Linking multi-scale observations and simulations of mixed-phase clouds based on DOE MARCUS, MICRE and AWARE campaigns

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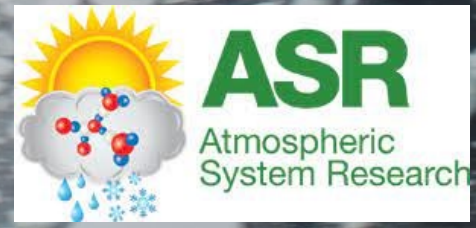
DOE ASR/ARM PI meeting

Southern Ocean Breakout October 25, 2022



Mixed-Phase Clouds in Observations and Simulations

Mixed Cloud Definition in AMS Glossary

A cloud containing both water drops (supercooled at temperatures below 0°C) and ice crystals, hence a cloud with a composition between that of a water cloud and that of an ice-crystal cloud.

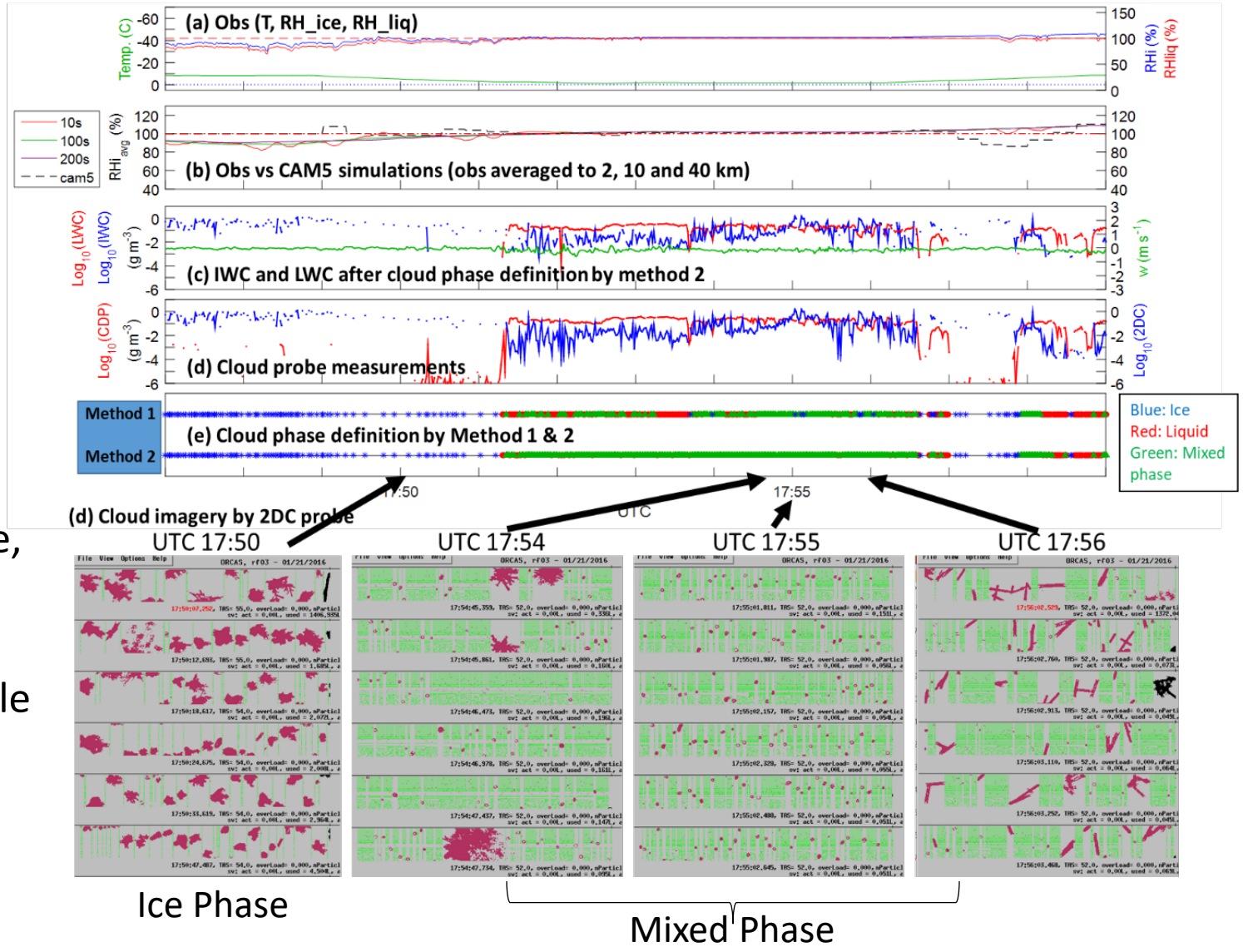
Three topics:

(1) What have we learned from scale-aware, definition-aware model evaluation?

(2) What are the impacts from synoptic scale dynamics and geographical locations?

