Long-Range Transport of tropospheric NO_2 as seen by GOME and SCIAMACHY

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Introduction

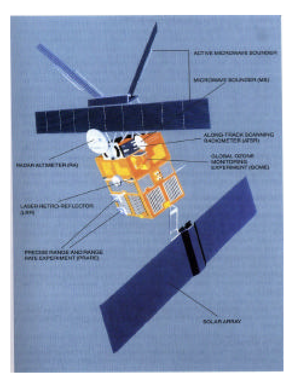
Recent studies show that air pollution from anthropogenic emissions is not only a problem locally but can travel far distances and even reach other continents. To understand the influence of this long range transport on air quality along its path it is crucial to investigate frequencies and patterns of transport events. Satellite instruments provide a unique data set of continuous measurements to study these transport events.

The satellite instruments GOME and SCIAMACHY provide a long term data set of almost 10 years of continuous tropospheric NO_2 measurements. The resulting maps of tropospheric NO_2 are well known and nicely show global patterns of anthropogenic NO_x pollution. The examination of this time series of global measurements reveal typical pathways and conditions for the export of NO_2 from the North American continent eastward into the Atlantic Ocean and to Europe.

In this poster we focus on patterns and frequencies of enhanced tropospheric NO_2 over north Atlantic.

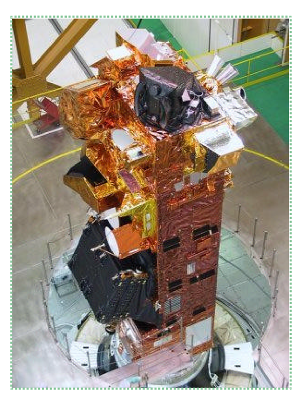
Instruments

GOME (Global Ozone Monitoring Experiment):



- 4 channel UV/visible grating spectrometer
- nadir viewing
- ground pixel 40 x 320 km^2
- global coverage in 3 days
- global data from July 1995 - June 2003
- operating on ERS-2
- sun-synchronuos orbit, 10:30 LT equator crossing

SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography:



- 8 channel UV/visible/NIR grating spectrometer
- nadir viewing, limb, solar & lunar occultation
- ground pixel 30 x 30 .. 30 x 240 km^2
- global coverage in 6 days
- data since August 2002
- operating on ENVISAT
- sun-synchronuos orbit, 10:00 LT equator crossing

Acknowledgements

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NO_2 Transport Climatology

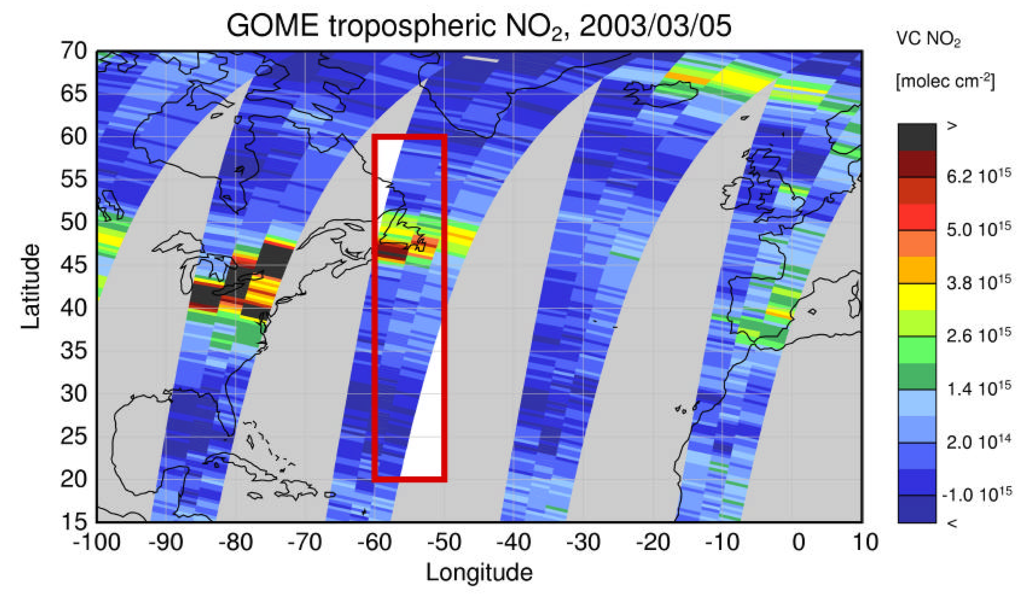

Figure 1: Tropospheric NO_2 from GOME on 05 March 2003. Events of enhanced NO_2 inside the area highlighted by the red square are consiered in the analysis.

Approach

Slant columns of NO_2 are retrieved using the Differential Optical Absorption Spectroscopy (DOAS) technique. The tropospheric column is basically the excess column after subtraction of the measurements over a reference sector in the pacific. Applying an air mass factor yields the tropospheric vertical column of NO_2.

