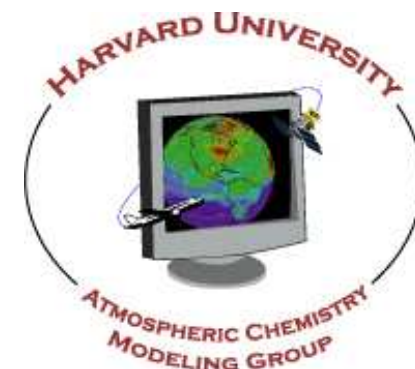
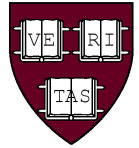


# Concurrent measurements of tropospheric NO<sub>2</sub> from OMI and SCIAMACHY

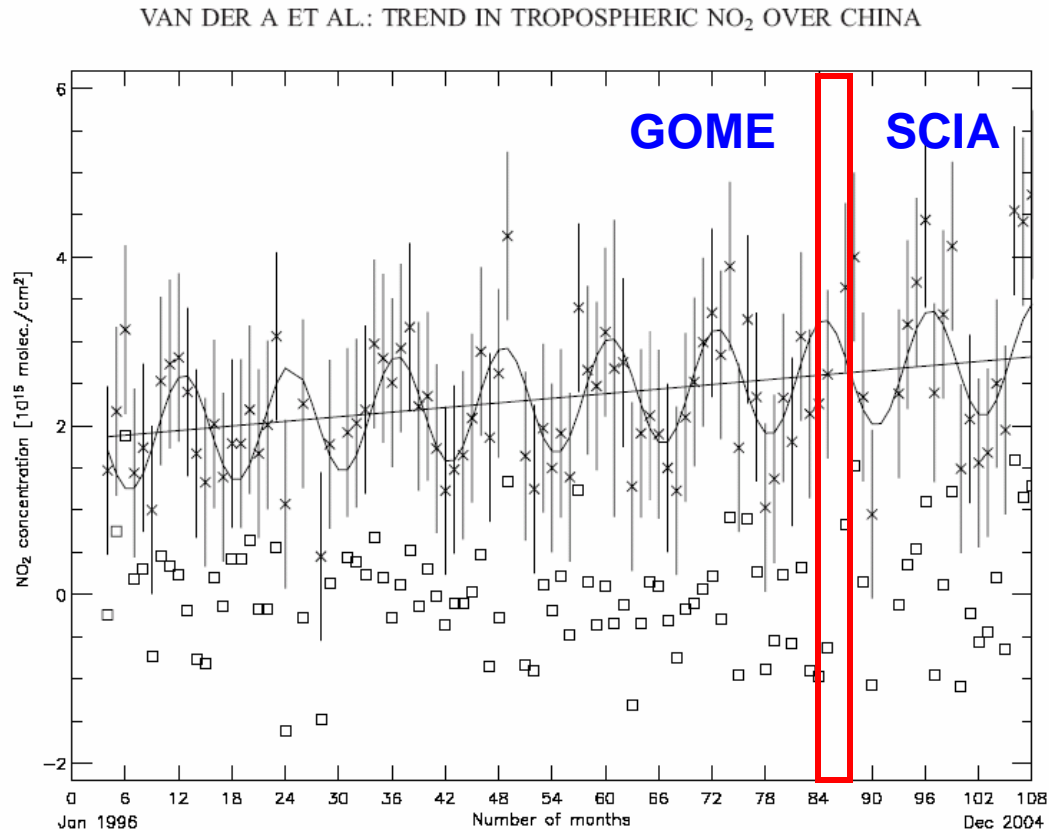


Folkert Boersma, Daniel Jacob, Henk Eskes, Rob Pinder, Jun Wang, and Ronald van der A



# Motivation

- Examine consistency between two satellite data sets
- Example:

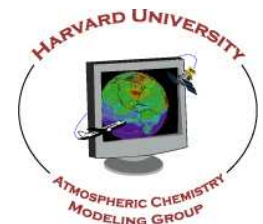


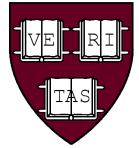
Jan-May 2003:  
Overlap  
between GOME  
and SCIA

Average  
difference:  
 $0.03 \pm 0.16 \cdot 10^{15}$

**Figure 3.** An example of a time series for one grid cell near Ji'an (115.5, 27.5). The Y axis shows the monthly mean NO<sub>2</sub> tropospheric column, and the X axis shows the month index starting January 1996. The crosses mark the measurements by GOME and SCIAMACHY. The solid line is the fitting result, consisting of a linear growth and a seasonal component. The difference between fit and measurement is marked by the open squares.

van der A et al.  
(2006)

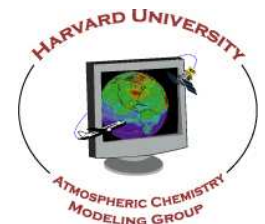
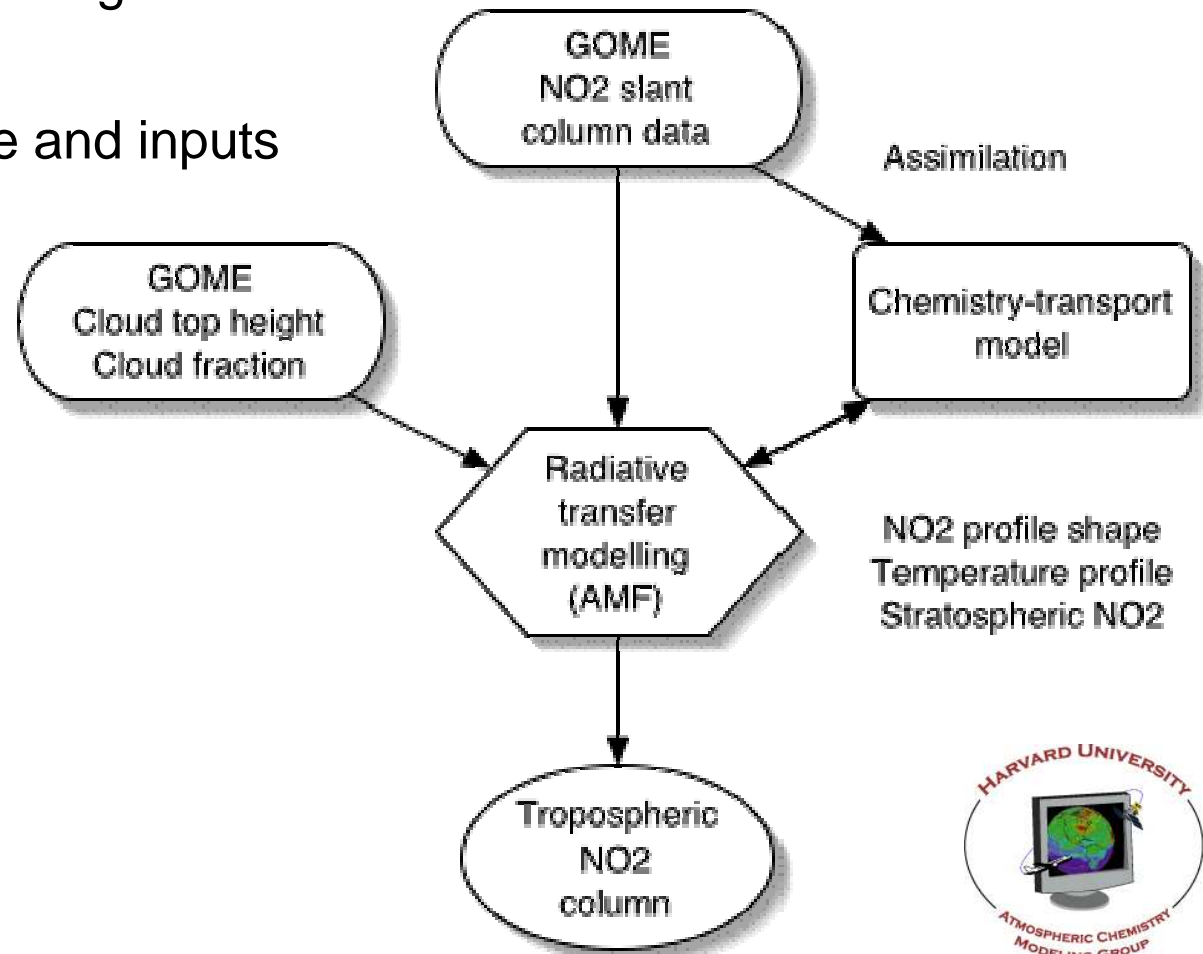