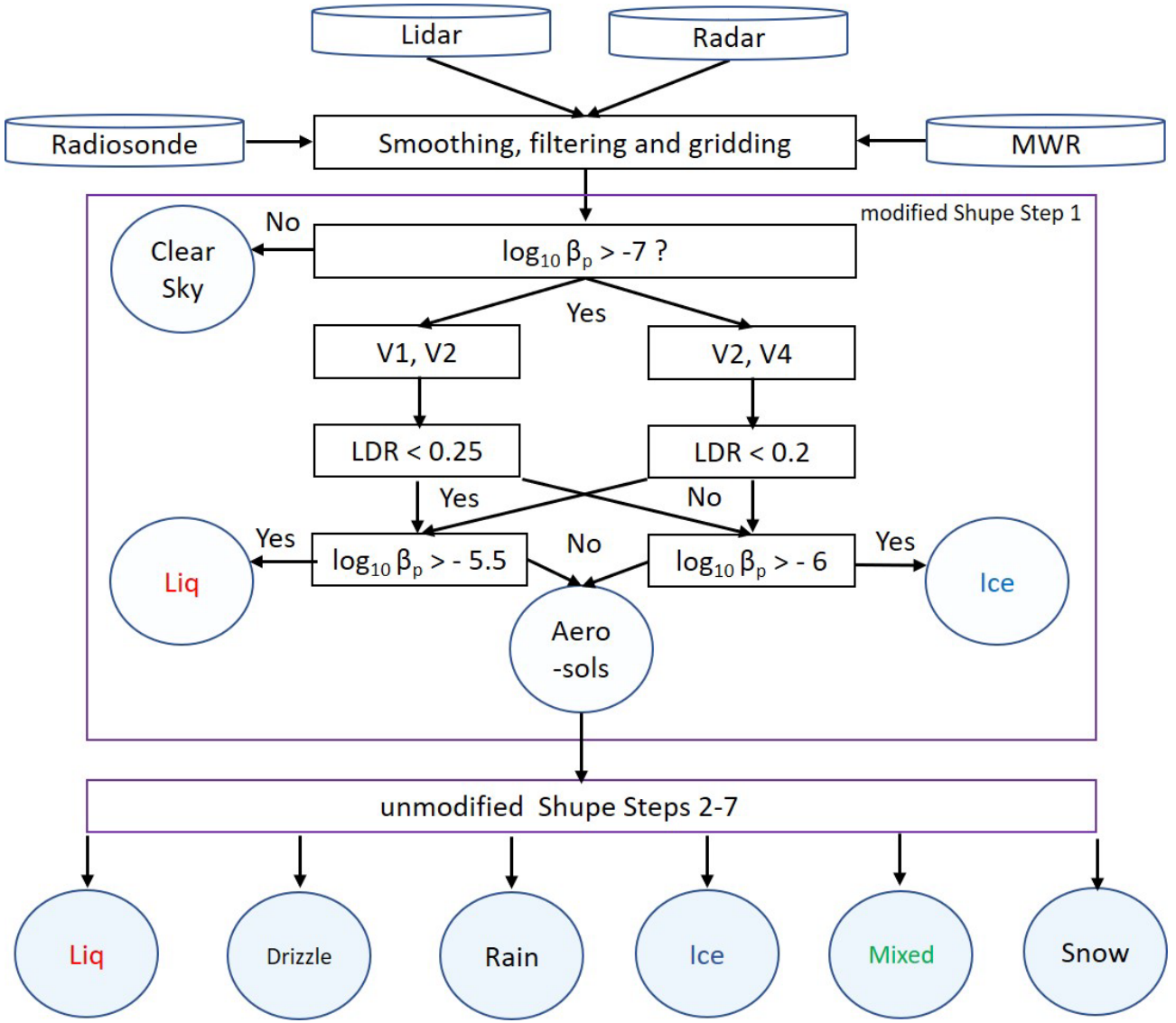
(3) What new observations do we need?

Examples of ice and mixed-phase clouds in NSF ORCAS campaign



CLOUD PHASE ID METHOD USING MICROPULSE LIDAR (MPL) AND MARINE W-BAND ARM CLOUD RADAR (MWACR)

- Low level clouds < 5 km high;
- 40 days between the dates: Oct 2017 – Mar 2018
- $\beta = \text{Log}_{10}$ Backscatter (m^{-1} sr^{-1})
- LDR = Lidar Depolarization Ratio
- Ref = Radar Reflectivity (dBZ)
- V_D = Radar Doppler velocity (m s^{-1})
- W_D = Radar Spectral width (m s^{-1})
- This method is built upon the method of Shupe (2007), but is revised to fit the conditions of the MARCUS campaign



