Comparison of water vapor, clouds, and precipitation derived from satellite sensor to measurements by airborne remote sensing instruments on HALO

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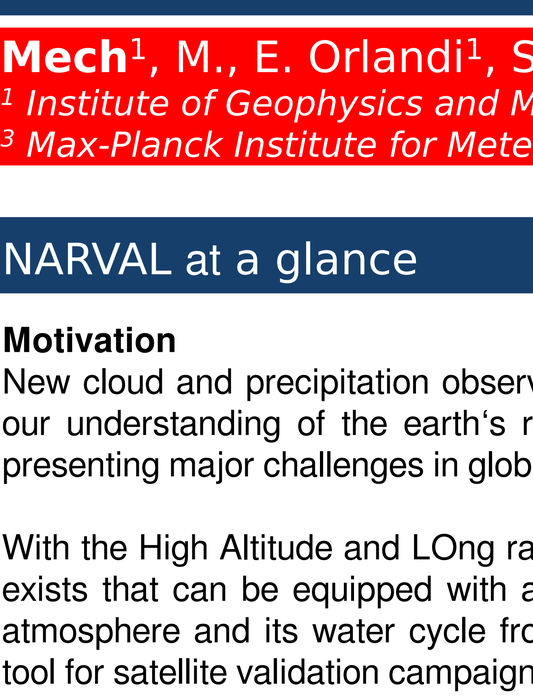
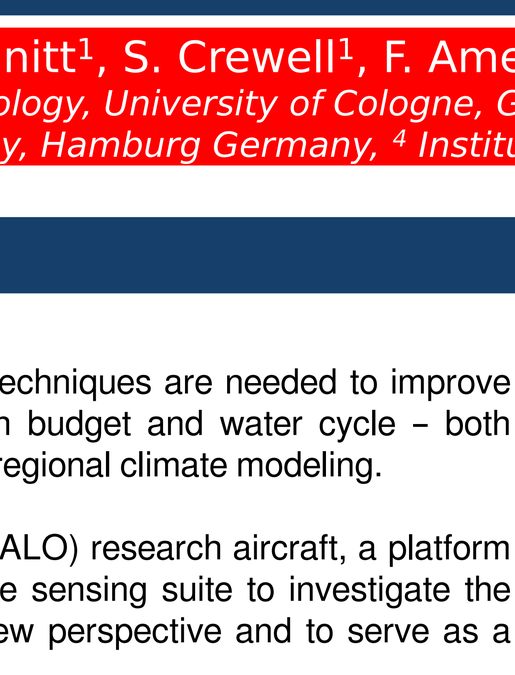
NARVAL at a glance

Motivation
New cloud and precipitation observation techniques are needed to improve our understanding of the earth's radiation budget and water cycle – both presenting major challenges in global and regional climate modeling.

With the High Altitude and LOng range (HALO) research aircraft, a platform exists that can be equipped with a remote sensing suite to investigate the atmosphere and its water cycle from a new perspective and to serve as a tool for satellite validation campaigns.

NARVAL (**N**ext Generation **A**ircraft **R**emote Sensing for **Val**idation Studies)
- South (10.-21. Dec 2013, 8 flights) over tropical and subtropical Atlantic for investigation of precipitation in shallow maritime convection (trades & post-frontal extra-tropics)
- North (7.-21. Jan 2014, 7 flights) over the North Atlantic for observation of post-frontal clouds and precipitation in higher latitudes

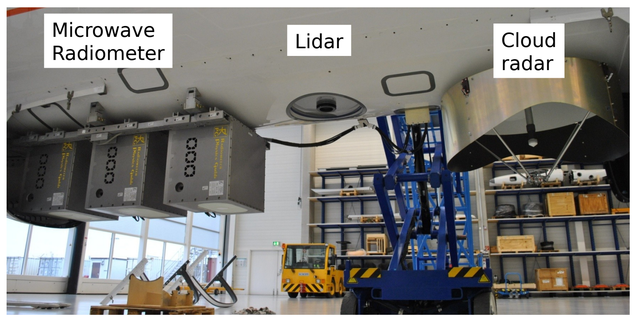




NARVAL South (left) and North (right) flight tracks for all of the 15 research flights in December 2013 to January 2014 over subtropical and tropical and the Northern Atlantic.

Aircraft & Instrumentation

Gulfstream G550
- Range of 10h / 10000 km
- Cruise speed ~ 200 m/s
- Altitude max. 15.5 km
- Payload max. 3 t
- BAHAMAS for aircraft data
- Dropsondes
- Belly pod for remote sensing sensors



Microwave Radiometers
- 26 channels (22 to 183 GHz)
- FOV @ 12 km (1.3 – 0.8 km)

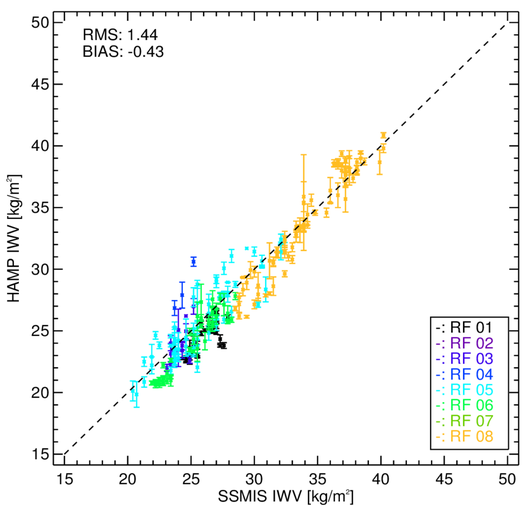
WALES lidar
- Water vapor absorption lidar with four wavelengths