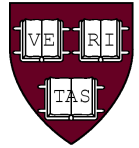


# GOME and SCIAMACHY NO<sub>2</sub>

Same retrieval:

- Slant columns from BIRA
- Stratospheric columns through data assimilation in TM4
- Same AMF look-up table and inputs



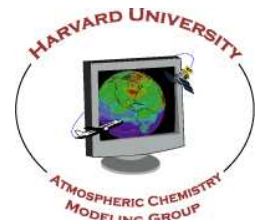


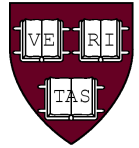
## OMI and SCIAMACHY NO<sub>2</sub>

- GOME and SCIAMACHY overpass at similar times (10:30 and 10:00)
- OMI and SCIAMACHY overpass at different times (13:30 and 10:00)
- Consistent retrieval algorithms
- NO<sub>2</sub> has a relatively short lifetime (4-24 hours)
- NO<sub>x</sub> has diurnal cycle in source and loss terms

### QUESTION:

Can we observe fast photochemistry and changes in emissions from space?





# Common algorithm

SCIAMACHY and OMI NO<sub>2</sub> with same retrieval

## Similarities

- Non-linear least squares fitting for slant columns
- Stratospheric columns through data assimilation in TM4
- Same AMF approach and inputs (albedo, profile shape, temp.)

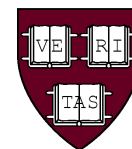
## Main differences

- Slant column fitting details
- Cloud inputs

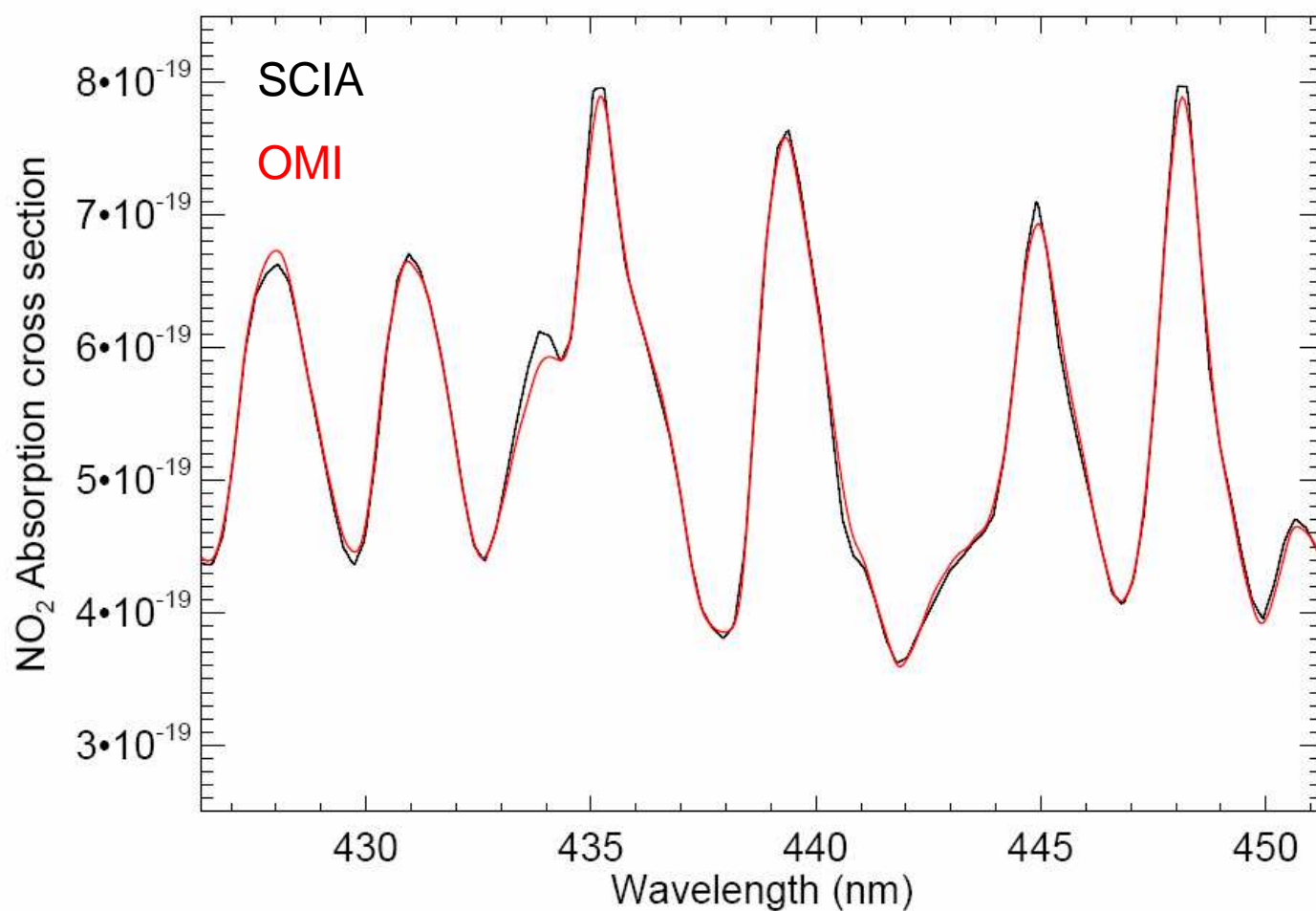
Table 2. Spectral fitting characteristics for SCIAMACHY and OMI NO<sub>2</sub> retrievals.

Instrument	SCIAMACHY	OMI
Fitting window	426.3–451.3 nm	405.0–465.0 nm
Fitted species	NO <sub>2</sub> , O <sub>3</sub> , Ring, O <sub>2</sub> -O <sub>2</sub> , H <sub>2</sub> O	NO <sub>2</sub> , O <sub>3</sub> , Ring
Spectral resolution	0.44 nm	0.65 nm
Fitting method	Non-linear least squares	Non-linear least squares
NO <sub>2</sub> cross section spectrum	SCIAMACHY PFM [Bogumil et al., 2003]	Vandaele et al. [1998] convolved with OMI ITF <sup>a</sup>

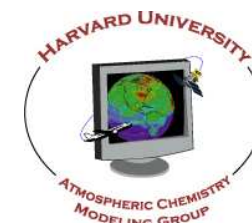
<sup>a</sup> Dirksen et al. [2006]

