Sources and Formation Mechanisms of Liquid-Bearing Clouds Over MOSAiC

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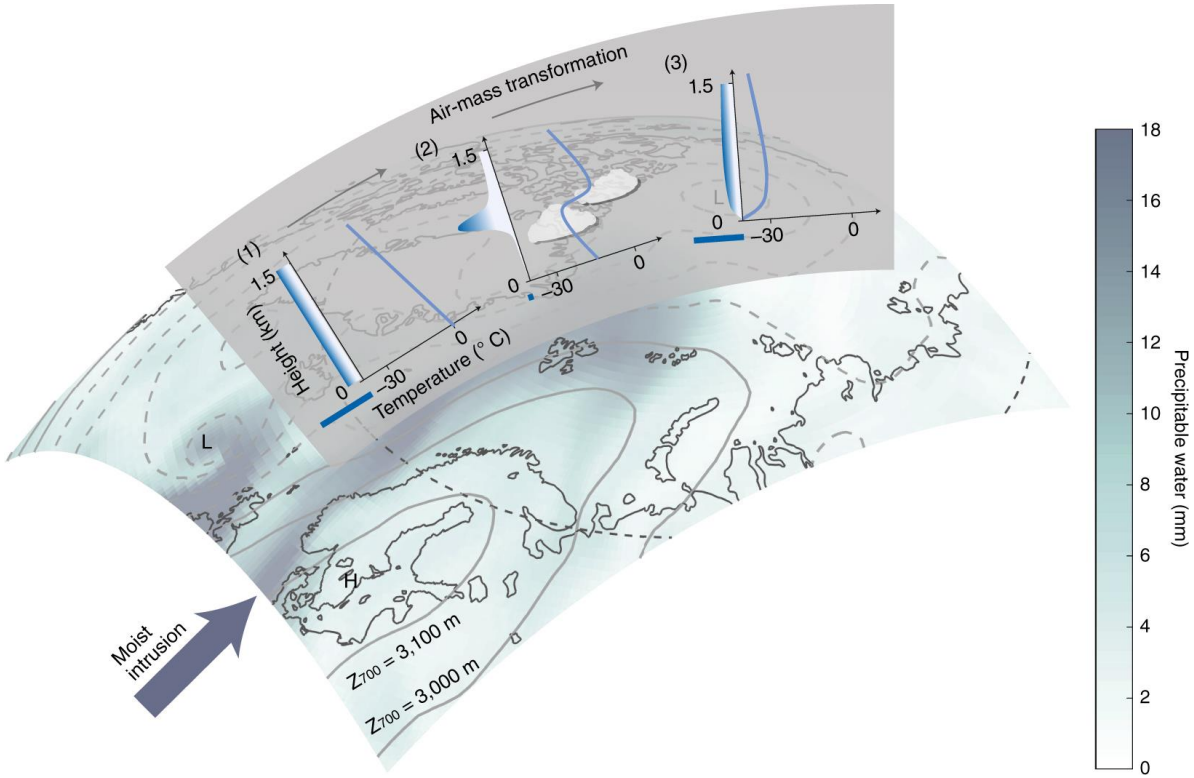
Background

- Arctic cloud formation mechanisms:
  1. Moisture mass flux originating in:
     - Open water at lower latitudes
     - Open water Arctic sectors
     - Continental sources (mainly during summer)
  2. Vertical ascent via turbulence (mixed layers) or upward motion of stable subsaturated layers
  3. Prolonged radiative cooling of elevated air



