Applications of NO_2 satellite observations

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Outline

- NO2 data sources
- Tropospheric NO2 data applications
  - Air quality monitoring
  - Trends
  - Emission inventory
  - Variability and source detection
- Conclusions

Tropospheric NO2 data sources

Data providers:

- Univ. Bremen (GOME, SCIAMACHY)
- DLR (GOME, SCIAMACHY, GOME-2)
- NASA (OMI)
- TEMIS (GOME, SCIAMACHY, OMI, GOME-2)
- PROMOTE

Archive (images and data)

OMI: *DOMINO version 1.0.2 (2004-today, collection 3, Product Specification)*
individual days | monthly mean | overpass data

DOMINO version 0.9.3 (2006-2008, collection 2)
individual days | monthly mean

GOME-2: *TM4NO2A version 1.10 (2007-today):*
individual days | monthly mean | overpass data

SCIAMACHY: *TM4NO2A version 1.10 (2002-today):*
individual days | monthly mean | regional monthly mean

TM4NO2A version 1.04 (2004-2006) :
individual days | monthly mean

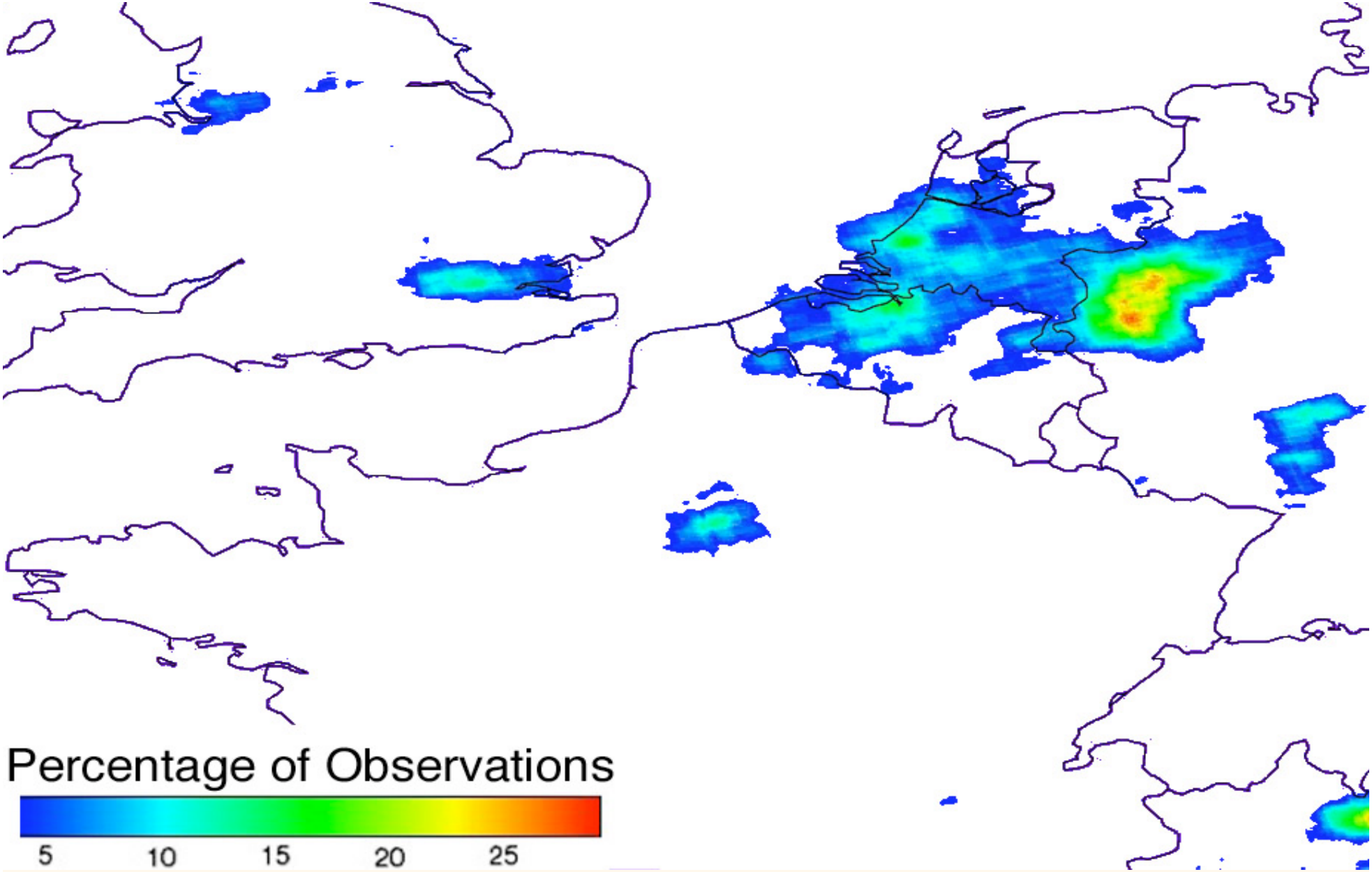
GOME: *TM4NO2A version 1.04 (1996-2003):*
individual days | monthly mean | regional monthly mean

Air quality monitoring

Daily monitoring

Events: Olympic games 2008

Shipping routes



Percentage of observations that exceeds a threshold of $2x10^{16}$ molecules/cm2 ($15x10^{3}$ µg/m2).

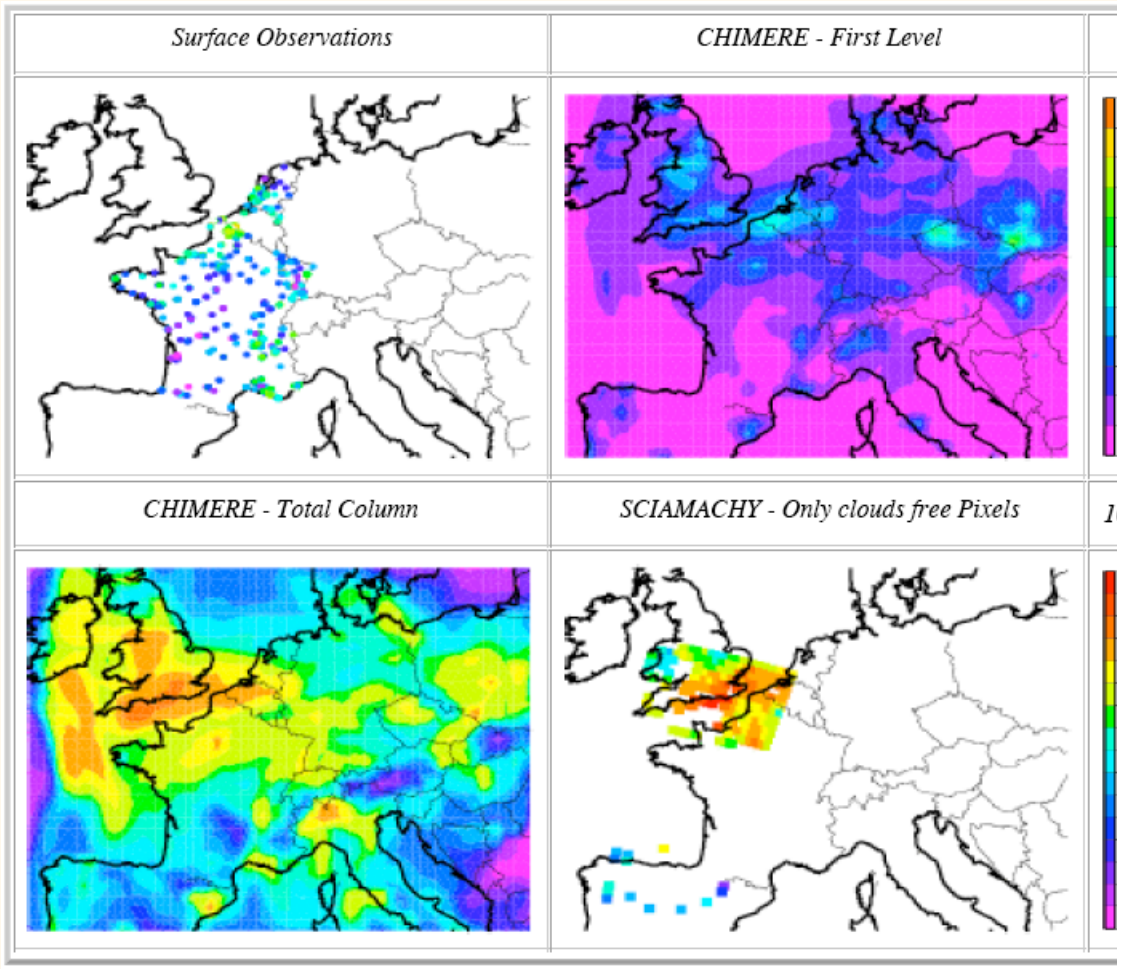
Veefkind et al. (2007)

Air quality

Understand and forecast air pollution:

- CTM input data are uncertain (emissions, meteo)
- Surface obs. difficult:
  - representativity for grid cell
  - no information on vertical distribution
- Satellite data allow extensive evaluation of CTMs

