Influence of sea ice leads and polynyas on Arctic cloud properties

B07

Heike Kalesse-Los
Pablo Saavedra Garfias

1. Summary

Research questions

Q1 How is **cloud cover** changed in the presence of leads or polynyas?

Q2 How are macro-, microphysical and radiative **cloud properties** influenced by leads or polynyas?

Q3 Are there **differences** in Q1 and Q2 for Central vs. Western Arctic?

Research focus of B07 is on process-level understanding **SQ1** with contributions to **CCA1** (Temperature lapse-rate feedback in Utqiaġvik, Alaska; Linke et al. 2023), **CCA3**.

2. Achievements phase II

Central Arctic: MOSAiC expedition

Water vapor transport used as mechanism to study coupling between wintertime clouds (**Nov 2019-April 2020**) observed above RV *Polarstern* and upwind sea ice leads.

When clouds are coupled to upwind sea ice leads via water vapor transport, we found:

- A systematic increase of cloud liquid water as a function of sea ice state (Fig. 1a)
- Lower liquid cloud base height (Fig. 2a) and larger cloud thickness (Fig. 2b)
- In-cloud temperature lapse-rate is positive, i.e. cloud top T inversion (Fig. 2c)
- Ice water fraction asymmetry enhanced as compared to decoupled cases (Fig. 3b)

