Water Vapor Profiles from SCIAMACHY lunar occultation measurements

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Introduction

The SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY, SCIAMACHY on board Envisat satellite measures 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 geometry yielding total columns as well as vertical profiles of the atmospheric trace gases from troposphere upto the mesosphere. In our study, the SCIAMACHY Lunar occultaion measurements (over the southern hemispheric region) have been used for the first time to derive the vertical profiles of the stratospheric water vapor. The SCIAMACHY Lunar occultaion stratospheric H_2O preliminary sensitivity studies and the initial comparison/validation of SCIAMACHY Lunar occultaion stratospheric H_2O measurements are presented here.

The Southern Hemisphere Polar Stratosphere

ANTARCTIC POLAR STRATOSPHERE

Month	Time	Season	Temp. H. Alt.	Temp. L. Alt.	Polar Vortex H. Alt.	Polar Vortex L. Alt	Ozone Hole	O_3	Scia.Lun. Occ Meas.
Jan		Early Summer							
Feb									
Mar		Early Fall			Begins			Steady Increase	
Apr		Early Fall			Begins			Steady Increase	
May					Max.			Steady Increase	
Jun		Early Winter	Coldest Temp.			Max.		Max.	
Jul		Mid Winter	Coldest Temp.			Max.		Decrease slowly	
Aug		Mid Winter			Break up begins		Begins	Rapid drop	
Sep		Late Winter		Coldest Temp.			Max.	Rapid drop	
Oct		Spring arrives					Begins to contract		
Nov		Mid Spring			Ends			Steady recovery	
Dec		Late Spring					Ends	Steady recovery	

- Time: *White=Day, Black =Night;* H. Alt. =Higher Altitude, L. Alt. =Lower Altitude. Blue cells indicates the SCIAMACHY lunar occultation coverage.

Table1: The Southern Hemisphere Yearly Events Table with the SCIAMACHY Lunar occultation measurements coverage.

SCIAMACHY Lunar Occultation measurements

SCIAMACHY carries out the lunar occultation measurements in the southern hemisphere between the latitudes 40 °S and 90 °S owing to the sun-synchronous orbit of Envisat and the position of the instrument on the satellite. SCIAMACHY executes lunar occultation when the lunar visibility occurs on the night side in the moon pointing mode. The viewing direction is adjusted by the moon follower (MF) towards the brightest point on the moon. The events start when the phase of the moon is around 0.6 or greater and ending shortly after the full moon. The tangent height range for which the moon is followed is around 17 km upto more than 350 km. Table 1 shows the yearly Southern Hemisphere events pattern. For the years 2003-2009, the average SCIAMACHY measurements coverage (the last column in table 1) spans each year from January to June and then the last two months.

H_2O Retrieval and Optimization

- Using the SCIAMACY lunar occultation measurements (L1B data, version 6.03) to derive the vertical profiles of the stratospheric water vapor from around 15 km to 50 km in the NIR spectral range.
- Application of SCIATRAN 3.0 as the radiative transfer code as well as the retrieval code.
- Selection of 1350 nm – 1420 nm from the water vapor absorption window in channel 6 of SCIAMACHY avoiding the absorption by the CO_2 around 1430 nm.

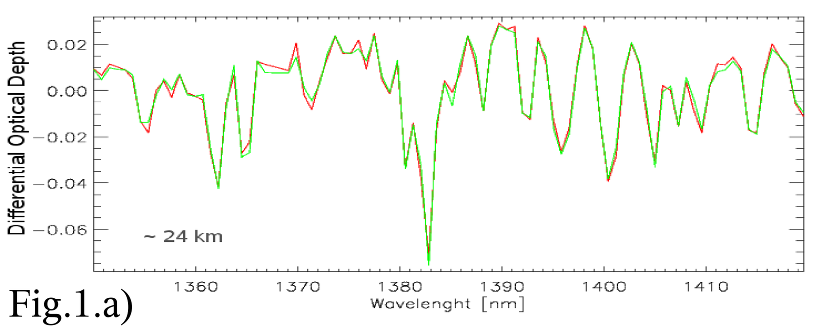

Fig.1.a)

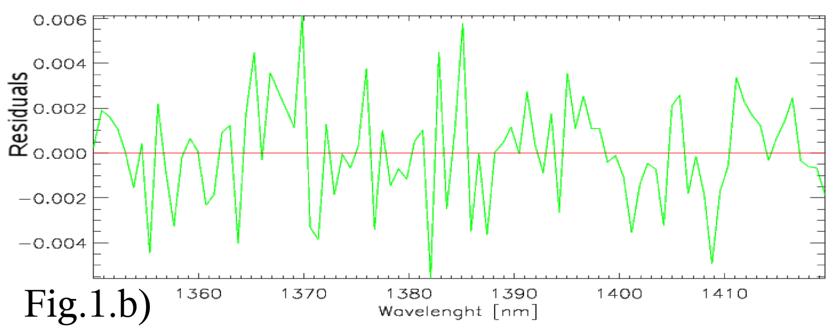

Fig.1.b)

