An observational and modeling case study of post-frontal boundary-layer convection over the Southern Ocean in MARCUS

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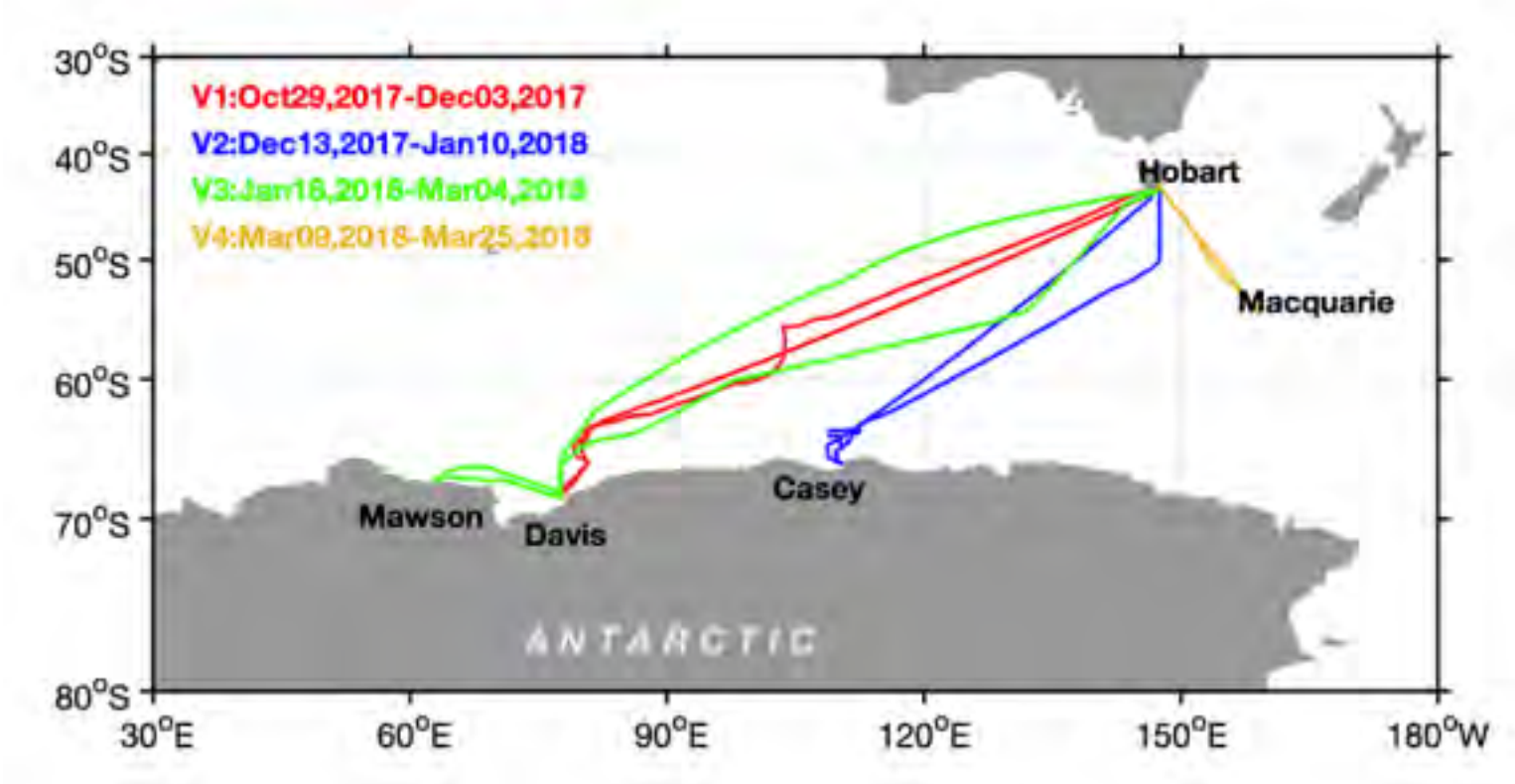
MARCUS

- Deployment of AMF2 on *Aurora Australis* between October 2017 and March 2018



MARCUS

- Deployment of AMF2 on *Aurora Australis* between October 2017 and March 2018
- Objectives: “understand the synoptically varying vertical structure of SO BL clouds and aerosols” and “find the mechanisms controlling supercooled liquid and mixed-phase clouds”

Quantification of CAO conditions

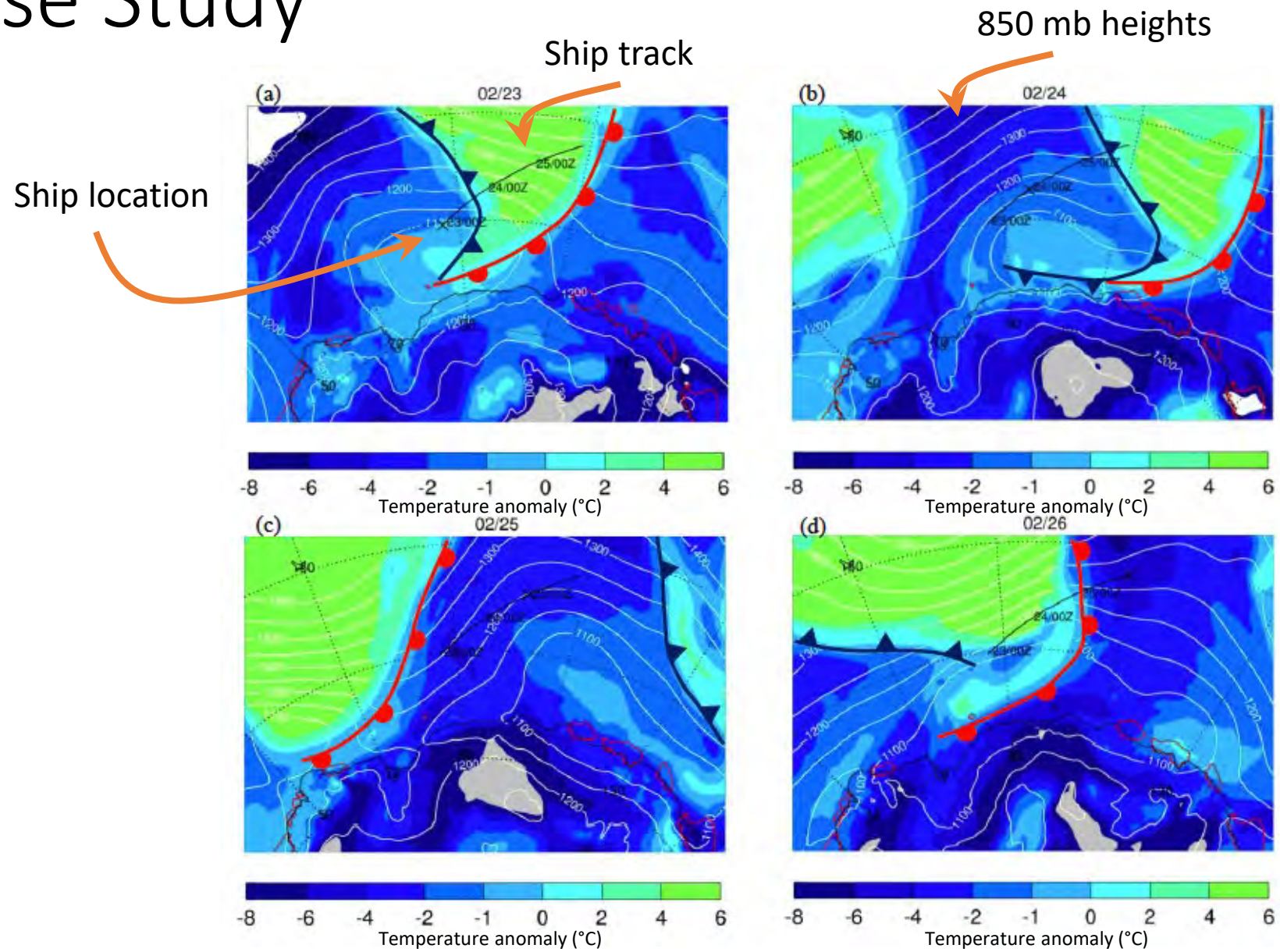
- We use a measure of low-level thermal instability as an indicator of the frequency of CAO conditions:

$$\mathrm{M_e} = \theta_{\mathrm{e_{surface}}} - \theta_{\mathrm{e_{900\ mb}}}$$

Specifically, we look for $M_e > 0$ (~75% of the time during MARCUS)

