University of Miami ACTIVATE effort

Seethala Chellappan, Paquita Zuidema

1. Examine the winter cold-air outbreak data from the point of view of generalizing their attributes & extending to satellite, reanalysis datasets. Focusing on 5 cases we believe are encompass the phase space in N_d, LWP, T_{ct}

2. This includes assessing remotely-sensed cloud properties (N_d, LWP, T_{ct})

3. Examine cloud microphysics as a function of ASTER-derived cloud spatial scales

What we did

- Selected 5 cold-air-outbreak cases spanning a representative range of environmental/aerosol conditions

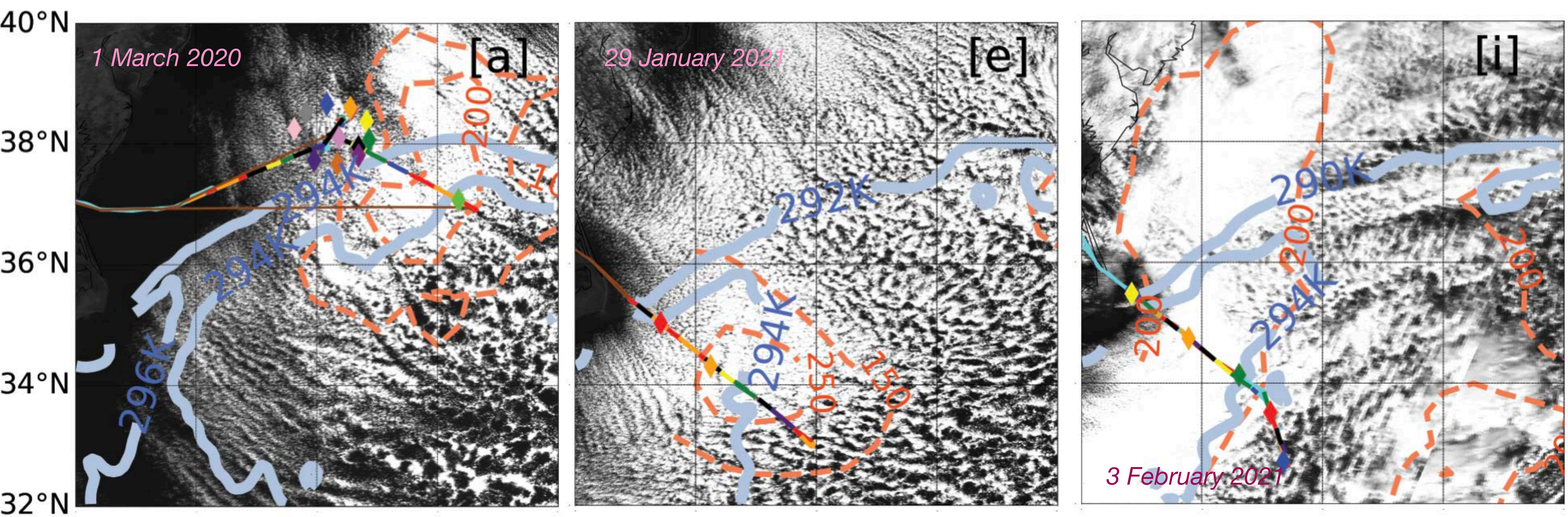
flight-maxima LWPs: 80-250 g m^{-2} (MODIS)

cloud top temperatures flight-minima: -5 to -15 ^oC

in-situ flight-maxima N_d *: 500-1540 cm^{-3}

=> examine the *in-situ* ice microphysics for dependencies

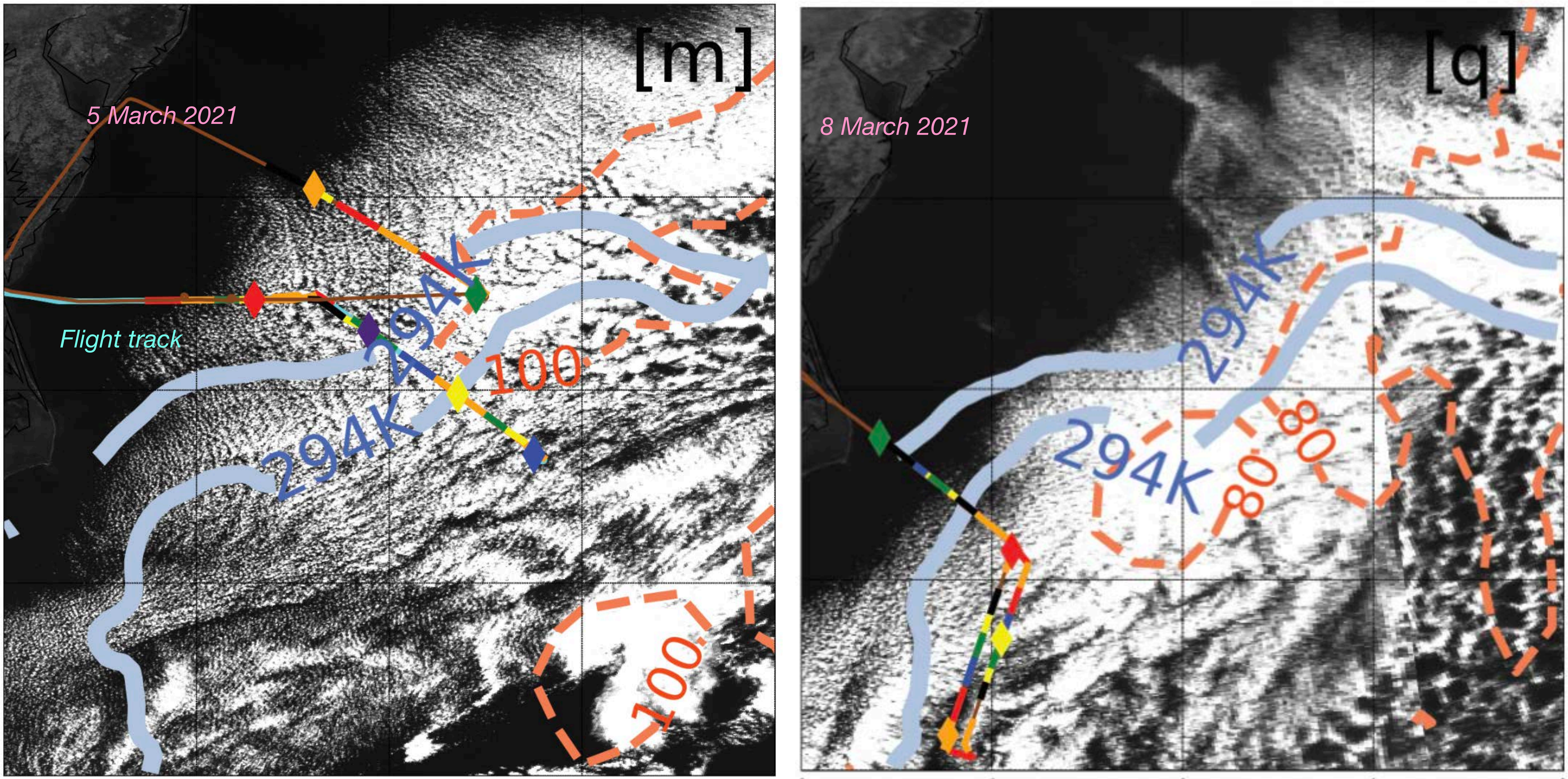
a framework



Blue- SST; orange - MODIS LWP

*continental aerosol outflow; ***Painemal et al 2021 JGR; Tornow et al 2021 GRL.***

in-situ near-cloud-top effective radii only reach 9 micron at best.



Blue- SST; orange - MODIS LWP

What we have learned #1:

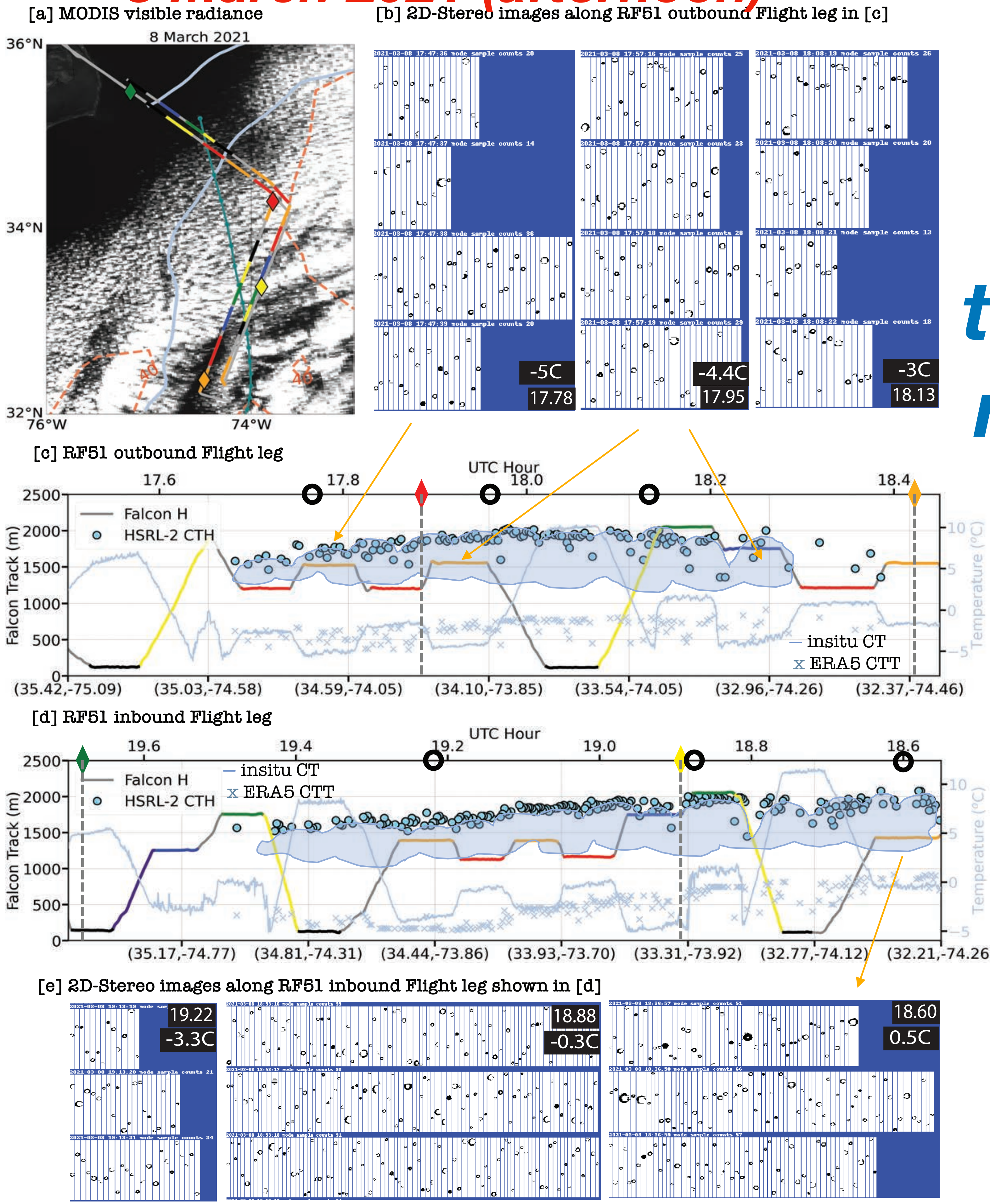
Wintertime cold-air outbreak clouds over the western Atlantic are not ice-deprived

4 out of the 5 cases already contained ice as soon as clouds developed

This despite cloud top temperatures > -15C, and small dropsizes

Original premise that clouds start all-liquid then transition to mixed-phase thrown out the window

8 March 2021 (afternoon)



the one flight with no evidence of ice

$$\overline{N_d} = 1000 - 1100 cm^{-3}$$

$$T_{ct} \sim -5°C$$

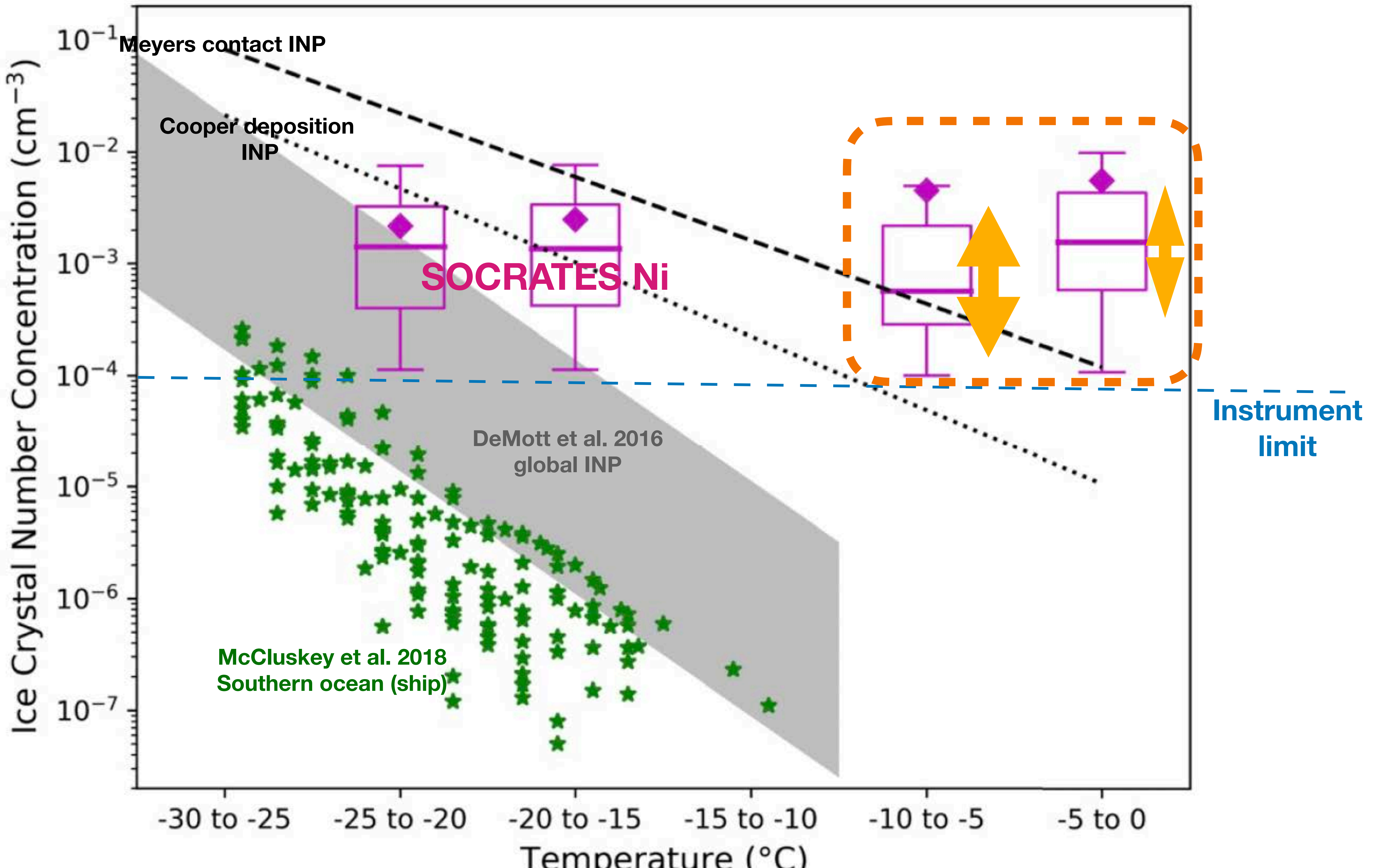
RSP LWPs <~ 80 g m^{-2}

Surface wind speeds low (~8 m/s)

No near-surface rain

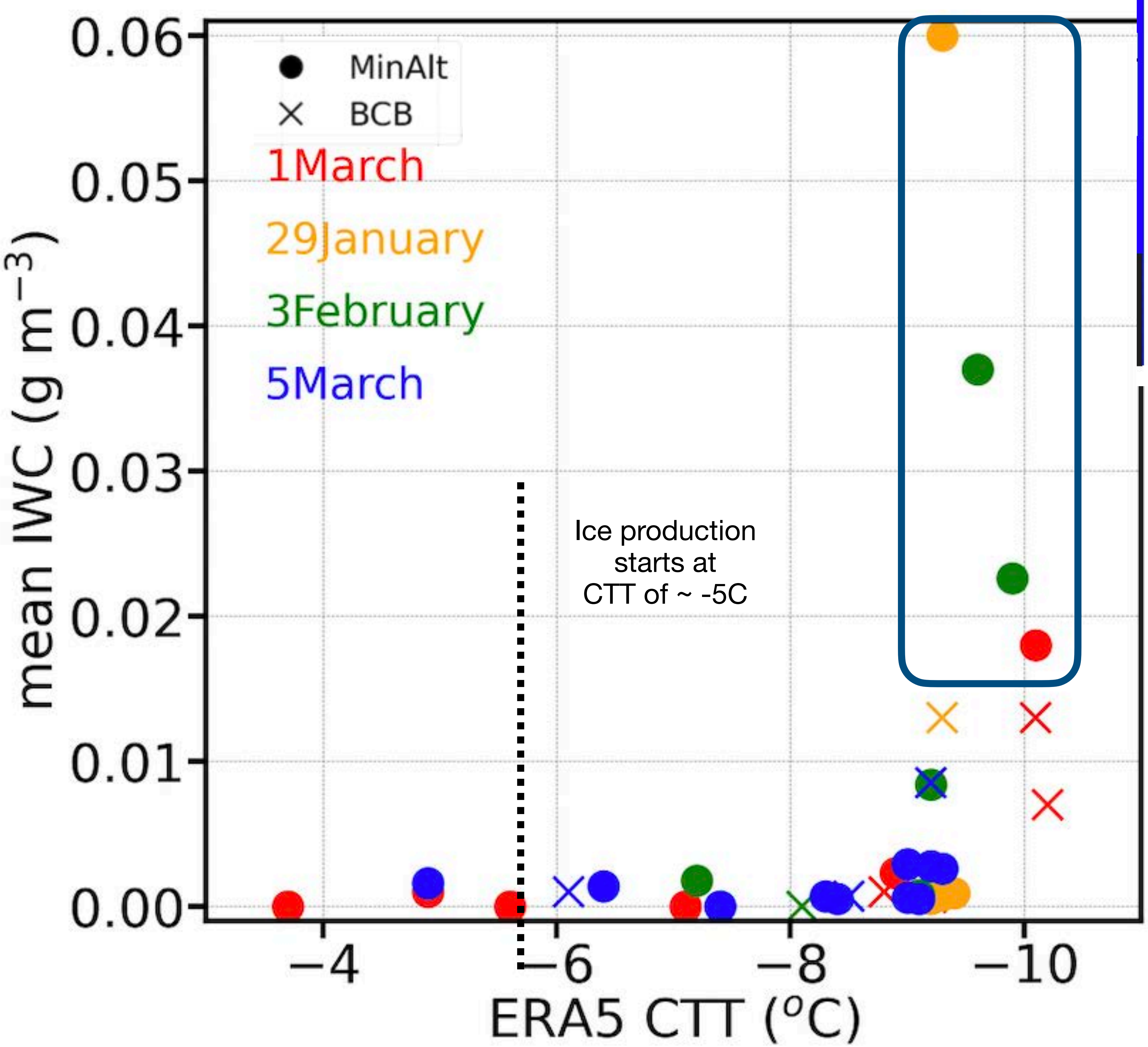
(cloud clearing most likely through cloud top entrainment)

