Characterization of Arctic mixed–phase clouds by airborne in–situ measurements and remote sensing

B03

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1 Summary

- Significant role of mixed-phase clouds in the Arctic energy budget
- Lack of comprehensive and complementary observations
- Uncertain processes
  - Droplet formation and **ice nucleation**, interaction with aerosol
  - Persistence of boundary layer clouds despite **precipitation**
  - **Vertical and horizontal variability** of ice and liquid water
  - Resulting cloud **radiative effects** on Arctic energy budget

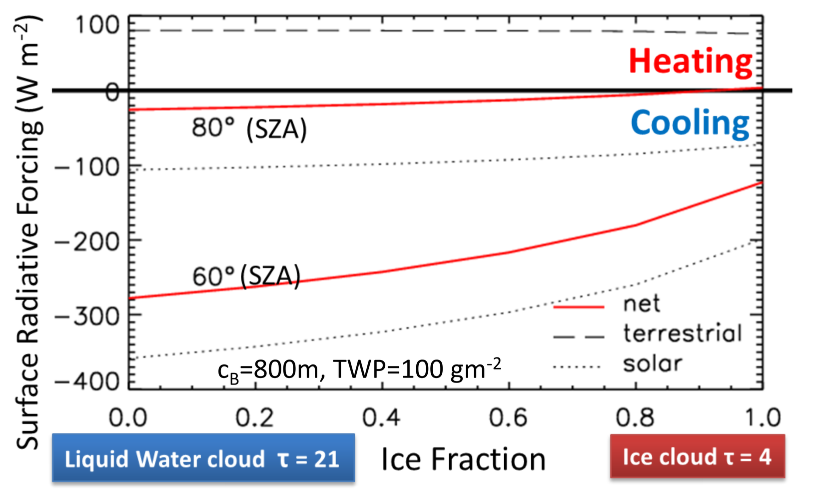


Fig. 1: Surface radiative forcing of a mixed-phase cloud.

Hypothesis

A higher ice fraction in mixed–phase clouds shortens their lifetime by enhanced precipitation and reduces their solar cooling by decreasing the cloud optical thickness

2 Research rationale

Collocation of airborne remote sensing and in situ observations

- **ACLOUD** campaign: - **Polar 5 & 6** aircraft (80 flight hours each)
  - **Funded** by AWI in June 2017
- Two identical aircraft (in situ / remote sensing)
- **Collocation** within 1 km (300-10.000 ft altitude)
- Link to ground-based observations from Polarstern (PASCAL) and Ny-Ålesund

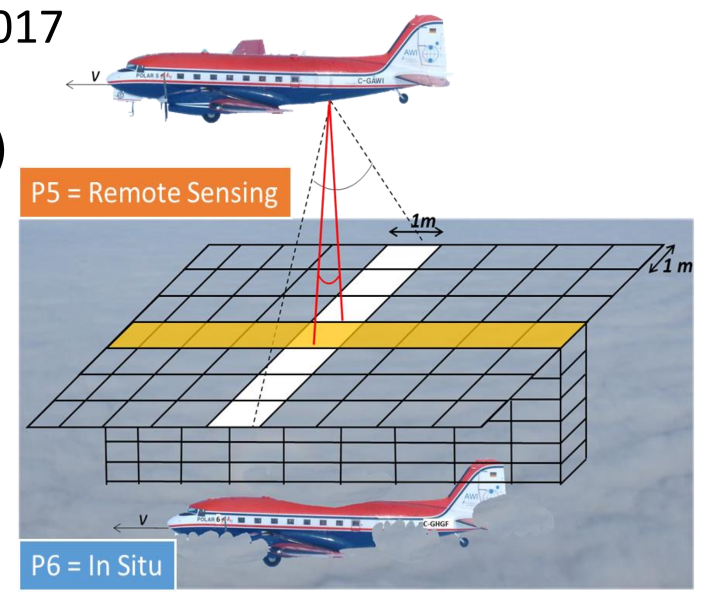


Fig. 2: Strategy of collocated in situ and remote sensing measurements during ACLOUD.

