Comparison of water vapor and cloud macrophysical properties derived from satellite sensors and from airborne remote sensing instruments on HALO

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1. Introduction

The representation of clouds is one of the largest sources of uncertainty in general-circulation and numerical weather prediction models. On a global scale, atmospheric water vapor and cloud macrophysical properties, e.g. size distribution and liquid water path (LWP), can be observed with the help of satellites, which, however, miss the small-scale features due to the coarse spatial resolution. Measurements with a finer resolution can be performed on airborne remote sensing platforms, such as the novel German High Altitude and LOng (HALO) range research aircraft. Within the NARVAL campaigns, HALO was equipped with a remote sensing suite consisting of a 26 channel passive microwave radiometer, cloud radar, water vapor lidar, spectrometer and drop sondes. The first campaign (NARVAL-South in December 2013) investigated cumulus clouds in the trade wind region.

Fig. 1: The HALO aircraft at the Barbados airport during the NARVAL-South campaign (left), cumulus cloud fields over the Atlantic Ocean [credits: C. Klepp] (right).

2. Instruments and measurement campaign

- **HAMP (HAlo Microwave Package)**

Radiometer: 26 channels spanning from 22 to 183 GHz, sensitive to water vapor, temperature and hydrometeor concentrations

Footprint at 13 km: from 1.2 km (K-band) to 0.6 km (183 GHz)

Radar: 36 GHz Pulsed Doppler radar

130 m footprint at 13 km

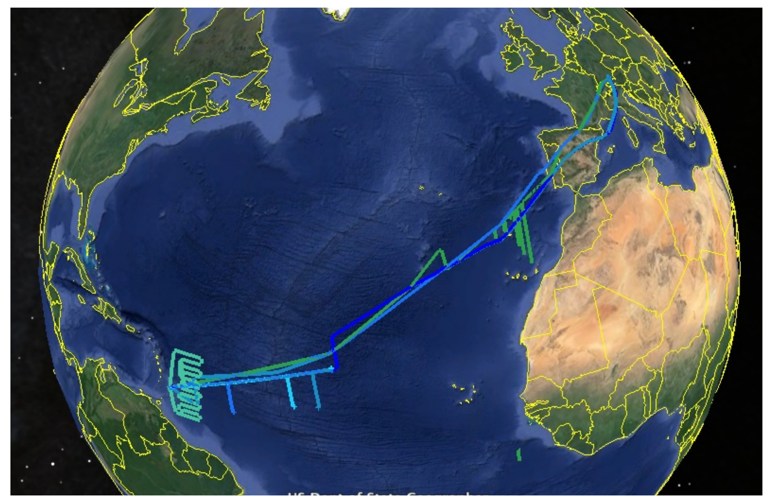
-38 dBZ sensitivity @ 5 km

- **HALO SR (Solar Radiation)**

UV/VIS and NIR spectrometer

Fig. 3: Remote sensing suite on HALO. From left to right: radiometer boxes, lidar and radar.

Fig. 2: NARVAL-South flight patterns.



NARVAL-South
10 – 21 December 2013

- 8 flights over tropical and subtropical Atlantic
- 75 dropsondes released
- Tropical boundary layer cloud formation and evolution

3. Retrieval validation

IWV – Integrated water vapor

- Regression-based retrieval using K-band and 90 GHz channels
- Comparison with dropsonde :
  RMS = 1.4 kg/m^2
  BIAS = 0.07 kg/m^2

