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Cloud morphology evolution in Arctic cold-air outbreak: A COMBLE case study

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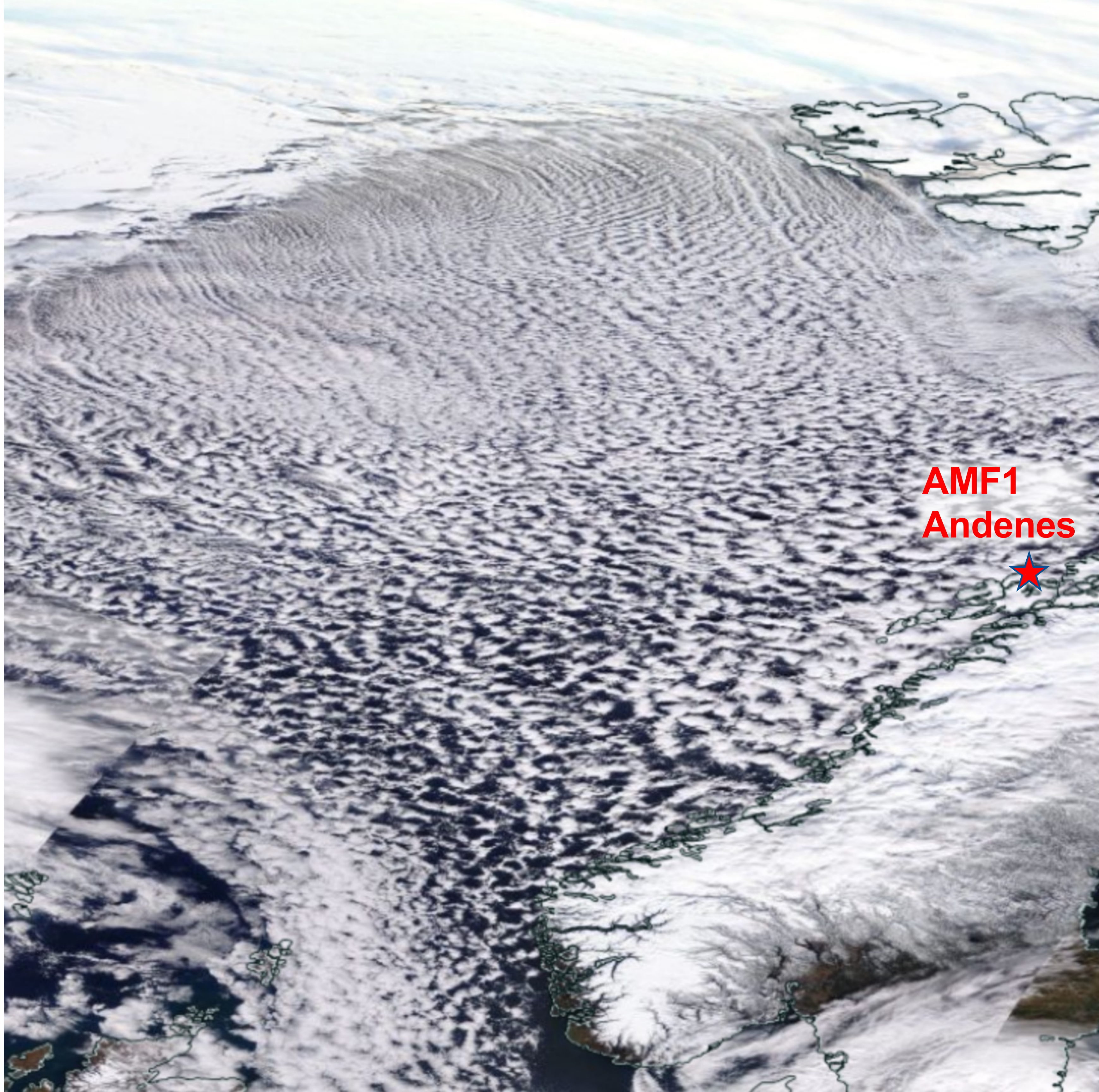

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Introduction

- Cloud feedbacks play an important role in Arctic warming and sea ice loss. Cloud morphology, e.g., cloud areas and their spatial distributions, is among factors that directly impact their radiative effects
- Cold-air outbreak (CAO) in the Arctic features strong heat fluxes from comparatively warm ocean surface into the advected colder air and induce rapid cloud formation, which is difficult to simulate in numerical models

