In-situ measurements of low-level clouds over the sea ice and the open ocean in the Arctic during spring and summer

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SPP PROM all hands meeting

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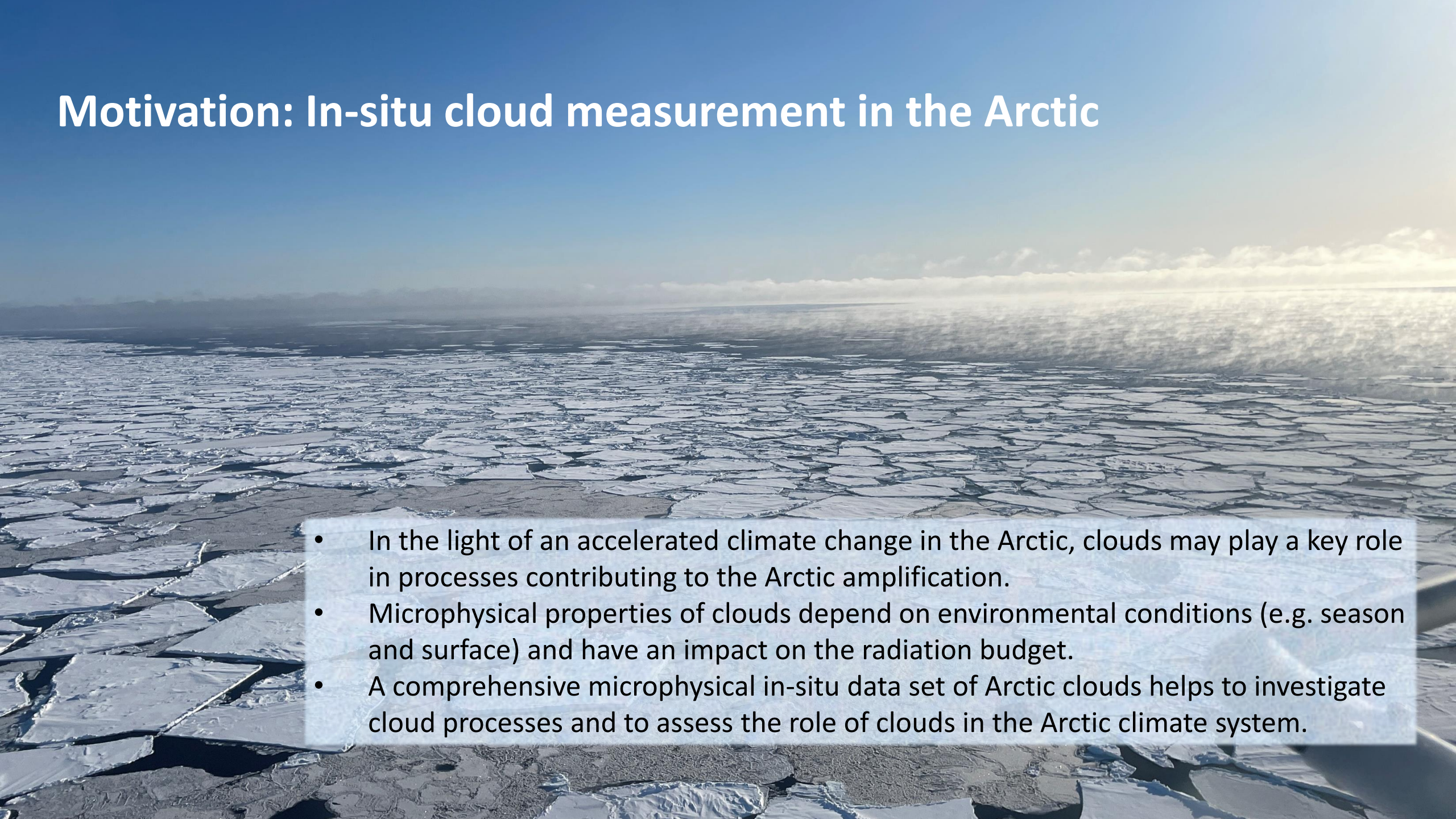
Project: POLICE, PIs: Silke Trömel, Clemens Simmer, Christiane Voigt

Motivation: In-situ cloud measurement in the Arctic



- In the light of an accelerated climate change in the Arctic, clouds may play a key role in processes contributing to the Arctic amplification.
- Microphysical properties of clouds depend on environmental conditions (e.g. season and surface) and have an impact on the radiation budget.
- A comprehensive microphysical in-situ data set of Arctic clouds helps to investigate cloud processes and to assess the role of clouds in the Arctic climate system.

