Validation of SCIAMACHY limb NO_2 profiles using solar occultation and limb measurements

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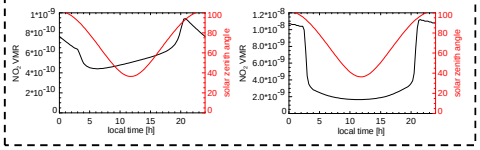
Introduction

What are the key points?

- The goal is the validation of the SCIAMACHY NO_2 IUP V3.1 limb dataset
- Comparison with several years of data sets from different solar occultation and limb instruments
- Strong diurnal variation of NO_2 necessitates photochemical correction to allow comparison of NO_2 profiles at different local times
- An estimate of the diurnal effect error on the mean relative errors is also given.
- Validation of SCIAMACHY limb NO_2 IUP V3.1 with solar occultation instruments published in [Bauer et al, 2012]
- NEW: Comparison with NO_2 limb data products from OSIRIS and MIPAS, which were active for the lifetime of SCIAMACHY
- MIPAS: Comparison before/ after resolution change performed seperately.

The figures below highlight the main challenge in the validation of NO_2 profiles - the strong diurnal variation of NO_2. Example on the lefthand side: 16 km altitude, righthand side 30 km. Both figures show model results at May, 66° N.



SCIAMACHY limb NO_2 IUP V3.1: Retrieval method

Algorithm

- Forward modeling (SCIATRAN)
  - Fully spherical for SS
  - Approximation for MS
  - ⇐ Viewing geometry and geolocation from the measurements
  - ⇒ Simulated limb spectra, Weighting functions
- Pre-processing (DOAS-like fit) at each tangent height
  - Shift and squeeze correction
  - Spectral corrections
  - ⇐ Limb spectra: measured & simulated, Vertically integrated WFs
  - ⇒ Correction parameters
- Main inversion procedure
  - Solution: *Optimal Estimation*
  - Measurement vector: differential spectral signal at all selected tangent heights
  - State vector: trace gas number densities at altitude levels
  - ⇐ Limb spectra: measured & simulated (all corrections from the pre-processing step applied), Weighting functions, A priori constraints
  - ⇒ Vertical distributions of trace gas number densities

Next iteration

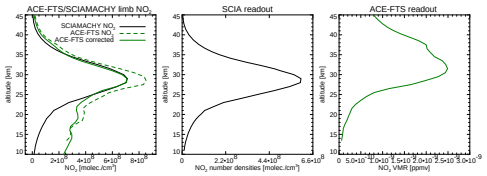
Retrieval parameters

Spectral range: 420 – 470 nm

Tangent height range: 9 – 39 km Reference: limb measurement at 42 km tangent height

Photochemical correction

Comparison of a single SCIAMACHY NO_2 limb V3.1 measurement with ACE-FTS:



Note: If an instrument provides data only in VMR, it is converted to number densities using the temperature and pressure profiles provided with these data.

The **photochemical correction** is performed using look up tables with diurnal cycles of NO_2, i.e. the NO_2 profile of the respective other measurement is rescaled to the solar zenith angle (SZA) of the SCIAMACHY measurement.

Look up table with precalculated diurnal cycles:
- 2 km vertical resolution
- 2.5° latitude grid size
- 3 cycles per month

Diurnal cycles provided by Chris McLinden, model used from the University of California [McLinden et al, 2000, Prather 1992]

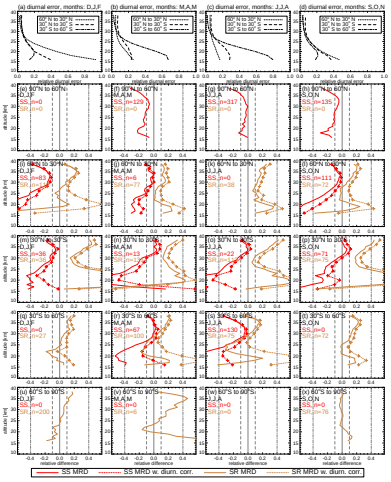
Diurnal effect error: Retrieval error caused by the change of NO_2 along the line of sight of the instrument, due to change in SZA. For SAGE II and ACE-FTS, estimates are given, see plots on the righthand side.

Collocation criteria

For solar occultation instruments: (SAGE II, HALOE, ACE-FTS)
- maximum spatial difference: 500 km
- maximum time difference: 8 hours
- tropopause height criterium: only accept collocations if the difference in the tropopause height of the four SCIAMACHY ground pixel coordinates and the respective other measurement at tangent point is less than or equal to 2 km. This criterium is not applied if all tropopause heights are below 10 km.
- potential vorticity (PV) criterium (needed to avoid polar vortex): Collocation accepted if PVU > 40, between 30 and -30, or PVU < -40 (for all four SCIAMACHY ground pixel coordinates and the respective other measurement at tangent point)

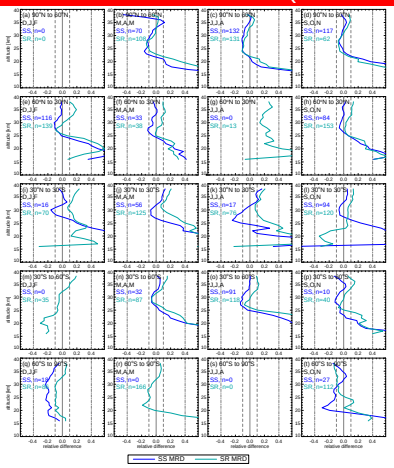
For limb geometry: (MIPAS, OSIRIS)
- maximum spatial difference: 200 km
- maximum time difference: 2 hours (MIPAS) or 8 hours (OSIRIS)
- tropopause height criterium: as above
- potential vorticity criterium: as above
- Collocations are not accepted, if clouds are detected in SCIAMACHY field of view.