Goals

- In this work, we study the area distributions of cloud populations and their organizations along the fetch of cold-air advected from the Arctic through selected cases observed during the Cold-air Outbreaks in the Marine Boundary Layer Experiment (COMBLE) campaign

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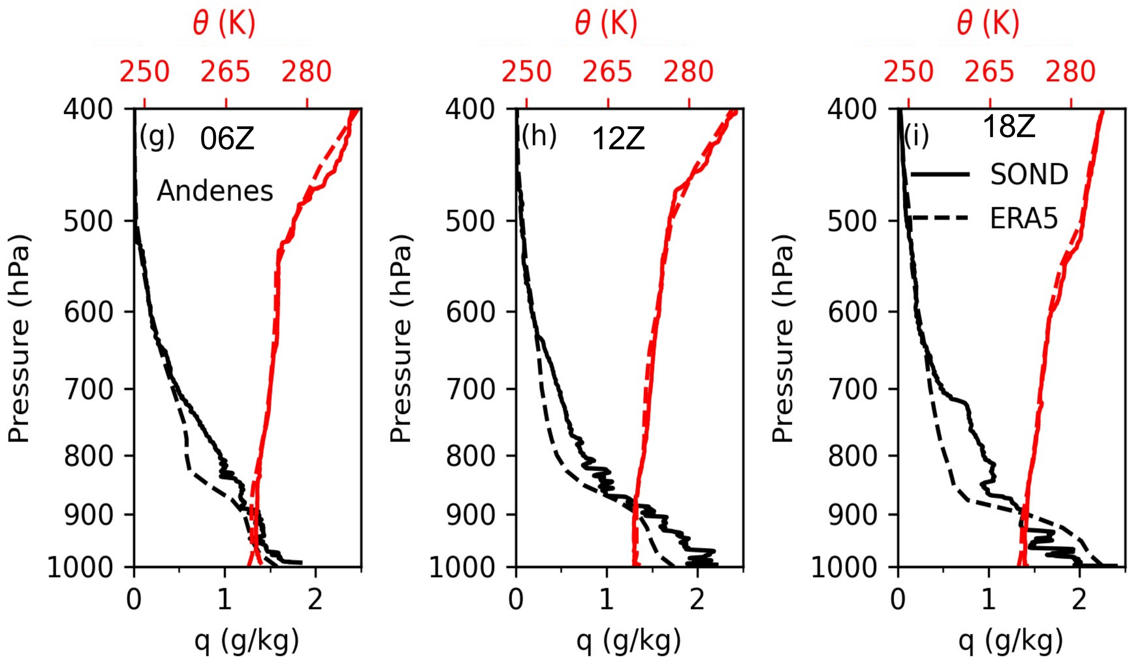
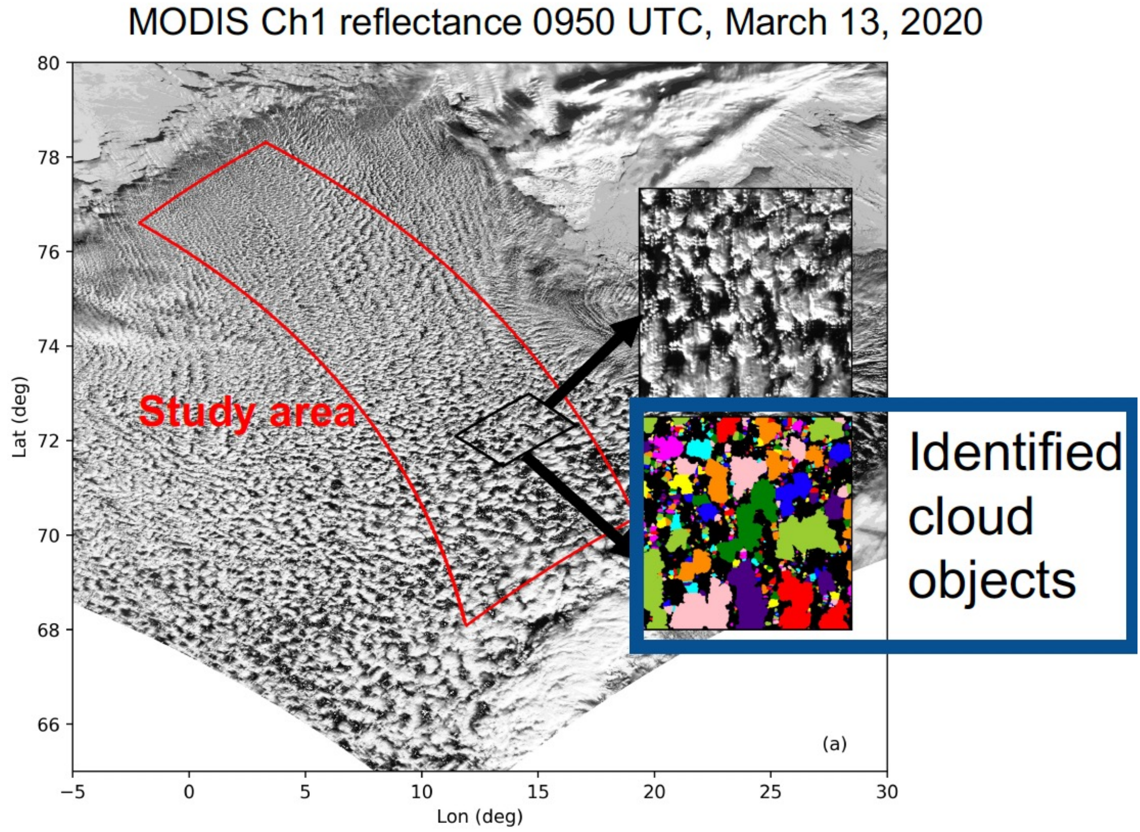
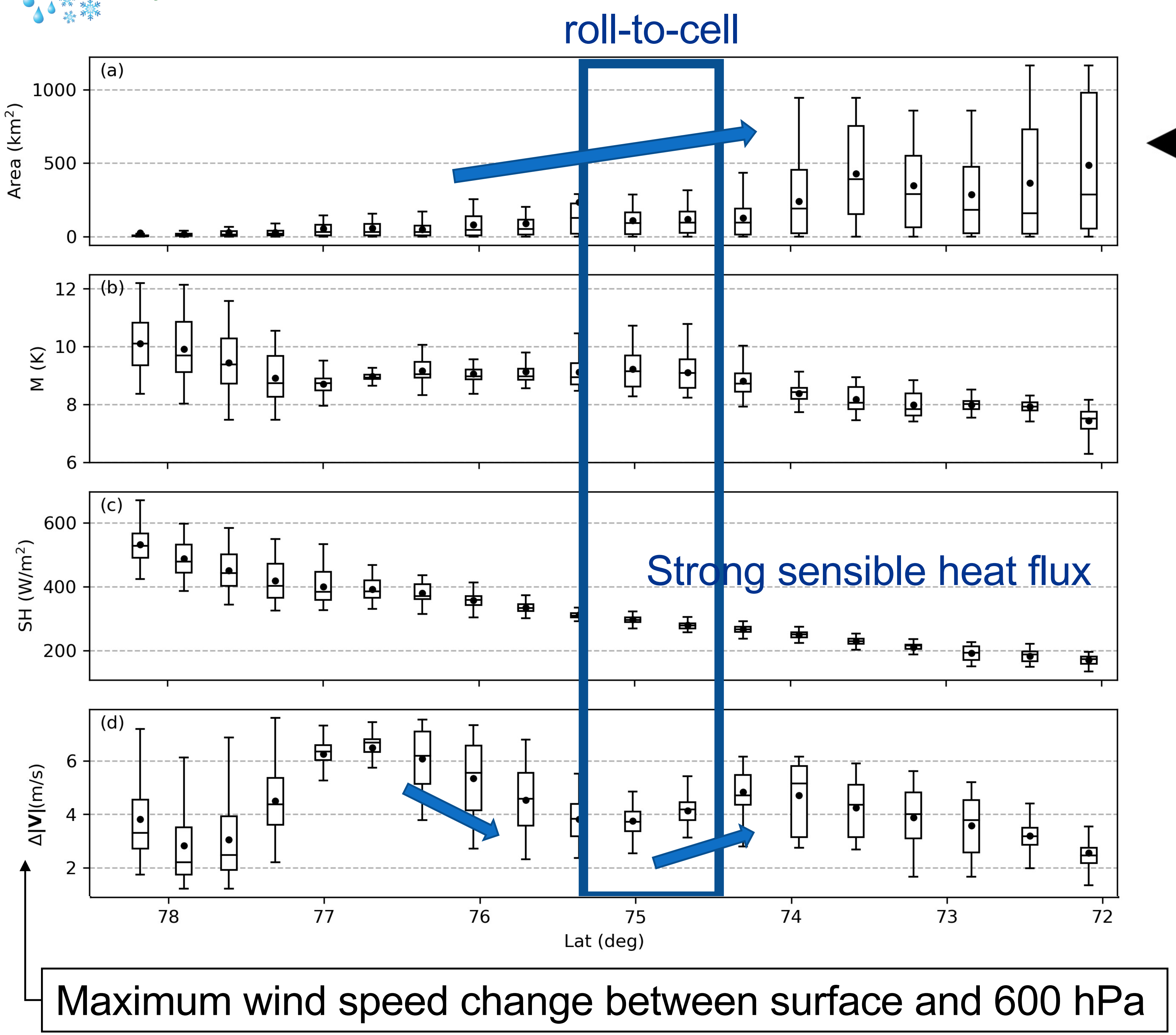
Data and method

