A CCN Budget Model Perspective

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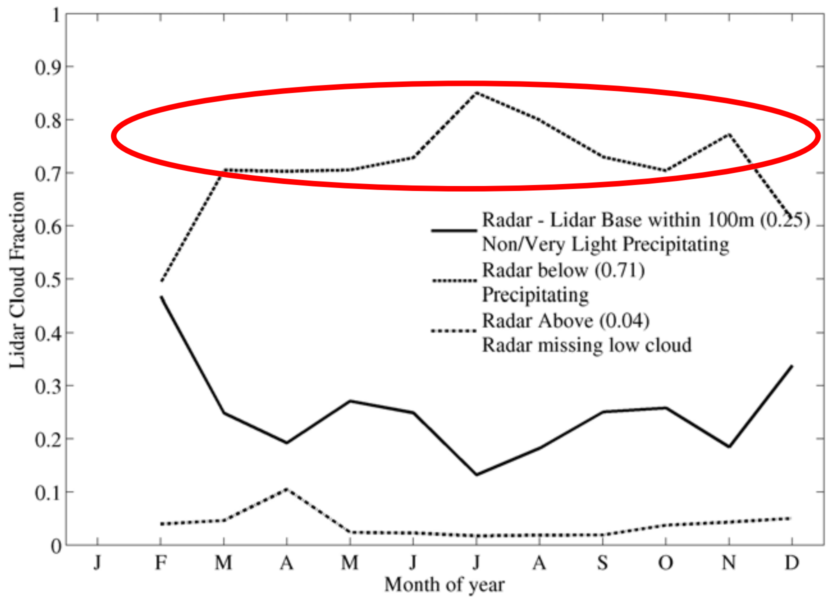
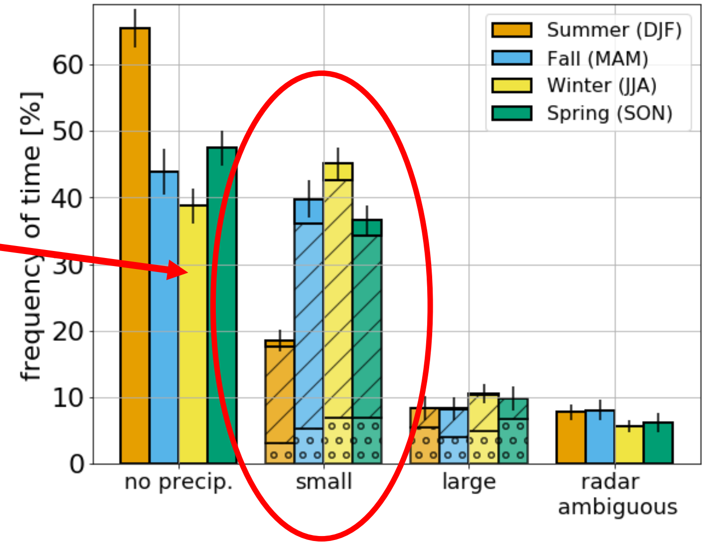
ASR 2022 Fall Meeting, Southern Ocean breakout

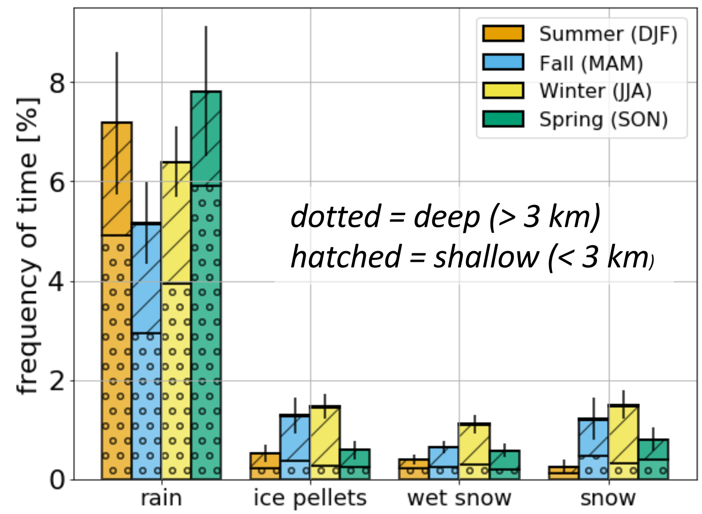
MICRE: Most SO low-altitude cloud is drizzling

There is a high occurrence of small particle precipitation (drizzle) surface precipitation, especially during the Fall, Winter and Spring

With precipitation present more than 100m below lidar-derived cloud-base ~70 % of the time.

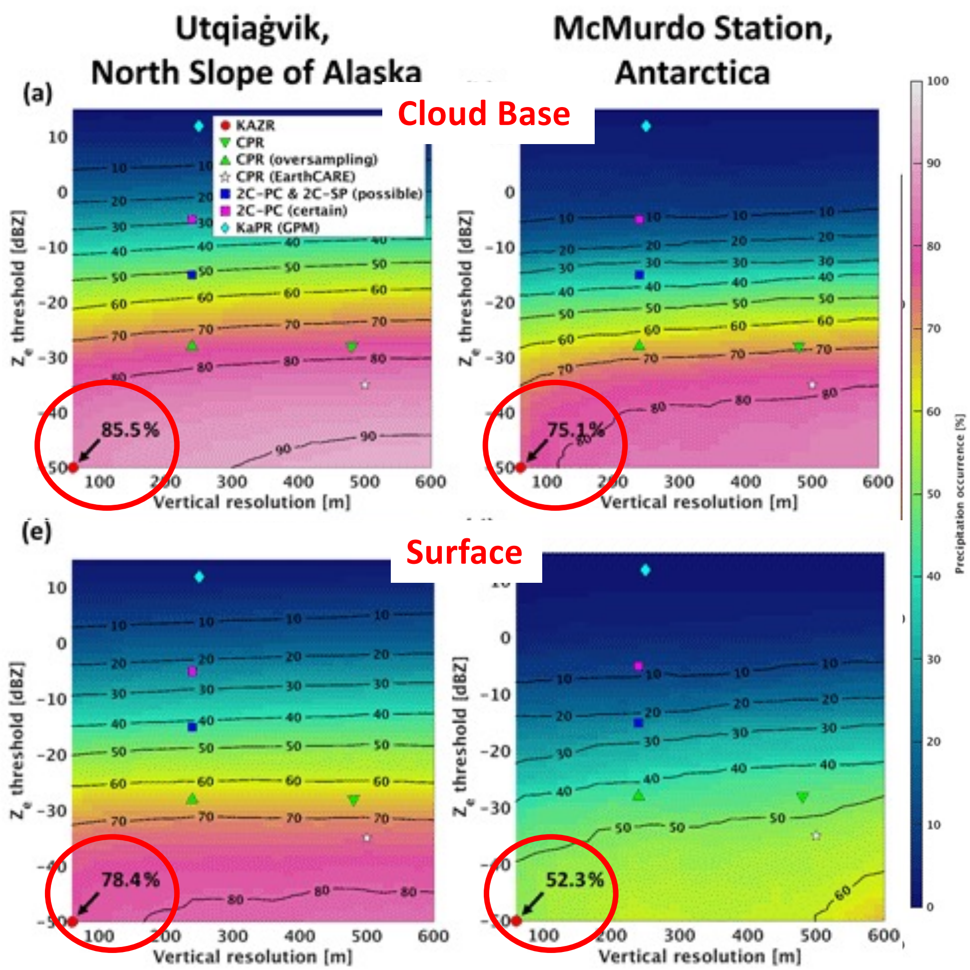






Tansey et al. (2022) JGR

Not unique to Macquarie Island …



Supercooled Clouds at Utqiagvik & McMurdo also have a high occurrence of drizzle

Silber et al. (2021), *ACP*

Simple budget model for the CCN/cloud droplet number (Wood et al. 2006)