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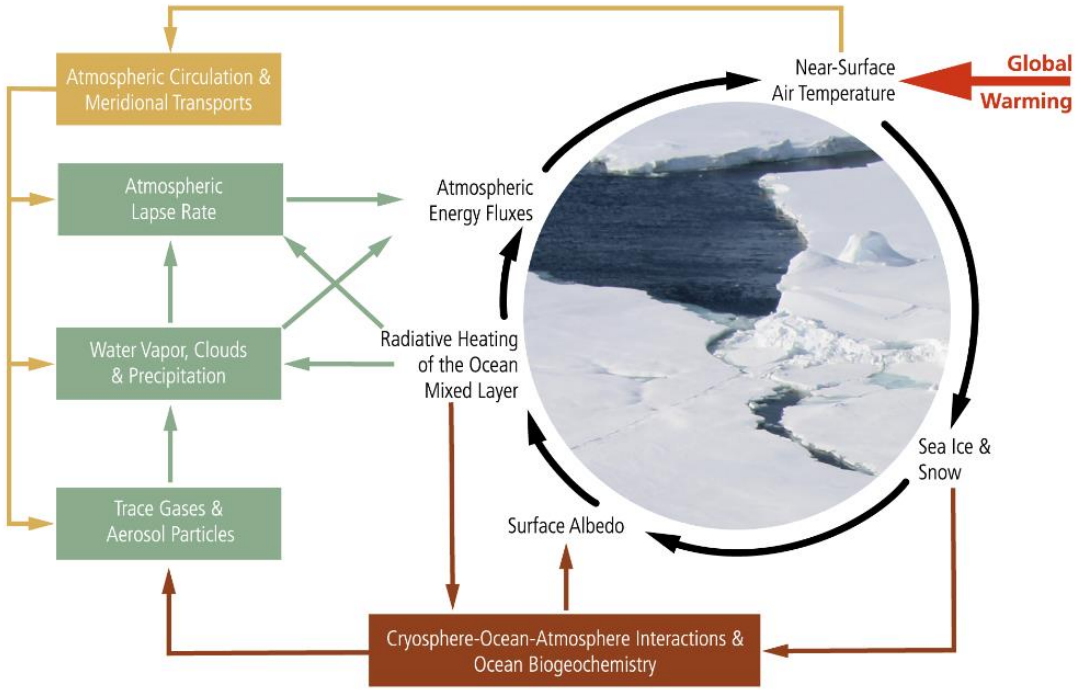
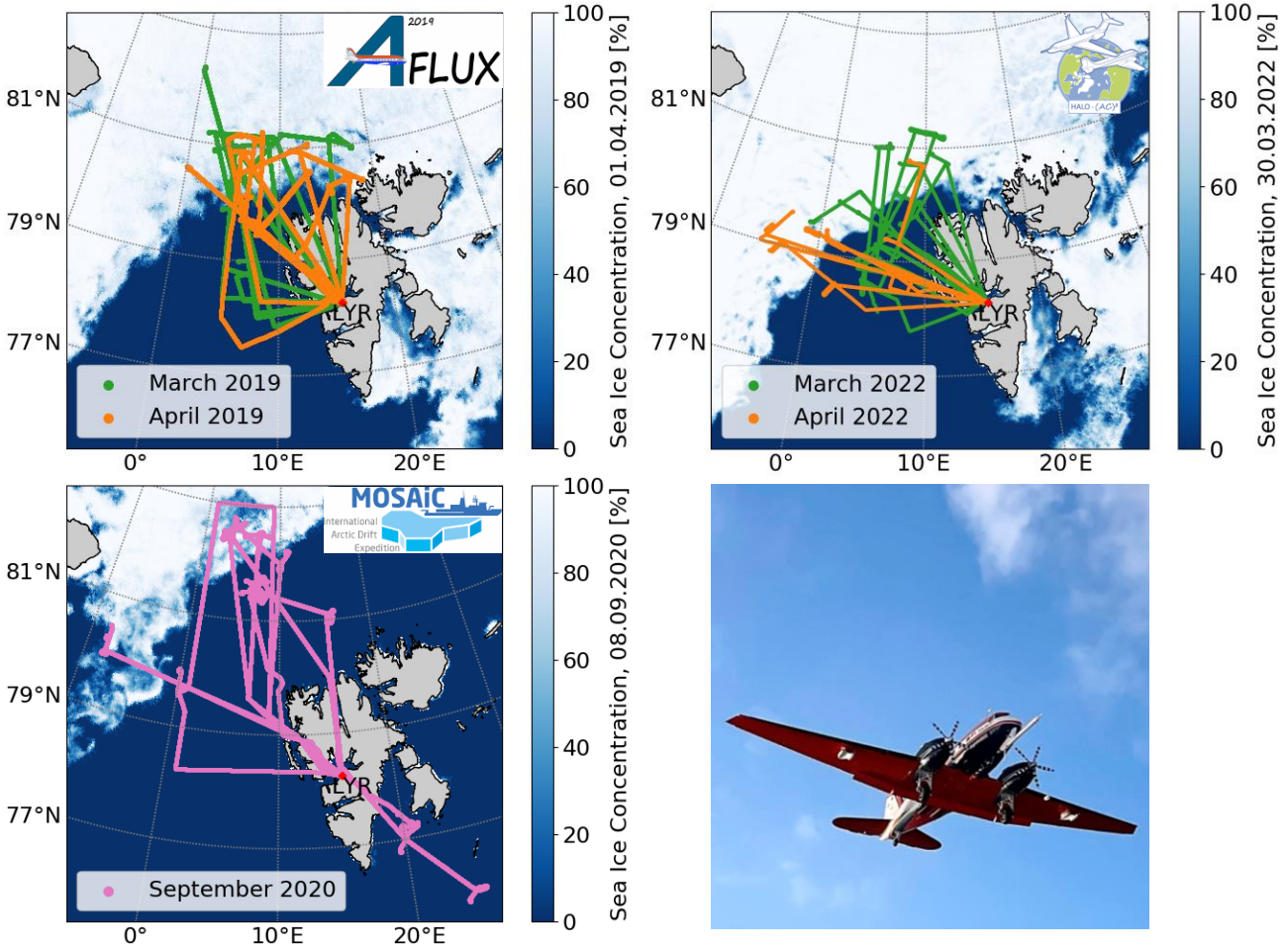


Wendisch et al., in rev. 2022

Overview: AFLUX & MOSAiC-ACA & HALO-(AC)^3



Campaigns

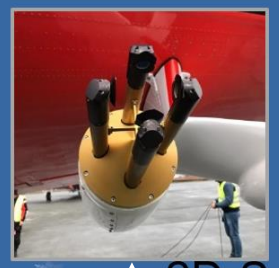
- 37 scientific flights in the summer and spring
- 70 h in-situ measurements of clouds in liquid, ice, and mixed phase
- Cloud measurements in altitudes between 60 m and 3700 m
- Spring cloud temperatures between -29 °C and -2 °C (AFLUX)
- Summer cloud temperature between -21 °C and 13 °C (MOSAiC)

In-situ instrumentation on Polar 5/6 during ALFUX, MOSAiC-ACA and HALO-(AC)³

CCP*
(CDP + CIP)

