Lessons learned from Southern Ocean cloud-aerosol-precipitation-radiation field campaigns in 2017-18 and needs for future observations

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U.S. DEPARTMENT OF ENERGY

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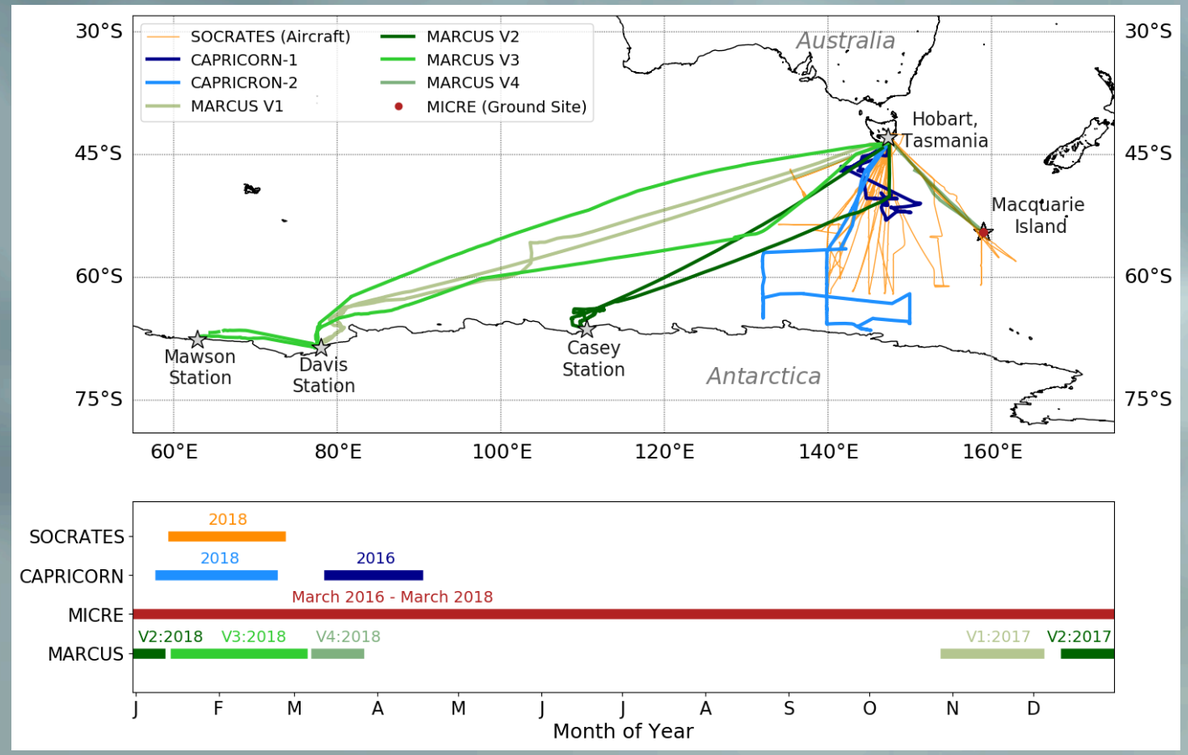

- **MARCUS, MICRE, CAPRICORN and SOCRATES projects in 2017-2018 time frame highly synergistic**
- **However, there is still much to be learned and new questions arising**

MARCUS Instrument Suite

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Active remote sensing: 95-GHz radar & stabilized platform, lidar, ceilometer, radar wind profiler

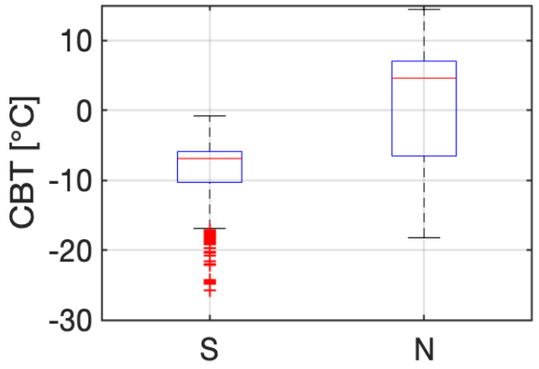
Passive remote sensing: AERI, Radiometers, Infrared thermometer, total sky imager

