Groundbased DOAS Measurements in Nairobi (1°S, 37°E)

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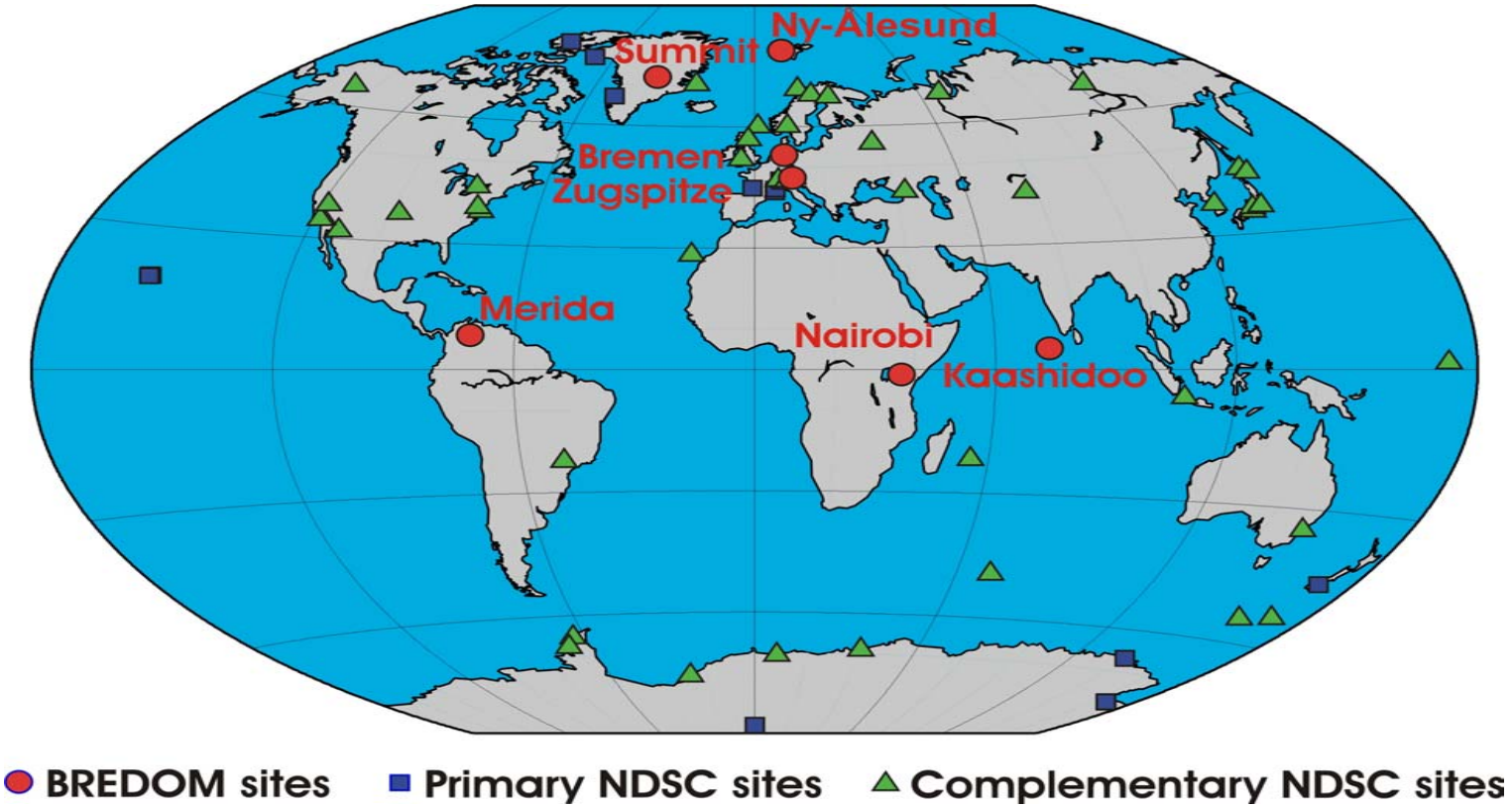
Overview

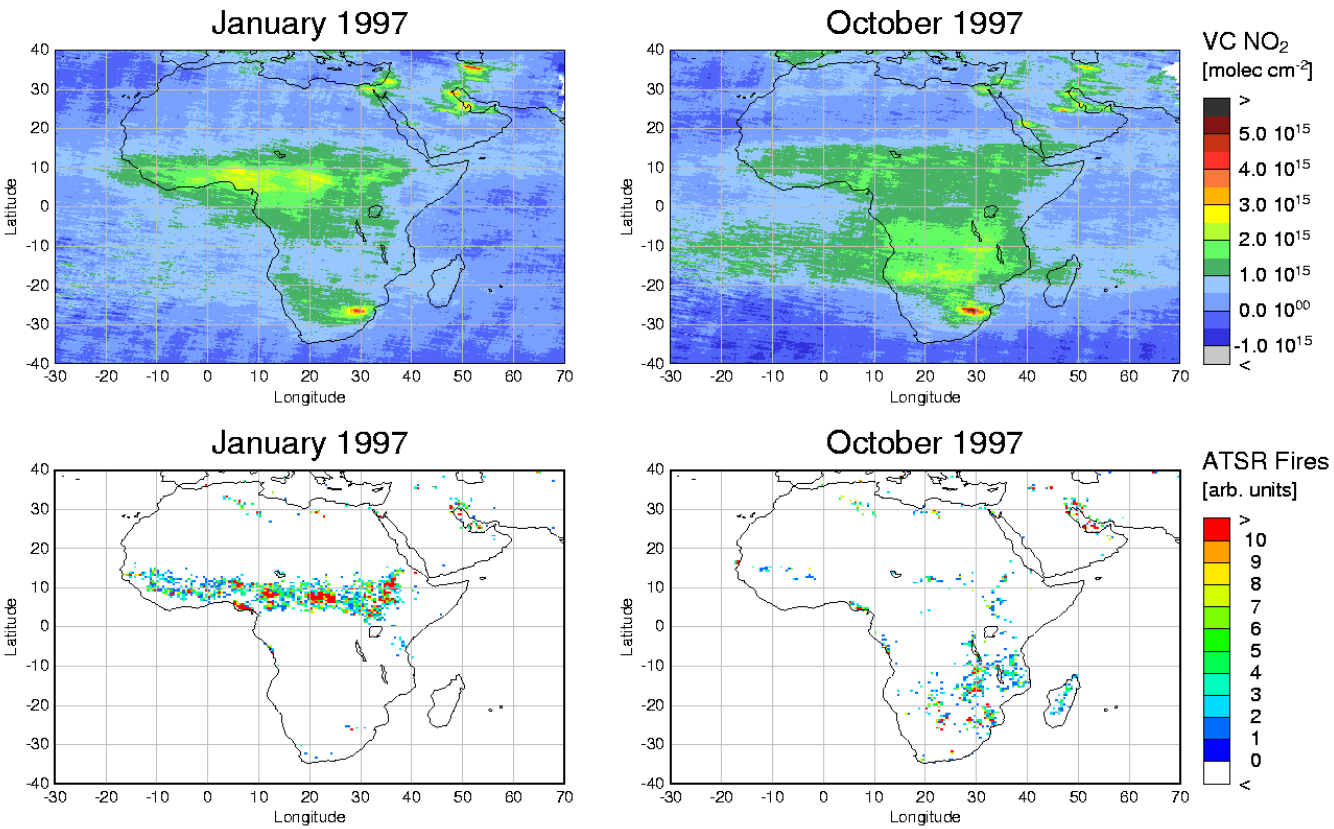
- Measurement Site
- Max-DOAS instrument
- Introduction into the DOAS (Differential Optical Absorption Spectroscopy) method
- Multiple axis method
- First results
- Summary and outlook

Measurement Site (I)

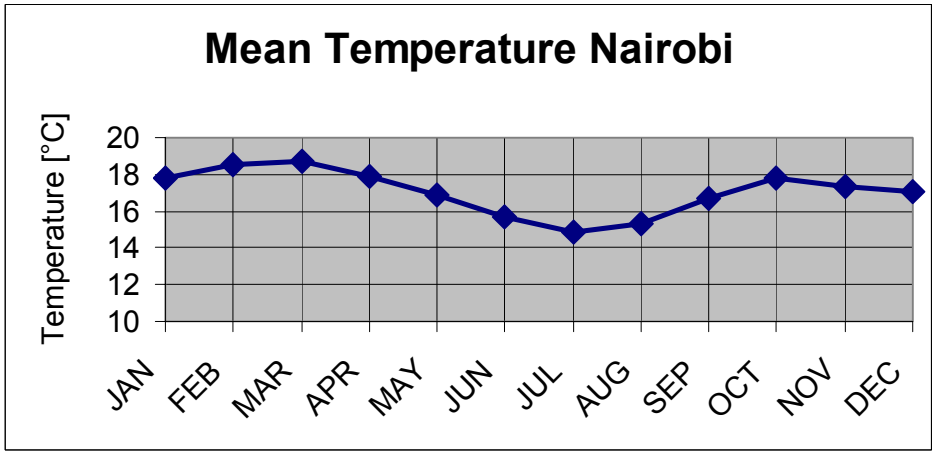


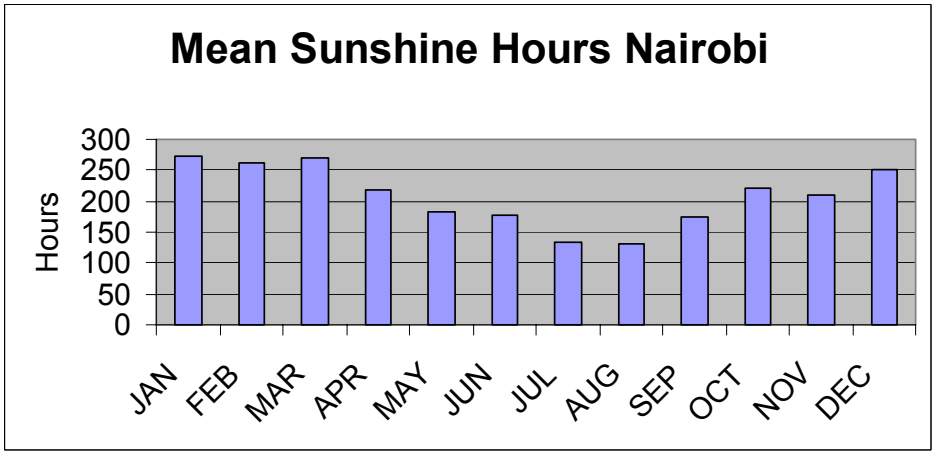
Measurement Site (II)

