Overview of post-frontal shallow clouds over the Southern Ocean

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Supercooled water (SLW) occurs regularly in post-frontal shallow clouds over the Southern Ocean (SO)

What processes control the depth, amount and longevity of supercooled water over the SO?

Does the pristine nature of SO mean properties of SO clouds differ from those of clouds over the Arctic?

How do our short-term field observations help inform remote sensing retrievals?

How do our observations aid in development and evaluation of multi-scale modeling studies?

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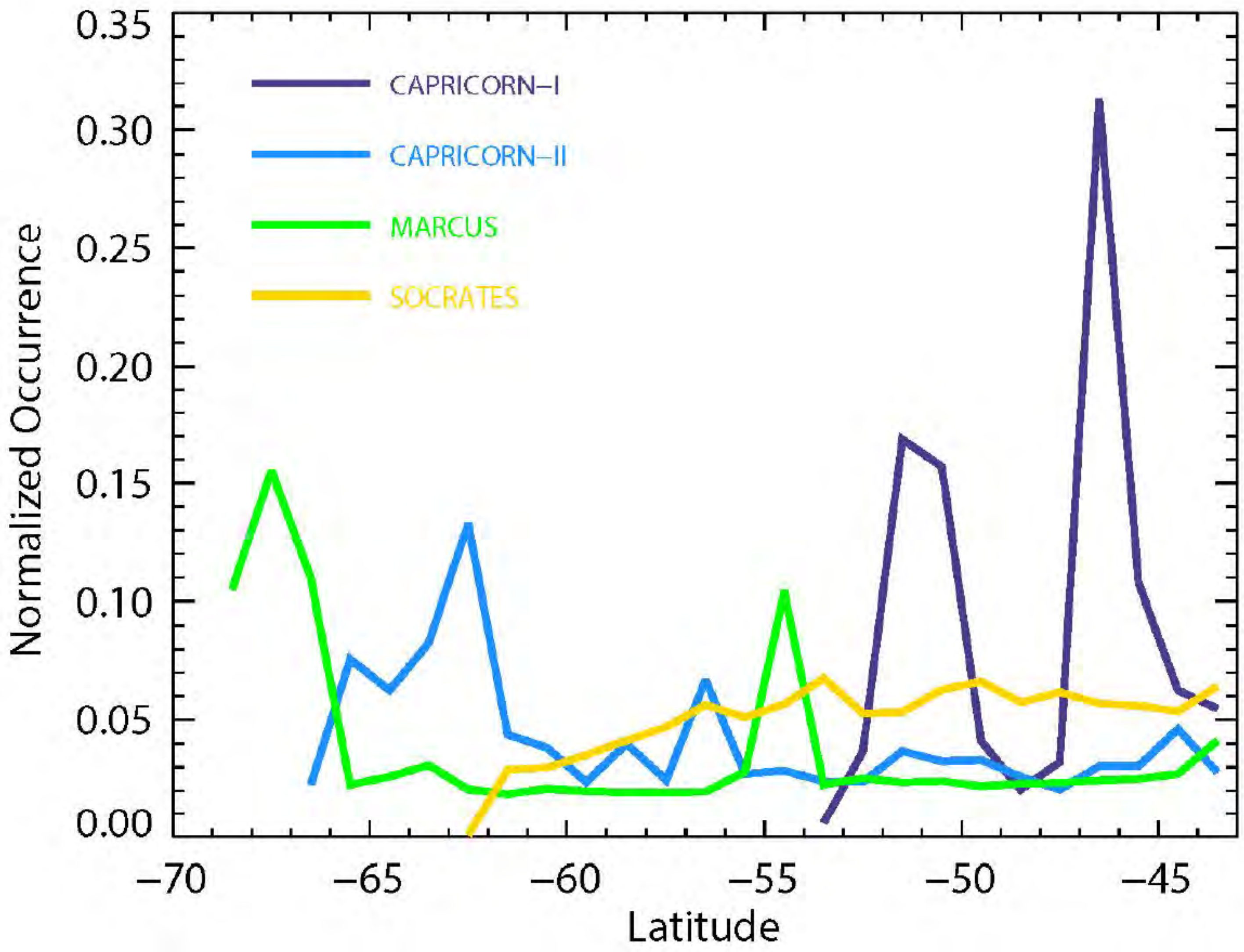
Synergy between projects



Campaign Advantages

MICRE: Long seasonal sample

CAPRICORN: More detailed oceanographic, aerosols & surface flux measurements

MARCUS: Seasonal cycles poleward of 60˚S

SOCRATES: Process studies and remote sensing evaluation

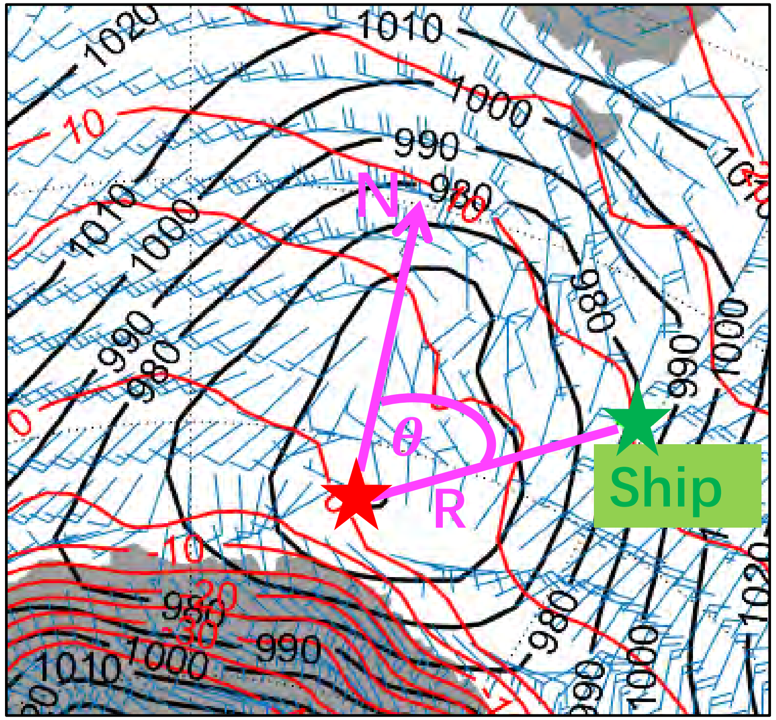
Clouds: Ship- and Ground-based Remote Sensing

- **Ding/McFarquhar VAP segregate data by environmental, geographic & meteorological conditions observed during MARCUS to identify controls of SLW**

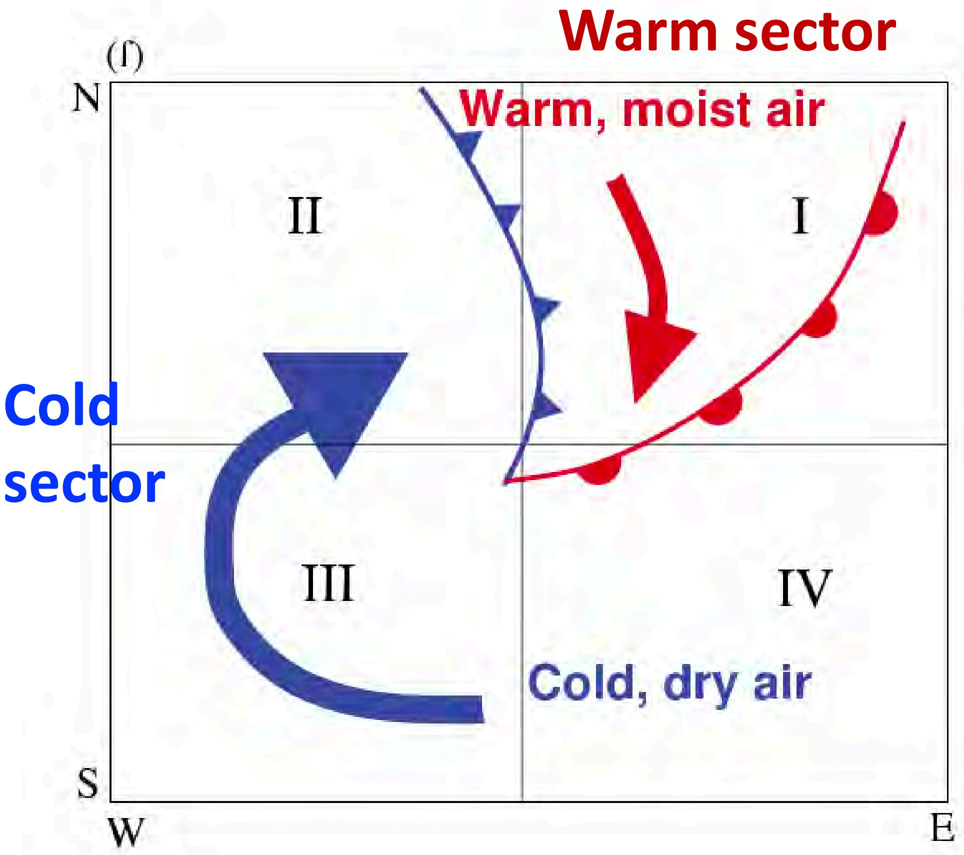
Variable	Source
Sea surface temperature (SST)	Infrared Thermometer
Cloud base temperature (CBT)	Cloud base height (CBH) from Ceilometer merged with T profiles from 6hourly sounding
Precipitating /non-precipitating clouds (PC/NPC)	Maximum column radar reflectivity dBZ_{max}>-15 dBZ is PC, -30<dBZ_{max} <-15dBZ is NPC (Huang et al., 2016)
Coupled /decoupled	$\triangle c_b$ = CBH – LCL, $\triangle c_b$ >300m is decoupled & $\triangle c_b$ <300m is coupled (Comstock et al., 2005)
North/ South of the ocean polar front (NPF/SPF)	Daily SST from AVHRR (Dong et al., 2006)
Air mass origin westerly/ easterly (W/E)	48hrs HYSPLIT back trajectory simulation
Location relative to cyclone	Sea level pressure (SLP)

4. Relative location in cyclone system

Conceptual models:

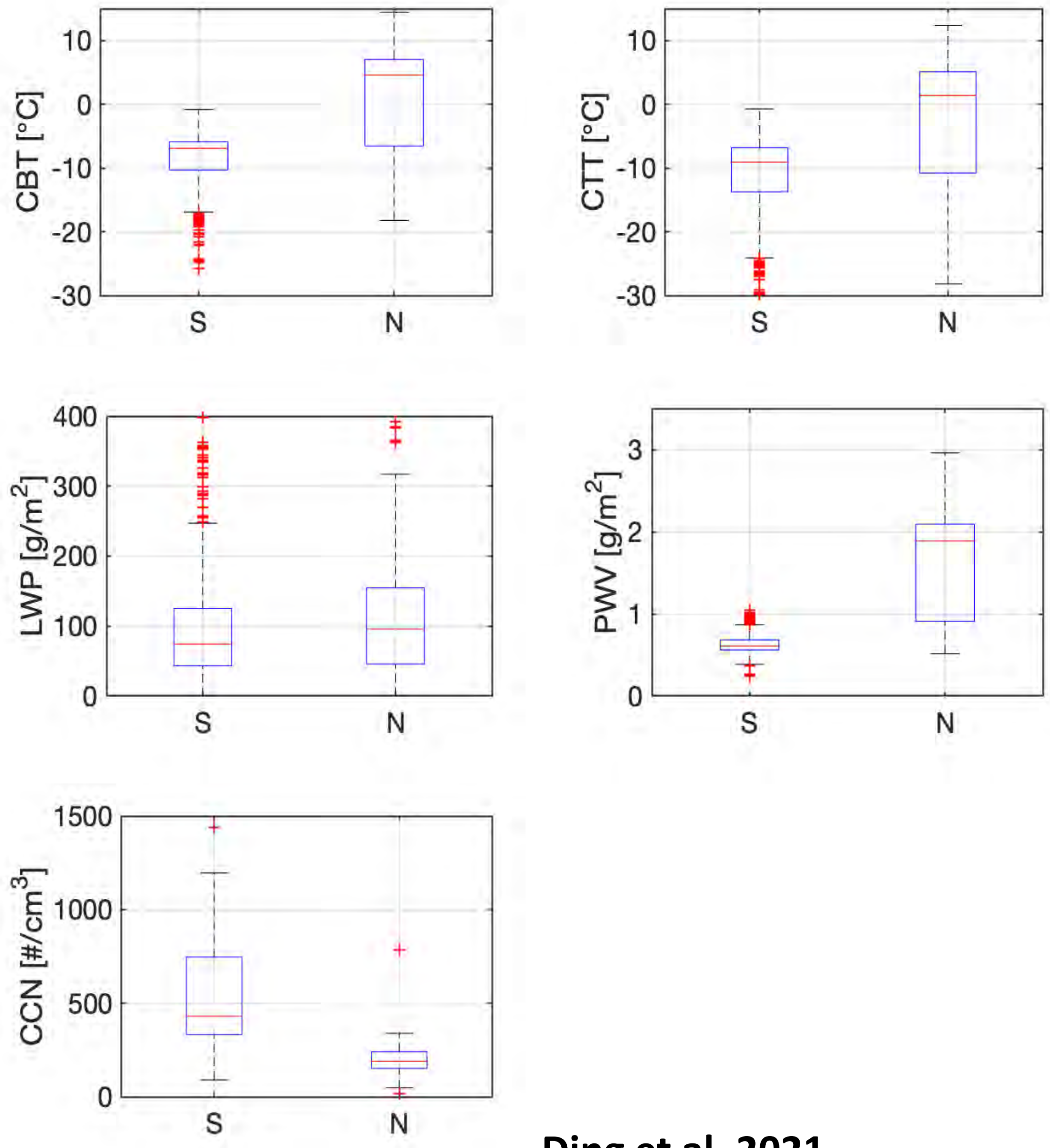


Ding et al. 2021



Bodas-Salcedo et al. (2016)
Lang et al. (2018)

Clouds: Ship- and Ground-based Remote Sensing



Ding et al. 2021

- How properties of single-layer, non-precipitating clouds with z_b < 3 km & > 500 km from nearest cyclone center varied whether north or south of 60˚S.

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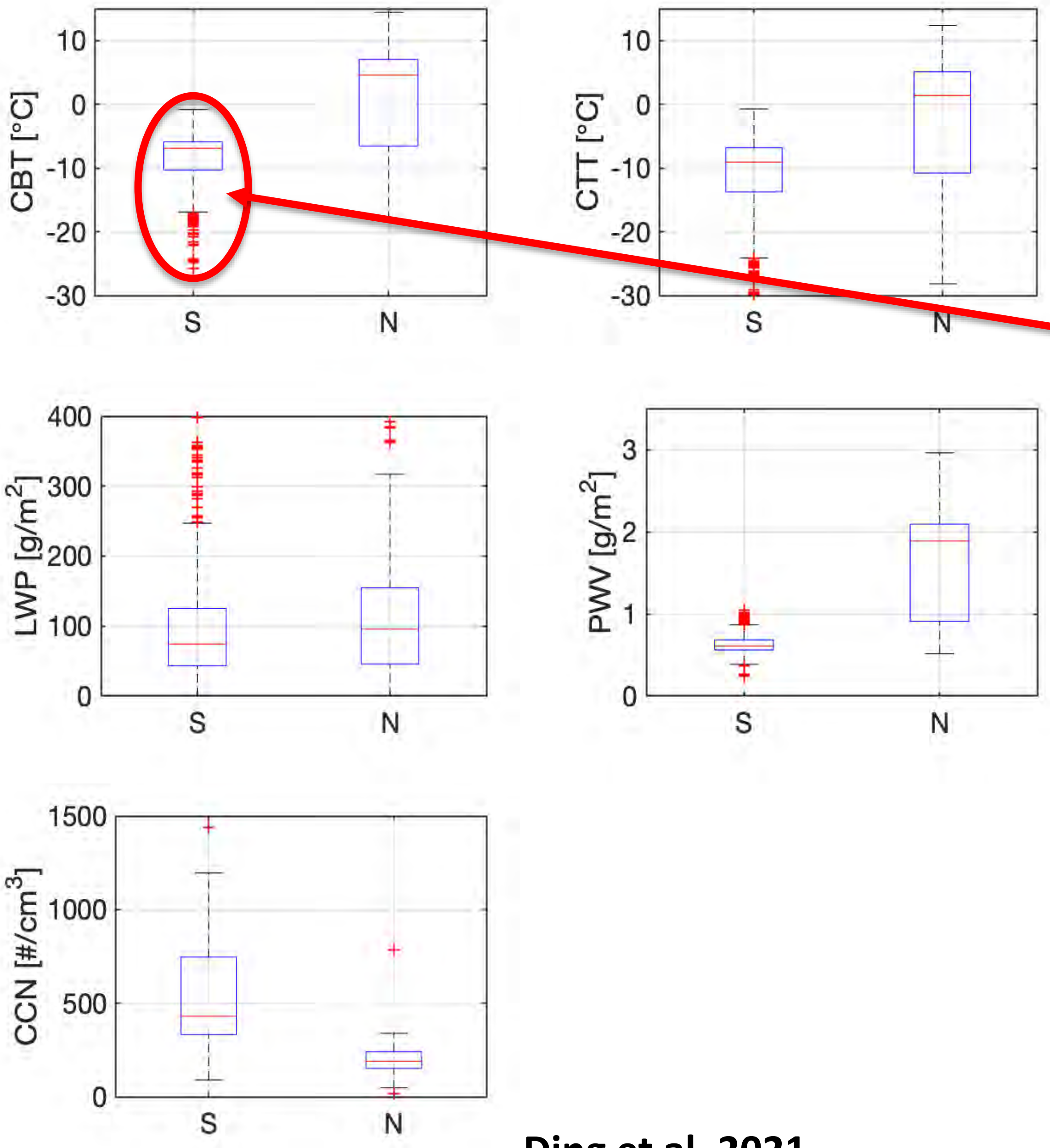

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- Average cloud base T ~ -10˚C S of 60˚S

Ding et al. 2021

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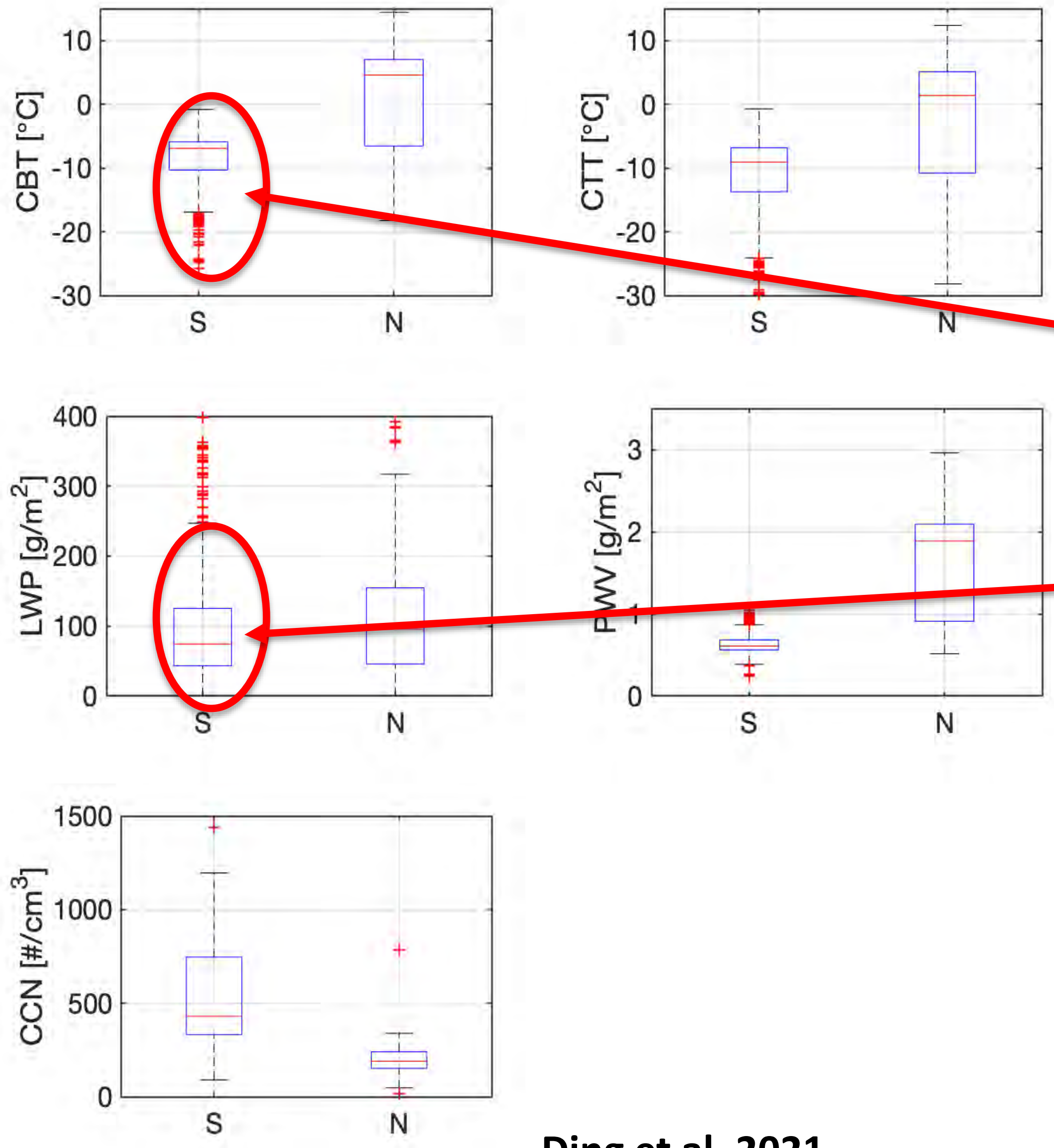

