



# Ground based DOAS (Differential Optical Absorption Spectroscopy) Measurements at different latitudes

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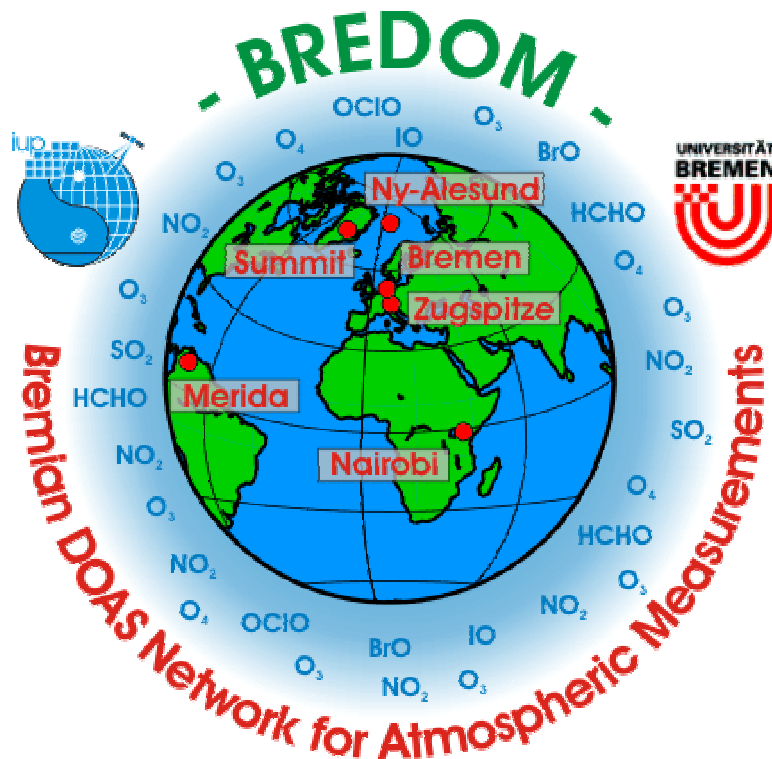


## Overview

- Bremian DOAS Network for Atmospheric Measurements
- DOAS Method
- MAX DOAS Instrument
- Selected results
  - Summit
  - Zugspitze
  - Merida
- Summary and Outlook



# Bremian DOAS Network for Atmospheric Measurements (BREDOM)



In operation:

- Ny Ålesund (79°N, 12°E)
- Summit (72°N, 38°W), 3200m
- Bremen (53°N, 9°E)
- Merida (8°N, 71°W), 4765m
- Nairobi (1°S, 37°E)

Temporary in operation:

- Zugspitze (47°N, 10°E), 2650m

## BREDOM (II)

### Advantages:

- Two tropical stations
- Similar setup for all measurement sites
- High-sensitivity DOAS-instruments for stand-alone operation
- Multiple viewing directions (MAX-DOAS)

### Target Quantities:

- $O_3$  and  $NO_2$  as well as minor absorbers (e.g. BrO, OCIO, IO, HCHO)

### Aims:

- Validation of satellites (e.g. SCIAMACHY on ENVISAT)
- tropospheric and stratospheric amounts of trace gases
- Comparison of measurements at different latitudes

## DOAS Method (I)

- DOAS technique is based on Lambert-Beer-Law

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

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

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

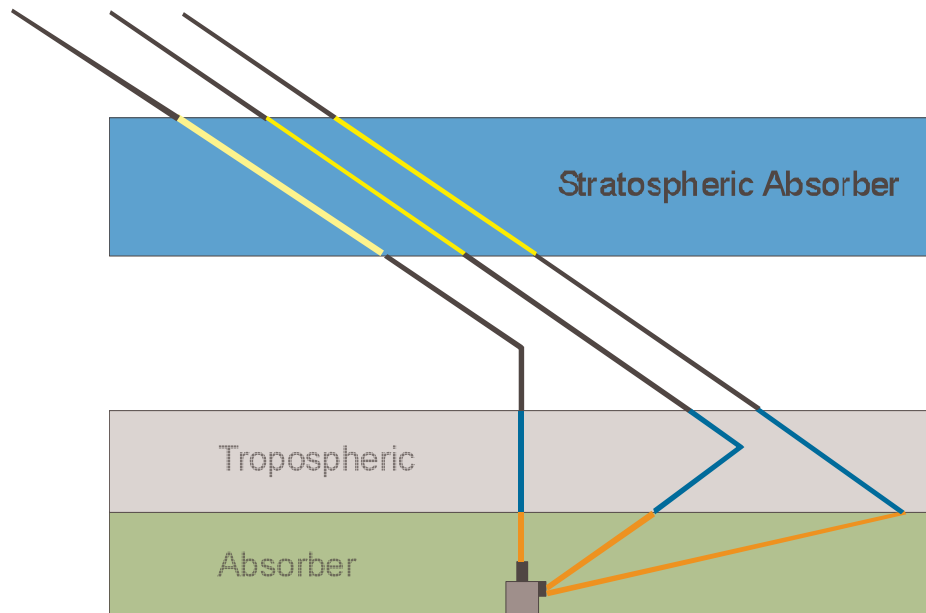
## DOAS Method (II)

- Vertical column (VC):  
sum of all molecules in a virtual column perpendicular to the earth's surface

$$\text{AMF (SZA)} = \text{SC} / \text{VC}$$

- 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 assumed profiles of absorbers

## Multi Axis (MAX) DOAS

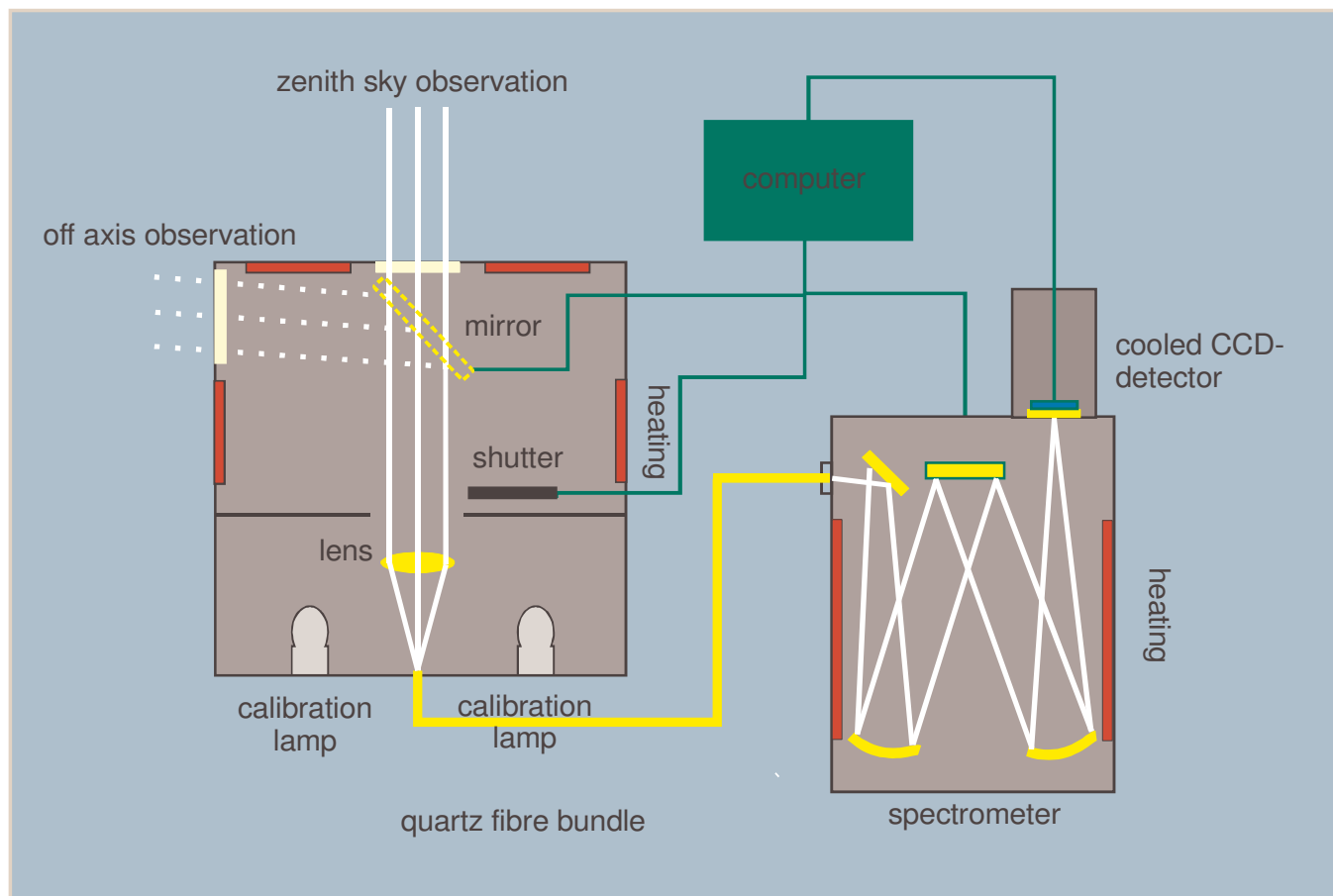


- Measurements close to the horizon have a long light path through the troposphere and are thus sensitive for tropospheric trace gases
- Zenith sky measurement are mainly sensitive to stratospheric absorbers