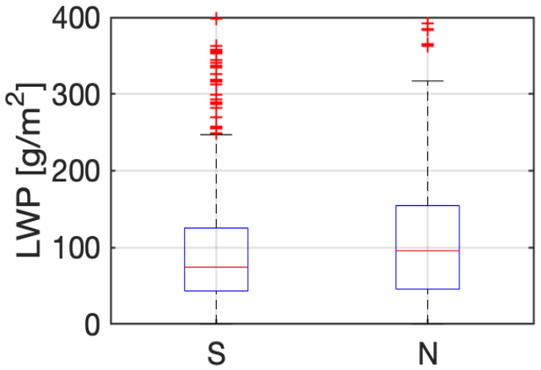
In-situ aerosols: Size distributions, optical properties, absorption

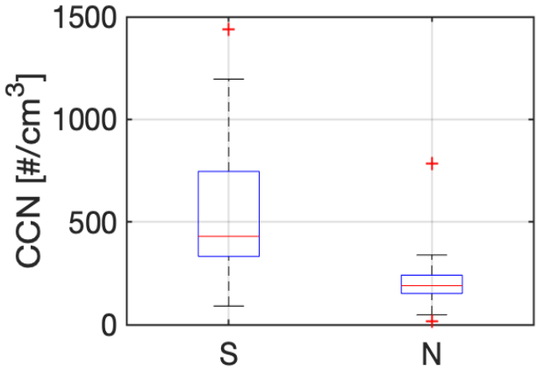
Gases: CO, O_3

Meteorology: Wind speeds, rain gauges, disdrometers & soundings 4 times per day

Clouds: Ship- and Ground-based Remote Sensing







- 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.

Ding et al. 2022

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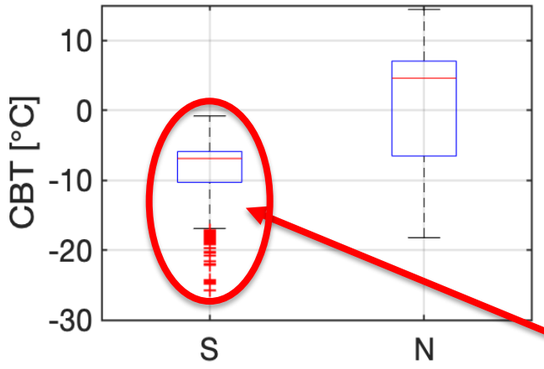

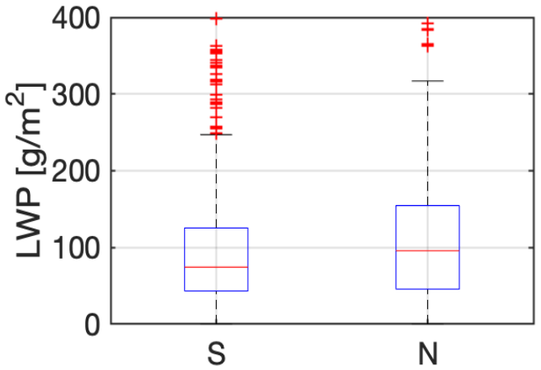

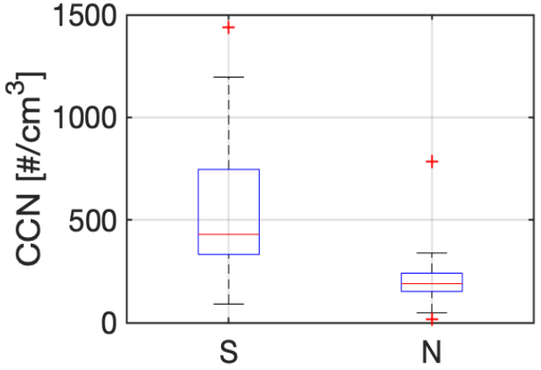

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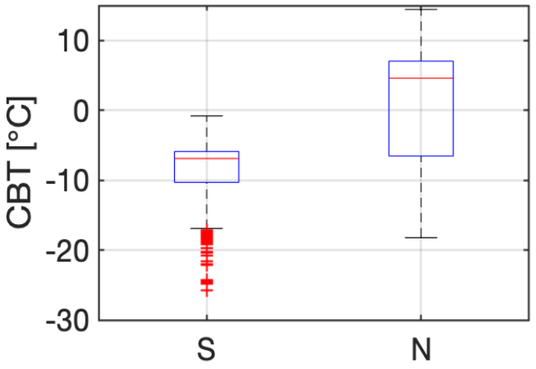