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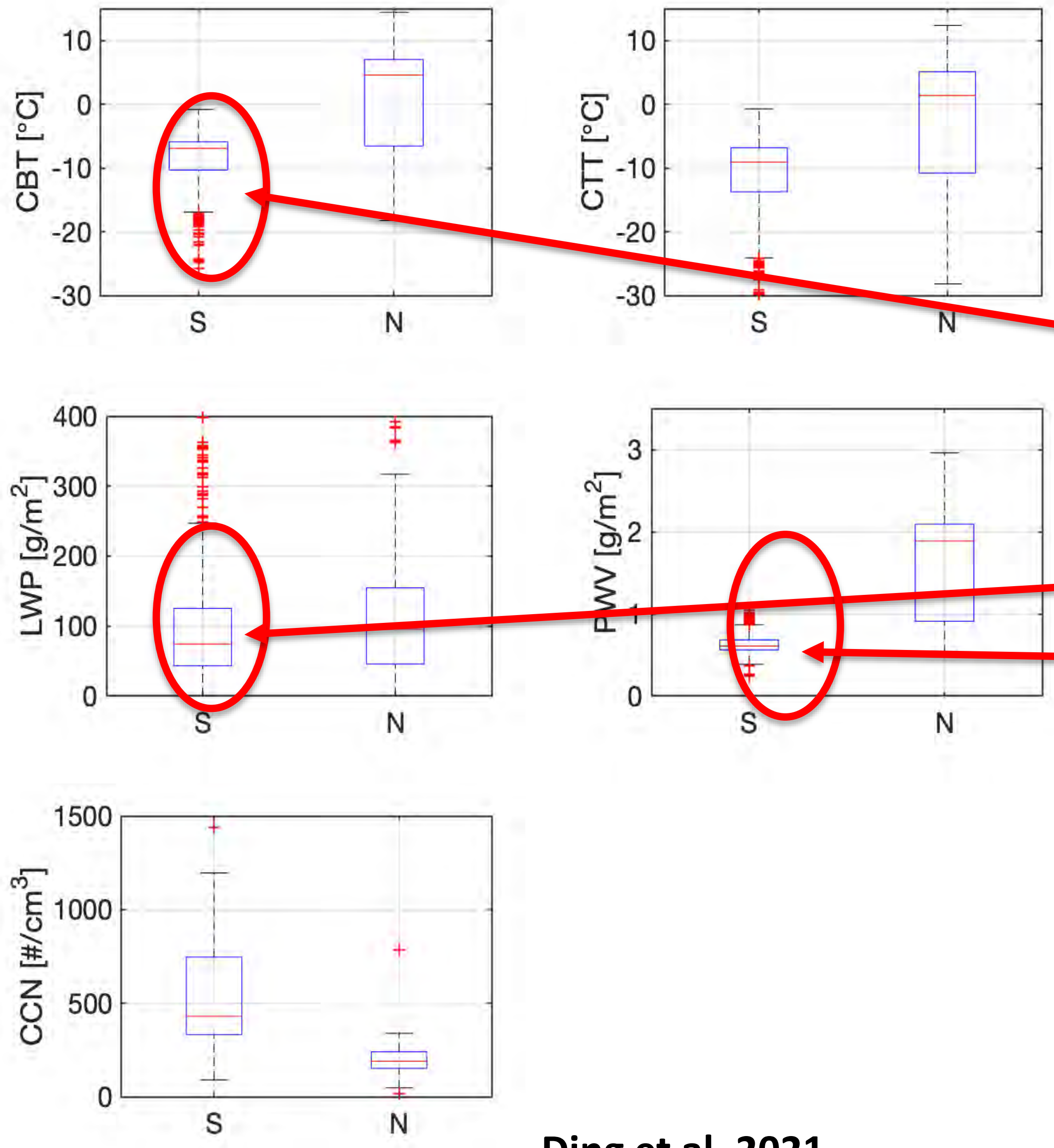

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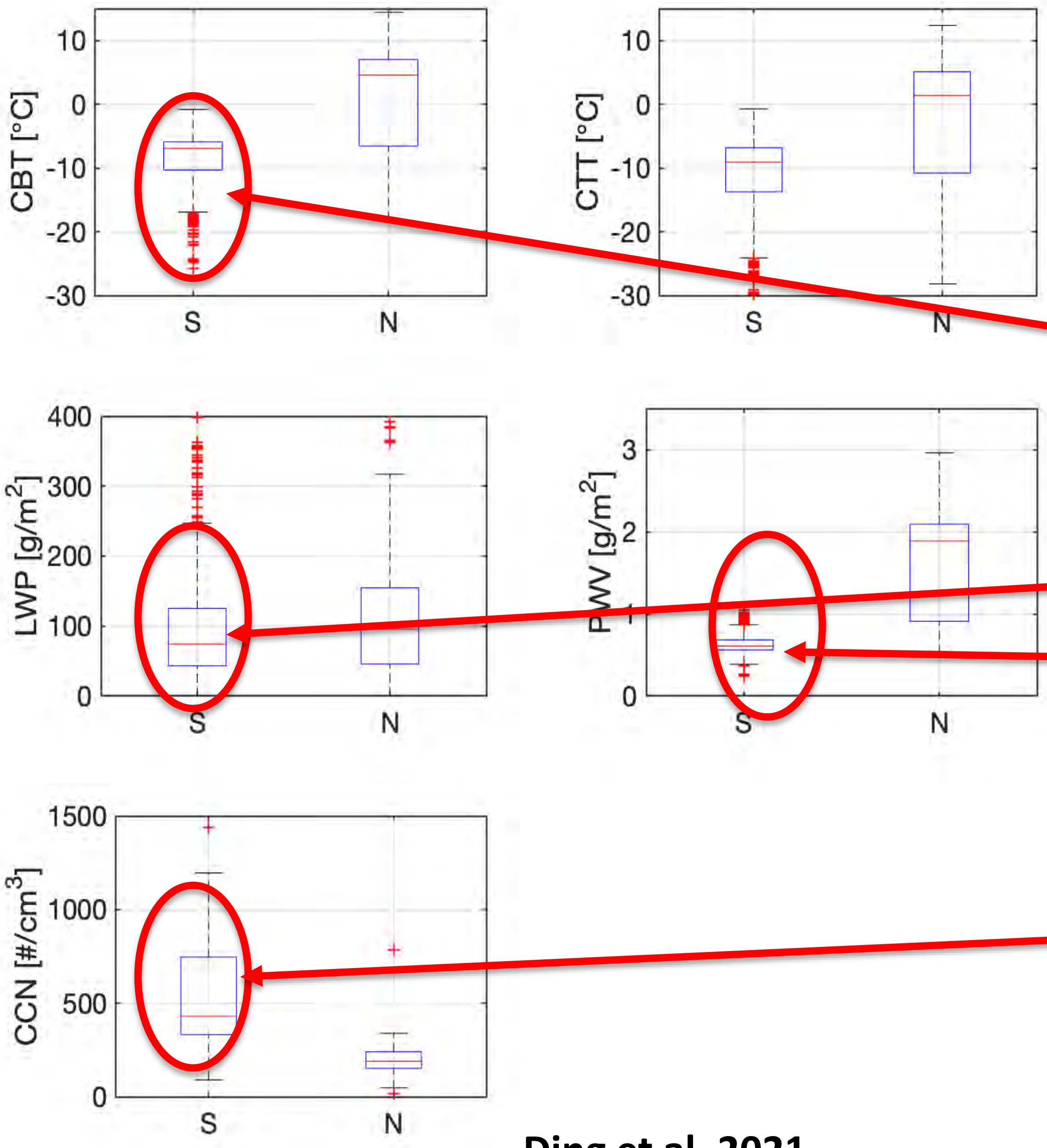

Ding et al. 2021

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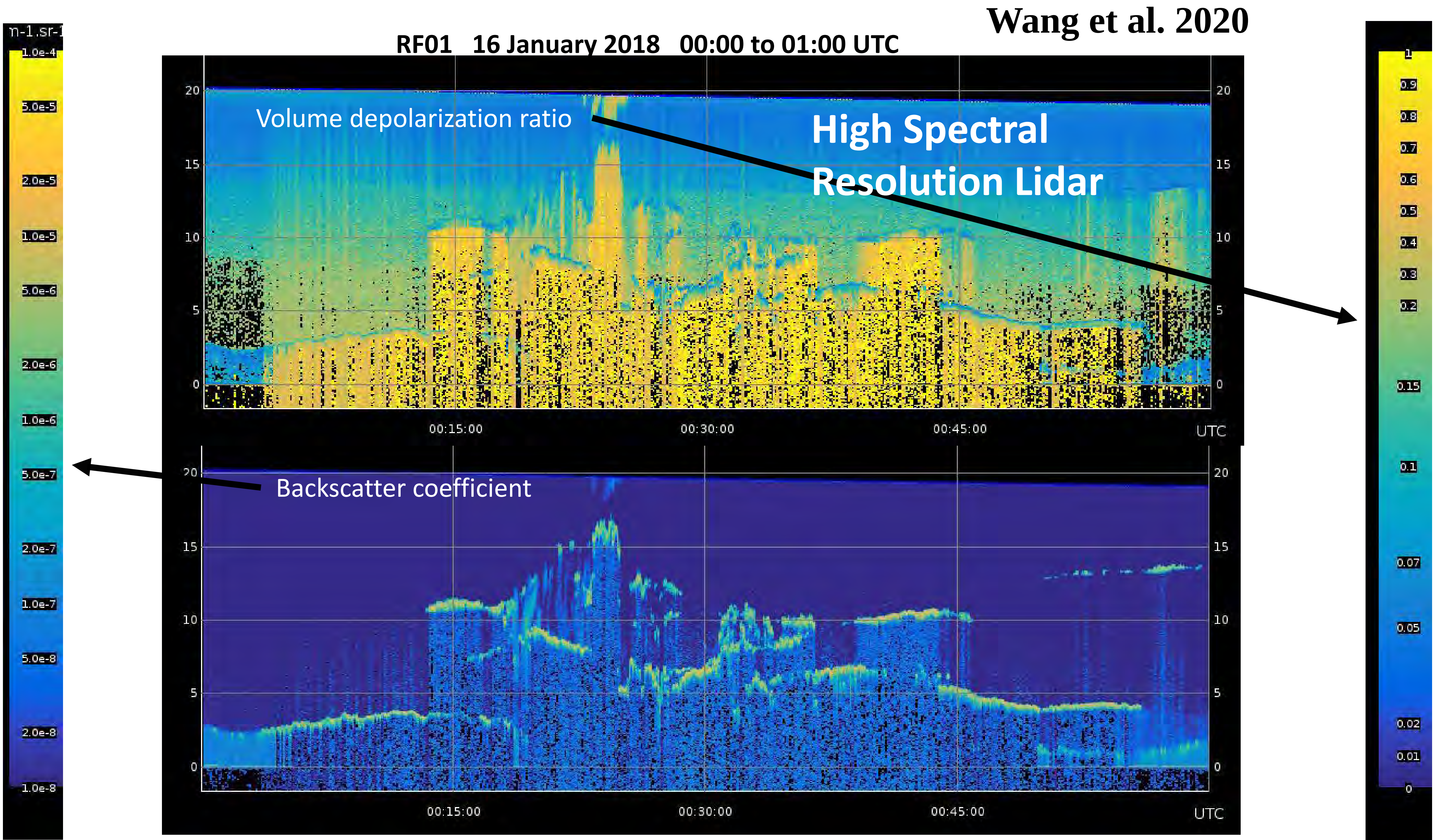
- Average cloud base T ~ -10˚C S of 60˚S → SLW extensive south of polar front even though less precipitable water
- CCN and retrieved N_c peaked in December and appear less south of 60˚S