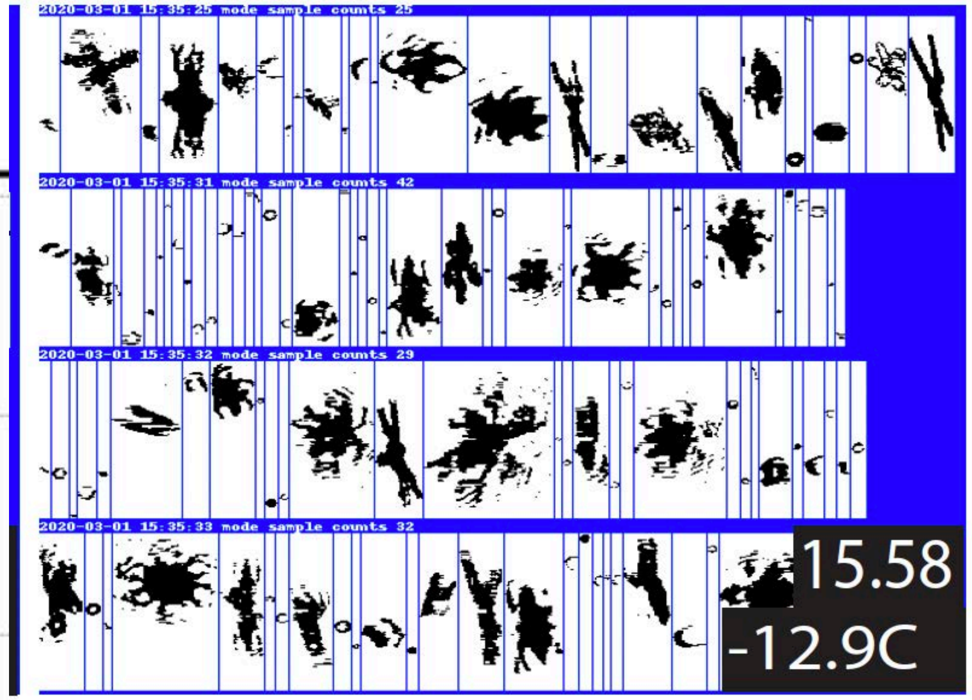
ACTIVATE ice crystal number concentrations indicate secondary ice production, on par with southern ocean values



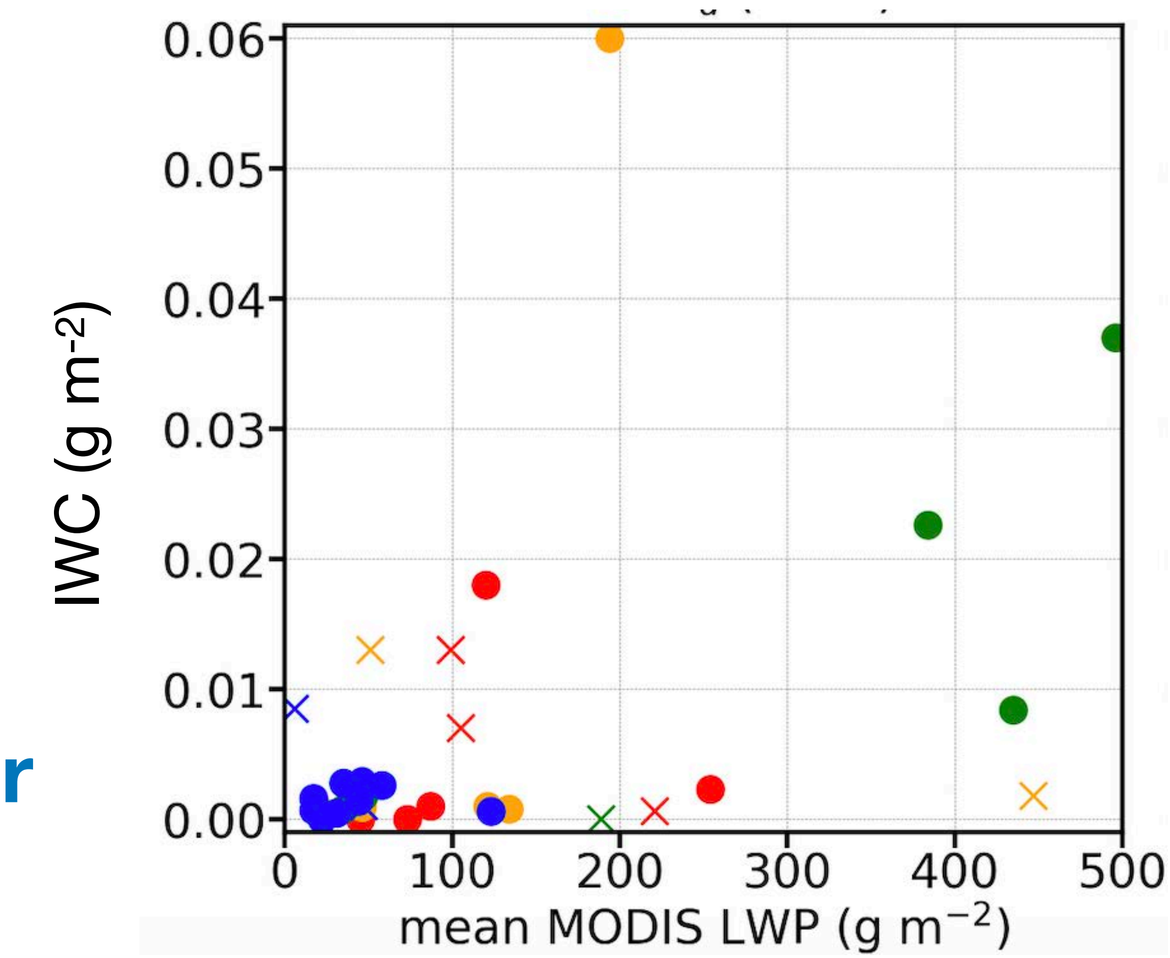
Atlas et al., 2022, AGU Advances

Ice water contents are higher when vapor diffusional growth dominates, particularly dendritic growth

