Trends and seasonal variability in tropospheric NO_2

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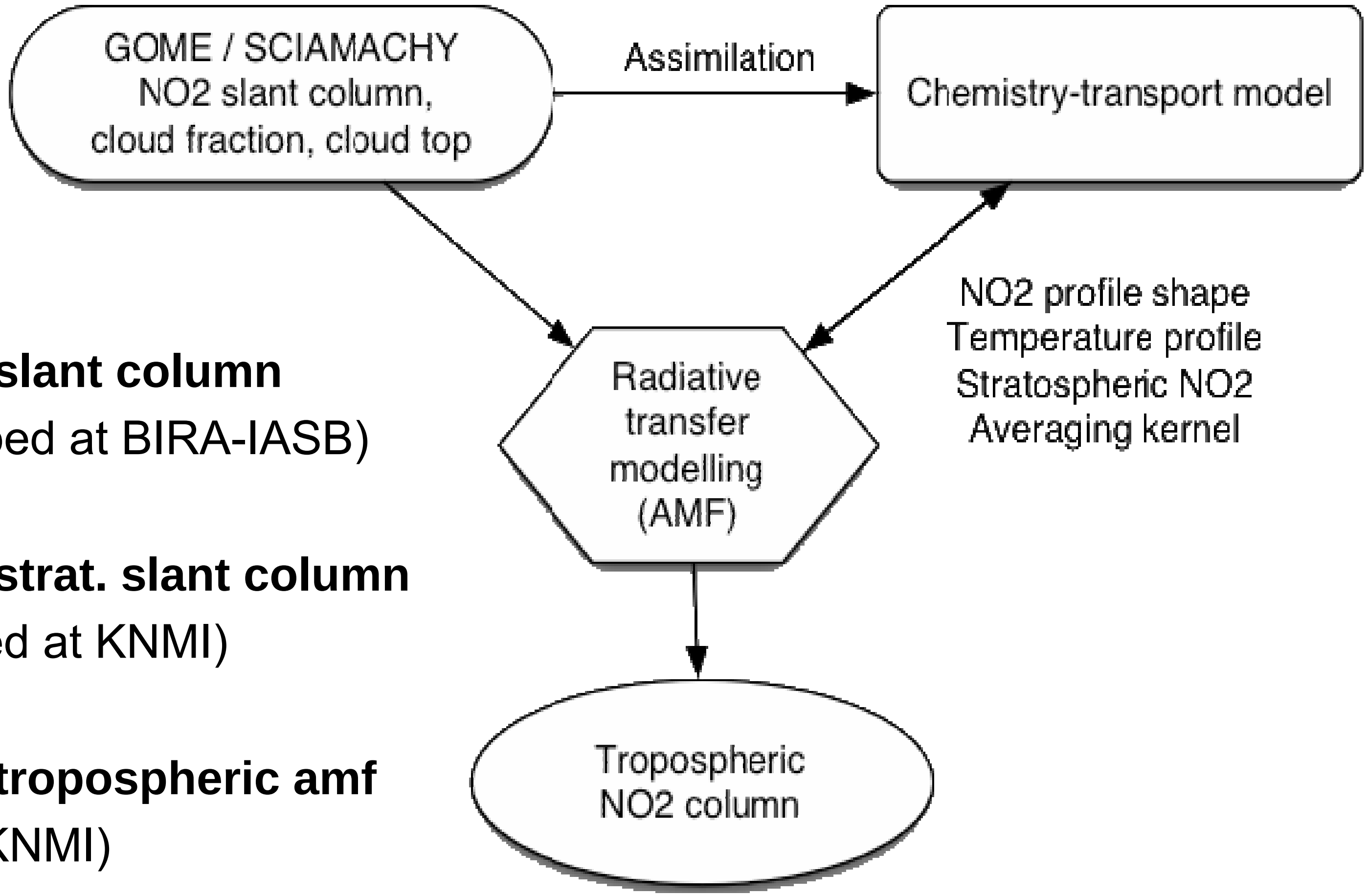
ESA-NRSCC
DRAGON
Cooperation
Programme