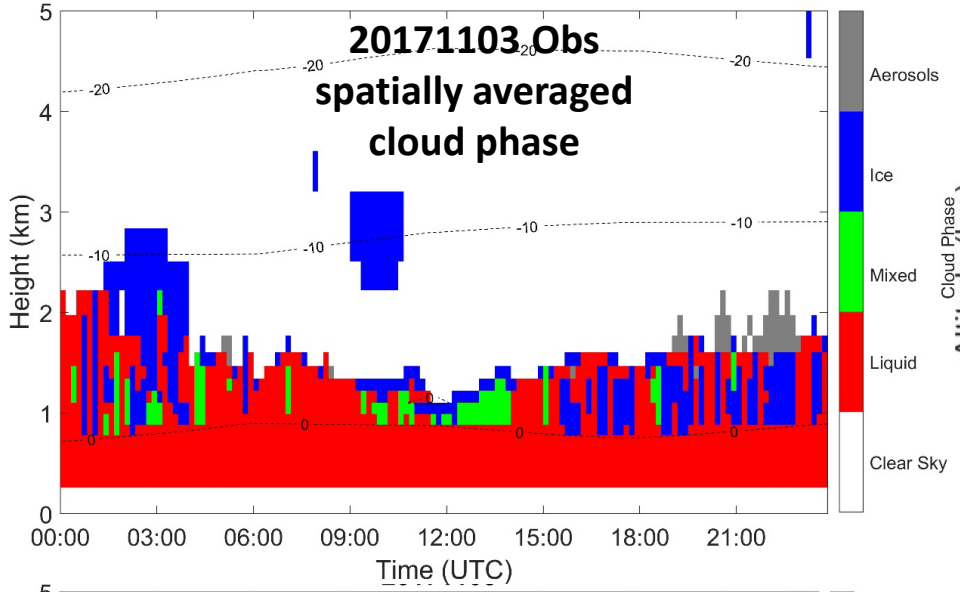
MARCUS case study: Nov 3, 2017

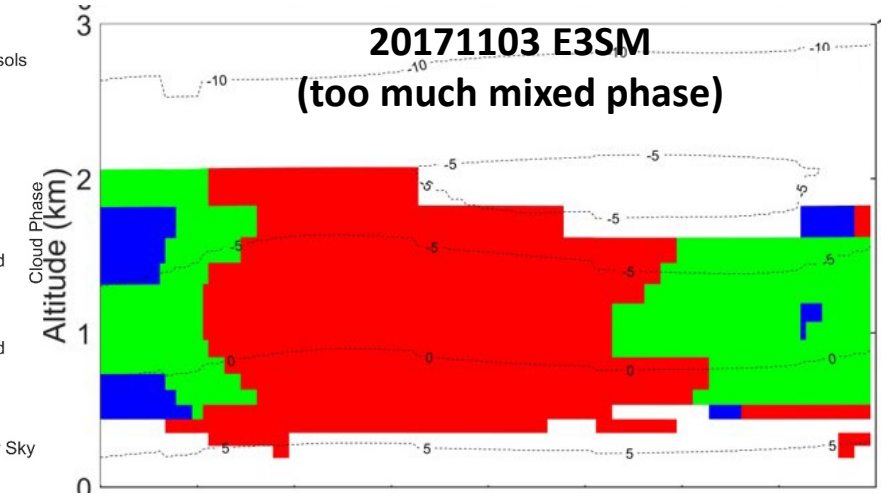
Modification of Shupe (2007) cloud phase id to evaluate global climate models

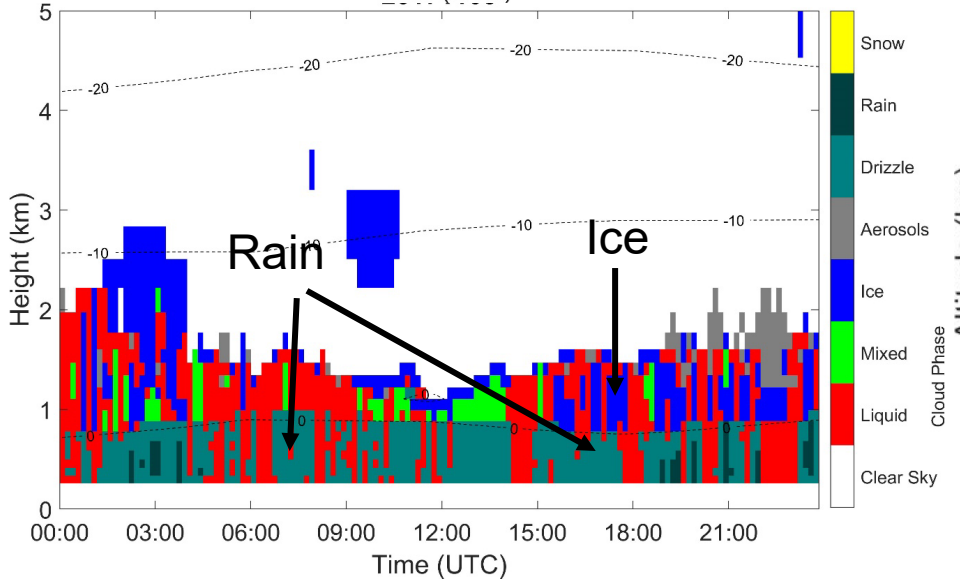
Cloud phase definition:
Ice mass fraction or
ice pixel fraction
(<0.1 liq, 0.1-0.9 mixed, >0.9 ice)

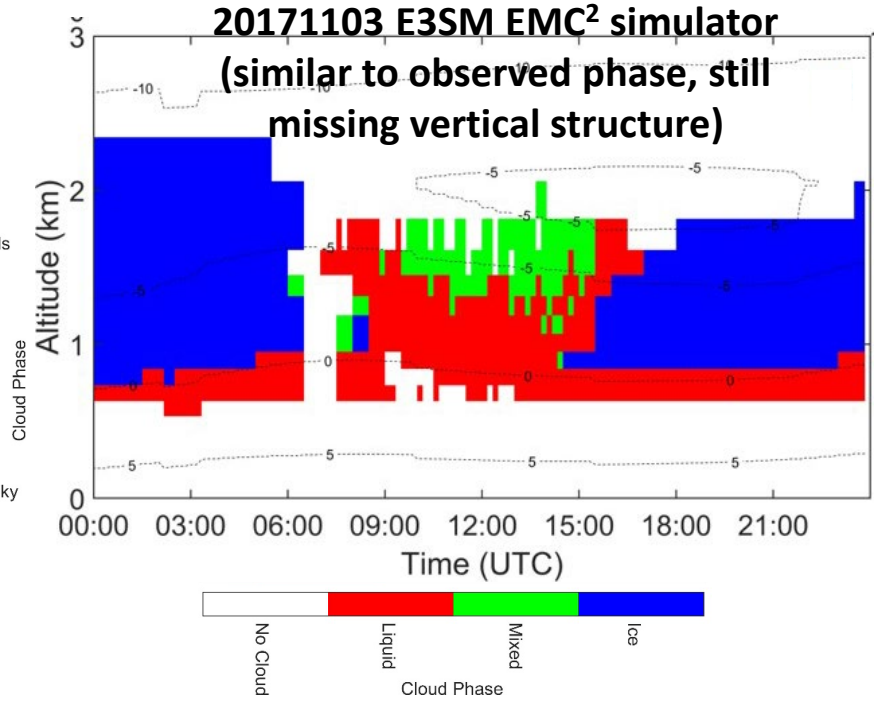
E3SM	EMC²
✓ Type of clouds	✓
✓ Cloud top	✓
✓ Cloud base	✓
X *Cloud phase*	✓
X *Vertical structure*	X

