The EarthCARE–GPM coincidence dataset: Synergistic spaceborne radar analysis of vertical motions in cloud and precipitation systems

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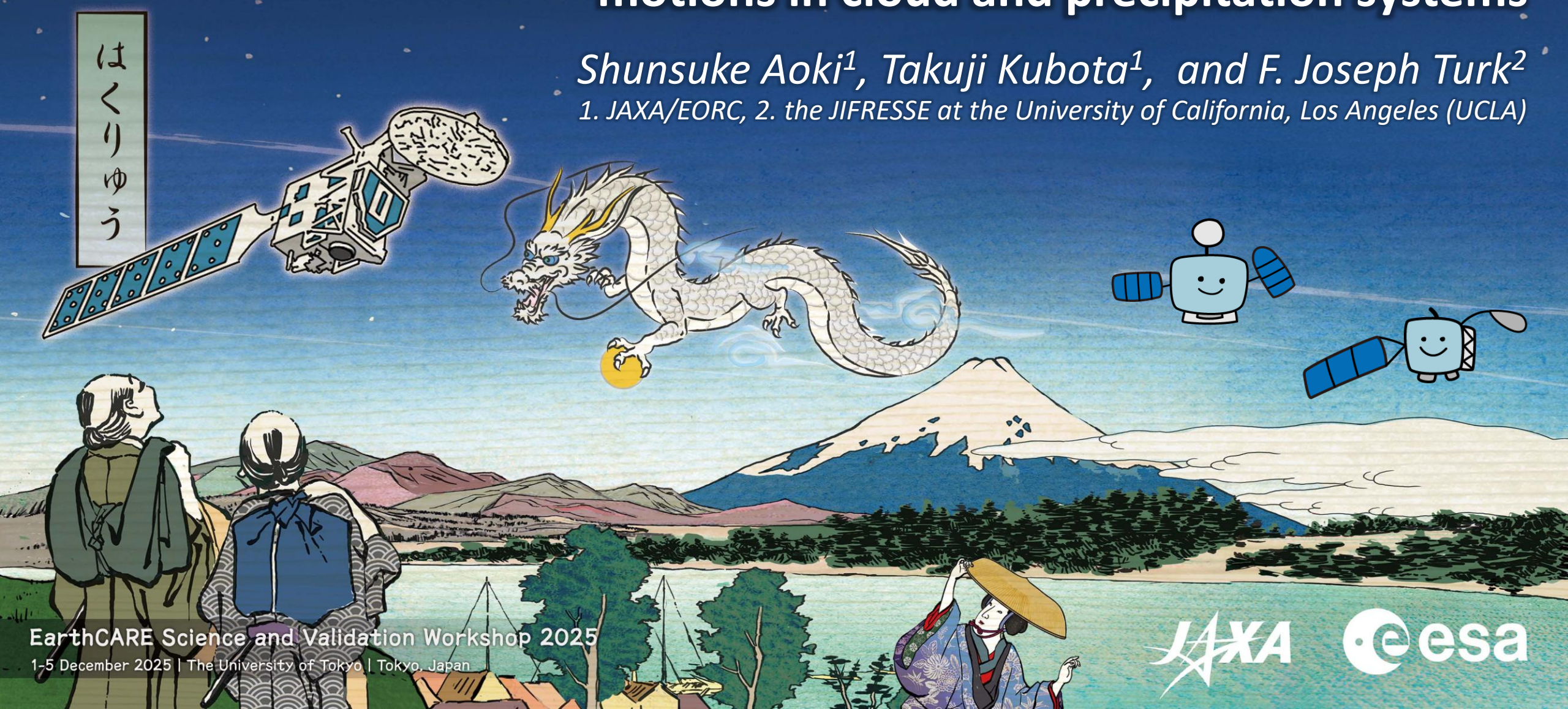
1. JAXA/EORC, 2. the JIFRESSE at the University of California, Los Angeles (UCLA)

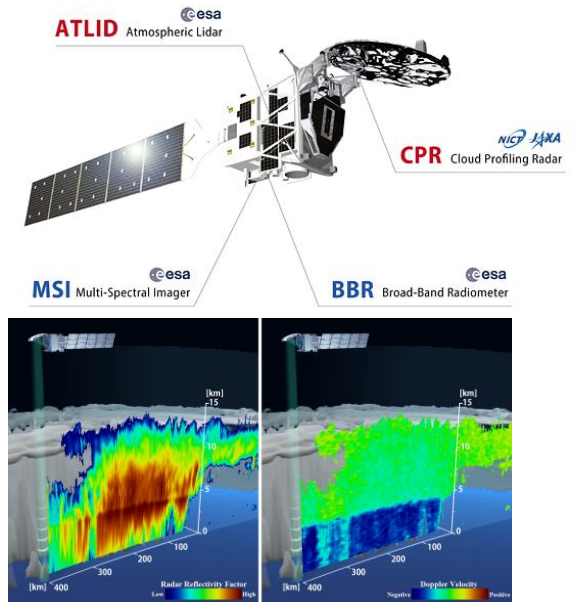


EarthCARE Science and Validation Workshop 2025

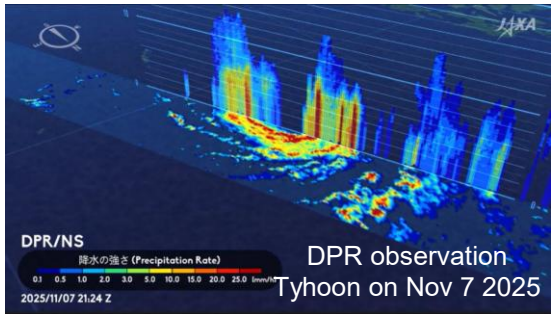
1-5 December 2025 | The University of Tokyo | Tokyo, Japan

Spaceborne Cloud and Precipitation Radar Observations by EarthCARE and GPM

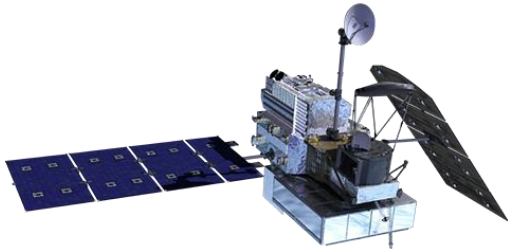
- EarthCARE CPR continues CloudSat's W-band cloud observations with **the world's first spaceborne Doppler velocity measurements**.
- The **Dual-frequency Precipitation Radar (DPR; Ku & Ka-band)** and the **Microwave Imager (GMI)** onboard the **GPM** Core Observatory have continued observations for more than 11 years.
- The CloudSat–TRMM/GPM Coincident Dataset (by Dr. Joe Turk), which offers "pseudo triple-frequency" radar reflectivity + microwave radiometer observations , has been widely used for studies on ice microphysics, light rainfall, and snowfall, etc.