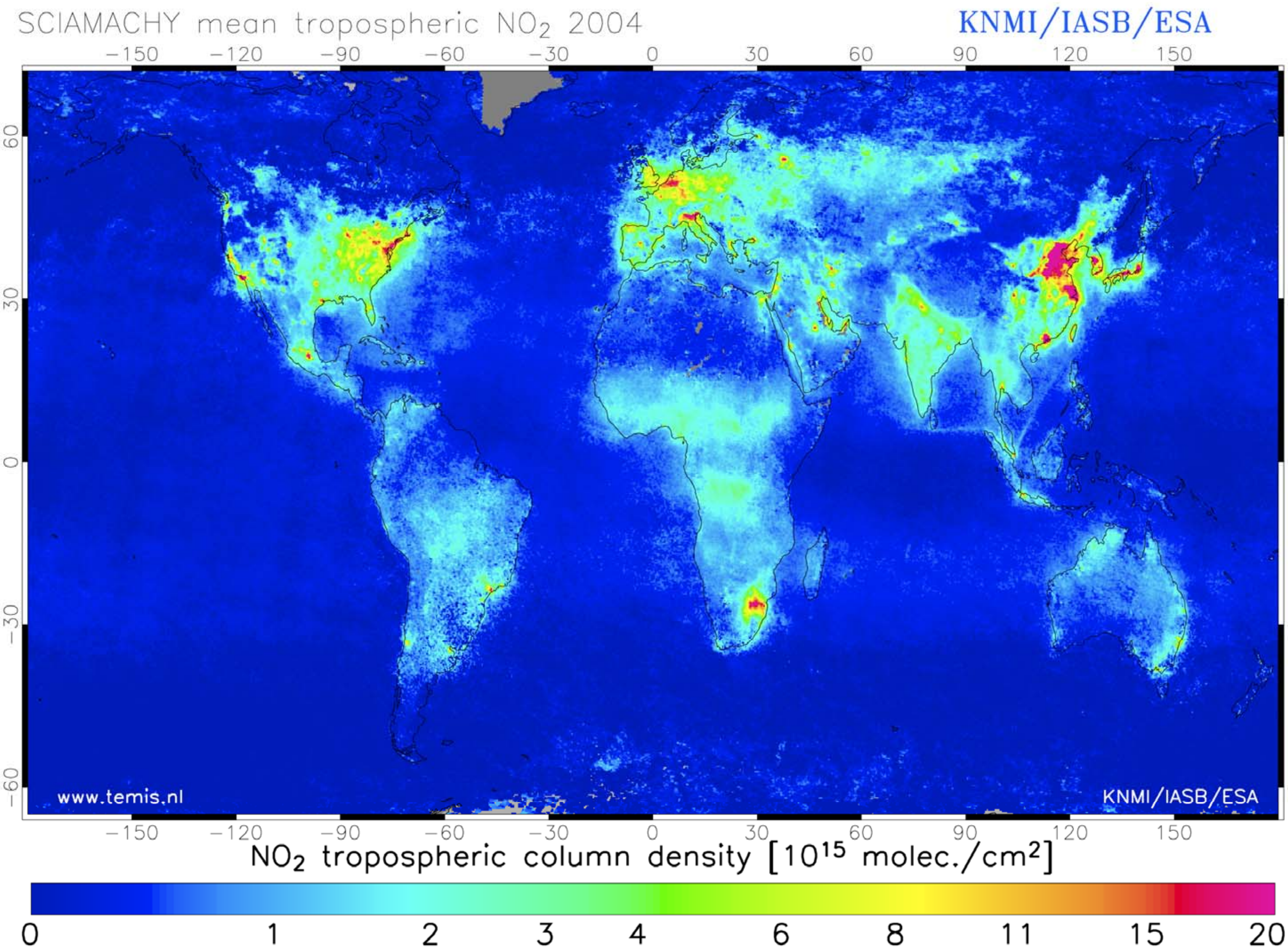
Combined retrieval-modelling-assimilation approach



1. DOAS → slant column
(GwinDOAS, developed at BIRA-IASB)

2. Assimilation → strat. slant column
(TM4-DAM, developed at KNMI)

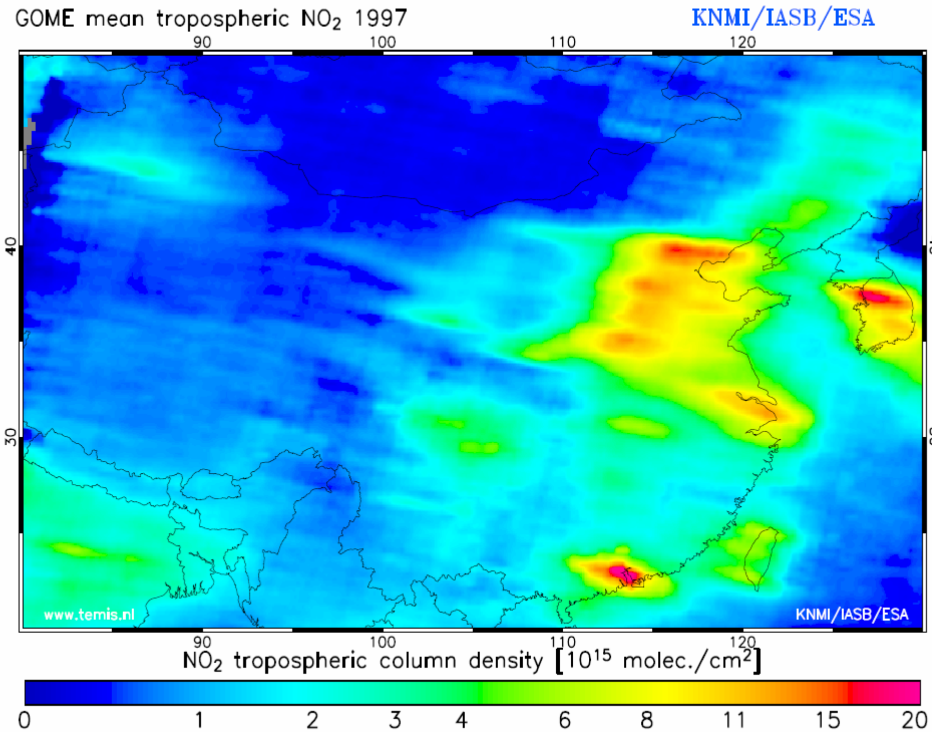
3. Modelling → tropospheric amf
(DAK, developed at KNMI)


SCIAMACHY mean tropospheric NO_2 2004
KNMI/IASB/ESA
−150 −120 −90 −60 −30 0 30 60 90 120 150
60 30 0 −30 −60
www.temis.nl
KNMI/IASB/ESA
NO_2 tropospheric column density [10^{15} molec./cm^2]
0 1 2 3 4 6 8 11 15 20