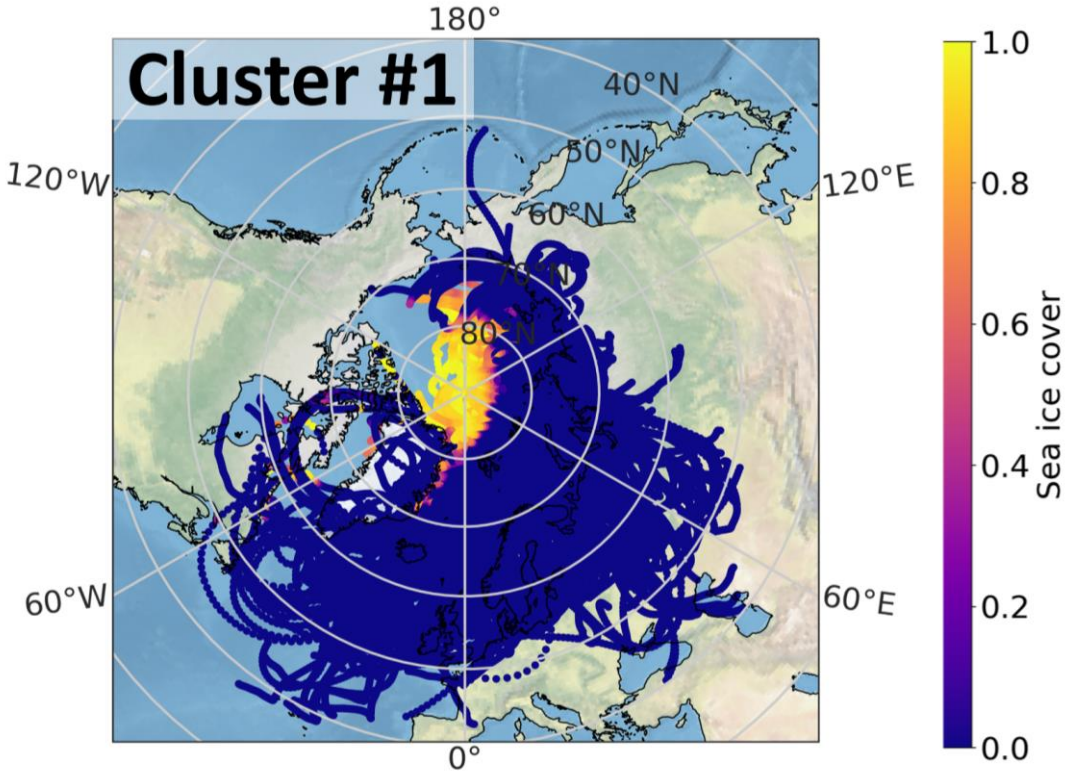
Pithan et al., 2018

Objective

- To date, the occurrence and characteristics of individual Arctic cloud layers have not been quantitatively linked with these cloud formation mechanisms.
- Using measurements from the recent MOSAiC expedition and reanalysis data, we seek to address the following questions:
  - What is the frequency of occurrence of these cloud formation mechanisms over the sea-ice covered central Arctic?
  - Is the persistent radiative cooling formation mechanism significant for the Arctic?

Method

1. Detect liquid-bearing clouds over the full atmospheric column using the 6-hourly sounding measurements from MOSAiC
2. Use the HYSPLIT model informed by ERA5 for each detected layer to calculate 120-h (5-day) back trajectories
3. Calculate a set of 4 variables describing the airmasses along trajectories
4. Utilize these 4 variables to cluster the back trajectories using a Bayesian Gaussian mixture model algorithm with a Dirichlet process prior

