5th Limb Workshop, Helsinki, Finland, 16 - 19 November 2009

Retrievals of the water vapor content in the upper troposphere and lower stratosphere from SCIAMACHY limb measurements

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Motivation

Water vapor is important for

- Climate (greenhouse gas, hydrological cycle)
- Atmospheric chemistry (HOx, PSCs formation)
- Atmospheric dynamics (tracer), especially stratosphere-troposphere exchange

Main sources of the global information on stratospheric water vapor

- HALOE, SAGE II, and POAM ceased operation in 2005/2006
- Continuous satellite observations: SMR, ACE-FTS, MLS, MIPAS, SCIAMACHY, GOMOS

Our goals

- ENVISAT (MIPAS, SCIAMACHY) has sufficient overlap with HALOE/SAGE (2002-2005) for extending time series, the mission extension to 2013 is approved
- Limb emission/scatter sounder (as MIPAS and SCIAMACHY) have a better spatial sampling than occultation instruments

SCIAMACHY characteristics

Instrument: UV-Visible-near IR spectrometer with 8 spectral channels

- Spectral range: 214 – 2380 nm
- Spectral resolution: 0.2 – 1.5 nm

Orbit parameters:

- Sun-synchronous (10:00 AM local equator crossing time)
- ~ 800 km mean altitude
- 98.55^{o} inclination

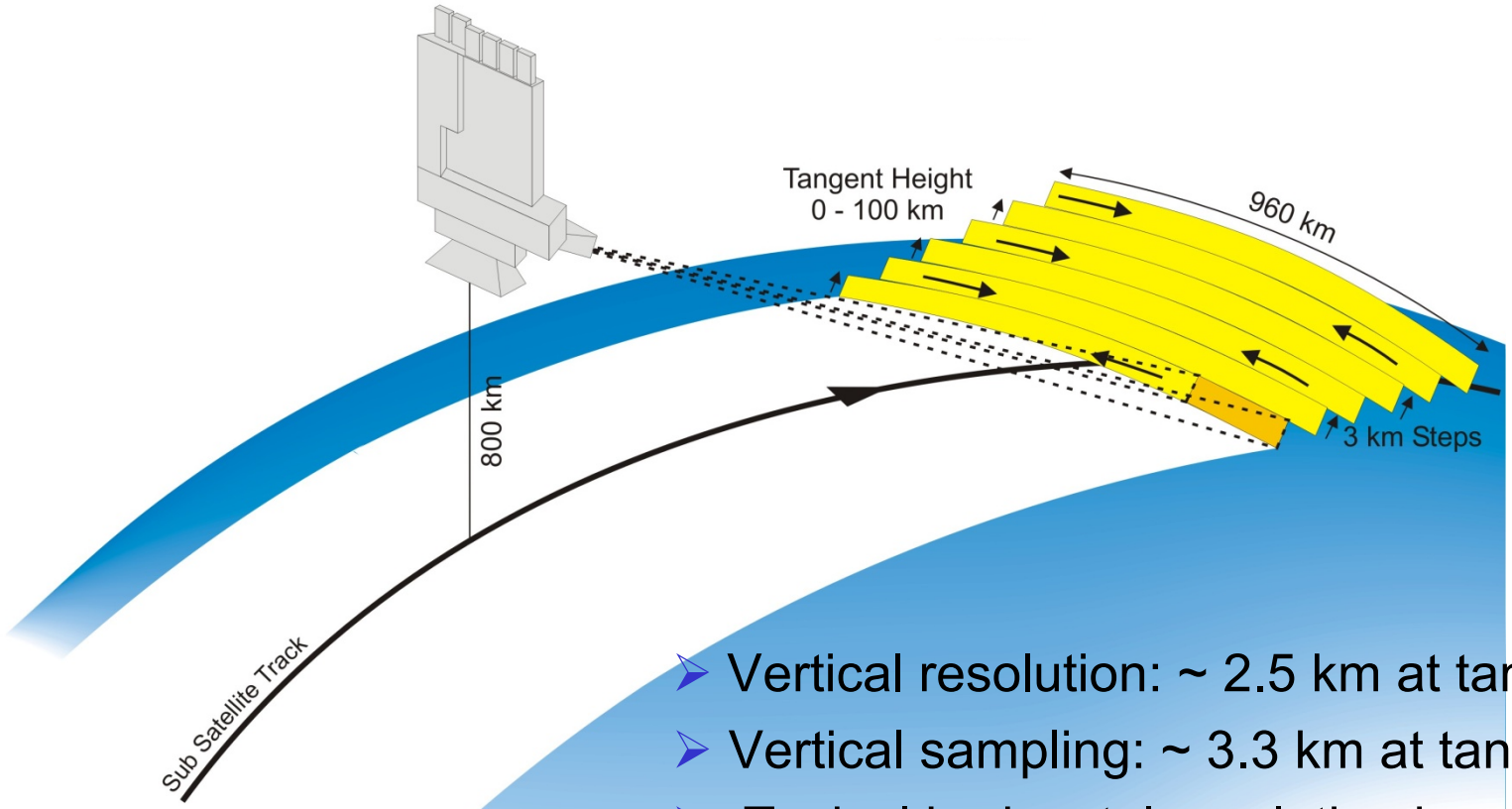
Measurement geometries

- Nadir (scattered solar light)
- Limb (scattered solar light)
- Occultation (transmitted solar/lunar light)

Selected for the UTLS water vapor retrieval:

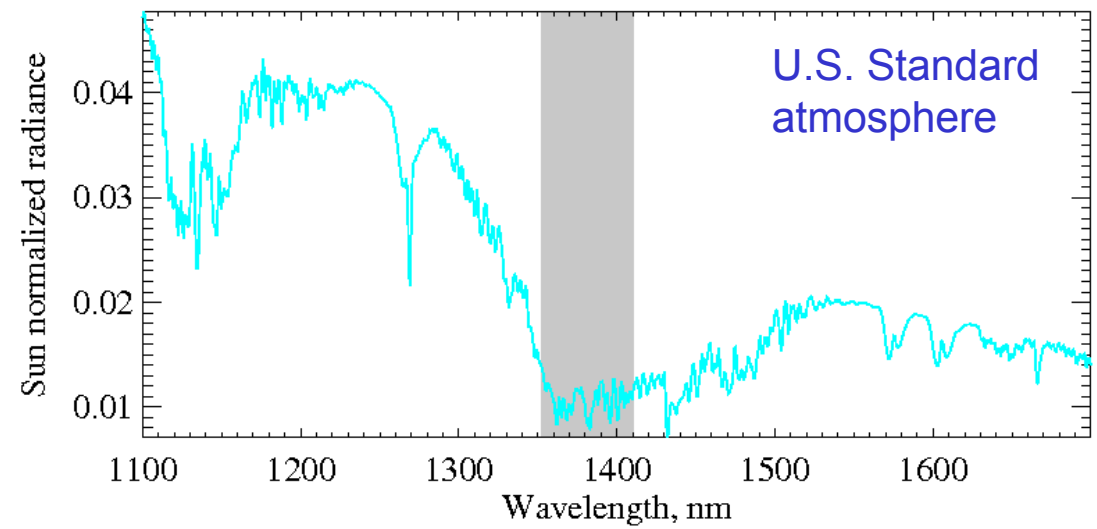
- Limb viewing geometry, tangent heights between 12 and 25 km
- Spectral channel 6, 1050 – 1700 nm at 1.5 nm spectral resolution

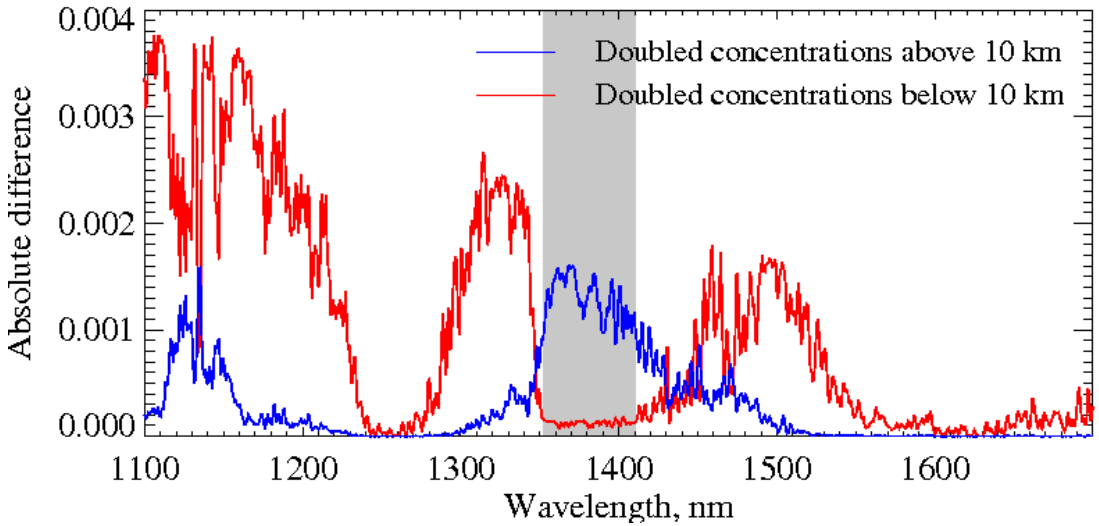
Limb measurement sequence



- Vertical resolution: ~ 2.5 km at tangent point
- Vertical sampling: ~ 3.3 km at tangent point
- Typical horizontal resolution in azimuth: 240 km
- Horizontal resolution in flight direction: ~ 400 km
- Duration of limb sequence: 60 sec
- Global coverage: 6 days at the equator

Selection of spectral range





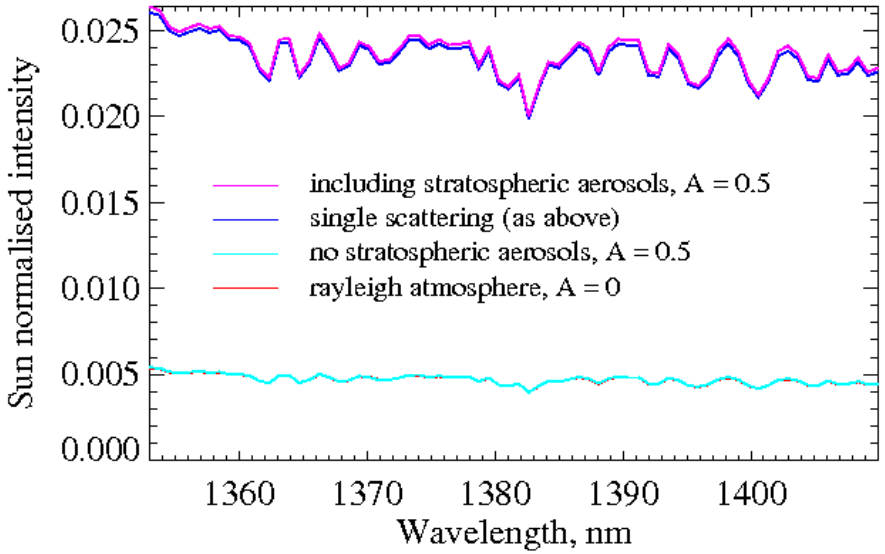
Simulated limb spectrum at 12 km tangent height

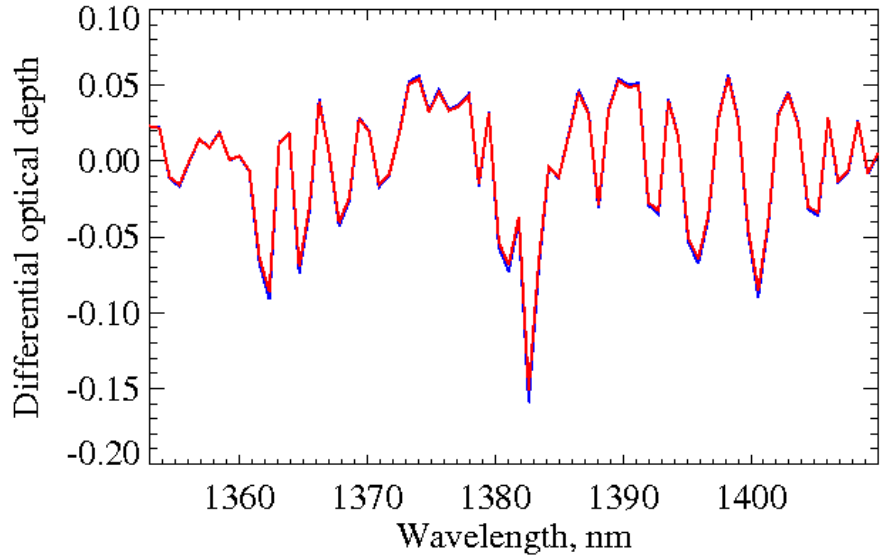
"Stratospheric part":
altitude > 10km
"Tropospheric part":
altitude <= 10 km