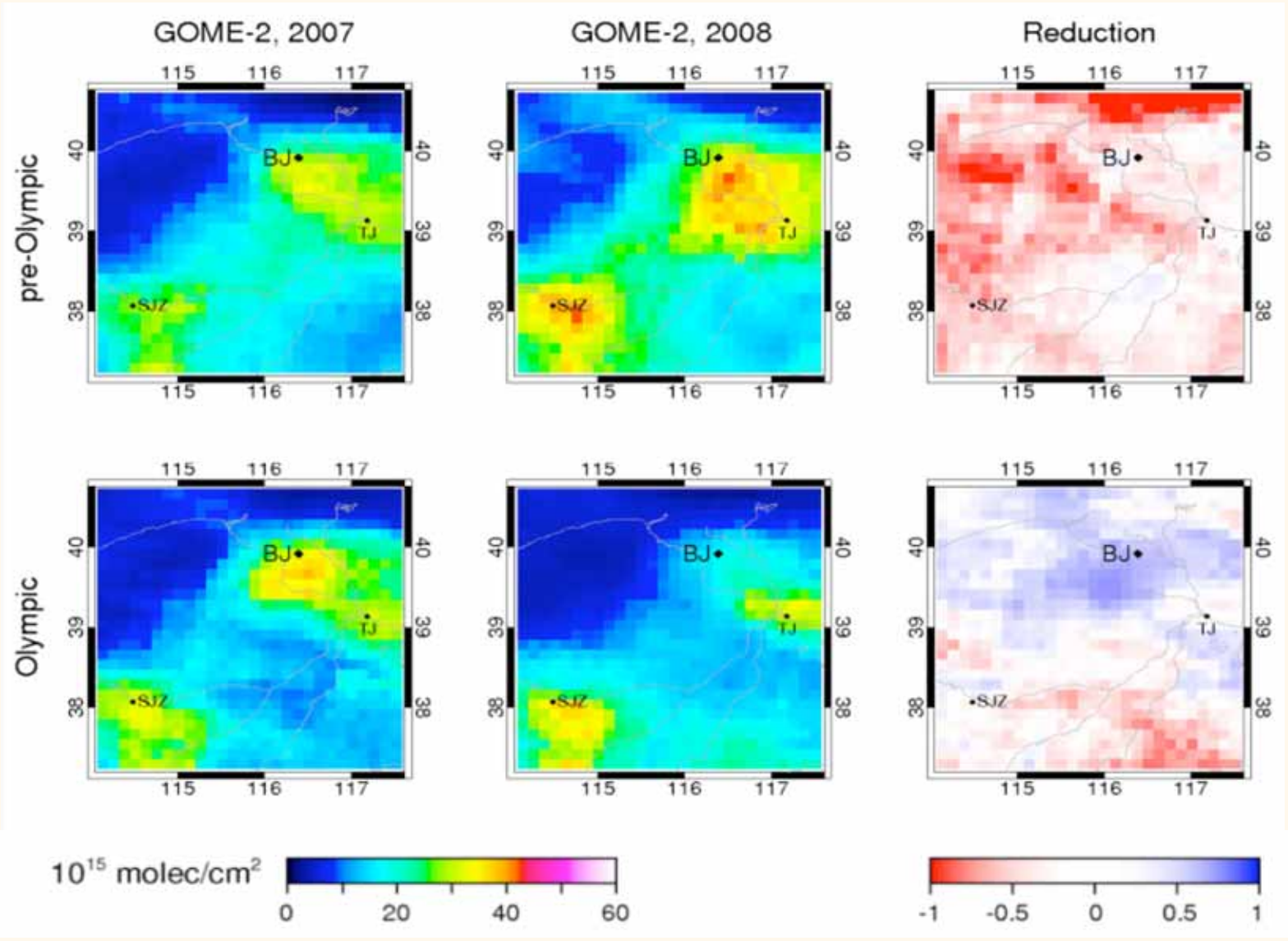
Blond et al., JGR, 2007



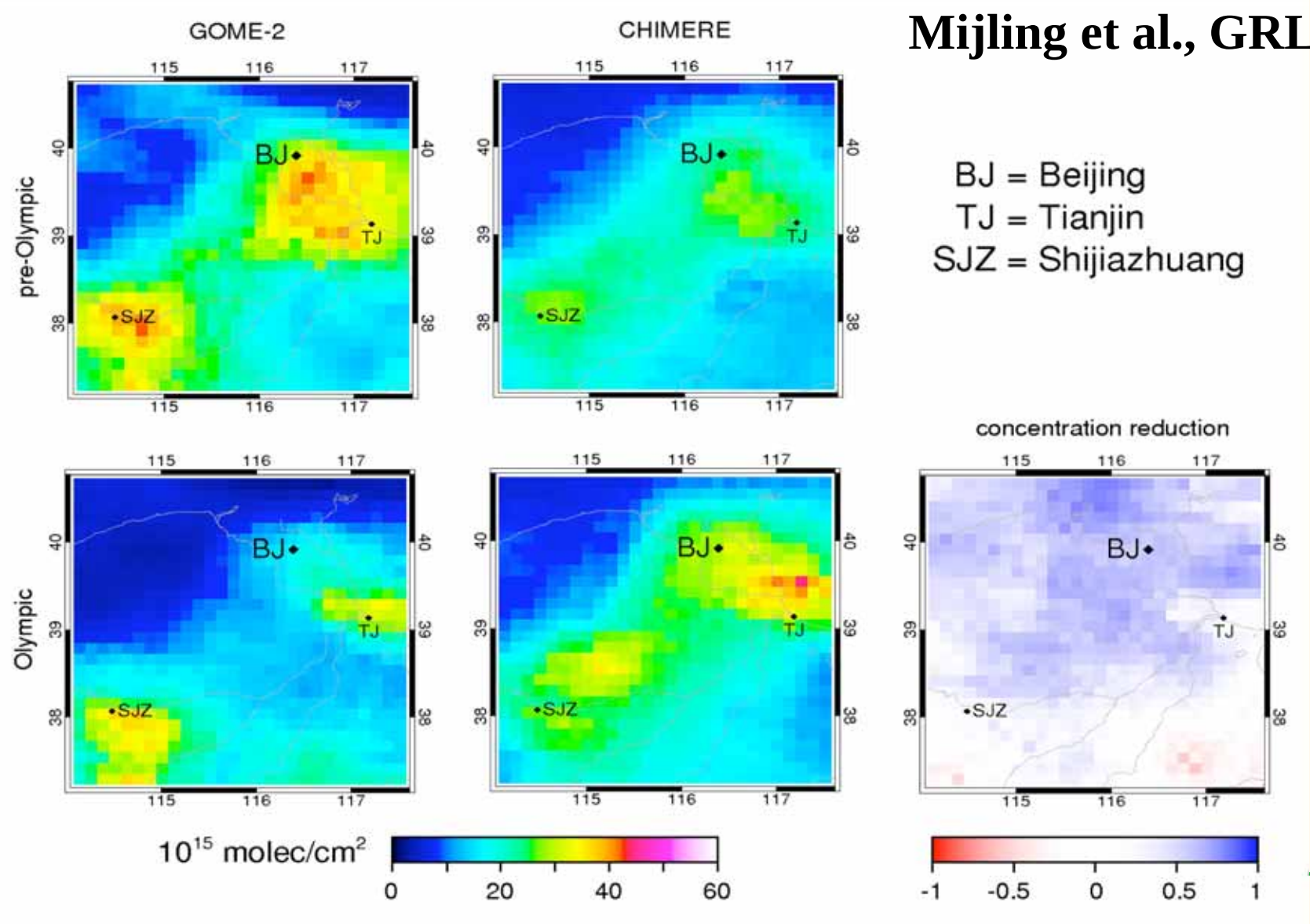
Air Quality Measures during the Olympic Games 2008

23 June	Reduction governmental vehicles by 50% (~210.000 cars)
1 July	Ban 300.000 high-emission vehicles
8 July	Closure of 260 factories in Tangshan (150 km East of Beijing)
20 July	Traffic restriction by odd/even number plates (1.5 – 2 million cars) Closure 150 polluting factories Suspension of construction activities 30% reduction of energy production by coal-fired power plants
25 July	Suspension of polluting industry (40) and construction sites (26) in Tianjin (120 km South East of Beijing)
8-24 Aug	Olympic Games 
28 Aug	Traffic restriction by even/odd number plates lifted outside 5th ring road
6-17 Sep	Paralympics 
21 Sep	Most traffic restrictions lifted

