Odin-SMR retrievals of water in the tropical tropopause layer

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Introduction

Cloud ice mass and water vapour in the tropical upper troposphere are two connected components controlling the Earth's radiation balance, thus affecting the Earth's climate. Furthermore, the transport of water vapour from the upper troposphere to the stratosphere can be connected to high altitude ice clouds.

Odin-SMR (Sub-Millimetre Radiometer) is a passive limb-sounding radiometer operating at around 500 GHz and has the possibility, opposite to more traditional sensors, to observe these quantities simultaneously.

Retrieval scheme [1,2,3], results, and comparisons of cloud ice mass [4] (partial ice water path above 12 km, where mean cloud ice mass results from Odin-SMR have been shown to be close to Aura-MLS but more than 50% lower than CloudSAT) and humidity [5] (in two layers around 200 and 130 hPa, where the humidity climatology derived from Odin-SMR was shown to be consistent, with differences less than 15%, to UARS-MLS, Aura-MLS, and MIPAS) have been published.

Regarding the cloud ice mass retrievals, two major retrieval uncertainties have been identified, the so called beam filling effect, and uncertainties in assumed cloud particle size distribution (PSD). The beam filling effect arises from cloud inhomogeneity and non-linear radiative transfer. The work presented here seeks to improve the retrievals, by using a more sophisticated retrieval scheme. The beam filling effect is treated in detail, by using realistic *a priori* cloud structure data.

Odin-SMR

- limb sounder which scans the atmosphere from 5-70 km in the orbit plane
- operates around 500 GHz
- launched in 2001and still in operation
- sun-synchronous orbit which passes over the tropics around 06:00 and 18:00 local time
- lowest tangent point measurements have sensitivity to high altitude ice clouds (Fig. 2) and humidity

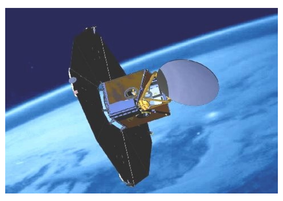

Figure 1. Odin.

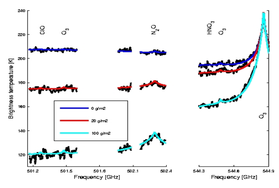

Figure 2. Measured and simulated spectra of Odin-SMR stratospheric mode.

Bayesian retrieval scheme
atmospheric and cloud states

The Bayesian retrieval scheme is based on generating a large dataset of realistic atmospheric/cloud states from *a priori* data and corresponding simulated mesurements. This is achieved by combining:

- 2-D cloud structure data (Fig. 3) from the CloudSat 94 GHz Cloud Profiling Radar, and a Fourier transform algorithm program to generate stochastic 3-D cloud structure fields (Fig. 4), in order to deal with cloud inhomogeneities

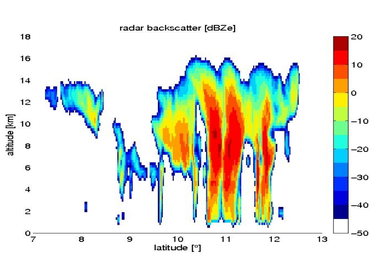

Figure 3. 2-D radar backscattering measurement by CloudSAT.

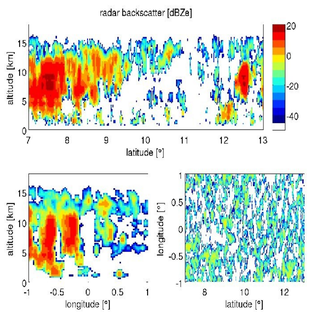

Figure 4. Example of a stochastic 3-D radar backscattering field generated from Fig. 3. Upper panel shows a longitudinal cross-section, lower left panel shows a latitudinal cross-section, and lower right panel shows a cross-section in the altitude dimension.

- atmospheric data from ECMWF to include the variability of temperature and water vapor in the atmospheric states
- in-situ collected cloud microphysics data from sensors onboard airplanes, is used to convert the backscattering fields to ice water content fields (Fig. 5)

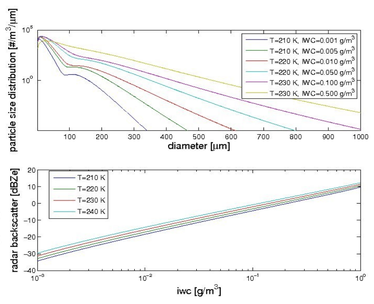

Figure 5. Upper panel shows example of the parameterised PSD used in the study. The PSD depends on temperature and IWC. The lower panel shows calculated dBZe as function of IWC and temperature.

Bayesian retrieval scheme
forward model simulations and inversions

- a radiative transfer Monte Carlo (ARTS-MC) forward model to simulate measurements (Fig. 6 & 7)

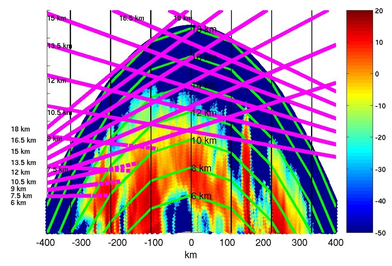

Figure 6. Odin- SMR line of sights.