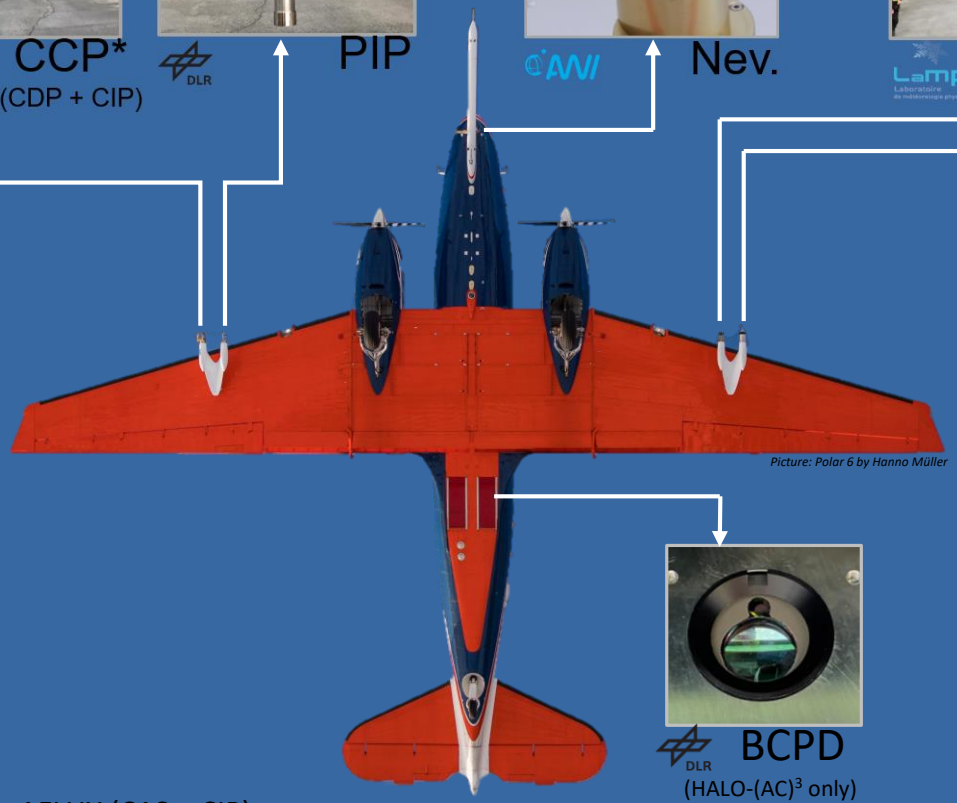
PIP

Nev.



2D-S

PN



Picture: Polar 6 by Hanno Müller

BCPD
(HALO-(AC)³ only)

*CAPS during AFLUX (CAS + CIP)

Raw image data from the PIP

Probe		Range	Cloud properties
PN	Scattering measurement	~µm – 800 µm (bulk measurement)	Scattering phase function, extinction coeff., asymmetry parameter
2D-S	Imager	20 – 1280 µm	Size distribution, N_{tot}, CWC, shape
Nevzorov	Hot wire probe	0.01 – 3.0 g m^{-3} (bulk measurement)	LWC, TWC
PIP	Imager	200 – 6400 µm	Size distribution, N_{tot}, CWC, shape
CIP	Imager	30 – 960 µm	Size distribution, N_{tot}, CWC, shape
CDP/CAS	Size spectrometer	2.5 – 50 µm	Size distribution, N_{tot}, CWC

In-situ instrumentation: Scattering probes (CDP)

Optical setup CDP:

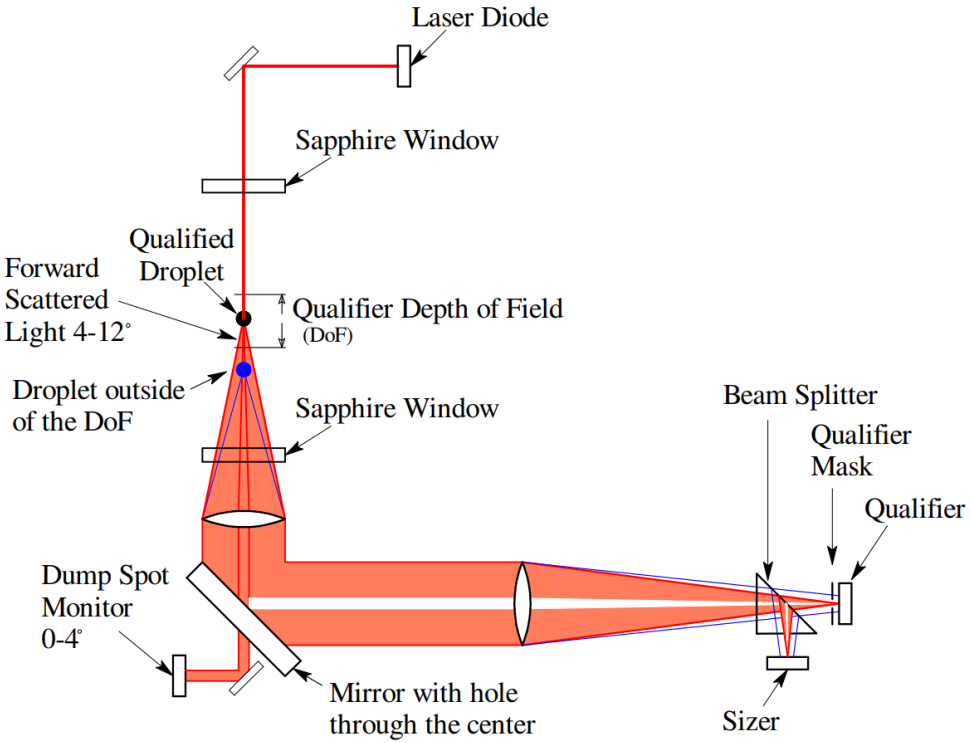
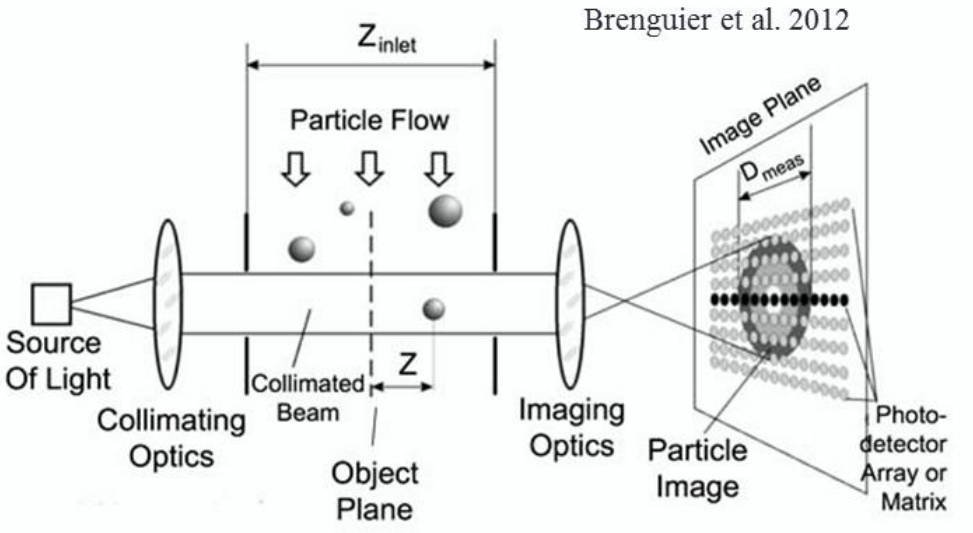


Figure by Lance et. al, 2010

Scattering Probe: CDP

- Physical principle: $\sigma(4-12°)_{forward} \sim D_{particle}$
- Sizing: 2.8 µm – 50 µm

