Impact of low-level clouds and surface conditions on Arctic atmospheric boundary layer turbulence and radiation

A03

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1. Summary

A03 concentrates on the **complex interplay between radiative and turbulent processes** and how they are **influenced by low-level clouds and surface characteristics.**

Research questions

Q1 How strongly do the radiative fluxes evolve in air mass transformation processes?

Q2 Can airborne near-surface turbulence measurements improve the parametrizations of turbulent fluxes?

Q3 Do new parametrizations of air-ice-ocean interaction processes improve the representation of large scale meteorological variables in climate models?

A03 contributes to CCA1, CCA2 & SQ1

2. Achievements phase II

Surface cloud radiative effect (CRE)

- Solar CRE depending on surface albedo, solar zenith angle, cloud optical thickness
- Solar cooling effect significantly larger over open ocean than over sea ice
- Although thermal-infrared (TIR) CRE strongly depending on cloud and thermodynamic properties, total CRE mainly driven by variability of solar CRE

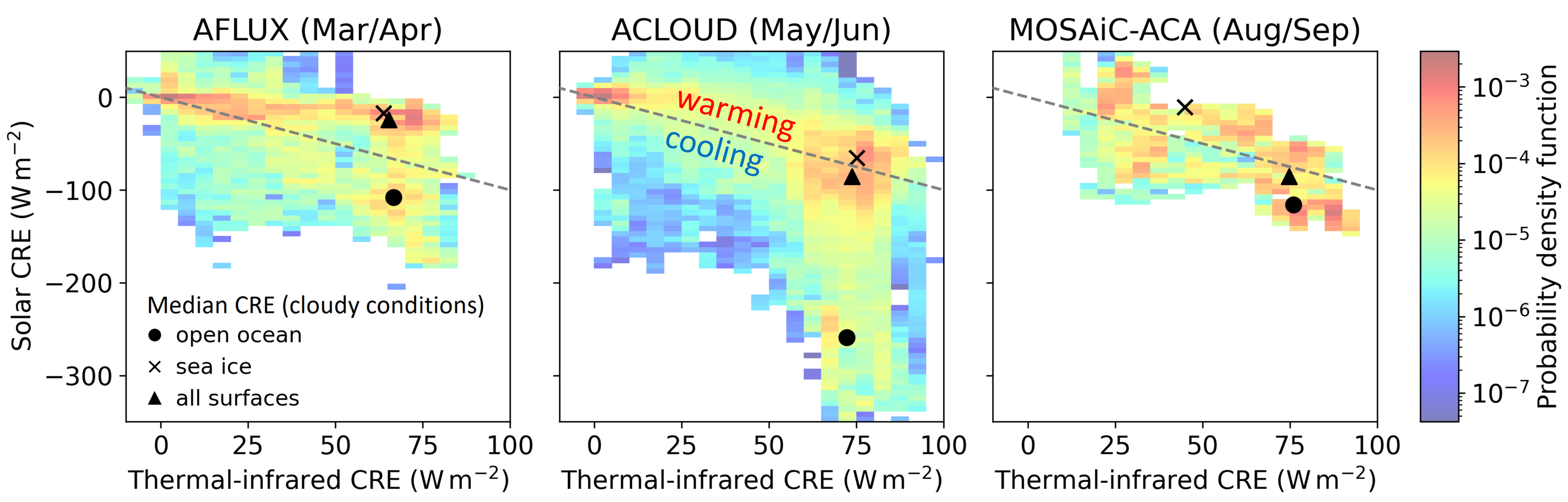


Fig. 1: Two-dimensional probability density function of solar and thermal-infrared CRE for AFLUX, ACLOUD, and MOSAiC-ACA. The dashed lines represents zero total CRE.