⇒

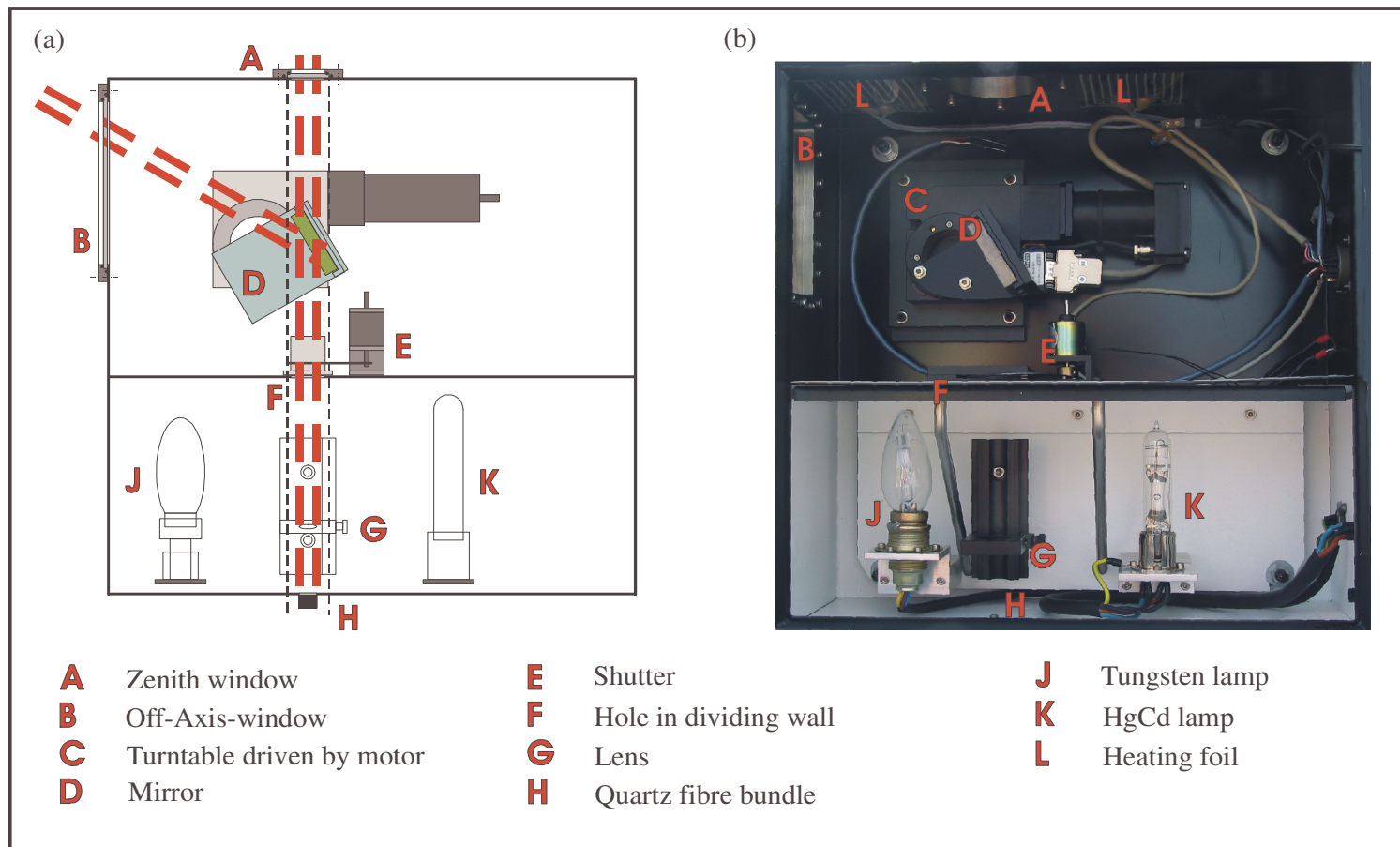
- MAX DOAS allows to gain information on the vertical distribution of atmospheric trace gases

# DOAS instrument (I)





## DOAS instrument (II)



## DOAS instrument (III)

- Czerny-Turner Spectrograph L.O.T. MS 260i, MS 257
- CCD Andor DV420-BU (1024 x 256 Pixel), DV440-BU (2048 x 512 Pixel)
- UV/VIS wavelength region: 320 – 410 nm
- Spectral resolution:  $\sim 0.5$  nm
- Pointing of the telescope alternating between zenith and horizon  
(4 off axis viewing directions:  $4^\circ$ ,  $7^\circ$ ,  $16^\circ$ ,  $30^\circ$ )
- Daily calibration measurements



## Stratospheric NO<sub>2</sub> at different latitudes

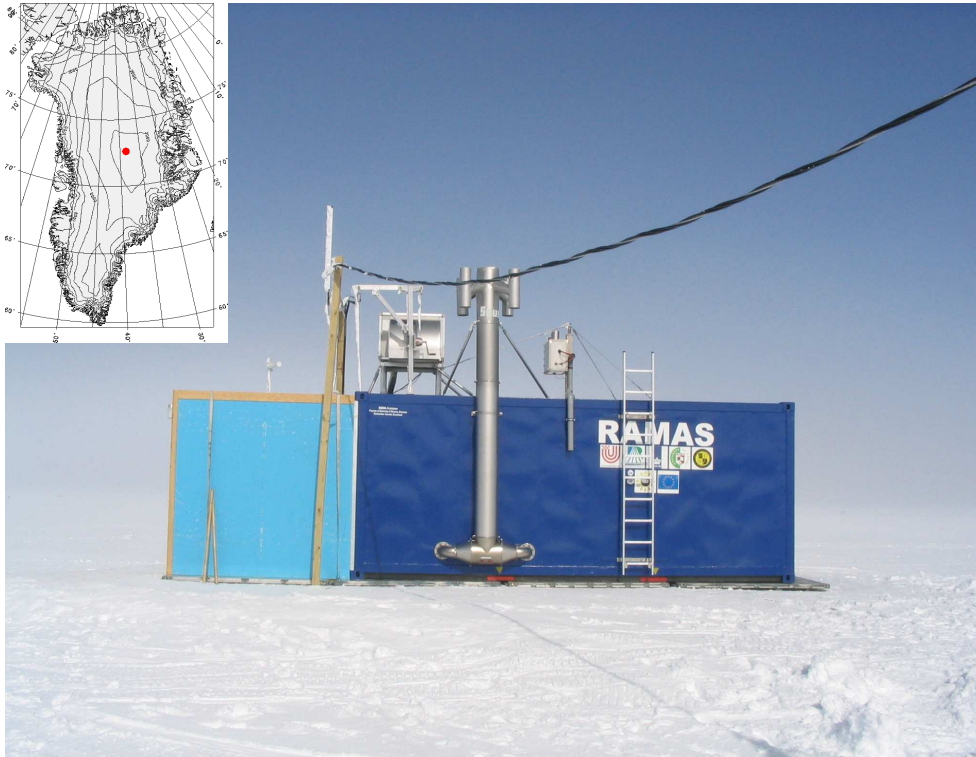
- Photolysis of N<sub>2</sub>O<sub>5</sub> depends on solar irradiation and temperature

What do we expect?