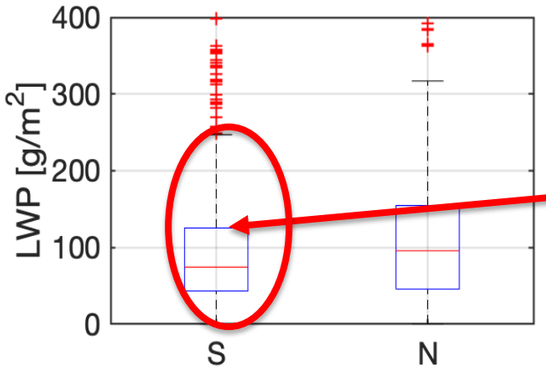

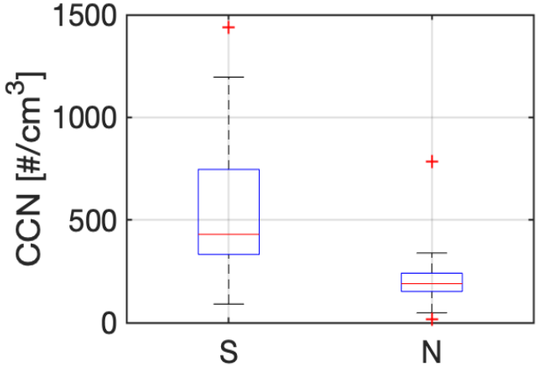

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Ding et al. 2021

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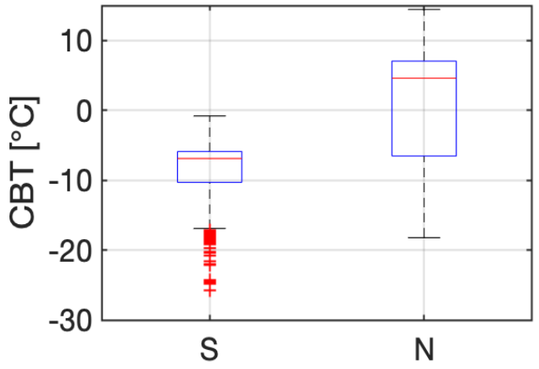