(Desai et al. in revision)





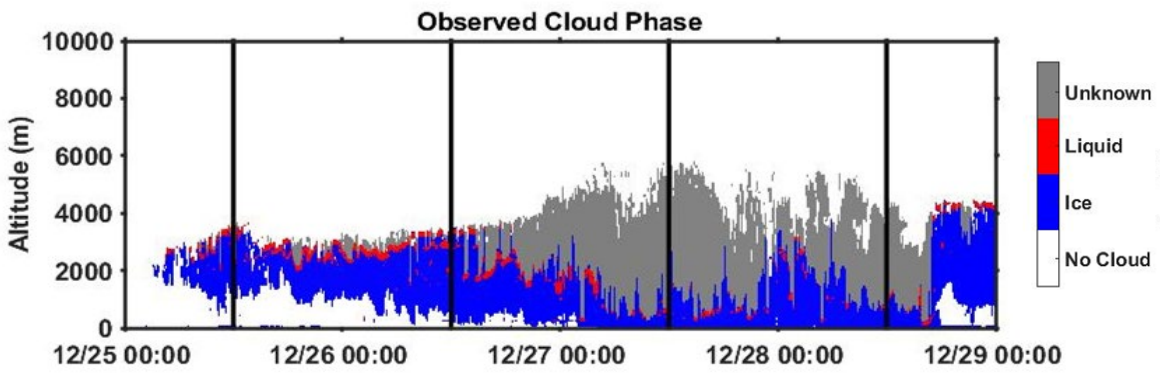


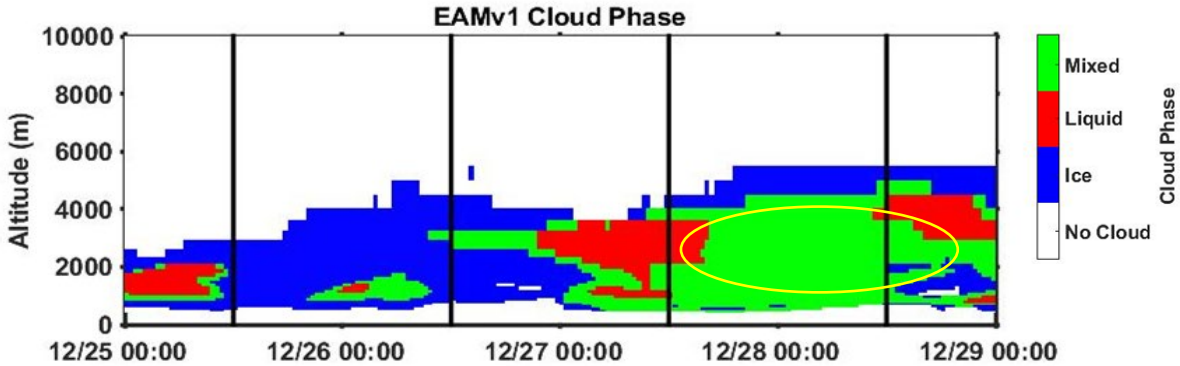


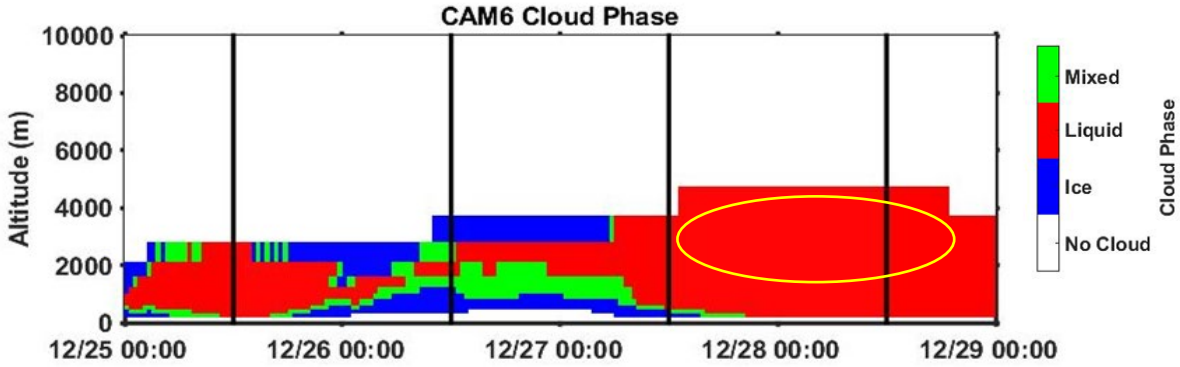
AWARE case study: Dec 25-29 2016

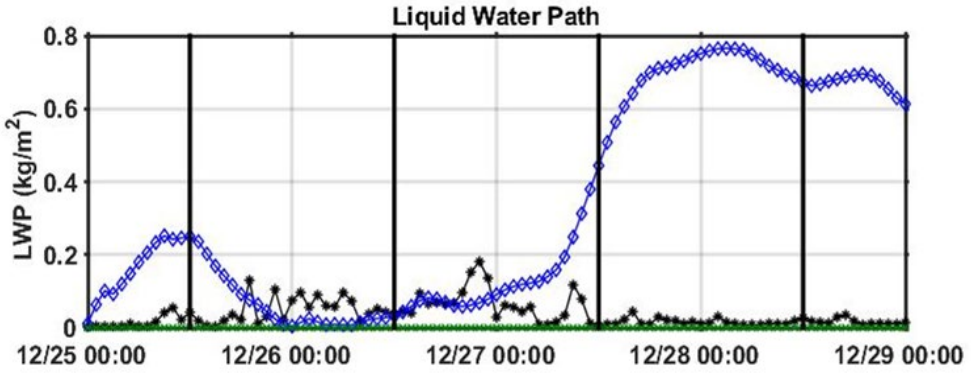
A case study compares cloud phase among AWARE observations, E3SM1/EAMv1, CESM2/CAM6.