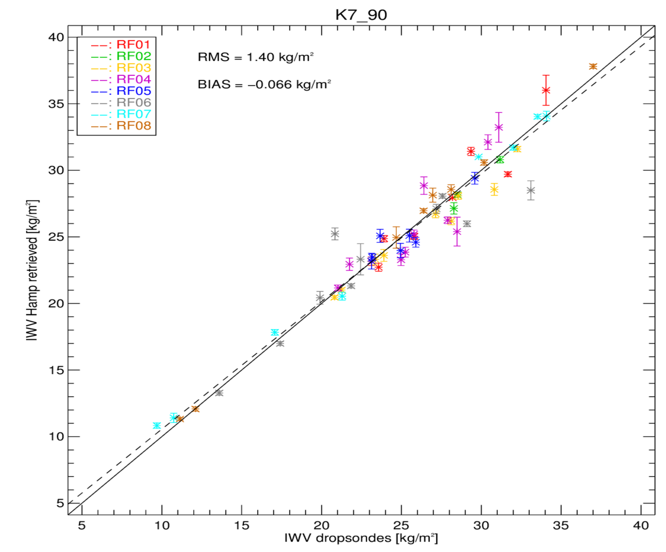


Fig. 5: IWV retrieved using HAMP (y axis) and measured by dropsondes (x axis).

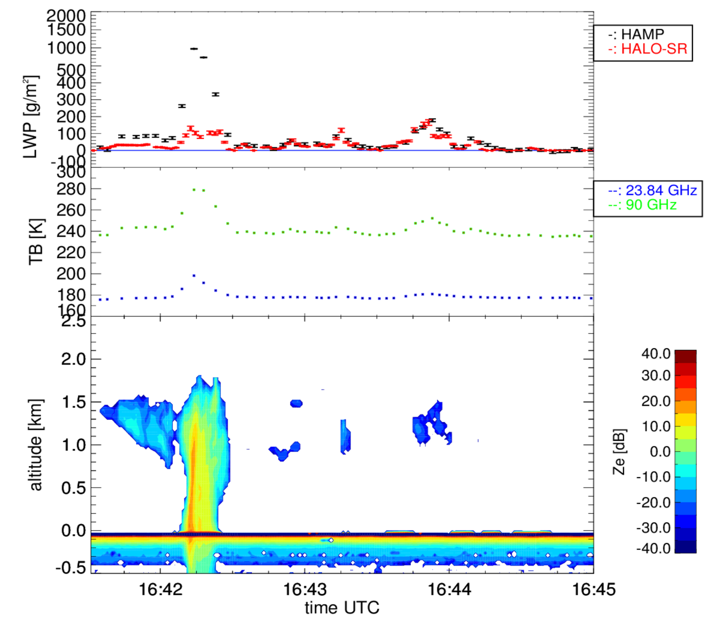


Fig. 4: *LWP retrieved using HAMP and HALO-SR (top), 22.24 and 90 GHz brightness temperatures (midlde), 36 GHz radar reflectivity (bottom).*

LWP – Liquid Water Path

LWP uncertainty : 8 g/m^2

- Independent LWP retrieval using HALO-SR data is in good agreement for shallow clouds
- For deeper clouds HALO-SR underestimate LWP due to vertical homogeneity assumption
- Possible rain contamination for LWP greater than 500 g/m^2

