EarthCARE-Tropical cyclone Model Intercomparison Experiments: Investigating Distributions of Cloud Particle Types in Tropical Cyclones Using EarthCARE observation

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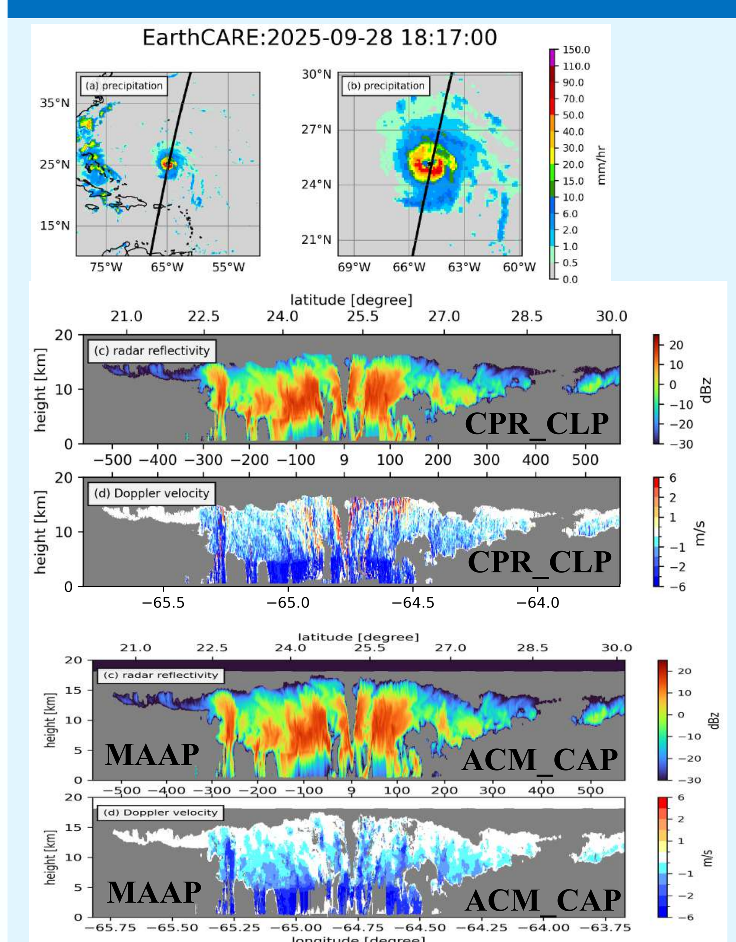
1. Objective

