SCIAMACHY Lunar Occultation
Water Vapor measurements: Retrieval and Validations

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Introduction

The Satellite:

Envisat:-

Orbit :- Sun-Synchronous
Altitude:- ~800 km, **Inclination:-** 98.55°
Descending mode:- 10 a.m. local solar time
*Orbit Period:-* 100.6 min. 14 orbits per day

The Instrument:
SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY, SCIAMACHY on board Envisat (ESA).

Instrument type: 8-channel grating Spectrometer
Measurement Type and Geometries: The solar irradiances and earthshine radiances from the UV to the NIR (240 nm-2380 nm) spectral region in nadir, limb and solar/lunar occultation.
Spectral Resolution: 0.2-1.56 nm

Scope of SCIAMACHY's Measurements:
The instrument provides total columns as well as vertical profiles of the atmospheric trace gases relevant to ozone chemistry, air pollution and global climate change issues, covering troposphere upto the mesosphere. The SCIAMACHY lunar occultaion measurements have been used for the first time to derive the vertical profiles of the southern hemispheric stratospheric water vapor. The retrieval and the comparisons/validations of SCIAMACHY lunar occultaion stratospheric H_2O measurements are presented here.

SCIAMACHY Lunar Occultation Measurements
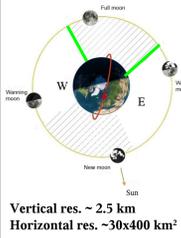
Lunar occultation latitudinal range:
SCIAMACHY lunar occultation measurements are carried out in the southern hemisphere between 40 °S and 90 °S (on the night side).
Monthly lunar visibility:
Moon phase > 0.5 till shortly after the full moon (region within green lines in the figure).
Scanning:
With the Moon follower device's adjustment at the brightest point, the moon is observed for the tangent height range from 17 till 350 km).
*Yearly coverage:*
SCIAMACHY lunar occultation average yearly coverage is from January - June and then the last two months i.e. November and December. This makes the lunar occultation water vapor measurements important for the study of dynamics related to the southern hemispheric polar vortex.

Vertical res. ~ 2.5 km
Horizontal res. ~30x400 km²

H₂O Retrieval and Optimization

- *Data Used:* SCIAMACY lunar occultation L1B data, version 6.03 to derive the vertical profiles of the stratospheric water vapor from around 17-50 km in the NIR spectral range.

- *Wavelength Window:* 1350 – 1420 nm, SCIAMACHY channel 6, avoiding CO_2 absorption ~ 1430 nm (Fig.1)

- Extraction of the lunar spectrum for 11 tangent heights between 17 to 50 km selecting 120 km as the reference spectrum, and detection and removal of the bad pixels.

Fig.1)
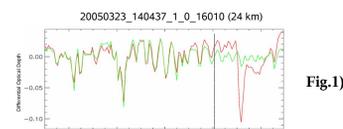
SCIATRAN 3.0 application as a Radiative Transfer Code & the Retrieval Code (Fig.2):
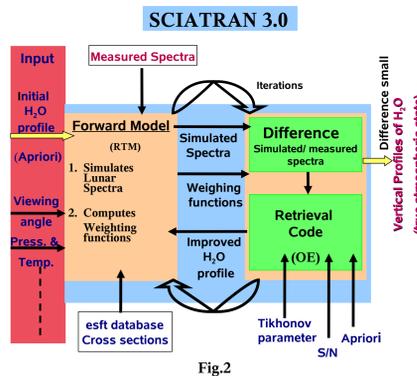*The SCIATRAN 3.0 Adaptations:*

- Implementation of the line absorber treatment by the 'esft' (exponential sum fitting of transmissions) approximation (esft parameters calculation using HITRAN 2008).

- Applied Convolution for the intensity and radiance slit function where the internal wavelength grid is read from esft database for RTM calculations.
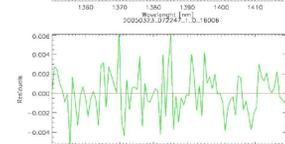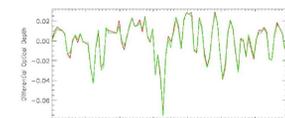
- Constraining the retrieved profiles' smoothness by the "*Tikhonov regularization*" which applies smoothing during optimal estimation. Selected an appropriate Tikhonov parameter value (3.5) preventing loss in the measurement information.

- Signal to noise ratio, (S/N) estimated from the fit residuals of the retrieval.

