Variation of cloud properties ascribed by sea ice states in the central and western Arctic

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Abstract

Based on wintertime observations during the MOSAiC expedition in 2019-2020, it was found that Arctic cloud properties show significant differences when clouds are coupled to the fluxes of water vapor transport coming from upwind regions of sea ice leads. Among these differences are that cloud liquid water path is considerably increased as a function of lead fraction for observations of lead fraction above 0.02, whereas ice water path only shows some moderate level of dependency on lead fraction when deep precipitating clouds are considered. Cloud macro-physical properties like cloud base height and cloud thickness were found to be lower and thicker, respectively, for clouds coupled to the water vapor transport.

To substantiate the findings from the MOSAiC data set, long-term measurements (2012-2022) at the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) at the North Slope Alaska (NSA) site in Utqiagvik, Alaska are being used to study the climatology of clouds and their properties coupled to the sea ice concentration in the Western Arctic. The same methodology used for the MOSAiC study is feasible to be applied to the NSA ARM site thanks to the standard instrumentation dataset provided by the ARM program. The study focuses on the atmospheric boundary layer topped water vapor transport as mechanism to link the influence of sea ice leads or polynyas, to the clouds. Statistical results will be presented and set into context to the results found for the MOSAiC expedition.

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MOSAiC
International Arctic Drift Expedition

ARM
U.S. DEPARTMENT OF ENERGY | Office of Science

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Abstract | Discussion | Metrics

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Status: this preprint is open for discussion and under review for Atmospheric Chemistry and Physics (ACP).

Asymmetries in winter cloud microphysical properties ascribed to sea ice leads in the central Arctic

Pablo Saavedra Garfias, Heike Kalesse-Los, Luisa von Albedyll, Hannes Griesche, and Gunnar Spreen

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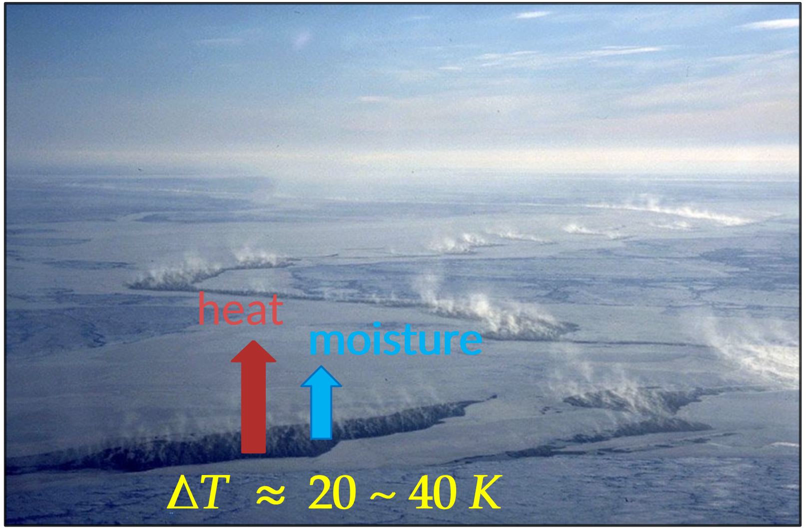
Short summary

Wintertime Arctic clouds act as warming mechanism since they trap heat to the lower atmosphere....
- Read more

SEA ICE LEADS IN THE ARCTIC

have an effect on Arctic clouds by changing their microphysical and radiative properties, and thus enhance Arctic Amplification.



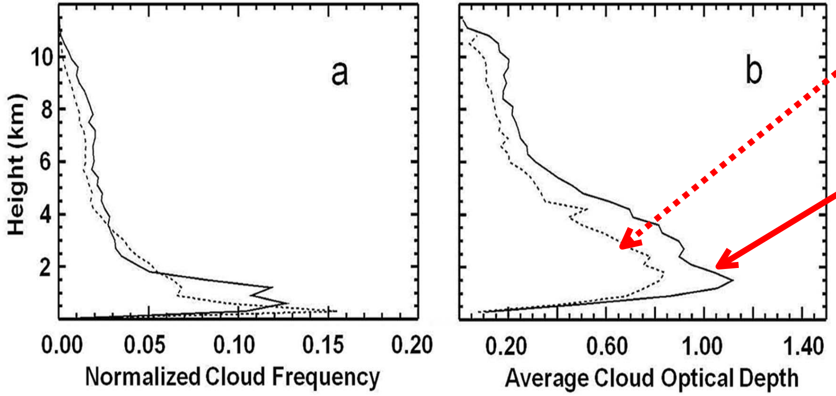
(University of Hamburg, Germany)

How do sea ice leads or polynyas:

- interact with boundary layer clouds?
- influence the macrophysical and microphysical cloud properties?

MOTIVATION

Palm et al. JGR (2010)

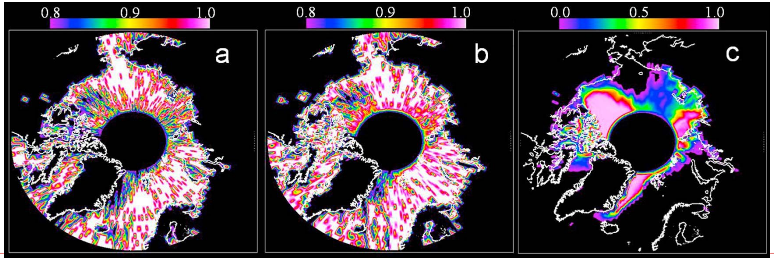


Over Ice (dashed line)

Over Water (solid line)

