COMPEX – Airborne remote sensing of Arctic clouds and precipitation in complex environments

M. Mech, L. van Gelder, S. Schnitt, F. Goy, A. Pant, J. Panton, and S. Crewell

UNIVERSITY OF COLOGNE

Intro

In the framework of the "**ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms (AC)³**" project, a series of **Arctic airborne research campaigns** has been conducted. Thereby, a suite of remote sensing instruments operated on the Alfred Wegener Institute's (AWI) Polar research aircraft to investigate and understand the role of clouds and precipitation in the Arctic climate system and their contribution to the **Arctic Amplification**.

Polar 5 - Alfred Wegener Institute operated by Kenn Borek Air (CDN) Basler BT-67 (former DC-3 build in 1943) one-way range ~900 km, height < 5 km; 2 pilots, max. 6 scientists

Microwave Radar/radiometer for Arctic Clouds (MiRAC)
94 GHz, FMCW, Ze, Doppler,, 89 GHz passive, 25° backwards, LWP, SR (MiRAC-A)
183 (6 channels), 243, and 340 GHz passive MW, WV and IWP (MiRAC-P)

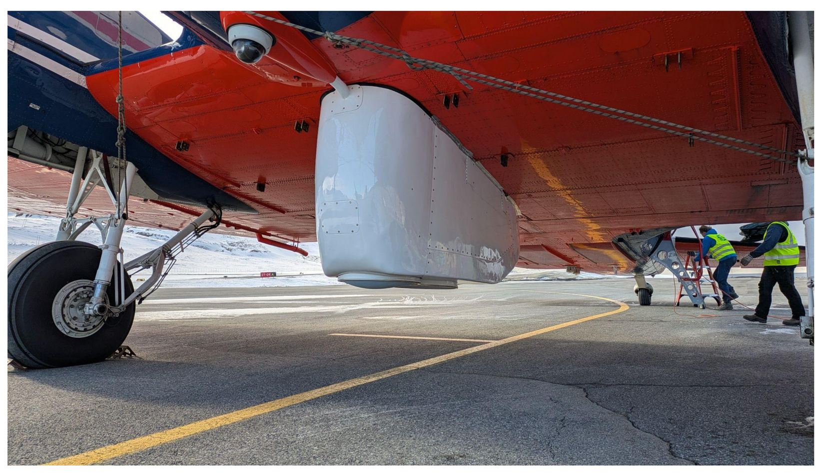
New! G-band Radar for Water vapor and Arctic Clouds (GRaWAC) (Schnitt et. al, 2025)
167.3 and 174.7 GHz, FMCW, Ze, differential absorption, in-cloud water vapor profiles and IWV, differential reflectivity G-W band for microphysics

Airborne Mobile Aerosol Lidar (AMALi)
Attenuated backscatter at 355 and 532 nm (+depol), aerosol, cloud mask, and top height

AISA HAWK/FOX
Imaging spectrometer, push broom sensor, 2D field of upward radiance

Broadband and spectral radiation
Pyranometer + Pyrgeometer - up and down
SMART-Albedometer (300-2300 nm @ 2 Hz)

AVAPS dropsonde system, fish-eye, KT-19



GRaWAC and MiRAC-A in dual bellypod attached to Polar 5.

Clouds over cOMIPEX environment
Longyearbyen, Svalbard, Norway
14 Mar to 15 Apr 2026

Airborne observations to connect the column over Ny-Ålesund to the broader area over the Kongsfjorden. Collect dataset for product and model validation.

Observations dedicated to low-level clouds in MIZ and over sea ice in the origin of cold air outbreaks (CAO) with improved instrumentation

Perform observations over sea ice to increase understanding of sea ice emissivity in the microwave region for cloud and precipitation retrievals.

EarthCARE validation data sets in Arctic environments by collocated flights.

