

Differential absorption G-band radar operated on an airborne platform for Arctic clouds and water vapor observations

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UNIVERSITY
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Radars for cloud and precipitation studies

Last decades have seen the emergence of cloud and precipitation radars

- Spaceborne for global assessments
 - CloudSat -> EarthCARE: unique insights into cloud vertical structure
 - GPM: dual frequency radar for quantitative precipitation
- Airborne radar operation as satellite demonstrators and validation tools
- Latest technological developments with ground-based radars



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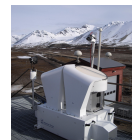
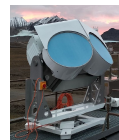
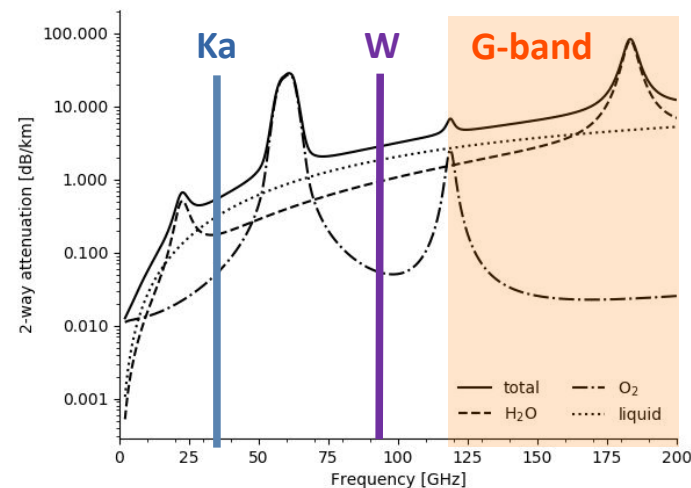
Remaining Gaps

- Sensitivity to small particles (→ higher frequencies)
- Characterization of hydrometeor microphysics (→ multiple freqs)
- Water-vapor (profiles) within clouds / virgae



Why G-band radar?

- 94 GHz (W-band) cloud radars have become workhorses for cloud profiling from various platforms
- Multiple frequency measurements (X, K, W) for hydrometeor characterization
- G-band radars have been proposed* to address gaps
 - can expand multi-frequency applications
 - dual G-band radars as Differential Absorption Radar (DAR)
- Today, less than a handful of experimental G-band radars exist (each limited DAR only, no Doppler, airborne, lab, ground..)



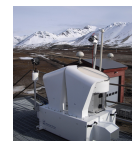
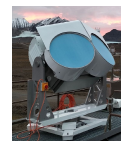
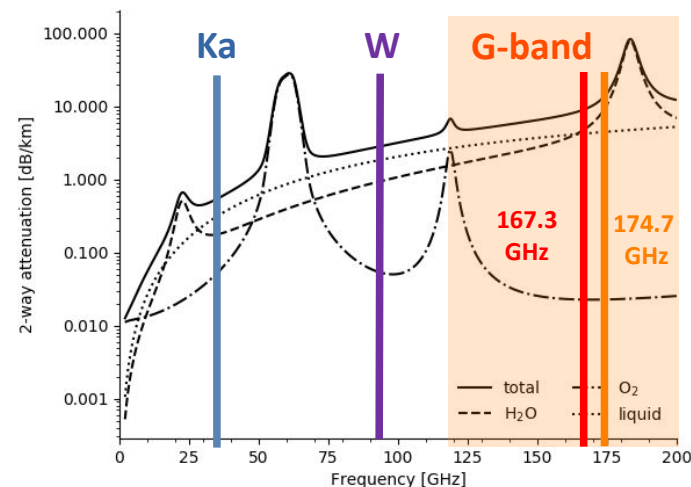
*Battaglia, A., C. D. Westbrook, S. Kneifel, P. Kollias, N. Humpage, U. Löhnert,, J. Tyynelä, and G. W. Petty, 2014: G band atmospheric radars: new frontiers in cloud physics, *Atmos. Meas. Tech.*, [doi:10.5194/amt-7-1527-2014](https://doi.org/10.5194/amt-7-1527-2014).

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Why DAR?