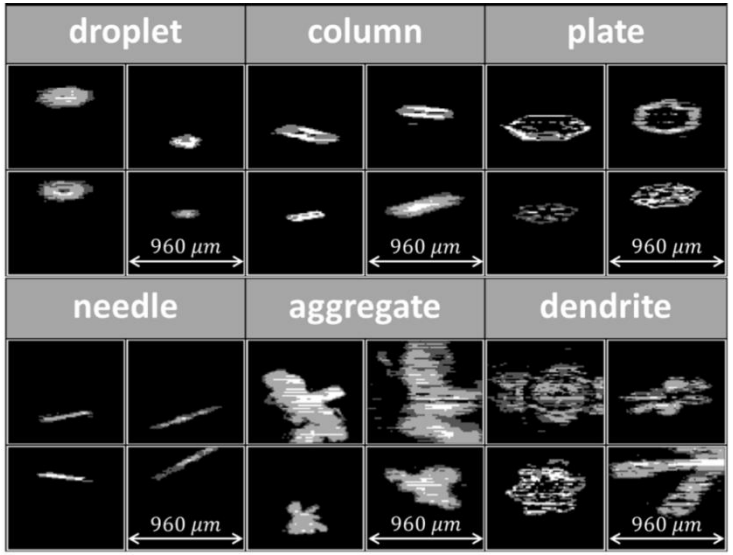
In-situ instrumentation: Optical array probes (CIP, PIP)



- „Scanning shadow of cloud particles“
- State of the photo diode array read with $f \sim V_{TAS}$
- Particle size: - 15 µm – 960 µm (CIP)
  - 100 µm – 6.4 mm (PIP)

Optical Array Probe

Example of OAP data (CIP-AFLUX data)



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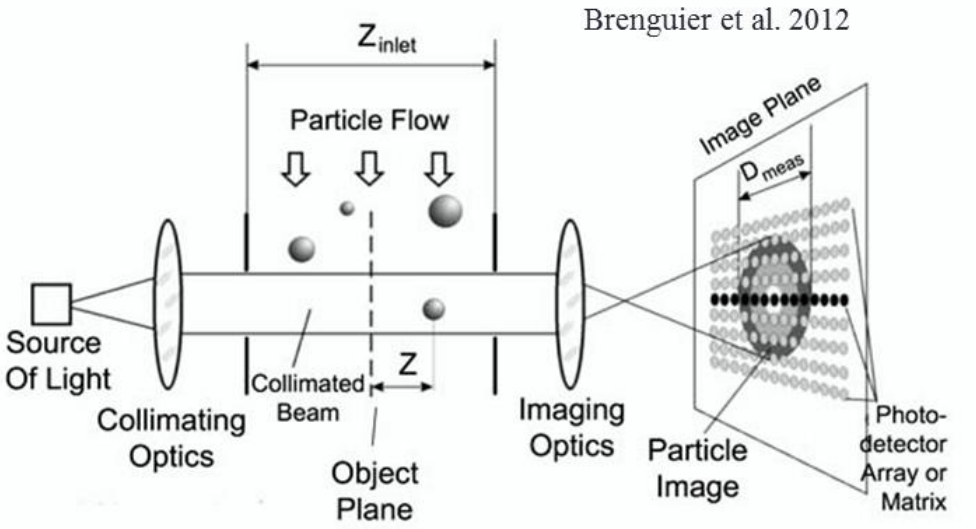

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Simlar instruments used for POLICE project: OLYMPEX

HVPS + 2DS

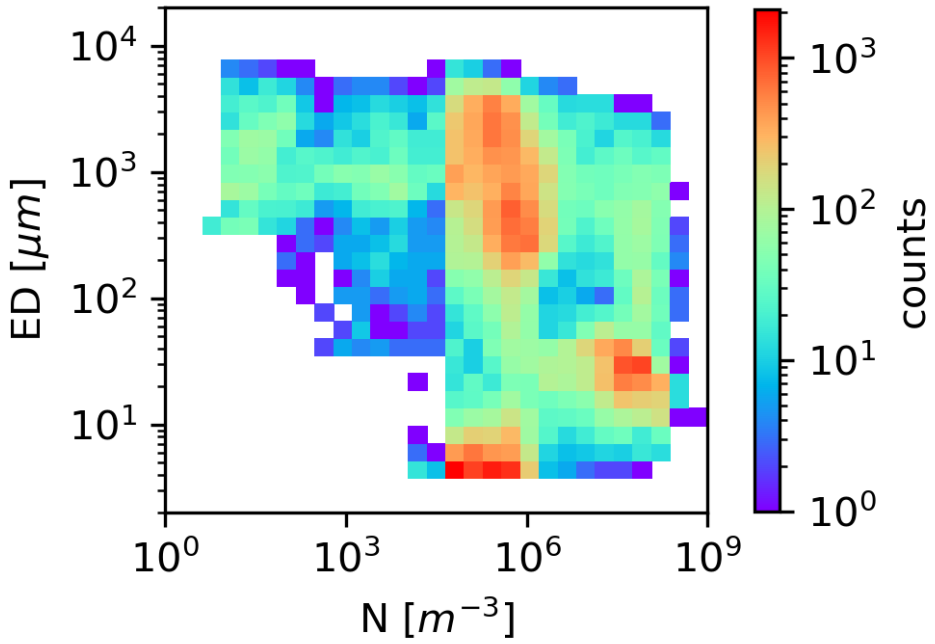
Picture by NASA

Combined size spectra:
100 µm – 3.25 cm

Key Question:
Microphysical properties of Arctic low-level clouds depending on different environmental conditions

Microphysical properties of low-level arctic clouds at different seasons and surface conditions

