# Characterisation of Arctic mixed-phase clouds by airborne in situ measurements and remote sensing

**B03**

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## 1. Summary


Research questions:

B03 aims at generating and analyzing **a categorized observational data set of Arctic cloud and aerosol particle properties** to answer the following questions:

**Q1** How do cloud properties change during air mass transformations?

**Q2** Does the source of cloud forming particles change in air mass transformations?

**Q3** Are there seasonal and regional differences in respect to Q1 and Q2?

**Q4** What are the effects on precipitation and cloud radiative forcing?


## Hypothesis

**Changes of cloud properties and cloud forming particles along air mass transitions are in the same order as those due to seasonal variability.**

## 2. Achievements phase I

### Observations during ACLOUD + AFLUX

- novel remote sensing and in situ instrumentation
- spatial **distribution of ice particles** differs in clouds formed in **cold/warm** air masses and over **sea ice/open ocean**
- different origin of **cloud forming particles**:
  - **open ocean** = below cloud mixing
  - **closed sea ice** = cloud top entrainment

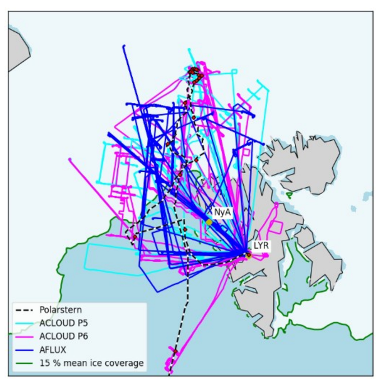


*Fig. 1: Flight tracks of ACLOUD (22 flights, 165 h, Wendisch et al., BAMS, 2019) and AFLUX (13 flights, 67 h).*

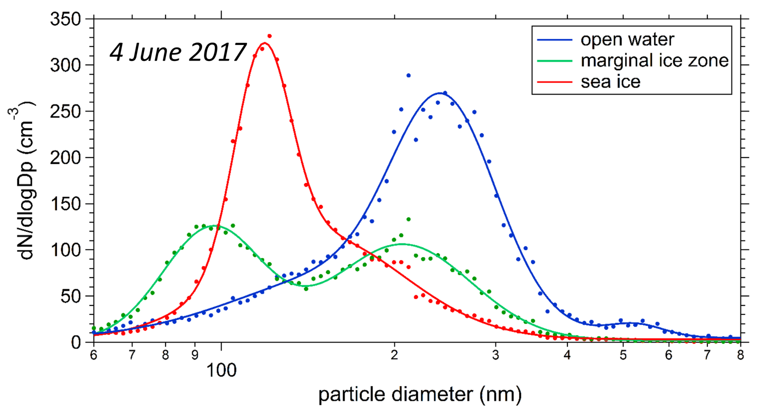



*Fig. 2: Cloud droplet residual number size distribution in clouds over open water, the marginal sea ice zone and sea ice*

