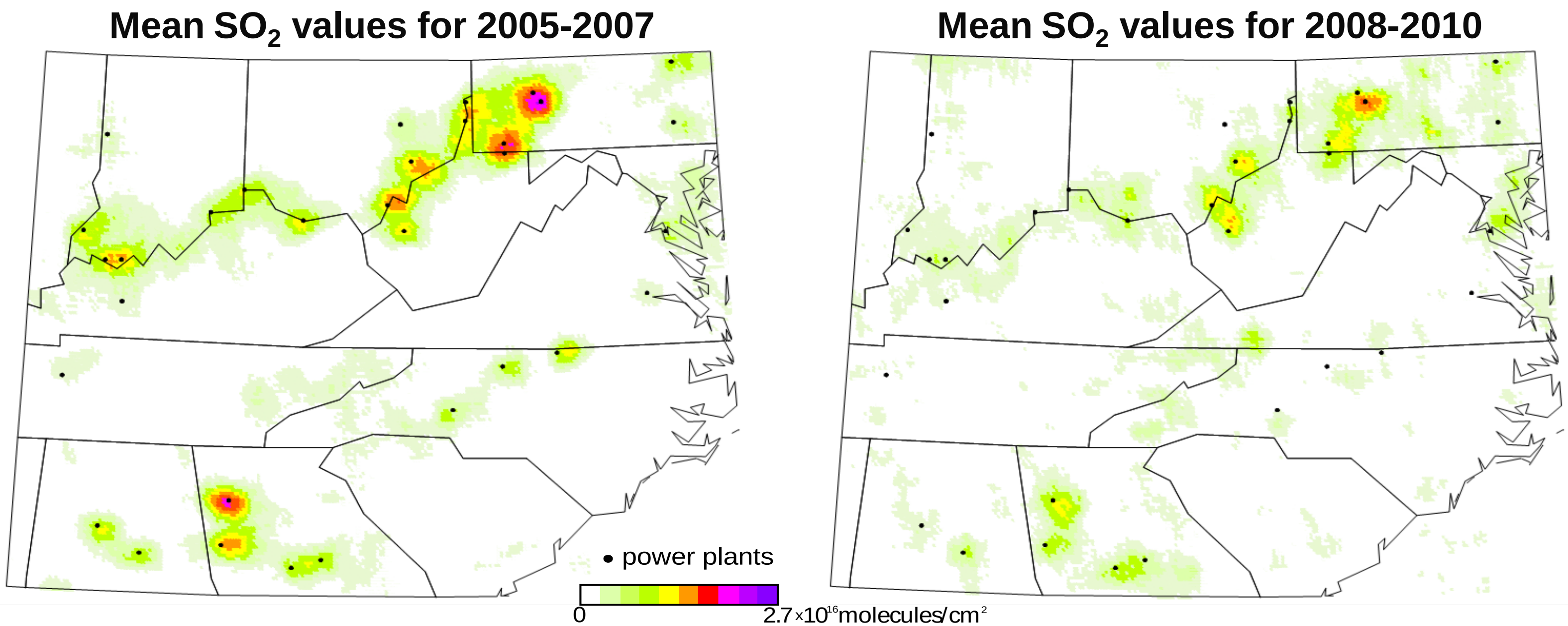
Local Sensitivity of Column Changes to Emission Changes



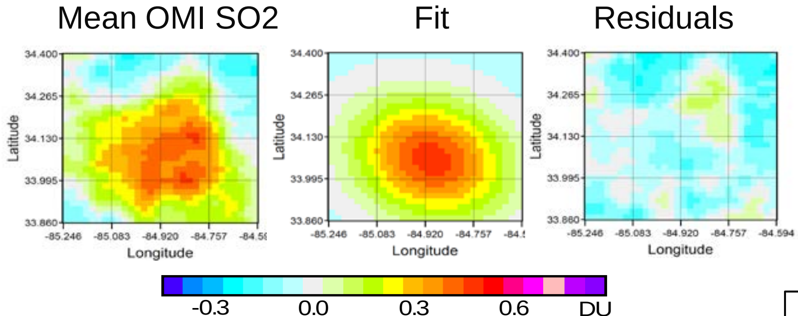
Forecast global inventory for 2009, based on bottom-up inventory for 2006 and monthly OMI NO_2 for 2006-2009

Lamsal et al., GRL, 2011

OMI demonstration of decreasing SO_2 emissions from large power plants in the eastern U.S. (Fioletov, Krotkov)