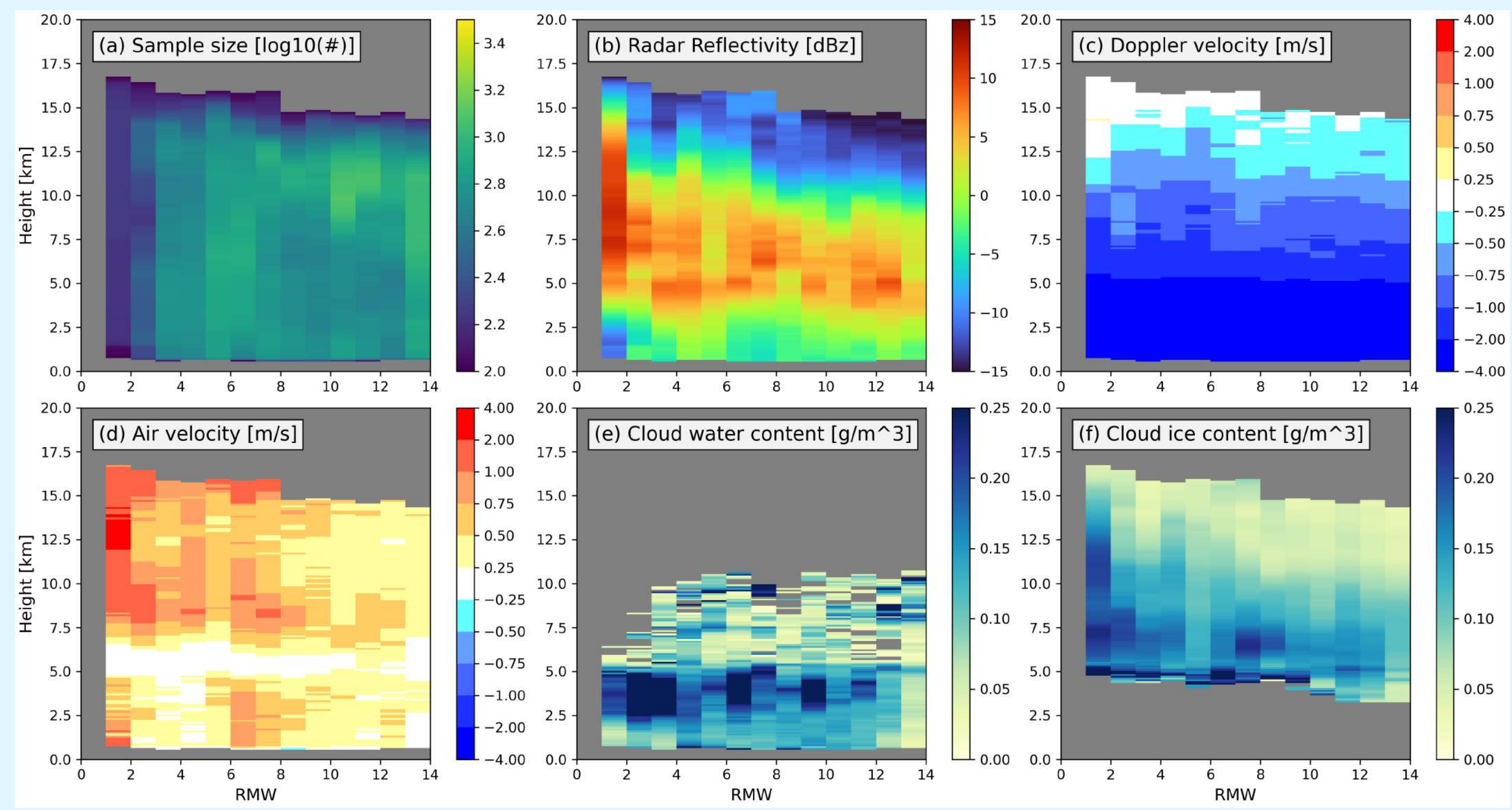
This study aims to develop an EarthCARE-based benchmark for evaluating cloud particle types, Doppler velocity, and vertical motion in tropical cyclones (TCs). We first characterize radial-height microphysical structures from the eyewall to outer rainbands and cloud particle types on Doppler velocity PDF. We then show preliminary results of NICAM experiments and will further apply these diagnostics to NICAM results.