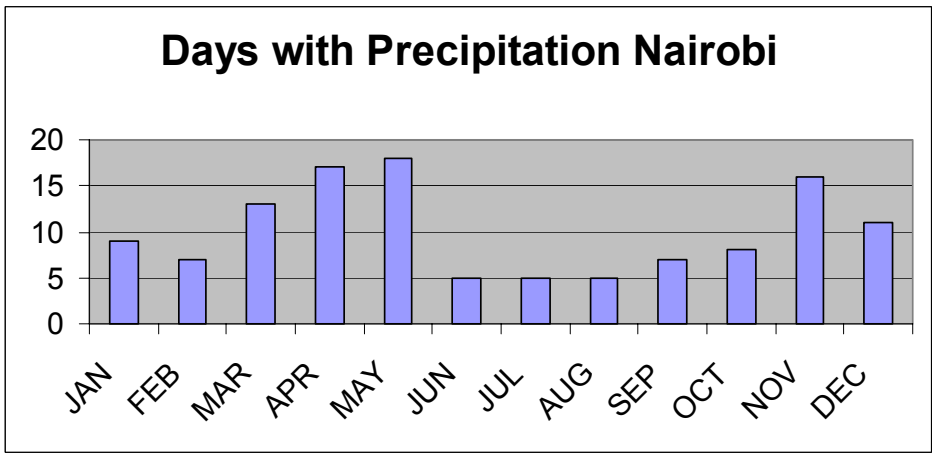
GOME NO_2 and ATSR/ESA fires in Africa 1997

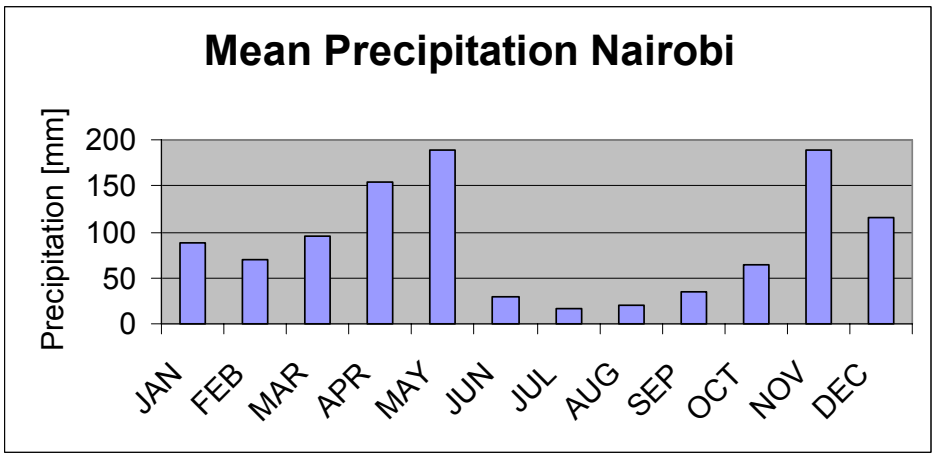


Measurement Site (III)





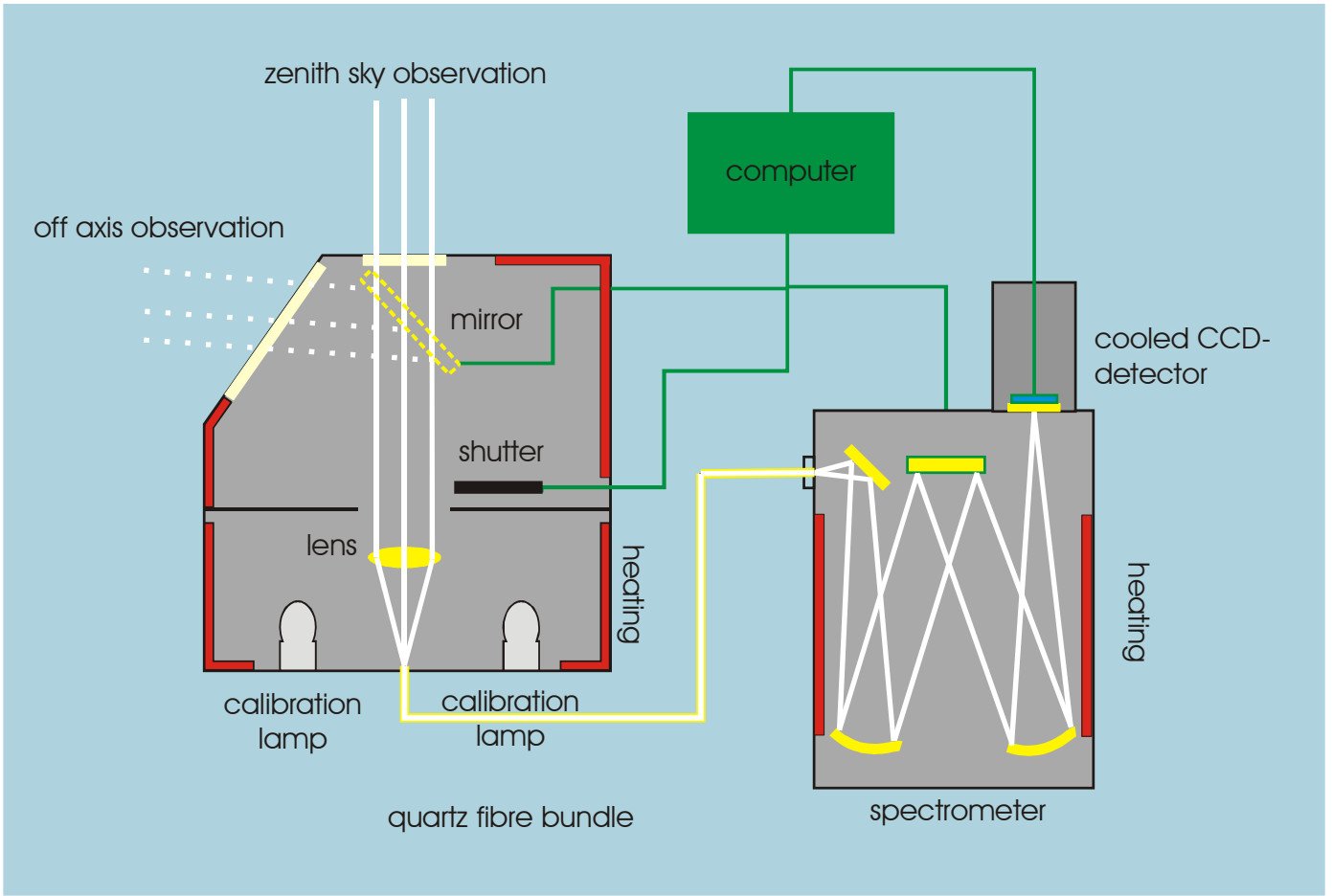




Measurement Site (IV)

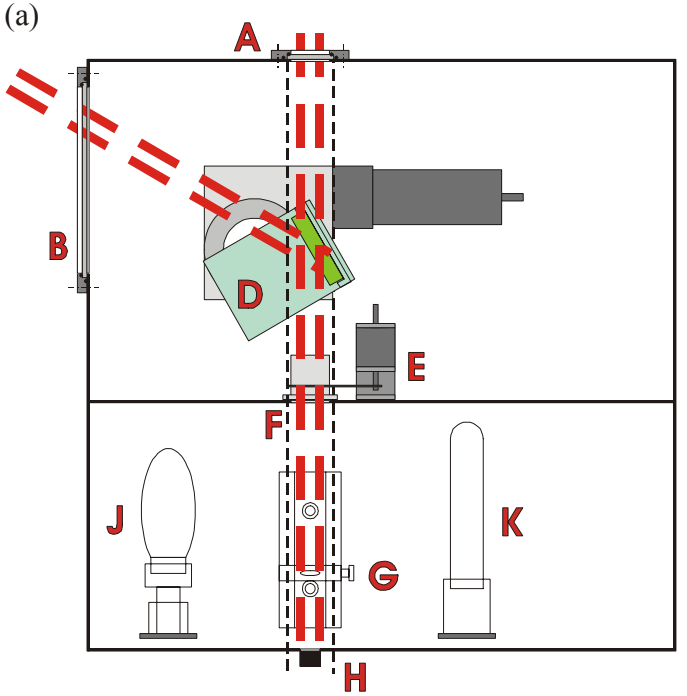
- Nairobi (1.2°S, 36.8°E)
- 1624 m above sea level
- Installed in the headquarter of the United Nations Environmental Programme (UNEP), 15 km away from downtown Nairobi
- Viewing direction: South to Downtown

DOAS instrument (I)

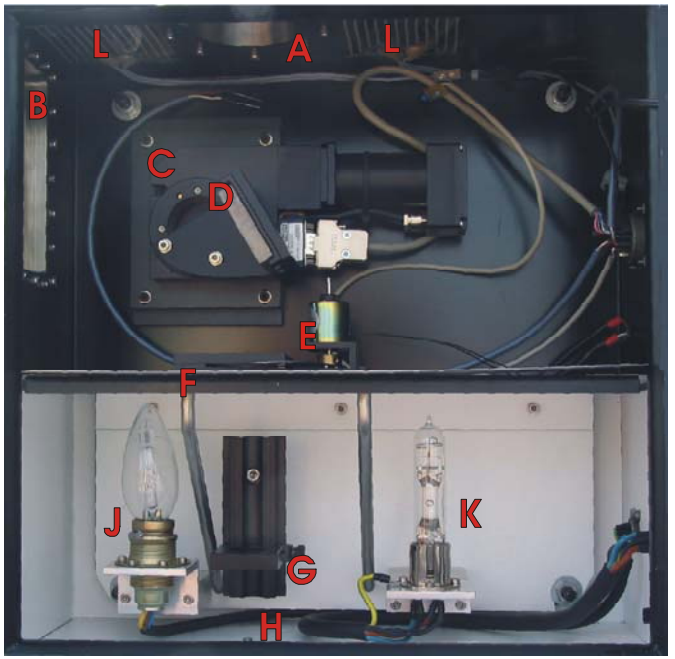


DOAS instrument (II)

