Process–level assessments of Arctic low–level clouds

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1 Summary

Understand cloud "inner-workings", interaction with surface, radiation and large-scale dynamics to answer the question:
How do Arctic low-level clouds respond to global climate change?

Two relevant "cloud regimes"

CR1: Low–level, mixed–phase stratus
CR2: Convective clouds following Arctic Cold–Air-Outbreaks (CAOs)

} Impact on Arctic water and energy balance, source of large uncertainty in global models

Hypothesis

An improved representation of Arctic low–level clouds in climate models by means of novel observation and small–scale modelling approaches is essential to realistically reproduce Arctic feedback mechanisms.

2 Research rationale

Integrate Large Eddy Simulation (LES) & state-of-the-art observations to improve representation of three major uncertainties of Arctic cloud feedback mechanisms

I) Low-level mixed-phase clouds

Are LES runs in the Arctic suited for improving cloud representation in Global Circulation Models (GCM) in the Arctic?

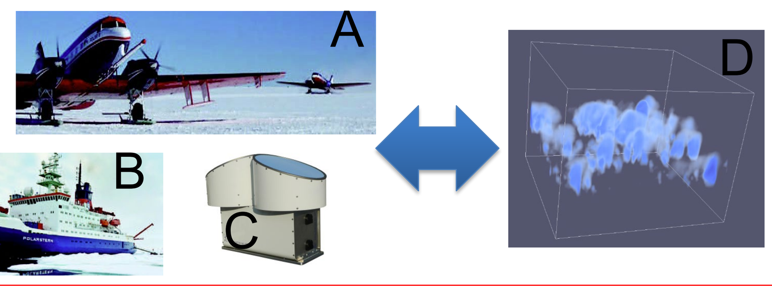


Fig. 1: A combination of aircraft in-situ (A), research-vessel (B) and ground-based Doppler radar (C) observations will be used to create constrained variational retrievals in order to evaluate the LES (D)

Assess LES Arctic cloudy atmosphere (i.e. cloud geometry, cloud phase partitioning, microphysical processes) with a multiple sensor approach

II) Cloud coupling to heterogeneous surfaces

Only crude cloud–surface interactions schemes exist: Develop a new atmosphere and sea/ice/land-surface coupled LES.

Simulate the impact of surface heterogeneity on cloud patterns and radiative feedback across the Arctic

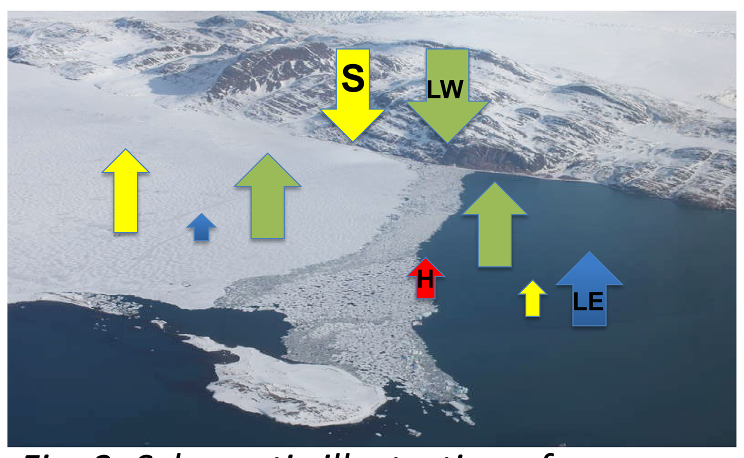
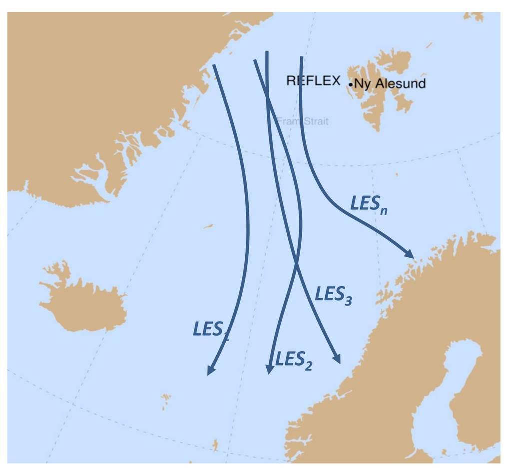


Fig. 2: Schematic illustration of energy fluxes over sea and sea ice

III) Modeling internal scale-growth in convective cloud fields: CAOs

Dynamical aspects of clouds in CAOs are not fully understood yet, such as the distinct scale–growth and organization and the role of cloud microphysics