- Measurements at two frequencies along the 183 GHz line allow to derive in-cloud water vapor profiles
- Profile extension via simultaneous passive measurements



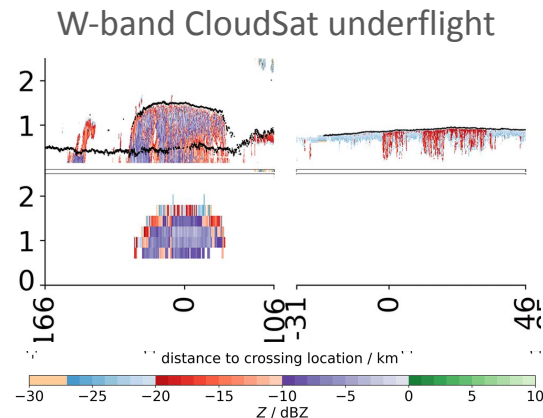
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Why DAR?

- Measurements at two frequencies along the 183 GHz line allow to derive in-cloud water vapor profiles
- Profile extension via simultaneous passive measurements
- Especially suited for (supersaturated) ice clouds and the Arctic, where most clouds experience light precipitation (missed by CloudSat)
- Opportunity to study moisture recycling (evaporation rate)



Schirmacher et al., 2023, AMT

*Battaglia, A., C. D. Westbrook, S. Kneifel, P. Kollias, N. Humpage, U. Löhnert, J. Tyynelä, and G. W. Petty, 2014: G band atmospheric radars: new frontiers in cloud physics, *Atmos. Meas. Tech.*, [doi:10.5194/amt-7-1527-2014](https://doi.org/10.5194/amt-7-1527-2014).

GRaWAC: G-band Radar for Water Vapor and Arctic Clouds

Frequency modulated continuous wave (FMCW) radar

Dopplerized, dual-frequency measurements at 167.3 and 174.7 GHz

Versatile deployment from ground, ship, and aircraft under all weather conditions

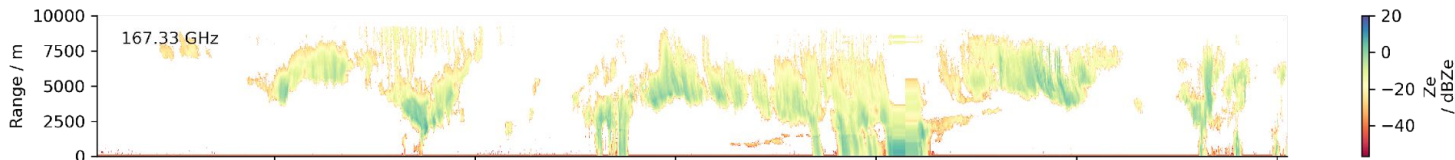
Frequencies ideal for Differential Absorption Radar: retrieval of water vapor profiles in all-weather conditions [1,2,3]



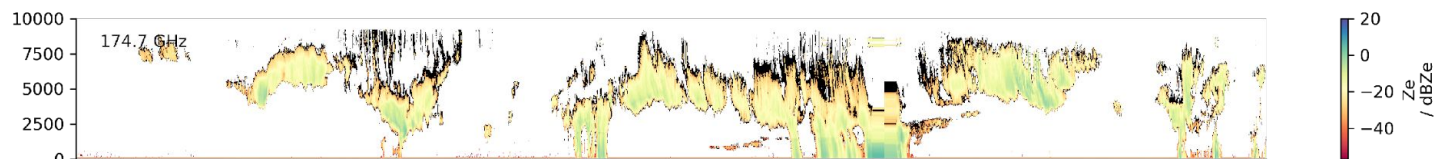
| parameter | specification | |
|---------------------------------------|-----------------|-----------------|
| frequency / GHz | 167.3 ± 0.1 | 174.7 ± 0.1 |
| wavelength / mm | 1.8 | 1.7 |
| transmit power / mW | 70 | 90 |
| gain / dB | 54.6 | |
| receiver noise / dB | 5.5 | |
| receiver intermediate frequency / MHz | 4 | |
| dynamic range / dB | 58 | |
| antenna diameter / m | 0.5 | |
| beam width / ° | 0.36 | |
| power consumption / W | 700 | |
| weight / kg | 116 | |
| dimension / m ³ | 115 x 90 x 90 | |