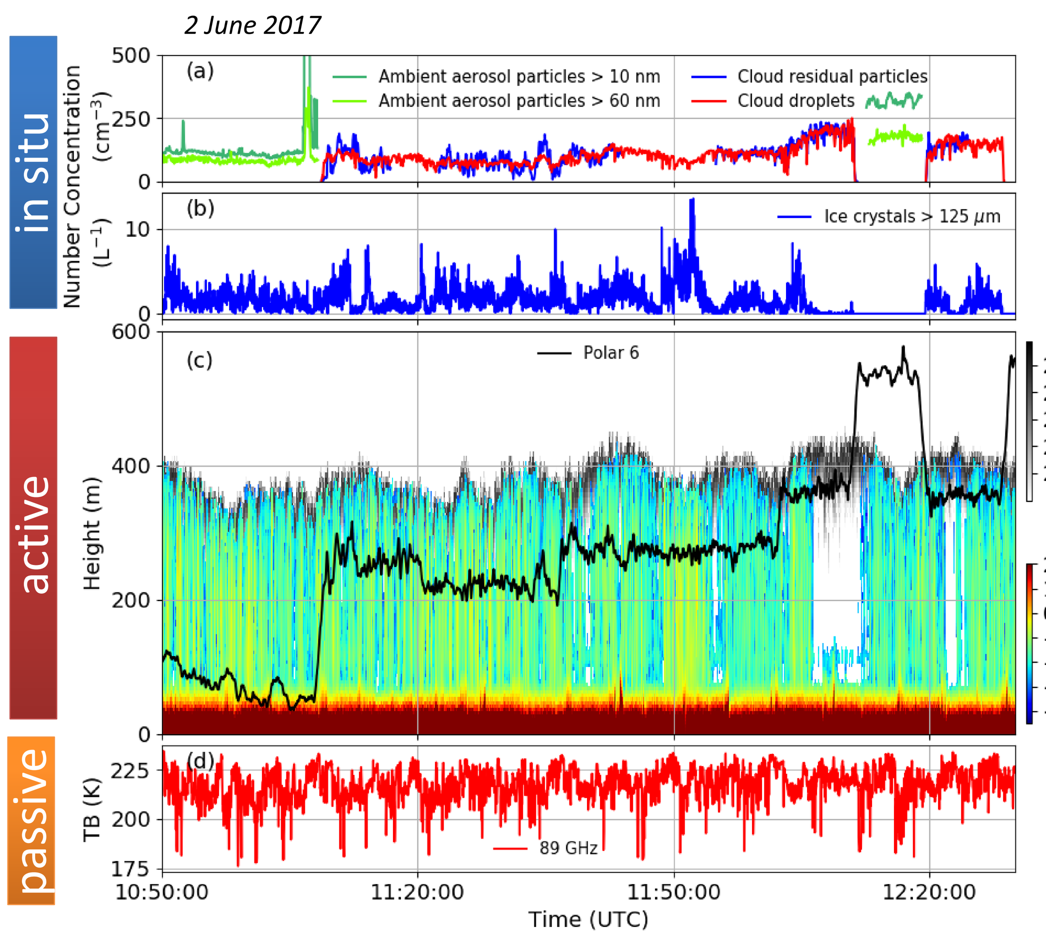



*Fig. 3: Combination of collocated active/passive remote sensing and in-situ cloud/aerosol measurements on 2 June 2017 (close to RV Polarstern).*

### Synthesis and collaboration

- **combined analysis** of collocated in situ and remote sensing
- **comparison** to Large Eddy Simulations (LES) by E03
  - → **too little ice**
- maps of cloud top radiative cooling (A03)
- high spatial and temporal variability of cloud systems (Schäfer et al., ACP, 2018)

Cold air mass (25 May 2017) passive Warm air mass (2 June 2017)

