Warm clouds over the tropical Atlantic

insights on liquid water path from synergistic airborne measurements

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Motivation

The liquid water content of clouds is an important quantity, but it's measurement is challenging. Satellite derived liquid water paths (LWP) show a rather high uncertainty in the tropics (Fig. 1).

LWP and the connected integrated water vapor (IWV) can be measured from aircraft with better spatial and temporal resolution.

Here we try to answer the questions:

- How accurate are the airborne measurements?
- How different is LWP of tropical clouds between wet and dry season?

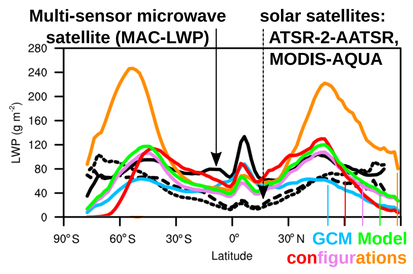


Fig. 1: Zonal LWP.
From Lohmann and Neubauer, 2018, doi: 10.5194/acp-18-8807-2018, Fig. 1 (licensed under cc-by 4.0, modifications: added arrows and annotations).

Airborne observations

Instruments on-board the **H**igh **A**ltitude and **LO**ng range research aircraft:

HAlo **M**icrowave **P**ackage (HAMP):

- 26 channel microwave radiometer
- 35.5 GHz cloud and precipitation radar

WAter vapor **L**idar **E**xperiment in **S**pace airborne demonstrator:

- Aerosol backscatter lidar
- water vapor DIAL

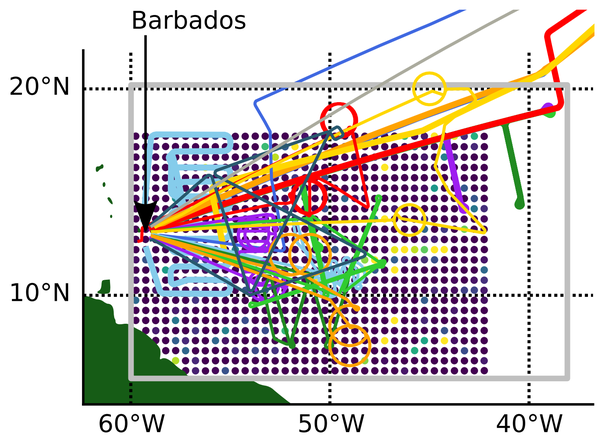


Fig. 2: Flight tracks on top of sub-sampled ICON LWP. Thin lines NARVAL1, thick lines NARVAL2. Sub-sampled ICON output over 48 days is used as retrieval database.

Neural network retrievals for IWV, LWP, and rain water path (RWP) are developed using a database of cloud resolving ICON (1.25 km grid) simulations.

Retrievals use different inputs:

IWV: 8 passive microwave channels: 22 – 31 GHz (K-band), 90 GHz

LWP: K-band, 90 GHz, lidar cloud mask (clear sky drift offset correction)