2. Data and Method



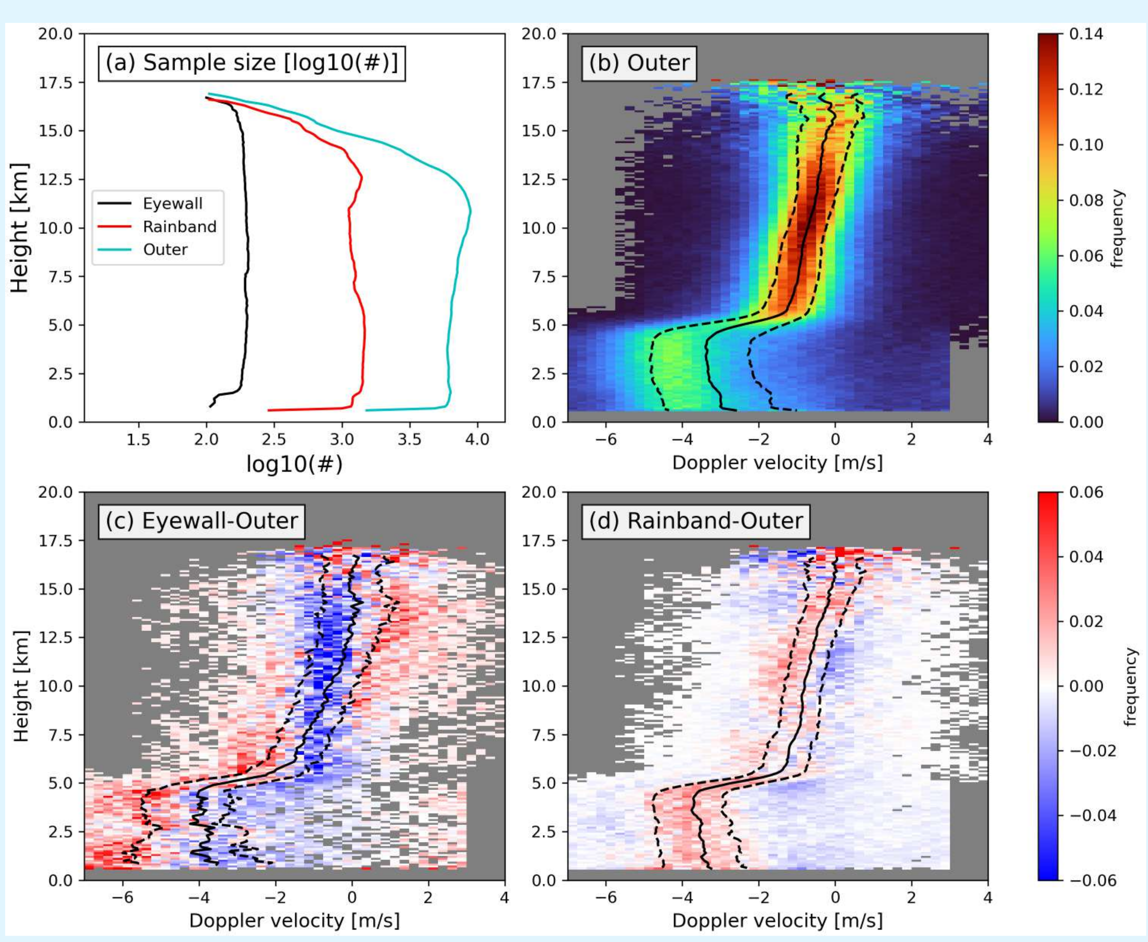
- EarthCARE CPR and CPR-ATLID synergy products (Sato et el., 2025; Okamoto et al., 2024) are collocated with IBTrACS (Knapp et al., 2010; Gahtan et al., 2024) TC tracks to construct storm-relative statistics based the distances from the storm center, which normalized by the radius of maximum wind.
- NICAM simulations with different initial conditions are then sampled using the Joint-Simulator to generate EarthCARE-like radar signals for direct comparison with the observations.

