One Year of Groundbased Multi Axis DOAS Measurements in Nairobi

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Introduction

Figure 1: Telescope on the top roof stairs of a UNEP building

Pollution and climate change are significant global environmental issues. To improve our understanding of the impact of both natural phenomena (e.g. lightning, volcanic eruptions) and anthropogenic emissions from fossil fuel combustion and biomass/bio fuel burning, global measurements of key atmospheric trace gases are required.
Since there are a lot of measurement stations of atmospheric trace gases at high and mid latitudes but only a few in tropical regions, it was decided to install a DOAS station in Nairobi (1,2°S, 36,8°E). In late August 2002 the Nairobi multi-axis DOAS (MAX-DOAS) station started its measurements and since then has been measuring continuously in operation.
In this poster multi-axis measurements of ozone and NO_2 from different seasons will be presented.
A short overview about the experimental setup of the instrument will be given in the talk of Folkard Wittrock ("Overview of Bremen MAX-DOAS Measurements since 1998").

Figure 2: Inside equipment of the MAX-DOAS instrument with Spektrometer, CCD and PC

Seasonal Variation of NO_2 and O_3

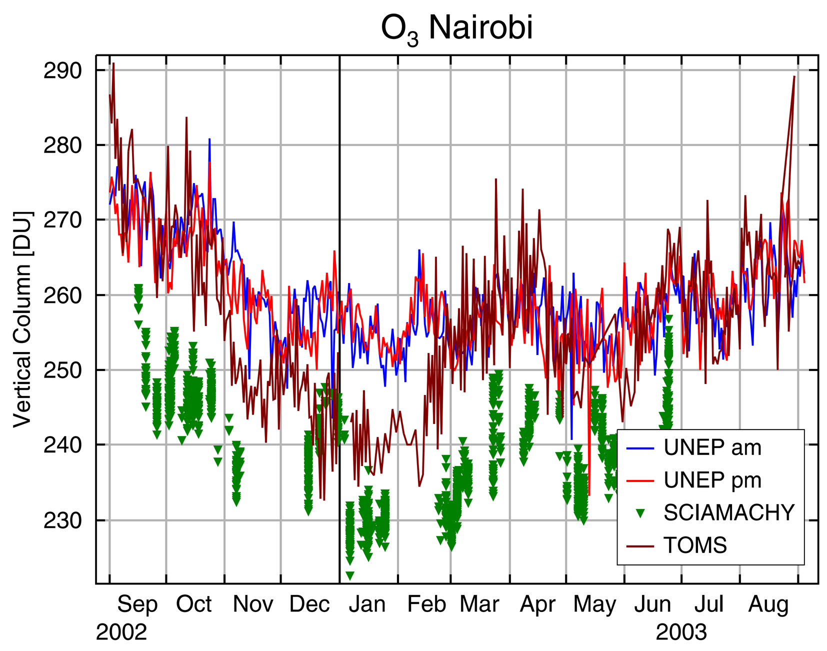

Figure 3: Seasonal variation of the zenith sky ozone measurements in Nairobi

Figure 3 shows the vertical columns (VC) of ozone derived from the morning (blue) and afternoon (red) measurements of the zenith sky viewing direction. As can be seen there is a seasonal variation of about 20 DU during the last year. During one of the raining seasons from August to October higher ozone values of about 270 to 275 DU occur. With the beginning of the dry season the values decrease to value of about 255 DU. From November to July the ozone columns vary around this value. With the beginning of the raining season the ozone values starts to increase. During the second rainy period from April to May no higher ozone values can be observed. In comparison to the ground based measurements the TOMS (brown) and SCIAMACHY (green) measurements show in principle the same seasonal variation. The values of the SCIAMACHY measurements are to low. This is may be related to the use of the software version SCIA/3.53 in the SCIAMACHY data calculation.
In figure 4 the morning and evening values of NO_2 can be seen. They show a pronounced diurnal variation which is part due to photolysis of N_2O_5 in stratosphere and the diurnal variation of NO_2 in the troposphere. It can clearly be seen that during the summer time from December to March the variation from day to day is less then during the rest of the year. The SCIAMACHY data (green) show a good agreement with the morning measurements of the ground based station.