Wang et al. 2020
RF01 16 January 2018 00:00 to 01:00 UTC
Volume depolarization ratio
High Spectral Resolution Lidar
Backscatter coefficient
m-1.sr-1
1.0e-4
5.0e-5
2.0e-5
1.0e-5
5.0e-6
2.0e-6
1.0e-6
5.0e-7
2.0e-7
1.0e-7
5.0e-8
2.0e-8
1.0e-8
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.15
0.1
0.07
0.05
0.02
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0
20
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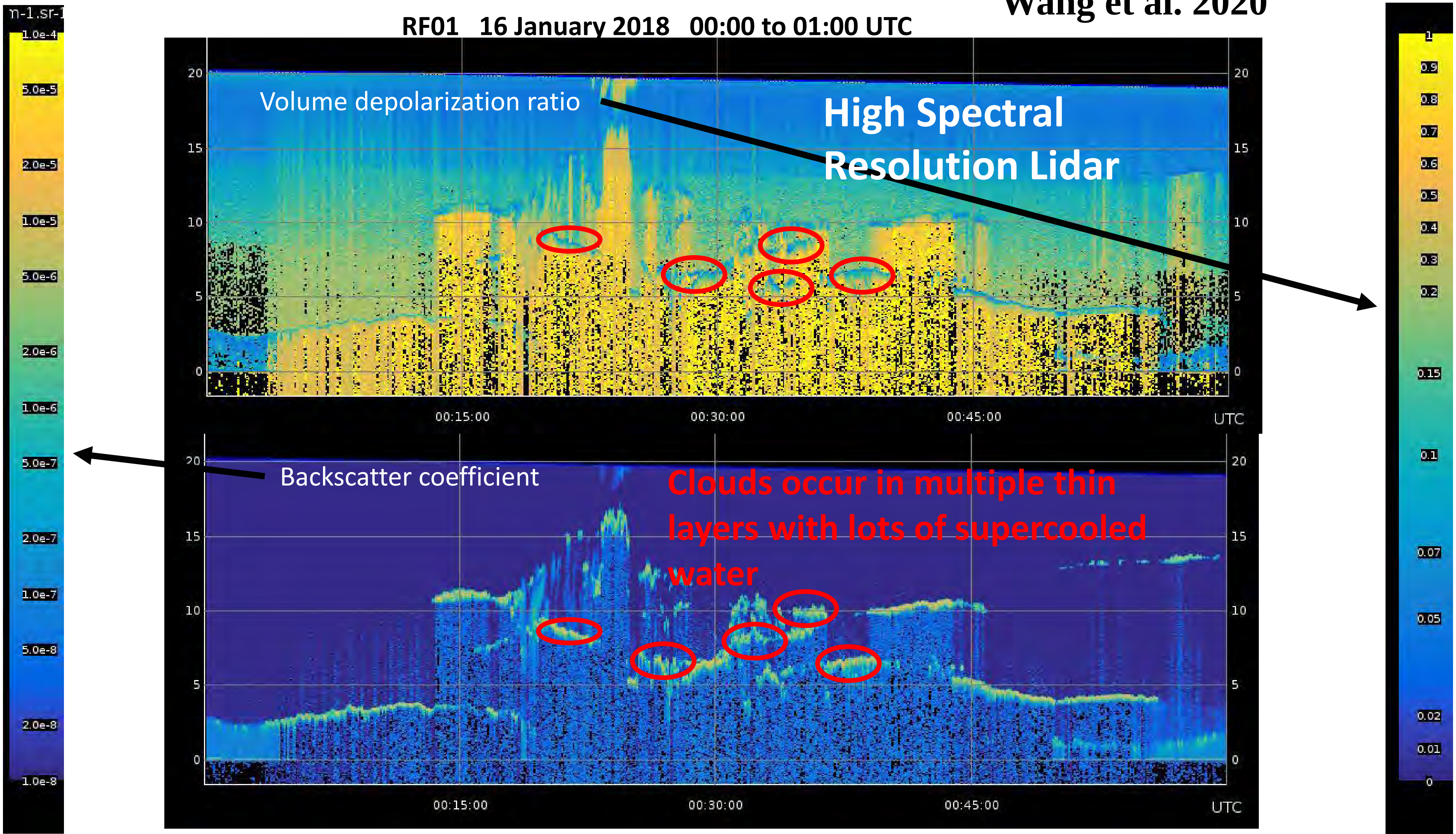
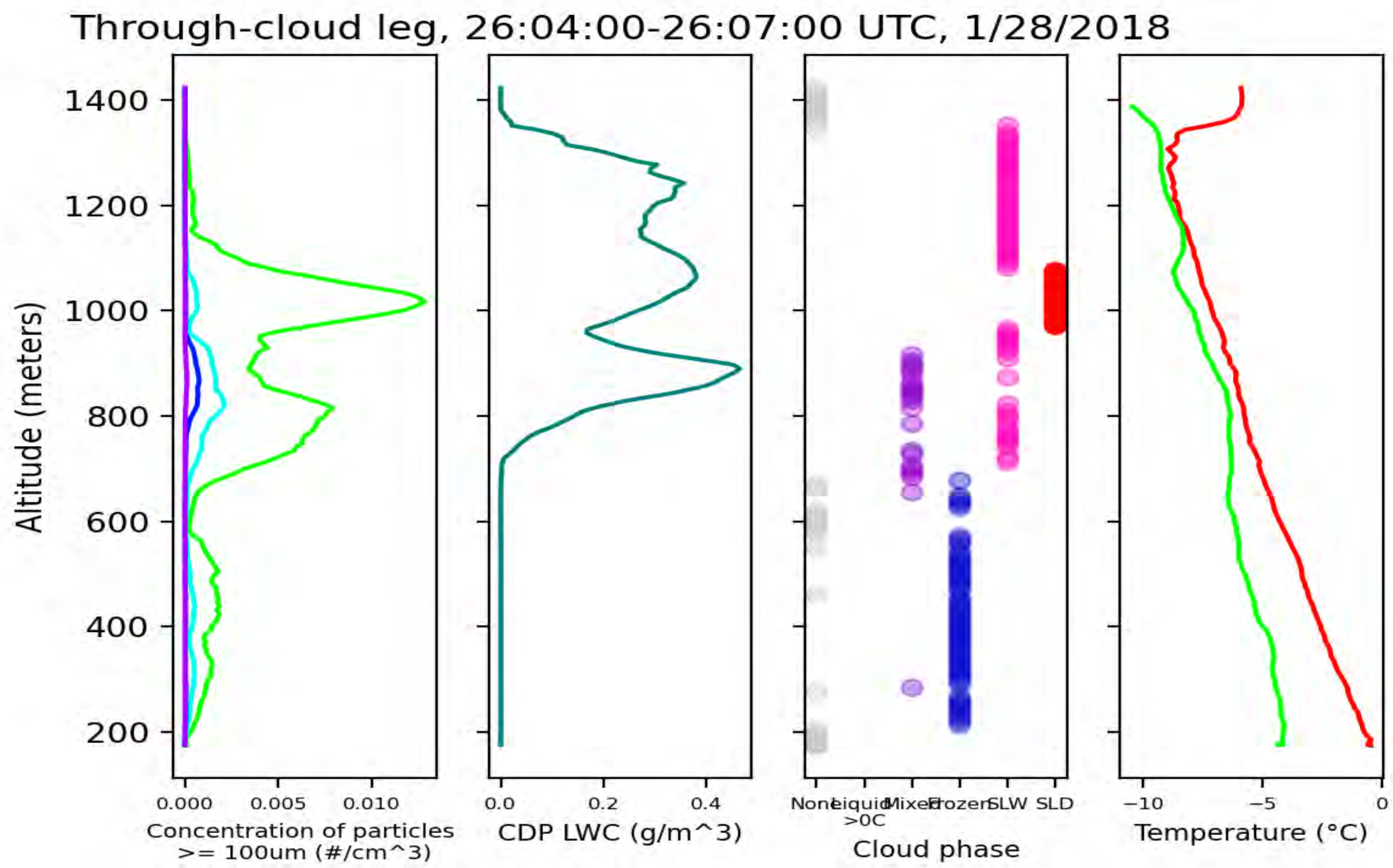
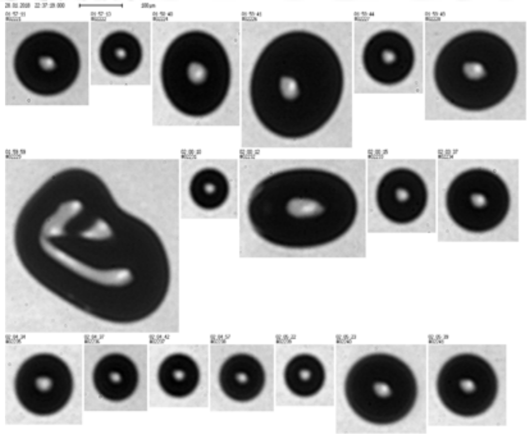
Wang et al. 2020

RF01 16 January 2018 00:00 to 01:00 UTC

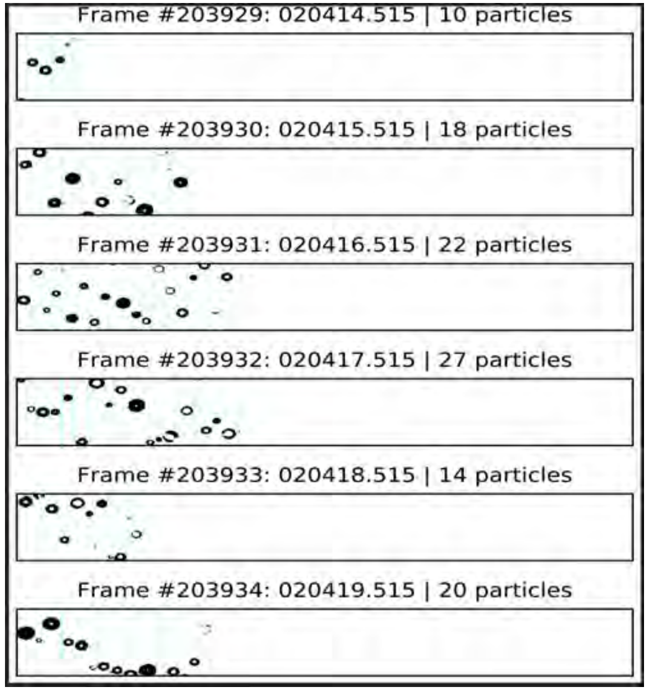




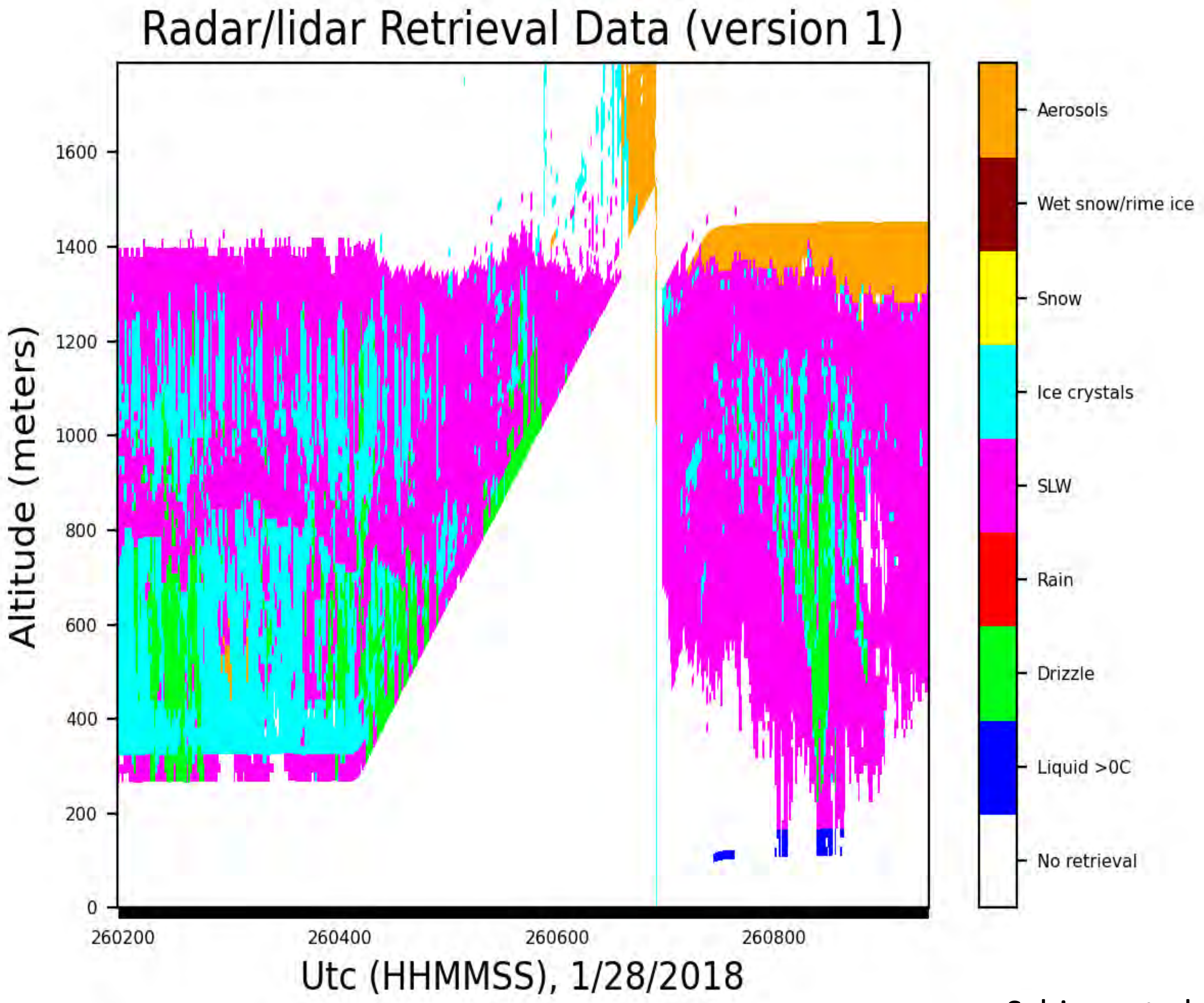


Vertical profile of clouds sampled during SOCRATES gives more information about vertical structure of cloud