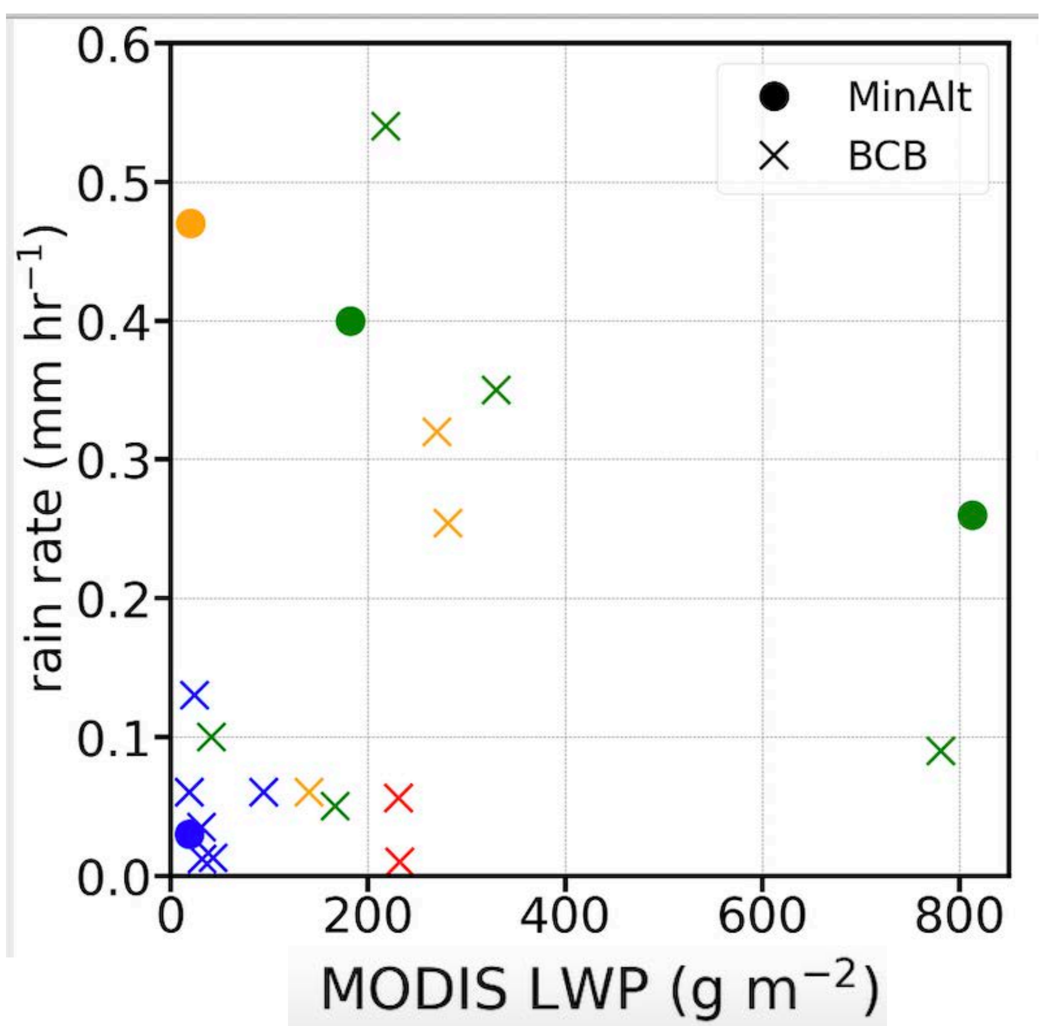


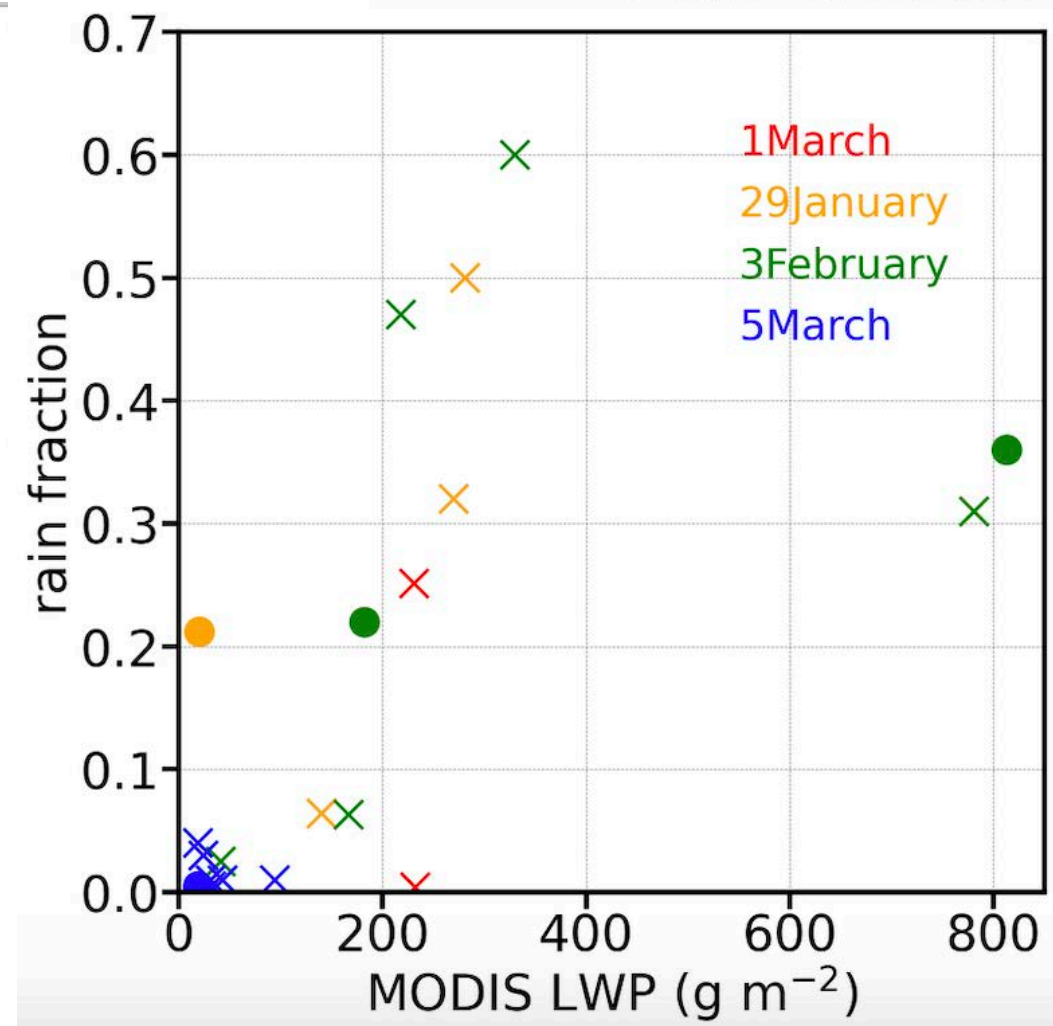


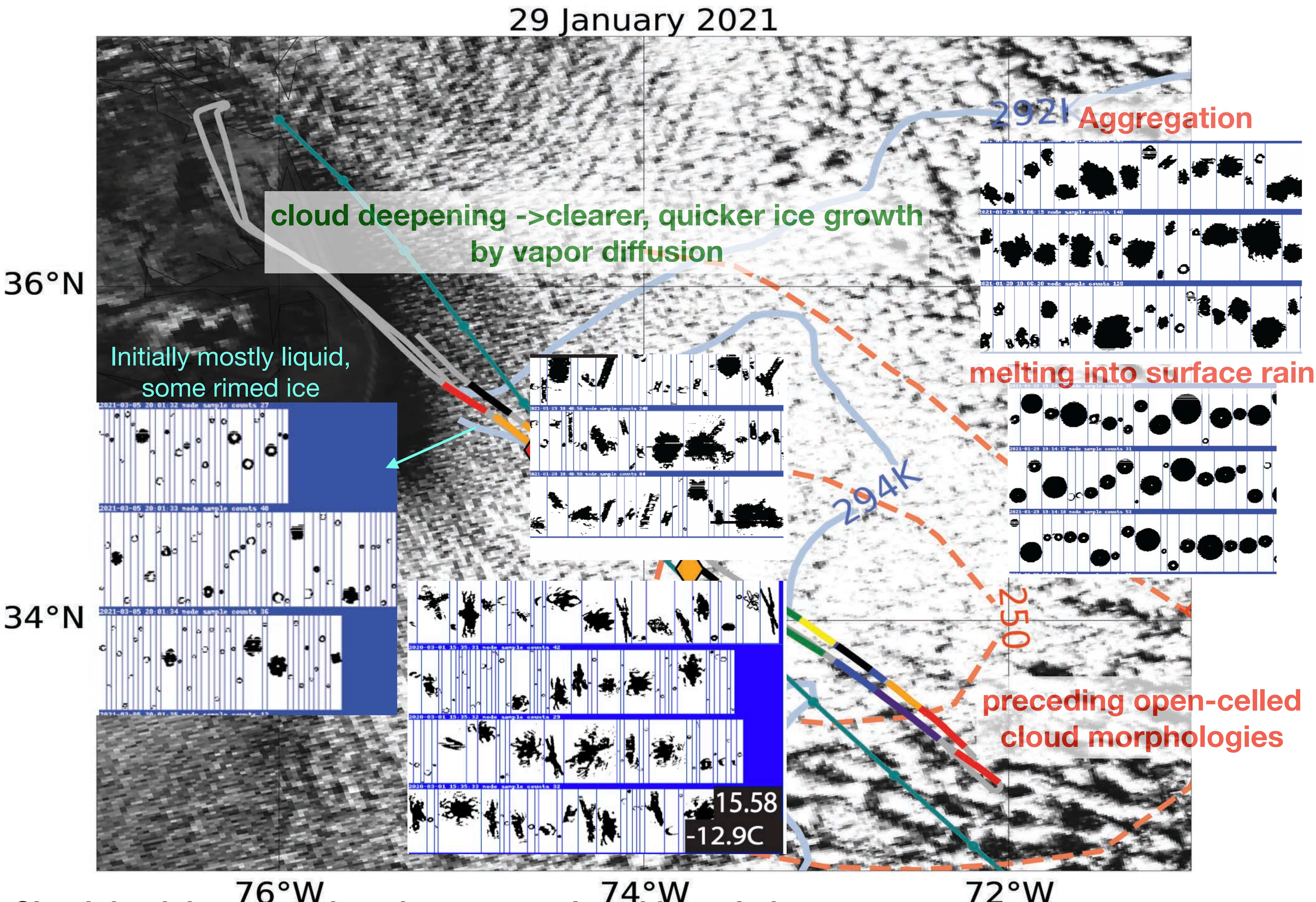
Ice water contents are higher for deeper clouds (colder tops), producing more liquid