RWP: K-band, 90 GHz, integrated radar reflectivity, LWP

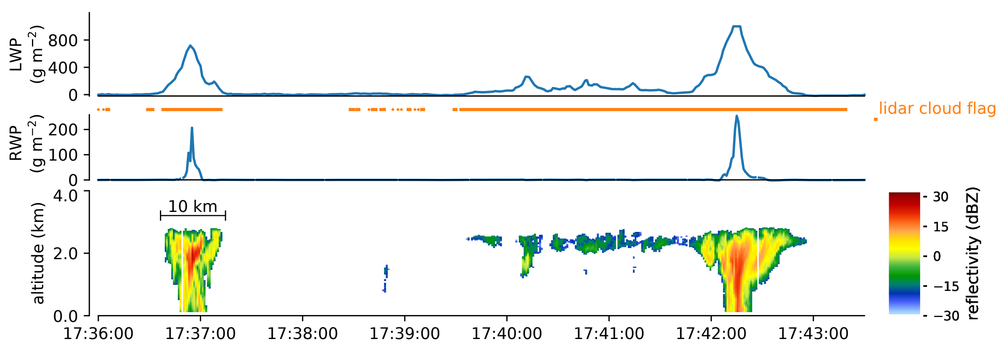
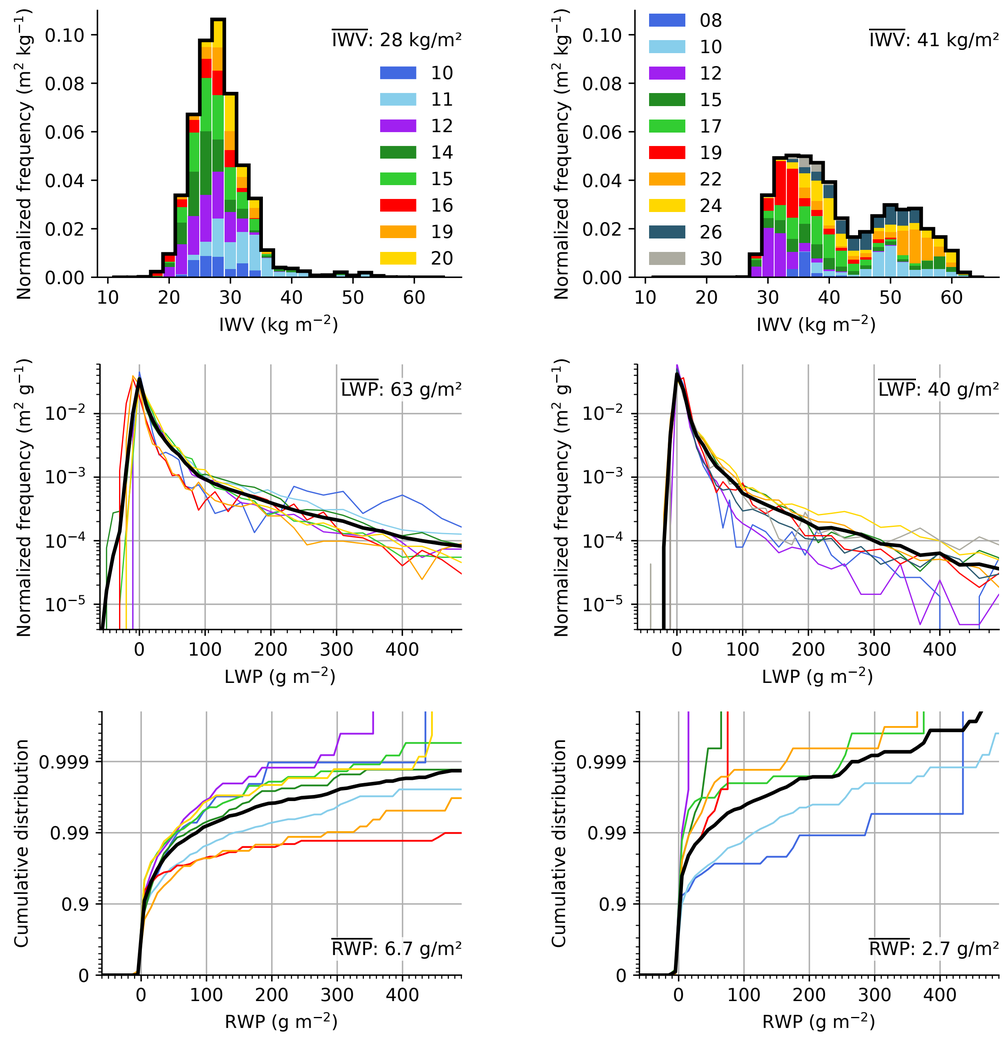


Fig. 3: Example of LWP and RWP retrieval output on December 20, 2013.