4. SSMIS and MODIS comparison

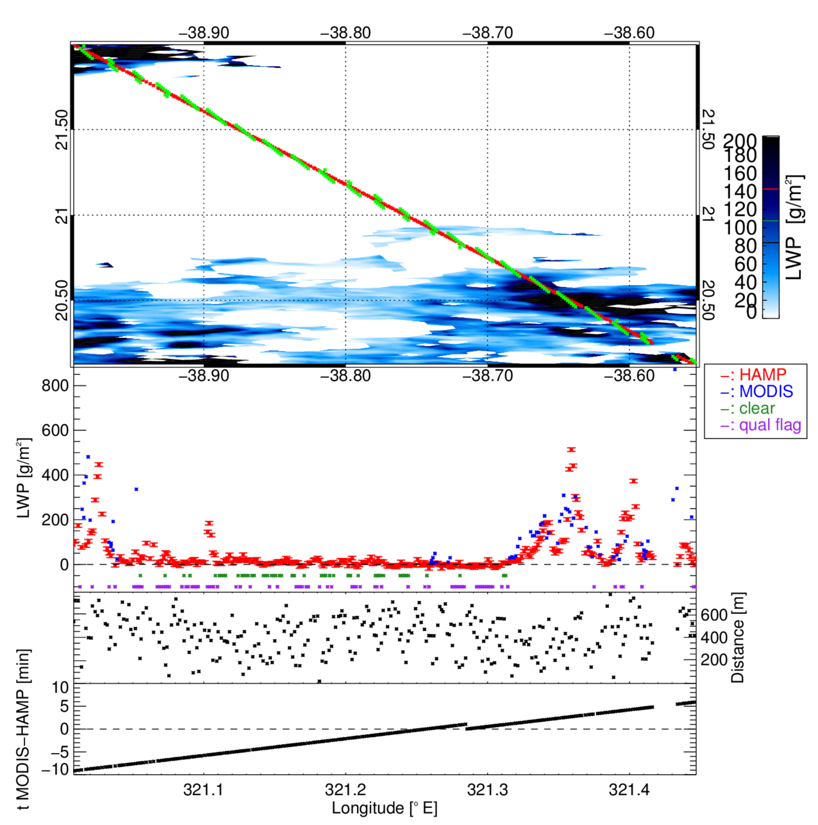


Fig. 6: *MODIS LWP and HALO flight track (top), MODIS and HAMP LWP retrieval and MODIS-HAMP center footprint distance (middle), MODIS-HAMP time difference (bottom). MODIS level 2 collection 5.1 data have been used.*

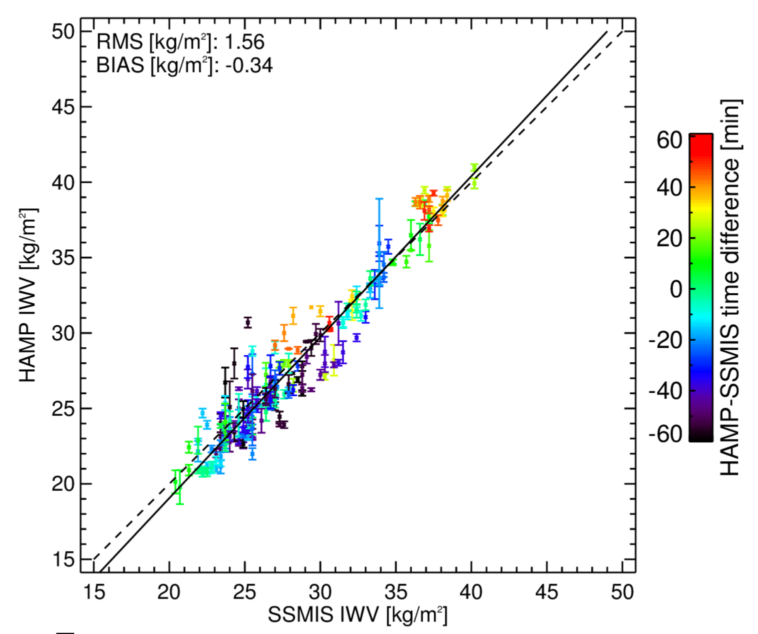


Fig. 7: IWV retrieved using HAMP and SSMIS. Gridded IWV data retrieved by RSS (Remote Sensing System) have been used.

- **SSMIS:** the retrievals agree within their uncertainties, with SSMIS slightly overestimating HAMP IWV.
- **MODIS:** overall good agreement with MODIS overestimating low (<200 g/m^2) LWP.

5. Macrophysical cloud properties

- A cloud mask has been developed using HALO-SR data
- 70 % of clouds have horizontal dimension smaller than 2 km
- ○ Synergy with cloud radar and lidar will be developed to improve this product

