Multi-axis DOAS observations of atmospheric trace gases in Bremen

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Introduction

Figure 1: ENVISAT satellite launched on 1. March 2002.

A new approach to derive profile information for different atmospheric trace gases from ground-based UV/VIS measurements is described. MAX-DOAS is based on the well-known UV/VIS instruments, which use the sunlight scattered in the zenith sky as the light source and the method of **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (**DOAS**) to derive column amounts of absorbers like ozone and nitrogen dioxide. Substantial enhancements have been applied to this standard setup to use different line of sights near to the horizon as additional light sources (**MAX** - multi axis).
In addition, this measurement technique can be used for both ground based observations (e.g. Network for Detection of Stratospheric Change - NDSC) and validation of satellite instruments (e.g. Global Ozone Monitoring Experiment - GOME, Scanning Imaging Absorption Spectrometer for Atmospheric Chartography - SCIAMACHY) which allows to combine highly time and spatial resolved data of selected locations with data of global coverage.
Results from measurements at the Bremen part of the BREDOM (**Bre**mian **DO**AS Network for Atmospheric **M**easurements) are presented and interpreted with the full-spherical radiation transport model SCIATRAN.

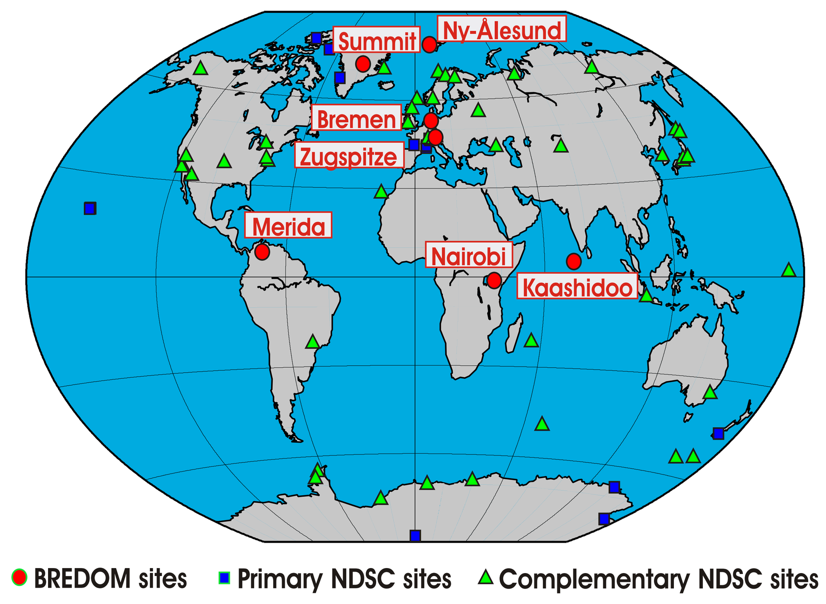

Figure 2: A map of the presently operational BREDOM and NDSC stations.

Experimental Setup

Sunlight scattered from the sky is collected by a telescope and transmitted to a Czerny-Turner spectrograph L.O.T. Ms257 (focal length 257 mm, 1200 l/mm grating) via a depolarizing quartz-fiber bundle. A charge coupled device (CCD) Andor DV-440BU (2048x512 pixel) is used as a detector allowing simultaneous measurements over the complete wavelength range. The pointing of the telescope is alternating between zenith and horizon, which yields profile information of the absorbers. The observation in different lines of sight (4 off-axis between 0 and 30° above horizon, 1 zenith) is realized by a mirror (3) fixed on a rotation stage moved by a computer controlled servomotor. In zenith sky mode the lens (5) is directly illuminated. In the off axis mode the mirror is moved into the light path and reflects the collected light to the lens. The instrumental setup of the telescope is shown in figure 3.

