Evidence of Secondary Ice Production based on In-situ and Remote Sensing Observations in the High Latitudes

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DOE ASR DE-SC0021211
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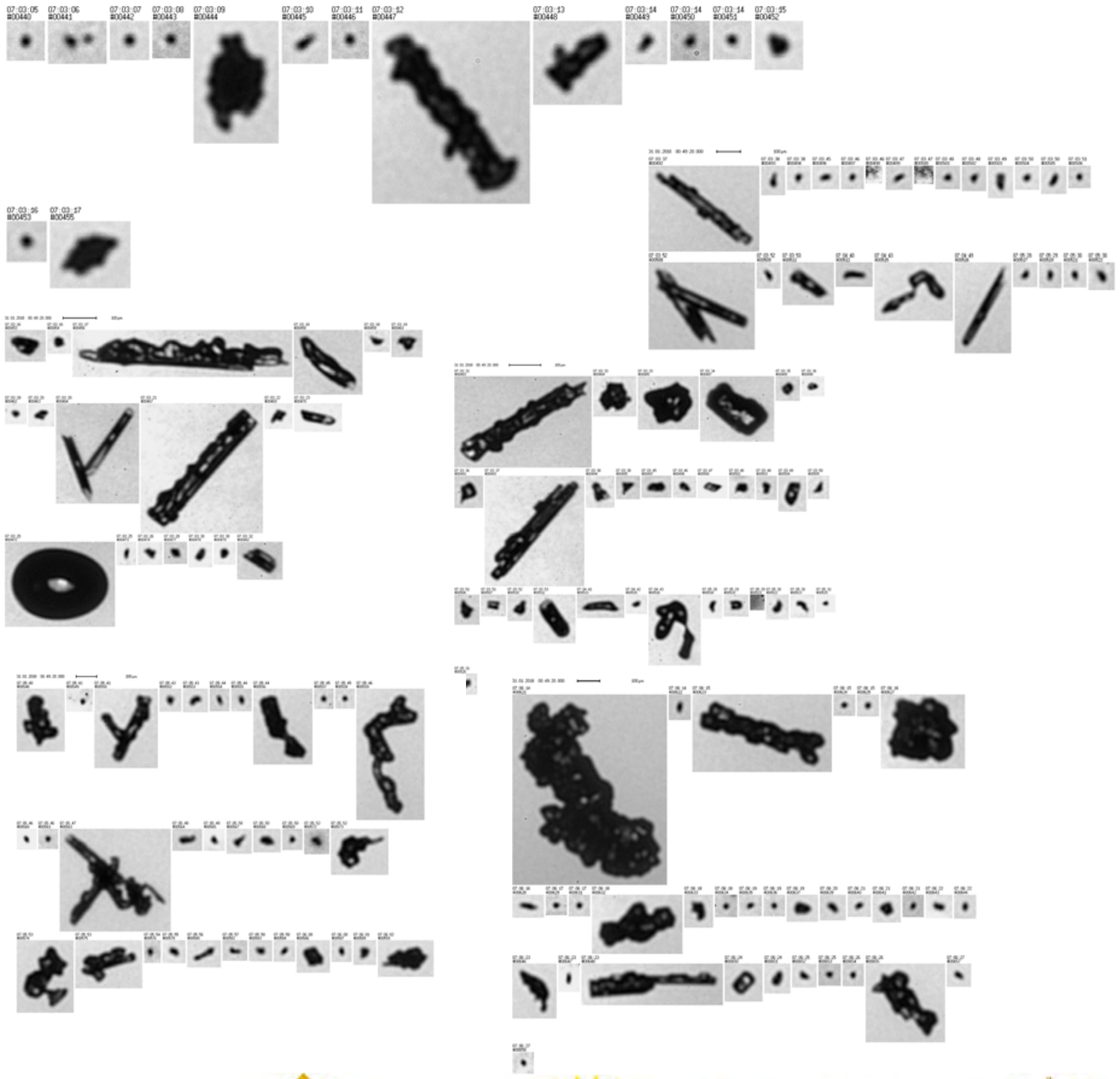
DOE ASR/ARM PI meeting
SIP Breakout October 26, 2022



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ASR Atmospheric System Research

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Identifications of Secondary Ice Production (SIP) based on Observations

Motivation

1. **A large dataset is needed to conduct statistical analysis of SIP processes**
2. **Individual impacts of thermodynamic and dynamical conditions**

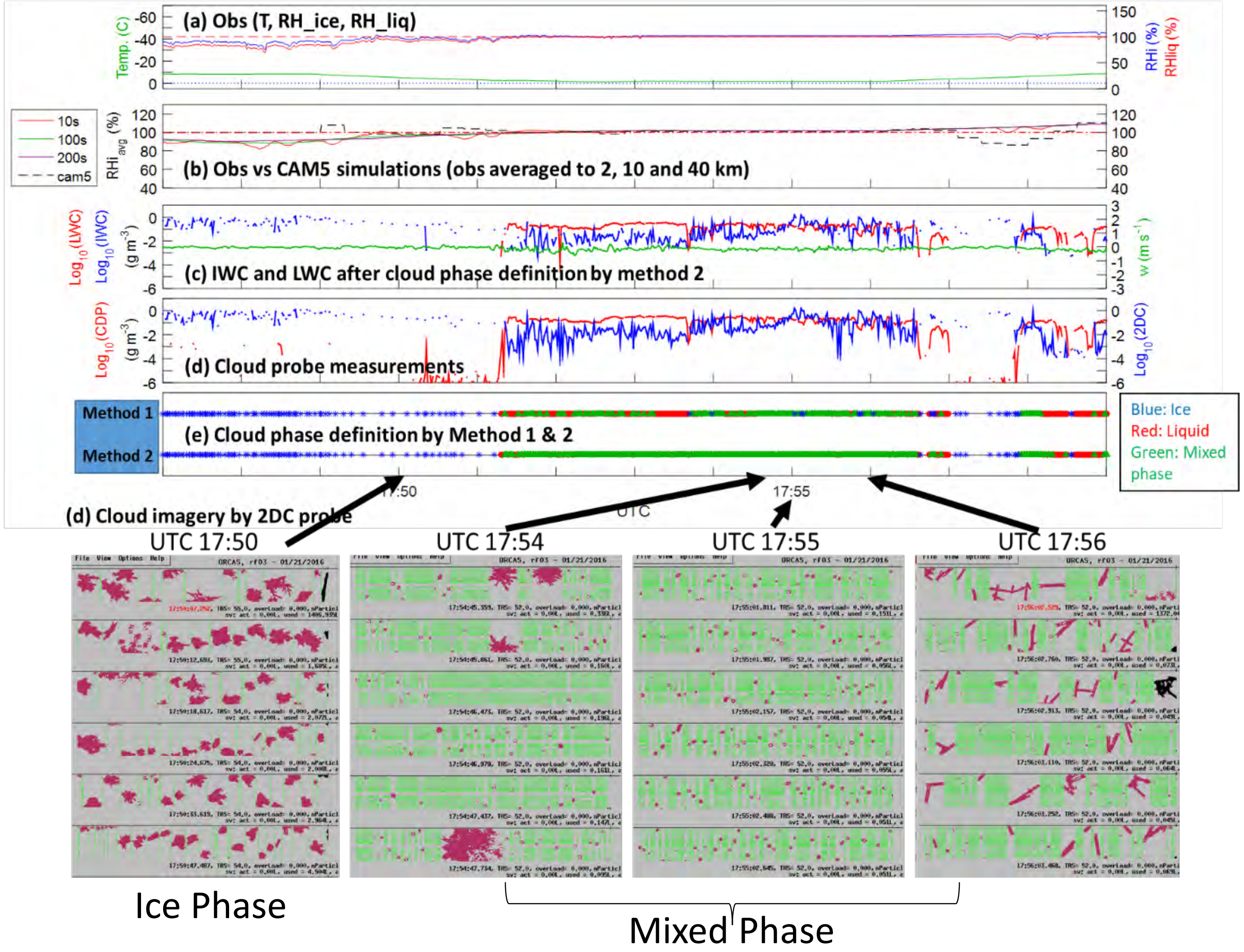
Three topics:

(1) Strong updraft vs. turbulent motion

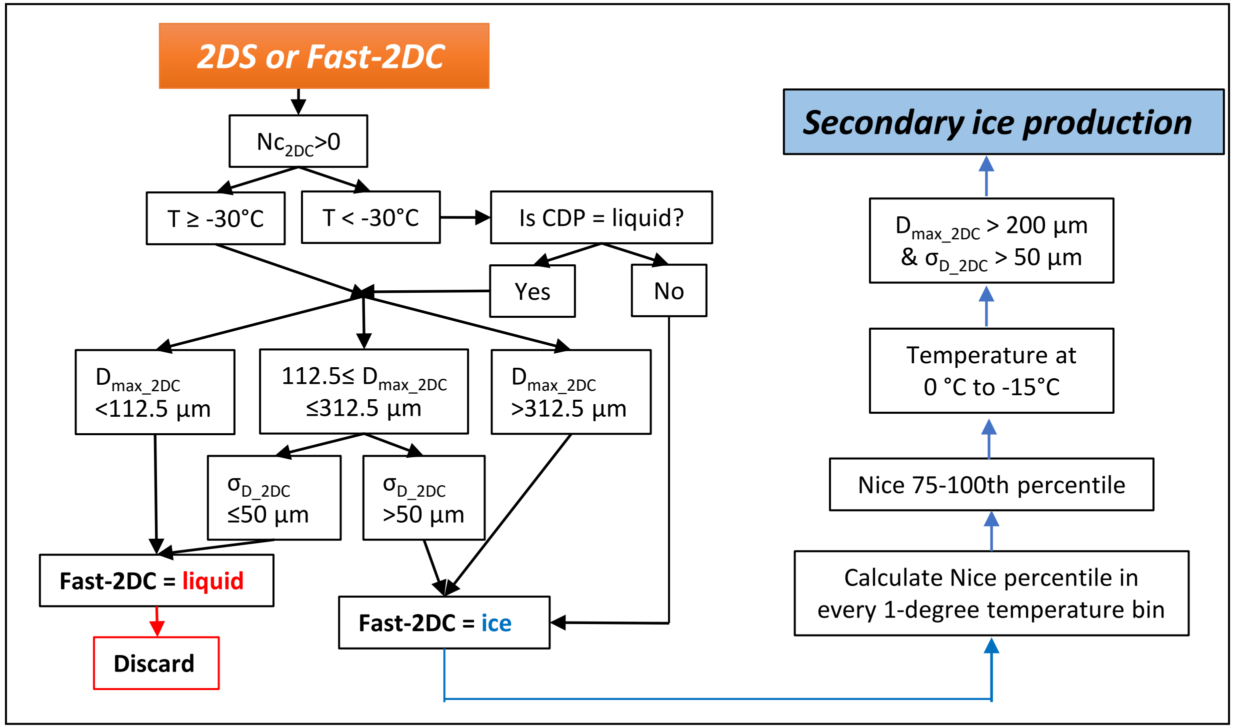
(2) Hemispheric comparisons

(3) Comparisons with E3SM EAMv1

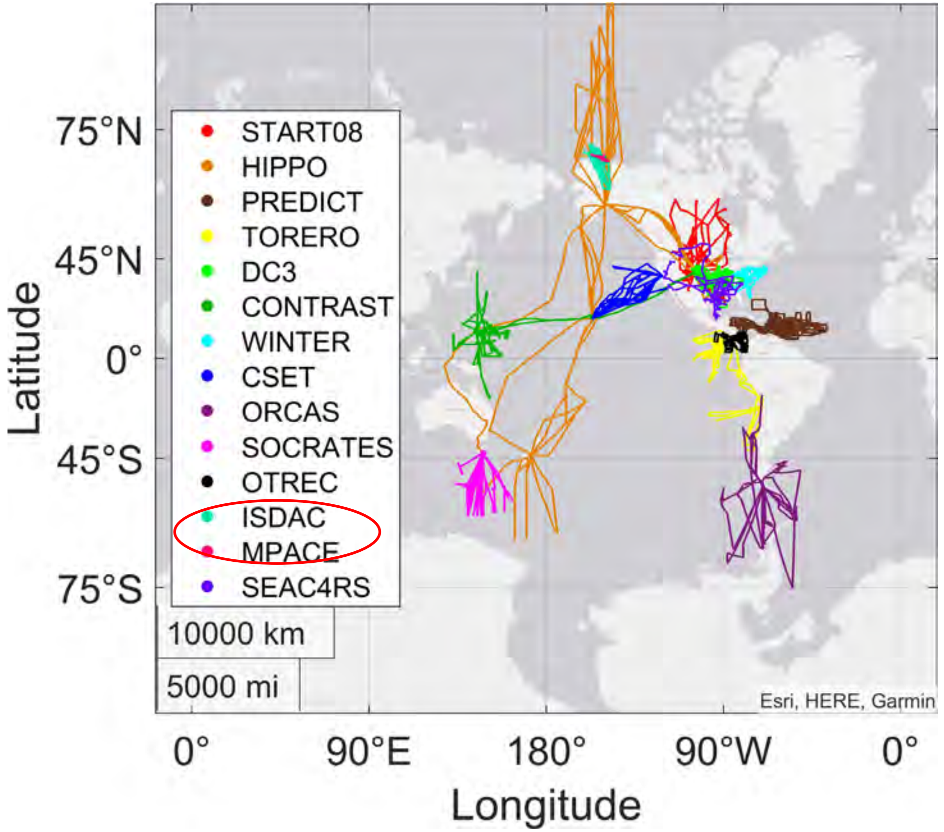
Examples of ice and mixed-phase clouds in NSF ORCAS campaign