Selected spectral range: 1353 -1410 nm

Tangent heights included: 12 – 25 km

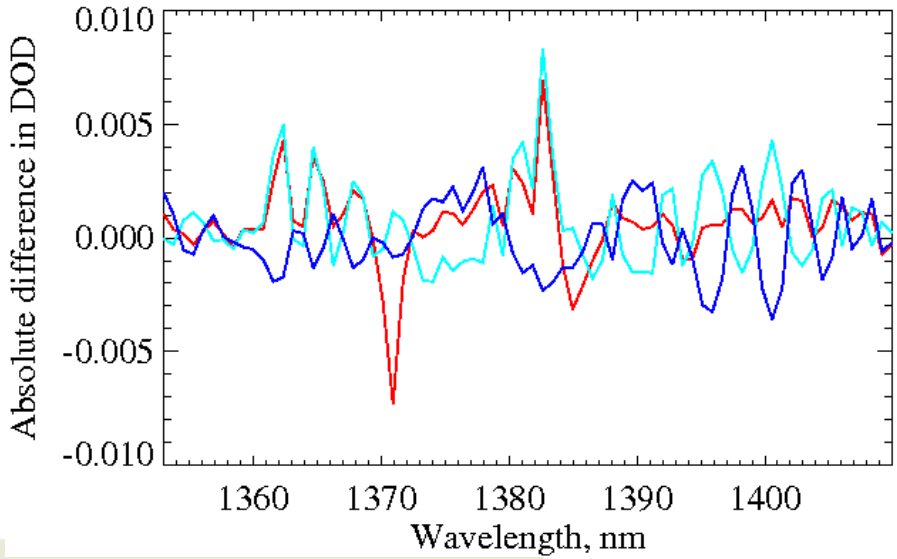
Relative contributions of scattering/reflection processes





Example simulation:

- 15 km tangent height
- 48°N, 120°W
- Winter
- Solar zenith angle 69°



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Retrieval method

Next iteration

Forward modeling, SCIATRAN 3.0
- Fully spherical for SS
- Approximation for MS

Viewing geometry and geolocation from the measurements

Simulated limb spectra
Weighting functions

Pre-processing (DOAS-type fit) at each tangent height
- Spectral misalignment correction

Measured and simulated limb spectra
Vertically integrated WFs

Correction parameters

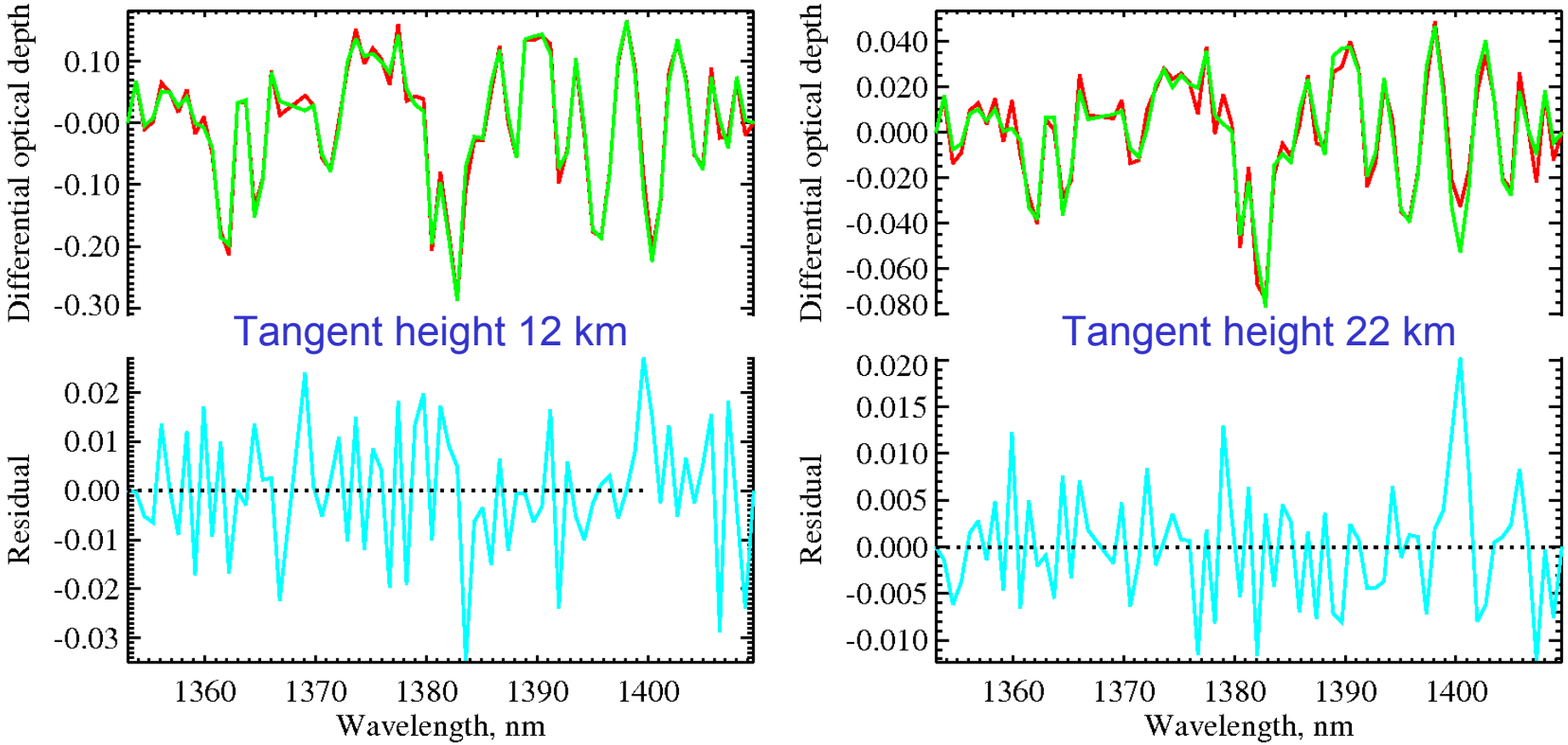
Main inversion procedure
- Solution: Optimal Estimation type with additional smoothing
- Measurement vector: differential spectral signal at all selected tangent heights (12 - 25 km)
- State vector: trace gas number densities at al altitude levels

Measured and simulated limb spectra with all corrections from the pre-processing step applied
Weighting functions
A priori constraints

Vertical distributions of trace gas number densities

Example spectral fits

Example spectral fits for SCIAMACHY orbit 9986 on January 27th, 2004, 17:18 UTC at 38°N,108°W, SZA@TP = 64°



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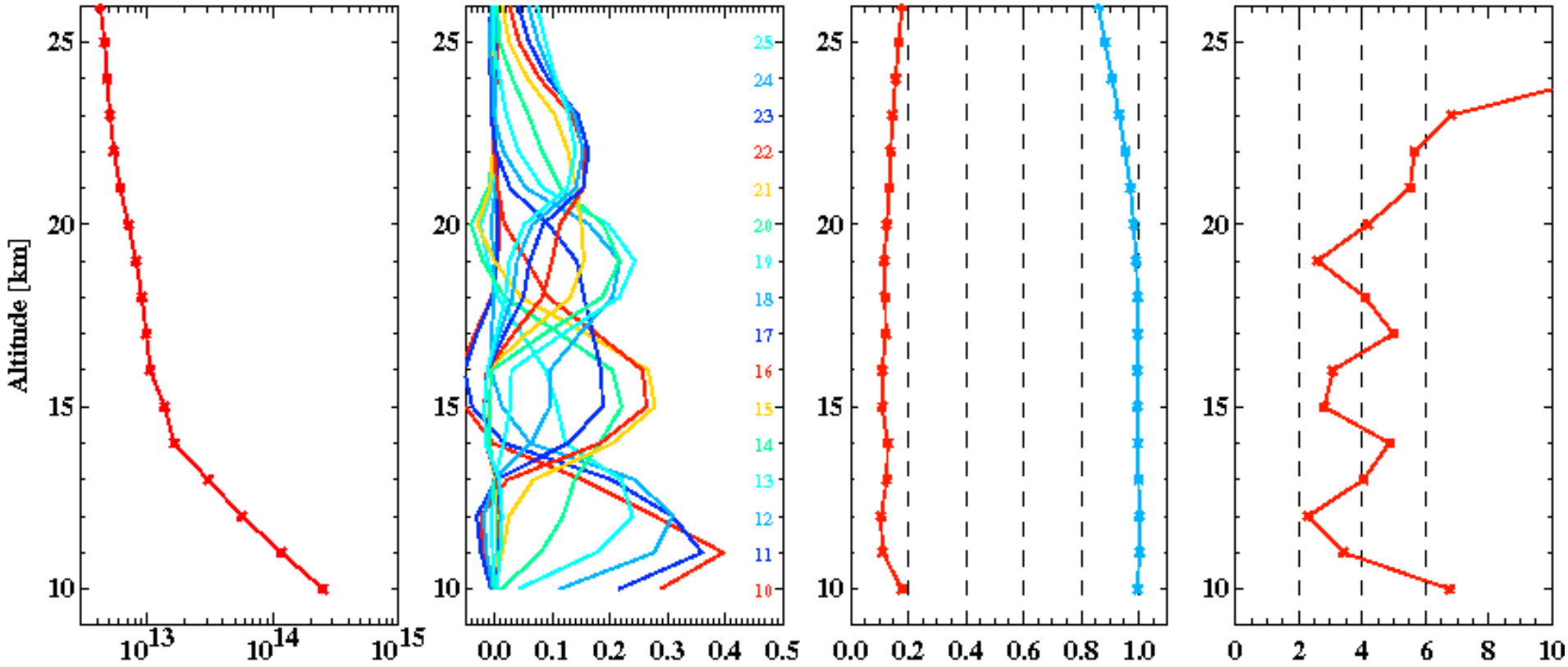
Sensitivity of SCIAMACHY limb measurements

Water vapor number density, molecules/cm^3

Averaging kernels

Measurement response and theoretical precision

Vertical resolution of the retrieval, km



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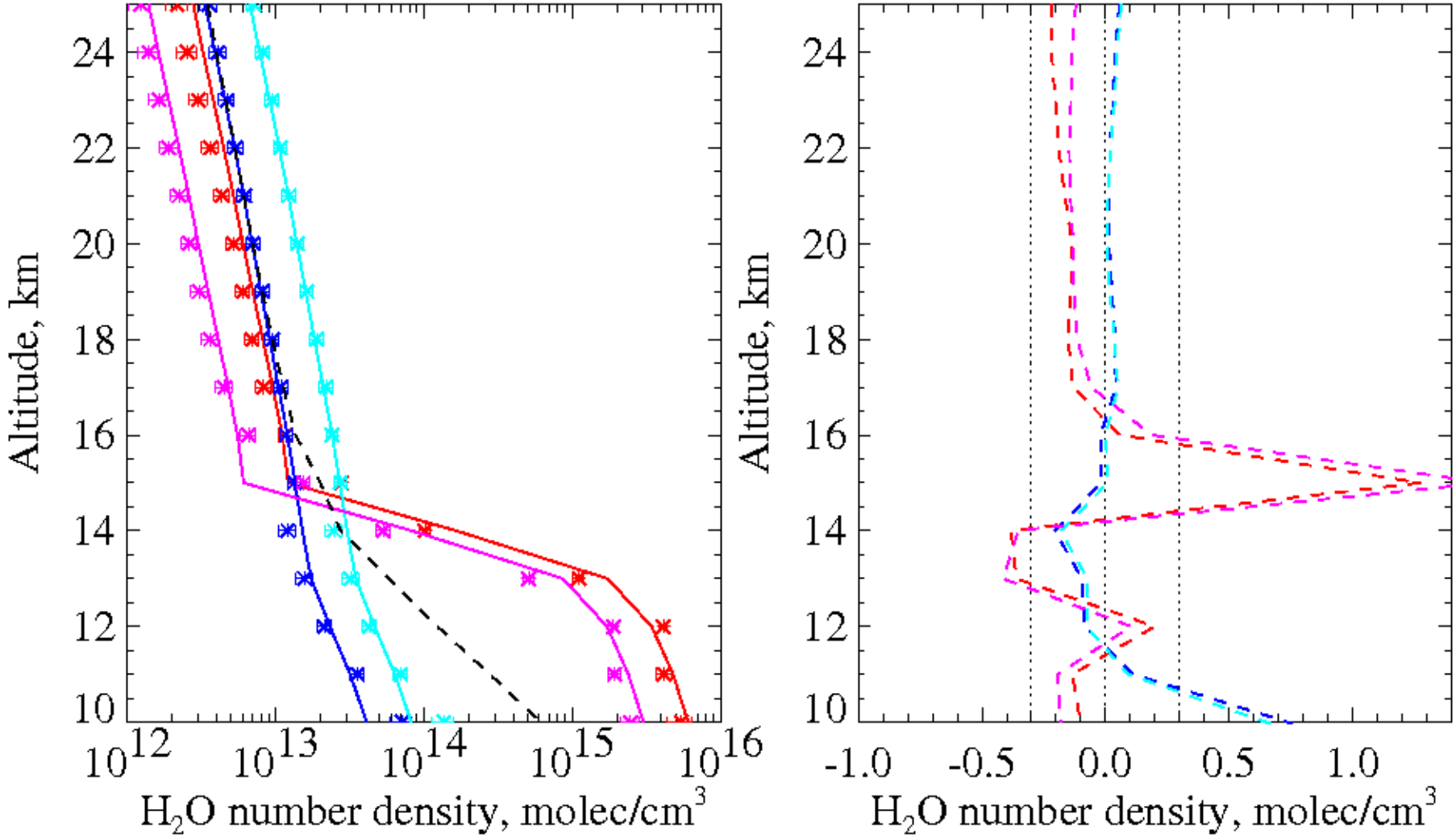
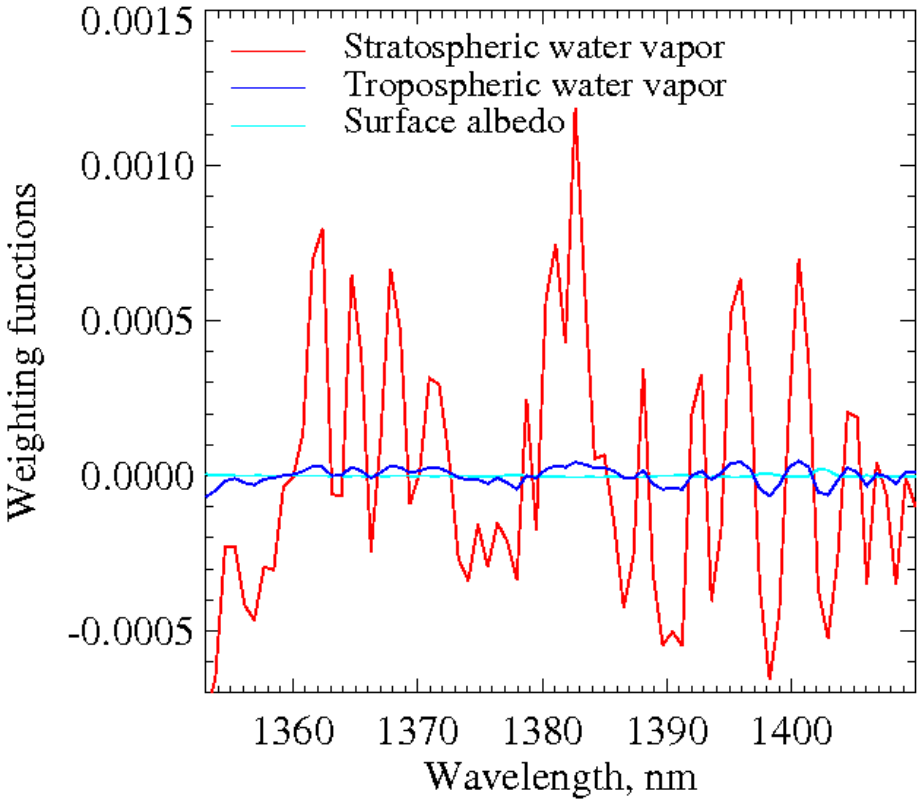
Dependence on a priori information