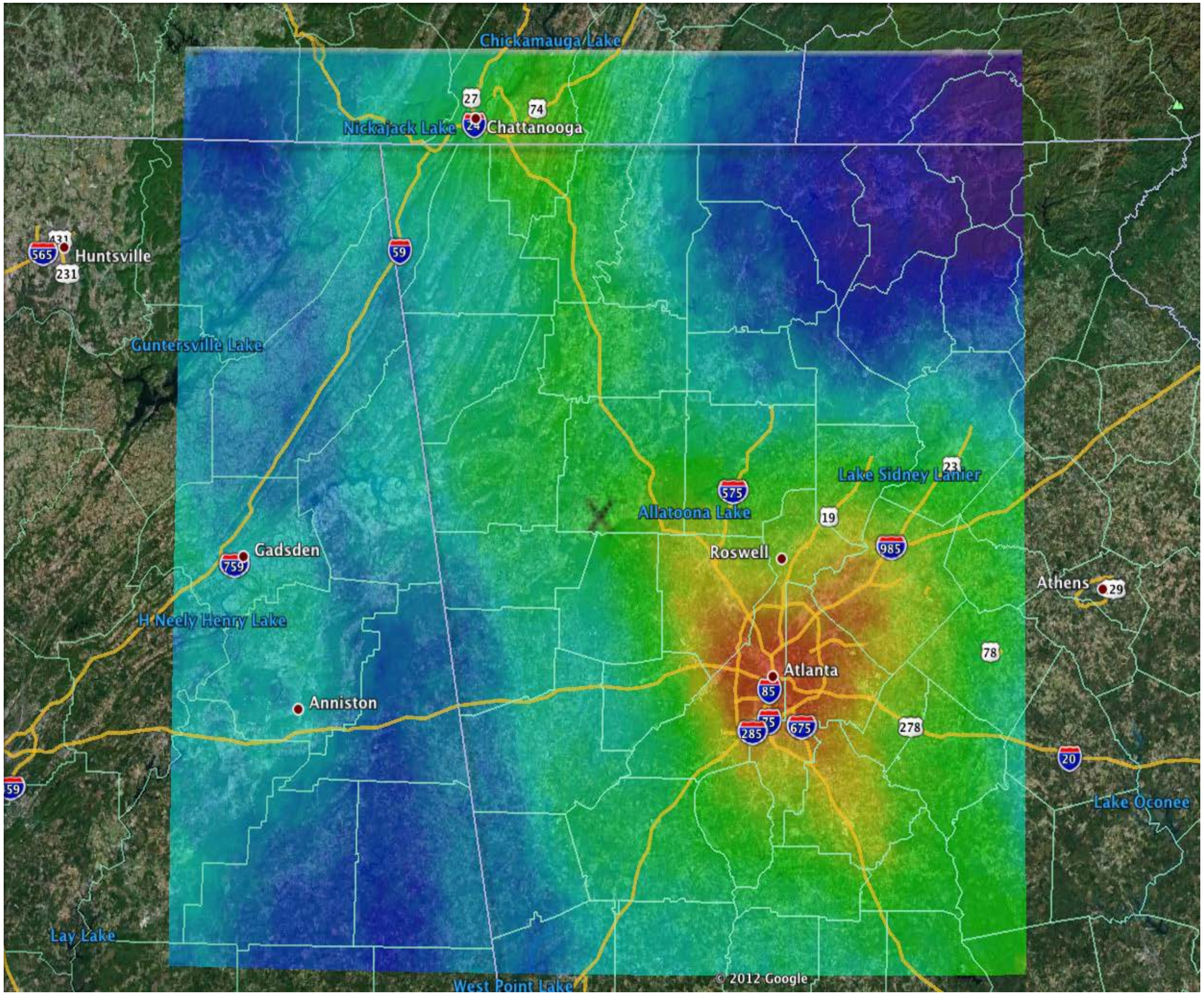


Uses best fits of a 2-D Gaussian function applied to mean OMI SO_2 for 2005-2007, integrated around the source.



