Long-term observations of reactive trace gases in the troposphere by remote sensing techniques

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Abstract

- The DOAS-group - one department of the Institute of Environmental Physics (IUP) - is working since 1993 on UV/visible remote measurements of atmospheric composition
- Satellite data of the Global Ozone Monitoring Experiment (GOME), the SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY (SCIAMACHY) and the GOME-2 instrument are analysed with the DOAS algorithm and validated by ground based MAX-DOAS measurements
- Near real time and off-line scientific data products from both satellite and ground-based instruments can be found on our data page (www.doas-bremen.de) and on different data bases (e.g. NDACC and CAL/VAL)
- This study presents selected results focussing on tropospheric trace gases.

Instruments and Retrieval

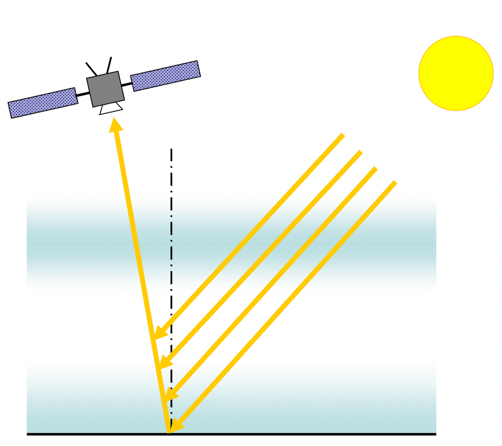


Fig 1: Sketch of the measurement geometry for the satellite. The light observed by the satellite is either reflected on the surface or scattered back from the atmosphere.

Measurement Technique:

- Differential Optical Absorption Spectroscopy (DOAS) on UV/visible sun light scattered back and reflected from the atmosphere and surface
- use of Lambert-Beer's law to determine the absorption along the effective light path
- use of radiative transfer simulations to determine the effective light path

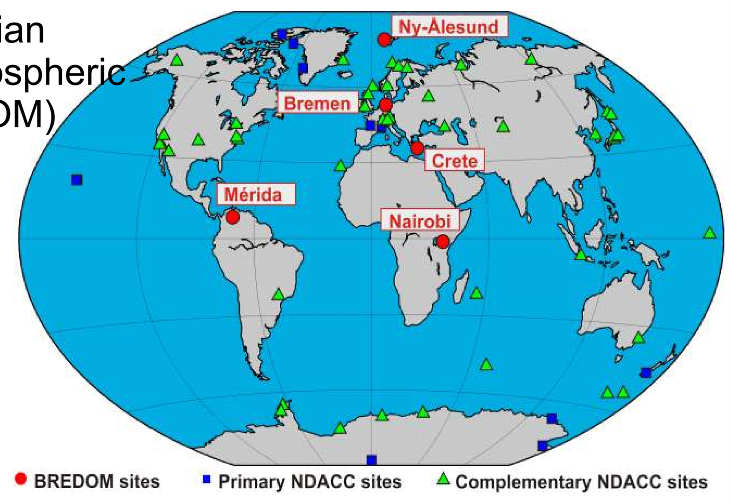
Instruments used:

GOME
- data from 09.1995 - 6.2003
- 320 x 40 km^2 pixels
- global coverage 3 days
- 10:30 LT equator crossing

SCIAMACHY
- data since 08.2002
- 60 x 30 km^2 pixels
- global coverage 6 days
- 10:00 LT equator crossing

GOME-2
- data since 01.2007
- 80 x 40 km^2 pixels
- global coverage 1.5 days
- 9:30 LT equator crossing

Fig 2: Map of the Bremian DOAS network for atmospheric measurements (BREDOM) and NDACC sites



Ground-based (BREDOM)
- five permanent stations, all equipped with Multi Axis Differential Optical Absorption Spectroscopy (MAXDOAS) instruments. These instruments are basically UV/visible spectrometers observing scattered light in different viewing directions.