Key Instrumentation

In Situ

- **CVI + CPC, OPC, UHSAS, PSAP**
  - Ambient aerosol and residuals (IN, CCN)
  - Size distribution (0.06 - 10 µm)
  - Chemical composition
- **CCP, PIP, NIXE-CAPS, HALOHolo**
  - Cloud particle and precipitation size distribution (0.6 µm – 6.4 mm)

Remote Sensing

- **Eagle/Hawk imaging spectrometer**
  - 0.3-2.2 µm, <10 m spatial resolution
  - Maps of cloud phase, optical properties
- **Microwave Radar/radiometer for Arctic Clouds (MiRAC)**
  - 94 GHz FMCW radar + 89 GHz passive channel
  - 183.31(6x) / 243 / 340 GHz microwave radiometer
- **Airborne Mobile Aerosol Lidar for Arctic research (AMALi; AWI)**

Specific Objectives

(A)	Number, size and shape of ice particles in the cloud, and of precipitating ice particles
(B)	Horizontal and vertical distribution of ice and liquid water in stratiform mixed–phase clouds
(C)	Impact of aerosol particles and ice nucleation processes on (A) and (B)
(D)	Variability of cloud radiative forcing due to (A) and (B)

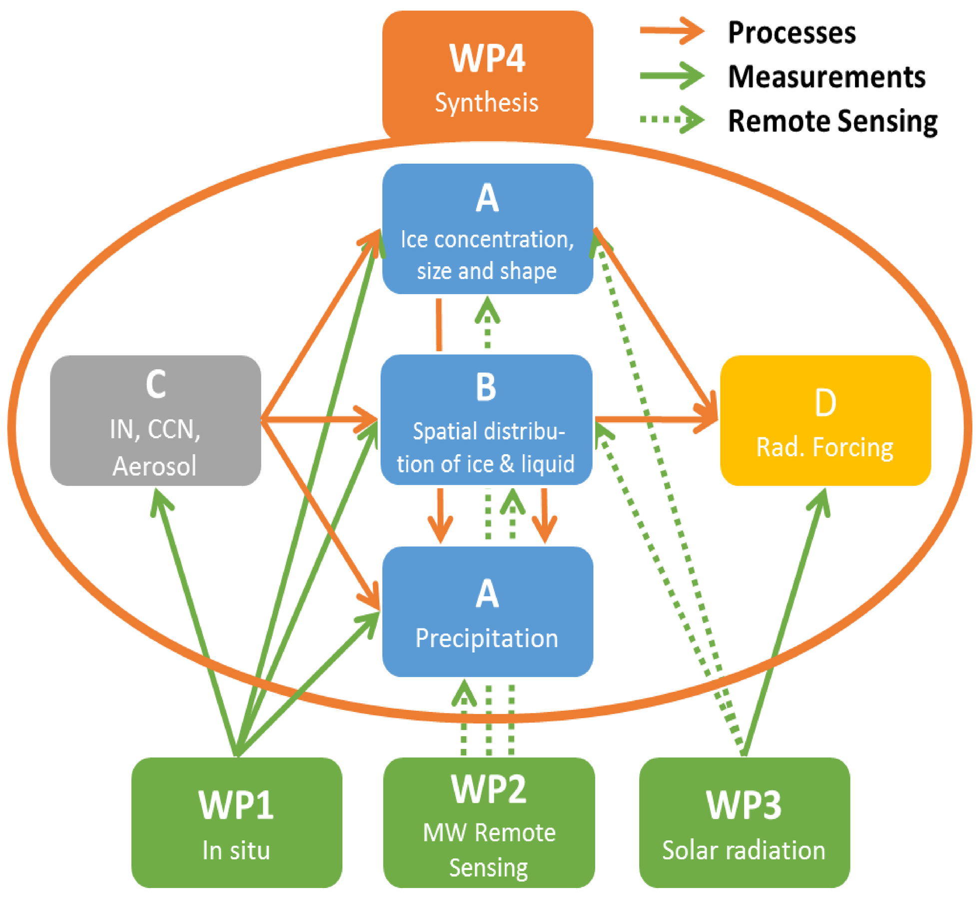


Fig. 3: Topics and work packages of B03.