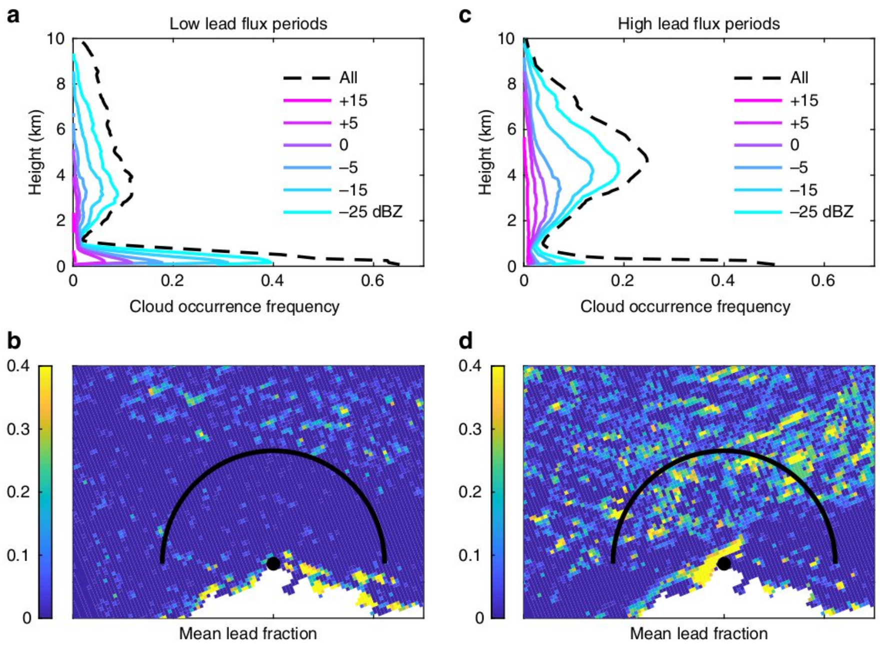
Influence of Arctic sea ice extent on polar cloud fraction.

Obs. October, period from 2003 to 2007



MOTIVATION

"Midwinter Arctic Leads Form and Dissipate Low Clouds"
Li et al. Nature Com. (2020)



Based on observation from North of Alaska for Feb. 2011 (b) and Feb. 2010 (d).

→ Newly refrozen leads dissipate low level clouds.

Central Arctic

MOSAiC EXPEDITION

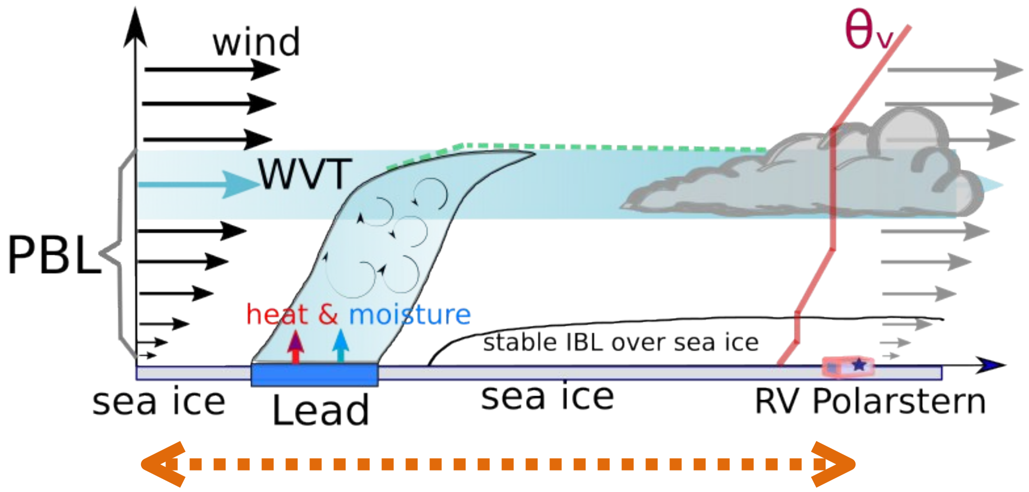
RV *Polarstern* drifting with the sea ice across the central Arctic from Sept. 2019 to Oct. 2020

Ship-base remote sensing observations of clouds aloft the RV *Polarstern*

Here we focus only the winter time period from Nov 2019 to Apr 2020 when the leads are more active.