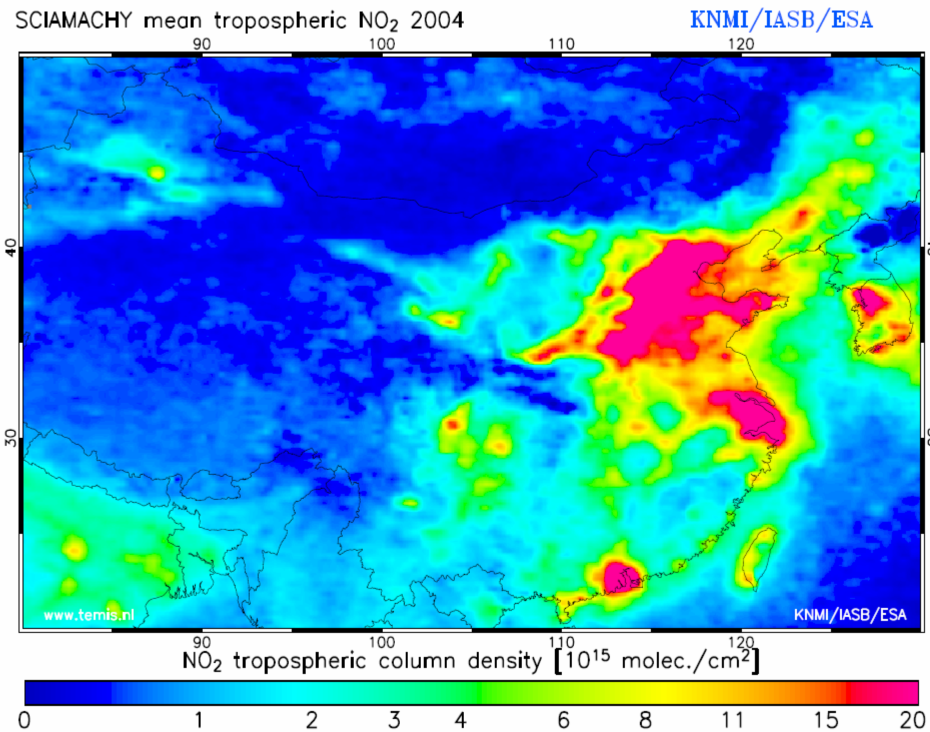
NO_2 over China

Annual mean of the tropospheric NO2 column

GOME-1997



SCIAMACHY-2004



NO_2 data set

- GOME: April 1996 – March 2003
- SCIAMACHY: April 2003 – December 2005
- Time series gridded to 1 x 1 degree
- Convolution of SCIAMACHY data to spatial resolution of GOME.
- Cloud filtering using FRESCO
  (only pixels with a radiance
  from clouds of less than 50 %)

Analysis of time series 1996-2005

$$Y_t = Y_0 + Bt + A \cdot \sin(\omega t + \delta) + N_t + U_t$$
$$N_t = \varphi N_{t-1} + \varepsilon_t$$

Y	monthly mean of tropospheric NO_2
t	number of months after $t=0$
Y_0	offset value at $t=0$
B	monthly trend
A	amplitude of seasonal variability
ω	period (fixed at $\pi/6$ month^{-1})
δ	phase shift
U_t	bias between GOME and SCIAMACHY
N_t	remainder
φ	autocorrelation in N
ε	noise

Statistical significance

From E.C. Weatherhead et al., JGR 103, 1998:

- Error on trend:

$$\sigma_B \approx \frac{\sigma_N}{n^{3/2}} \sqrt{\frac{1+\phi}{1-\phi}}$$

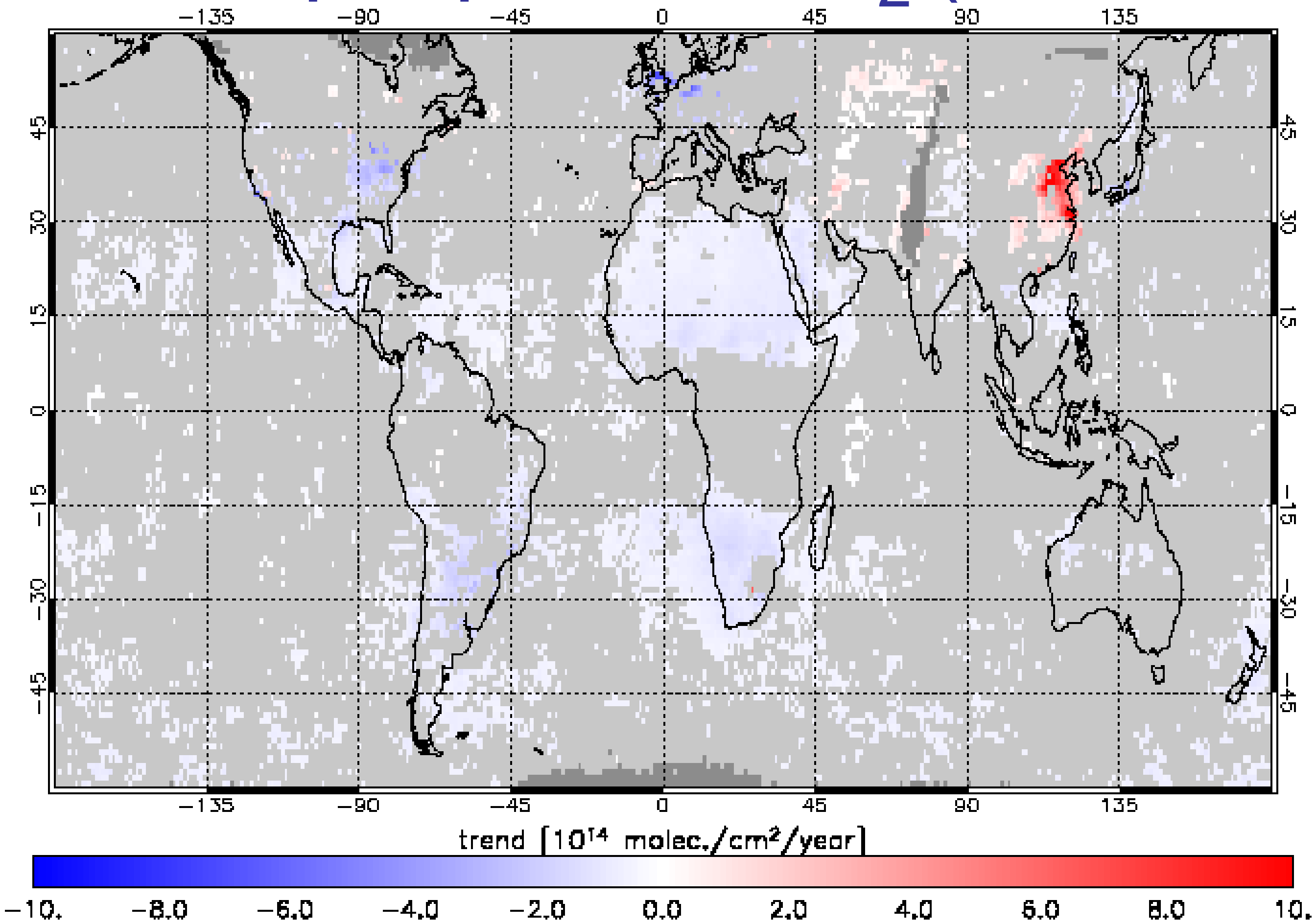
  Φ autocorrelation in N

  n number of data points

  σ_N variance in N

- Trend B is real with 95 % confidence level if $B/\sigma_B > 2$

Trend in tropospheric NO_2 (1996-2005)



Grey : no significant trend

Dark grey : not enough measurements

Cities with strong trends

[10^{15} molec/cm^2/year]

	NO_2 in 1996	Trend	Error on trend	Growth (Ref. year 1996)
Beijing	11.3	1.1	0.26	10 %
Ruhr area	11.1	-0.43	0.12	-3.9 %
Tokyo	10.8	-0.18	0.20	-1.6 %
Shanghai	5.1	1.5	0.21	30 %
Delhi	4.1	0.28	0.065	6.9 %
Tehran	4.1	0.26	0.52	6.5 %
Buenos Aires	3.4	-0.10	0.06	-2.9 %
Novosibirsk	1.3	0.13	0.04	11 %

Sources

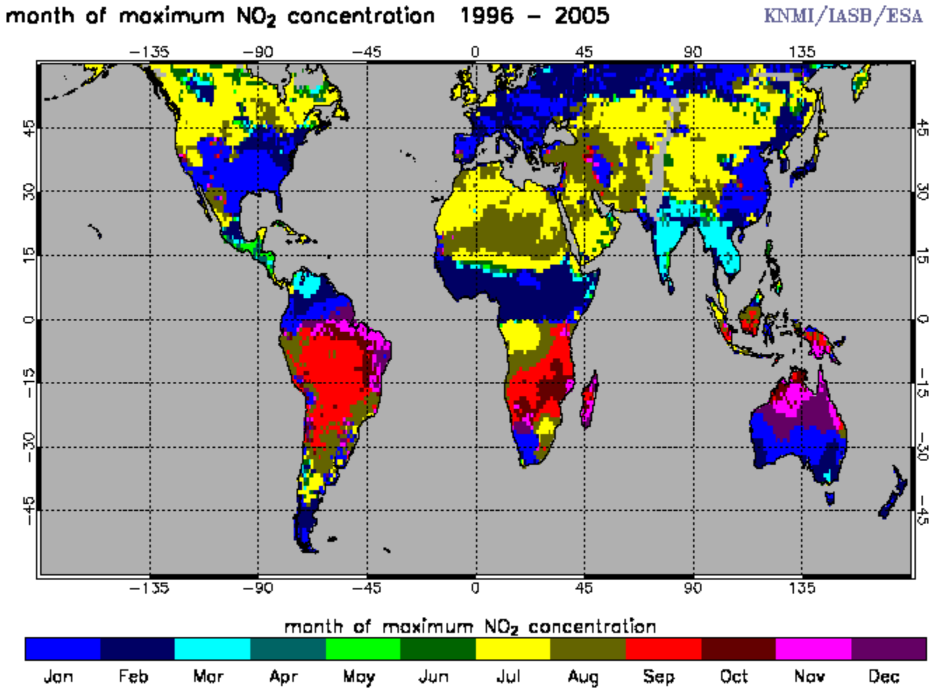
- NO_x sources:
  - Anthropogenic (traffic, industry, power plants)
  - Soil emissions (grasslands, induced by rain)
  - Biomass burning (tropics, dry season)
  - Lightning (measured at 10.00 am)

- Phase shift to identify sources:

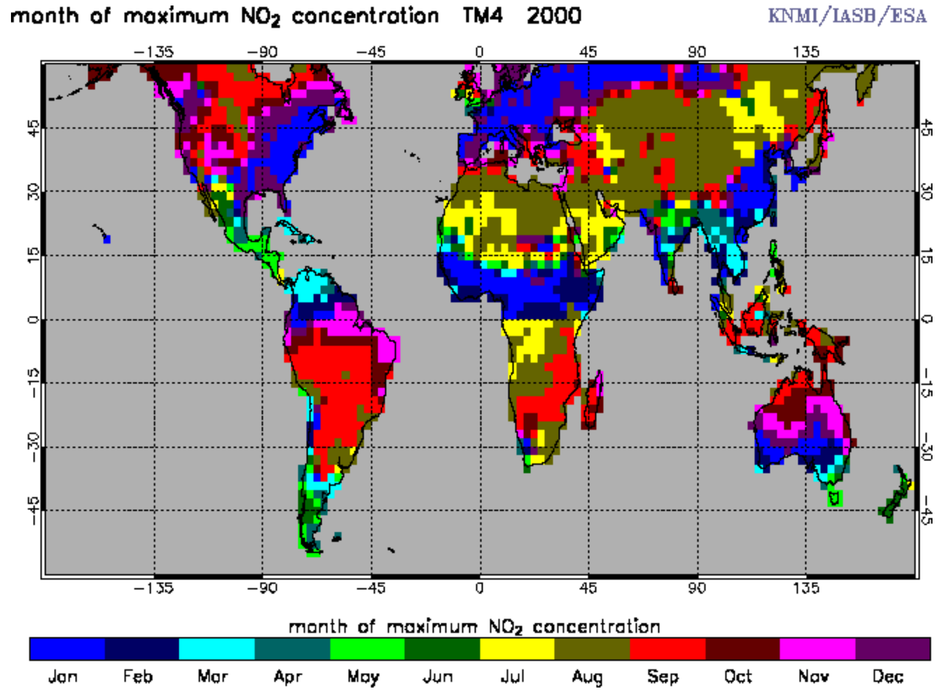
– Anthropogenic	winter maximum
– Soil emissions	summer maximum, rainfall
– Biomass burning	dry season
– Lightning	-