- Small liquid drops near cloud top
- Drizzle ~200 m below liquid drops
- Sometimes precipitating ice beneath



Schima et al. 2021



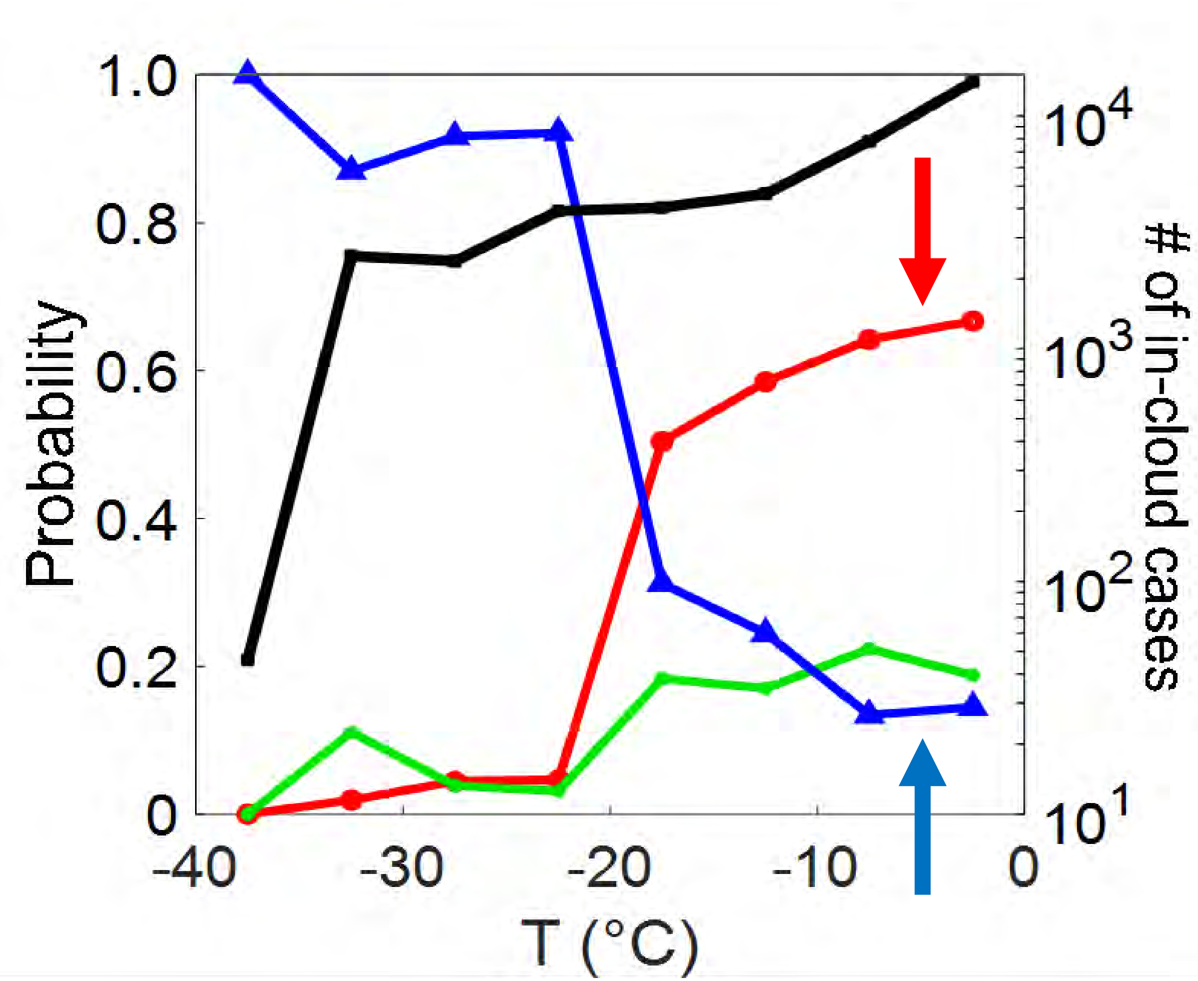
Phase identification from remote sensing data during SOCRATES (HCR, HSRL) gives a similar picture of SLW near top, with drizzle and ice below

Some ambiguity in distinguishing between ice crystals and drizzle

Schima et al. 2021

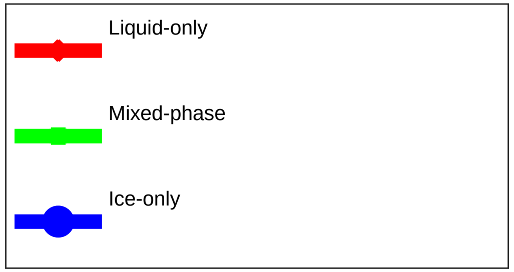
Clouds: In-Situ Data and Process Studies

Relative phase occurrence frequency



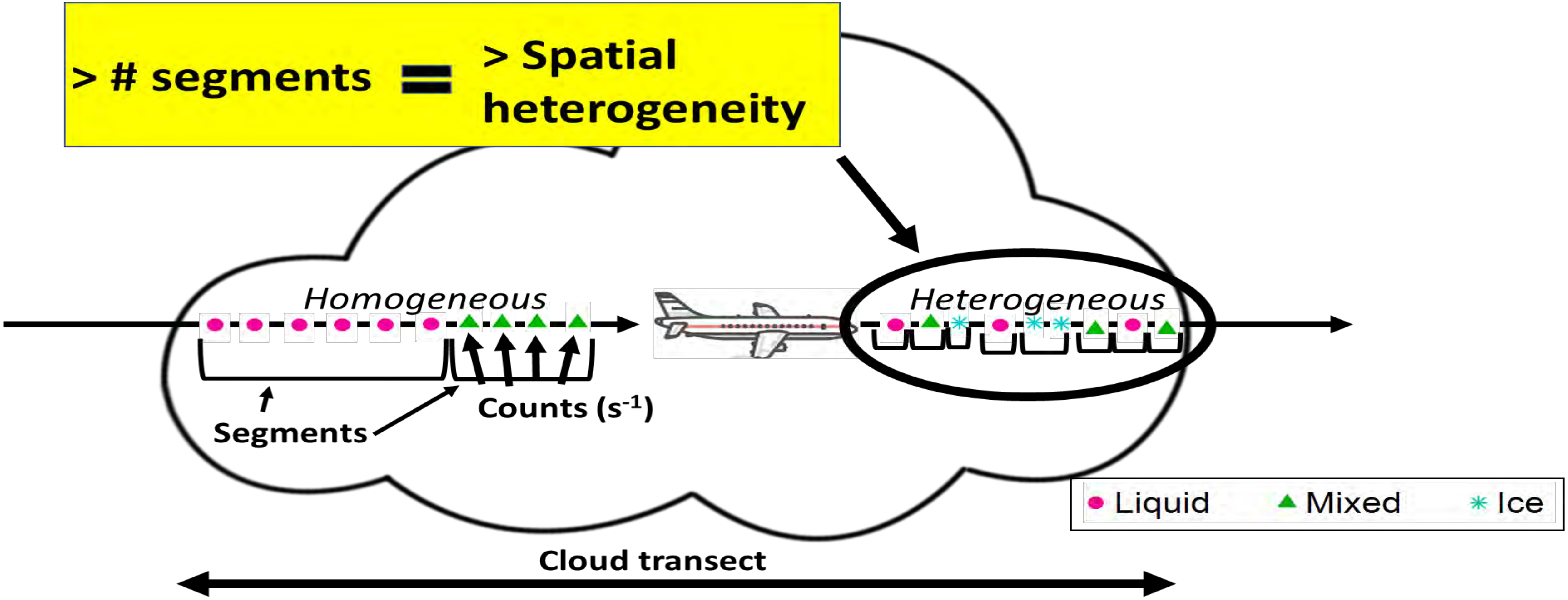
Applied Multinomial logistic Regression (MLR) analysis to 2DS images

Large frequency of SLW from -20° to 0°C
Ice-phase observed from -5° to 0°C

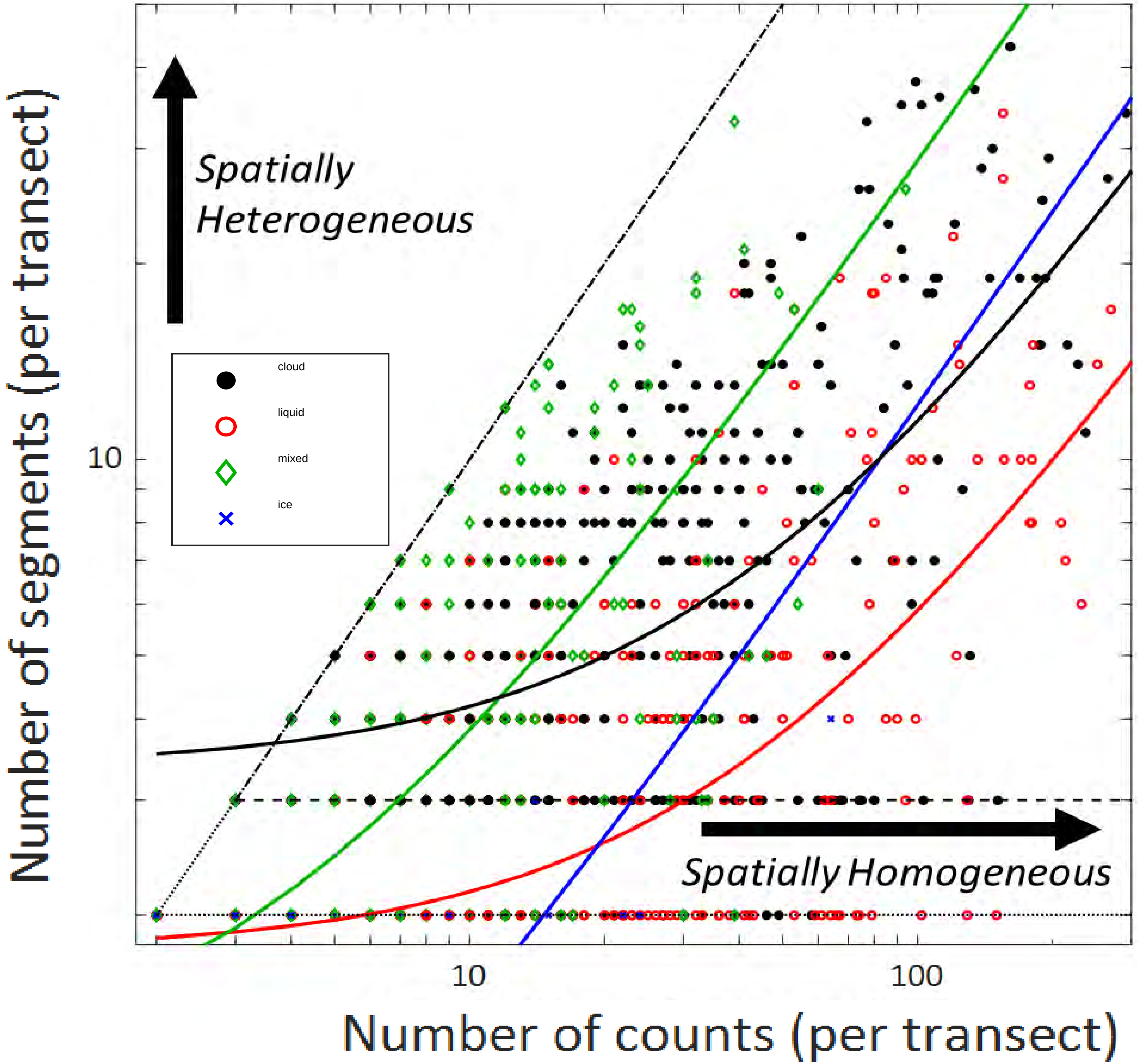


D'Alessandro et al. 2021

Characterizing phase heterogeneity/homogeneity



D’Alessandro et al.