METHODOLOGY

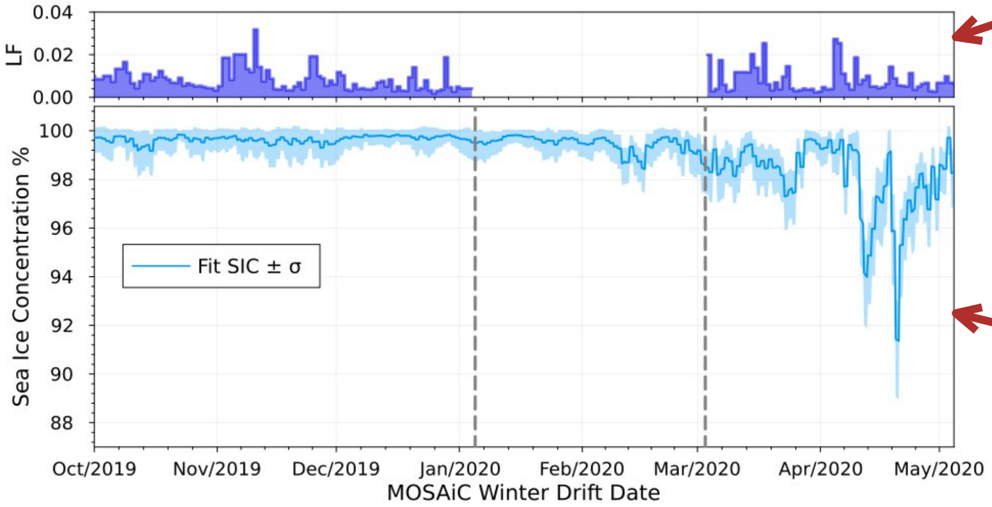
Gedankenexperiment

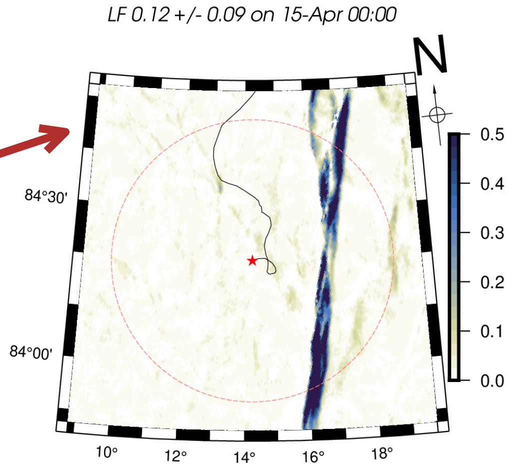


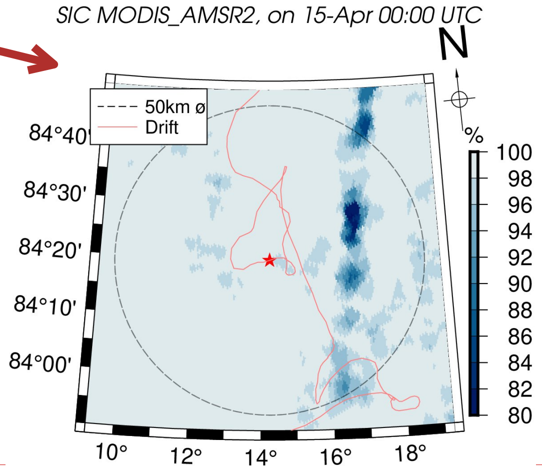
50 km range from RV *Polarstern*

- Only upwind leads are relevant,
- Water vapor transport (WVT) as mechanism to entangle sea ice leads with observed clouds,
- Wind direction from max. vertical gradient of boundary layer WVT,
- Clouds coupled to WVT (expected interaction with WVT),
- Due to IBL, surface coupling is not relevant (~ 4.7%),
- Clouds could be originated or influenced by sea ice leads.

SEA ICE DURING MOSAIC



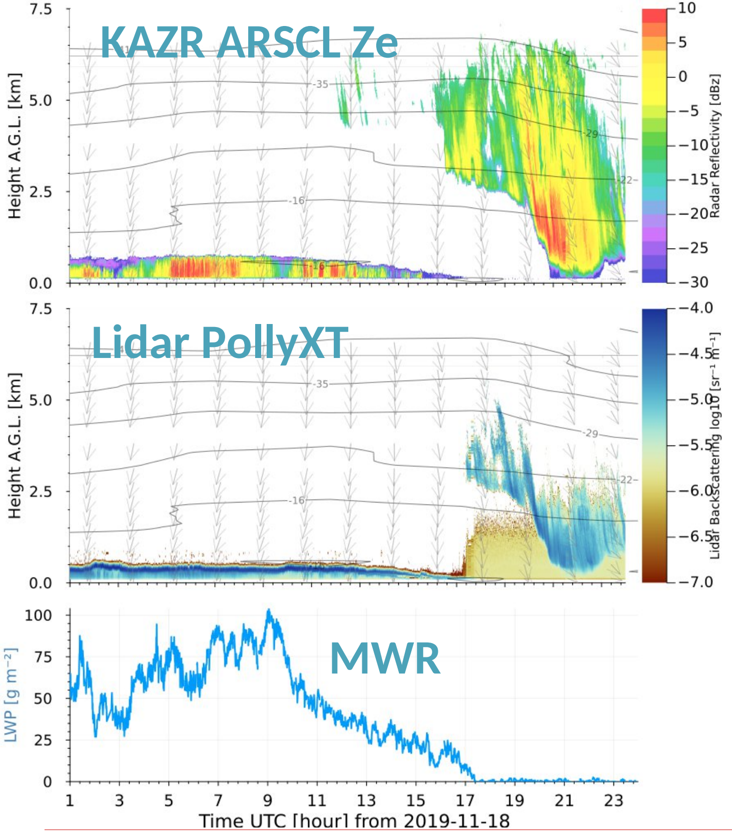


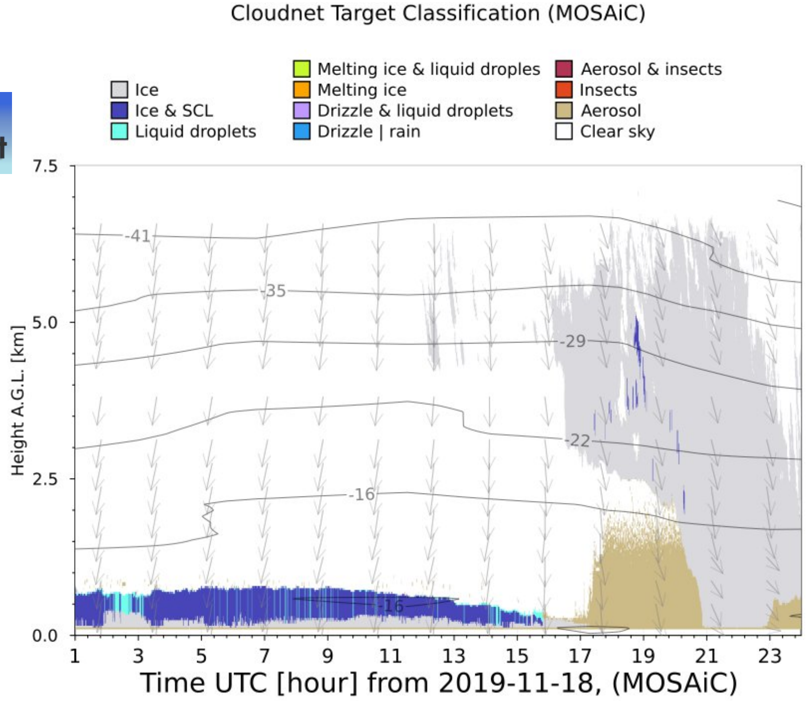


Sea Ice lead fraction (LF) and concentration (SIC) from two satellite products:

- SENTINEL-A1 SAR (LF @ 700 m)
- merged MODIS-AMSR2 (SIC @ 1 km and 3.12 km)