- Shift & squeeze applied on the reference spectrum w.r.t. the measured spectrum & on the modelled spectrum w.r.t. the measured spectrum, (improves the residuals).
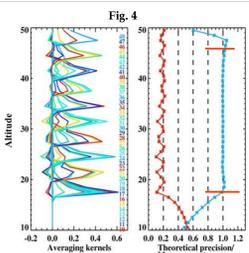

Fig.2

23ʳᵈ March, 2005, orbit =16006, sza =109.137°, moon phase =0.931, Tangent Height =24 km

Fig.3.a)

Fig.3.b)

Spectral Fit Plot (Fig.3.a)
Green line = The modelled differential optical depth,
Red line = The measured differential absorption spectrum of H_2O.

Good Fit

Residual Plot (Fig. 3.b)
The difference between the measured and the simulated differential transmitted spectra.

Residuals within 0.005

The Averaging Kernels

Fig. 4

Fig. 4. The averaging kernels for the measurement on 23ʳᵈ Mar., 2005 (sza = 109.13° and moon phase = 0.931) for the retrieval altitude from 17 to 50 km.

- The H_2O averaging kernels (fig. 4) are based on the 1 km grid Sciatran uses for the radiative transfer calculations.
- The averaging kernels below 47 km have sharp peaks indicating higher sensitivity of the retrieval. The averaging kernels of several altitudes have peaks at the same altitude due to the difference between SCIAMACHY's vertical sampling (3.3km) and the retrieval resolution (1 km).
- The response function plotted at the right side of fig. 4 shows that between 17 to 47 km, the retrieval profile is determined by the measurement only without contribution from the apriori(value ~ 1). Above 47 km the apriori has a little influence (value < 1).

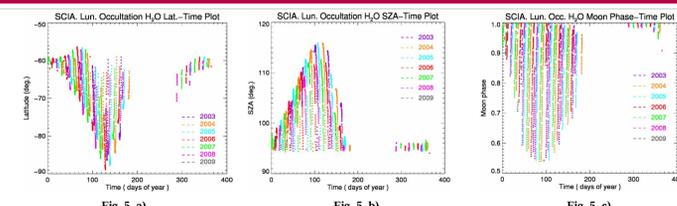## Latitude, SZA & Moon Phase distribution for Lun. Occ. Measurements

Fig. 5 , a, b & c, latitude, sza and moon phase distribution respectively for the years 2003 - 2009.

Fig. 5. a)   Fig. 5. b)   Fig. 5. c)

The moon phase and solar zenith angle values determine the quality and the strength of the spectral signal.

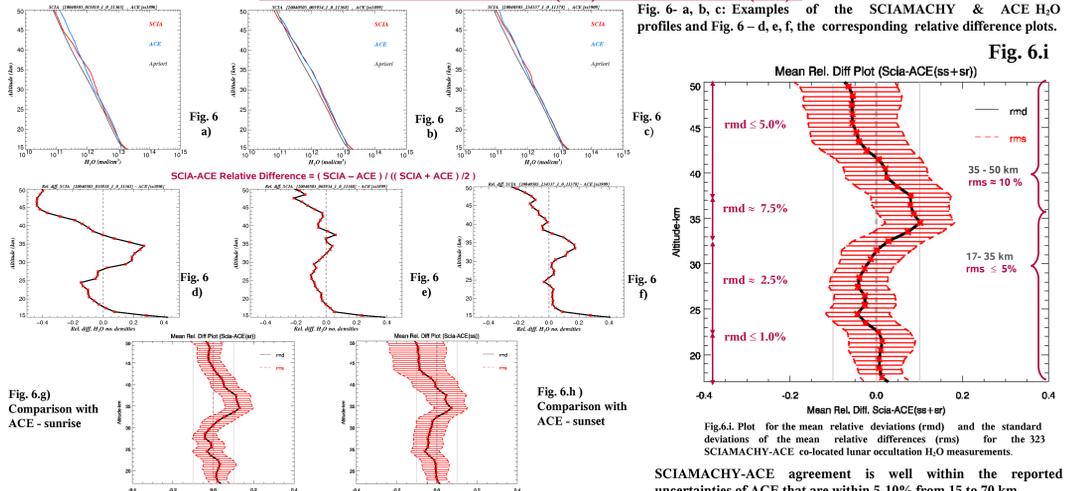Criteria for the measurements: Moon phase > 0.75 and sza > 96 °   **1786 Profiles**