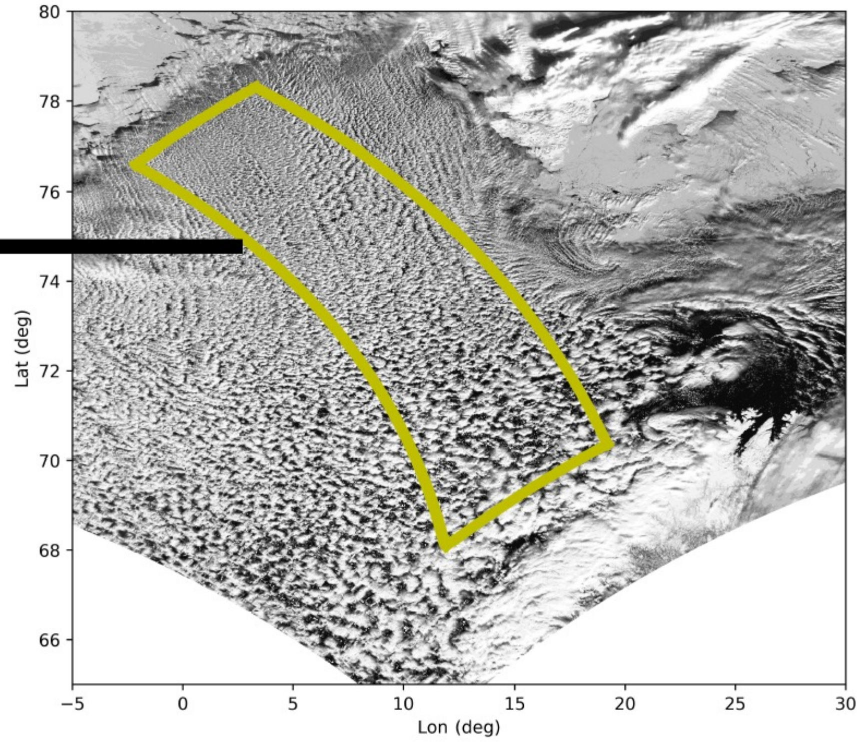
- **ARM and ERA5**: atmospheric conditions (sea surface temperature, wind speed, cold-air outbreak index $M = \theta_{sfc} - \theta_{800}$, surface sensible heat flux, etc.). ERA5 temperature and moisture profiles agree well with ARM balloon sounding measurements during COMBLE
- **MODIS**: visible channel (0.62-0.67 μm) reflectance is used to identify individual cloud areas through an object segmentation procedure. A similar approach is being applied to **KAZR** and **KaSACR** at Andenes
- Two cases are selected: March 13 and March 29, 2020. Only results from the March 13 case are shown





Latitudinal change of cloud area with environment





- Cloud area (s) increases southward (away from cold air source)
- Strong surface heat flux throughout the cold air fetch
- Roll-to-cell transition is accompanied by increasing boundary layer height and decreasing wind shear