SCIAMACHY IUP vs. SAGE II (2003/2004)



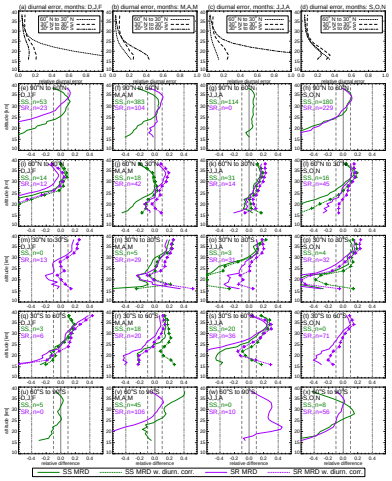
SAGE II: aboard the United States Earth Radiation Budget Satellite (ERBS), 1984 to August 2005. SAGE II data version: 6.2 (SS: SAGE II sunset measurement, SR: sunrise) The diurnal effect error correction estimate is only feasible, if the SCIAMACHY SZA is small -> This is not performed for high latitudes due to high SCIAMACHY SZA.

SCIAMACHY IUP vs. HALOE (2003/2004)



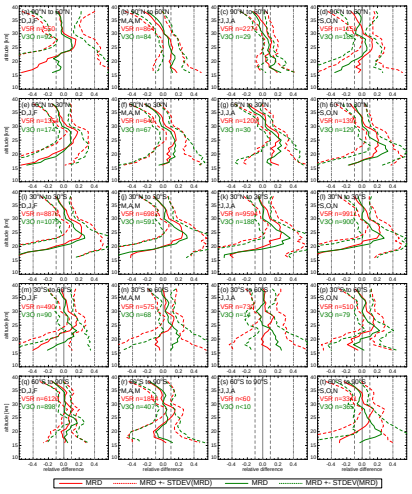
HALOE: aboard the UARS satellite (Upper Atmosphere Research Satellite) ,1991 to 2005, data version: 19
No diurnal effect error correction necessary, as the HALOE product already accounts for this error.

SCIAMACHY IUP vs. ACE-FTS (2004/2005)



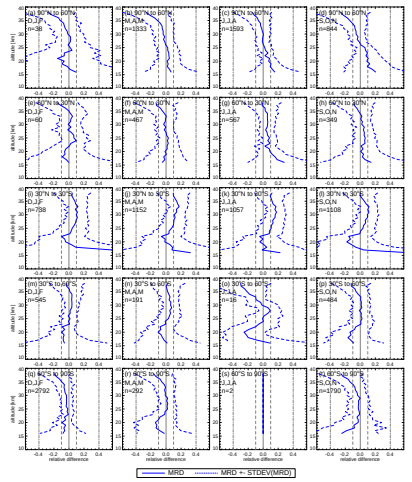
ACE-FTS: aboard the Canadian satellite SCISAT-1, launched in August 2003, data version 2.2

SCIAMACHY IUP vs. MIPAS (2003 – 2011)



MIPAS: stationed aboard ENVISAT (March 2002 to April 2012)
V3O: MIPAS from 2003 – before resolution change (retrieval version 15)
V5R: MIPAS from 2006 – 2011 – after resolution change (retrieval version 220)

SCIAMACHY IUP vs. OSIRIS (2003 – 2011)



OSIRIS: aboard the Canadian satellite Odin, launched in February 2001, data version 3

Conclusions

In the 20 to 40 km altitude range, mean relative differences between limb geometry SCIAMACHY NO_2 profiles and the solar occultation instruments are found to be typically within 20 to 30%, as published in [Bauer et al, 2012]. The mean partial NO_2 columns in this altitude range agree typically within 15% (both global monthly and zonal annual means). Larger differences are seen for SAGE II comparisons, which is consistent with the results presented by other authors. For SAGE II and ACE-FTS, the observed differences can be partially attributed to the diurnal effect error.

For the comparison with the limb geometry instruments MIPAS and OSIRIS, the mean relative differences are typically smaller relative to the results from the SCIAMACHY limb NO_2 validation with solar occultation instruments, especially for the SCIAMACHY/OSIRIS comparison. This can be attributed to instrument similarities (SCIAMACHY/OSIRIS) and a less difficult photochemical correction, as the changes in NO_2 levels between two limb measurements are usually small, as long as the SZAs of the two measurements are similar (OSIRIS at high latitudes/MIPAS).

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