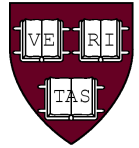


# Similar NO<sub>2</sub> absorption cross sections



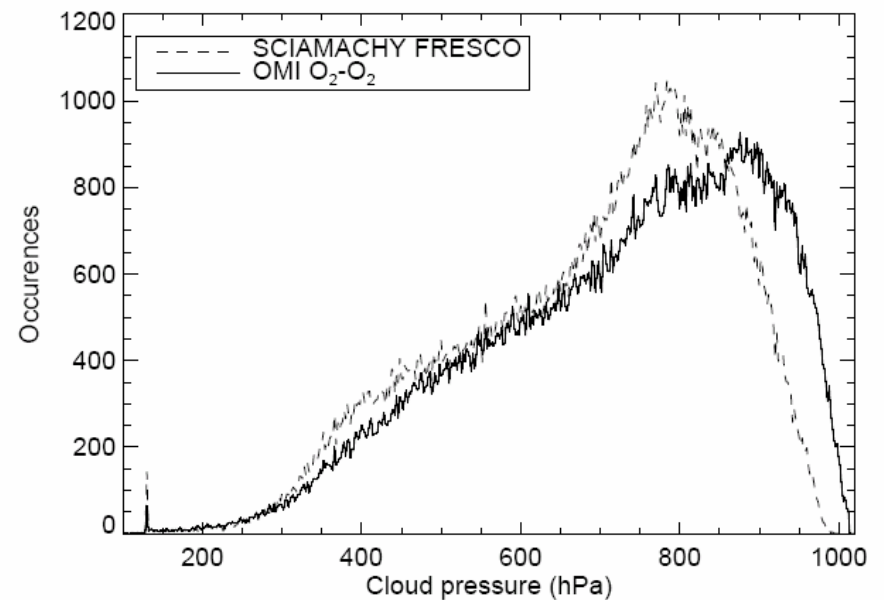
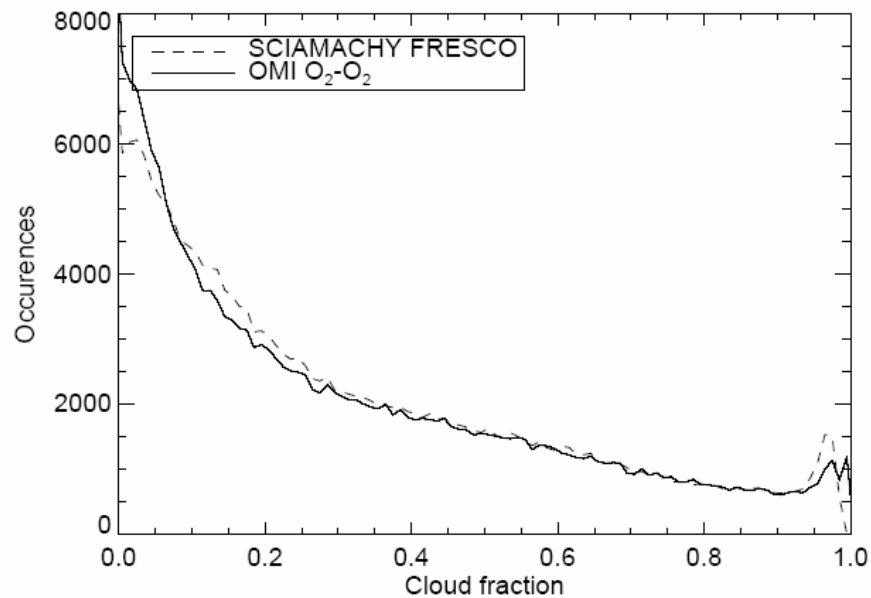
Relative amplitude  
SCIAMACHY 2.4%  
stronger than for OMI





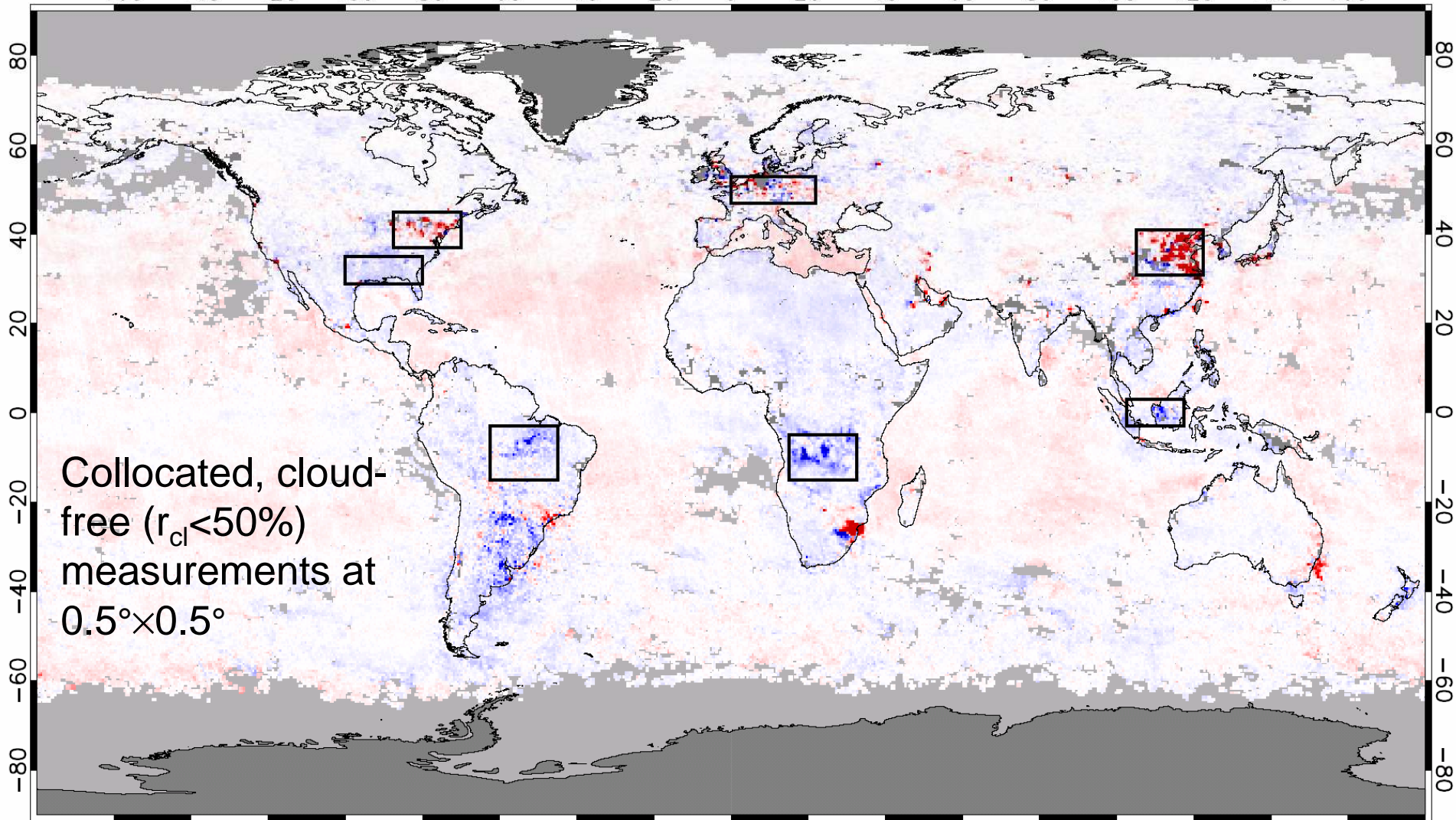
# Similar cloud retrievals

- Clouds
  - SCIAMACHY: FRESCO+ (760 nm)
  - OMI: O<sub>2</sub>-O<sub>2</sub> (470 nm)
  - Average cloud fraction agrees within 1.5%
  - Bias between cloud pressures of ~60 hPa

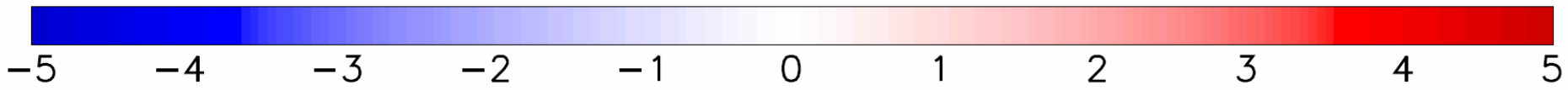


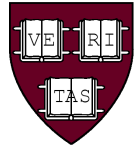
# Difference SCIAMACHY – OMI tropospheric NO<sub>2</sub> August 2006