Results and Comparison/Validation

1- Comparison/validation with the ACE-FTS solar occultation H_2O measurements (*Atmospheric Chemistry Experiment Fourier Transform Spectrometer onboard Canadian Satellite SCISAT-1***)**
SCIAMACHY: vertical resolution=2.5km, **ACE-FTS:** vertical resolution=3 - 4km
Collocation period: 2004-2009, **Collocation Criteria:** Distance < 1000 km & Time < 12 hrs
"323 Collocations:- ACE - sunrise(166) & ACE - sunset (157)"

Fig. 6- a, b, c: Examples of the SCIAMACHY & ACE H_2O profiles and Fig. 6 – d, e, f, the corresponding relative difference plots.

Fig. 6 a)   Fig. 6 b)   Fig. 6 c)

SCIA-ACE Relative Difference = (SCIA − ACE) / ((SCIA + ACE) / 2)

Fig. 6 d)   Fig. 6 e)   Fig. 6 f)

Fig. 6.g) Comparison with ACE - sunrise

Fig. 6.h) Comparison with ACE - sunset

Fig.6.i Plot for the mean relative deviations (rmd) and the standard deviations of the mean relative differences (rms) for the 323 SCIAMACHY-ACE co-located lunar occultation H_2O measurements.

SCIAMACHY-ACE agreement is well within the reported uncertainties of ACE that are within 5-10% from 15 to 70 km.
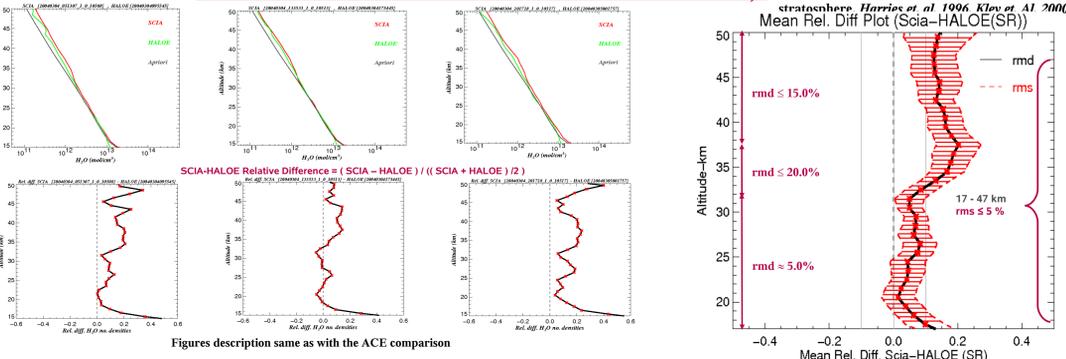
SCIAMACHY – ACE comparison (fig.6.i): **rmd:-** Within 2.5% between 17-32km, 7.5% around 35km and within 5% for 37-50km. **rms:-** Within 5% between 17-35km.

2- Comparison/validation with the HALOE solar occultation H_2O measurements (*HALogen Occultation Experiment***)**
SCIAMACHY: vertical resolution=2.5km, **HALOE:** vertical resolution=2.0km
Collocation period: 2003-2005, **Collocation Criteria:** Distance < 1000 km & Time < 12 hrs
"52 Collocations:- HALOE sunrise events & none with sunset"

NOTE: HALOE H_2O is biased low by 5% in the stratosphere. Harries et al. 1996, Kley et Al. 2000).

SCIA-HALOE Relative Difference = (SCIA − HALOE) / ((SCIA + HALOE) / 2)

Figures description same as with the ACE comparison

SCIAMACHY – HALOE comparison: **rmd:-** Within 5% between 17-32km, reaching 20% around 37km and within 15% for 37-50km. **rms:-** Well within 5% from 17 till 47km.