- Summit  
highest values in summer, lowest during wintertime
- Zugspitze  
high in summer, low in winter
- Merida  
low but highest NO<sub>2</sub> values during wintertime

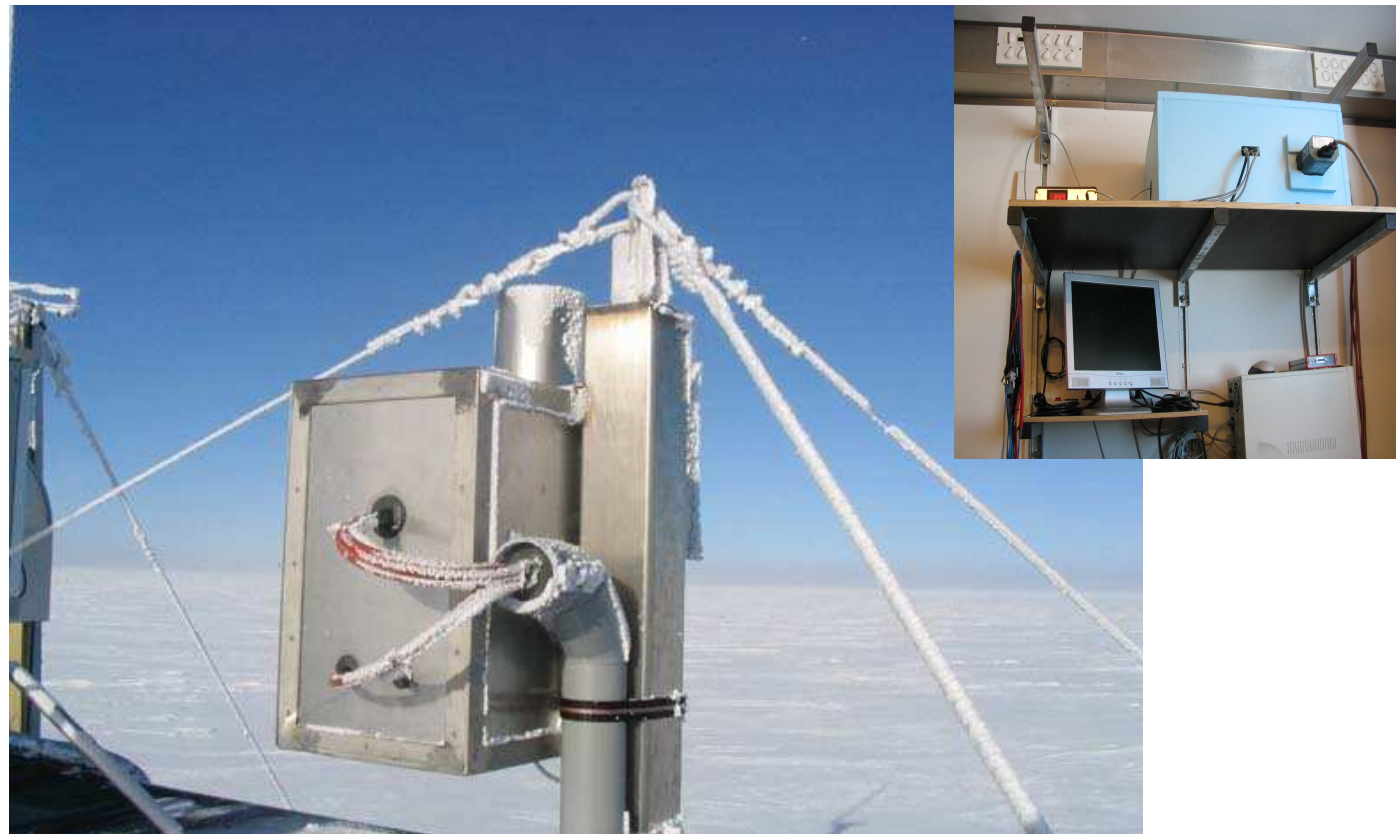


## Measurement Site Summit (I)

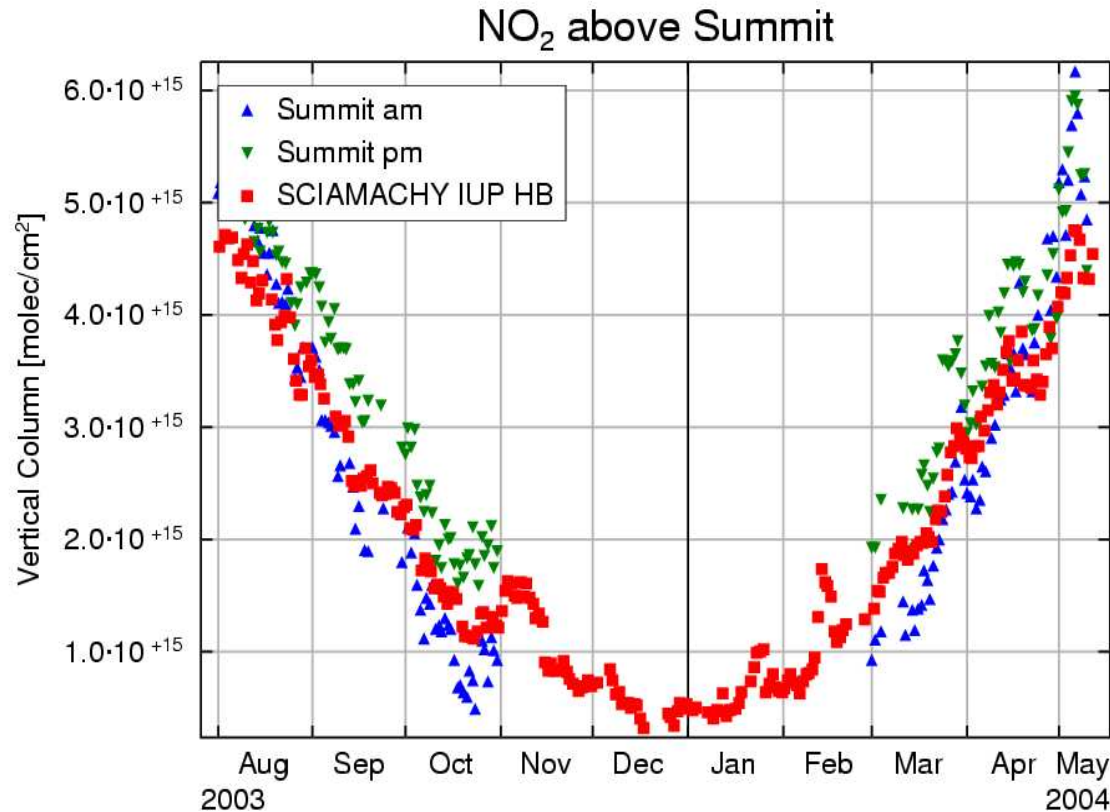


- Summit 72,34 °N, 38,29 °W
- 3200 m above sea level
- characterized by:
  - low temperatures,
  - very low water vapour column and
  - a clean troposphere

## Measurement Site Summit (II)



# Results

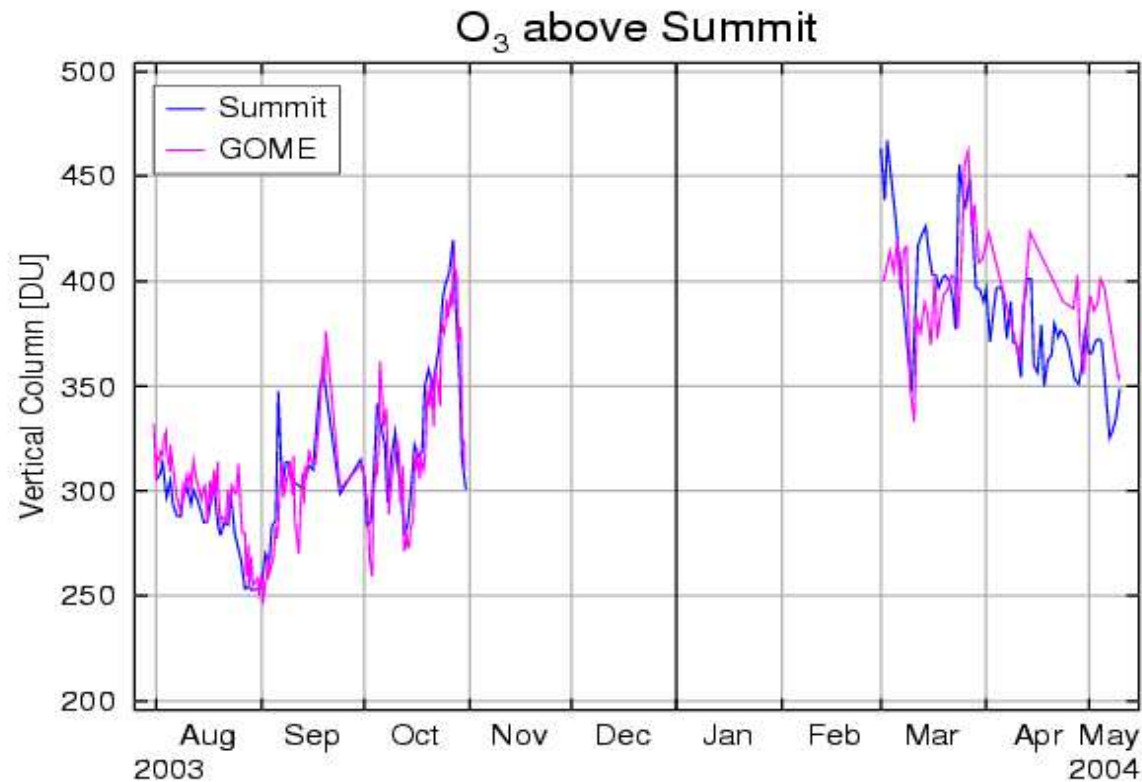


SCIAMACHY: Andreas Richter, IUP Bremen

- diurnal variation of NO<sub>2</sub>
- good agreement between SCIAMACHY and ground based data
- offset in SCIAMACHY slant column added
- **SCIAMACHY NO<sub>2</sub> column within 500 km radius of station!**