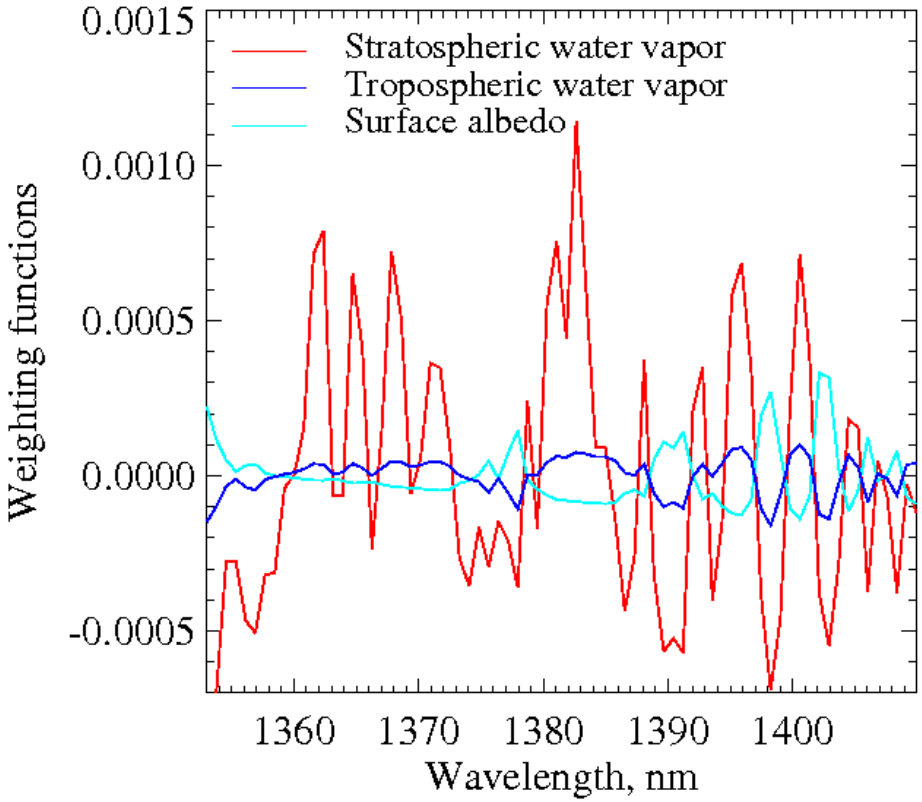


Sensitivity to the surface albedo and tropospheric H_2O

Moderate surface elevation, normal tropospheric water vapor content



High surface elevation (>2 km) and/or low tropospheric water vapor content



Tangent height = 15 km, SZA@TP = 64 deg, A = 0.5, U.S. Standard 1976 H_2O

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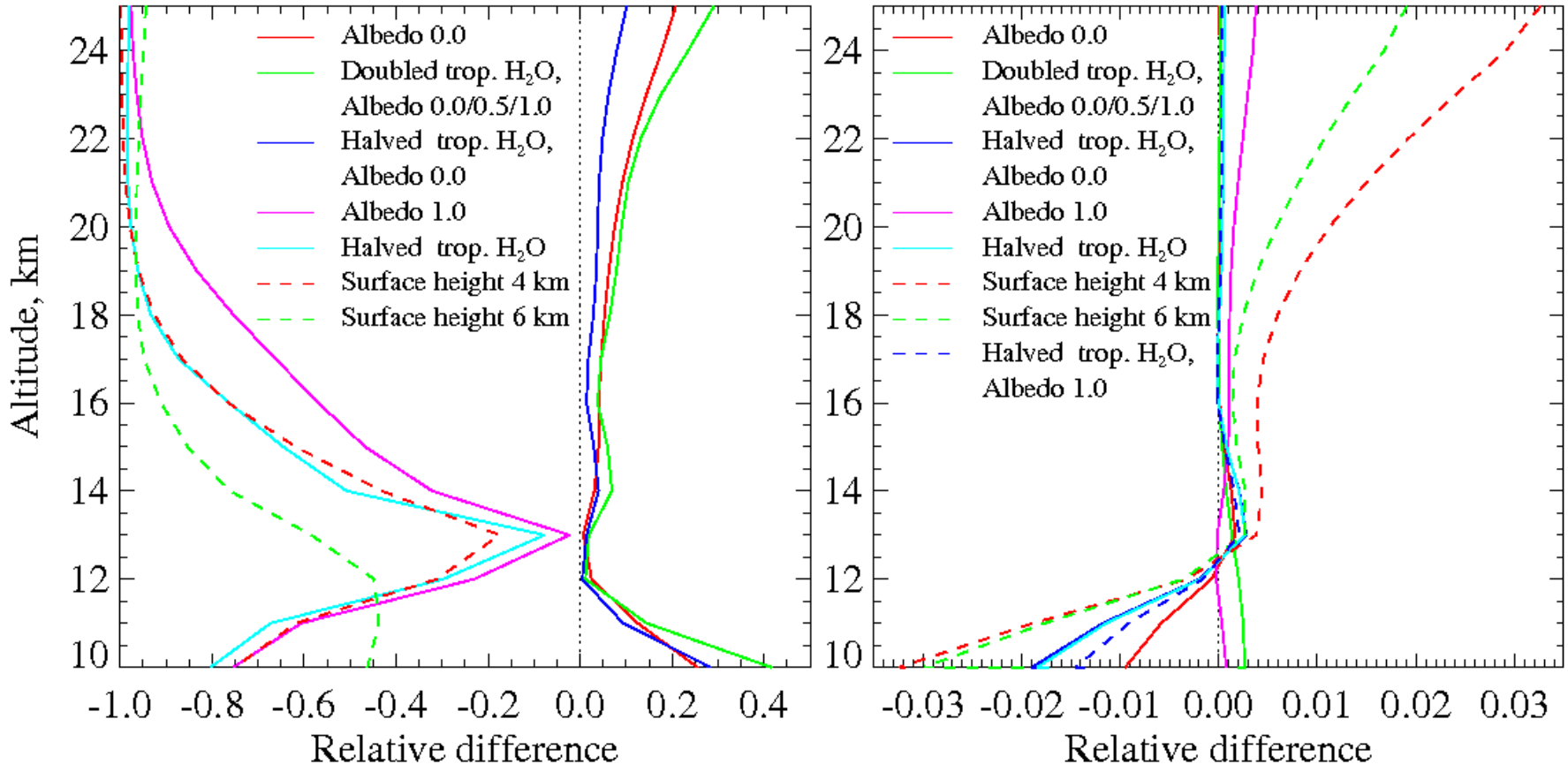
Influence on the retrieval (synthetic retrievals)

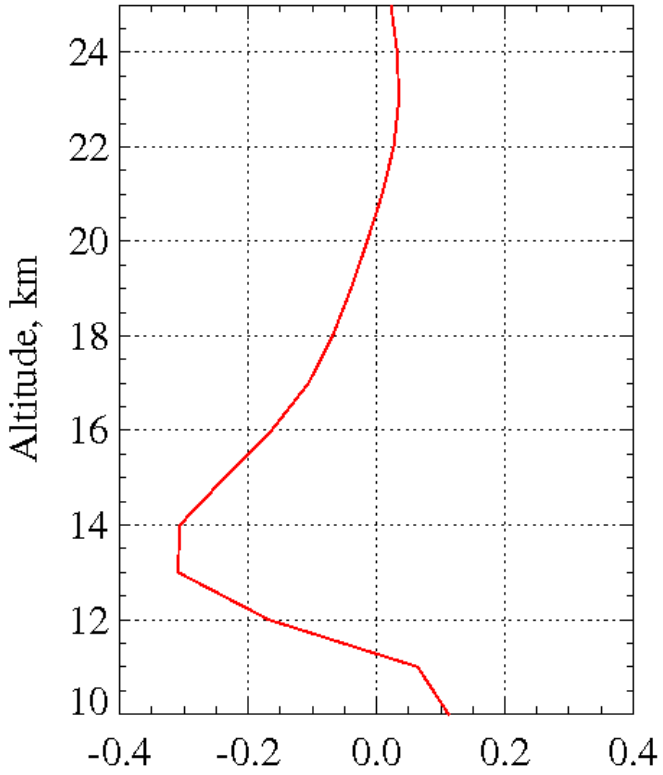
Surface albedo and tropospheric water vapor column are neglected

Surface albedo and tropospheric water vapor column are retrieved

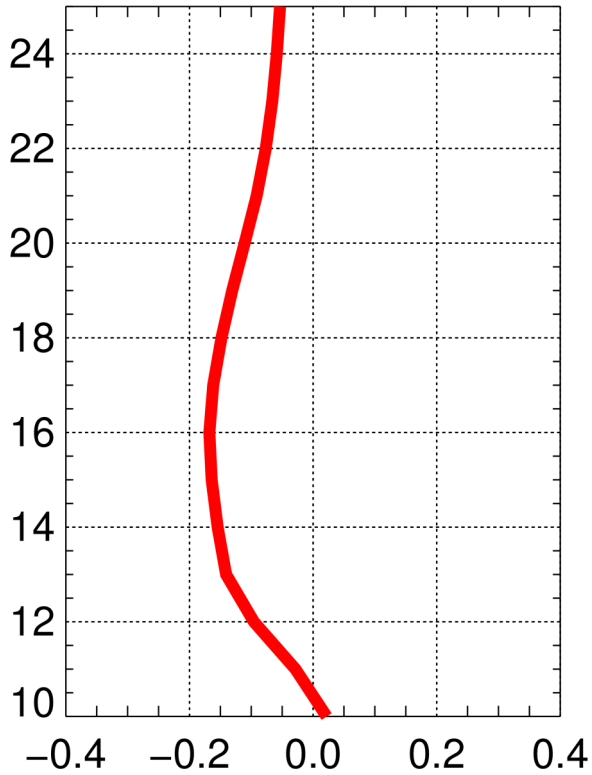


Simulations were performed for surface albedo of 0.5 and surface elevation of 2.2 km

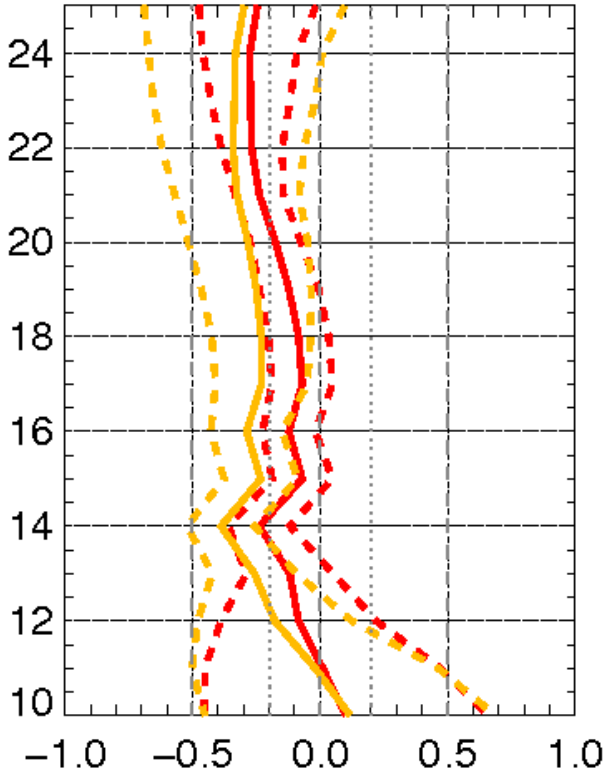
Sensitivity to the stratospheric aerosols



Error due to stratospheric aerosol in synthetic retrievals: simulations with aerosol, retrieval in aerosol free atmosphere



Mean relative difference between retrievals for ACE-FTS collocations (10) neglecting and accounting for stratospheric aerosols



Mean relative difference with respect to ACE-FTS results retrieving including and neglecting aerosols