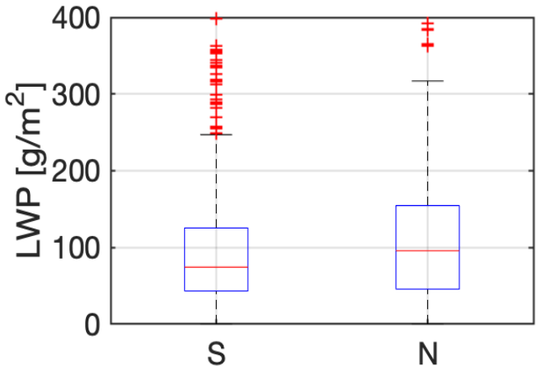

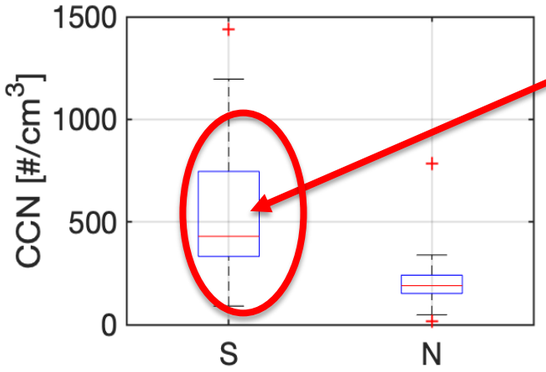

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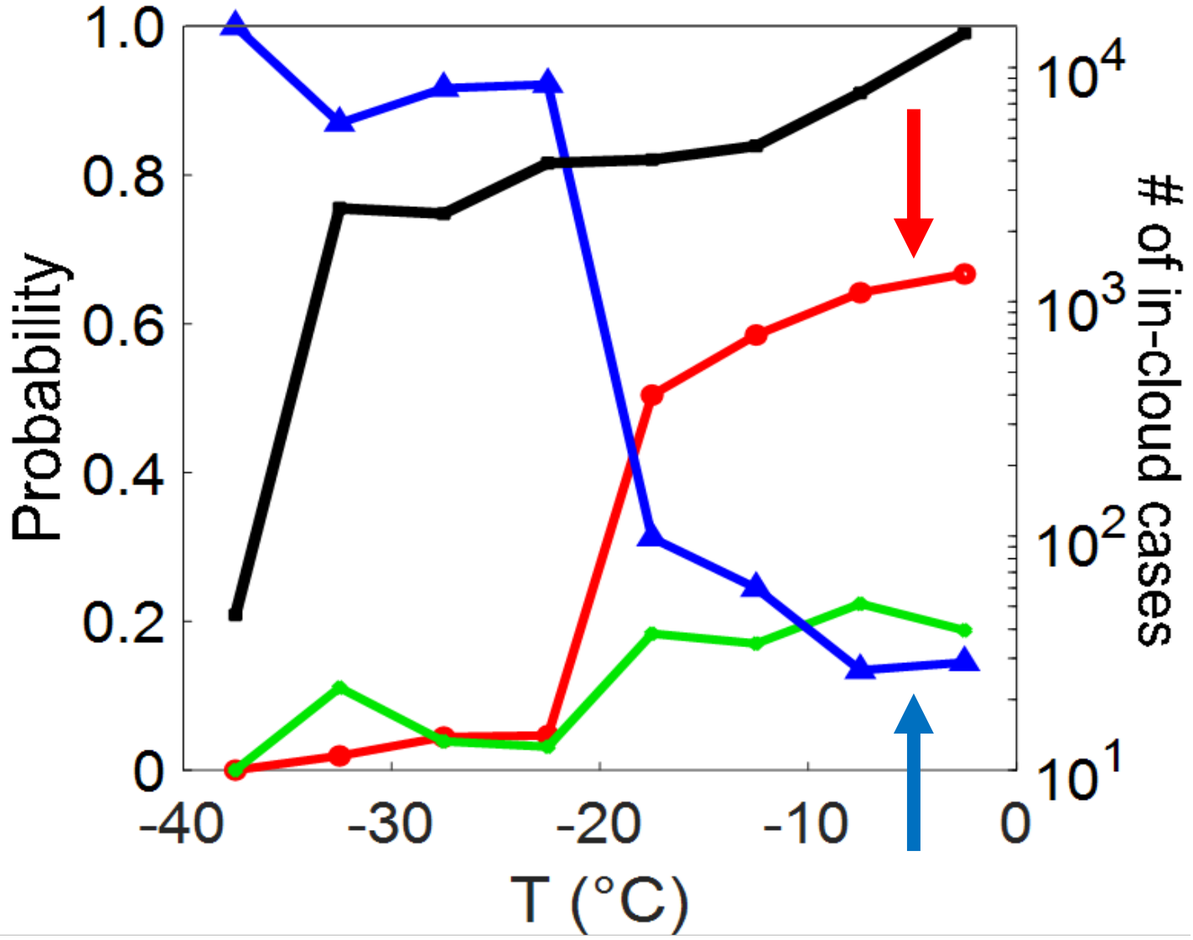
- Average cloud base T ~ -10˚C S of 60˚S
- LWP large south of polar front, so there must be extensive supercooled liquid water
- CCN and retrieved N_c greater south of 60˚S

Ding et al. 2021

Clouds: In-Situ Data and Process Studies

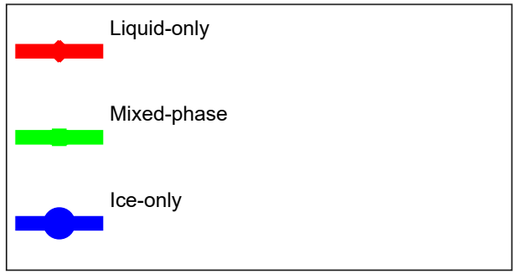
Relative phase occurrence frequency needs in-situ data