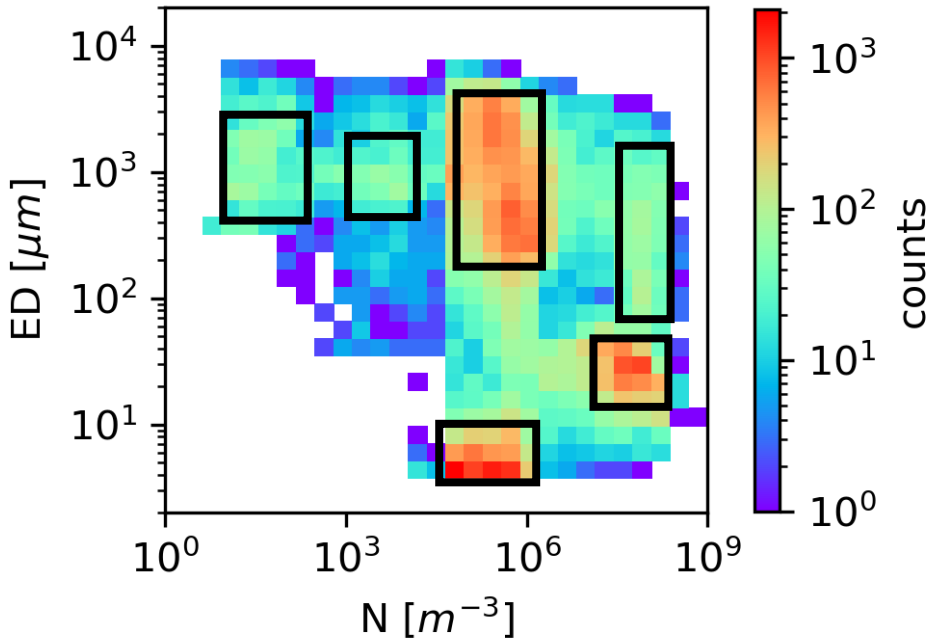
1Hz cloud data analysis: AFLUX & MOSAiC-ACA



- 1 HZ combined data of CDP/CAS, CIP and PIP
- All horizontal in-situ data of low-level clouds

Microphysical properties of low-level arctic clouds at different seasons and surface conditions

1Hz cloud data analysis: AFLUX & MOSAiC-ACA



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Microphysical properties of low-level arctic clouds at different seasons and surface conditions

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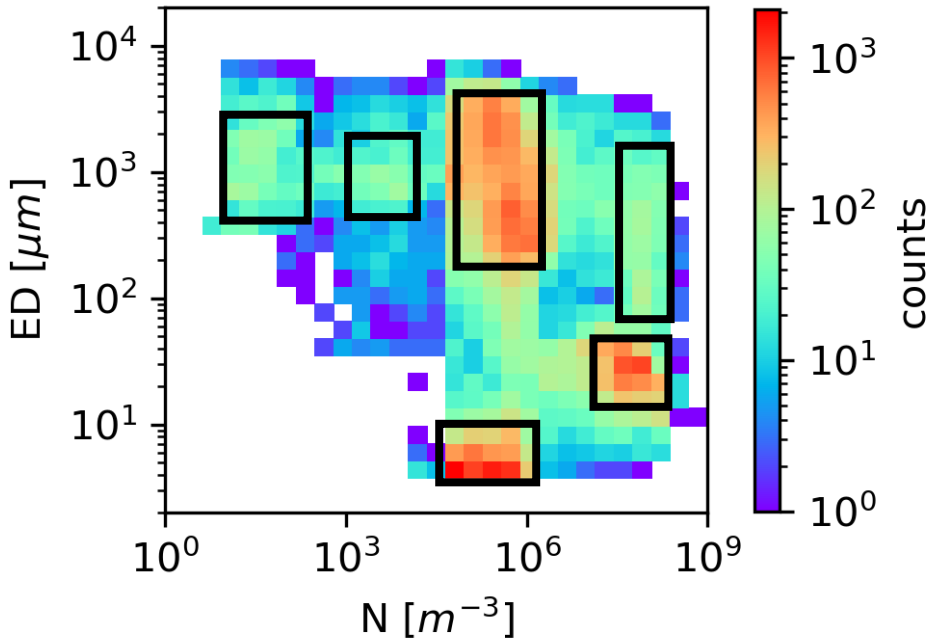
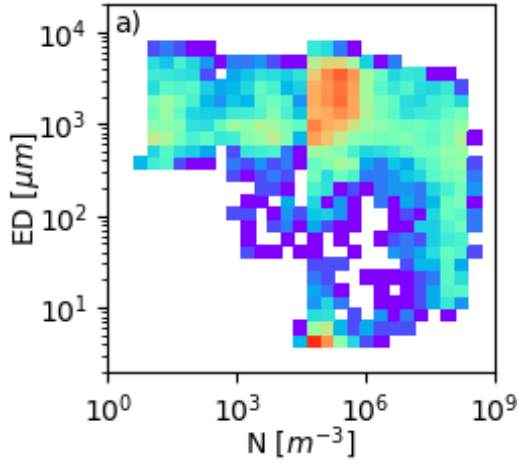
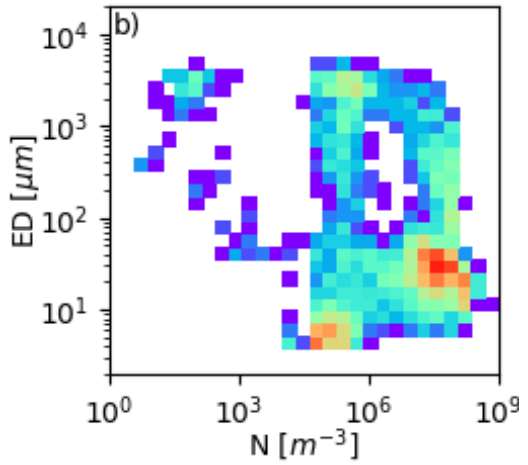
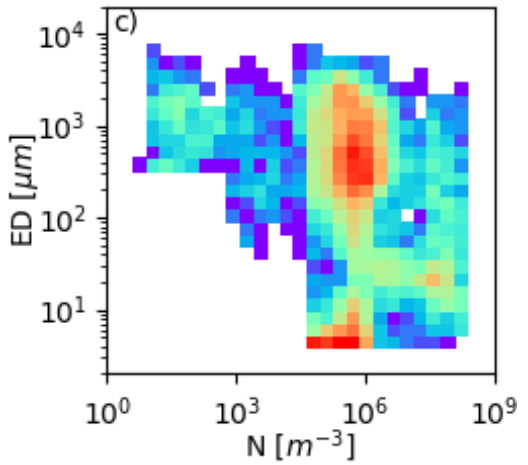
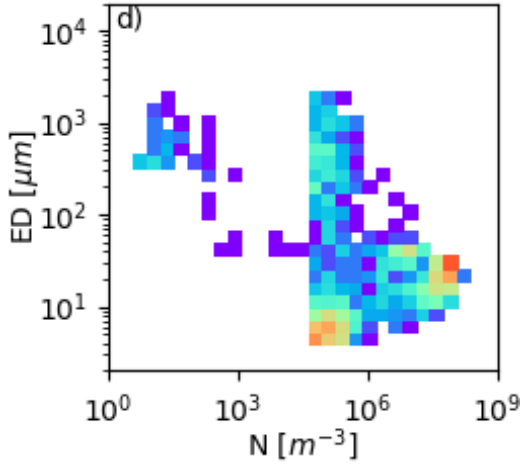