Concentration reduction during the Olympic Games: Satellite



Concentration reduction during the Olympic Games: Satellite and Model



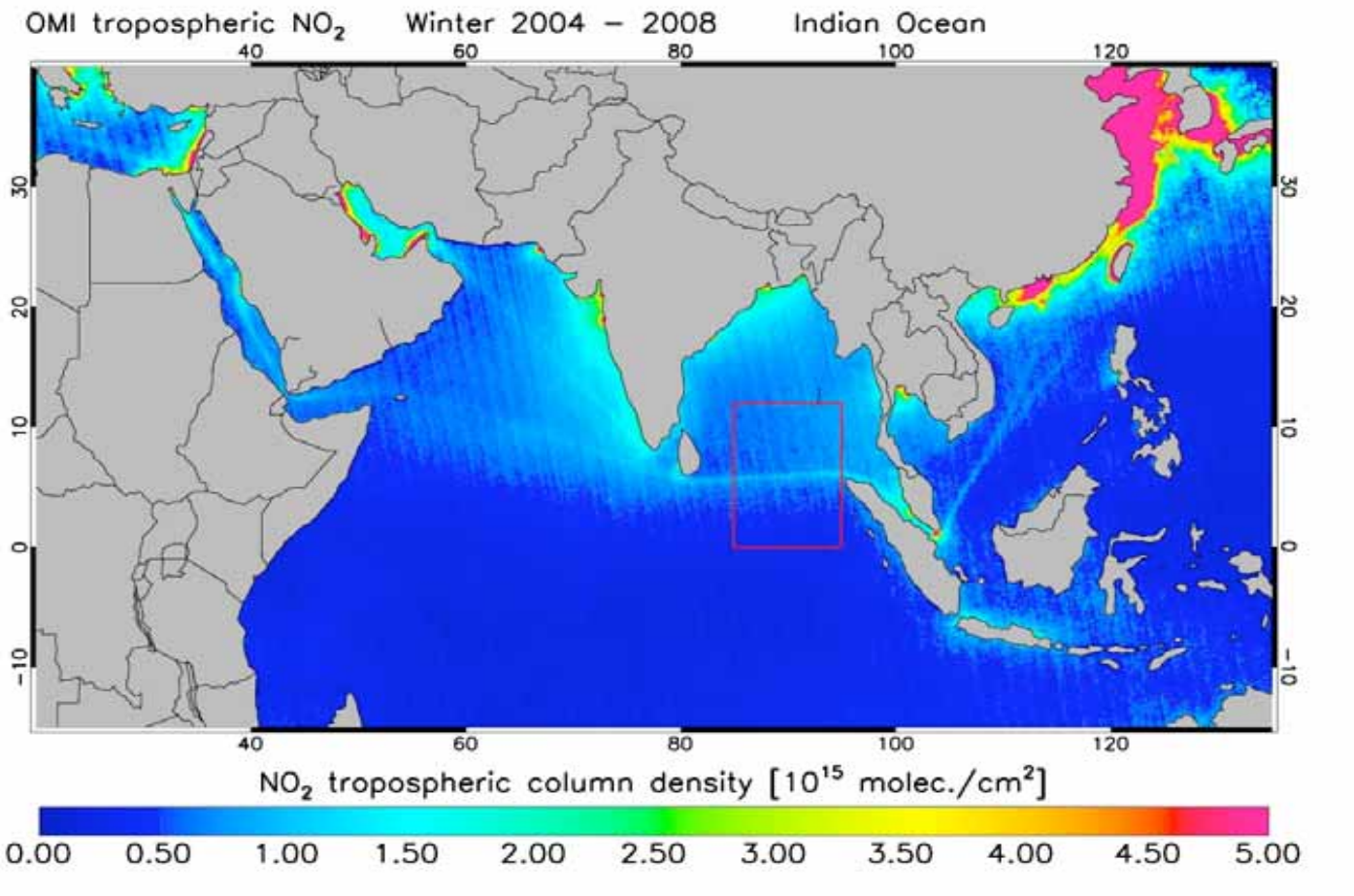
Mijling et al., GRL, 20

Shipping routes

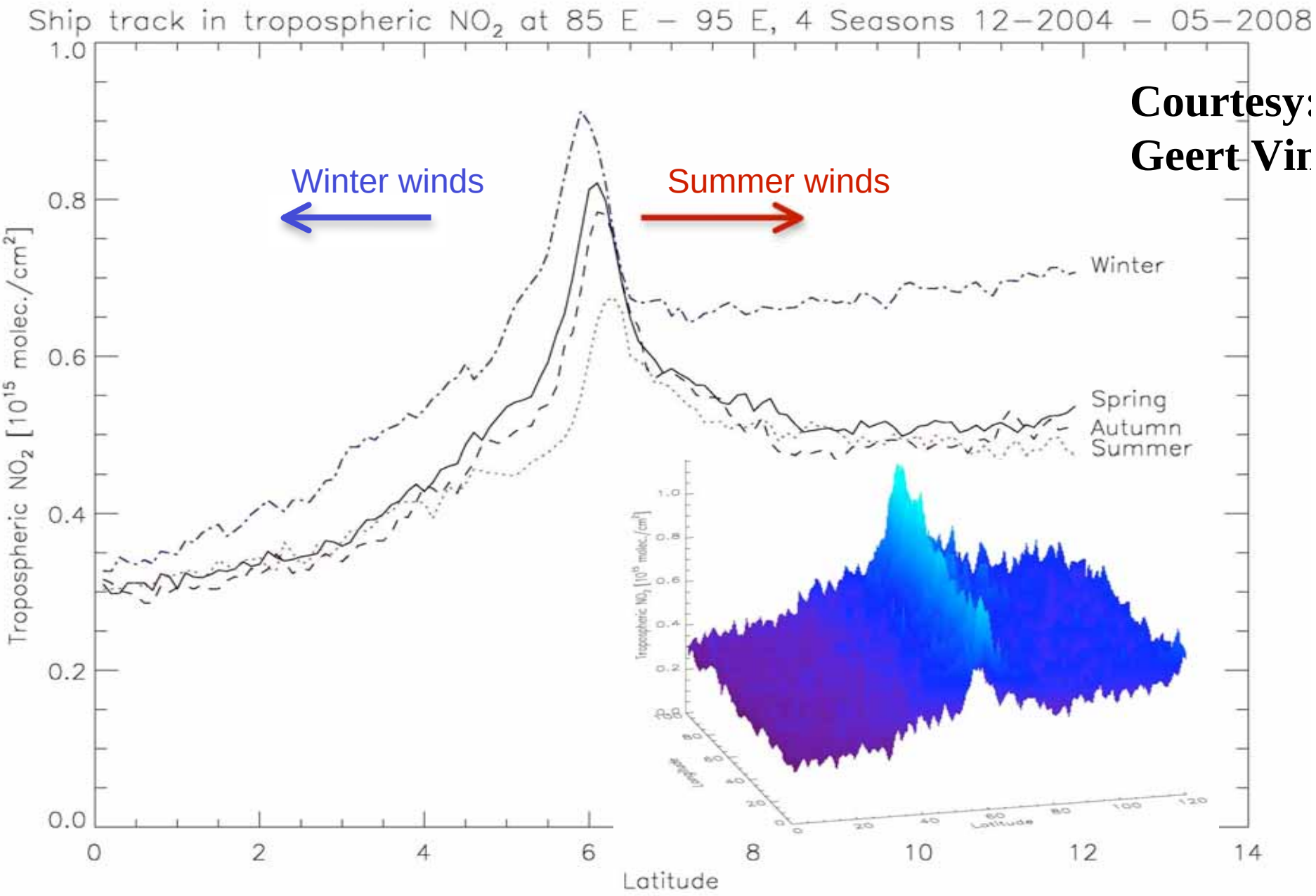
ESA portal 22 May 2009:

- The shipping route map derived from the analysis of Wide Swath Medium resolution mode products from the Advanced Synthetic Aperture Radar (ASAR) instrument on ESA's Envisat satellite between 2002 to 2009. (Credits: CLS - KNMI – ESA)

Shipping routes



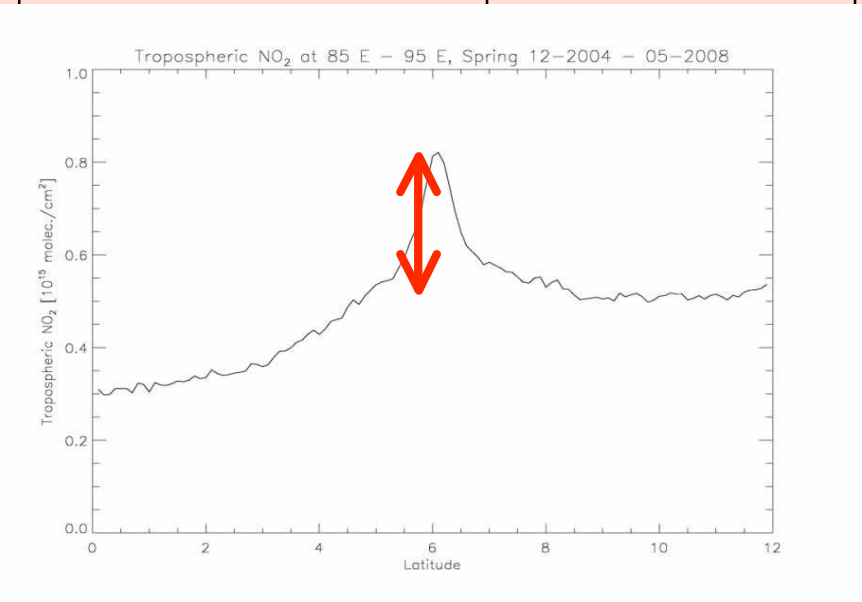
- Seasons average over available da set
- Focuss on area o ship track



