Satellite Observations of NO_2 over Megacities

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Why look at Megacities?

- the fraction of world population living in large cities is increasing rapidly
- 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

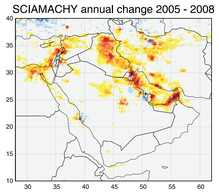
SCIAMACHY NO_2 Trends

Instrument:
- SCIAMACHY (Scanning Imaging Spectrometer for Atmospheric Chartography)
- data since August 2002
- spatial resolution 60 x 30 km^2
- global coverage in 6 days

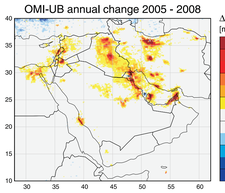
Analysis:
- **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (DOAS) NO_2 retrieval
- reference sector for stratospheric correction
- tropospheric AMF as described in Richter et al., 2005
- linear trend on annual mean values at a 0.125° x 0.125° resolution
- no error weighting or significance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

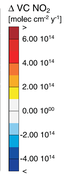
Results:
- general decrease in the US and parts of Europe and Japan (see large figure)
- strong increase for many big cities (see box to the right)
- very consistent pattern, low scatter
- good agreement between SCIAMACHY and OMI results (see below)

SCIAMACHY annual change 2005 - 2008



OMI-UB annual change 2005 - 2008





Consistency:
- SCIAMACHY and OMI based NO_2 trends in very good agreement
- OMI NO_2 uses operational slant columns + UB processing
- large NO_2 increases are evident throughout the Middle East with very few exceptions e.g. (Israel)
- some differences are visible, probably from difference in sampling and overpass

Acknowledgements

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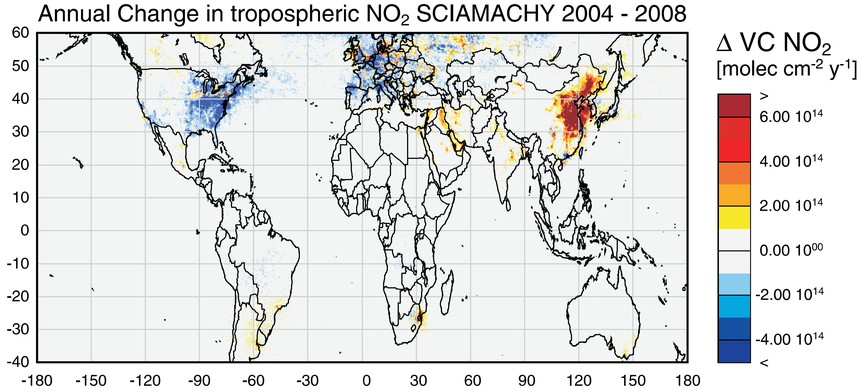
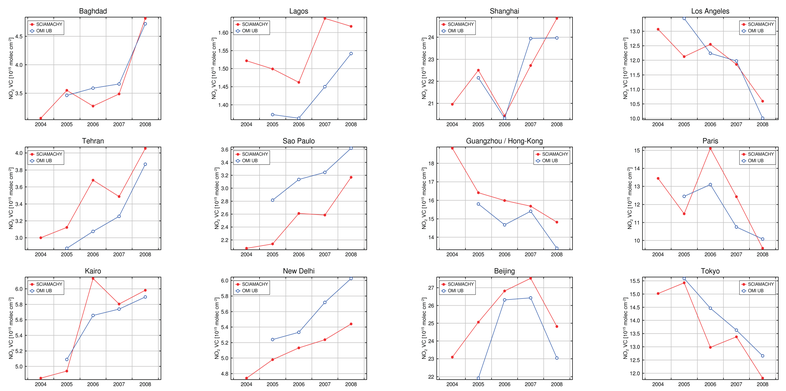
- OMI NO_2 slant columns have been provided by NASA
- Parts of this project have been funded by the University of Bremen, the European project CityZen and the ESSReS Research School

Annual Change in tropospheric NO_2 SCIAMACHY 2004 - 2008



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

- 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

Selected References

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