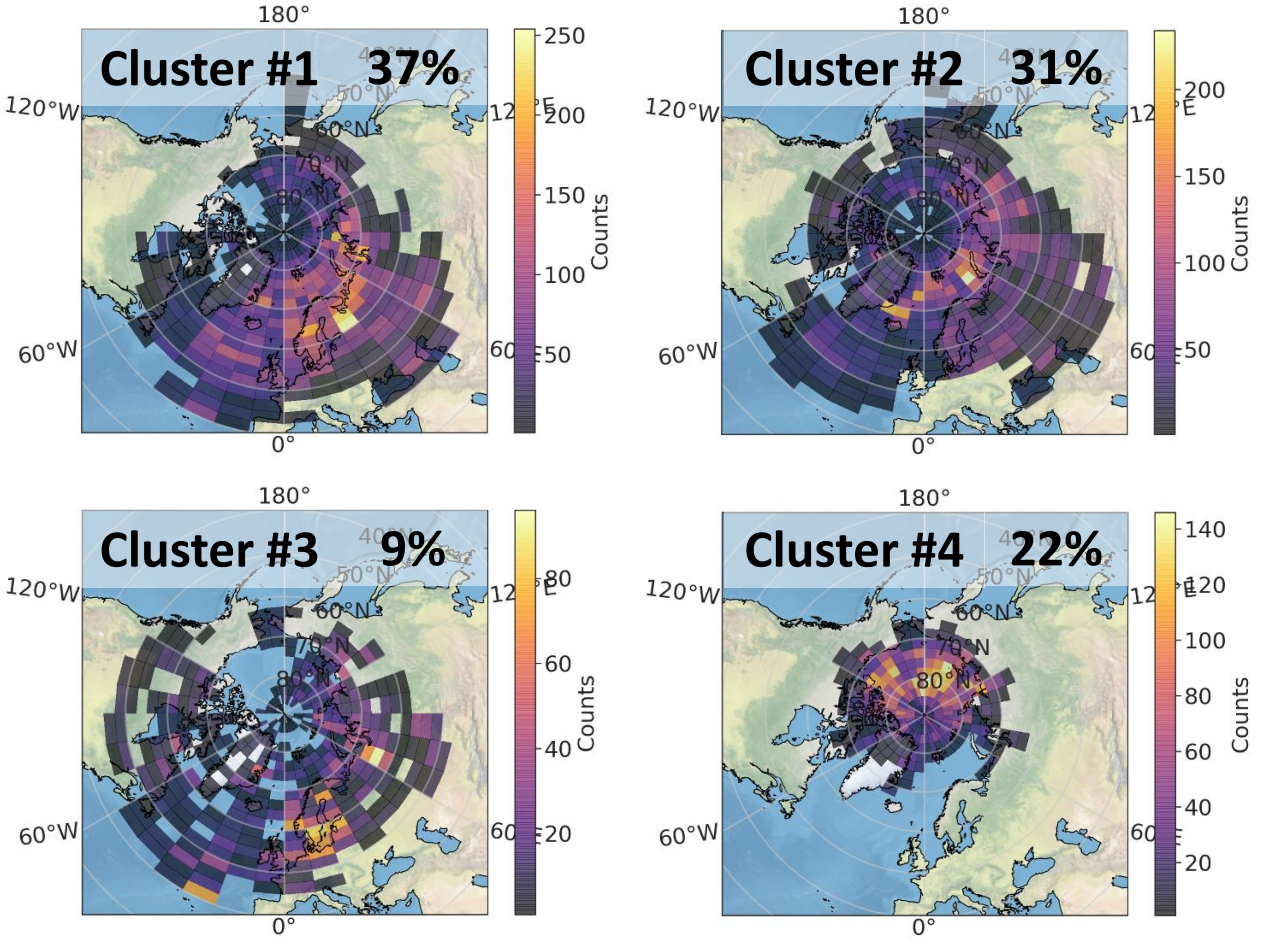


Silber and Shupe, Elementa, 2022

Clusters

- Clusters 1: moist air intrusions mainly from open water at low- to high-latitude onto patchy sea-ice-covered regions.
- Clusters 2: moist air intrusions mainly from open water at mid- to high-latitudes onto patchy or fully covered sea-ice regions.
- Cluster 3: elevated decoupled airmasses mostly of coastal or continental origin.
- Cluster 4: Arctic air circulating over sea ice.

Density maps for 96-120 h



Silber and Shupe, Elementa , 2022

Main Findings

- Arctic cloud formation via persistent radiative cooling of elevated stable subsaturated airmasses can occur frequently and may lead to a substantial cloud radiative impact on the surface
- Warm moist air intrusions into the central Arctic typically result in multilayer liquid-bearing cloud structures with a large number of overlying layers
- More than half of all multilayer profiles include cloud layers associated with different sources
- Two-thirds of the clouds observed over MOSAiC that were associated with Arctic air circulating over high sea-ice concentration regions (cluster 4) were likely partially induced or augmented by open water patches and ice leads that moistened the associated airmasses
- Back trajectory dataset is useful for Lagrangian case study modeling