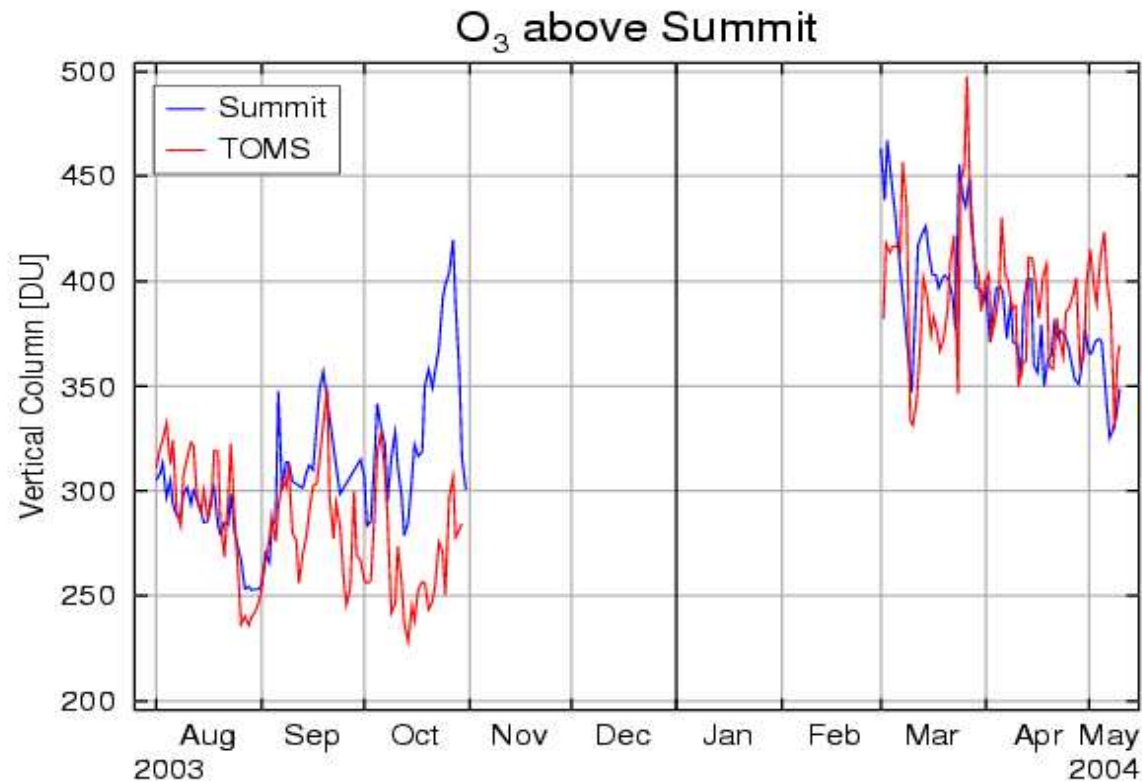


## Results



- excellent agreement in 2003
- day to day variation picked up correctly
- differences in 2004
- GOME O<sub>3</sub> column within 500 km radius of station!

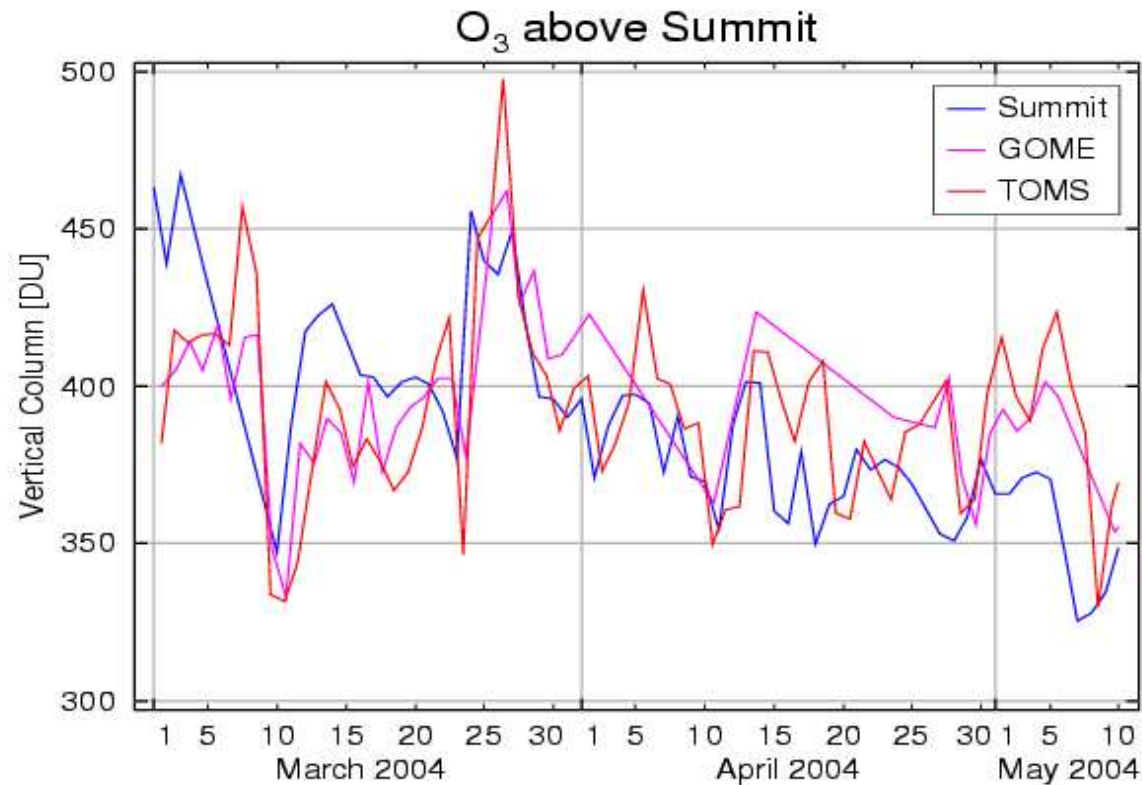
## Results



- day to day variation picked up correctly
- disagreement in 10/2003 and 05/2004



## Results



- similar trend of GOME and TOMS measurements
- in principle good agreement between Satellite and ground based measurements



## Summary Summit

- DOAS instrument at Summit has been operating since August 2003
- Scientific  $\text{NO}_2$  product shows good agreement with ground based measurements (an offset of  $1\text{E}15$  molec/ $\text{cm}^2$  is added)
- in principle  $\text{O}_3$  from GOME and TOMS are in good agreement with ground based measurements

