Aerosol, clouds, and radiation characteristics from observations and Big Data analysis

A01

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1. Summary

Modeling, ground-based remote sensing, and radiative flux observations during the PASCAL + MOSAiC expeditions allowed us to resolve the **relationships between the state of the atmosphere, the properties of aerosol and clouds, and the forcing at the sea ice surface in the Central Arctic** along a full annual cycle.

Research questions

Q1 What are the contributions of major atmospheric regimes to Arctic aerosol and cloud properties observed during MOSAiC?

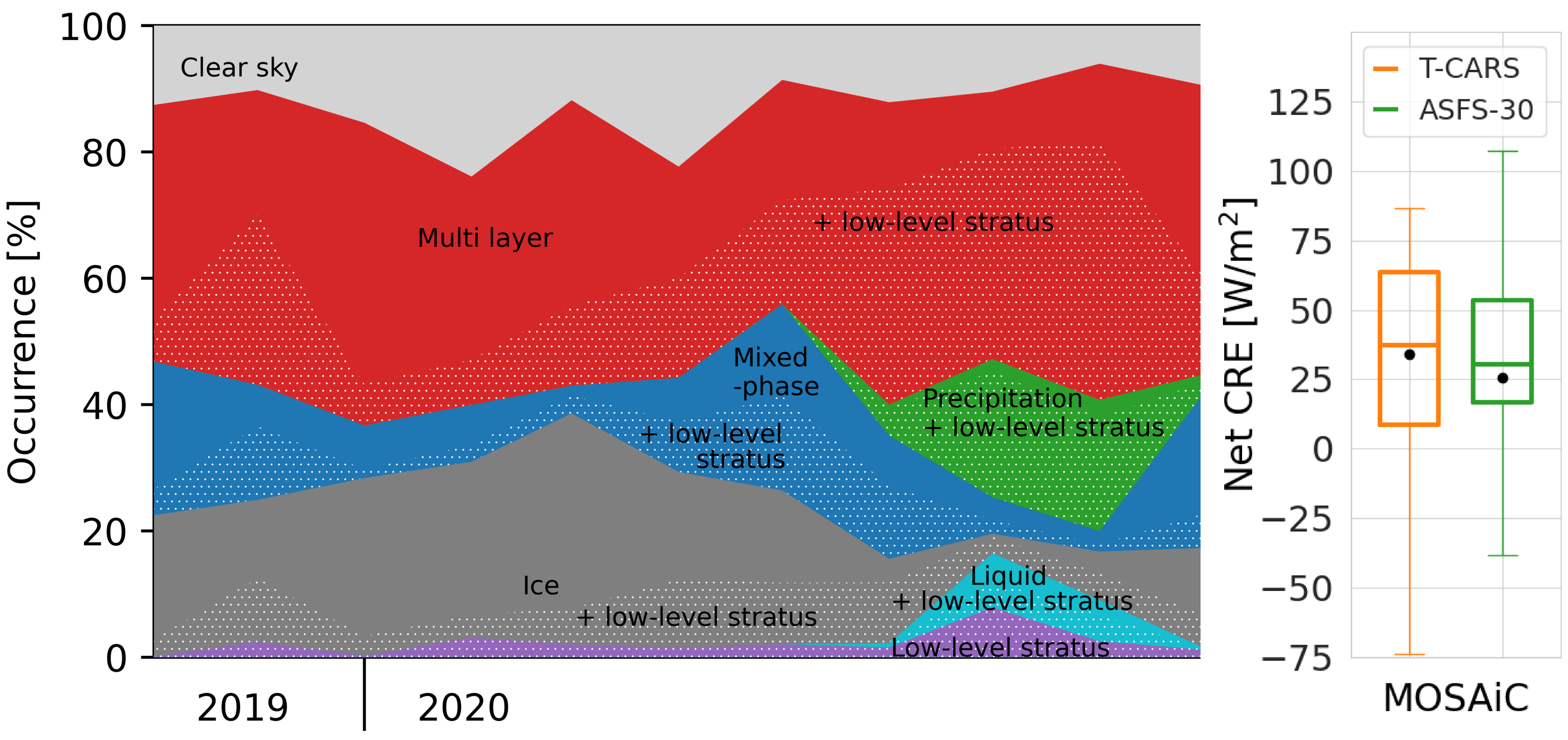
Q2 Can we retrieve the conditions of the atmospheric column accurately enough to achieve a radiative closure for the whole MOSAiC drift experiment?

Q3 Do the combined high-resolution data sets contain hidden information on fast-acting feedback mechanisms that function as emergent constraints on Arctic amplification?