Ground based deployment in March 2024

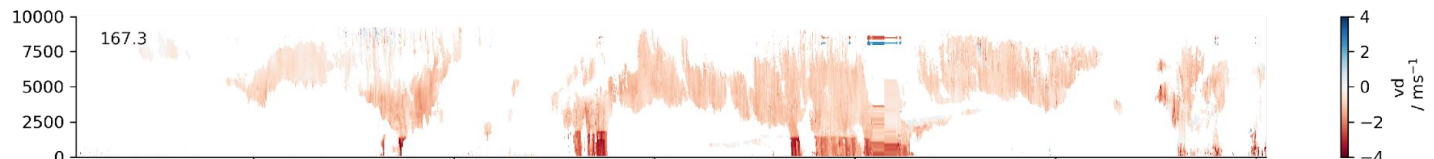
Reflectivity at
167.3 GHz



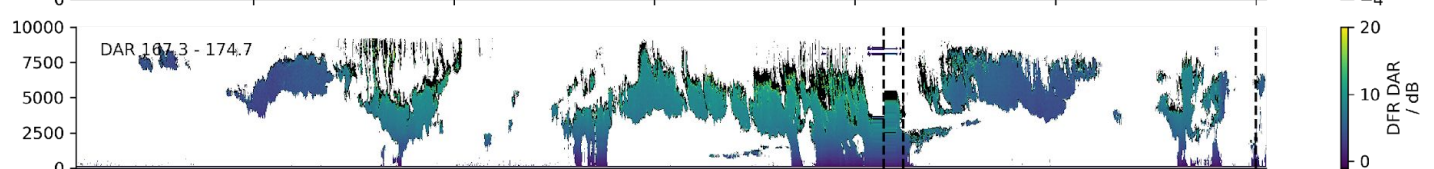
Reflectivity at
174.7 GHz
(black colors: nan-values
due to post-processing)



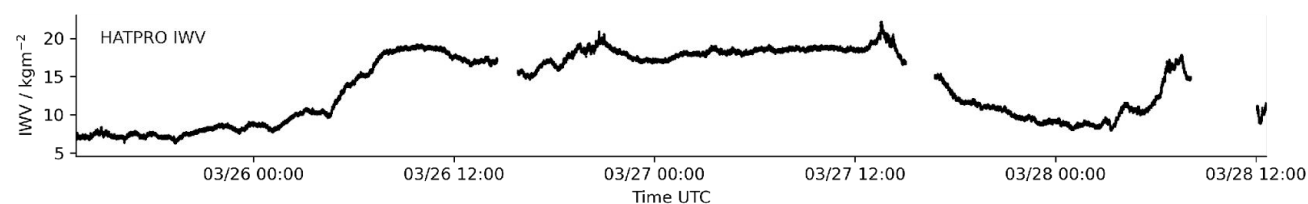
Mean Doppler velocity
at 174.7 GHz



Dual-Frequency Ratio
 $DFR = Z_{e,167.3} - Z_{e,174.7}$
(black colors: nan-values
due to post-processing)
(black — : sounding launches)