Mixed-phase most heterogeneous; liquid phase most homogeneous

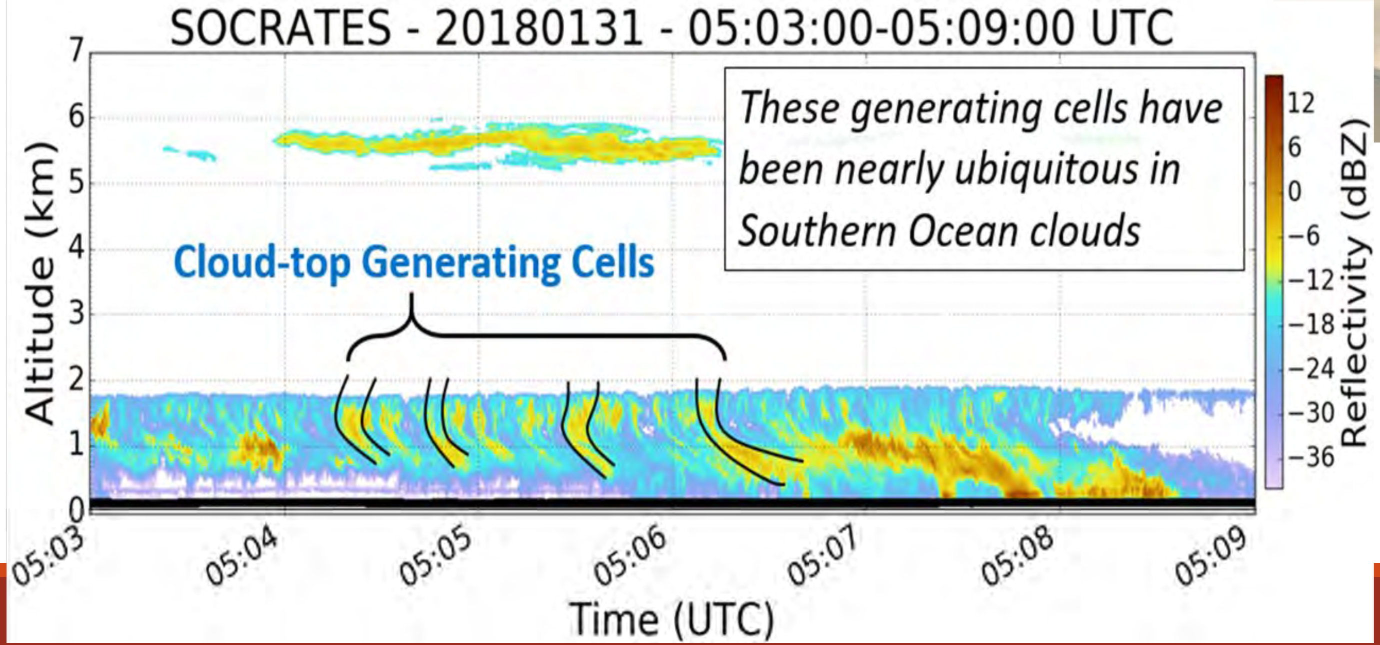
Average values (solid lines) for each phase show liquid phase occurrence frequencies are greater than mixed and ice phase for all transect lengths.

D'Alessandro et al.

Clouds: In-Situ Data and Process Studies

Generating cells (GCs)

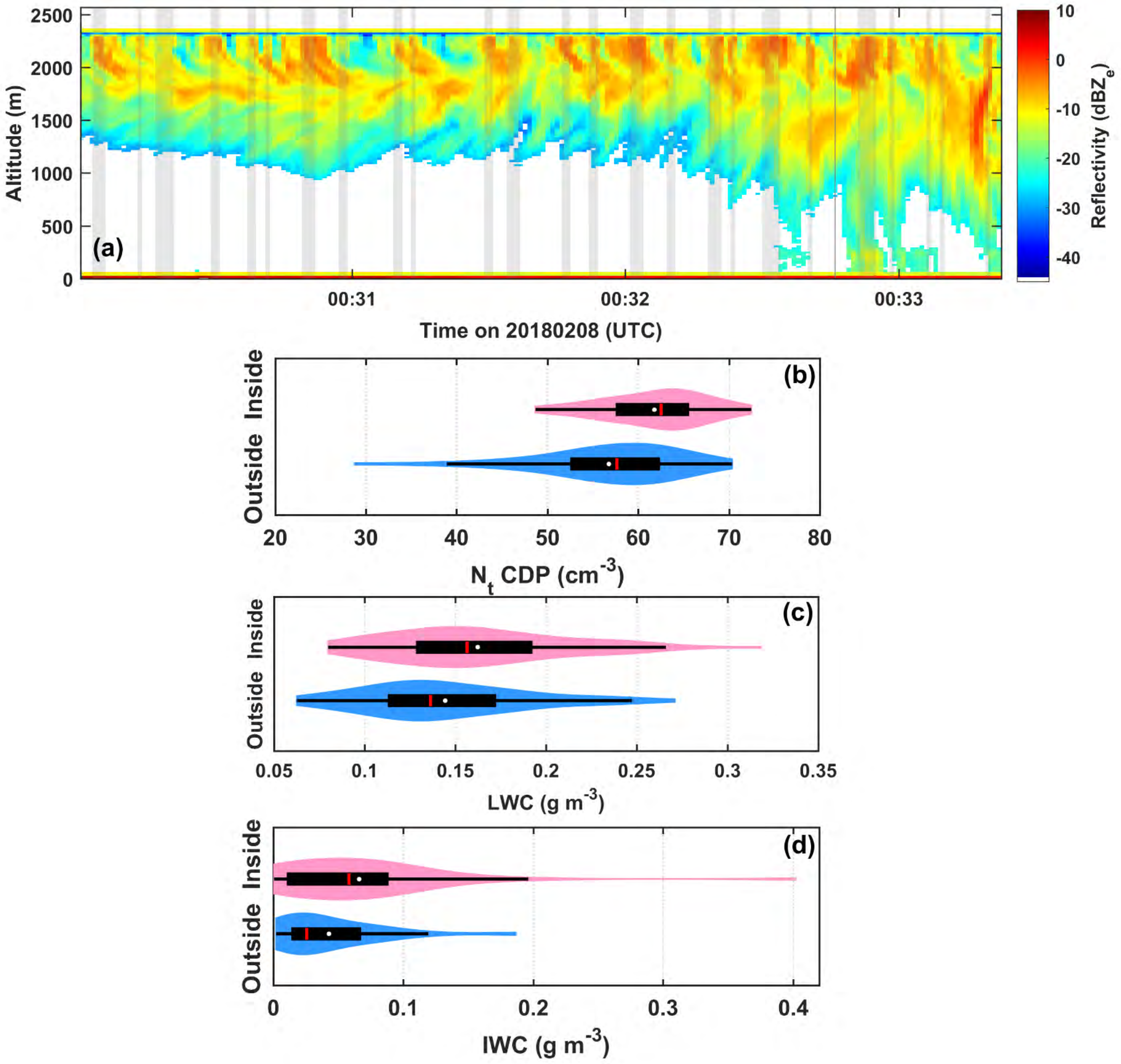
Term ‘generating cell’ describes small region of locally high Z at cloud top from which enhanced reflectivity trail characteristic of falling snow originates (AMS Glossary 2013).



Cloud deck with tops around 2 km at 0217 UTC 5 Feb 2018; many GCs protruding from top of cloud deck. (Photo courtesy Joseph A. Finlon)