3 Research plan

WP1: In situ observations of ice and aerosol particles (TROPOS)

- CVI for physico–chemical characterization **cloud residuals** and ambient aerosol
- Number, size, shape of cloud particles with emphasis on **ice crystals**

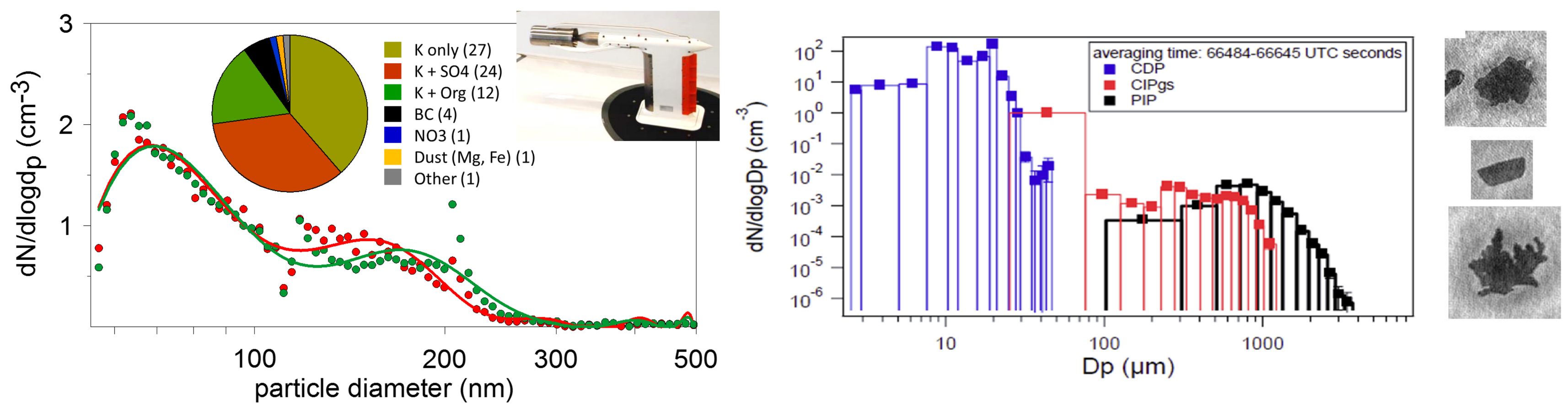


Fig. 4: Examples of ice residues (left, ML-Cirrus) and cloud particle (right, VERDI) characterization.

WP2: Vertical profiling of ice and liquid water (UNI-K)

- **Vertical hydrometeor distribution** from sensor synergy
- Amount and pattern of **precipitation**

