Consistency of vertical air motion and diabatic heating profiles derived from EarthCARE and GPM observations

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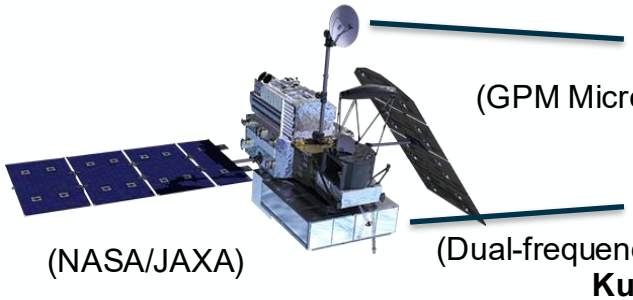
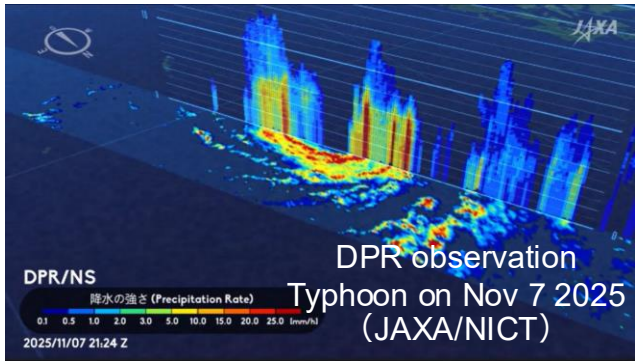
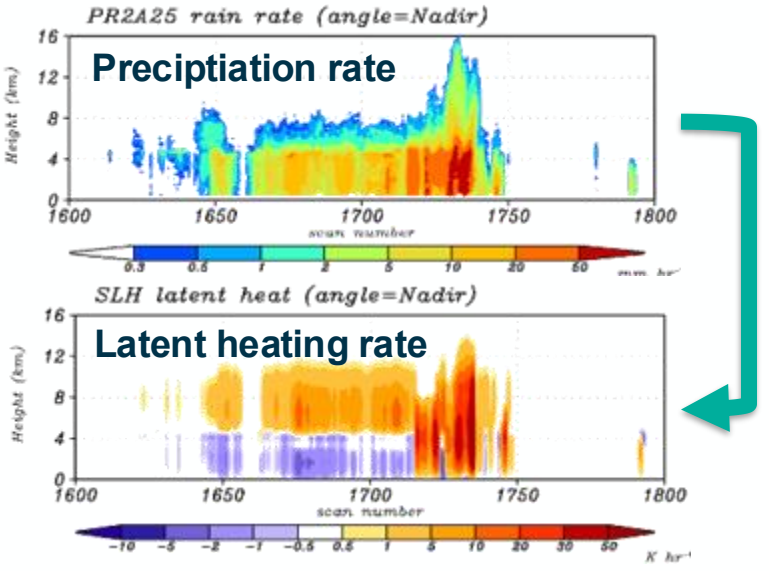
Precipitation measurements by GPM

- Diabatic heating associated with clouds and precipitation plays an essential roles in driving atmospheric circulation across a wide range of scales.
- **Global Precipitation Measurement (GPM)** Core Observatory has observed precipitation for more than 11 years, revealing its 3D structure. GPM also estimates **latent heating (*LH*)** rates associated with condensation and evaporation with the aid of cloud-resolving model simulations.

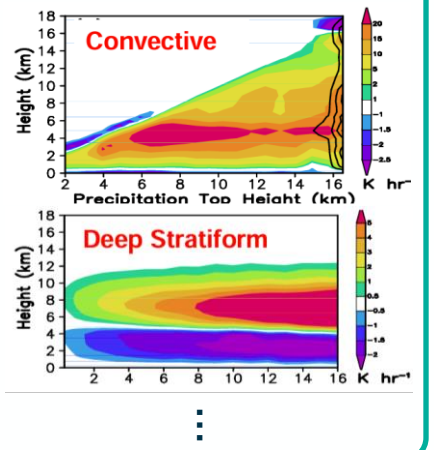




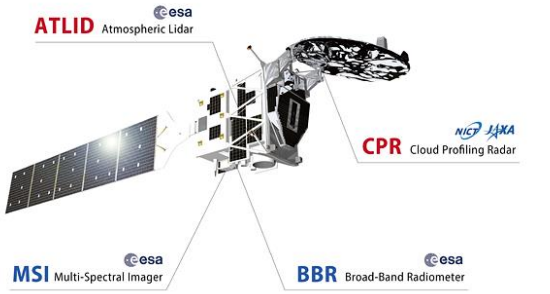
TRMM/GPM Spectral Latent Heating (SLH) product
(e.g. Shige, Takayabu et al. 2004 JAMC)



Pr-LH Lookup tables by CRM simulations



Relationship between Vertical Air Motion and Latent Heating



EarthCARE

- Estimates **vertical air motions (V_{air})** from CPR Doppler velocity through $V_{\mathrm{d}} - V_{\mathrm{tz}}$ (e.g., the CPR_CLP), and
- Estimates **radiative heating rate (Q_R)** using radiative transfer model (e.g., the ALL_RAD products).