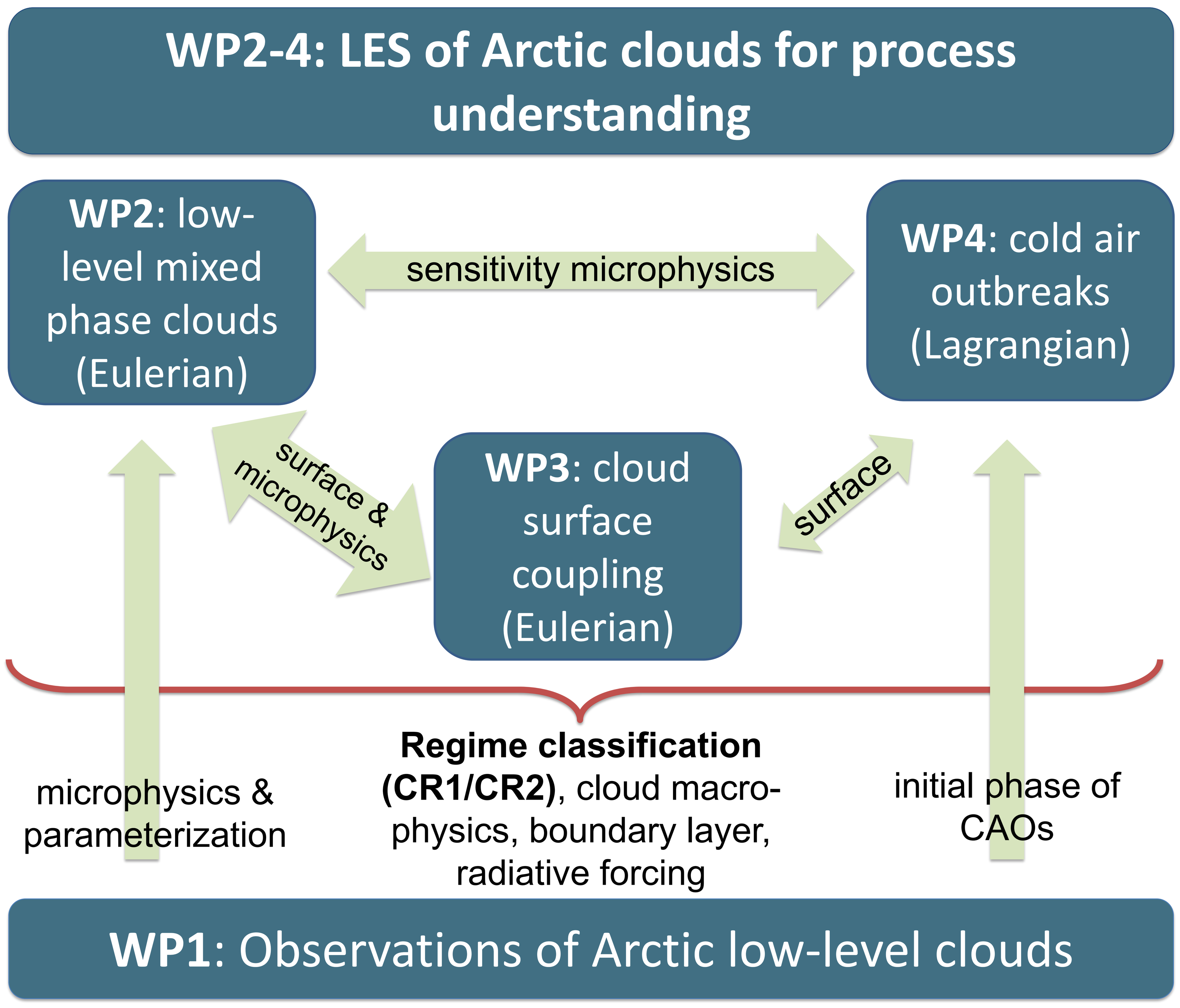


- Capture full life-cycle of convective cloud fields as function of large-scale forcings, turbulence, convection, microphysics and radiation with Lagrangian LES
- Evaluation with observational data from past & (AC)³: aircraft and research vessel campaigns, observatories at Ny Ålesund and across Arctic

Fig. 3: Schematic illustration of an ensemble of Lagrangian LES realizations (driven by ECMWF analyses) along CAO-trajectories through the Fram Strait

Develop an updated convection scheme (scale-adaptive) and implement into climate model for studying the impacts of CAOs on Arctic amplification