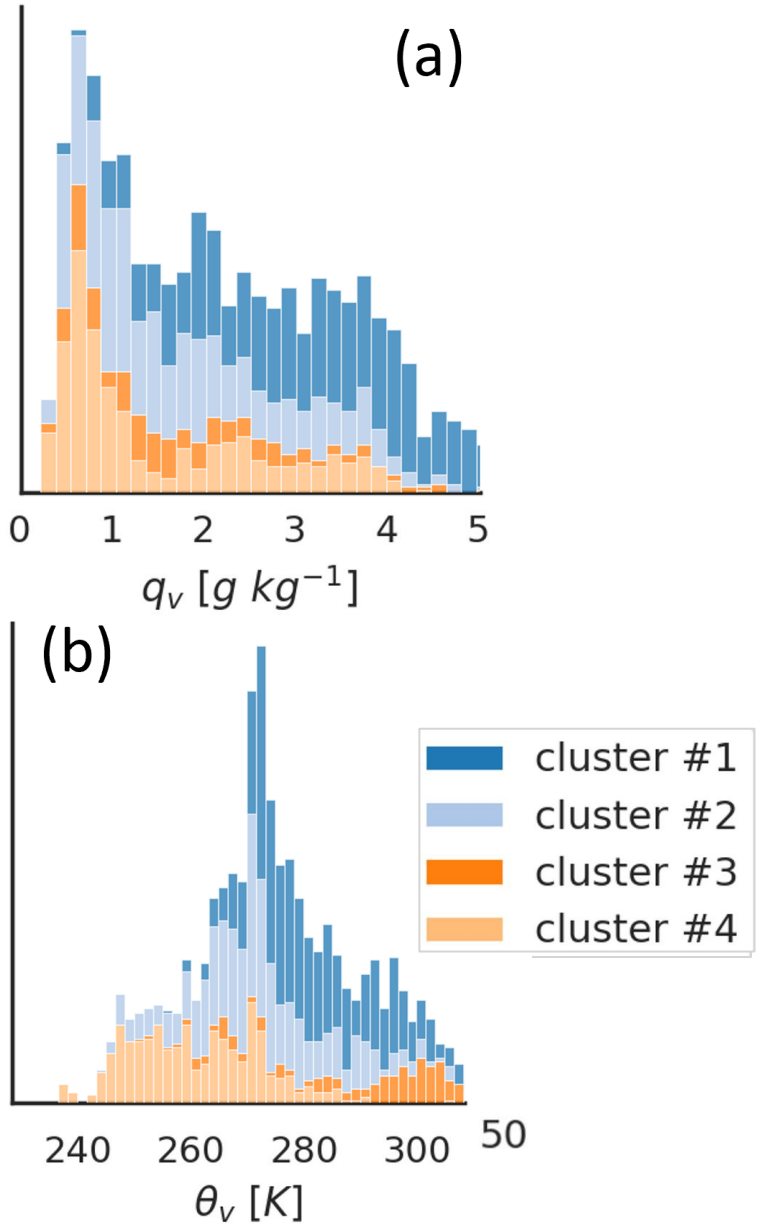
Silber, I., and M. D. Shupe (2022), Insights on Sources and Formation Mechanisms of Liquid-Bearing Clouds over MOSAiC Examined from a Lagrangian Framework, Elementa, https://doi.org/10.1525/elementa.2021.000071.

Acknowledgements:

This study is supported by the DOE ASR grants DE-SC0021004 and DE-SC0021341

Analysis of Cluster #4

- Airmasses circulate for prolonged periods over central Arctic regions characterized by widespread sea ice
- The driest and least energetic airmasses of all 4 clusters
- Moisture loss/gain analysis suggests some interaction with open water patches and/or ice leads in 1/3 of cases
- In another 1/3 of cases, airmasses are strictly in the free troposphere and subside for up to 24 hours prior to the MOSAiC overpass
- These clouds were likely formed via the persistent radiative cooling of elevated stable subsaturated airmasses
- Considering similar conditions in some cluster 2 and 3 cases, it is possible that this formation mechanism is rather frequent, responsible for up to 1 of every 5 detected cloud layers
- Analysis of surface radiation measurements suggests significant CRE.



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