(a)



(b)



A	Zenith window	E	Shutter	J	Tungsten lamp
B	Off-Axis-window	F	Hole in dividing wall	K	HgCd lamp
C	Turntable driven by motor	G	Lens	L	Heating foil
D	Mirror	H	Quartz fibre bundle		

DOAS instrument (III)

- Czerny-Turner Spectrograph L.O.T. MS257
- CCD Andor DV440-BU (2048 x 512 Pixel)
- UV/vis wavelength region: 320 – 410 nm
- Spectral resolution: ~0.5 nm
- O_3, NO_2, BrO, HCHO, IO, OClO
- Pointing of the telescope alternating between zenith and horizon (4 off axis viewing directions: 4°, 7°, 16°, 30°)
- Daily calibration measurements

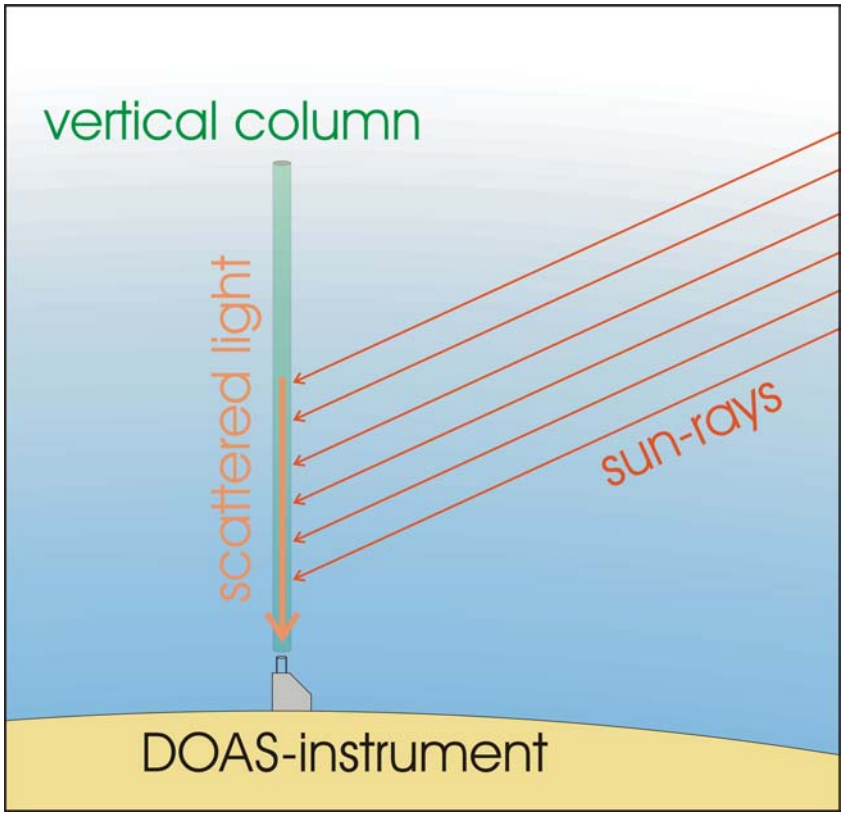
DOAS method (I)

- Comparison of the actual measurement with a reference
- Lambert-Beer-Law
- Approximation of Rayleigh- and Mie- scattering with a polynomial

$$\ln \frac{I_0(\lambda)}{I(\lambda)} = \sum_i \sigma_i'(\lambda) SC_i + \sum_p a_p \lambda^p$$

- Result: slant column along the lightpath $SC = \int \rho_i(s)\, ds$

DOAS method (II)



- Slant column (SC):
  Number of molecules which cause the measured absorption
- Vertical column (VC):
  sum of all molecules in a virtual column perpendicular to the earth‘s surface

The radiative transfer model SCIATRAN (Rozanov et.al.) calculates the air mass factor (AMF) between SC and VC considering the sum of slant light paths and estimated profiles of absorbers

$$AMF(SZA) = SC / VC$$

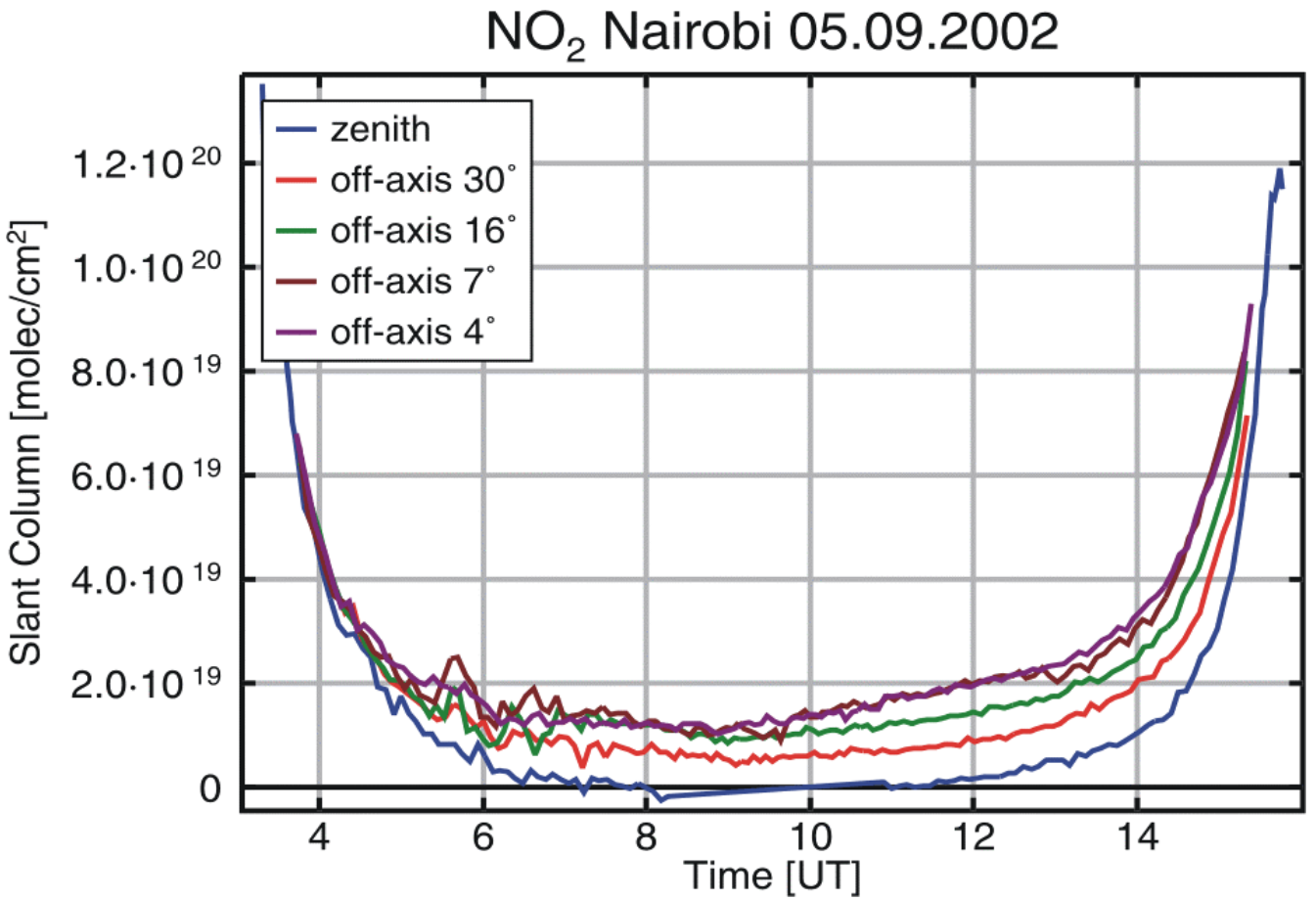
Off Axis DOAS (I)

- Concentration of the absorber is given in vertical columns (VC) which are calculated from the SC and the airmass factor (AMF) by: VC = SC / AMF

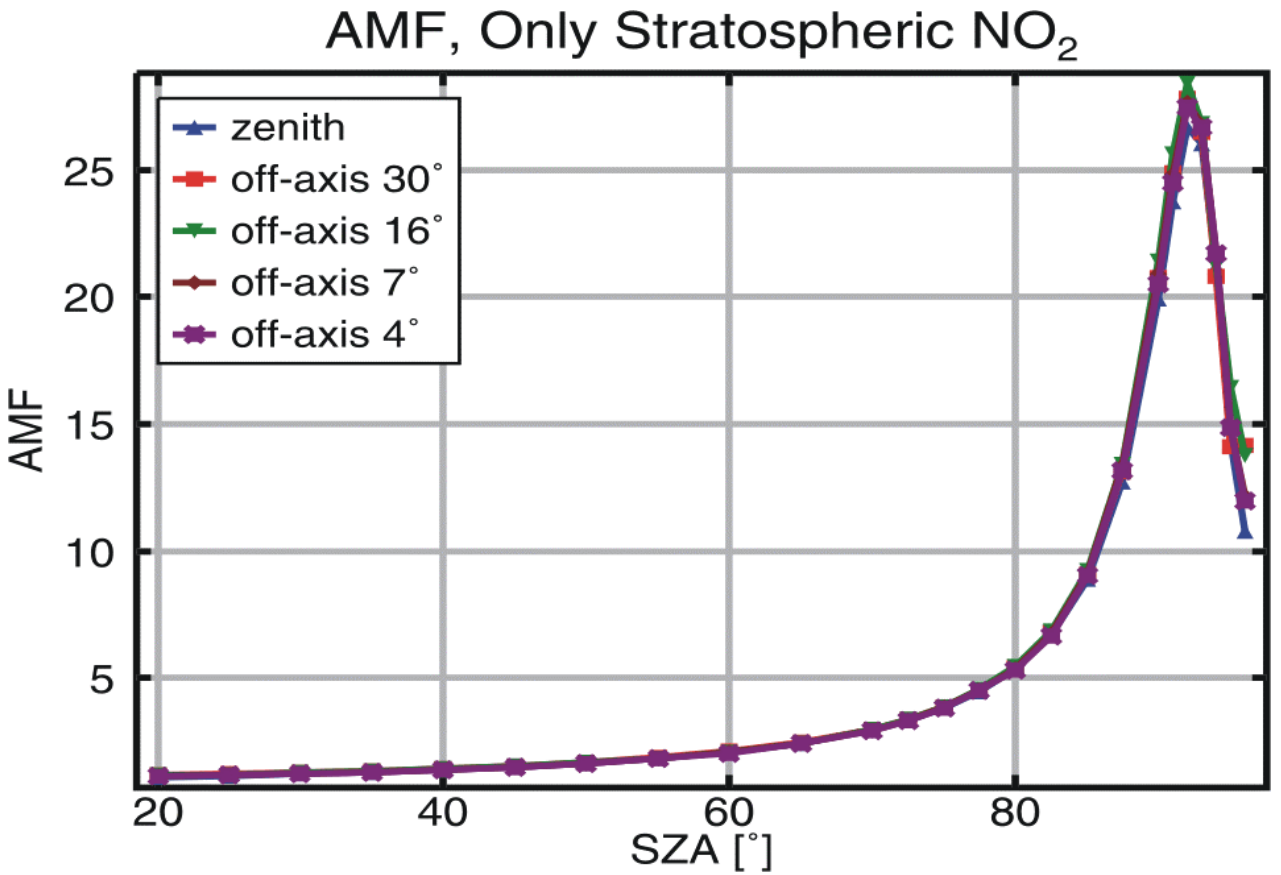
- The VC for all viewing directions has to be the same for the correct calculation of AMF, profile information can be obtained by using different AMFs calculated with different profiles of the absorber