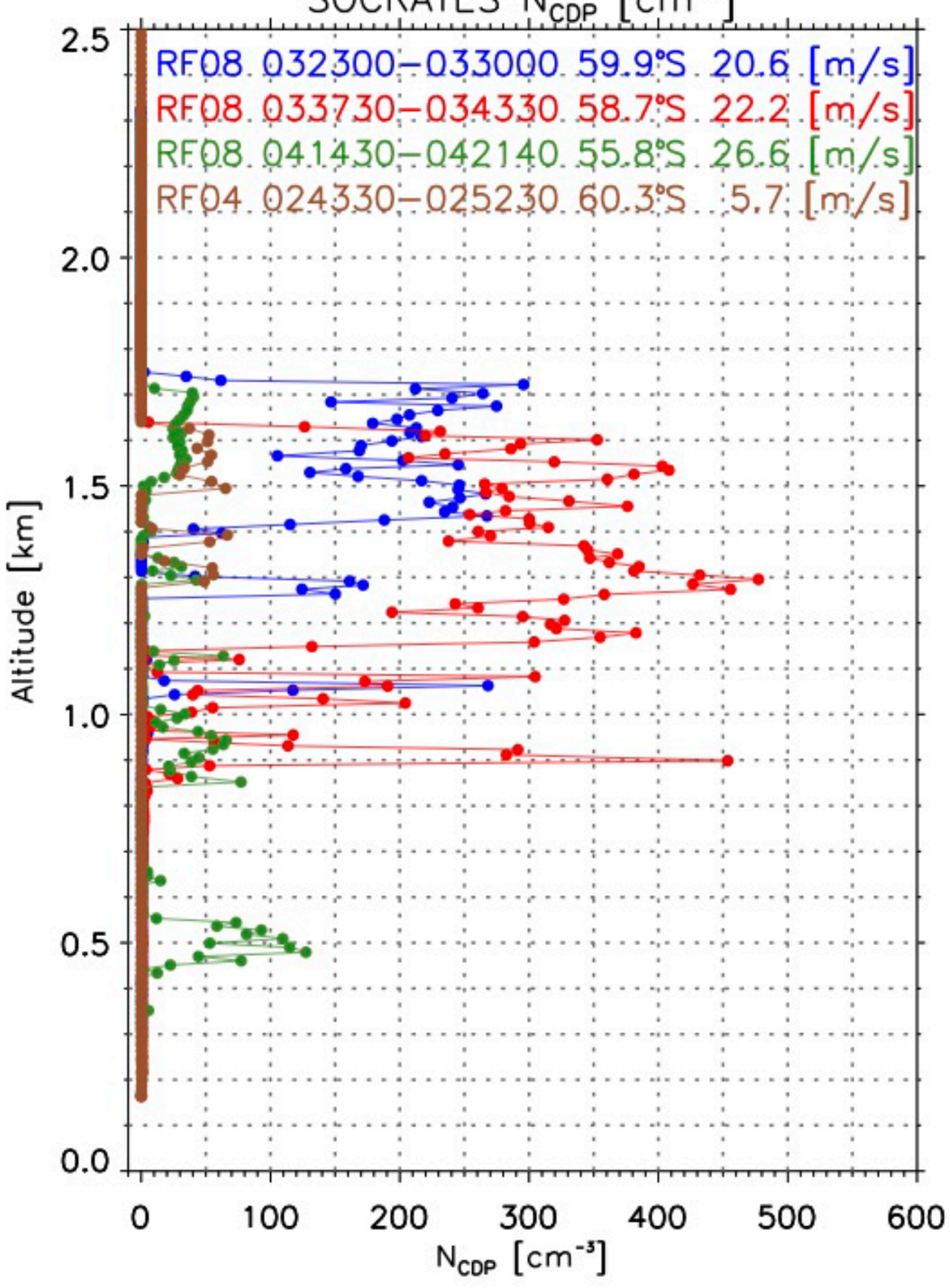
D'Alessandro et al. 2021



Large frequency of SLW from -20° to 0°C

Ice-phase observed from -5° to 0°C