Fioletov et al., GRL, 2011

OMI NO_2 retrievals over North Georgia using oversampling

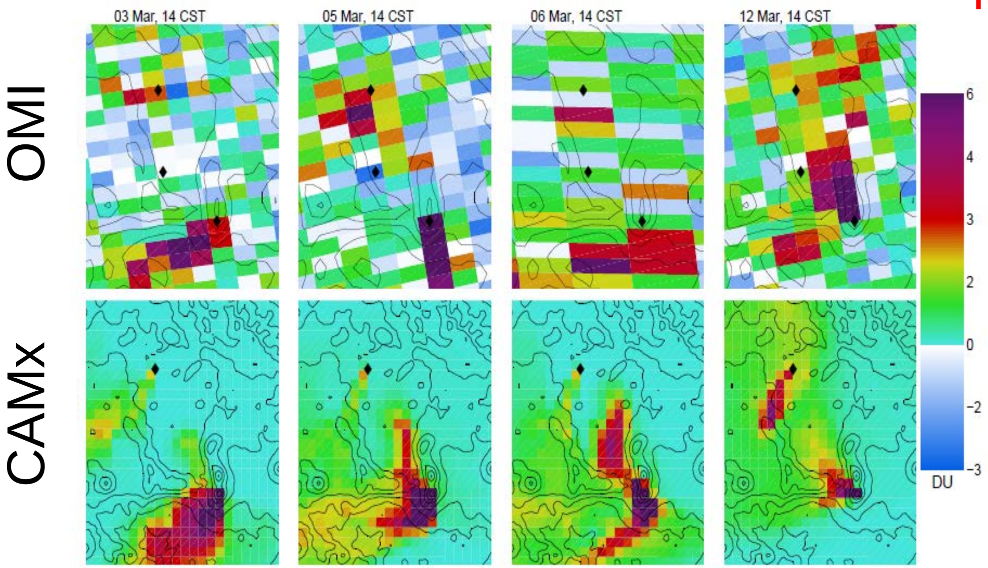


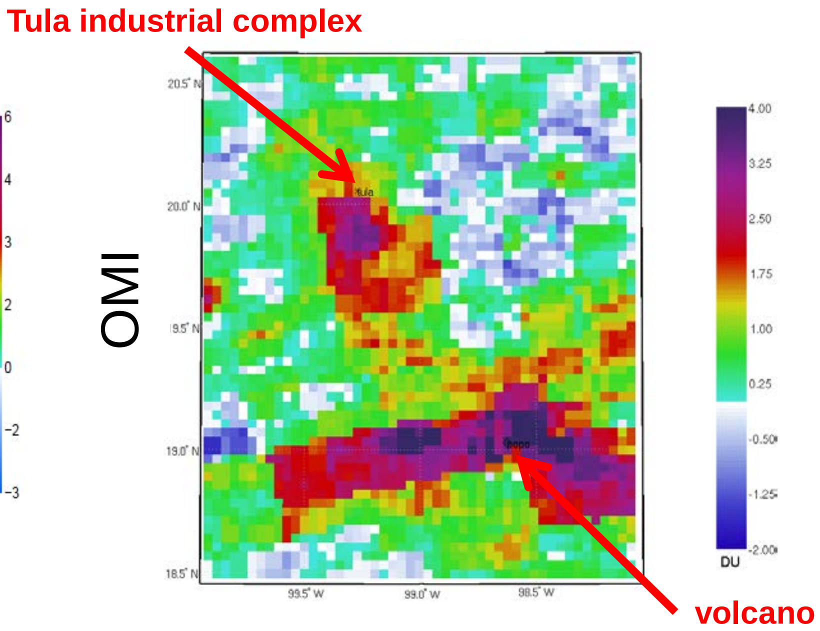
Bryan Duncan, unpublished, 2012

High-resolution plume analysis using oversampling of OMI swath data for SO_2 over Mexico City (de Foy, Krotkov)

Two large SO_2 point sources on either side of Mexico City were clearly detected by OMI, but the coarse resolution did not give a detailed view of plume transport.

Oversampling the data to a 3 km 3 km grid and averaging over long time periods reveals fine features in the plume transport.