- Stratospheric amounts do not influence the dependency of the AMF

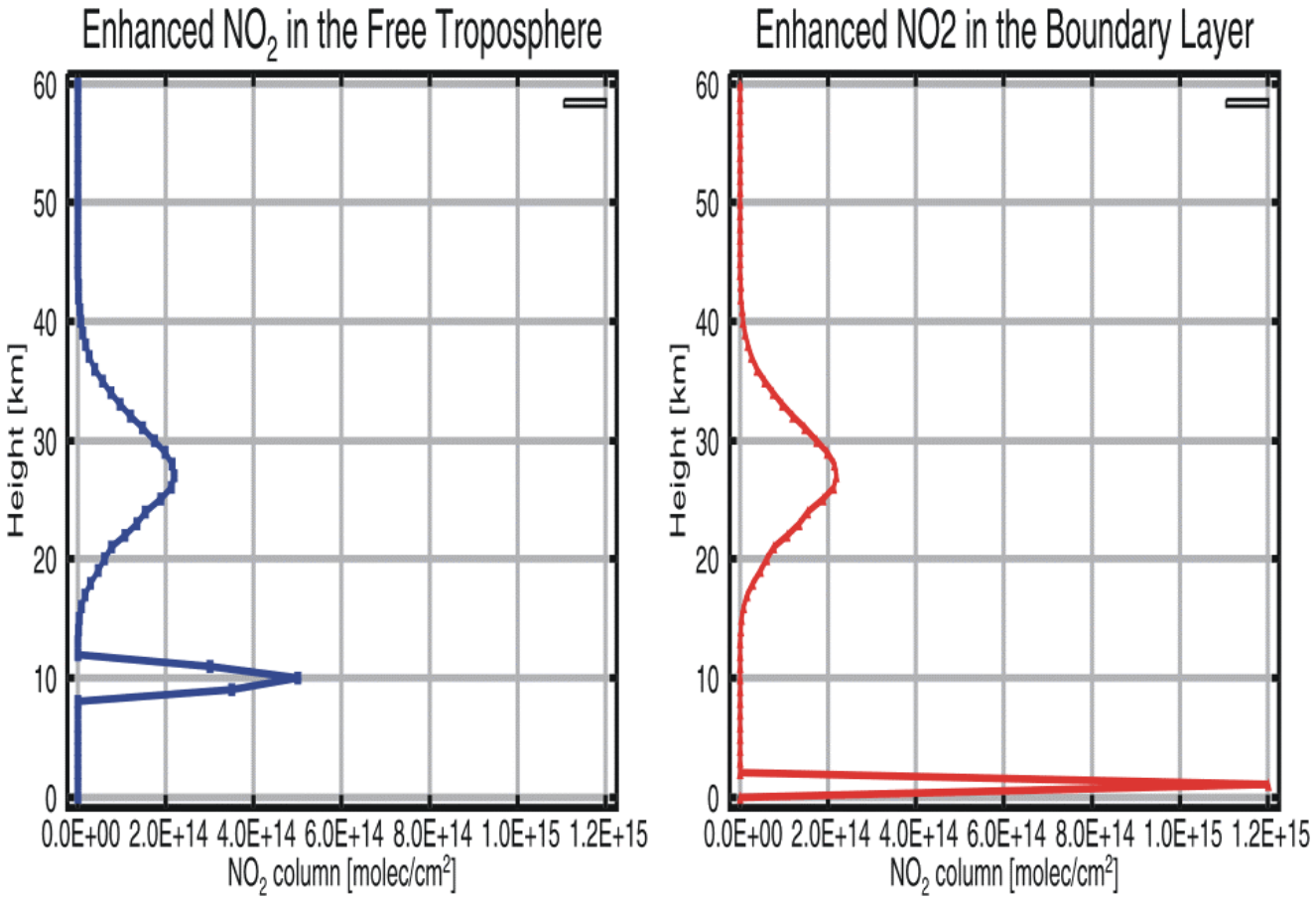
Off Axis DOAS (II)-Example, Slant Columns