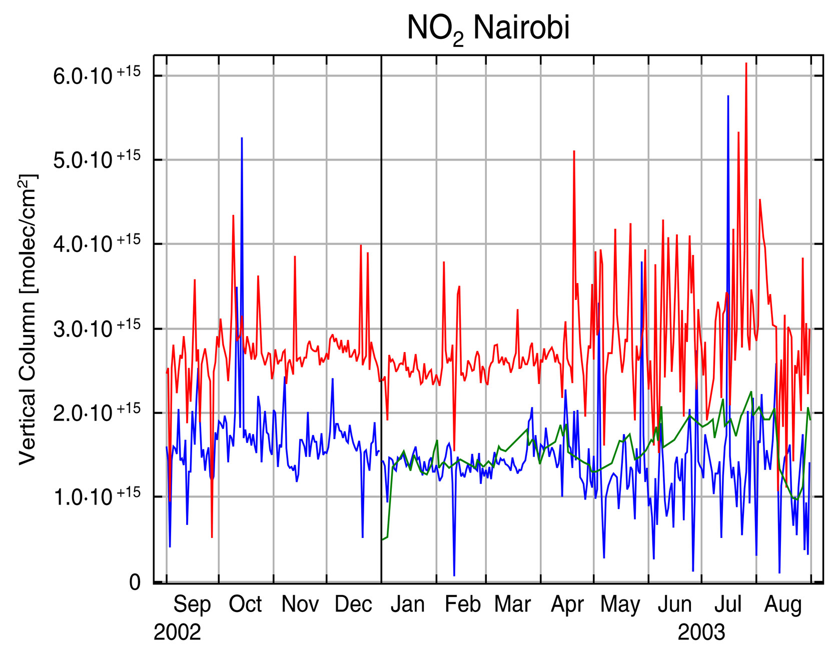

Figure 4: Seasonal variation of the zenith sky NO_2 measurements in Nairobi

Off Axis Example NO_2

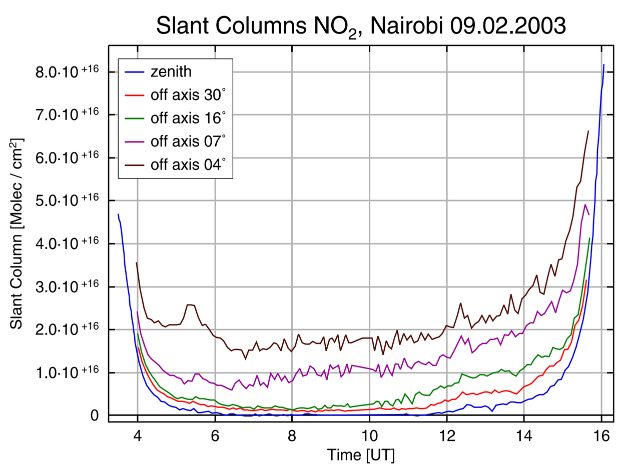

Figure 5a: Slant Columns of NO_2, Nairobi 09.02.2003

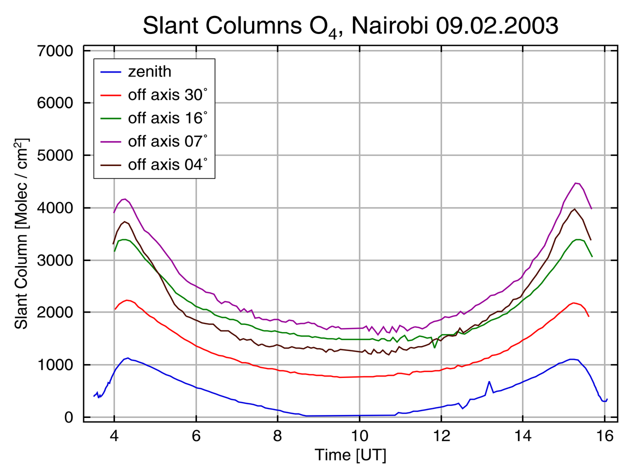

Figure 5b: Slant Columns of O_4, Nairobi 09.02.2003

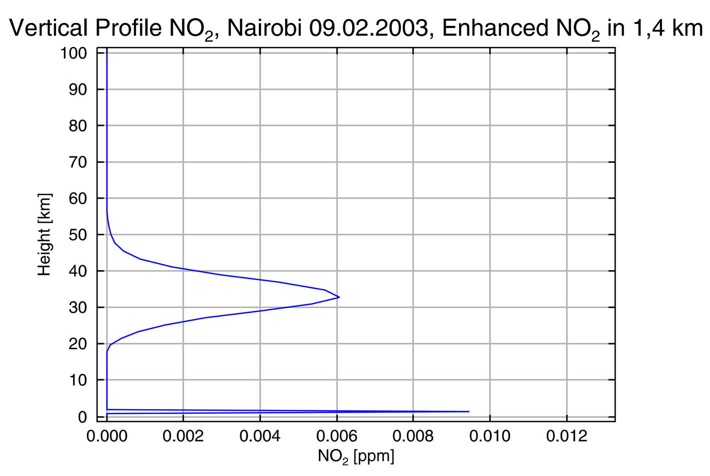

Figure 5c: Vertical Profile of NO_2, Nairobi 09.02.2003

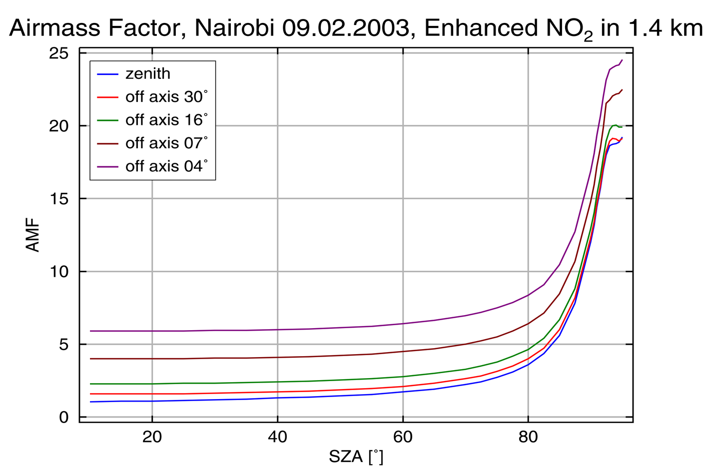

Figure 5d: AMF of NO_2, calculated with SCIATRAN[4], Nairobi 09.02.2003

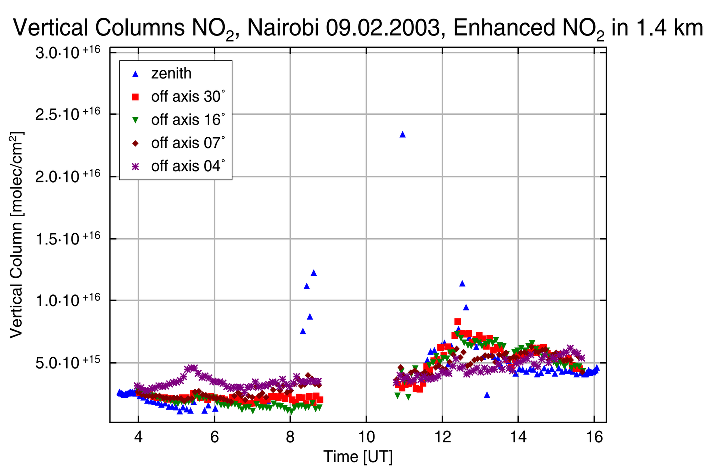

Figure 5e: Vertical Columns of NO_2, Nairobi 09.02.2003

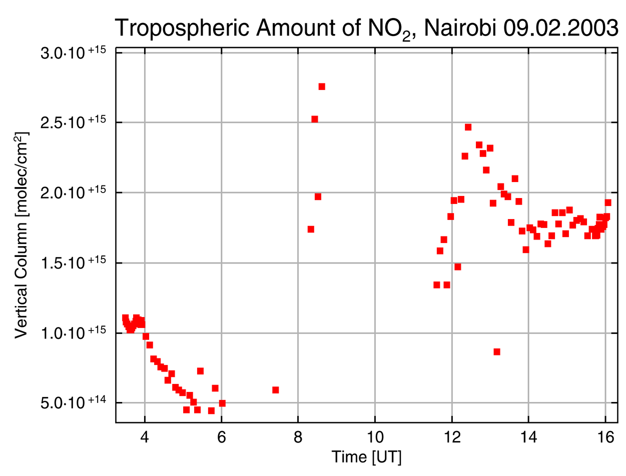

Figure 5f: Tropospheric Amount of NO_2, Nairobi 09.02.2003

Two days with off axis measurements are shown, the 9th of February in the summer time and the 5th of May 2003 in one of the raining seasons.
The 9th of February 2003 was a day with temperatures ranging from 16°C to 29°C and a relative humidity of about 65% in the morning and 35% in the afternoon. It was partly cloudy but no rain during the whole day.[5] This can also be seen in figure 5b where the O_4 slant columns as an indicator for clouds are presented.
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 can nicely be seen in figure 5a where the slant columns (SC) of NO_2 for different lines of sight (LOS) are presented.
For the concentration of the absorber given in vertical columns (VC = SC / AMF) a calculation of the air mass factor (AMF) is necessary. In this study the AMF between SC and VC considering the sum of slant light paths and estimated profiles of absorbers are calculated by using the radiative transfer model SCIATRAN [4]. By testing different AMF calculated with different profiles of the absorber profile information can be obtained. For the correct calculation of AMF the VC for all viewing directions has to be the same. Figures 5c and 5d show the assumed profile (enhanced NO_2 in about 1.5 km) and the resulting AMF for the best results of VC calculation (figure 5e).

The tropospheric amount of NO_2 obtained from the difference of the calculations of the vertical column with a stratospheric profile and a stratospheric/tropospheric profile is shown in figure 5f. An increase of about $2.5*10^{15}$ molec/cm² during the day can be seen.