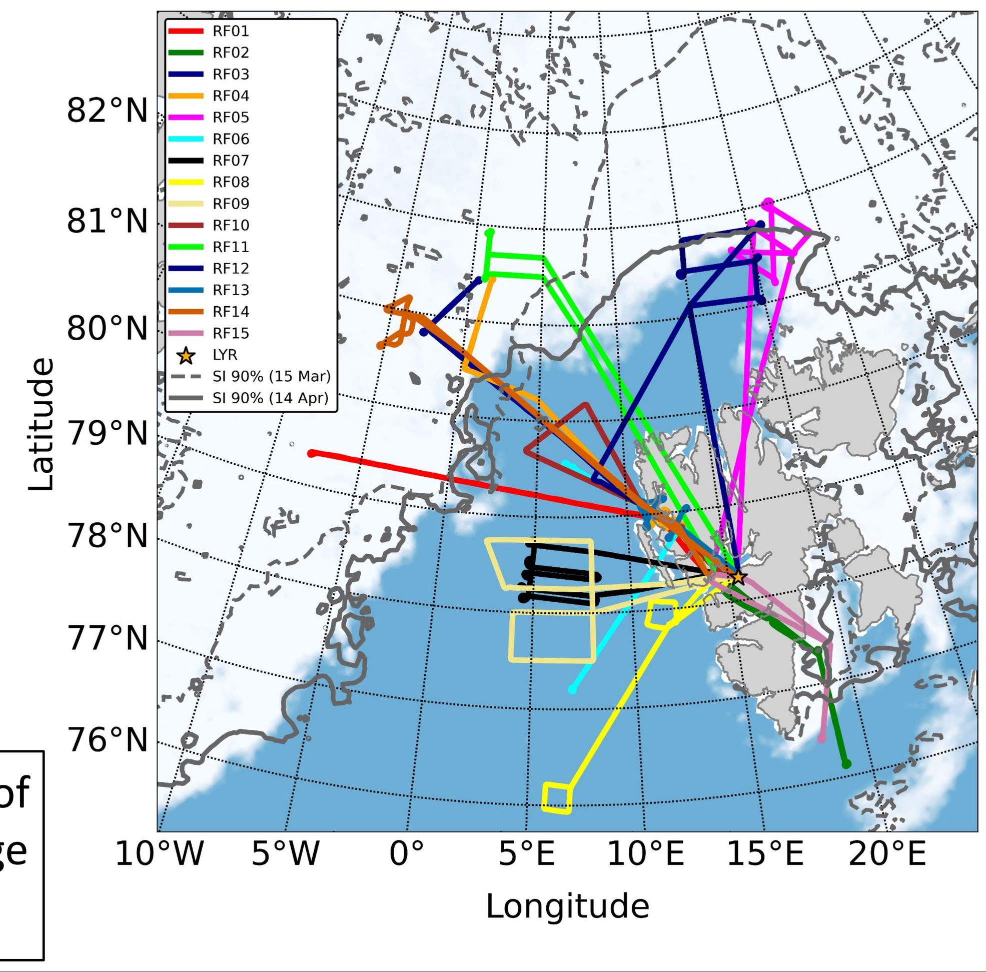
COMPEX in a nutshell

Conditions in COMPEX area

- 2 m temperature 6K above 1971-2000 mean
- Sea ice concentration around Svalbard among the lowest ones
- Few weak to moderate cold air outbreaks

