Using Satellite Measurements to study the Impact of MegaCities on Air Pollution

ID 420

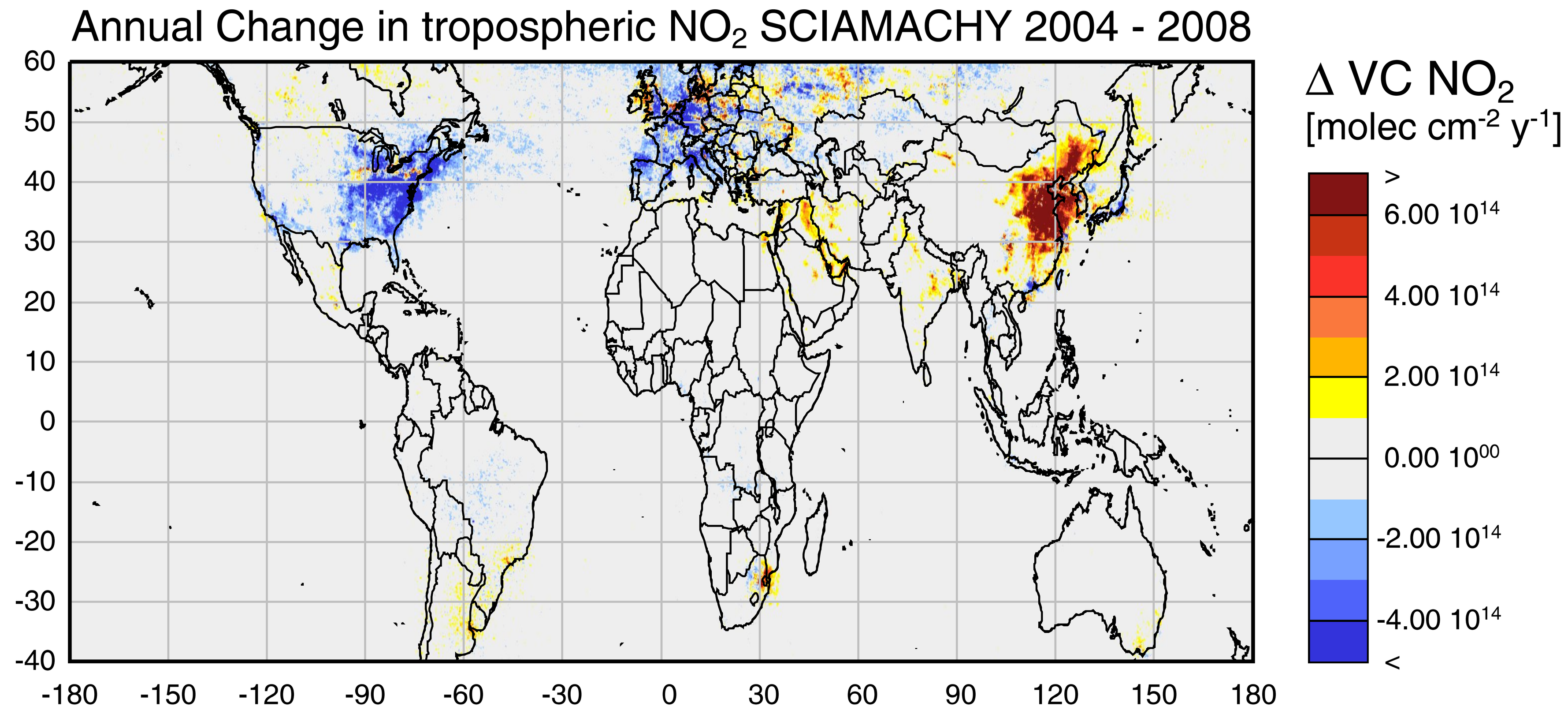
Andreas Richter, Joana Leitao, Andreas Hilboll*, Folkard Wittrock, Mihalis Vrekoussis, and John P. Burrows
Institute of Environmental Physics/Remote Sensing, University of Bremen,
FB 1, P.O. Box 330440, D-28334 Bremen, Germany
Email: Andreas.Richter@iup.physik.uni-bremen.de

Why to look at Megacities?