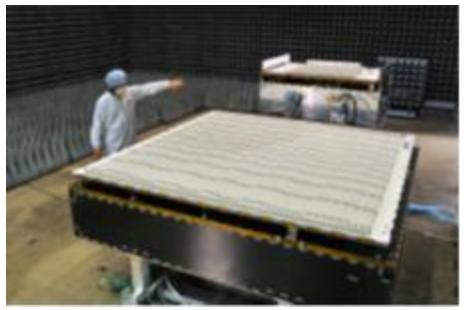


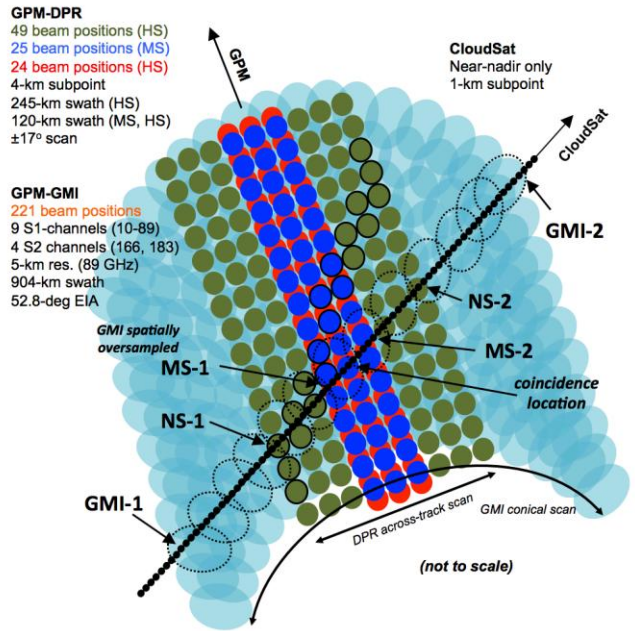
CPR first images (JAXA/NICT)



DPR observation
Tyhoon on Nov 7 2025


GPM Core Observatory
(JAXA/NASA)

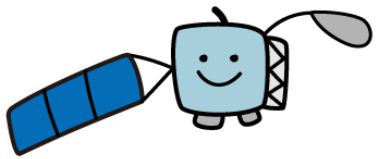

DPR (JAXA/NICT)



Schematics of CloudSat-GPM coincidence (Turk et al. 2021)

EarthCARE–GPM Coincidence Dataset

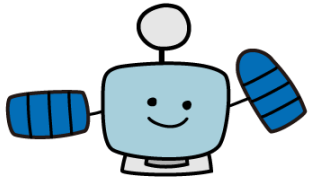
- Compiles orbit-crossing cases between EarthCARE and GPM within ±15 minutes.
- **Now, publicly available with the Data DOI on the JAXA website!**
  - ✓ https://doi.org/10.57746/EO.01ka7xakvwj6pcthxkvgt0vr0y
- Extracts data within the coincident sections while preserving the original data structure as it is.
- Dataset for more than 1-year since Aug 2024 (**>3000 cases**), and more in the future.



EarthCARE

CPR, ATLID, MSI, BBR

×



GPM

DPR, GMI

Currently incl
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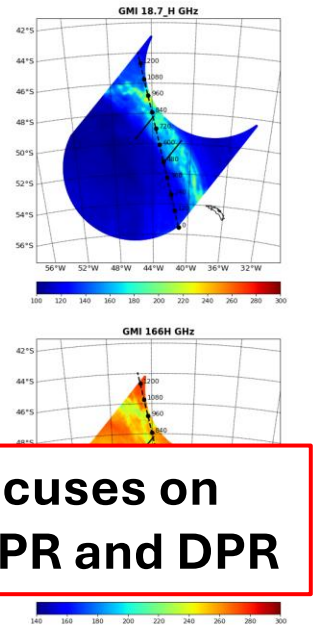
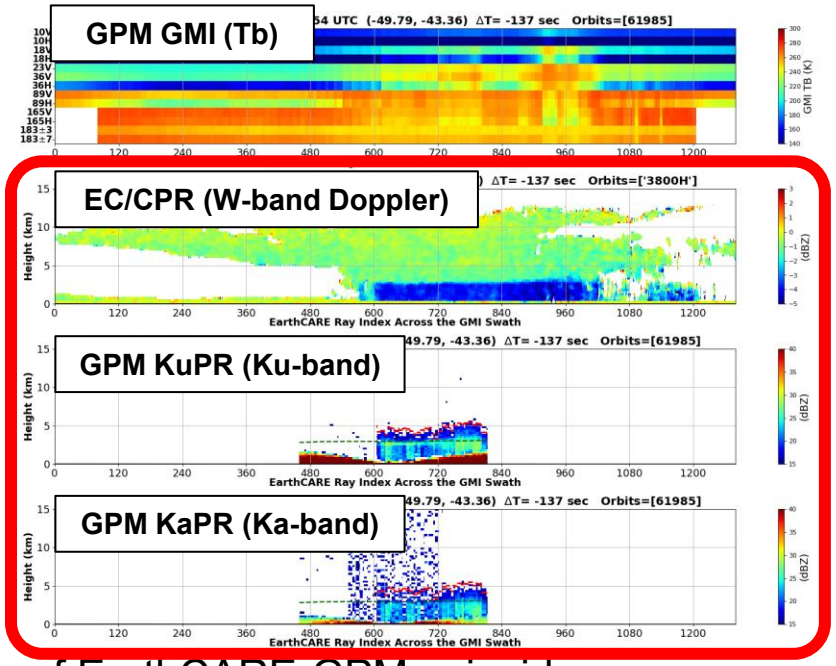
L2 pr

This presentation mainly focuses on match up analysis between CPR and DPR





A case of EarthCARE-GPM coincidence

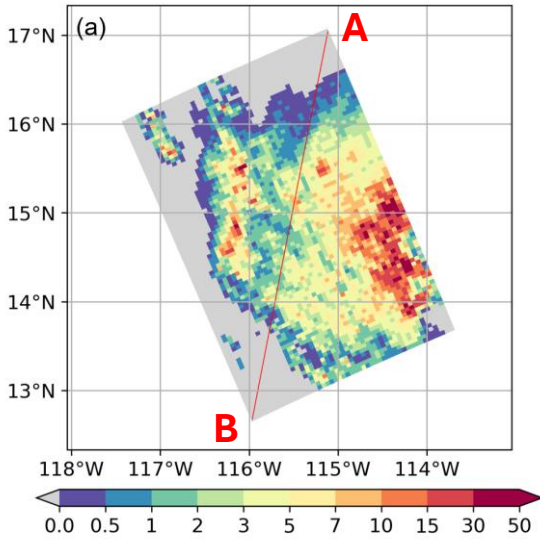
Case 1: Stratiform Precipitation

A tropical cyclone over the eastern Pacific

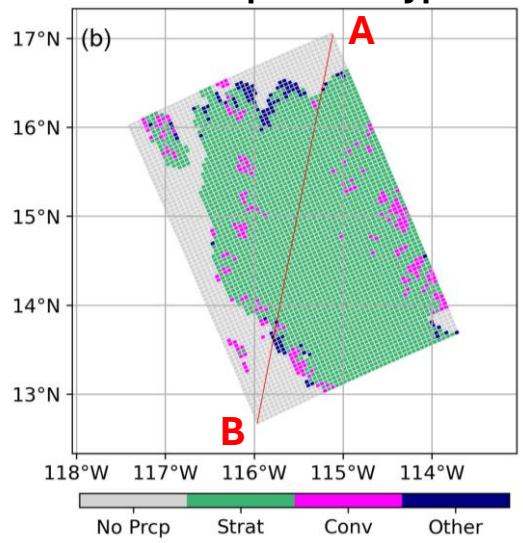
(time difference: 5.6 min)

- Doppler velocity differs significantly above and below the melt layer (rain or snow).
- Even with some attenuation occurring in CPR, Doppler velocity can still be measured.