Month of maximum NO_2

GOME/SCIAMACHY

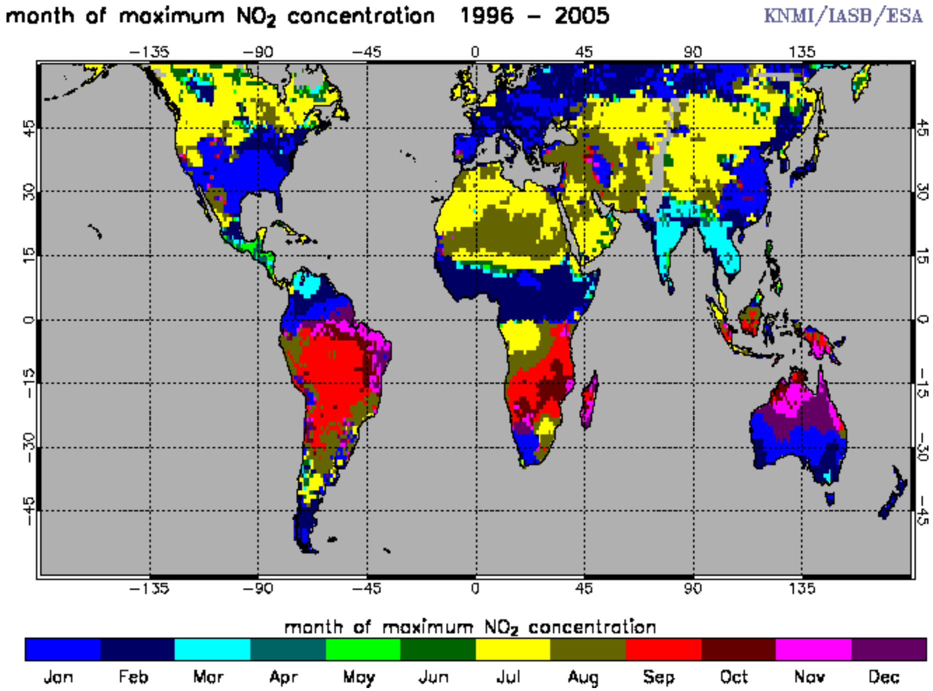


TM model

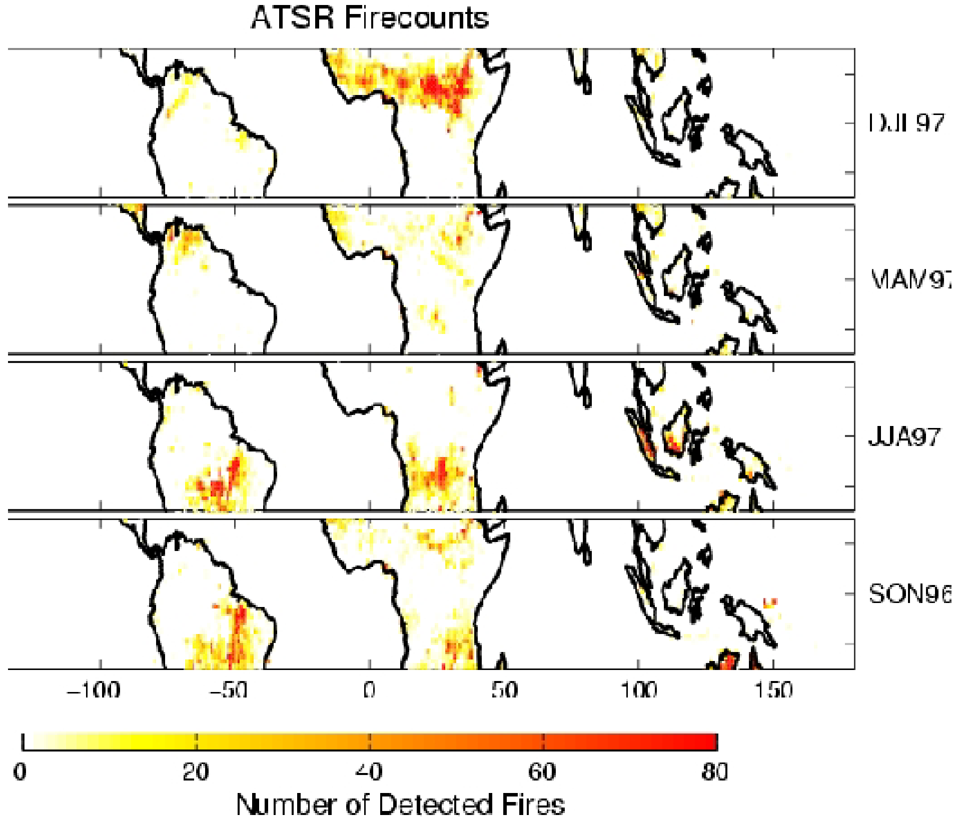


Biomass burning

GOME/SCIAMACHY



ATSR firecounts



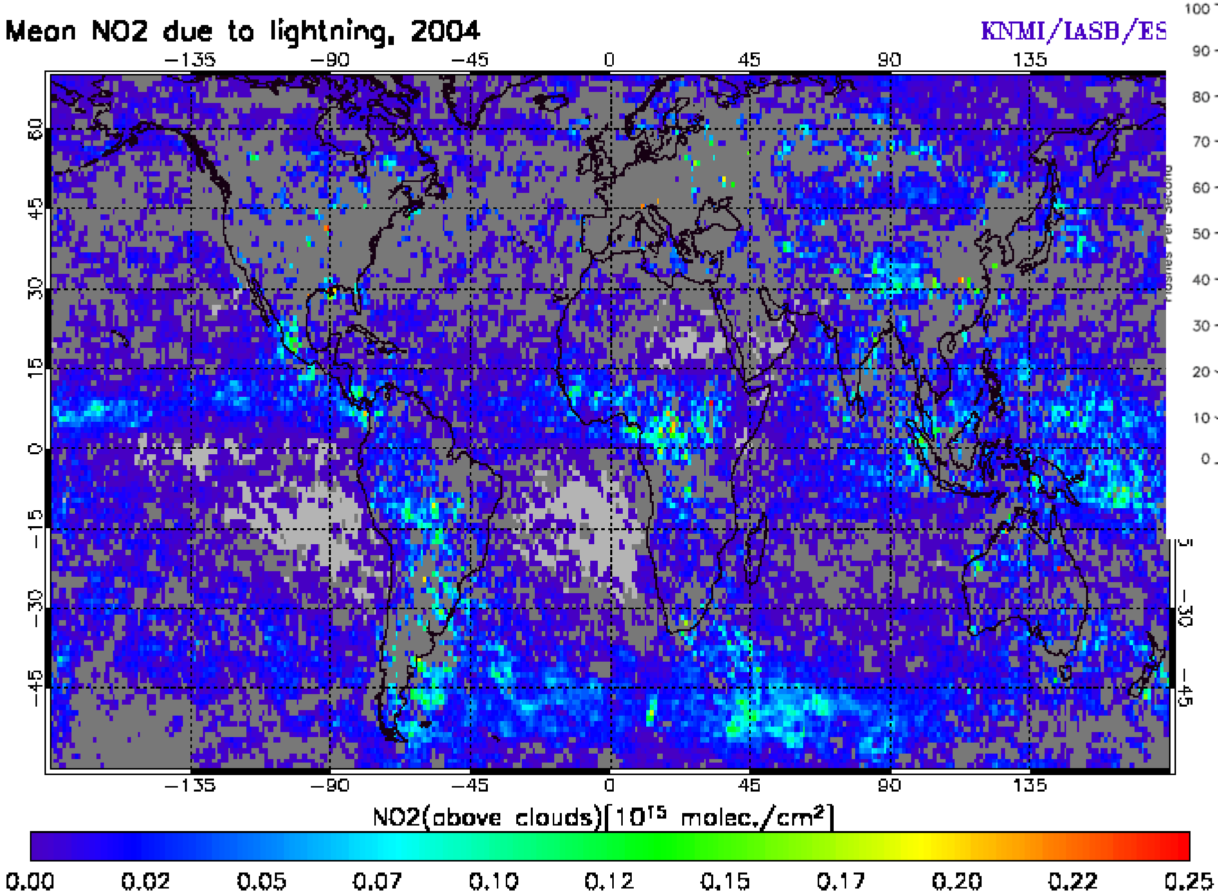
Other parameters

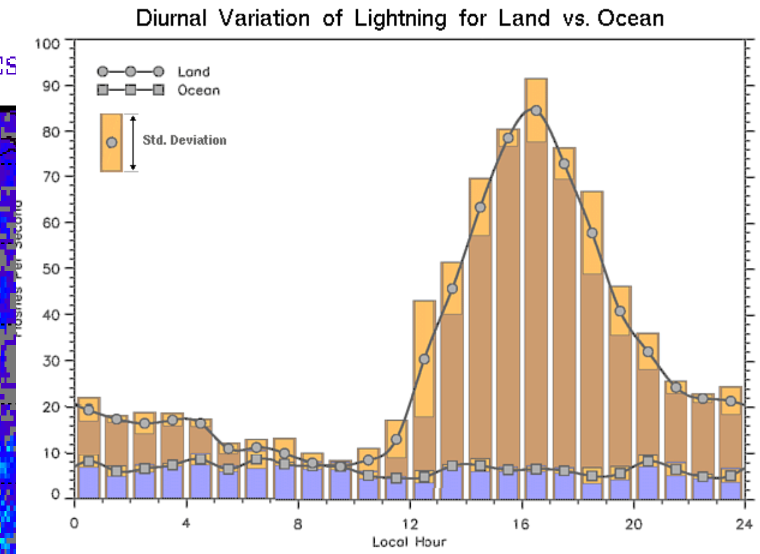
- Variability, defined as seasonal signal over the yearly mean:
  - To distinguish anthropogenic sources (constant emissions) and biomass burning (strong seasonality)
- Comparing cloudy pixels with clear-sky pixels
  - To distinguish lightning, whose signal is higher in cloudy pixels