Source Terms

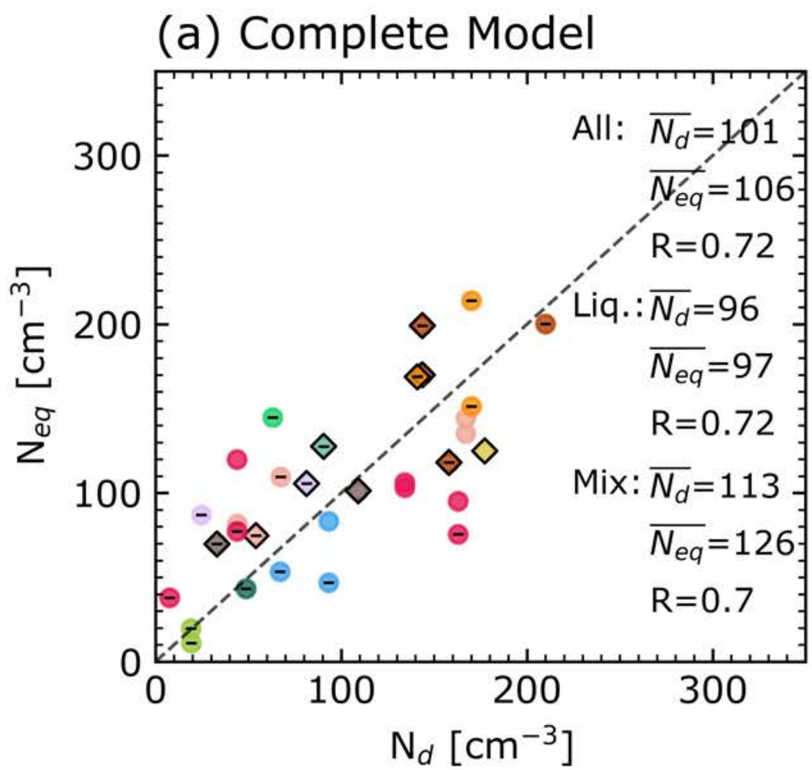
Entrainment from FT — Surface emission

$$N_{eq} = \frac{\left(N_{FT} Dz_i + F(\sigma) U_{10}^{2.8}\right)}{\left(Dz_i + hKP_{CB}\right)}$$

Entrainment to the FT — Coalescence scavenging

Sinks Terms

(P_{CB} = cloud based precip rate)



Kang et al. GRL 2022 DOI: 10.1029/2021JD035370

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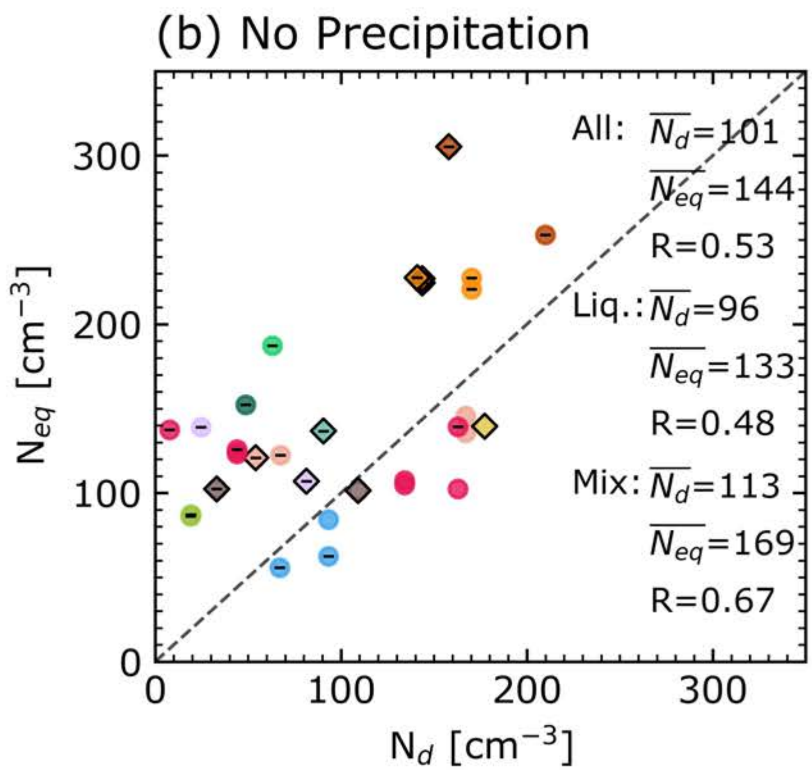

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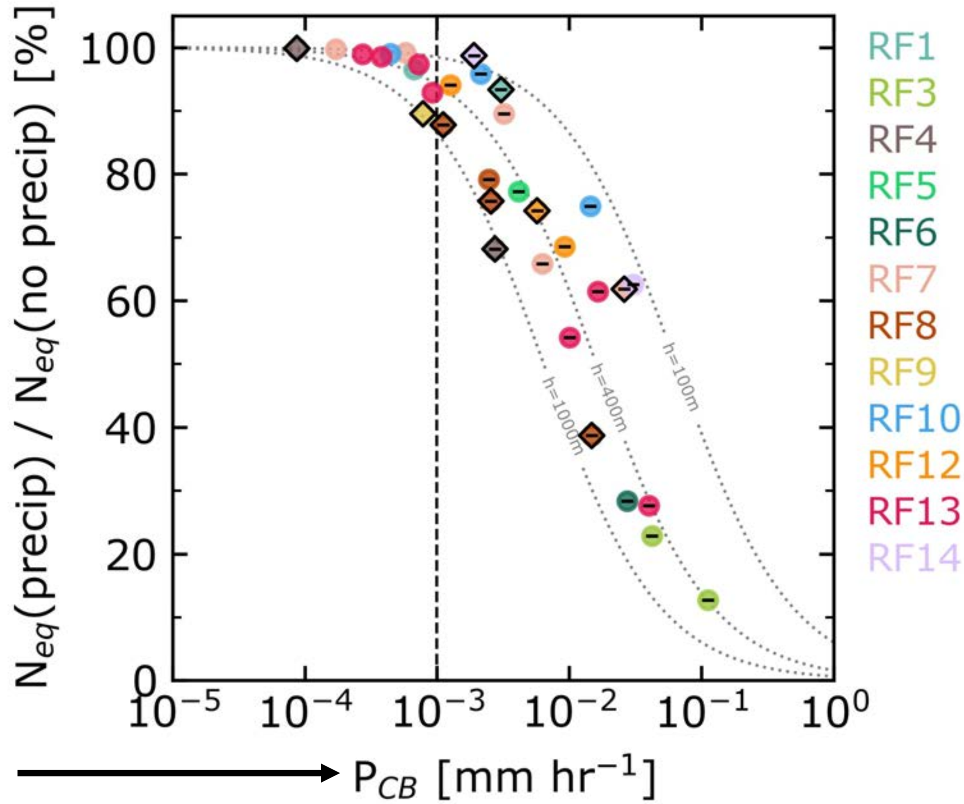
Simple budget model for the cloud droplet number (Wood et al. 2006)

$$\frac{N_{eq}(with\ Precip)}{N_{eq}(No\ Precip)} = \frac{1}{\left(1 + \frac{hKP_{CB}}{Dz_i}\right)}$$