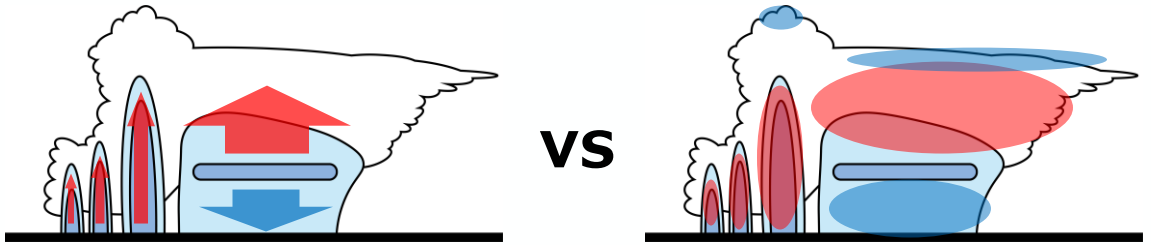
- In principle, large-scale V_{air} in precipitation systems should be thermodynamically linked to *LH* from precipitation and Q_{R} from surrounding clouds, as described by thermal budget equation (Yanai et al. 1973):

Apparent heat source in large-scale

$$Q_1 \equiv \frac{\partial \bar{s}}{\partial t} + \bar{v}\cdot\nabla\bar{s} + \bar{\omega}\frac{\partial \bar{s}}{\partial p} = Q_R + LH - \nabla\cdot(\overline{s'v'}) - \frac{\partial \overline{s'w'}}{\partial p}$$

Dry static energy $s = c_pT + gz$

CPR Doppler Velocity | **EarthCARE** | **TRMM/GPM SLH $(Q_1 - Q_R)$**



Are spaceborne-retrieved V_{air} and diabatic heating estimates consistent between EarthCARE and GPM?

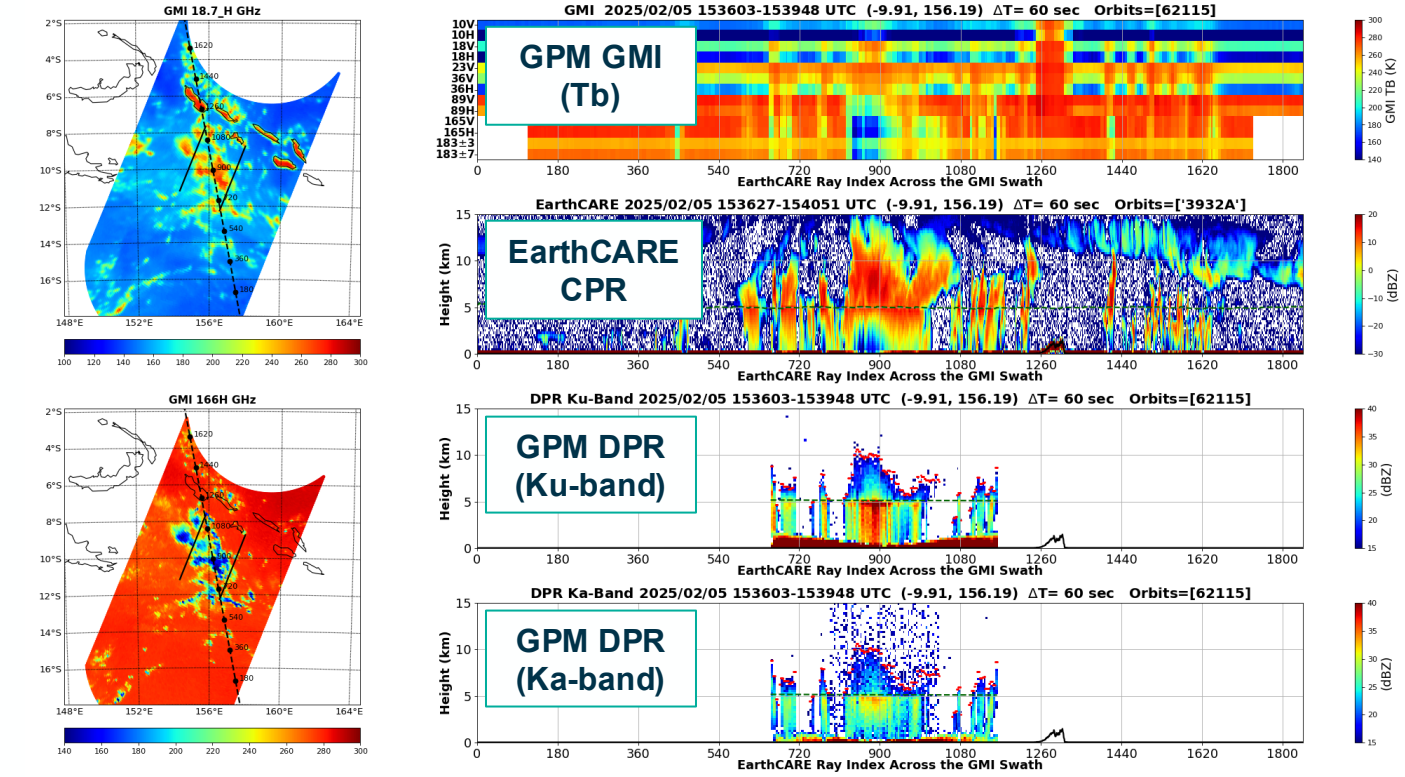
EarthCARE-GPM coincidence dataset

Compiles orbit-crossing cases between EarthCARE and GPM within ±15 minutes.

Publicly available with the Data DOI on the JAXA website:

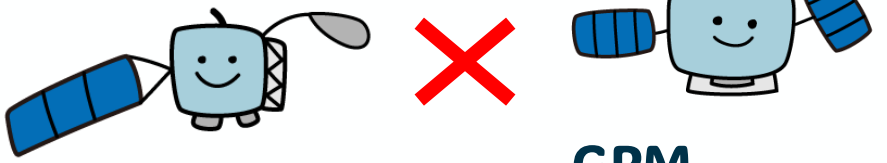
✓Aoki. S., T. Kubota, and F. J. Turk, 2025, https://doi.org/10.57746/EO.01ka7xakvwj6pcthxkvgt0vr0y.

