# Sensor synergy to detect clouds and precipitation: results of the first HALO-HAMP flight campaign.

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## 1. Introduction

Clouds and precipitation play an important role in the atmospheric water cycle and radiation budget. Unfortunately, the understanding of the processes involved in cloud and precipitation formation and their description in global and regional models are still poor. Not only models poorly describe such processes, also satellites retrievals often show discrepancies in surface precipitation estimates. To improve our understanding of these processes and to reduce model and retrieval uncertainties, new observation and retrieval techniques exploiting the synergy between active and passive sensors are needed.
With these foci the German research aircraft HALO (High Altitude Long-range Aircraft) took part to the NARVAL (Next-generation Aircraft Remote-sensing for VALidation studies) campaigns in December 2013 and January 2014.

***Fig. 1:*** The HALO aircraft at the Barbados airport during the NARVAL-South campaign (left) and in Reykjavik during NARVAL-North (right).

## 2. HALO payload

- **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:**

Pulsed Doppler radar at 36 GHz

130 m footprint at 13 km

-38 dBZ sensitivity @ 5 km

***Fig. 2:*** Installation of the remote sensing suite on HALO. From left to right: radiometer boxes, lidar window and radar antenna.

- **WALES lidar:**

Water vapor absorption lidar

Four wavelength, three in the 935 nm $H_2O$ absorption band

- **Dropsonde dispenser**
- **HALO SR (Solar Radiation)**

UV/VIS and NIR spectrometer

- **Mini DOAS**

Trace gas, water vapor and ice detection

## 3. NARVAL campaigns

**NARVAL-South**
10 – 21 December 2013

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

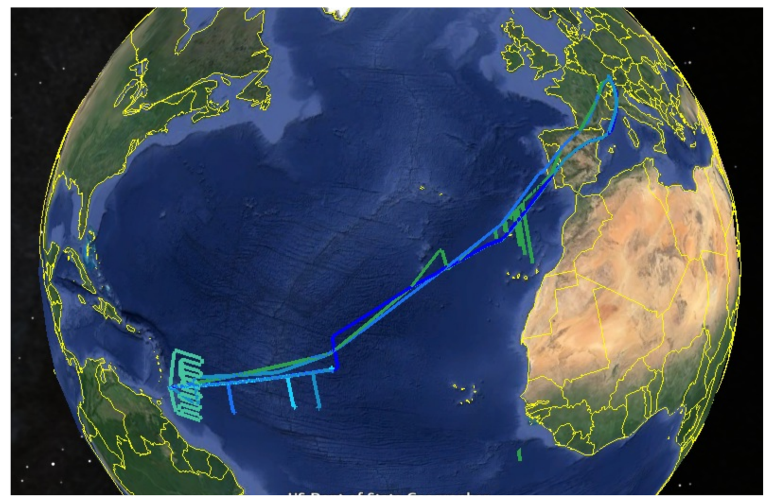

***Fig. 3:*** NARVAL-South flight patterns.

**NARVAL-North**
7 – 21 January 2014

- 5 flights over North Atlantic
- 2 transfer flights with several ground-based super-site overpasses
- 42 dropsondes released
- Investigate North Atlantic postfrontal shallow convection
- Validate satellite precipitation retrievals Klepp (2005)

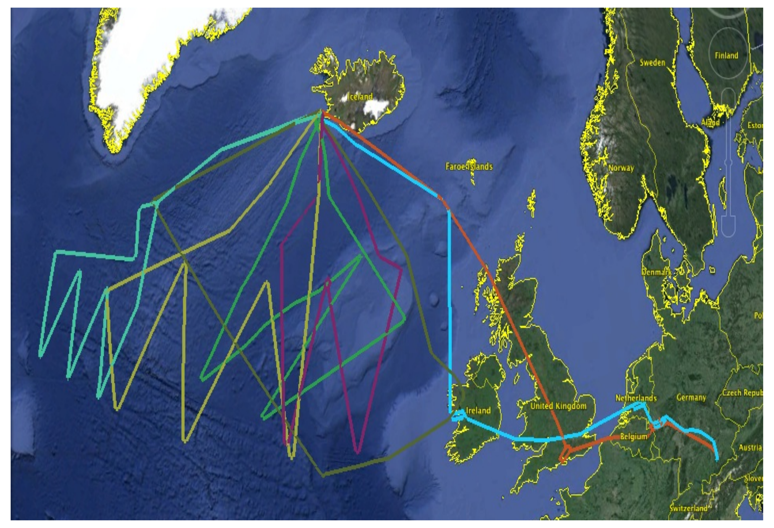

***Fig. 4:*** NARVAL-North flight patterns.

## 4. Sensor synergy

- **Radar – radiometer – lidar:**
Liquid water and snow content profiles
- **Radar – radiometer:**
Precipitation
- **Lidar – radiometer:**
Water vapor profiles
- **Radiometer – dropsonde:**
Temperature profiles
(see poster n. 11 in session 'Calibration techniques and methods')

