Use of Satellites in AQ Analysis and Emissions Improvement

Satellite Products for Air Quality Applications

- Particulate Pollution
  - True Color Imagery
  - Aerosol Optical Depth -all aerosol types
  - Aerosol Index- smoke, dust above PBL
  - Vertical Extinction Profiles – Ground and satellite based Lidars
- Trace Gases
  - NO_2, SO_2, CO
  - Methane
  - Formaldehyde

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Great but….how well do satellite data represent surface Air Quality ?

- RGB imagery – Visual aerosol representation of dust, industrial pollution, and smoke
- AOD good quantitative agreement with $PM_{2.5}$ over dark surfaces and the eastern US but it is a column measurement !
- Aerosol Index – qualitative representation of smoke and dust *above the PBL*
- NO_2 - good qualitative agreement for urban areas and large point sources (e.g. EGUs)
- SO_2 – large sources only, e.g. volcanoes (not for day to day variability)

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Tools for Data Access, Visualization and Analysis
(not a comprehensive list !)

- **Giovanni** (NASA/GSFC)
- **NEO** (NASA/GSFC)
- **AERONET Synergy Tool** (NASA/GSFC)
- **DataFed** (U. of Washington)
- **RSIG** (EPA)
- **VIEWS/TSS** (available soon, NASA Roses project to incorporate satellite data)

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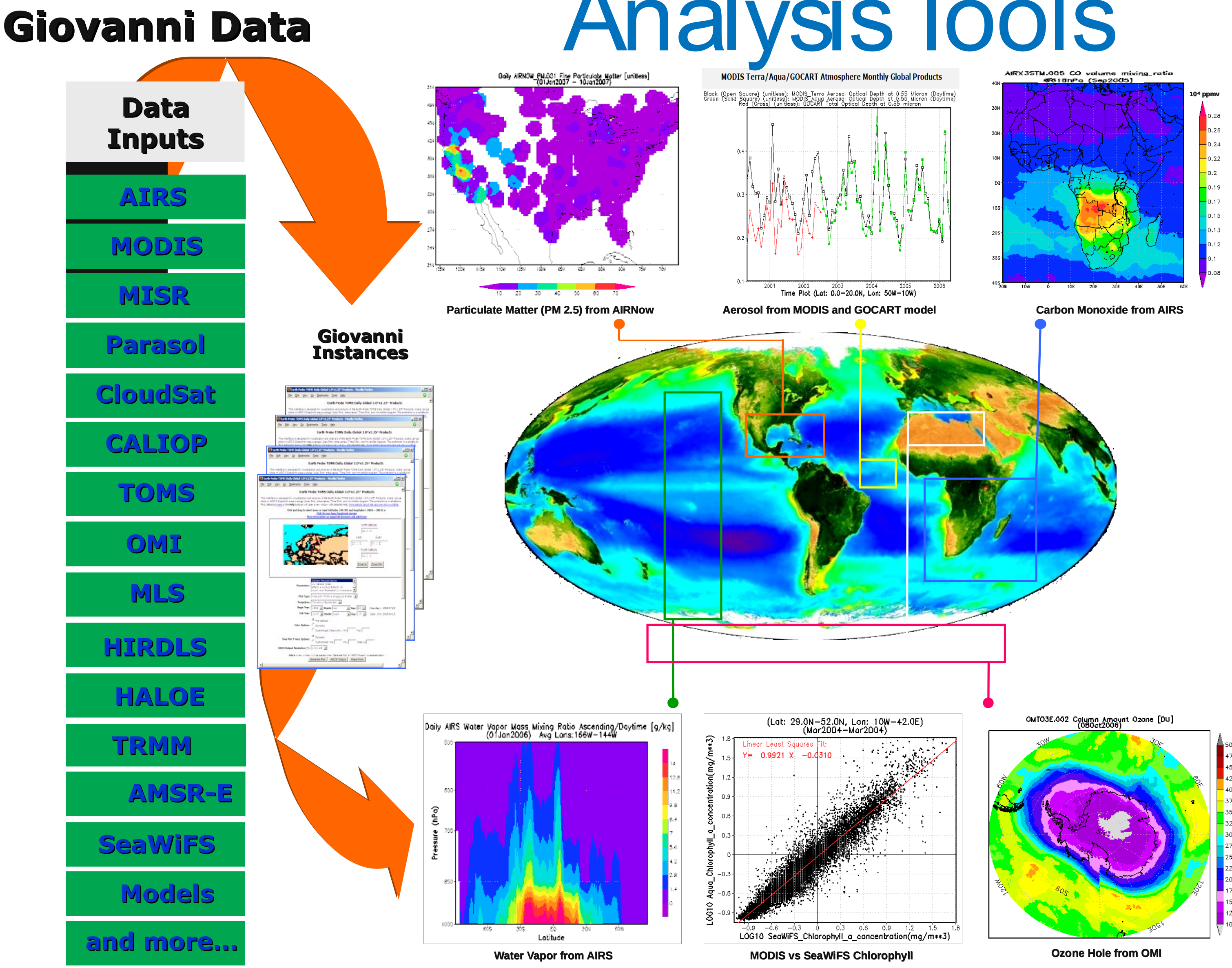
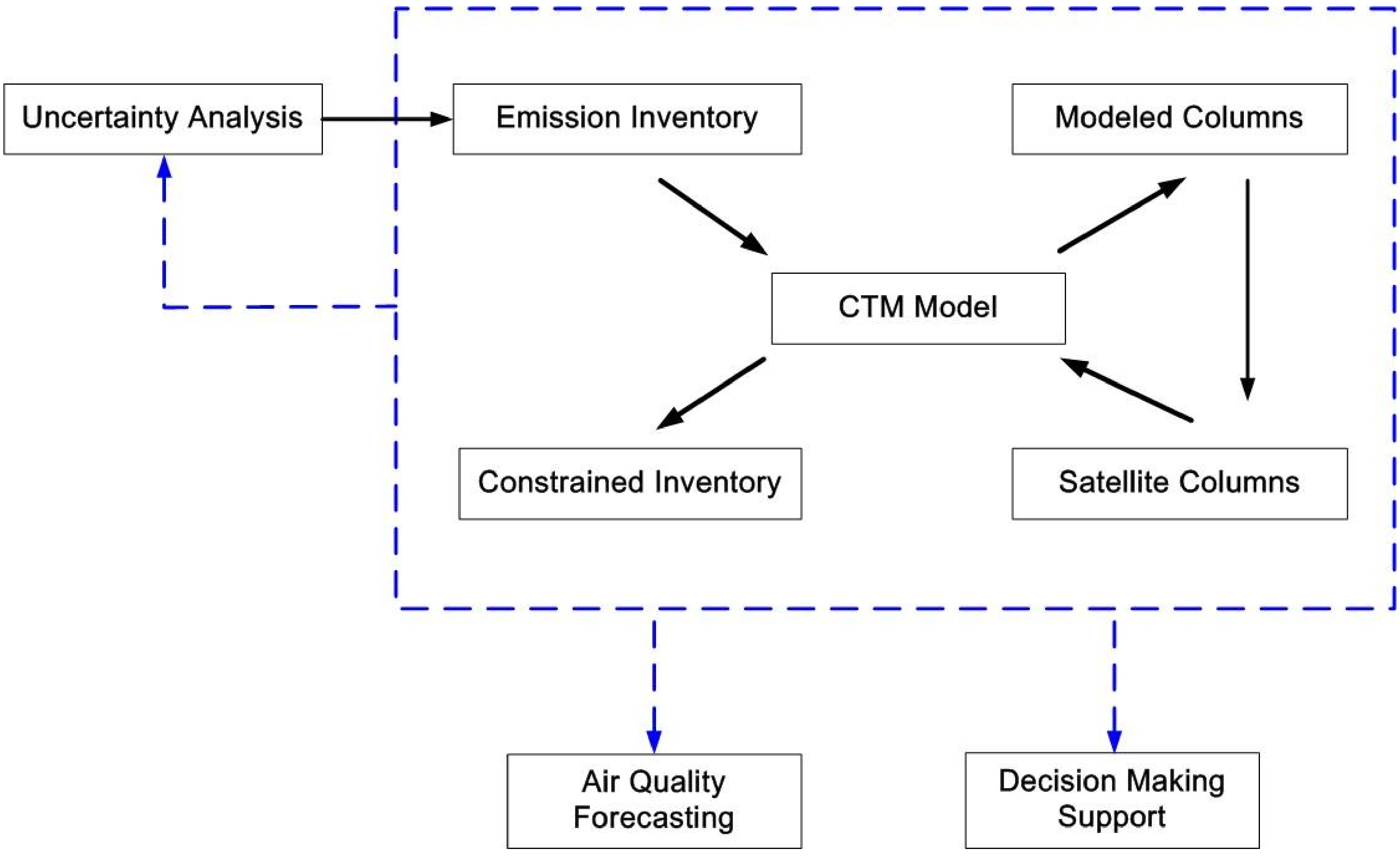
Analysis Tools