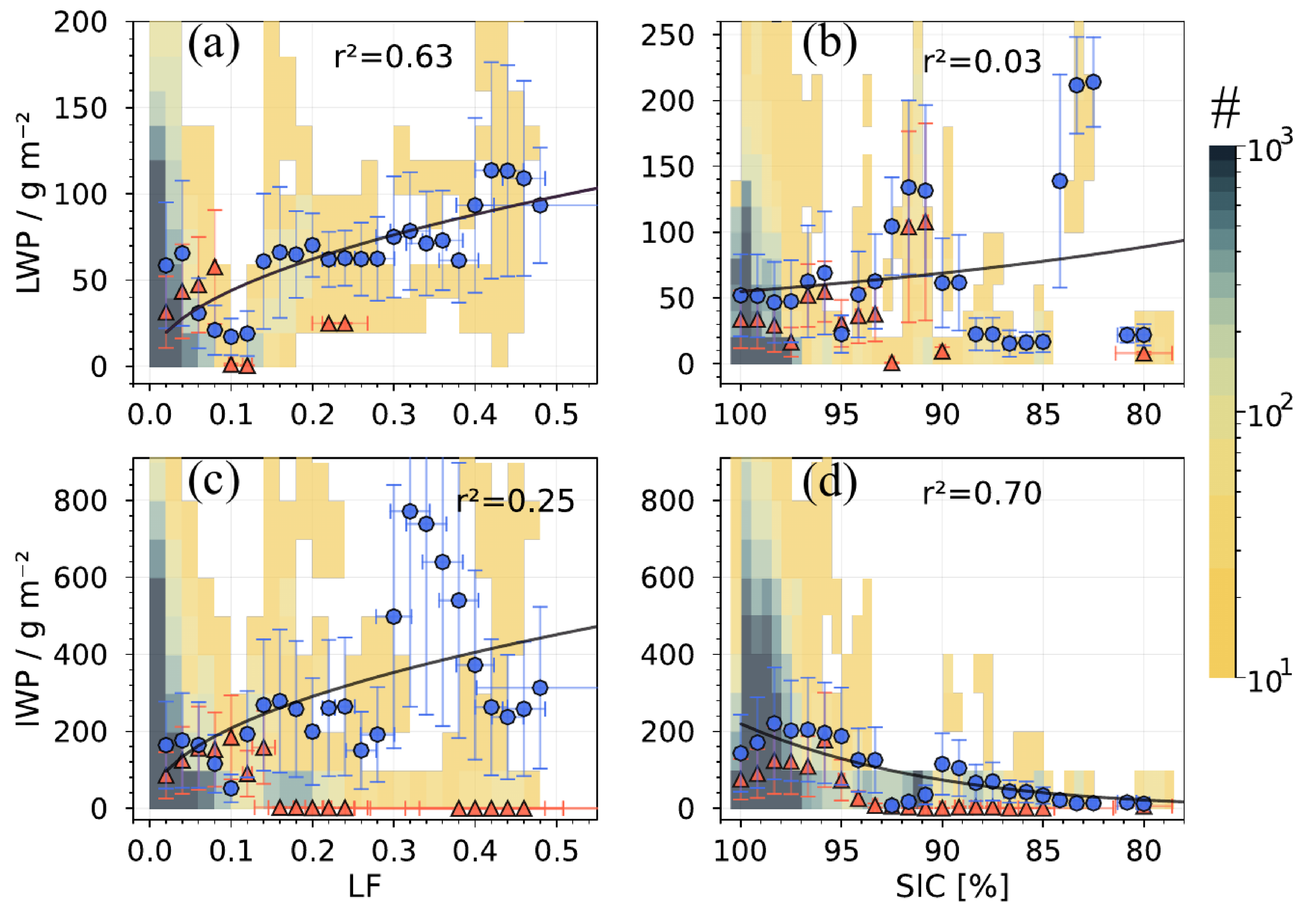


*Fig. 1: MOSAiC observations of liquid & ice water path (LWP & IWP) with respect to sea ice lead fraction (LF) and -concentration (SIC) with resolutions of 700m & 3km, respectively. Panels: (a) LWP vs LF, (b) LWP vs SIC, (c) IWP vs LF, (d) IWP vs SIC. **Coupled** cases in blue, **decoupled** in orange.*

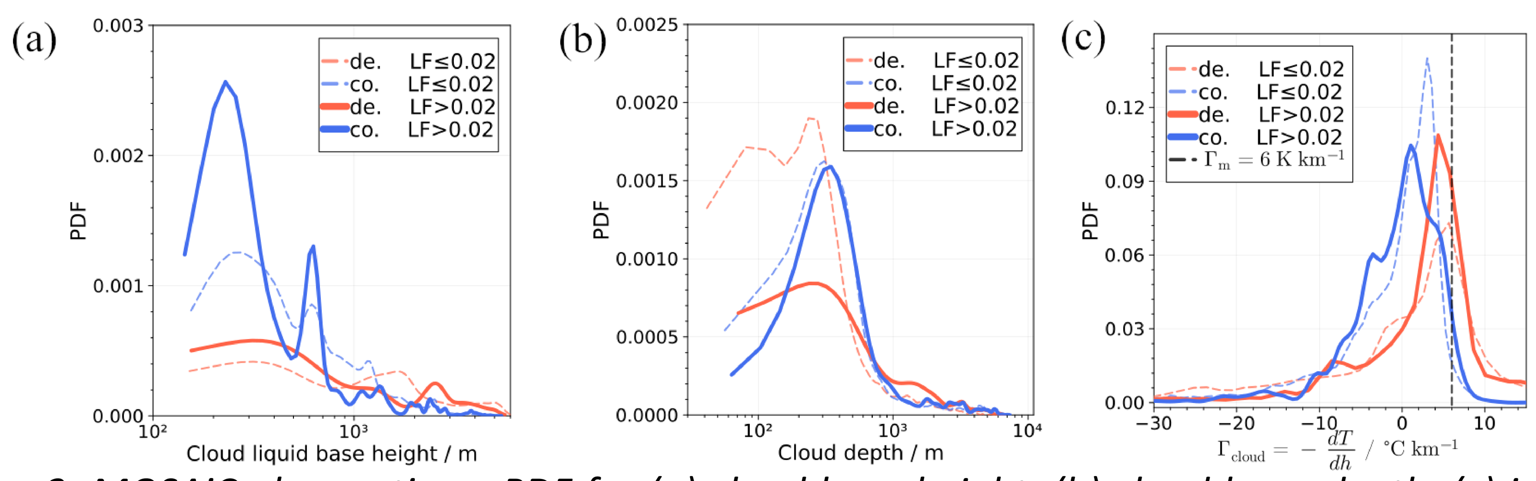


*Fig. 2: MOSAiC observations: PDF for (a) cloud base height, (b) cloud layer depth, (c) in-cloud lapse rate. **Coupled** cases are shown in blue, **decoupled** in orange. Dashed lines and solid lines show cases with LF < 0.02 and LF > 0.02, respectively.*

