Influence of spatial heterogeneity and temporal evolution of surface properties on radiative energy fluxes in the coupled atmosphere - sea ice - ocean system

C01

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1. Summary

Research questions:

Role of spatiotemporal changes of surface heterogeneity for the radiative energy budget

Q1 How strong is the **influence of spatial heterogeneities of surface properties on the radiative energy fluxes** in the two ocean and atmosphere compartments, and how does it depend on spatial scales?

Q2 How is the **temporal evolution of effects of sea ice development** (melt, freeze-up) **on radiative energy fluxes** in different regions and ice regimes?

Q3 Which of the two surface parameters, temperature or albedo, has the stronger **impact on the local changes of the cloud radiative forcing (CRF)** depending on season and region?

2. Achievements during phase I

Validation of HIRHAM-NAOSIM surface albedo scheme (A03, D03)

- Temporal bias → **new temperature threshold parameters**
- Significant illumination dependence → **new cloud cover flag**

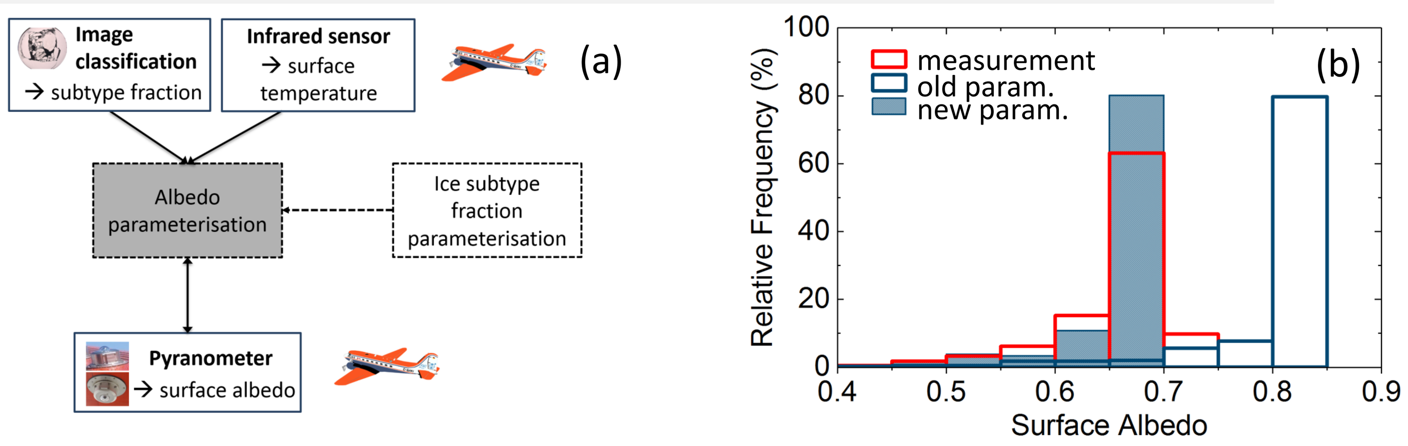


Fig. 1: a) Flow chart of validation procedure, b) Example measured vs parameterised surface albedo for 25 June 2017 (ACLOUD campaign). Adapted from Jäkel et al. (2019), TC.