A method to identify secondary ice production based on in-situ aircraft-based observations



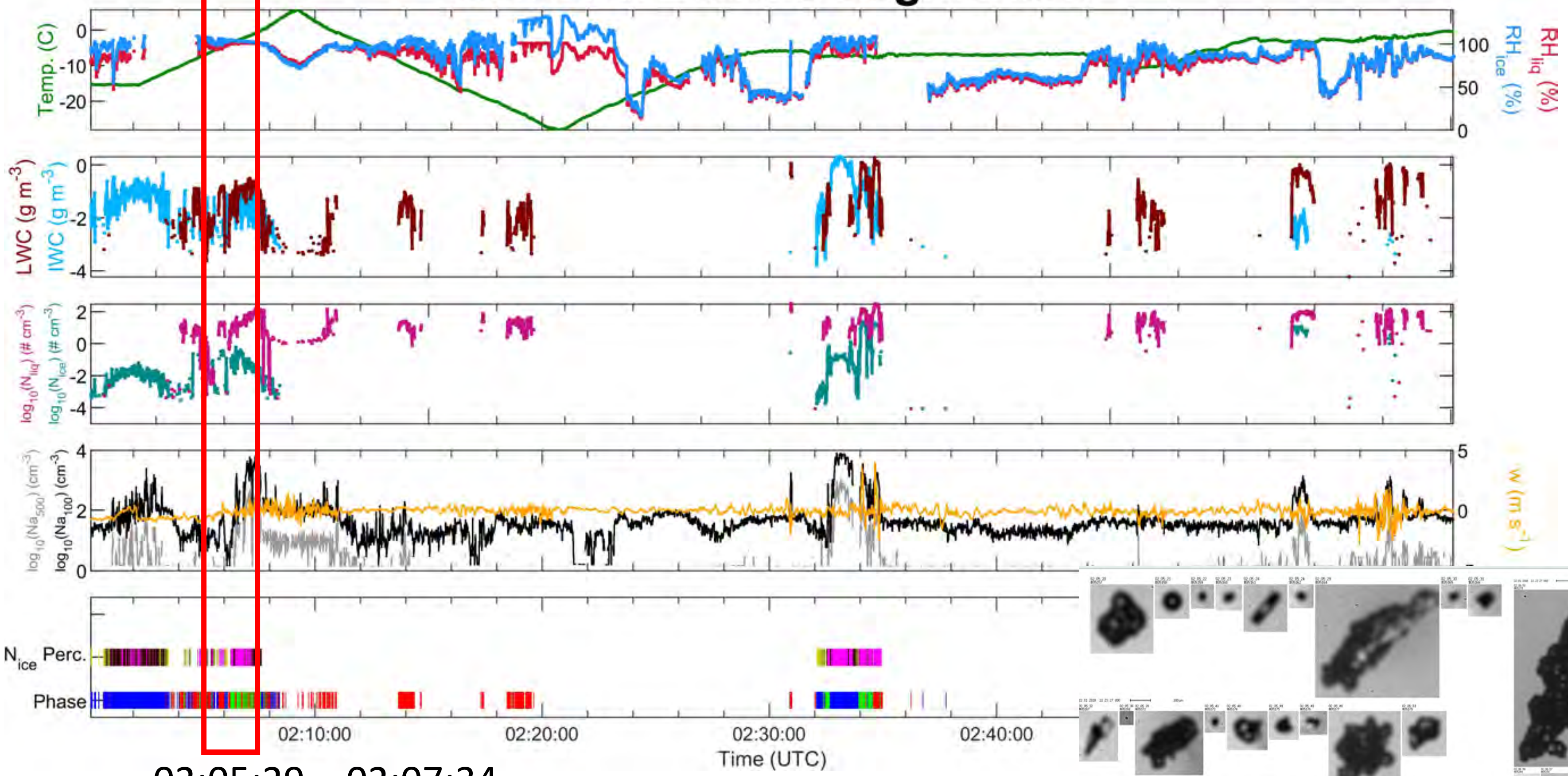
Yang et al., in prep.



(1) The method has been verified against cloud images from PHIPS and 2DC probes.

(2) Applied to a global-scale aircraft dataset, including DOE ARM MPACE and ISDAC campaigns