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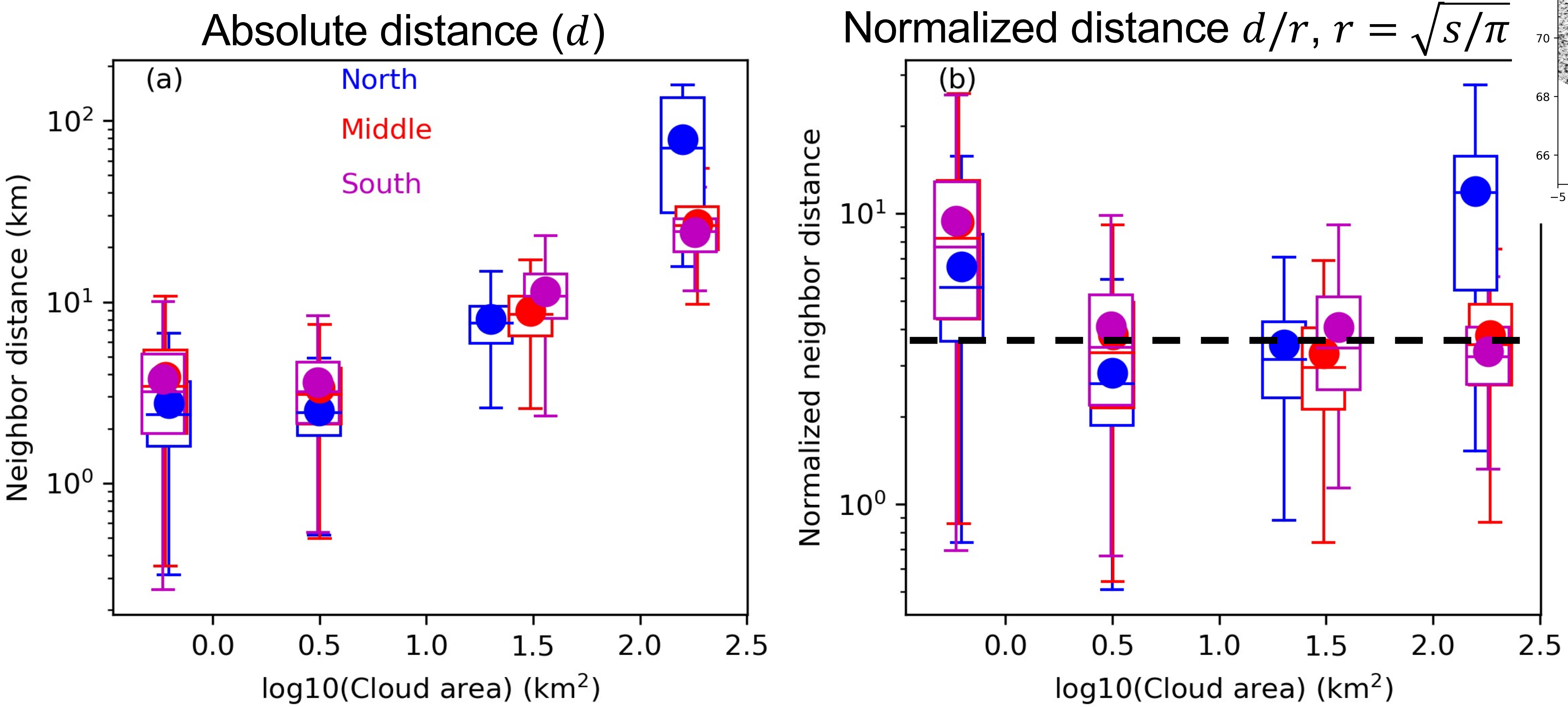
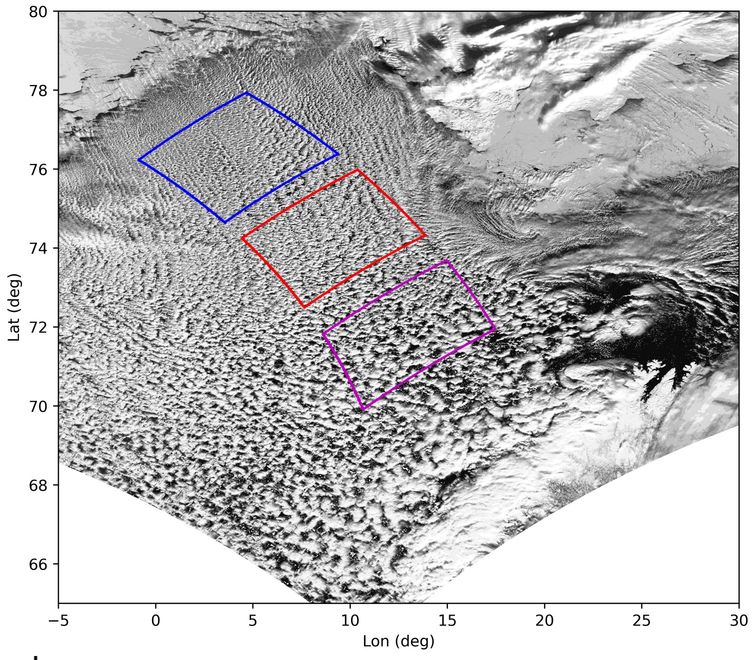
Distances between clouds