GPM DPR
Surface Precip Rate [mm/h]



GPM DPR
Precipitation Type



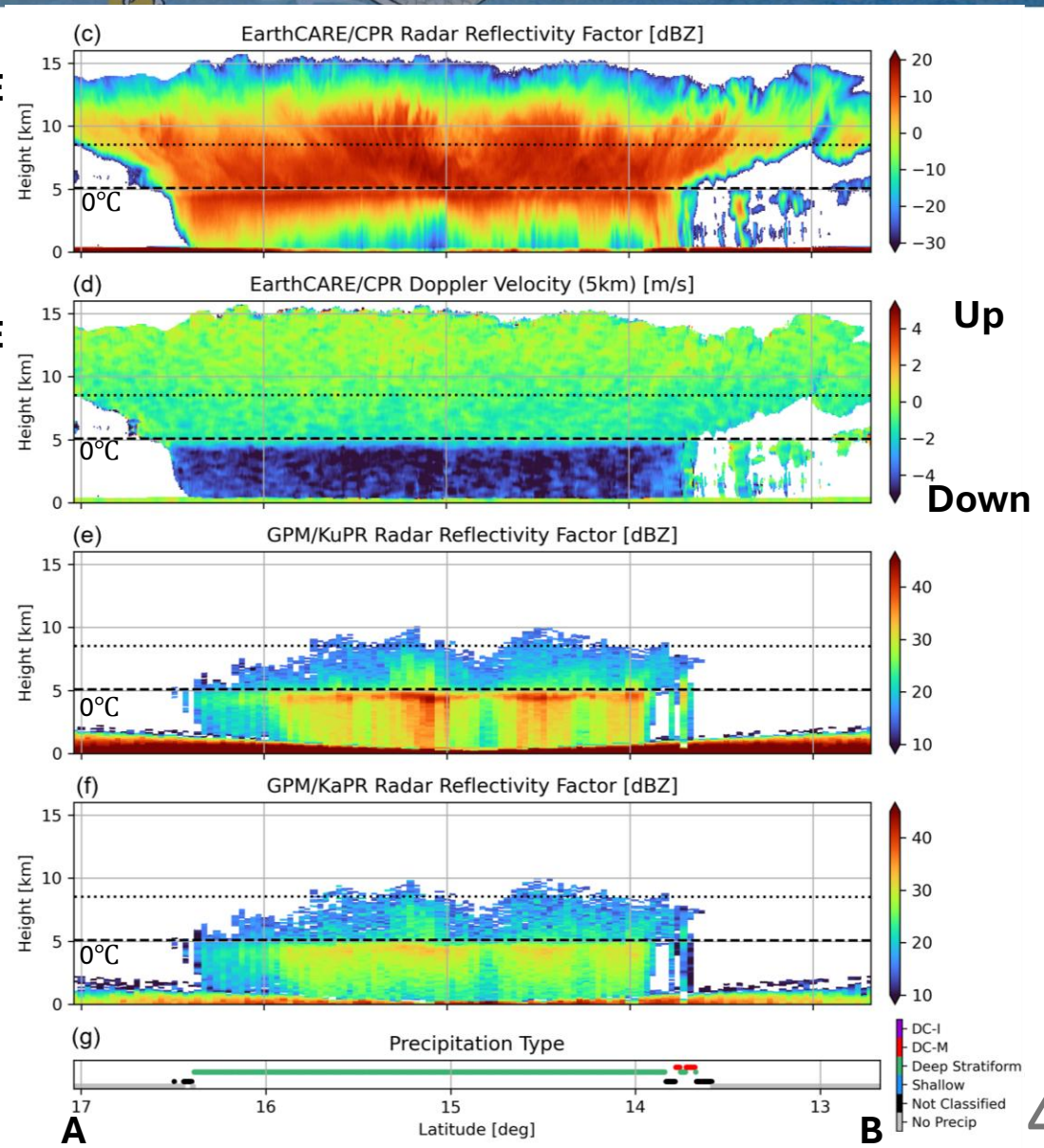
Coincident event at 22UTC on 22 Aug 2024 (frame 1337E)

EarthCARE CPR Z

EarthCARE CPR Vd

DPR Z(Ku)

DPR Z(Ka)



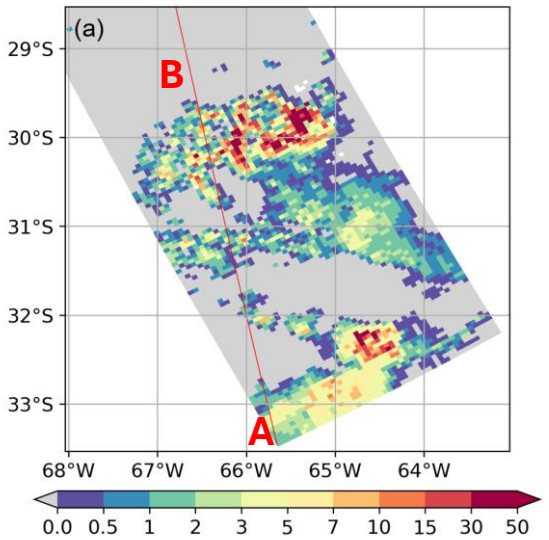
Case 2: Convective Precipitation

A convective system over Argentina

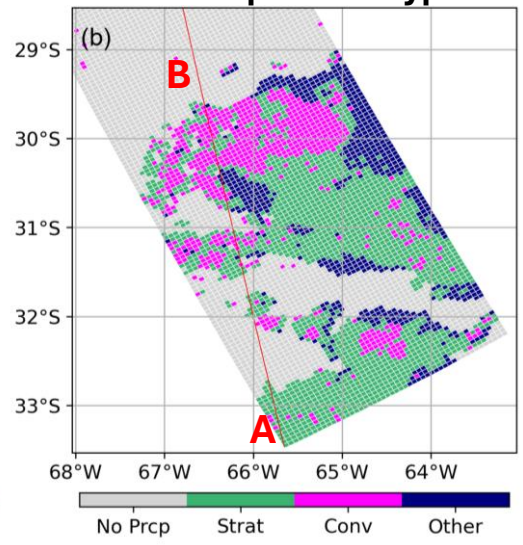
(time difference: 3.8 min)

- Compared to a stratiform case, the difference in Doppler velocity above and below the 0°C level is unclear.
- Maybe due to faster falling speed of graupel/hail.