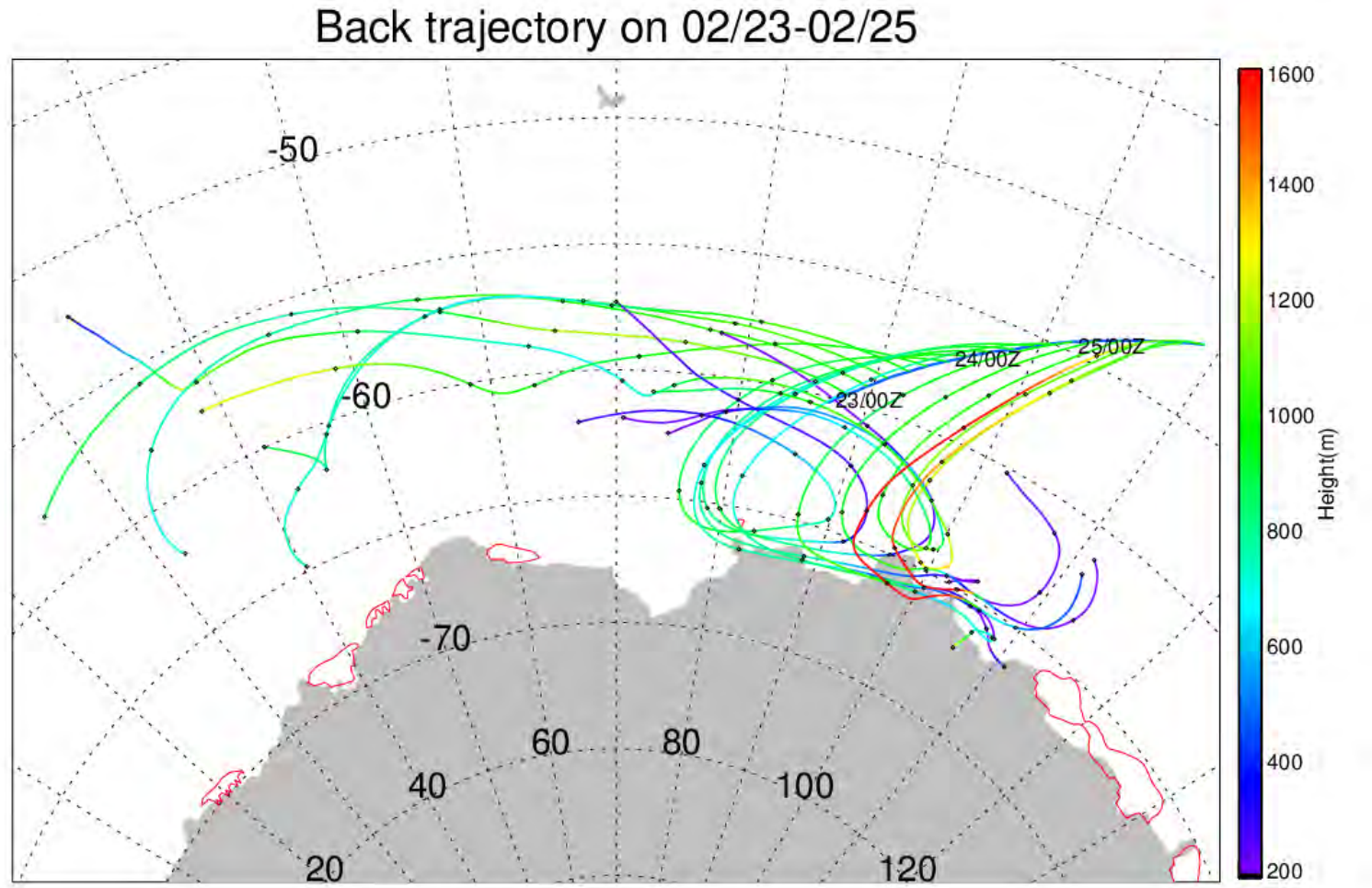
- We identify a specific case to study in detail: 02/22/18 – 02/25/18.

Case Study


Ship track
850 mb heights
Ship location
(a)
02/23
(b)
02/24
(c)
02/25
(d)
02/26
-8 -6 -4 -2 -1 0 2 4 6
Temperature anomaly (°C)

Case Study

HYSPLIT back trajectories indicate cyclonic flow that takes parcels over the Antarctic coastline before moving northward toward the observation locations