Courtesy:
Geert Vir

Estimates of NO2 concentrations due to ships

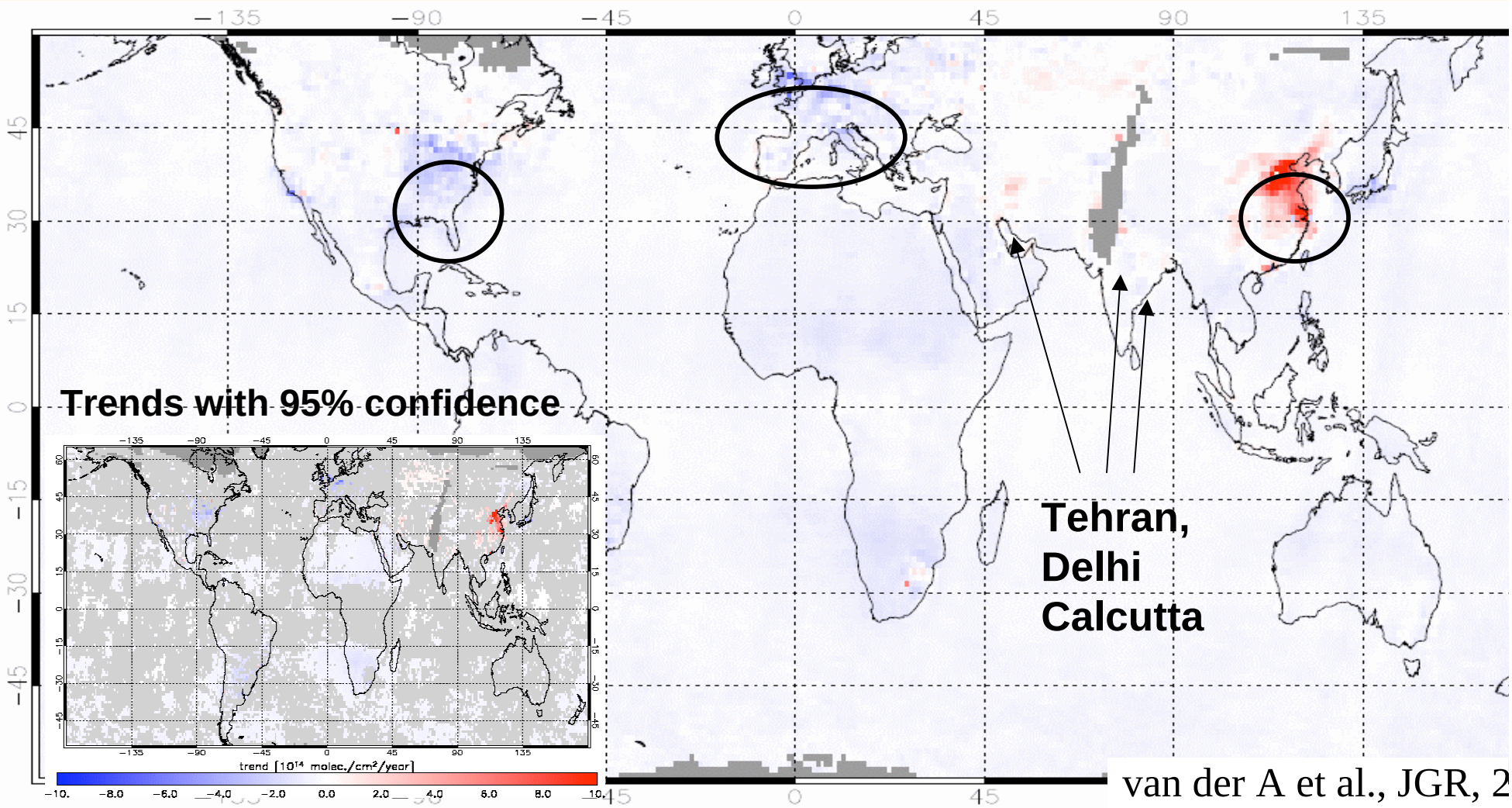
Shipping lane	Estimate (molecules cm^{-2})	Instrument	Source
India to Indonesia	0.35×10^{15}	GOME	[Beirle et al., 2004]
India to Indonesia	$\sim 0.4 \times 10^{15}$	SCIAMACHY	[Richter et al.,2004]
India to Indonesia	0.4×10^{15}	OMI	Vinken et al., in preparation



Trend analyses

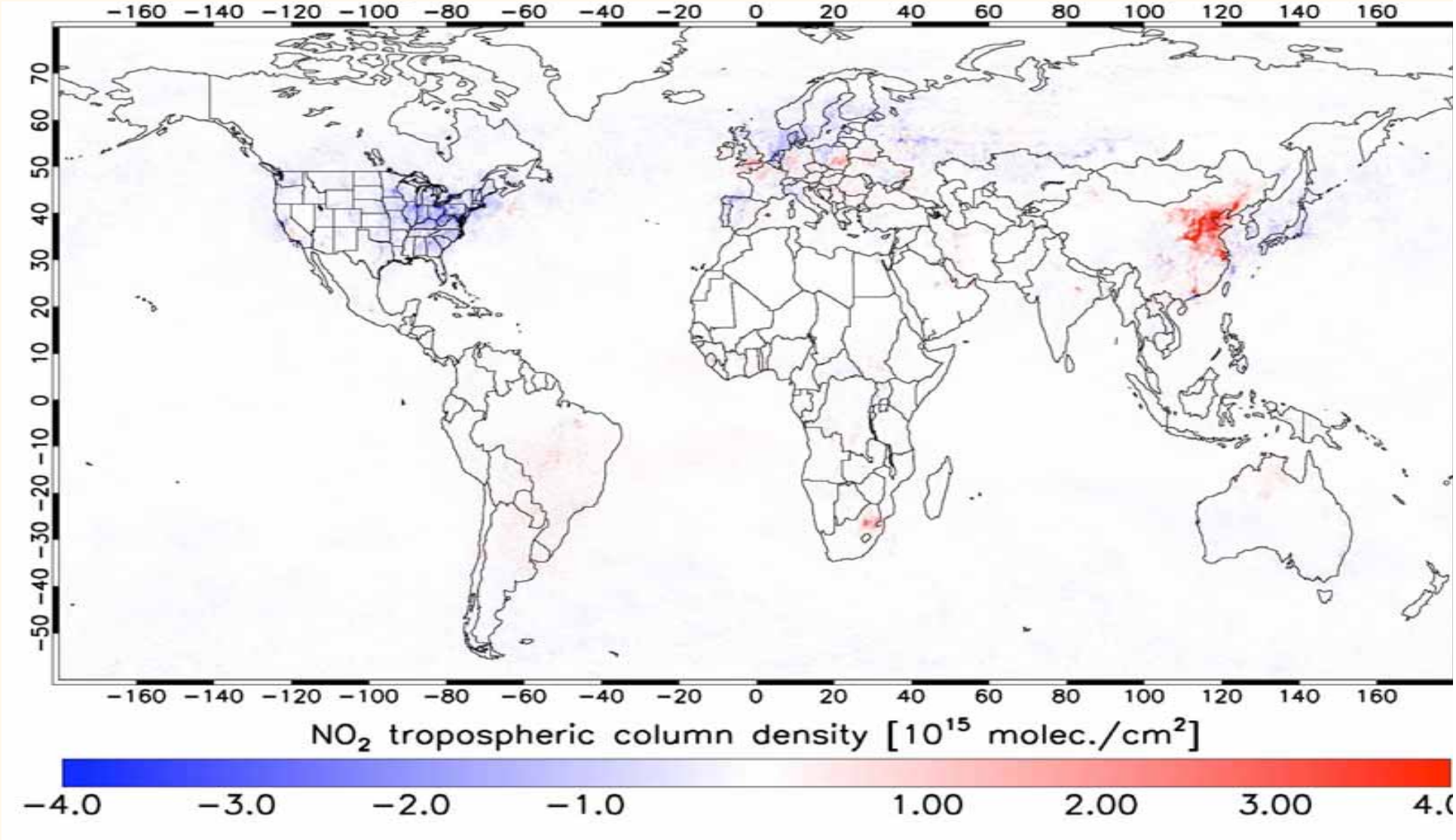
Trend in concentrations
Trend in emissions

Trend in tropospheric NO_2 (1996-2006)



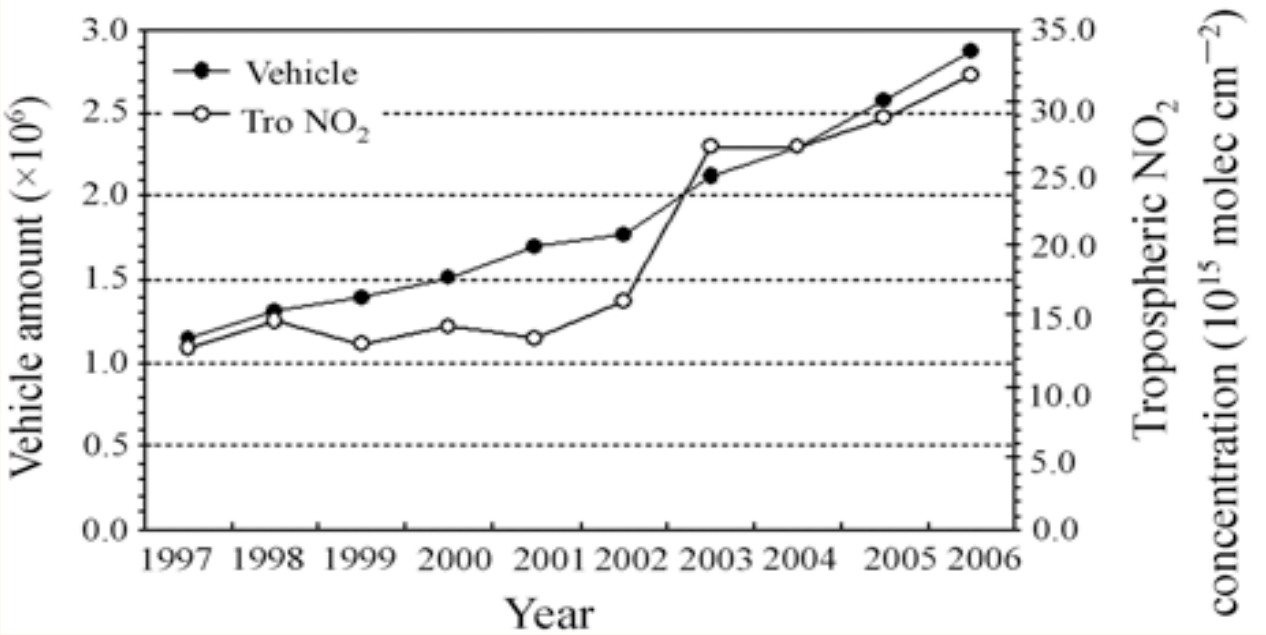
van der A et al., JGR, 2

Continuation with OMI (2004 - now)