GPM DPR
Surface Precip Rate [mm/h]



GPM DPR
Precipitation Type



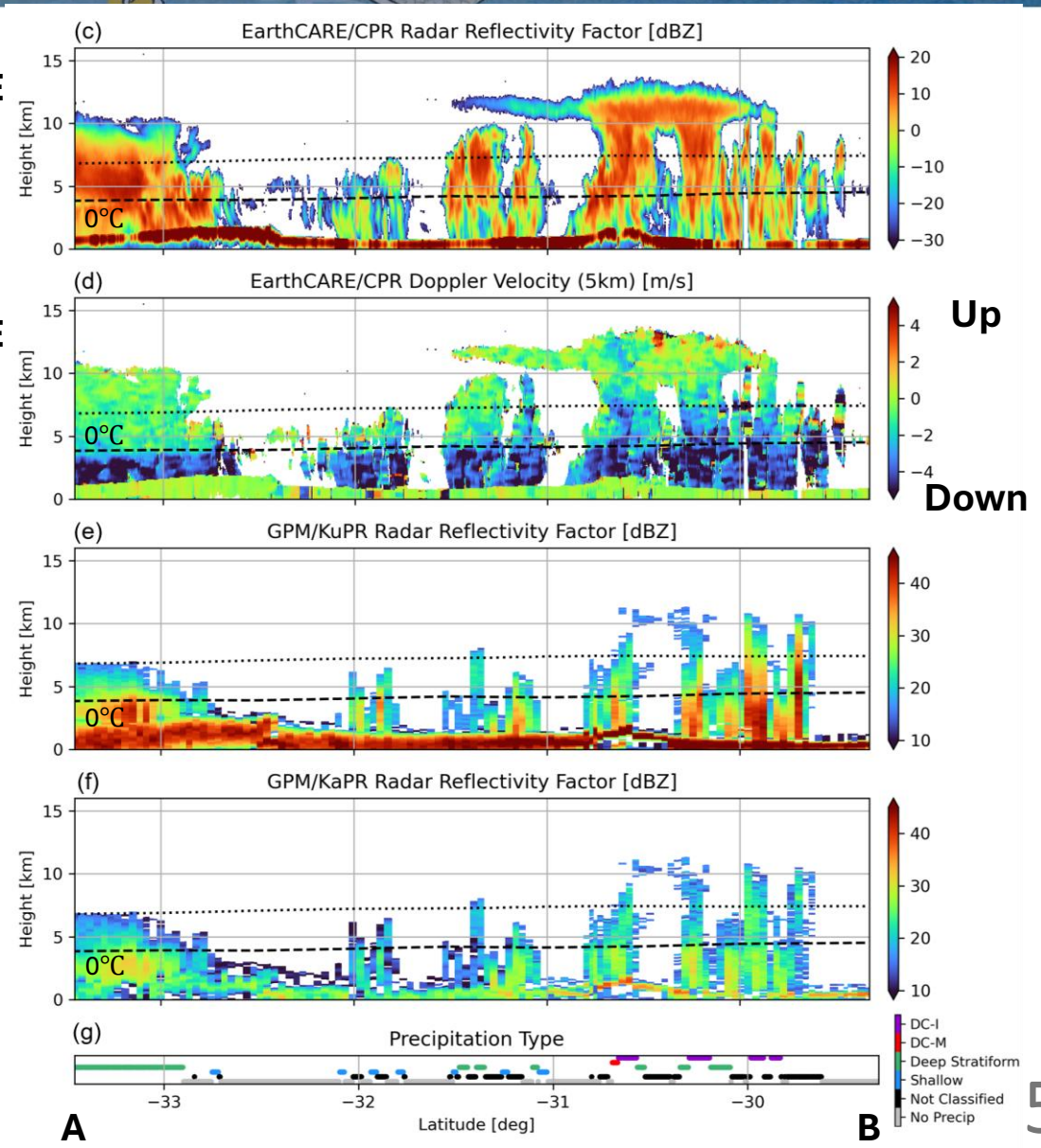
Coincident event at 7UTC on 23 Mar 2025 (frame 4661H)

EarthCARE CPR Z

EarthCARE CPR Vd

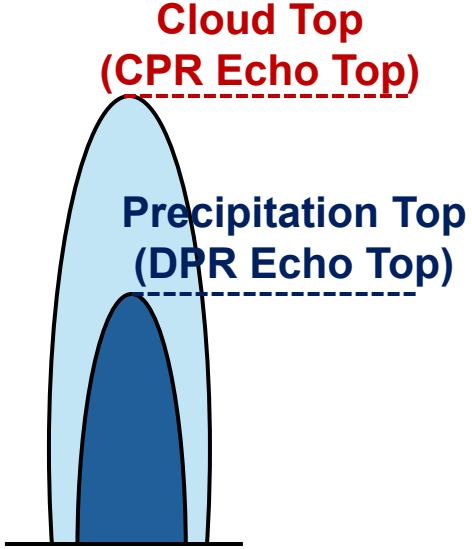
DPR Z(Ku)

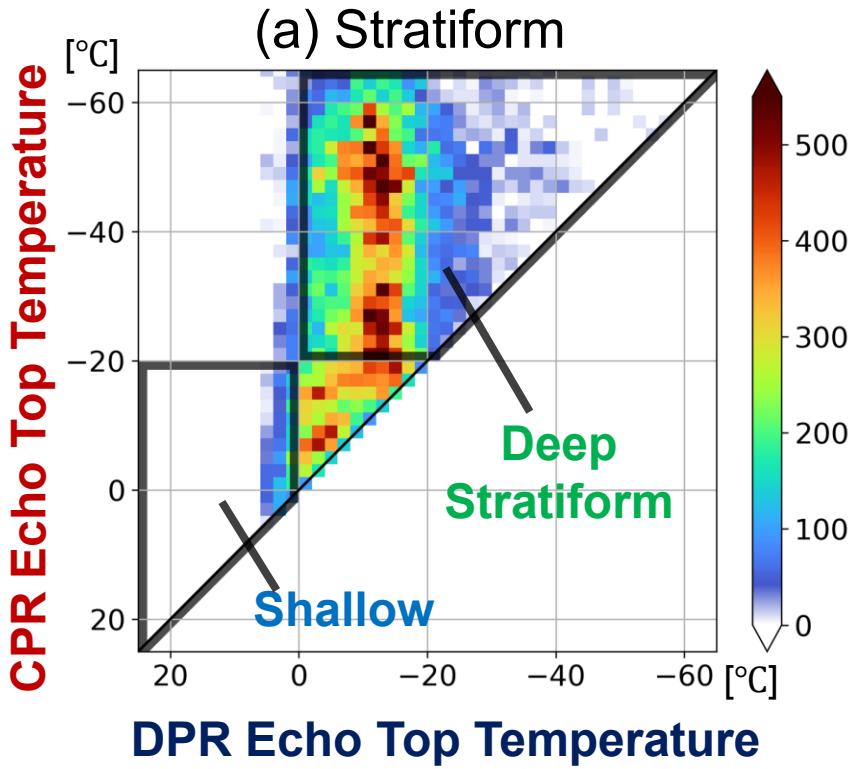
DPR Z(Ka)