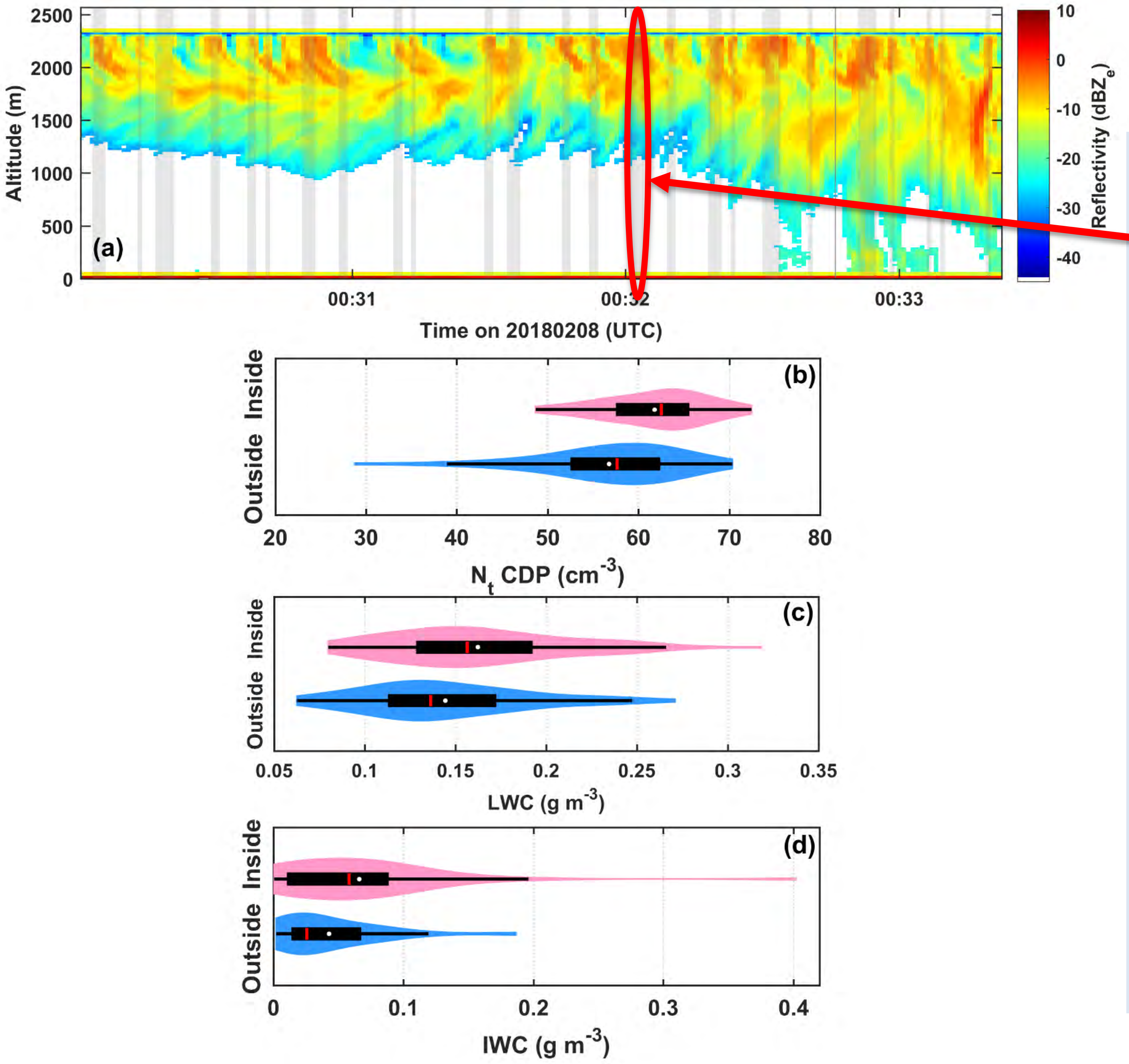
Wang et al. 2020

Wang et al. 2020



GCs identified by prominence > 4 dBZ

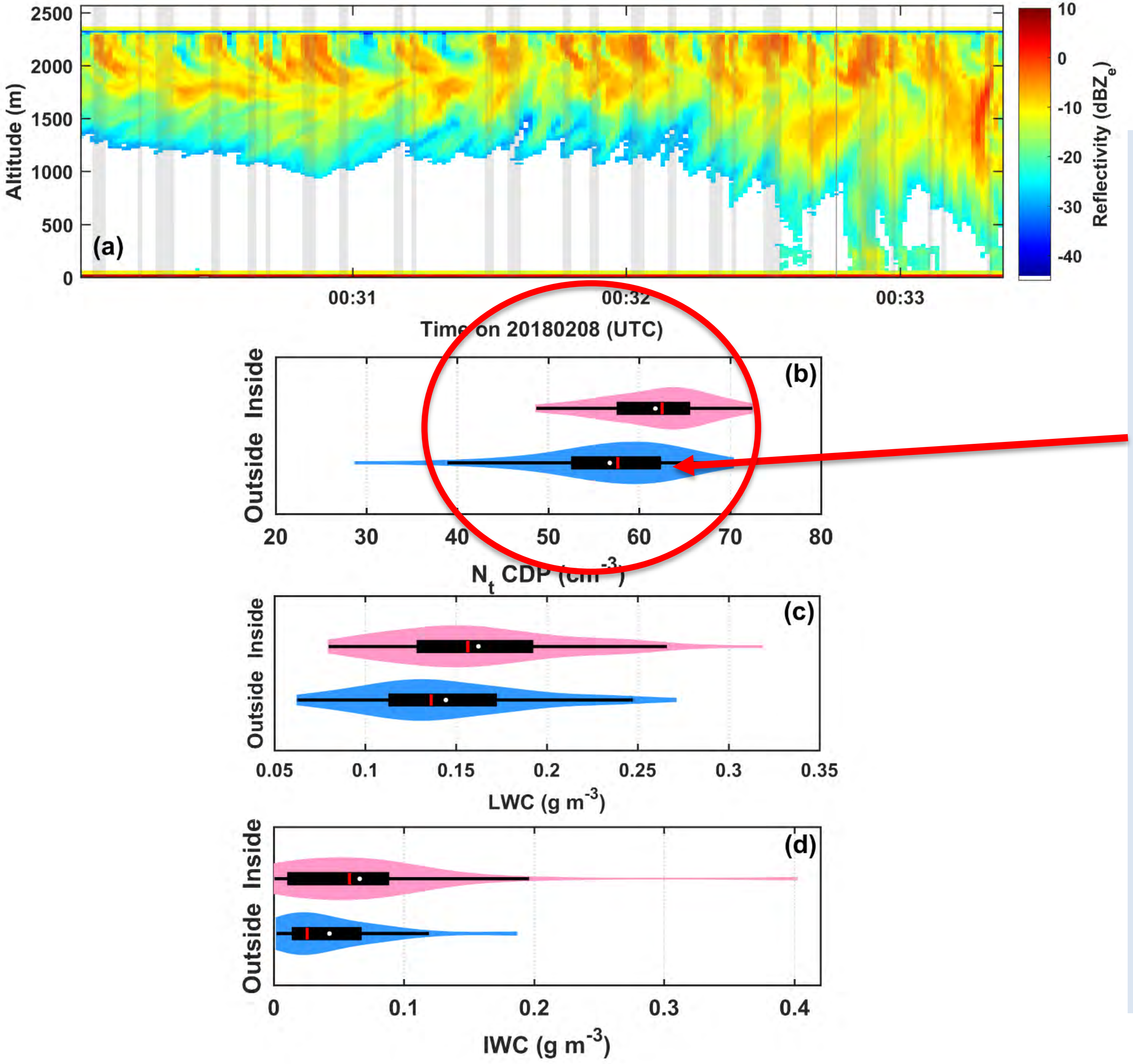
Wang et al. 2020



GCs identified by prominence > 4 dBZ

Mean GC width 395 m, narrower than found in previous studies

Wang et al. 2020



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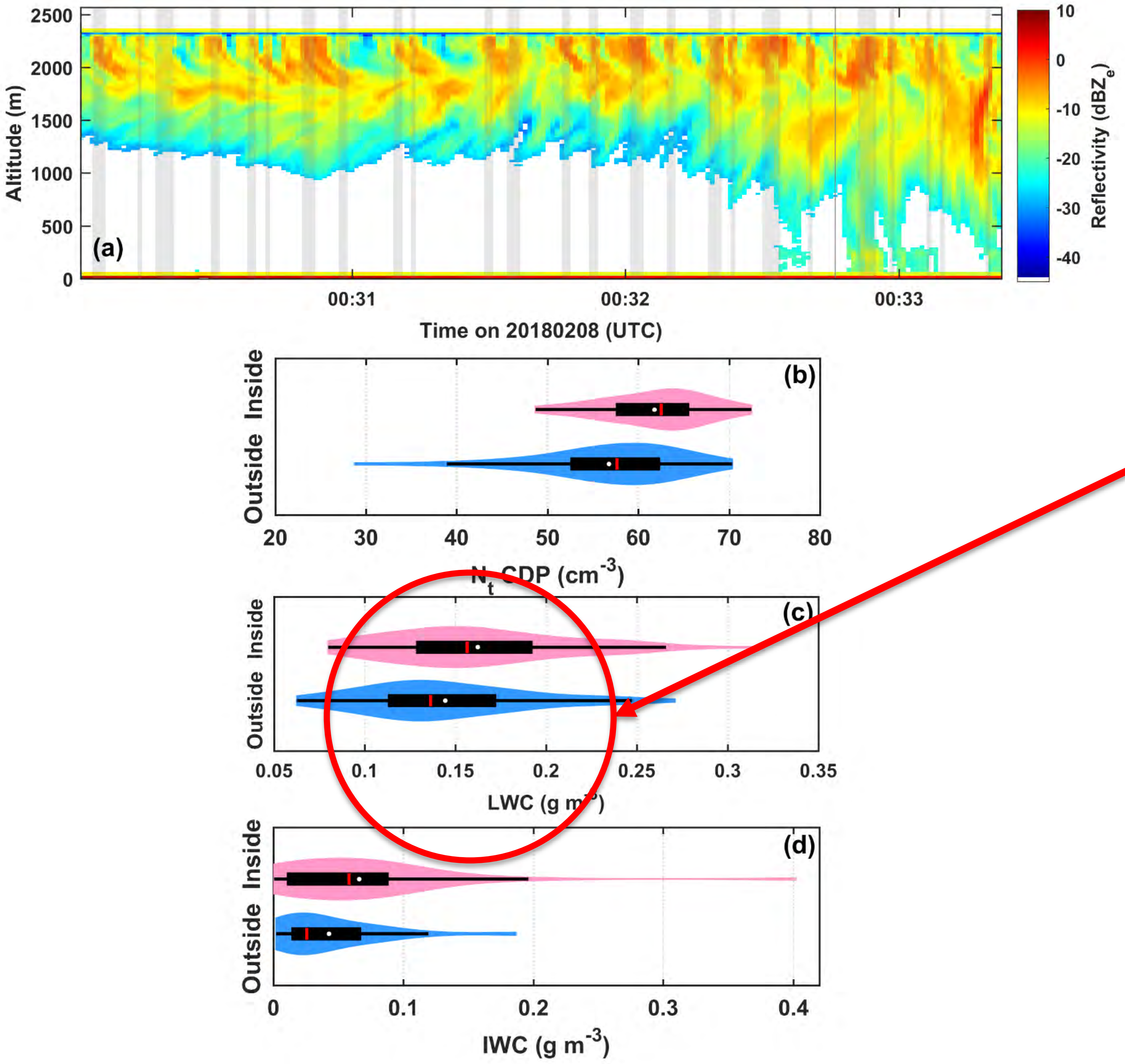
Nt,

Wang et al. 2020



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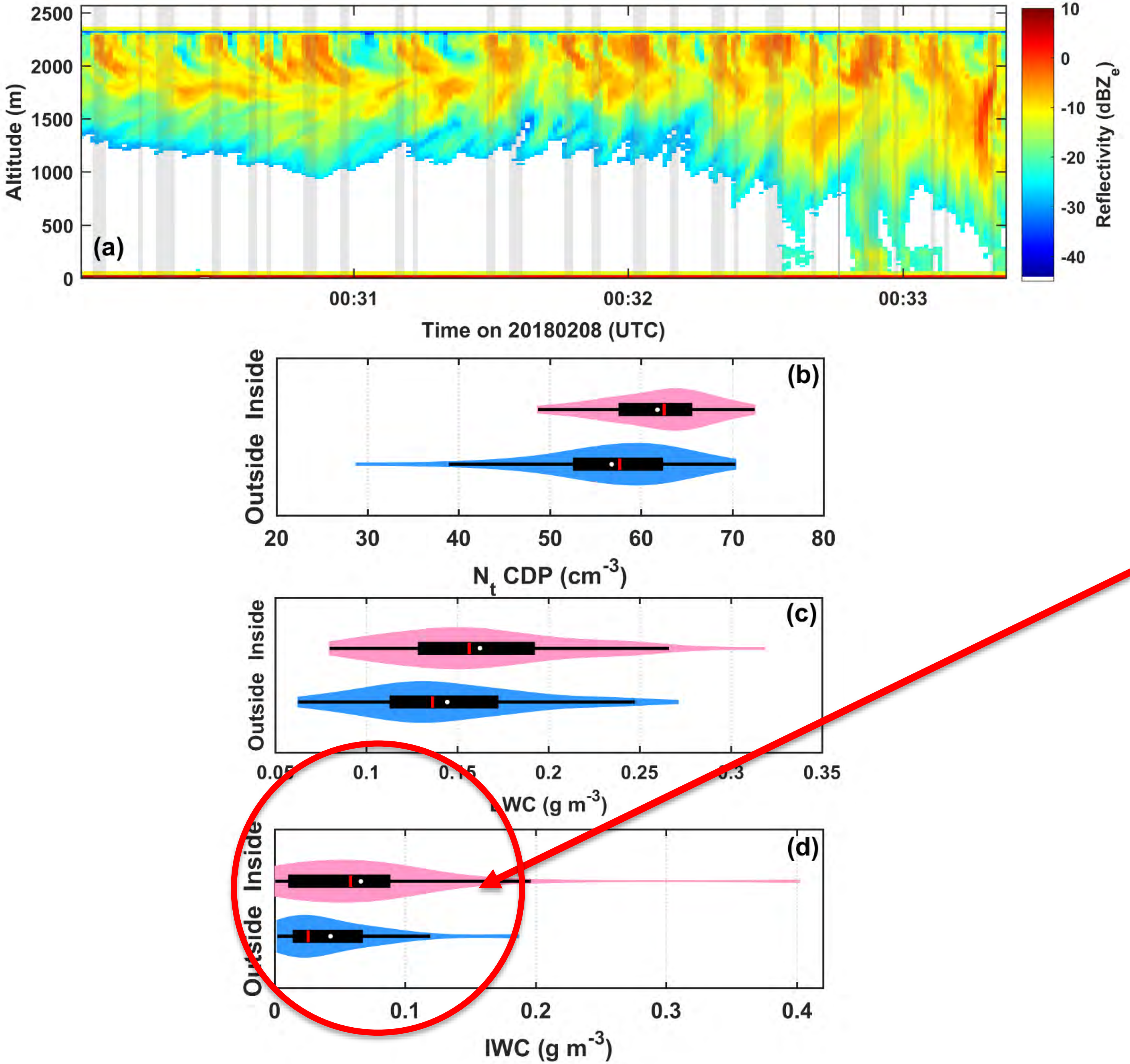
Nt, LWC