For each cloud, identify five nearest neighbors from the same area category





Three sub-regions:
North: rolls
Middle: roll-to-cell
South: cells

- Absolute neighbor distance increases exponentially with the increase of cloud area
- Except for very small clouds ($s < 1$ km^2) and biggest clouds in the north, neighbor distance normalized by equivalent cloud radius ($r = \sqrt{s/\pi}$) converges to 3.5

→ centers of comparably sized clouds are separated by a distance of 3.5 r

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Summary

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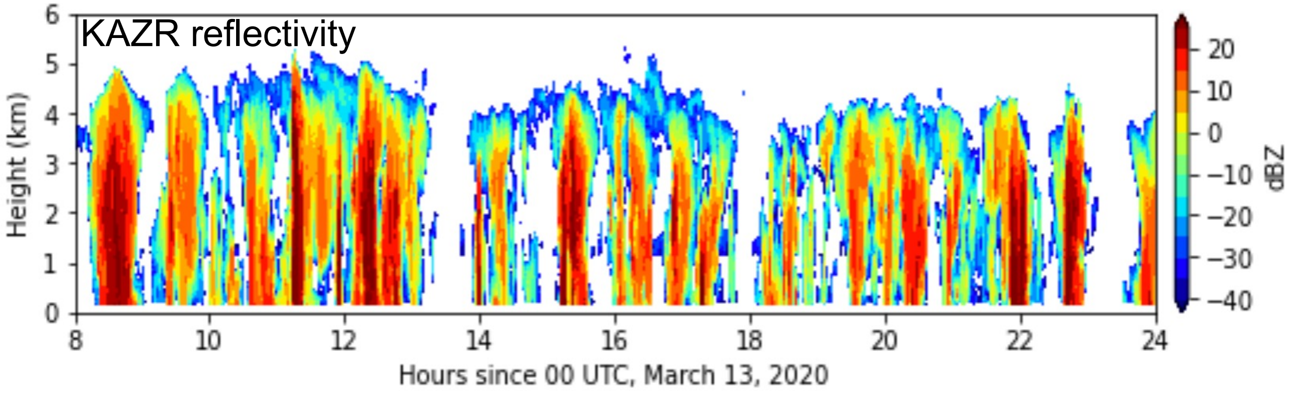
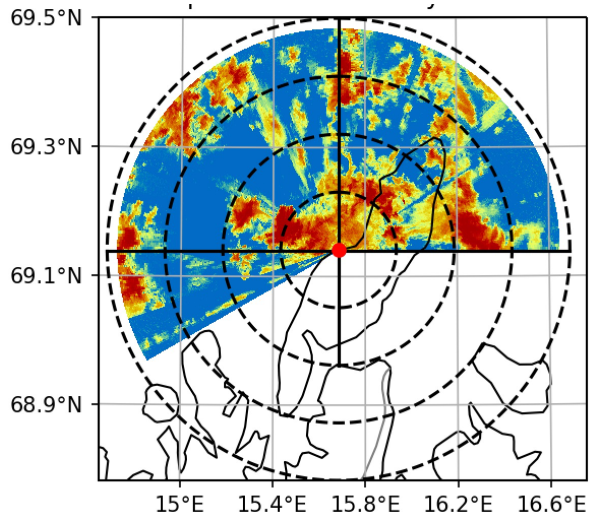
- An object segmentation procedure is applied to MODIS visible channel reflectance during a CAO event and cloud areas are extracted
- Roll-to-cell transition is accompanied by increasing boundary layer height and decreasing wind shear
- Clouds with comparable sizes tend to separate by a distance of $3.5\sqrt{s/\pi}$, where s is cloud area
- Next: Apply an analogous approach to ARM radars and model simulations to compare cloud morphology statistics from surface, satellite, and model



KaSACR reflectivity @ 10 UTC, Mar 13



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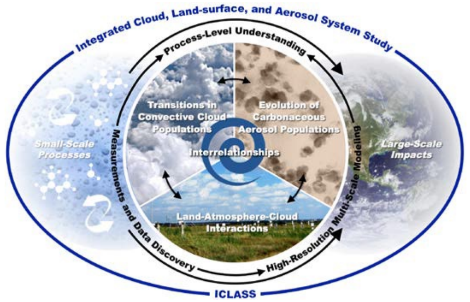

ARM

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