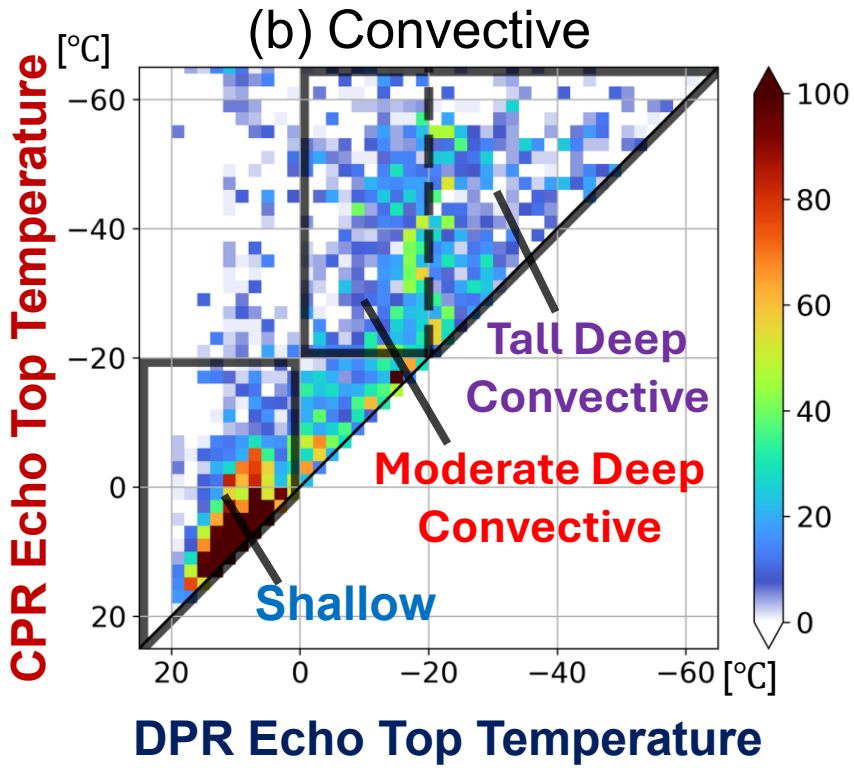


Precipitation Type Classification

- Statistical analysis from Aug 2024 to Jun 2025 (11 months). CPR L1b vCa/b and DPR L2 V07C are used.
- Joint histograms of precipitation top height vs cloud top height (Masunaga et al.2005; Stephens and Wood 2007)
- Categorized into 4 types according to DPR precipitation type classification and echo top height.

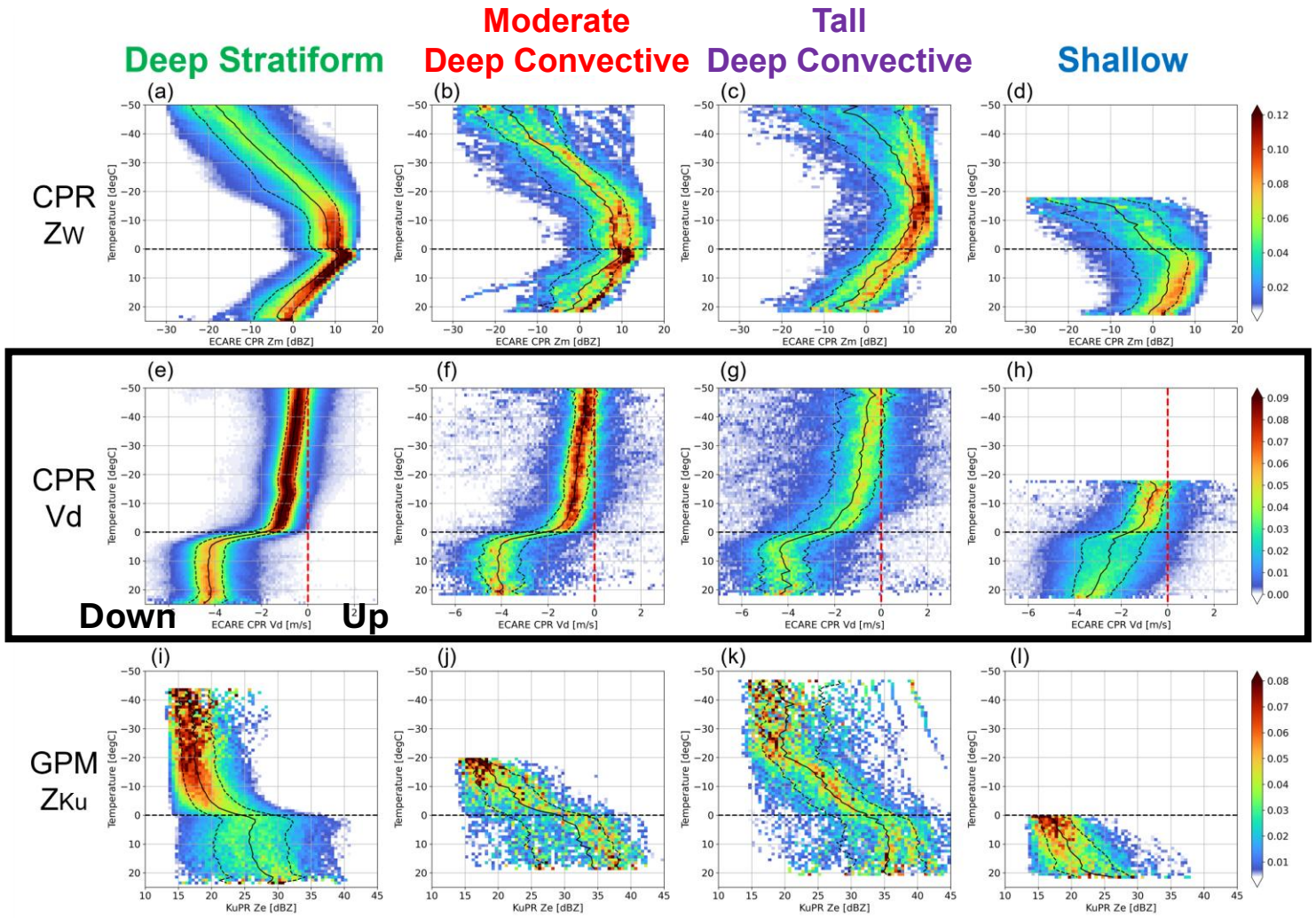




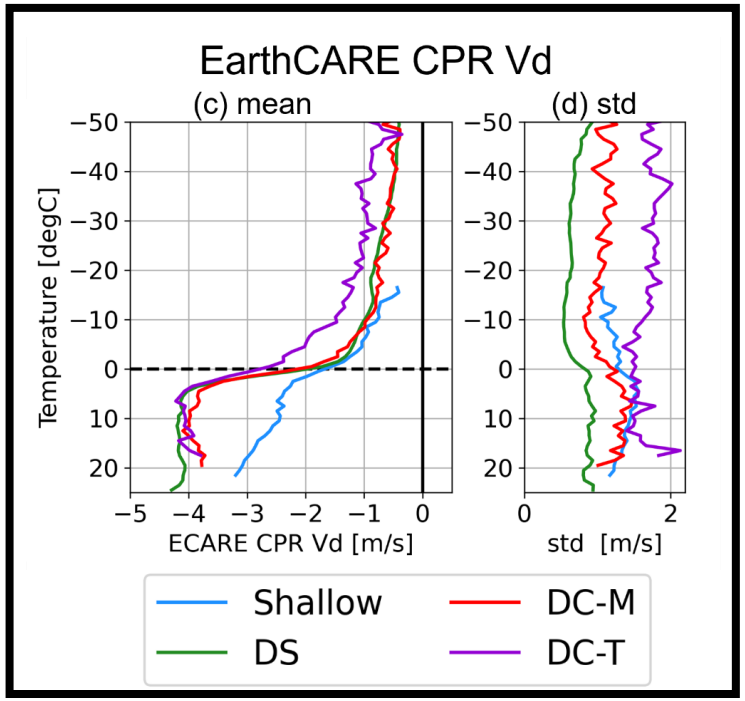


Vertical Profiles of Z and Vd for Each Type

- Contoured frequency by temperature diagrams (CFEDs), normalized at each height.



Below the −10 °C level, radar reflectivity is strongly affected by attenuation, whereas Doppler velocity is much less influenced.