**Figure 5** shows data collected during three pre-campaign flights which took place over Germany on the 7 and 11 June and 24 July 2013 to test the in-flight performance of the HALO payload.

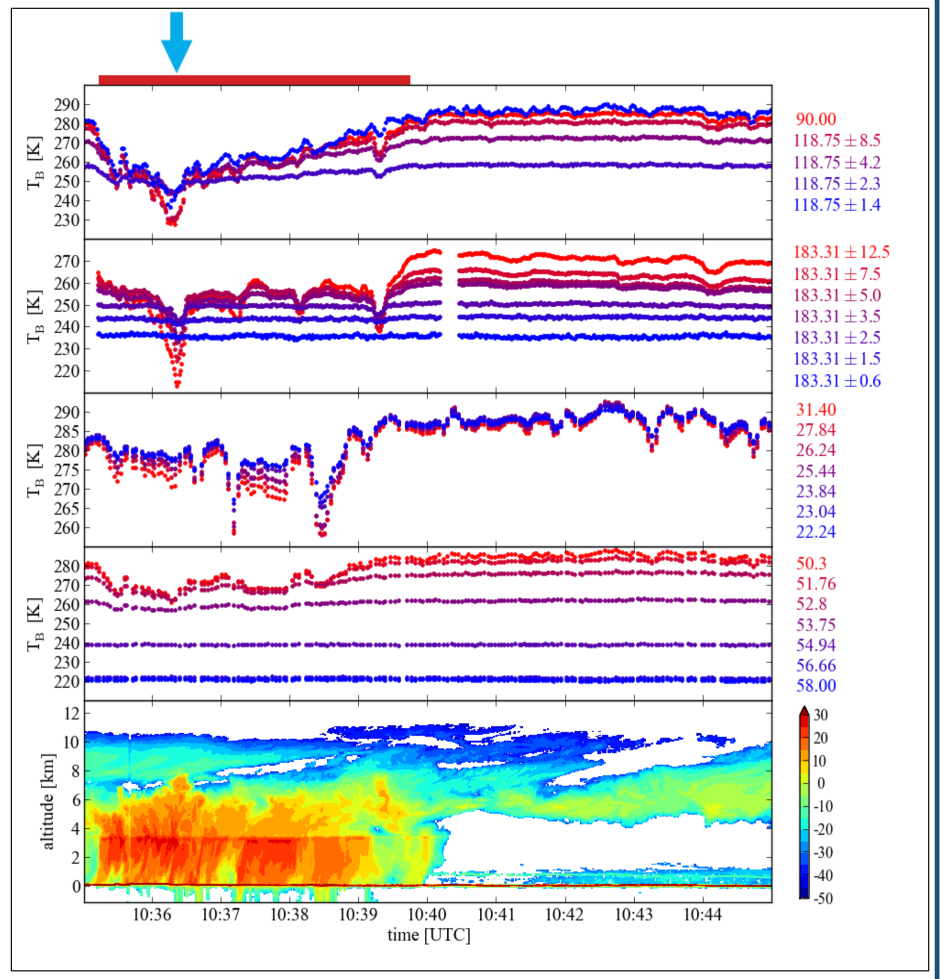

***Fig. 5:*** Radar reflectivity and brightness temperatures (Tb) over land for the 24th July flight. Red bar indicates Tb depression due to liquid water absorption, blue arrow shows depression due to ice scattering. Mech et al (2014)

## 5. Liquid water and water vapor column retrieval

- K-band used to retrieve precipitable water (PW) and liquid water path (LWP)
- K-band allows retrievals for the whole atmospheric column also in the presence of thick clouds
- Comparison with dropsonde:
RMS = 0.6 mm for precipitable water

