Validation of SCIAMACHY NO_2 with Lauder ground-based observations – challenges and results

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Photo courtesy of ESA

Poster XY82

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 seized in April 2012. Its three different viewing geometries (nadir, limb, and solar/lunar occultation) made this instrument unique for atmospheric observations. Alternatives are not available. For this investigation we used NO_2 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 till 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 time period 2003-2011.

Challenges

- Ground-based instrument designed for measurements at high SZAs (sunrise, sunset), when the absorbing air mass is the highest
- NO_2 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 means 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)

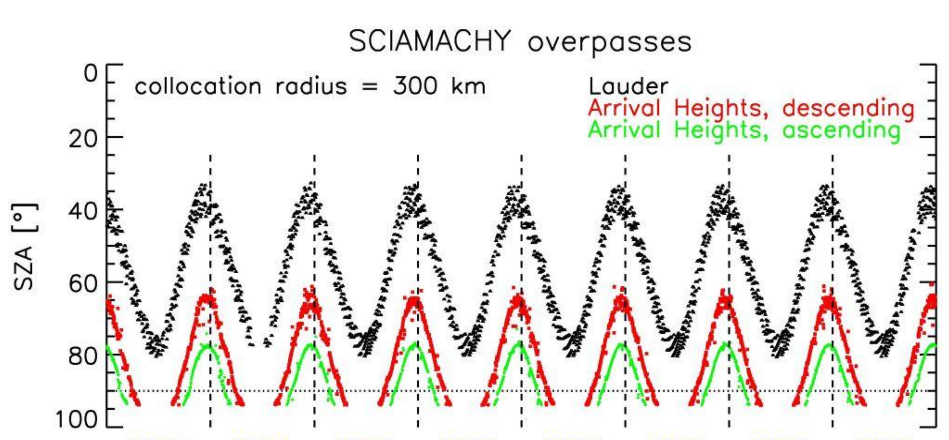


Fig. 1: Solar zenith angle of measurements at SCIAMACHY overpasses at Lauder and Arrival Heights (upper figure), collocation radius 300 km. The smaller the SZA are the more accurate the ground-based observations are.

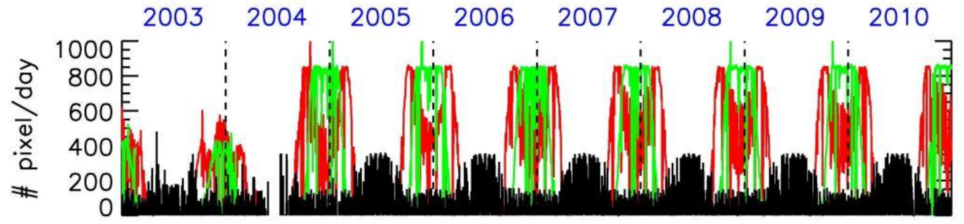
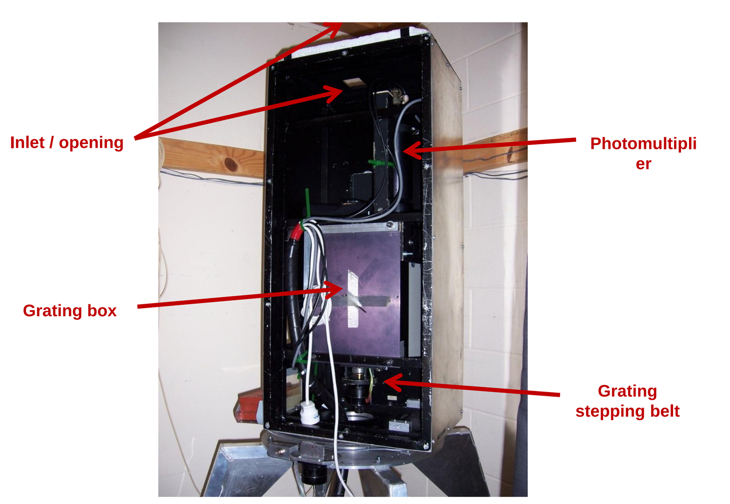


Fig. 2: Number of SCIAMACHY pixel per day with the 300 km collocation radius.