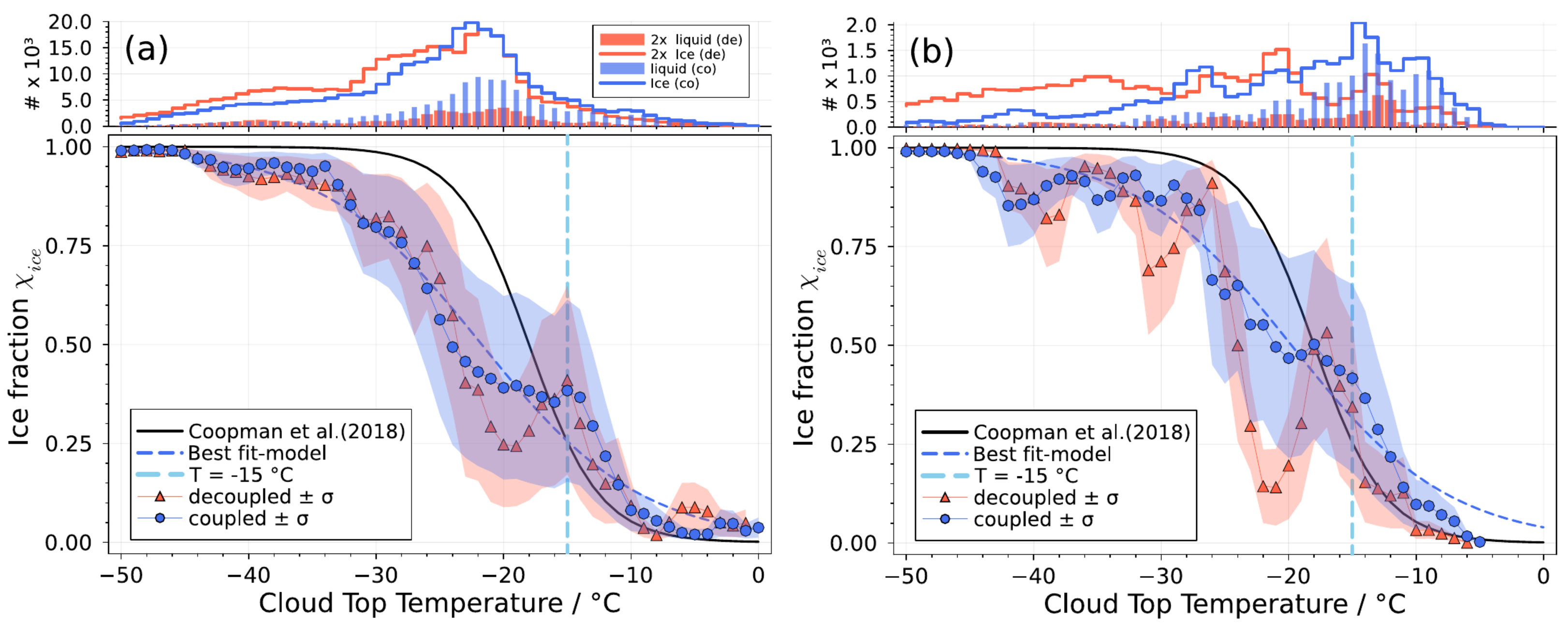
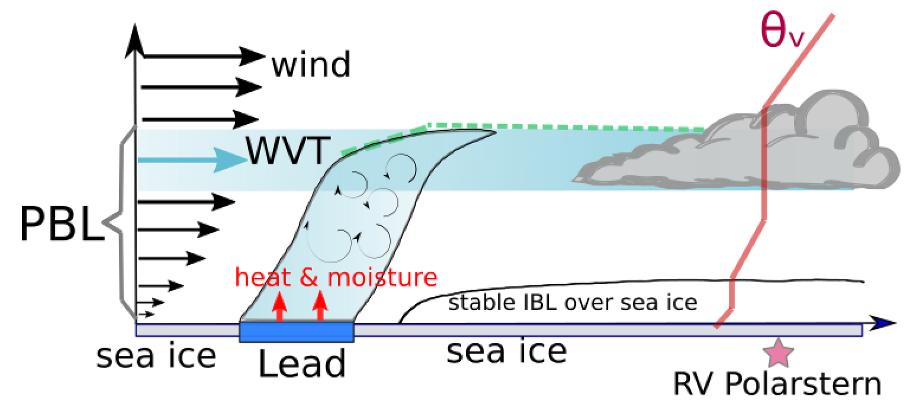


*Fig. 3: MOSAiC Observations for Ice water fraction (χ_{ice}) as a function of cloud top temperature. **Coupled** cases are shown in blue, **decoupled** in orange. Upper row: frequency of occurrence (FoO) of the ice and liquid components of χ_{ice}. Lower row: χ_{ice} for all cases (a, left column) and χ_{ice} for cases with LF > 0.02 (b, right column).*

Hypothesis

Sea ice leads or polynyas influence the microphysical and radiative properties of boundary layer clouds, and thus enhance Arctic amplification.



Western Arctic: North Slope of Alaska (NSA = Utqiaġvik)

Application of the methodology developed for MOSAiC to long-term wintertime observation of clouds at ARM site in Utqiaġvik (**2012-2020**).