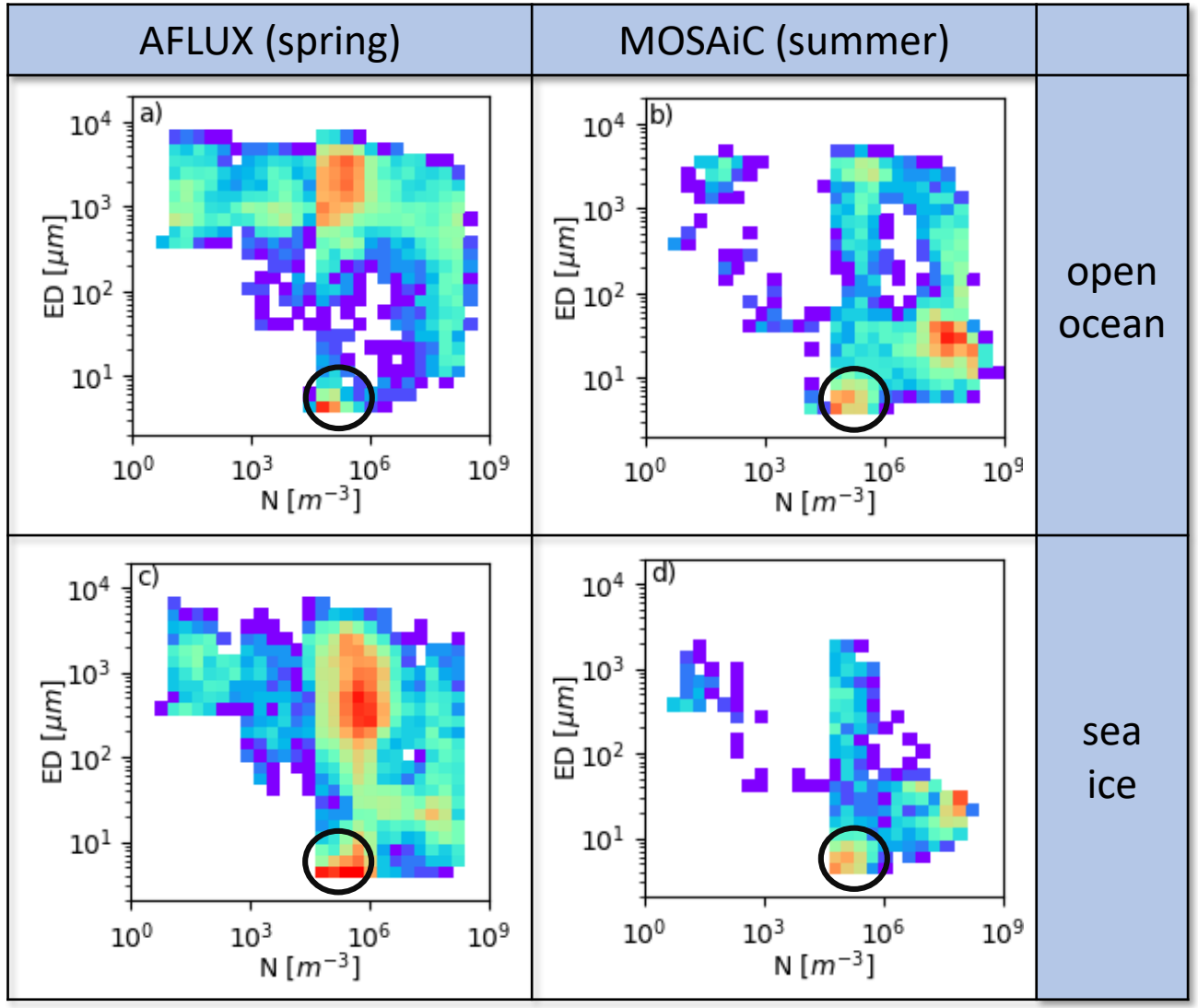
AFLUX (spring)	MOSAiC (summer)	
		open ocean
		sea ice

Microphysical properties of low-level arctic clouds at different seasons and surface conditions

1Hz cloud data analysis:

- Occurrence: In all cases
- Microphysics:
  - Small particles only (< 8 µm)
  - “high number concentrations”
  - No distinct phase determination

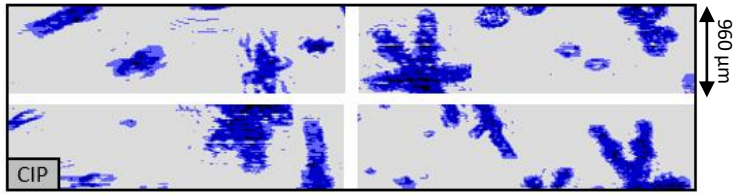
  → **Marine aerosol** from ocean or leads



Microphysical properties of low-level arctic clouds at different seasons and surface conditions

1Hz cloud data analysis:

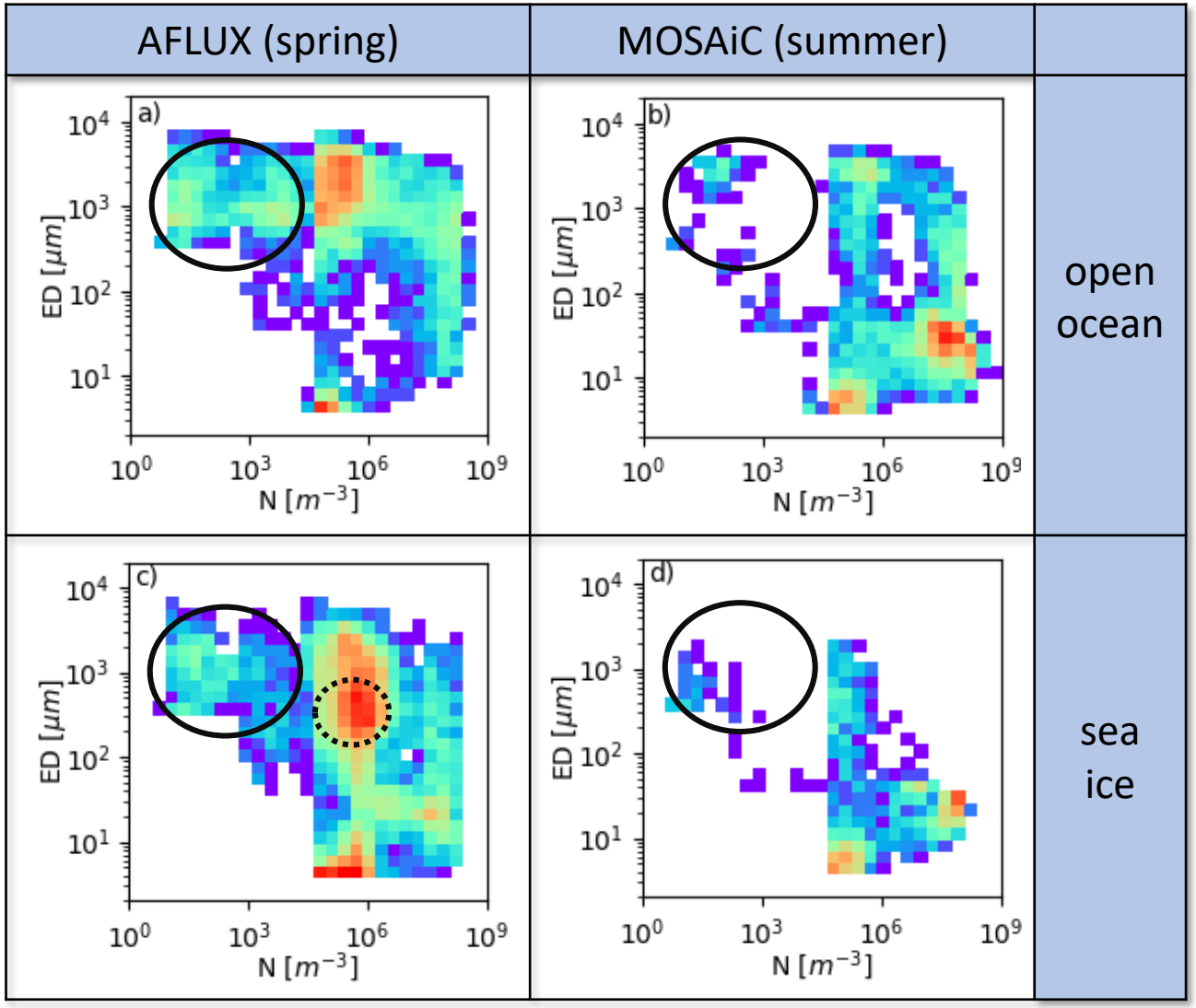
Random image data:



- Occurrence: In all cases, more present in spring, during summer only in “very small” number concentration

- Microphysics:
  - Pristine ice crystals and aggregates
  - Precipitating particles from cloud layer above ($N < 10^2\ m^{-3}$)
  - Glaciated cloud ($N > 10^2\ m^{-3}$)
  - Additional pure ice phase: In spring over the sea ice at $N = 10^6\ m^{-3}$

→ **Ice clouds / ice phase precipitation**



Microphysical properties of low-level arctic clouds at different seasons and surface conditions

1Hz cloud data analysis:

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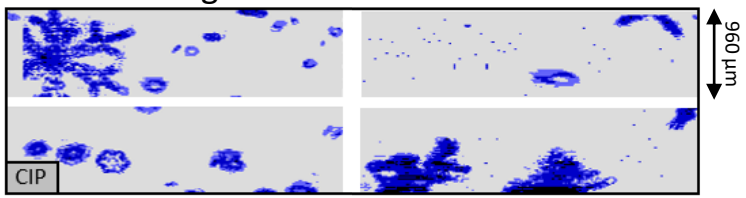
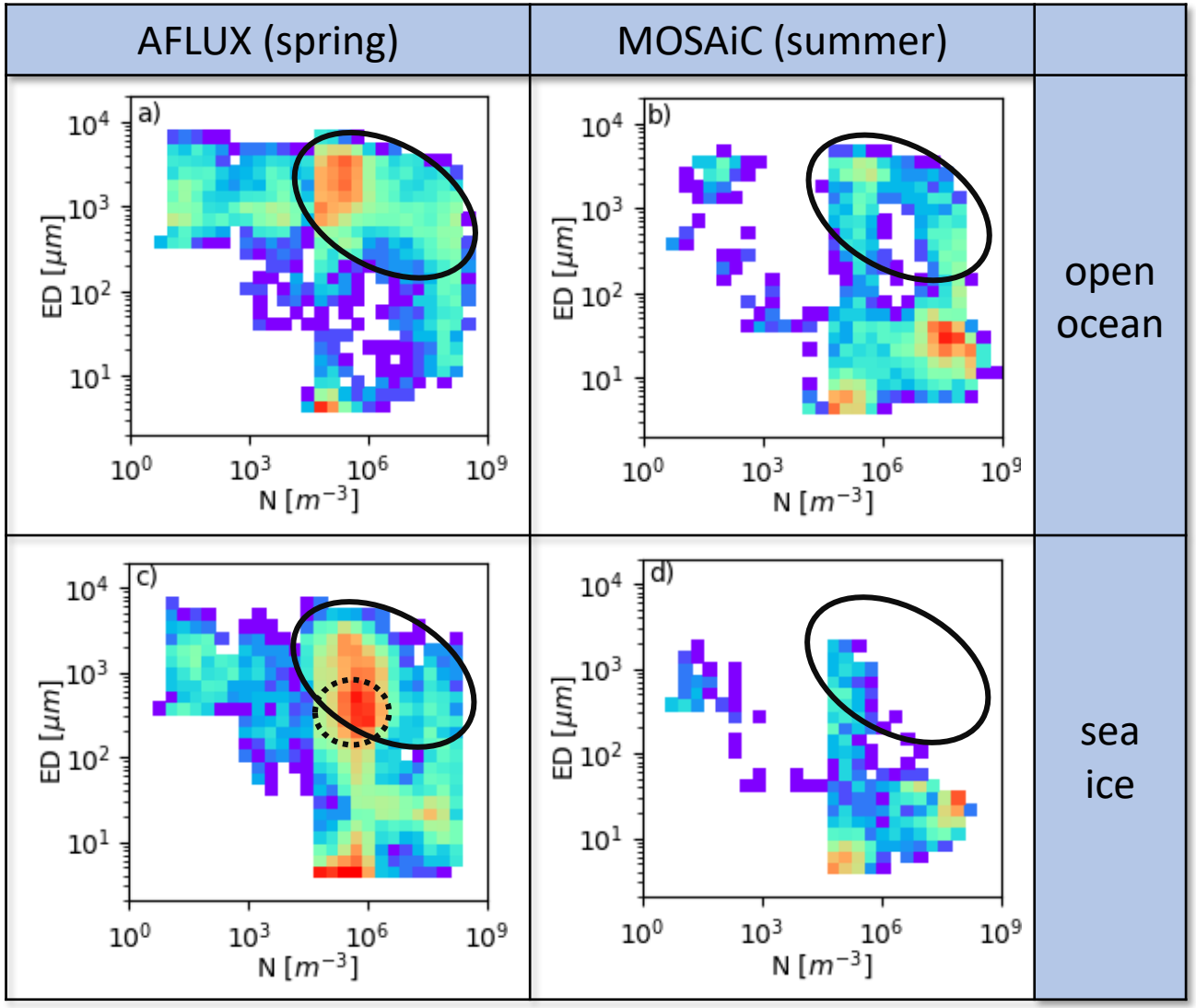


