Odin-SMR measurements of tropical upper tropospheric water

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Overview

- For inversion details see: Rydberg et al. AMT, 2009

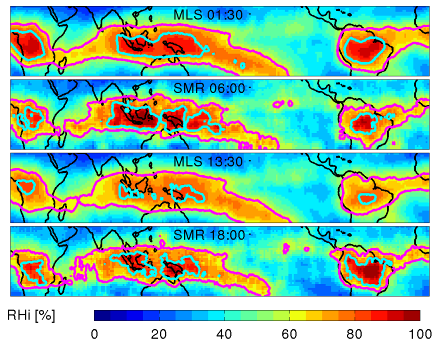
- Single spectra with tangent altitudes below 9 km
  - footprint $\approx$ 40 x 2 km^2
- The dataset
  - + 8 years
  - - sparse
- Relative humidity [%]
  - + moderate/low cloud impact on RH_i retrievals
  - - individual RH_i a priori influenced (or noisy)
- Ice water content [g/m^3]
  - + covers most important range, no saturation
  - - cloud inhomogeneities and particle size distribution (PSD) are main retrieval uncertainties

- High random errors, but what about systematic errors?

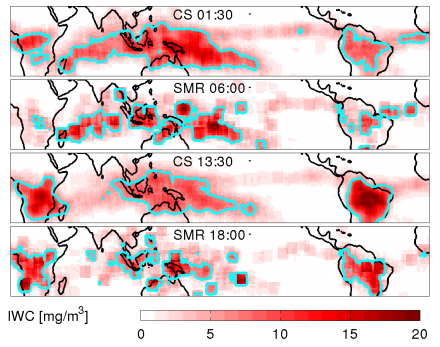
RH$_i$ and IWC from MLS, CloudSat and SMR

Long term averages for NH winter+spring, 11 - 15 km

Relative humidity (RH$_i$):



Ice water content (IWC):

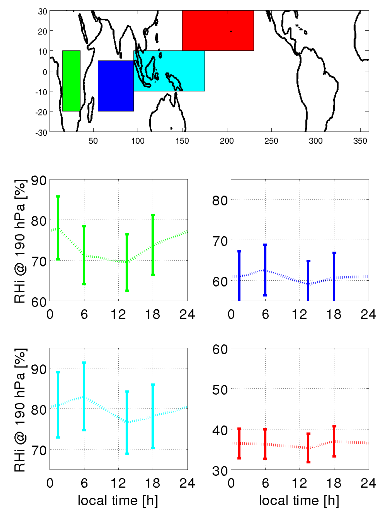


- Different time spans covered / Chalmers CloudSat inversions
- Total averages
  - SMR 0.75 %RH$_i$ below MLS
  - SMR here 19 % below CloudSat

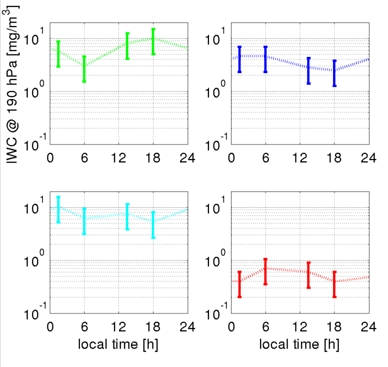
Regional diurnal variations

MLS and CloudSat: 1.30/13.30, SMR: 6.00/18.00

Relative humidity (RH_i):



Ice water content (IWC):

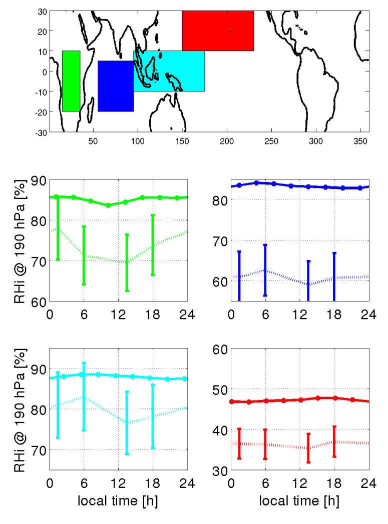


- RH_i: ±10 % !?
- IWC: ±40 % (due to PSD)