rain (if present) rates are also higher for higher LWPs





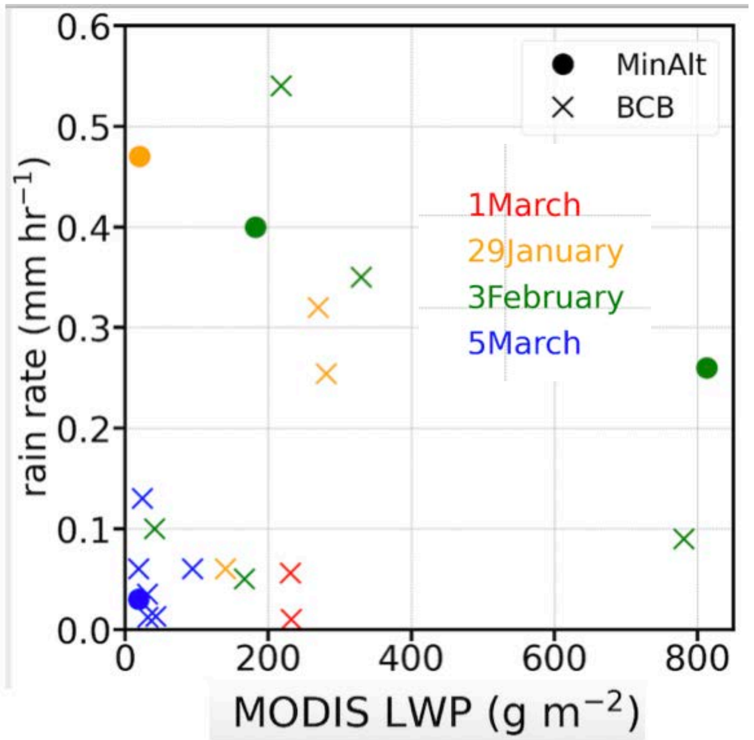


Cloud depth becomes the primary control on this evolution

High N_d almost a given (extending the closed cells)

pzuidema@miami.edu

Because the MODIS LWPs can reach up to 800 g m^{-2} we are also investigating the profiles to put MODIS on a better footing



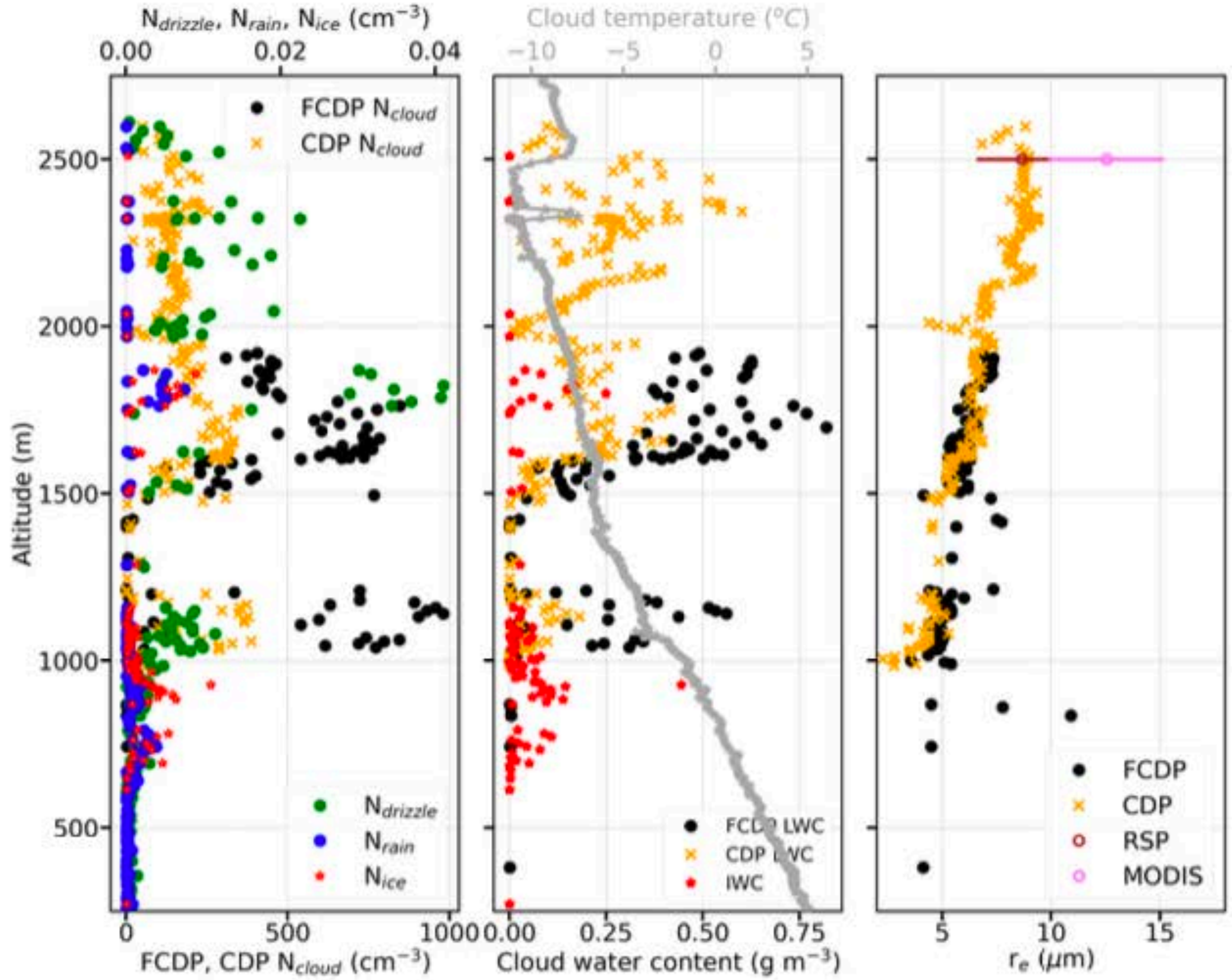


Figure 11. *In situ* February 3, 2021 morning RF44 descent at 33.91°N, 73.07°W profiles. Same conventions as in Fig. 5. FCDP failed in upper cloud layer. CDP N_d not yet corrected.

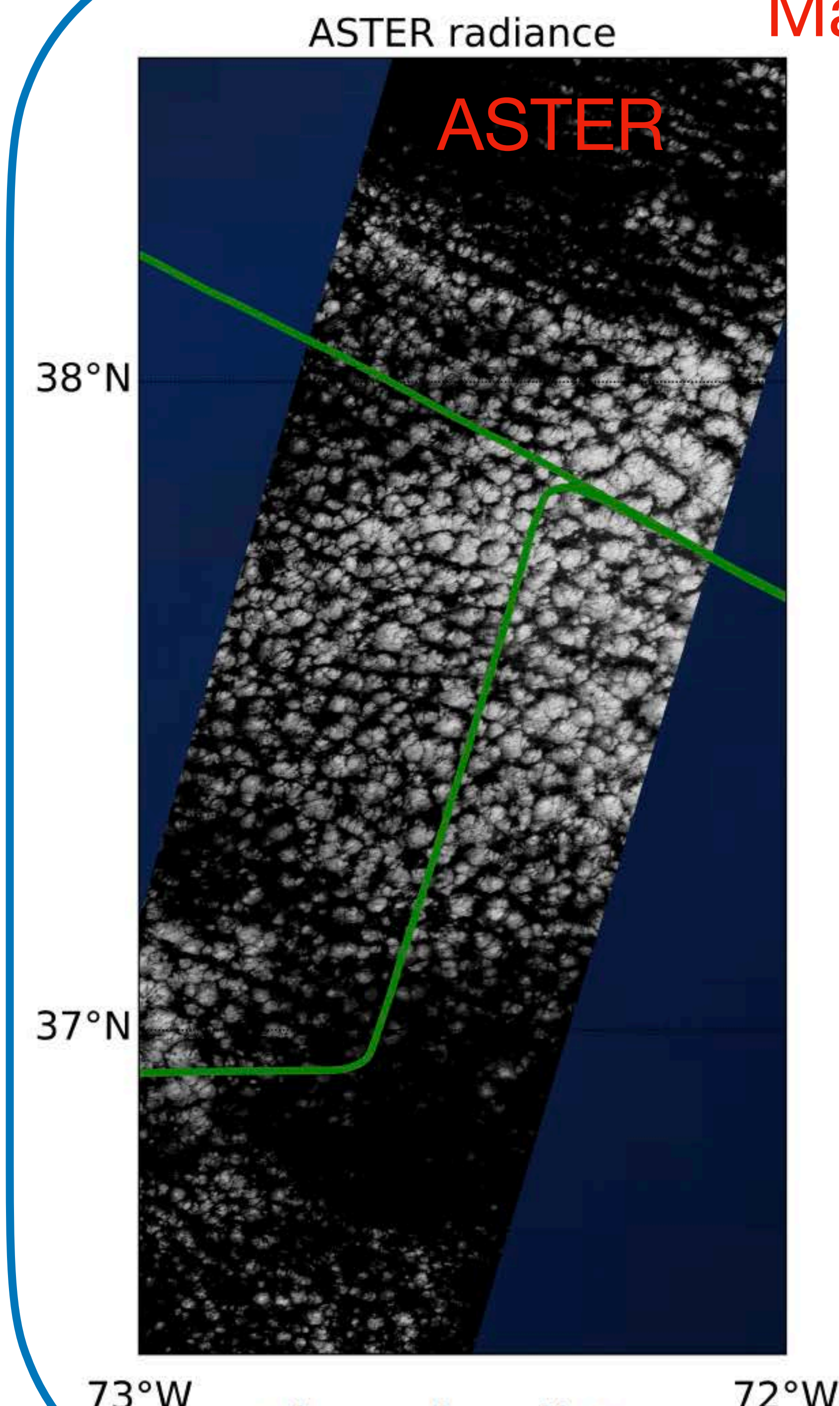
The 5-case CAO analysis is fairly mature.

