Investigating Marine Boundary Layer Cloud and Drizzle Microphysical Properties over the Southern Ocean Using Airborne In Situ and Radar Measurements

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Seeking postdoc/research scientist roles — Scan to Connect.

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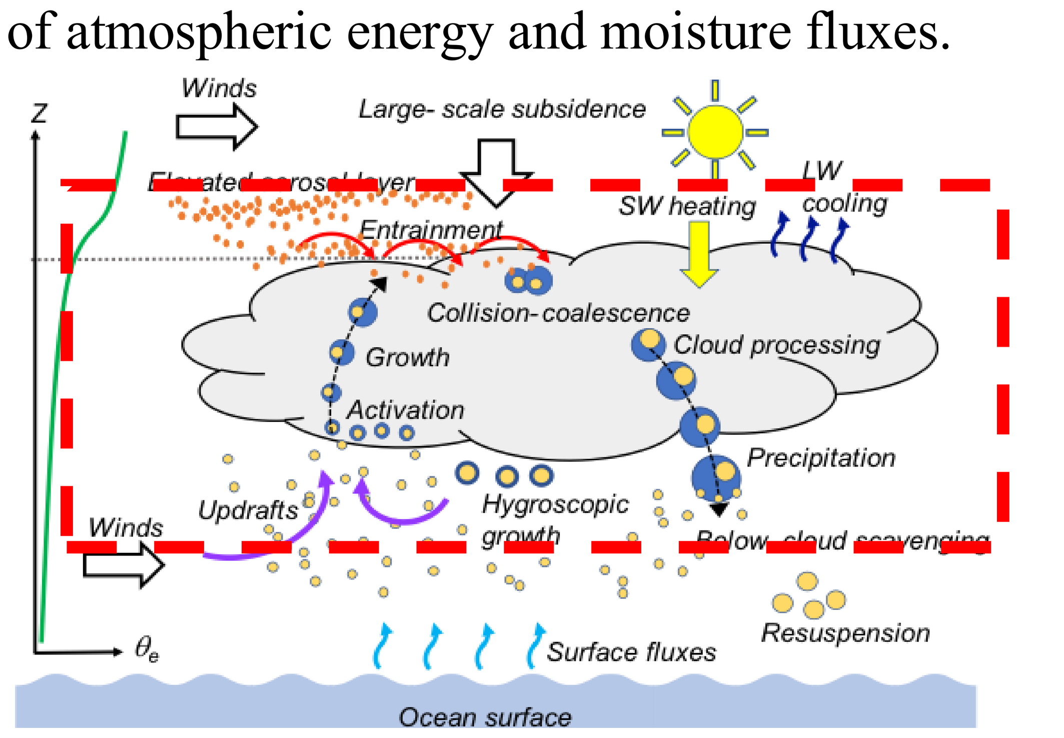
1. MOTIVATION

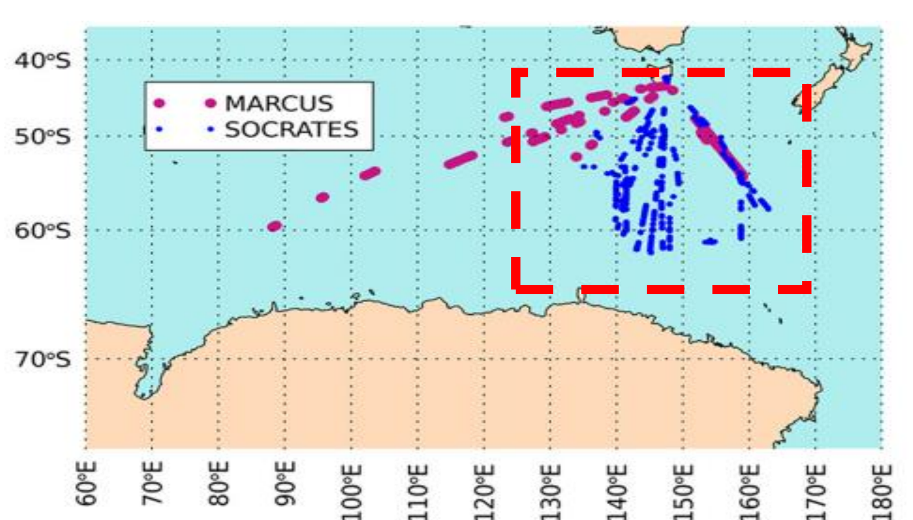
- Low-level marine boundary layer (MBL) clouds strongly regulate regional radiation and climate through their control of solar reflection and surface energy balance.
- Climate models show uncertainties due to poor representation of cloud structure and drizzle processes.
- Understanding the vertical structure and microphysical properties of clouds and drizzle is essential for improving model representations of atmospheric energy and moisture fluxes.