Note: is akin to the domain-mean rate (not the single column)

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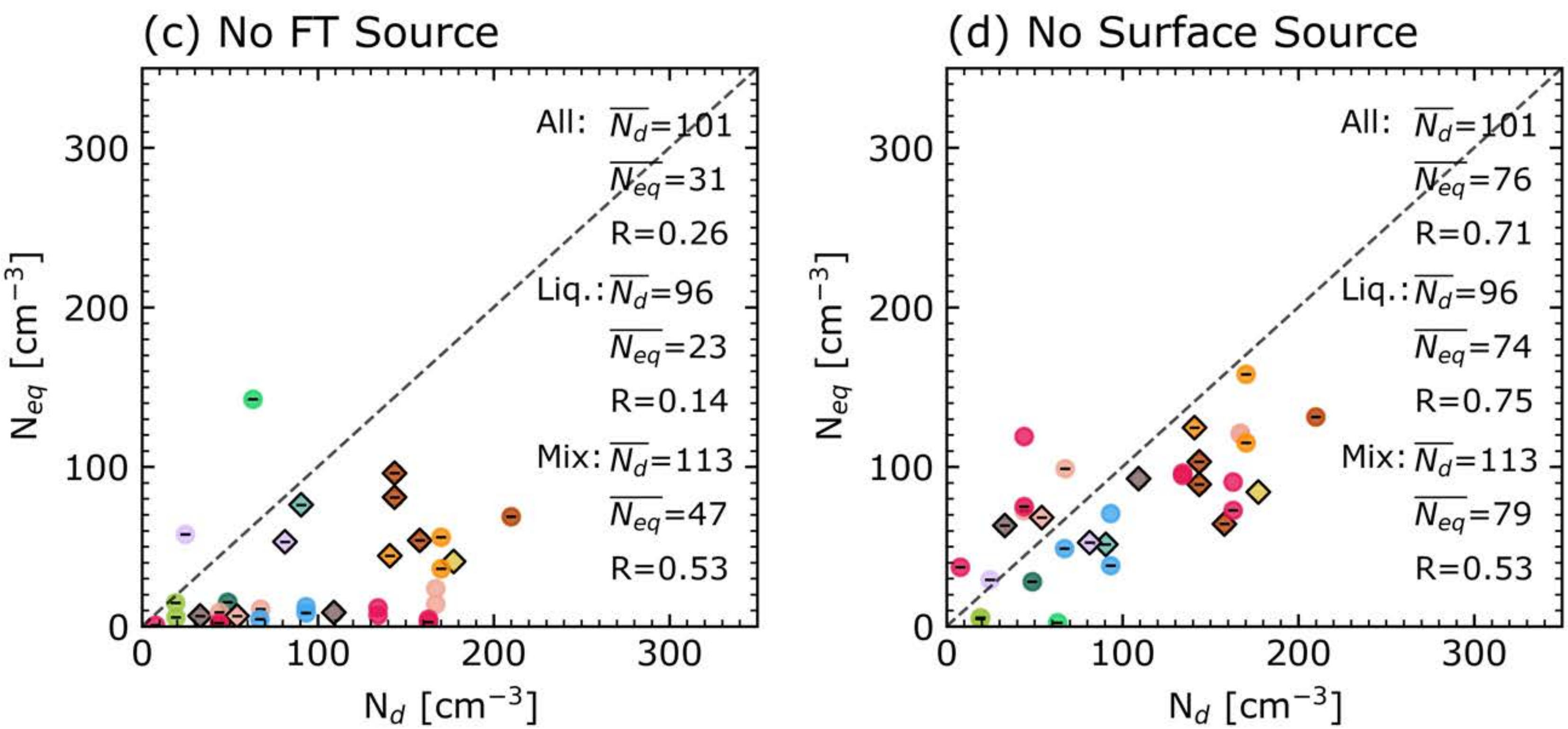
Simple budget model for the cloud droplet number (Wood et al. 2006)



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Summary of Key Points

- Light precipitation (drizzle) is common and important for understanding cloud-aerosol interaction in SO Stratocumulus (and plays a key role in controlling the mesoscale structure an ultimately the shortwave cloud radiative effect).

- Implications for experiment design
  - Need information on light precipitation / collision-coalescence processes
  - FT is an important source of CCN (at least in the SH summer)
    ➔ Need to characterized FT concentrations & entrainment
  - Surface contributed less that FT most of the time, but also needs to be characterized.

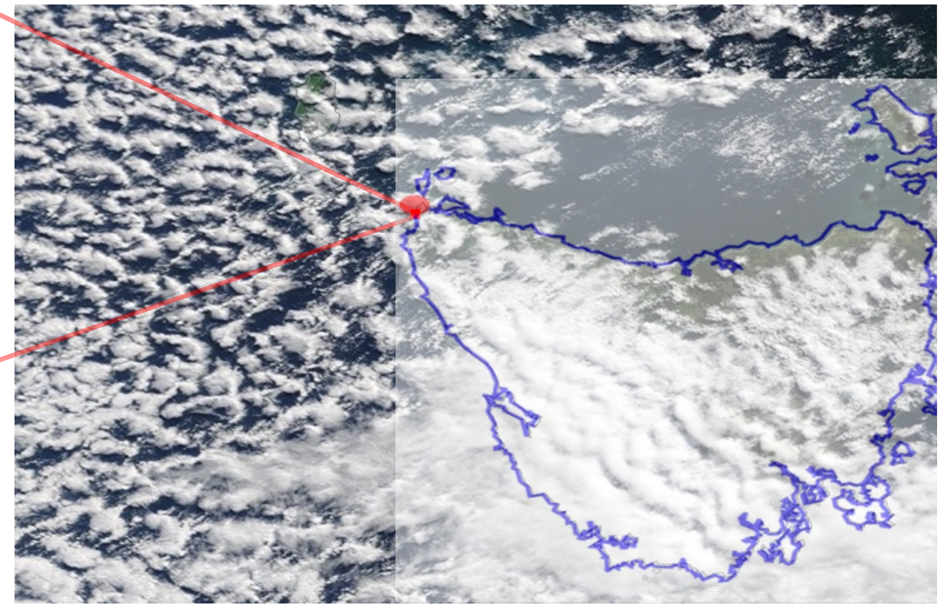
Extra Slides

ASR 2022 Fall Meeting Breakout

Cloud-aerosol-precipitation-radiation interaction studies over the Southern Ocean and Antarctic

- The intent of this session is to review the understanding of cloud-aerosol-precipitation-radiation interactions that have been gained from analysis of data collected during recent field campaigns and related model studies.
  - What have we learned?
  - What questions remain?
- Discussion will center on the development of strategies that need to be undertaken to address remaining questions.