Global tropospheric NO_2 changes observed from space

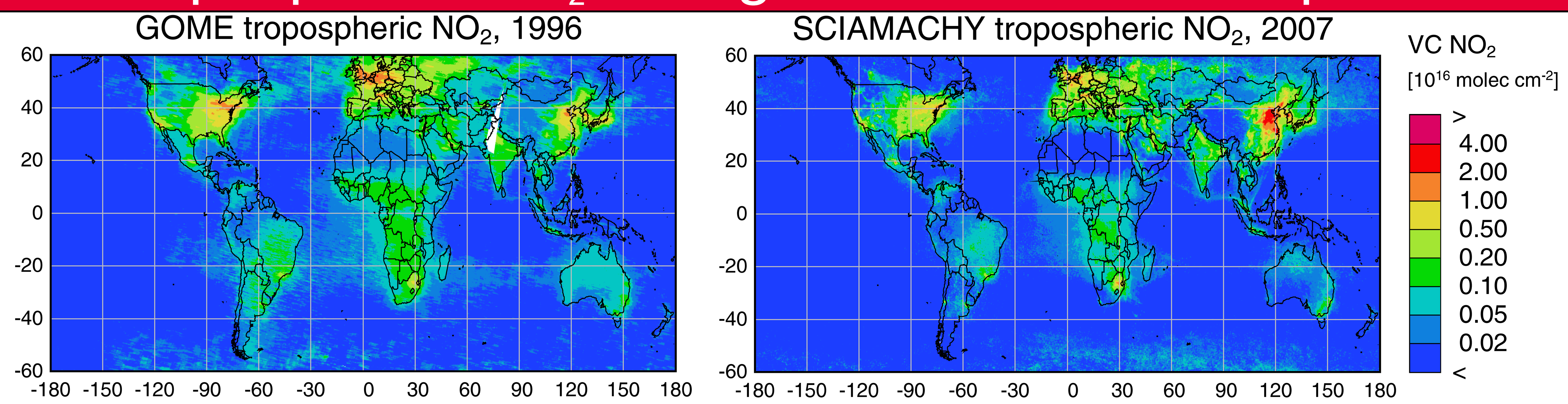


Fig. 4: Annual averages of tropospheric NO_2 columns from GOME for 1996 (left and SCIAMACHY for 2007 (right)
- the overall patterns in the two measurements agree very well
- the range of observed columns is very large (note the logarithmic colour scale)
- SCIAMACHY measurements provide more detail as result of the better spatial resolution
- NO_2 columns over large parts of China are much larger in 2007 than in 1996
- NO_2 columns over Europe and the US are somewhat smaller in 2007 than in 1996

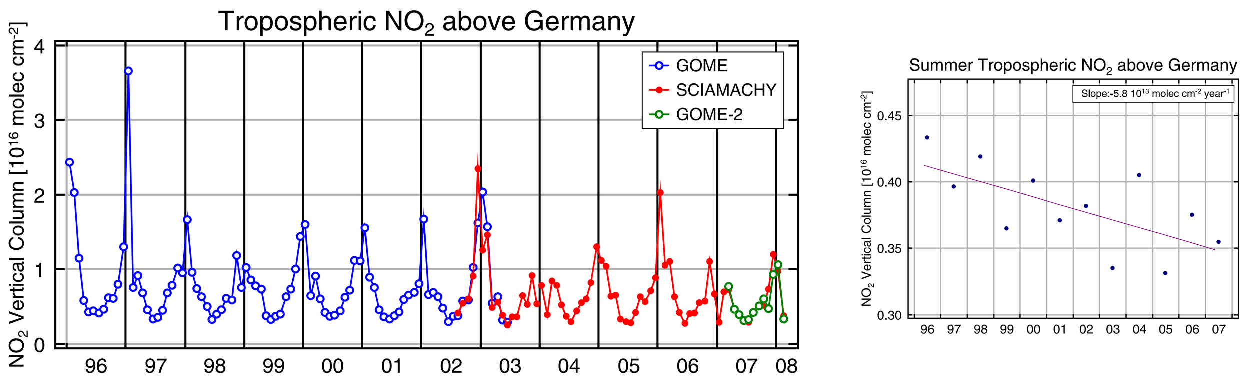


Fig. 5: Monthly averages of tropospheric NO_2 above Germany (left) and evolution of the summer values (May - August, right). The area used for averaging is (46 - 55°N, 6 - 15°E)
- there is a clear seasonal cycle with higher values in winter than in summer
- the winter values are dominated by large variability which is linked to poor sampling in the cloudy season in combination with pollution events
- the agreement between the three sensors is very good in the periods of overlapping measurements
- there is a downward trend in the summer values of about 17% over the 12 years which appears to level off in the last years