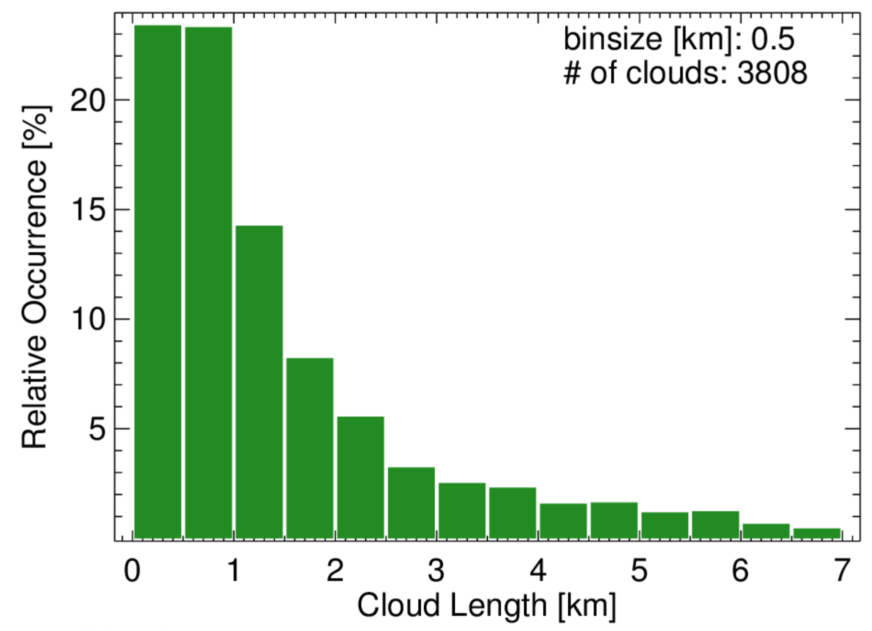


Fig. 9: Cloud length distribution with 500 m binsize.

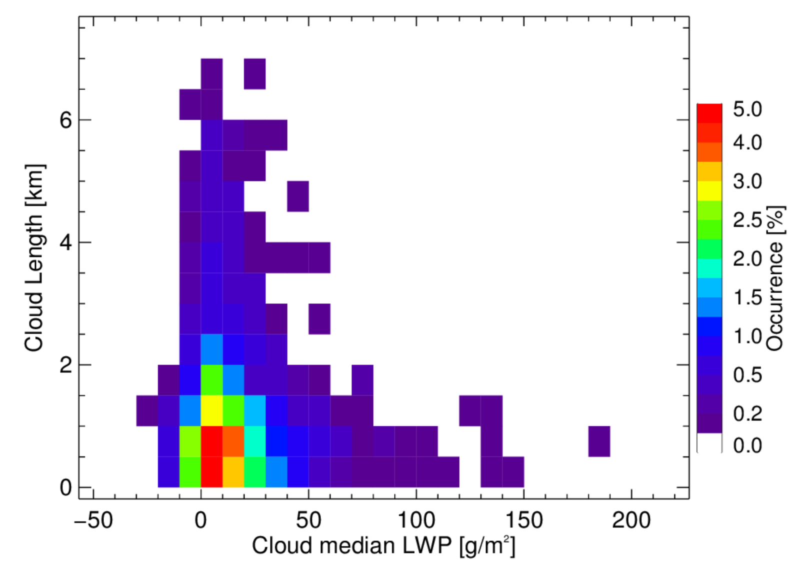


Fig. 8: 2D histogram of cloud length and median LWP.

- Combining cloud length and LWP can give insight into the cloud development stage
- ○ Use LES simulations to interpret the tales of the distribution

6. Conclusion

- The German research aircraft HALO successfully accomplished two measurements campaigns with its remote sensing suite on-board.
- Integrated water vapor retrieval has been developed and shows good agreement with dropsonde measurements (RMS = 1.4 kg m^{-2}) and SSMIS retrieval (RMS = 1.6 kg m^{-2}).
- Liquid water path retrieval have been developed for HAMP radiometer and compared with two independent optical retrievals, showing good agreement.
- A MODIS-like cloud mask retrieval has been developed for the HALO-SR spectrometer, allowing the combination of cloud length and LWP information for the same cloud field.

7. Future work

- Separate analyses for precipitating and non-precipitating clouds
- Evaluate LES model performance using airborne data
- Combined LWP and cloud size horizontal distribution are derived to give guidelines for the development of parameterization for atmospheric models

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