SOCRATES RF3 Segment#6



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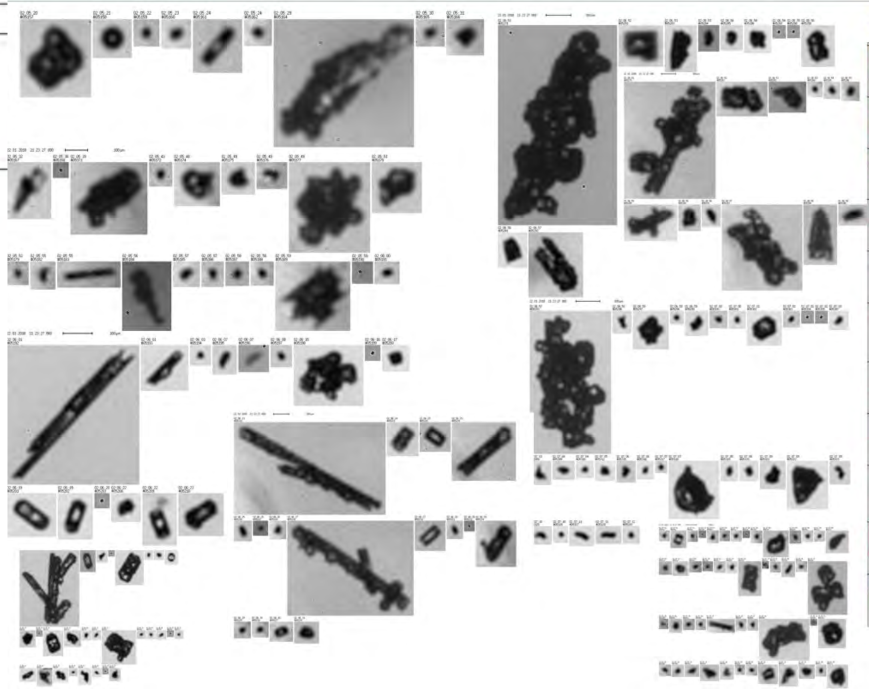

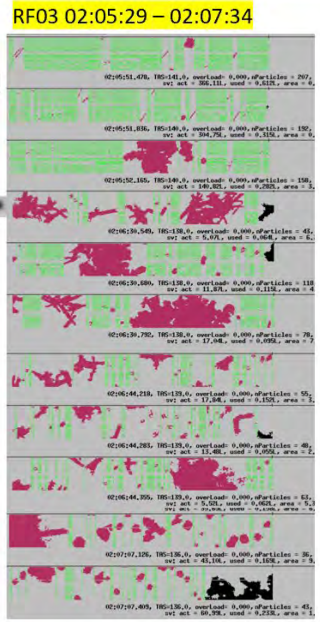

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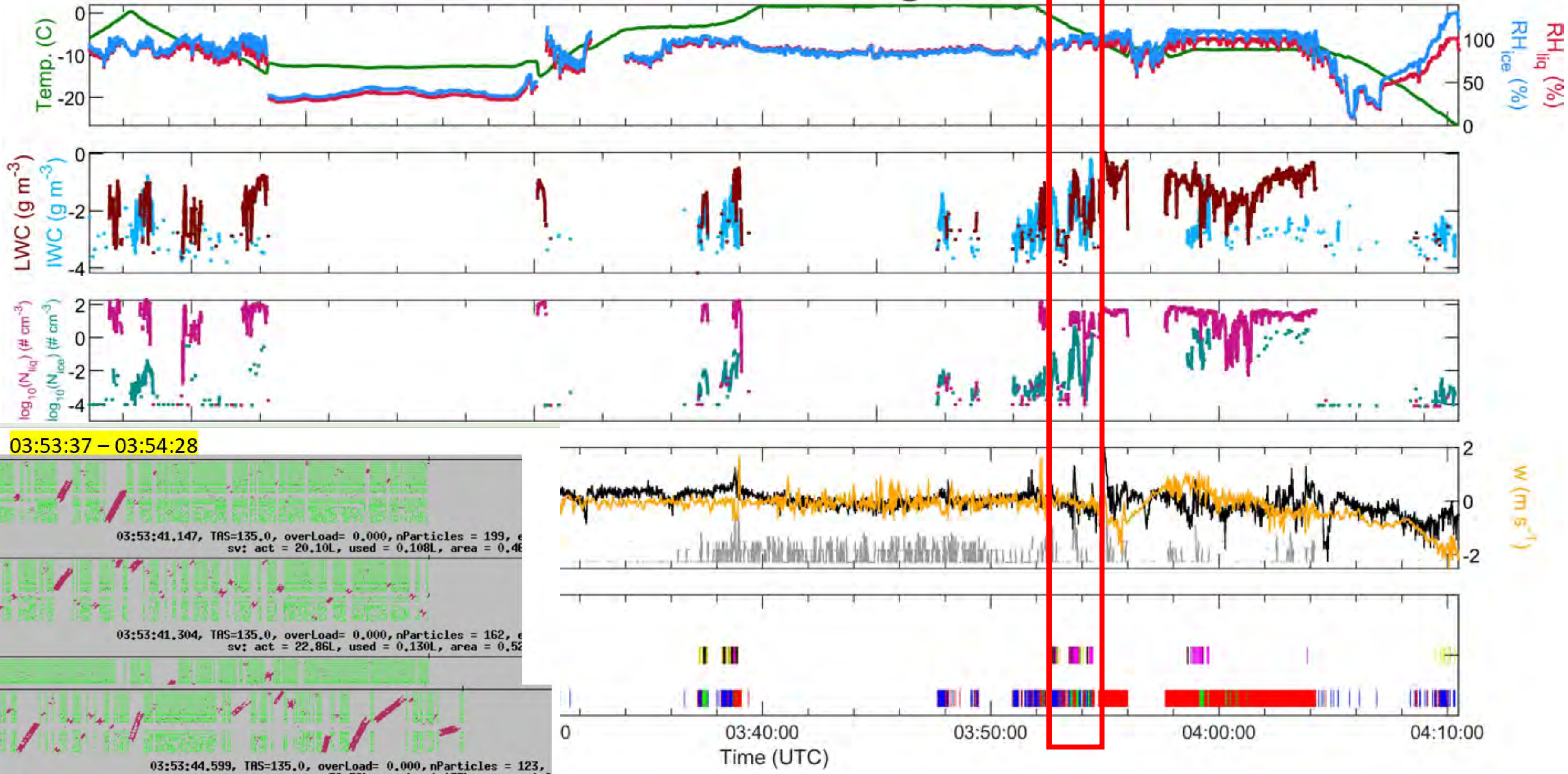

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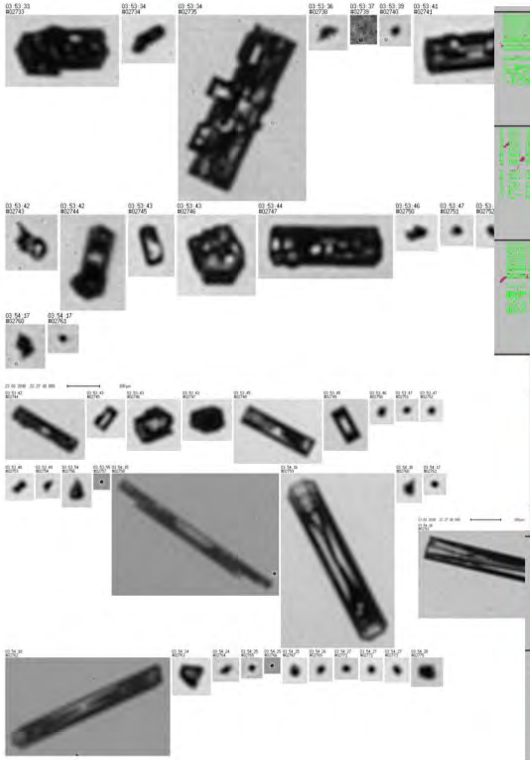