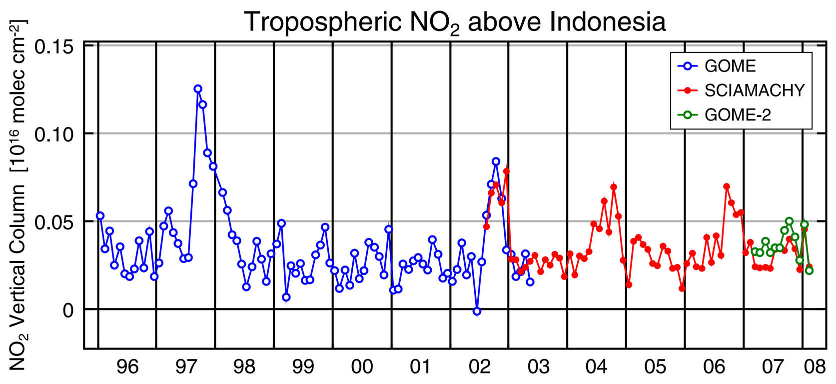


Fig. 6: Monthly averages of tropospheric NO_2 above the area around Watukosek (15 - 0°S, 110 - 115°E) derived from GOME, SCIAMACHY, and GOME-2 measurements.
- the agreement between the different sensors is good (note the different scale)
- there is no conceivable seasonal variation and no apparent trend
- El Nino years are associated with large increases in NO_2 columns which affect a wide area. This is the result of intense biomass burning in dry years and the resulting smog.

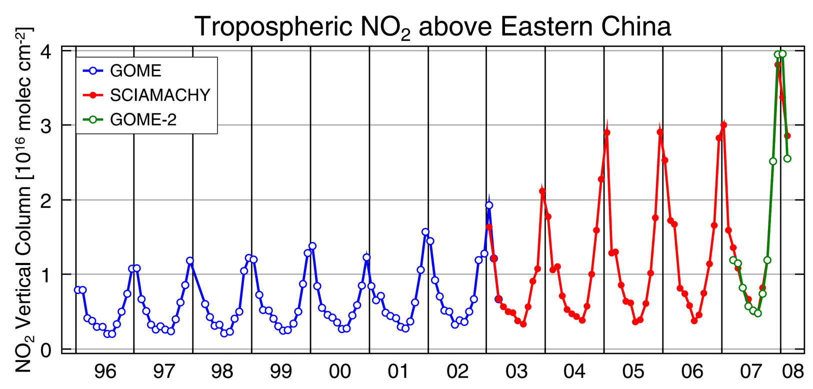


Fig. 7: Monthly averaged tropospheric NO_2 above Eastern China (30 - 40°N, 110 - 123°E)
- the agreement between the different sensors is very good
- there is a clear seasonal cycle with higher winter values
- the variability is much smaller than over Germany, mainly as result of larger averaging area
- there is a clear upward trend with very large winter values in the latest years but also clearly increasing summer columns
- this is mainly due to increased emissions but changes in aerosol load and associated changes in sensitivity may also contribute