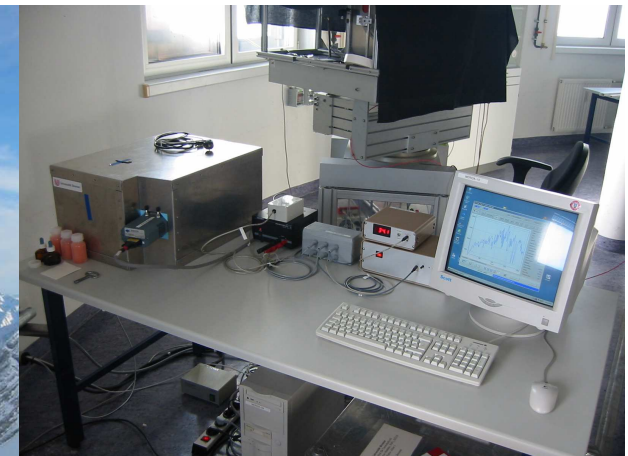


## Measurement Site Zugspitze (I)



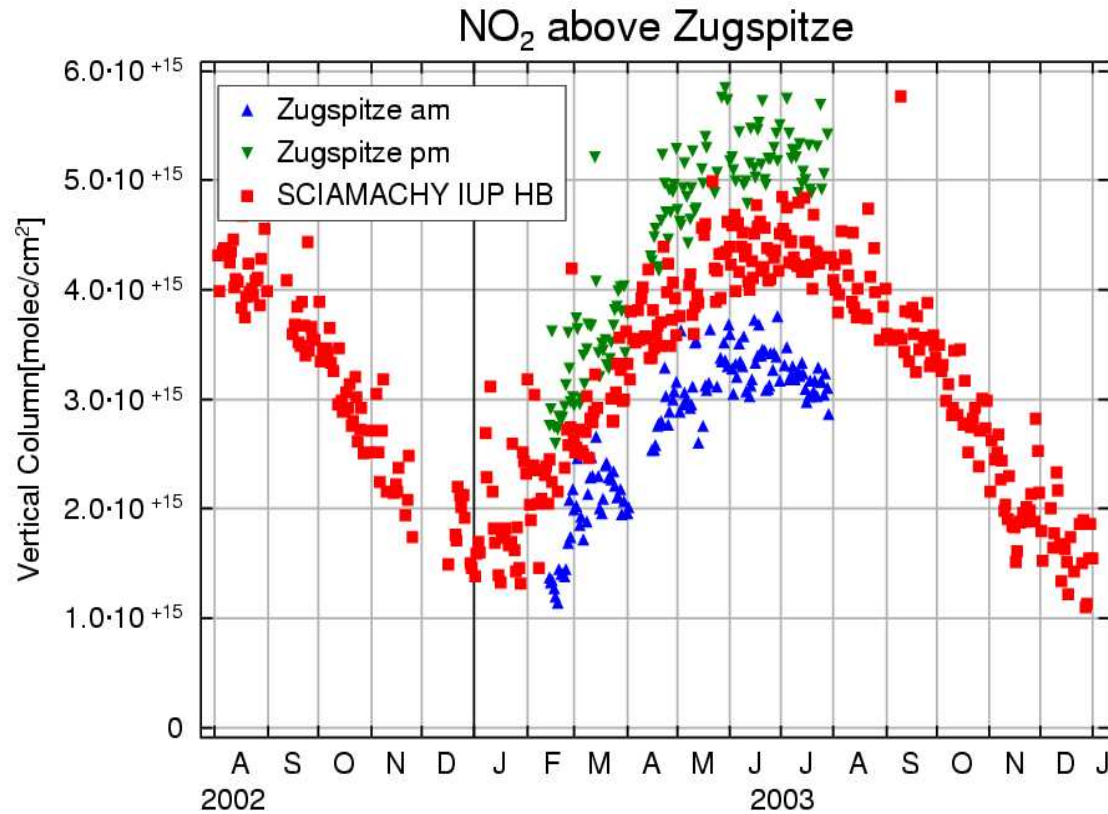
- Zugspitze ( $47,3^{\circ}\text{N}$ ;  $10,6^{\circ}\text{E}$ )
- 2650 m above sea level
- Installed at **Umwelt Forschungsstation Schneefernerhaus (UFS)**
- Viewing direction: SE

## Measurement Site Zugspitze (II)



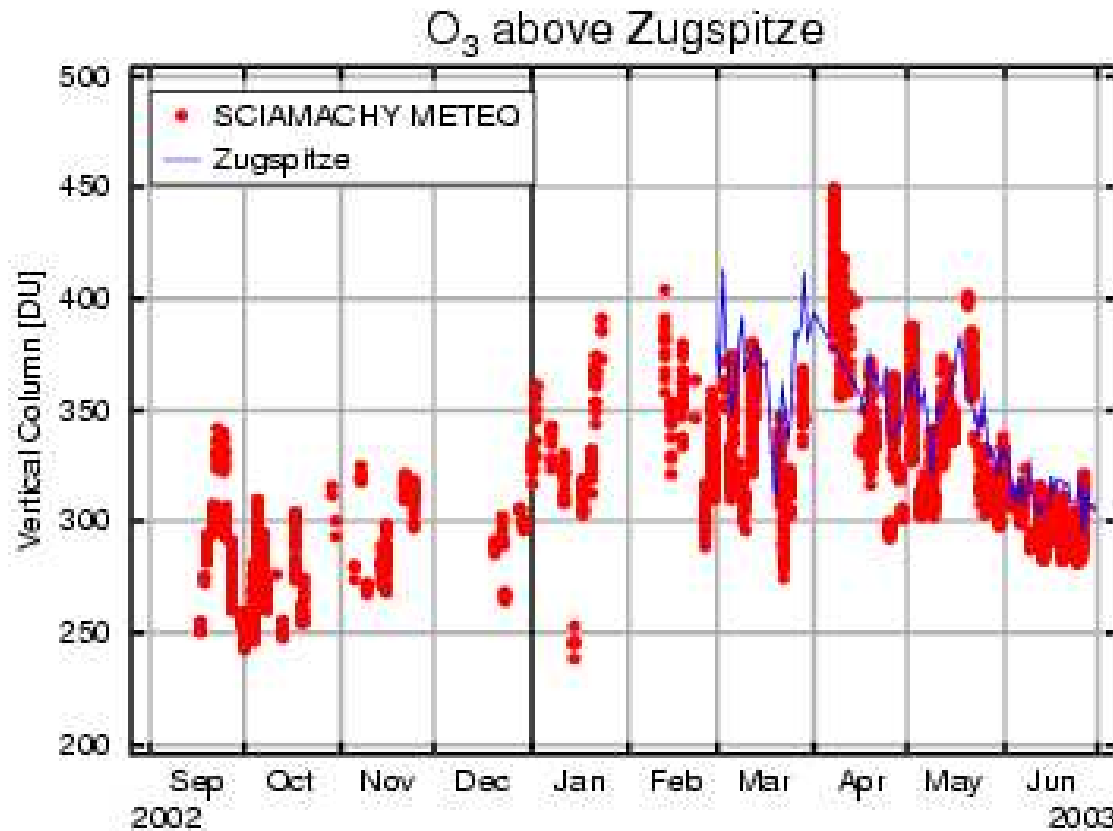


# Results



- diurnal variation of NO<sub>2</sub>
- similar trend of SCIAMACHY and ground based measurements
- offset in SCIAMACHY slant column added
- **SCIAMACHY NO<sub>2</sub> smallest column within 500 km radius of station!**

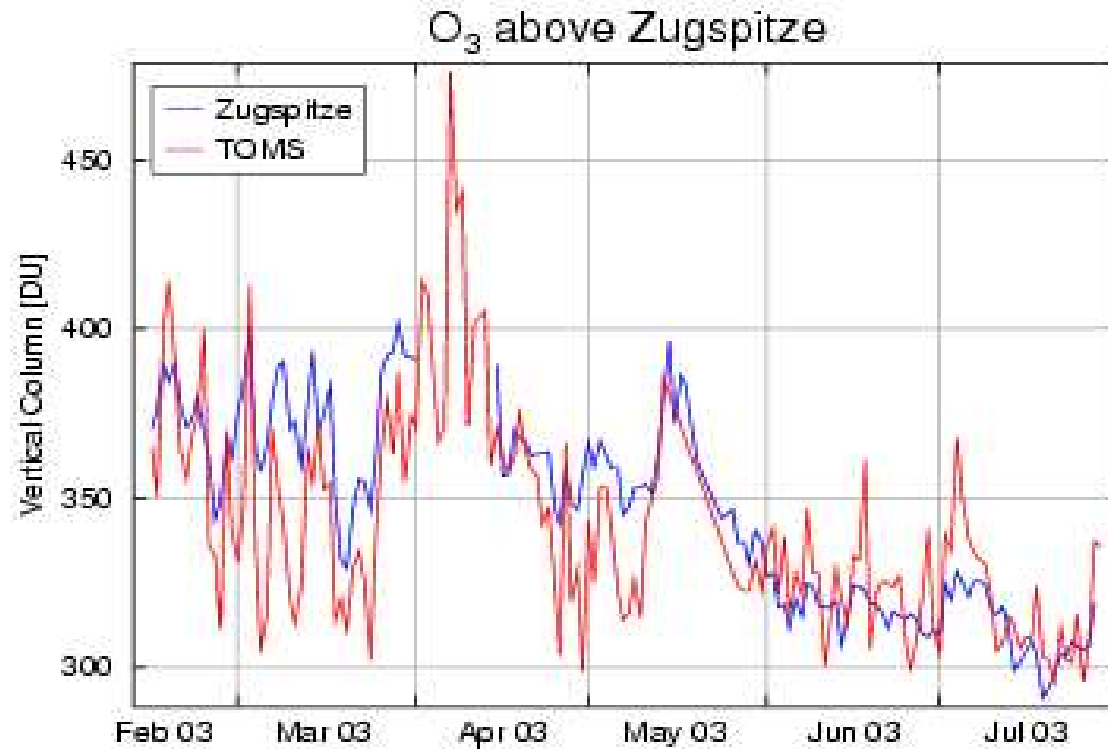
# Results



- day to day variation picked up correctly
- SCIAMACHY data overall to low

SCIAMACHY: Andreas Richter, IUP Bremen

# Results



- good agreement between TOMS and ground based data
- seasonal variation is well represented

SCIAMACHY: Andreas Richter, IUP Bremen



## Summary Zugspitze

- Temporary installed (Feb. 2003 – Jul. 2003)
- excellent agreement between  $\text{NO}_2$  from SCIAMACHY and ground based measurements (an offset of  $1\text{E}15$  molec/cm<sup>2</sup> is added)
- SCIAMACHY Meteo product is overall to low
- $\text{O}_3$  from TOMS and ground based measurements are in good agreement
- seasonal variation well represented