Dry vs. wet season

Dry season, NARVAL1-South, December 2013

Wet season, NARVAL2, August 2016



cloud fraction: 47 %
ice scattering: 0.5 % of time
observation time: ~25 h

cloud fraction: 30 %
ice scattering: 1.6 % of time
observation time: ~40 h

Fig. 6: Frequency distributions of IWV, LWP and RWP during dry and wet season. Colors denote flight days in Dec 2013 and Aug 2016. LWP distribution includes only measurements, when lidar cloud flag reports a cloud. RWP distribution for measurements, when LWP > 50 g/m².

Conclusions

High resolution (< 1 km) high accuracy products of

- IWV (accuracy ~ 0.6 kg/m²)
- LWP (error: < 20 g/m² for LWP < 100 g/m²; < 20 % above)
- RWP (ETS[1] > 50 % for 10 g/m² < RWP < 250 g/m²

are available: search *HALO LWP* in *https://cera-www.dkrz.de*

[1] equitable threat score, also known as Gilbert skill score (GSS)

Dry vs. wet season:

- Dry season had less IWV
- Dry season cloudier
- Dry season clouds contain more water and produce more rain
- Dry season showed frozen precipitation less often

Accuracy assessment

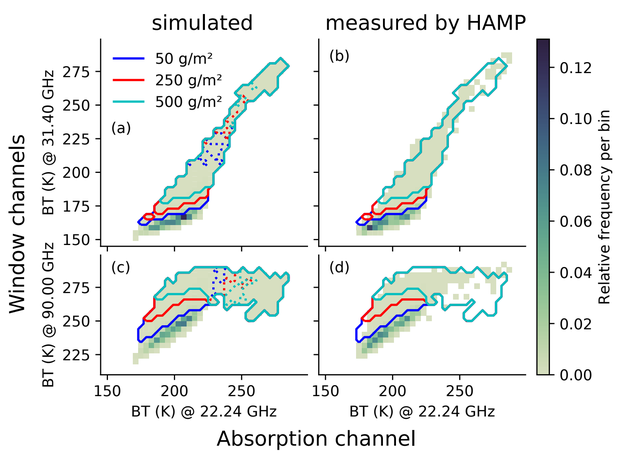


Fig. 4: 2D-histograms of brightness temperatures (BT) occurrences in ICON/radiative transfer simulations (a, c) and HAMP measurements (b, d).

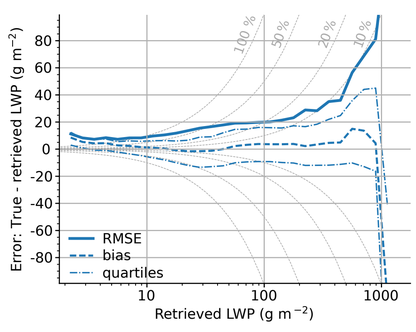


Fig. 5: Expected retrieval error as function of retrieved LWP estimated from the retrieval database. Retrieval is trained for 1 g/m² < LWP < 1000 g/m² and assessed for cloudy sky.

Outlook

- Use HAMP to complement BCO time series with airborne nadir view for investigation of precipitating clouds
- Analyze precipitation efficiency via relation between CWP, RWP and vertical structure of radar echo.
- Investigate rain/cloud partitioning and inhomogeneities in satellite footprints
- Looking forward to EUREC^{4}A: EUREC^{4}A will provide more comprehensive view of large scale forcing, cloud age and horizontal 2D cloud extent.

Reference & Acknowledgment

- Jacob, M., F. Ament, M. Gutleben, H. Konow, M. Mech, M. Wirth, and S. Crewell: " Investigating the liquid water path over the tropical Atlantic with synergistic airborne measurements", *Atmos. Meas. Tech. Discuss.*, 10.5194/amt-2019-18, in review, 2019.
- The work has been supported by the German Research Foundation within the DFG Priority Program (SPP 1294) under grant CR111/10-11. We would like to thank Daniel Klocke for running the ICON simulations.

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