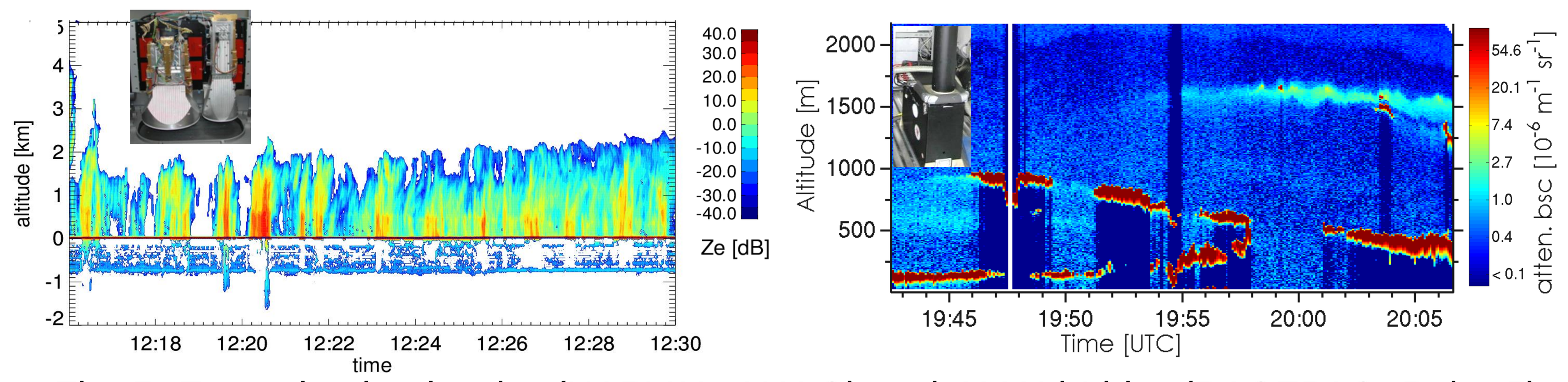


Fig. 5: Example cloud radar (NARVAL, HALO) and AMALi Lidar (RACEPAC, Polar 5) measurements similar to the proposed setup.

WP3: Horizontal mapping of ice by solar remote sensing (UNI-L)

- Identify **small scale variability** of cloud properties (up– and downdrafts)

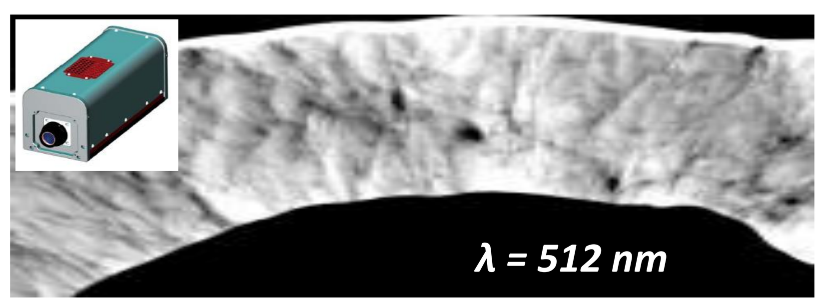


Fig. 6: Radiance above clouds with high spatial resolution.