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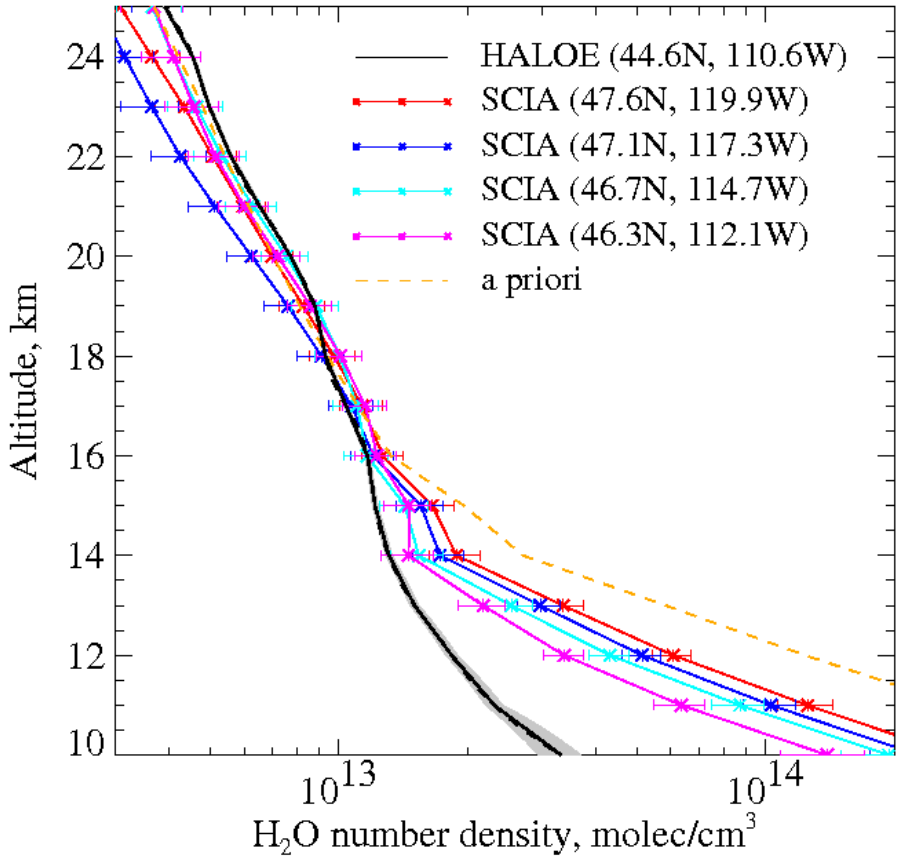
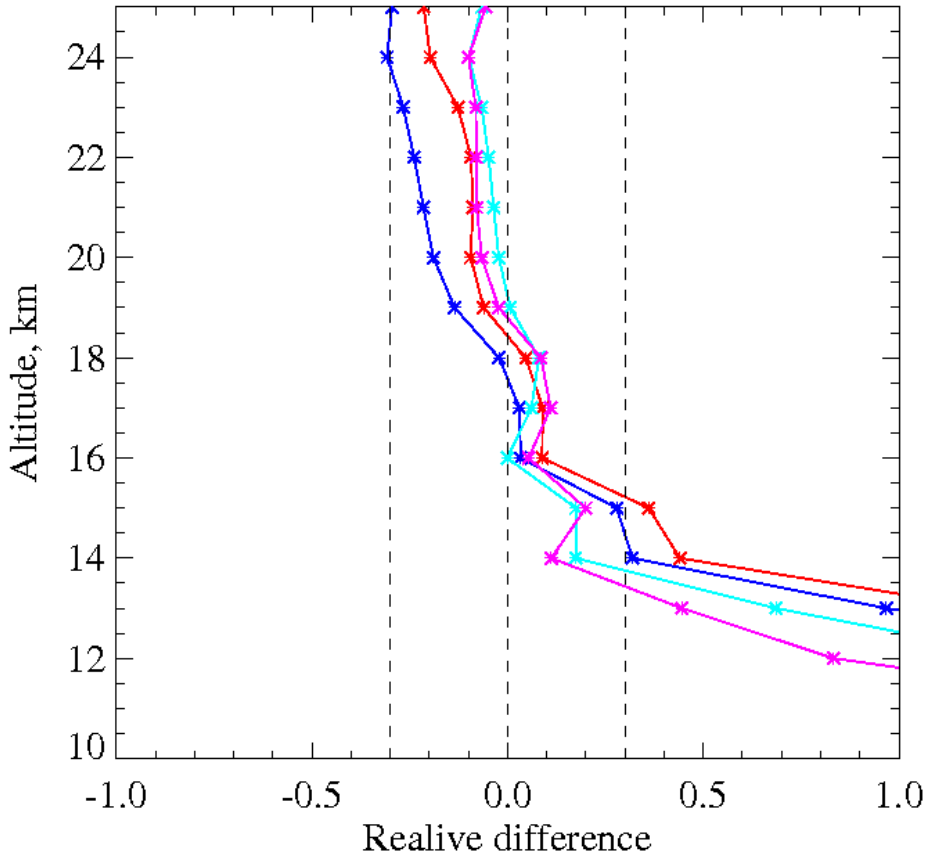
Single comparison: HALOE

HALOE: space-borne solar occultation measurements at 6.6 μ

February 6, 2003 (orbit 4905), SCIA: 18:12 UTC, HALOE: 14:40 UTC





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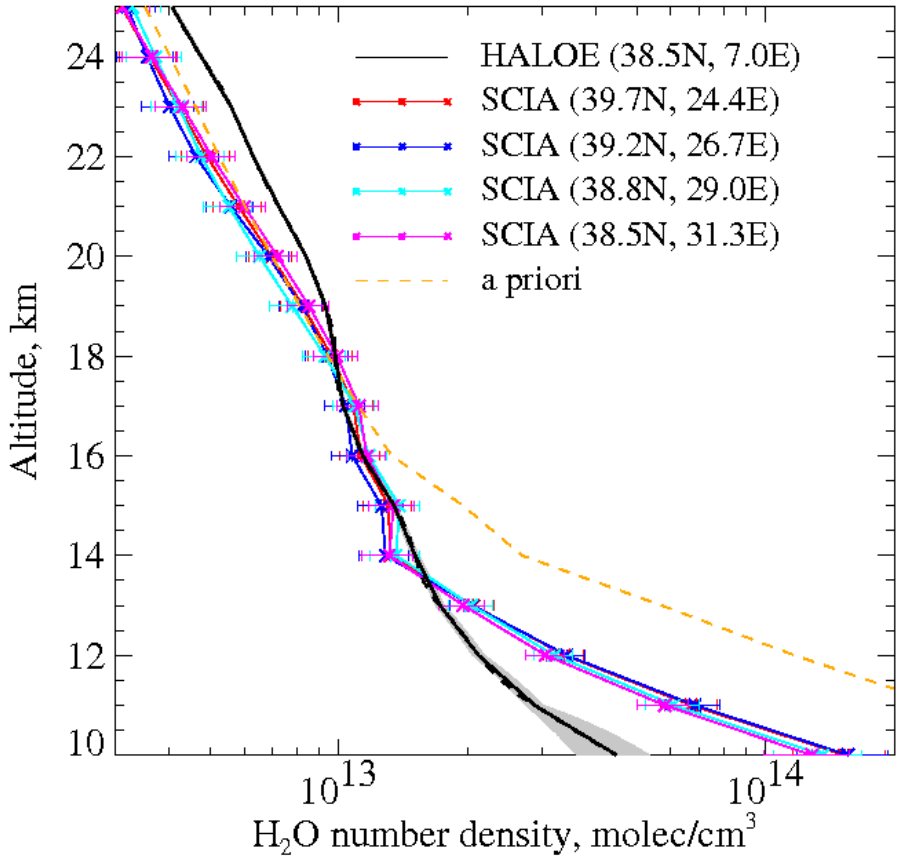
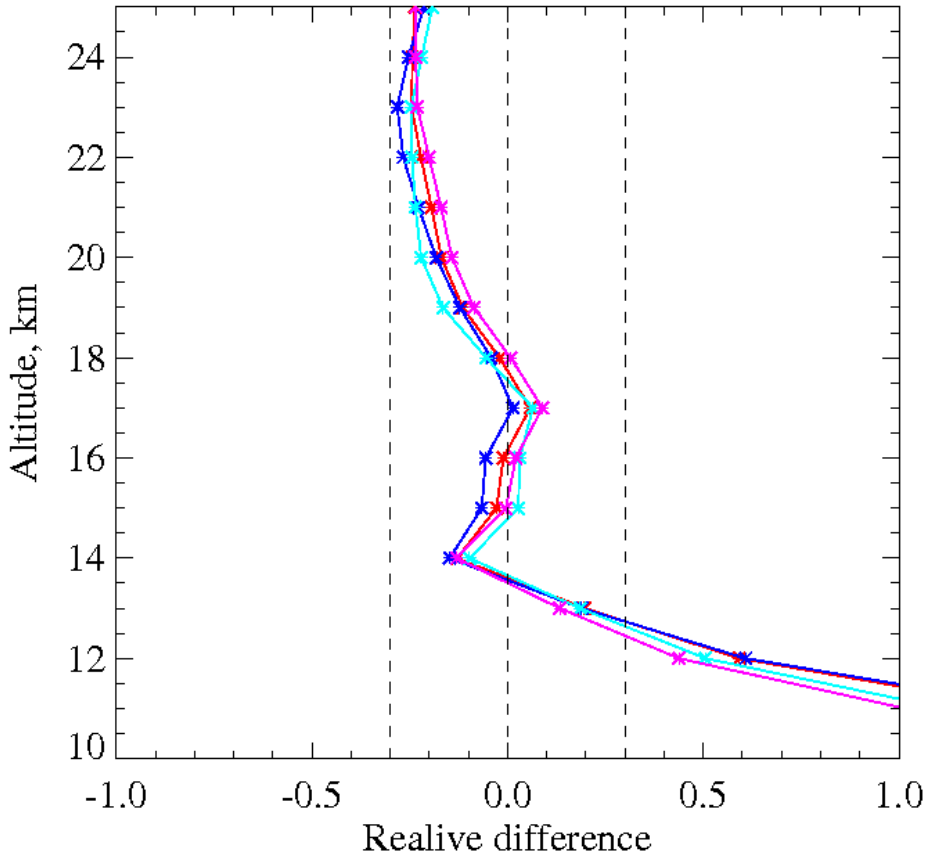
Single comparison: HALOE