The difficulties to obtain good results for the vertical column calculation can be seen in figure 6a to 6c where in the morning were clear sky or partly cloudy conditions and during the afternoon a change to bad weather conditions took place. Figure 6b shows the resulting VC for a profile with enhanced NO_2 in about 2 km. This profile gives nice results for the morning values but shows a disagreement between the zenith and the off axis directions for the afternoon. The best results for the afternoon shows figure 6c where tropospheric NO_2 in a layer in about 7 km altitude is assumed. The vertical columns show a good agreement except the lowermost LOS. But it can also be seen that the result shows larger differences between the vertical columns of the different lines of sight than the VC under good weather conditions.

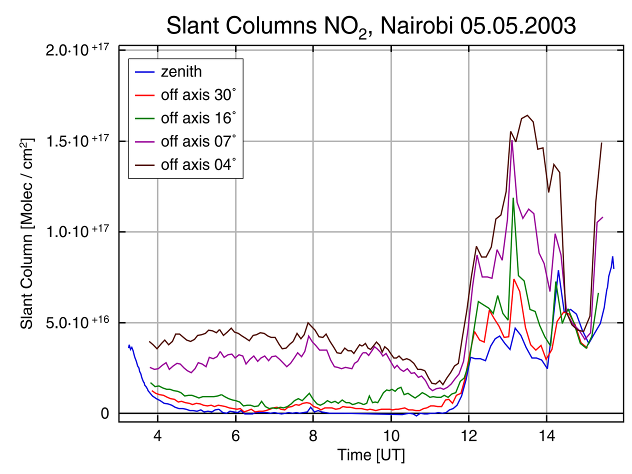

Figure 6a: Slant Columns of NO_2, Nairobi 05.05.2003

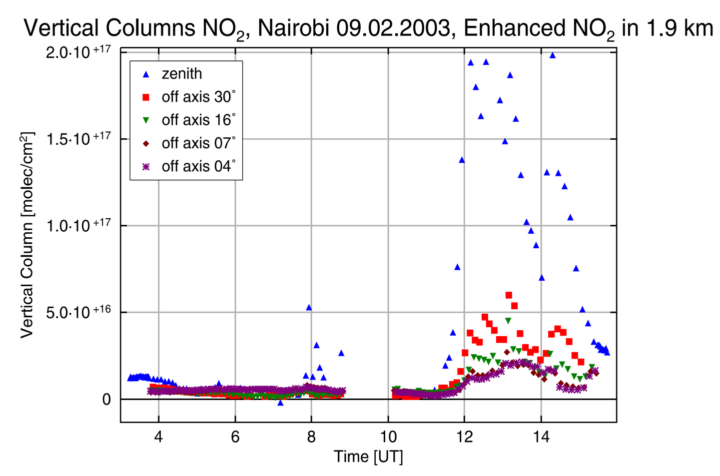

Figure 6b: Vertical Columns of NO_2, Nairobi 05.05.2003 (Enhanced tropos. NO_2 in 1,9 km)

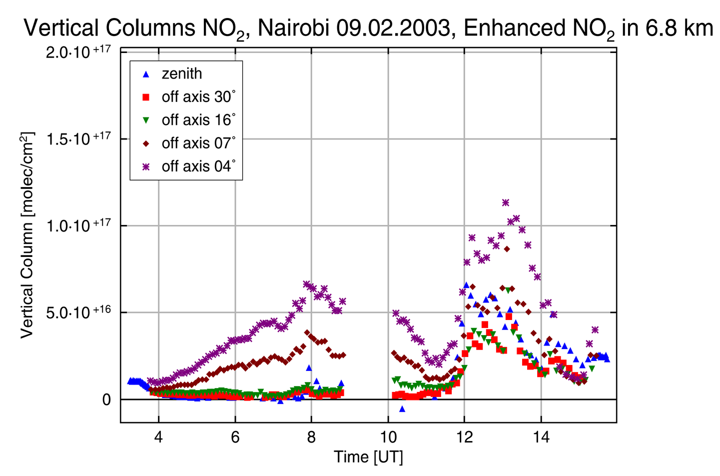

Figure 6c: Vertical Columns of NO_2, Nairobi 05.05.2003 (Enhanced tropos. NO_2 in 6,8 km)

Conclusions

At end of August 2002 the Nairobi multi-axis DOAS (MAX-DOAS) station started its measurements and since then has been measuring continuously in operation.
During this period a seasonal variation of ozone of about 20 DU has been observed. The NO_2 values show an oscillation around $1.5*10^{15}$ molec/cm² in the morning and around $2.8*10^{15}$ molec/cm2 in the evening. But there is a stronger diurnal variation during the raining seasons.
An example of the NO_2 measurements with different lines of sight show the capability to derive some information about the vertical distribution of the absorber, by using different assumed absorber profiles.

References

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[4] 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.
[5] Weather informations provided by Wetter.com, www.wetter.com

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