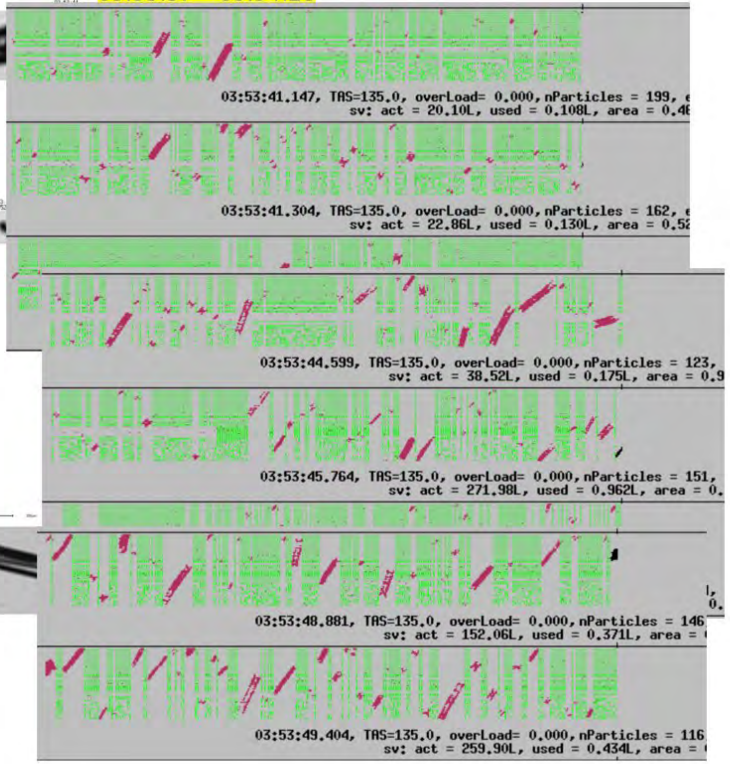

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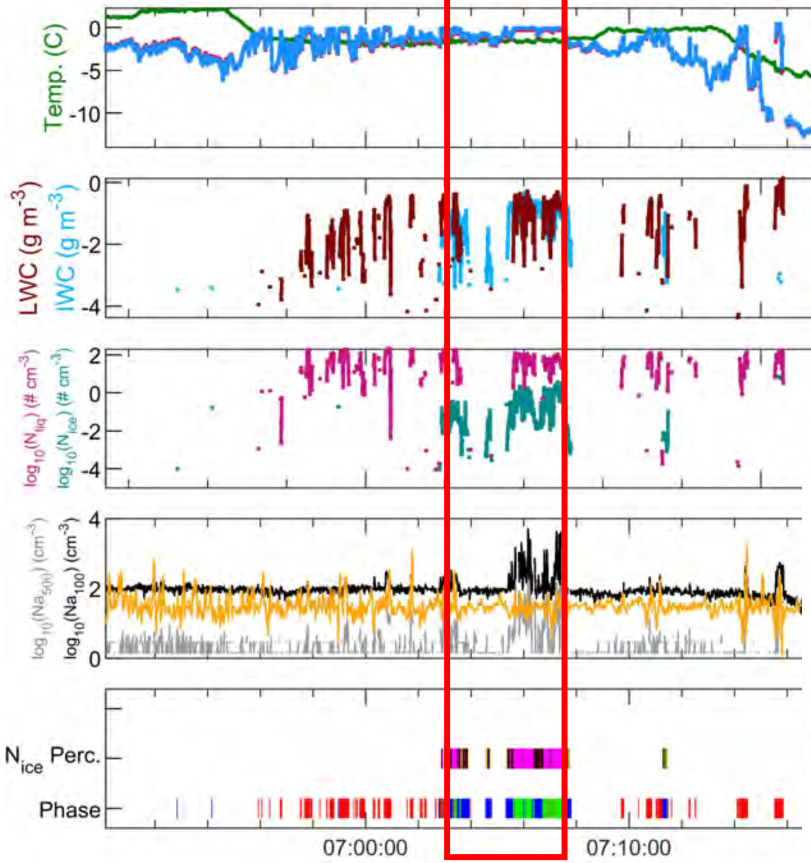