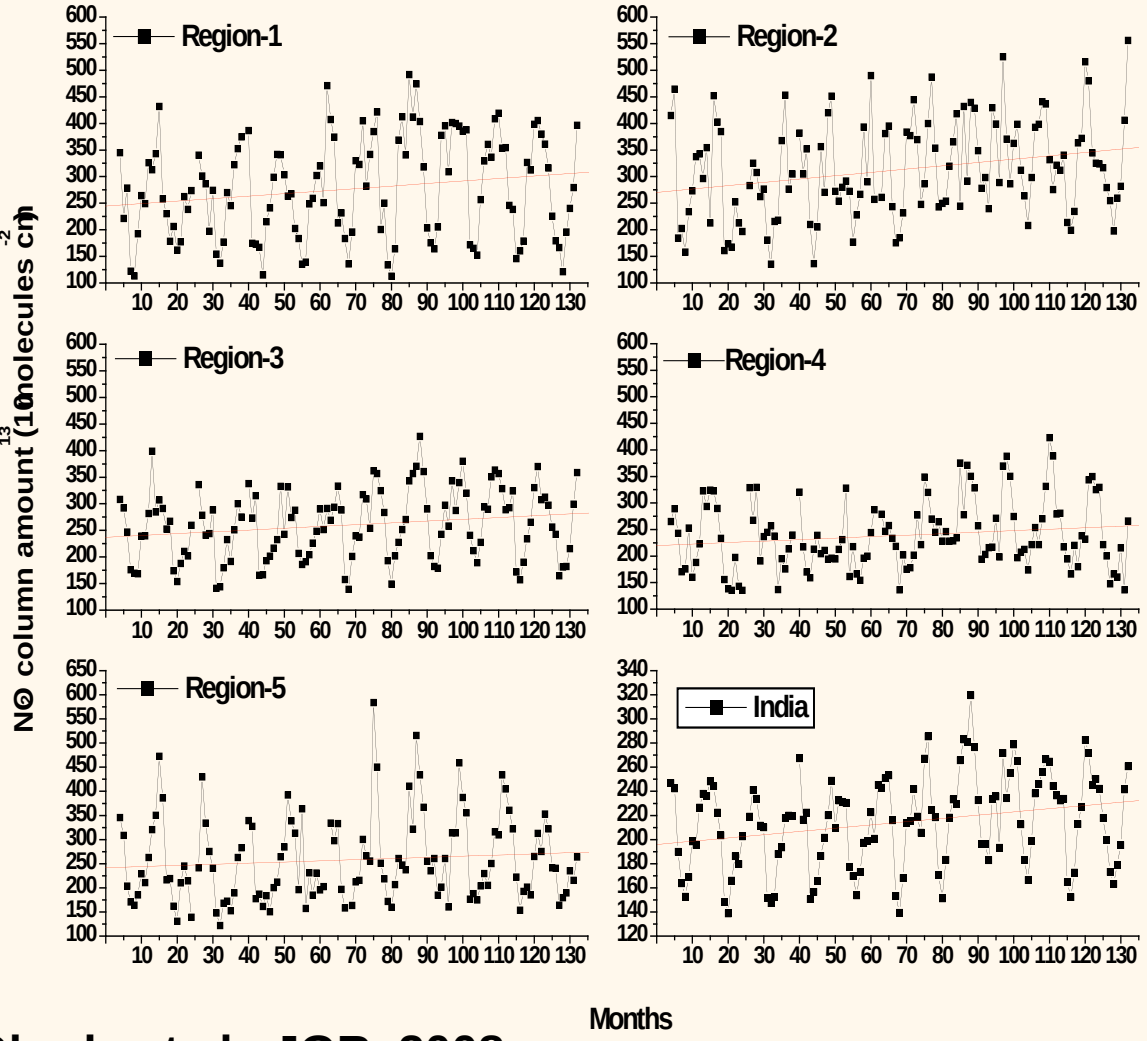
Trend and traffic in China

- Correlation between vehicle population and tropospheric NO2 in Beijing



Zhang XY, Zhang P., Zhang Y., Li XJ & Qiu I Sciences in China Series Earth Sciences, 2007

Trend of tropospheric NO_2 (1996-2006) in India



Ghude et al., JGR, 2008

Region Mumbai: 2.4 %/Yea

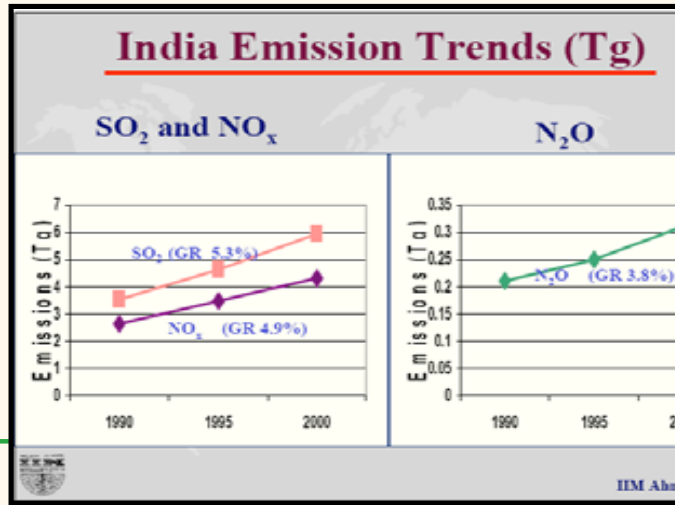
Region Delhi: 3 %/Year

Region Ganges: 1.6 %/Yea

Region South: 1.55 %/Yea

Region Central: 1.3 %/Yea

All India : 1.4 %/Yea



Trends in NOx emissions

NOx emission inventory calculated from ten years of NO2 data

Stavrakou et al., GRL, 2007

Trend Results:

- Emission decrease last decade:
  - Europe 9%
  - Japan 25 %
  - US 26 %
- Emission increase last decade:
  - Far East 9%
  - Beijing/Shanghai 100%
- Trend emissions in line with calculated trends on tropospheric NO2 column