Cloud And Precipitation Experiment at Kennaook (Cape-K)

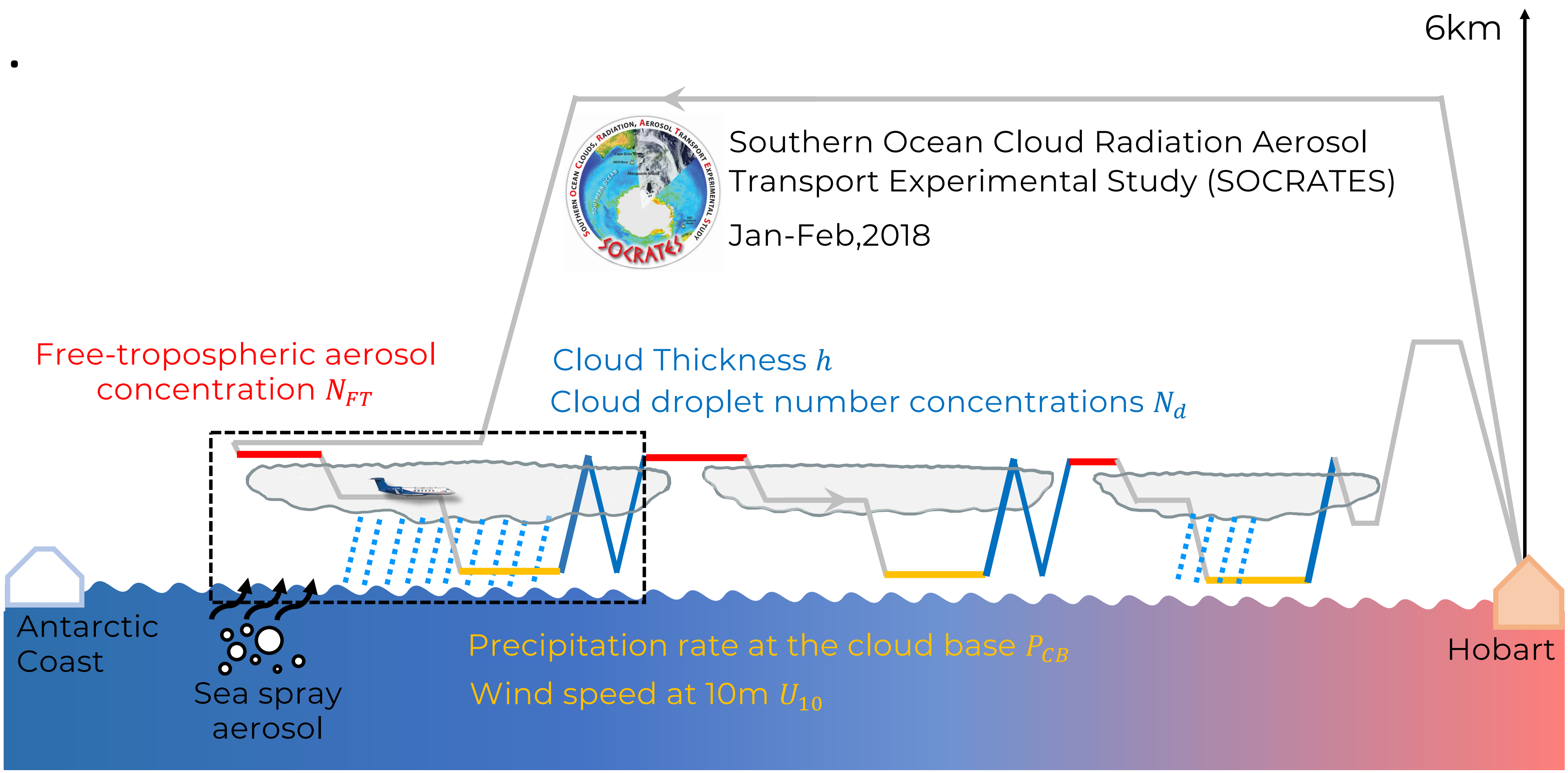


- 18 month AMF deployment to Kennaook/Cape Grim Baseline Air Pollution Station covering two winter seasons.
- This station has produced a long record of Southern Hemisphere aerosol and gas-phase chemistry but few cloud and precipitation measurements have not been collected there (until now).

Objectives:

- Document the seasonal cycle of SO low-cloud and precipitation properties and examine how they co-vary with aerosol and with dynamical and thermodynamical factors.
- Compare and contrast these relationships with observations from other surface sites and campaigns including other recent SO campaigns.
- Study aerosol-cloud-precipitation interactions in low clouds and explore how these interactions can best be represented in models at various scales.

SOCRATES Flight



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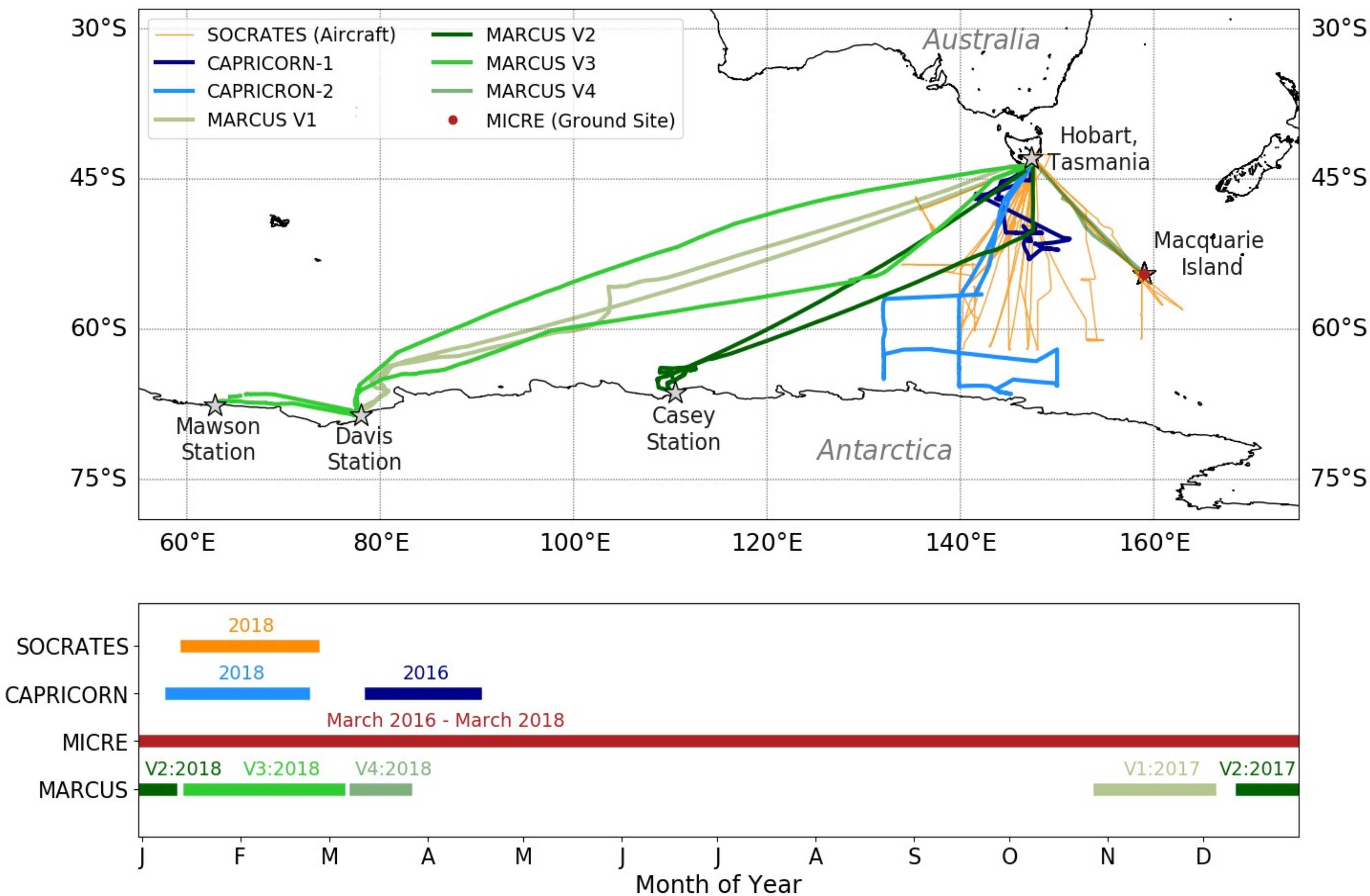
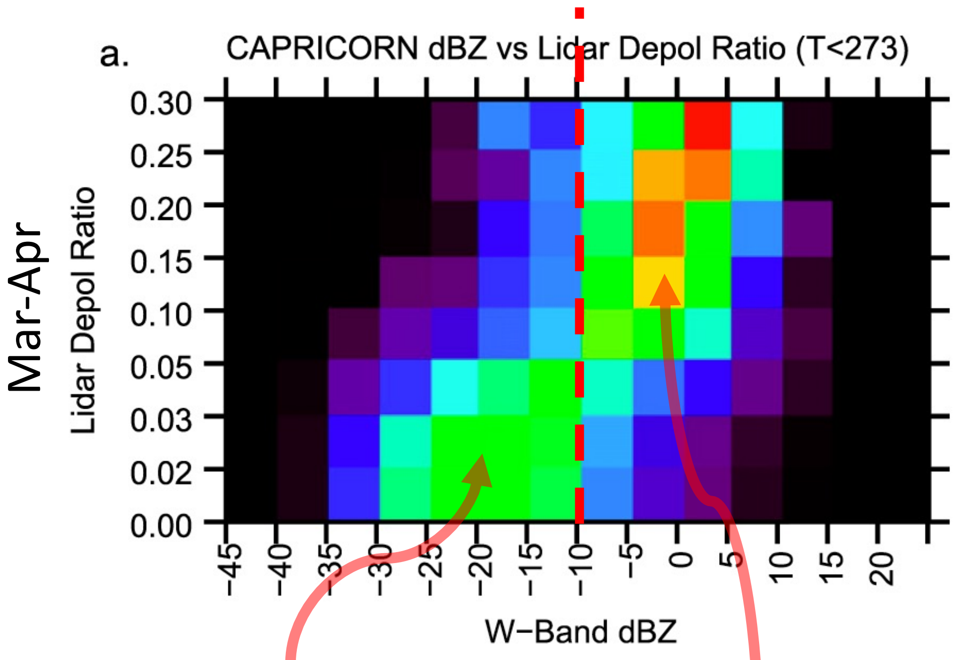
Southern Ocean Experiments (2016-2018)