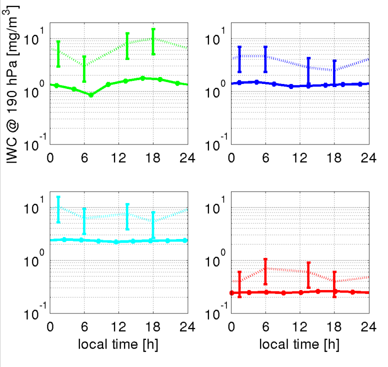
Comparison between satellite and ECHAM

Precipitating part of IWC missing for ECHAM

Relative humidity (RH_i):



Ice water content (IWC):

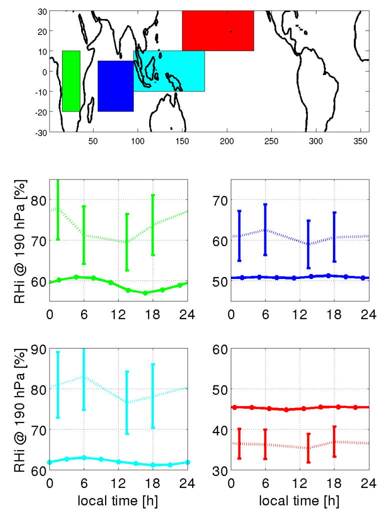


- Not complete IWC for ECHAM!

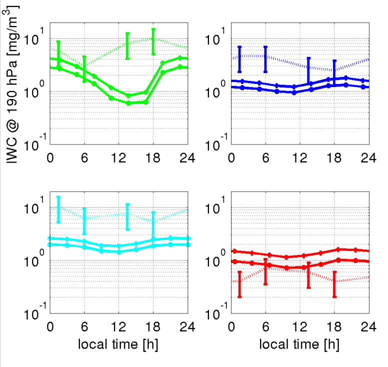
Comparison between satellite and another GCM

Preliminary results

Relative humidity (RH_i):



Ice water content (IWC):