NDACC DOAS NO_2 instrument at NIWA Lauder



Photos courtesy of Allan Thomas, NIWA Lauder

Approaches

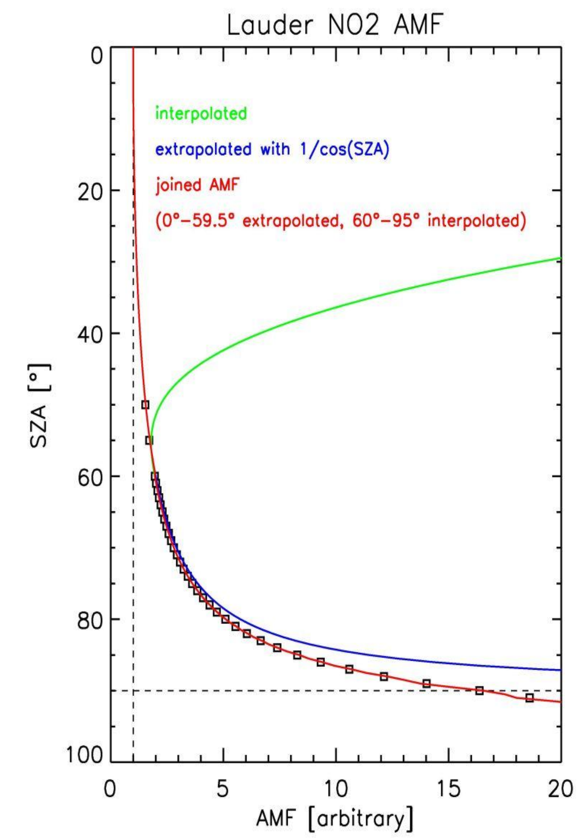
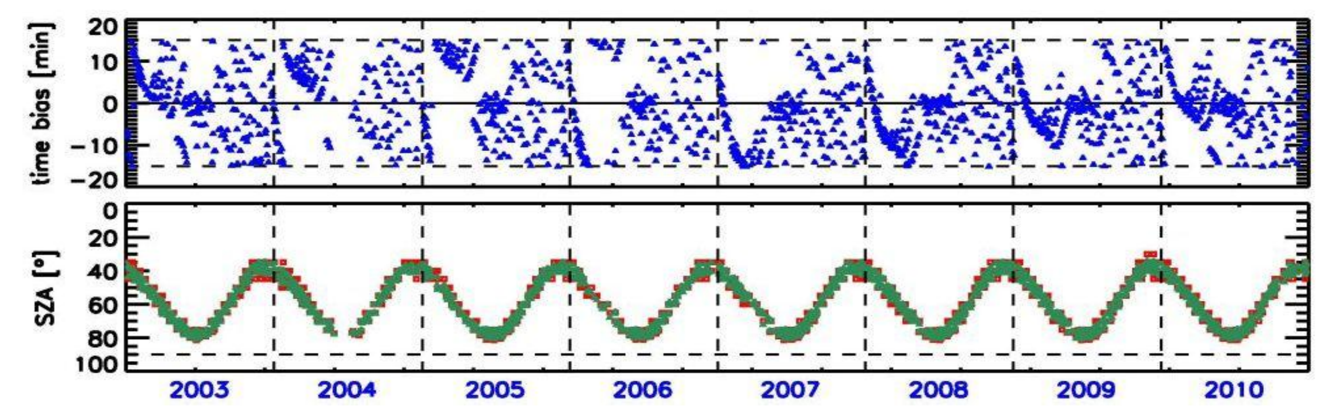


Fig. 3: Air mass factors (AMFs) for Lauder, New Zealand (solid squares). Available AMFs have been interpolated (green) and extrapolated (blue) to receive joined solar zenith angle (SZA) dependent (0.5° step) AMFs.

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 inter- and extrapolation of available AMFs (cf. Fig. 3). Each Lauder measurement included in this direct comparison had to be made with 15 min of the SCIAMACHY overpass (cf. Fig 4 "time bias"). The SZA varies during the year (cf. Fig. 4 "SZA"). 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.

Fig. 4 (below): Difference in observation time (SCIAMACHY ←→ Lauder) and SZA at coincidence



B linear interpolation

The diurnal variation of NO_2 shows an almost linear trend after the morning decrease (cf. Fig. 5). After sunrise, NO_2 is being photochemically destructed and stored in compounds like N_2O_5. Between app. 85° SZA in the morning and in the afternoon we linearly fit the daytime 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.