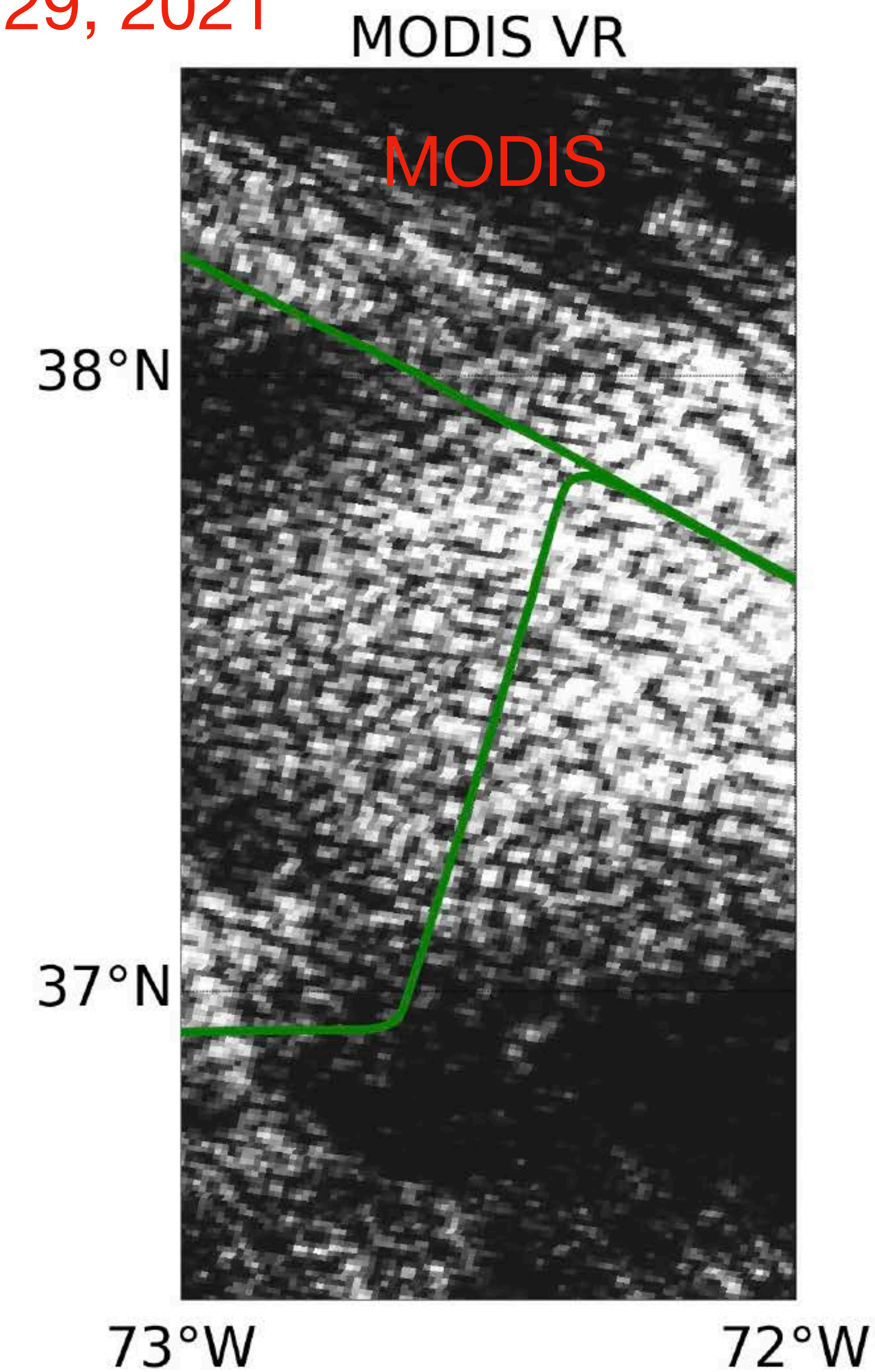
Plan is to extend the profile analysis to all the wintertime ACTIVATE cases as a remote sensing assessment

Shares some goals with the ASTER assessment
(For which we hope to say something about remotely-sensed microphysics as a function of cloud macrophysics)

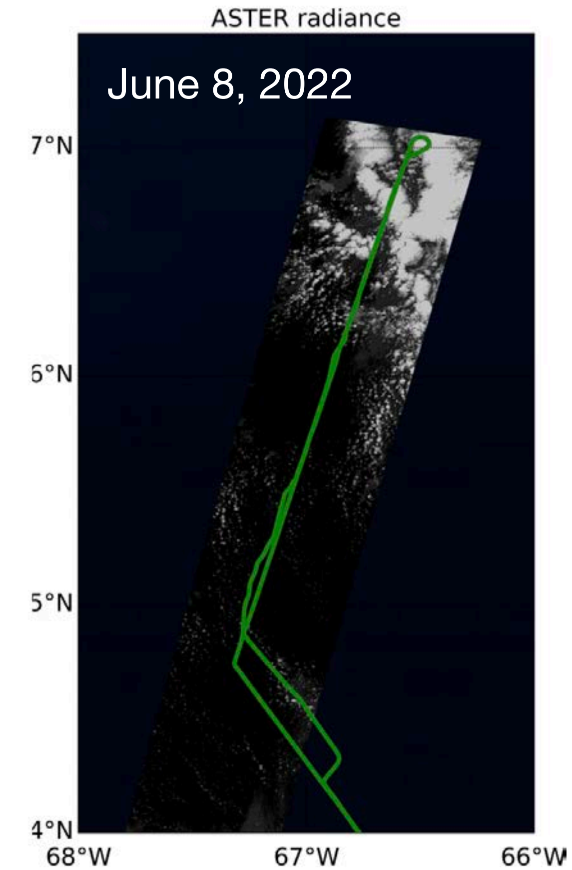
Three ASTER* under flights with broken, low clouds & minimum upper-level cloud