Model Setup

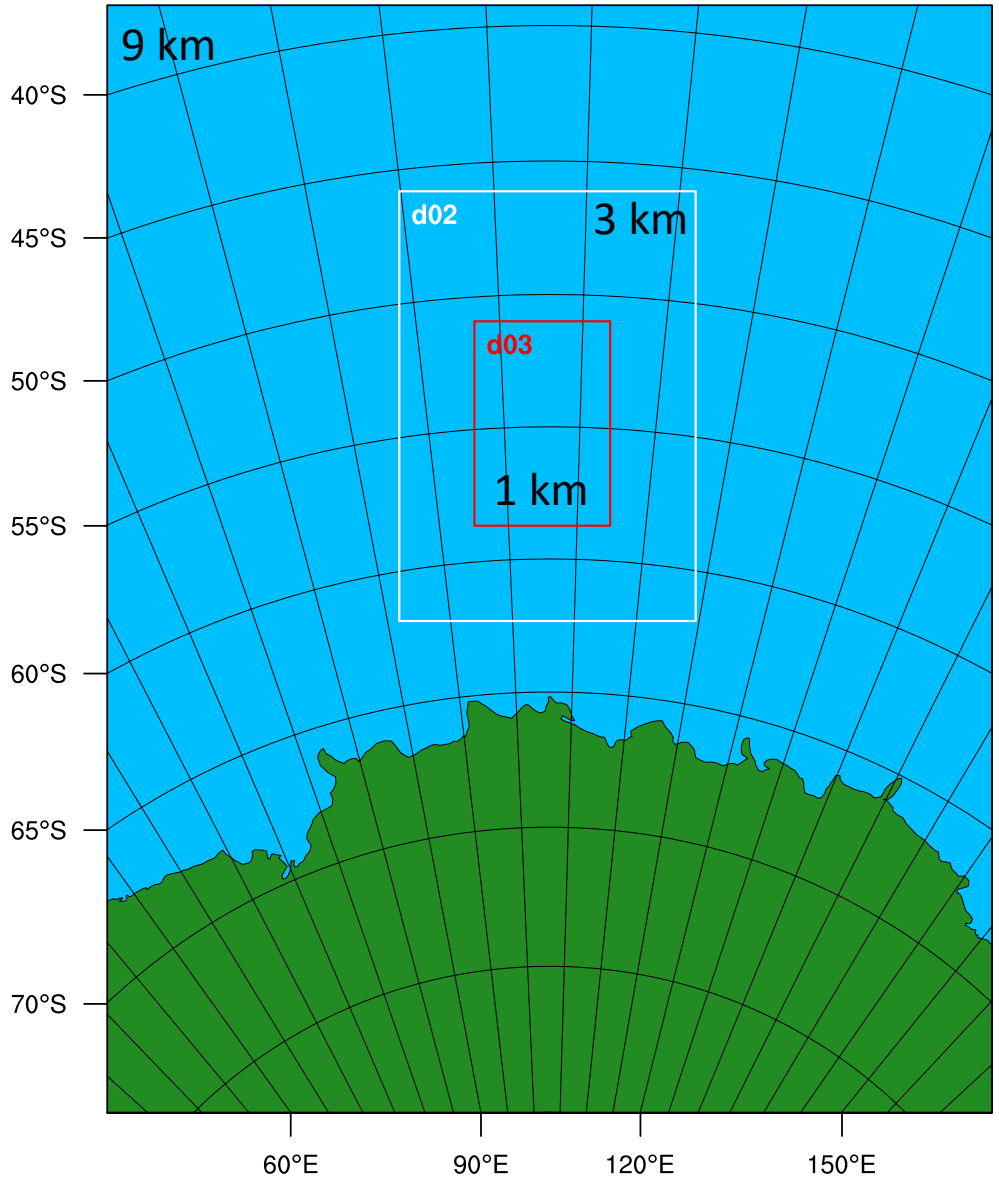
Nested domain configuration

Initialized at 0Z on 2/23/18 and run for 4 days

6-hourly GFS analysis boundary conditions

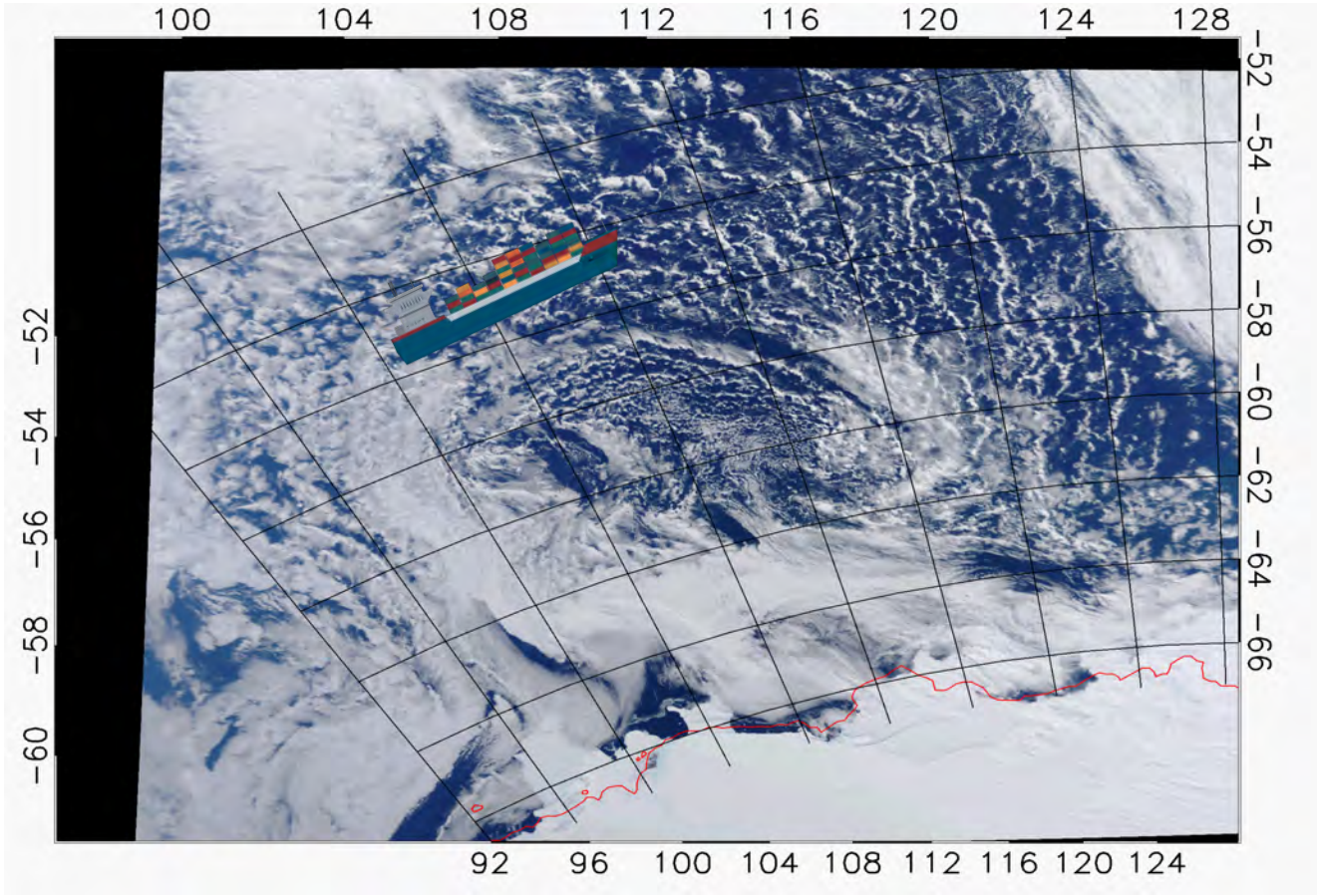
Microphysics: P3 (Morrison and Milbrandt, 2015)
Radiation: RRTMG (Iacono, 2008)
PBL: MYJ (Janjic, 1994)
Surface: Noah-MP (Niu et al., 2011)
Convection : Kain-Fritsch (outermost domain only; Kain, 2004)

1-min output of specified fields in innermost domain

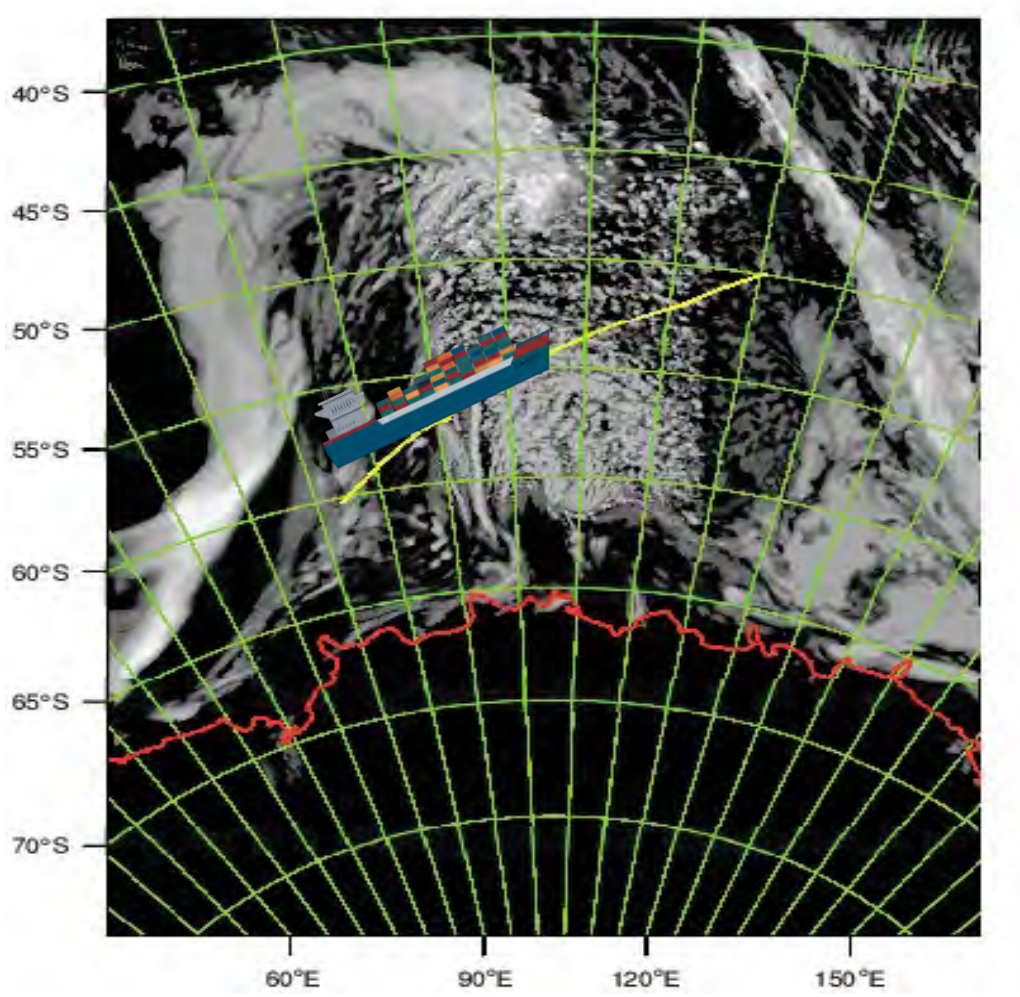


Analysis: Large-scale Cloud Structure

MODIS observation at 2:10 UTC on 2/25/18



Gray-scaled LWP from outer domain



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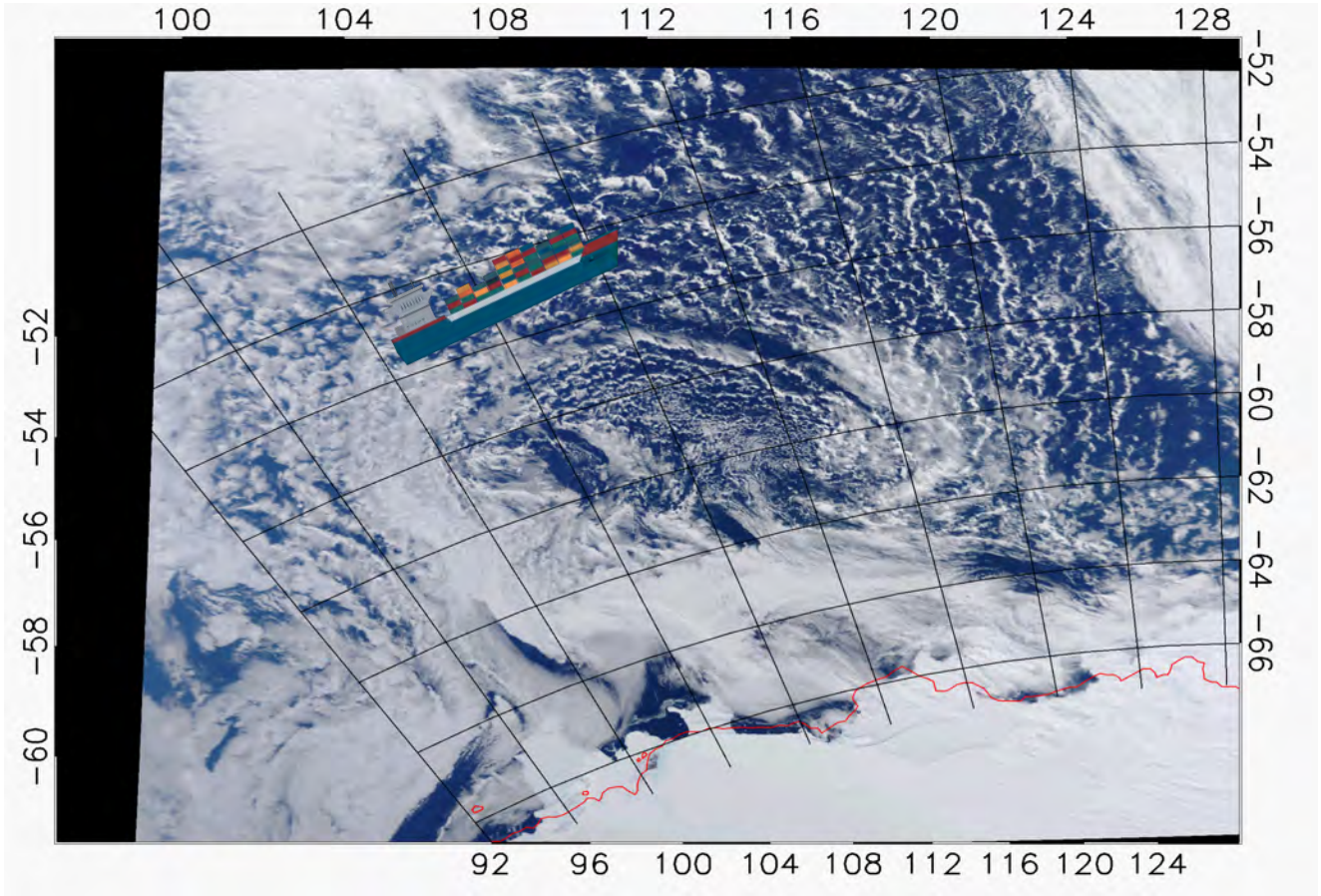