CLOUD CLASSIFICATION



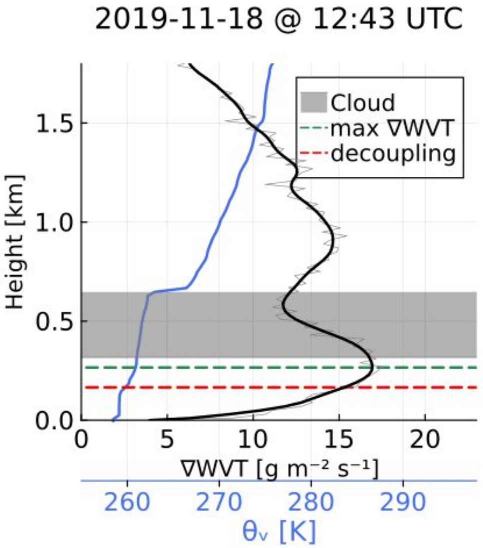


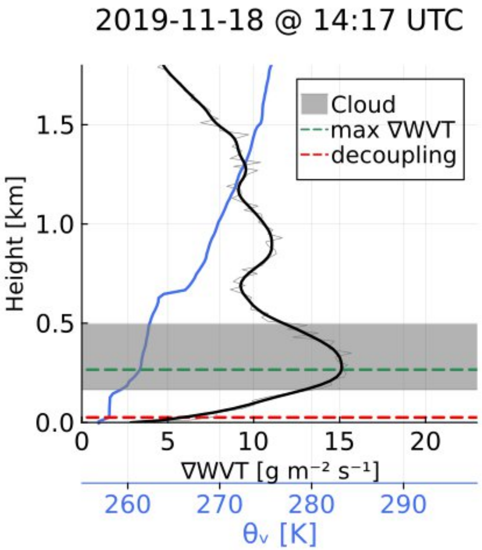
Cloud properties: LWC, IWC, ice & droplets r_{eff}, cloud top temperature, cloud base & depth

CLOUD COUPLING

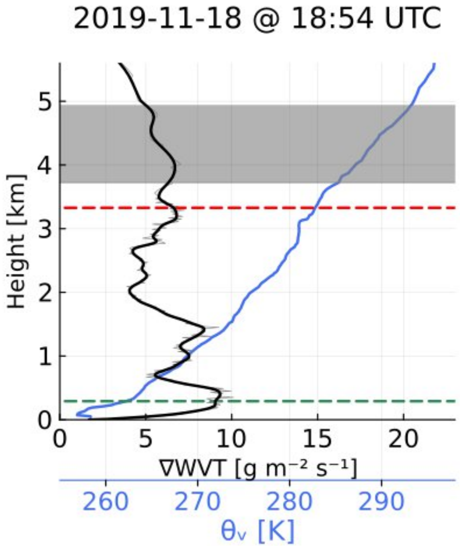
$$\nabla WVT = -\frac{10^2}{g} q_v \cdot V_w \frac{dP}{dz}$$

