What can we learn from polarised MAX-DOAS measurements?

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Introduction

- Rayleigh scattering in the atmosphere polarises scattered sun light
- The degree of polarisation depends on viewing geometry, solar position, wavelength, and cloud and aerosol loading
- Polarisation affects Differential Optical Absorption Spectroscopy (DOAS) measurements in several ways:
  - Light paths through the atmosphere are different for photons having different polarisation
  - The polarisation state of the incoming light depends on aerosol loading and aerosol type
  - If no depolarising element is used in the instrument, polarisation can also affect the DOAS retrieval itself
- Thus polarised measurements have the potential to provide additional information on both aerosols and the vertical distribution of absorbers

Here a MAX-DOAS instrument was equipped with a computer controlled polariser and measurements at different polarisations were performed

Measurements

Measurement set-up:
- The MAX-DOAS instrument on the roof of the IUP building in Bremen was equipped with a computer controlled UV-Glan-Thomson polariser
- The polariser was positioned in the telescope right in front of the entrance of the quartz fibre bundle

Measurement pattern:
- Measurements were performed on several clear days in October 2017
- The measurement cycle consistet of
  - Measurements in the Almucantar
  - Measurements in the Principal Plane
  - Normal MAX-DOAS measurements
- For the Almucantar and Principal Plane measurements, 4 polariser positions were taken for each measurement (0°, 45°, 90°, 135°)
- For the MAX-DOAS measurements, only 0° and 90° observations were taken

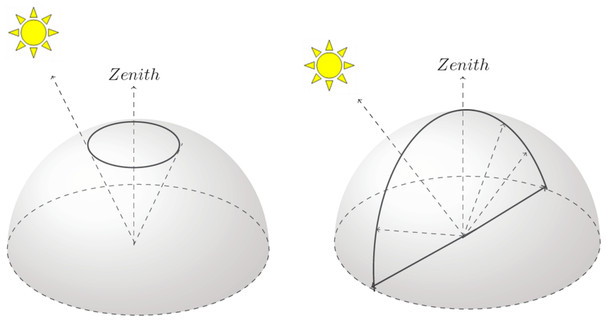

Fig. 1: Sketch of the Almucantar (left) and Principal Plane (right) observation geometries used

Simulations

Modelling set-up:
- The radiative transfer model SCIATRAN 3 was used for modelling the three Stokes components I, Q, and U
- Calculations were performed including full multiple scattering and a surface albedo of 0
- Both scenarios with and without aerosols were included

Consistency check:
- As a check, SCIATRAN calculations were compared to the results published in Emde et al., 2010 for the Monte Carlo RTM MYSTIC
- As in previous comparisons, excellent agreement was found

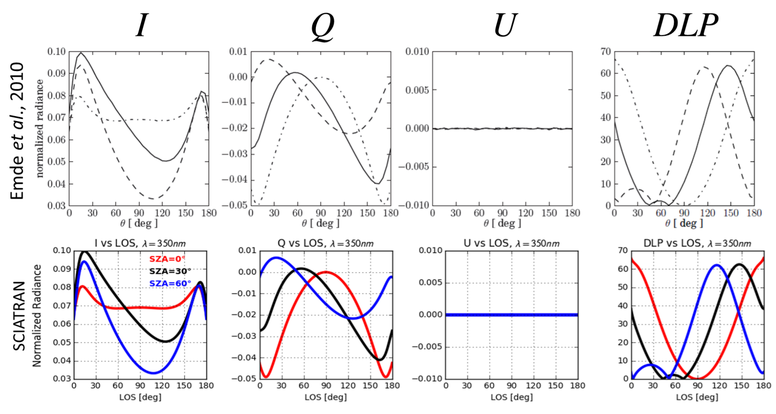

Fig. 2: Comparison of simulation results from Emde et al., 2010 (top) and SCIATRAN (bottom). Simulations are for the Principal Plane and at three solar zenith angles (0°, 30°, 60°). Shown are the first three Stokes components I, Q, and U and the degree of linear polarisation (DLP)

Comparison Measurements / Model

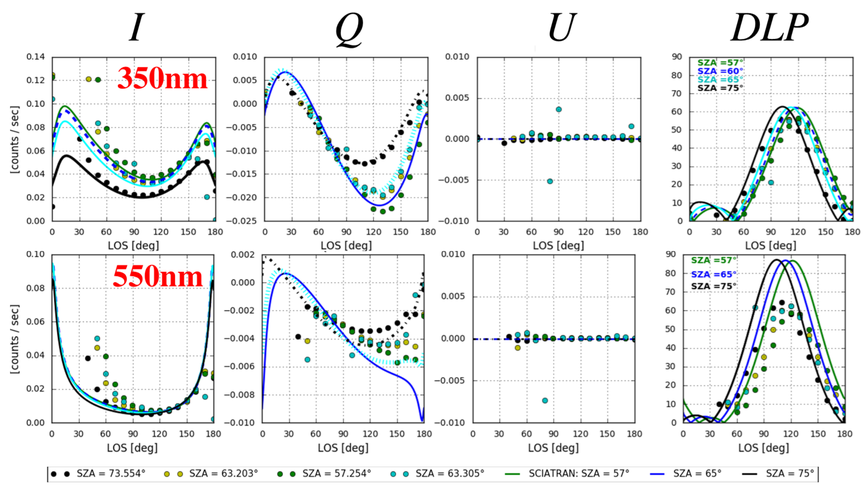

Fig. 3: Measurements and model (Rayleigh only) in the Principal Plane at four solar zenith angles and two wavelengths. The agreement at 350 nm is good, at 550 nm it is much worse, in particular towards the sun.

