Comparative Characterisation of Maritime Clouds in Dry and Wet Season over the Tropical North Atlantic by Airborne Observations

Marek Jacob[1], F. Ament[2,6], A. Ehrlich[3], T. Kölling[4], H. Konow[2], M. Mech[1], E. Orlandi[5], S. Schnitt[1], K. Wolf[3], S. Crewell[1]
[1]University of Cologne, Germany, [2]Universität Hamburg, Germany, [3]Universität Leipzig, Germany, [4]Ludwig-Maximilians-Universität München, Germany,
[5]Radiometer Physics GmbH, Meckenheim, Germany, [6]Max Planck Institute for Meteorology, Germany

1. Motivation

- The representation of trade wind clouds still poses a major uncertainty in climate models.
- To gain a better understanding of the relevant processes and to evaluate process-model performance detailed observations are needed that are not available from the current satellite fleet.

2. Campaign Setup

Next-Generation Aircraft Remote-Sensing for Validation campaigns (NARVAL) using the High Altitude Long range research aircraft (HALO).

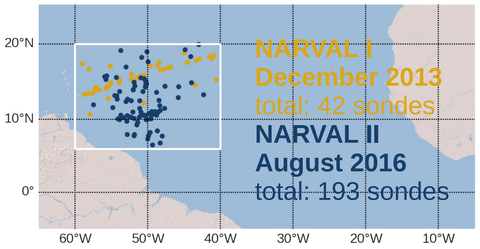
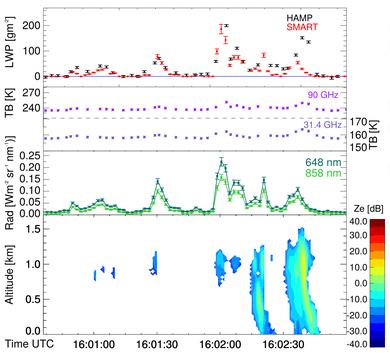


Fig 1: Operational area represented by a subset of all released drop sondes.
White box: Area of investigation

- HALO Microwave Package (HAMP)
  - passive: Microwave Radiometer (MWR) with 26 channels: 22 – 200 GHz
  - active: 35.6 GHz Cloud Radar
- Spectral Modular Airborne Radiation measurement system (SMART)
  - Spectral solar irradiance ($F^{\downarrow}$, $F^{\uparrow}$) and radiance ($I^{\uparrow}$)
  - Spectral range: 300 – 2200 nm
- Spectrometer of the Munich Aerosol Cloud Scanner (specMACS)
  - Field of view: 32.7° and 35.5° with 1312 and 320 pixels respectively
  - Spectral range: 417 – 1016 nm and 1015 – 2496 nm



Retrieved liquid water path (LWP): HAMP: linear regression model SMART: MODIS like retrieval

Brightness temperatures (TB) of two exemplary MWR channels

Radiances (Rad) of two exemplary SMART wavelengths

Radar reflectivity profile (Ze) measured by HAMP radar

Fig 2: Example of HAMP and SMART measurements. Figure published in [1].

3. Water Vapor Environment

- Agreement within the measurement uncertainties of amplitude and variance between HAMP and spaceborne Special Sensor Microwave Imager / Sounder (SSMIS).

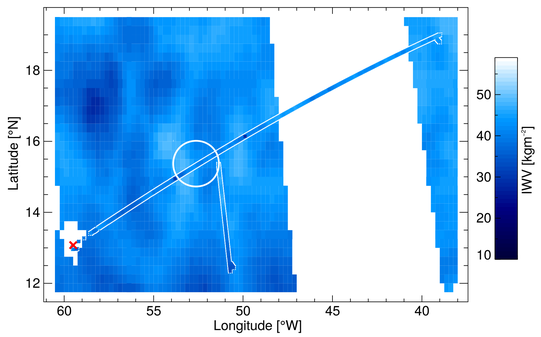


Fig 3: Integrated Water Vapor (IWV) measured by SSMIS (background) and HAMP (flight track) on Dec. 15, 2013. The encircled area is show in Fig 4 in more detail. Figure published in [1].

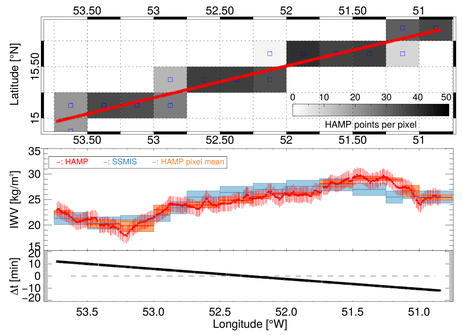


Fig 4: Comparison of coincident IWV measurements. Top: HAMP measurements per SSMIS pixel. Middle: Direct comparison with HAMP uncertainty (red). Bottom: time difference. Figure published in [1].

4. Clouds Close-Up

- High cloud variability observed within the resolution (7x4 km) of the Global Precipitation Measurement (GPM) Microwave Imager (GMI) and even within HAMP footprint (1x1 km).