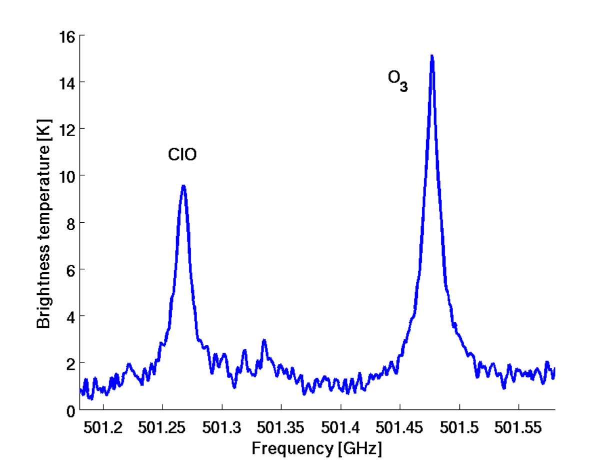


- Upper model line estimate of complete IWC

Inversion issues

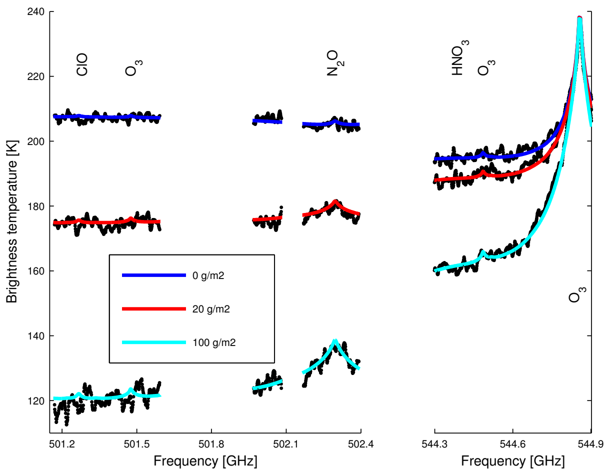
Example on optically thin spectrum

Average of some spectra around $z_t = 35$ km



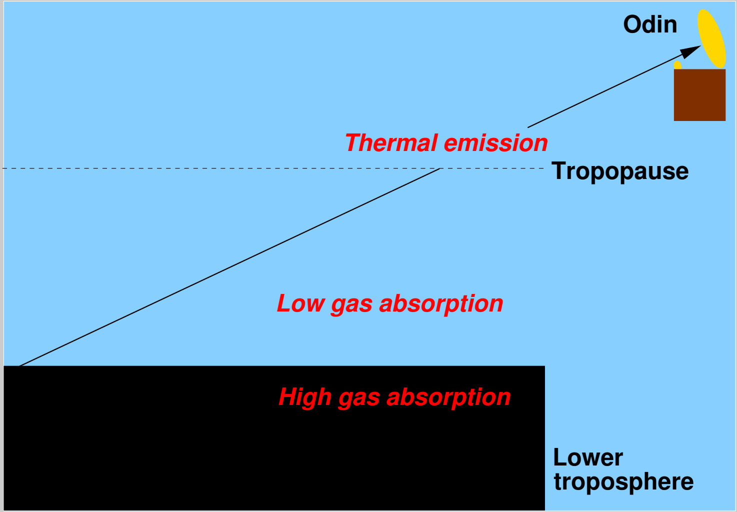
Optically thick Odin-SMR spectra

Representative examples for $z_t \leq 9\,\mathrm{km}$

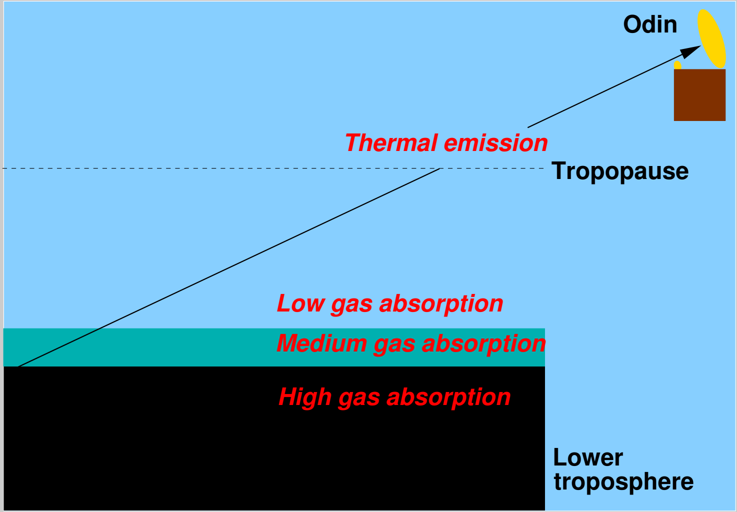


- All radiative transfer calculations performed by ARTS

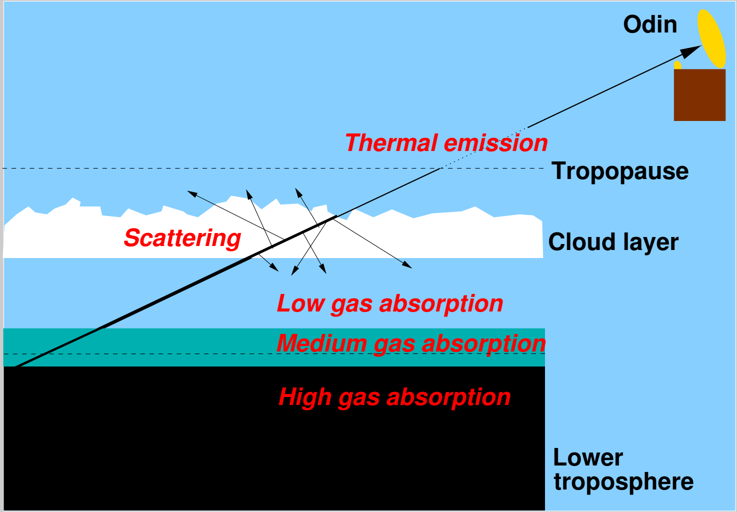
Measurement principle



Measurement principle

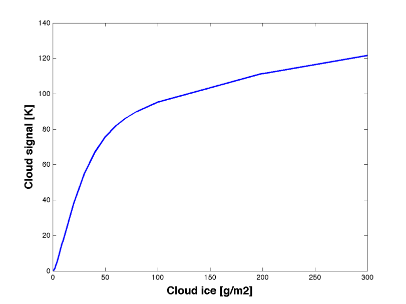


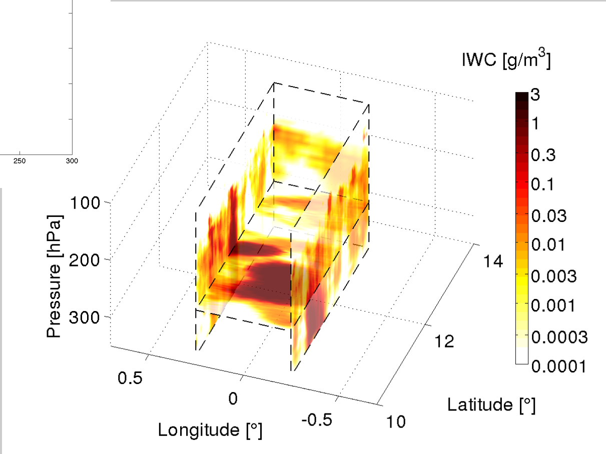
Measurement principle



Cloud inhomogeneities must be considered

CloudSat used to generate 3D cloud scenarios





Bayesian Monte Carlo integration

Allows fast bayesian inversions with non-gaussian statistics

- Create a retrieval database ($\mathbf{x}_i$)
- Retrieved state ($\hat{\mathbf{x}}$) is a weighted mean of $\mathbf{x}_i$

$$\hat{\mathbf{x}} = \frac{\sum_i \mathbf{x}_i P(\mathbf{y}|\mathbf{x}_i)}{\sum_i P(\mathbf{y}|\mathbf{x}_i)}$$

- where