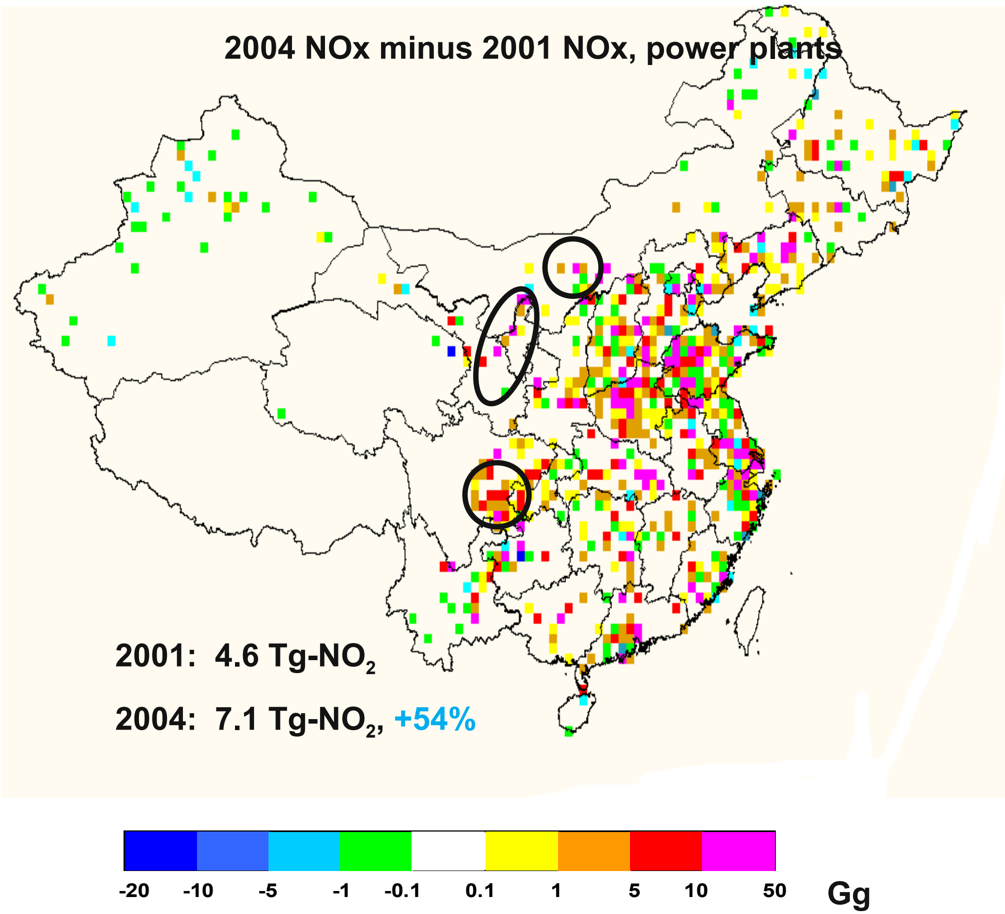


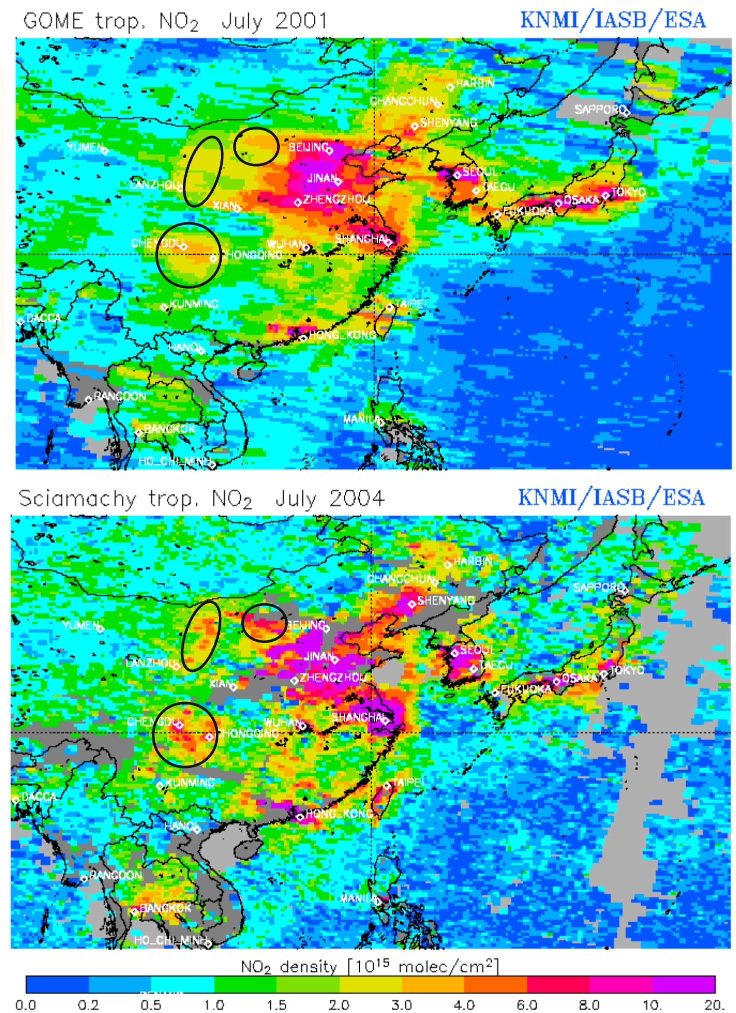
http://aerocenter.gsfc.nasa.gov/asrs

The project is designed to develop new approaches to integrate satellite data with chemical transport models and emission inventories for improved AQM

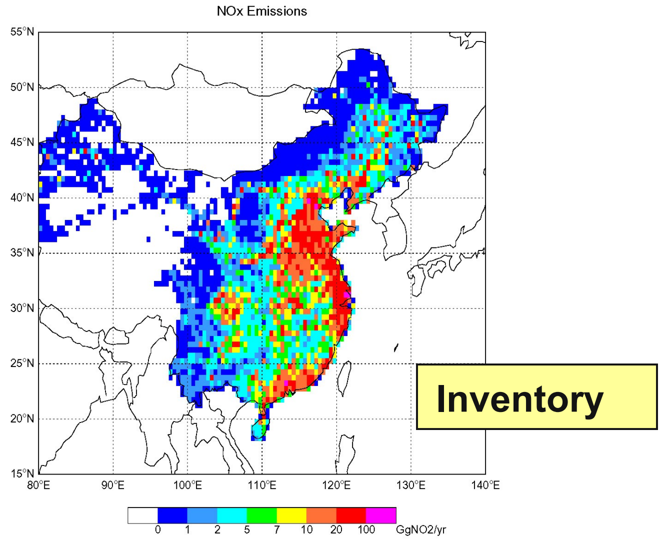


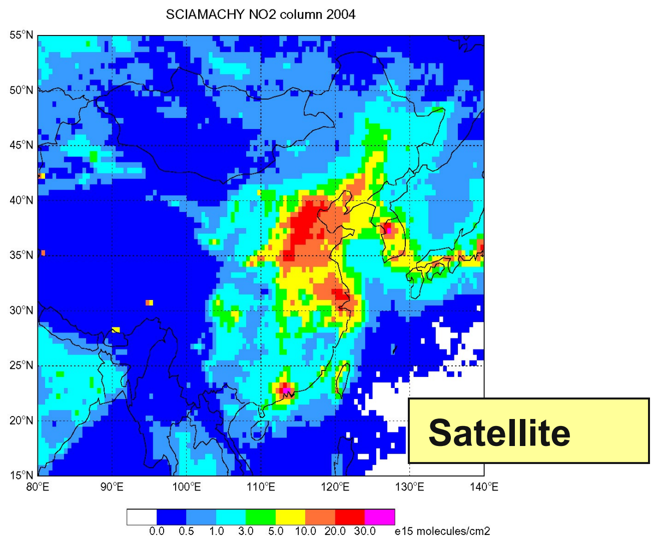
Satellites appeared to have observed new power-plant construction in China (2001-2004), through detection of their NOx emissions

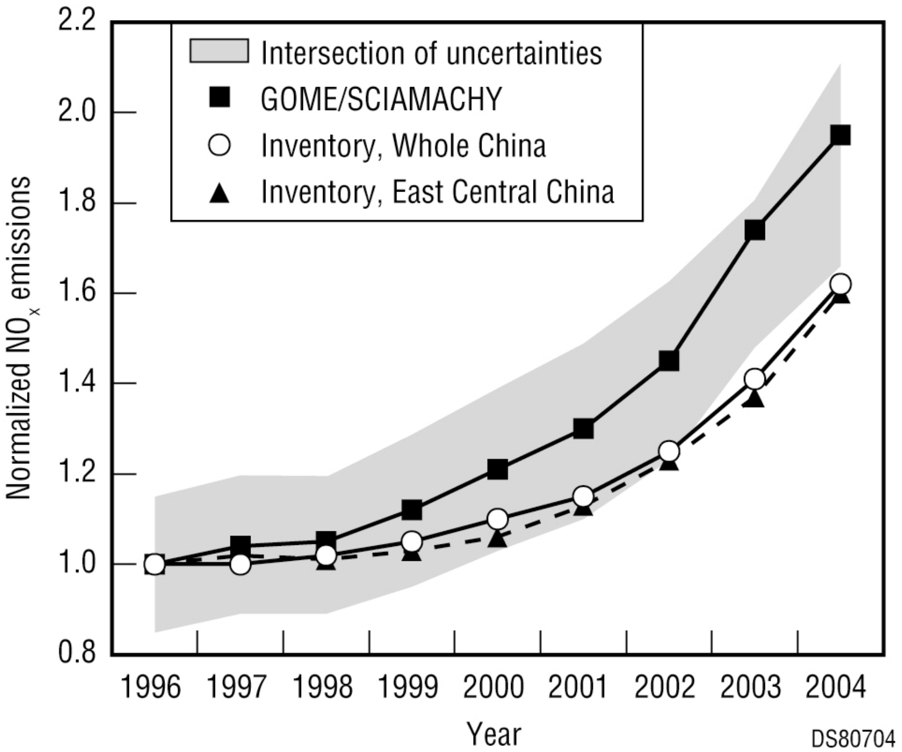




New bottom-up NOx emission inventory for China and comparison with satellite observations

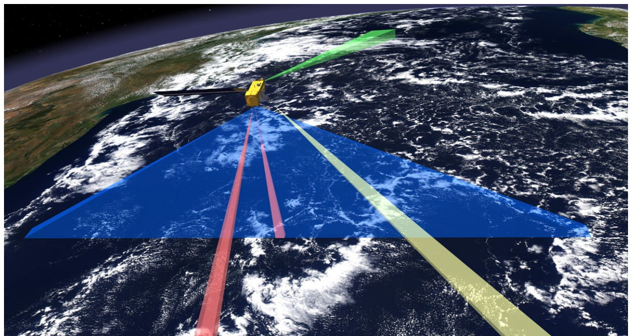


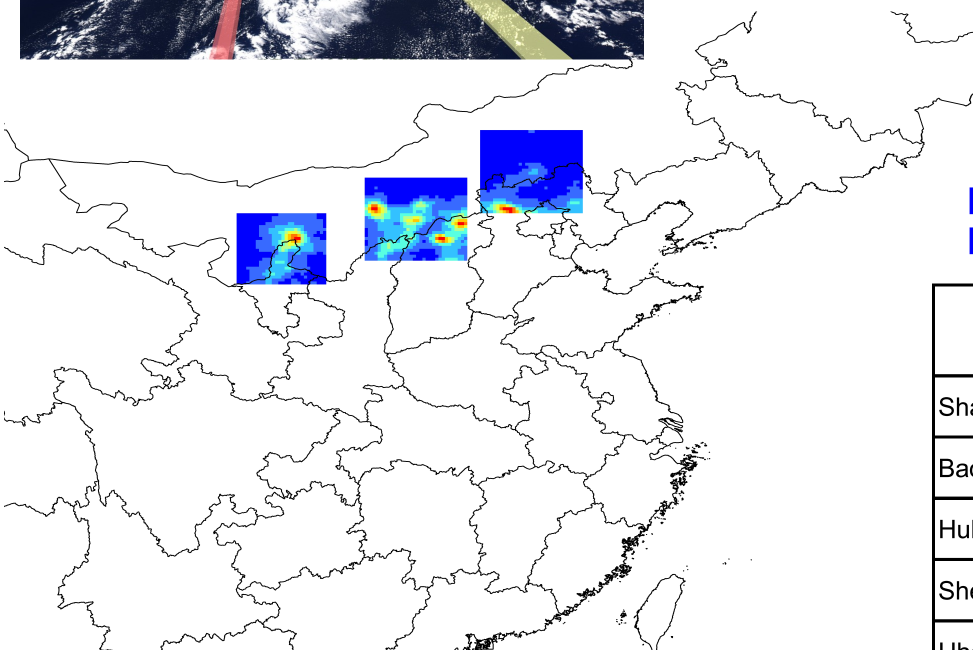




Zhang et al., JGR, 2007

We are exploring the potential of monitoring the change of power plant emissions in China from space