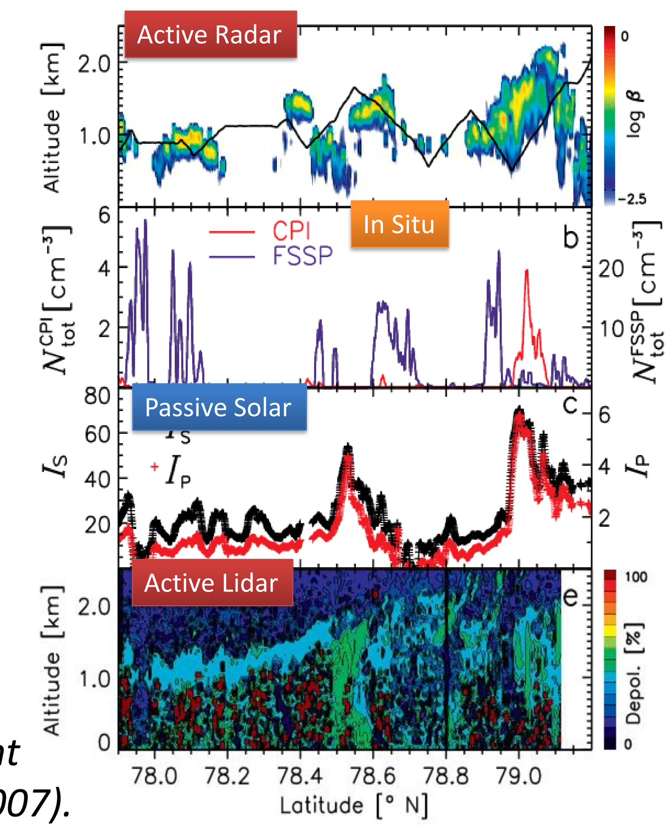
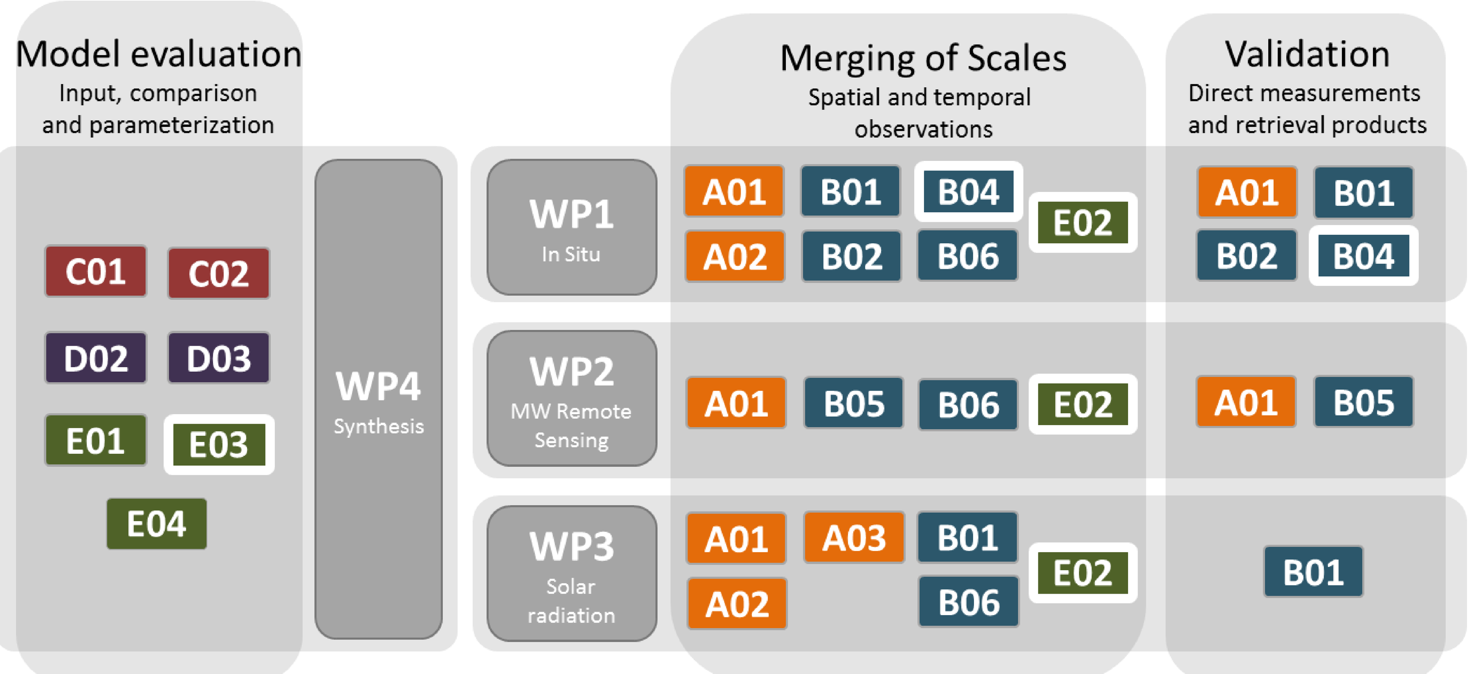


Fig. 7: Measurement composit (ASTAR 2007).

WP4: Synthesis (ALL)

- Validation and retrieval improvement
- Impact of IN on the cloud microphysical properties and precipitation
- Cloud radiative forcing
- Model evaluation

4 Role within (AC)³ & perspectives



Collaboration within (AC)³

- Evaluation of Large Eddy Simulations (**E03**)
- MiRAC observations and data processing in close collaboration with **E02**
- Evaluate the representativeness of ground-based aerosol characterization (**B04**)

Perspectives

- Target the most relevant cloud regime
- Operation of the German research aircraft **HALO** during **MOSAiC**
  - Extend the observations to **higher altitudes** and **larger area**
  - Improved and extended instrumentation

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