Figure 3:
View of the DOAS telescope:

1 quartz glass window zenith
2 quartz glass window off axis
3 mirror
4 shutter
5 lens
6 HgCd lamp
7 tungsten lamp
8 quartz fibre

Measurements

Off axis DOAS measurements provide profile information about the absorber. The light paths through the absorber in the troposphere will be enhanced for lower angles to the horizontal line. This is shown in figure 4a-c where the slant columns (SC) of NO_2 for different lines of sight in Bremen are presented. The three day period from the 09th to 11th of Dec. 2002 was chosen because of its nearly stable weather conditions. During this period, a significant increasing of NO_2 for the off axis viewing directions can be noticed.Usually, the concentration of the absorber is given in vertical columns (VC) which are calculated from the SC and the air mass factor (AMF) by: $VC = SC / AMF$.
The radiative transfer model SCIATRAN [2] calculates the AMF between SC and VC considering the sum of slant light paths and estimated profiles of absorbers. Profile information can be obtained by testing different AMF calculated with different profiles of the absorber. For the correct calculation of AMF the VC for all viewing directions has to be the same. Figure 5 shows the assumed profile (enhanced NO_2 in the lowermost 2 km) and the resulting AMF for the best results of VC calculation (figure 7a-c).
To check the quality of the profile information, the calculated data of the lowermost 2 km and ground based in situ measurements from BLUES (Bremer Luftueberwachungssystem) were compared (see table below).

Date	DOAS [μg/m³]	BLUES [μg/m³]
09.12.2002	1,9	17,1
10.12.2002	2,9	27,7
11.12.2002	4,2	34,6

It can clearly be seen that in both measurements an increasing of NO_2 during the observed period is represented, but the total amount of NO_2 of the DOAS instrument is about ten times less than the BLUES data. This could be related to the different measurement heights, DOAS ~ 20m, BLUES 3,5m and different measurement sites. In contrast to the DOAS station the BLUES station is close to an industrial area and a busy road. Probably the BLUES measurements are more influenced from direct emissions of the traffic and the surrounding area.

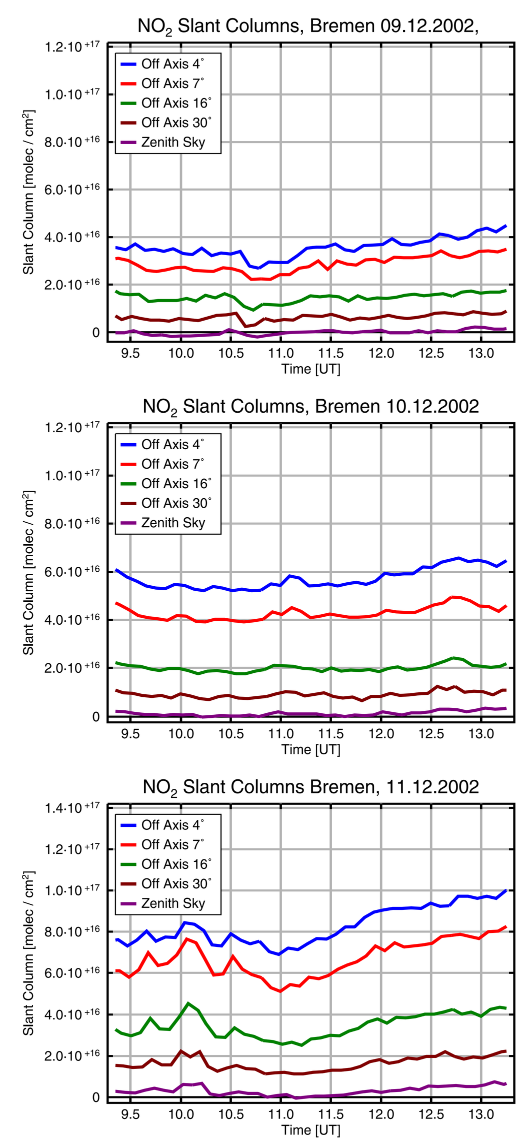

Figure 4a-c: Slant Columns of NO_2 for different viewing directions on Dec. 09-11 in Bremen.