We selected Inner Mongolia for a case study

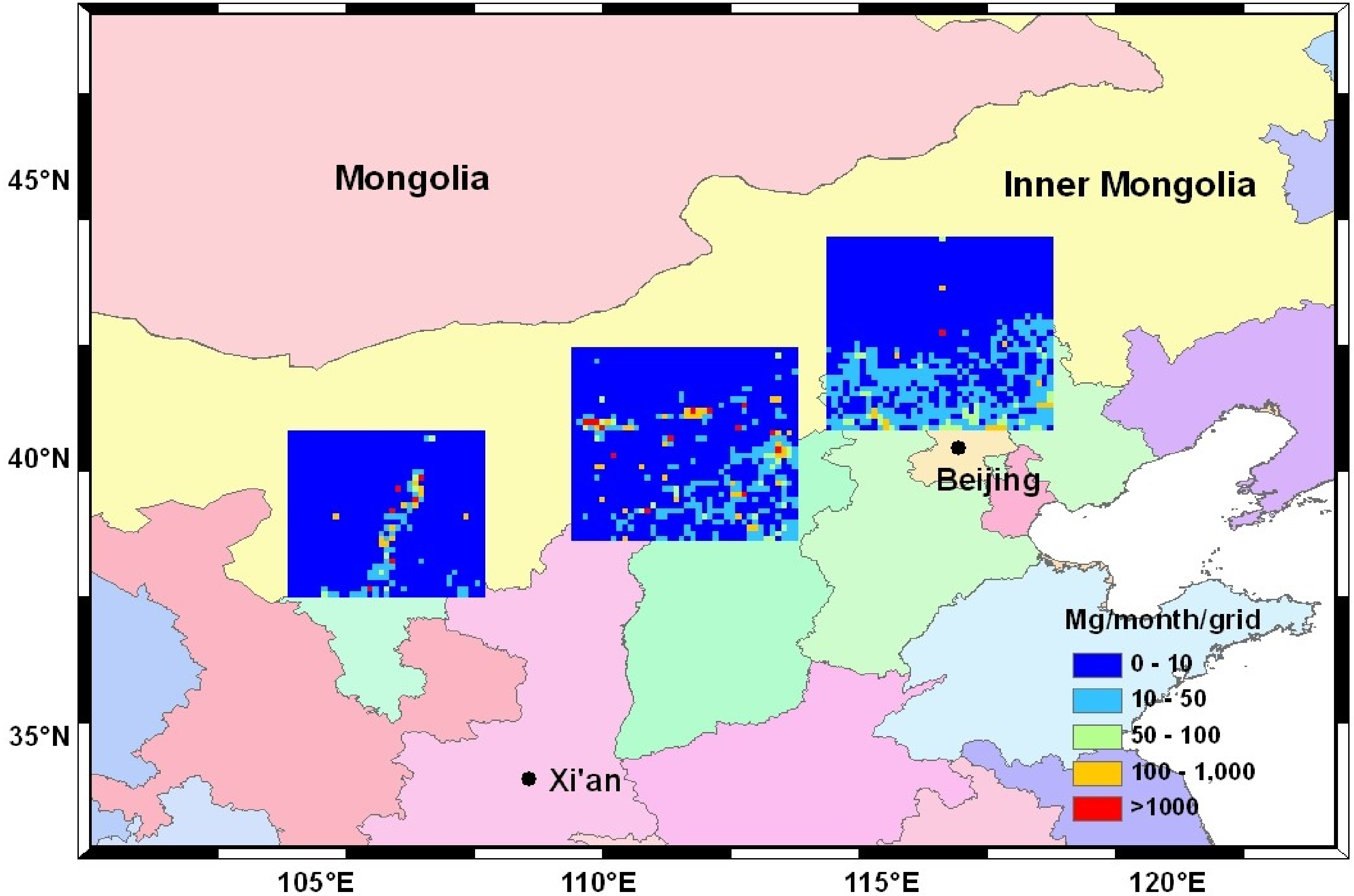
We compared the inventory and satellite data by pixel in the region where new power plants are located

Major new large power plants built in Inner Mongolia in 2006 and 2007

Power plant name	Capacity (MW)	Year of build	NOx emissions (ton/month)
Shangdu	1800	2006-2007	1726
Baotou power cluster	2825	2006-2007	3310
Huhehaote	2400	2005-2006	2803
Shenmu (in Shaanxi)	1200	2006-2007	1465
Uhai power cluster	1870	2005-2006	2610

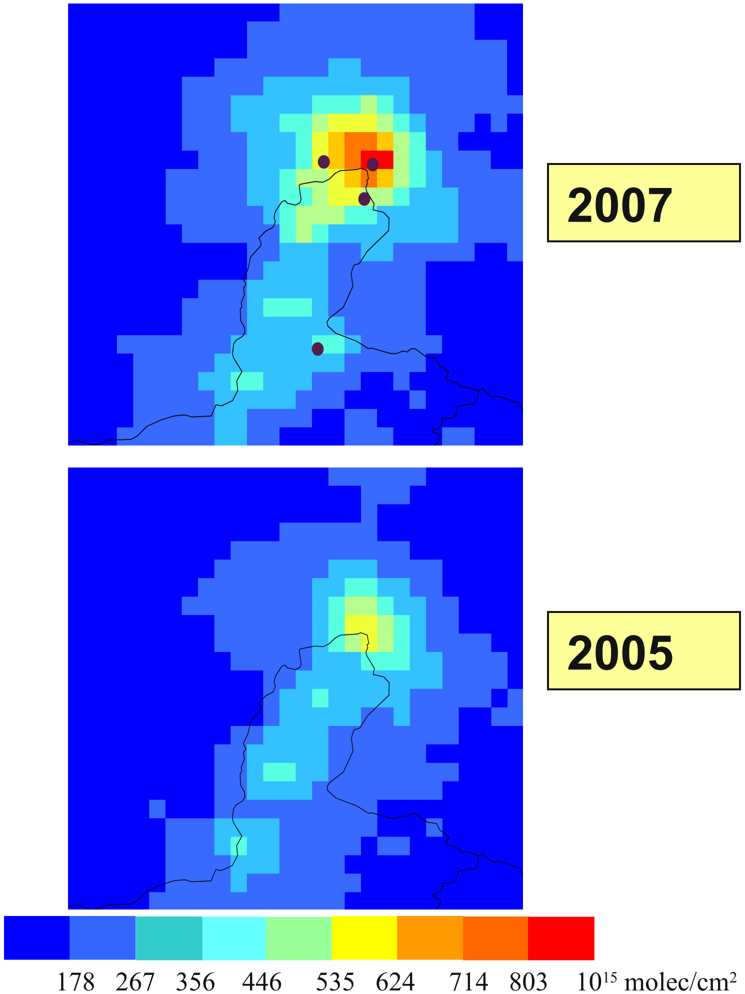
Streets et al.,

Three regions were selected for study

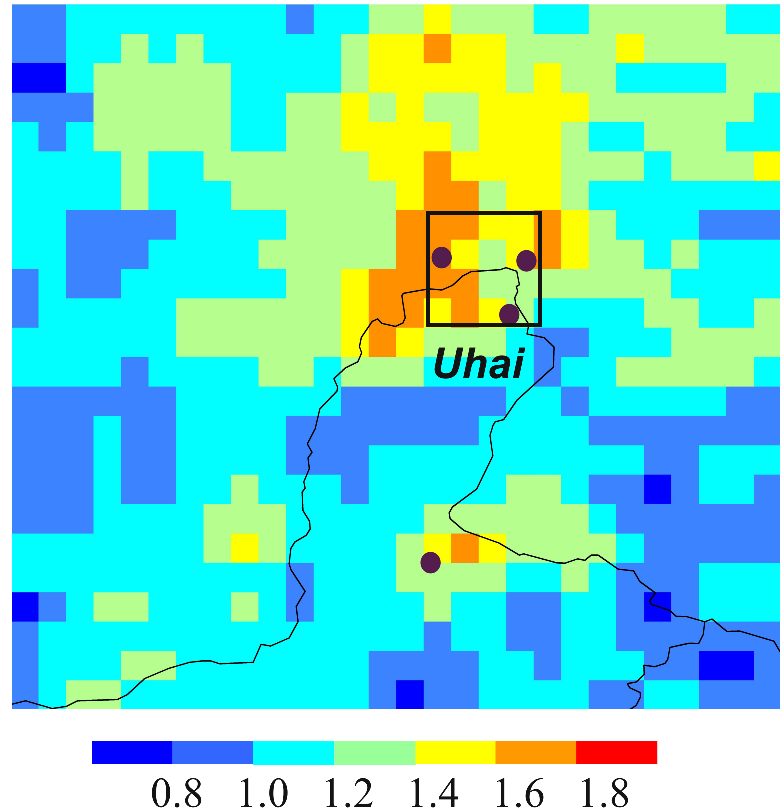


Streets et al.,

Satellite-observed NO_2 columns near new power plants (shown by ●) show significant increases between 2005 and 2007



OMI NO_2 columns

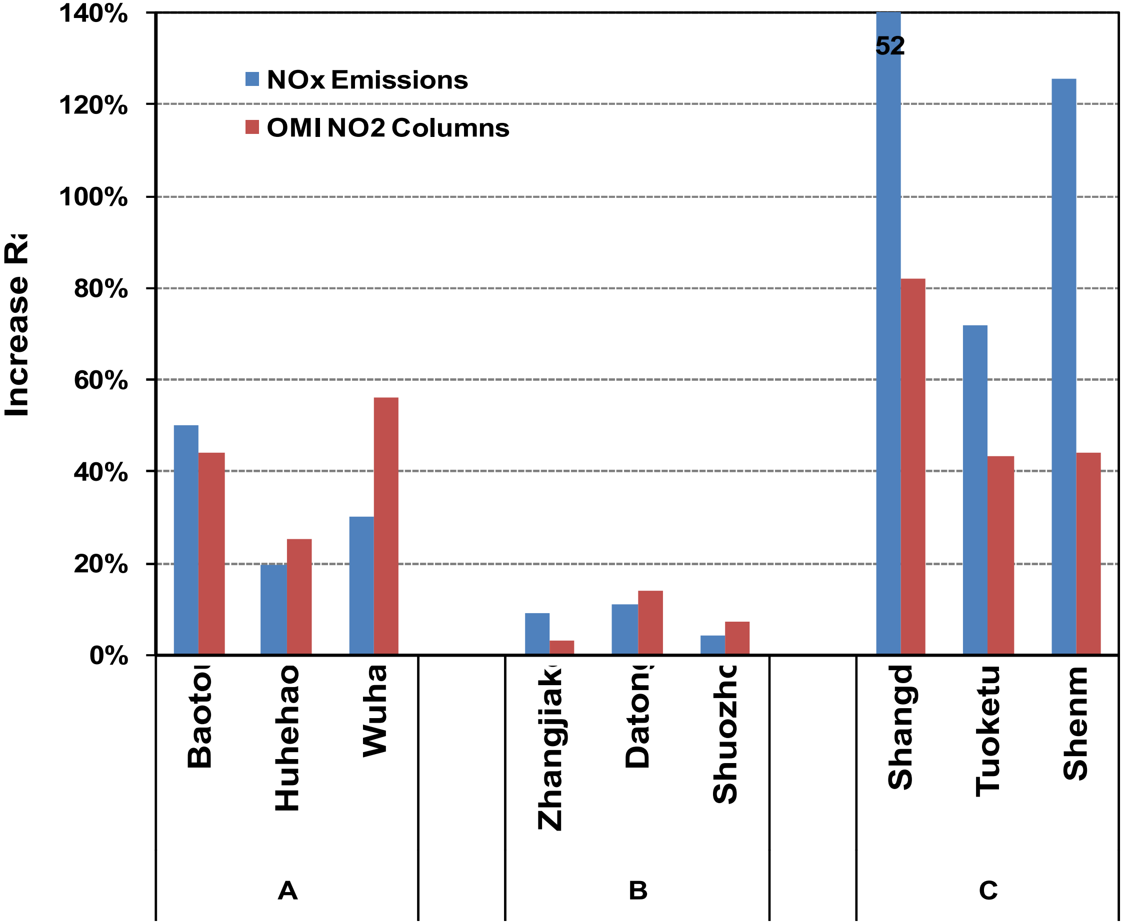


Ratio of OMI NO_2 columns between 2007 and 2005

[pixel size = 0.125°(~12 km)]