## Measurement Site Merida (I)

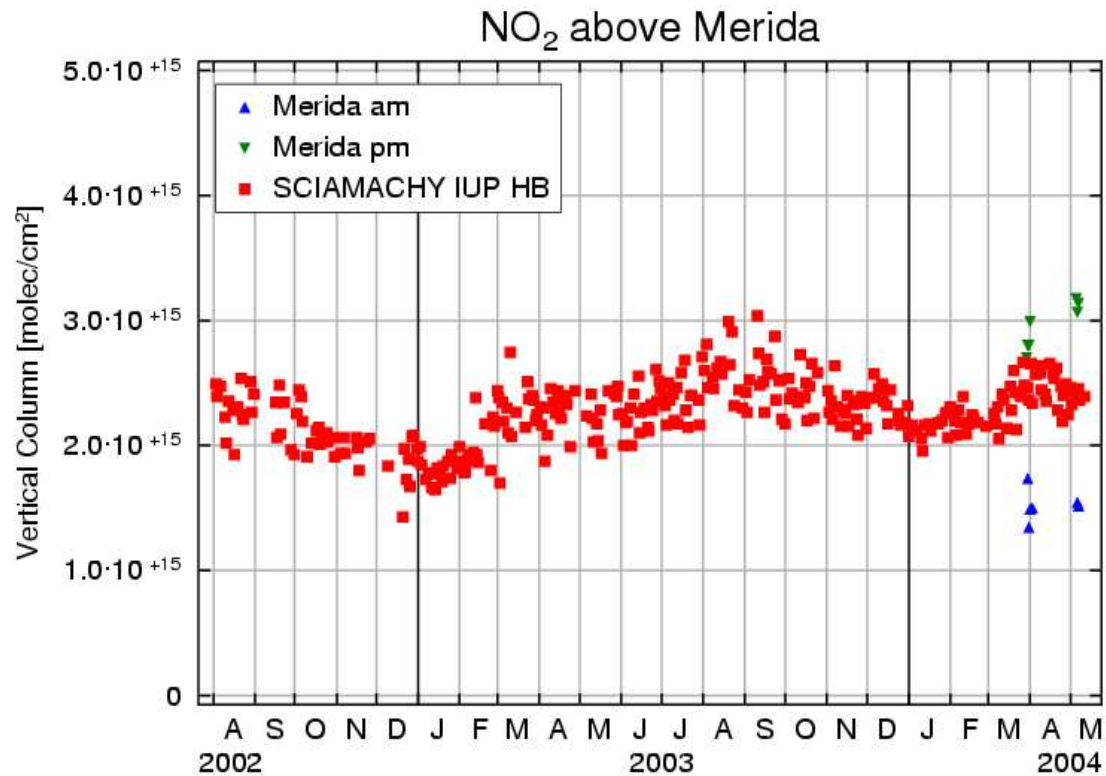


- Merida (8,3°N; 71,6°E)
- 4765 m above sea level
- located inside the MARS (Merida Atmospheric Research Station) building at Pico Espejo
- viewing direction: S
- operational since 04/2004

## Measurement Site Merida (II)



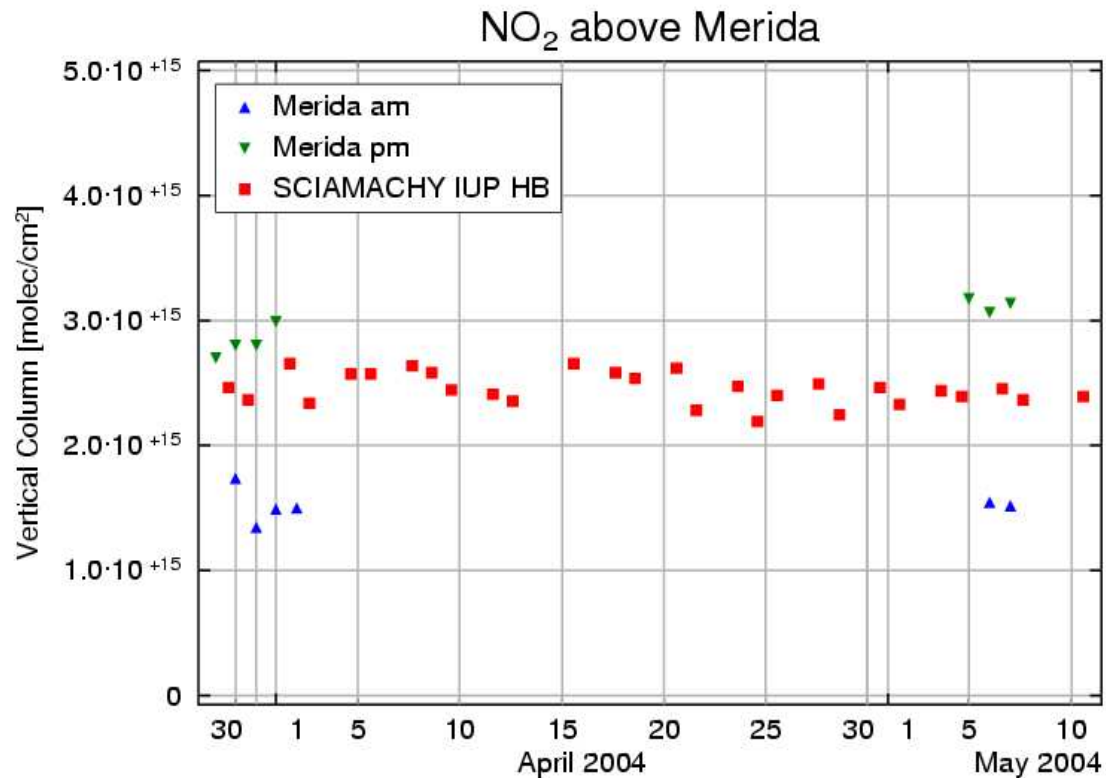
# Results



- diurnal variation of NO<sub>2</sub>
- no seasonal trend of SCIAMACHY NO<sub>2</sub> measurements

SCIAMACHY: Andreas Richter, IUP Bremen

# Results

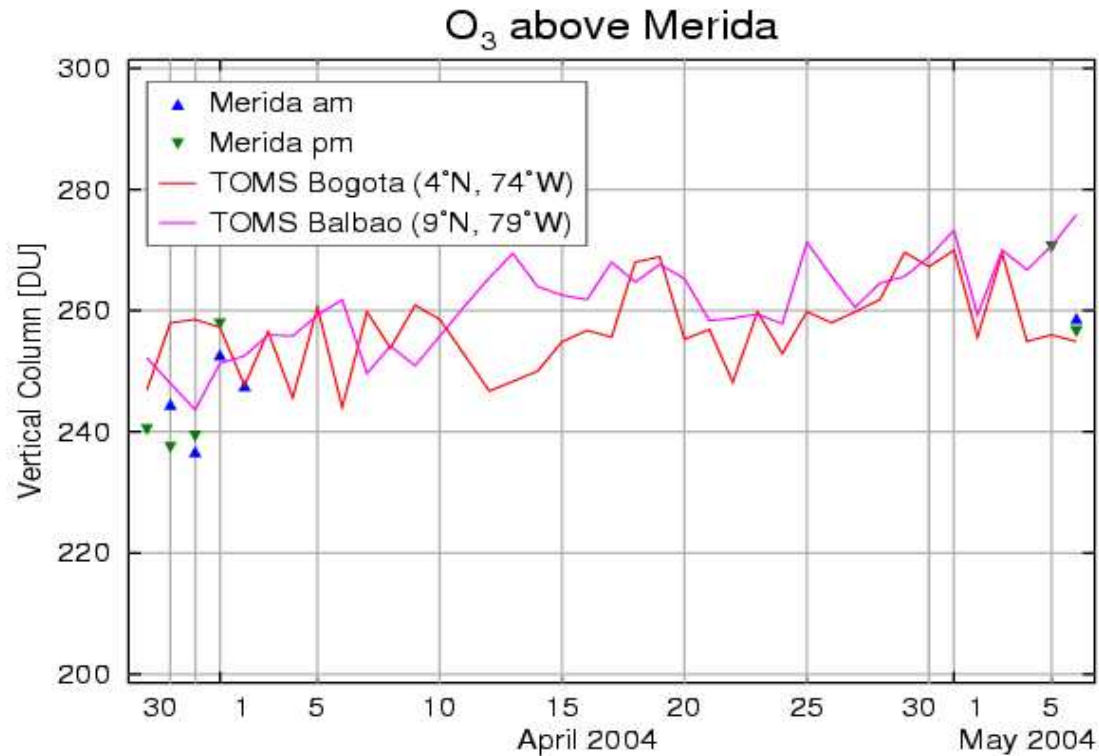


- offset in SCIAMACHY slant column assumed
- good agreement between SCIAMACHY and ground based data
- **SCIAMACHY NO<sub>2</sub> column within 500 km radius of station!**