2. STUDY SITE & DATASET

The **Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES)** campaign (Jan - Feb 2018) over the coast of Hobart, Tasmania (42-62°S and 133°-163°W), used NSF/NCAR GV aircraft to collect in situ and remote sensing data over the SO MBL clouds.

- **In Situ Probes -** Cloud Droplet Probe (CDP) and 2D Stereo, Particle Imaging Probe (2D-S).
- **Remote Sensors -** 94.40 GHz HIAPER Cloud Radar (NCAR HCR) and 532 nm High Spectral Resolution Lidar (GV HSRL).



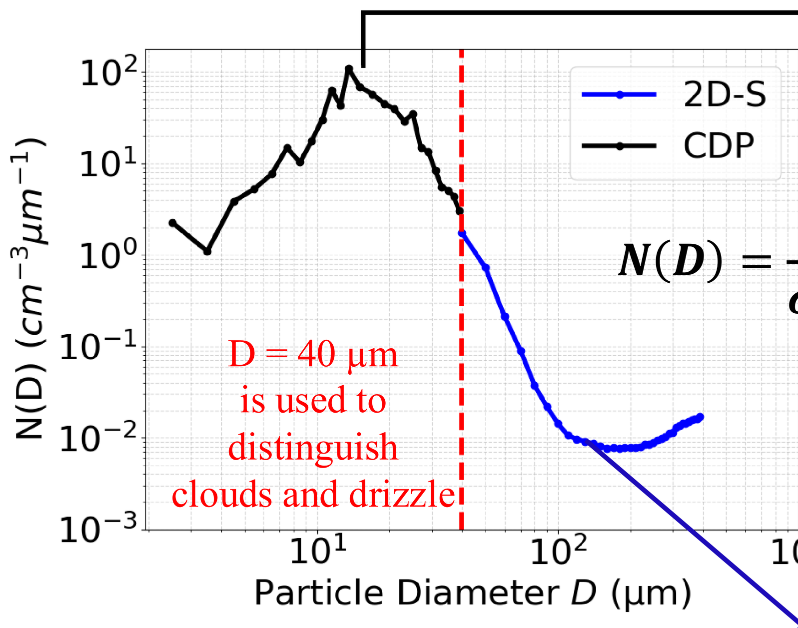
3. PURPOSE OF STUDY

- Use in situ droplet size distributions (DSD) to derive empirical relationships between reflectivity, effective radius (r_e), and liquid water content (LWC) for single-layer low-level (< 3 km) MBL cloud and drizzle.
- Apply derived relationships to airborne and ground-based radar to extend spatial coverage and retrieve vertical microphysical structure.