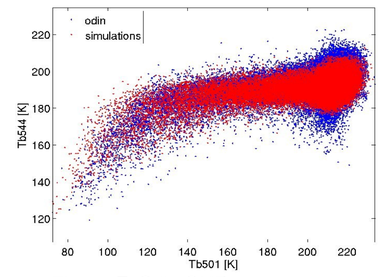

Figure 7. Odin-SMR measurements and simulated measurements.

- a Bayesian retrieval algorithm, to deal with the non-uniqueness of the inverse problem (Fig. 8-11)

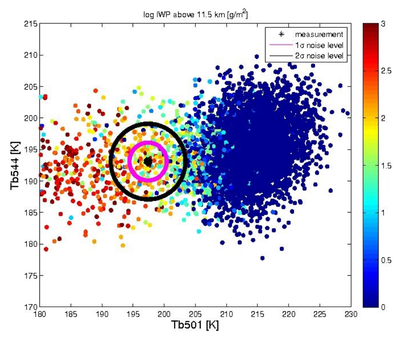

Figure 8. Retrieval illustration.

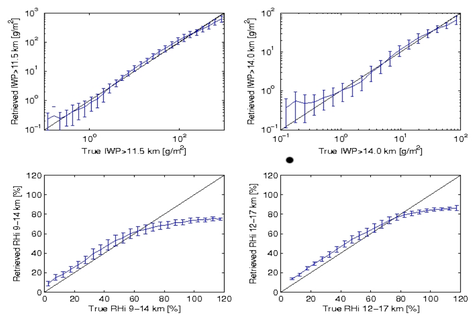

Figure 9. Test inversion statistics.

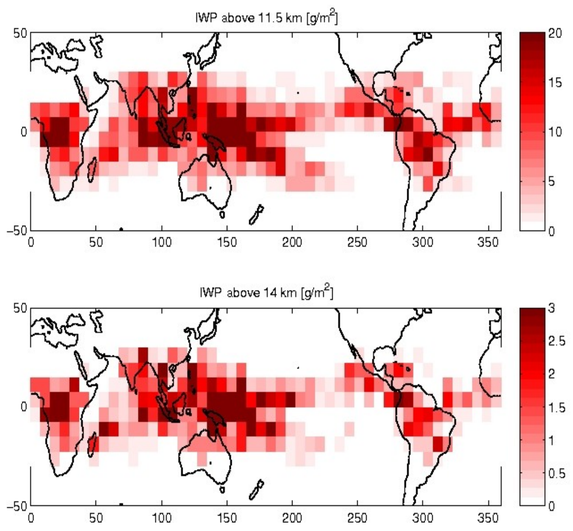

Figure 10. Multi year mean IWP above 11.5 km (top panel) and 14 km (lower panel) fields from Odin-SMR.

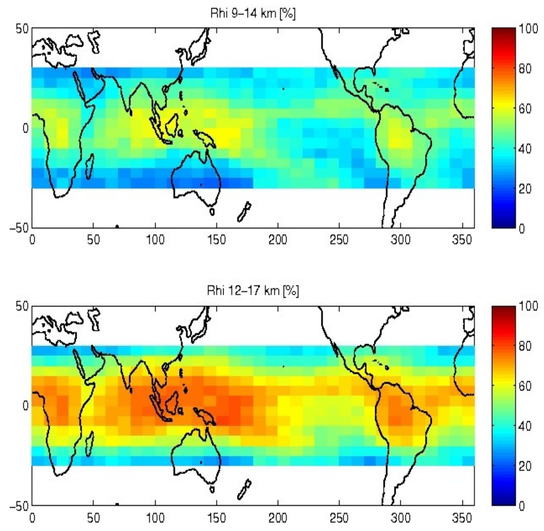

Figure 11. Multi year mean relative humidity fields between 9-14 km (top panel) and 12-17 km (lower panel) from Odin-SMR.

Conclusions and future work

By using a Bayesian retrieval algorithm, cloud structure inhomogeneities is now handled more stringently than before in the retrievals of cloud ice mass from Odin-SMR. The method used is general, and can be applied to similar instruments. The work is ongoing, and a more sophisticated treatment of the cloud microphysics is planned. Since Odin is sampling around 06:00 and 18:00 local time, and CloudSat and Aura MLS around 01:30 and 13:30, the data can as example be combined to study diurnal cycles of tropical upper tropospheric water.

Related work

[1] Eriksson *et al, The water budget of the uppermost tropical troposphere, poster @ SPARC, 2008*

[2] Eriksson *et al*. *First Odin sub-mm retrievals in the tropical upper troposphere: ice cloud properties*, Atmos. Chem. Phys., 2007

[3] Ekström *et al*. *First Odin sub-mm retrievals in the tropical upper troposphere: humidity and cloud ice signals*, Atmos. Chem. Phys., 2007

[4], Eriksson et al, *Comparison between early Odin-SMR, Aura MLS and CloudSat retrievals of cloud ice mass in the upper tropical troposphere*, Atmos. Chem. Phys., 2008

[5] Ekström et al. *Comparison of satellite limb-sounding climatologies of the uppermost tropical troposphere,* Atmos. Chem. Phys., 2008

Acknowledgment

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