HALOE: space-borne solar occultation measurements at 6.6 μ

February 15, 2003 (orbit 5028), SCIA: 8:28 UTC, HALOE: 17:05 UTC

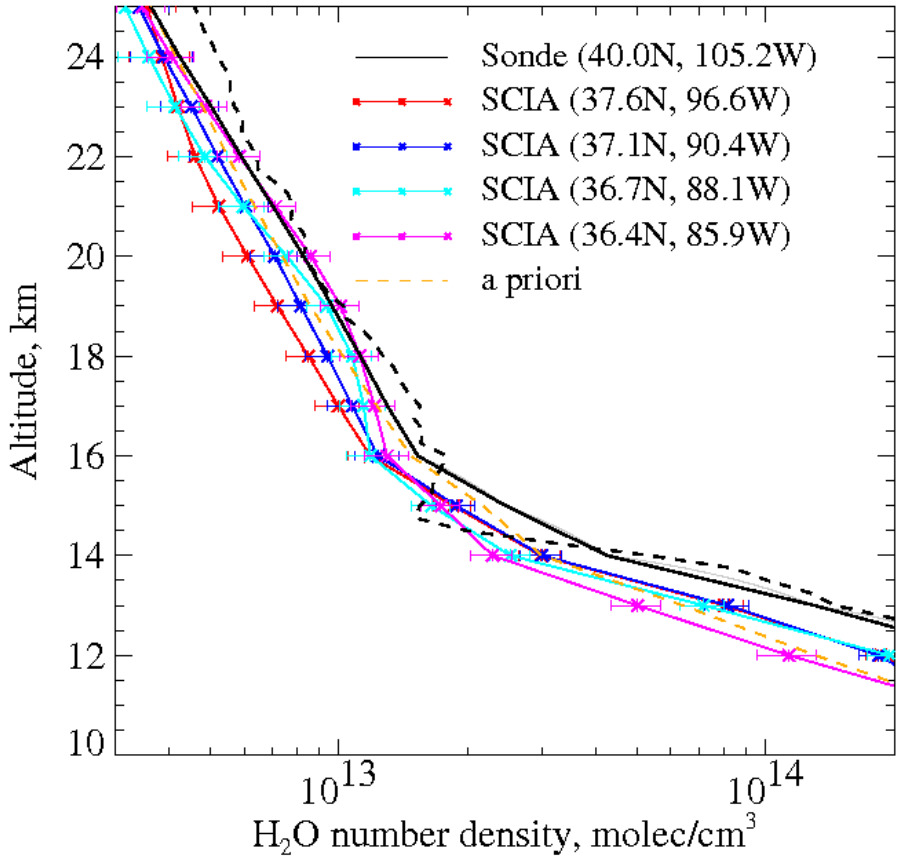


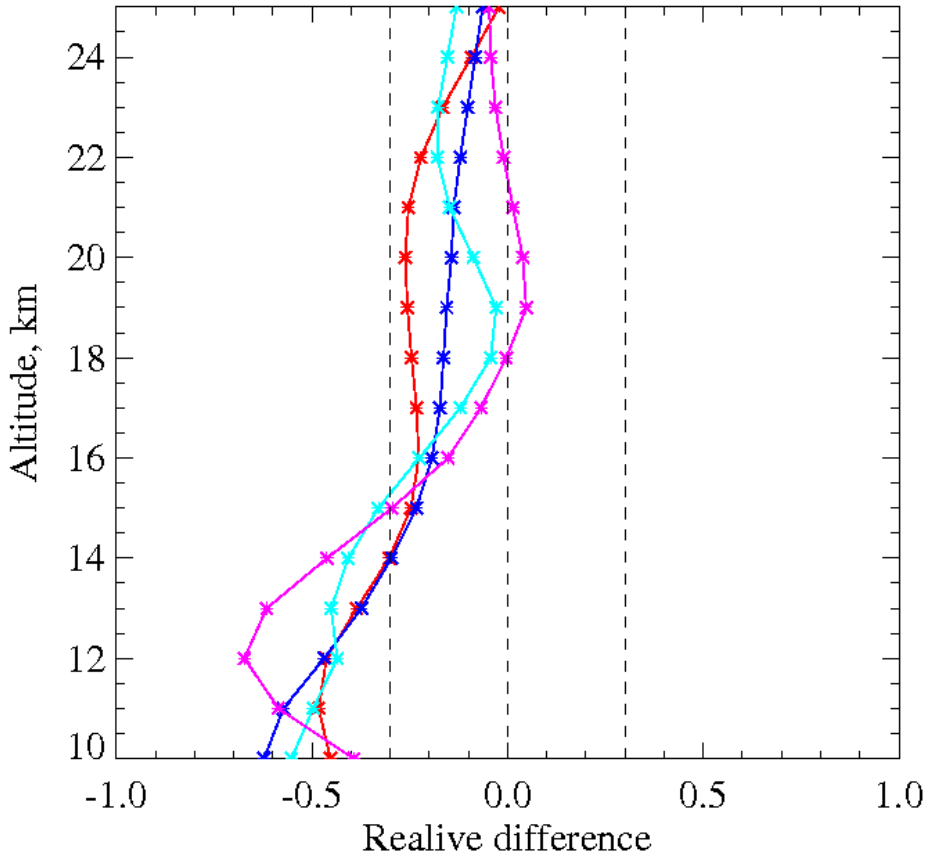


Single comparison: frost point hygrometer

In situ measurements at Boulder station: balloon-borne frost point hygrometer

November 20, 2003 (orbit 9012), SCIA: 16:15 UTC, Balloon: 18:16 UTC

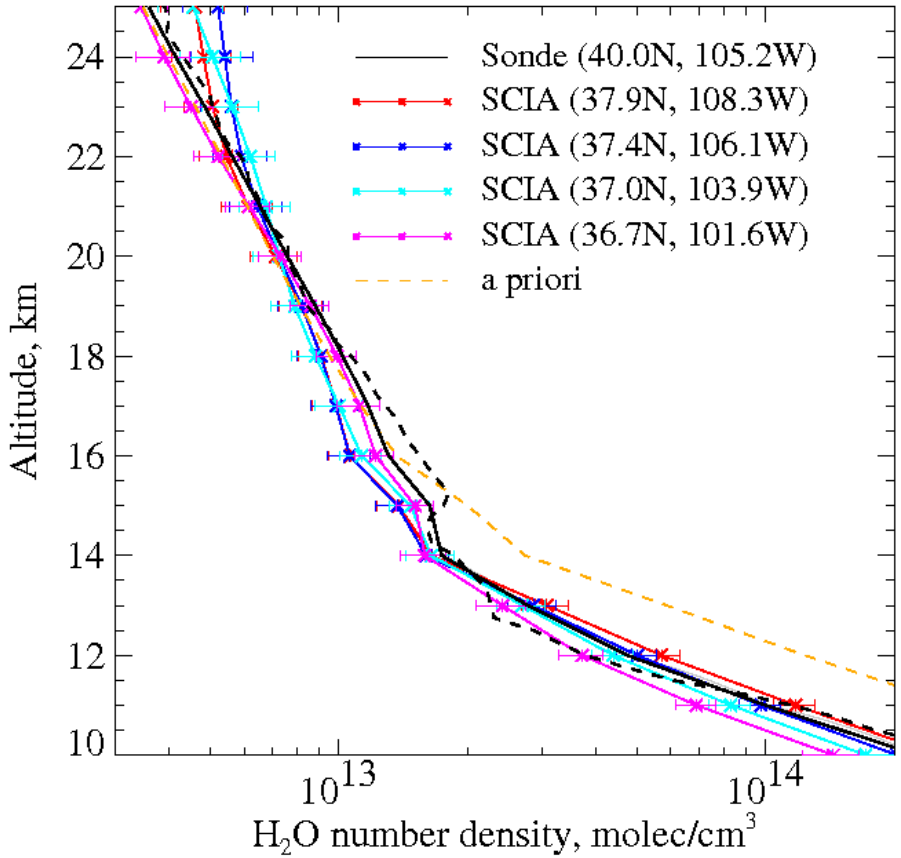


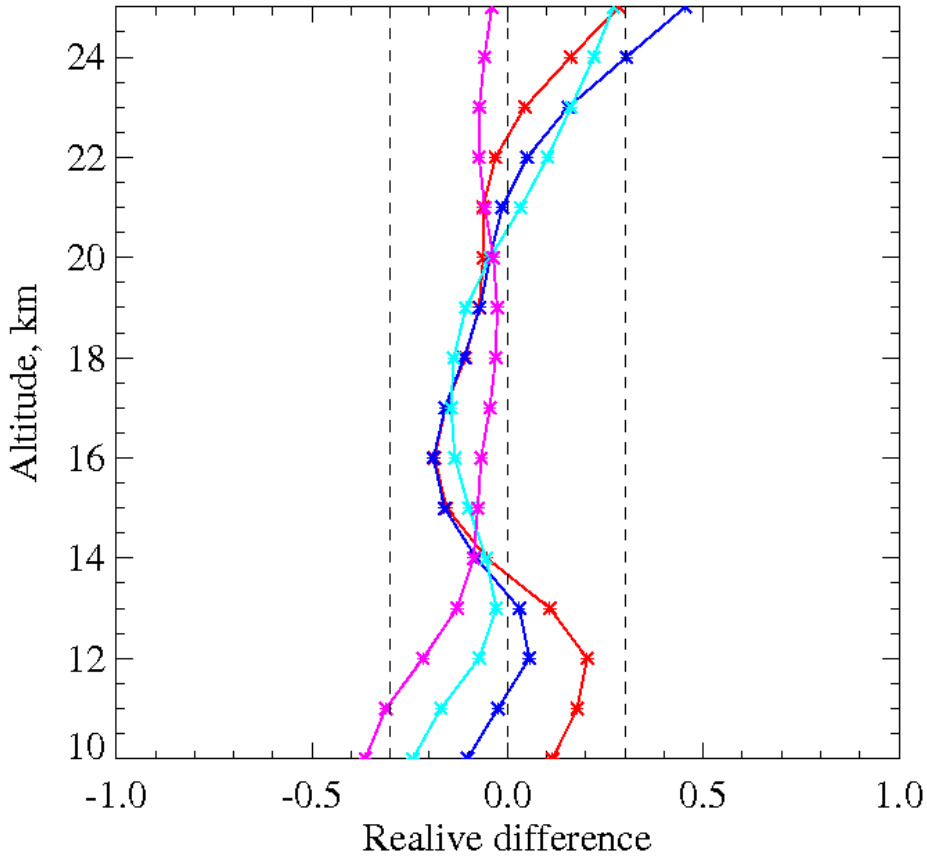


Single comparison: frost point hygrometer

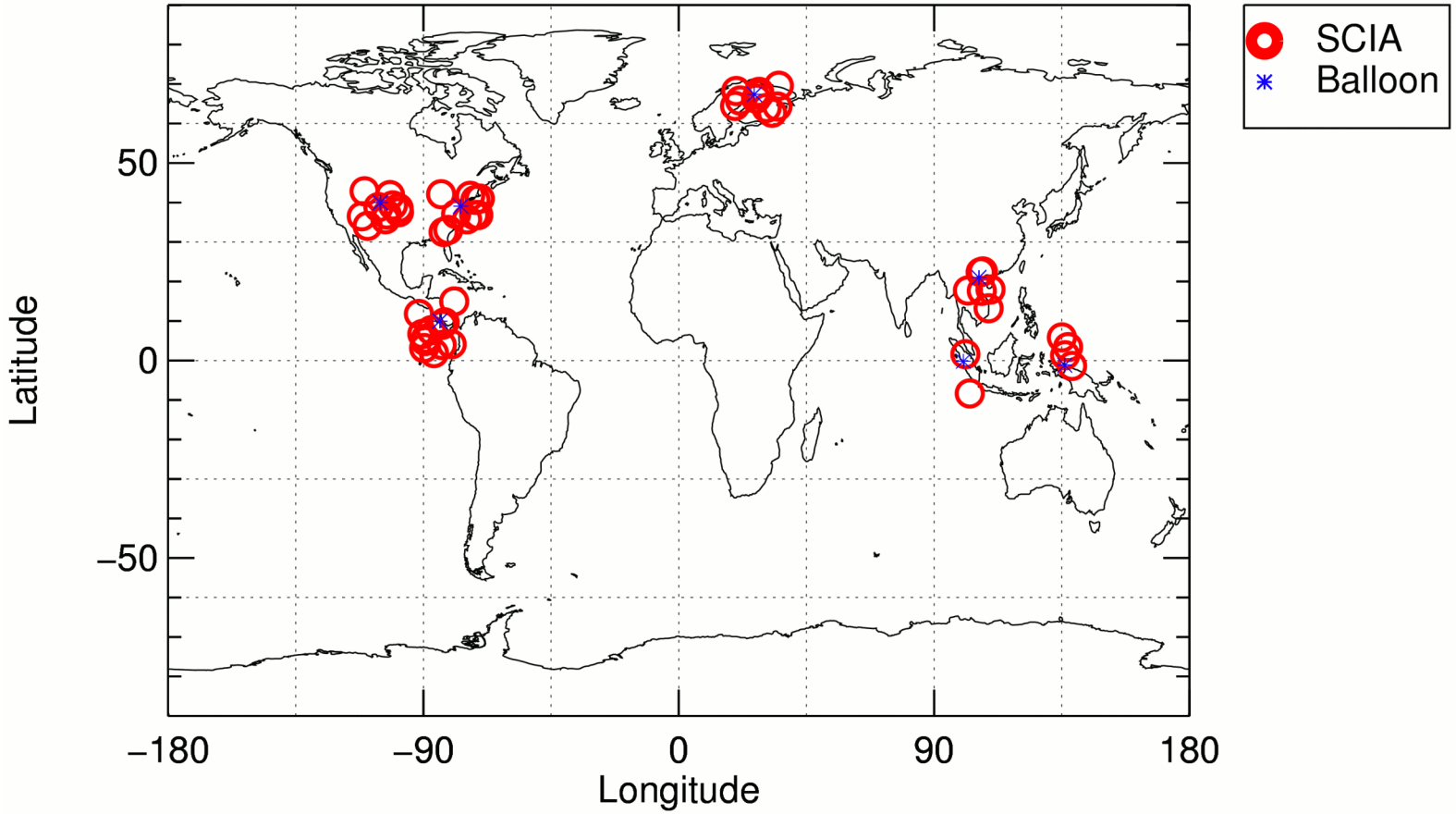
In situ measurements at Boulder station: balloon-borne frost point hygrometer

January 27, 2004 (orbit 9986), SCIA: 17:18 UTC, Balloon: 18:18 UTC





Statistics: Cryogenic Frostpoint Hygrometer (CFH)