Extended data base of turbulent/radiative fluxes in polar clouds

- Different turbulence structure between polar and lower latitude marine stratocumulus
- Arctic humidity conditions important for cloud turbulence
- Large impact of multi-layer clouds on ABL radiation and turbulence

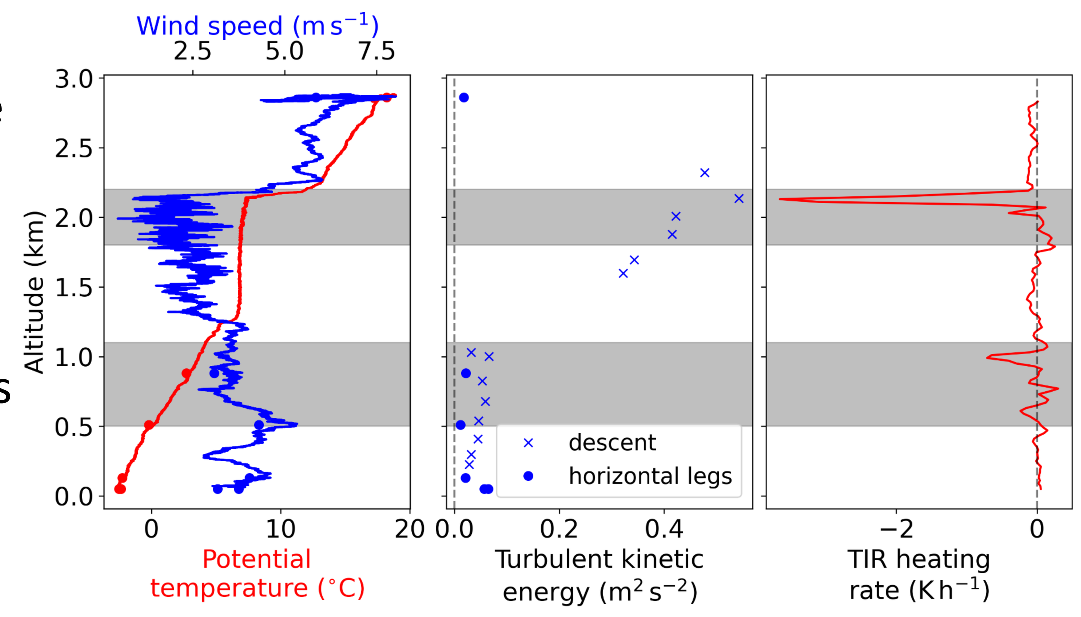


Fig. 2: Impact of multi-layer clouds (grey) on turbulence and radiation.

Parametrization of near-surface transfer coefficients over sea ice

- New type of non-iterative parametrization of surface fluxes for stable conditions
- Applicable with a package of state-of-the-art stability correction functions including new ones for sea ice, based on SHEBA data