- the fraction of world population living in large cities is rapidly increasing
- large cities are pollution hot-spots as result of intense traffic, energy use and industrial production
- pollution in large cities affects many people
- many of the emerging large cities are located at low latitudes, providing ideal conditions for photochemical smog formation
- large cities have the potential to export pollution to cleaner regions, in particular if convection is strong

- here, we do not limit ourselves to true Megacities but look at large cities and regions with high population density
- we also look only at NO_2 which can be seen as a proxy for typical urban pollution
- the work presented is part of the new EU project CITYZEN

SCIAMACHY NO_2 Trends



Analysis:

- **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (DOAS) NO_2 retrieval on SCIAMACHY data
- reference sector for stratospheric correction
- tropospheric AMF as described in Richter et al., 2005
- linear trend on annual mean values at a 0.125° x 0.125° resolution
- no error weighting or significance limits yet

Results:

- general decrease in the US and parts of Europe and Japan
- large increase over China but not everywhere
- strong increase for many big cities (see box to the right)
- very consistent pattern, low scatter

Why to use Satellites and which?

Pros of satellites:

- global coverage
- long and consistent time-series
- the only available system

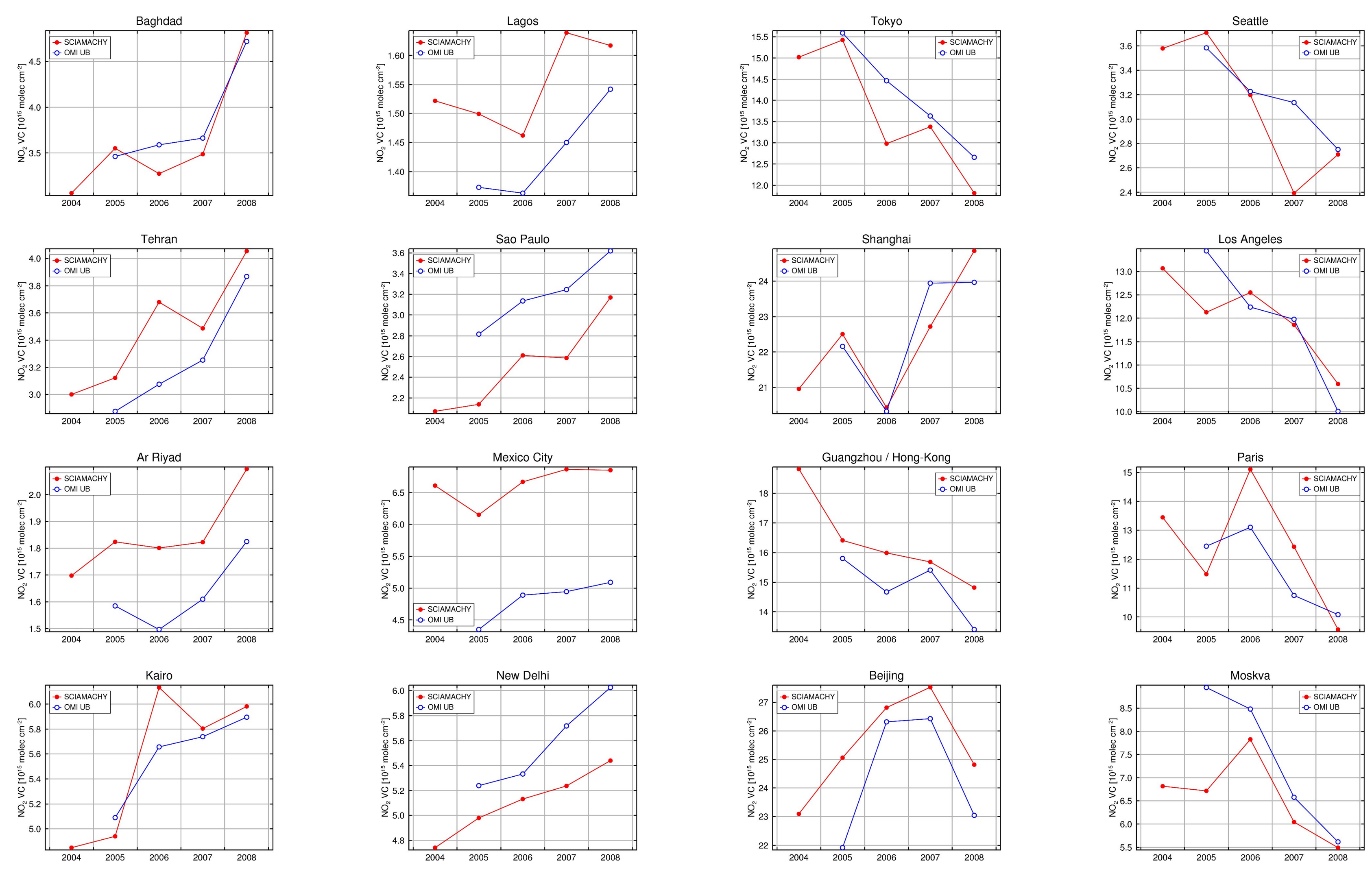
Cons of satellites:

- low spatial resolution
- no vertical resolution
- indirect measurement
- measurements limited to few species

Available satellites for NO_2:

- **GOME** (7.1995 - 6.2003) 320 x 40 km², 3 day coverage
- **SCIAMACHY** (8.2002 - today) 60 x 30 km², 6 day coverage
- **OMI** (8.2004 - today) up to 13 x 24 km², 1 day coverage
- **GOME-2** (1.2007 - today) 80 x 40 km², 1.5 day coverage

NO_2 Changes over selected Cities



Data sets

- SCIAMACHY data as described to the left
- OMI data are based on NASA V3 slant columns applying UB stratospheric correction and airmass factors for higher consistency
- regions selected to contain visible plume of city (somewhat arbitrary)
- agreement between OMI and SCIAMACHY not expected to be perfect (different overpass time, different spatial resolution, different spatial sampling)

Observations

- most of the tendencies are very consistent over the years and between instruments
- there is some interannual variability which often is seen by both sensors
- in some regions in China, the upward trend has been stopped in spite of overall increases
- over Beijing, the 2008 values are markedly lower than in previous years

Uncertainties in Satellite Trends

Uncertainties in satellite derived trends comprise random and systematic parts. When looking at relative changes, many systematic errors cancel as long as they don't change. Therefore, the most problematic error sources are those linked to changing conditions, e.g. aerosol load, land use or instrument changes.

Random Errors:	Possible approaches:
uncertainty in retrieval (fitting error)	more averaging, larger fitting window
random uncertainties from airmass factor	use of better a priori data
impact of clouds on retrieval	improved cloud products
variations in stratospheric NO_2 not fully accounted for	improved stratospheric NO_2 correction from models / measurements
poor temporal and spatial sampling	combination of several instruments
Systematic Errors:	
instrumental drift	comparison of different instruments
changes in aerosol load	use of measured aerosol AOD
changes in NO_2 / NOx ratio	model sensitivity studies
changes in NO_2 lifetime	model sensitivity studies
changes in vertical distribution of NO_2	models / measurements?

Conclusions and future Work

Conclusions

- satellite derived tropospheric NO_2 columns for the last years show consistent and large changes over many regions of the world
- notable increases are observed for large cities in the developing world, decreases in the US, Europe and Japan
- the increase in China continues overall but downward trends are found for Hong-Kong and Beijing indicating a change in emissions
- results from SCIAMACHY and OMI show good overall consistency in spite of differences in the retrieval and measurement conditions

Future work

- reduction of trend uncertainty by improved stratospheric and aerosol corrections
- improved consistency between instruments
- statistical treatment of uncertainties and significance of observed changes

Acknowledgements

- SCIAMACHY radiances and irradiances have been provided by ESA through DLR
- OMI NO_2 slant columns have been provided by NASA
- Parts of this project have been funded by the University of Bremen, the CityZen project and the ESSReS Research School

Selected References

Bucsela, E.J. *et al.*, (2006), Algorithm for NO2 Vertical Column Retrieval From the Ozone Monitoring Instrument, IEEE Trans. Geo. Rem. Sens., **44**, No. 5, 1245-1258.
Ghude, S. D.et al., (2008), Detection of surface emission hot spots, trends, and seasonal cycle from satellite-retrieved NO2 over India, J. Geophys. Res., 113, D20305, doi:10.1029/2007JD009615.
Konovalov, I. et al., (2008), lSatellite measurement based estimates of decadal changes in European nitrogen oxides emissions, *Atmos. Chem. Phys.*, **8**, 2623-2641
Richter, A., et al.,(2005) Increase in tropospheric nitrogen dioxide over China observed from space, *Nature*, **437**, 129-132, doi: 10.1038/nature04092.
Uno, I. et al., (2007), Systematic analysis of interannual and seasonal variations of model-simulated tropospheric NO_2 in Asia and comparison with GOME-satellite data, *Atmos. Chem. Phys.*, 7, 1671-1681.
van der A, R. J. et al., (2006), Detection of the trend and seasonal variation in tropospheric NO2 over China, J. Geophys. Res., 111, D12317, doi:10.1029/2005JD006594.
van der A, R. J. et al., (2008), Trends, seasonal variability and dominant NOx source derived from a ten year record of NO2 measured from space, J. Geophys. Res., 113, D04302, doi:10.1029/2007JD009021.

Universität Bremen

see also: www.iup.uni-bremen.de/doas