3- Comparison/validation with the MLS H_2O measurements (*Earth Observing System (EOS) Microwave Limb Sounder onboard NASA's Ssatellite EOS-Aura***)**
SCIAMACHY: vertical resolution=2.5km, **MLS:** vertical resolution=1.5km ~15km, 3.5-4.6km at 20-50km, >5.5km at >50km
Collocation period: 2003-2010, **Collocation Criteria:** Distance < 1000 km & Time < 12 hrs
"Total 1334 Collocations"

**SCIA- MLS Relative Difference = (SCIA − MLS) / ((SCIA + MLS) / 2)**
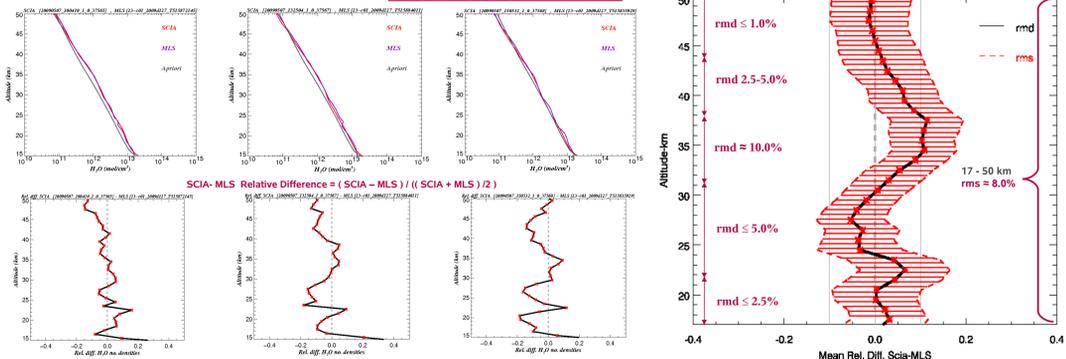
SCIAMACHY – MLS comparison: **rmd:-** Within 2.5-5.0% for17 till 32km, reaching 10% around 35km, within 2.5-5.0% for 39-44km and around 1.0% from 45 to 50km. **rms:-** Within 8% on the average for 17 till 50km.

4- Comparison/validation with the MIPAS H_2O measurements (*Michelson Interferometer for Passive Atmospheric Sounding onboard ESA's ENVISAT satellite***)**
SCIAMACHY: vertical resolution=2.5km, **MIPAS:** vertical resolution=3km, MIPAS H_2O data version used=Version 4.0
Collocation period: 2005-present, **Collocation Criteria:** Distance < 1000 km & Time < 12 hrs
"Total 571 Collocations"

SCIA- MIPAS Relative Difference = (SCIA − MIPAS) / ((SCIA + MIPAS) /2)
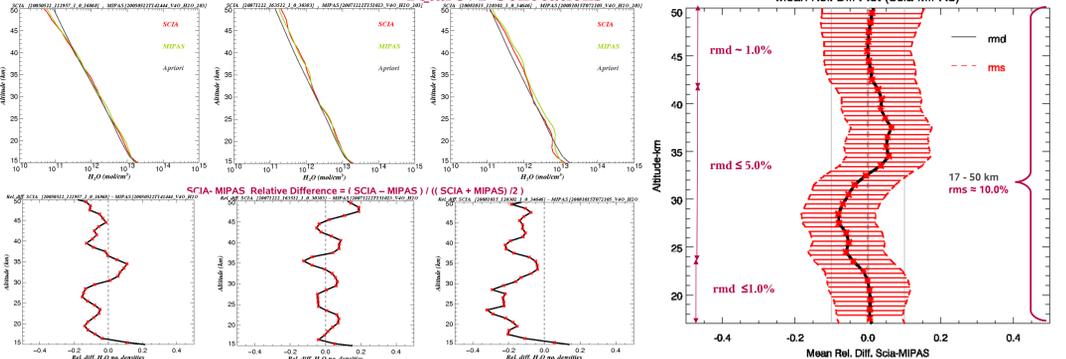
SCIAMACHY – MIPAS comparison: **rmd:-** Within 1.0% for 17 till 22km, less than 5.0% from 23 to 41km, within 1.0% for 43-50km. **rms:-** Within 10% between 17 till 50km.

Conclusions and Outlook

- The SCIAMACHY lunar occultation measurements have been used for the first time to derive the water vapor profiles for the southern hemisphere high latitudes and are presented here (the retrieval optimizations, the retrieval & the validations).
- The SCIAMACHY lunar occultation H_2O measurements comparisons with the ACE-FTS instrument have shown a very good agreement (well within the reported uncertainties of ACE that are within 5-10% from 15-70 km). The comparisons with HALOE and MLS and MIPAS also showed good results.
- Interpretation and analysis of the retrieved dataset with respect to the physical & chemical processes determining distribution of H_2O in the southern hemisphere will be performed.
- From SCIAMACHY lunar occultation, CH_4 retrieval will be tried (longer lifetime of CH_4 terminates ClOx cycle in a denitrified polar vortex).

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