SCIAMACHY: Andreas Richter, IUP Bremen



# Results



- no diurnal variation of  $O_3$
- good agreement between TOMS and ground based data



## Summary Merida

- DOAS instrument at Merida has been operating since April 2004
- Scientific  $\text{NO}_2$  product shows good agreement with ground based measurements (an offset of  $1\text{E}15$  molec/ $\text{cm}^2$  is added)
- $\text{O}_3$  from TOMS and ground based measurements are in good agreement



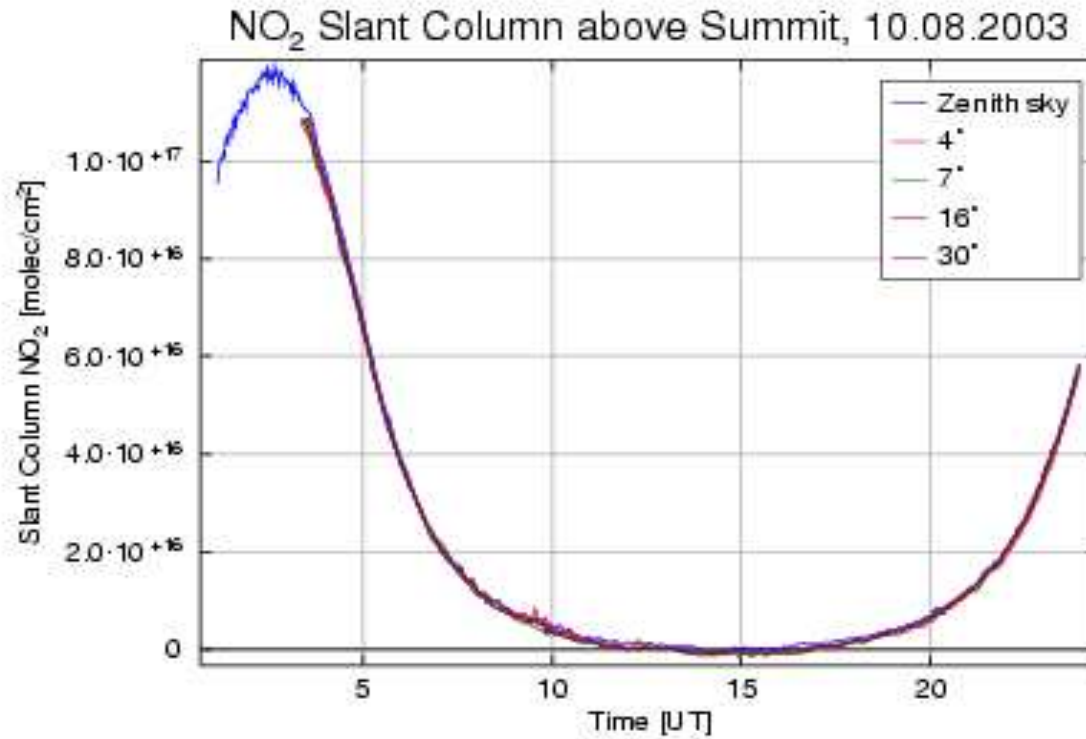
## Off Axis Measurements

### Why we do Off Axis measurements?

- monitoring of trace gases mainly located in the troposphere
- distinction of tropospheric and stratospheric column amount
- derive a coarse vertical profile of the absorbers

### What do we expect?

- only stratospheric absorbers  
SC of zenith sky and off axis measurements close together
- tropospheric and stratospheric absorbers  
increasing SC for lower lines of sight