Streets et al.,

Changes in NO_x emissions and NO_2 columns, 2005-2007



A = urban regions with new power plants

B = urban regions with no new power plants

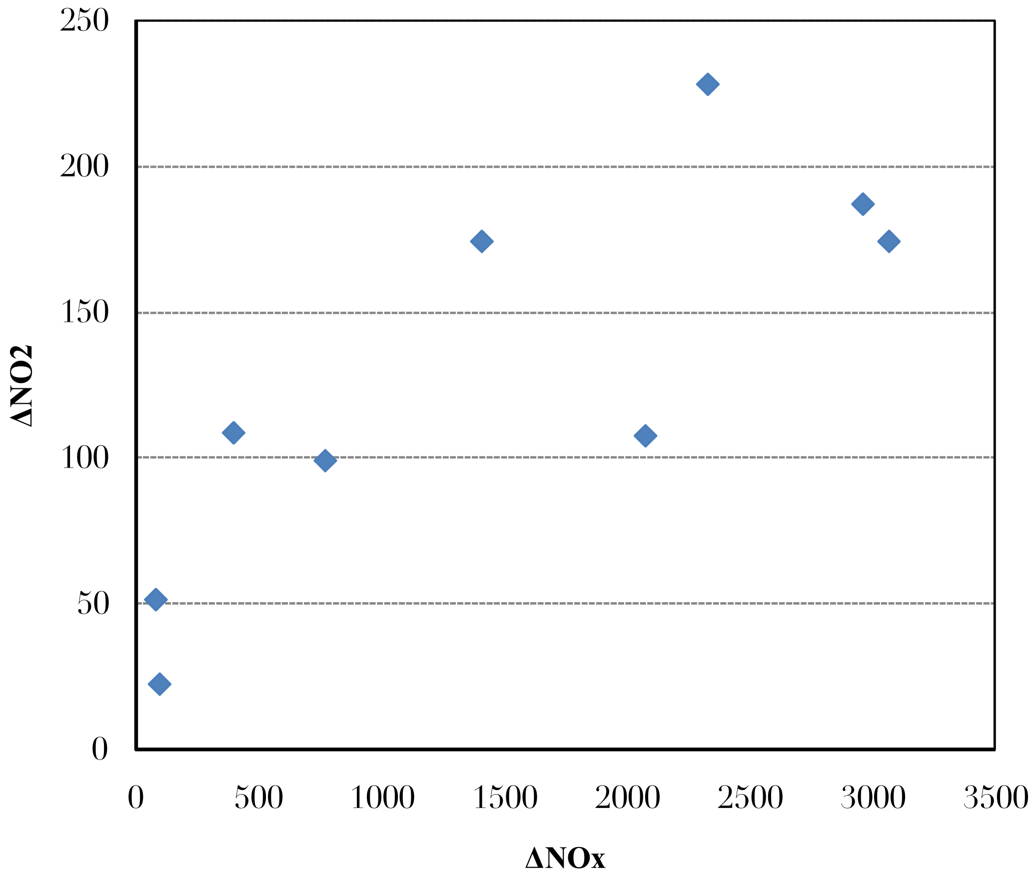
C = rural regions with new power plants

(each region is 0.5 deg x 0.5 deg, containing 16 OMI pixels)

The increase rates of NO_x emissions and NO_2 columns agree quite well in the urban regions. In the rural regions where emissions from power plants are dominant, NO_x emissions show a larger increase rate than NO_2 columns. This is probably due to absence of dispersed NO_2 in rural areas in 2005 in the inventory.

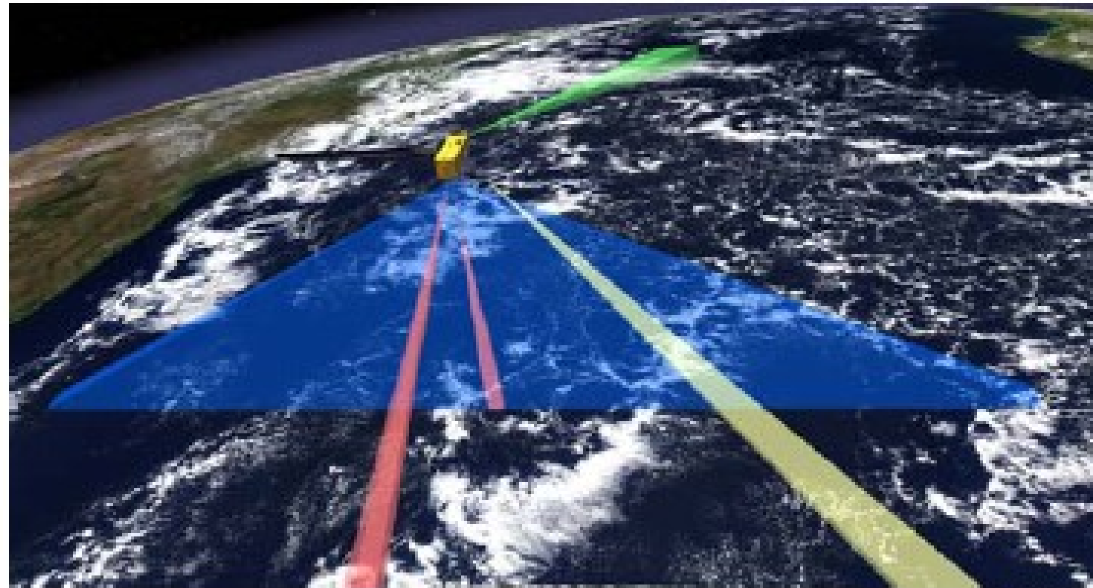
Streets et al.,

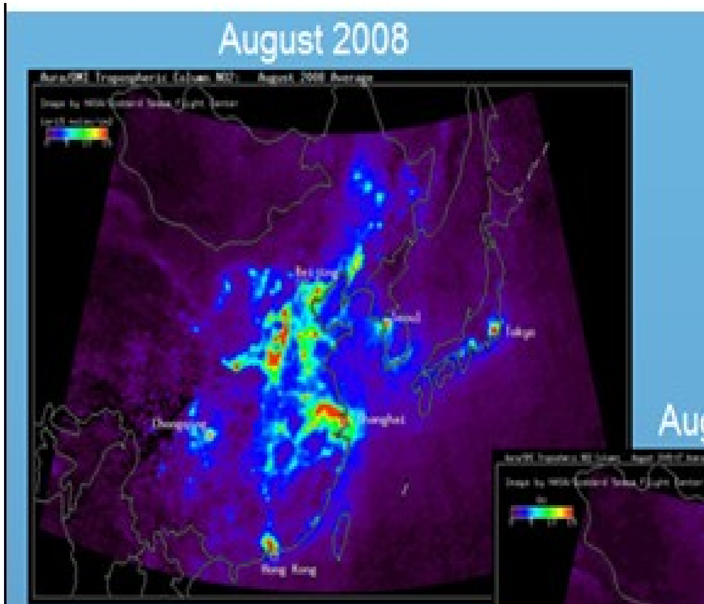
A simple plot of changes in emissions vs columns is not great

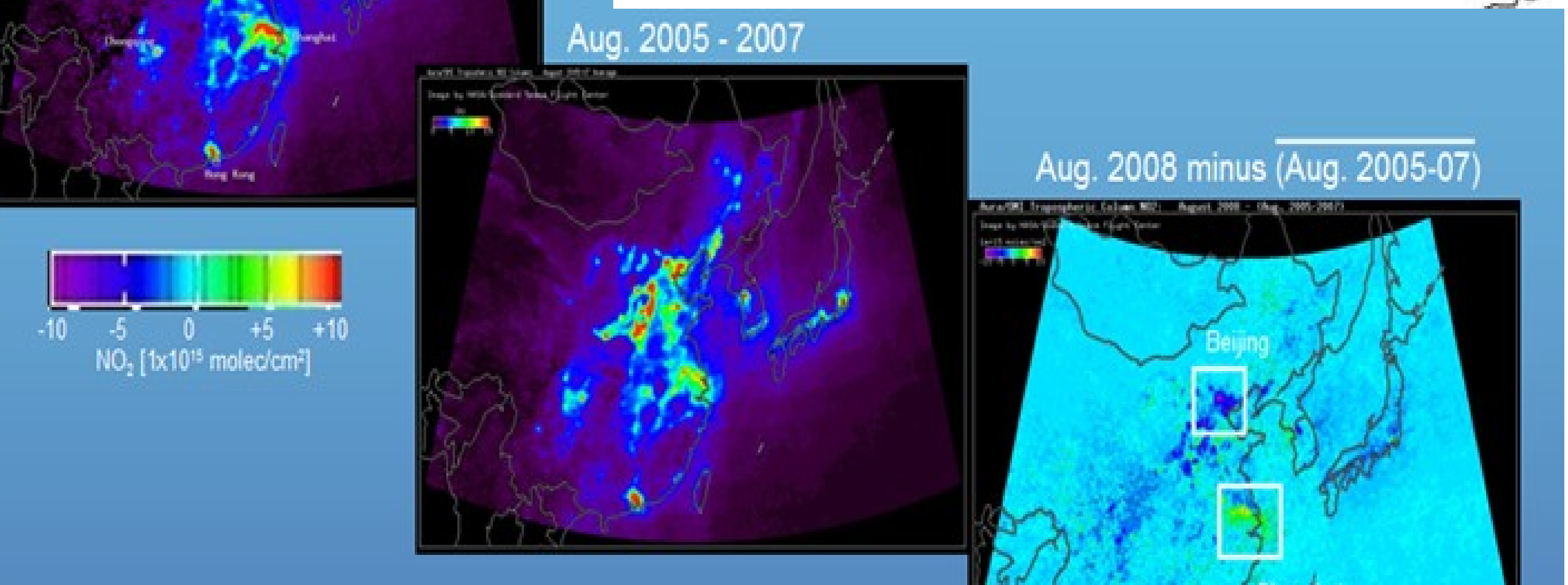


Streets et al.,

Satellite Detection of Emissions (OMI)