-160 -140 -120 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140 160

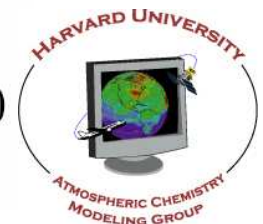
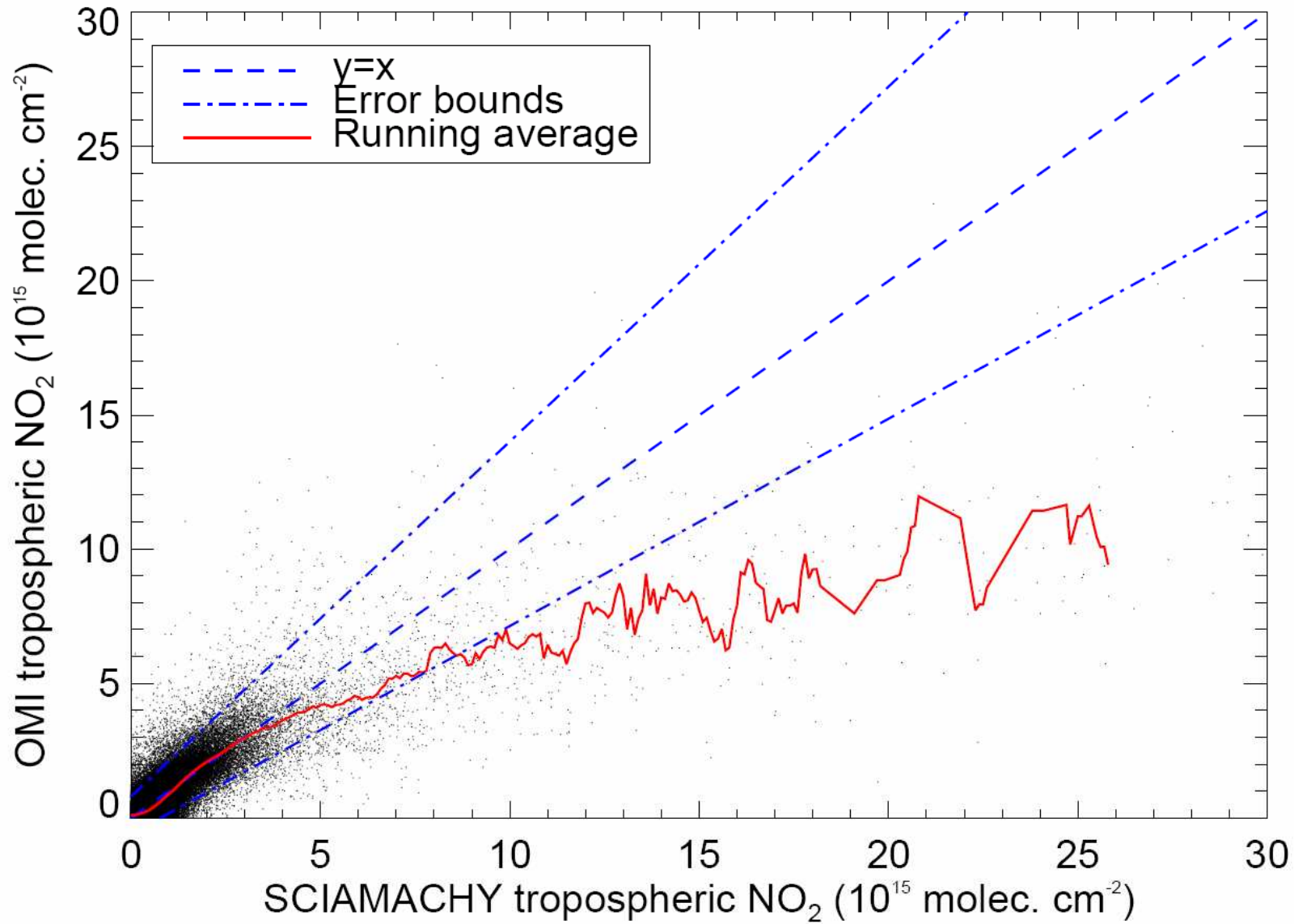


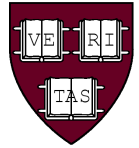
NO<sub>2</sub> column density [ $10^{15}$  molec./cm<sup>2</sup>]





# Differences larger than expected uncertainties





## Differences over source regions

What is the cause of the differences?

- slant columns → information in the spectra
- AMF → information in the physics of retrieval

Compare slant columns and AMFs correcting for different viewing geometries:

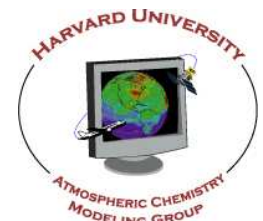
- slant columns:

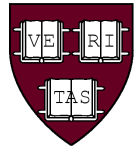
$$N_s/M_g$$

- AMFs:

$$M_{tr}/M_g$$

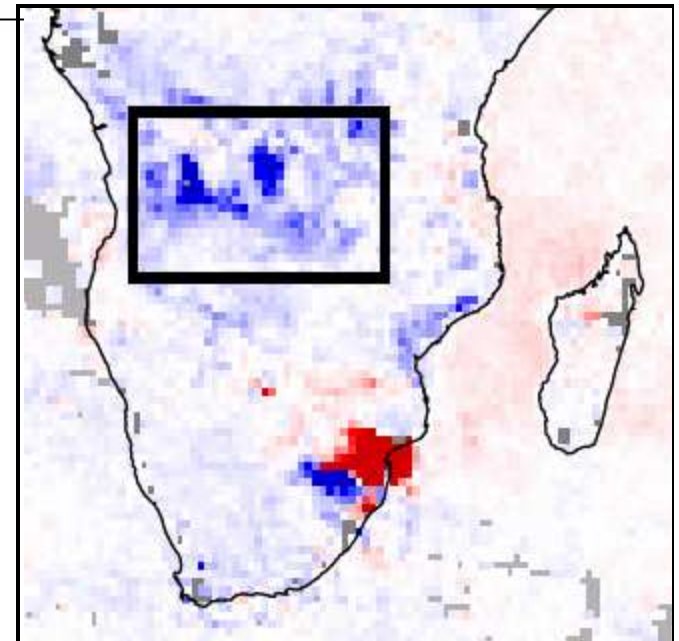
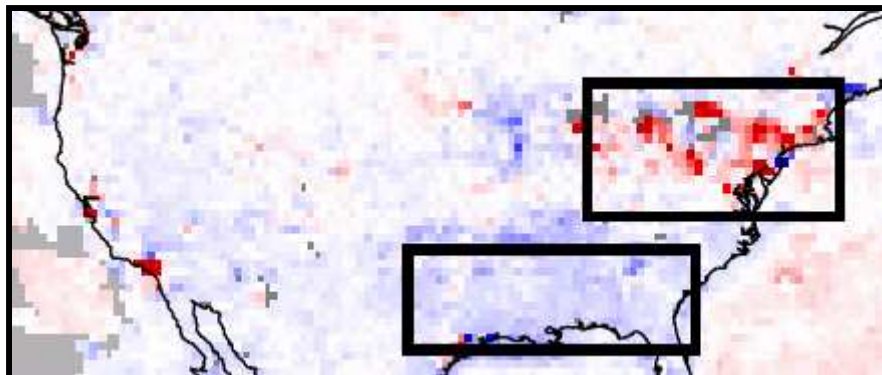
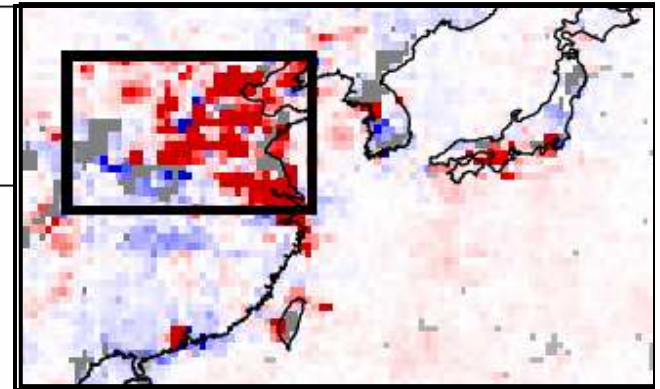
$$M_g = \frac{1}{\cos(\theta)} + \frac{1}{\cos(\theta_0)}$$

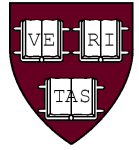




# Ratio SCIAMACHY:OMI over source regions

Region <sup>b</sup>	Observed column	Normalized slant column <sup>c</sup>	Normalized AMF <sup>c</sup>
Northeastern U.S.	1.18	1.06	0.90
Northern Europe	1.05	1.03	0.98
Northeastern China	1.37	1.25	0.91
Southeastern U.S.	0.70	0.72	1.07
Southern Africa	0.69	0.65	0.94
Brazil	0.65	0.59	0.90
Indonesia	0.63	0.62	1.01