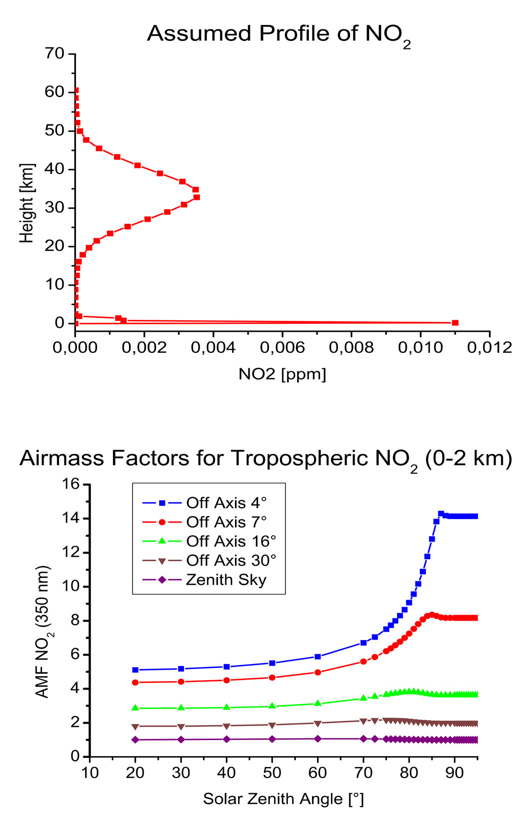

***Figure 5:** Estimated vertical profile of NO_2 and resulting AMF calculated from SCIATRAN.*

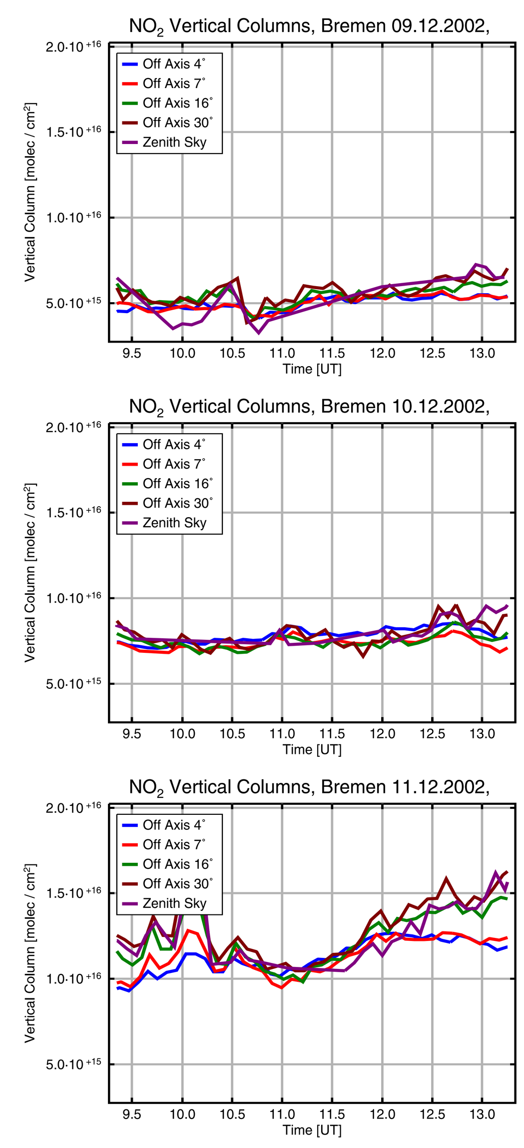

Figure 7a-c: Vertical Columns of NO_2 for different viewing directions on Dec. 09-11 in Bremen.

References

[1] Wittrock, F., H. Oetjen, A. Richter, A. Rozanov, and J.P. Burrows, MAX-DOAS measurements of atmospheric trace gases, to be submitted to Applied Optics, 2003
[2] Rozanov, A., V. Rozanov, and J.P. Burrows, A numerical radiative transfer model for a spherical plantary atmosphere: combined differential-integral approach involving the Picard iterative approximation, Journal of Quantitative Spectroscopy & Radiative Transfer, 69, 491, 2001.
[3] Wittrock, F., M. Eisinger, A. Ladstätter-Weißenmayer, A. Richter and J.P. Burrows, Groundbased UV/VIS measurements of O3, NO2, BrO and OClO over Ny Alesund (78°N), Polar stratospheric ozone, Air pollution research report 56, Proceedings of the 3rd European Polar Ozone Symposium, Schliersee, Germany, CEC, 329-334, 1996.

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Conclusions

Results of the new multi axis- (MAX-) DOAS instrument from measurements in Bremen are presented. The capability to derive not only column amounts of NO_2 but also some information about the vertical distribution is demonstrated.
The profile information obtained from the DOAS measurements were compared with in situ measurements from BLUES (Bremer Luftueberwachungssystem). For both instruments an increasing of NO_2 during the observed period is shown, but the total amount of NO_2 of the DOAS instrument is more less than the BLUES data.

Acknowledgements

Parts of this project (50EE0005) have been funded by:
- the German Federal Ministry of Education and Research (BMBF)
- the German Aerospace Agency (DLR)
- the German Research Council (DFG) and
- the University of Bremen.

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