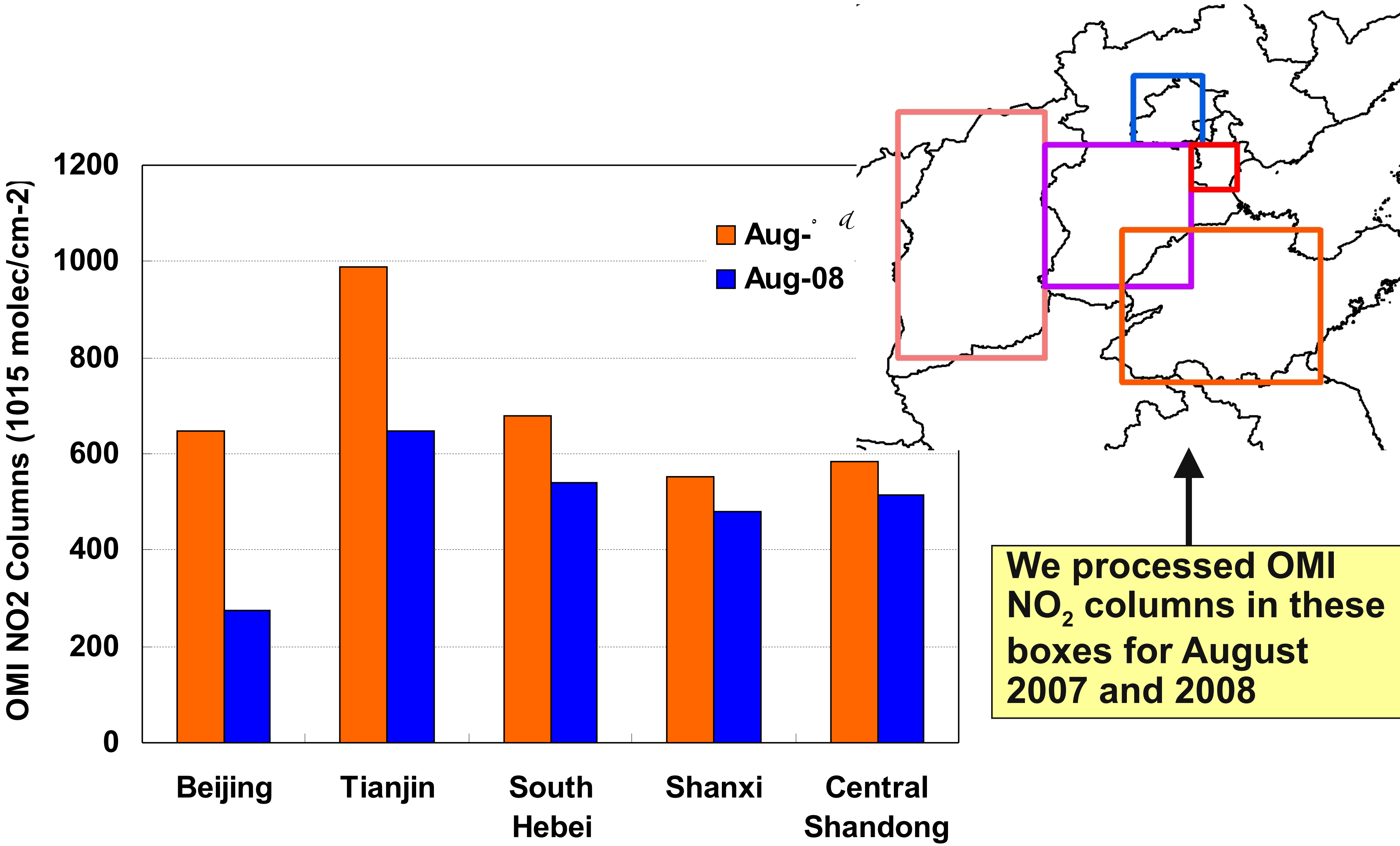






NASA Applied Science
Witte et al., NASA GODDARD

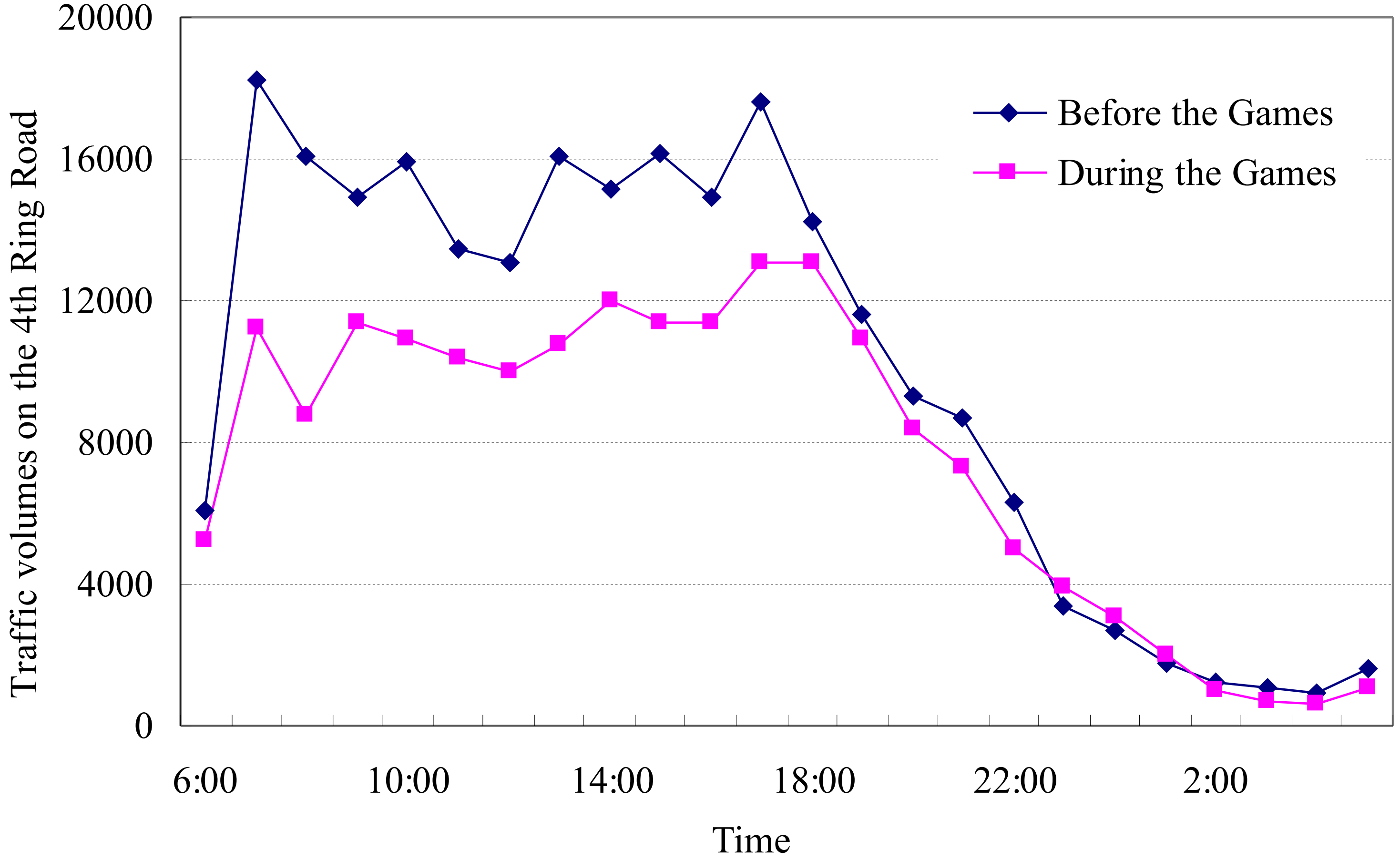
NO$_2$ decreases were observed in Beijing as well as all its neighboring provinces



We processed OMI NO$_2$ columns in these boxes for August 2007 and 2008

Streets et al.,

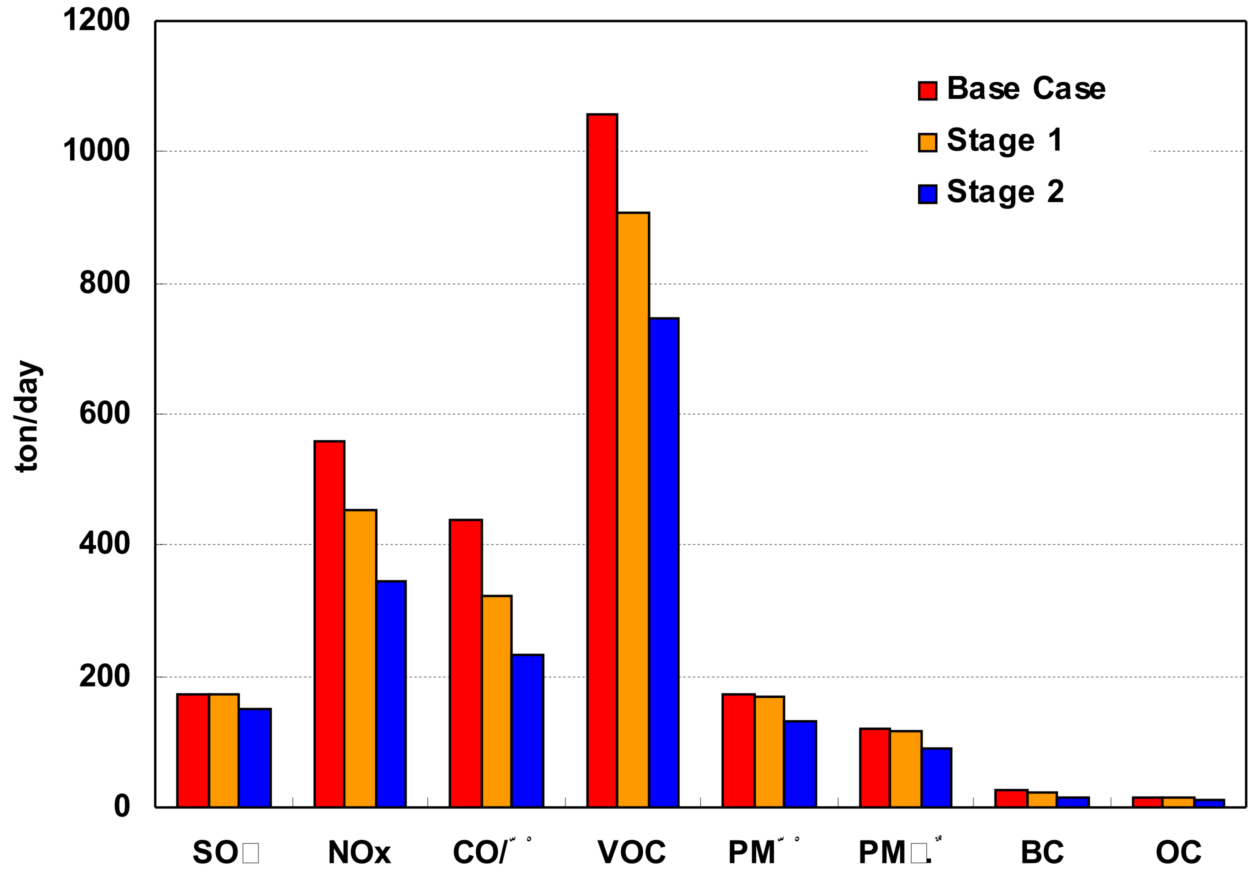
Traffic flow was monitored before and after the Olympic Games. Average speeds increased from 20.3 km/hr to 26.1 km/hr



Traffic volume decreased by about 24%

Streets et al.,

Daily emissions during the Beijing Olympic Games have been prepared by Argonne and Tsinghua for use in CTM modeling



Base Case: Before July 1

Stage 1 controls: July 1-20

Stage 2 controls: After July 20

Streets et al.,

OMI Satellite Analysis of NO2 And SO2 Columns Were Able To Detect The Emission Changes

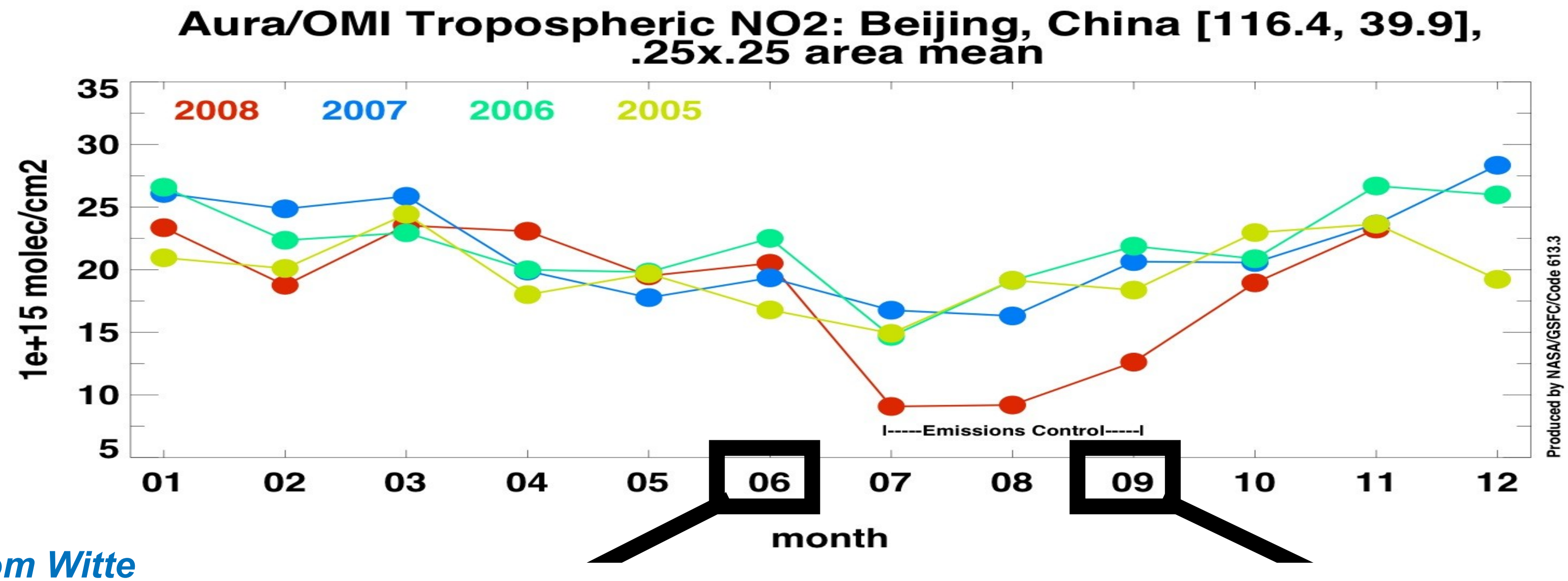


Figure from Witte et al., 2008.

Over what scales can we detect the signal? To what extent can we attribute the signal to emissions vs meteorology?