9. KEY TAKEAWAYS

- **Robust empirical relationships derived from in situ measurements enable retrieval of SO MBL cloud and drizzle microphysics (r_e, LWC) from radar reflectivity.**
- **Consistent airborne–ship agreement shows cross-platform robustness.**
- **Derived method applicable to similar W-band marine observations; recalibration is needed for other frequencies or regimes.**

4. CLOUD AND DRIZZLE PROFILES FROM CDP & 2D-S

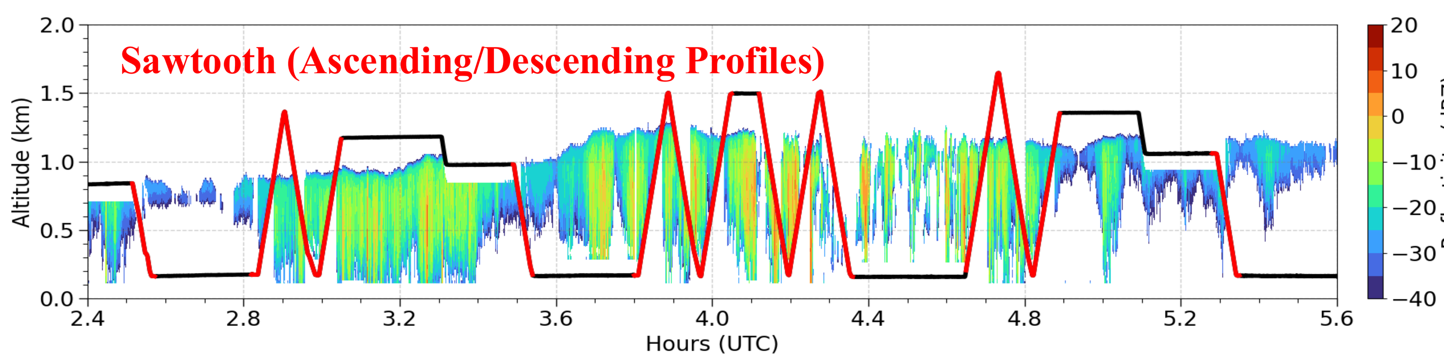


Lognormal Distribution fit for CDP cloud spectra (2-40 µm)

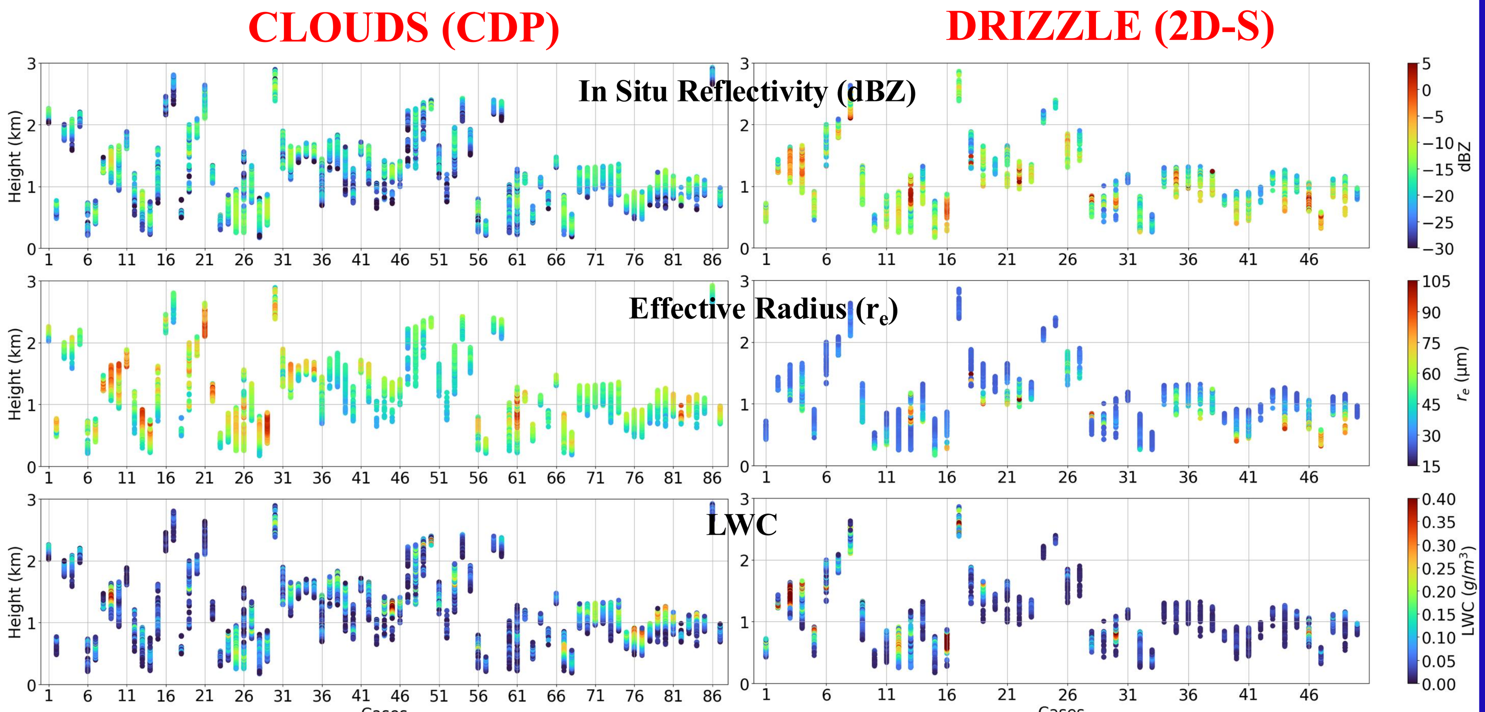
$$N(D) = \frac{N}{\sigma_x\sqrt{2\pi}}\exp\left(-\frac{[lnD - lnD_0]^2}{2\sigma_x^2}\right)$$