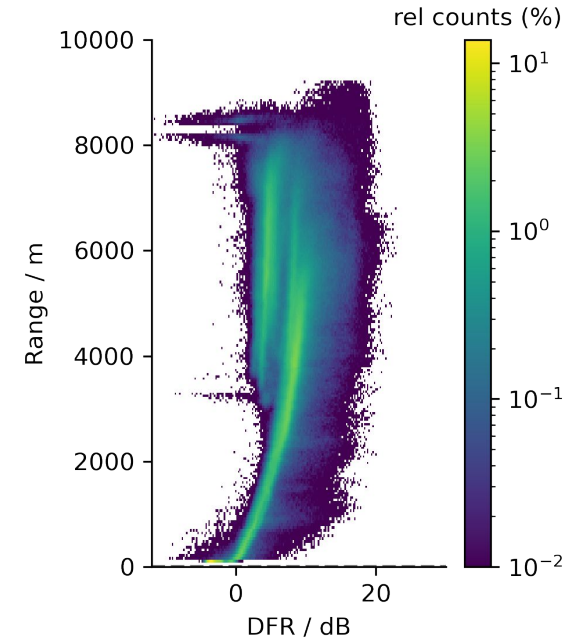
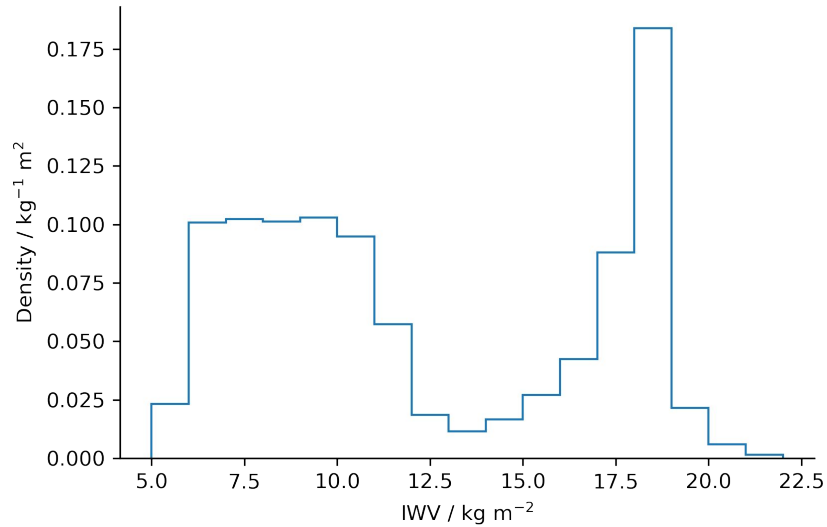


HATPRO Column water vapor
(IWV)