User registration for EarthCARE-GPM coincidence dataset



EarthCARE

CPR, ATLID, MSI, BBR



GPM

DPR, GMI

Currently includes EC/CPR, GPM/DPR, GMI, though we plan to expand to **other EarthCARE L2 products** in the future.

EarthCARE-GPM coincidence dataset

Compiles orbit-crossing cases between EarthCARE and GPM within ±15 minutes.

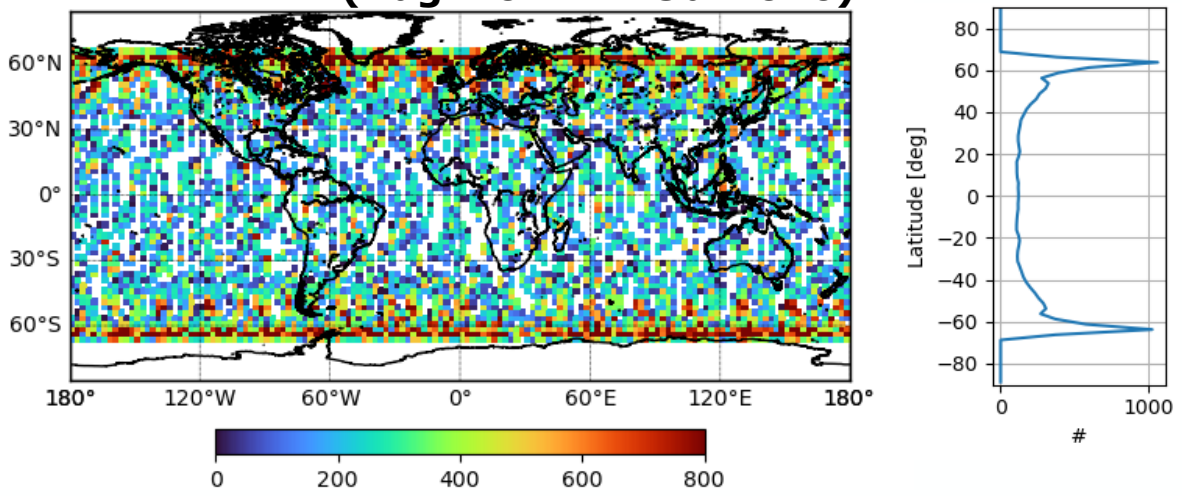
Publicly available with the Data DOI on the JAXA website:

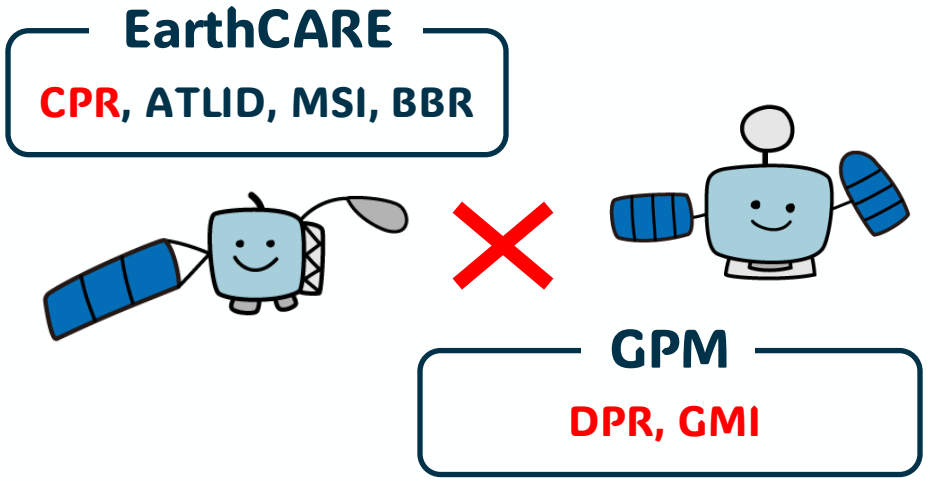
✓Aoki. S., T. Kubota, and F. J. Turk, 2025, https://doi.org/10.57746/EO.01ka7xakvwj6pcthxkvgt0vr0y.

Extracts data within the coincident sections while preserving the original data structure as it is. Dataset for more than 1-year since Aug 2024 (**>4500 cases**), and more in the future.

User registration for EarthCARE-GPM coincidence dataset

Number of EarthCARE-GPM coincident footprints (Aug. 2024 – Feb. 2026)





Currently includes EC/CPR, GPM/DPR, GMI, though we plan to expand to **other EarthCARE L2 products** in the future.

Methods

- We performed comparison for EarthCARE-GPM coincidence dataset.

$$Q_1 \equiv \cancel{\frac{\partial \bar{s}}{\partial t}} + \cancel{\bar{v} \cdot \nabla \bar{s}} + \bar{\omega}\frac{\partial \bar{s}}{\partial p} = Q_R + LH - \nabla \cdot (\overline{s'v'}) - \frac{\partial \overline{s'w'}}{\partial p}$$

Q1 estimated from EarthCARE V_{air} ($Q_{1,V_{air}}$)