McFarquhar et al. BAMS 2020
DOI: 10.1175/BAMS-D-20-0132.1

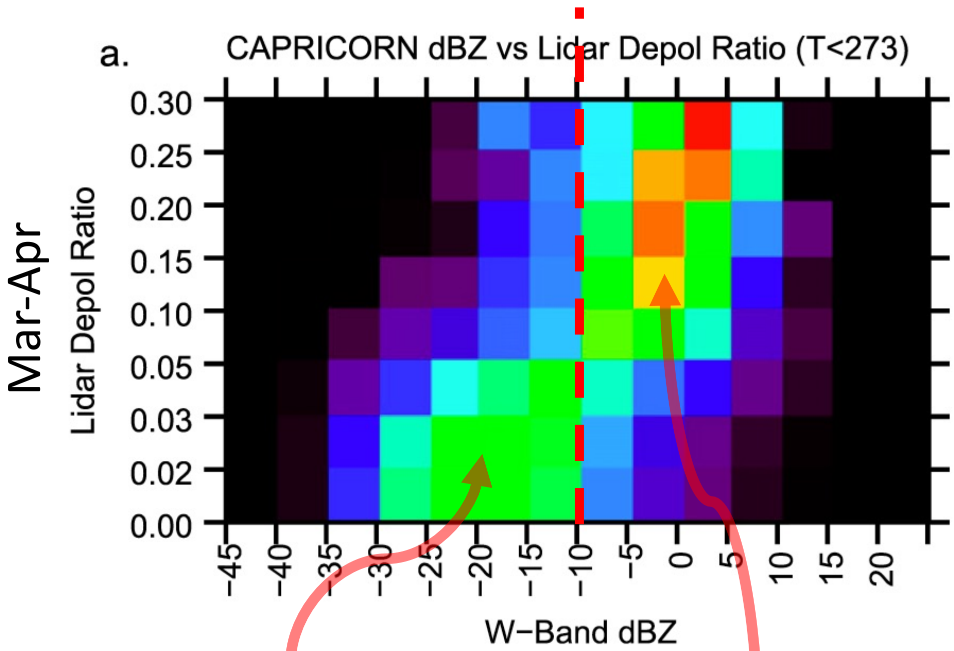

SOCRATES (Aircraft)
CAPRICORN-1
CAPRICRON-2
MARCUS V1
MARCUS V2
MARCUS V3
MARCUS V4
MICRE (Ground Site)
Australia
Hobart, Tasmania
Macquarie Island
Mawson Station
Davis Station
Casey Station
Antarctica
30°S
45°S
60°S
75°S
60°E
80°E
100°E
120°E
140°E
160°E
SOCRATES
CAPRICORN
MICRE
MARCUS
2018
2018
2016
March 2016 - March 2018
V2:2018
V3:2018
V4:2018
V1:2017
V2:2017
J F M A M J J A S O N D
Month of Year