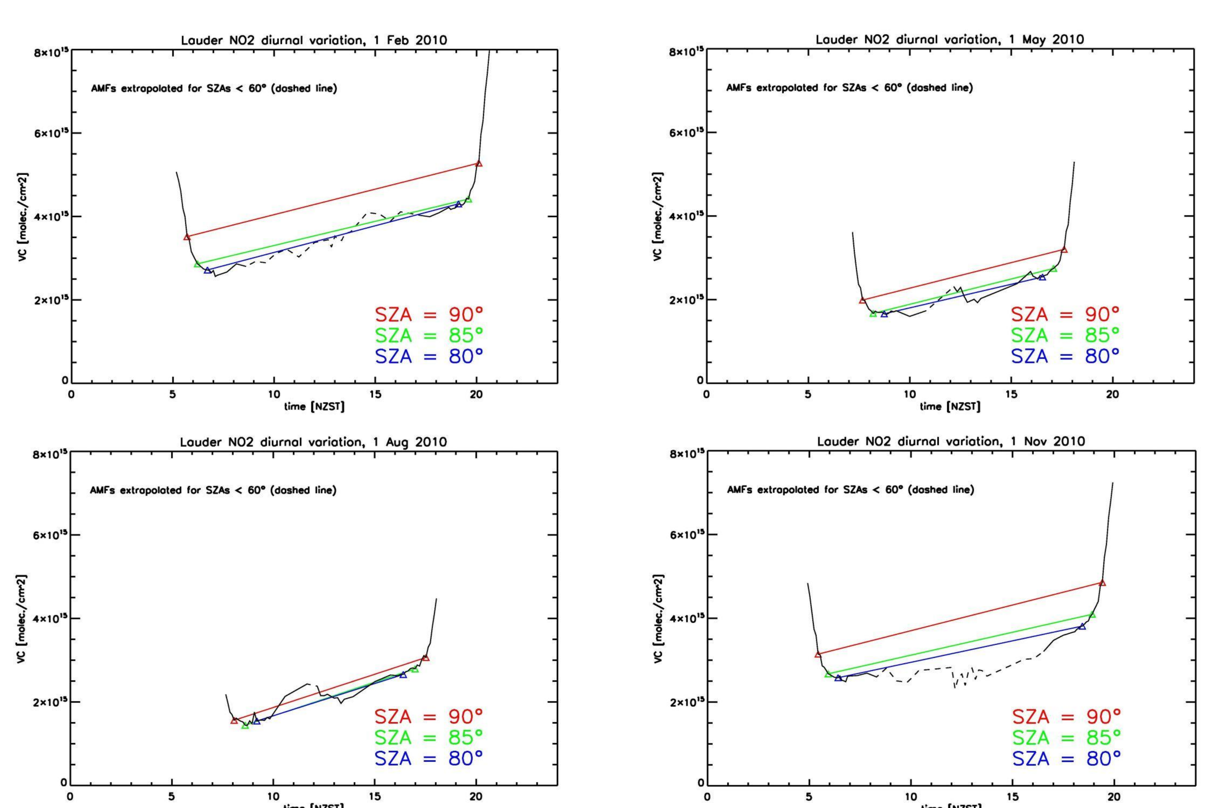


Fig. 5: Diurnal variation of Lauder NO_2 on February 1 (upper left), May 1 (upper right), August 1 (lower left), and November 1 (lower right) 2010. Dashed lines denote measurements at SZA < 60°. Linear interpolation has been used to estimate to course of NO_2 during the day.

C lookup table

This method uses the complete Lauder ground-based data set to build an archive on the diurnal variation of NO_2. 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 NO_2 vertical columns at the time of coincidence from morning 90° SZA NO_2 vertical columns (cf. Fig. 6).