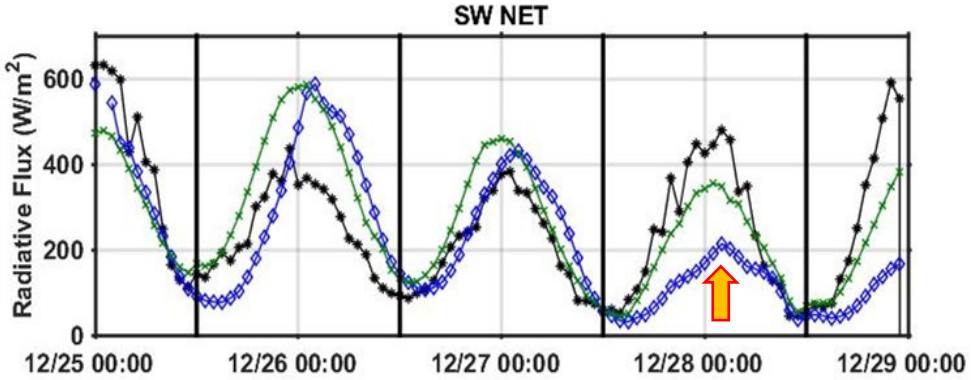
E3SM EAMv1 overestimates mixed phase frequency, which correlate with the bias of net SW and longwave radiation.

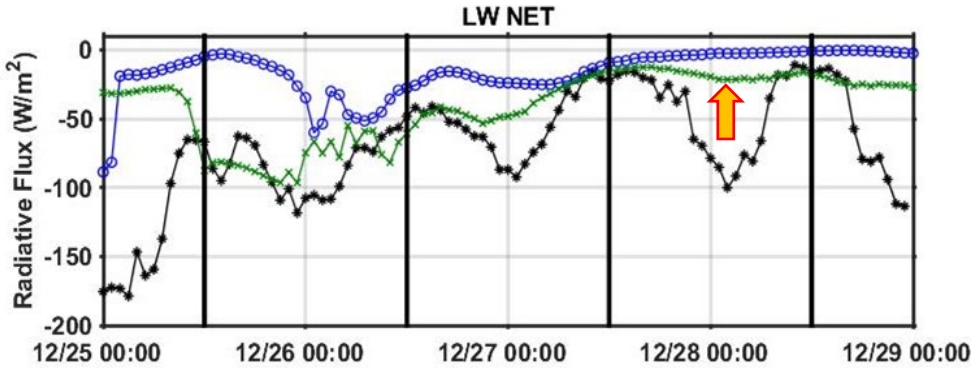






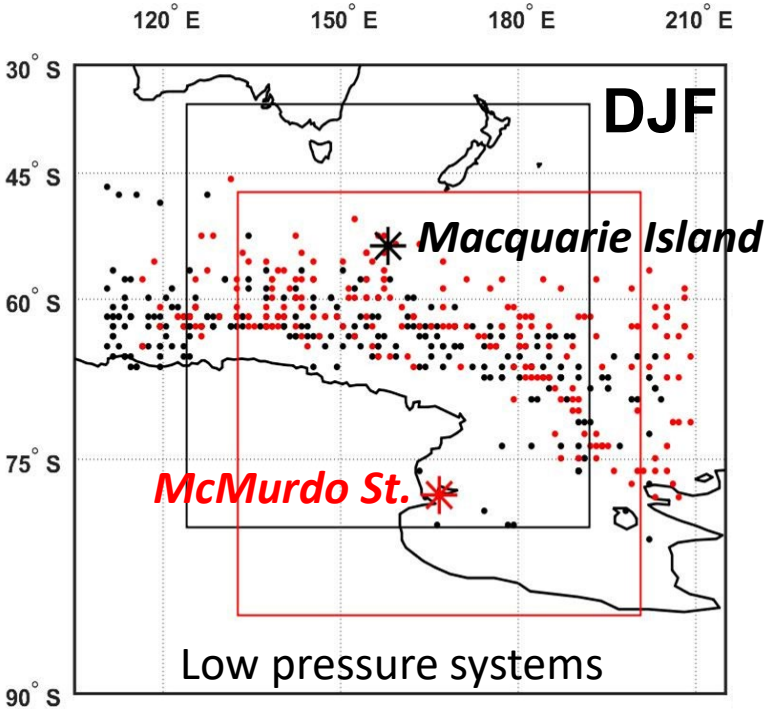






(Barone et al. in prep)