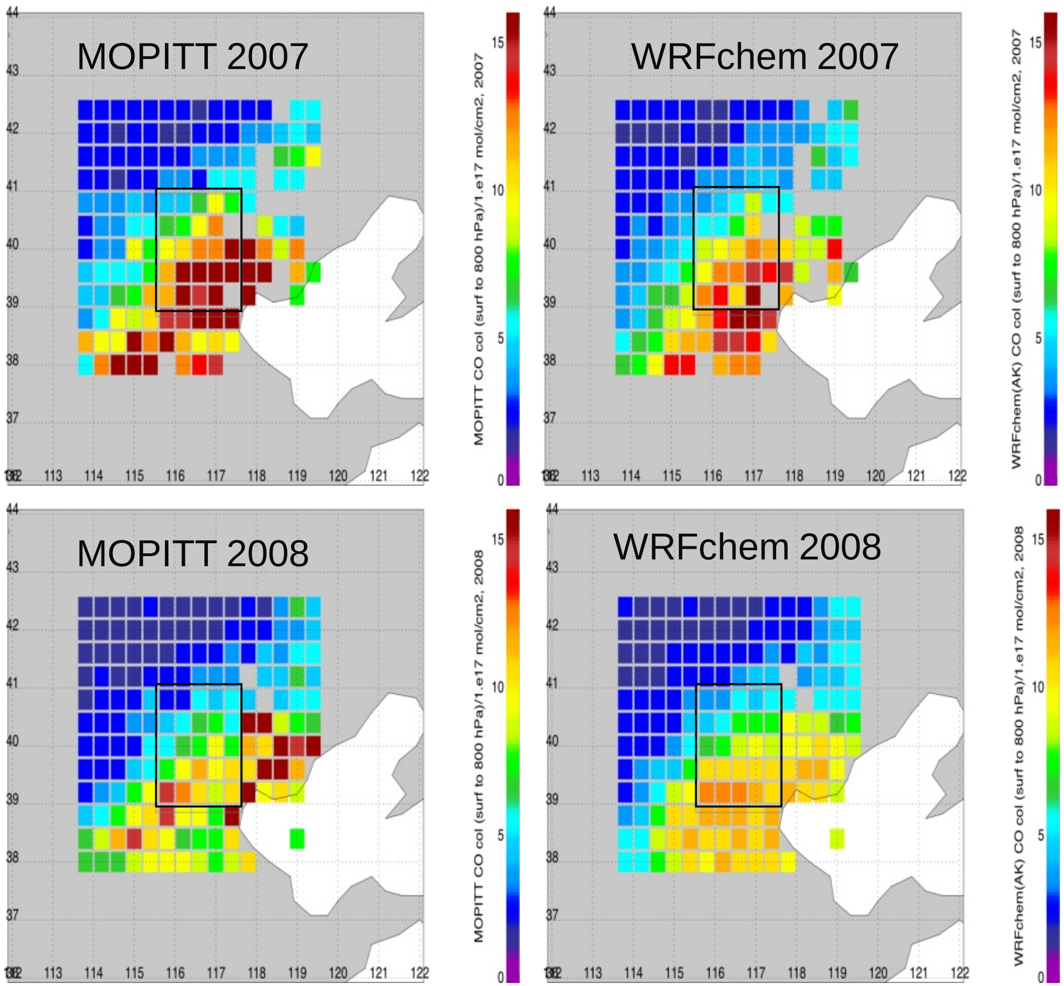




Using models as a bridging tool between column measurements from satellite remote sensing and surface measurements shows that in this case, the volcano accounts for less than 10% of SO_2 impacts in Mexico City, and the industrial complex accounts for approximately 50% of impacts.

de Foy et al., ACP, 2009

Estimates of reduced CO and CO_2 emissions due to traffic restrictions during the 2008 Beijing Olympics (Carmichael, Worden)