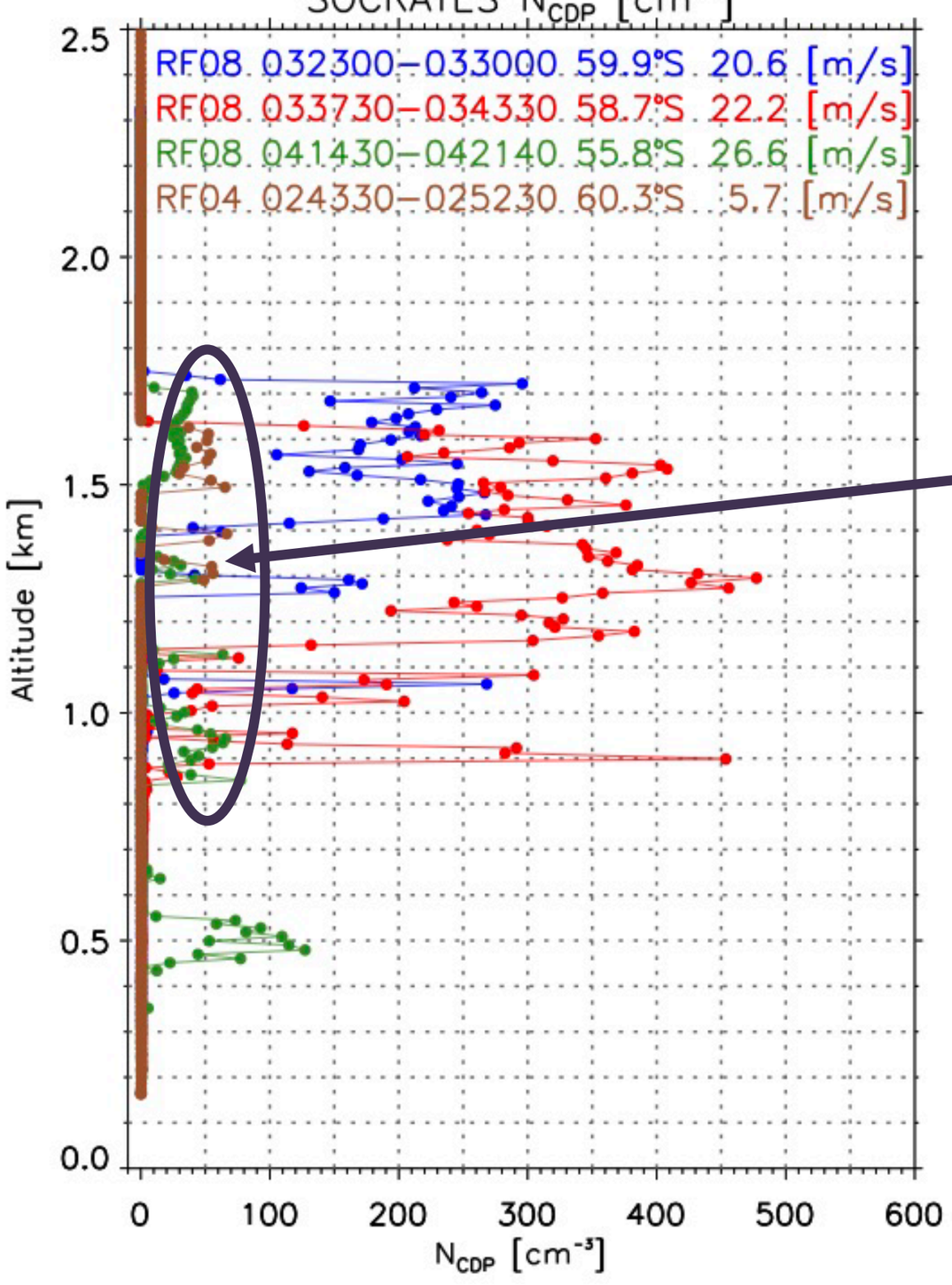




Cloud Droplet Probe (CDP)

- **Cloud droplet concentrations measured by CDP can vary a lot depending on where/when measured**