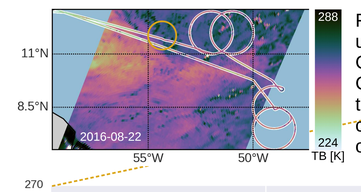


Fig 5: GPM underpass with GMI swath (89 GHz) and flight track. Orange circle: moment of underpass.

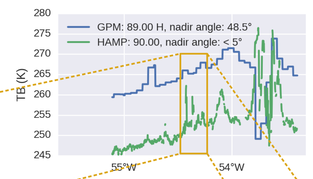


Fig 6: Comparison of HAMP and GMI brightness temperatures at 90 GHz and 89 GHz during underpass. Note different viewing angles.

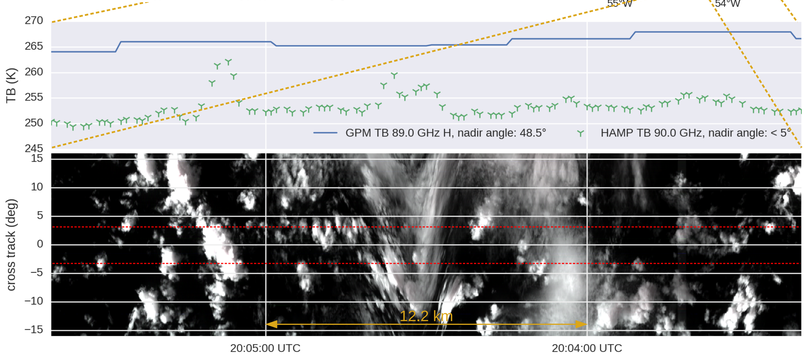


Fig 7: Zoom in Fig 5. Top: Brightness temperature measurements of HAMP and GMI in native spacial resolution. Bottom: 1600 nm channel of hyperspectral cross-track imager specMACS on HALO. View in nadir direction. Red lines: 3dB beam width of HAMP.

5. Dry vs. Wet Season

- Sharp moisture boundary in dry season around 3 km.
- Variable and high reaching moisture in wet season.

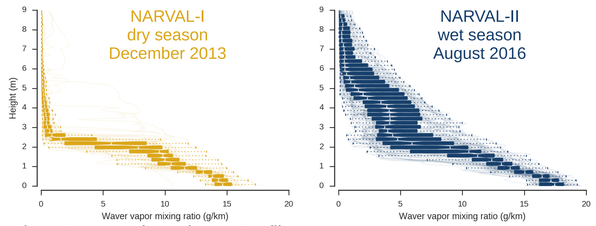


Fig 8: Dropsonde Moisture Profiles.

- Dry season: narrow distribution of IWV
  - homogeneous shallow cumulus convection
- Wet season: broad distribution of IWV
  - relative location of convective systems
  - sampling reflects the variability

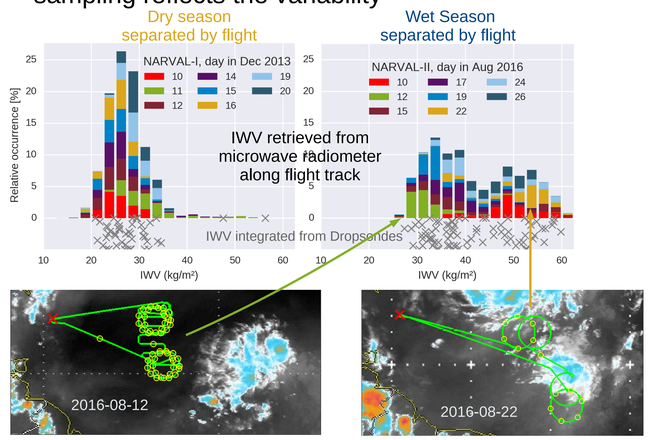


Fig 9: Top: Frequency distribution of IWV along flight tracks in the Tropics. Bottom: Water vapor satellite images.

- Similar differences in LWP between seasons as IWV
- Up to 10% of all clouds show light precipitation

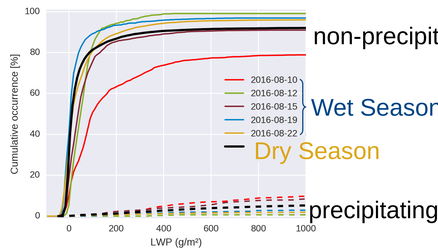


Fig 10: Cumulative occurrence of LWP for non-precipitating (solid) and precipitating (dashed) clouds along flight tracks in the Tropics.

6. Acknowledgment and reference

This study is supported by the Deutsche Forschungsgemeinschaft (DFG) within the priority program SPP 1294. The authors like to thank the whole NARVAL team for the successful realization of NARVAL-I and NARVAL-II. Thanks to B. Stevens for the inspiration for Fig 1 and 8.

[1] Schnitt, S., E. Orlandi, M. Mech, A. Ehrlich, and S. Crewell, "Characterisation of Water Vapor and Clouds During the Next-generation Aircraft Remote-sensing For Validation (NARVAL)-south Studies", 10.1109/JSTARS.2017.2687943

marek.jacob@uni-koeln.de