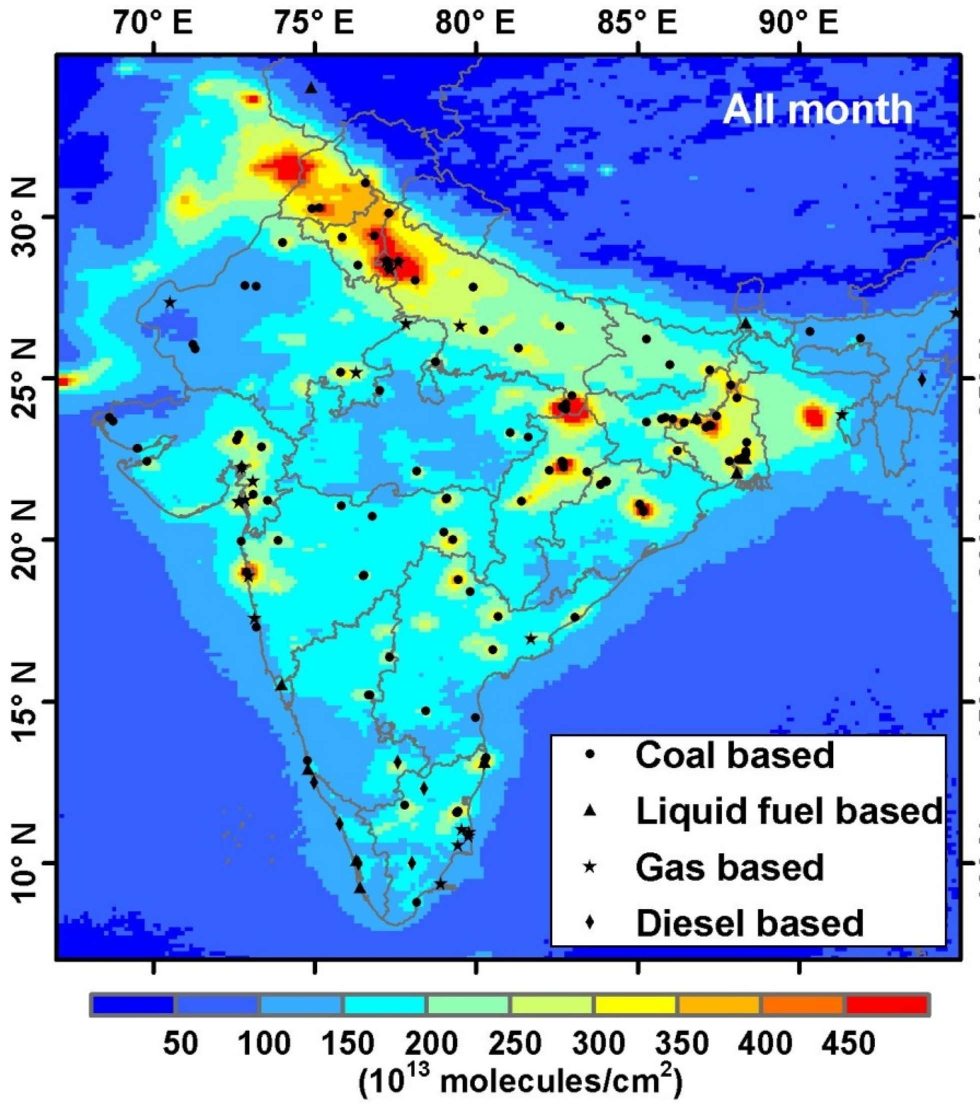


A net emissions reduction of 4.6 ± 1.6 Gg[CO]/day estimated for the multi-spectral MOPITT CO measurements from 2008 compared to 2007. This is in agreement with the reduction of 4.75 Gg[CO]/day from the bottom-up emissions used in WRF-Chem.

There was an estimated 2.4 Gg[CO]/day reduction due to the traffic restrictions during the Beijing Olympics and 46 to 59 Gg[CO_2]/day for the corresponding reduction in CO_2.