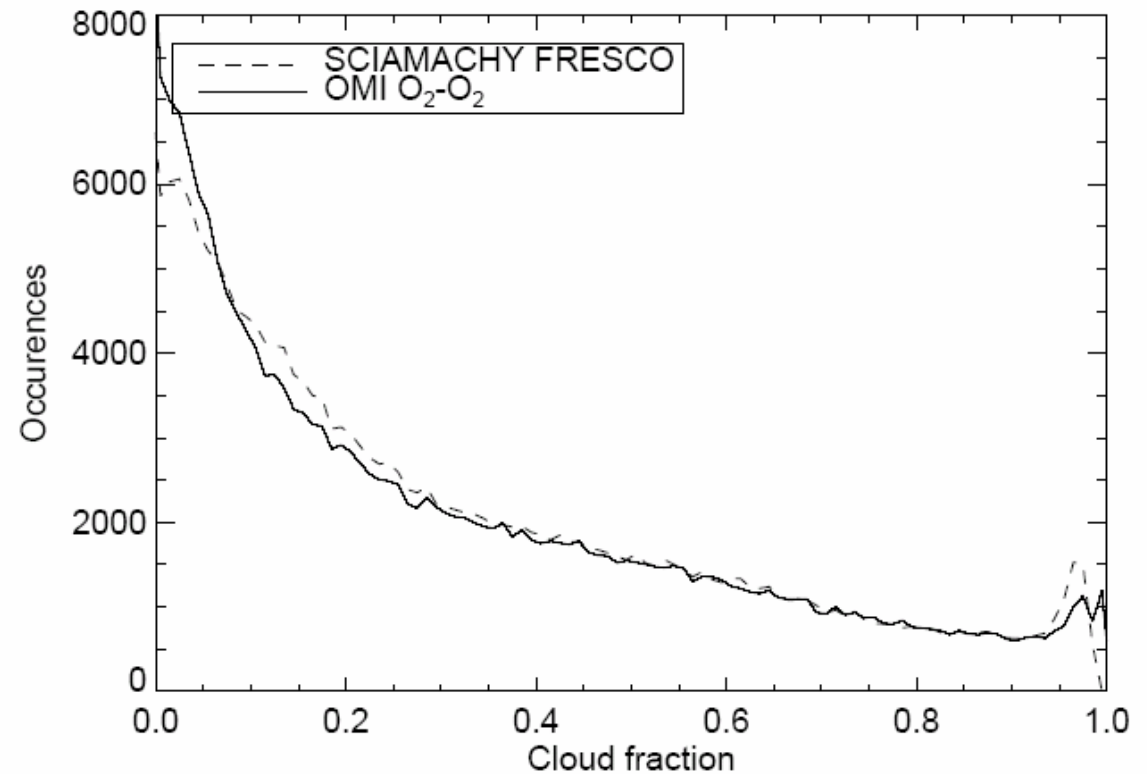




# What causes AMF differences?

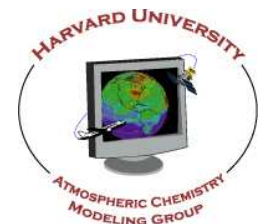
AMF depends on:

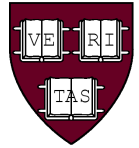
- ~~albedo~~
- ~~cloud fraction~~
- cloud height
- a priori profile shape



Cloud fractions are the same within 0.05 (bias <0.015)

Differences too small to explain AMF differences of up to 20%



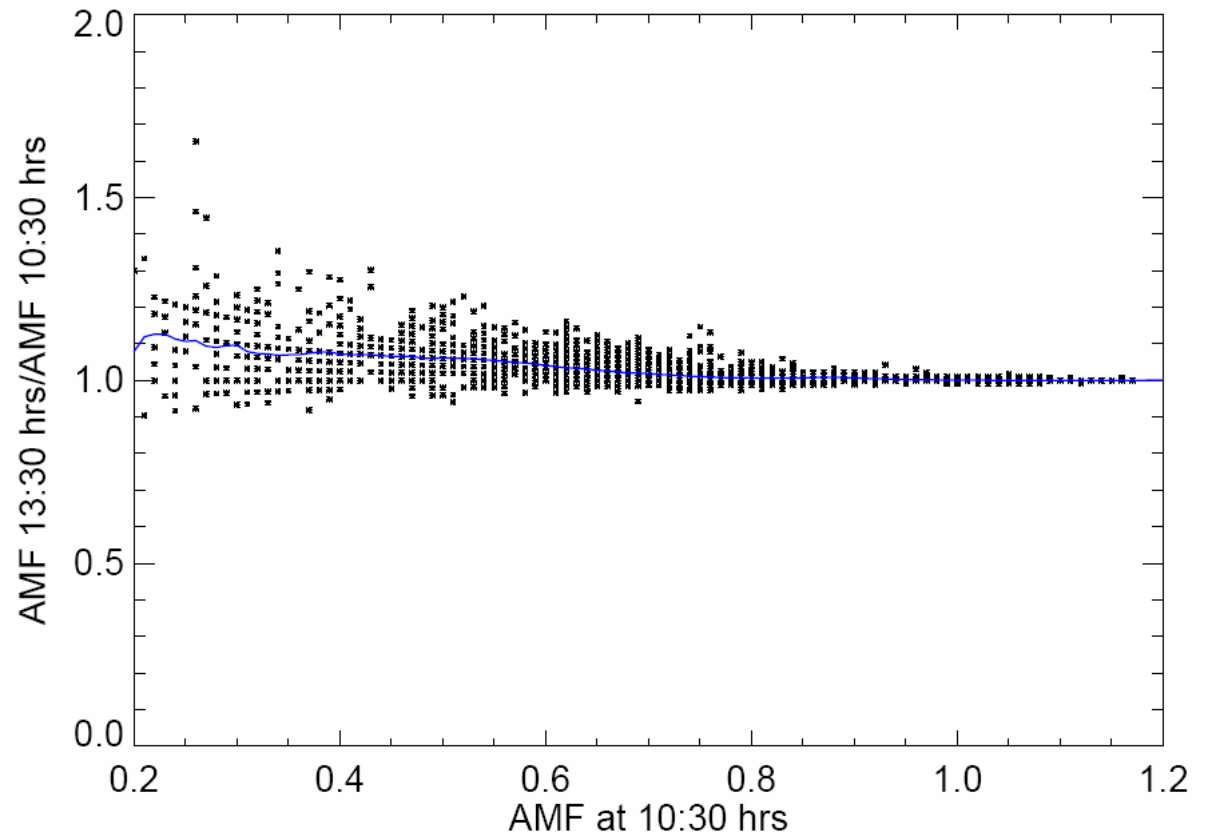


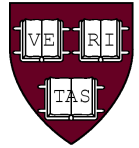
# What causes AMF differences?

Differences in NO<sub>2</sub> profile shape

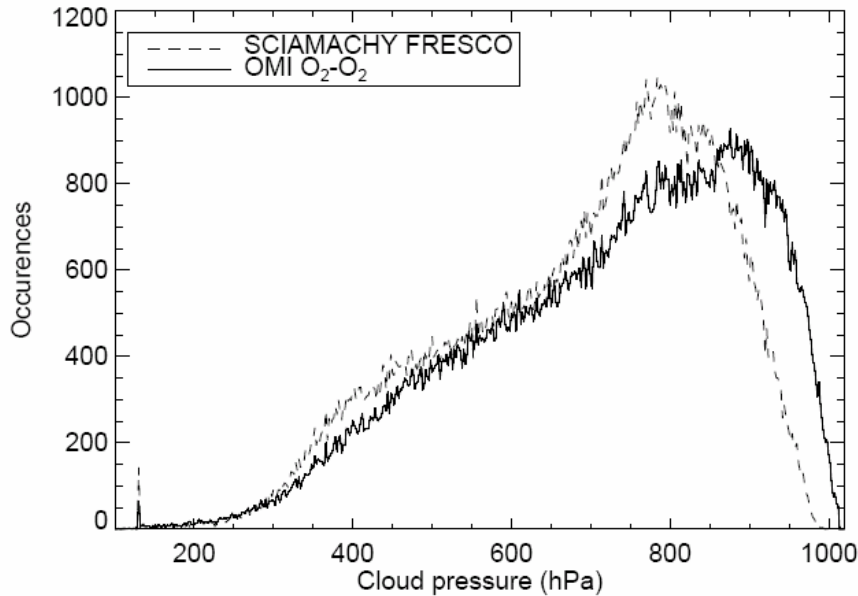
- Better mixed boundary layer at 13:30 hrs
- NO<sub>2</sub> profile peaks at higher altitudes