$$N(D) = N_0 D^{\mu}\exp(-\lambda D)$$

Gamma Distribution fit for 2D-S drizzle spectra (40-400 µm). (>400 is precipitation-sized droplets hence ignored)



- Sawtooth flight tracks (ascending/descending) that transect the entire cloud vertical profile are selected for constructing in situ CDP + 2D-S profiles.
- $Z = \int N(D)D^6 dD$, $LWC = (\pi/6)\rho_w \int N(D)D^3 dD$,
- $<r^k> = N^{-1}\int r^k N(D)dD$, $r_e = <r^3>/<r^2>$

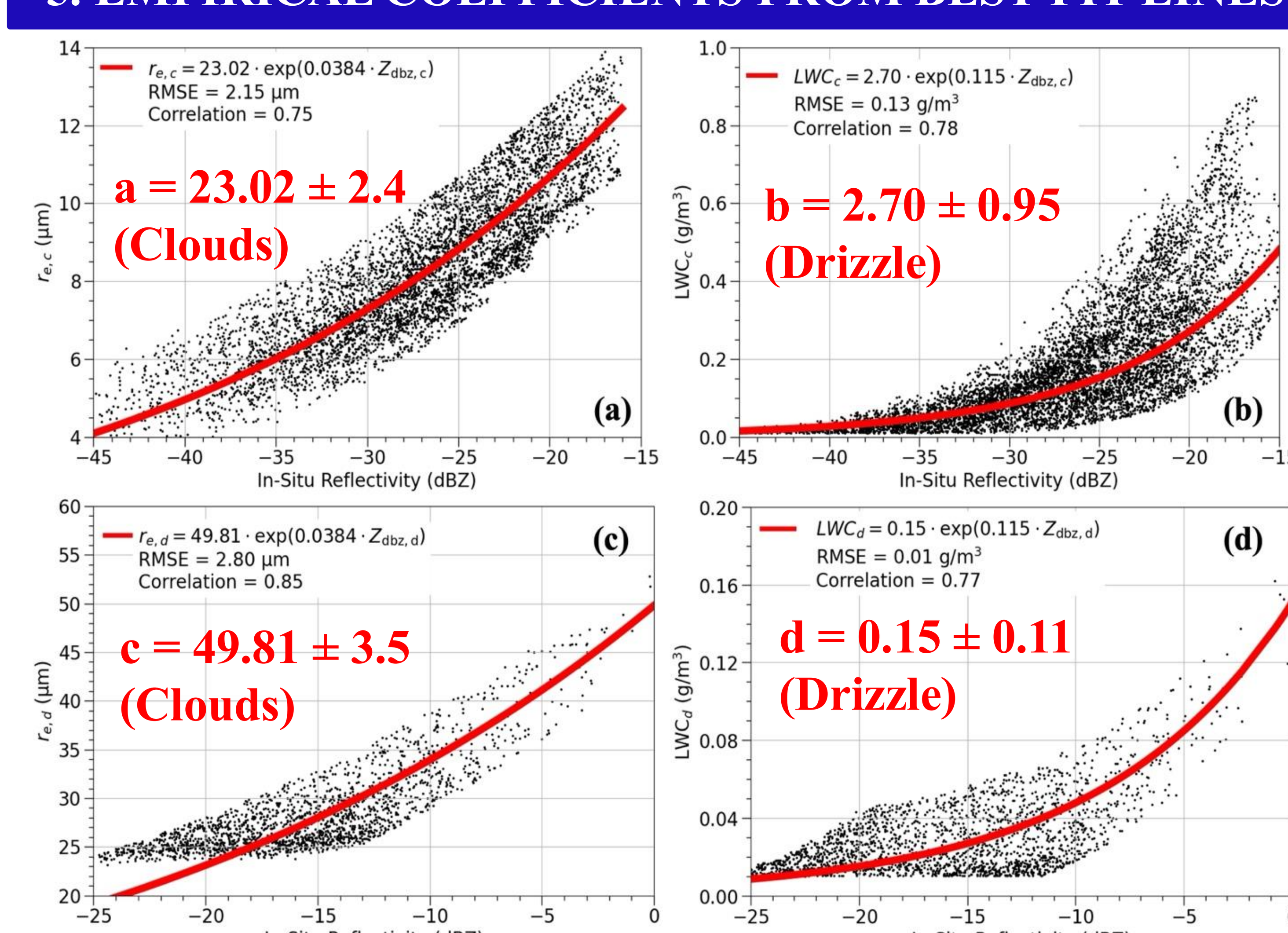


87 profiles are composed from 7,329 in situ CDP cloud spectra at 1 Hz

50 profiles are composed from 3,564 in situ 2D-S drizzle spectra at 1 Hz

- $r_{e,c} = a \cdot exp(0.0384Z_{dbz,c})$, $r_{e,d} = c \cdot exp(0.0384Z_{dbz,d})$
- $LWC_c = b \cdot exp(0.115Z_{dbz,c})$, $LWC_d = d \cdot exp(0.115Z_{dbz,d})$