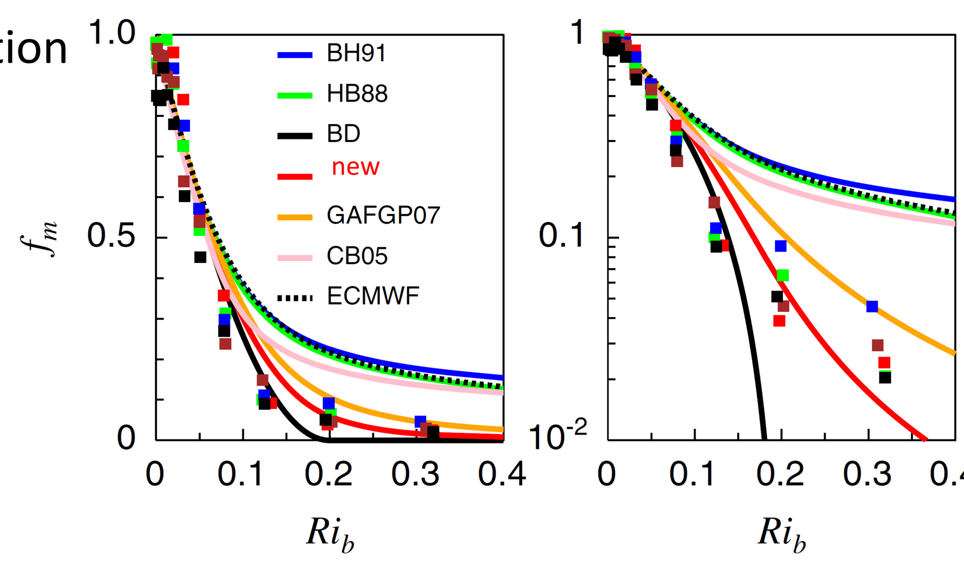


Fig. 3: Normalized transfer coefficients (squares: SHEBA).

Strong lead impact on air-ice-ocean interaction

- New parametrization of lead-generated convection
- Atmospheric forcing and lead geometry important
- Lead width influences flux profiles

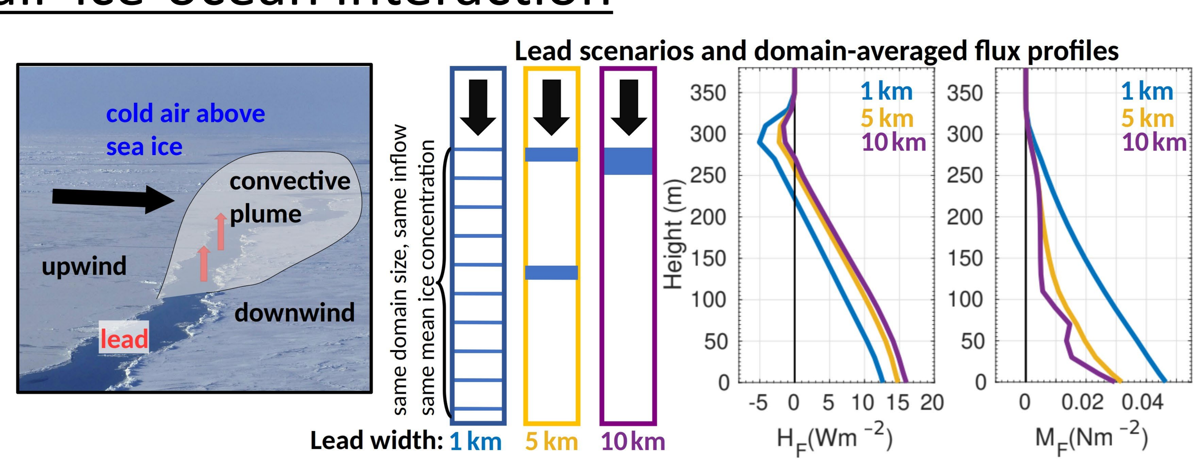


Fig. 4: Convection over leads (sketch) and modelled lead scenarios with domain-averaged fluxes.