Sensitivity study with TM gives on average up to 15% higher AMFs at 13:30 compared to 10:30



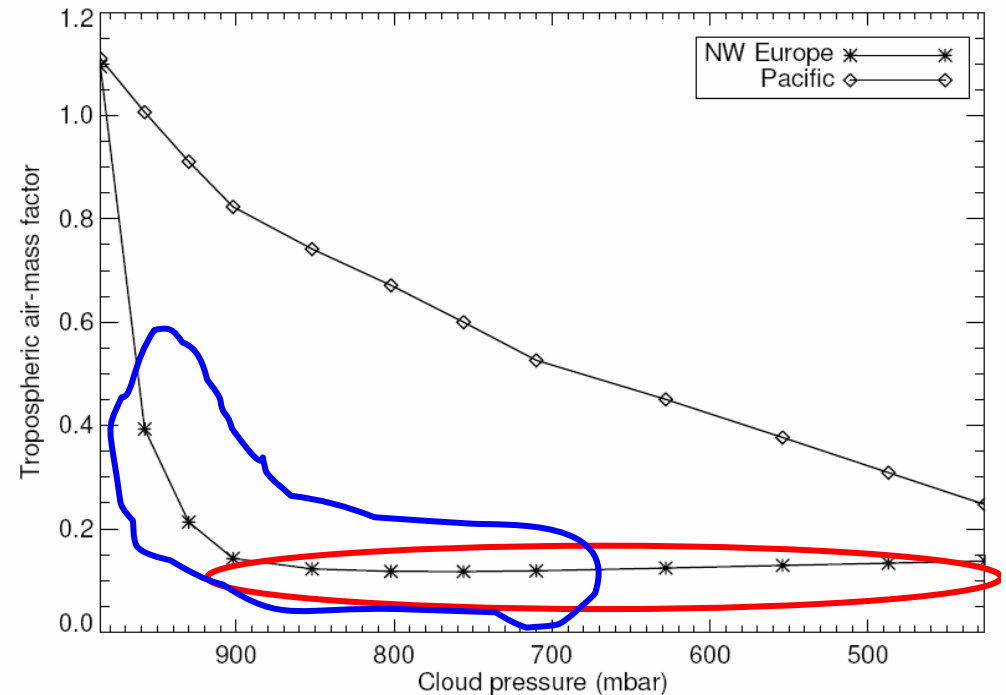


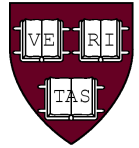
# What causes AMF differences?



Differences in cloud pressures  
(+60 hPa)

Sensitivity study with 60 hPa  
higher cloud pressures gives  
~10% higher OMI AMFs



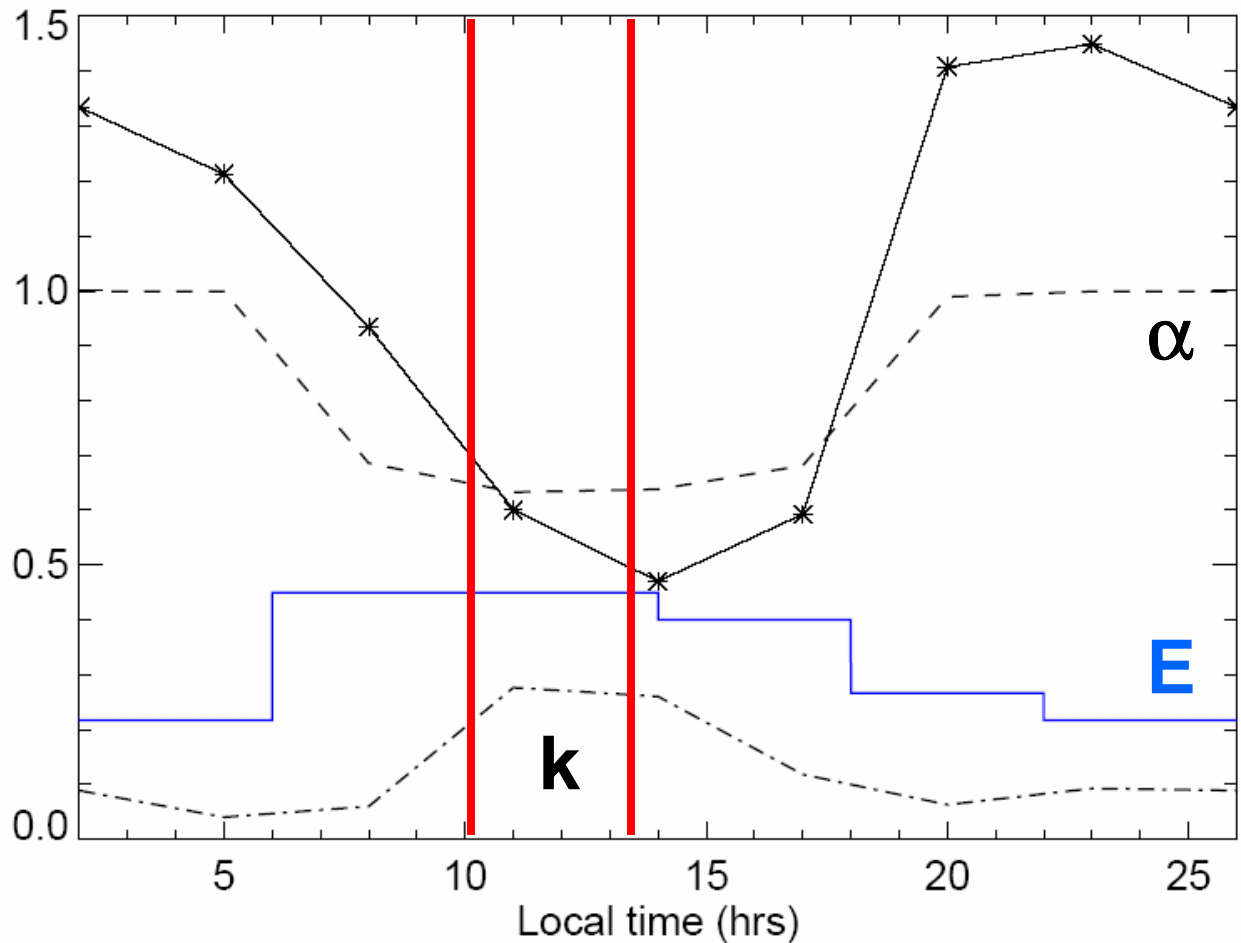
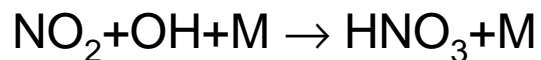


