Validation of SCIAMACHY NO₂ with Lauder ground-based observations – challenges and results

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Introduction

SCIAMACHY is a 8-channel satellite mounted spectrometer measuring in the UV/vis/NIR spectral region. Data are available since August 2002. Unfortunately, communication with its host satellite Envisat ceased in April 2012. Its three different viewing geometries (nadir, limb, and solar/kinokar occultation) made this instrument unique for atmospheric observations. Alternatives are not available. For this investigation we used NO₂ data acquired with the DOAS (Differential Optical Absorption Spectroscopy) method in the nadir observation mode, i.e., the total vertical column. The fitting window for the respective retrieval is 425 to 450 nm. The sampling of collocated SCIAMACHY pixel is very good (several hundred per day).

The ground-based spectrometer at Lauder and Arrival Heights are part of the Network for the Detection of Atmospheric Composition Change (NDACC). They make continuous measurements from sunrise to sunset. Therefor the coincidence with an satellite overpass are relatively high.

This poster deals with the validation of SCIAMACHY NO₂ vertical columns with ground-based data acquired at Lauder, New Zealand, and Arrival Heights, Antarctica. Both locations are expected to show little or no anthropogenic influence in NO₂ vertical columns. The main challenge during the validation work was the difference in satellite overpass and daytime (sunrise/sunset) of best ground-based measurement. We will present approaches to deal with these issues and show the results for the period 2003-2011.

Challenges

- Ground-based instrument designed for measurements at high SZAs (sunrise, sunset), when the absorbing air mass is the highest
- NO₂ has a pronounced diurnal variation
- SCIAMACHY overpasses are between 09:45h and 10:15h local time (given a 300 km radius around Lauder), in summer time this low SZAs
- Three approaches taken into consideration:
  a) Direct comparison of VCs using extrapolated AMFs for low SZAs
  b) Linear interpolation of diurnal variation during midday
  c) Ratio approach, using monthly averages of diurnal variation (lookup table)

Approaches

A direct comparison

SCIAMACHY and Lauder NO₂ vertical columns have been directly compared. The resolution of the computed AMFs for Lauder, New Zealand has been increased by interpolation of available AMFs (cf. Fig. 3). Each Lauder AMF was then integrated in this direct comparison had to be made with 15 min of the SCIAMACHY overpass (cf. Fig 4 "time bias"). The closer the SZA is to 90° the more precise are the measurements of the ground-based instrument. Due to the sun-synchronous orbit of Envisat coincidences at high SZA are rare for the latitude of Lauder.

linear interpolation

The diurnal variation of NO₂ shows an almost linear trend after the morning decrease (cf. Fig. 5). After sunrise, NO₂ is being photodecomposed and stored in compounds like N₂O₅. Between app. 85° SZA in the morning and in the afternoon we linearly fit the day values in order to acquire the NO₂ vertical column at the time of SCIAMACHY overpass (low SZA) from the early morning measurement (high SZA) with a higher accuracy. Daytime values have been interpolated for every single day of the observation period.

lookup table

This method uses the complete Lauder ground-based data set to build an archive on the diurnal variation of NO₂. We calculate for every month of the year a mean ratio of overpass values to the morning 90° SZA values. The resulting lookup table is used to deduce NO₂ vertical columns at the time of coincidence from morning 90° SZA NO₂ vertical columns (cf. Fig. 6).

Results

A direct comparison reveals issues with measurements at low SZAs. The bias is greater during the summer months. After the stopping belt of the grating has been replaced in April 2006 the NO₂ data look more consistent. The bias ranges between -10 to 60%.

Linear interpolation proofs to be most efficient, but early morning chemistry leads to an overestimation of NO₂ (upper two plots). 85° SZA (middle two plots) shows most promising results. Instrumental issues emerge again for 80° SZA (lower two plots).

The use of lookup tables still rely of the measurements at small SZAs (< 60°). The results are therefore showing the same issues with the less accurate measurements during summer/midday.

- Varying length of daytime (between am 90° SZA and pm 90° SZA) was addressed normalizing to the full length of one day:
  - 1. Time of sunrise set to 0°
  - 2. Time of sunset set to 24°
- NO₂ VCs normalized to sunrise values (am 90° SZA)
- Mornint NO₂ decrease till app. 80° SZA then (linear) increase till late afternoon, rapid increase at dusk
- Seasonal variation: increasing afternoon NO₂ between Jan and Oct, nadir in Nov-Dec, possible link to break-up of polar vortex or ozone hole, respectively

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