- Western Arctic sea ice climatology differs compared to central Arctic (Fig. 4)
- Clouds coupled to upwind sea ice conditions can have larger LWP (Fig. 4)
- Coupled clouds are more efficient to increase net surface radiative balance (Fig. 5)

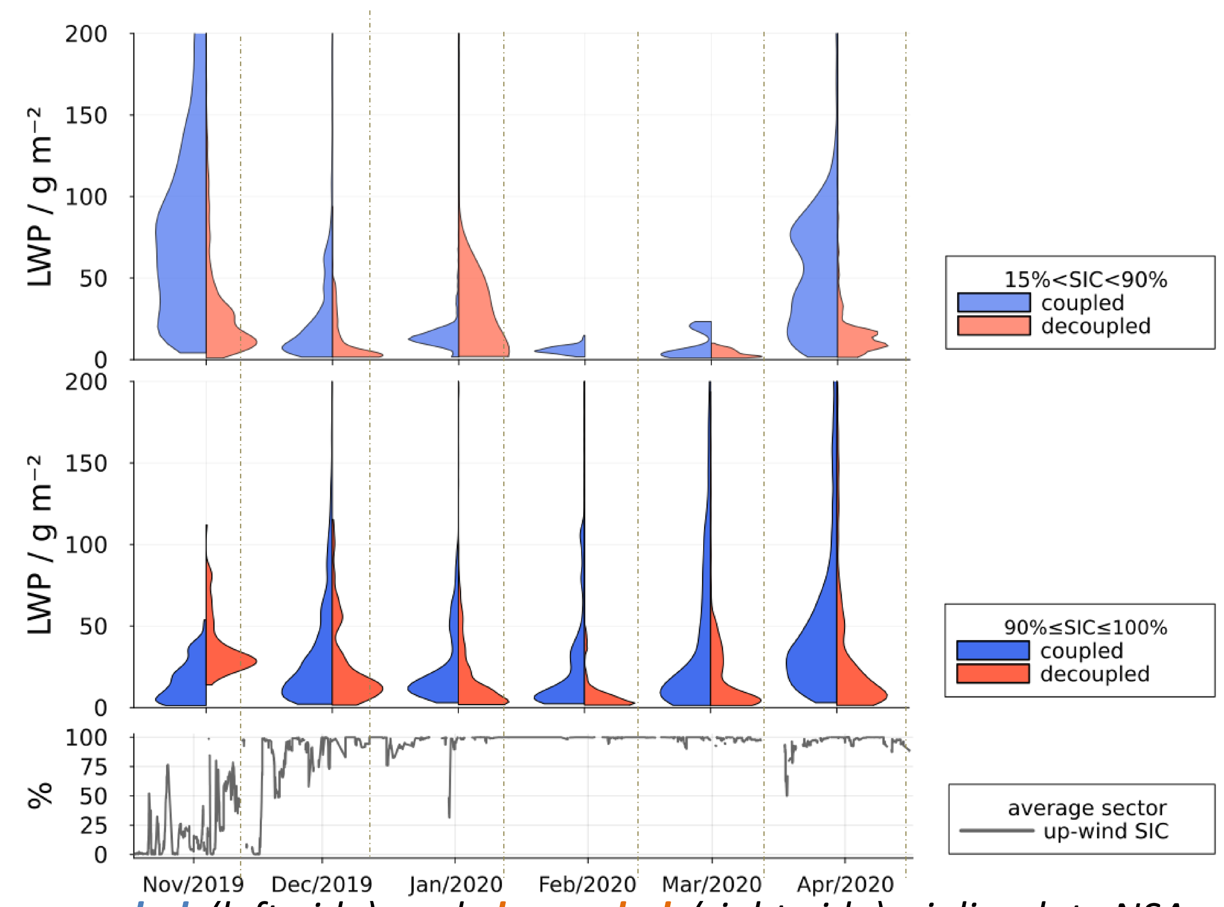


*Fig. 4: PDFs for **coupled** (left-side) and **decoupled** (right-side) violin-plot. NSA wintertime Nov 2019 – April 2020. Top: LWP of clouds for SIC between 15 and 90%. Middle: LWP for SIC > 90%. Bottom: time series of up-wind average SIC.*