Temporal and spatial variability of glyoxal

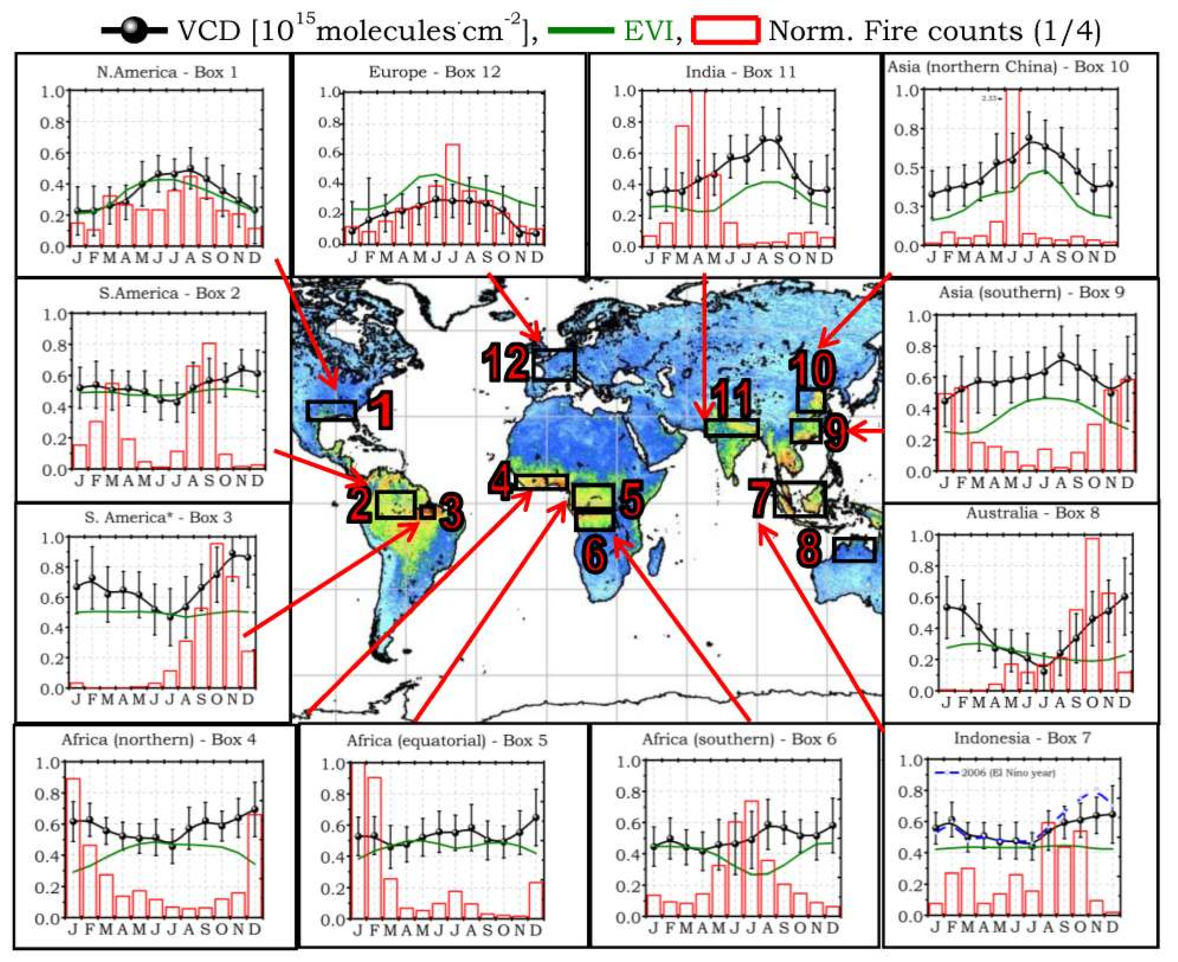
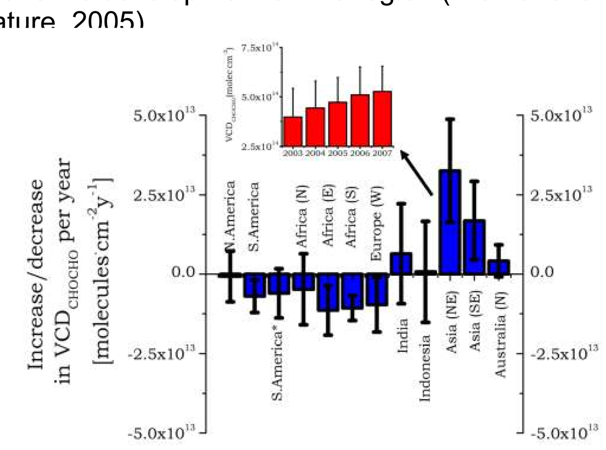


Fig. 8: Monthly mean variability of the glyoxal (CHOCHO) vertical column (black dotted line) computed over 12 selected photochemical hotspots from SCIAMACHY data. The green line illustrates the Enhanced Vegetation Index calculated from MODIS data and the red columns depict the one fourth of the normalized per year, fire counts as computed from the AATSR instrument. The highest CHOCHO amounts are found over regions controlled by strong biogenic and pyrogenic emissions.