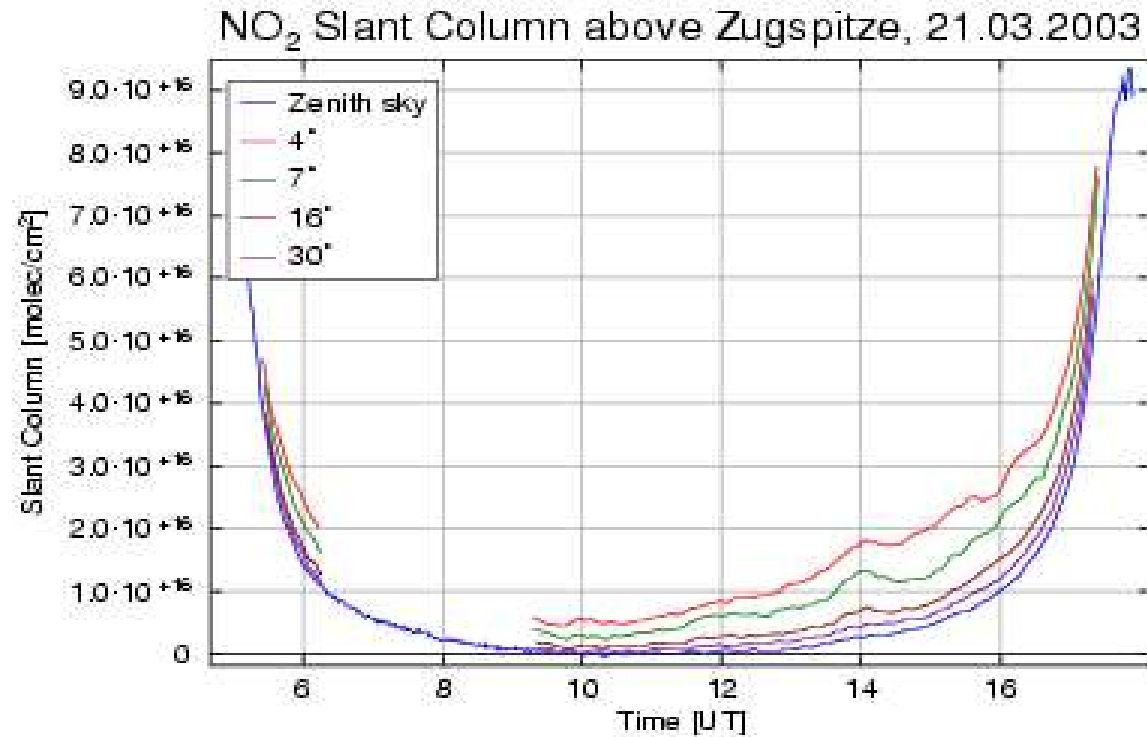


- similar NO<sub>2</sub> SC for all lines of sight

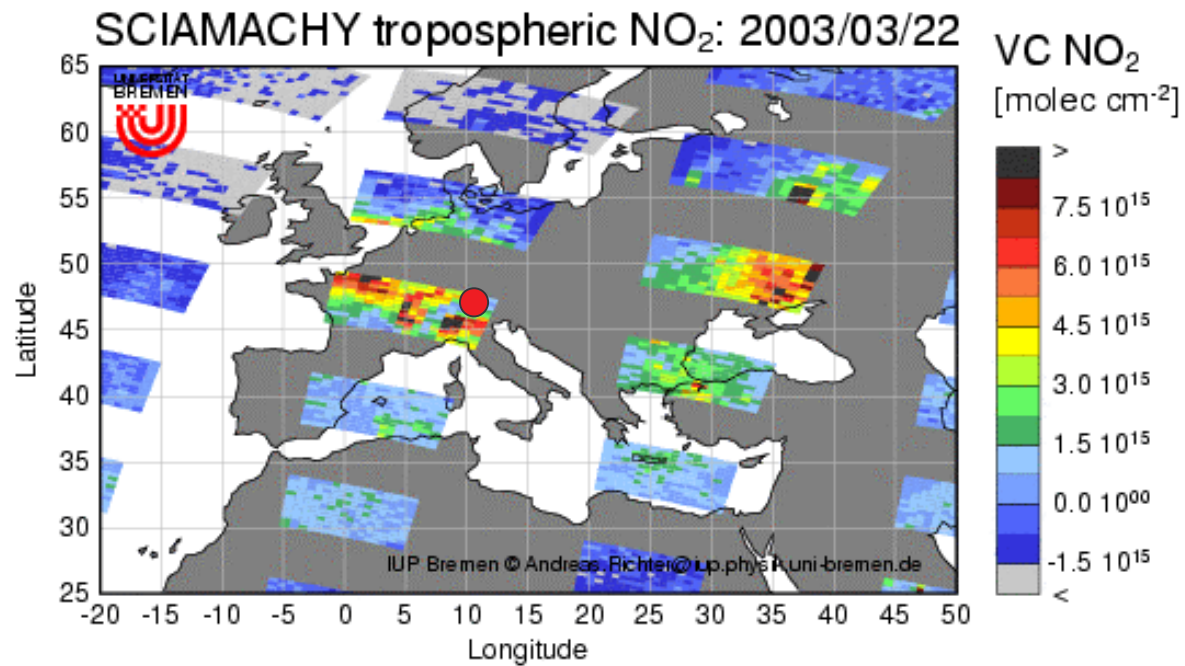
=>

- no tropospheric NO<sub>2</sub>

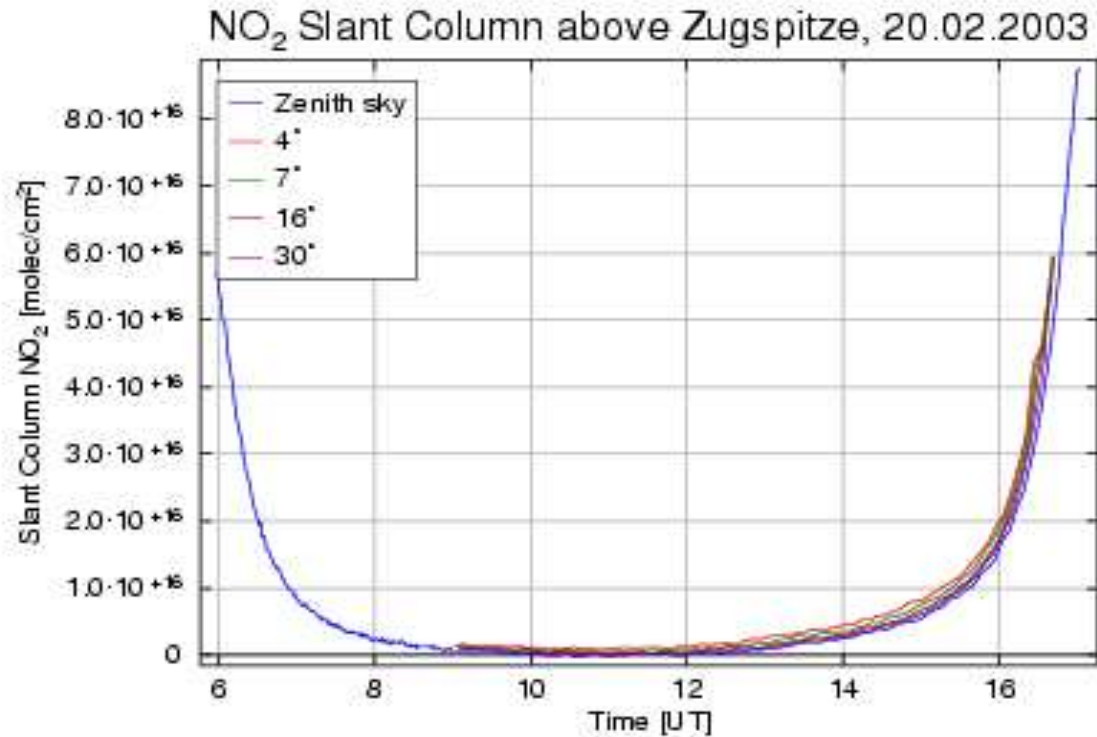




- increased SC for off-axis viewing directions
- =>
- tropospheric NO<sub>2</sub>



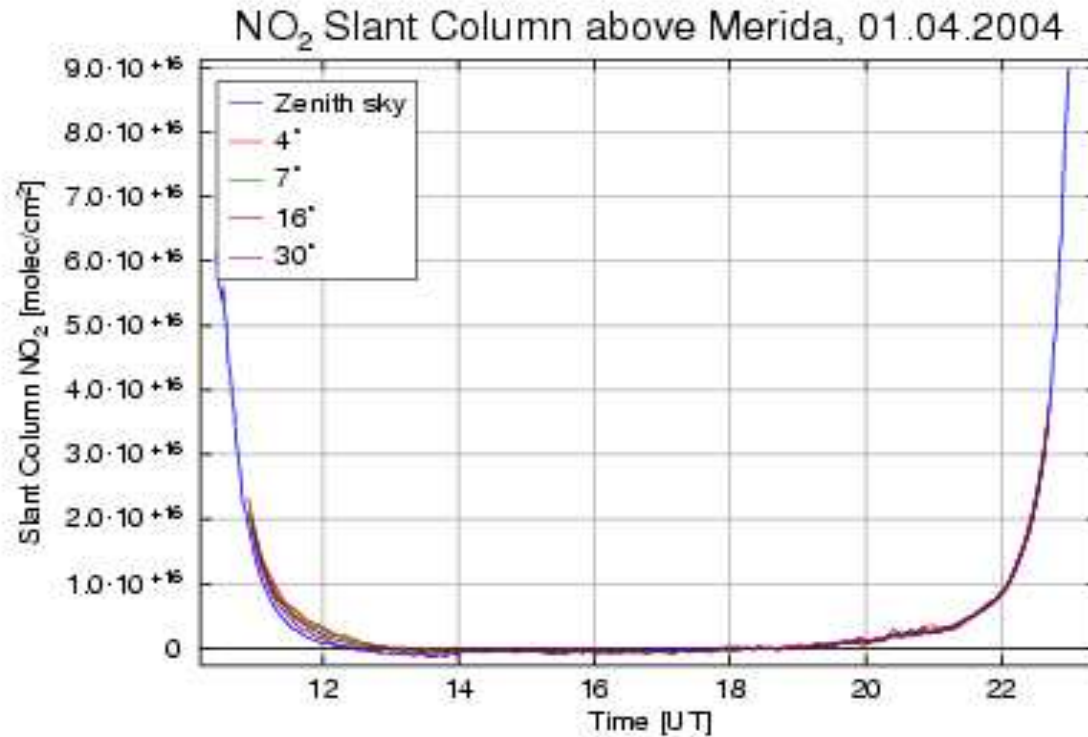
- tropospheric NO<sub>2</sub> is also seen from SCIAMACHY



- in principle similar NO<sub>2</sub> SC for all lines of sight

=>

- no tropospheric NO<sub>2</sub>

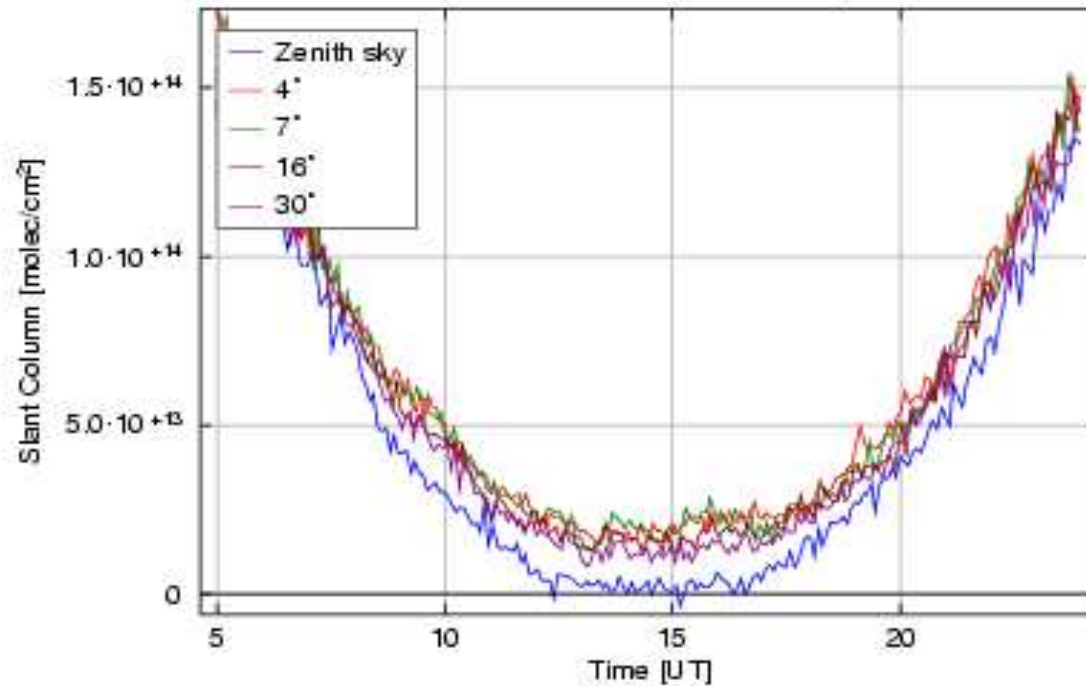


- in principle similar NO<sub>2</sub> SC for all lines of sight except in the morning

=>

- tropospheric NO<sub>2</sub> in the morning

BrO Slant Column above Summit, 10.08.2003



- increased SC for off-axis viewing directions
- =>
- tropospheric BrO

## Summary

- 1 more station has been added to the BREDOM network
- 5 Ground-based UV/visible instruments from the BREDOM network have been operated to collect data for SCIAMACHY validation
- Validation of scientific  $\text{NO}_2$  product shows excellent agreement at all stations (an offset of  $1\text{E}15$  molec/ $\text{cm}^2$  is added)
- Good agreement between  $\text{O}_3$  from GOME and TOMS with ground based measurements
- MAX DOAS can be used to provide profile information



## Outlook

- Improvement of the multi-axis method
- Focus on tropospheric columns
- Long-term validation of SCIAMACHY products



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## The End