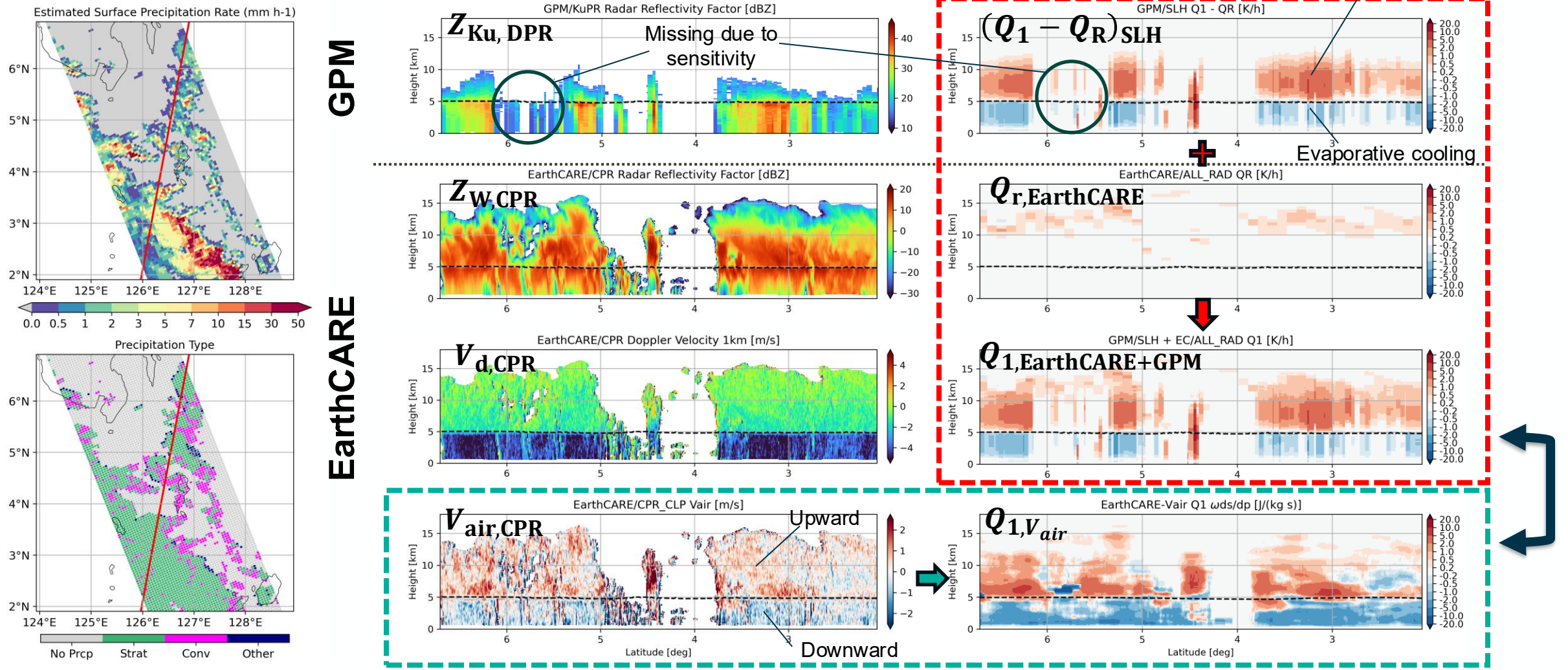
- V_{air} from the JAXA L2a CPR Cloud Product (CPR_CLP vCa)
- Weak temperature gradient approximation for simplicity, i.e. $Q_{1,V_{\mathrm{air}}} \approx \bar{\omega}\frac{\partial \bar{s}}{\partial p}$.
- Spatial averaging was applied using a 20 km horizontal and 500 m vertical moving average, with only echoes with Z > −20 dBZ were used.
- We assumed ω = 0 outside clouds.

Q1 estimated from GPM-SLH and EarthCARE-Q_R ($Q_{1,\mathrm{EarthCARE+GPM}}$)

- $Q_1 - Q_R$ from the GPM Spectral Latent Heating product (SLH V07)
- Q_R from the EarthCARE JAXA L2b four-sensor synergy radiative product (ALL_RAD vBa)

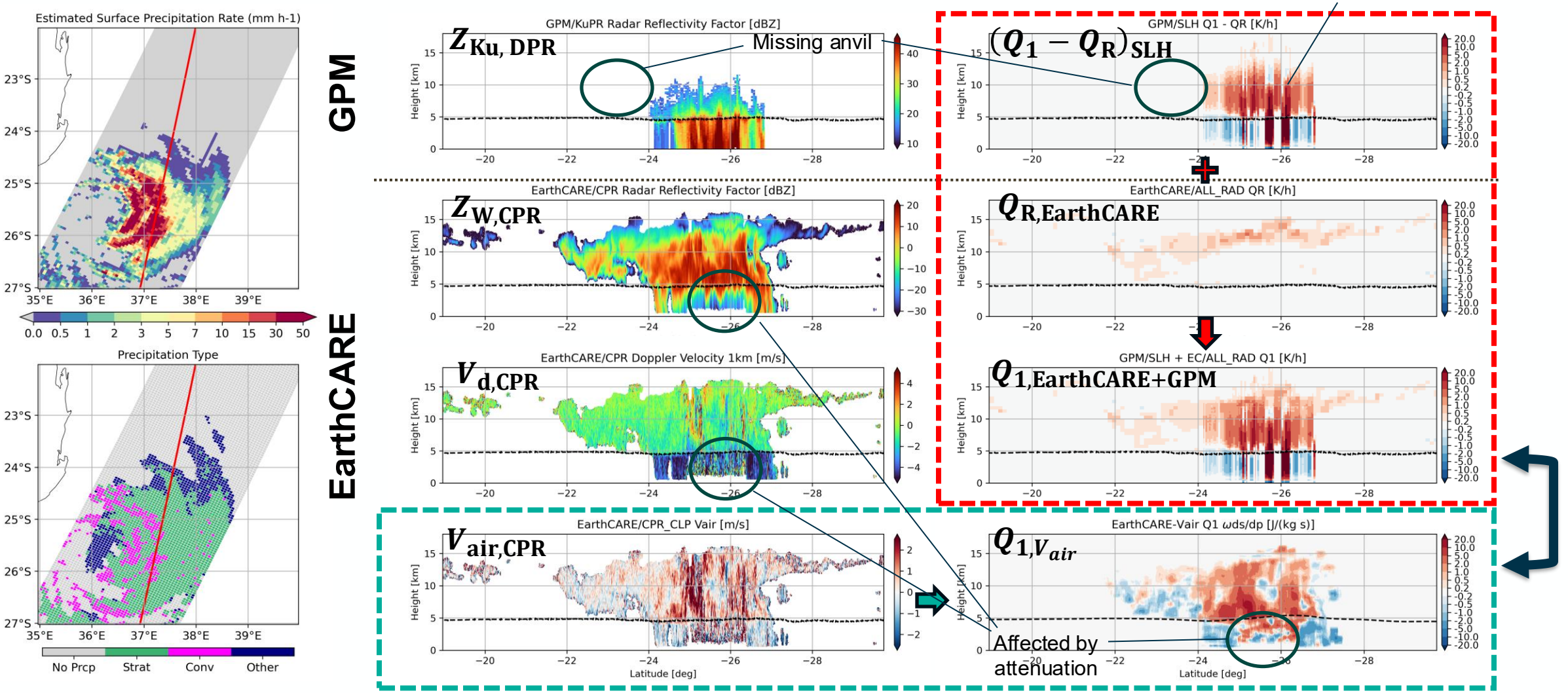
Case1: Stratiform precipitation in Maritime Continent