Statistics

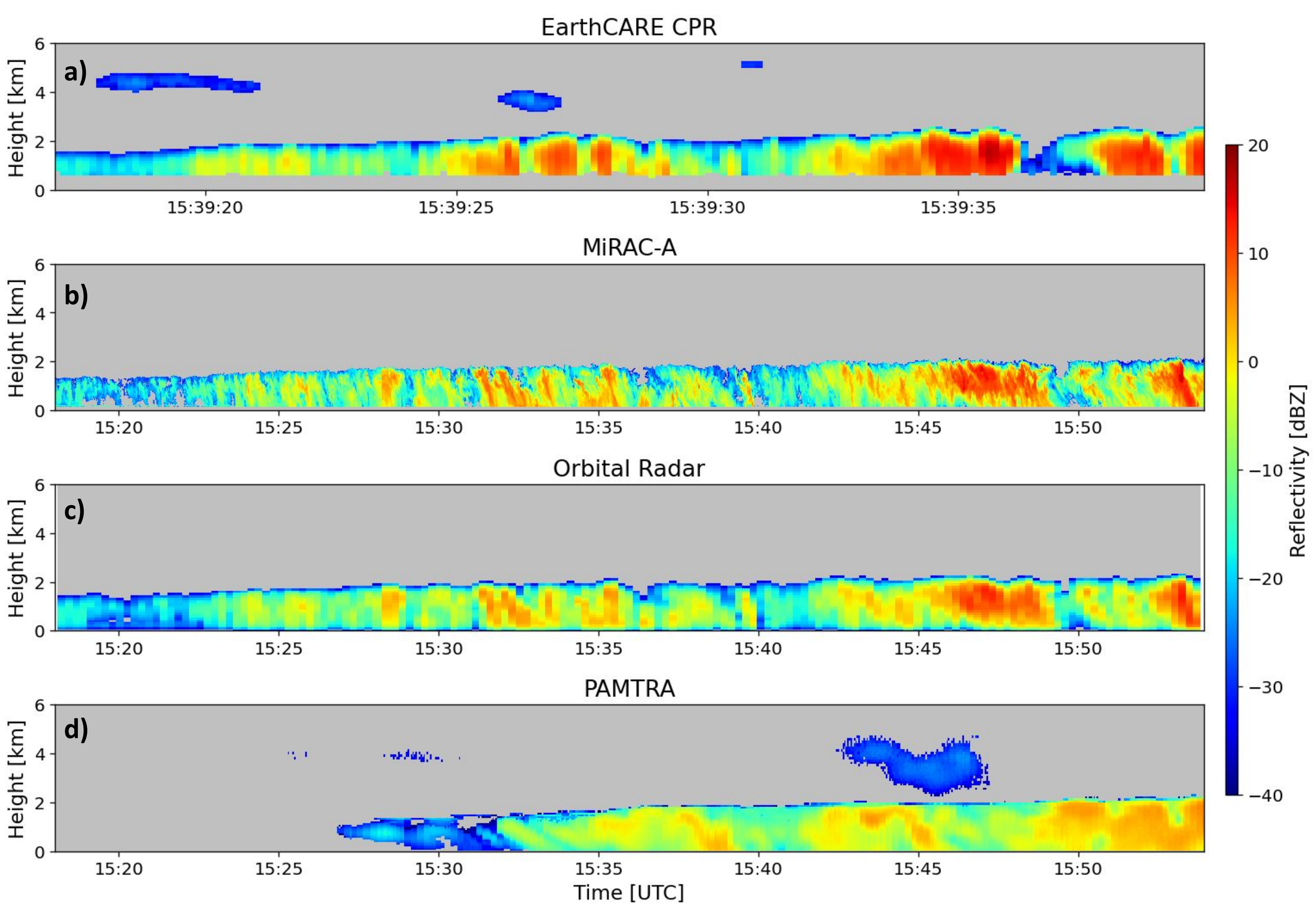
- 15 flights (60 hours)
- 2 EarthCARE underflights
- 75 dropsondes



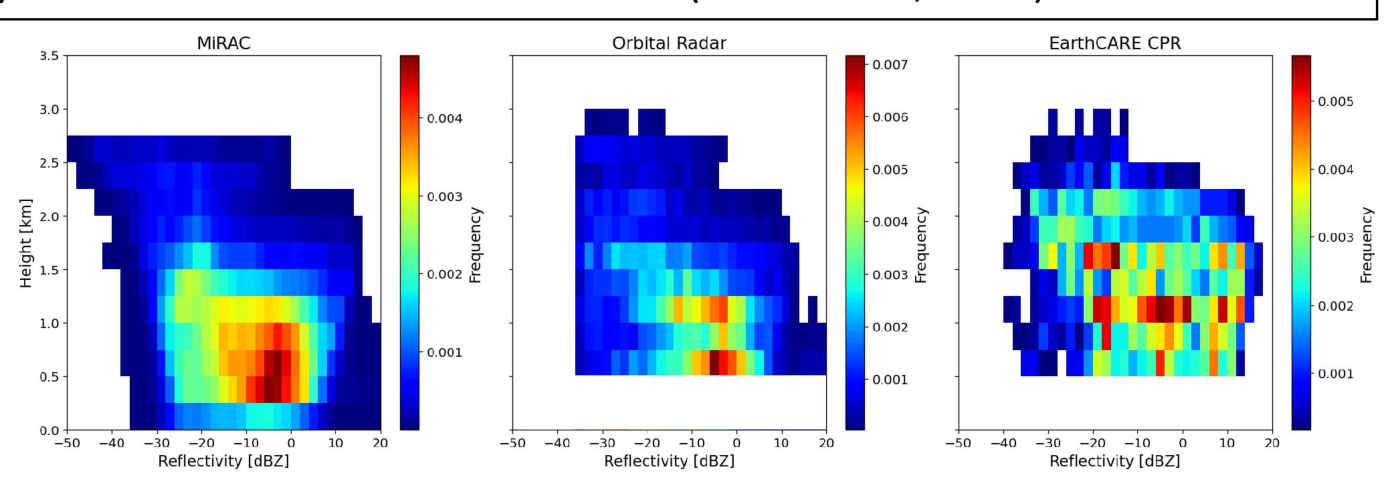
Research flights of COMPEX out of Longyearbyen and sea ice coverage at beginning and end of campaign.

