Airborne remote sensing of cloud droplet number concentration using synergetic passive solar and microwave radiation measurements

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1 Motivation

- Radiative forcing of clouds depends on cloud properties (τ, r_{eff}, N, LWP, LWC)
- Same LWC, different N -> different albedo (Twoomey-Effect)[2]
- Cloud inhomogeneity (LWC, N) of marine shallow cumulus mostly not covered by satellite observations

2 Campaign NARVAL-II

Next generation Aircraft Remote-sensing for Validation studies

- Using the High Altitude and Long Range Research Aircraft (HALO) of DLR
- Subtropical and ITCZ region
- 08 August – 30 August 2016
- 10 Flights, 94 hours, 74000 km
- Investigate maritime shallow cumulus

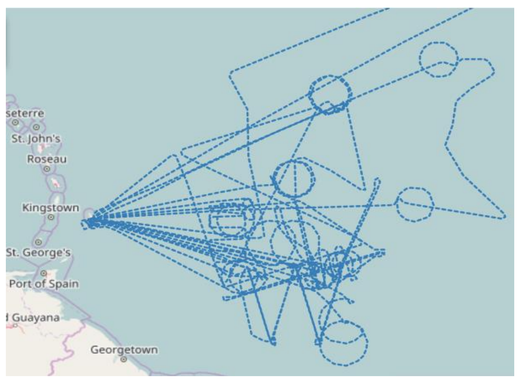


Fig. 1: Illustration of research flights with HALO during NARVAL-II.

3 Instrumentation

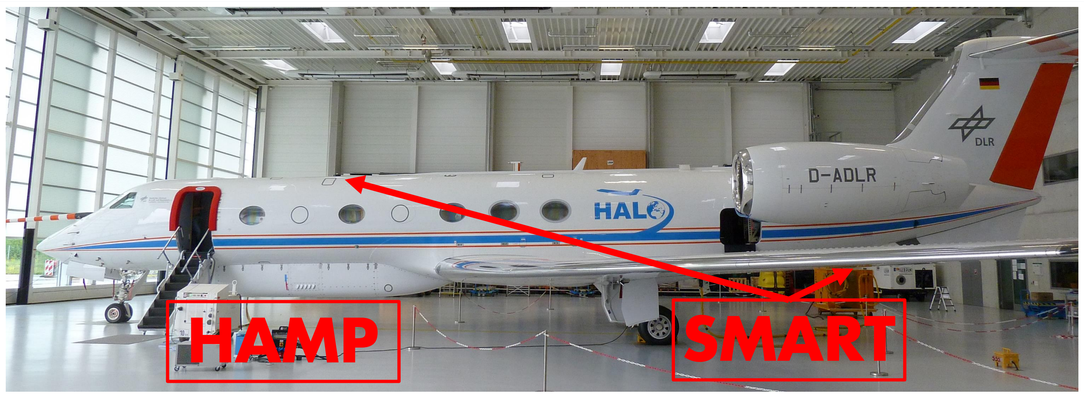


Fig. 2: Location of the HAMP radiometer + radar and SMART optical inlets.

SMART-Albedometer

Spectral Modular Airborne Radiation measurement sysTem - Albedometer

- Spectral solar **irradiance** ($F^{\downarrow,\uparrow}$) and **radiance** ($I^{\uparrow}$) with 2° FOV
- Spectral range: 300–2200 nm
- Temporal resolution 2 Hz
- Retrieved quantities: optical thickness, effective radius, therm. phase, cloud radiative forcing

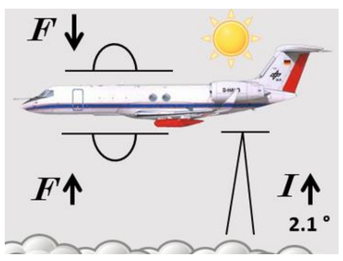


Fig. 3: Upper and lower optical inlets of SMART-HALO and measurement geometry.