In AQ Predictions Emissions Are A Major Source Of Uncertainty – Data Assimilation Can Produce Optimal Estimates (Inverse Applications)

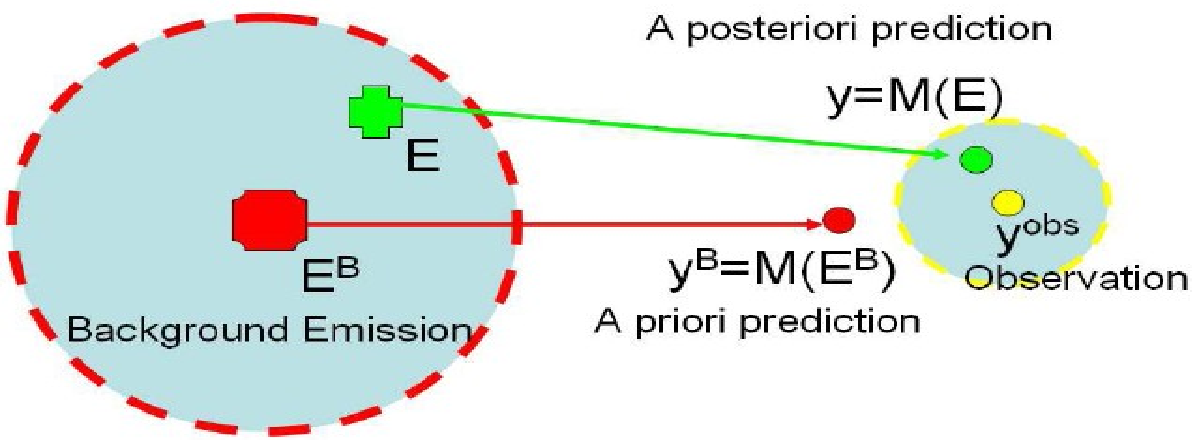


Fig. 14. A-basic methodology of top-down estimates of emissions.

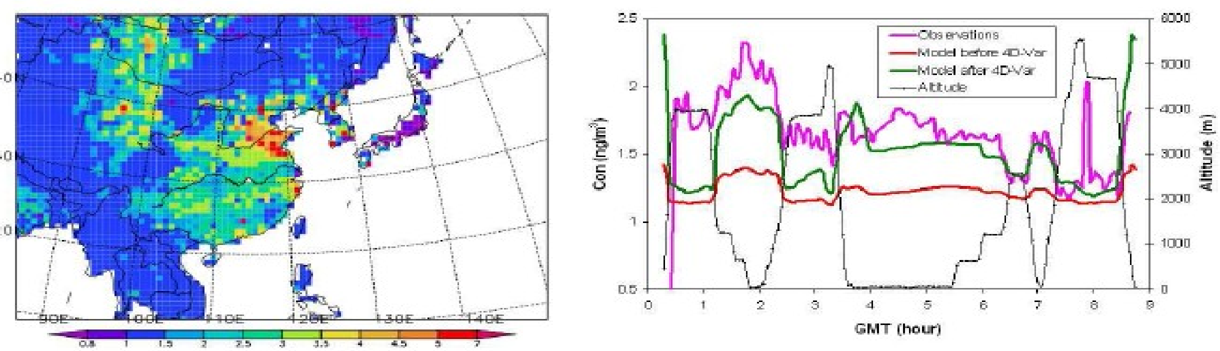


Fig. 15. Optimal mercury emission scaling factors obtained using the 4D-Var approach and the mercury measurements on board the C-130 during the Ace-Asia experiment. Results are for a month-long assimilation window (April 2001).

Li et al., Atmos. Env., 2007

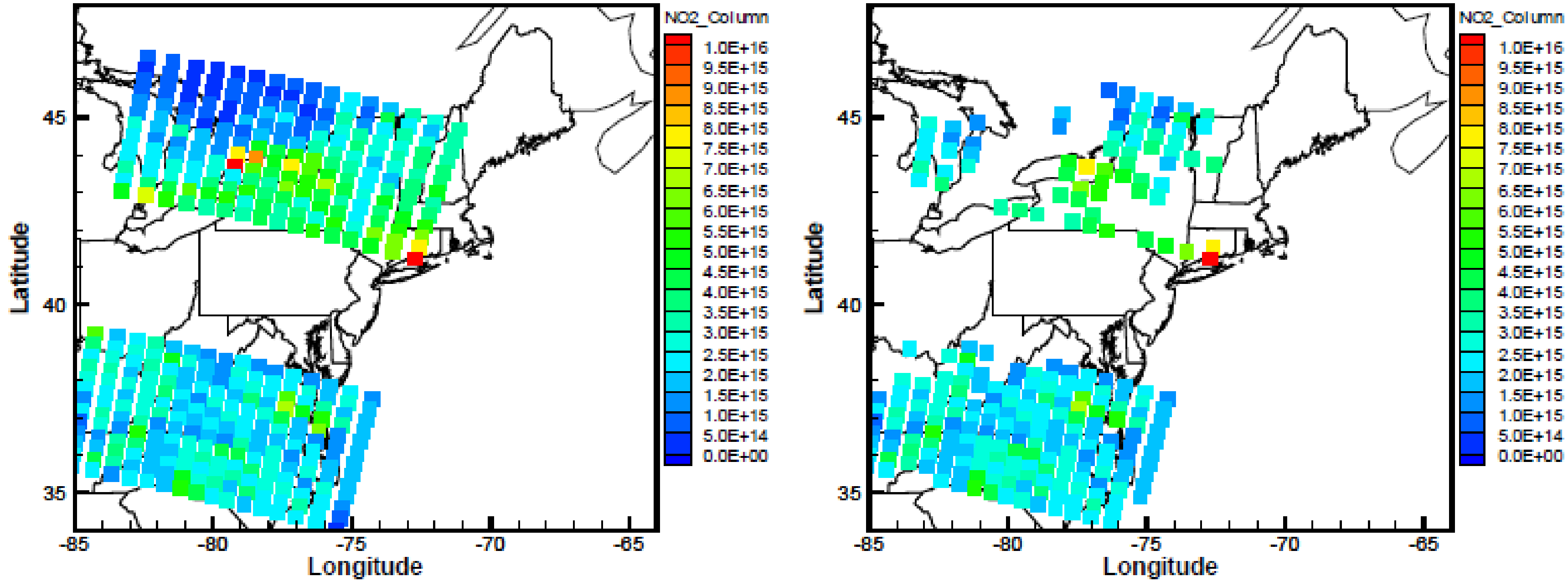


Figure 1: SCIAMACHY NO_2 columns on July 20, 2004. Unit: molecules/cm^2. Original data shown on the left (a); data with the normalized intensity less than 0.15 shown on the right (b).

Chai et al., AE, 2009

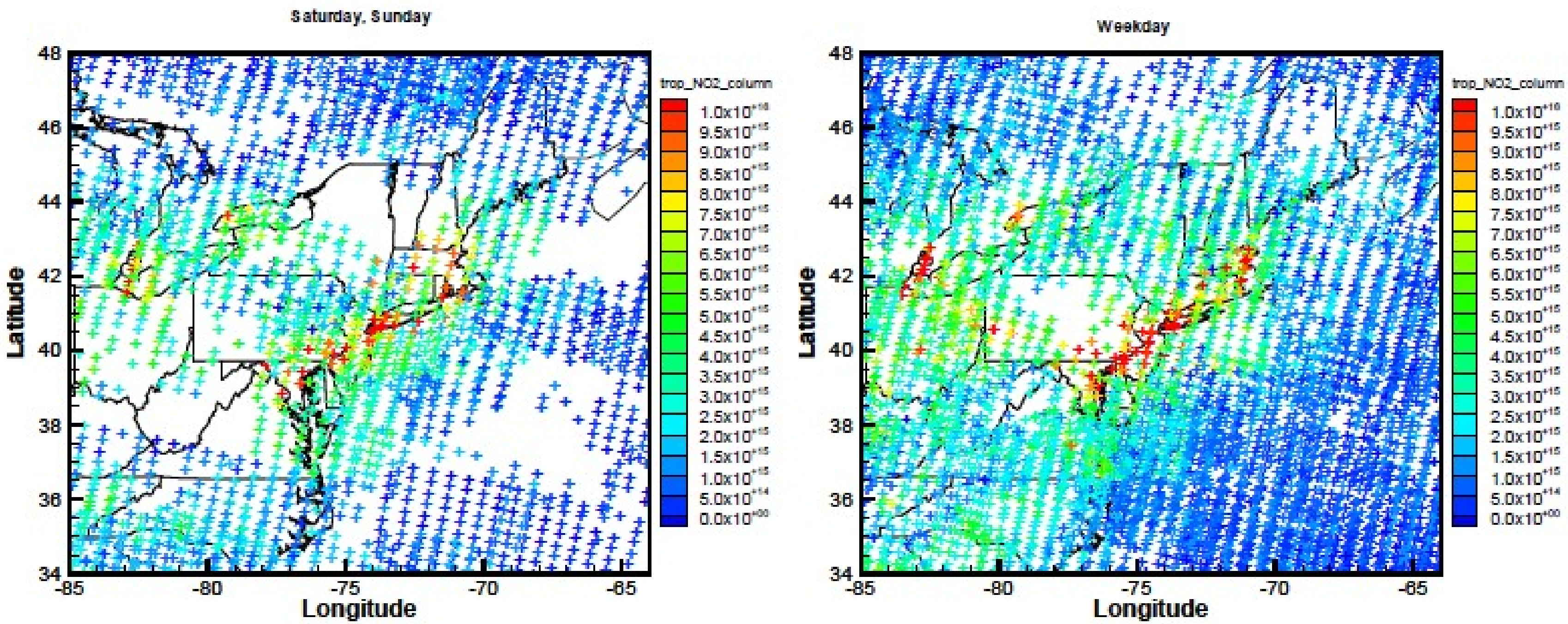


Figure 2: SCIAMACHY NO_2 columns from July 1 to August 31, 2004. Unit: molecules/cm^2. Left: accumulated data during the weekends. Right: accumulated data during the weekdays.