# Diurnal variation of NO<sub>2</sub> columns

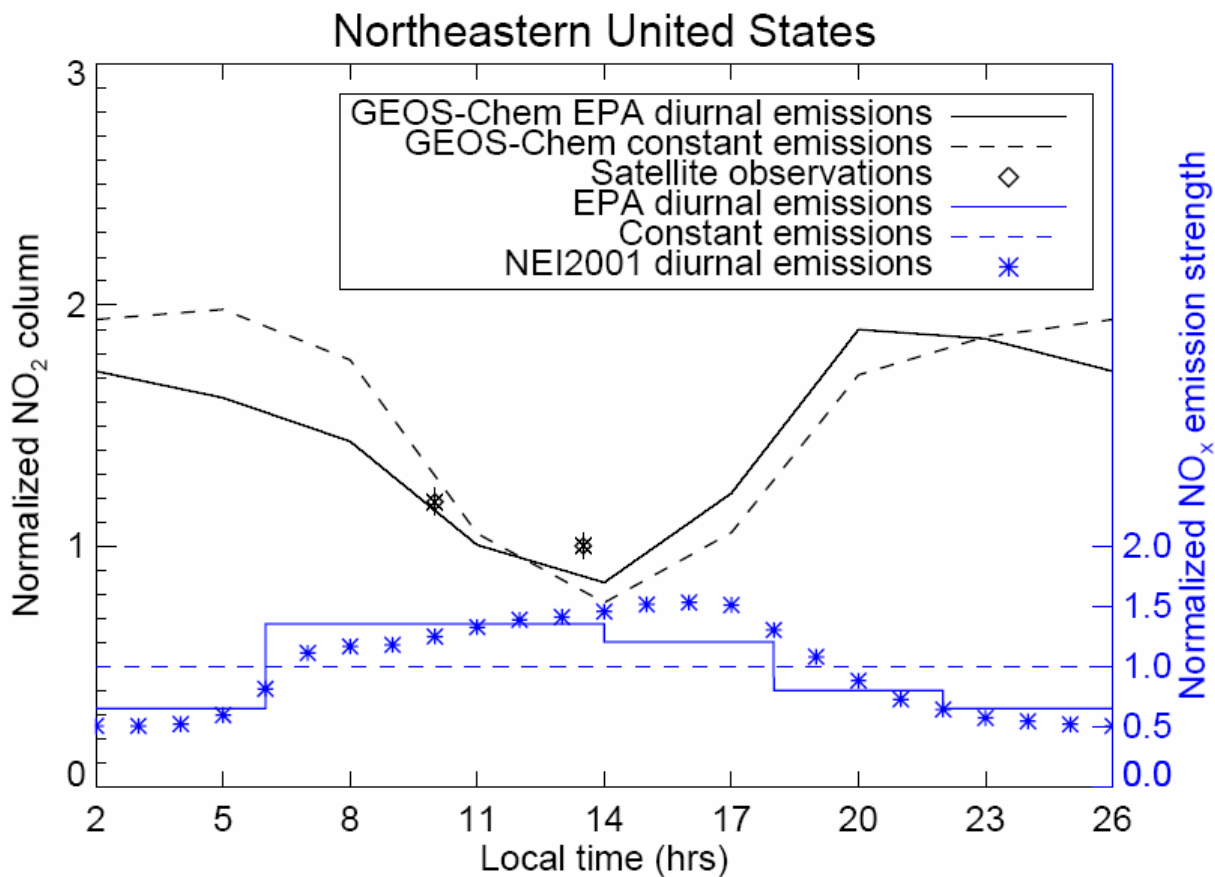
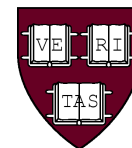
$$\frac{dN_{NO_2}}{dt} = \alpha(t) [E(t) - k(t)N_{NO_x}(t)]$$

- $N_{NO_2}$ : NO<sub>2</sub> column
- $\alpha(t)$ : NO<sub>2</sub>:NO<sub>x</sub> ratio
- $E(t)$ : NO<sub>x</sub> emissions
- $k(t)$ : rate constant
- $N_{NO_x}$ : NO<sub>x</sub> column

rate constant  $k(t)$  applies to conversion of NO<sub>x</sub> to HNO<sub>3</sub>

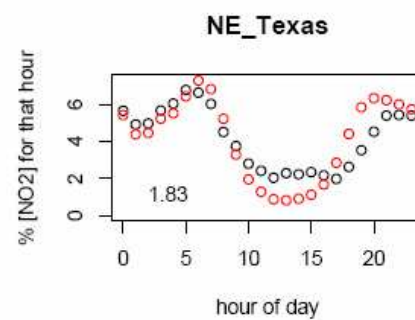
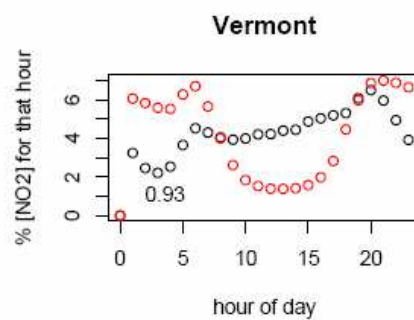
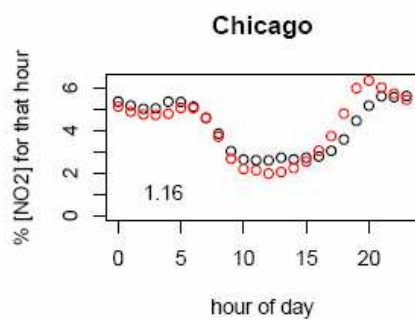
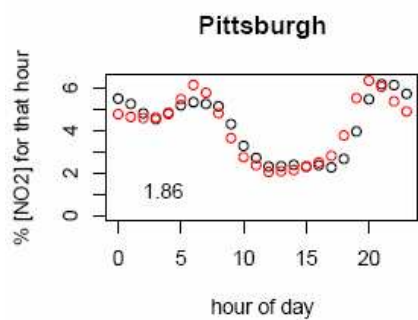
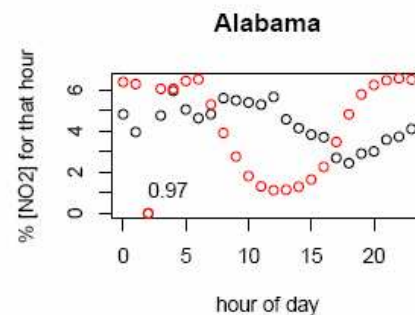
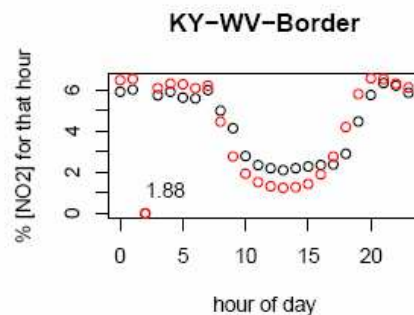
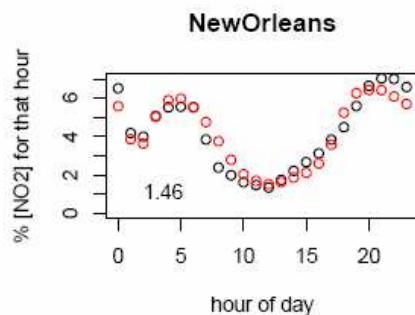
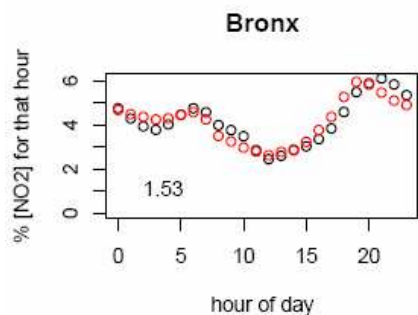
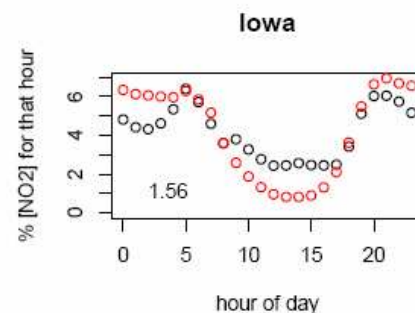
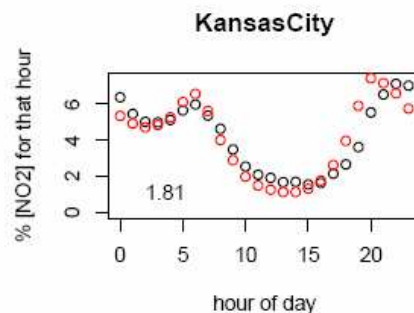
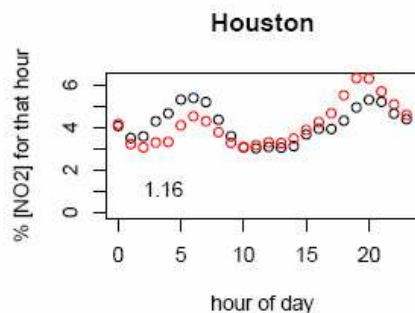
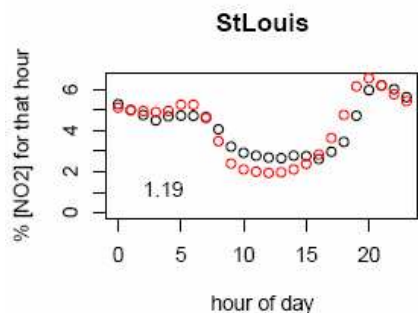
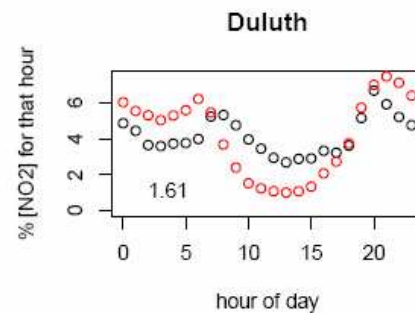
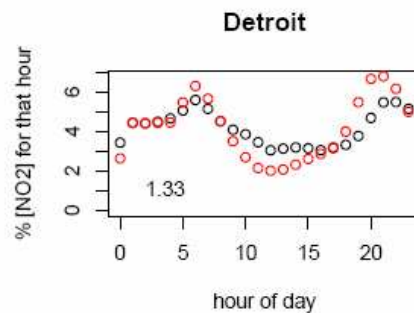
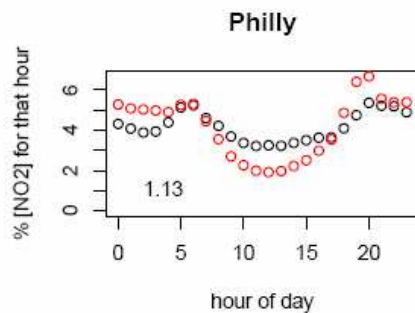
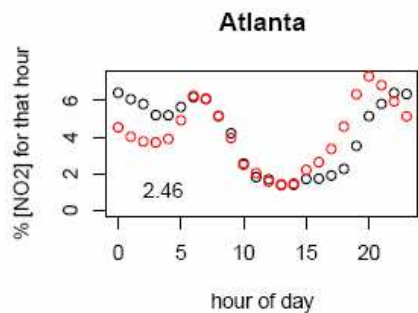