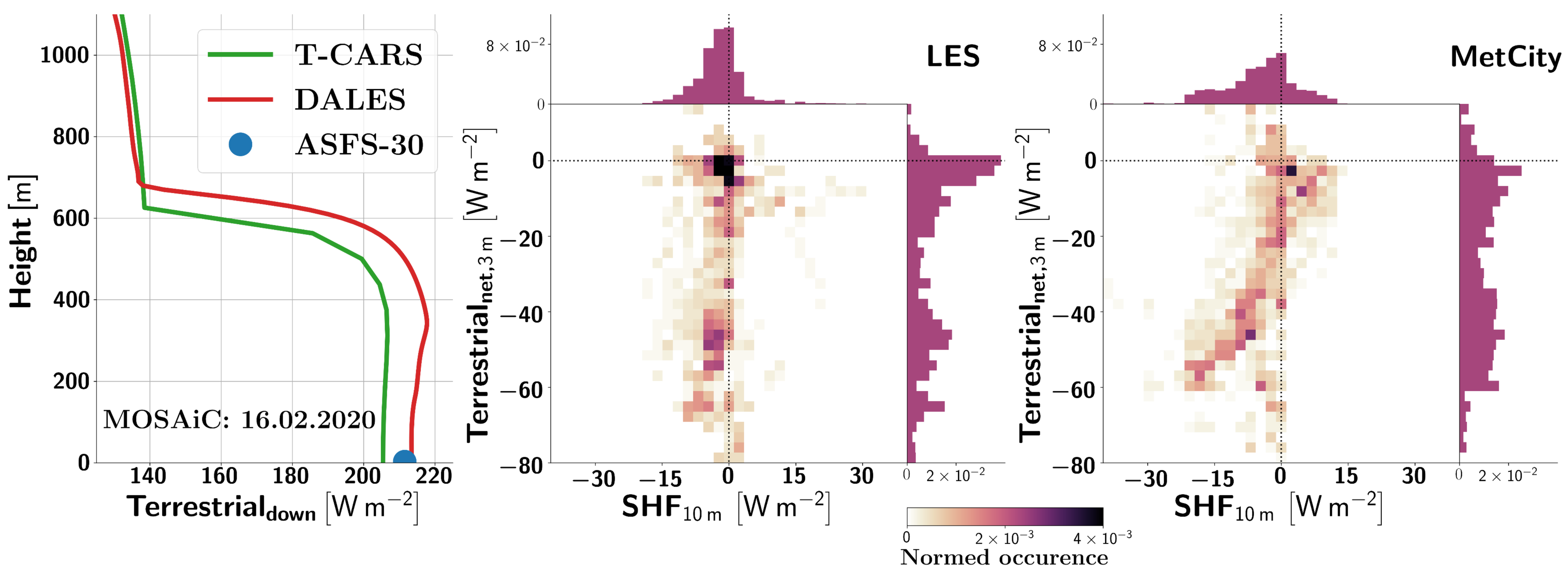
→ Contributions to CCA1, CCA2, CCA3, and CCA4 & SQ1, SQ2, and SQ3

2. Achievements phase II

MOSAiC: Annual cycle of Arctic cloud properties and radiation



Daily turbulence-resolving LES realizations (DALES) during MOSAiC



Hypothesis

Machine learning algorithms and radiative closure help to quantify physical and dynamical emergent constraints affecting Arctic amplification.