Balloon-borne in situ observations using a Cryogenic Frostpoint Hygrometer

Collocation: < 1000 km, < 5 hours

November 2004 - March 2008, SCIA: about 250 profiles, balloon: 56 profiles

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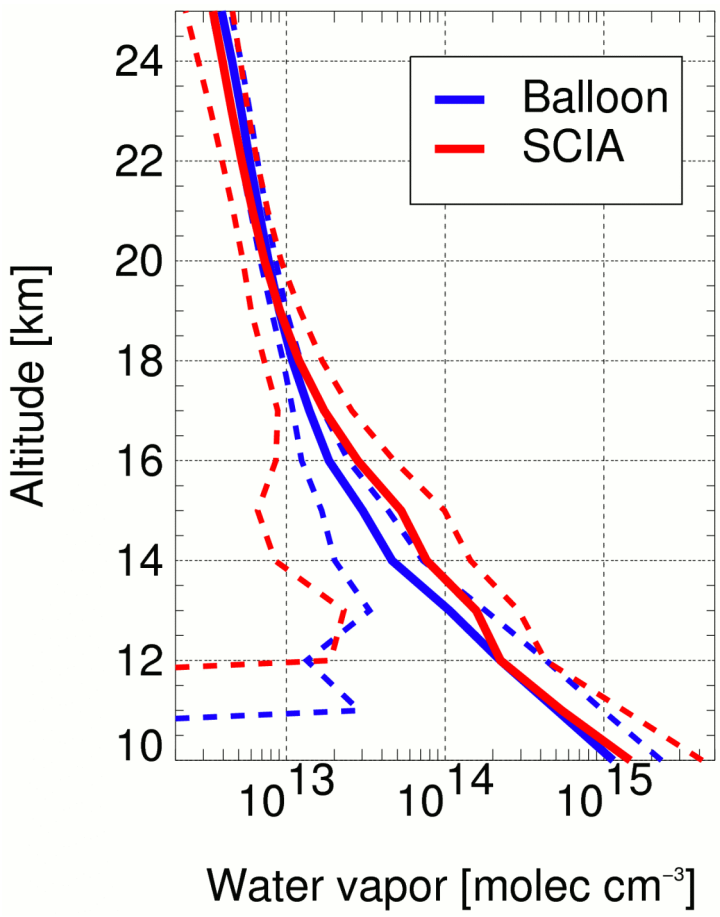
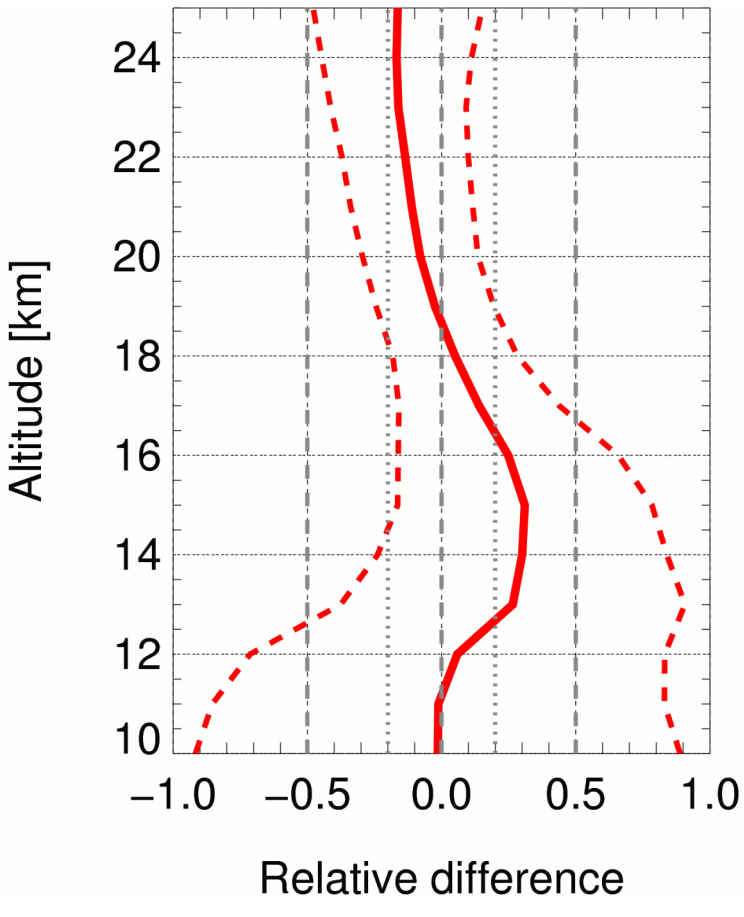
Statistics: Cryogenic Frostpoint Hygrometer (CFH)

Average profiles



Mean relative difference



Dashed lines show standard deviations

CFH data courtesy of Holger Vömel, Deutscher Wetterdienst

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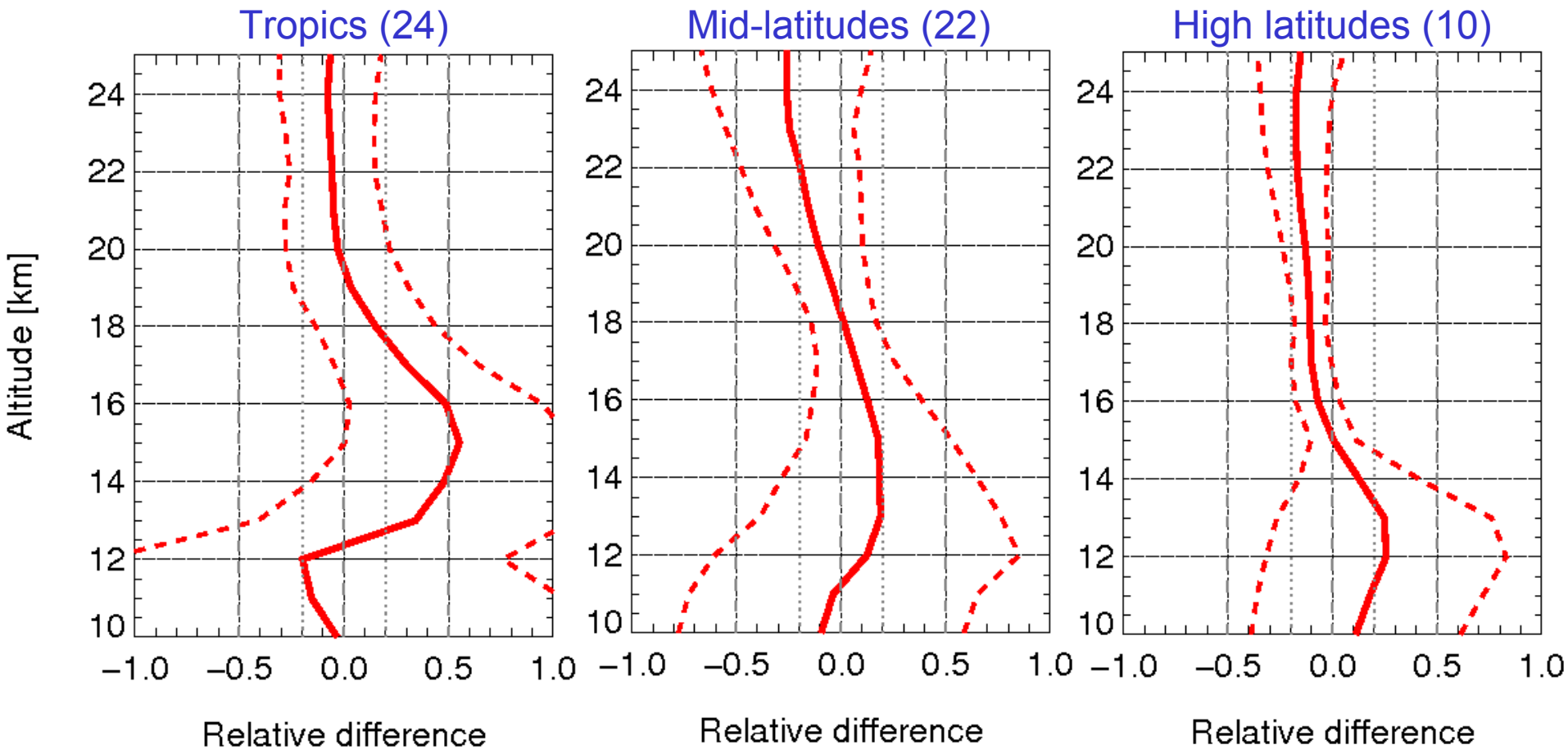
Statistics: Cryogenic Frostpoint Hygrometer (CFH)

Mean relative differences



Dashed lines show standard deviations

CFH data courtesy of Holger Vömel, Deutscher Wetterdienst

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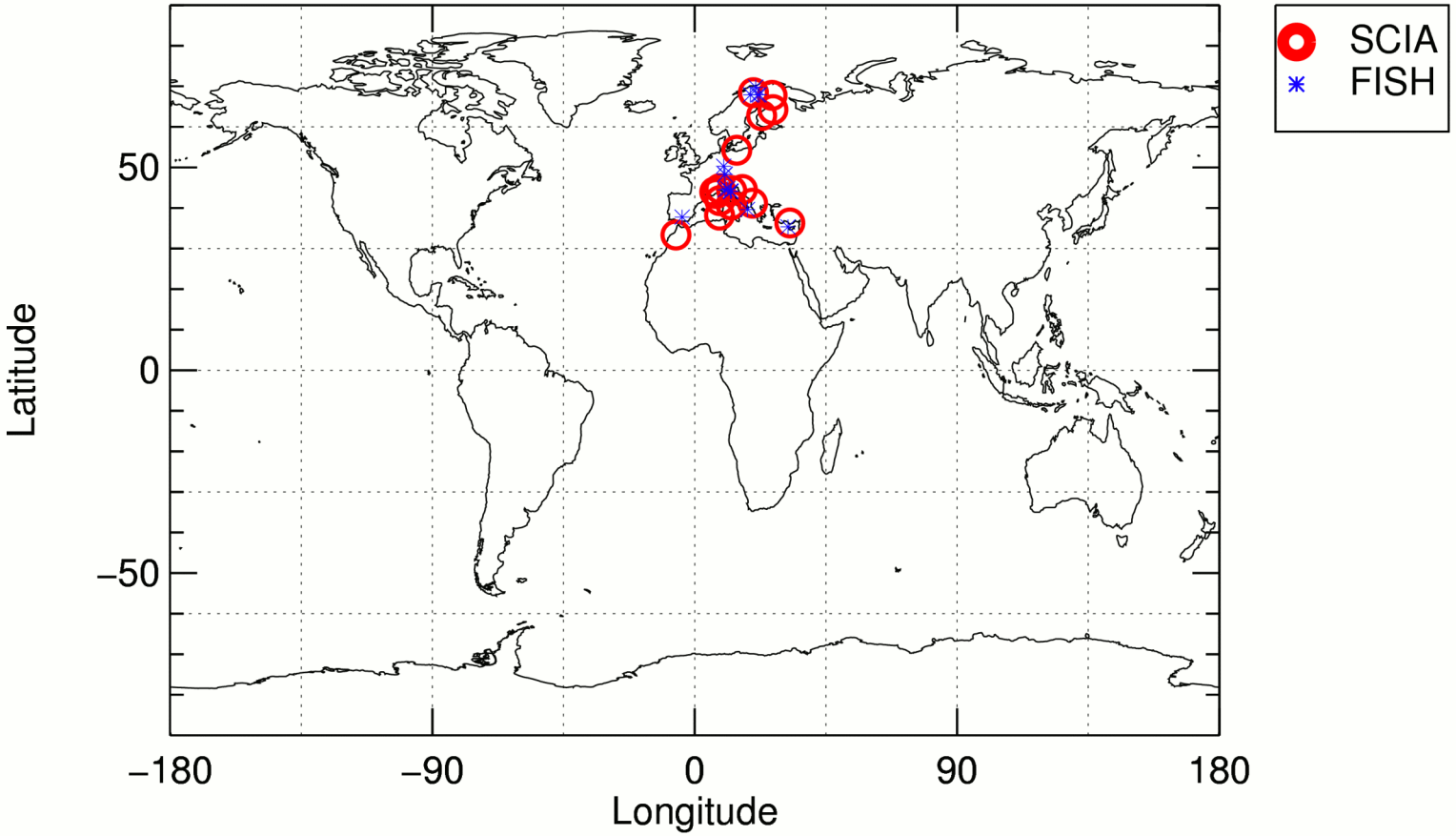
Statistics: Fast In situ Stratospheric Hygrometer (FISH)



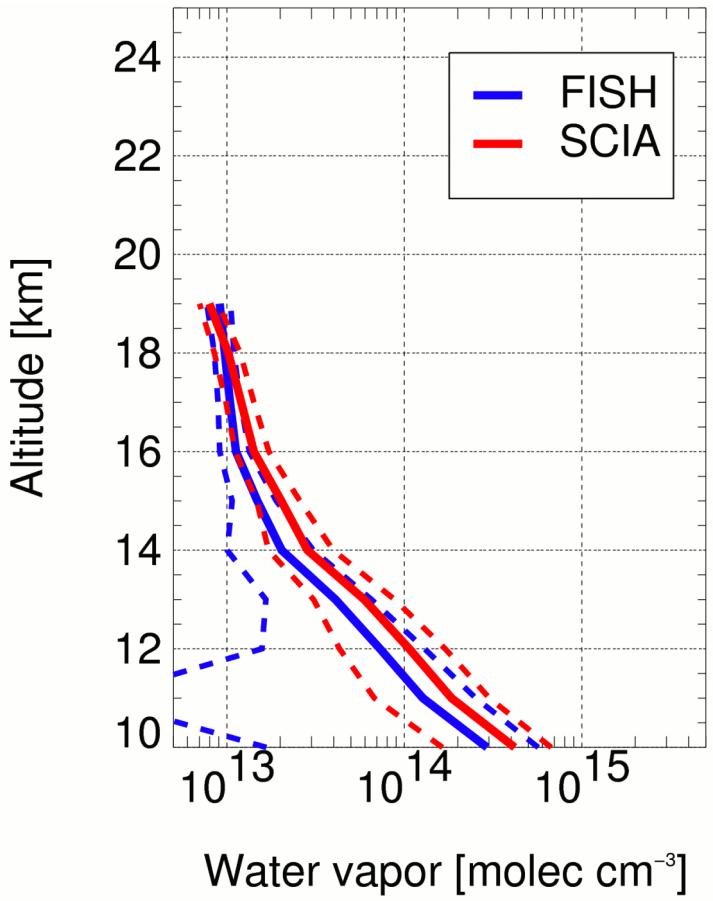
Airborne in situ observations using the Fast In situ Stratospheric Hygrometer

Collocation: < 1000 km, < 6 hours, tropical measurements are not considered

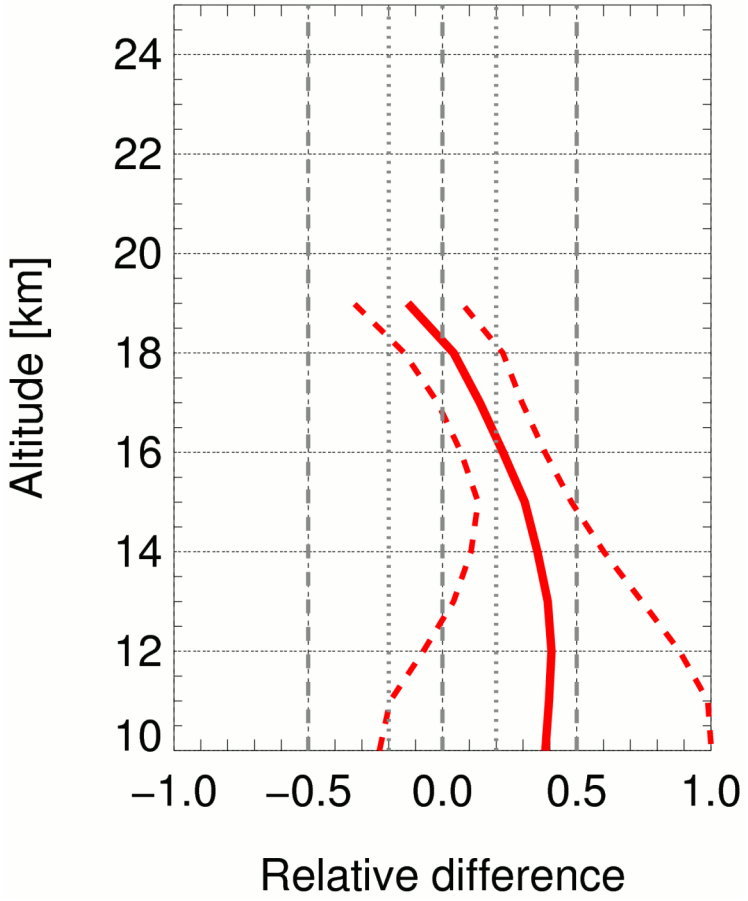
October 2002 - August 2006, SCIA: 102 profiles , FISH: 22 profiles