COUPLED

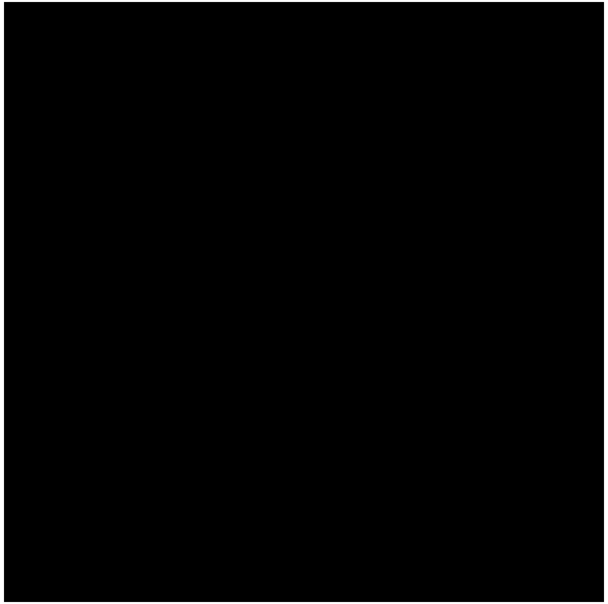


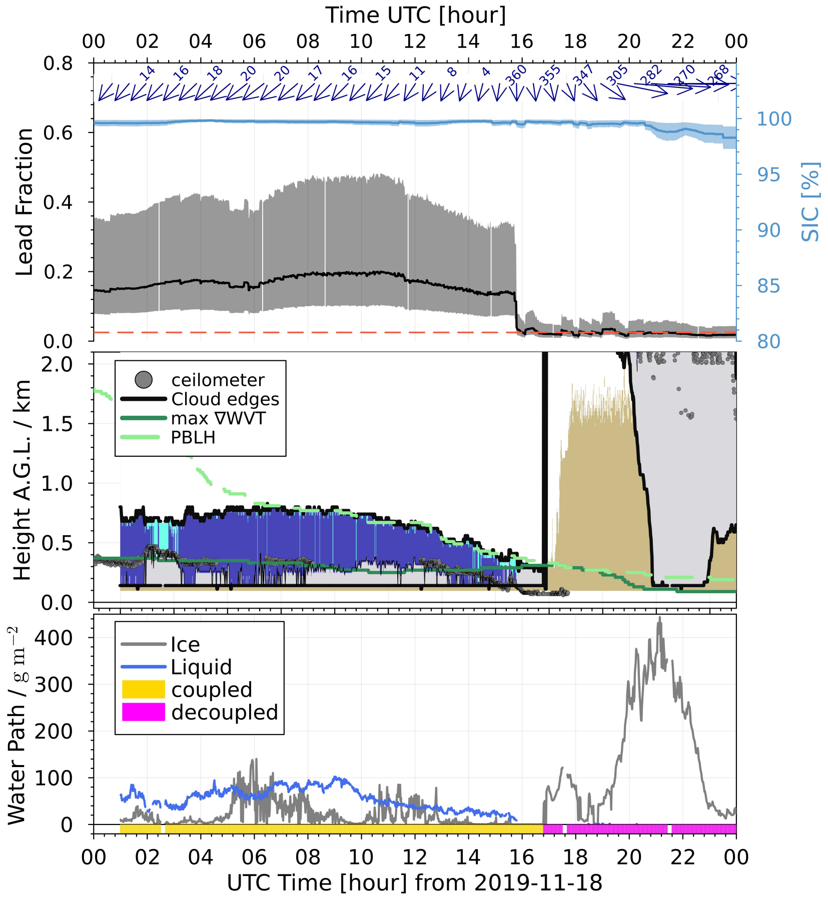


DECOUPLED

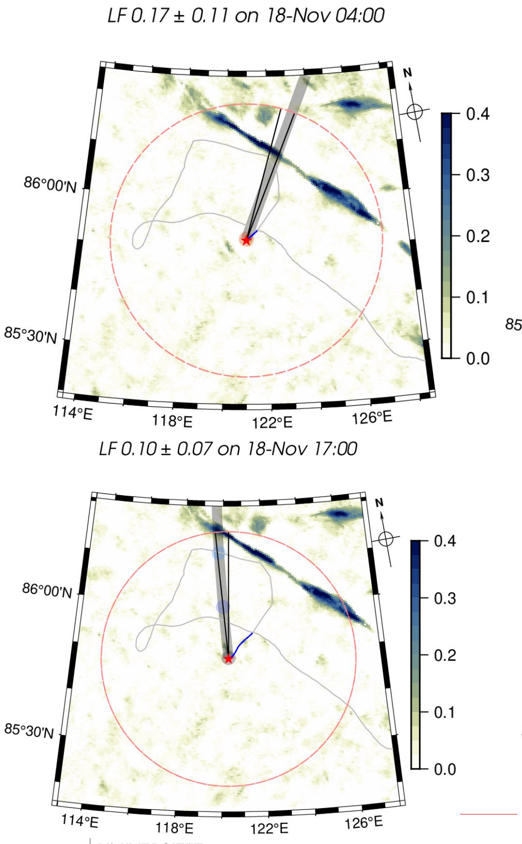


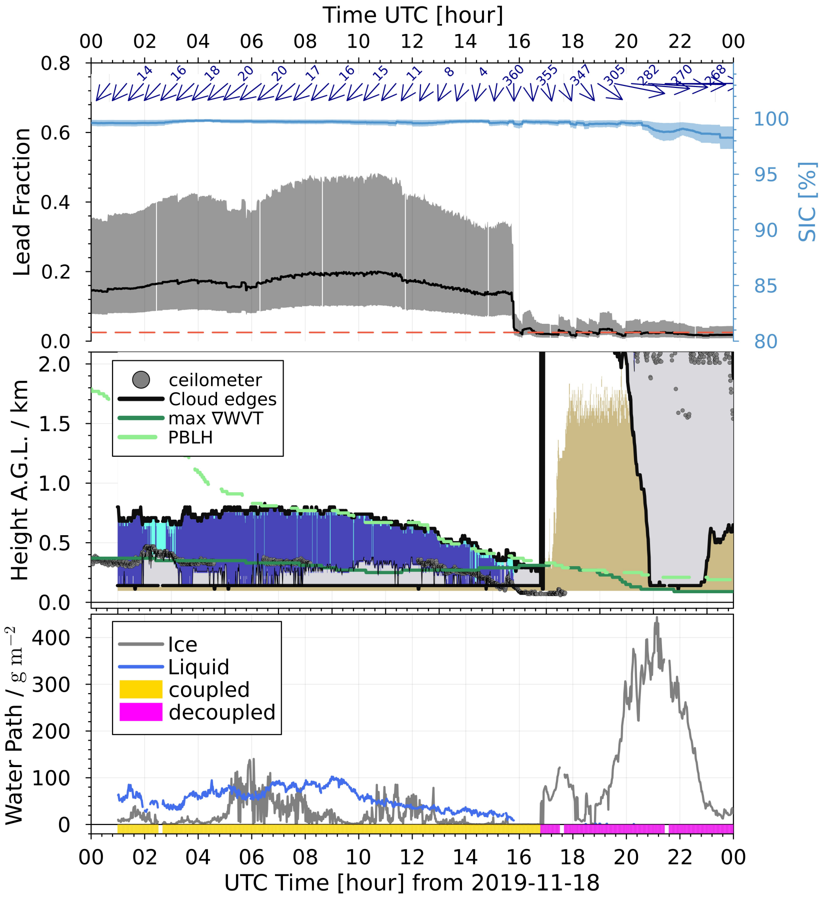