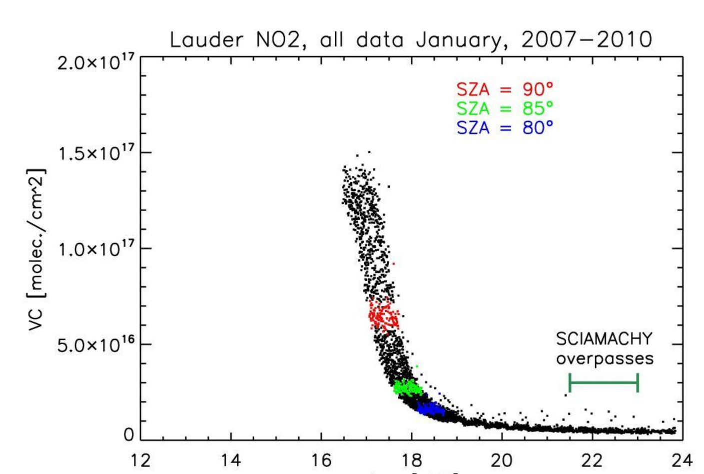
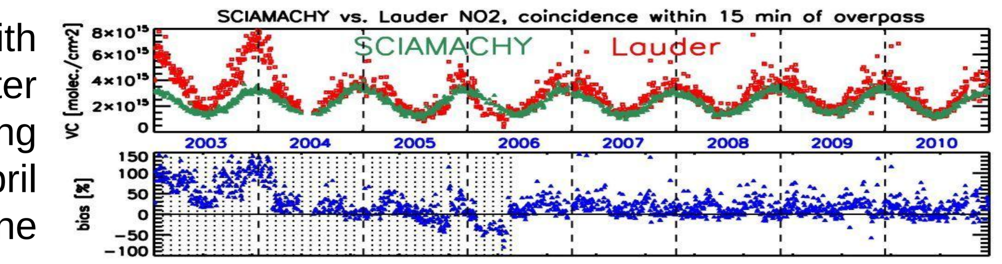


Fig. 6: Lauder NO_2, a summary of all January vertical columns. Colored marks indicate data measured at 90° SZA (red), 85° SZA (green), and 80° SZA (blue), respectively. The morning overpass "window" of SCIAMACHY is also marked in the above plot.

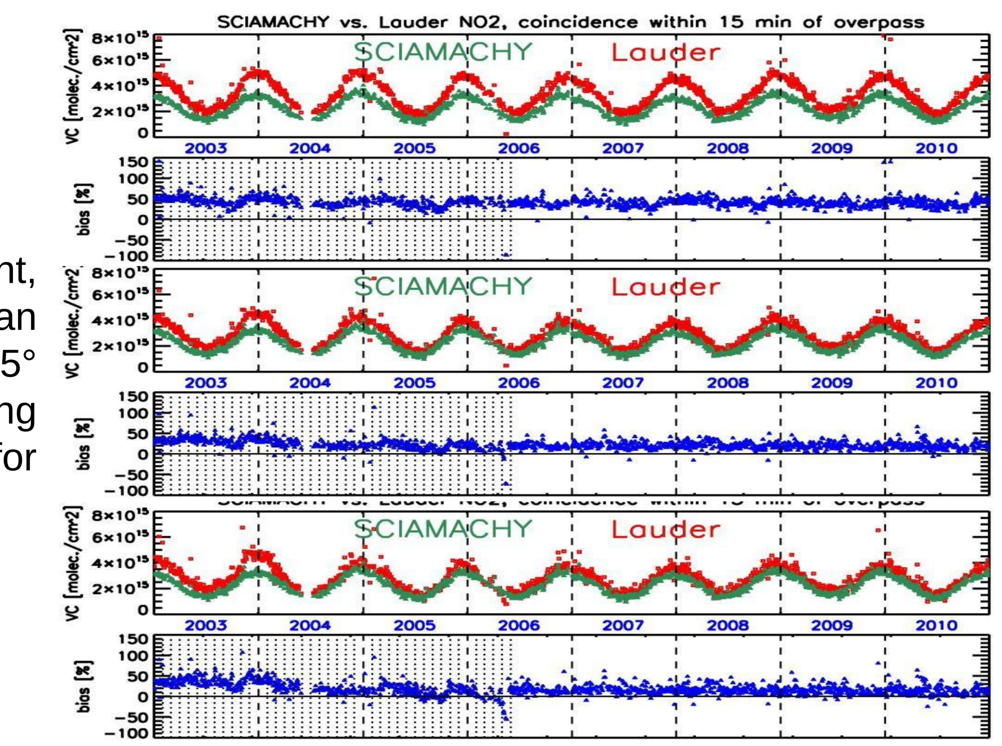
Results

- A direct comparison reveals issues with measurements at low SZAs. The bias is greater during the summer months. After the stepping belt of the grating has been replaced in April 2006 the NO_2 data look more consistent. The bias ranges between -10 and 60 %.