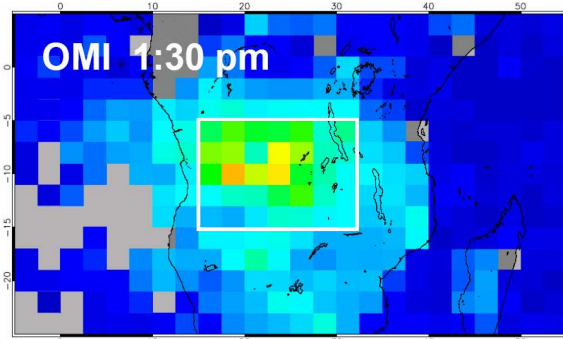
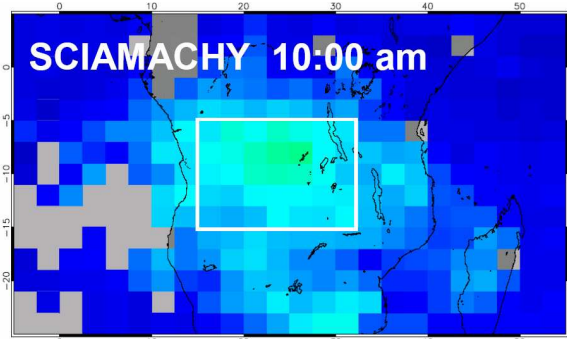
# GEOS-Chem



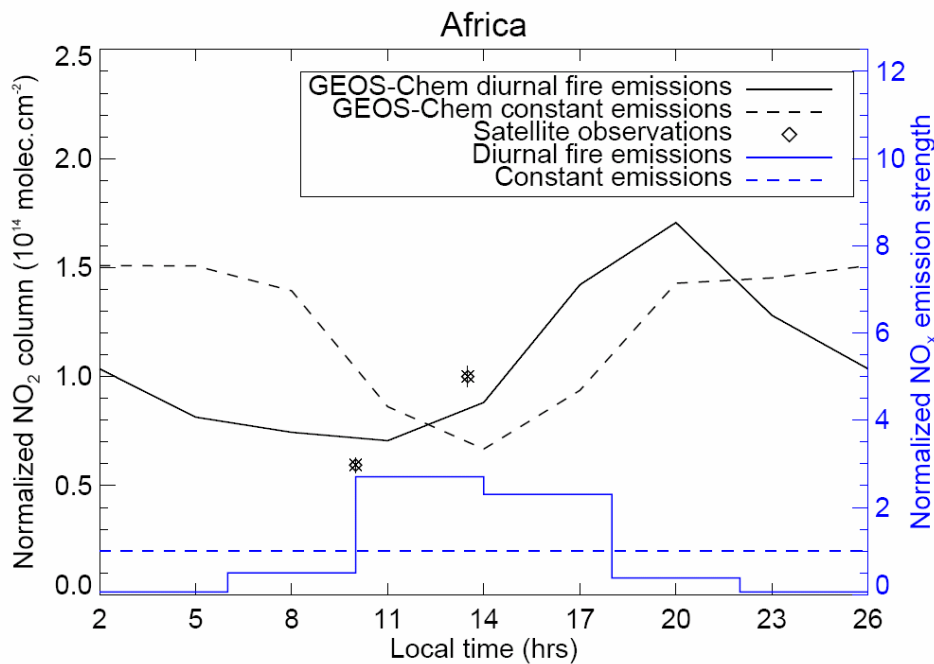
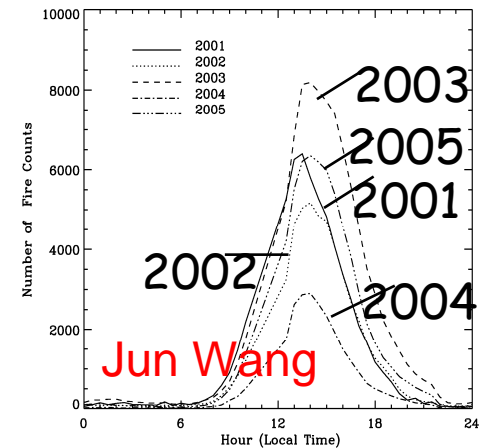
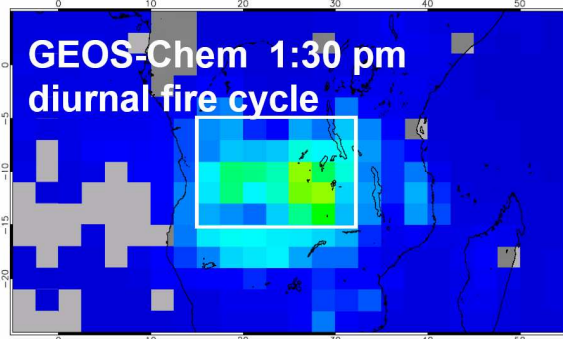
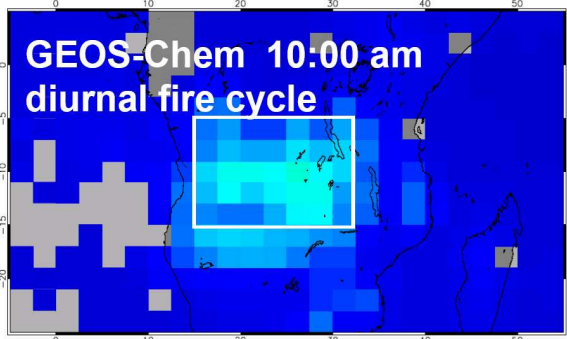
**Relative decrease in NO<sub>2</sub> column from 10:00 to 13:30 pm**

	<b>Observed</b>	<b>GEOS-Chem</b>
US:	-16%	-28%
EU:	-6%	-13%
China:	-26%	-22%





**Biomass burning mainly in afternoon**



**Relative increase in NO<sub>2</sub> column from 10am to 1:30 pm**

	<b>Observed</b>	<b>GEOS-Chem</b>
Africa:	+48%	+16%
Indon.:	+60%	+10%
Brazil:	+54%	+13%