Improvement of MERIS spectral-to-broadband conversion

- Previous: averaging → **Revised: empirically derived weighting**

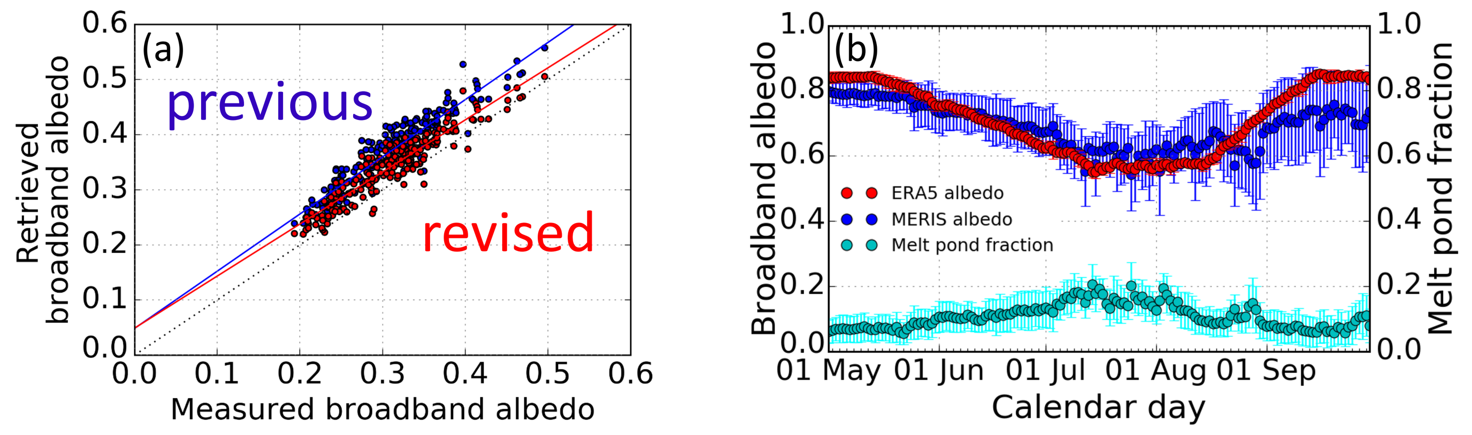


Fig. 2: a) Measured vs MERIS derived surface albedo over landfast ice close to Barrow on 6 June 2008, b) ERA5 vs. MERIS surface albedo and MERIS melt pond fraction for ERA5 sea-ice concentration of 100 % averaged over years 2003 – 2011 (adapted from Pohl et al., 2019, TC).

3D radiative effects: Surface heterogeneity & CRF (A03, B03)

- Solar warming mainly a 3D effect
- 3D effects negligible for spatial averaging > 3 km

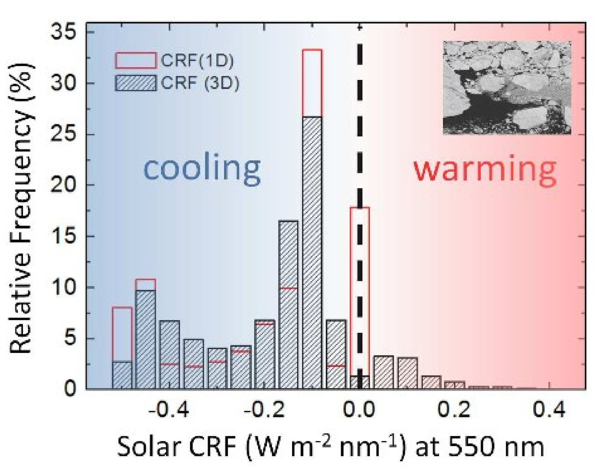


Fig. 3: Solar cloud radiative forcing (CRF) at 550 nm derived from 1D and 3D simulations.

Model development and improvement (B02)

- New 3D radiative transfer model (backward Monte Carlo) **LEIPSIC → retrieval tool**
- Snow/ice surface implementation in SCIATRAN → **near-field effects in snow are negligible**

Hypothesis

The spatial heterogeneity and temporal evolution of surface properties (sea ice types, snow, open ocean, melt ponds) have a major impact on radiative energy fluxes in the coupled Arctic climate system.

3. Research plan phase II

General goals

- Radiative transfer and sea ice melt as function of sea ice and ocean properties for a full annual cycle → **new sea ice and ocean component**
- Surface heterogeneity & CRF → **extension to thermal-infrared wavelength range**
- Large scale and long term observations of sea ice albedo and melt ponds → **extension of satellite datasets (Sentinel-3) & improved retrievals**
- Surface albedo parameterisation for climate models → **new parameters & seasonal dependence**

Methods and work packages

- Combining observations (ground-based, ROV - Remotely Operated Vehicles, helicopter, aircraft, satellite) → **seasonality & inter-annual variability** of spectral and broadband radiative quantities during **MOSAiC** and **HALO-(AC)³**
- **Derivation of sea ice properties** and their variability in space and time
- Interpretation and linking with 1D and 3D **radiative transfer models**