Fig. 1- a, the spectral fit and fig. 1-b, the residual plots for the selected wavelength window for the measurement on 23rd Mar., 2005, orbit = 16006, sza = 109.137 and moon phase = 0.931 for the tangent height of about 24 km. The w.l. region 1350-1420 nm is selected to remove the absorption by CO_2 around 1430 nm. Green line in plot (a) indicates the modelled differential optical depth of H_2O and the red line stands for the measured differential absorption spectrum of H_2O. The residuals (plot b) are within the order of 0.005.

- Detection and removal of bad pixels during data extraction.
- Extraction of the lunar spectrum for 11 tangent heights between 17 to 50 km and the selection of the tangent height above the atmosphere ~ 115 km as the reference spectrum.

- The Sciatran 3.0 settings comprised:
  - Implementation of the line absorber treatment by 'esft' (exponential sum fitting of transmissions) approximation using esft database and performing convolution.
  - Application of the tangent height dependent Tikhonov regularization to constraint the smoothness of the retrieved profiles.
  - Setting the signal to noise ratio (S/N) ~ 425, estimated from the fit residuals of the retrieval.

Latitude, SZA and Moon Phase distribution for Lun. Occ. Measurements

Fig. 2. a)

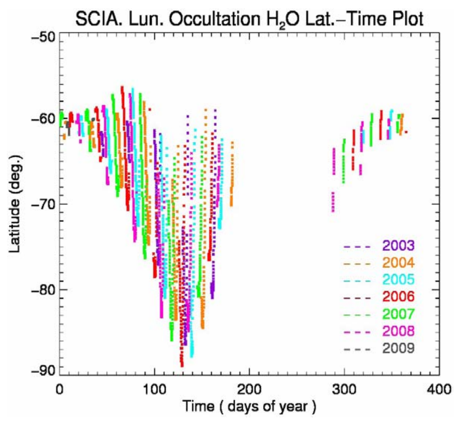

Fig. 2. b)

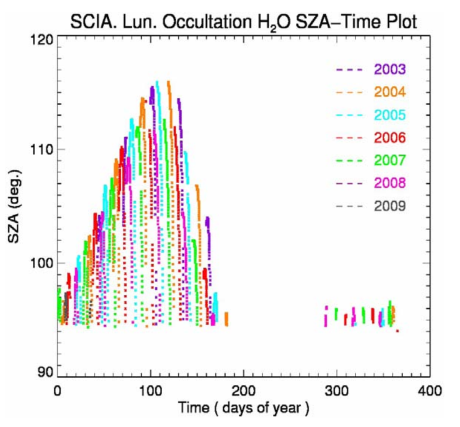

Fig. 2. c)

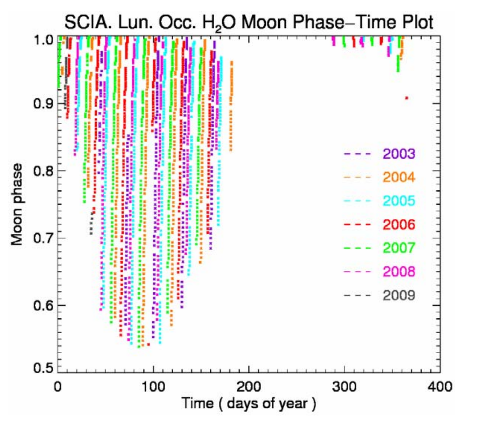

Fig. 2 , a, b & c, Latitude, sza and moon phase distribution respectively for the years 2003 - 2009.

Table1: The SCIAMACHY lunar occultation ranges for the latitude, moon phase and the sza for the years 2003 - 2009

	Latitude	SZA	Moon Phase
Minimum	-56.361°	94.047°	0.539
Maximum	-88.902 °	115.921°	0.999

The moon phase and solar zenith angle values determine the quality of the spectral signal. For the lunar occultation H_2O study, the measurements with the moon phase > 0.75 and sza > 96 ° were selected to obtain the H_2O profiles with strong signal.