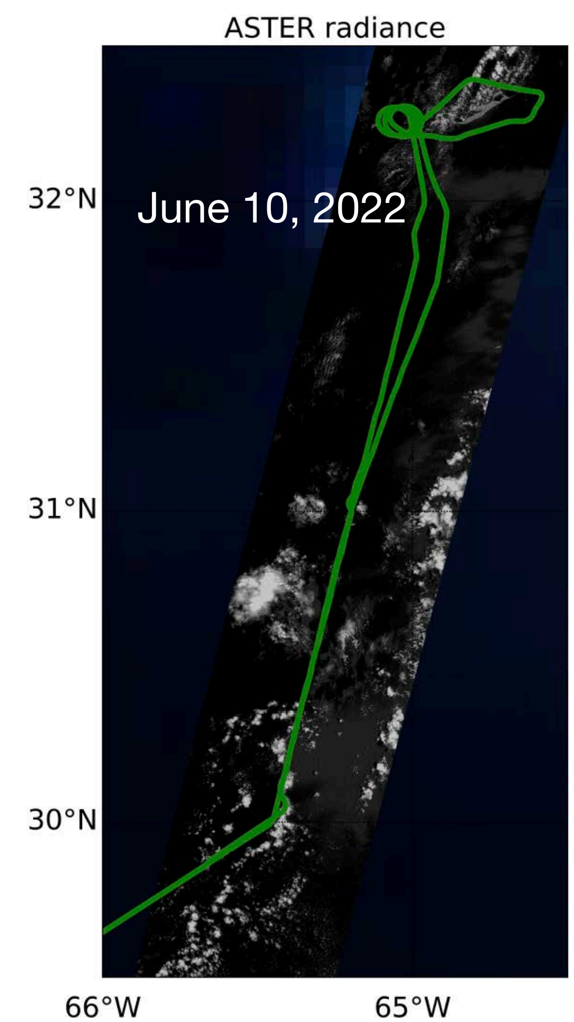
March 29, 2021





Closed cell Scu





* Advanced Spaceborne Thermal Emission and Reflection Radiometer

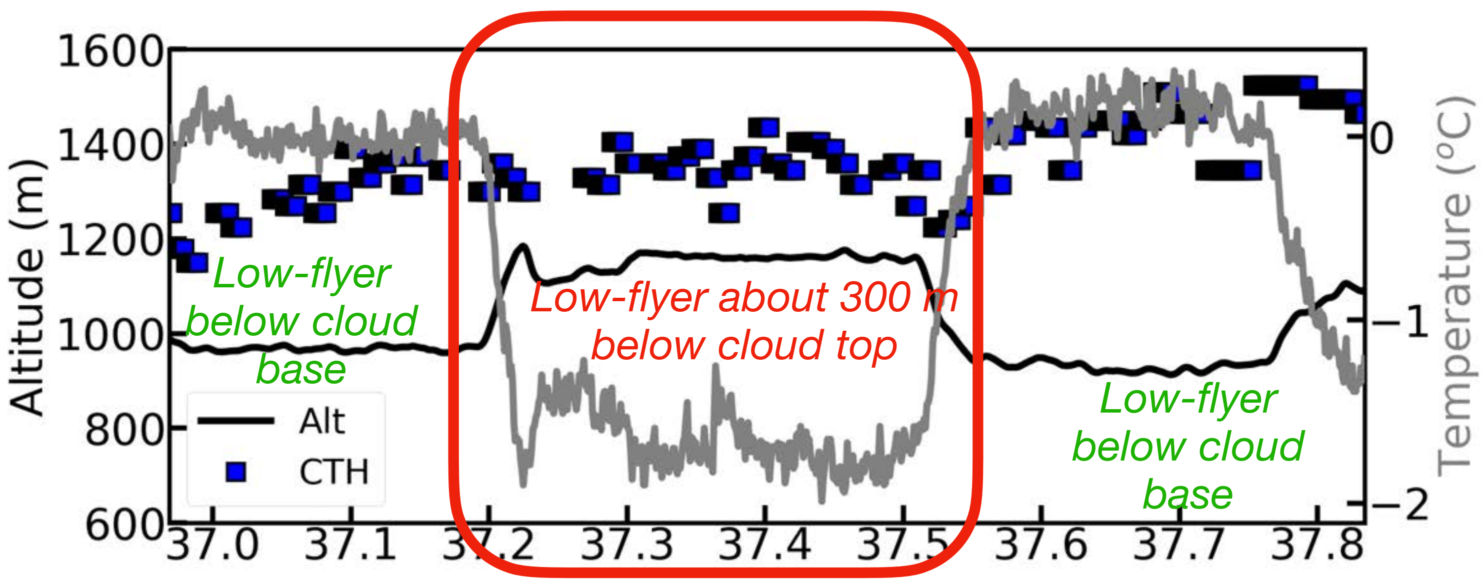
- 15-m spatial resolution cloud mask over a 60 km swath, based on 3 visible nadir bands (0.52- 0.86)+ 11micron (90m resolution)

- No ASTER microphysical retrievals

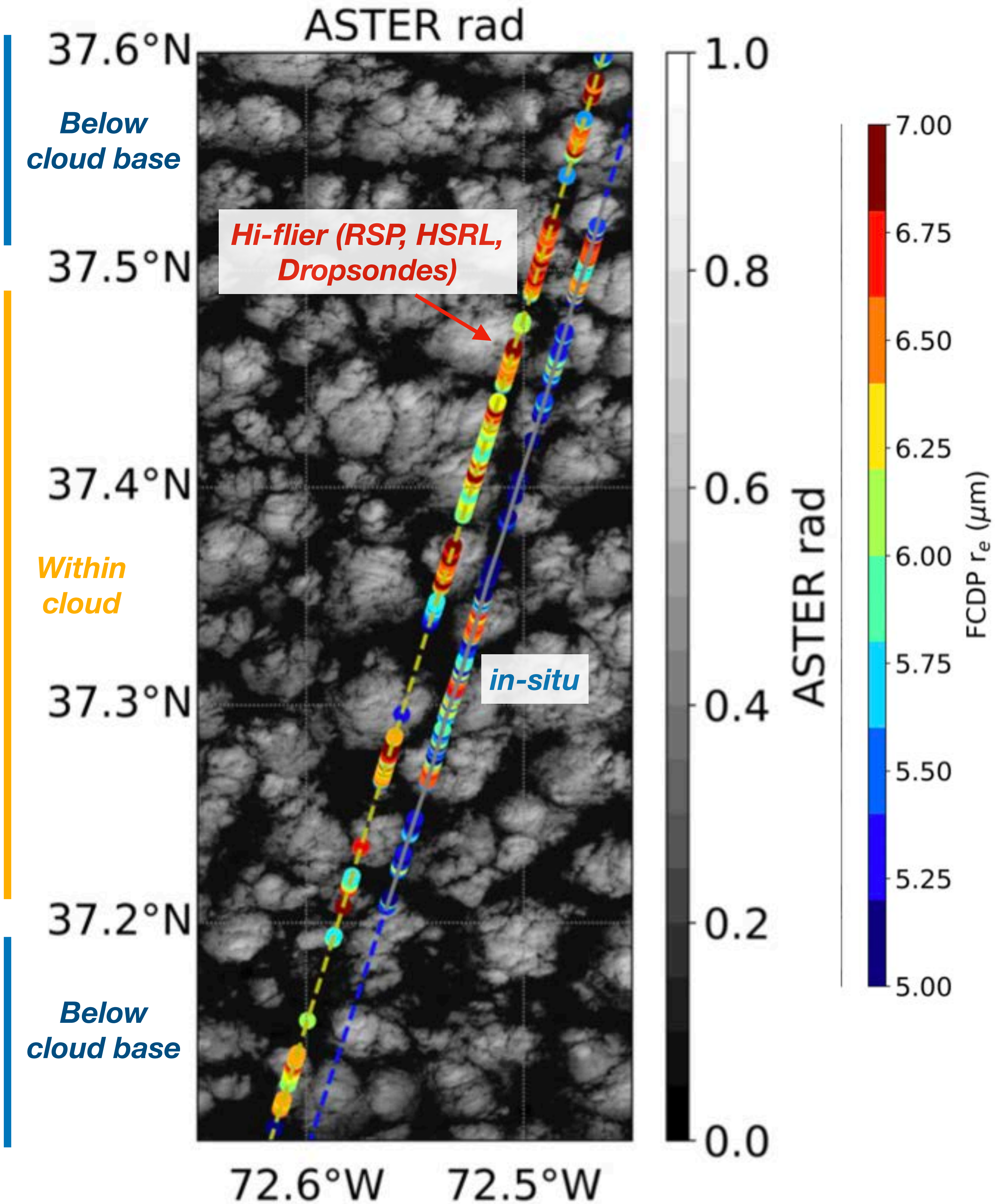
- RSP derives cloud optical depth (τ), effective radius (r_e) using a polarized cloud bow retrieval @ 0.863 micron

- N_d, LWP derived using $N_d = 1.4067x10^{-6}[cm^{-1/2}]\frac{\tau^{1/2}}{r_e^{5/2}}$ and $LWP = \rho_w \frac{5}{9} r_e \tau$ (Painemal and Zuidema, 2011), ‘confident cloudy’ MODIS cloud mask