Lightning

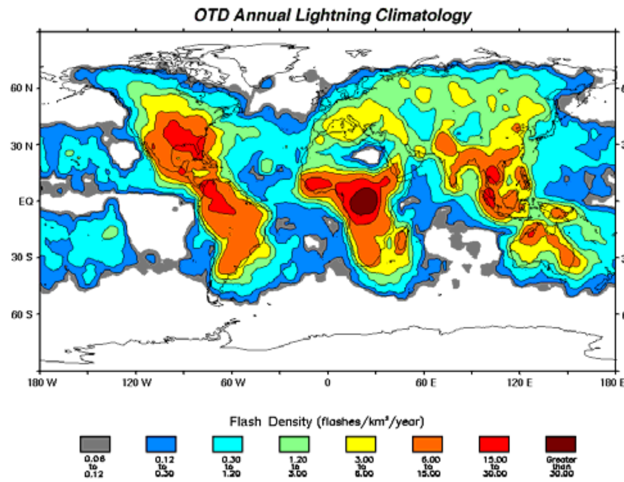
- Lightning occurs mainly in clouds above 500 hPa.
- NO_2 measured in pixels with clouds above 500 hPa (derived with FRESCO) minus background value.
- Background value derived from cloudy pixels between 1000 hPa and 500 hPa.

NO_2 due to lightning





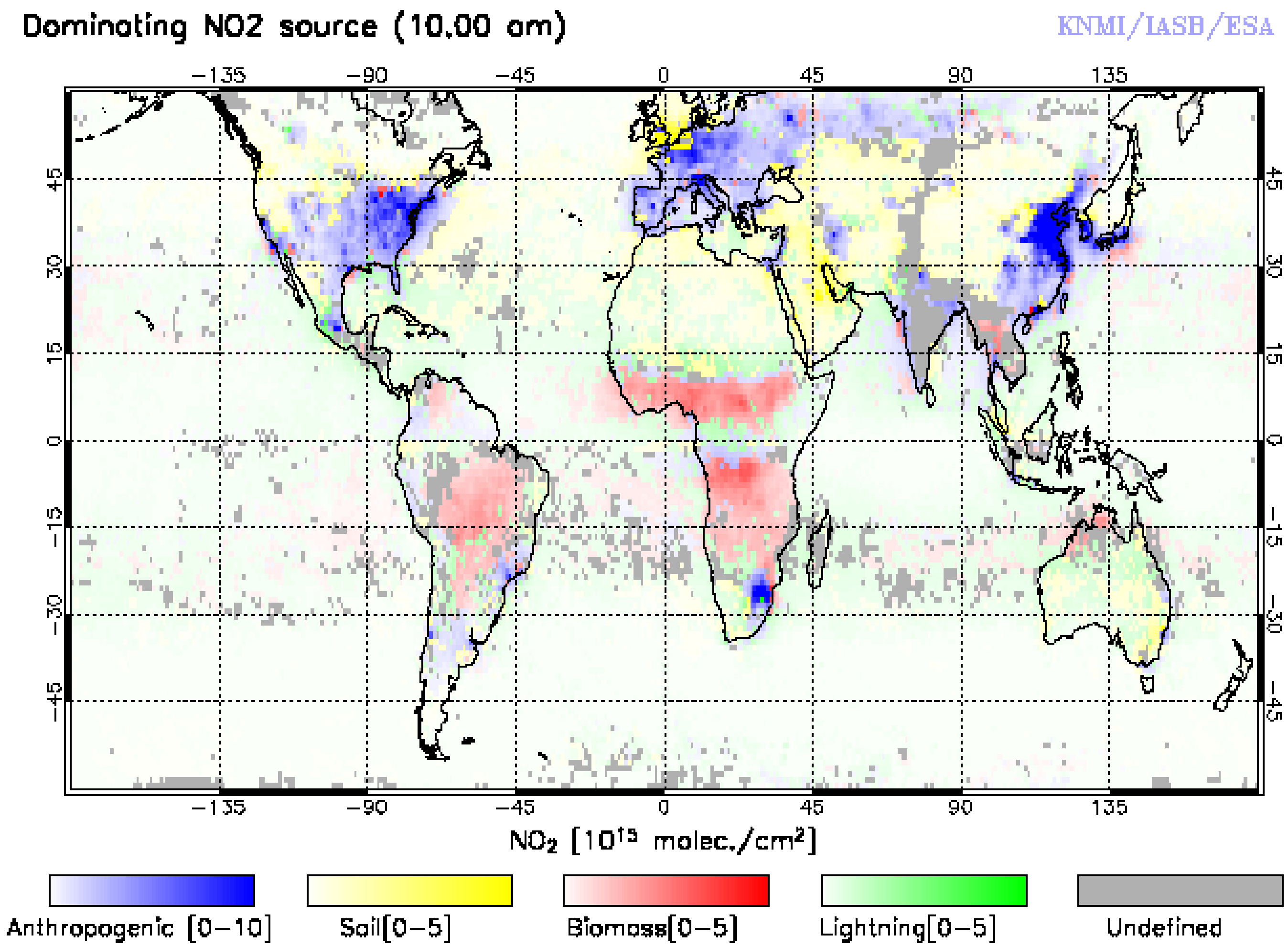
Diurnal variation OTD/LIS
source:K.Driscoll