- Occurrence: In all cases; less observed during summer; hardly observed during summer over the sea ice at N > 10^6 m^{-3}

- Microphysics:
  - Aggregates and pristine ice crystals
  - Coexisting liquid droplets (except AFLUX: Sea ice; here pure ice phase)
  - Wide range of particle sizes

→ **Arctic mixed phase cloud**



Microphysical properties of low-level arctic clouds at different seasons and surface conditions

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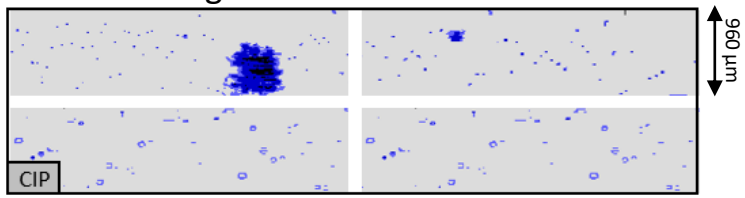
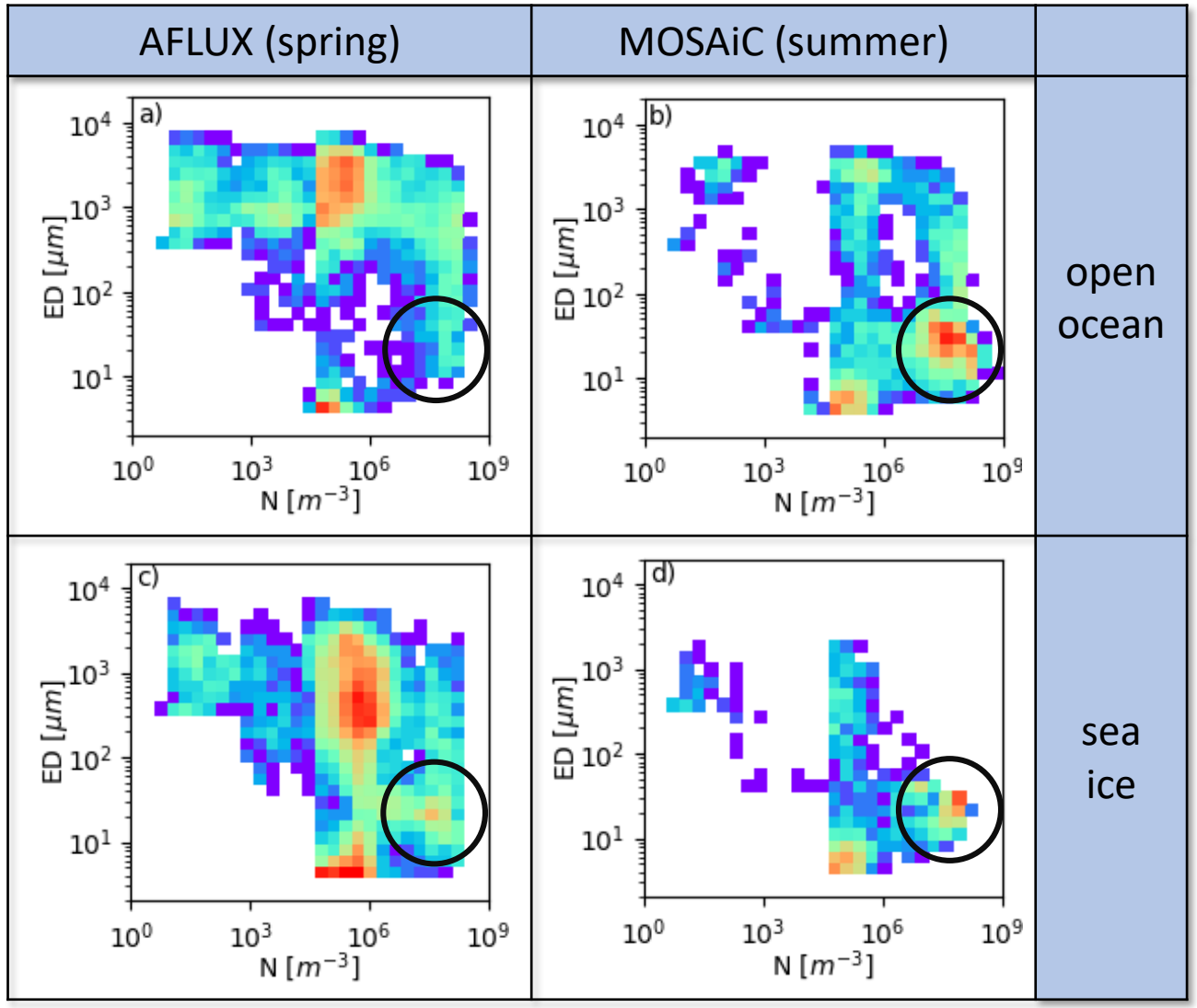
Random image data:



- Occurrence: In all cases (more during MOSAiC)
- Microphysics:
  - In spring: Mixed-phase clouds with smaller ice crystals
  - In summer: Liquid clouds

→ **Liquid clouds** during summer, MPC in spring



Microphysical properties of low-level arctic clouds at different seasons and surface conditions

Key findings:

- Arctic cloud microphysics significantly changes with surface condition and seasonal meteorological variations
- Number concentration raised by a factor of 50 during summer compared to spring; Cloud water content is raised by a factor of two
- Pure liquid is dominant phase in summer; in spring liquid phase exclusively found coexisting with ice phase
- Larger hydrometeors over the ocean

Acknowledgement:
“Fusion of Radar Polarimetry and Atmospheric Modelling” – SPP-2115, PROM
“ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms“ - (AC)^3