Variability and source detection

Diurnal cycle

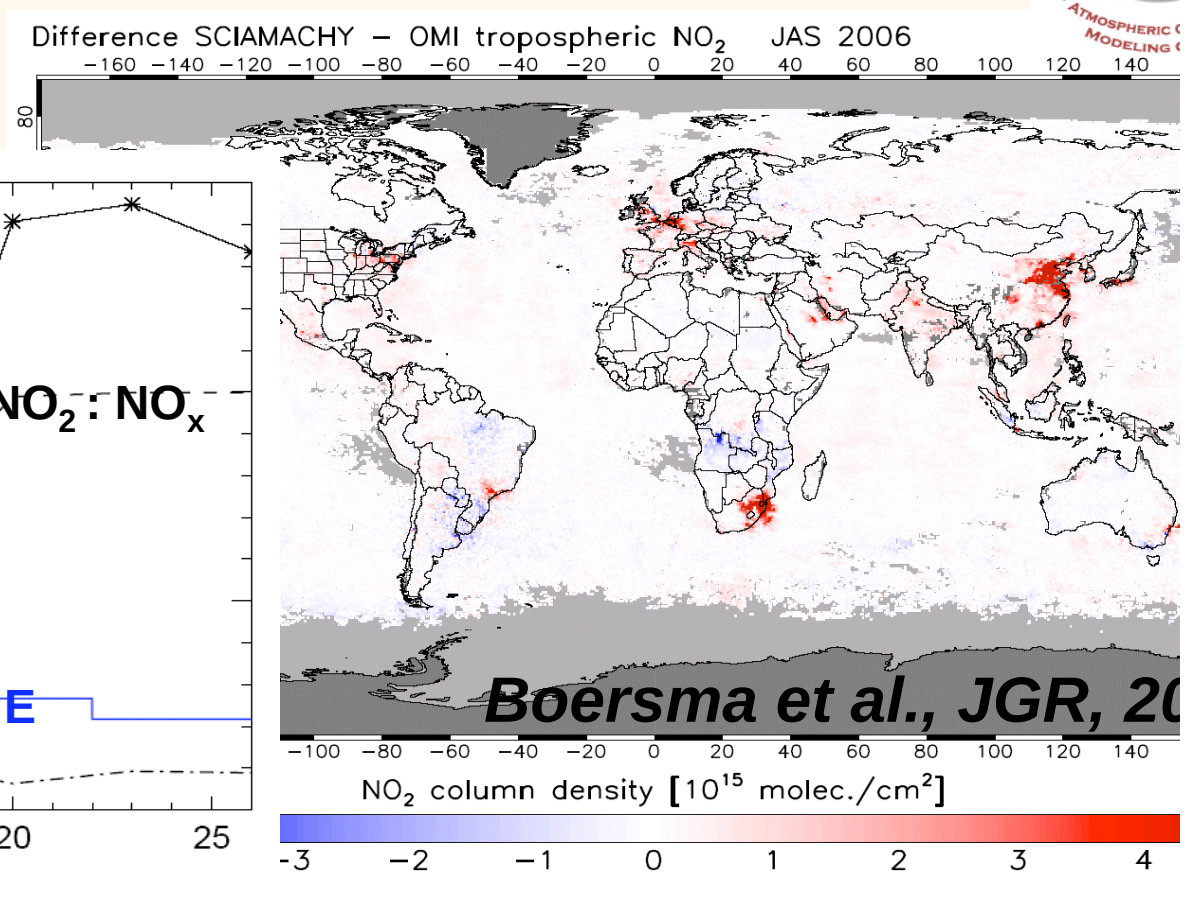
Weekly cycle

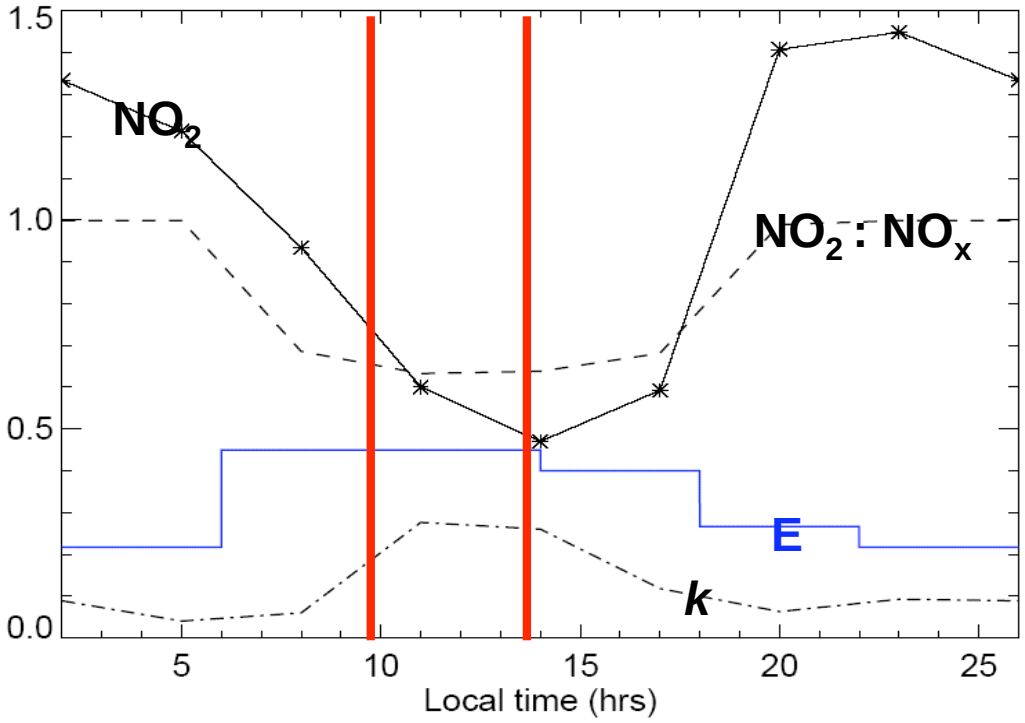
Seasonal cycle

Source detection from variability

NO2 variability: Diurnal cycle

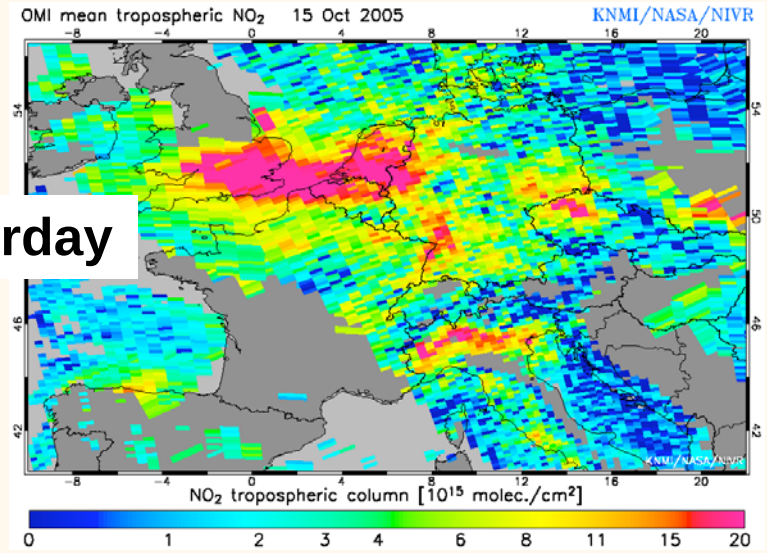
- Use of OMI (13.30 h) and SCIAMACHY (10.00h) to analyse diurnal cycle (including comparison with GEOS-Chem model)
  - Industrial areas: SCIA higher than OMI
  - Tropical biomass burning: OMI higher than SCIA