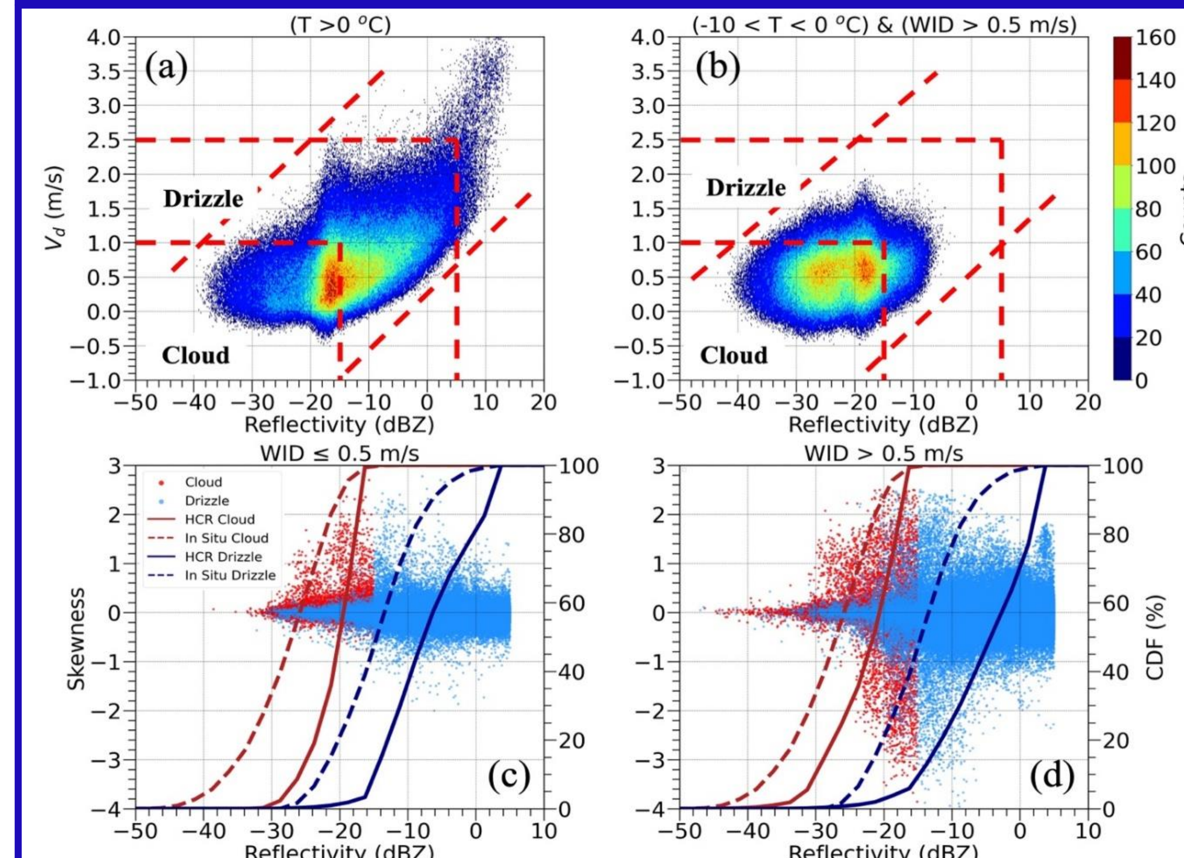
5. EMPIRICAL COEFFICIENTS FROM BEST-FIT LINES