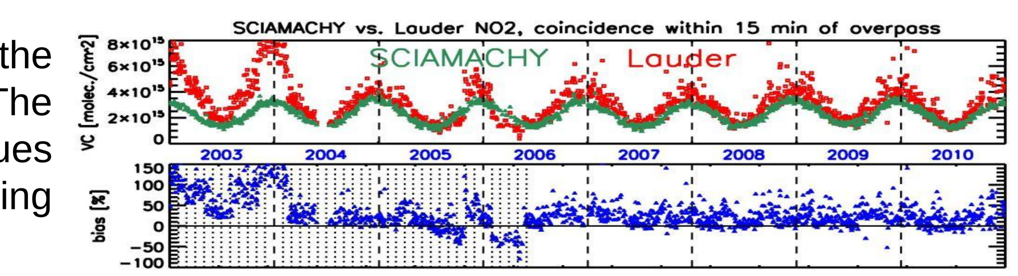
A

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



B

- 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.



C

NO_2 diurnal variations

- Varying length of daytime (between am 90° SZA and pm 90° SZA) was addressed normalizing to the full length of one day
  i. Time of sunrise set to „0"
  ii. Time of sunset set to „1"
- NO_2 VCs normalized to sunrise values (am 90° SZA)
- Morning NO_2 decrease till app. 80° SZA, then (linear) increase till late afternoon, rapid increase at dusk
- Seasonal variation: increasing afternoon NO_2 between Jan and Oct, reset in Nov/Dec, possible link to break-up of polar vortex or ozone hole, respectively?

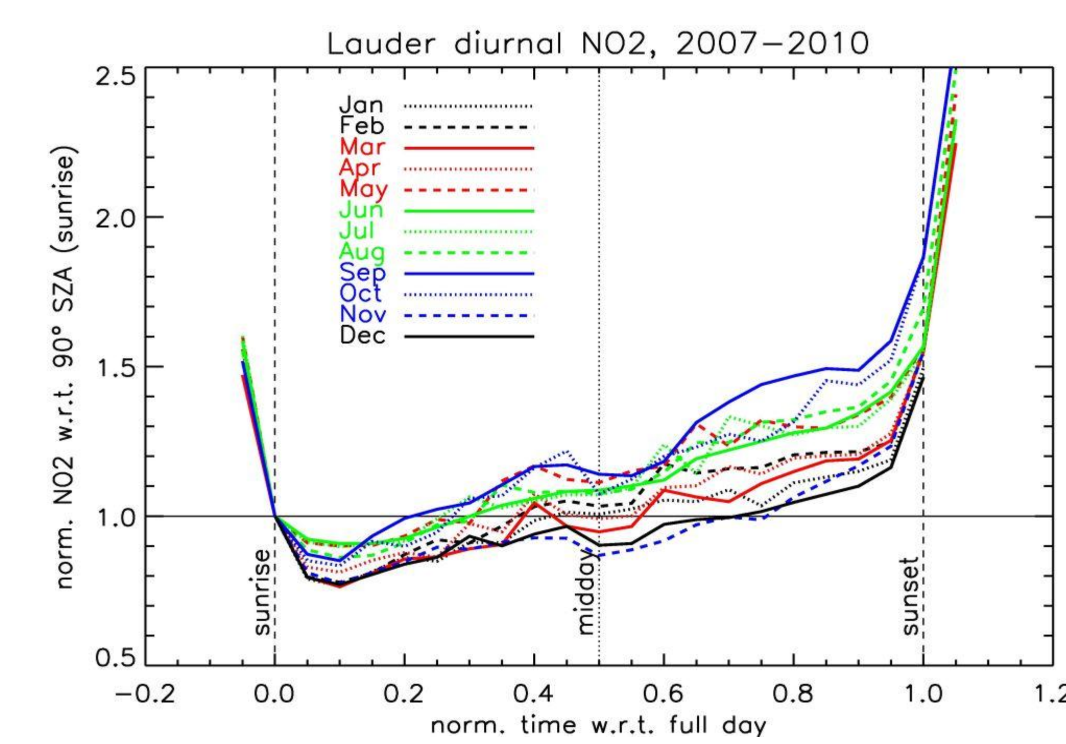


Fig. 8: Double normalized diurnal NO_2 variations of vertical columns at Lauder, New Zealand, separated by month of year.

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