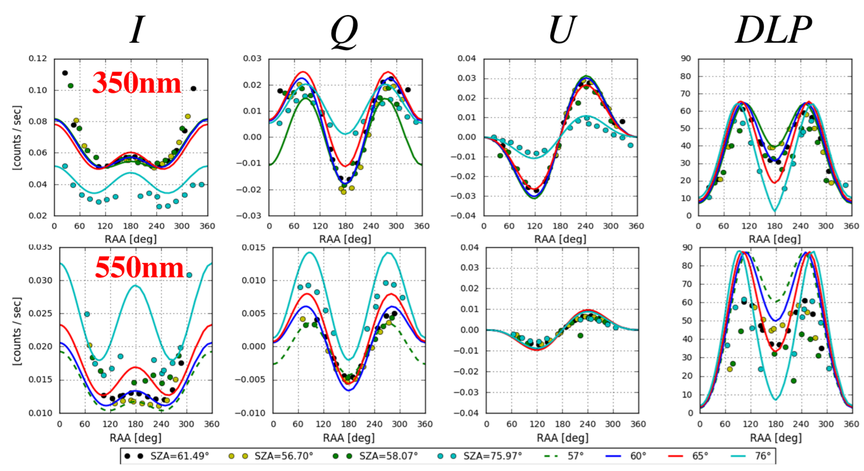

Fig. 4: Measurements and model (Rayleigh only) in the Almucantar at four solar zenith angles and two wavelengths. The agreement at 350 nm is good, at 550 nm it is much worse.

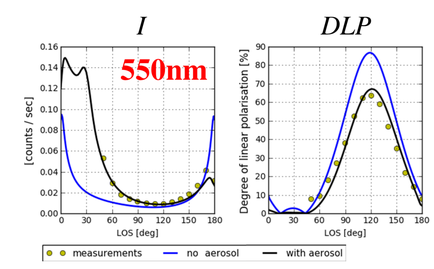

Fig. 5: Measurements and model with aerosols (AOD 0.1, urban aerosol) show much better agreement, here for one SZA in the Principal Plane. Measured intensity towards and away from the sun is better reproduced as well as the degree of polarisation.

Polarised MAX-DOAS

- Standard MAX-DOAS observations were also performed in two polarisation directions
- As expected, zenith-observations are insensitive to polariser position
- For off-axis observations, differences of a few % were found in the NO_2 columns for the two polarisations
- ratio does not depend on viewing azimuth but rather on time

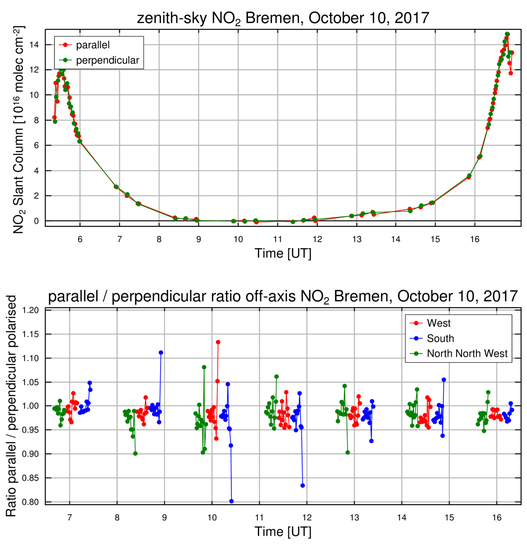

Fig. 6: Top: Zenith-sky NO_2 slant columns taken at orthogonal polariser positions. Bottom: Ratio of off-axis NO_2 slant columns taken at orthogonal polariser positions in three azimuthal directions. Each off-axis scan contains the following elevation angles: -1°, 0°, 1°, 2°, 3°, 4°, 5°, 6°, 7°, 8°, 10°, 5°, and 30°

Conclusions

- The MAX-DOAS instrument at IUP Bremen was equipped with a computer controlled polariser and polarised measurements were performed in the Principal Plane, the Almucantar and in normal MAX-DOAS mode
- Results were compared with SCIATRAN calculations and good agreement was found with Rayleigh simulations in the UV but in the visible, aerosols need to be considered
- The results of the DOAS fits show relatively small but systematic differences between the polarisation directions, but no dependency on viewing azimuth
- More measurements and more detailed simulations are needed to better assess the information content of such data

Acknowledgements

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Selected References

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see also: www.iup.uni-bremen.de/doas

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