Low depolarization ratio
➔ spherical particles
➔ Liquid precipitation

High depolarization ratio
➔ Non-spherical particles

Mace and Protat JAMC 2018, DOI: 10.1175/JAMC-D-17-0194.1



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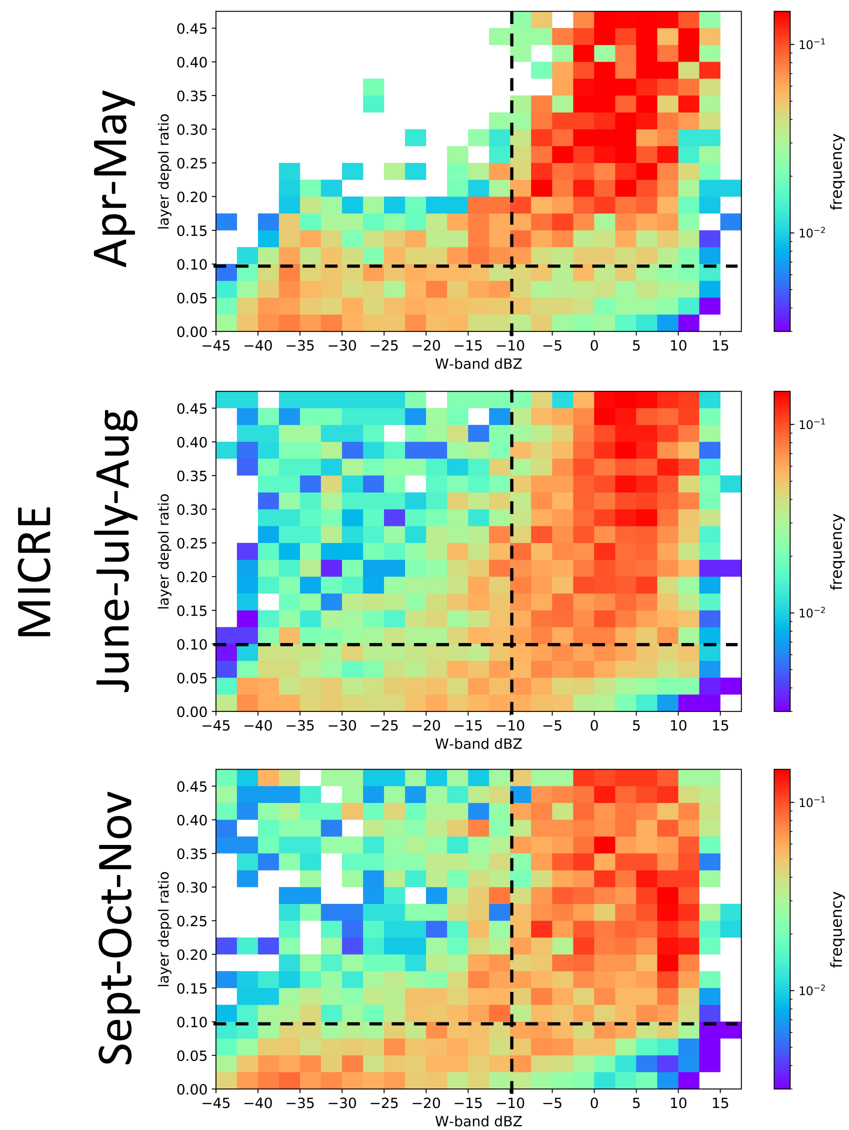
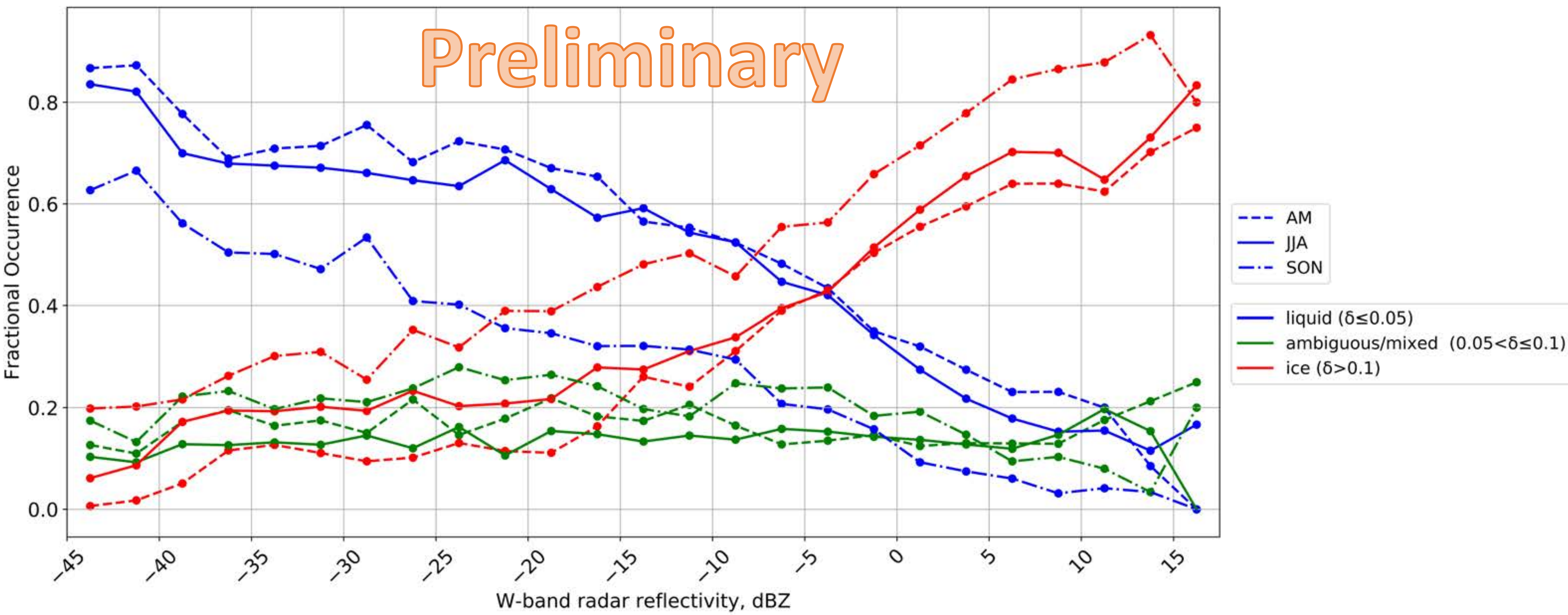


Mace and Protat JAMC 2018, DOI: 10.1175/JAMC-D-17-0194.1

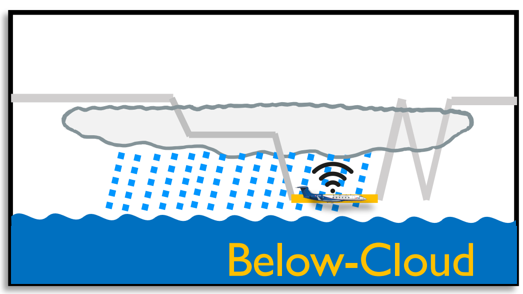
<u>Preliminary</u>: MICRE Below-Cloud (100-300 m) Precipitation Phase