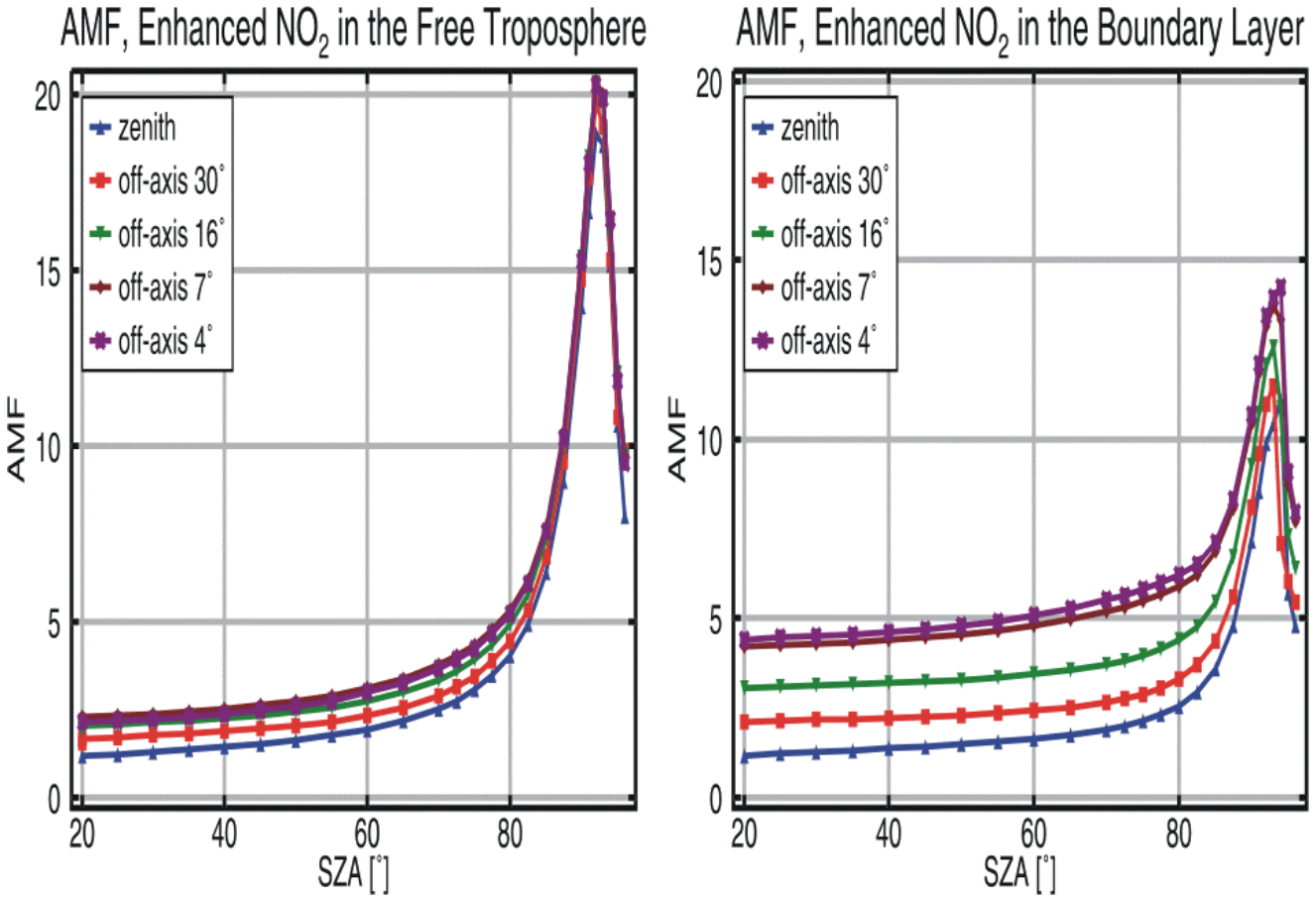
Off Axis DOAS (III)-Example, AMF



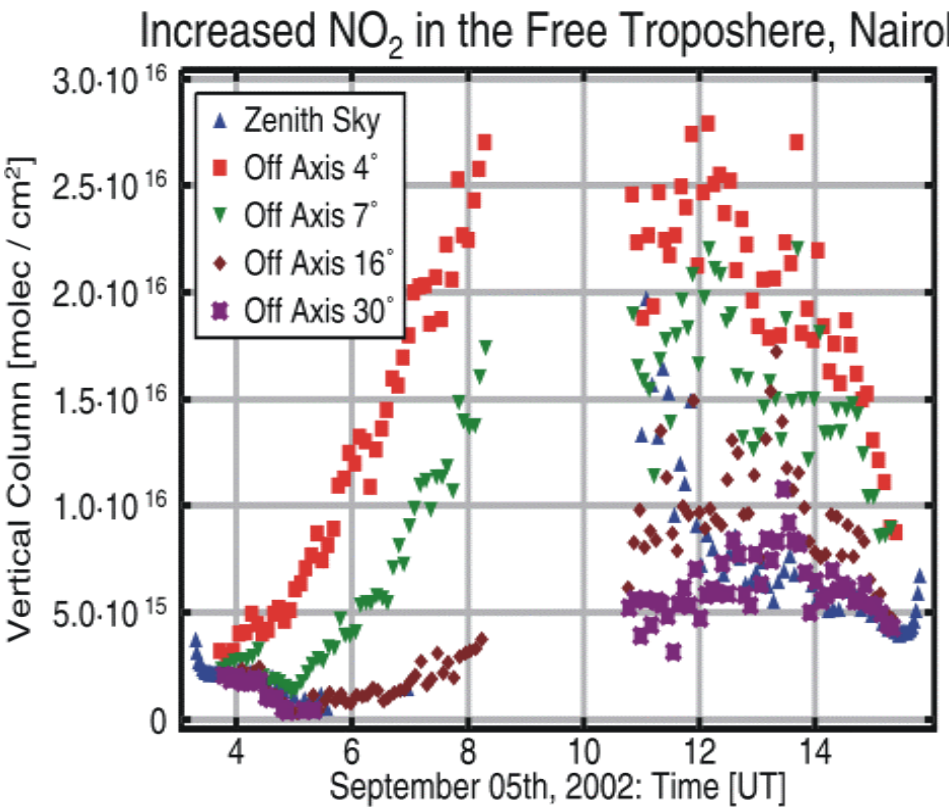
Off Axis DOAS (IV)-Example, Profiles

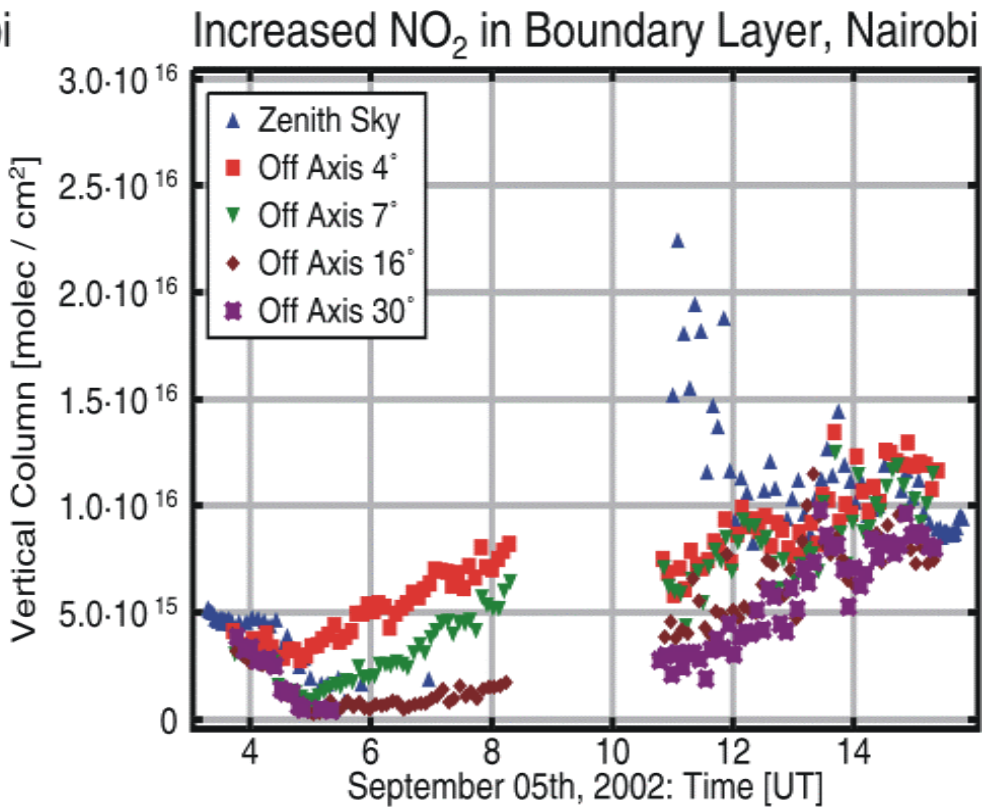


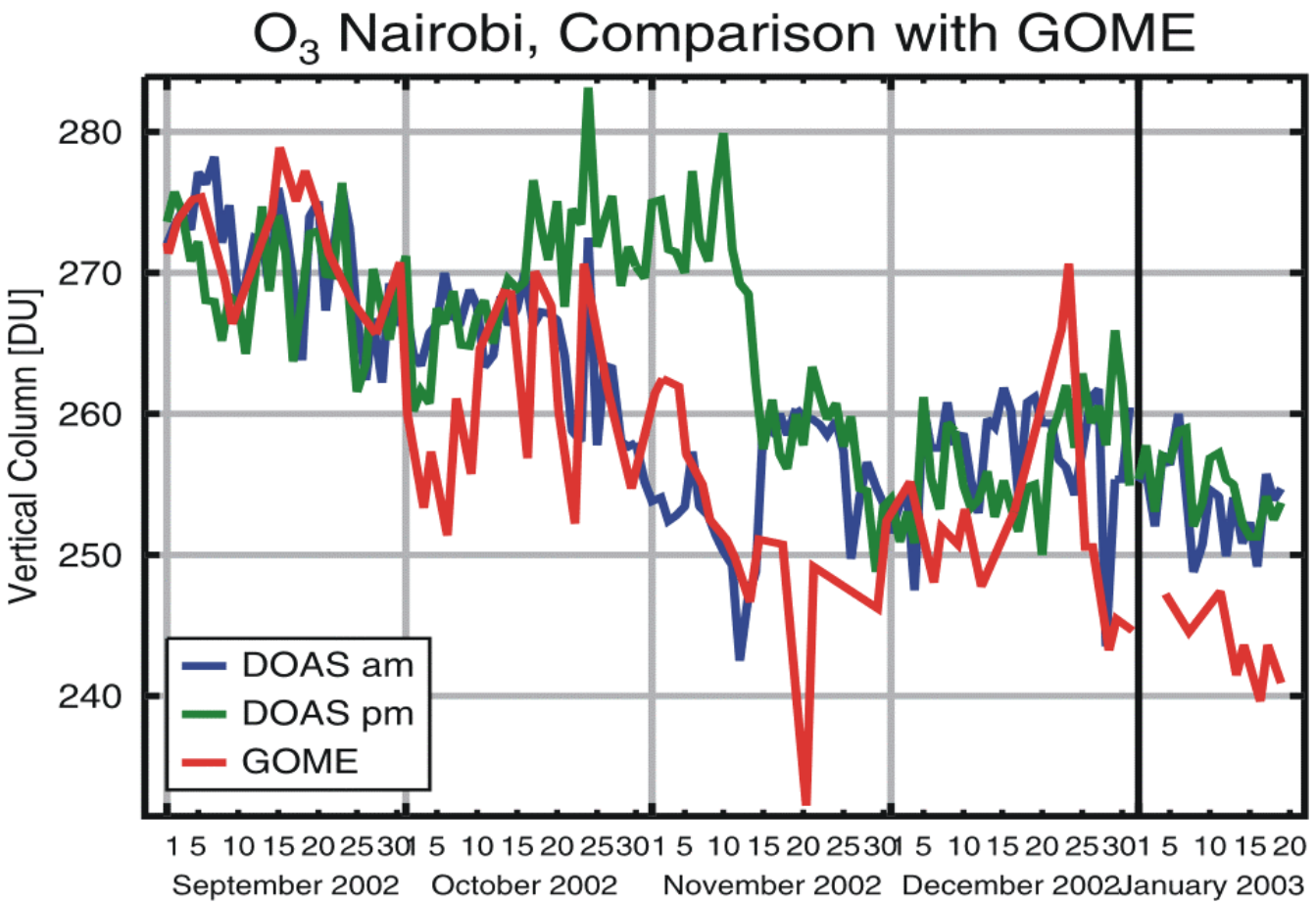
Off Axis DOAS (V)-Example, AMF



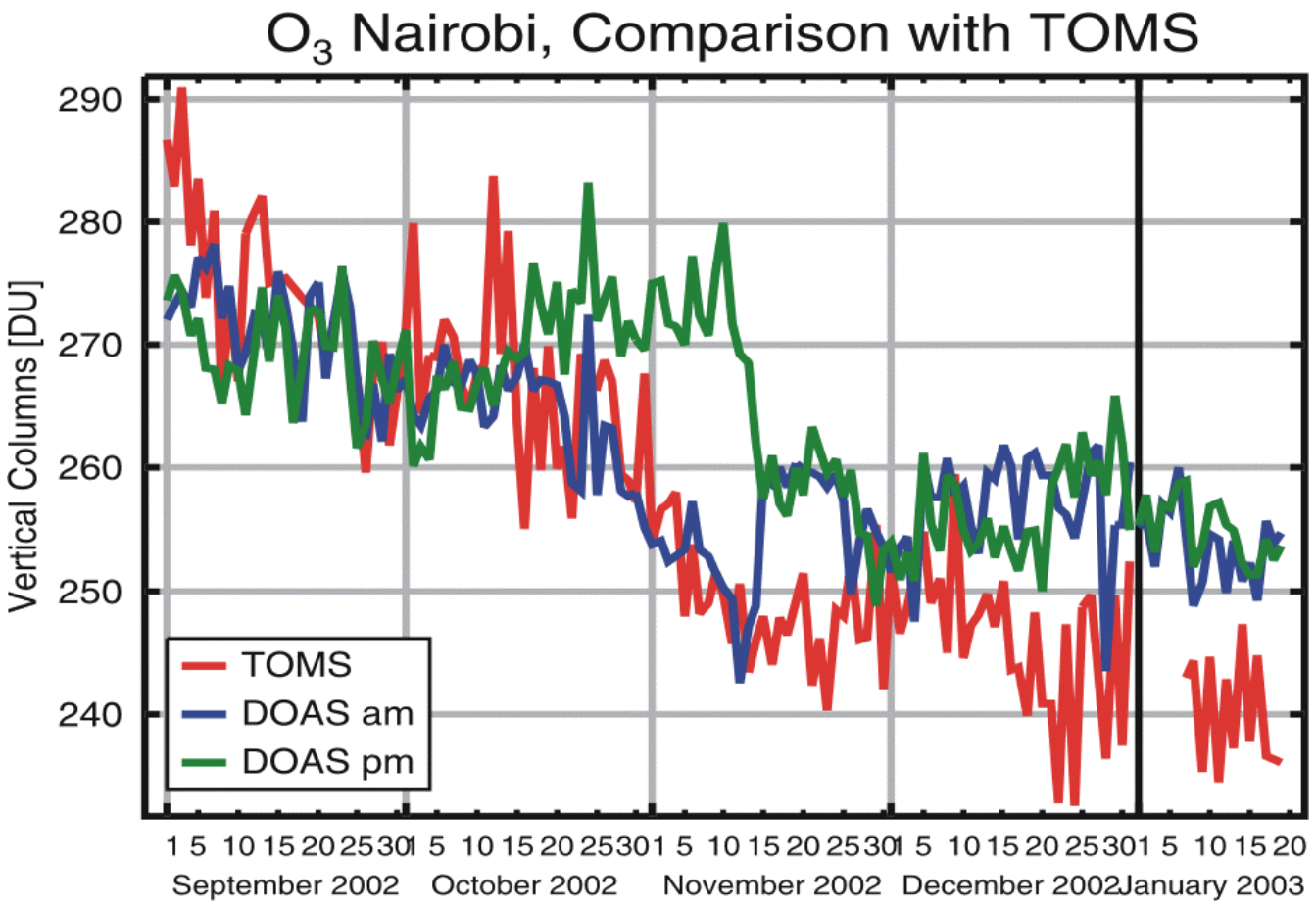
Off Axis DOAS (VI)-Example, Vertical Columns