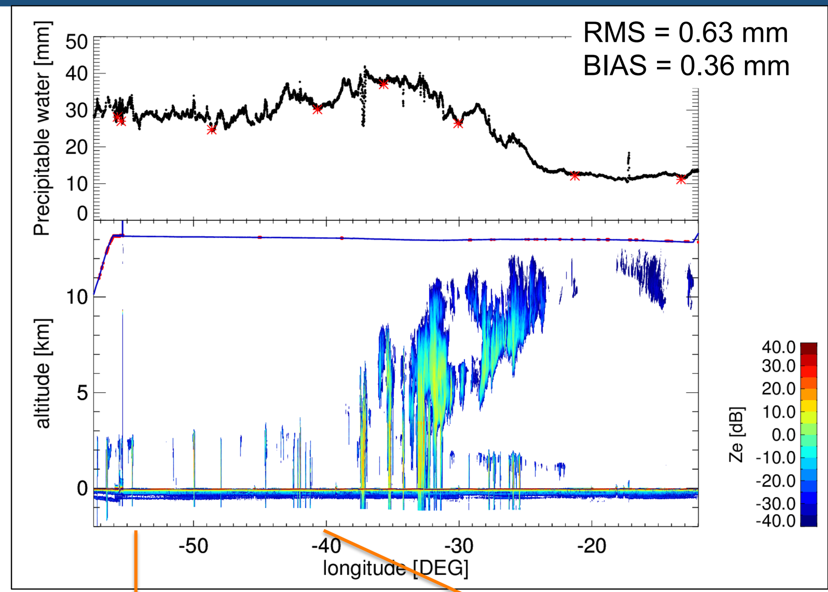


***Fig. 6:*** Retrieved precipitable water (PW) and radar reflectivity for the 20th December 2013 flight. Dropsonde PW in red.

- High sensitivity of LWP retrieval will be used for satellite comparison/validation
- Combine radar-radiometer-lidar to retrieve liquid water content profiles

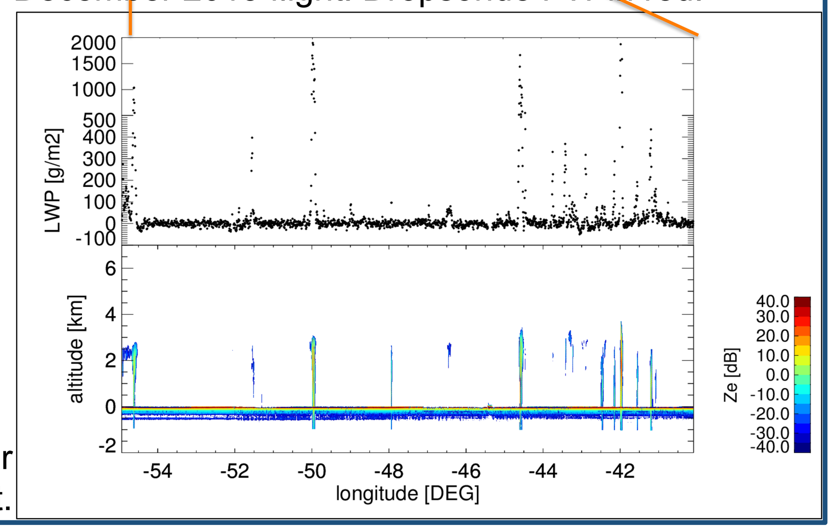


***Fig. 7:*** Retrieved Liquid water path and radar reflectivity for the 20th Dec. 2013 flight.

## 6. Conclusion and future work

- The German research aircraft HALO successfully accomplished two measurements campaigns with its remote sensing suite on-board.
- NARVAL-South investigated trade wind shallow cumulus convection.
- NARVAL-North explored frontal and post-frontal convection over North Atlantic.
- Precipitable water retrieval has been developed and shows good agreement with dropsonde measurements (RMS = 0.6 mm).
- Liquid water path retrieval shows high sensitivity to thin clouds.
- Multiple sensor retrieval for water vapor and hydrometeor concentration profiles are under development.
- Data collected will be used for satellite retrieval validation and process studies.

## 7. Bibliography and Aknoledgments

- C. Klepp, S. Bakan and H. Grassl, 2005, Missing North Atlantic cyclonic precipitation in ECMWF numerical weather prediction and ERA-40 data detected throught the satellite climatology HOAPS, Met. Zeit.
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The Authors would like to thank the whole NARVAL team: Max Plank Institute for Meteorology, DLR – German Aerospace Center, Forschungzentrum Juelich, Universities of Leipzig, Heidelberg, Hamburg and Cologne.



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