Long-term statistical analysis of wintertime cloud thermodynamic phase and micro-physical properties in relation to sea ice condition at NSA Utqia’gvik site

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Abstract

It has been found that wintertime mixed-phase cloud properties can present significant differences based on the degree of interaction with air masses coming from locations with reduced sea ice concentration or high presence of sea ice leads. When these air masses are represented by the water vapor transport (WVT) which can interact with the clouds, the properties of the clouds show contrasting differences with respect to cases where the WVT is not interacting with the cloud, i.e. it is not coupled to the cloud. These findings have been reported first for the analysis of the MOSAiC expedition dataset from 2019 to 2020 in the central Arctic (Shupe et al., 2022; Saavedra Garfias et al., 2023). In the present contribution, we expand that analysis to 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 Utqia’gvik, Alaska. Based on those 10 years of characterized cloud and sea ice properties, statistically more robust analysis is performed to support or contradict the MOSAiC results. Furthermore, the statistically richer data set from NSA allows to narrow down cases where the properties or coupled clouds to WVT are substantially dissimilar to decoupled cases. Among those are the increase of liquid water path correlated to a decrease of sea ice concentration and ice water paths which are not exhibiting an influence by sea ice concentration. The thermodynamic phase of the clouds also exposes differences based on the state of coupling among the cloud–WVT–sea ice system. These results are put into consideration for the modeling community since sea ice leads are not explicitly resolved in such models, thus the sea ice leads or polynyas effects to processes responsible for mixed-phase cloud formation/dissipation and thermodynamic phase balance are of considerable interest for the parametrization of energy exchange between the surface and the atmosphere in the Arctic.


References


Asymmetries in cloud microphysical properties ascribed to sea ice leads via water vapour transport in the central Arctic. (2023). \textit{Atmospheric Chemistry and Physics, 23}(22). \url{https://doi.org/10.5194/acp-23-14521-2023}
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Faculty of Physics and Earth Sciences

San Francisco, 15th December, 2023
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*

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Asymmetries in cloud microphysical properties ascribed to sea ice leads via water vapour transport in the central Arctic

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**CLOUD CLASSIFICATION**

- **KAZR ARSCL Ze**
- **Lidar PollyXT**
- **MWR**

Cloud properties: LWC, IWC, ice & droplets $r_{eff}$, cloud top temperature, cloud base & depth
SEA ICE – CLOUDS INTERACTION IN THE ARCTIC

have an effect on Arctic clouds by changing their macro-, micro-physical and radiative properties.

heat

moisture

$\Delta T \approx 20 \sim 40 \, K$

(University of Hamburg, Germany)
SEA ICE – CLOUDS INTERACTION IN THE ARCTIC

- Water vapor transport (WVT) as mechanism to entangle sea ice leads with observed clouds,
SEA ICE – CLOUDS INTERACTION IN THE ARCTIC

- Water vapor transport (WVT) as mechanism to entangle sea ice leads with observed clouds,

- Wind direction from max. $\nabla_z WVT$ within the boundary layer.

50 km range from Observatory
SEA ICE – CLOUDS INTERACTION IN THE ARCTIC

- Water vapor transport (WVT) as mechanism to entangle sea ice leads with observed clouds,
- Wind direction from max. $\nabla_z WVT$ within the boundary layer,
- Clouds coupled to WVT (interaction with WVT / leads),

50 km range from Observatory
SEA ICE – CLOUDS INTERACTION 
IN THE ARCTIC

- Water vapor transport (WVT) as mechanism to entangle sea ice leads with observed clouds,
- Wind direction from max. $\nabla_z WVT$ within the boundary layer,
- Clouds coupled to WVT (interaction with WVT / leads),
- Clouds decoupled to WVT (no interaction with WVT / leads),

50 km range from Observatory
Long-term statistical analysis of wintertime mixed-phase clouds properties at NSA | AGU 2023

SEa Ice – CLOUDS INTERACTION
IN THE ARCTIC

- Water vapor transport (WVT) as mechanism to entangle sea ice leads with observed clouds,
- Wind direction from max. $\nabla_z \text{WVT}$ within the boundary layer,
- Clouds **coupled** to WVT (interaction with WVT / leads),
- Clouds **decoupled** to WVT (no interaction with WVT / leads),
- Only upwind leads are relevant,

50 km range from Observatory
CLOUD PROPERTIES AND SEA ICE

LF 0.17 ± 0.11 on 18-Nov 04:00

Leipzig Institute for Meteorology
CLOUD PROPERTIES AND SEA ICE

LF 0.17 ± 0.11 on 18-Nov 04:00

LF 0.14 ± 0.10 on 18-Nov 14:00

1.1

AGU 2023

Leipziger Institut für Meteorologie
CLOUD PROPERTIES AND SEA ICE

SF 0.17 ± 0.11 on 18-Nov 04:00

SF 0.14 ± 0.10 on 18-Nov 14:00

SF 0.10 ± 0.07 on 18-Nov 17:00

Leipziger Institut für Meteorologie
STATISTICS FOR MOSAiC EXPEDITION

Data from Nov 2019-April 2020

Color histogram: all data
Symbols: only Cloud top < 3 km

LWP & IWV versus LF and SIC

Coupled
Decoupled

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Western Arctic

**ARM SITE (NSA) UTQIÁGVIK**

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

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

**AMSR2**

Sea ice concentration (SIC) @ 3.12km grid. *University of Bremen*
STATISTICS FOR UTQIAQVIK (NSA) 2012 - 2022

LWP & IWV versus SIC@3.12 km

Only Cloud top < 3 km
ICE WP TIME SERIES FOR UTQIAQVIK 2012 - 2022
Wintertime from Nov. to Apr.

- o Coupled
- ^ Decoupled
LIQUID WP TIME SERIES FOR UTQIAGVIK 2012 - 2022
Wintertime from Nov. to Apr.

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LIQUID WP TIME SERIES FOR UTQIAGVIK 2012 - 2022
Wintertime from Nov. to Apr.

Is the yearly variability influenced by sea ice?

o Coupled
^ Decoupled

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LIQUID WP TIME SERIES FOR UTQIAGVIK 2012 - 2022
Wintertime from Nov. to Apr.

Is the yearly variability influenced by sea ice?
LIQUID WP TIME SERIES FOR UTQIAQVIK 2012 - 2022
Wintertime from Nov. to Apr.

Is the yearly variability influenced by sea ice?
CONCLUSIONS

- MOSAiC findings confirmed at Utqiagvik site for 2012 to 2022:
  - enhancement of LWP with sea ice openings,
  - IWP no relationship with sea ice openings,
  - lower base height, deeper cloud layer, warmer cloud top temperature,
- wider variability for mixed-phase cloud properties during years with anomalous low sea ice during winter,
- 10 years obs. do not show significant trend in cloud properties.
CONCLUSIONS

- MOSAiC findings confirmed at Utqiagvik site for 2012 to 2022:
  - enhancement of LWP with sea ice openings,
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THANK YOU
LIQUID WP TIME SERIES FOR UTOIAGVIK 2012 - 2022

Is the trend influenced by large scale climate variability?
THERMODYNAMIC TIME SERIES FOR UTQIAQVIK 2012 - 2022

Skin Temp, °C

Wintertime

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\[ \bar{T}_{\text{cloud}} \]

\[ +0.2 \text{ K km}^{-1}\text{yr}^{-1} \text{ @Cls} [-0.3 0.7] \]

\[ +0.2 \text{ K km}^{-1}\text{yr}^{-1} \text{ @Cls} [-0.4 0.8] \]