Enhancements of the NO_2 columns in a zonal band between 50-60°W and 20-60°N (Fig. 1) were counted applying two threshold values. Measurements exceeding 2 10^{15} molec/cm² and covering an area of more than 10^5 km² were taken into account for our analysis.

Results

Figure 2 shows the results of this analysis using seven years of GOME data. The export of pollution from the boundary layer in the eastern US across the North Atlantic is nicely visible. This process is well known. It is the effect the warm conveyor belt (WCB) of cyclones that quickly lift the polluted air mass into the free troposphere where it is transported very fast to northern Europe.

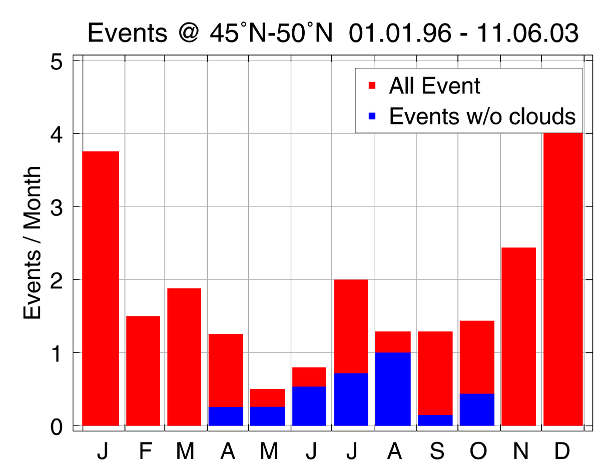

Figure 2a: 7 year histogram of NO_2 events at higher latitudes (45°N - 50°N)

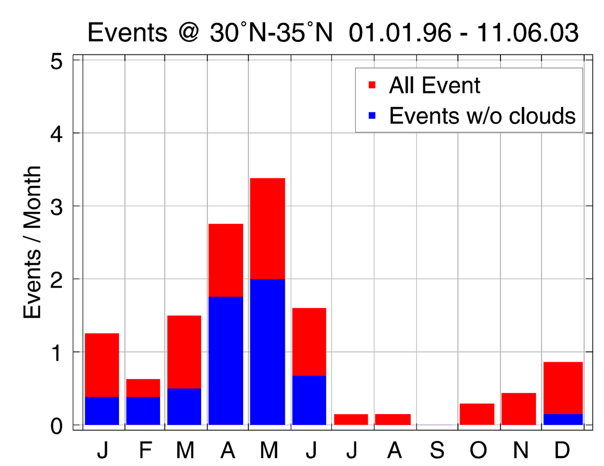

Figure 2b: 7 year histogram of NO_2 events at lower latitudes (30°N - 35°N)

The frequency of these cyclones is much higher in winter than in spring and summer. It also involves the formation of clouds. Both effects can clearly be seen in the NO_2 analysis (see Fig. 2a, histogram for the high latitudes).

Figure 2b shows the lower latitude histogram. Most of the year the number of events with enhanced tropospheric NO_2 is negligible and is explained by the strongly enhanced sensitivity of satellite measurements above clouds.

However, during spring (April to June) a significant amount of NO_2 is detected on a regular basis. In contrast to the export events in the north is there no influence of clouds due to the prevailing high pressure conditions at these latitudes.

The source of this NO_2 is not yet clear.