CLOUD PROPERTIES AND SEA ICE





CLOUD PROPERTIES AND SEA ICE

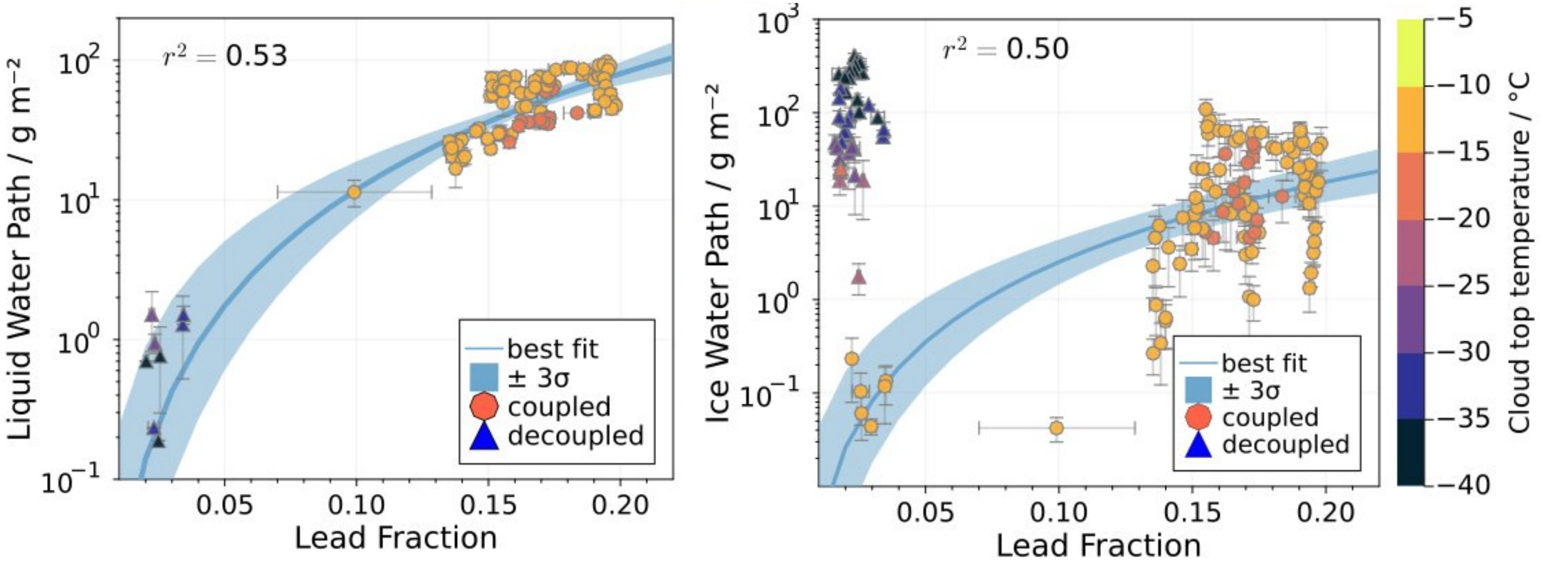




RESULTS

Based on the case study 18 Nov. 2019:

- Liquid water path trend to increase with LF,
- Ice water path less evident relationship with LF
- cloud top temperature warmer with LF



STATISTICS FOR MOSAIC EXPEDITION

Circles: coupled
Triangles: decoupled

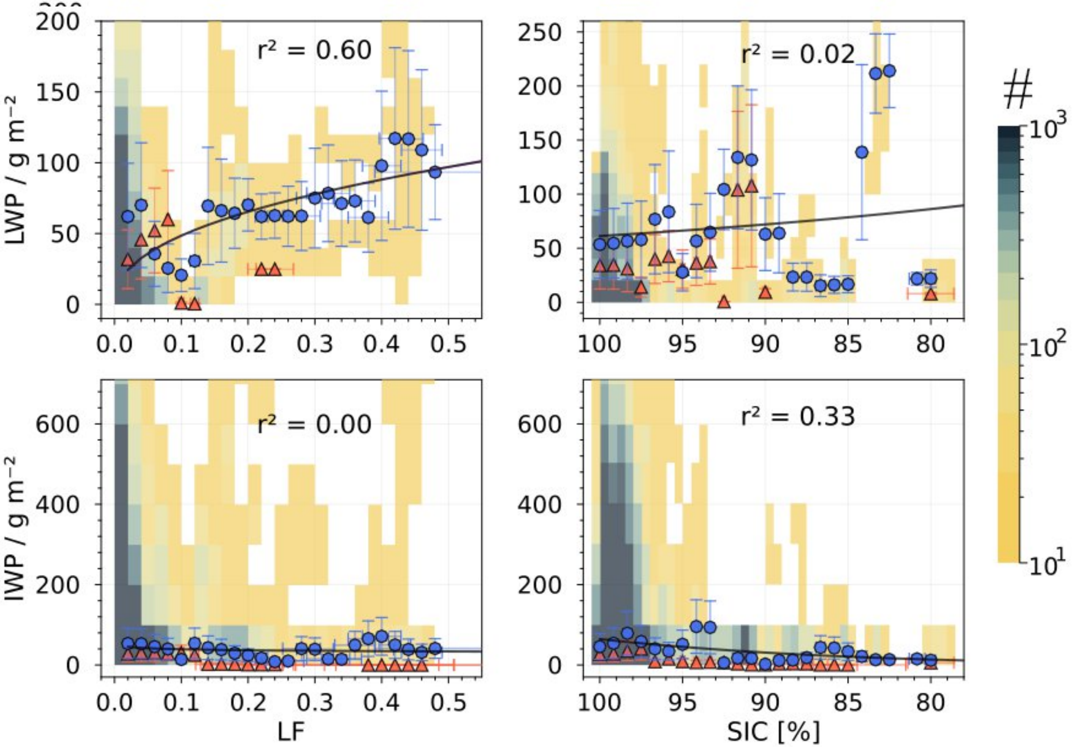
Data from Nov 2019-April 2020

Only Cloud depth < 3 km

Color histogram: all data

Symbols: average @ ΔLF= 0.02

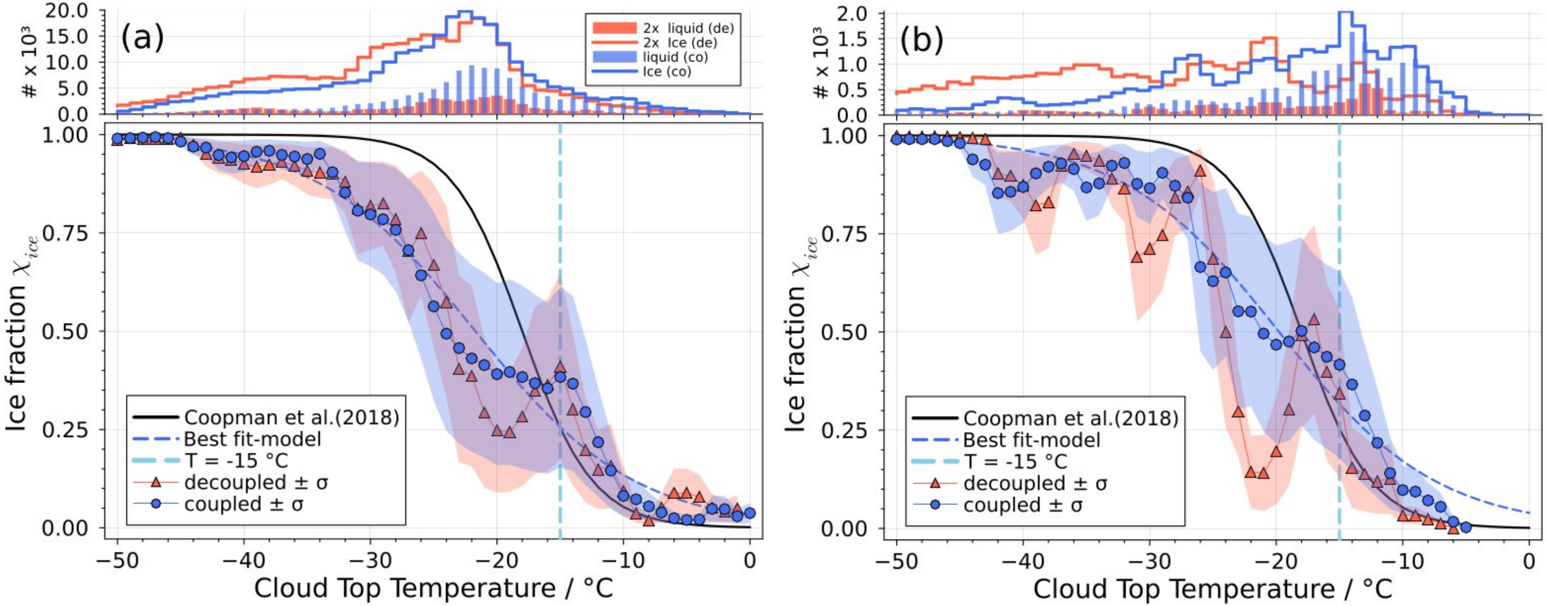
LWP & IWV versus LF and SIC



STATISTICS FOR MOSAIC EXPEDITION

$$\chi_{ice} = \frac{IWP}{IWP+LWP}$$

Ice water fraction versus Cloud top temperature



Coupled
Decoupled

(a) Left plot: All data

(b) Right plot: Cases with LF > 0.02

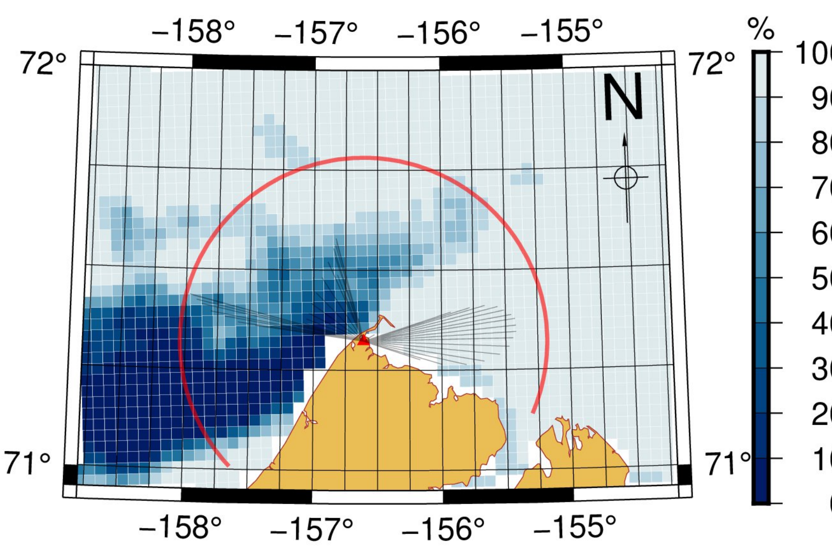
Western Arctic

NSA SITE UTQIAĠVIK

Similar remote sensing capabilities as the RV *Polarstern* during MOSAiC

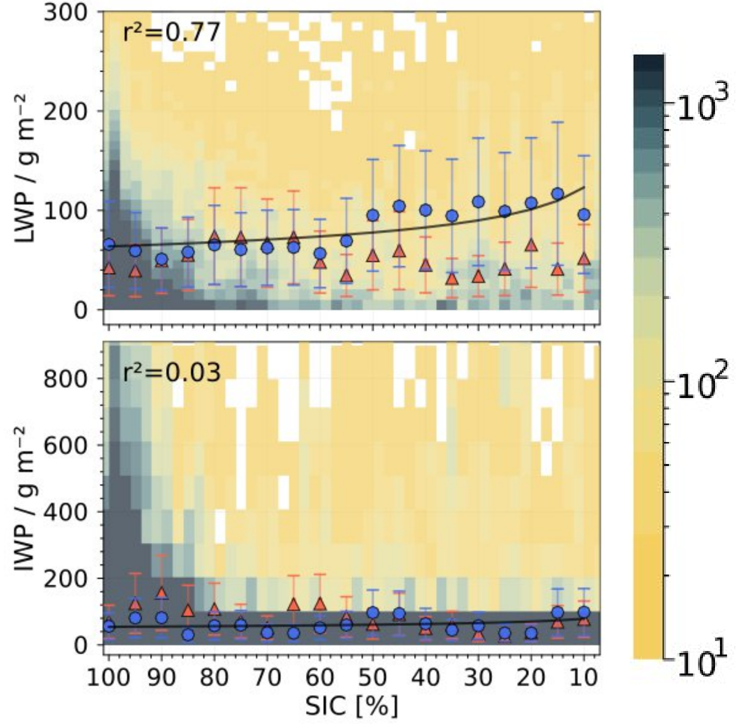
Only sea ice concentration @ 3.124km

Long-term wintertime observations period from **2012 to 2022** for the months Nov-Apr.



STATISTICS FOR WESTERN ARCTIC: NSA

LWP & IWV versus SIC@3.1 km



Circles: coupled

Triangles: decoupled

Data from 2012-2022 Wintertime Nov. to Apr.