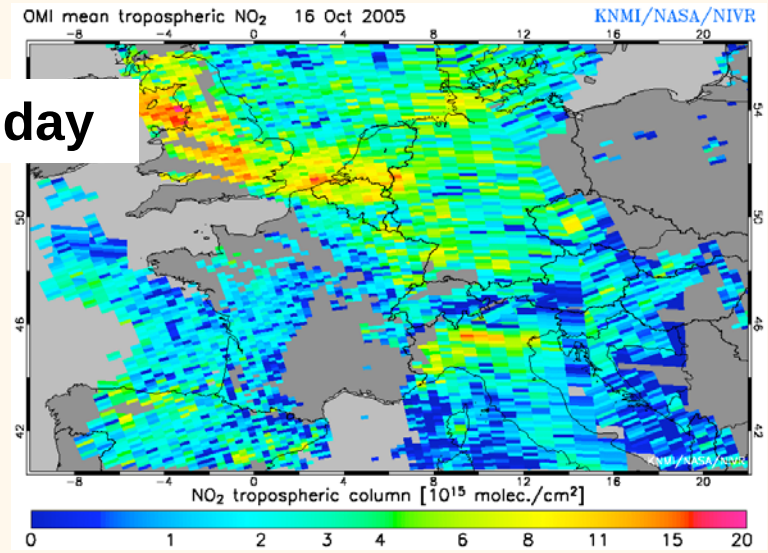


NO2 variability: Weekly cycle

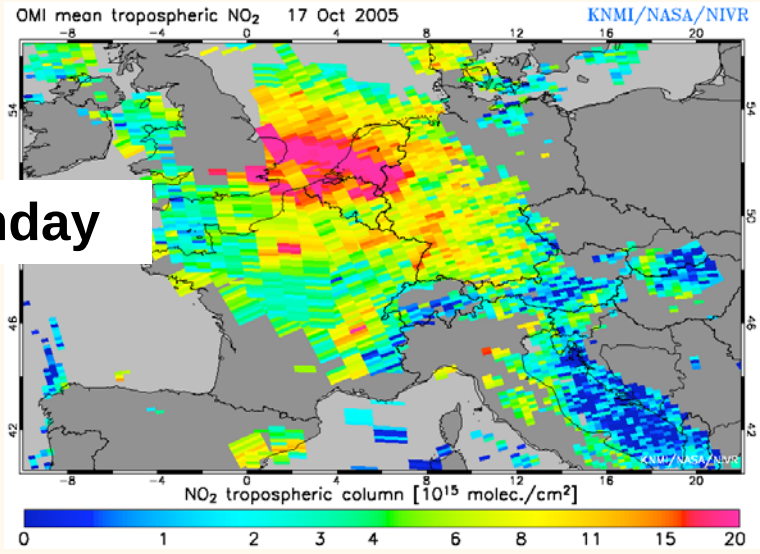
Saturday



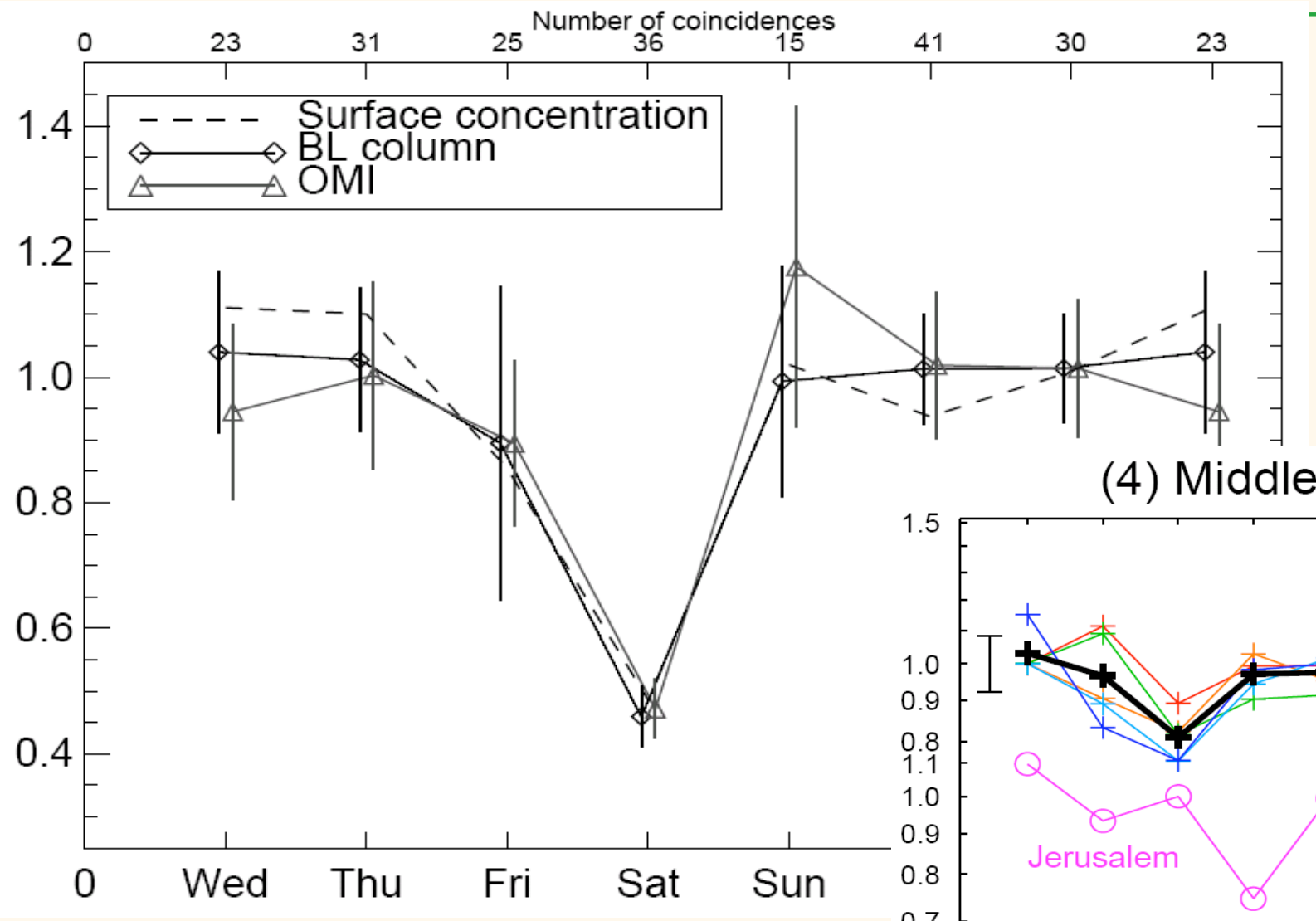
Sunday



Monday



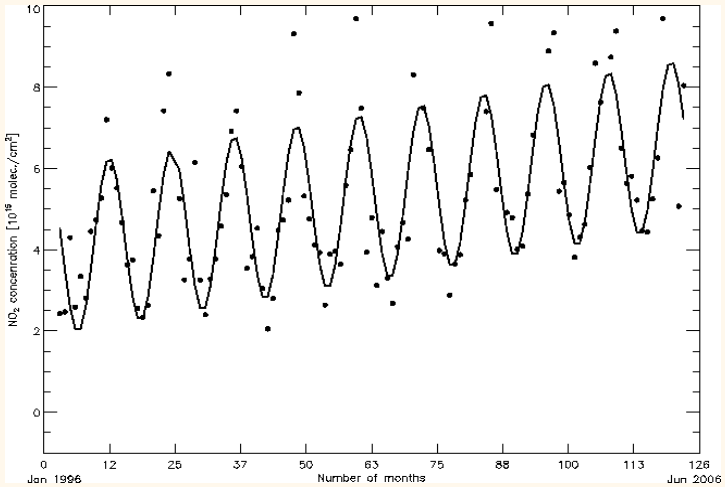
Weekly cycle in surface and OMI NO_2 columns



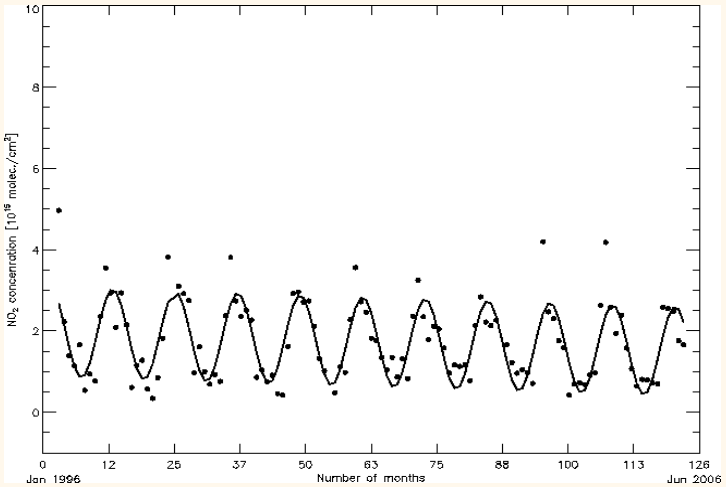
Beirle et al. (ACP, 2004)

NO2 variability: Seasonal cycle

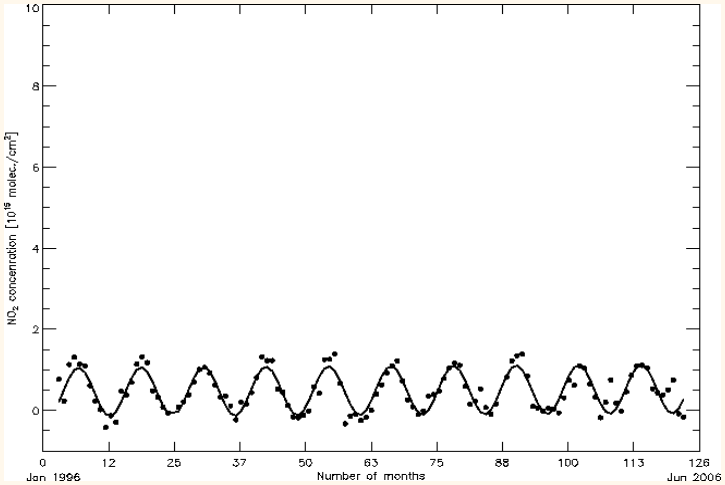
(monthly means 1996-2006)



Anthropogenic (Tehran)



Biomass burning
Ghana (10°N,0°)