McFarquhar et al. 2021



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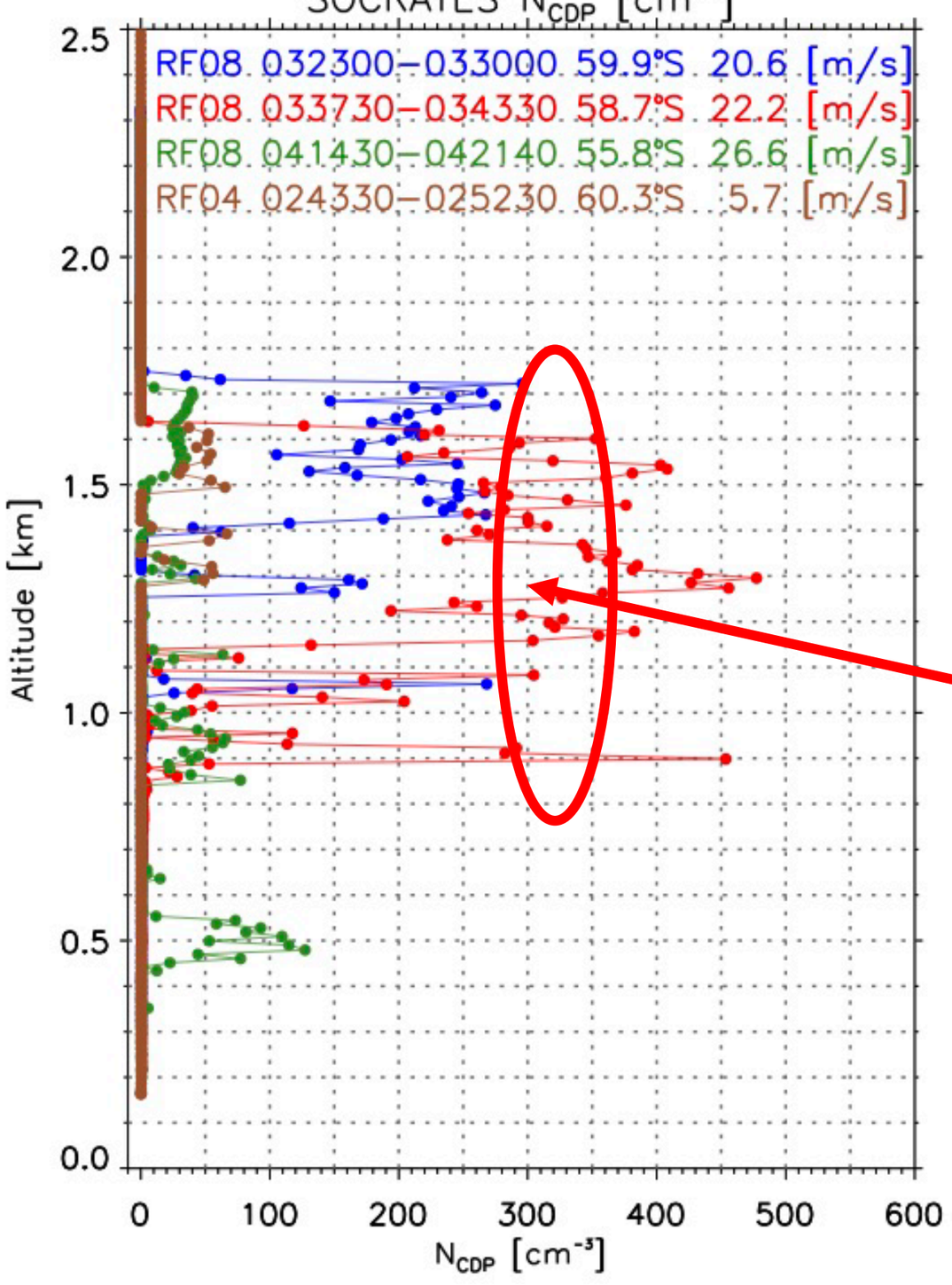
McFarquhar et al. 2021