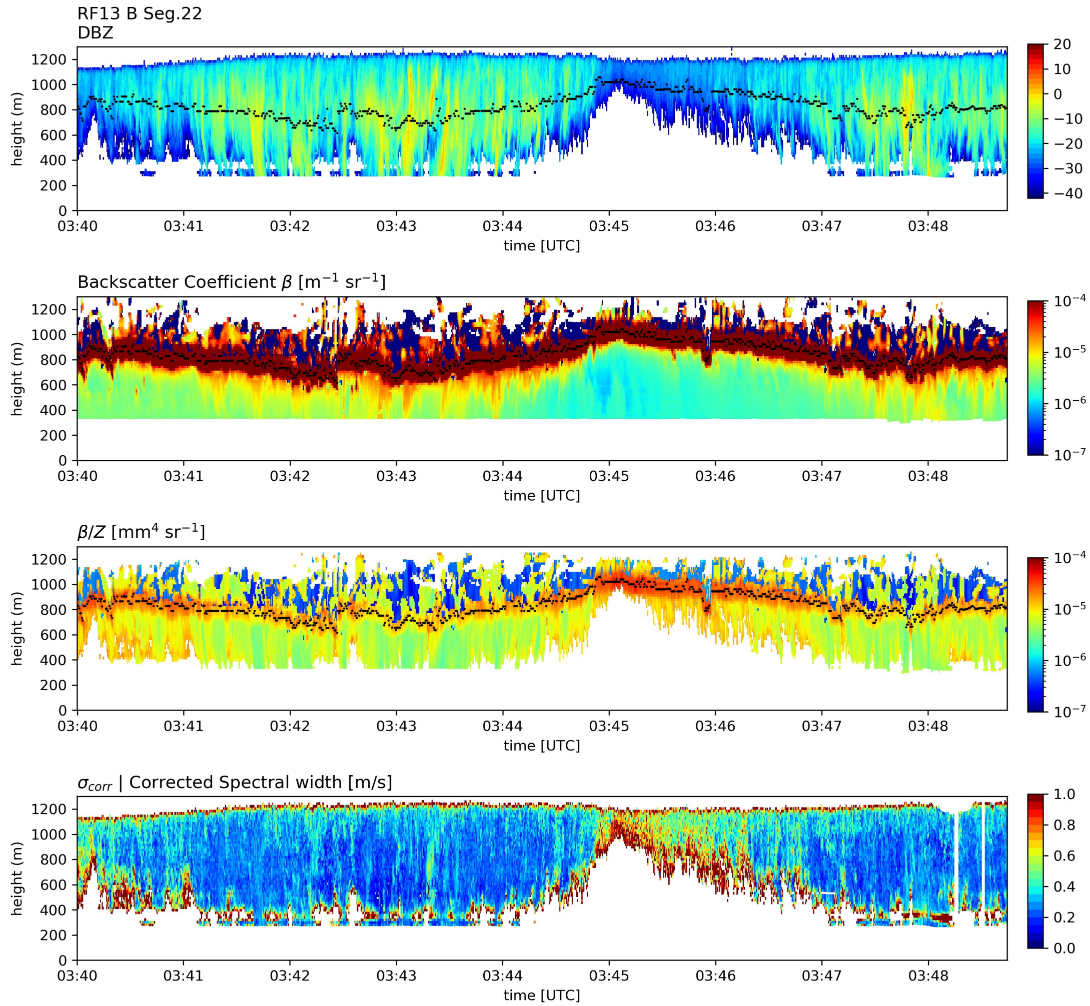


An example of the O'Connor radar-lidar precipitation retrieval for the SOCRATES flights.

Input

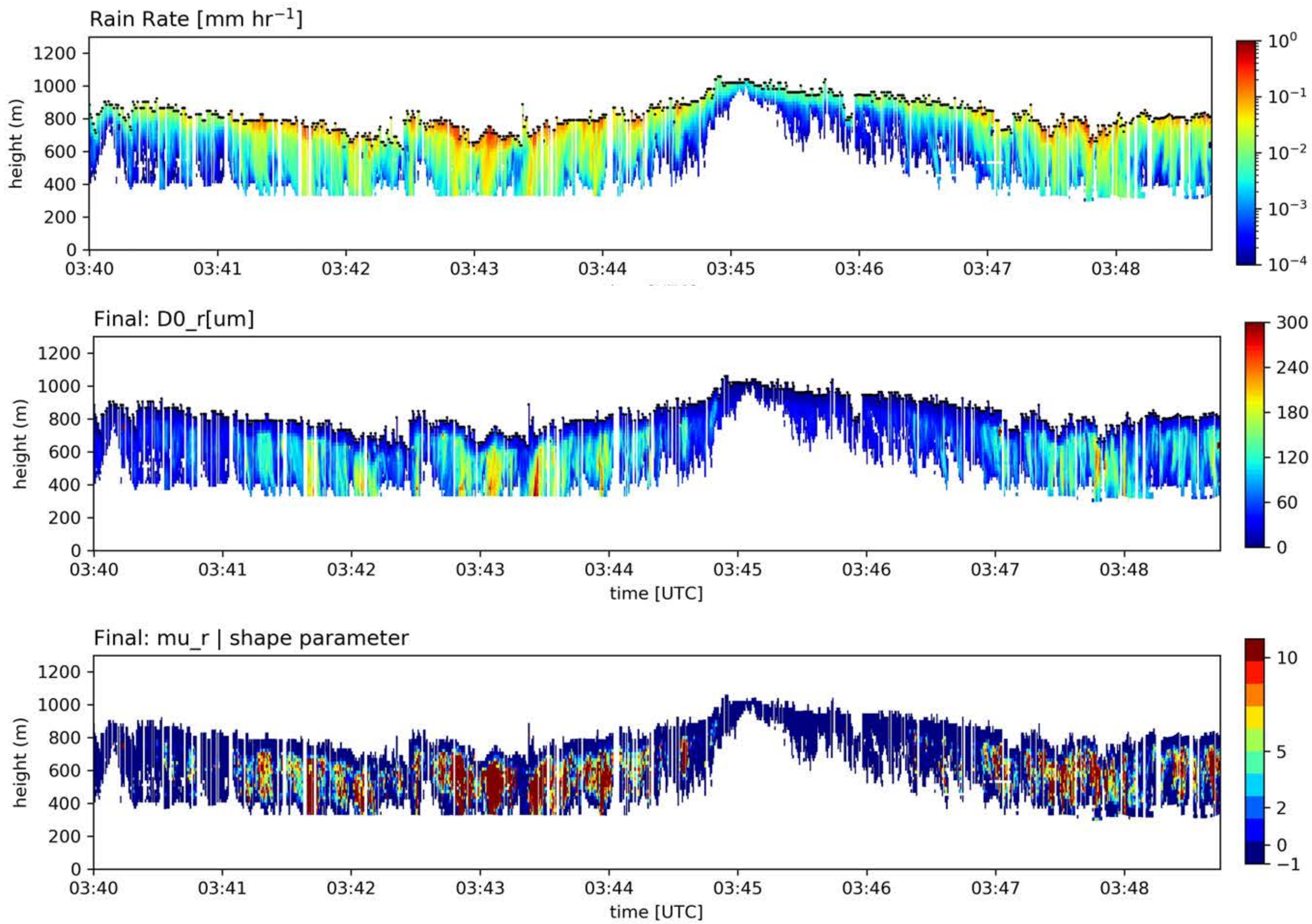
Note: in this case, aircraft is flying around 200m





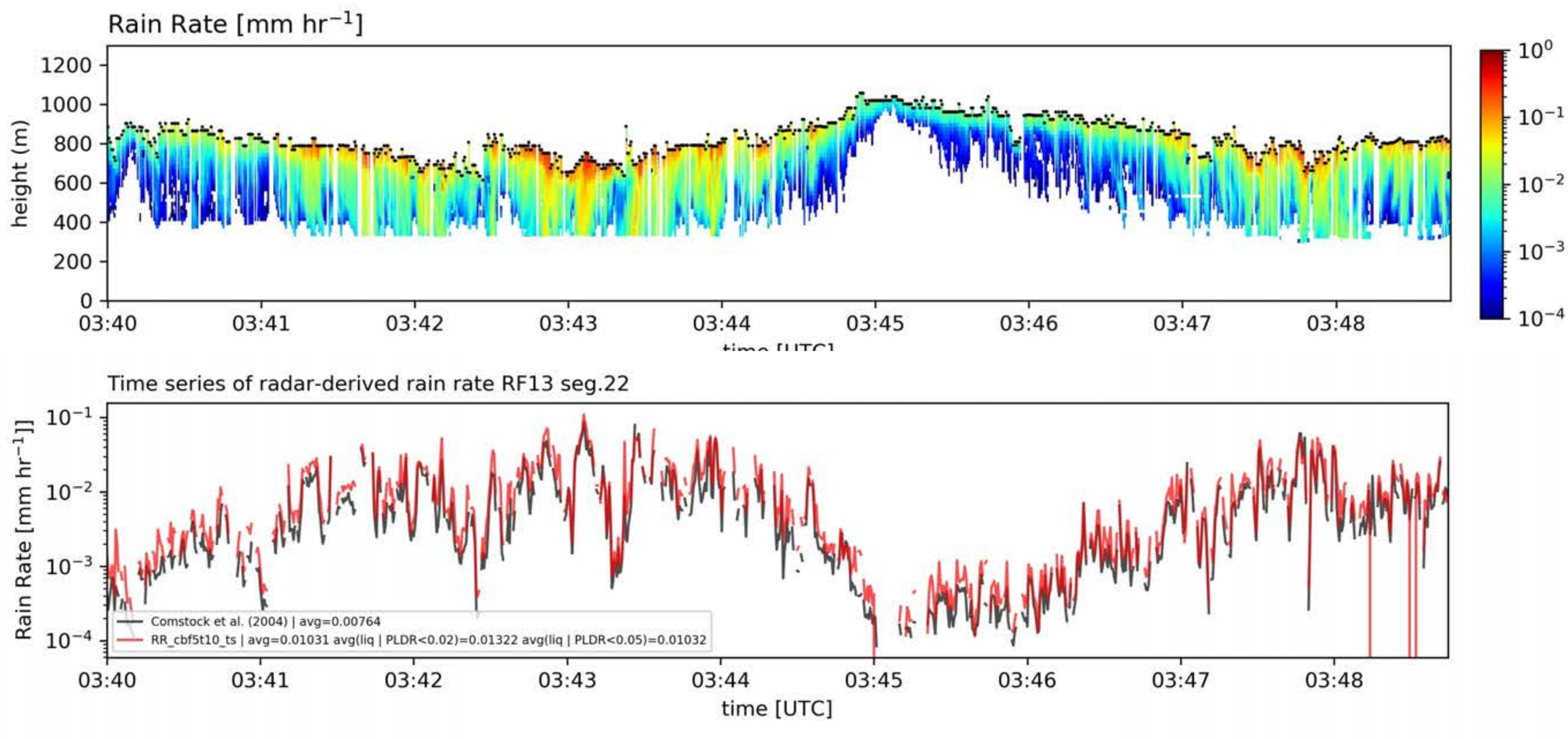
An example of the O'Connor radar-lidar precipitation retrieval for the SOCRATES flights.