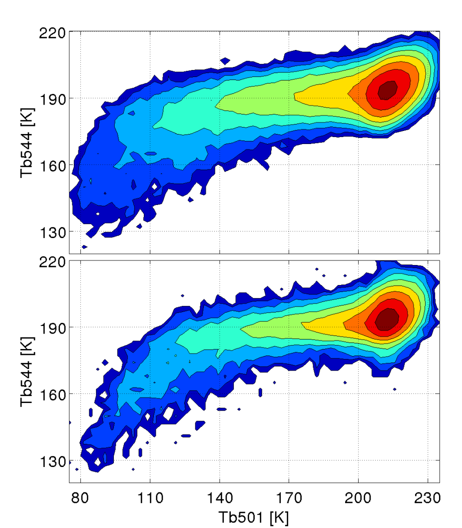
$$P(\mathbf{y}|\mathbf{x}_i) \sim \exp\left(-\frac{(\mathbf{y}-\mathbf{F}(\mathbf{x}_i))^T \mathbf{S}_e^{-1} (\mathbf{y}-\mathbf{F}(\mathbf{x}_i))}{2}\right)$$

+ Retrievals very fast when database is at hand
- Required size of database strongly dependent on $d_{\mathbf{y}}$

- Database must mimic reality

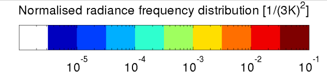
Quality of SMR retrieval database?

Comparison of brightness temperature distributions



◄ Database

◄ Observations



Conclusions

- Long, but sparse, dataset extracted
- Relative humidity
  - low cloud impact, but only average values useful
  - agreement with MLS
    - very good above 13.5 km
    - MLS wetter for high RH_i below ($\sim$10 RH_i)
  - improvements possible with “limb inversions”
- Ice water content
  - cloud inhomogeneities handled carefully
  - PSD assumptions: a problem for all sensors
  - good agreement with CloudSat (for same PSD)
- Details in Rydberg et al., *Atmos. Meas. Tech.*, 2009.

- The diurnal cycle in climate models is being studied
  - main problem is to get complete IWC out of models