Cloud Radar
- Pulsed radiometric Doppler radar at 36 Ghz (-38 dBZ sensitivity @ 5km range)

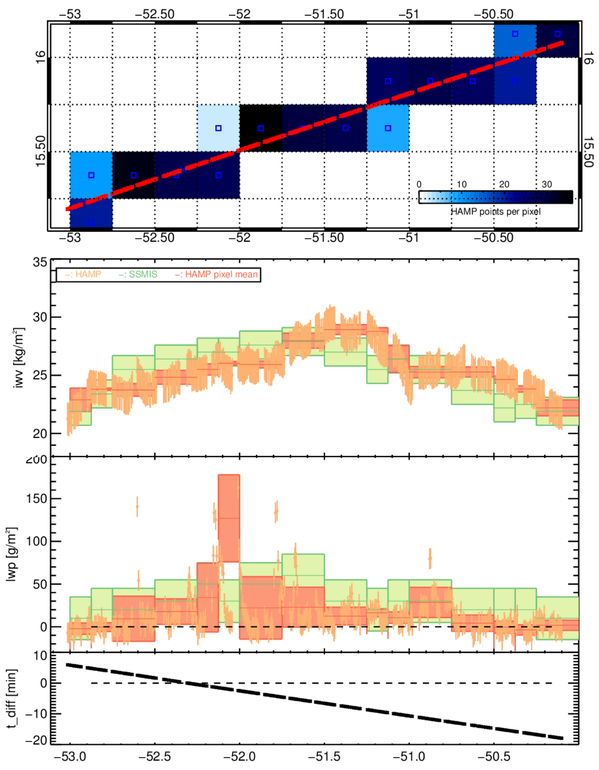
Passive Microwave Radiometers + Active Radar = HAMP
(HALO Microwave Package, Mech et al. , AMT, 2014)

Integrated Water Vapor and Liquid Water Path

Statistical retrievals based on dropsondes, artificial clouds, and radiative transfer simulations:
- HAMP accuracy: 1.4 kg /m^2 (IWV), 12 g/m^2 (LWP)
- Good agreement between HAMP and SSMIS for IWV over all flights
- Coarse resolution of SSMIS sufficient for IWV, due to smooth gradients
- SSMIS can not resolve smaller cloud structures
- HAMP average over SSMIS footprint for LWP in the same range as SSMIS measurements

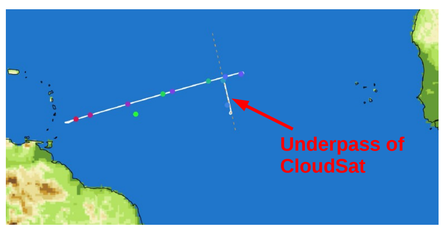


Point by point comparison of retrieved Integrated water vapor (IWV) for all NARVAL South research flights compared to SSMIS derived ones over ocean.

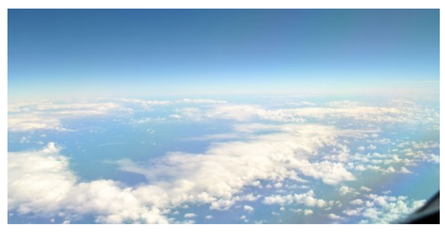


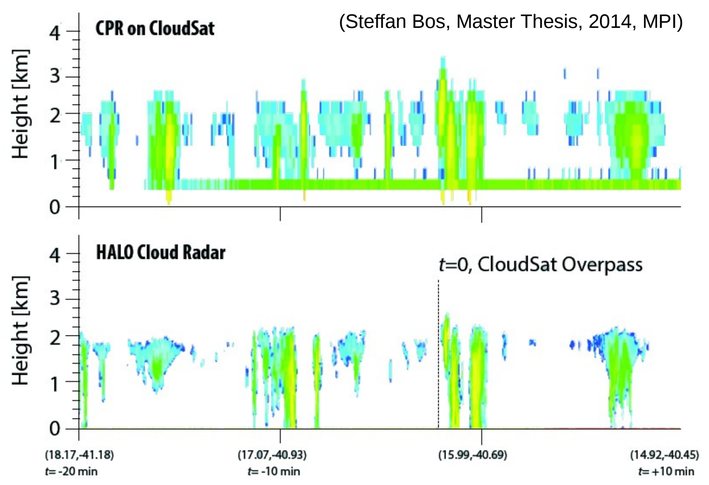
Matching of HALO flight path/measurements with gridded SSMIS observations for 20 min during RF05 (top). Comparison between retrieved IWV/LWP for HAMP and SSMIS measurements (middle), and time difference between observations (bottom).

Precipitation from Radar



Flight track of HALO (top) and camera picture of cloud structure (bottom) coincident with CloudSat underpass flight during RF03 on Dec 12 2013 over the subtropical Atlantic.





CloudSat near-surface returns are often corrupted by surface returns, shown here by a band of echoes near the surface (upper panel). HALO cloud radar confirms CloudSat cloud structures, with strong precipitation reaching the surface.

Conclusions

HALO successfully accomplished the NARVAL campaign with its remote sensing suite on-board

- 18 flights all in all 140 flight hours (8 South, 7 North, 3 Germany) with ~ 95% data coverage: 125 dropsondes, collocation with the A-Train, super-site overpasses
- Preliminary results are very promising and reveal great detail of water vapour, shallow cumulus clouds over tropical Atlantic and trade winds and postfrontal convective clouds, precipitation over the cold-season North Atlantic
- IWV and LWP (averaged over footprint) compare good between SSMIS and HAMP
- Small size cloud are not seen by SSMI because of the large footprint
- LWP bias in the case study is confirmed over larger dataset and need to be further investigated
- Evaluation of satellite precipitation products in progress

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