Trajectory Analysis

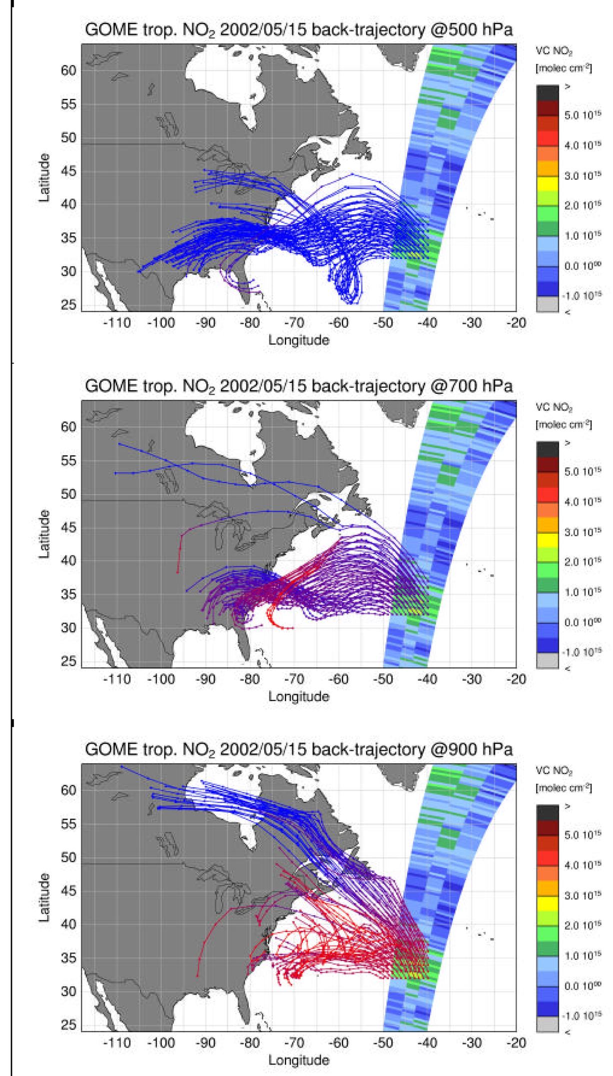

Figure 3 a-c: 4 day backward trajectories for enhanced NO_2 on 15 May 2002.

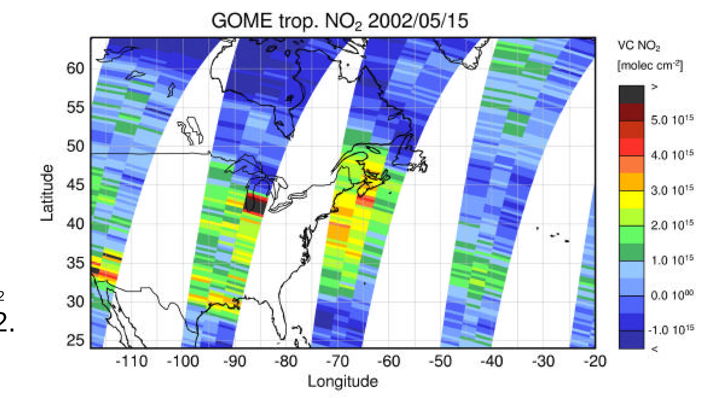

Figure 4: Tropospheric NO_2 from GOME on 15 May 2002.

Individual Events

In order to understand the sources of the enhanced NO_2 at lower latitudes over the Atlantic we focus on single events and study backward trajectories. The trajectories are based on gridded ECMWF data (1.5°x1.5° resolution) and computed by the model TRAJ.X. One typical example is given in the Figures 3a-c.

The trajectories are stopped after four days which is in the order of the life time of NO_2 in the free troposphere.

Prevailing wind conditions are usually from west thus export from the US is possible. However trajectories show also, that the investigated air masses are not coming from the US boundary layer. Trajectories in low layers do not reach the continent. Trajectories in the higher layers stay at higher altitude and show no evidence for lifting from the American boundary layer.

Other sources can be lightning and stratospheric intrusions. While the latter are unlikely in this area and are not seen in other datasets (such as the ozone fields) lightning certainly plays an important role (but could not yet be verified due to a lack of appropriate data). Another influential source are processes of turbulent lifting which are not resolved in the trajectories.

A more detailed analysis utilising the particle dispersion model FLEXPART to better determine the convective processes and use of lightning data from the US lightning detection network remains as future work.

Conclusions

- The storm track from North America across the Atlantic is clearly reproduced in the NO_2 data.
- Maximum during winter season with at least one NO_2 export event per week.
- During other month less than one event in two weeks on average.
- Evidence for regular patterns of high NO_2 over subtropical Atlantic in spring, but not conclusive if source is lightning or not resolved convection.

Selected References

H. Bovensmann, J. P. Burrows, M. Buchwitz, J. Frerick, S. Noël, V. V. Rozanov, K. V. Chance, and A. H. P. Goede, SCIAMACHY - Mission objectives and measurement modes, J. Atmos. Sci., 56, (2), 127-150, 1999

J. P. Burrows et al., The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, J. Atmos. Sci., vol. 56(2), pp. 151-175, 1999.

A. Richter and J.P. Burrows, Retrieval of Tropospheric NO_2 from GOME Measurements, Adv. Space Res., 29(11) ,1673-1683, 2002 .

S. Beirle, U. Platt, M. Wenig, T. Wagner, NOx production by lightning estimated with GOME, Adv. Space Res., 34, 793-797, 2004

N. Spichtinger, M. Wenig, P. James, T. Wagner, U. Platt and A. Stohl, Satellite detection of a continental-scale plume of nitrogen oxides from boreal forest fires, Geophys. Res. Lett., 28, 4579-4583, 2001

A. Stohl, H.Huntrieser, A.Richter, S.Beirle, O.Cooper, S.Eckhardt, C.Forster, P.James, N.Spichtinger, M.Wenig, T.Wagner, J.P.Burrows, U.Platt, Rapid intercontinental air pollution transport associated with a meteorological bomb, Atmos.Chem.Phys., 3, 969/985, 2003