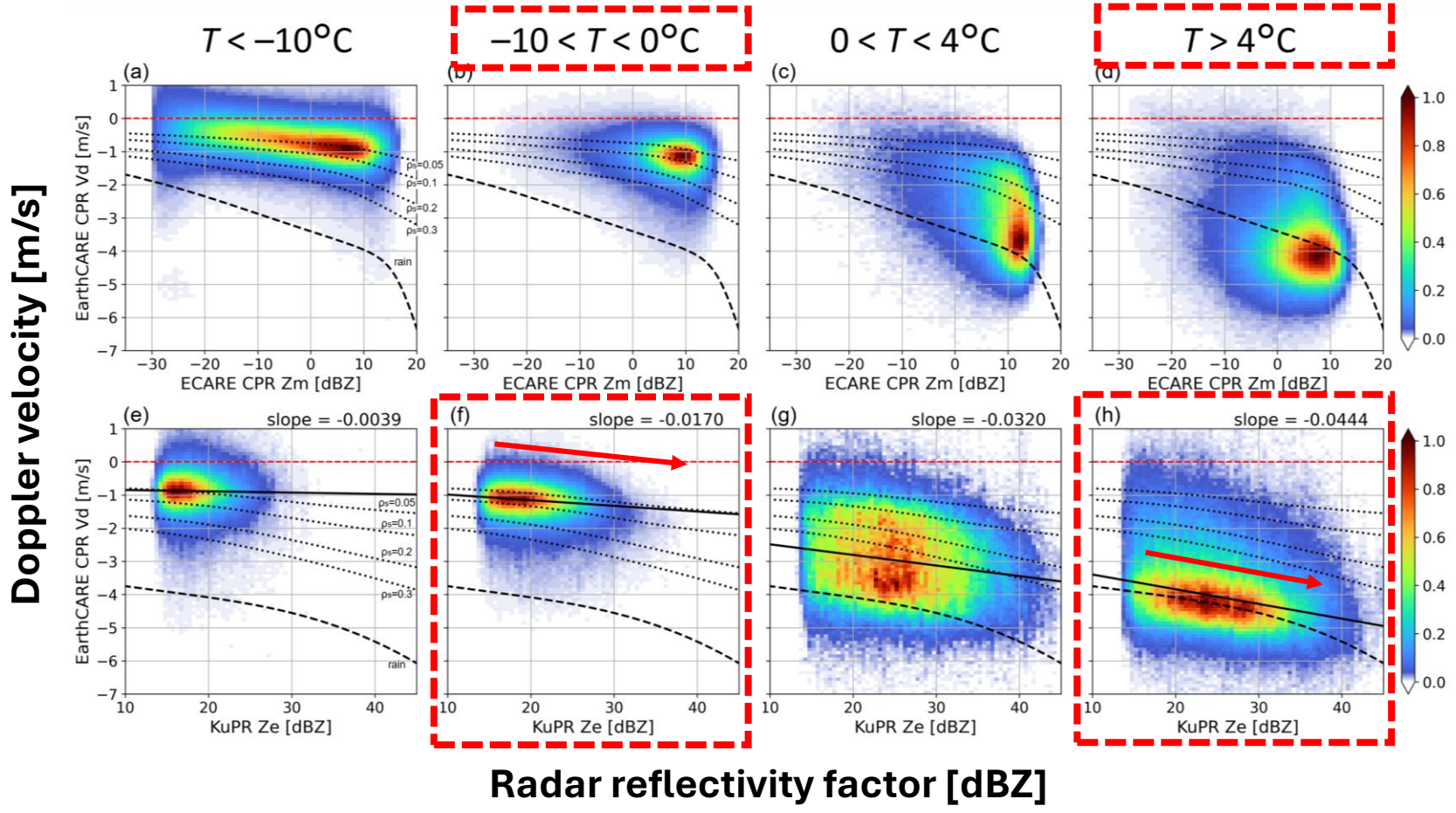


Joint Histograms of Z–Vd

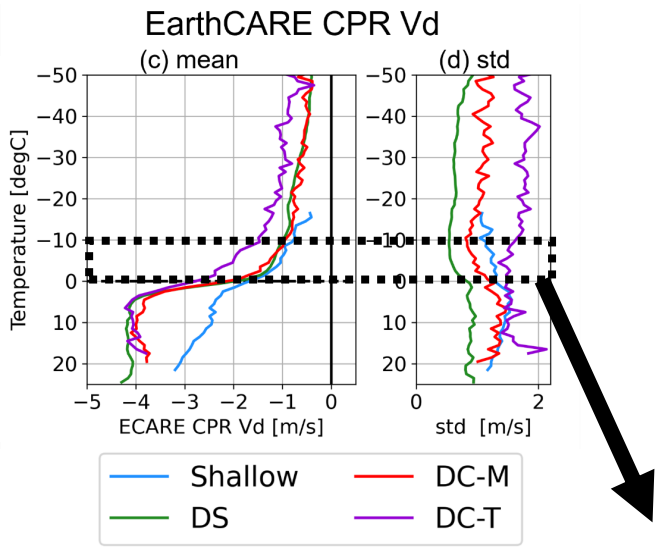
- For the upper-level ice: CPR Z increases with Vd, but KuPR has no sensitivity.
- For grown snow and rain: CPR Z reaches saturation due to the attenuation and Mie effect, while KuPR Z increases with Vd.

EarthCARE CPR Z (W)

GPM KuPR Z (Ku)



Z – Vd Diagram for Snow and Ice (-10 – 0℃)

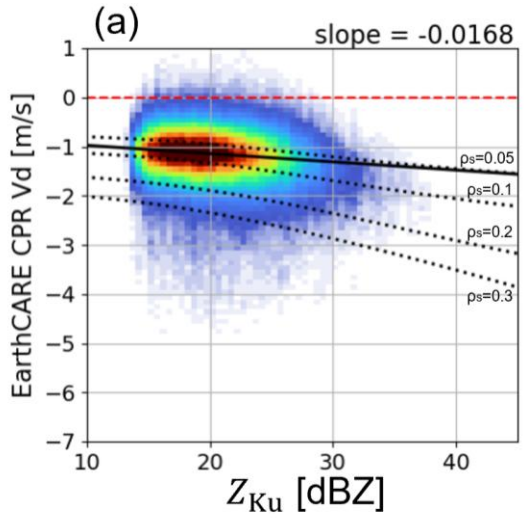


Higher Z(Ku) and faster downward Vd in **Convective** than in **Stratiform**

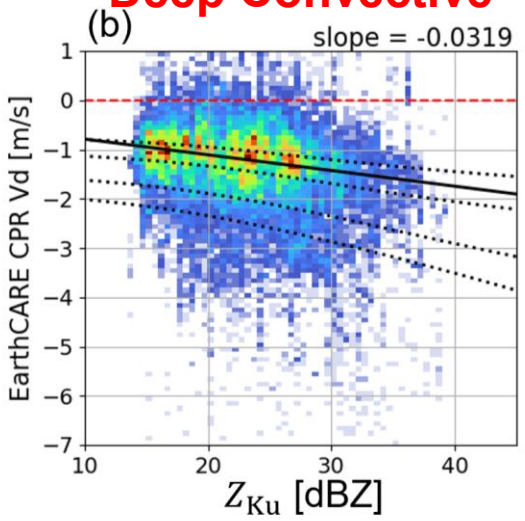
⇒ Large snow and ice particles (graupels or hails)

Future work: multi-frequency analysis and scattering simulations considering variations in ice particle properties (size, shape, density).