EarthCARE validation

In total **eight** collocations with **EarthCARE** during **COMPEX (2)** and **COMPEX-EC (6, 04/2025 Kiruna, Sveden)**.

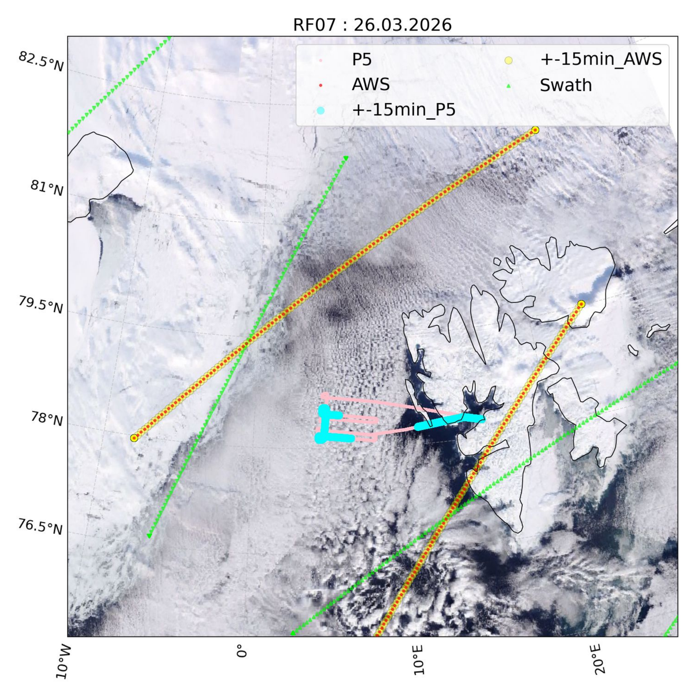


Reflectivity from **a)** EarthCARE CPR; **b)** MiRAC-A; **c)** MiRAC-A to EarthCARE CPR with Orbital-Radar simulator (Pfitzenmaier et al., 2025) ; **d)** simulated ICON-LEM and PAMTRA (Mech at al., 2020).

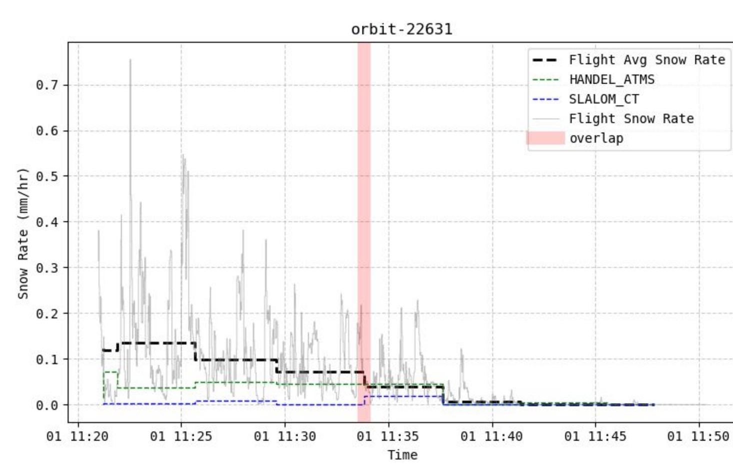


Cumulative frequency by altitude (CFAD) for MiRAC, orbital radar simulator, and EarthCARE.