Statistics: Fast In situ Stratospheric Hygrometer (FISH)

Average profiles



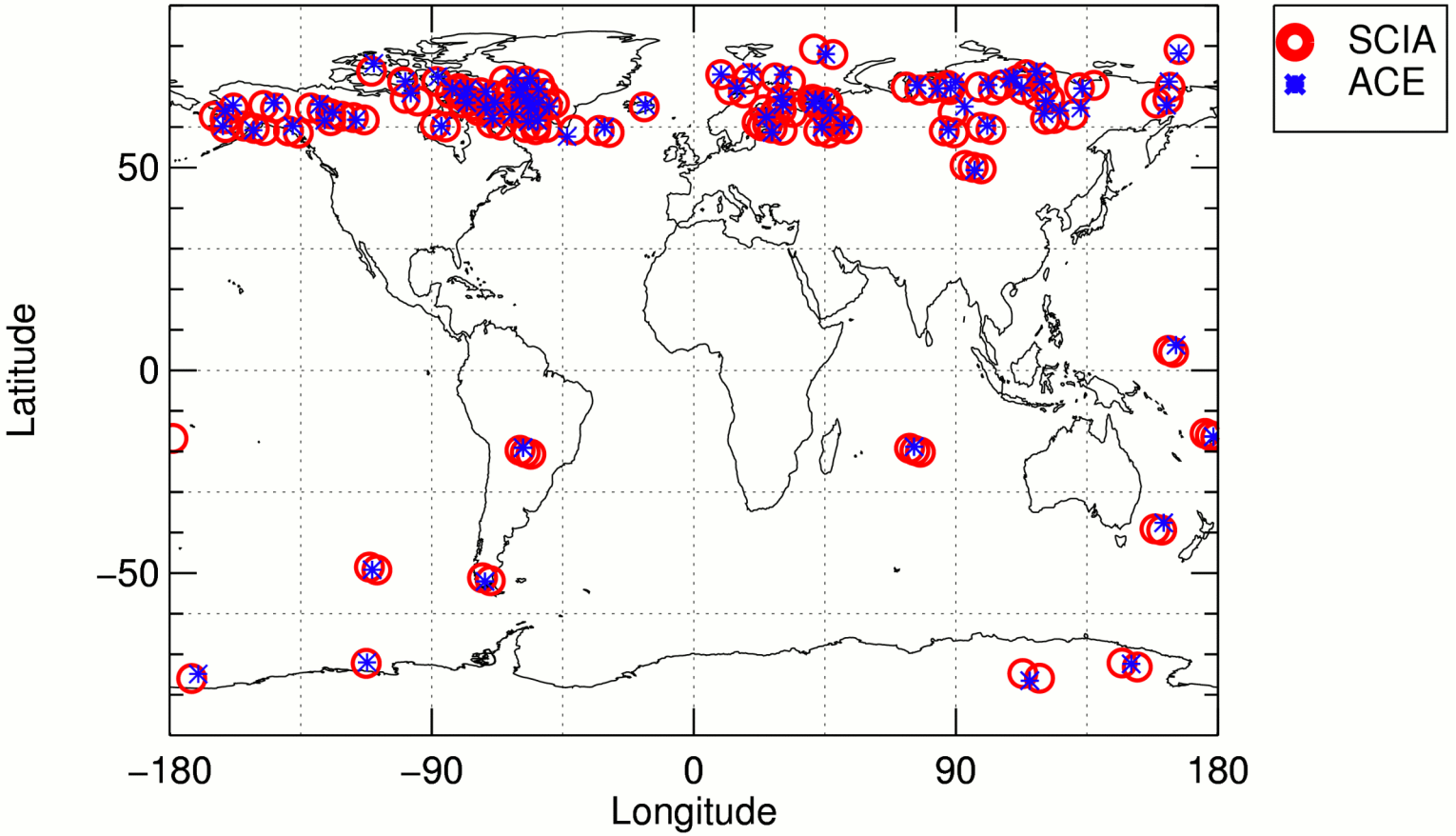
Mean relative difference



Dashed lines show standard deviations

We thank C. Schiller and N. Spelten (Research Center Jülich) for providing FISH data

Statistics: ACE-FTS



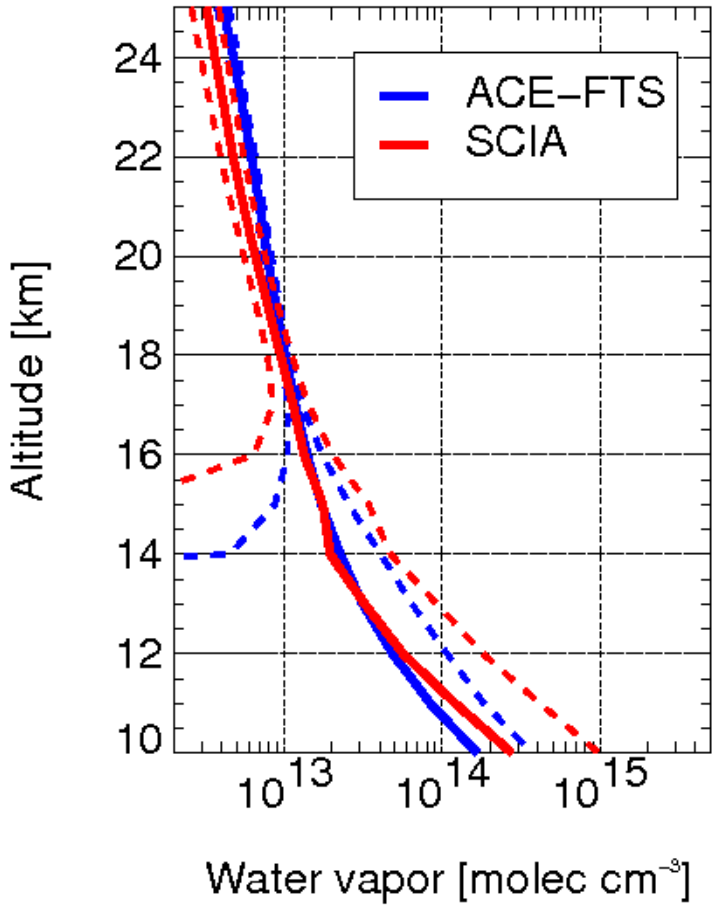
Atmospheric Chemistry Experiment - Fourier Transform Spectrometer

Collocation: < 2° Latitude, < 4° Longitude, < 4 hours

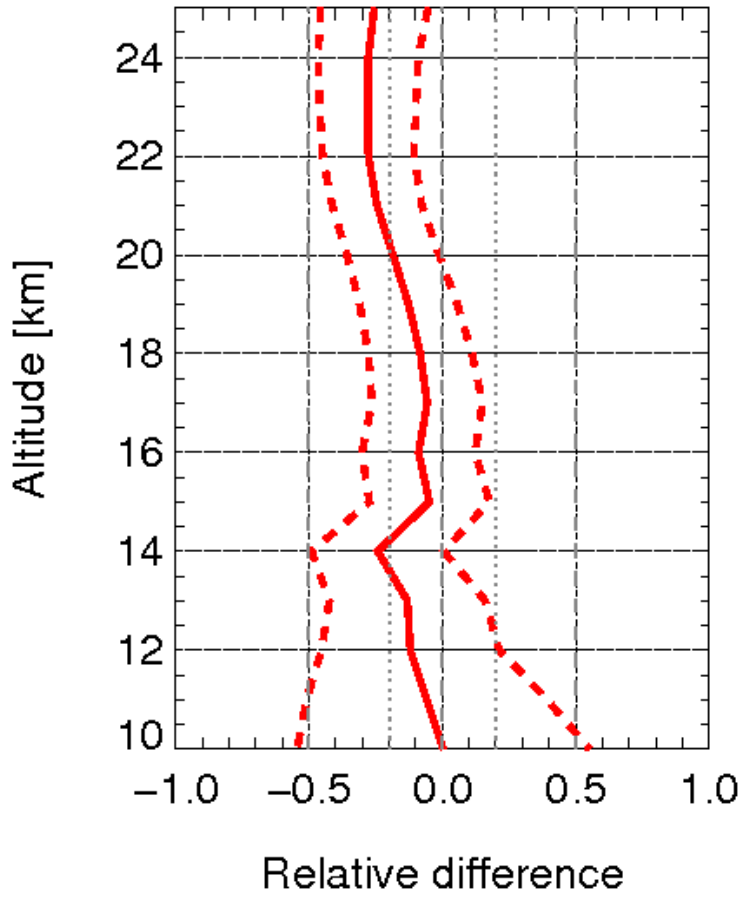
January 2005 - August 2007, 139 profiles