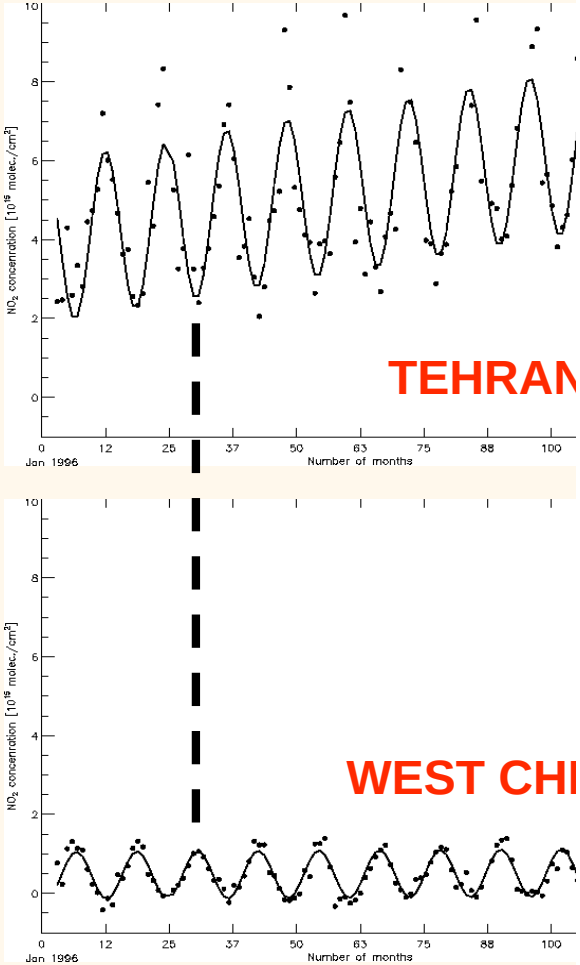


Soil
West-China (40°N,100°E

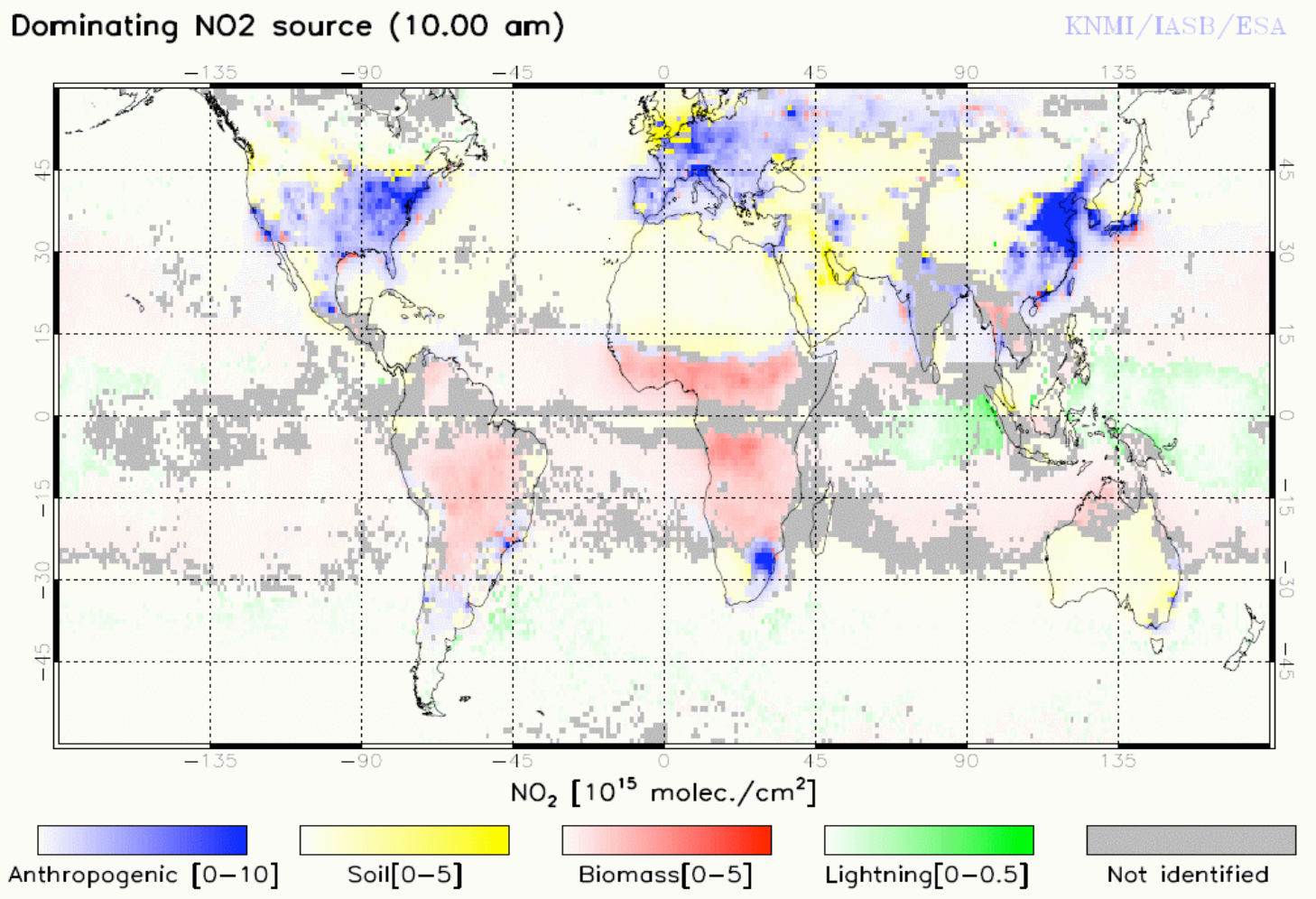
Sources of tropospheric NO_2

- NO_x sources:
  - Anthropogenic (traffic, industry)
  - Soil emissions (grasslands, rain)
  - Biomass burning (tropics, dry)
  - Lightning (tropics)

- Phase shift to identify sources:
  - Anthropogenic winter max.
  - Soil emissions summer max.
  - Biomass burning dry season
  - Lightning -



Source identification



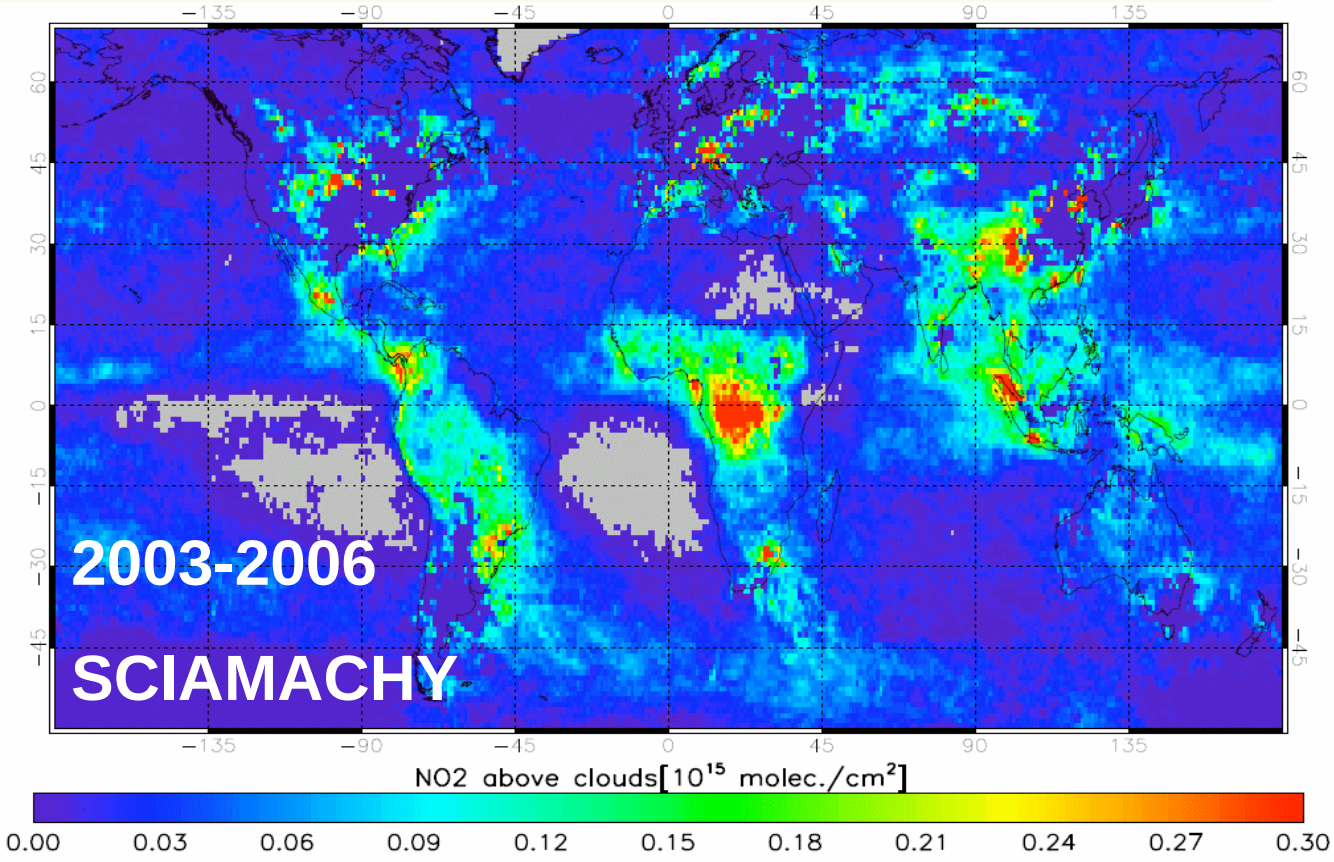
van der A et a

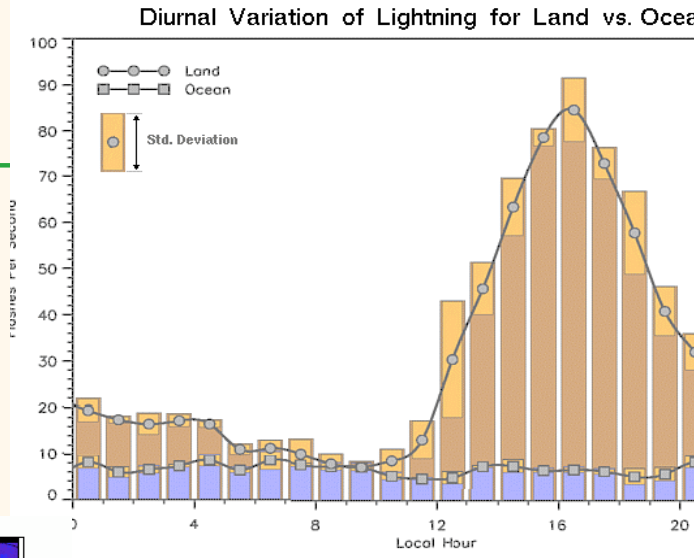
JGR, 2008

NO_2 due to lightning

- Select cloudy pixels with p_{cloud} < 600 hPa
- The clouds obscure other sources
- Normalize with PDF high clouds to get mean

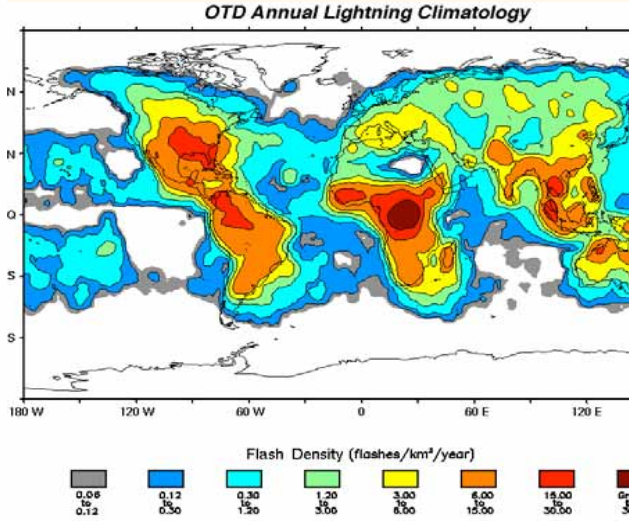
observed at 10.00 am





Diurnal variation OTD/LIS

source:K.Driscoll



Conclusions

- NO_2 data available on internet is widely used
- Growing number of users and applications
- Applications of NO_2 observations in air quality studies:
  - Daily monitoring of NO_2 (threshold exceeding, effect of air quality measures)
  - Shipping routes
  - Trends per region
  - Emission inventory
  - Source identification