6. SENSITIVITY TESTS

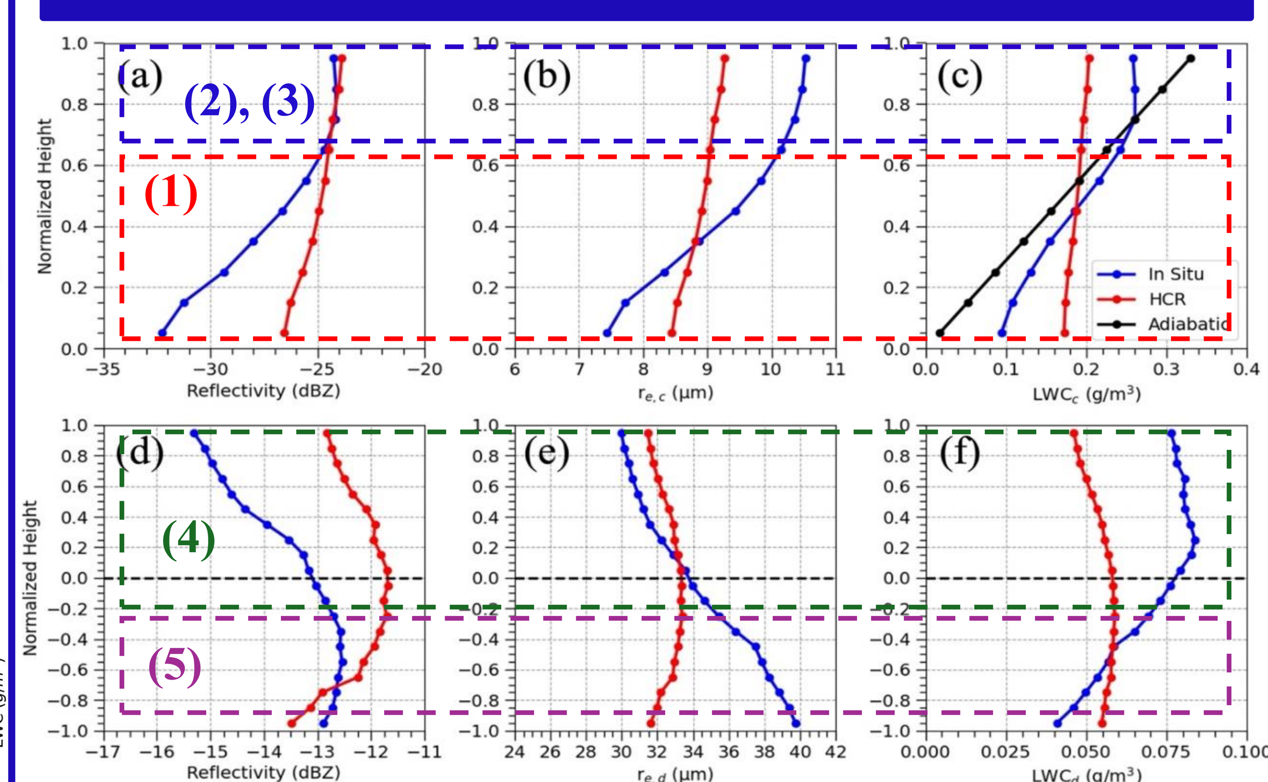
Sensitivity analyses showed that the empirical coefficients vary only moderately with changes in droplet number concentration **(N)** and DSD shape parameters (**σ_x and μ**): **by 4–8% for clouds and 10–26% for drizzle**, suggesting that the derived relationships are relatively stable against small variations for MBL clouds over the SO.

7. HCR RADAR PROFILES



- **Low Z (−30 to −15 dBZ):** Cloud and early drizzle overlap; narrow spectra (WID ≤ 0.5 m s^{-1}); skewness ~0 to slightly positive.
- **High Z / high WID:** Broader spectra with increasingly negative skewness as drizzle growth and settling dominate.