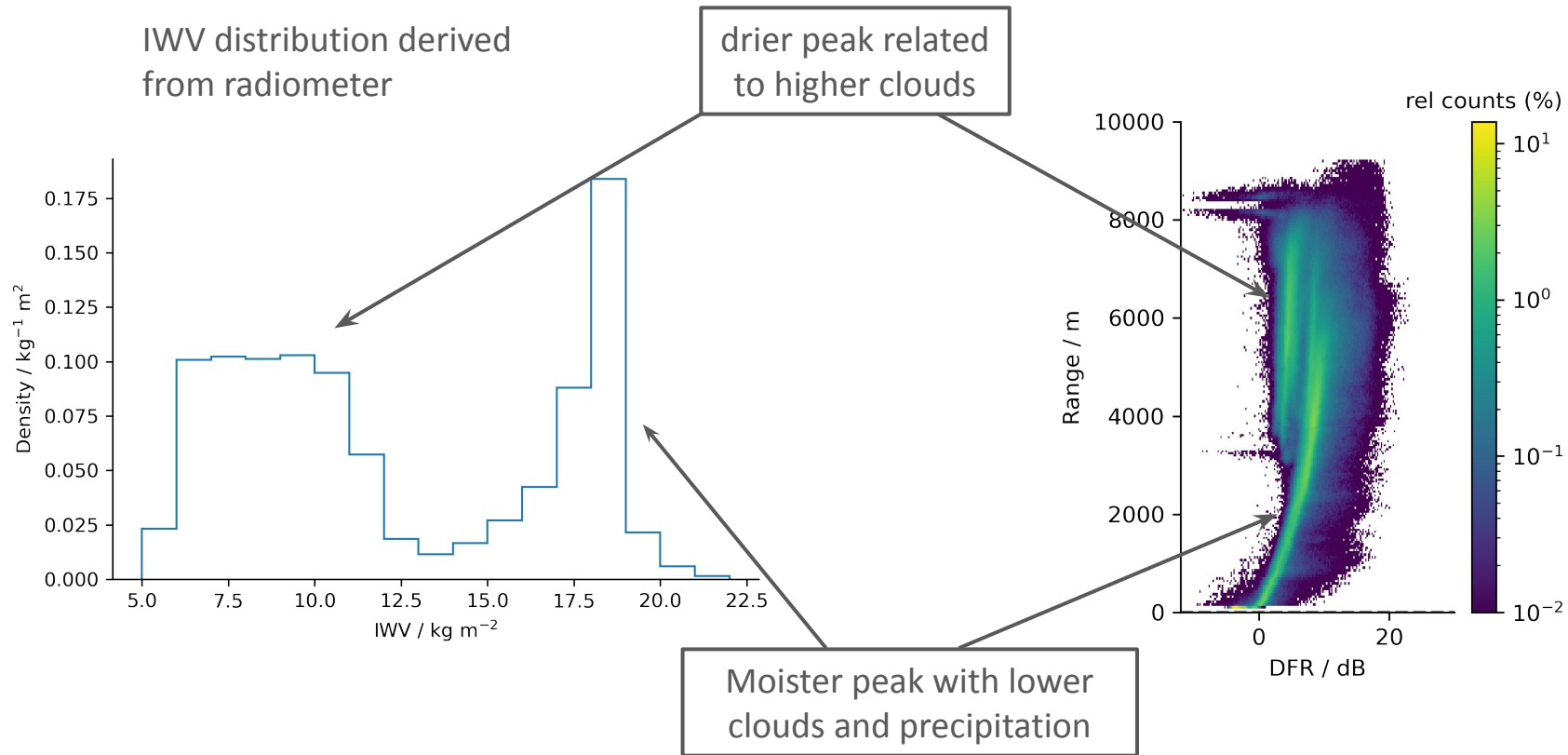


Bimodality in IWV distribution reflected in GRaWAC DAR CFAD

IWV distribution derived
from radiometer



Bimodality in IWV distribution reflected in GRAWAC DAR CFAD



Humidity profiles and Arctic
Mixed-phase clouds as seen
by Airborne G-W-band radars



Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

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Mixed-phase clouds as seen
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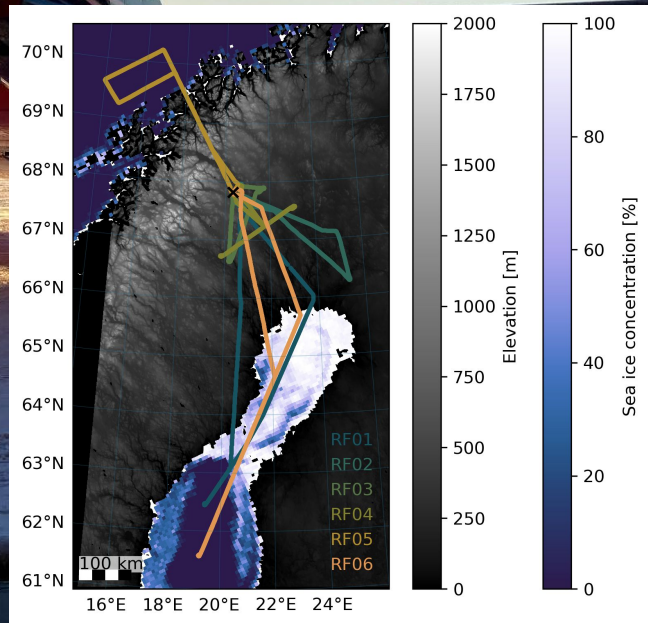
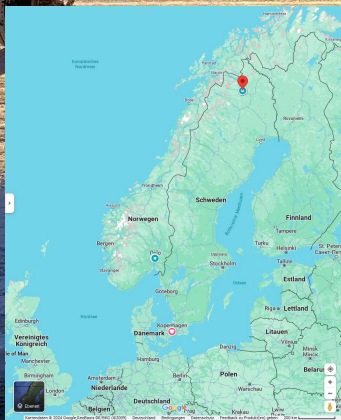
Kiruna (Sweden) - Arena Arctica

7. to 22. February 2024

Polar 6 research aircraft (BT-67)
from AWI

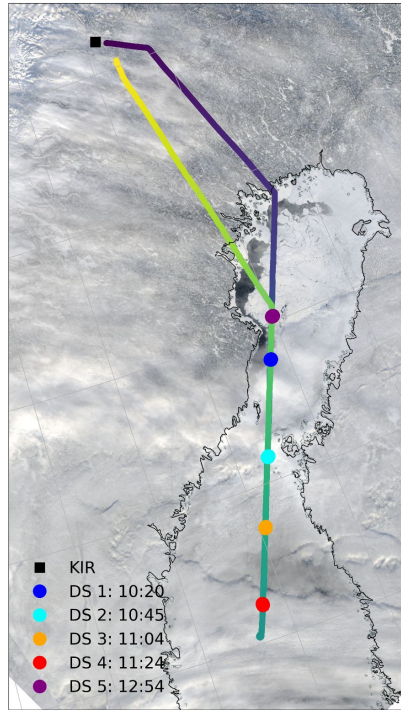
GRaWAC, MiRAC-A, MiRAC-P,
KT-19, dropsondes