Fig. 9: Linear regression analysis of the CHOCHO vertical columns (2003 to 2007) coupled with their uncertainties (2), over the selected hotspots. The red columns show the annual increase of the VCDs of CHO.CHO observed over Northeastern Asia. This increase is attributed, at least partially to the increase of the VOC emissions following the rapid and continuous economic development of this region (Richter et al., Nature, 2005).



Observations of iodine monoxide

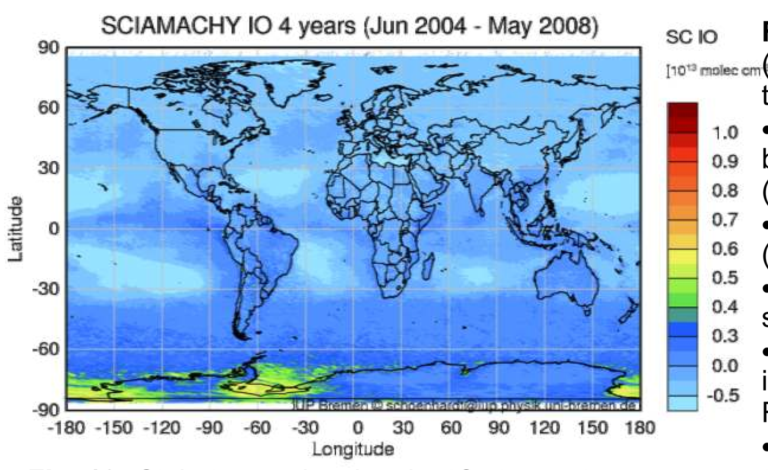
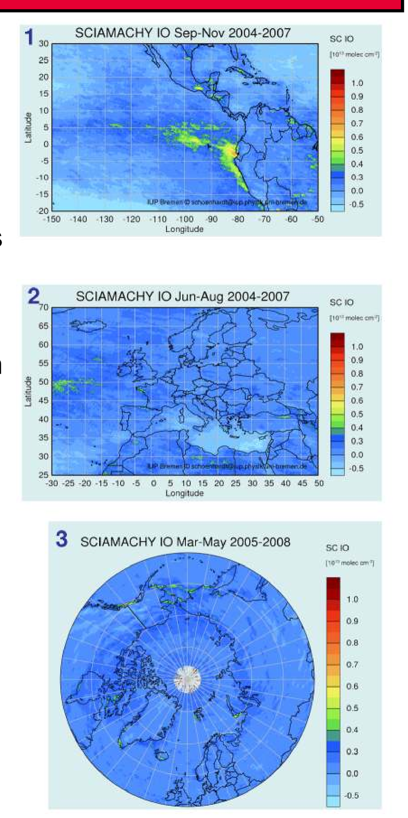


Fig. 10: Global map showing the IO slant column averaged over 4 years. Seasonal dependencies are therefore not resolved. The highest values are found in the Antarctic region. Here, the detection of IO benefits from a high ground spectral reflectance and high sensitivity to the ground layers. For 90% albedo and a ground scene size of 60x120 km², the limit is about $3x10^{12}$ molec/cm² for a single measurement.

Fig. 11: Interesting regions for IO detection:
(1) in some periods, enhanced IO is detected in the tropics, west of South America
- the origin might be biological productivity, possibly biogenic iodine compounds are released here

(2) European coastlines with strong tidal variation
- ground based instruments observe IO at low tides (production by algae after exposure to air)
- tidal selection criteria were applied to separate satellite observations at low tides.
- also in the sorted data, no enhanced IO was seen in the respective coastal areas (Mace Head, Roscoff).
- this result is not unexpected - the satellite pixels are much larger than the source regions, the IO amounts are below detection limit

(3) North polar region
- weak indications of IO along some coastlines in the North appear, but this is still under investigation.
- no widespread enhanced IO amounts are seen in the Northern Hemisphere, as compared to the Antarctic.
- no maximum like BrO at North Pole and Hudson Bay



Acknowledgements

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