Worden et al., GRL, 2012

Indian power-plant locations vs. NO_2 columns

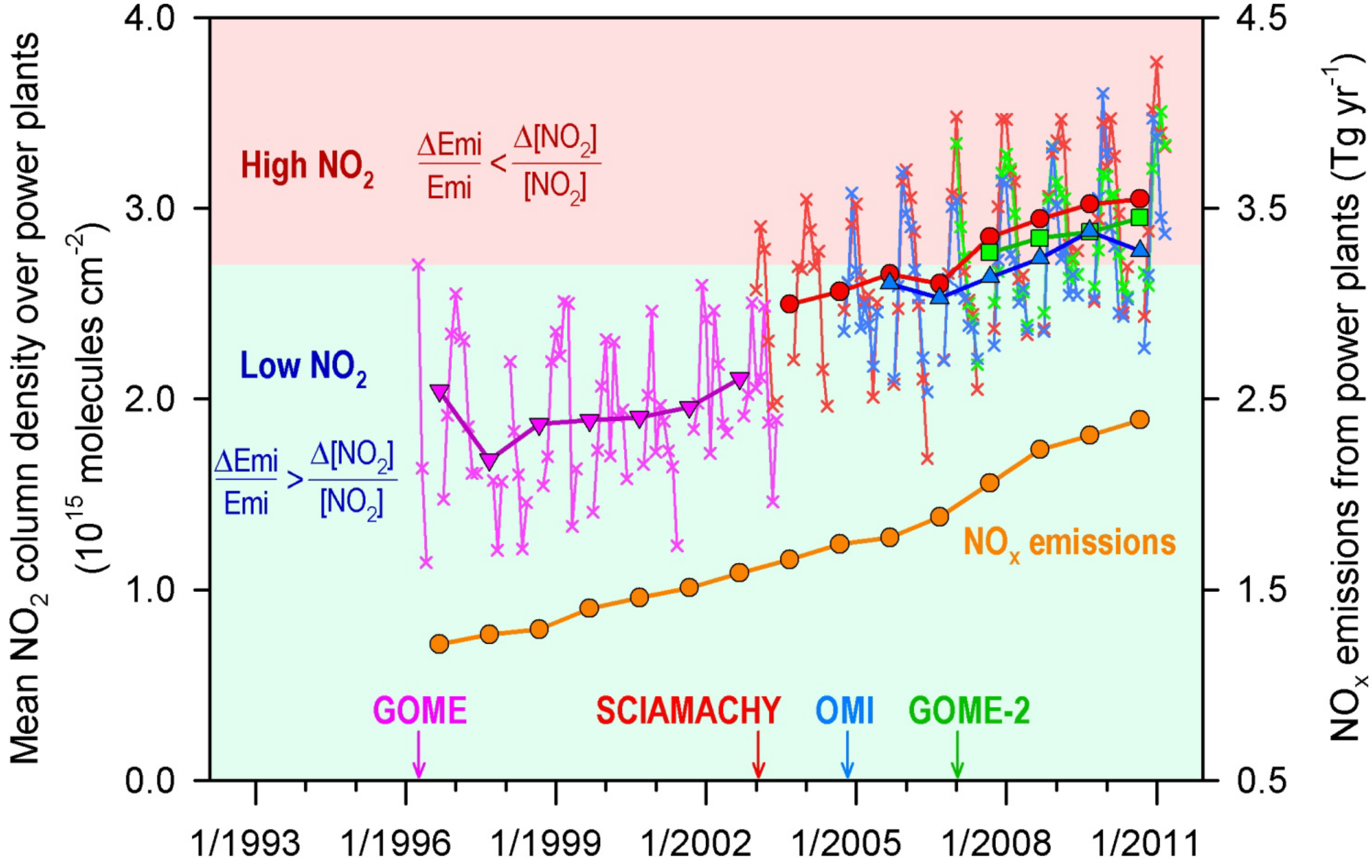


Graphic shows the spatial distribution of monthly mean tropospheric NO_2 from OMI during March 2005 – February 2011.

Data source: KNMI, DOMINO ver. 2.0, Level 3

Lu and Streets, EST, 2012

Satellite NO_2 trends for power plants are in good agreement with bottom-up NO_x inventory emission trends



Lu and Streets, EST, 2012

Satellite Retrievals and Emissions Estimation

Outline of review paper for Atmospheric Environment (~40 p) – heartily endorsed by Hanwant Singh

1 Introduction (0.5 p): AQAST, U.S. emission inventories, satellite retrievals
2 Satellites (1.5 p): platforms, instruments, and their characteristics
3 State-of-the-art of species observations (~15 p): retrieval methods, archived products, column maps, etc.
- 3.1 NO_2 (Krotkov)
- 3.2 SO_2 (Krotkov)
- 3.3 CO (Edwards, Pfister)
- 3.4 CH_4 (Jacob)
- 3.5 NMVOC (HCHO…) (Jacob)
- 3.6 NH_3 (Henze, Pinder)
- 3.7 PM (AOD …) (Liu)
- 3.8 Other (CO_2 …)

4 Applications for emissions estimation (~15 p)
- 4.1 Use of data assimilation, inverse methods, etc. (Henze, Carmichael)
- 4.2 Emission trends, updating (Martin, Lamsal)
- 4.3 Anthropogenic point sources (power plants, smelters, etc.)
- 4.4 Anthropogenic area sources (cities, rural areas, shipping, etc.)
- 4.5 Natural point sources (volcanoes)
- 4.6 Natural area sources (vegetation, fires, soil, lightning, etc.)
- 4.7 Field campaigns (DISCOVER AQ, etc.) (Dickerson, Krotkov)
- 4.8 Canadian, Mexican, other sources of pollution imported into the U.S. (de Foy)
- 4.9 Atmospheric lifetimes, other applications

5 U.S. emission inventories (~5 p)
- 5.1 Current status of satellite applications to constrain U.S. emissions
- 5.2 NEI and its uncertainty (EPA group)
- 5.3 Areas in which NEI could use improvement (EPA group)

6 Satellite retrievals and emission inventories (~3 p)
- 6.1 Most promising potential applications
- 6.2 Needs for future retrieval development