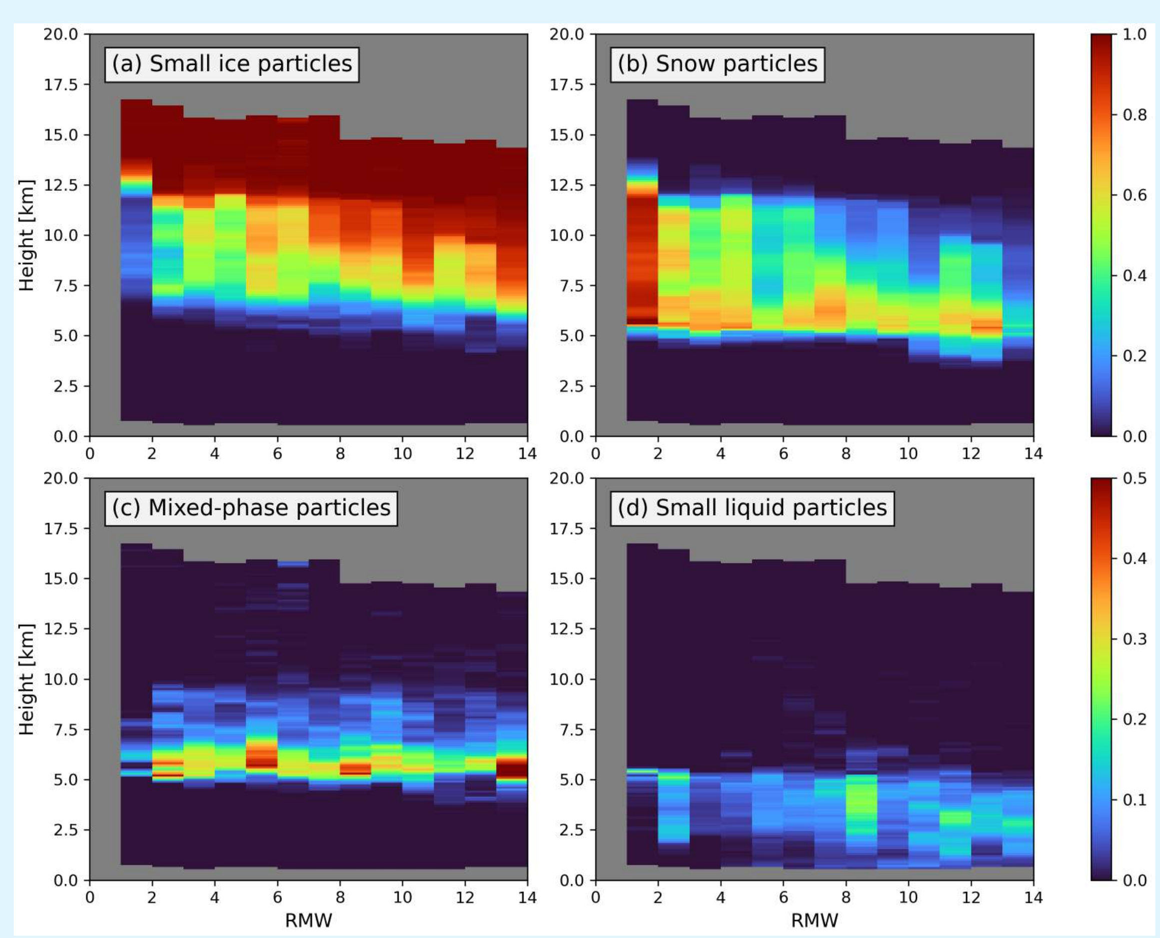
3. Radial mean structure

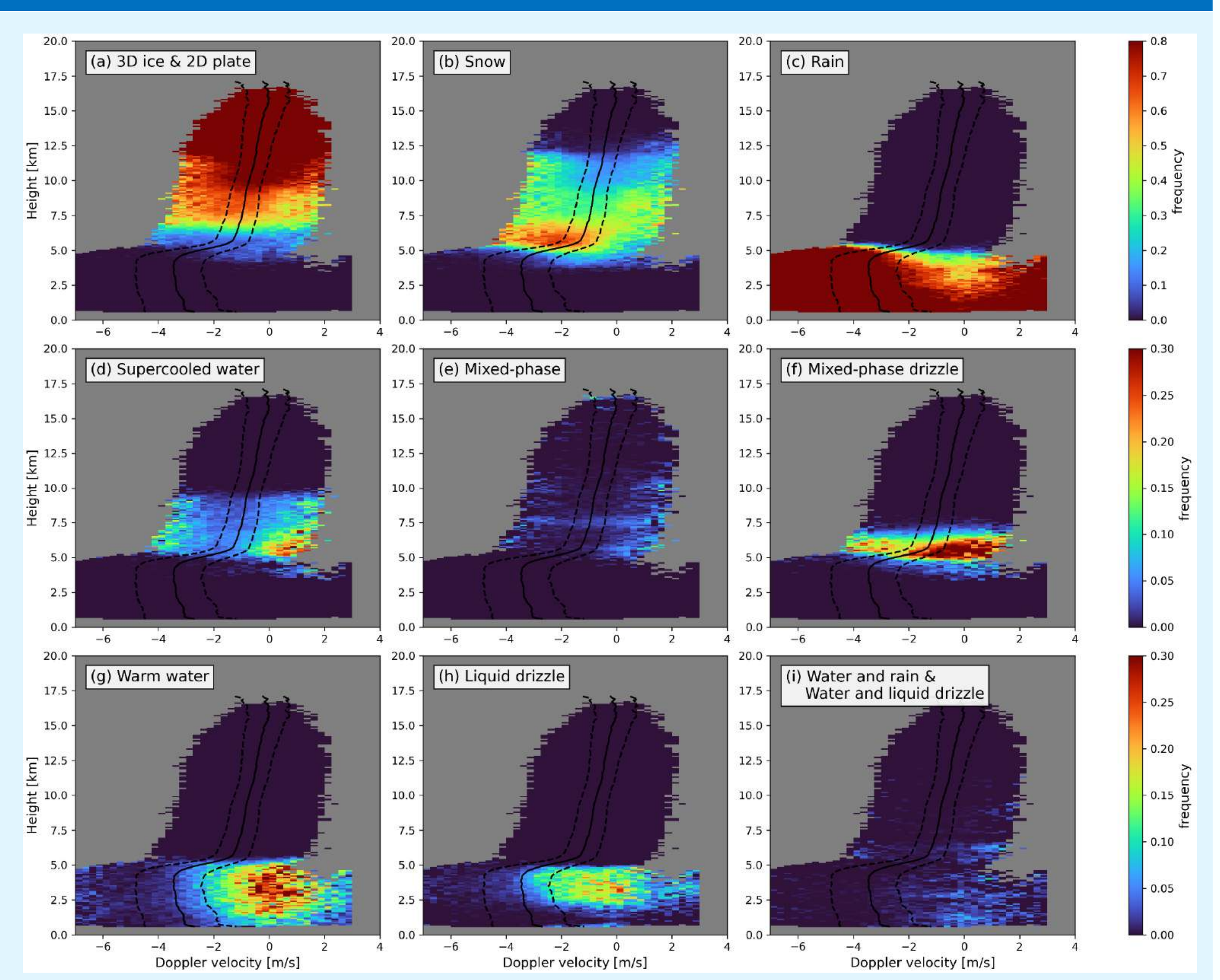


Radial-mean composites show a transition from convective-like eyewall structures to weaker, more stratiform rainband and outer-region structures. The eyewall is characterized by deeper reflectivity and stronger upward motion, while the rainband exhibits weaker vertical motion and enhanced reflectivity near