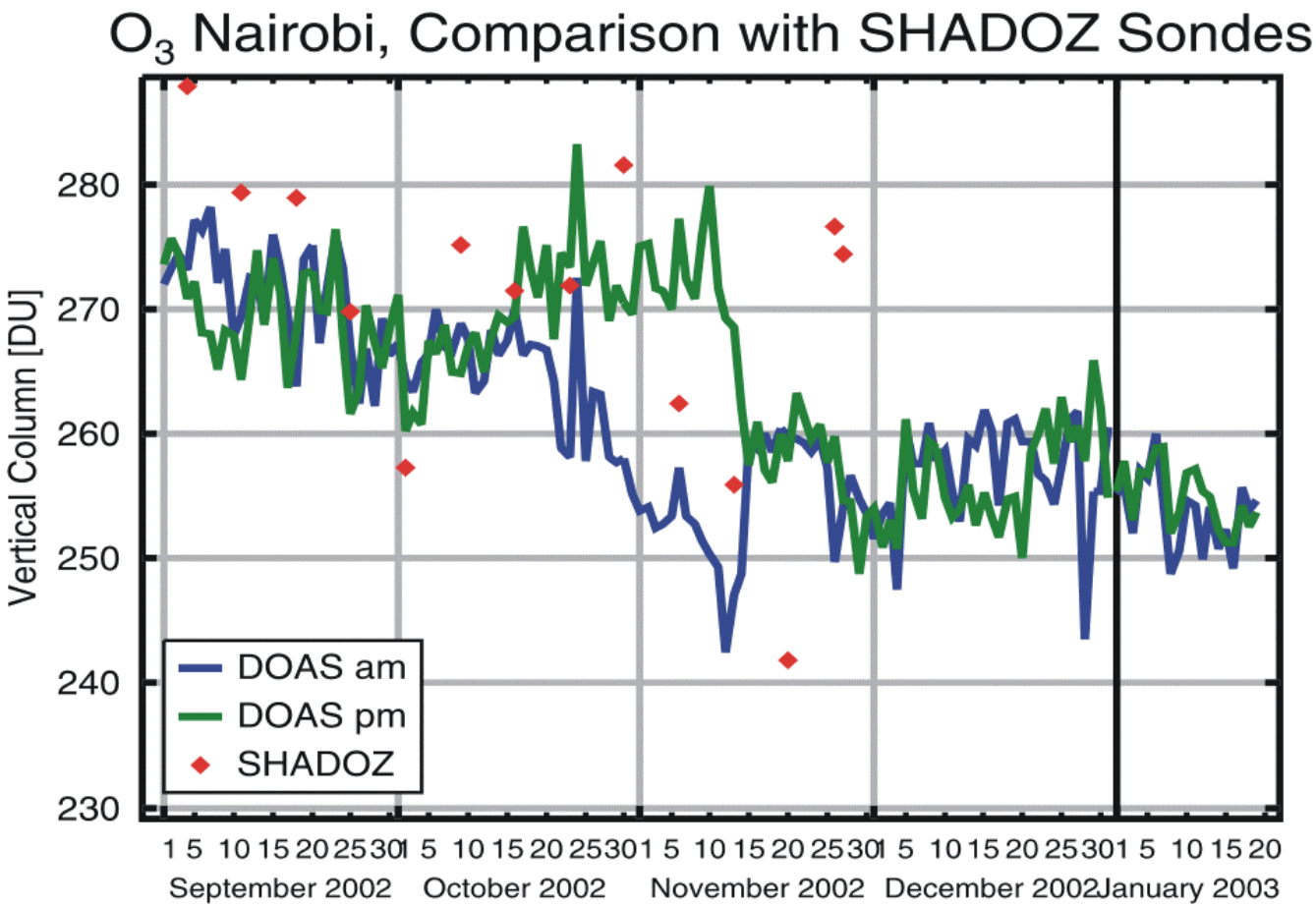




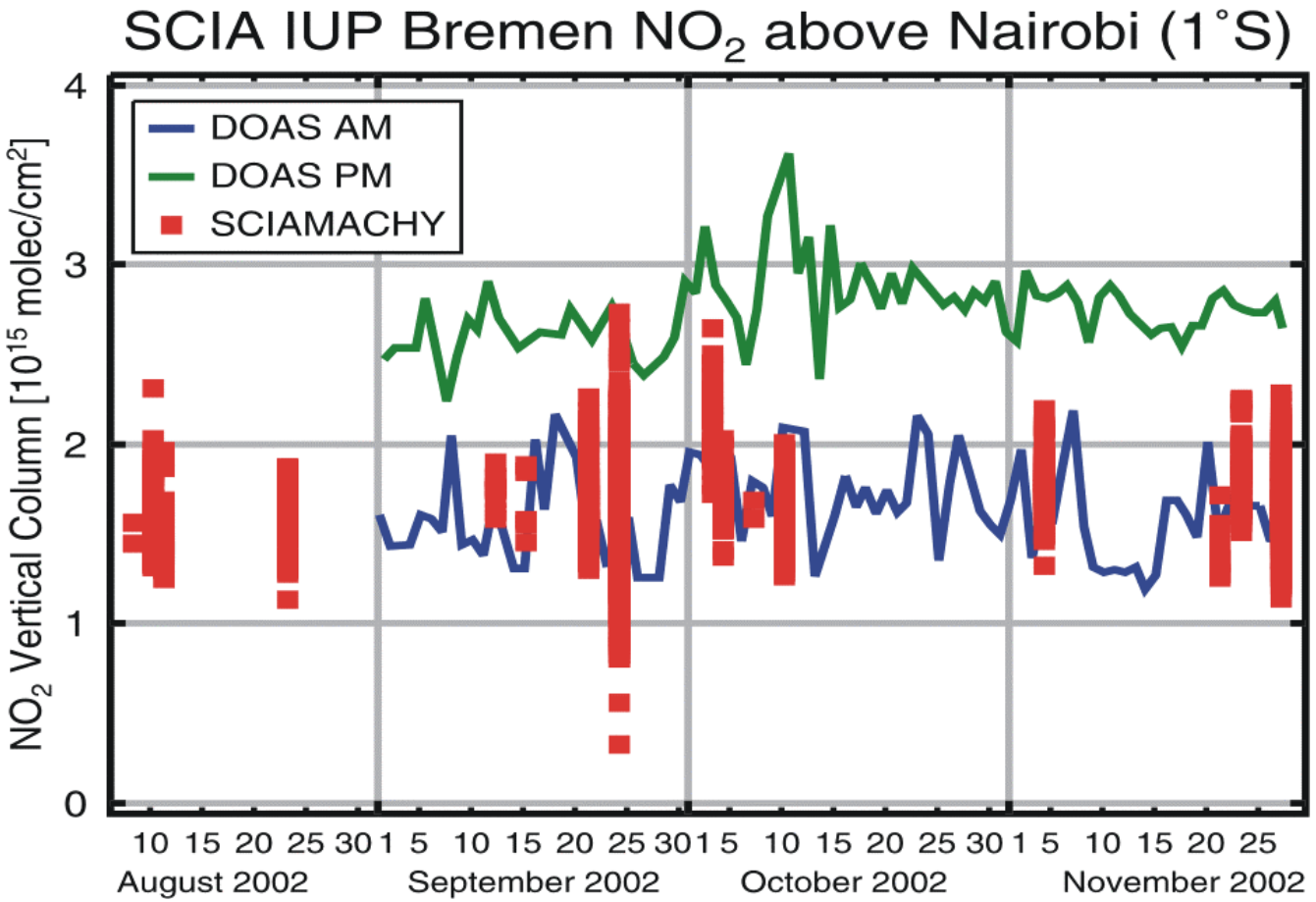
GOME, Andreas Richter IUP Bremen


O_3 Nairobi, Comparison with TOMS
Vertical Columns [DU]
290
280
270
260
250
240
TOMS
DOAS am
DOAS pm
1 5 10 15 20 25 30 1 5 10 15 20 25 30 1 5 10 15 20 25 30 1 5 10 15 20 25 30 1 5 10 15 20
September 2002
October 2002
November 2002
December 2002
January 2003