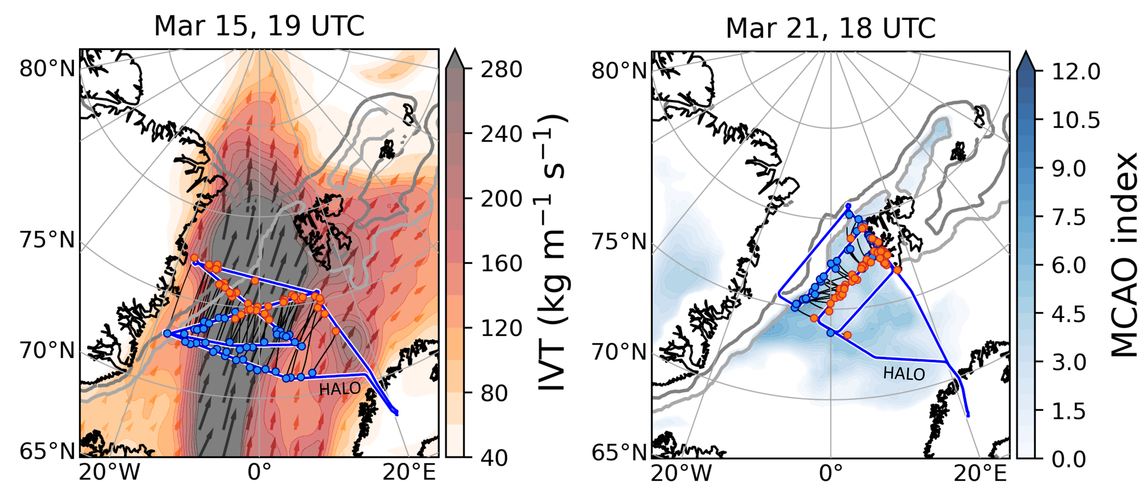
Hypothesis

Arctic atmospheric boundary layer clouds and near-surface processes significantly contribute to Arctic amplification

3. Research plan phase III

CRE analysis for air mass transformation and multi-layer clouds – Q1

- Investigating the evolution of clouds and respective CRE in air mass transformation processes
- Investigating the influence of multiple cloud layers on each other and on the radiative state of the ABL
- Analyzing the influence of an easterly wind regime on radiation and turbulence over the Fram Strait



Parameters to follow:

- Liquid/Ice water path
- Cloud fraction
- Cloud phase
- Cloud altitude
- Cloud radiative effect

Fig. 5: Air mass trajectory analysis for HALO research flight on 15 March 2022 (warm air intrusion) and on 21 March 2020 (marine cold air outbreak, MCAO). Blue and red dots mark trajectory start and end points on the flight track.

Airborne turbulence measurements using T-Bird and validation of parametrizations – Q2

- Airborne towed vehicle T-Bird worldwide unique device
- New possibilities to improve the understanding of air-ice interaction over inhomogeneous sea ice
- Determining transfer coefficients down to 15 m height
- Measuring lead convection in very shallow layers
- Simultaneous two-layer measurements together with noseboom
- Measurement campaign BACSAM II

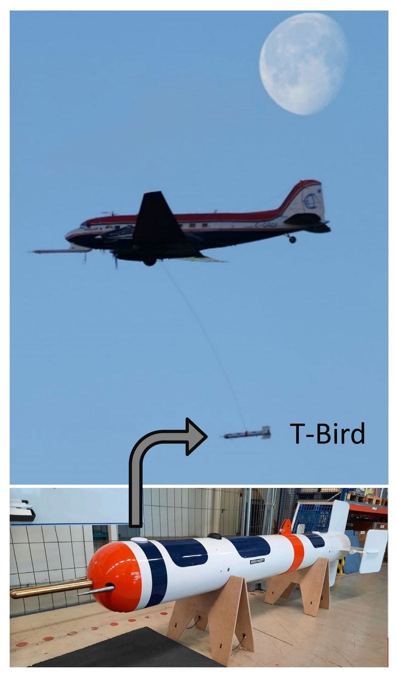


Fig. 6: Photos of T-Bird while it is operated on Polar 6 during BACSAM and in the laboratory.

Analysis of regional and global climate model results (i) using new turbulence parametrizations, (ii) Evaluation of modeled CRE – Q3

- For model application: Matching of surface layer flux parametrization with flux parametrizations above first grid level; focus on sea-ice cover dependence
- Supporting tests of new and improved turbulence parametrizations in regional and global climate models
- Selecting most suitable options for turbulence package
- Comparing CRE with model results in different seasons depending on sea ice and cloud cover

4. Legacy & Major expected results

Project Legacy

- Set of new parametrizations for implementation into climate models
- CRE characterized for different surface, cloud, and seasonal conditions
- New innovative measurement and analyzing tools

Major expected results within phase III

- Improved understanding of near-surface processes over marginal sea ice zone using new T-Bird system (low operation height, simultaneous measurements in 2 levels)
- Comparison of modeled with observed CRE (dependence on surface and season)
- Finalization and validation of improved surface-layer turbulence parametrizations

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