the melting level. These patterns highlight how EarthCARE captures the radial structures of TC dynamics and microphysics.

4. Doppler velocity PDF







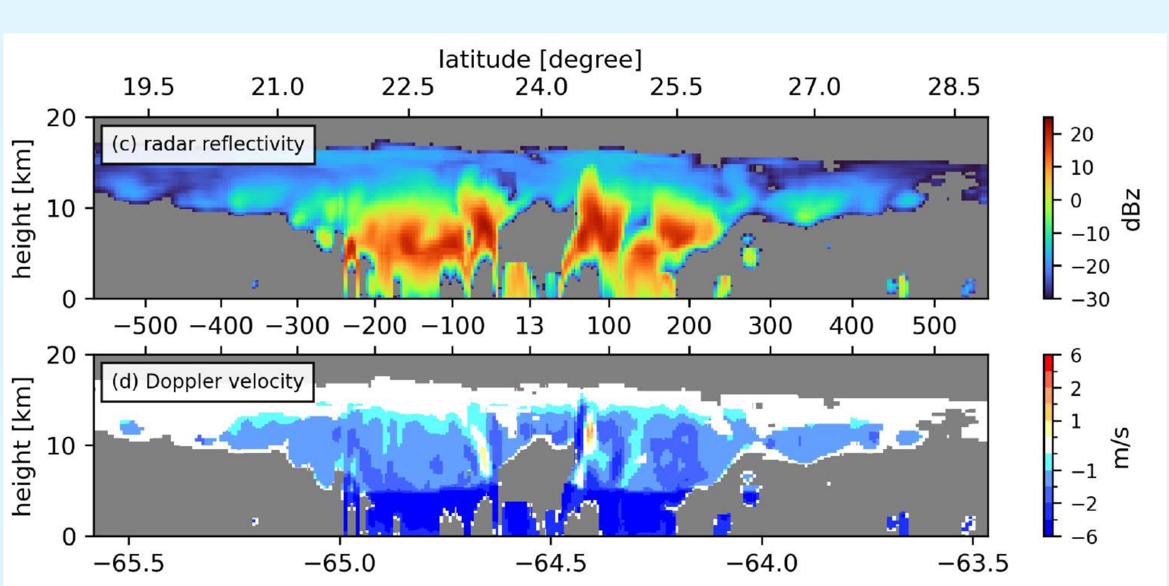
- The eyewall shows a broader Doppler velocity PDF, indicating stronger variability in vertical motion.
- The rainband shifts toward more negative Doppler velocities, suggesting a stronger influence of particle fall speed.