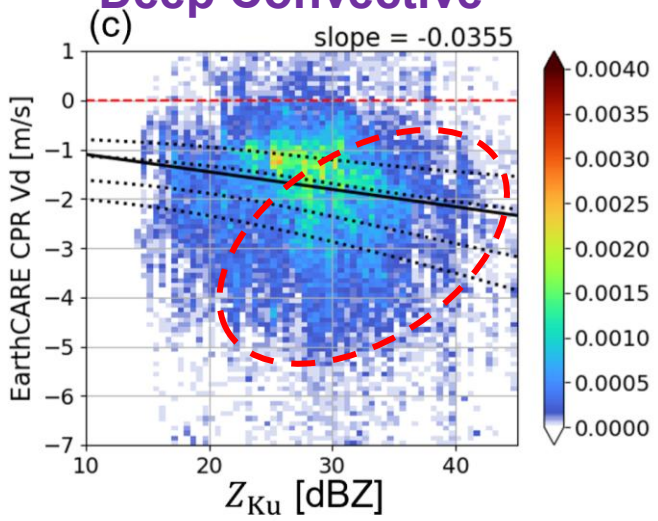
Deep Stratiform



Moderate Deep Convective



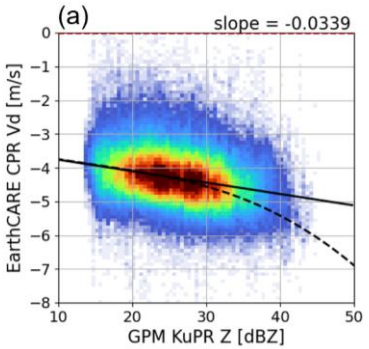
Tall Deep Convective



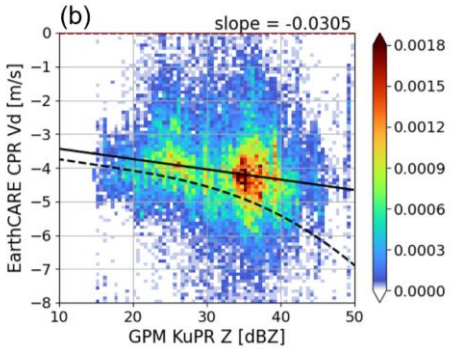
Z – Vd Diagram for Rain (4℃ –)

EarthCARE CPR Vd

Deep Stratiform



Deep Convective



Doppler velocity by CPR can be expressed as

$$\boldsymbol{V_d} = \boldsymbol{V_{air}} + \boldsymbol{V_t} + \boldsymbol{\varepsilon}$$

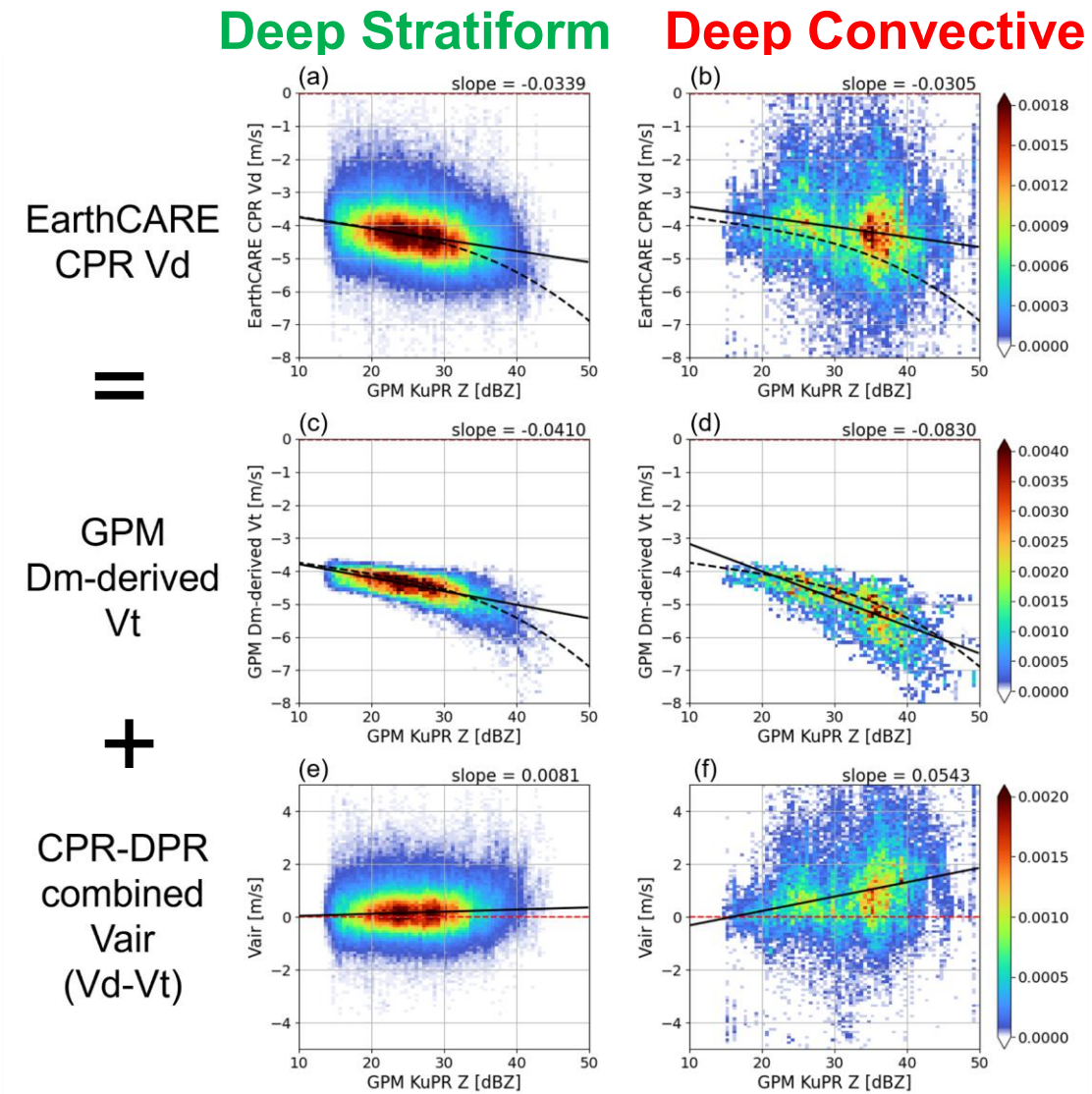
Vertical air motion

Reflectivity-weighted terminal velocity

Measurement error

$$V_t = \frac{\int v_t(D)N(D)\sigma_b(D)\,dD}{\int N(D)\sigma_b(D)\,dD}$$

Z – Vd Diagram for Rain (4℃ –)



Doppler velocity by CPR can be expressed as

$$V_d = V_{air} + V_t + \varepsilon$$

Vertical air motion

Reflectivity-weighted terminal velocity

Measurement error

$$V_t = \frac{\int v_t(D) N(D) \sigma_b(D)\, dD}{\int N(D) \sigma_b(D)\, dD}$$

We calculated V_t using drop size distribution $N(D)$ estimated by 2A.DPR algorithm:

$$N(D) = N_w f(D; D_m) = N_w \frac{6(\mu+4)^{\mu+4}}{4^4 \Gamma(\mu+4)} \left(\frac{D}{D_m}\right)^{\mu} \exp\left(\frac{(\mu+4)D}{D_m}\right)$$

$$v_t(D) = -3.78 D^{0.67} \sqrt{\rho_0/\rho}$$

σ_b is derived from Mie scattering calculations for spherical raindrops at W-band frequency.