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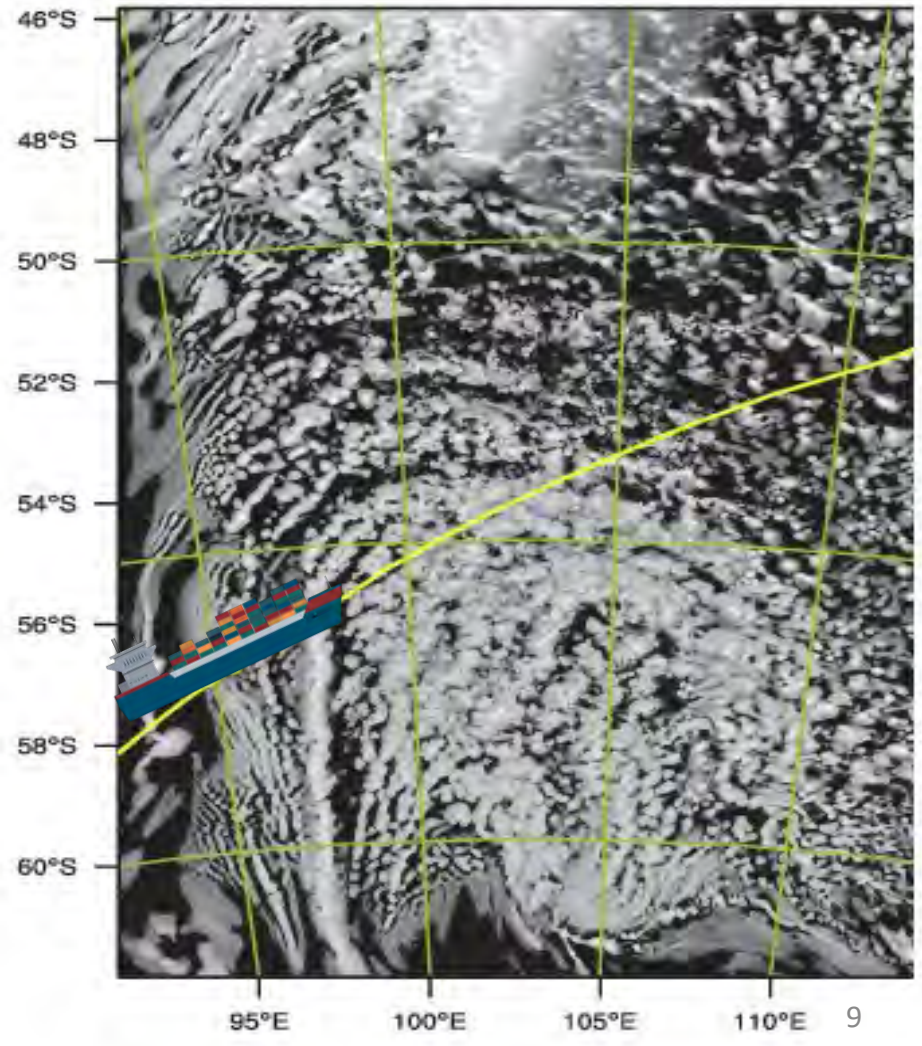

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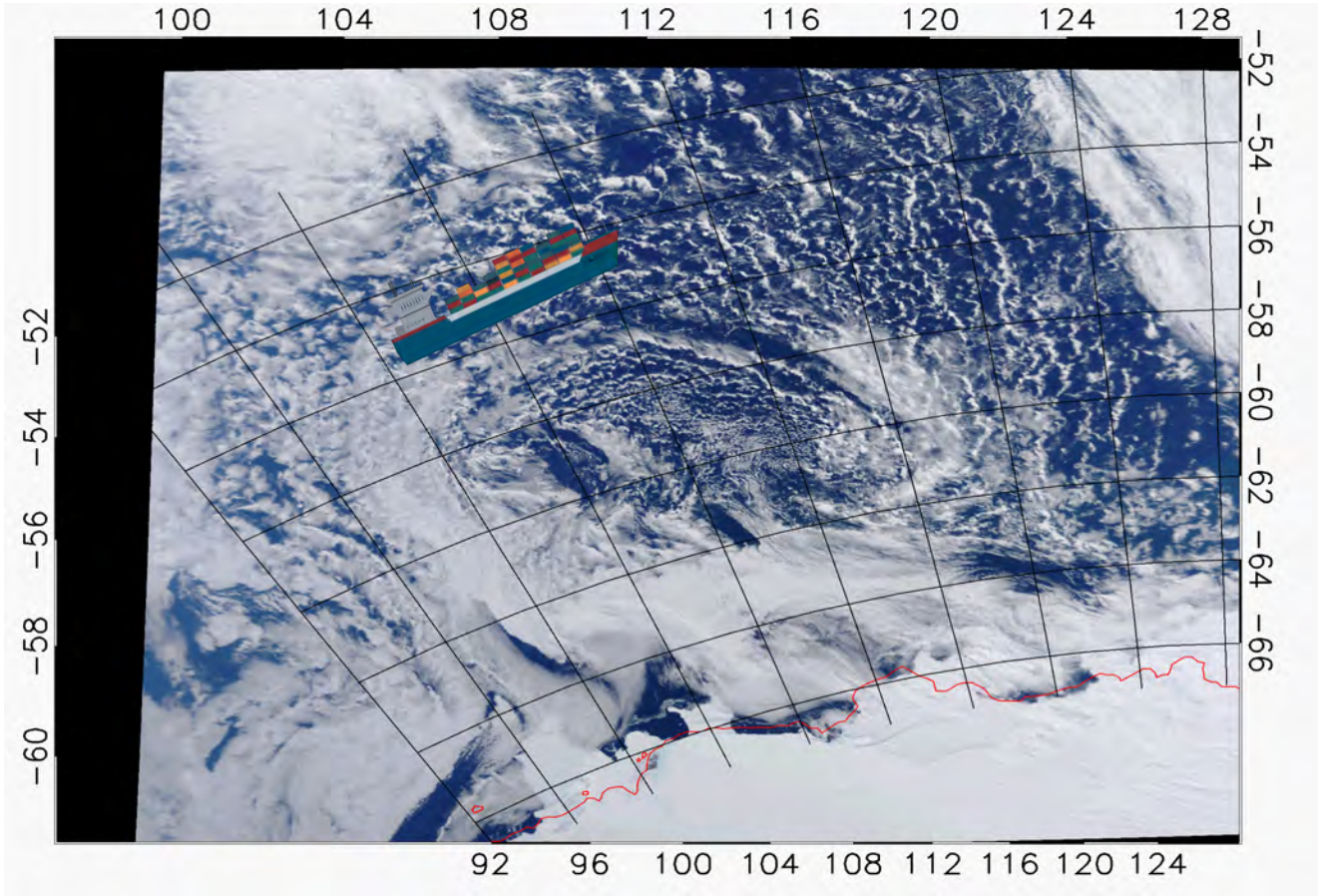