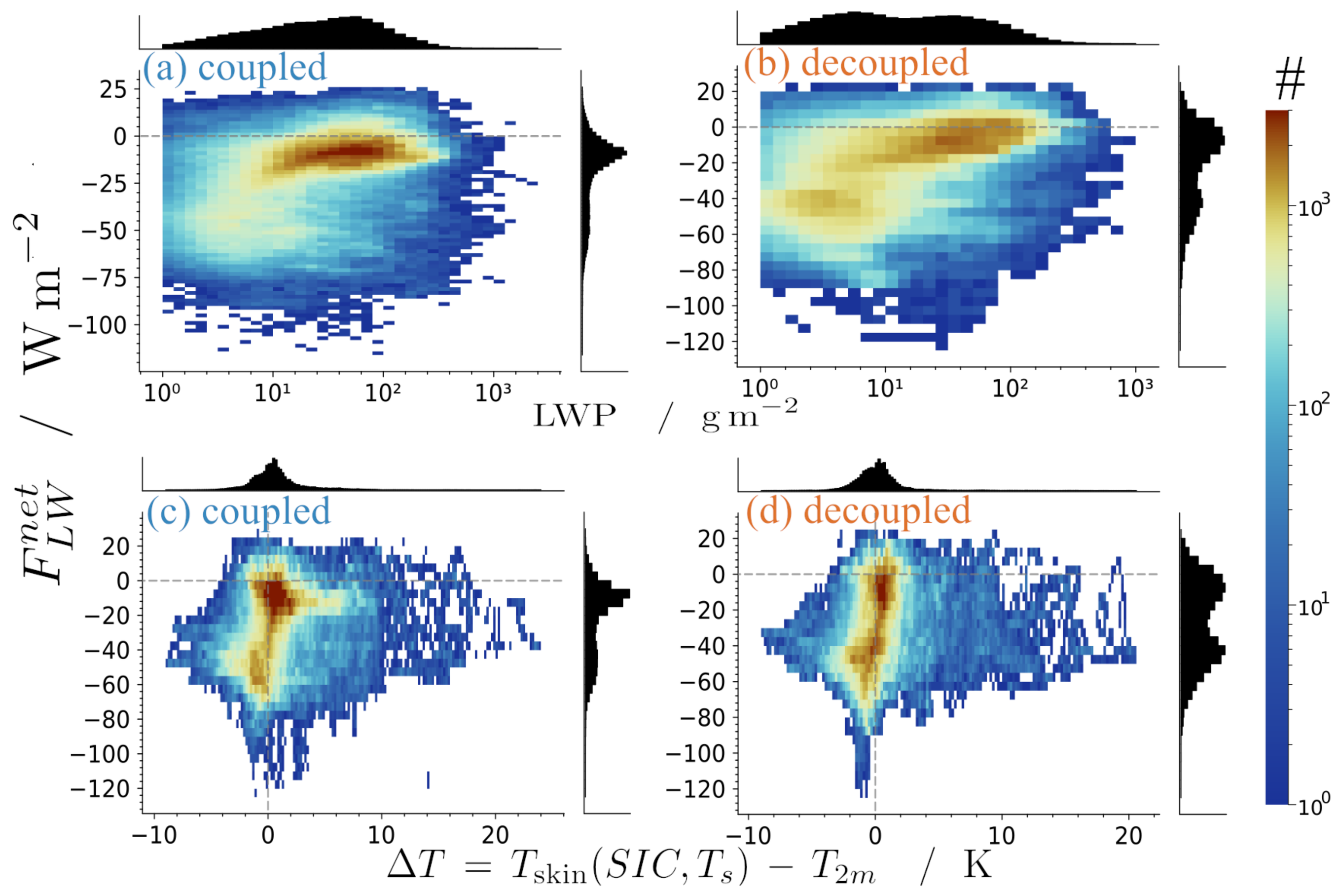


*Fig. 5: NSA winters 2012-2020 surface net longwave (LW) radiation $F_{LW}^{net} := F_{LW}^{\downarrow} - F_{LW}^{\uparrow}$. Top row: FoO of F_{LW}^{net} vs. LWP for (a) **coupled** and (b) **decoupled** cases. Bottom row: F_{LW}^{net} vs. ΔT as function of sea ice surface temperature, for (c) **coupled** and (d) **decoupled** cases.*

3. Legacy

Cloud properties influenced by sea ice state can be disentangled via

- Coupling to upwind sea ice condition by means of water vapor transport (Fig. 1,2,3,4)
- High resolution sea ice observations, e.g. SAR SENTINEL-1A, MODIS-AMSR2 (Fig. 1)

Most important findings

- **Q1** LW surface radiative effects differ for coupled/decoupled cases and as a function of sea ice state (NSA: Fig. 5)
- **Q2** LWP of coupled clouds are influenced by sea ice state (MOSAiC: Fig. 1,2,3; NSA: Fig. 4)
- **Q3** Similar relationships between cloud properties and sea ice are found (Fig. 1, 4)

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