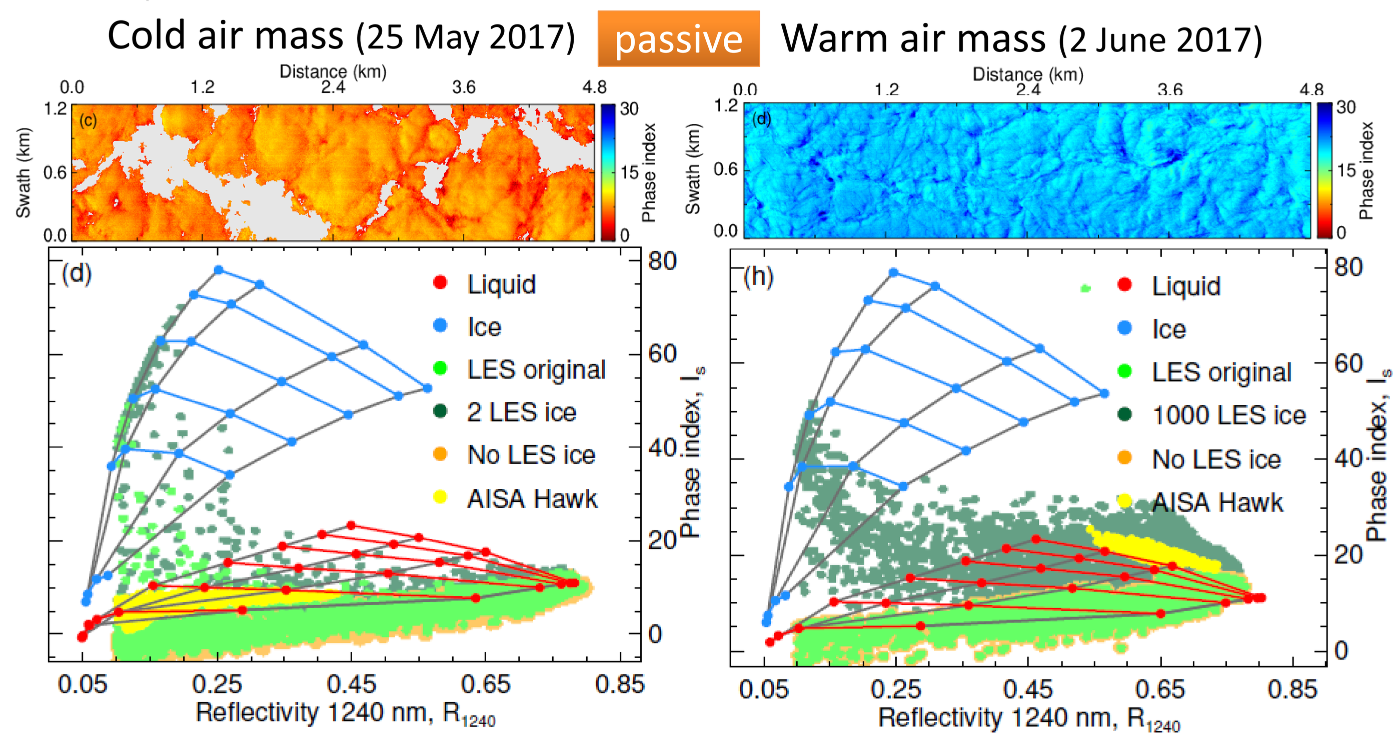
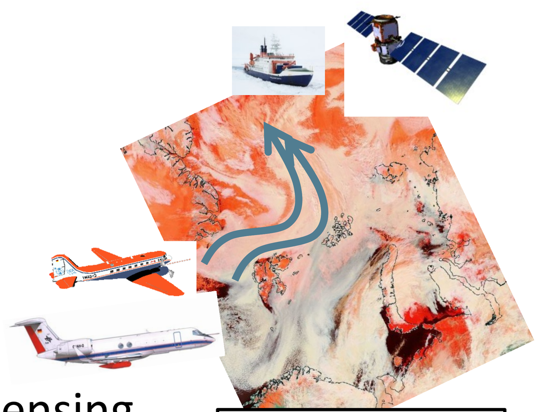



*Fig. 4: Simulated (LES) and observed (spectral imaging) cloud phase index for the two cloud cases in cold (left) and warm air mass (right)*

## 3. Research plan phase II



Regional observations along trajectories

### WP1 Aircraft campaigns

- 2020 spring + summer: **MOSAiC** (no in situ aerosol)
- 2021 spring: **HALO-(AC)³** + **Polar 5/6** in situ and remote sensing
- 2022 summer: **ATWAICE** (only in situ aerosol and cloud)
- coordination of flights to characterize **air mass transformations**

\+ ACLOUD + AFLUX

| Cloud and Aerosol Catalogue | | |
|---|---|---|
| cold air outbreak | vs. | warm air intrusion |
| sea ice | vs. | open ocean |
| early spring | vs. | late summer |
| inner Arctic | vs. | outer Arctic |
| surface-coupled cloud | vs. | decoupled cloud |

### WP2 Cloud remote sensing

- new thermal IR-imager (on HALO), lower frequency MW radiometer (20-60 GHz)
  - → extend cloud **retrieval over sea ice** (Ehrlich et al., AMT, 2017)
  - → enhanced information on **sea ice and temperature profiles**
- **synergistic hydrometeor classification** combining lidar, radar and radiometer
- exploiting the full potential of the Doppler spectra