2B.ECAREGPM.COIN.COIN2025.20260105-S053034-E053455.067267.V01.nc



Case2: Tropical cyclone in Indian Ocean

2B.ECAREGPM.COIN.COIN2025.20260214-S110819-E111831.067888.V01.nc



Case3: Extratropical cyclone in Central Asia

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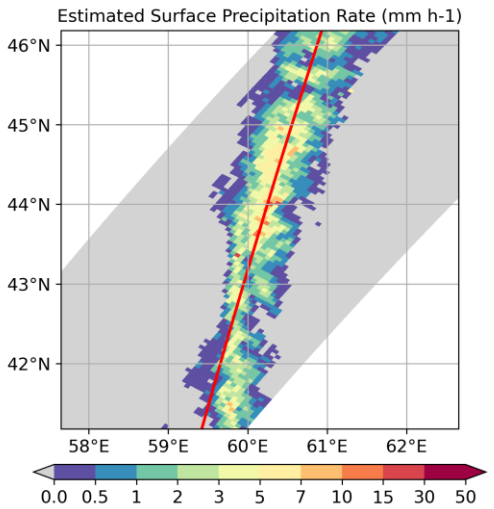
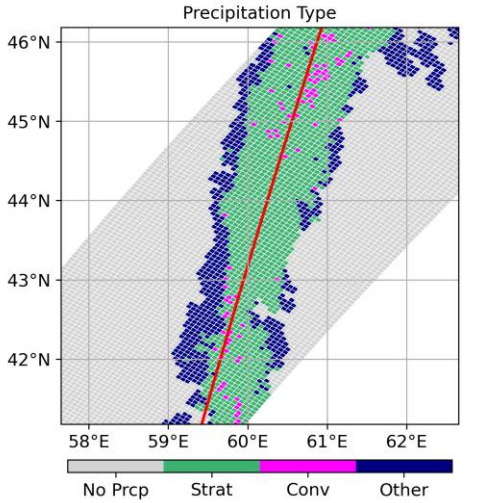
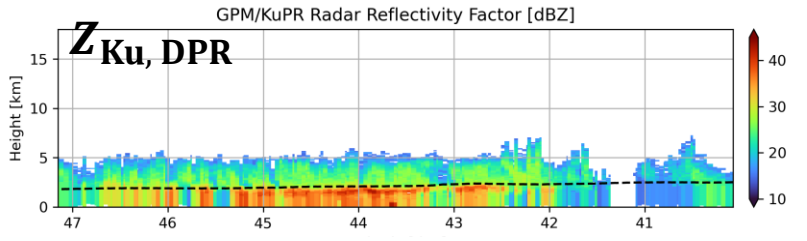
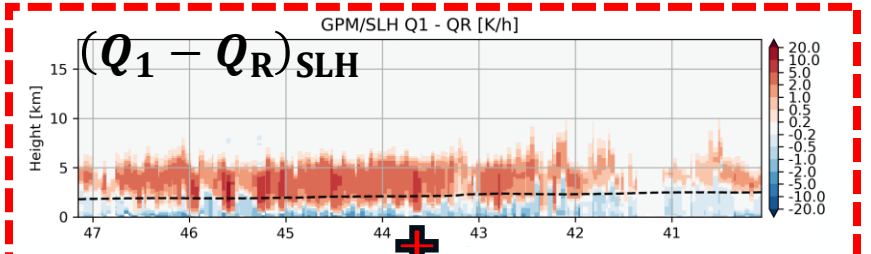