Scheme of source identification

Anthropogenic	Winter maximum (outside tropics)	Low variability
Biomass	Winter/Spring maximum	High variability
Soil	Summer maximum	High variability
Lightning	NO_2 (above clouds) > NO_2(clear-sky)	

Source identification



Emission estimate in China

- Assuming linear relation between NO_x emissions and observed tropospheric NO_2 column (Martin et al. 2003)
- Ratio between emissions and tropospheric column determined using TM model simulations per grid cell
- Distinction between sources based on what is shown before

NO_x emissions in China

Year	Anthropogenic emissions (Tg N yr^{-1})	Soil emissions (Tg N yr^{-1})
1997	5.5	0.41
1998	5.4	0.41
1999	6.0	0.42
2000	6.0	0.44
2001	6.0	0.37
2002	6.7	0.42
2003	7.9	0.46
2004	8.1	0.33
2005	9.2	0.35

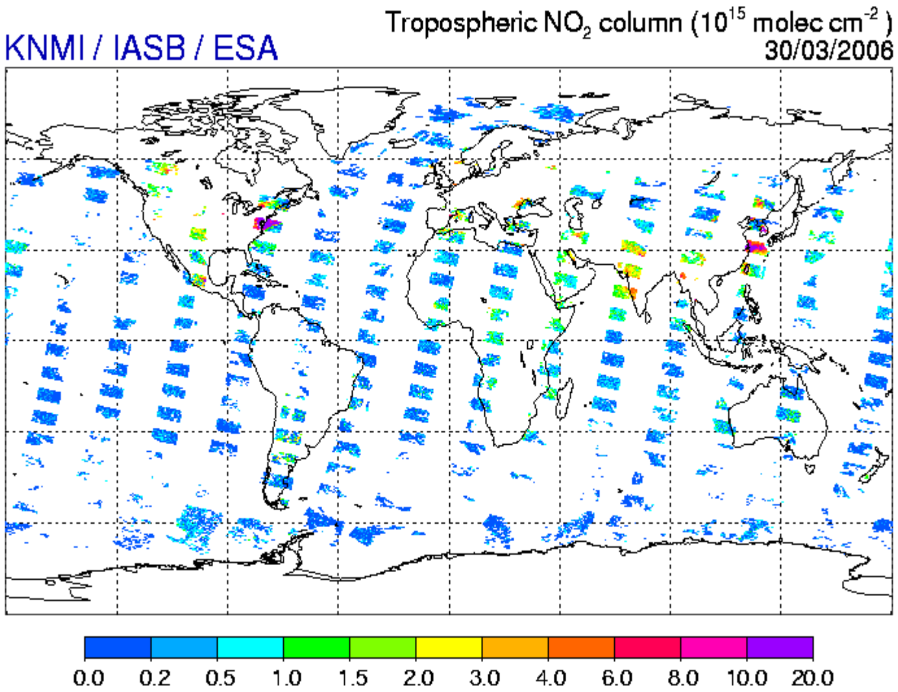
Summary

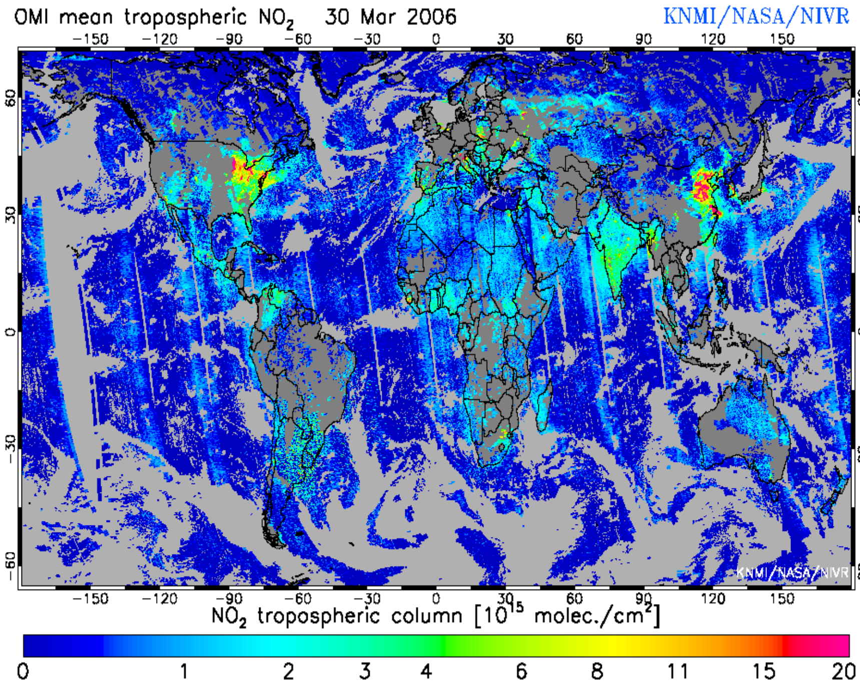
- More than 10 years of tropospheric NO_2 from GOME and SCIAMACHY (1996-2006) retrieved.
- Global trend study: strong pos. trends in Asia (China, Iran).
- Identifying sources using fitted variability.
- Observing NO_2 from lightning in satellite observations with clouds above 500 hPa.
- Emission inventory possible using model information.
- Details: van der A et al., JGR, 2006, in press.
  van der A et al., JGR, submitted.

Outlook

- Extend the time series with OMI data :
  - much larger amount of observation per month
  - overpass time more interesting for lightning observations

Data coverage





SCIAMACHY

OMI