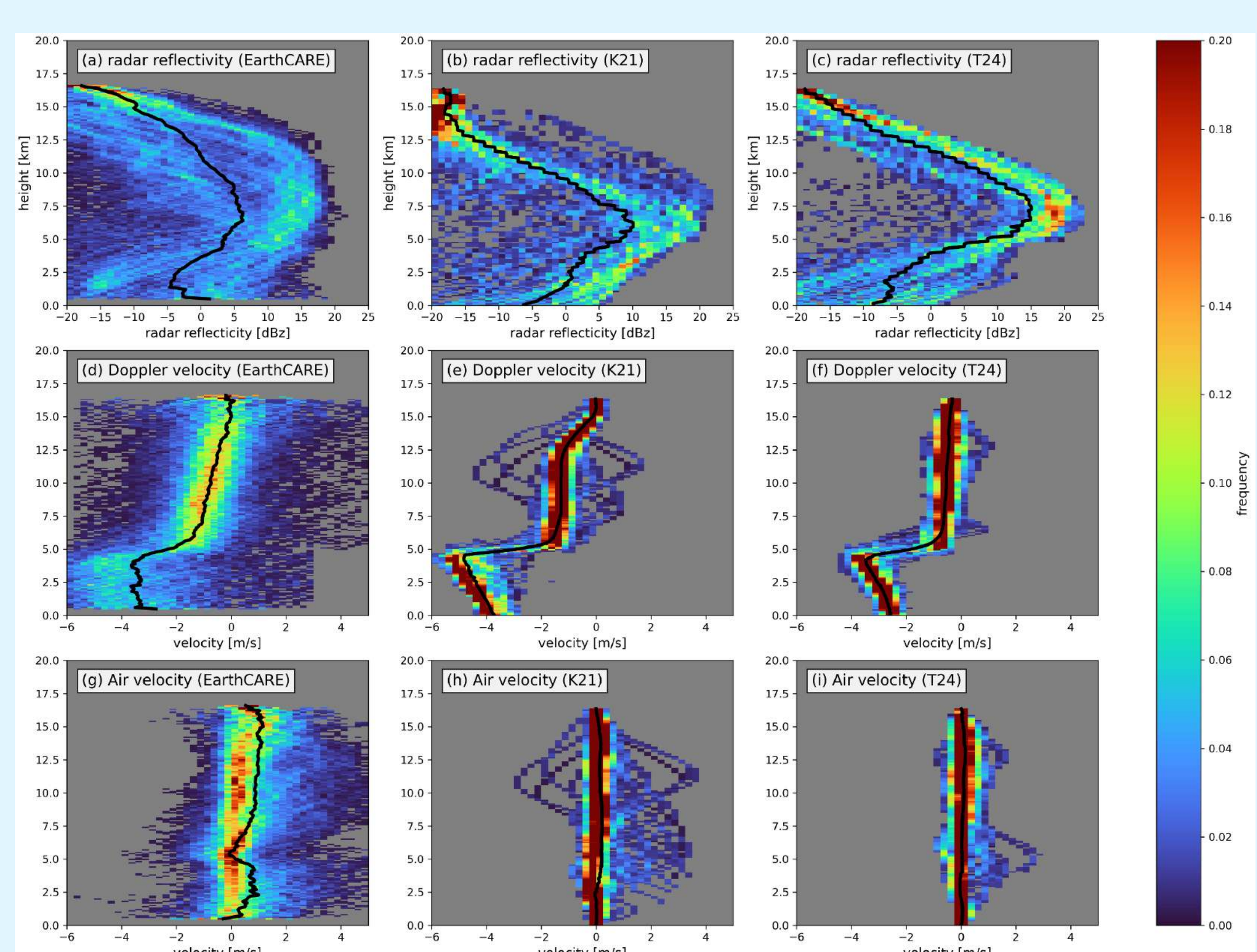
- Small ice particles dominate in the upper levels, while Snow is more frequent in the eyewall.
- Mixed-phase particles mainly appear near the melting level in the rainband region (5~10 RMW).

- Small ice dominates upper levels, while rain dominates below the melting level.
- Supercooled water and mixed-phase particles appear near the edges of the PDF, linking particle growth to updraft or fall-speed regimes.

5. NICAM simulations

NICAM simulated TC





- NICAM captures the overall TC structure, but underestimates storm intensity and vertical variability.
- EarthCARE-like diagnostics reveal overly confined Ze, Vd, and air-velocity distributions, highlighting the need to better constrain cloud microphysics in models.

Reference

The TC–EarthCARE colocation workflow can now be performed within the MAAP-PAL environment. If you are interested in the implementation details, the code is available in my MAAP-PAL public-bucket space: MAAP ID 198.

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