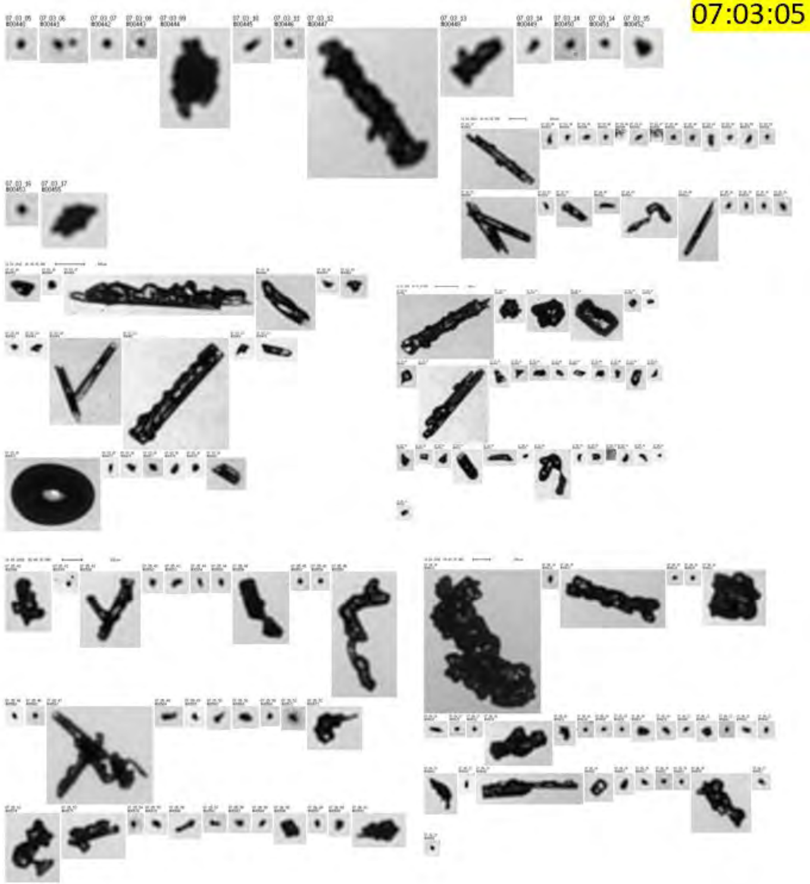
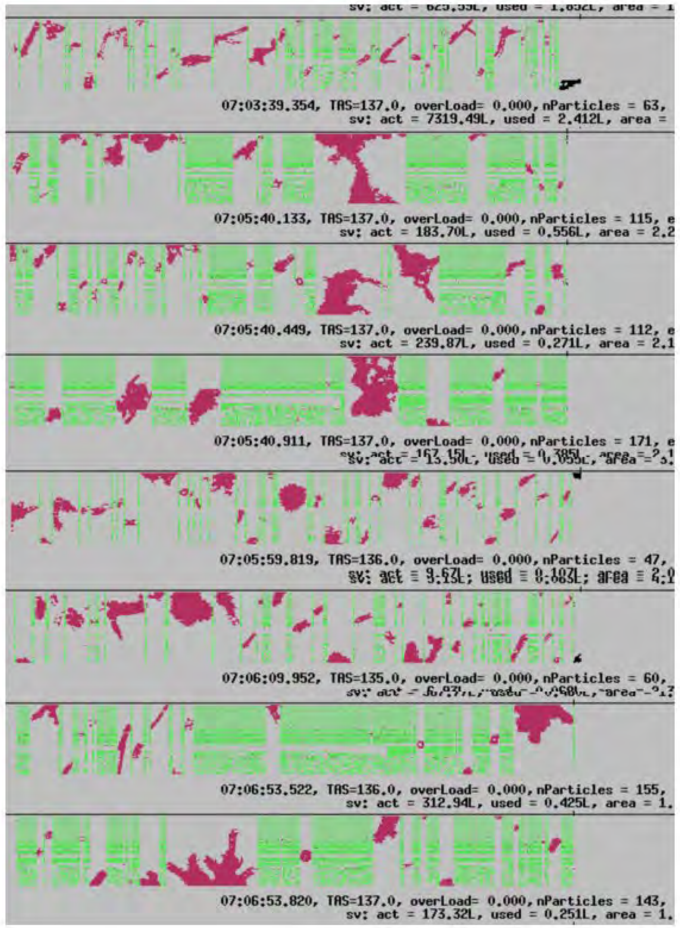
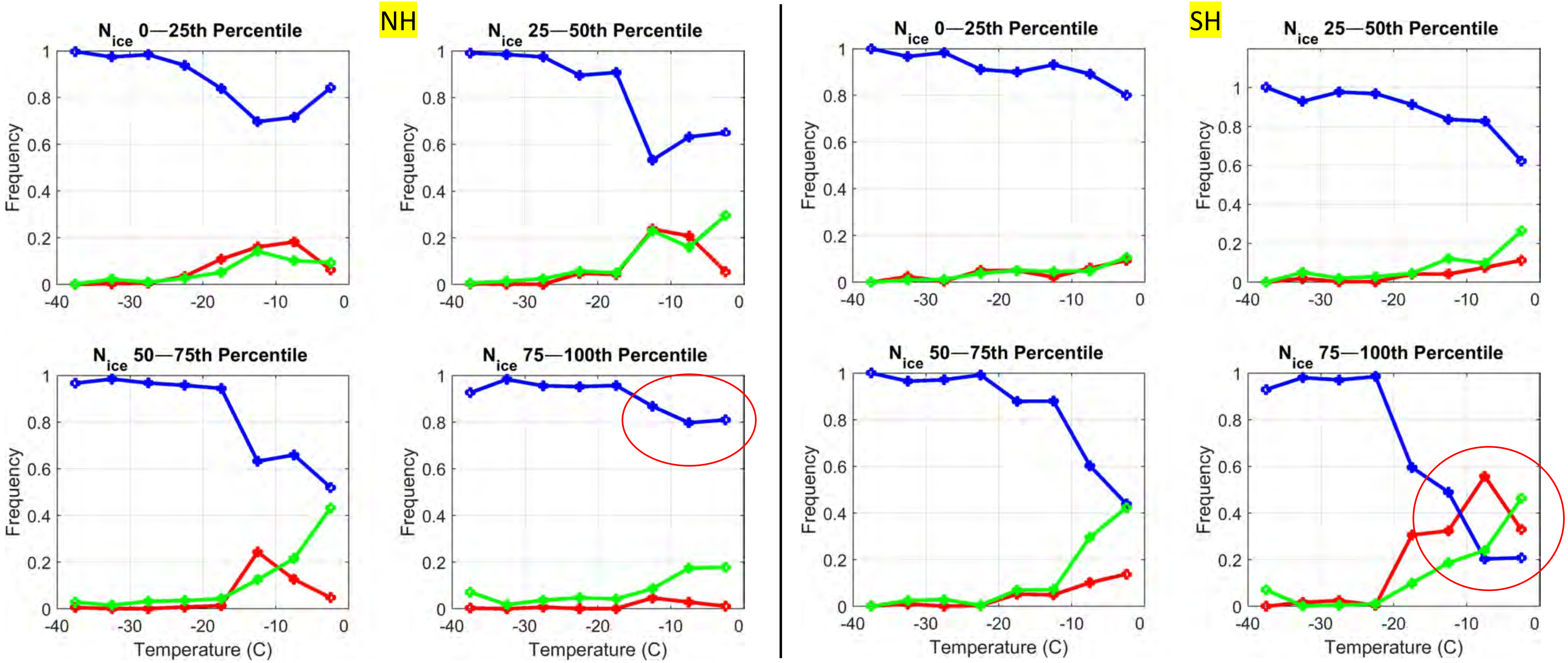