- *in-situ* N_d from FCDP (1.5-50 micron) and CDP



March 29, 2021, 15:37-15:50 UTC
~50 km span

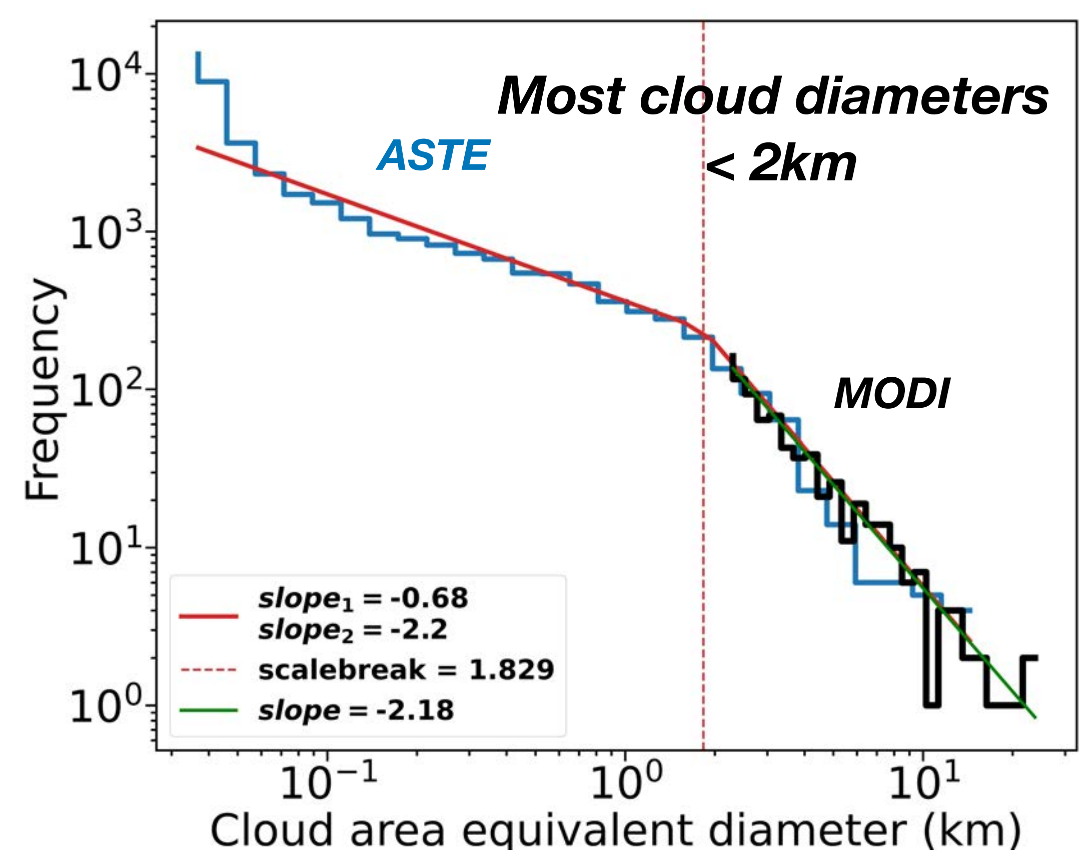


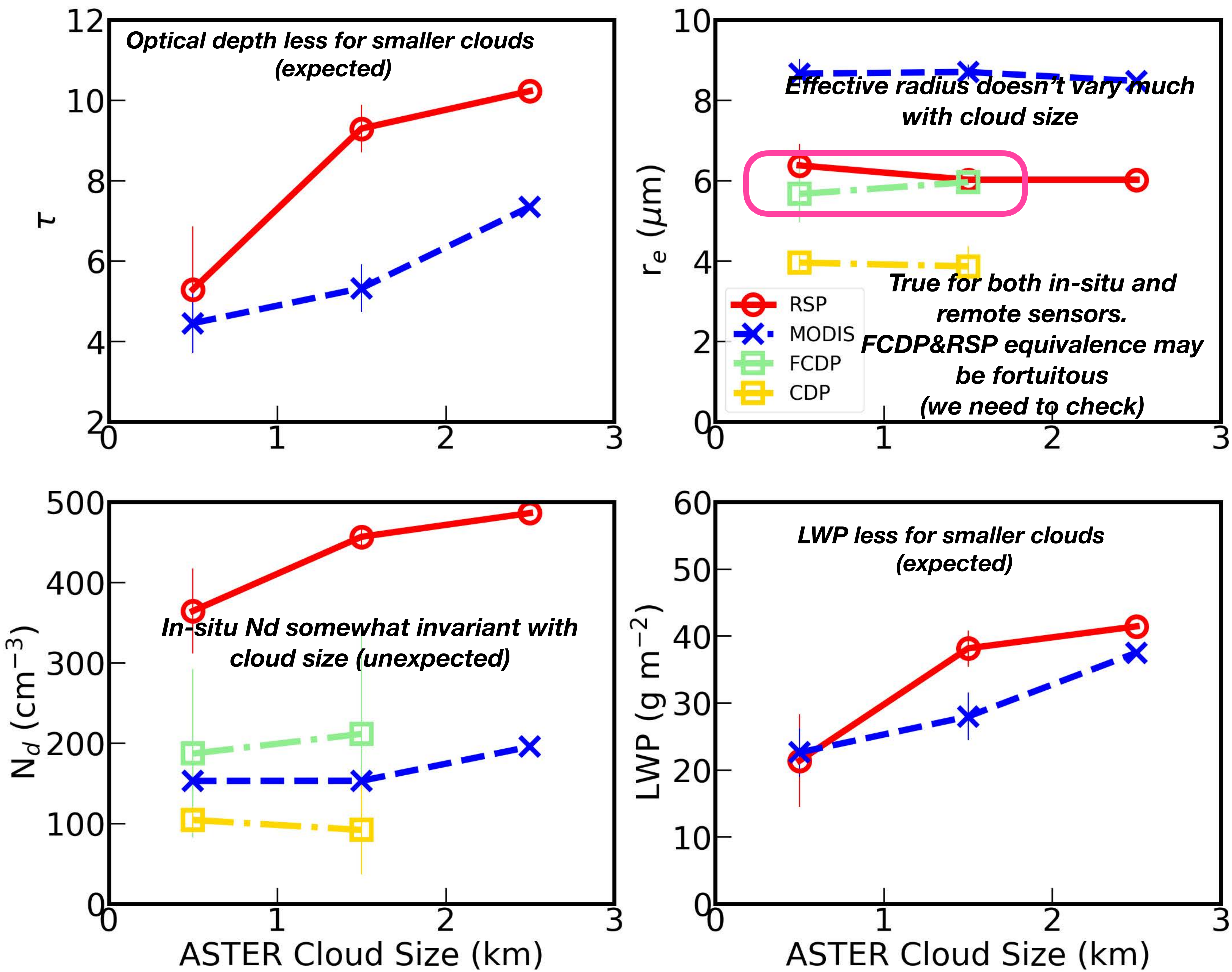
Includes in-situ corrected time offset; 5 minutes diff from ASTER, 2km offset between the two planes

Not a perfect colocation but: - a homogeneous aerosol & cloud environment:

- $N_{aerosol}$ (>100 nm) of 200-250 cm^{-3}
- H_{ct} of 1.2-1.4 km, T_{ct} > -10 ^{0}C
- Little (no?) rain

=> statistical relationships okay



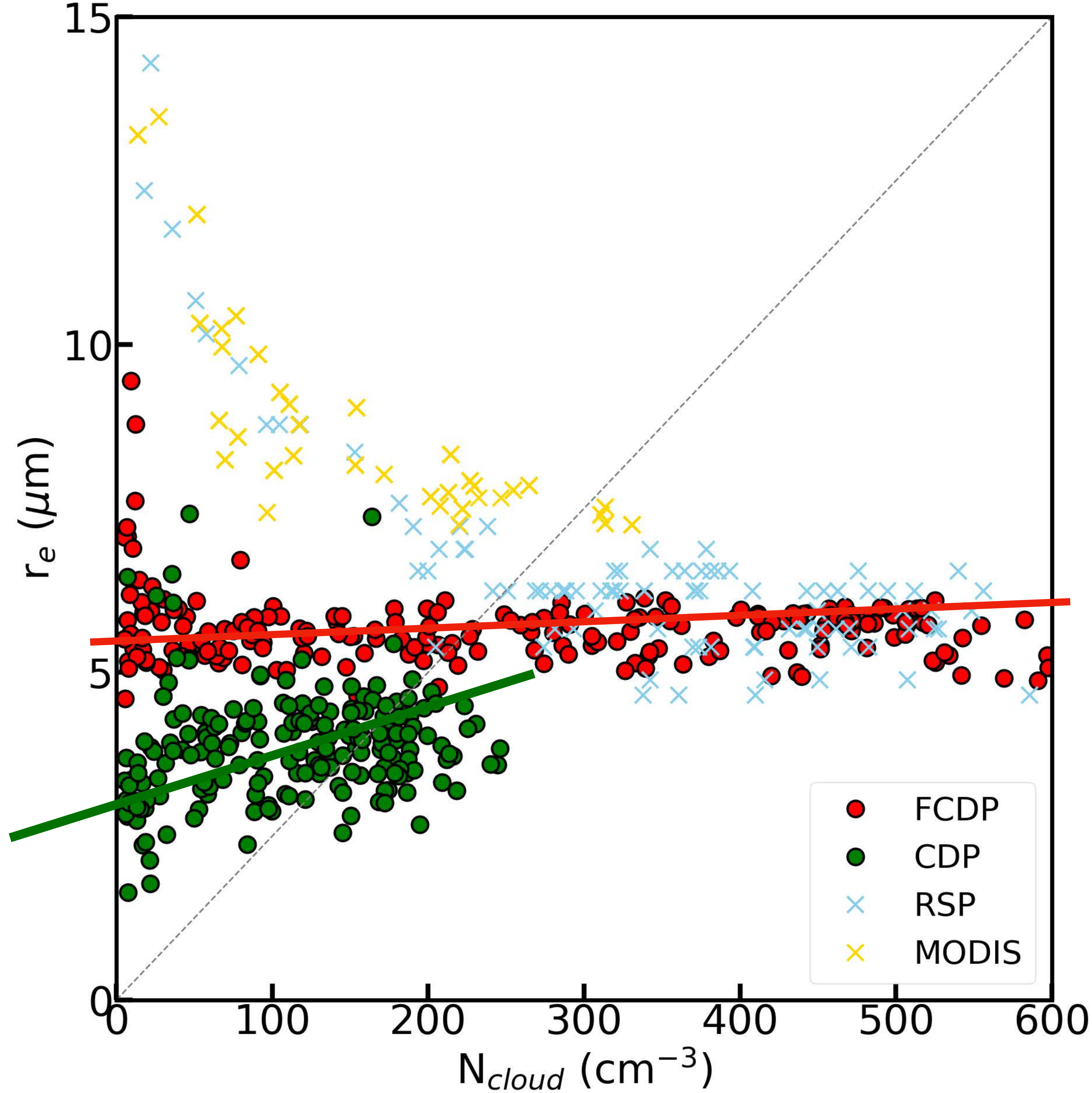


Based on 5 10-km domains

In-situ probes show Nd, re are [slightly] positively correlated, suggesting growing inner cloud cores & dissipating edges [but still need to put that on firmer ground]

While remote retrievals suffer at the edges, RSP extends to smaller cloud sizes/higher Nd

Good correspondence between RSP, FCDP Ignores 300m of vertical Displacement



can UC-12 camera imagery be used to extend to more scenes (10 m spatial resolution, ~15 km swath)?

Unclear, might at the least need to identify some useful cases