HAMP

HALO Microwave Package

- 23-channel microwave radiometer and cloud radar
- Retrieval of temperature and humidity profiles, LWP and hydrometeor properties

4 Method

Retrieval of τ and r_{eff}

- Use of spectral cloud top reflectivity
- Cloud mask algorithm
- Applying iterative retrieval with radiative transfer model

Retrieval of Liquid Water Path (LWP)

- From HAMP measurement

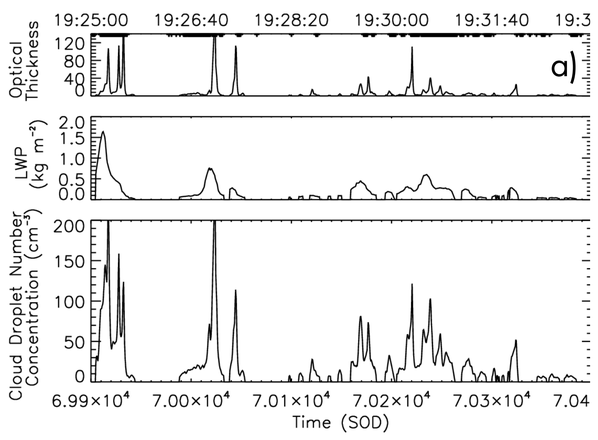
Calculating Droplet Number Concentration [1],[3],[4]

- Assuming: adiabatic cloud profile (non-precipitating)
- Spherical cloud droplets
- Only liquid water clouds
- Geometrical thickness z from LIDAR
- Avoid Condensation rate assumptions

$$N_d = \frac{\sqrt{(10)}}{4 \cdot \pi \cdot k} \cdot \sqrt{\frac{\frac{2 \cdot LWP}{z^2} \cdot \tau}{\rho_w \cdot r_{eff}^5}}$$

5 Results from Flight 19.08.2016

Retrieval of Cloud Droplet Number Concentration



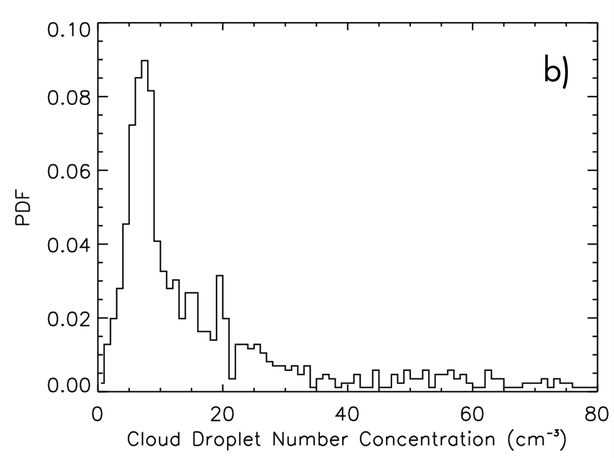


Fig. 4 a: Time series of optical thickness, liquid water path and retrieved cloud droplet number concentration. Fig. 4b: Propability density function of cloud droplet number concentration.

