Accuracy of limb sounding humidity data of the uppermost tropical troposphere

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The Odin satellite
A collaboration between Sweden, Canada, France and Finland

- Launched 2001
- Two instruments
- SMR:
  - 480 - 580 GHz
  - backend coverage $\approx 2$ GHz
  - several observation modes
  - stratospheric mode used here
- OSIRIS:
  - 280 - 800 nm + 1.27 $\mu$m
First UT retrieval principle
Only low tangent altitude below 9 km used

Thermal emission

Low gas absorption

High gas absorption

Lower troposphere

Tropopause

Odin
First UT retrieval principle
Only low tangent altitude below 9 km used

Thermal emission
Scattering
Low gas absorption
High gas absorption
Odin-SMR spectra
Measured and simulated for different ice water paths (IWP)
First SMR UT retrieval approach

- Limited to tropical latitudes ($\pm 30^\circ$)

- Water vapour
  - relative humidity ($\%RH_i$) around 12 and 15 km
  - vertical resolution $\approx 4$ km
  - high random error due to calibration issues (30/50 $\%RH_i$)
  - comparably low systematic error expected (max 20 $\%RH_i$)
  - $\leq 8\%$ totally masked by clouds (set to 100 $\%RH_i$)

- Cloud ice mass
  - IWP above $\approx 12$ km
  - cloud detection threshold $\approx 4$ g/m$^2$
  - homogeneous (1D) clouds assumed
  - a particle size distribution (PSD) must be assumed
Distribution comparisons
Relative occurrence of measured %RH

Flight corridors of MOZAIC @ 12km

“Cloud free” regions @ 15km
Mean water vapour fields
Multi-year averages

12 km

15 km

[Diagrams showing mean water vapour fields at 12 km and 15 km altitudes for Odin-SMR, Aura-MLS, and UARS-MLS.]
Comparison of seasonal regional averages

- Systematic error < 15 %RH$_i$ for all instruments?
Comparison of mean partial IWPs
Multi-year averages

Overall official means:
- SMR: 4.2 g/m²
- MLS: 3.7 g/m²
- CloudSat: 9.6 g/m²

SMR and MLS both use MH97 particle size distribution (PSD)

CloudSat mean with MH97 is 6.3 g/m²
Distribution comparisons
Relative occurrence of retrieved partial IWP

- Assumed 1D clouds cause systematic underestimation
  - coarse correction term now applied
Comparison of CloudSat and GCM mean IWP
All GCMs used by IPCC 2007
Summary

- Odin-SMR can measure water vapour down to \( \approx 11 \text{ km} \)
  - full potential not yet used

- UARS MLS, Aura MLS and Odin-SMR humidity retrievals:
  - “all weather” retrievals (limited cloud interference)
  - OK agreement between PDFs, and with MOZAIC
  - local mean values differ with \(< 15 \% \text{RH}_i\)
  - strong indications on good accuracy for all 3 instruments

- Improved cloud ice mass retrievals available
  - particularly through CloudSat, but also MLS and SMR
  - not shown:
    - cloud ice significant part of the water budget above 10 km in regions of strong convection
    - final moistening effect?
Vertical transport

**Tropical Tropopause Layer and Deep Convection**

- **17 km**: Overshooting convection
- **15 km**: Deep convective heating
- **11 km**: Deep outflow layer
- **5 km**: Shallow outflow layer
- **2 km**: Shallow convection

**Key Features**
- **CPT**: Clear stratospheric circulation
- **TTL**: Tropical tropopause layer
- **Q_clear**: Clear sky radiative cooling
- **CBL**: Convective boundary layer

**Temperature Gradient**
- 180K to 300K

Figure by SPARC
Humidity retrieval procedure

\[ T_B \text{ [K]} \]

Humidity [%RH\text{i}]

501.2 GHz
544.4 GHz

Clear-sky RH\text{i}

Weight
Saturation, 100%

Cloud signal $\Delta T_B$
“The ice fraction”: ice mass / total water mass
Based on Aura MLS and CloudSat official retrievals