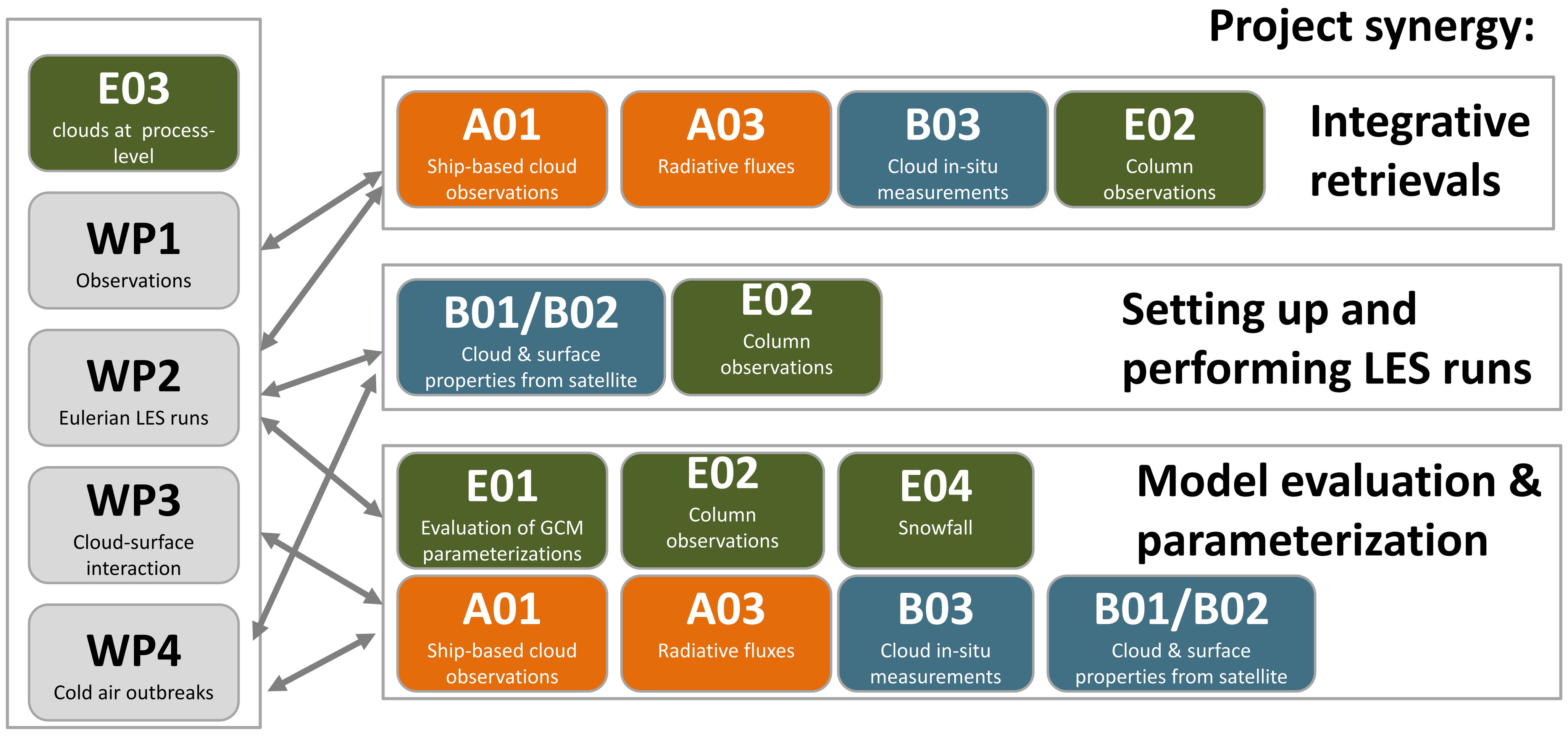
3 Research plan



WP1	WP2	WP3	WP4
1. Regime classification CR1/CR2 from observations 2. Mixed-phase cloud descriptors based on Doppler spectra, ship, and aircraft observations 3. Mixed phase cloud properties and processes	1. Large–scale forcings and boundary conditions for model simulations 2. Local (Eulerian) LES runs (long-term) 3. Analysis of LES performance and sensitivity to microphysical schemes	1. Surface parameterization scheme for land, ocean and ice 2. Impact of clouds on surface net radiation 3. Relation of Arctic clouds with land–, ocean–, and ice–surface processes	1. Lagrangian LES of CAOs 2. Interpretation/ evaluation against observational datasets 3. Parameterization development and single column climate model simulation

4 Role within (AC)³ & perspectives

Collaboration within (AC)³



Perspectives

- Long–term simulation (strength/occurrence frequency) of CAOs in climate models using adapted parameterization schemes under different climate forcing conditions; capture development of single events with HALO over-flights
- Evolution of cloud–surface interactions over long–time scales (e.g. decadal) in the Arctic region through statistical dynamical downscaling; MOSAiC as reference observations
- Enhanced remote sensing algorithms for clouds on a long-term basis and at various Arctic sites; EarthCARE assessment of vertical profiles

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