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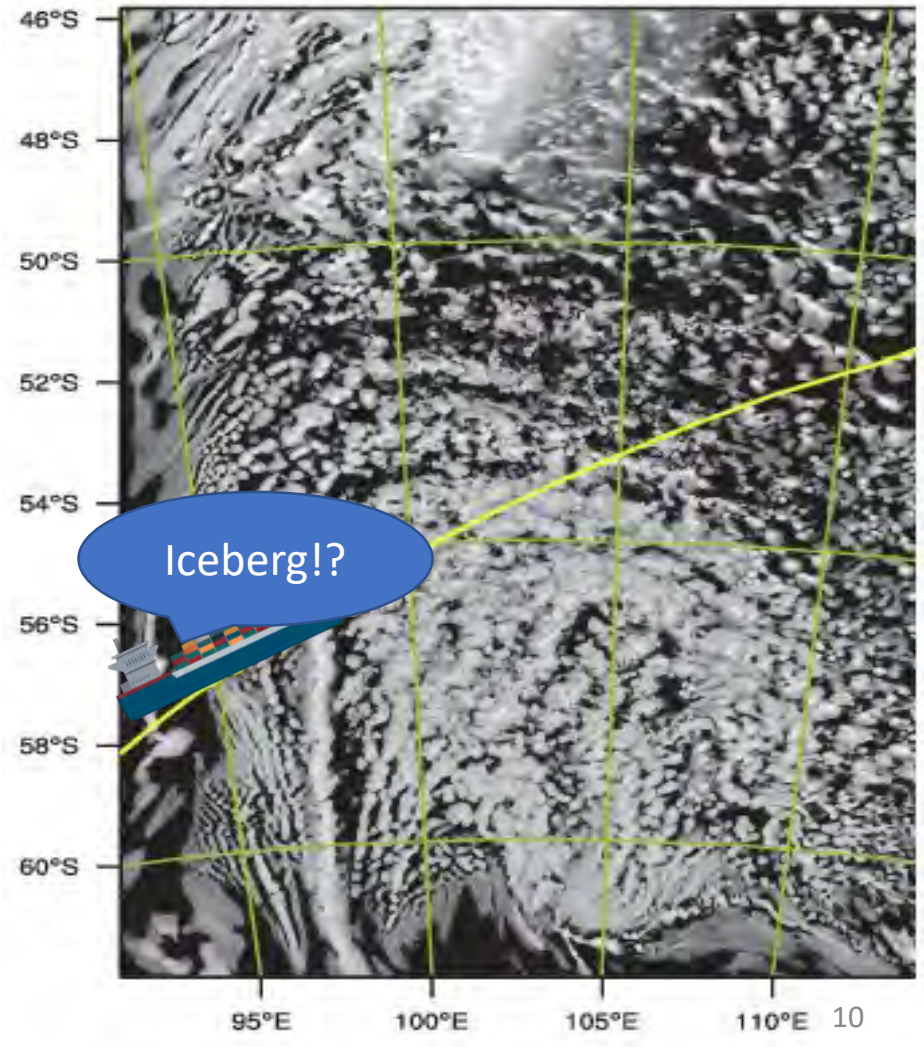
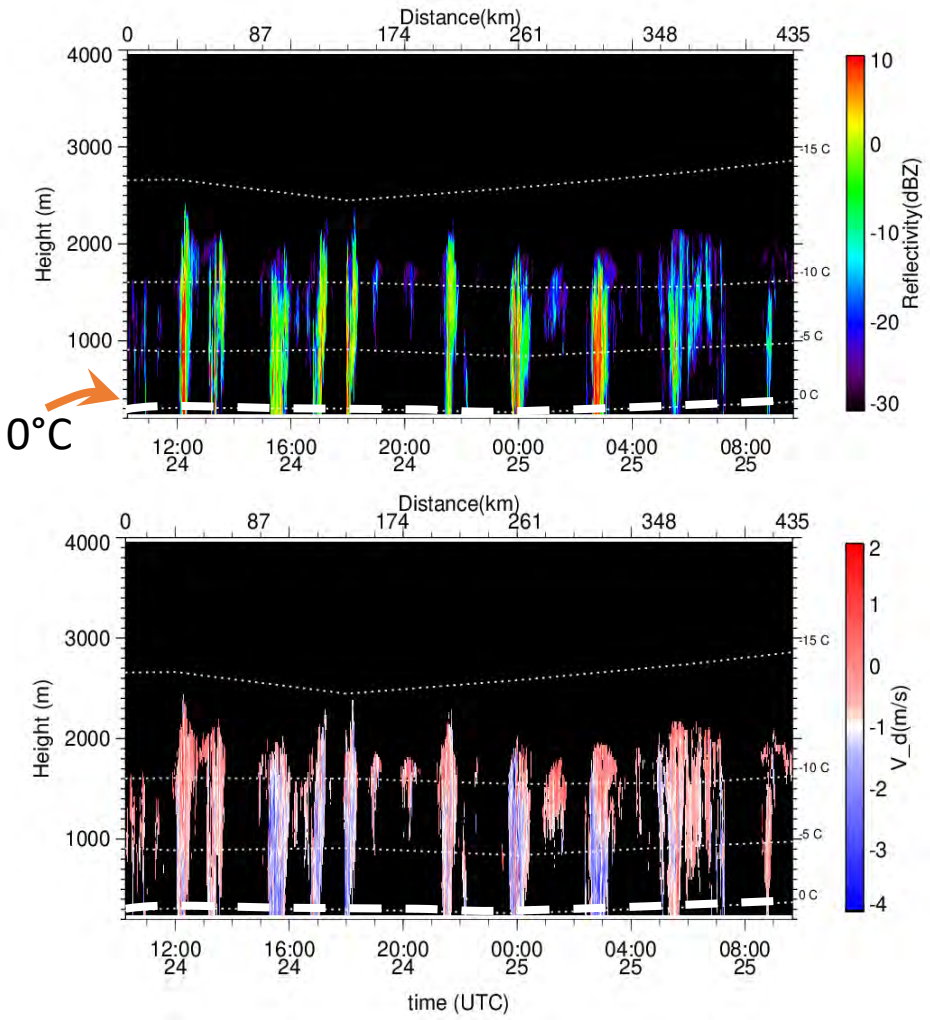
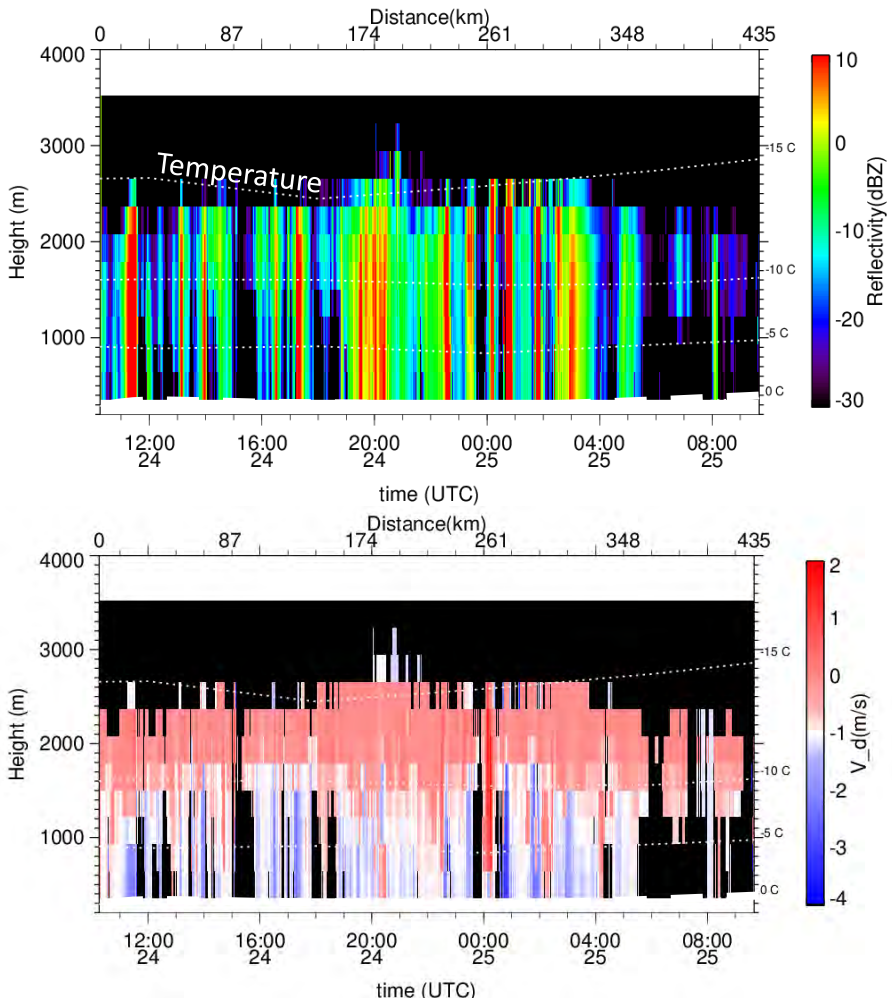