Statistics: ACE-FTS

Average profiles



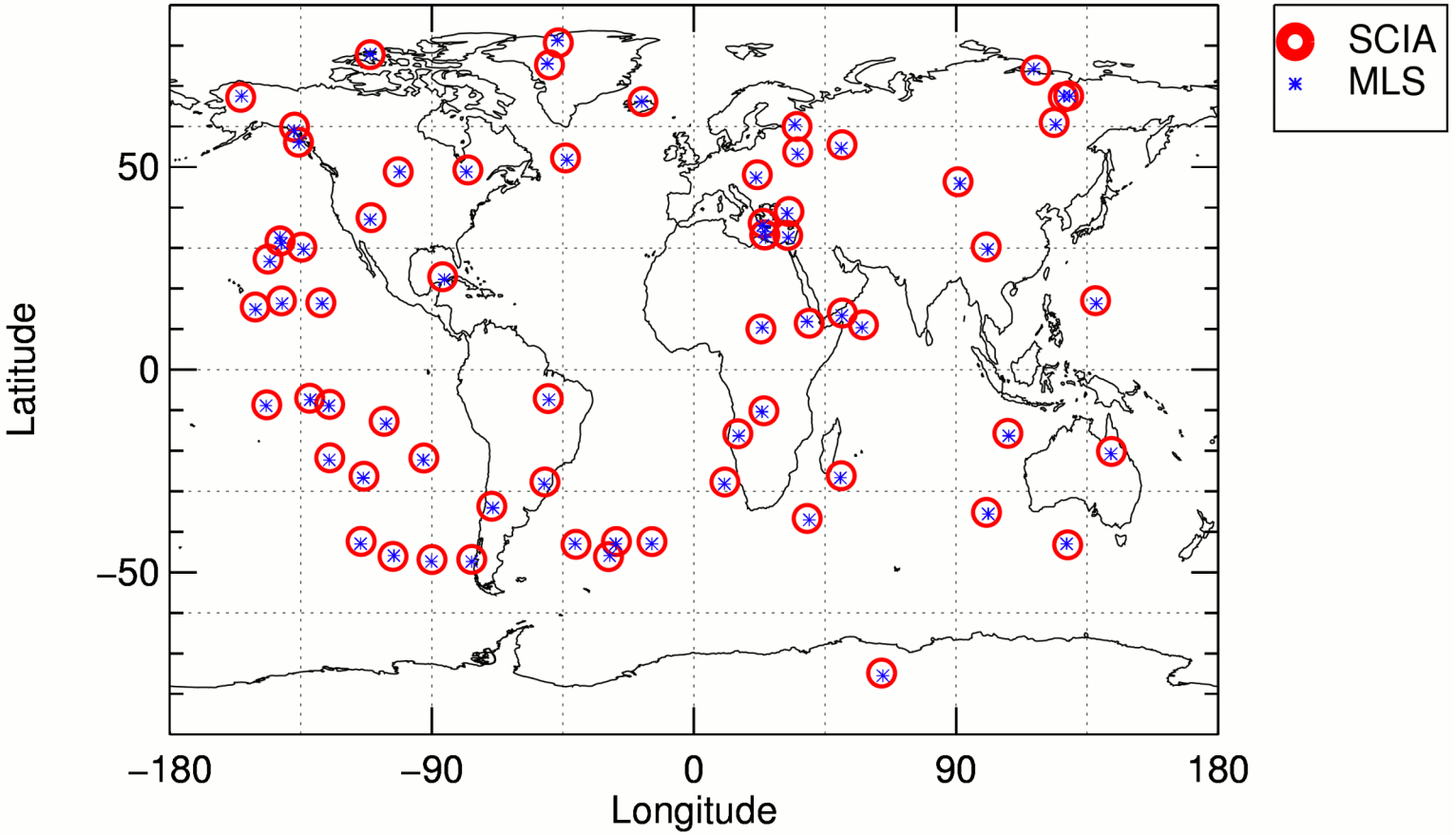
Mean relative difference



Dashed lines show standard deviations

We thank the Canadian Space Agency for providing ACE-FTS data

Statistics: MLS



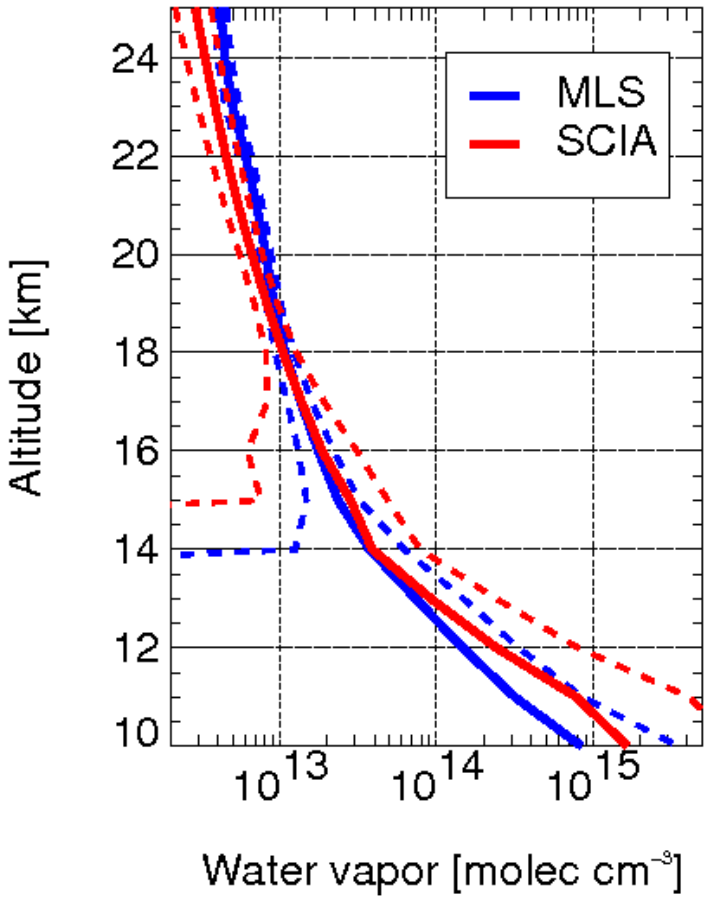
Microwave Limb Sounder (MLS) aboard the EOS-Aura

Collocation: < 100 km (10 km, < 60° Latitude), < 5 hours

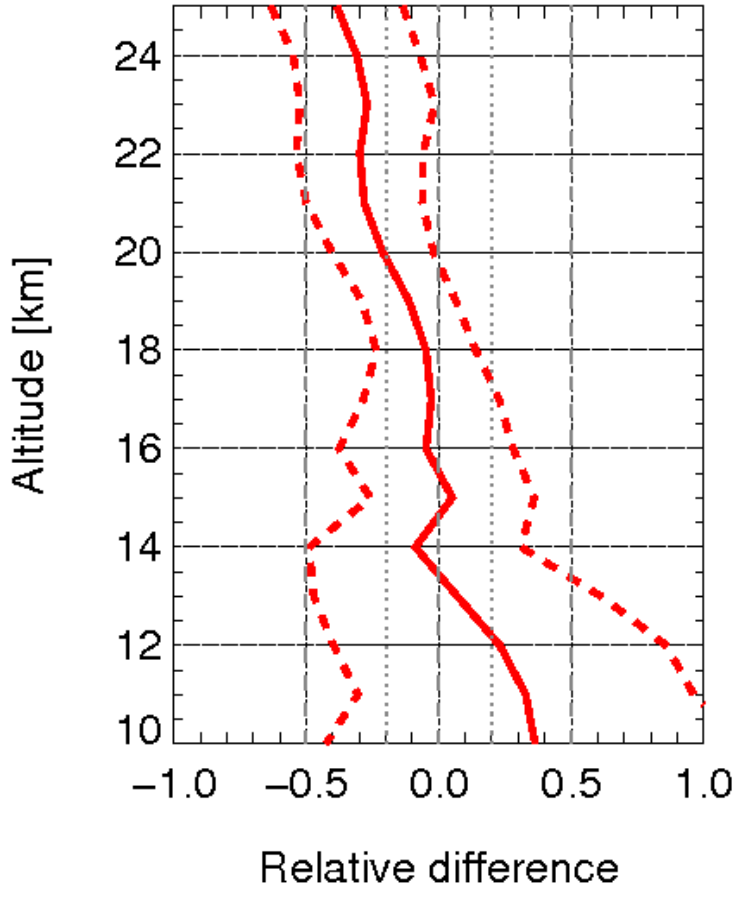
January 2005 - September 2008, 67 profiles

Statistics: MLS

Average profiles

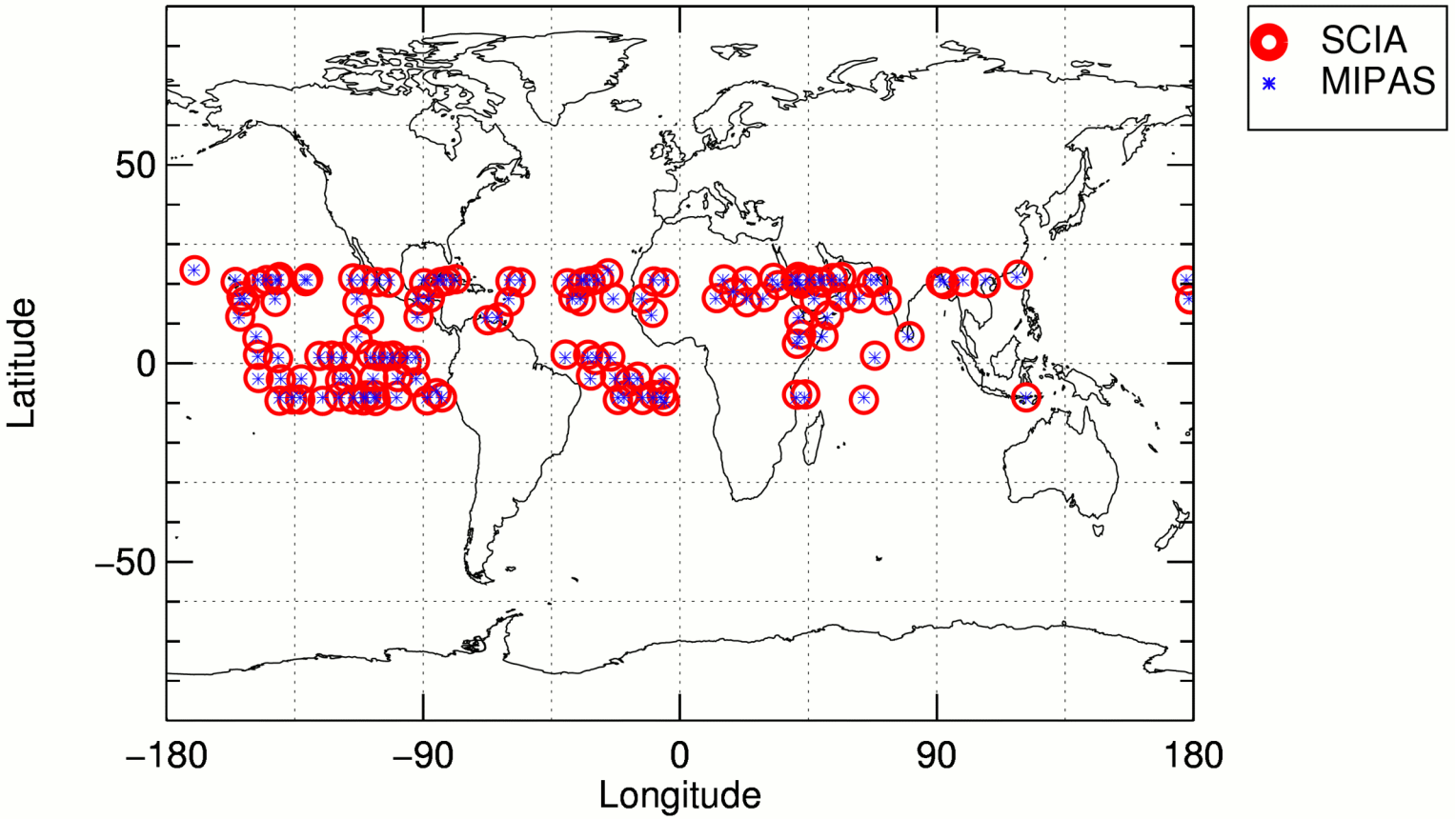


Mean relative difference



Dashed lines show standard deviations

Statistics: MIPAS



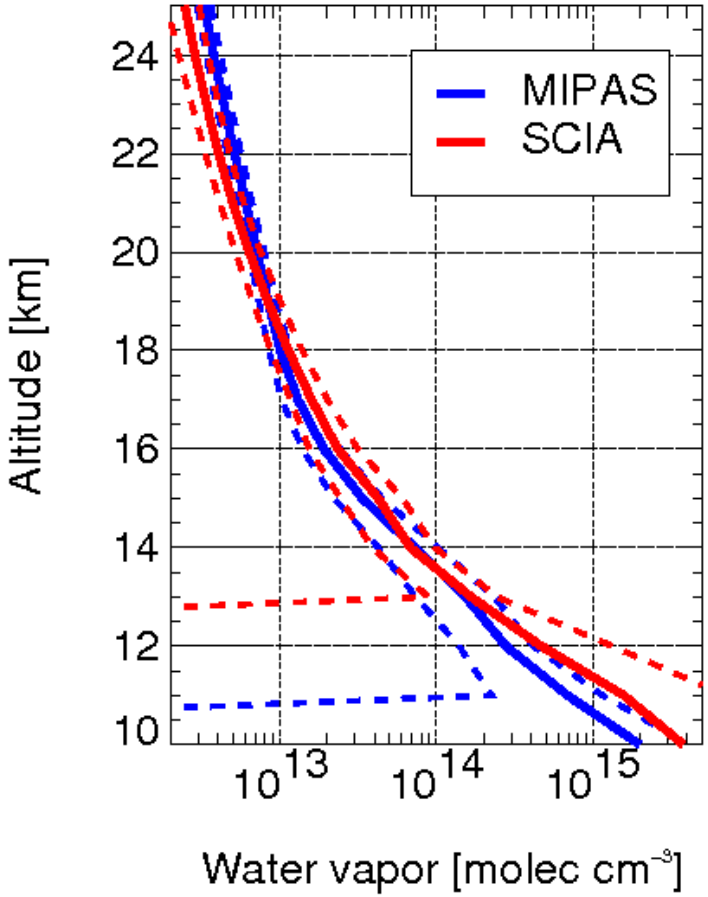
Michelson Interferometer for Passive Atmospheric Sounding (MIPAS)

Collocation: < 100 km, < 60○ Latitude, < 5 hours

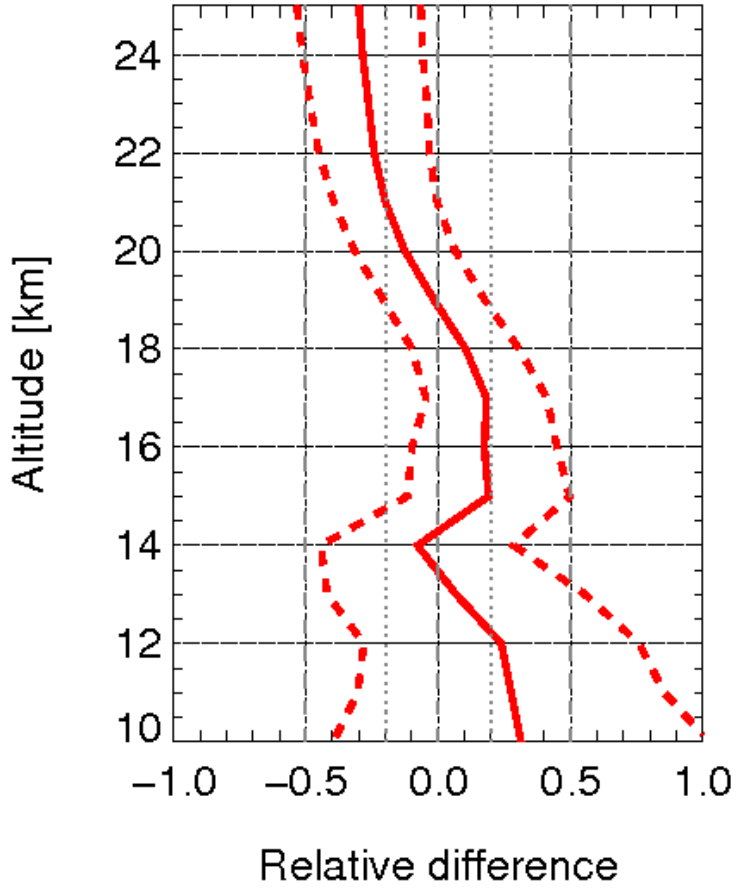
September 2003 - March 2004, 137 profiles

Statistics: MIPAS

Average profiles



Mean relative difference



Dashed lines show standard deviations
MIPAS data of version 30_13 were used

Conclusions

- A retrieval algorithm to obtain the vertical distributions of the water vapor in the lower stratosphere and upper troposphere from SCIAMACHY limb measurements in near infrared spectral range is developed. Retrievals are successfully performed.
- The retrieval algorithm is found to have best sensitivity between 12 and 21 km. The retrieval accuracy in this altitude range is estimated to be about 20 %.
- Comparisons with results of other instruments show a good agreement between 12 and 20 km (with exception of FISH where the difference reaches 30 – 40% below 15 km).
- Above 21 km there appears to be a dry bias in the SCIAMACHY data (30% with respect to satellite and 10 -20% with respect to balloon data).
- More comparisons are needed to quantify the latitudinal dependence of the observed differences.