Wang et al. 2020



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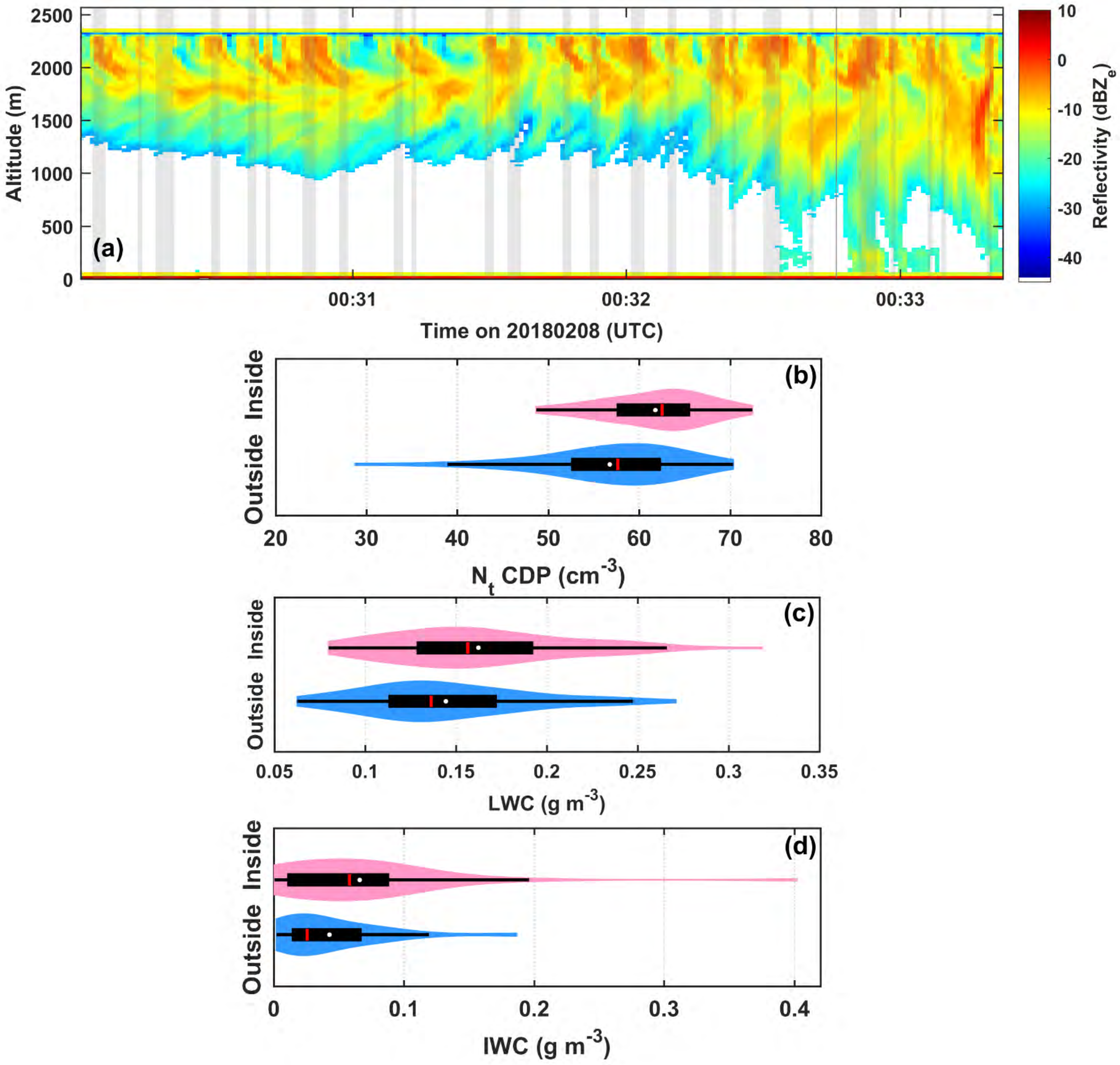
Nt, LWC and IWC

Wang et al. 2020



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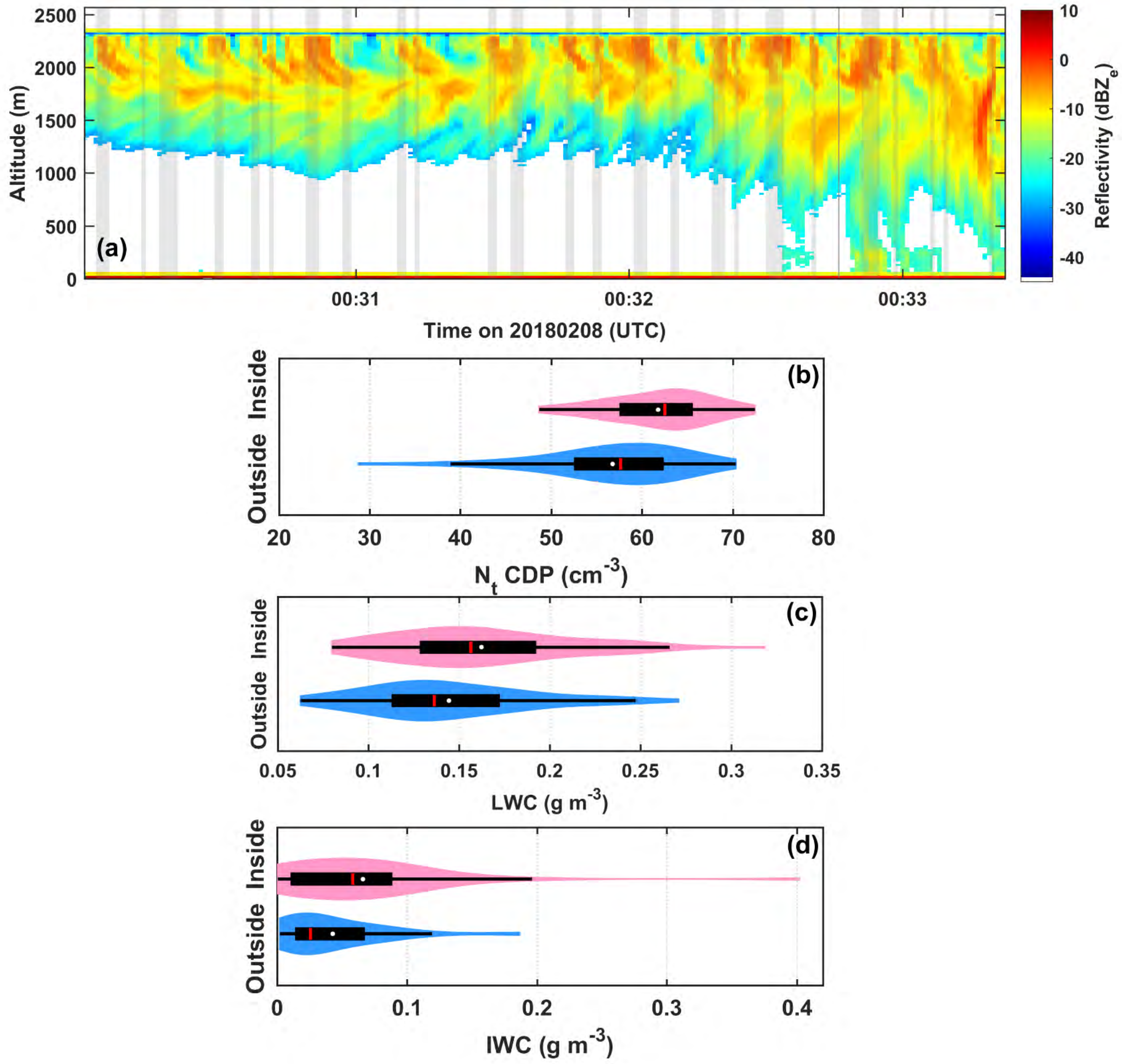
Nt, LWC, and IWC larger inside GCs compared to outside GCs

Wang et al. 2020



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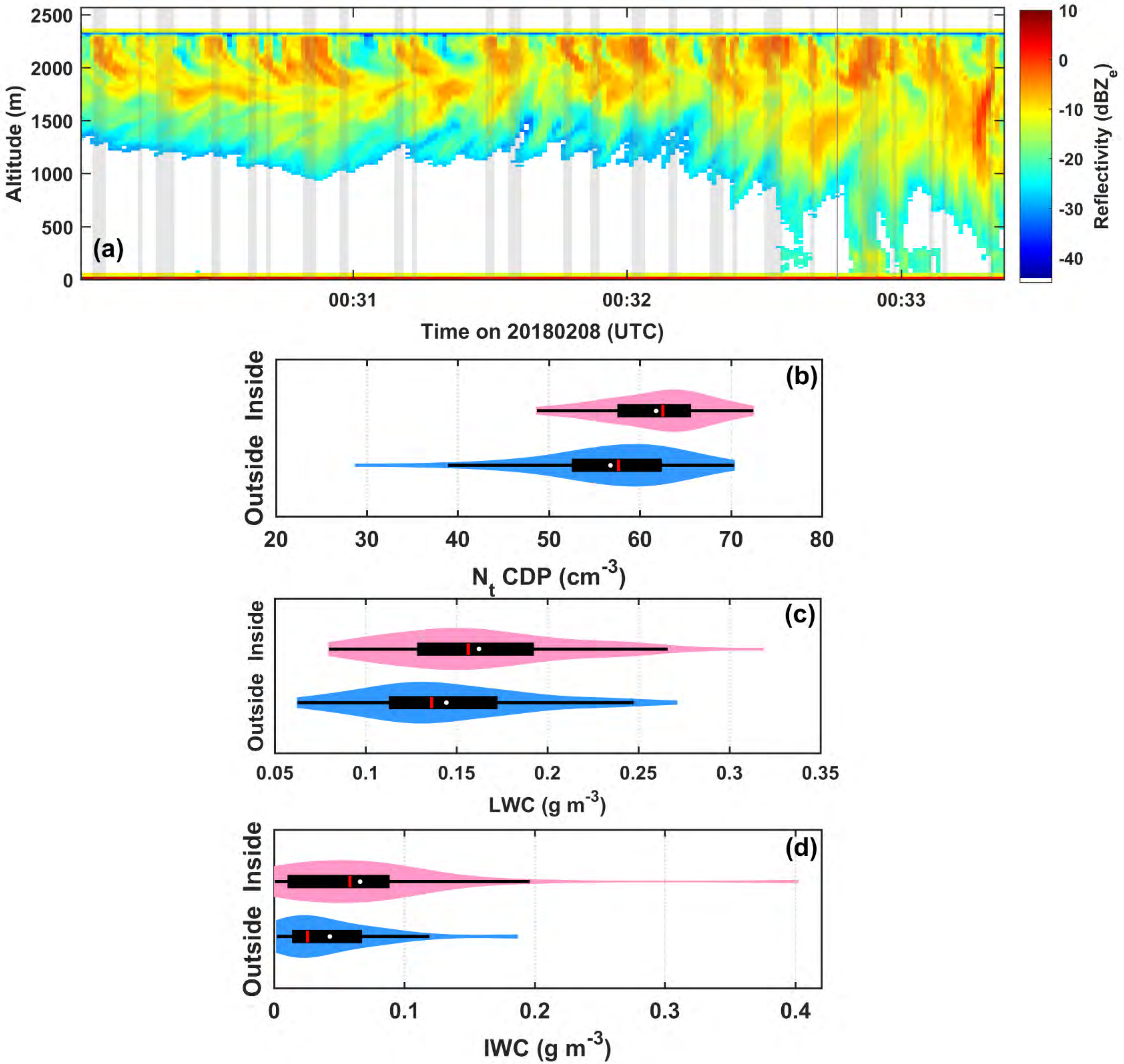
Mixing seems to minimize difference between GCs and areas outside GCs

Wang et al. 2020



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GCs provide favorable environment for growth by deposition and riming like observed in mid-latitude and Arctic cases

Summary

- Unique sets of data on SO clouds helps resolve structure of post-frontal shallow clouds over SO
  - Ground and air-borne remote sensing data
  - In-situ microphysics data
- Ubiquitous SLW in thin, multi-layer clouds with small-scale generating cells near cloud top exist
- Supercooled water near cloud top, with drizzle and ice crystals beneath is common vertical structure
- Horizontal heterogeneity of clouds also characterized with mixed-phase regions most heterogeneous