The Averaging Kernels

Fig. 3

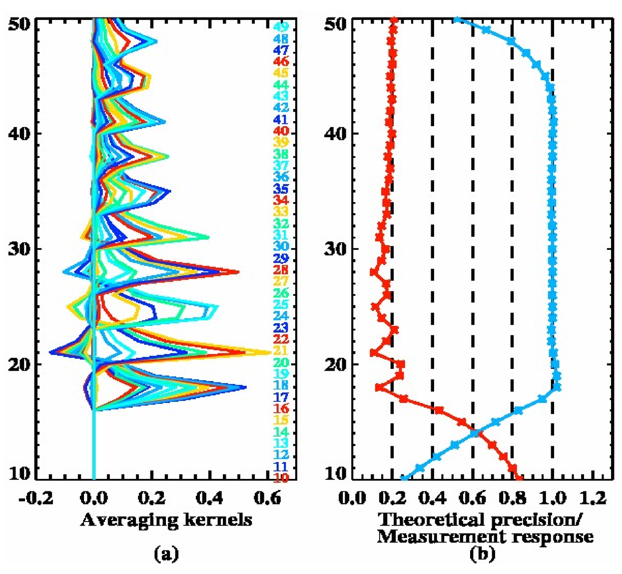

Fig. 3. The averaging kernels for the measurement on 23rd Mar., 2005 (sza = 109.13° and moon phase = 0.931) for the retrieval altitude from 17 to 50 km.

The H_2O averaging kernels (fig. 3-a) are based on 1 km grid Sciatran uses for radiative transfer calculations. The averaging kernels below 39 km have sharp peaks indicating higher sensitivity of the retrieval for this range. The averaging kernels above 30 km are wider due to the smoothing applied above this level. The averaging kernels of several altitudes have peaks at the same altitude because of the difference between the SCIAMACHY vertical sampling (3.3 km) and the retrieval resolution (1.0 km). The measurement response function plotted in figure 3-b, shows that between 17-45 km, the retrieval profile is determined only by the measurement without any contribution from apriori.

Results and Comparison/Validation

The SCIAMACHY lunar occultation H_2O retrieval profiles were compared with the solar occultation water vapor measurements from the ACE-FTS (Atmospheric Chemistry Experiment Fourier Transform Spectrometer) instrument on board the Canadian Satellite SCISAT-1. Within the maximum SCIAMACHY – ACE distance of ~ 975 km, 121 collocated measurements were found, out of which 80 measurements from the instruments were selected where SCIAMACHY's moon phase > 0.75 ° and sza > 96 ° and were used for the analysis/comparison (examples:- fig. 4).

Fig. 4 a)

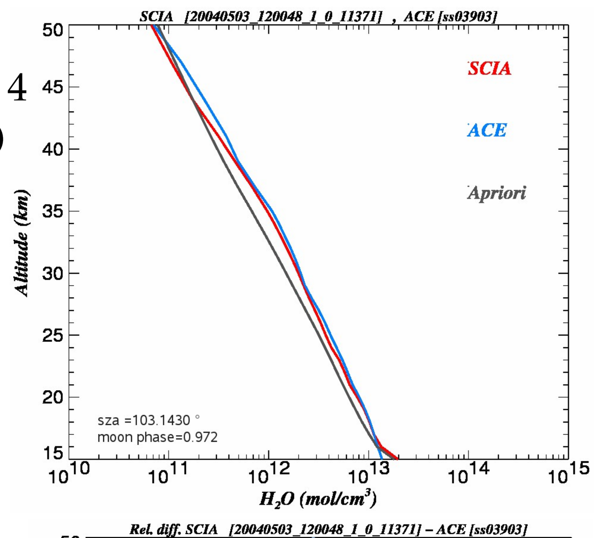

Fig. 4 b)

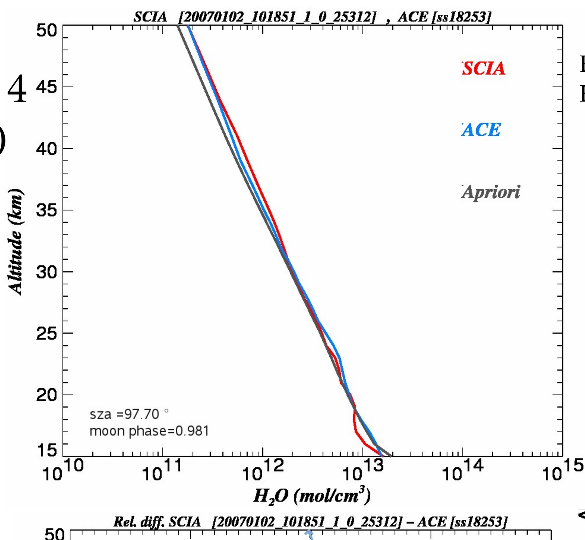

Fig. 4 c)