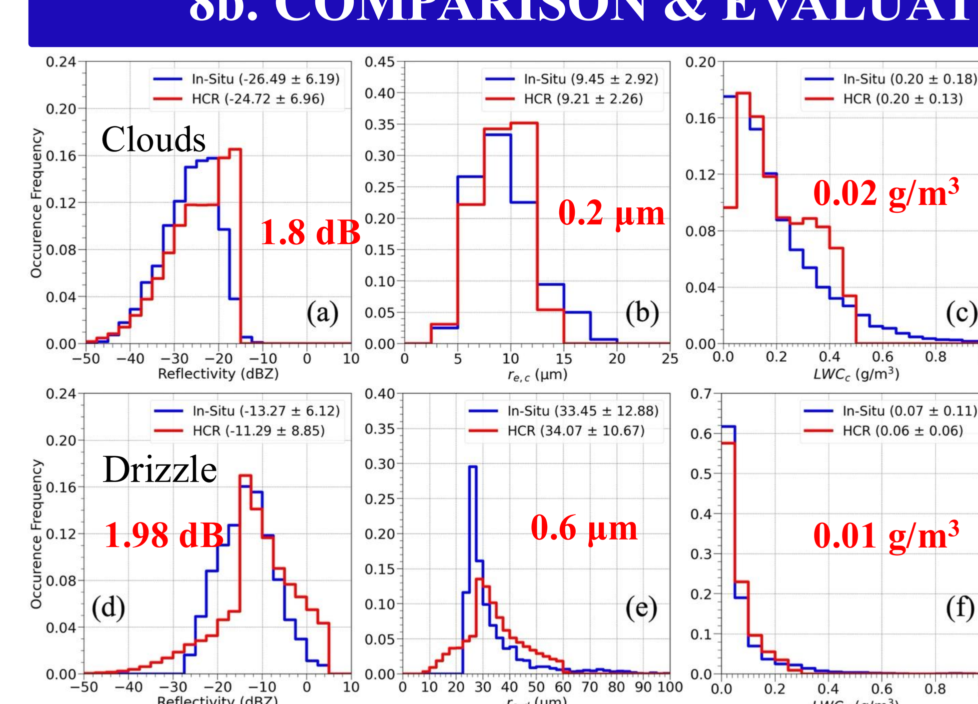
8. RESULTS & CONCLUSIONS



8a. VERTICAL PROFILES

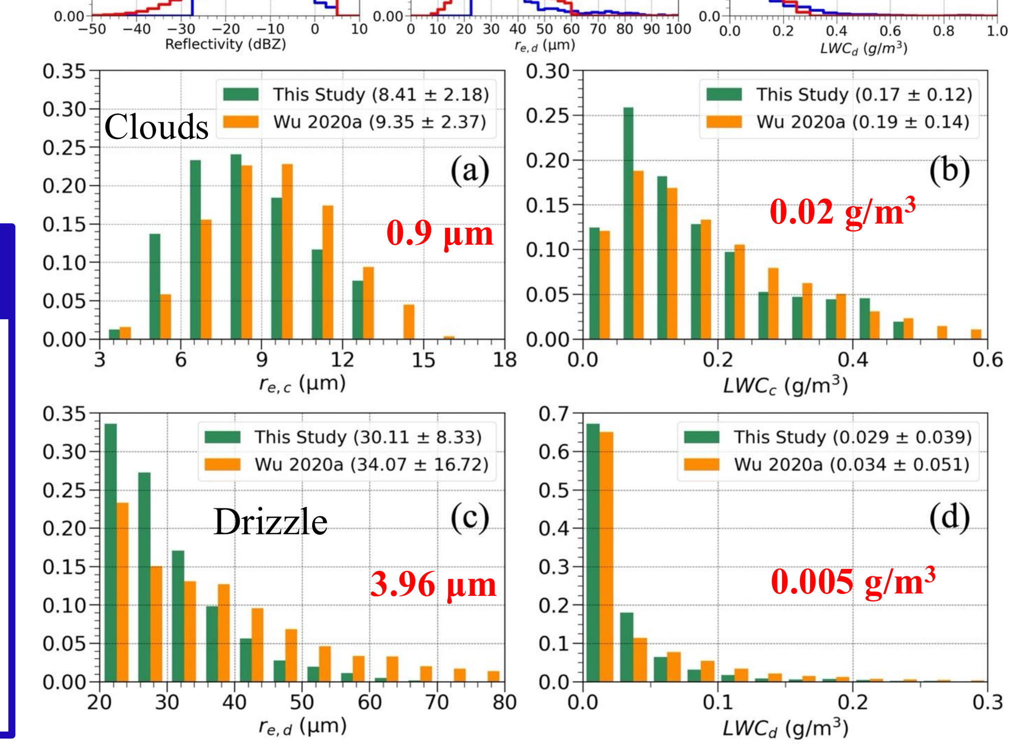
1. **Cloud Droplet Condensation Growth ↑**
2. **Cloud Top Entrainment – mixing of dry air evaporates droplets**
3. **Drizzle Initiation – larger cloud drops act as embryonic drizzle**
4. **Collision-Coalescence growth of drizzle ↓**
5. **Evaporation from dry air near surface (virga) or rain (if enough moisture)**

8b. COMPARISON & EVALUATION



Mean Differences (red)

SOCRATES In Situ (Obs.) Vs. HCR retrievals



SOCRATES HCR retrieval Vs. MARCUS Ship-Campaign WACR Retrievals (Wu 2020)

RADAR TECHNOLOGY community workshop