Analysis: Radar Variables

MWACR Observations



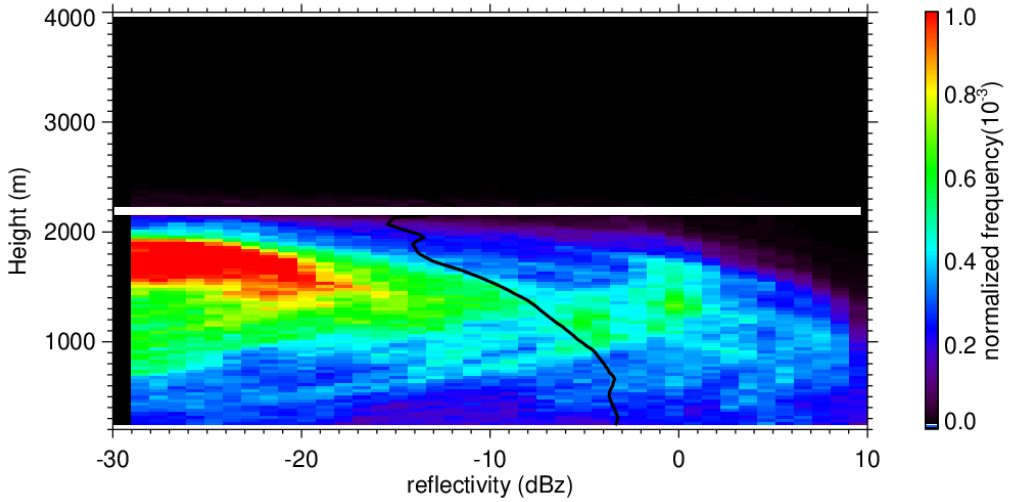
Model Simulations

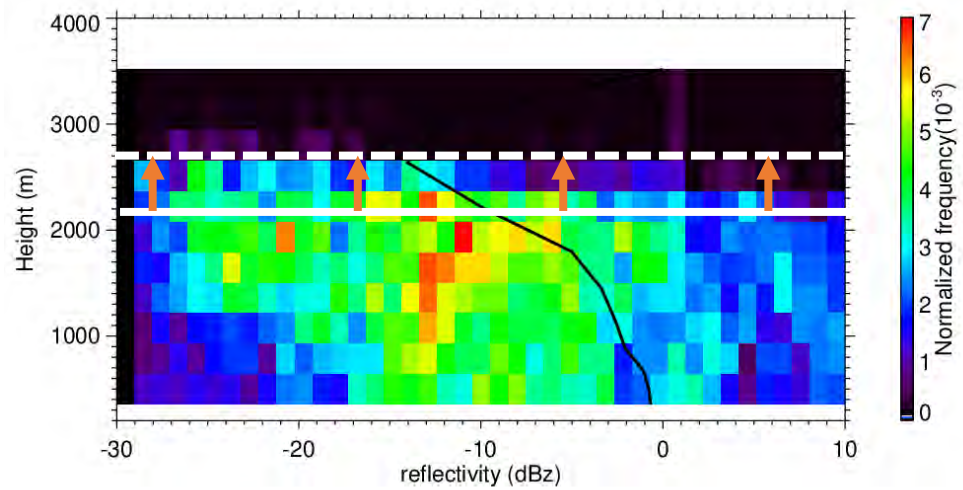


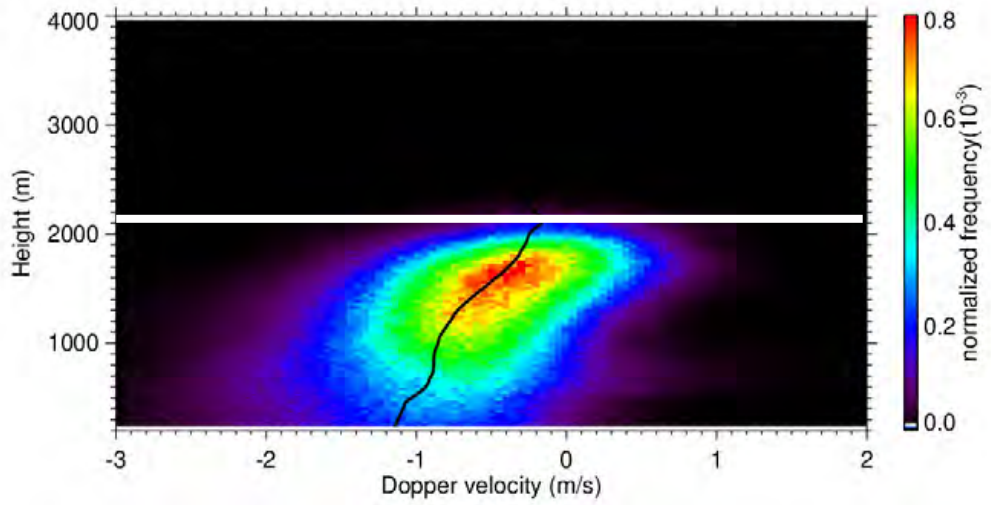
Analysis: Radar Variable CFADs

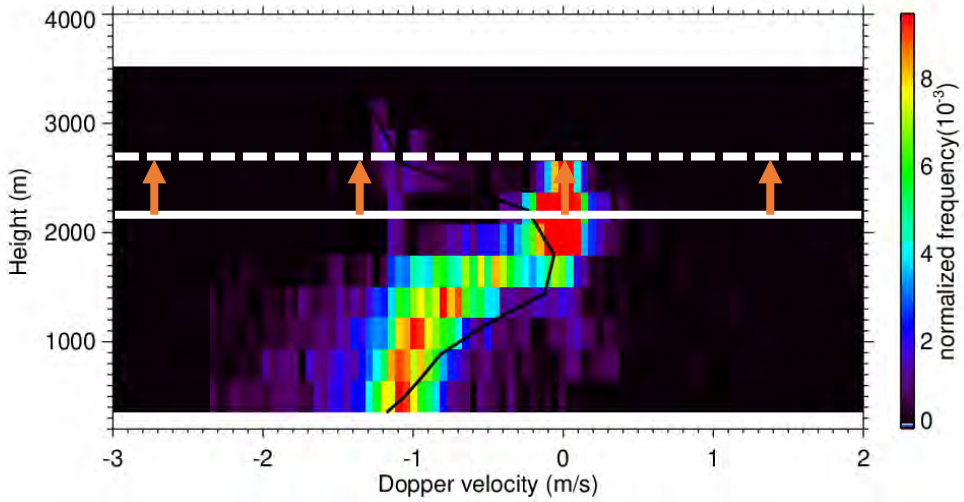
MWACR Observations

Model Simulations



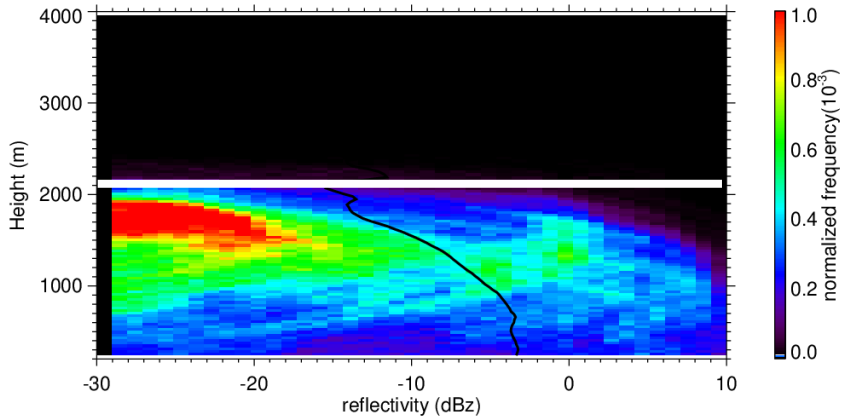


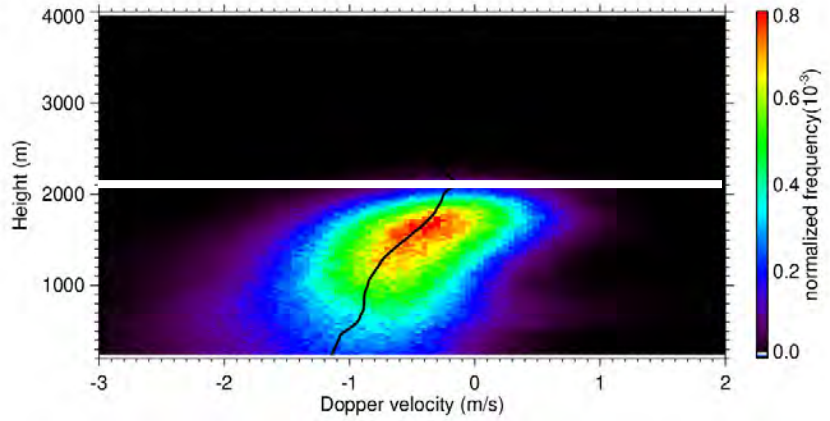




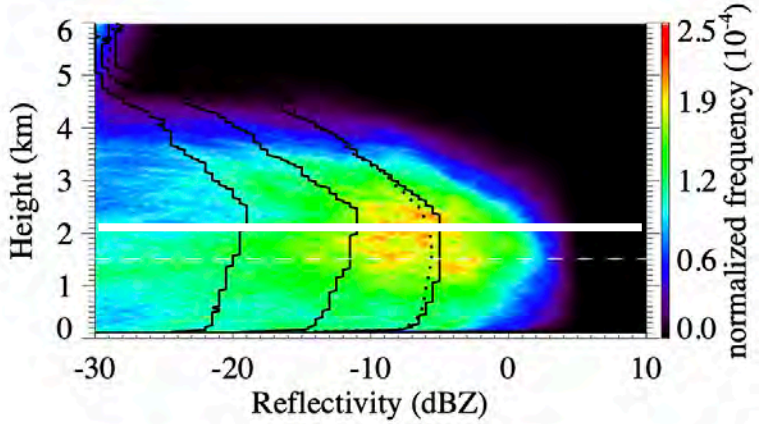
Analysis: Comparison with Other Sites

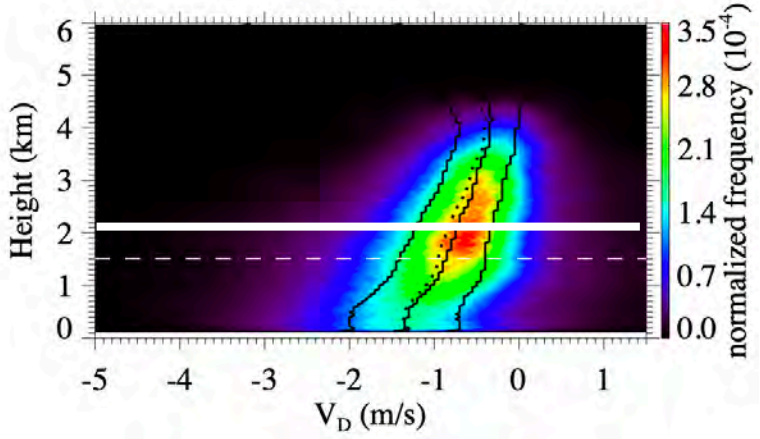
MARCUS
1000 UTC 02/24/18 – 1000 UTC 02/25/18