07:03:05 – 07:07:23



Cloud Phase Frequency Distribution in the Two Hemispheres

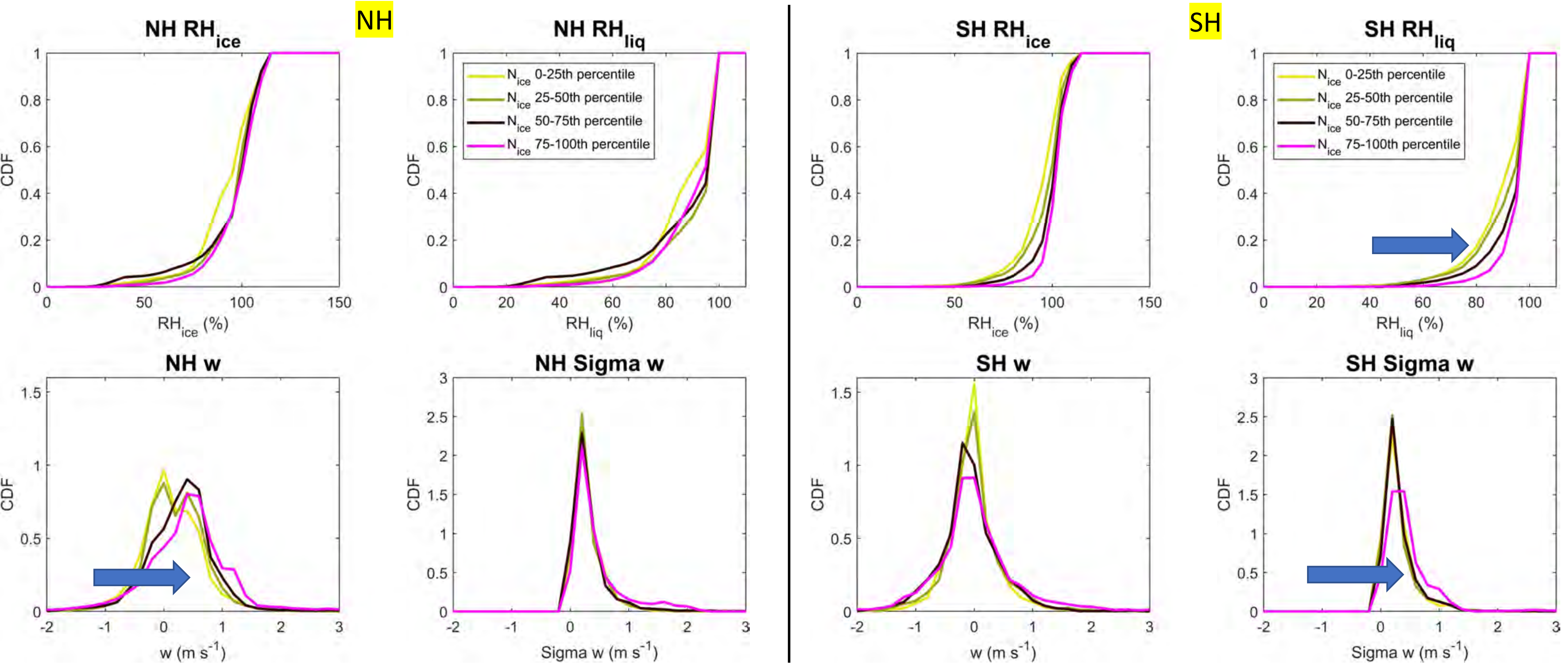


Focusing on secondary ice production at -15 to 0°C for the highest Nice percentiles (75-100th):

Northern Hemisphere: mostly ice phase

Southern Hemisphere: mostly liquid and mixed phase (*Supercooled liquid water plays a more important role in SIP in the SH*)