6 research flights over the Gulf of
Bothnia and the Norwegian Sea

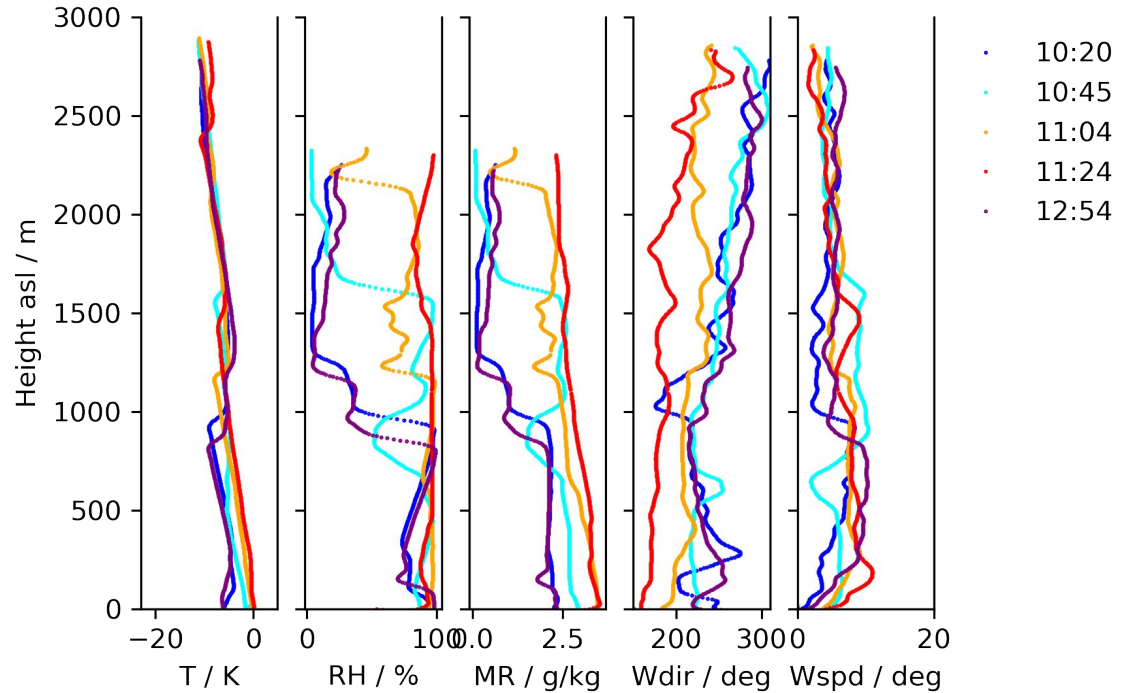


RF06 - 19.2.2024

multiple cloud layers over the Gulf of Bothnia

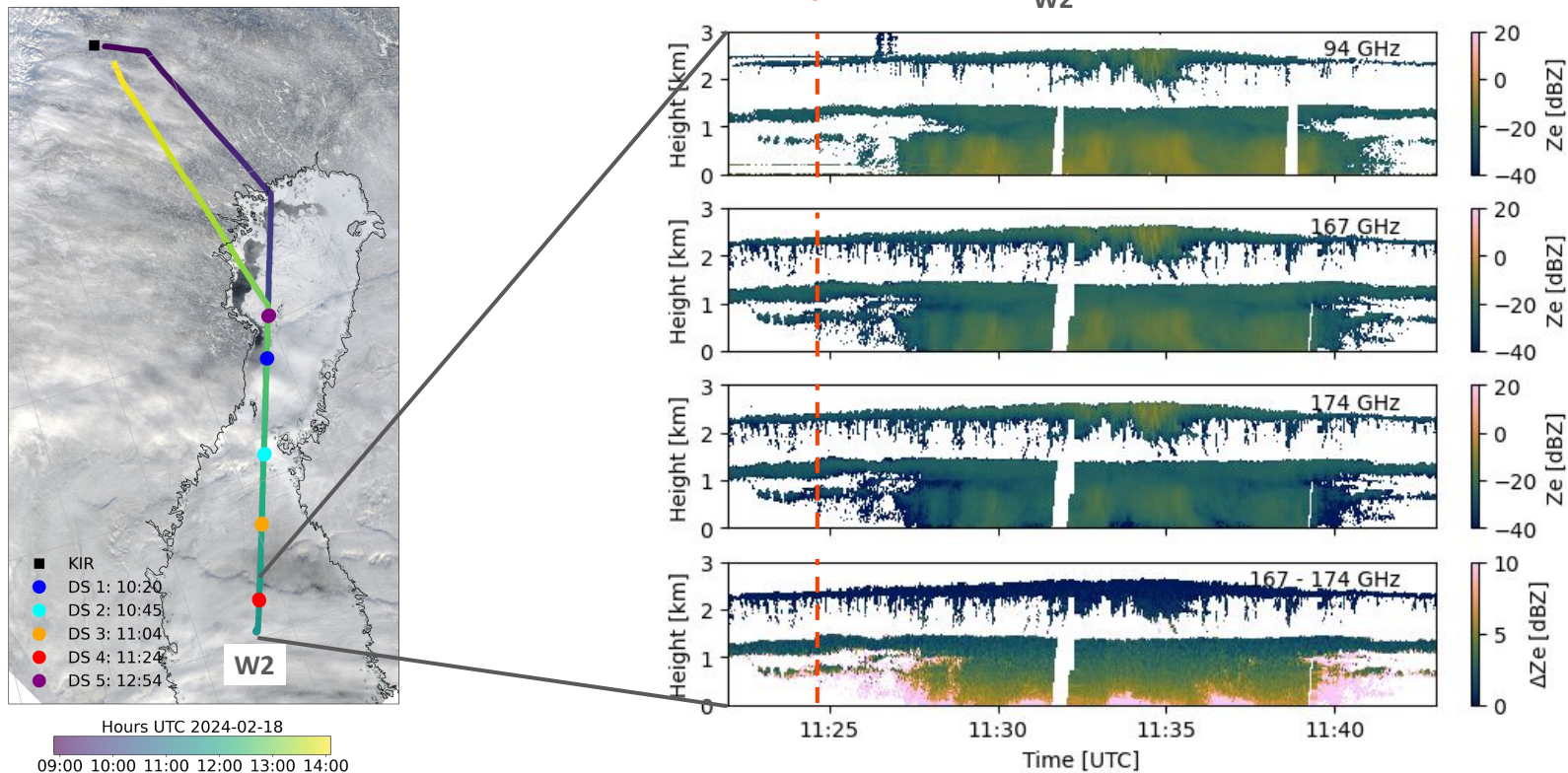


Hours UTC 2024-02-18
09:00 10:00 11:00 12:00 13:00 14:00



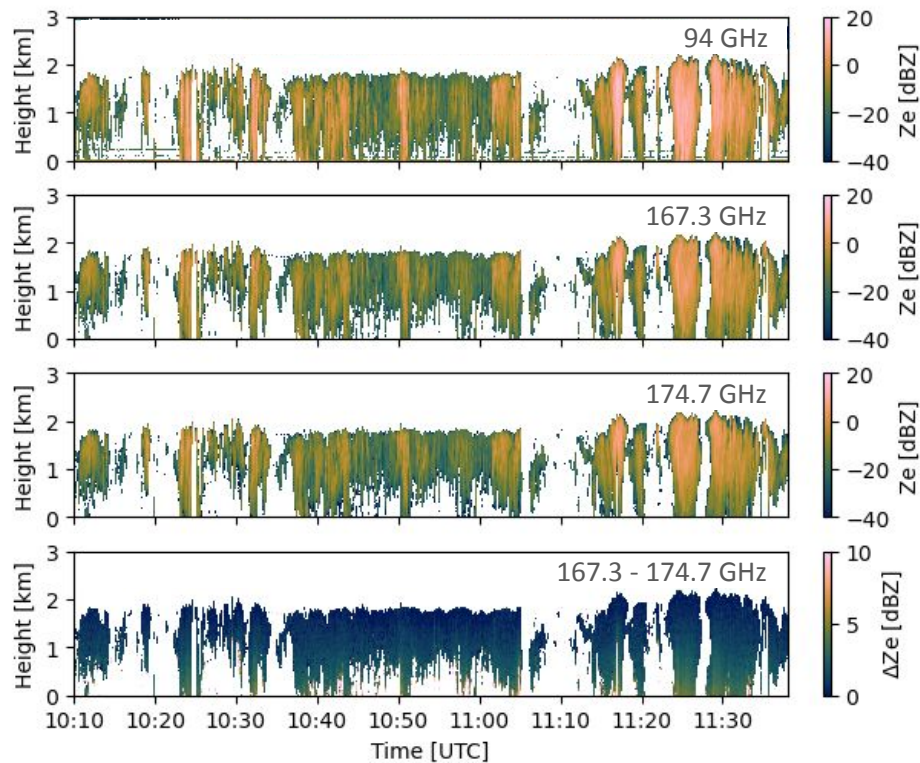
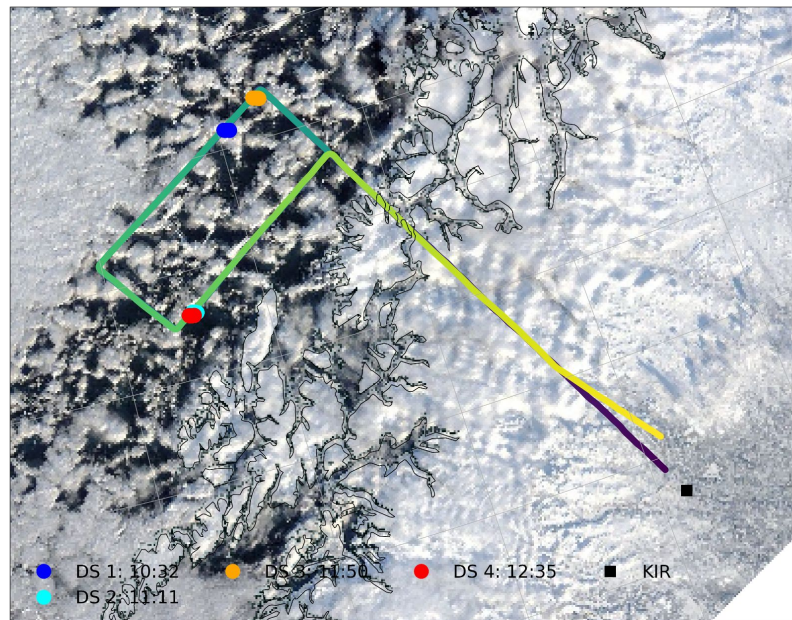
RF06 - 19.2.2024

multiple cloud layers over the Gulf of Bothnia



RF05 - 18.2.2024

cloud streets with open and closed cells over the Norwegian Sea



Summary and what to come

GRaWAC: G-band Radar for Water Vapor and Arctic Clouds

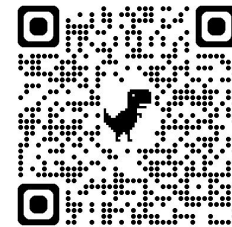
Dopplerized, **dual-frequency** FMCW radar at 167.3 and 174.7 GHz

Versatile deployment: ground, ship, and aircraft

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Unprecedented insights into **mixed-phase cloud processes**

Successfully conducted six research flights during **HAMAG** test campaign



HAMAG-blog



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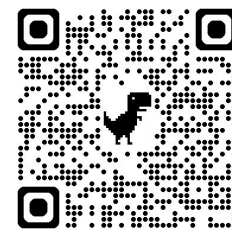
Future deployments

Polarstern ship cruise PS144: **VAMPIRE** (Water Vapor, Mixed-Phase Clouds, and Sea Ice Emissivity over the Central Arctic Ocean) - Summer 2024

Ground based deployment at the Arctic research base **AWIPEV** in Ny-Ålesund

COMPEX airborne campaign over the Fram strait - Spring 2026

Soon to be submitted to AMT: Look out for **S. Schnitt et al. and GRaWAC**



HAMAG-blog



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