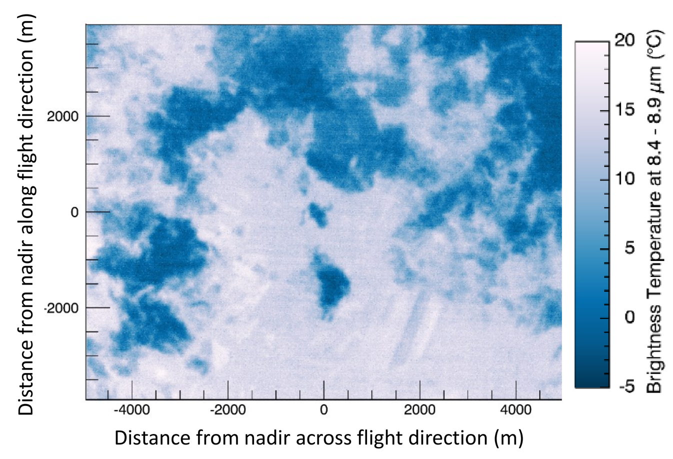



*Fig. 5: Example of brightness temperatures measured by the new thermal IR-imager.*

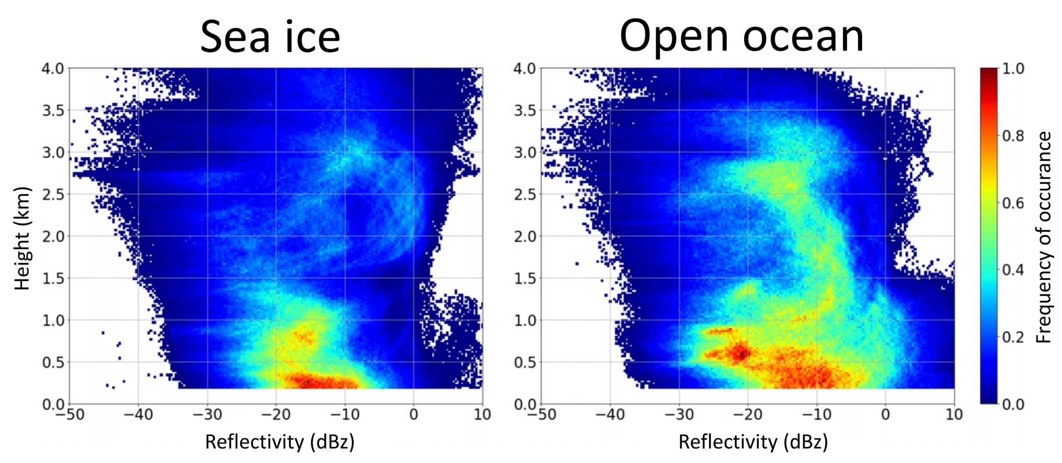


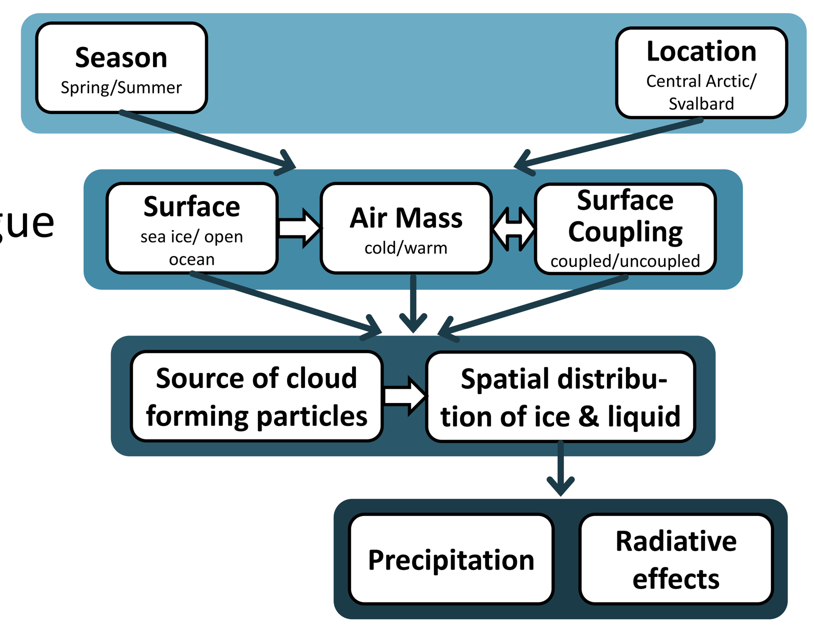

*Fig. 6: Radar reflectivity freq. of occurrence by altitude observed over sea ice and open ocean during ACLOUD (Mech et al., ACP, 2019).*

### WP3 In situ aerosol and cloud particle characterization

- new hygrometer for direct condensed water content and humidity
- counter-flow virtual impactor sampling strategy to **separate large ice particles**
- complementary characterization of **ambient aerosol and cloud particle residuals**
- identify **source/origin/pathway** of cloud forming particles

### WP4 Synthesis

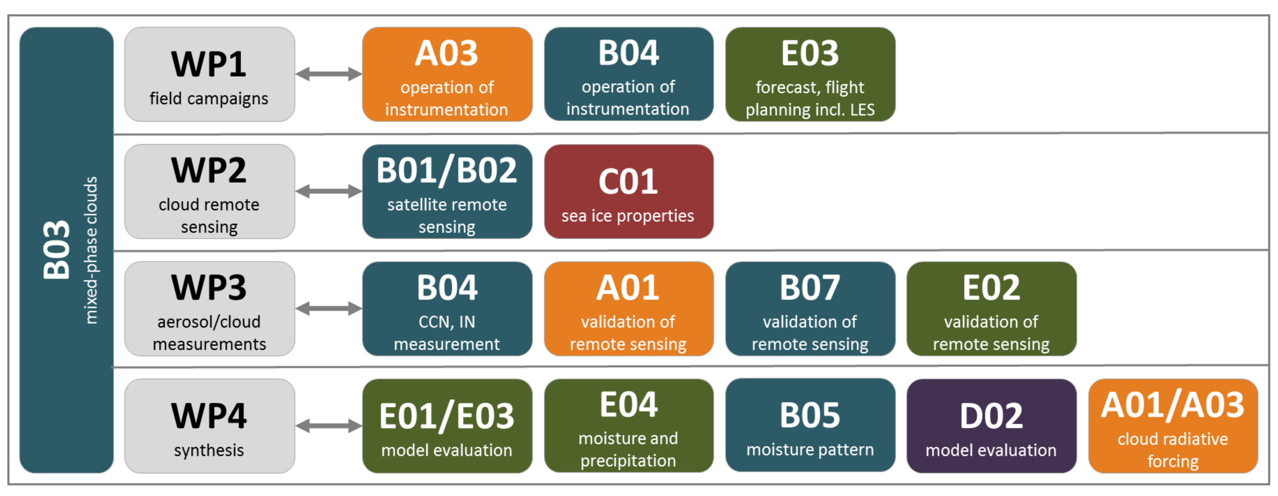
- **statistical analysis** of multi-campaign catalogue
- aerosol cloud interaction
- radiative forcing and precipitation
- model evaluation - **forward model approach**




## 4. Role within (AC)³ & perspectives

### Collaborations within (AC)³

- evaluation of mixed-phase cloud LES operated in a Lagrangian approach **CCA3**
- cloud, aerosol, moisture, and precipitation pattern in air mass transformation **CCA4**
- extended aerosol characterization with **B04**




### Perspectives

- assessing the capabilities of future spaceborne sensors: EarthCare, MetOp-SG Microwave Imager (MWI) and Ice Cloud Imager (ICI) by synergetic retrieval algorithms
- validating satellite products for aerosol cloud interaction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(AC)³ ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms

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