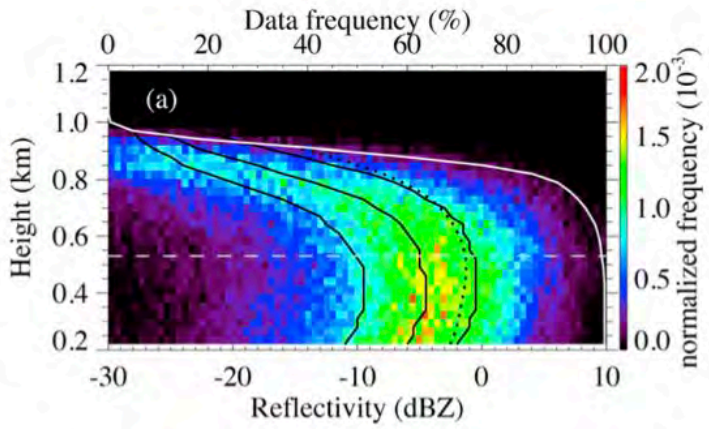


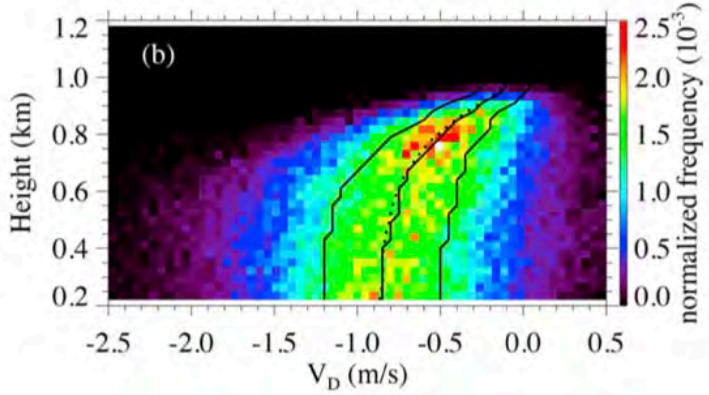
COMBLE
330 UTC 03/28/20 – 1200 UTC 03/30/20





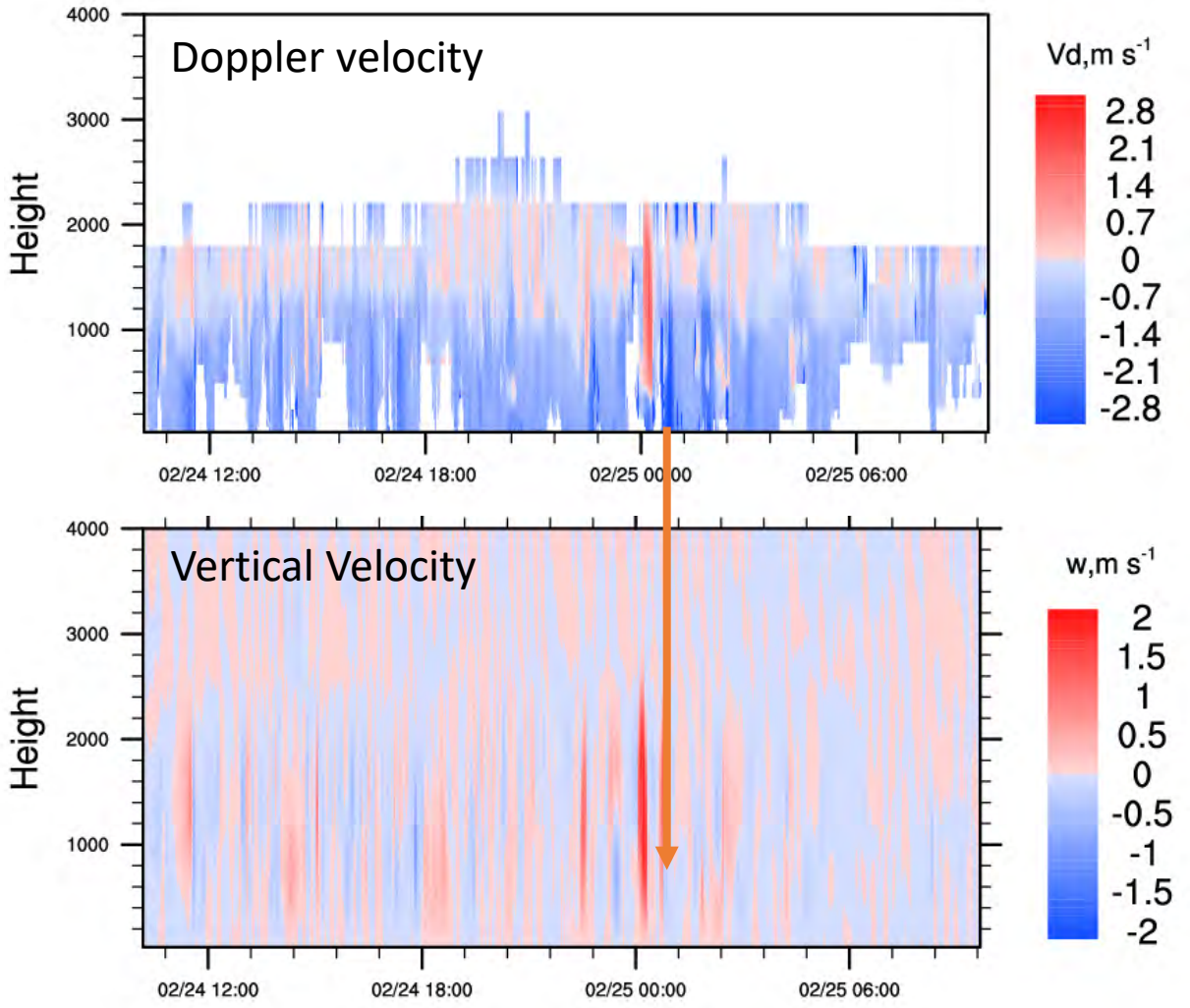
NSA
1600 UTC 10/26/11 – 0000 UTC 10/27/20





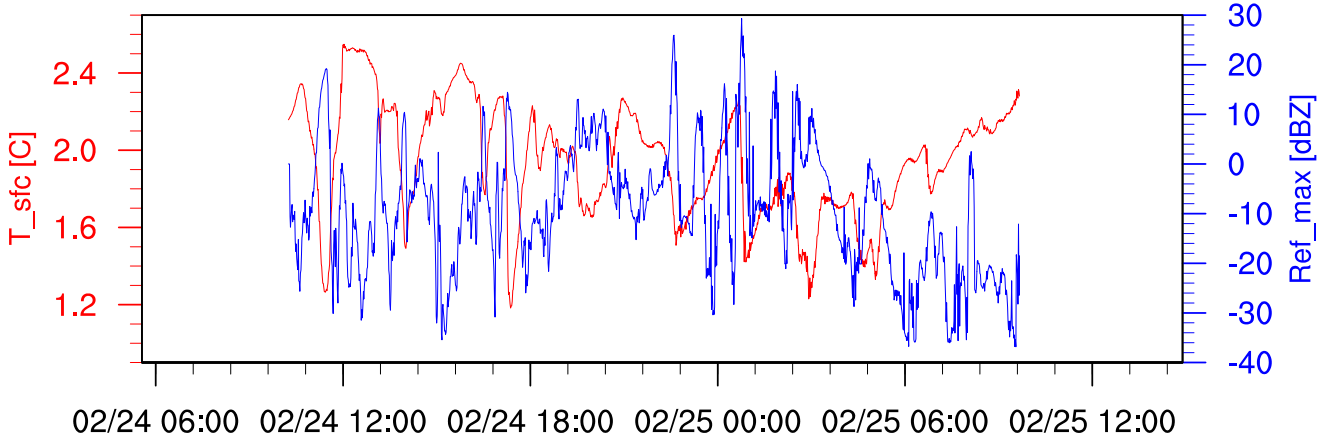
Analysis: Decomposition of Doppler Velocity