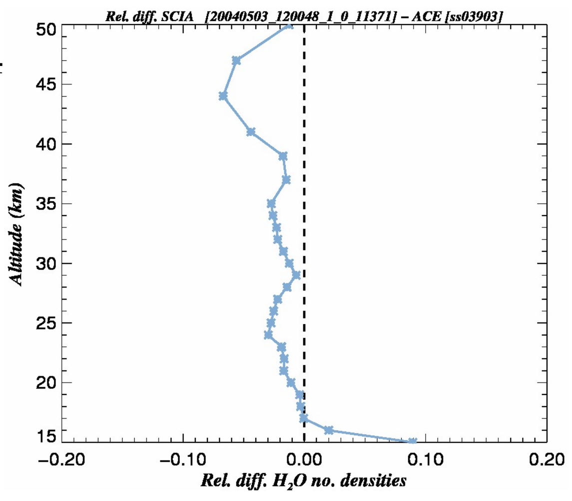

Fig. 4 d)

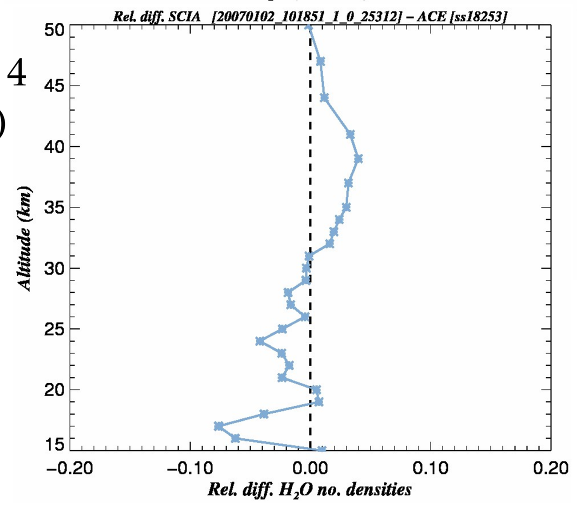

Fig. 4 , a, b, c & d: Examples of the SCIAMACHY & ACE H_2O profiles and the corresponding relative difference plots.

Fig. 5

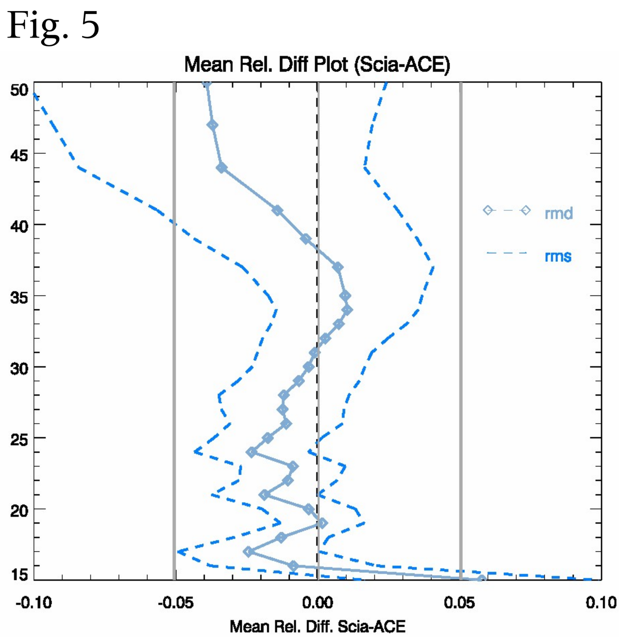

Fig.5. Plot for the mean relative deviations (rmd) and the standard deviations of the mean relative differences (rms) for the 80 selected SCIAMACHY-ACE co-located lunar occultation H_2O measurements.

In general the profiles from both instruments show a very good agreement at all altitude levels between 17 to 50 km (examples, fig. 4-a & b) with very small relative differences (Figures 4-c & d). For the 80 selected SCIAMACHY – ACE measurements, the mean relative deviations (rmd) are less than 2.5% for 17-39 km and within 5% upto 50 km as clear in figure 5. The respective standard deviations of the mean relative differences (rms) are within 5% approximately between 17-39 km.

Conclusions and Outlook

- ► The first time SCIAMACHY lunar occultation water vapor study (for the southern hemispheric high latitude) is presented here (the retrieval optimizations, the preliminary sensitivity studies and the validations).
- ► The SCIAMACHY lunar occultation H_2O measurements comparison and validation for 80 co-locations with the ACE-FTS instrument showed very good agreement specially for 17 to 39 km with the mean relative deviations lying within 2 .5% and the standard deviations of the mean relative differences less than 5% for the same altitude range.
- ► Studies will be carried out to further improve the results for the stratospheric higher altitudes.
- ► The SCIAMACHY lunar occultation H_2O retrieved dataset will be updated and its interpretation and analysis with respect to the physical and chemical processes determining the distribution of water vapor in the southern hemisphere will be done. A complete processed lunar occultation H_2O dataset is expected to provide a useful water vapor database.
- ► Further validations with other water vapor products will be performed.

Acknowledgements

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