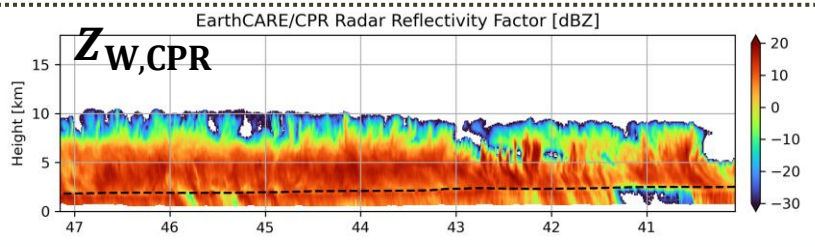


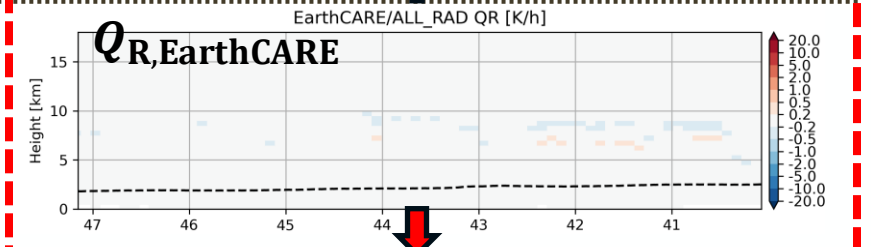
GPM

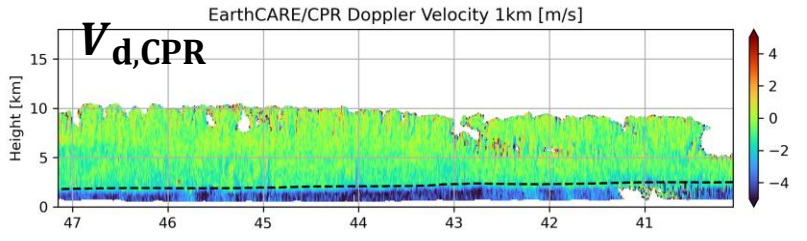
EarthCARE

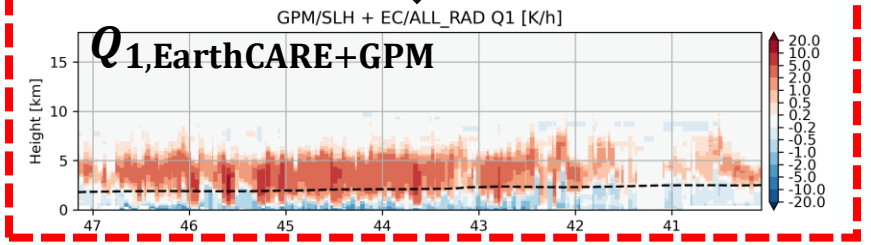


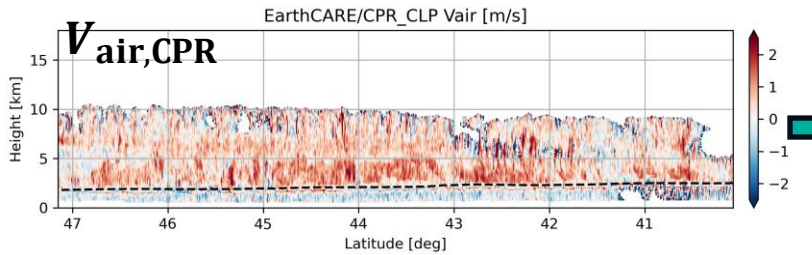


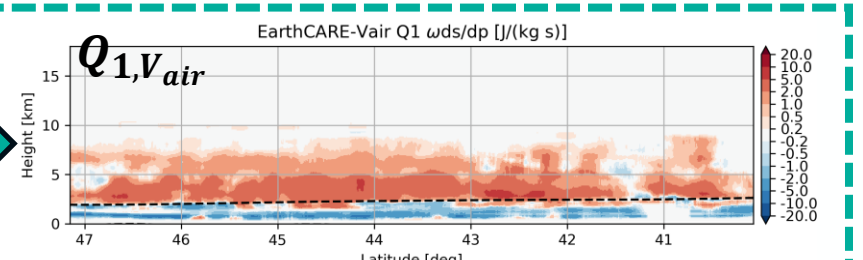






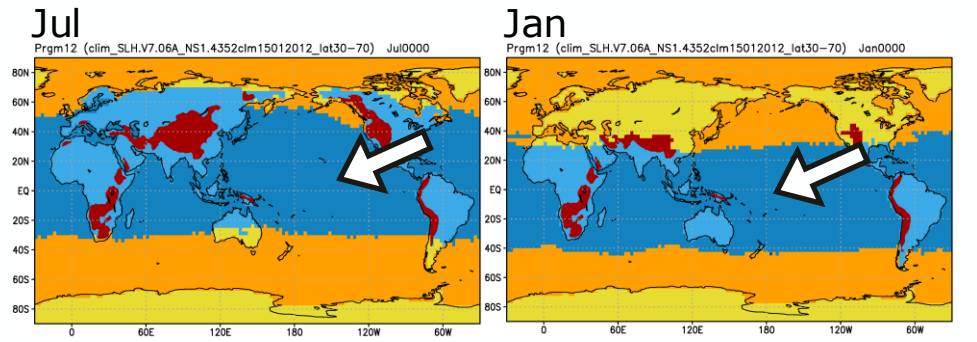






Precipitation type classification: Tropics

- Analyzed by precipitation type (stratiform/convective etc.), because the SLH algorithm uses different lookup tables for each type (period: Aug 2024–Feb 2026).
- The JAXA's radiation product (ALL_RAD) was not available before November 2025; therefore, Q_{R} was not included.



Deep Convective:

- **Heating maximum in the mid-troposphere.**
- CPR $Q_{1,V_{\mathrm{air}}}$ is underestimated in the mid-levels possibly due to W-band radar attenuation.
- GPM $Q_1 - Q_{\mathrm{R}}$ is underestimated in the upper levels possibly because the SLH LUTs in tropical regime are based on the 2D idealized model simulations.