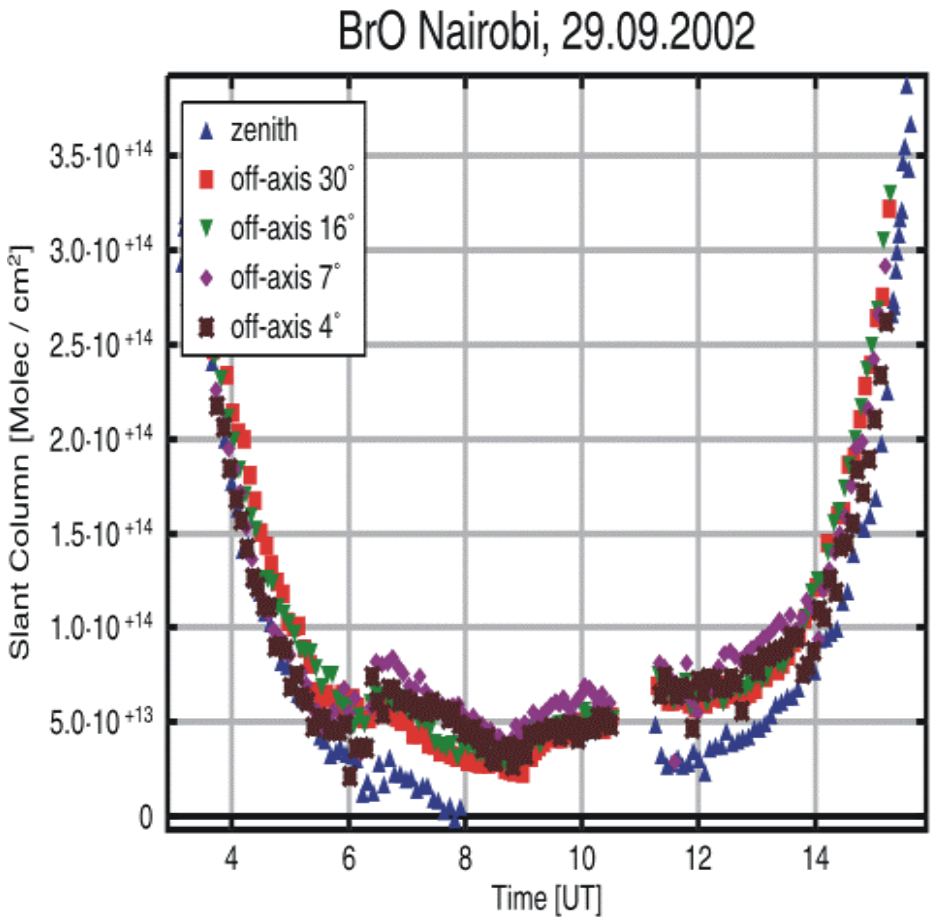
TOMS, NASA

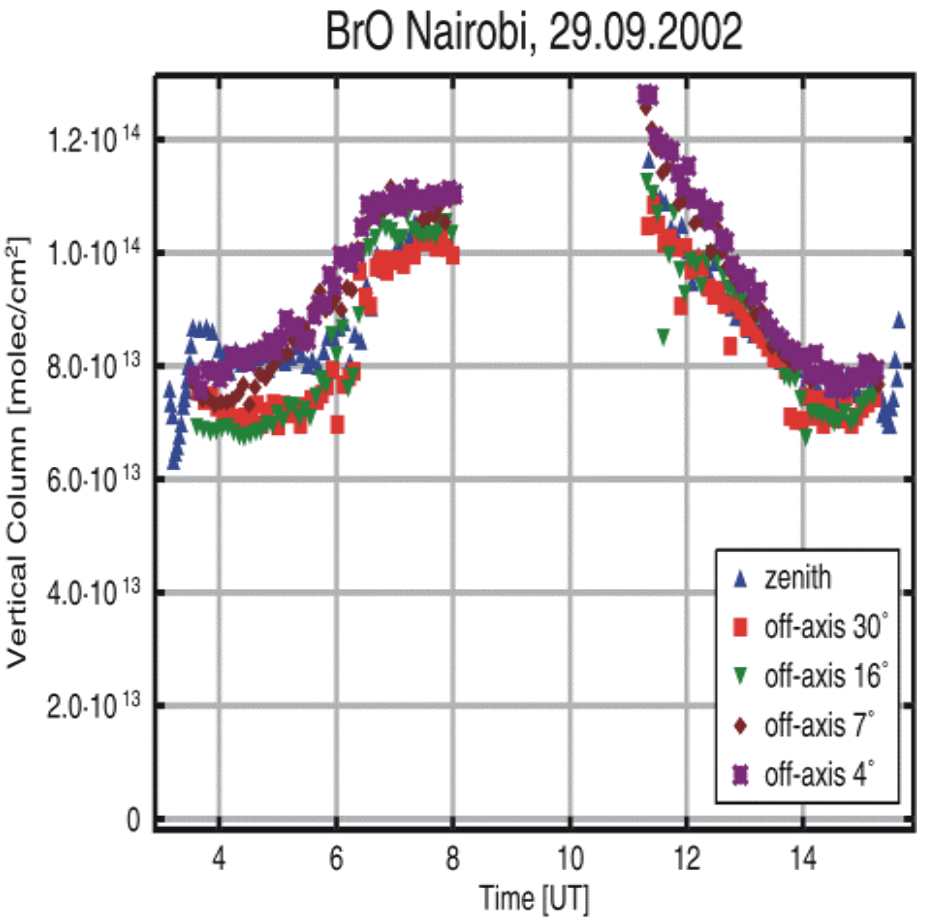


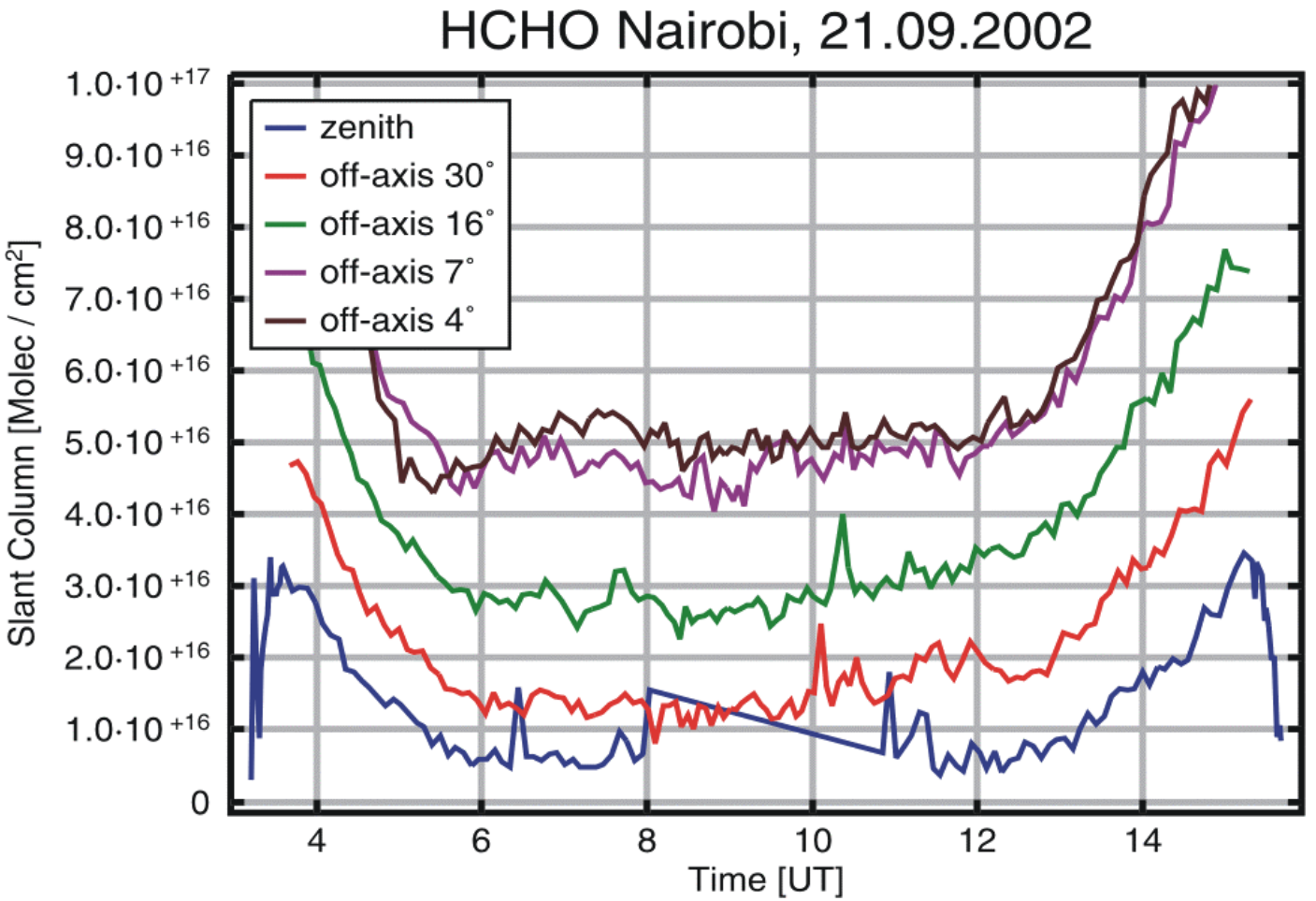
SHADOZ: The 1998-2000 SHADOZ (Southern Hemisphere Additional Ozonesondes) Tropical Ozone Climatology: Comparisons with TOMS and Ground-based Measurements, Thompson, A. M. et.al., *J. Geophysical Research - Atmospheres*, in press, 2002



SCIAMACHY: Andreas Richter, IUP Bremen


BrO Nairobi, 29.09.2002
zenith
off-axis 30°
off-axis 16°
off-axis 7°
off-axis 4°
Slant Column [Molec / cm²]
3.5·10 +14
3.0·10 +14
2.5·10 +14
2.0·10 +14
1.5·10 +14
1.0·10 +14
5.0·10 +13
0
4
6
8
10
12
14
Time [UT]


BrO Nairobi, 29.09.2002
Vertical Column [molec/cm²]
1.2·10 14
1.0·10 14
8.0·10 13
6.0·10 13
4.0·10 13
2.0·10 13
0
4
6
8
10
12
14
Time [UT]
zenith
off-axis 30°
off-axis 16°
off-axis 7°
off-axis 4°