Influence of Cloud Microphysics

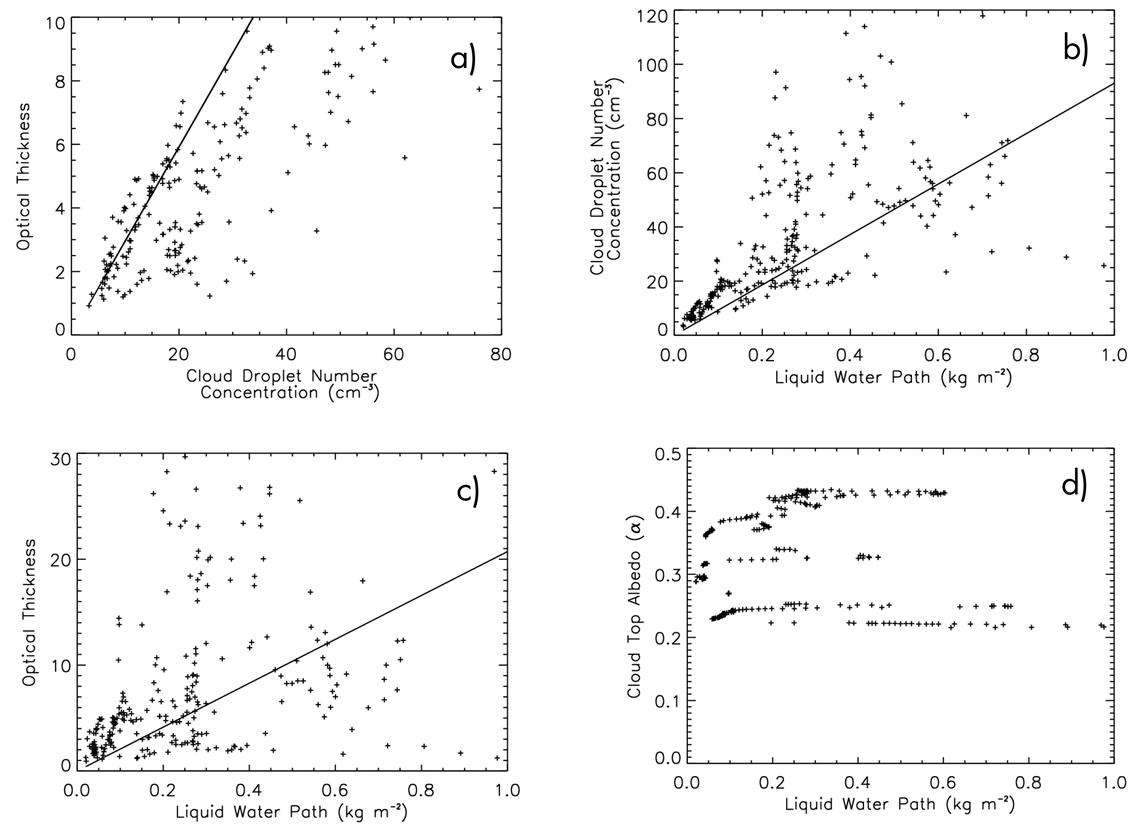


Fig. 5 a: Influence of cloud droplet number concentration on optical thickness. Fig. 5 b,c, d: Influence of liquid water path on cloud droplet number concentration, optical thickness and cloud top albedo.

Influence of Cloud Distribution

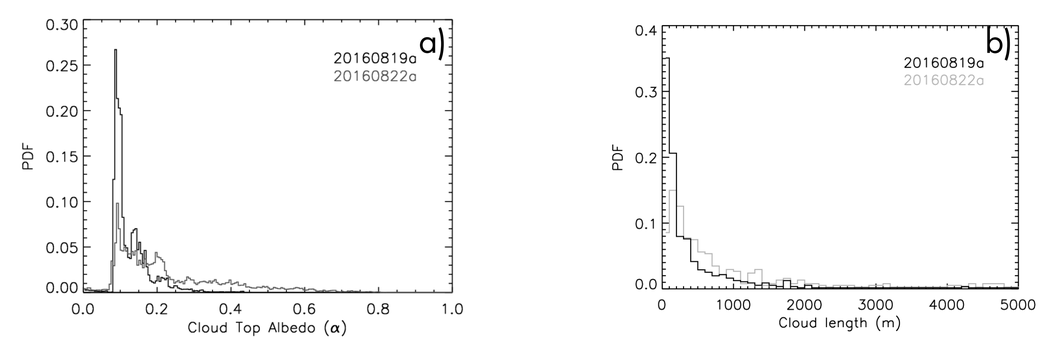


Fig. 6 a: Propability density function of cloud top albedo as a measure of total cloud cover for 19. and 22. of August. Fig. 6 b: Propability density function of cloud length for the same days.

6 Conclusion

- Synergetic retrieval of cloud droplet number concentration is possible
- Cloud top albedo depends on cloud inhomogeneity (cloud fraction and size)
- planed satellite comparison / validation -> investigate (sub-pixel heterogeneity)

References

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