Chai et al., AE, 2009

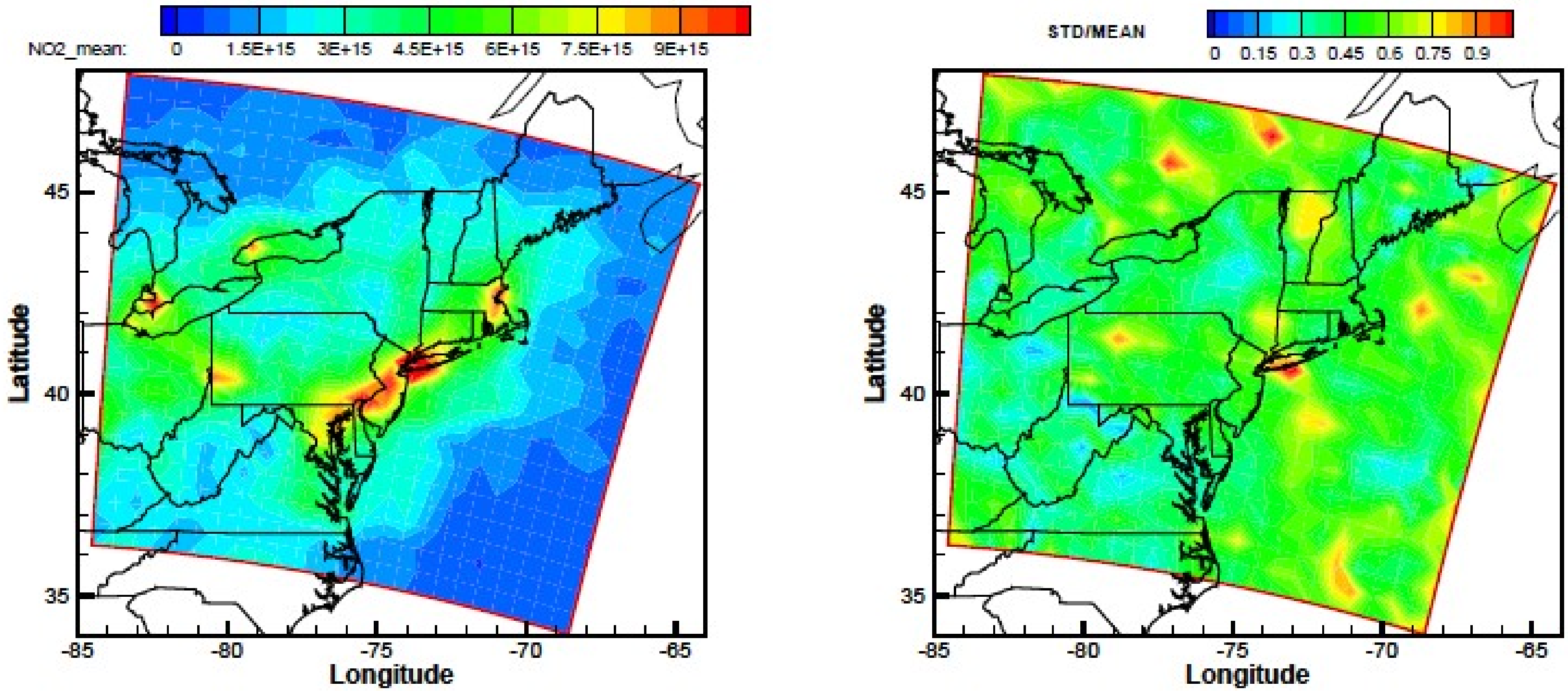
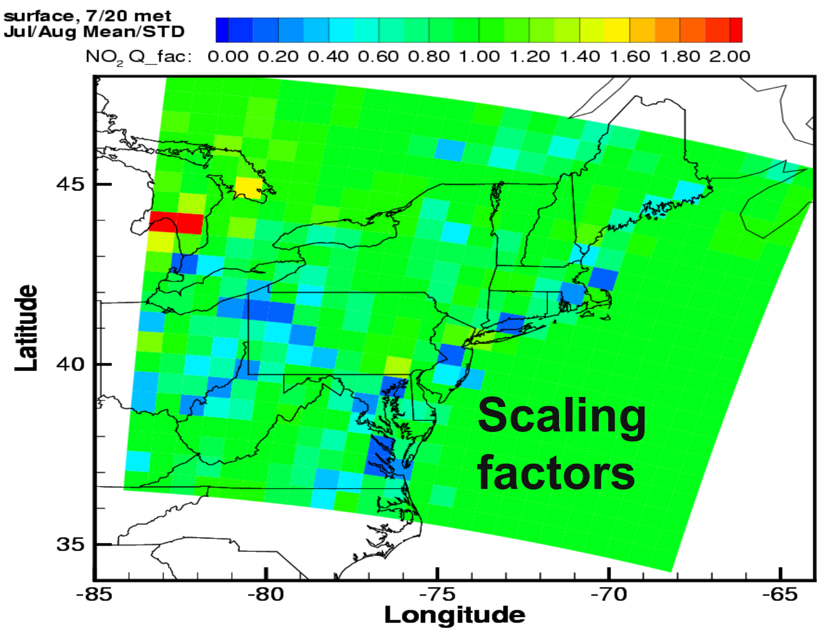
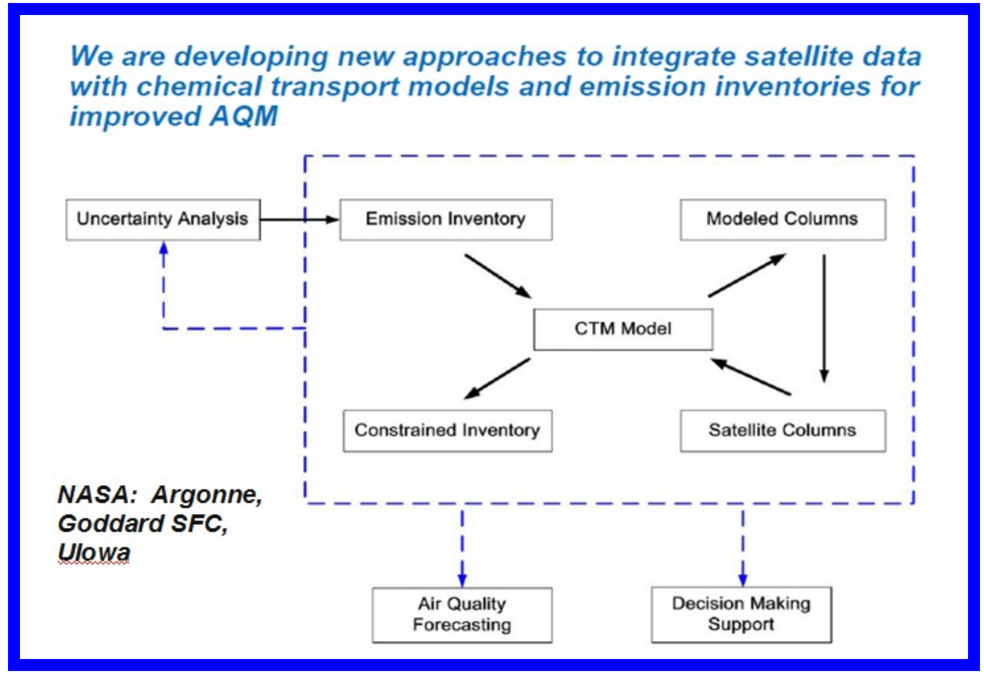


Figure 3: Mean (left, Unit: molecules/cm^2) and normalized standard deviation (right, STD/mean) of SCIAMACHY NO_2 columns from July 1 to August 31, 2004.

Chai et al., AE, 2009

Rapid Updates of Emissions Are Needed





4D-Var setup:

Time window:

July , 2004

Control:

Initial ozone, and NOx emissions

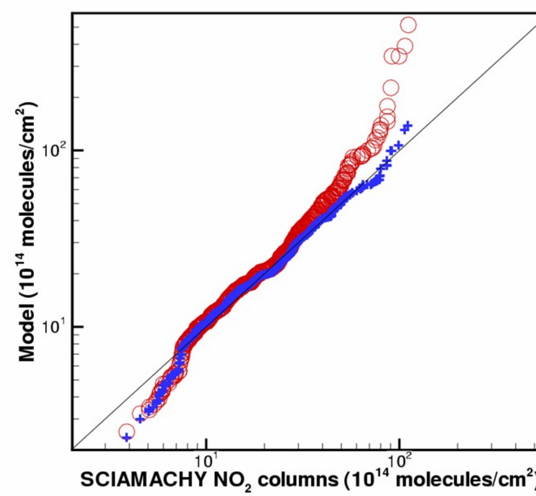
Observations:

Ozone from different platforms, and SCIAMACHY tropospheric NO_2 columns

Emission changes over domain (ratio of new emission over NEI01)

Case	Surface (level 1)	Elevated (2 & above)	Total (all levels)
1 E only	0.934	0.849	0.920
2 E & IC	0.928	0.881	0.908
"OI"	1.318	1.030	1.246

Quantile-quantile plot

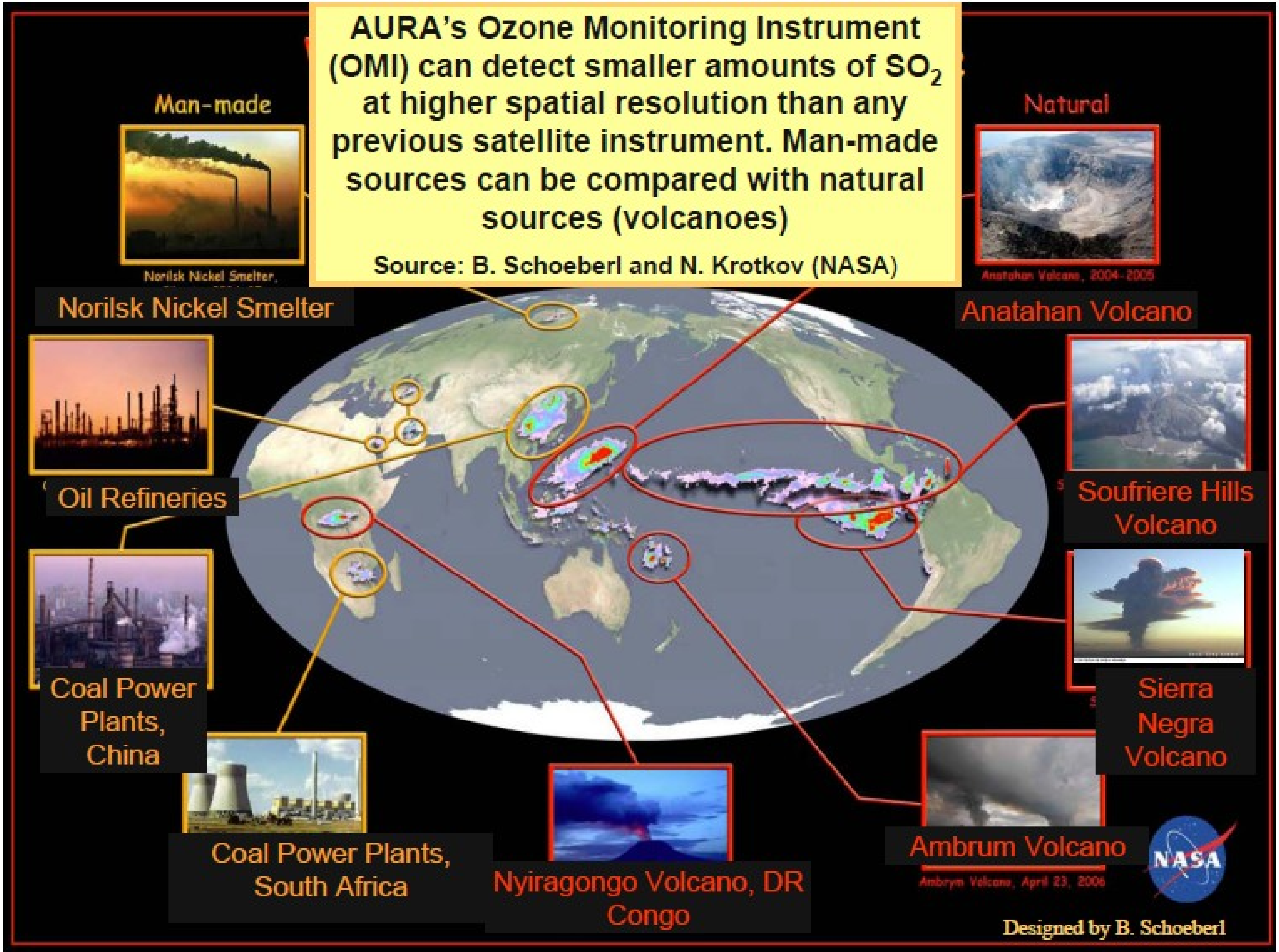


Blue:

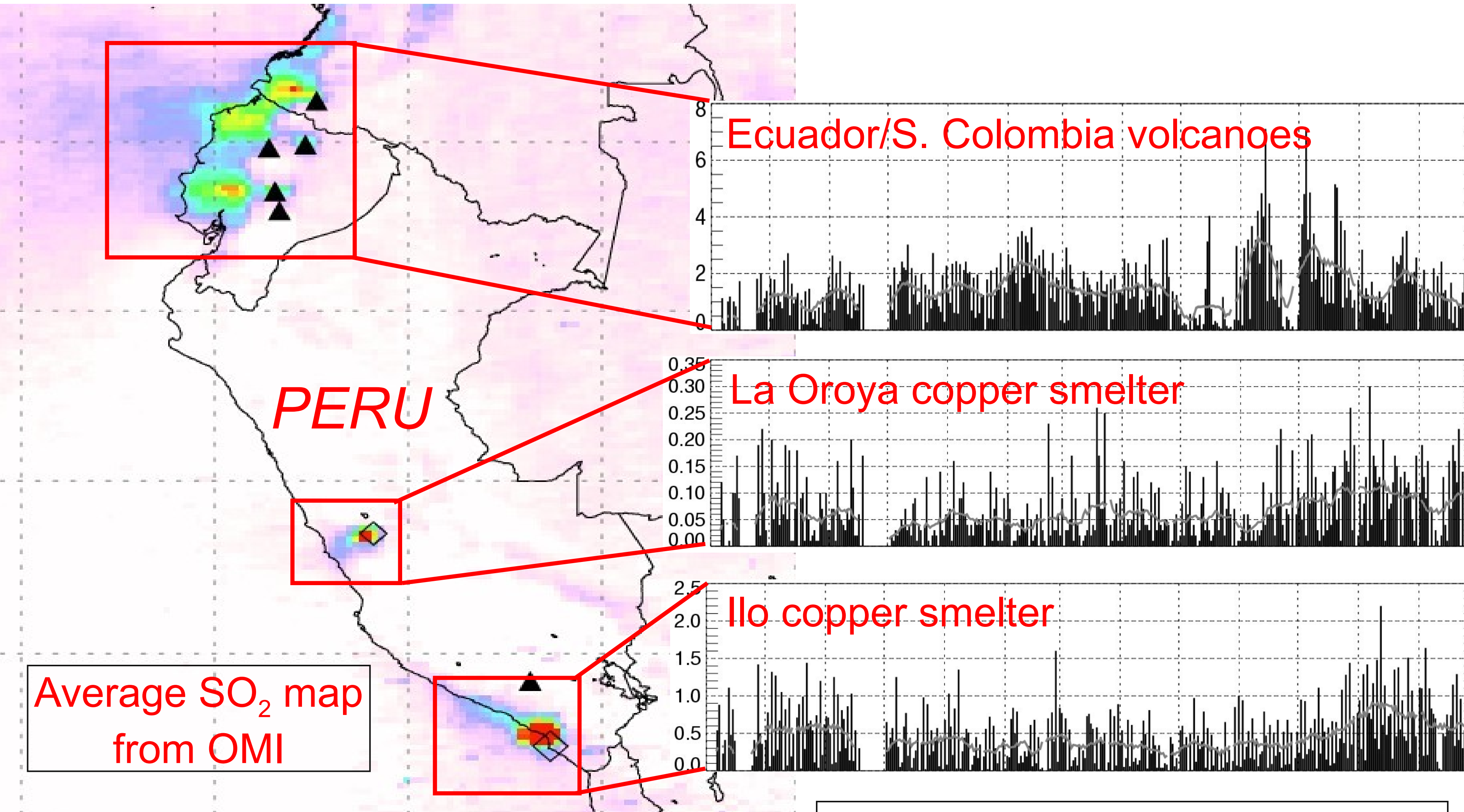
After NOx Emission adjustmentent

Red:

Before NOx Emission adjustmenter


AURA's Ozone Monitoring Instrument (OMI) can detect smaller amounts of SO_2 at higher spatial resolution than any previous satellite instrument. Man-made sources can be compared with natural sources (volcanoes)
Source: B. Schoeberl and N. Krotkov (NASA)
Man-made
Natural
Norilsk Nickel Smelter,
Norilsk Nickel Smelter
Anatahan Volcano, 2004-2005
Anatahan Volcano
Oil Refineries
Soufriere Hills Volcano
Coal Power Plants, China
Sierra Negra Volcano
Coal Power Plants, South Africa
Nyiragongo Volcano, DR Congo
Ambrum Volcano
Ambrym Volcano, April 23, 2006
NASA
Designed by B. Schoeberl

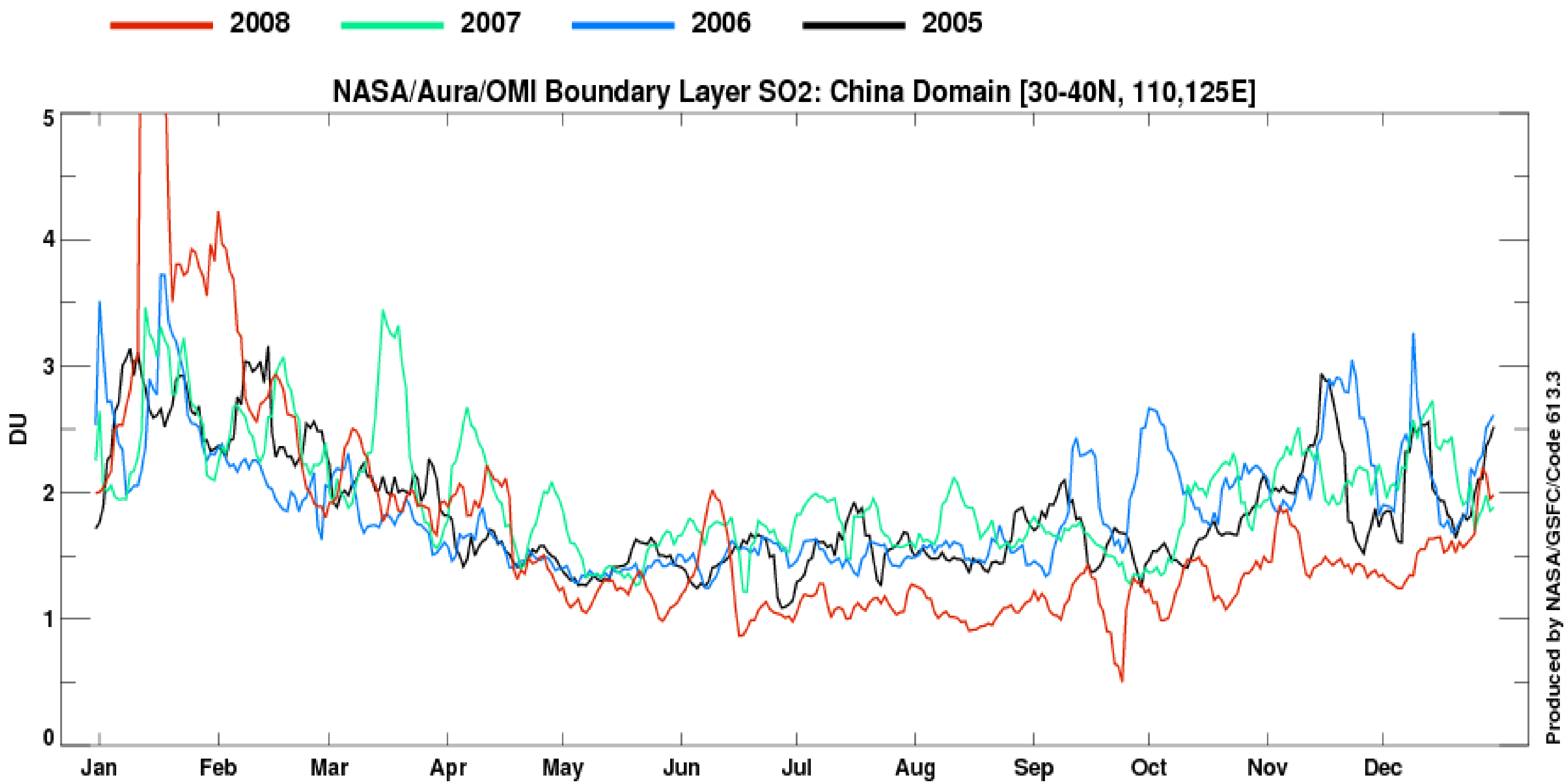
OMI measures SO_2 emissions in South America



Daily SO_2 emissions (kilotons) Sept 2004 - Sept 2005

Carn, S.A., N.A. Krotkov, A.J. Krueger, K. Yang, P.F. Levelt, "Sulfur dioxide emissions from Peruvian copper smelters detected by the OMI", GRL, 2007.

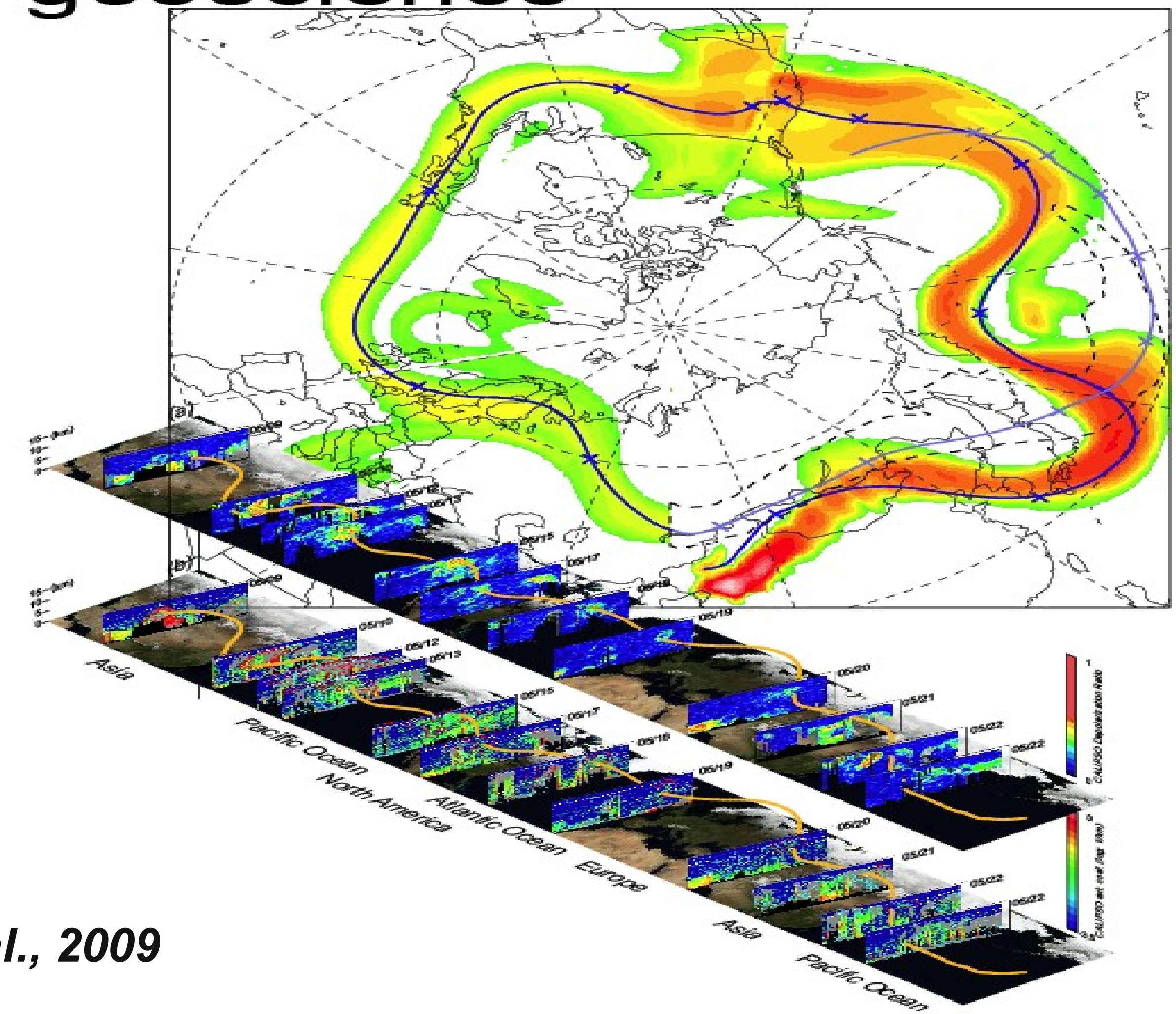
A Few Surprises SO2 Columns



Krotkov et al., NASA GODDARD

Through Better Models and Observations We Can Better Quantify The Long Reach Of Pollutant Transport

nature
geoscience



Uno et al., 2009