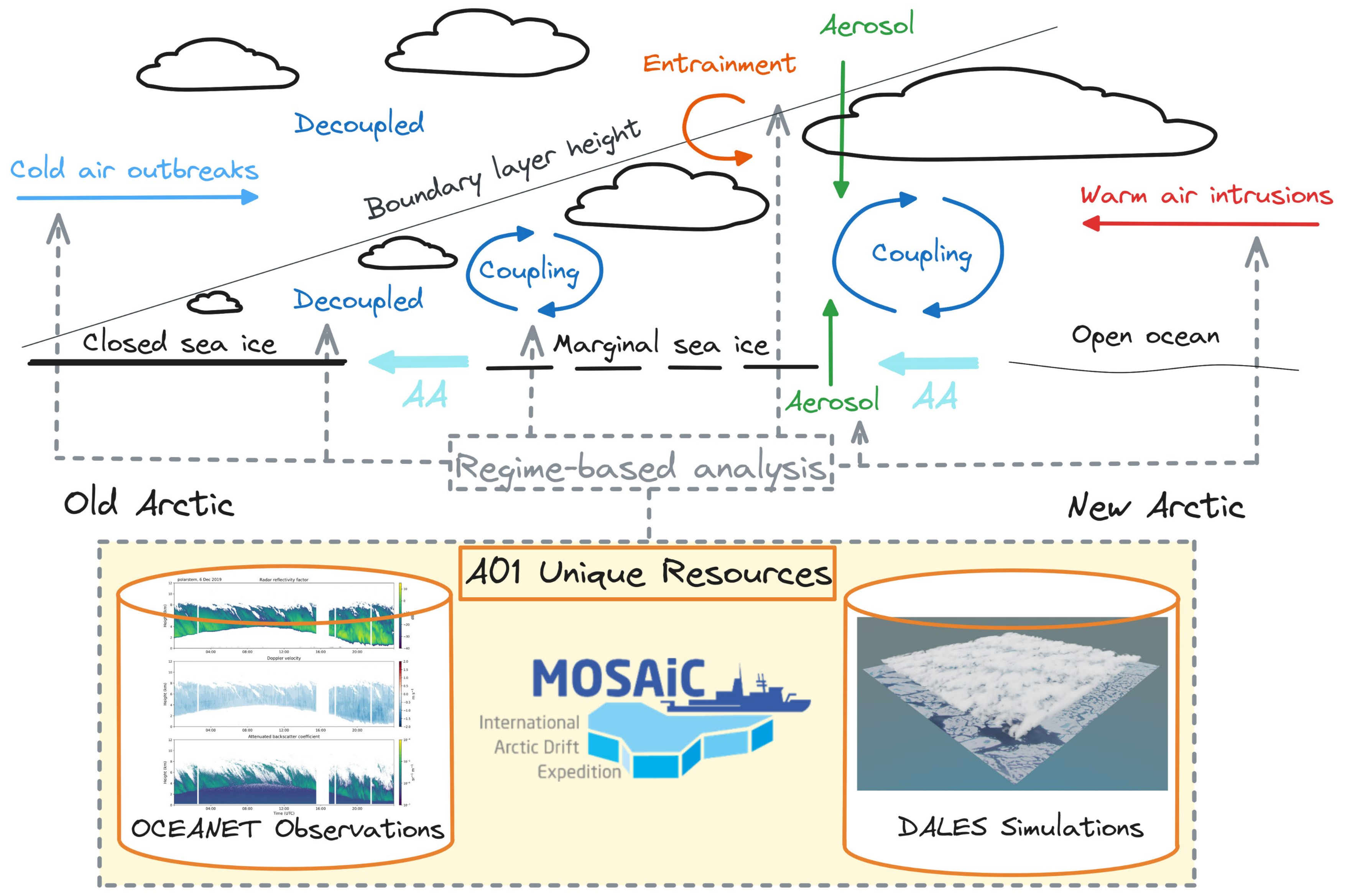
3. Research plan phase III

Work packages

- WP1 **Regime-based analysis** (Q1)
- WP2 **Radiative closure** (Q2)
- WP3 **Assessment of Arctic emergent constraints** (Q3)

General goals

- Identification of **atmospheric regimes** covering a broad range of spatial and temporal scales, based on the unique observation-simulation database of **cloud and aerosol macro- and microphysical properties** (WP1)
- Link **small-scale cloud and aerosol processes to Arctic amplification** (WP1)
- **Evaluation and uncertainty assessment** of identified regimes (WP1, WP2)
- **Radiative closure** between LES, remote-sensing, and in-situ measurements (WP2)
- **Sensitivity LES experiments for perturbed MOSAiC climates** to investigate fast feedback mechanisms contributing to the new Arctic (WP3)
- Test the **physical basis of candidate emergent constraints** in climate models through machine-learning-assisted **Big Data analysis** (WP3, in collaboration with E01)



AA: Arctic amplification

4. Legacy & Major expected results

Project legacy

Unique data sets derived within A01

- **MOSAiC drift covering daily LES** for present-day and perturbed climate
- **Observations-based data set** of clouds, aerosol, radiation, and water vapor mixing ratio

Main findings

- **Thermodynamic surface-coupling** of cloud effects on heterogeneous ice formation at temperatures above -15 °C: **Enhanced ice formation in surface-coupled clouds**
- Cloudnet-based **radiative transfer simulations** for the whole MOSAiC drift
- **Wildfire smoke** observed continuously in the upper troposphere and lower stratosphere, with proven effects on cirrus formation and polar stratospheric clouds

Major expected results within phase III

- **Contrast coupled and decoupled atmospheric situations** as they can be considered representatives of the old and the new Arctic, respectively
  → In a warmer Arctic, the boundary layer height and aerosol emissions from the ocean will likely increase and therefore the number of surface-coupled situations will increase, as well
- Put **regime-based investigations into context with climate projections of the future Arctic climate** → provide an outlook on how this future Arctic will look like with respect to the investigated aspects
- Gain a deeper insight into the **existence and physical validity of constraints on Arctic amplification** as emergent in climate models, based on databases in which the associated small-scale processes are either resolved (LES) or observed

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