Impacts of synoptic conditions on MICRE and AWARE observations of cloud fraction



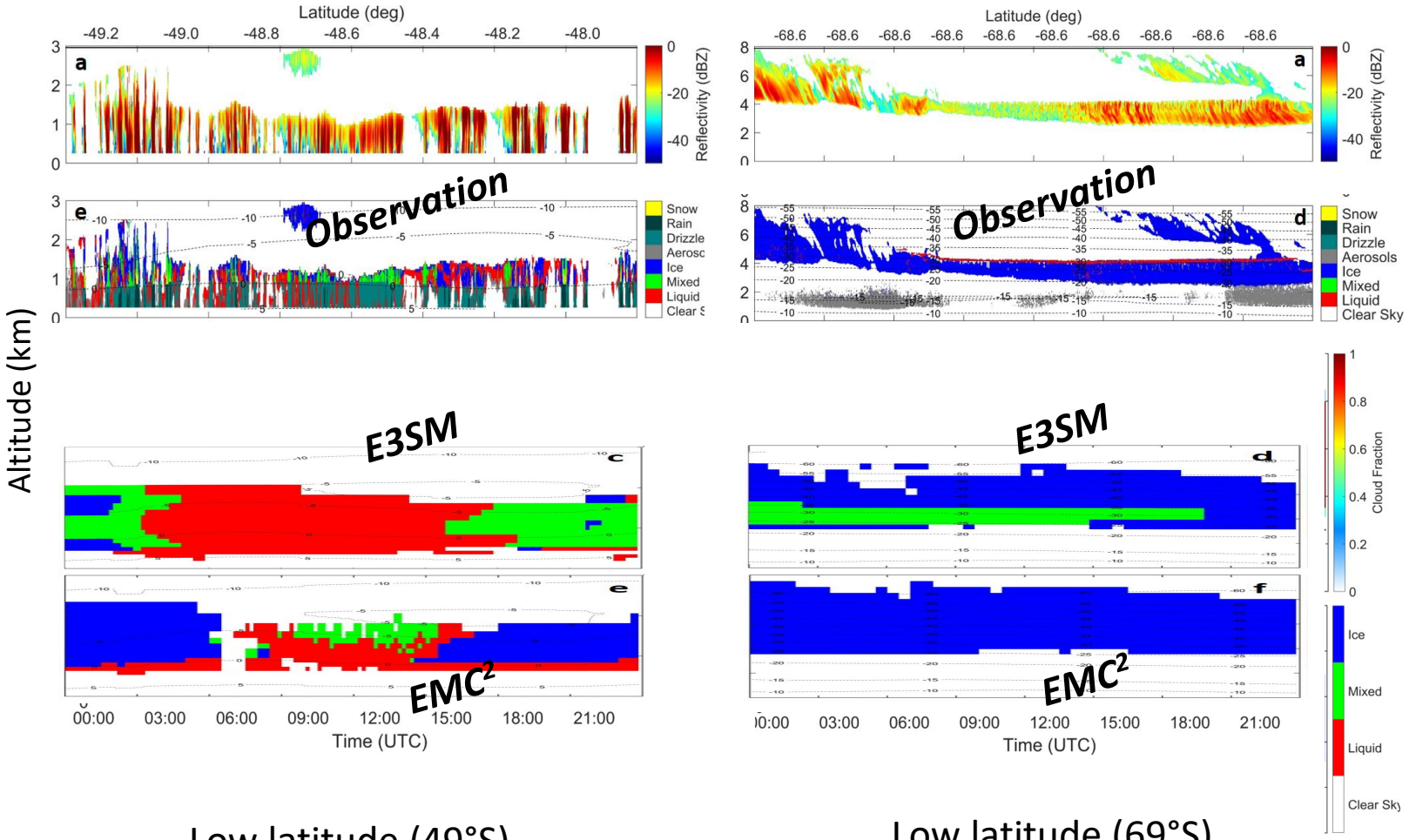
Italic: t-test passing 95% confidence interval for mean difference

Variables	MICRE			AWARE		
	Q2 & 3	Q1 & 4	|T|	Q2 & 3	Q1 & 4	|T|
CF OBS	0.8931	0.8986	0.45	0.7553	0.6542	*7.46*
CF CAM6	0.9613	0.9516	1.23	0.7933	0.6168	*12.13*
CF EAMv1	0.9693	0.9411	*4.59*	0.7294	0.5032	*14.40*
dCF CAM6	0.0609	0.0522	0.54	0.0379	-0.0374	*5.17*
dCF EAMv1	0.0200	0.0799	*3.58*	-0.0259	-0.1510	*8.55*

1) MICRE shows small differences between quadrants 2&3 versus quadrants 1&4 around low-pressure systems, while AWARE shows higher CF in Q23

2) E3SM shows stronger impacts from synoptic conditions compared with observations

A shift of cloud regimes from low to high latitudes in MARCUS campaign



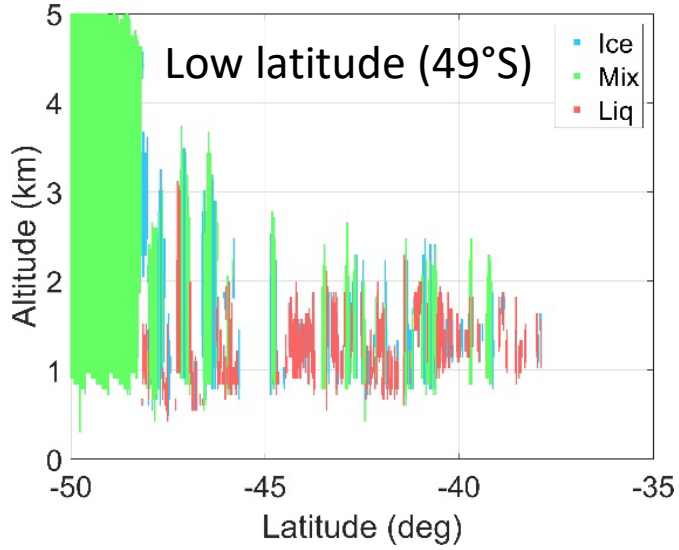
Low latitude (49°S)

Ice-topped clouds, with pockets of ice and liquid below 0°C

Low latitude (69°S)

Thin liquid cloud top with streaks of ice layers below

CloudSat/CALIPSO



Satellite cloud phase obtained using CloudSat/CALIPSO for 03 Nov 2017 shows coexisting liquid, mixed and ice phase between 1-2 km altitude, but do not show detailed vertical structure.