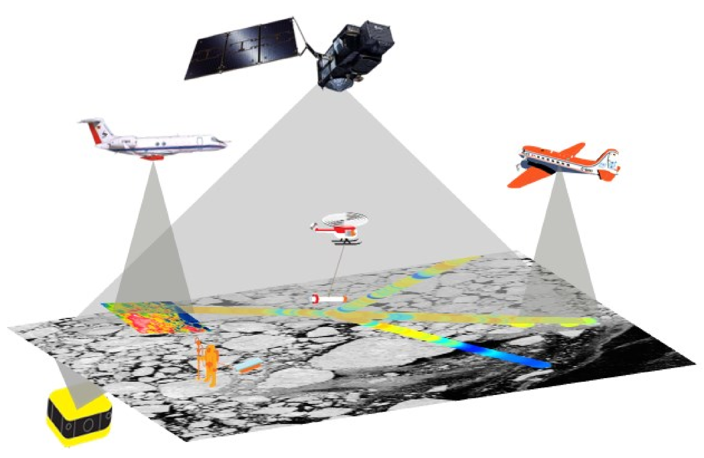
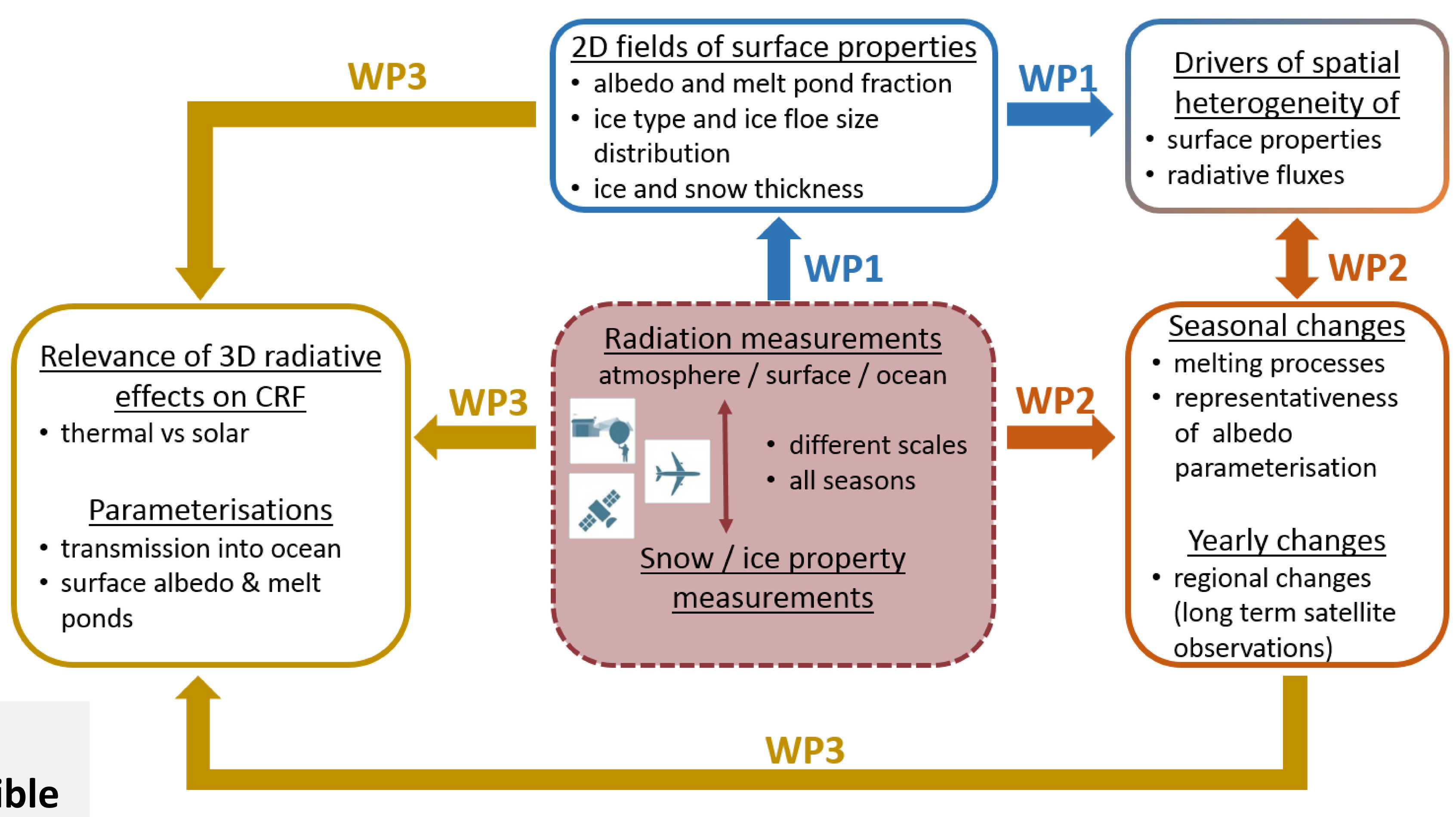