HCHO Nairobi, 21.09.2002
zenith
off-axis 30°
off-axis 16°
off-axis 7°
off-axis 4°
Slant Column [Molec / cm²]
1.0·10 +17
9.0·10 +16
8.0·10 +16
7.0·10 +16
6.0·10 +16
5.0·10 +16
4.0·10 +16
3.0·10 +16
2.0·10 +16
1.0·10 +16
0
4
6
8
10
12
14
Time [UT]

Summary

- Instrument installed in August 2002, still working
- Detection of O_3, NO_2, BrO, HCHO
- Multi-axis DOAS is working, a distinction of stratospheric and tropospheric compounds is possible
- Long-term validation of SCIAMACHY products

Outlook

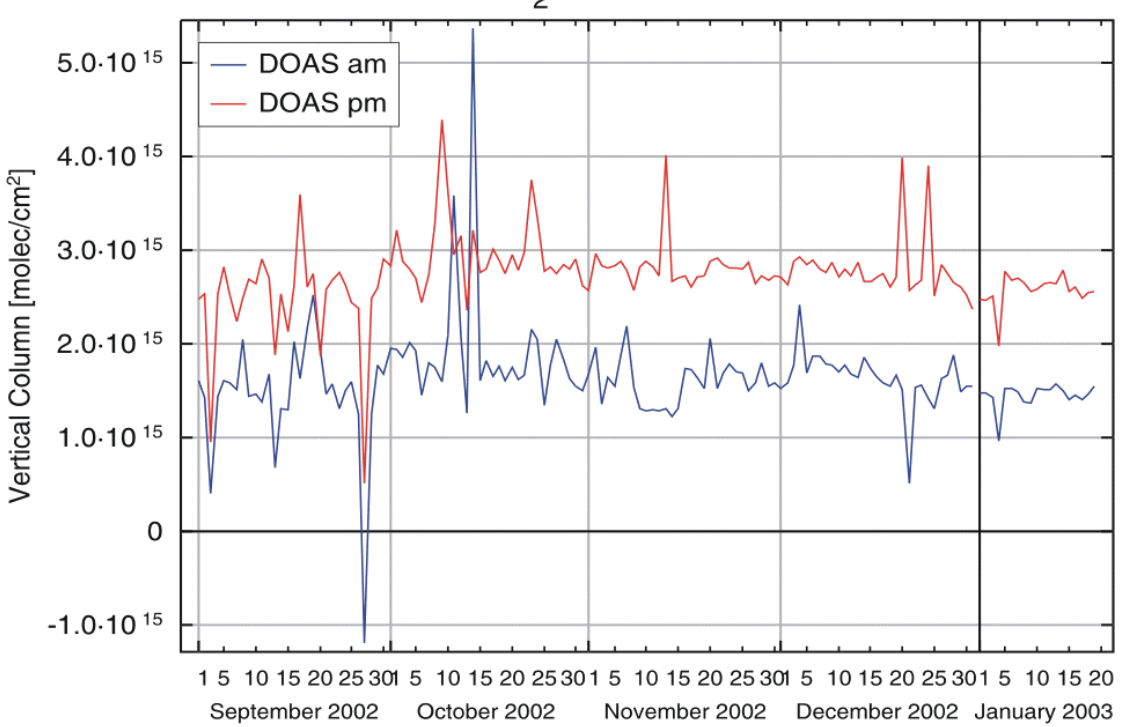
- Second spectrometer in summer 2003 for the visible range
- Improvement of the multi-axis method
- Validation of SCIAMACHY

Acknowledgements

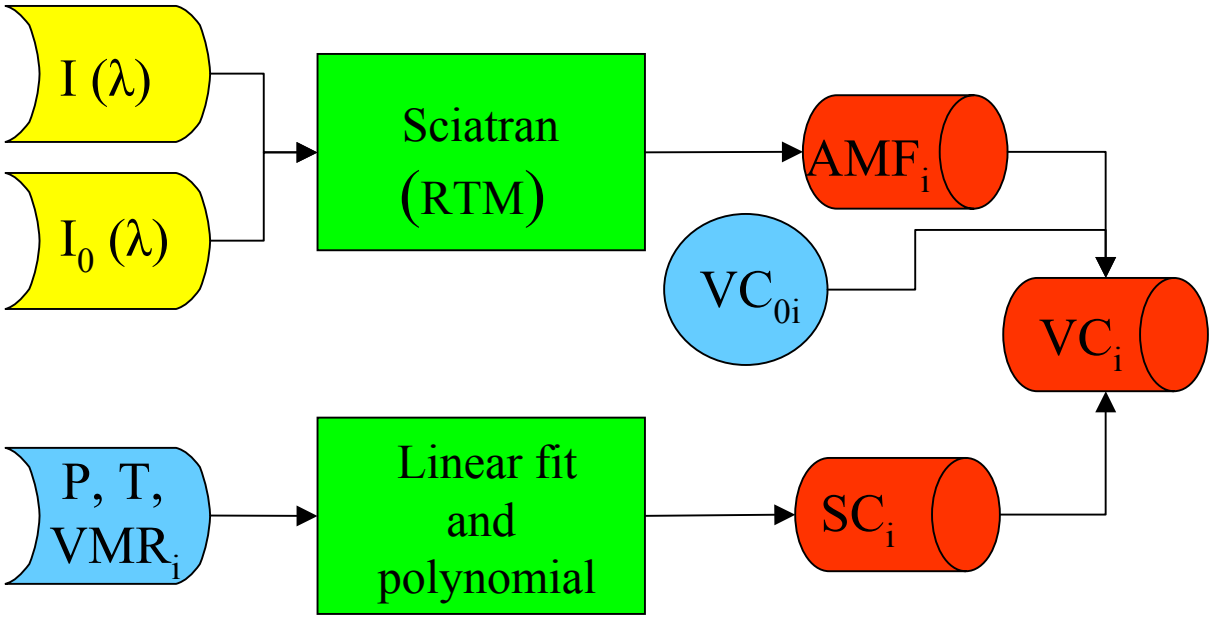
- German Federal Ministry of Education and Research (BMBF)
- German Aerospace Agency (DLR) and
- Deutsche Forschungsgemeinschaft (DFG, German Research Council)
- the UNEP, especially the staff from the Ozone Secretariat

The End

NO_2

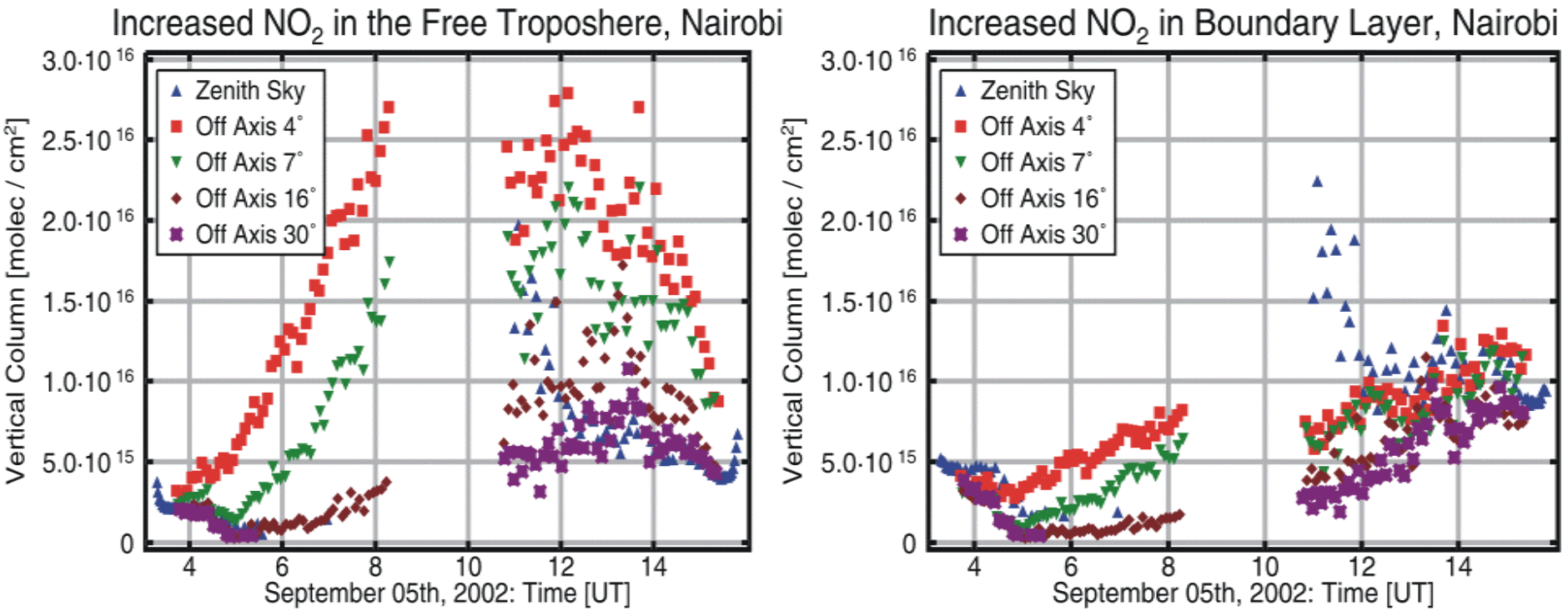

NO2 above Nairobi
DOAS am
DOAS pm
Vertical Column [molec/cm2]
5.0·10 15
4.0·10 15
3.0·10 15
2.0·10 15
1.0·10 15
0
-1.0·10 15
1 5 10 15 20 25 30
September 2002
1 5 10 15 20 25 30
October 2002
1 5 10 15 20 25 30
November 2002
1 5 10 15 20 25 30
December 2002
1 5 10 15 20
January 2003

DOAS method (III)



$$\ln I(\lambda) = \ln I_0(\lambda) - \sum_i \sigma_i(\lambda) SC_i - \sum_p a_p \lambda^p$$

Off Axis DOAS (IV)-Example, Vertical Columns



Analysis of NO_2 measurements in Nairobi (05.09.2002). Two different assumptions for the input profiles: [a] enhanced NO_2 in the free troposphere and [b] enhanced NO_2 in the boundary layer.