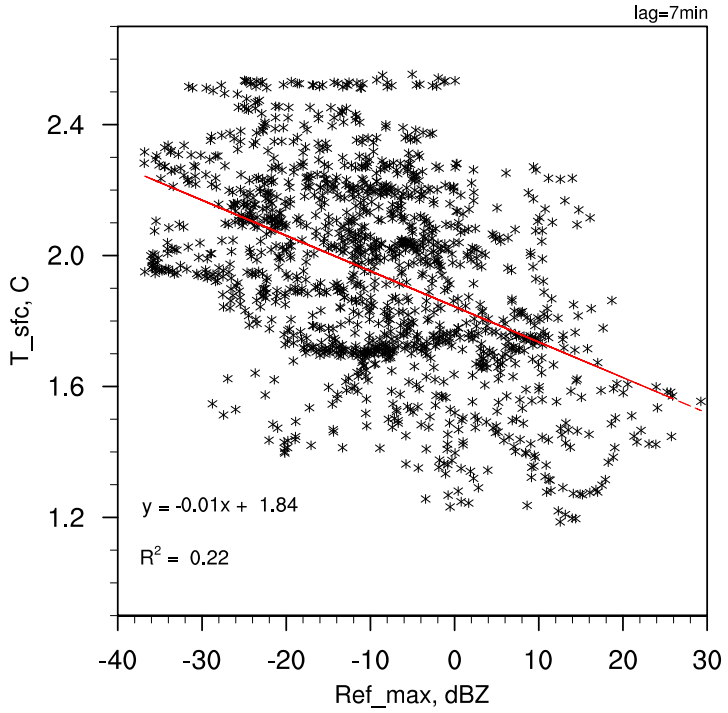
Model simulations allow us to dissect Doppler velocity field into its components!



Analysis: Structure

Simulations indicate a negative correlation between the surface temperature and reflectivity, indicating the presence of precipitation-driven shallow cold pools that drive subsequent convection



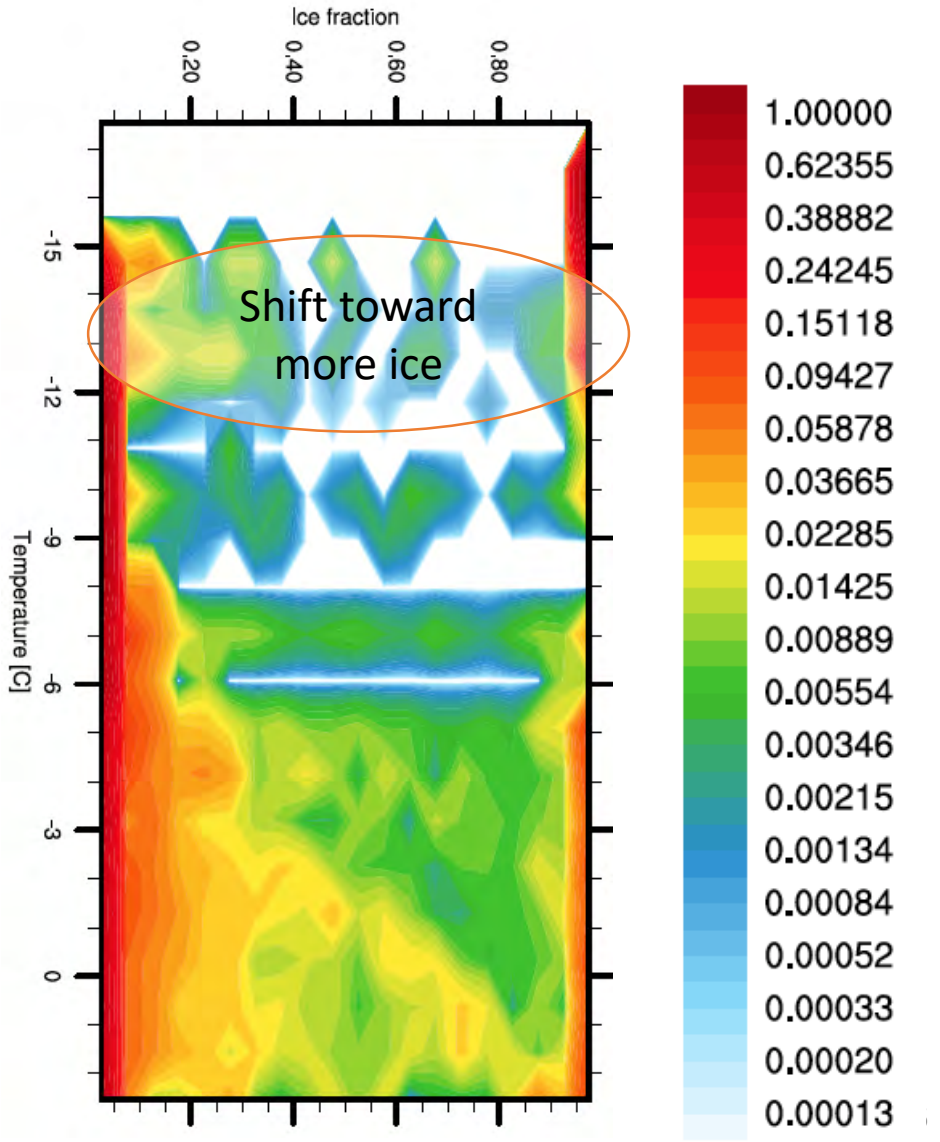


Analysis: Mixed-phase Characteristics

At temperatures above approx. -12°C, simulated cloudy grid boxes are mostly all liquid or all ice

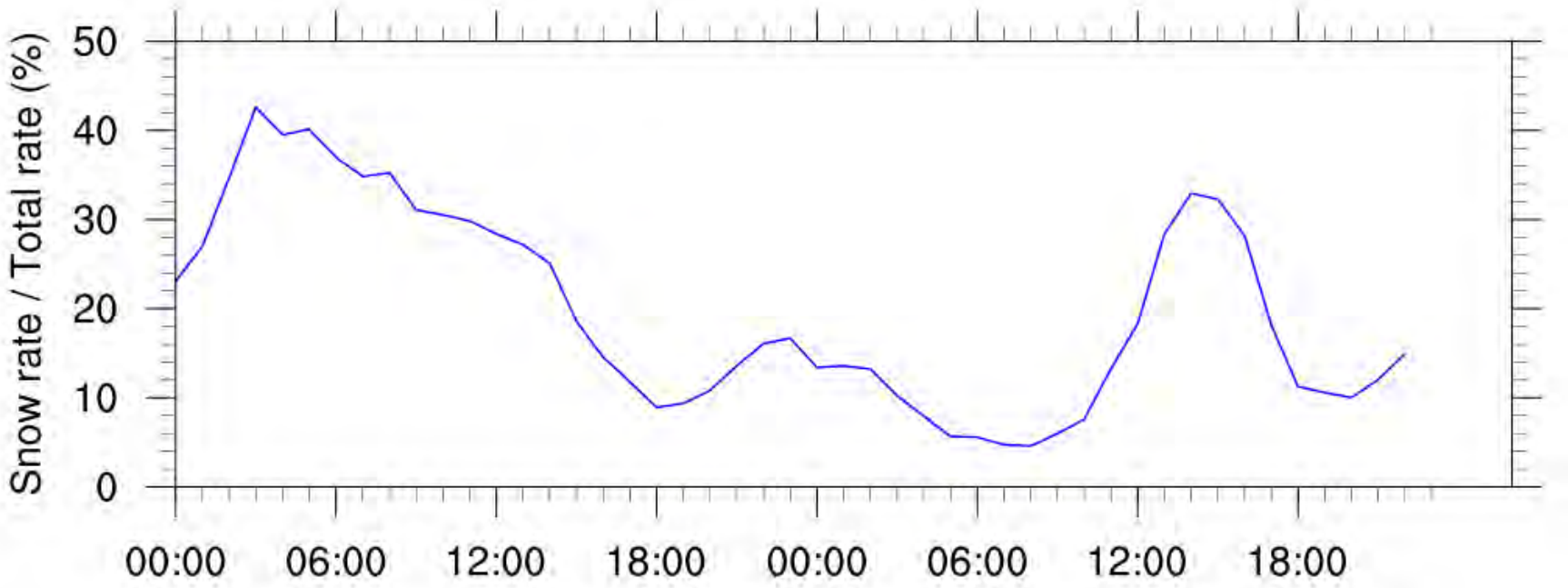
At temperatures below approximately -12°C, simulated clouds shift toward being entirely ice-phase clouds

Given clouds are deeper in the model, actual clouds observed during MARCUS likely contain less ice than indicated in the simulations



Analysis: Mixed-phase Characteristics

Snow accounts for <20% of precipitation most of the time following the ship track, but in some instances, especially early in the study period where temperatures are a bit lower, snow exceeds 40% of the precipitation rate.



Conclusions

- Model simulations capture the observed convective nature of clouds during the studied CAO event during MARCUS; however, the simulated clouds tend to be deeper on average (~500 m)

- Simulations indicate presence of shallow cold pools associated with convective clouds driving subsequent cloud formation

- Model indicates the presence of mixed-phase conditions transitioning to all ice at temperatures below -12°C

- Surface precipitation is typically <20% snow but does exceed 40% in some instances

Future:

Do we need an even higher-resolution nest to better resolve the observed spatial scale of the convective clouds?
Do results hold if we extend beyond the ship track?
How do these clouds differ from their siblings in the Northern Hemisphere?