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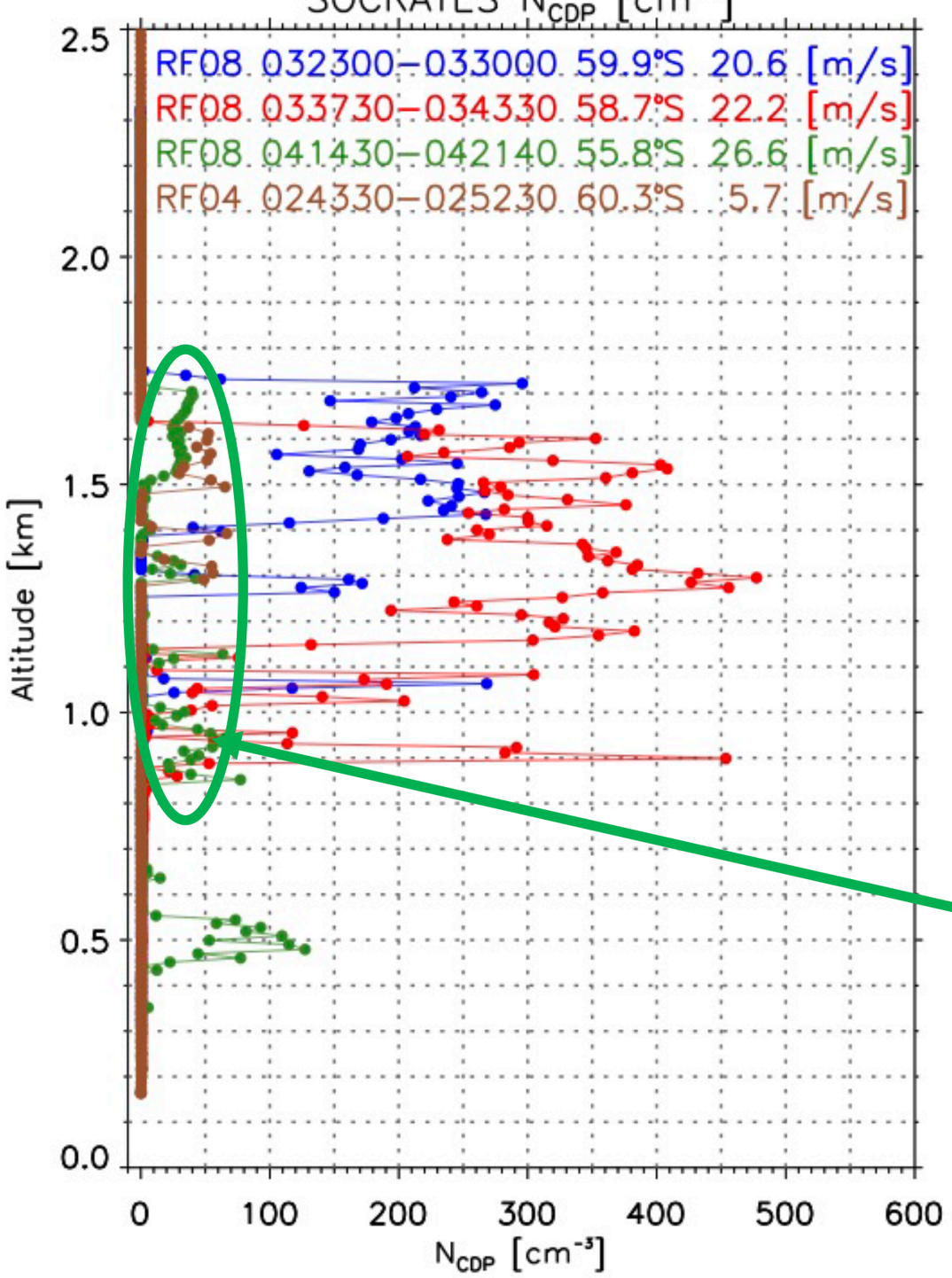

Cloud Droplet Probe (CDP)

- Cloud droplet concentrations measured by CDP can vary a lot depending on where/when measured
- Low concentrations common on many days (around 60 cm^{-3})
- Other days, typically when surface wind high, have much higher concentrations
- But, some cases with high wind speed still had lower concentrations!

McFarquhar et al. 2021

Summary

- Unique sets of data on SO clouds now available
  - 15 GV research flights
  - 4 voyages of Aurora Australis (spring, summer and fall)
  - 2 years of data at Macquarie Island
  - 2 cruises of R/V Investigator
- Transition in aerosol properties at ~60^{o}S to 62^{o}S
  - More CCN in south
  - More small aerosols (fewer large aerosols) in south
  - Impact of aerosols on cloud properties tied to meteorology
- Ubiquitous SLW over SO
  - Pervasive at temperatures as low as -20^{o}C
  - Occurs in thin, multi-layer clouds
  - Small-scale generating cells near cloud top provide protective environment
  - Properties dependent on aerosol amount & meteorological conditions

Future

- MARCUS/SOCRATES-II
  - Continue building database on seasonal/latitudinal variation, especially south of 60^{o}S
  - More comprehensive data on aerosol chemical properties, especially chlorophyl
    - Less contamination from ship stack; more aircraft aerosol composition
  - Oceanographic observations and fluxes
- Colocated aircraft observations
  - Explore observations in transition season where greater variability in blooms over course of project
  - Lagrangian rather than Eulerian experiment (try to trace how clouds evolve in subsequent flights)
  - Observations closer to Antarctic (south of 60S to look at increases in CCN; suitcase flights to Antarctic?)
  - Two aircraft for coincident remote sensing/in-situ data
  - Holographic observations would have strengthened cloud data

Discussion

- Any more contributions?
- What should a future Southern Ocean experiment look like?
  - Ship-based data? Nuyina?
  - What instruments are missing?
  - Does resupply ship work for observations? Other candidates?
  - Is Australasia sector best location to collect data?
  - Lack of winter observations?