- **Stratiform**: Distributed around 0 m/s
- **Convective**: large Z_{Ku} ➡ updrafts & turbulence

Summary

- We have developed the "EarthCARE-GPM Coincidence Dataset."
  Publicly available on the JAXA website with the Data DOI (10.57746/EO.01ka7xakvwj6pcthxkvgt0vr0y)!
- Focusing on Doppler velocity, we performed match up analysis between EarthCARE/CPR and GPM/DPR.
  - Classified into four types: **Deep Stratiform**, **Moderate/Tall Deep Convective**, and **Shallow**, each exhibiting distinct features.
  - The *Vd* from CPR enable us to obtain fall speed information even in rain and intense snowfall regions where CloudSat's reflectivity-only observations suffered from strong attenuation.
  - By combining *Vd* with DPR, we demonstrate the potential to retrieve particle properties and vertical air motion.

Aoki, S., Kubota, T., and Turk, F. J.: Exploring vertical motions in convective and stratiform precipitation using spaceborne radar observations: Insights from EarthCARE and GPM coincidence dataset, under review in *Atmos. Meas. Tech.* [preprint], https://doi.org/10.5194/egusphere-2025-3596, 2025.

- Related presentation tomorrow (Day2: Cloud and Precipitation Microphysics and Convective System: Observations)

H209	10:44	12	Investigation of the Optimal Degree of Snow Particle Riming in Dual-Frequency Radar Retrievals Using a GPM/DPR–EarthCARE/CPR Coincidence Dataset	Shizuka Ohhata
H210	10:56	12	Creation and validation of precipitation particles falling velocity with simultaneous observations of the GPM and EarthCARE satellite's radars	Kaya Kanemaru
H211	11:08	12	Validation of Hydrometeor Classification Products between EarthCARE CPR radar and GPM DPR radar (Online)	Minda Le

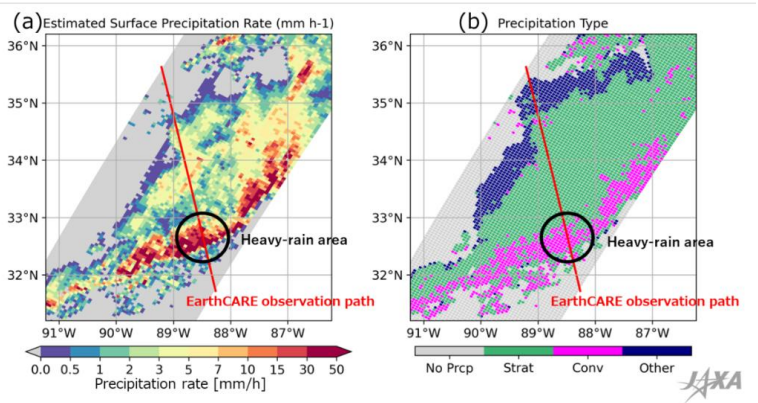
Future work

- Combining EarthCARE/CPR with **microwave radiometer (GMI)**
  - Refinement of snowfall and light rainfall retrieval algorithm in MWR.
  - EarthCARE–GPM provides observations during both day and night, while CloudSat–GPM was restricted to daytime.
  - Future development of EarthCARE-AMSR3 coincidence.

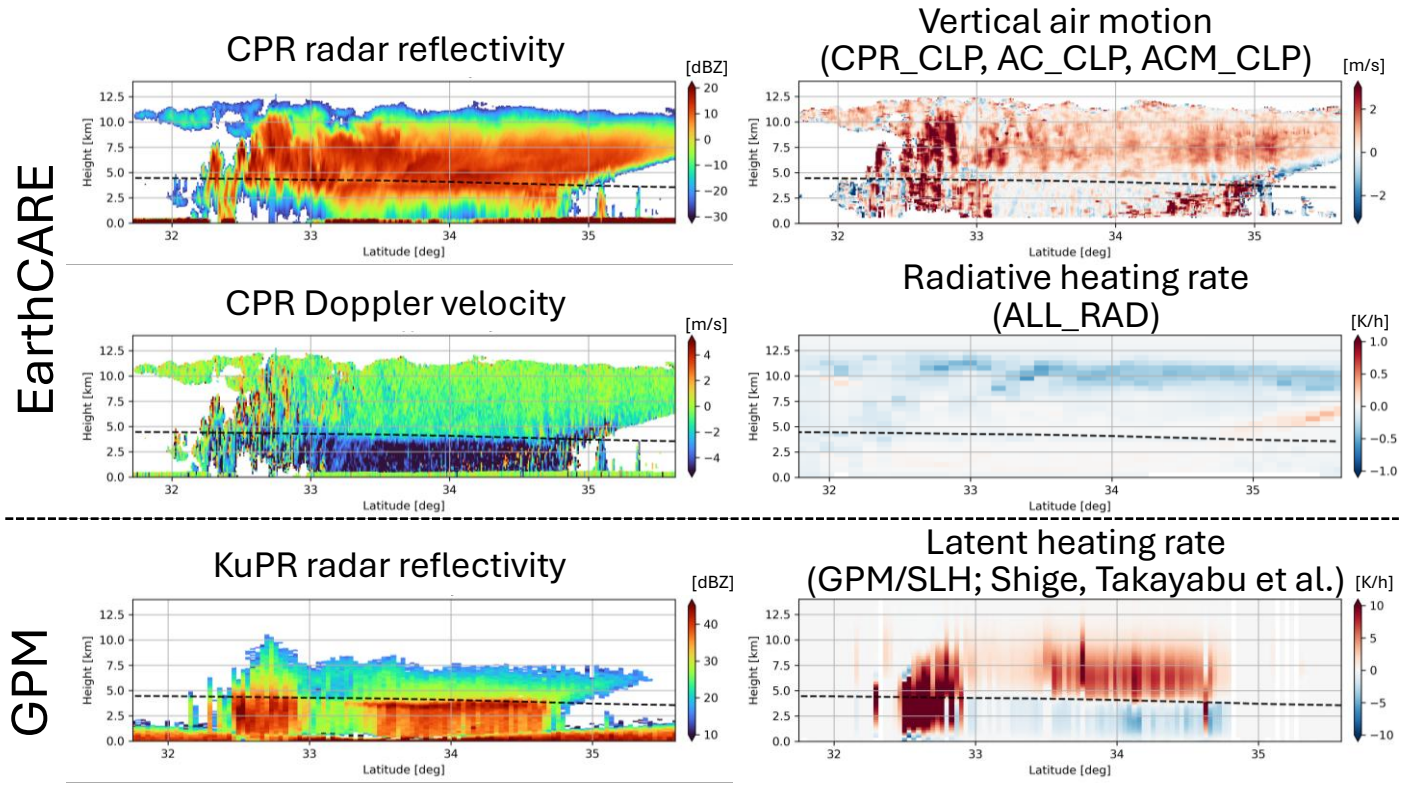
GOSAT-GW/AMSR3 (JAXA)
launched in Jun 2025

- Using additional sensors and products
  - ATLID, MSI, BBR
  - Latent and radiative heating rate

⇨ ***Synergistics analysis on aerosols, clouds, convection and precipitation***



Coincidence in US around 7:30 (UTC) on October 19, 2025.



Thank you!