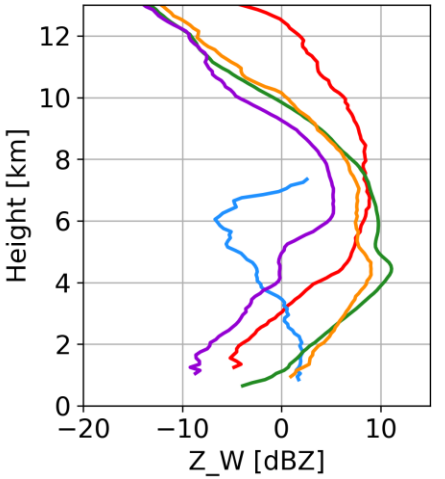
Deep Stratiform Pmax aloft, and Pmax near sfc:

- **Top-heavy heating structure is captured in both Q_1.**
- Overestimation below the melting layer likely due to difficulties in estimating V_{air} in rain layers.

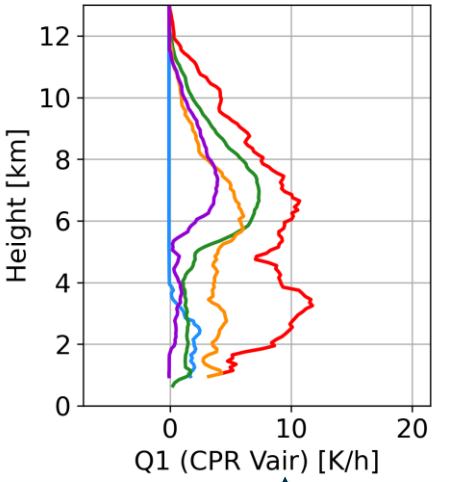
Shallow: GPM $Q_1 - Q_{\mathrm{R}}$ is overestimated possibly because the LUT assumes developing convection .

Other (Anvil): No SLH estimates are provided for anvils in the tropical regime.

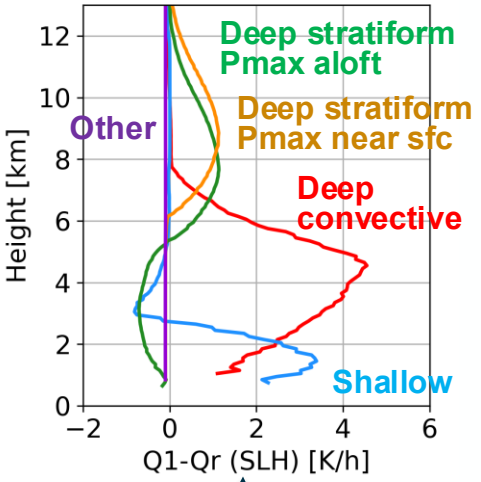
EC-CPR radar reflectivity



EC-CPR $Q_{1,V_{air}}$

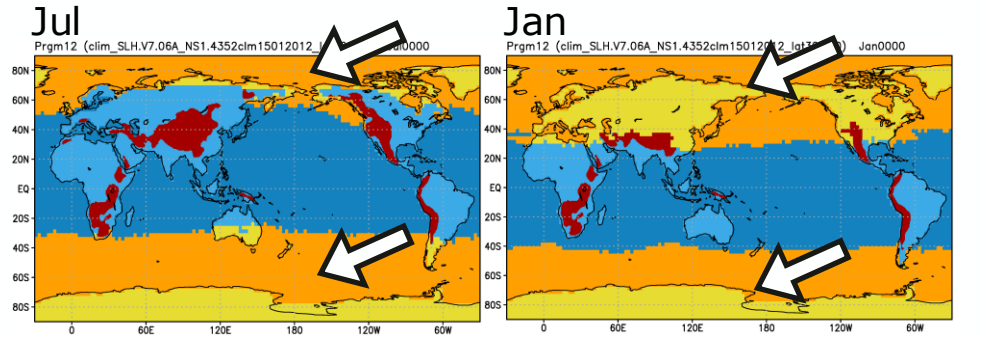


GPM-SLH $Q_1 - Q_{\mathrm{R}}$



Precipitation type classification: Mid-latitudes

- Analyzed by precipitation type (stratiform/convective etc.), because the SLH algorithm uses different lookup tables for each type (period: Aug 2024–Feb 2026).
- The JAXA's radiation product (ALL_RAD) was not available before November 2025; therefore, Q_{R} was not included.



Deep Convective, Shallow, and Deep Stratiform Pmax near sfc:

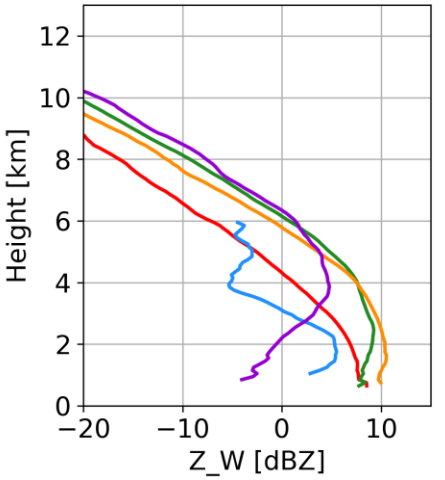
- Q_1 profiles are in good agreement.

Other (Anvil) and Deep Stratiform Pmax Aloft:

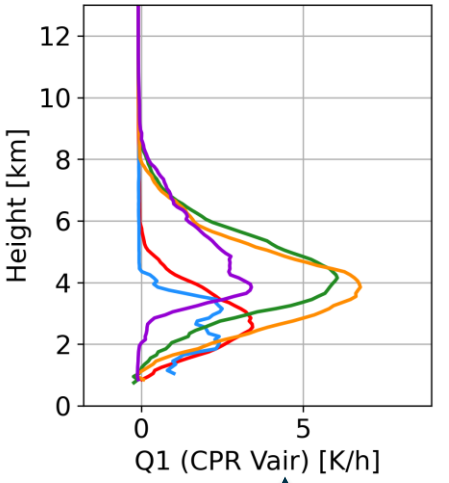
- $Q_{1,V_{\mathrm{air}}}$ from CPR tends to be overestimated possibly because precipitation not detected by KuPR, or contributions from horizontal advection terms ($\overline{v} \cdot \nabla \overline{s}$) in midlatitudes.