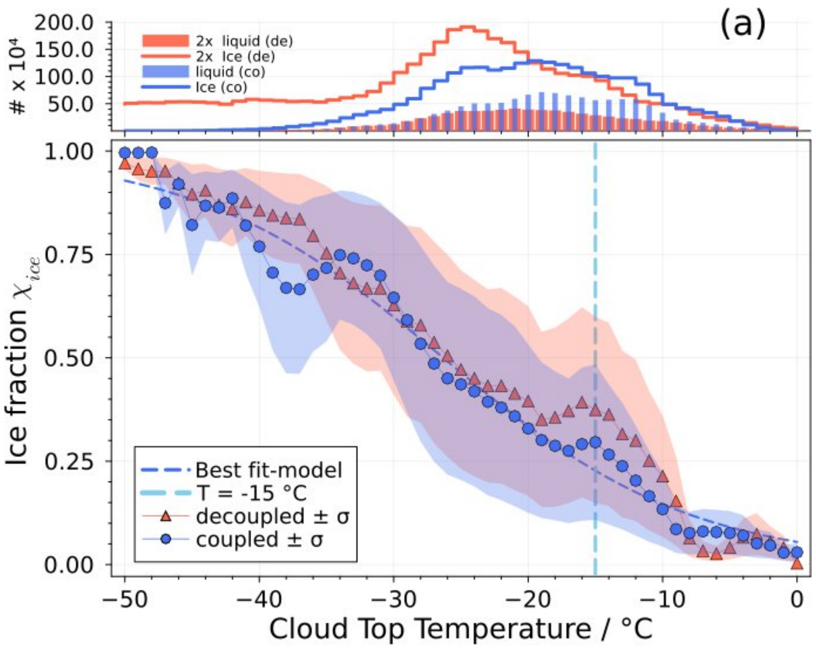
Only Cloud depth < 3 km

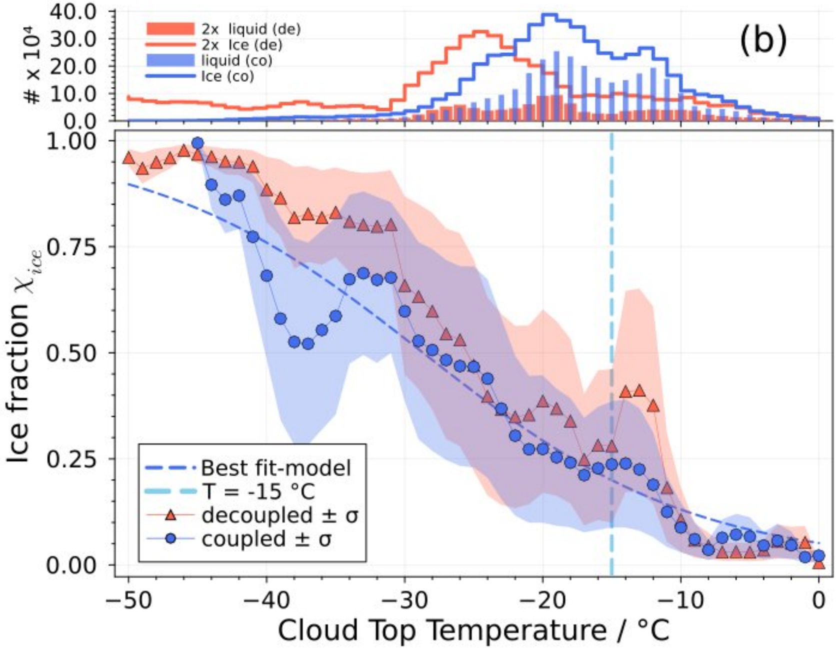
Color histogram: all data

Symbols: average @ ΔSIC=3%

STATISTICS FOR WESTERN ARCTIC: NSA

Data from 2002-2022 Wintertime Nov. to Apr.





(a) Left plot: All data

(b) Right plot: Cases with SIC < 90%

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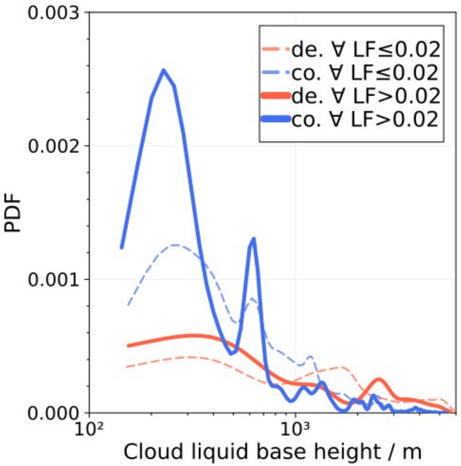
CONCLUSIONS

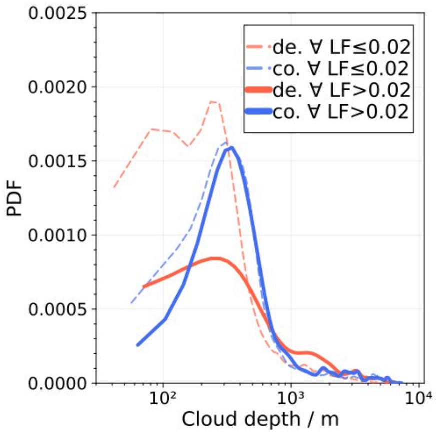
- Sea ice leads upwind entangle to cloud via WVT shows efficient to highlight significant differences on cloud properties,
- Coupled clouds:
  - enhancement of LWP with sea ice openings,
  - IWP no relationship with sea ice openings,
  - lower base height, deeper cloud layer, warmer cloud top temperature,
- Fraction of ice water content as a function of cloud top temperature uncovers asymmetries when segregated by the coupling status to the sea ice openings.

THANK YOU

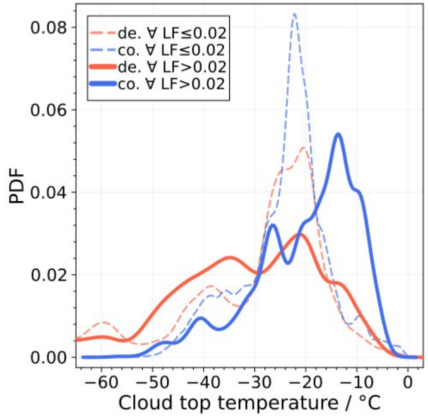
Leibniz-Institut für Troposphärenforschung

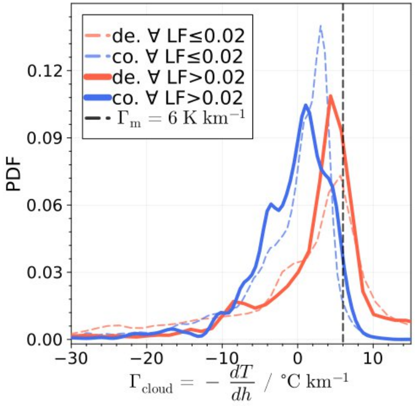
Universität Bremen

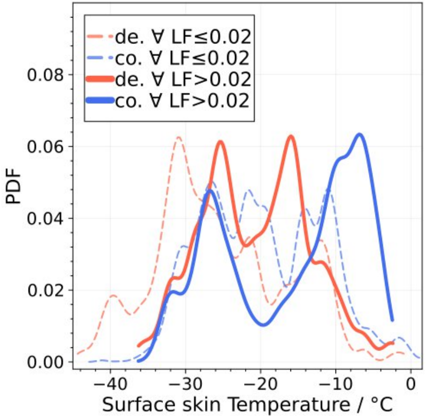




MOSAiC wintertime
All data from Nov 2019-April 2020







RESULTS

NSA Utkiaġvik wintertime
All data from 2012 - 2022