Fig. 4: Bridging scales in space and time with nested observations

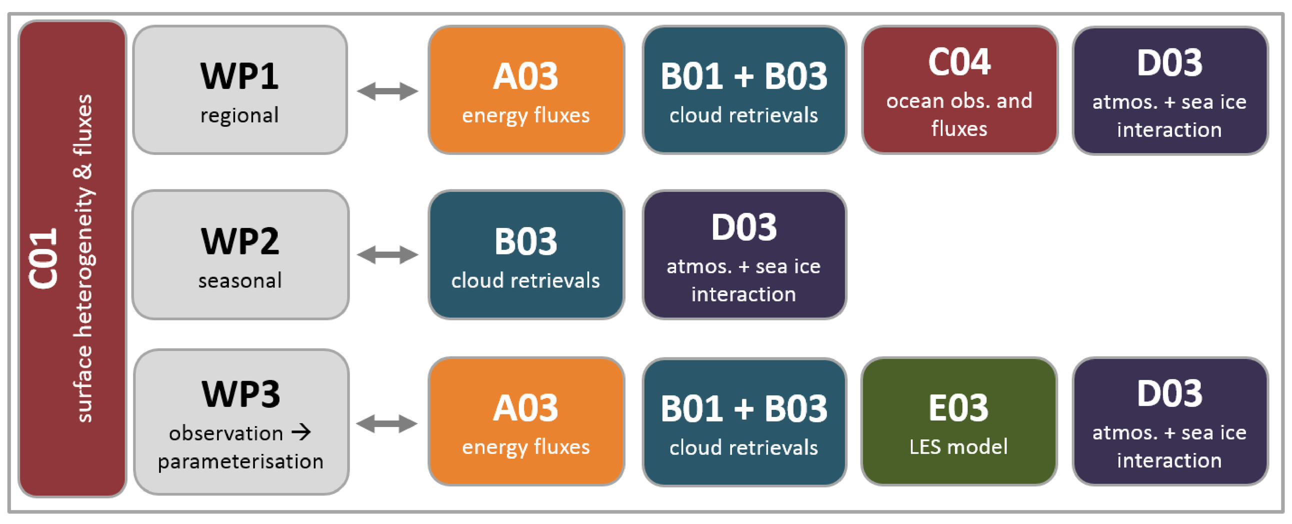
- WP1: Spatial heterogeneity – from ice floes to Arctic-wide observations
- WP2: Temporal evolution – from season to years
- WP3: From observations to parameterisations



4. Role within (AC)³ & perspectives

Collaborations within (AC)³

- Joint instrumental preparation / evaluation with **A03** / **B03**
- Satellite data from **D03** (snow depth, lead fraction, surface roughness)
- Improvement of the surface albedo parameterisation in HIRHAM-NAOSIM (**D03**)
- Contribution to **CCA2 "Surface processes"**



Perspectives

- Quantification of the retrieval uncertainties of Arctic cloud properties over highly heterogeneous surfaces
- Ice-ocean linkages and role of the upper ocean for sea ice melt and processes

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