Despite the magnitude of CPR Vair-based Q1 being about three times larger than that of GPM Q1 − Qr, the convective and stratiform profile shapes are similar.

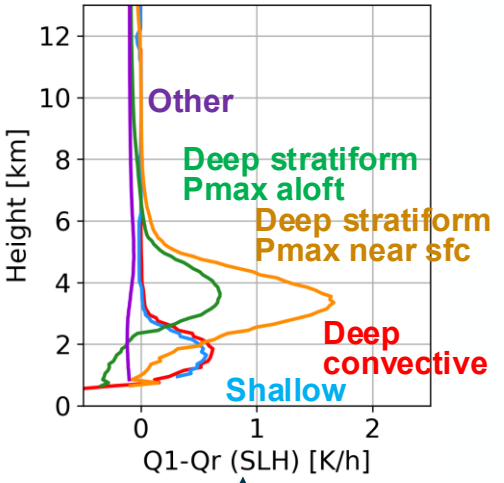
EC-CPR radar reflectivity



EC-CPR $Q_{1,V_{air}}$

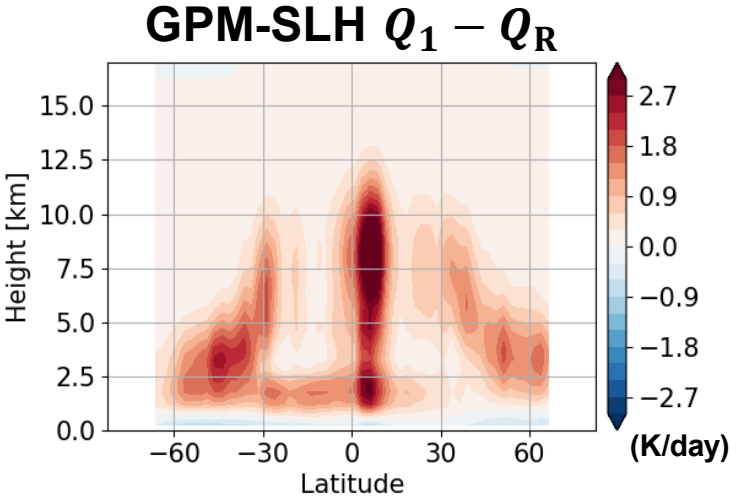


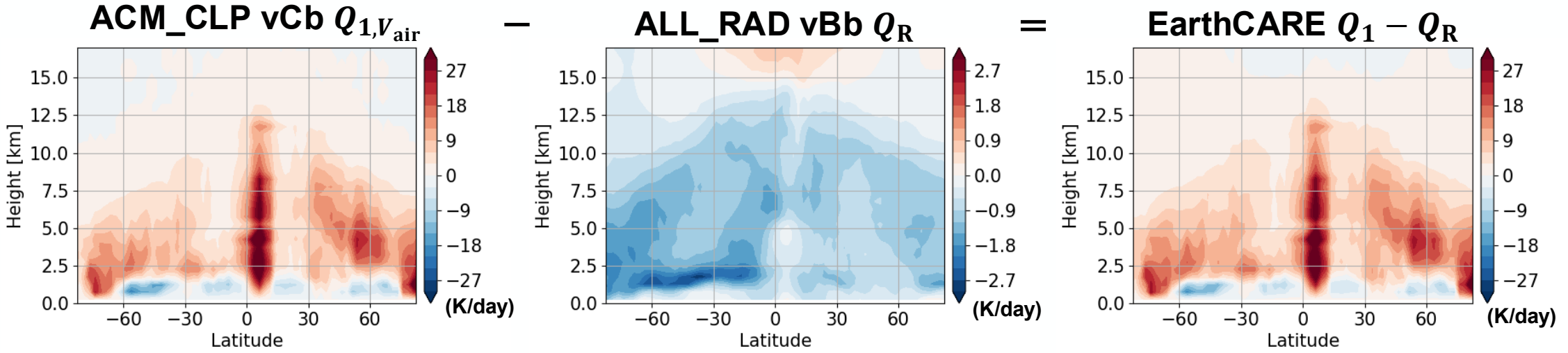
GPM-SLH $Q_1 - Q_{\mathrm{R}}$



Zonal mean Lat-height statistics

- A statistical comparison of $Q_1 - Q_R$ using the latest two weeks of data, not limited to coincidence cases, shows apparently similar patterns.
- However, this analysis involves various uncertainties.
  - Affected by limitations in the observational and retrieval methods.
  - In particular, EarthCARE products are still under development, and substantial differences exist among product versions.
  - Conversion from in-cloud $\boldsymbol{V_{air}}$ to large-scale $\boldsymbol{V_{air}}$ is another major uncertainty, especially because clear-air subsidence cannot currently be accounted for.





(Analysis period: 19 Mar – 3 May 2026)

Summary

- Using the both EarthCARE and GPM products, we investigated whether Q_1 estimated from EarthCARE V_{air} is thermodynamically consistent with Q_1 estimated by GPM latent heating estimates.
- Overall, precipitation-type-dependent features in the Q_1 profiles showed broad consistency between the two estimates. The differences between them likely reflect the strengths and limitations of each product.
- Both EarthCARE V_{air} and GPM's LH estimates involve substantial uncertainties from multiple preprocessing steps, and ground validation is difficult. We suggest that thermal budget analysis may provide a useful framework for evaluating these products.


JAXA
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EarthCARE 2026 Science and Validation workshop
8–12 June 2026 | Rhodes House | Oxford, UK

Thank you!