Retrieved



An example of the O’Connor radar-lidar precipitation retrieval for the SOCRATES flights.

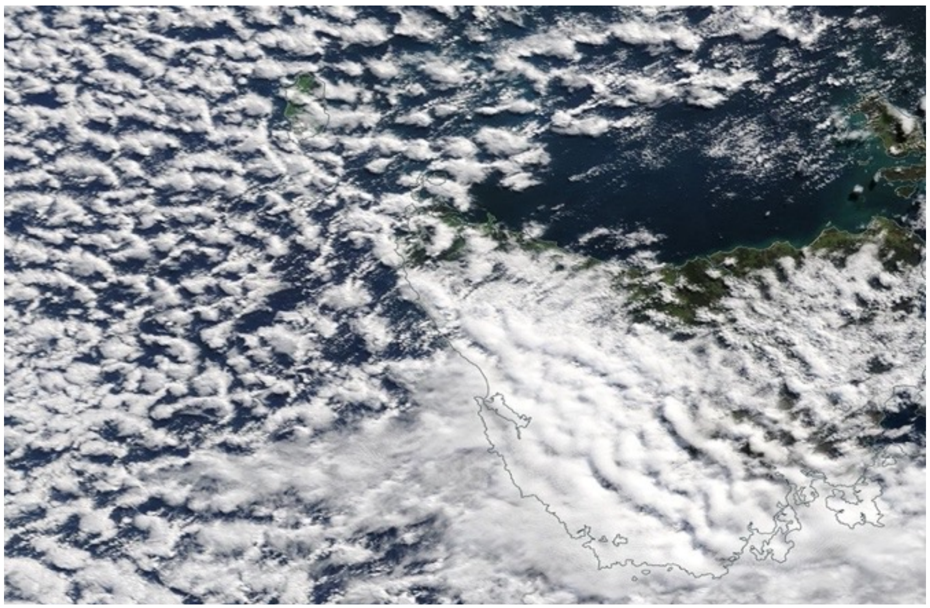
Rain Rate at cloud base

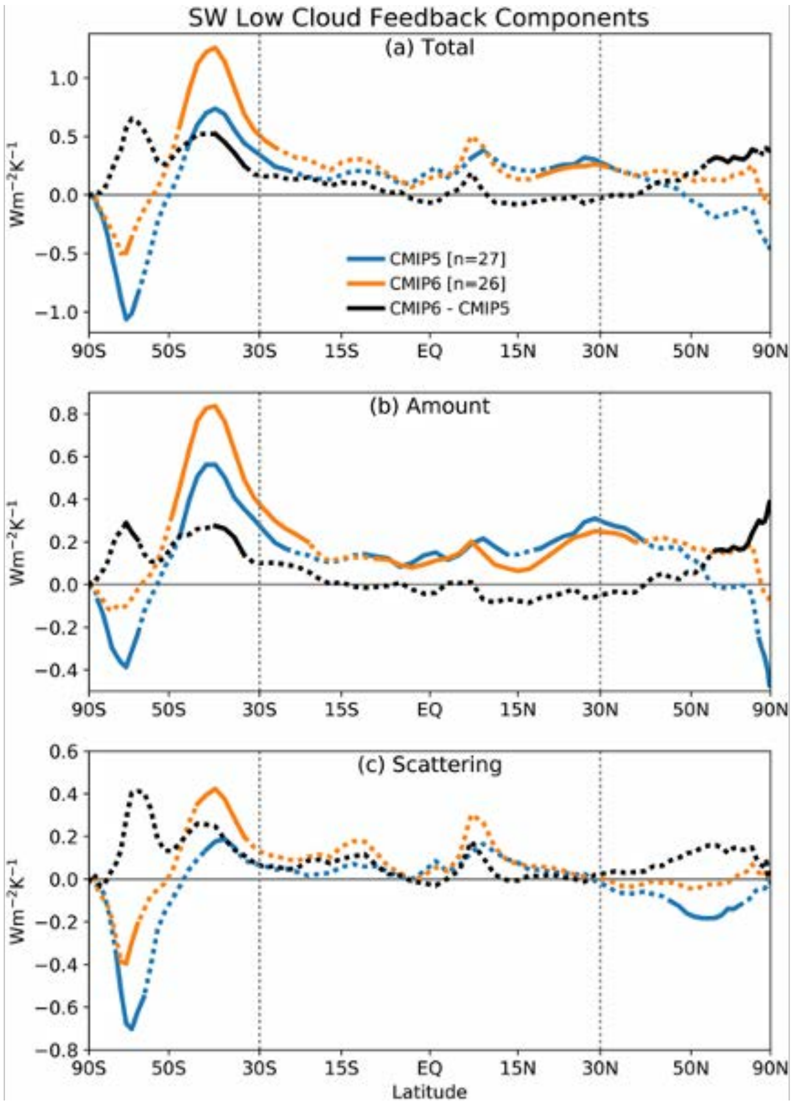


P_{CB} from radar-lidar retrieval

P_{CB} using Z-R relationship from Comstock et al. (2004)

Cloud And Precipitation Experiment at Kennaook (Cape-K)





- Climate models participating in the most recent Coupled Model Intercomparison Project phase 6 (CMIP6) simulate strong latitudinal gradients in the response of low-clouds to increases in greenhouse gases in the Southern Hemisphere high and mid-latitudes

- The strong gradients are driven primarily by opposing changes in **low-cloud-amount** and **low-cloud-optical-depth**.

- *Poleward of about 50^o S:* there is a relatively strong increase in the mean cloud optical depth, thought to be driven by an increase in cloud liquid water and results from a reduction in ice microphysical processes in mixed-phase clouds and the reduced efficiency of converting cloud liquid water into precipitation without ice.

- *Equatorward of about 50^o S:* there are larger reductions in low-cloud-amount than poleward of 50^o S.