Snowfall rates derived from airborne radar by Z-S relation



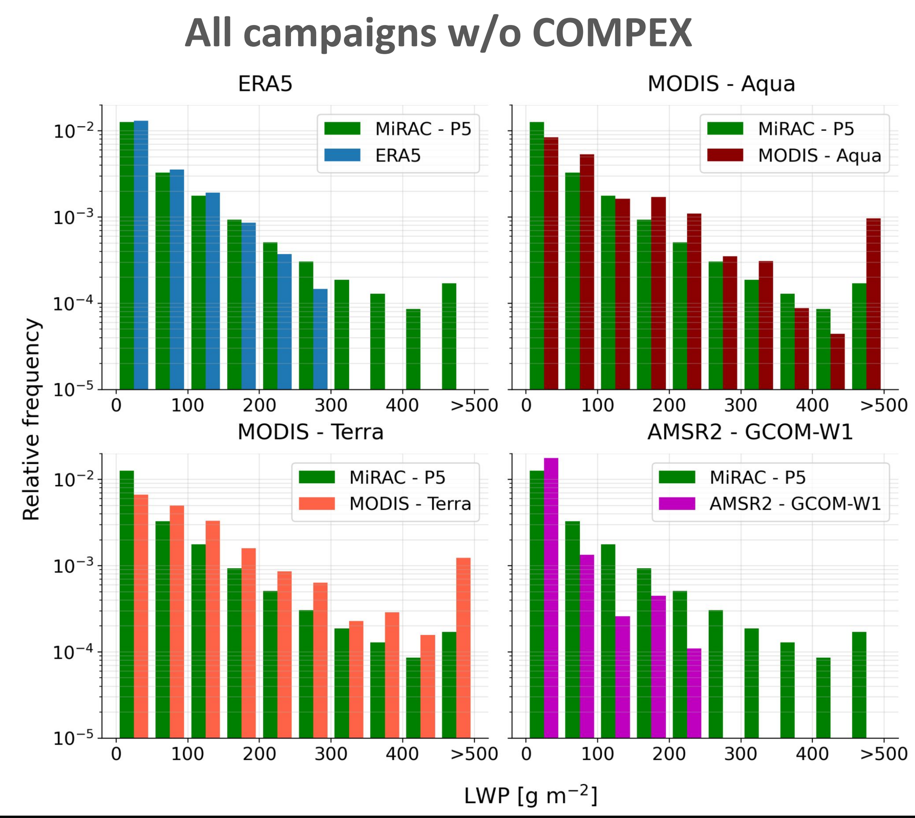
Collocation of Polar 5 on RF07 with Arctic Weather Satellite. Blue flight track shows +/- 15 mins match with respective overpass swath.



MiRAC-A vs ATMS snowfall rates (HANDEL_ATMS and SLALOM_CT; check Camplani et al., 2023).

Liquid water path - aircraft vs reanalyses/satellites

dropsonde over ocean artificial clouds → PAMTRA → $LWP = c_0 + \sum_{i=1}^{3} c_i * \Delta T_b^i$



LWP distribution from MiRAC measurements and of collocated datasets in 50 g m^{-2} sized bins.

COMPEX

… extends the series of Arctic airborne remote sensing campaigns in the framework of **(AC)3** to **seven** with in total **132 flights** over **400 flight hours**.

… operated a **state-of-the-art** remote sensing suite on the AWI Polar 5 aircraft, including **W- and G-band radars with DAR** capabilities.

… airborne observations will help to increase our understanding of **cloud and precipitation processes** in the **Arctic**.

… provides remote sensing observations of cloud and precipitation properties and thermodynamic profiles for **validation/evaluation** of **models**, **satellite** observations, and cloud and precipitation **products**.

References

Mech, M., Maahn, M., Kneifel, S., Ori, D., Orlandi, E., Kollias, P., Schemann, V., and Crewell, S.: PAMTRA 1.0: the Passive and Active Microwave radiative TRAnsfer tool for simulating radiometer and radar measurements of the cloudy atmosphere, Geosci. Model Dev., 13, 4229–4251, https://doi.org/10.5194/gmd-13-4229-2020, 2020.

Pfitzenmaier, L., Kollias, P., Risse, N., Schirmacher, I., Puigdomenech Treserras, B., and Lamer, K.: Orbital-Radar v1.0.0: a tool to transform suborbital radar observations to synthetic EarthCARE cloud radar data, Geosci. Model Dev., 18, 101–115, https://doi.org/10.5194/gmd-18-101-2025, 2025.

Schnitt, S., Mech, M., Goliasch, J., Rose, T., and Crewell, S.: G-band Radar for Water vapor and Arctic Clouds (GRaWAC): novel insights on Arctic water vapor, clouds and precipitation, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-5563, 2025.

Data availability and usage

All data available through the ac3airborne python toolbox. Usage and description in "How to ac3airborne".

Contact: mario.mech@uni-koeln.de