Thermodynamic and dynamical conditions for SIP

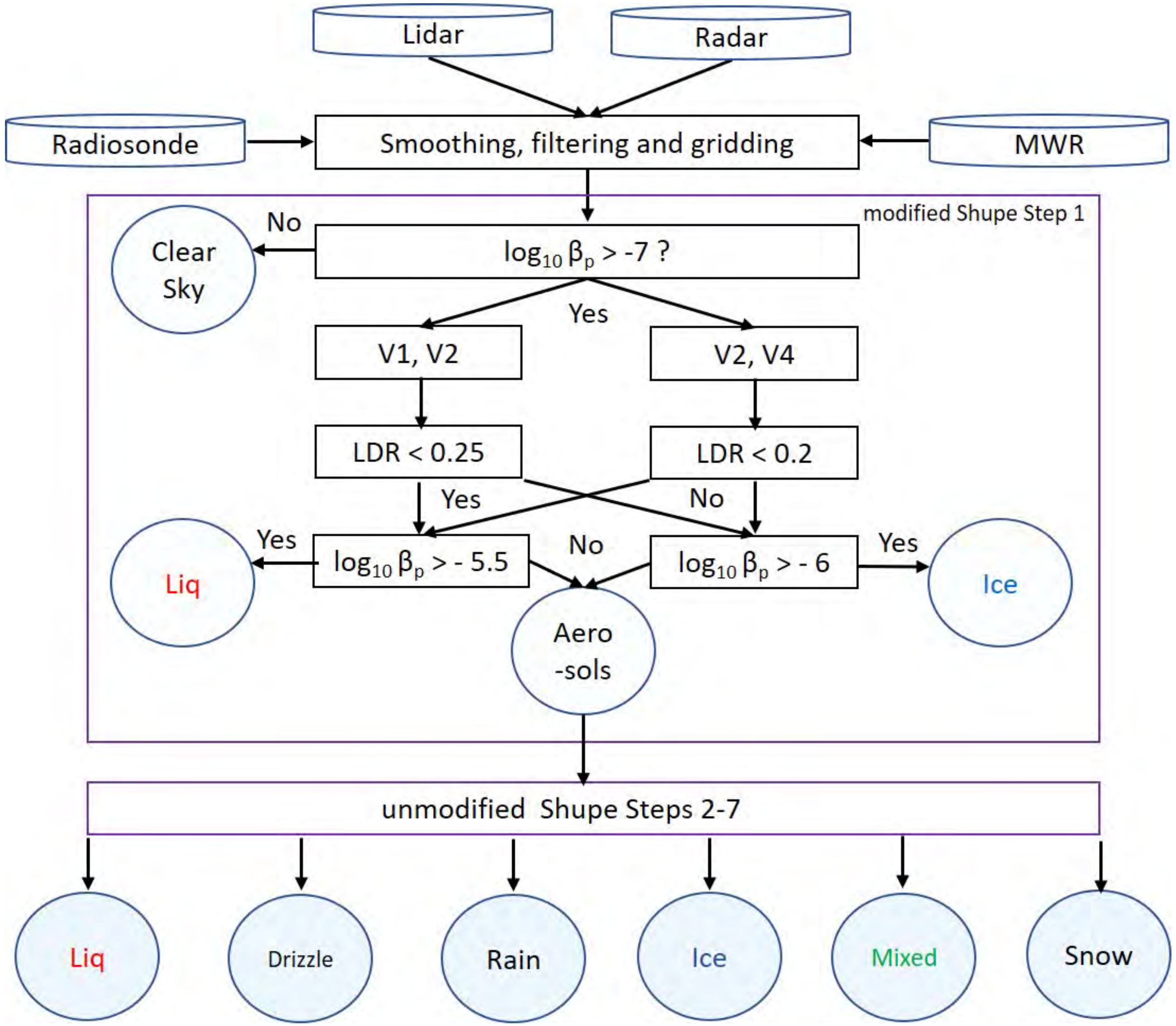


Northern Hemisphere: SIP is associated with higher updraft

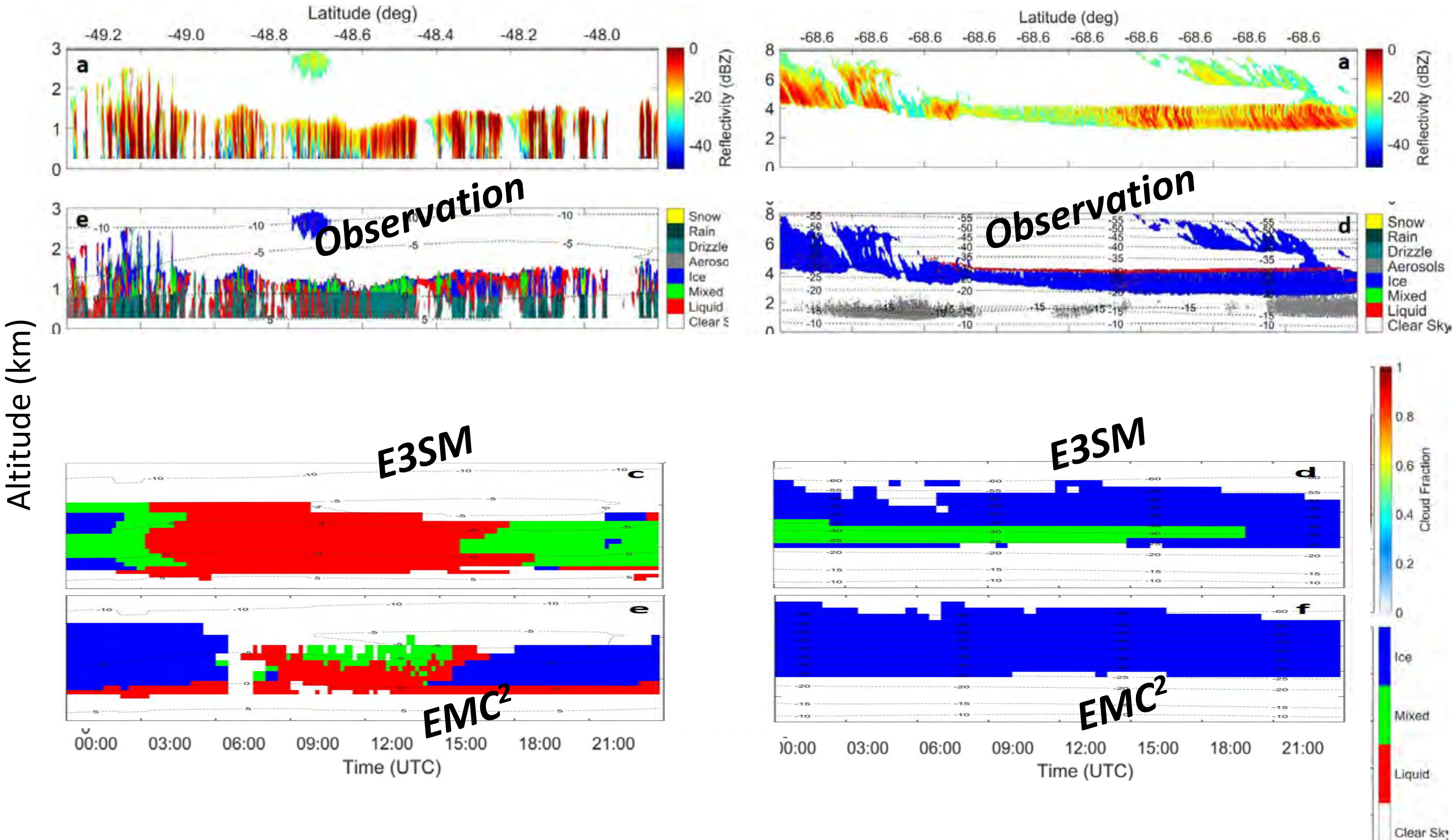
Southern Hemisphere: SIP is associated with stronger turbulence and higher RHliq

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
  - β = 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



Evidence of SIP at lower Southern 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

Using lidar & radar to identify cloud phases

1) Lower Southern Latitudes (~40-50degS) show more ice-topped cloud layers
2) Low INP conc at temperatures warmer than -10°C suggest SIP
3) E3SM EAMv1 nudged simulations underestimate ice phase
4) EMC^2 simulator shows more ice phase

Two model biases:

Missing **ice** cloud top at **low S lat**

Missing **liquid** cloud top at **high S lat**

(Desai et al., in revision, JGR)

Summary

Methodology:

- A new method has been developed to identify SIP automatically based on in-situ observations
- Using revised cloud phase id method for shipborne observations, we also found evidence of SIP

Hemispheric comparisons of SIP:

- The NH shows higher updrafts in SIP, most in ice phase
- The SH shows stronger turbulence, most in liquid/mixed phase

Model comparisons:

- E3SM nudged simulation underestimate ice phase, while EMC^2 simulator matches well with observations
- Difficult to represent cloud-top phase correct
- Low lat (40-50°S) has ice-topped layer;
- high S lat (60-70°S) has liquid-topped layer