What new observations do we need?

Science questions:

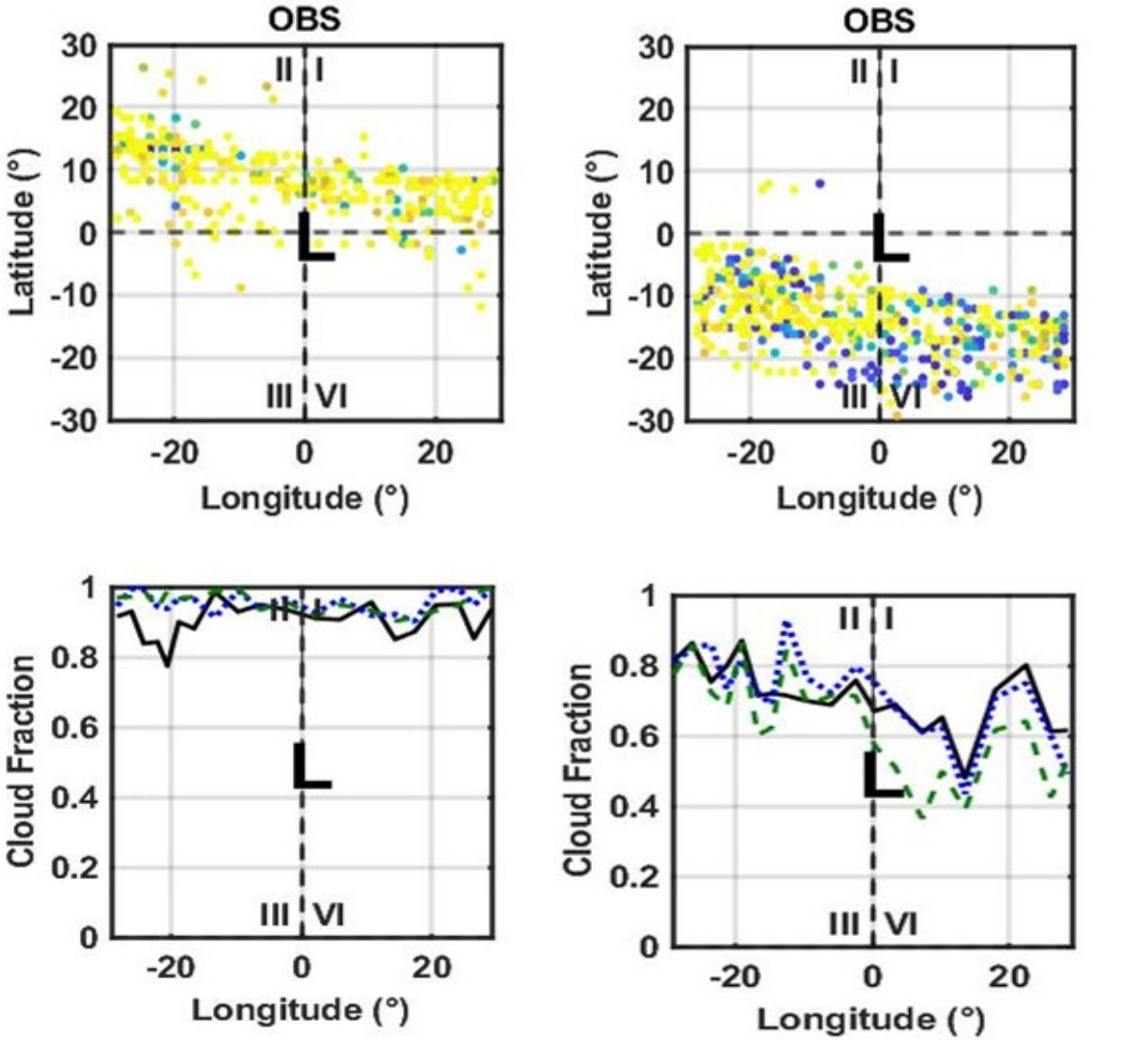
- What processes drive the shift of cloud regimes from lower to higher latitudes?
- What is the reason that E3SM EAMv1 does not reproduce the cloud vertical structure?

Sampling strategy:

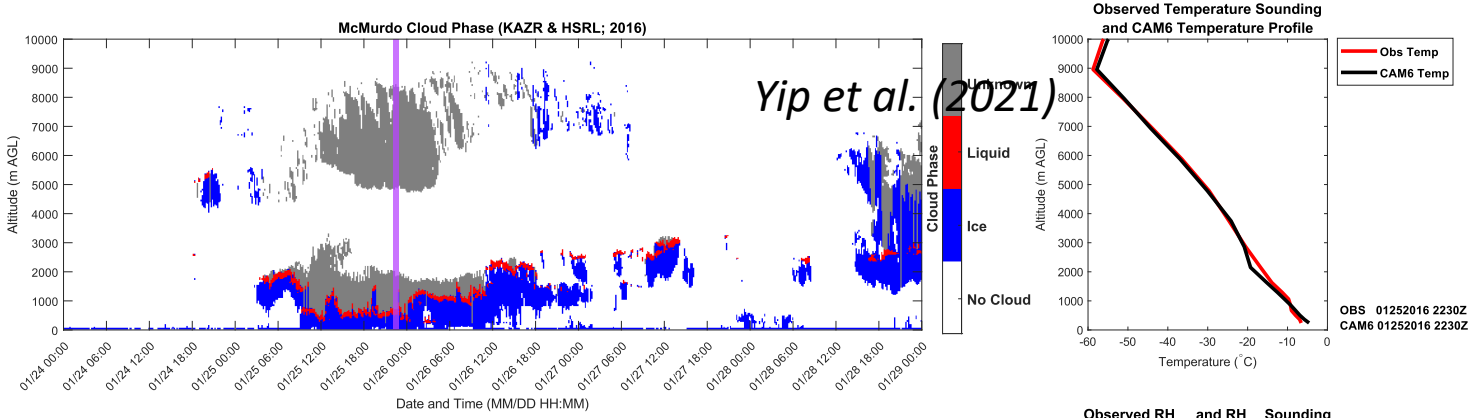
- A continuous, long-term dataset is needed for statistical comparisons
- Unbiased sampling
- Shipborne observations: multiple legs from lower to higher latitudes
- Aircraft observations: Lagrangian sampling follow a low-pressure system

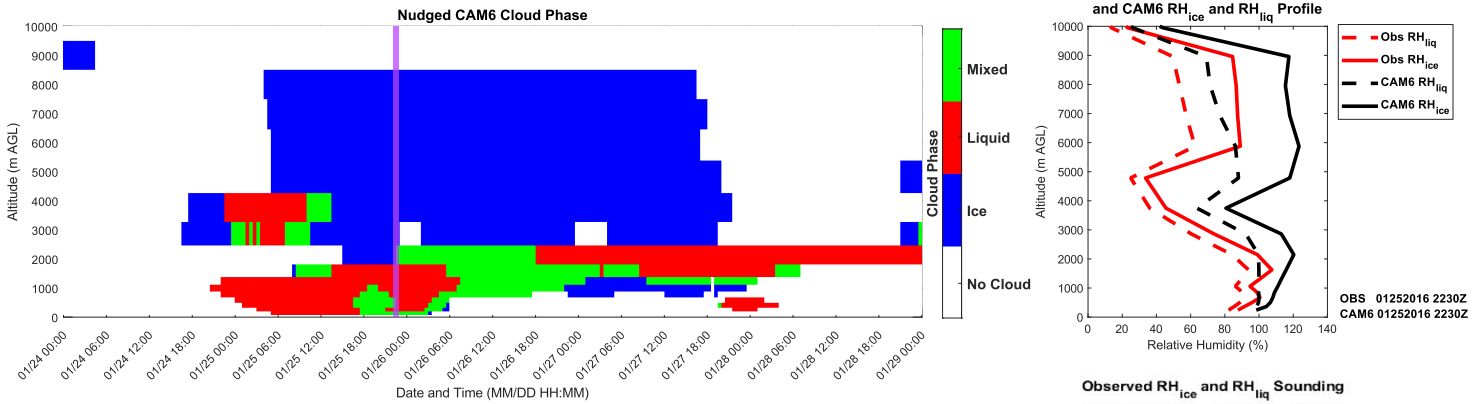
Instrument payload:

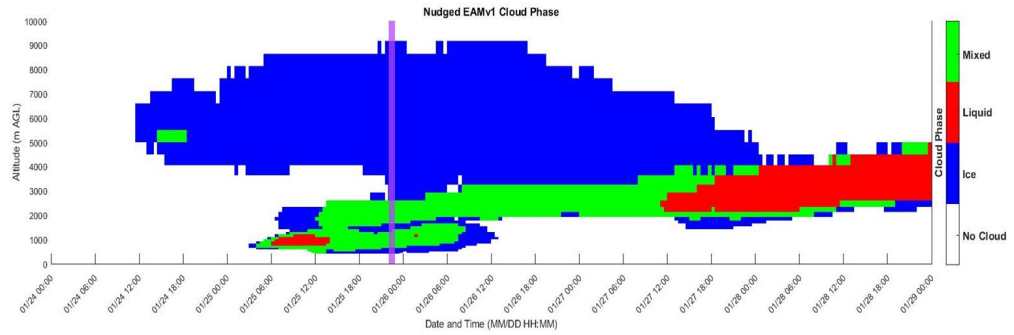
- At least a combination of radar & lidar
- Preferably collocated comparisons of various measurements (MPL, HSRL, radars, shipborne, airborne, ground-based)

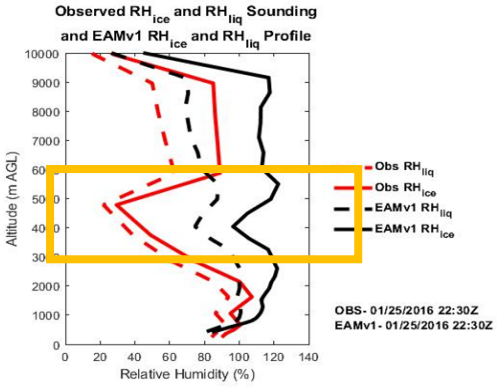

OBS
OBS
Latitude (°)
Longitude (°)
Cloud Fraction
II
I
III
VI
30
20
10
0
-10
-20
-30
-20
0
20
1
0.8
0.6
0.4
0.2
0

DOE/NSF AWARE Campaign January 24, 2016: Multi-layer Clouds









CAM6 and EAMv1 capture thin liquid cloud top, but misidentifies dry layers as ice phase due to RH biases