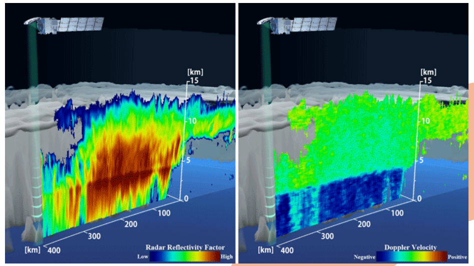
# Creation and validation of precipitation particles falling velocity with simultaneous observations of the GPM and EarthCARE satellite's radars

*Kaya Kanemaru[1]、Taisei Tsuji[2,3], Shunsuke Aoki[3]
(1. NICT, 2. Toyama university, 3. JAXA/EORC)

# Background

*Realize First-ever Doppler measurement of spaceborne precipitation radar*

## Doppler measurement for cloud




©JAXA/NICT/ESA

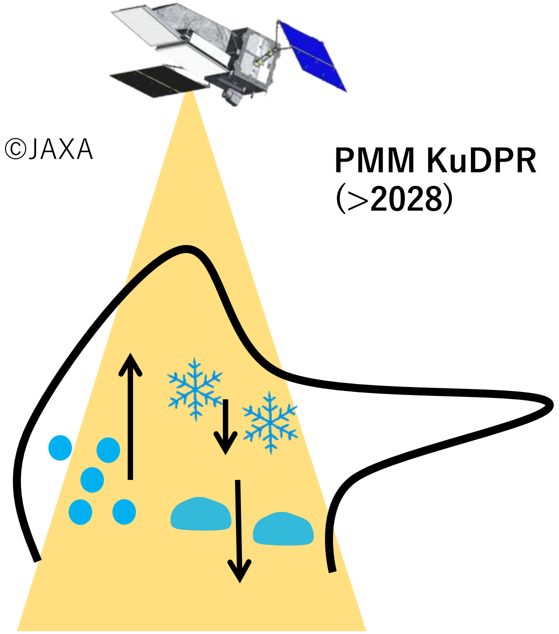
EarthCARE CPR
(2024/06-NOW)

JAXA/NICT co-develop

## Signal processing  of SAR

Pi-SAR2
(2008-2016)

©NICT

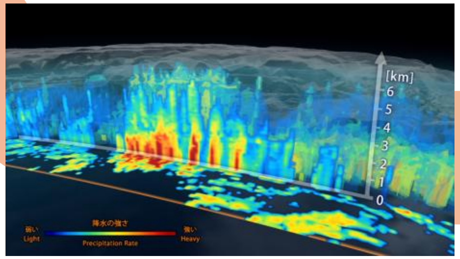


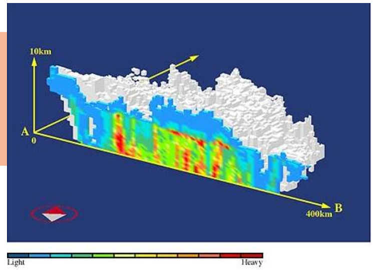
©JAXA

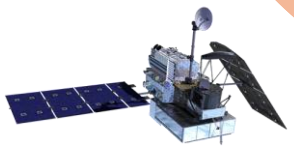
PMM KuDPR
(>2028)

Design of future spaceborne Doppler radar

## Accurate precipitation observation







GPM DPR
(2014/03-NOW)

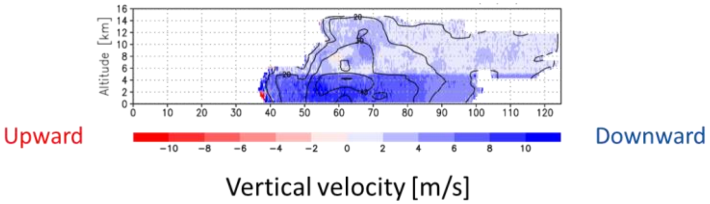
©JAXA/NASA

JAXA/NICT co-develop

JAXA/NICT co-develop

TRMM PR
(1997/12-2015/04)

Simulation study



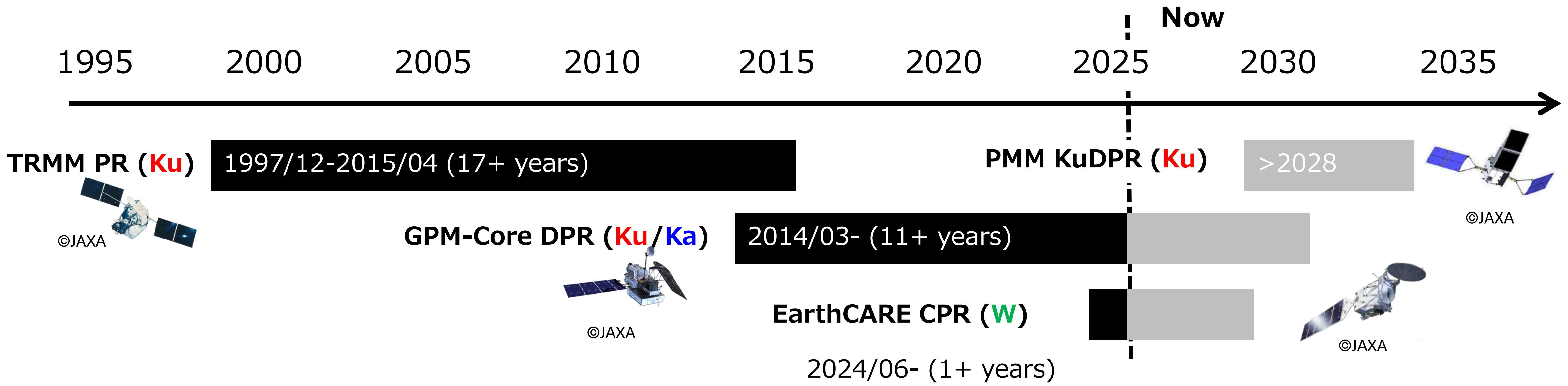

Algorithm development of Doppler processing

# Purpose

TRMM: Tropical Rainfall Measuring Mission
PR: Precipitation Radar
GPM: Global Precipitation Measurement
DPR: Dual-frequency Precipitation Radar

PMM: Precipitation Measuring Mission
KuDPR: Ku-band Doppler Precipitation Radar
EarthCARE: Earth Cloud Aerosol and Radiation Explorer
CPR: Cloud Profiling Radar

- JAXA starts development of PMM (Precipitation Measuring Mission). KuDPR (Ku-band Doppler Precipitation Radar) will realize first-ever Doppler measurement in convective clouds with spaceborne precipitation radar.
- NICT collaborates as co-development of PR/DPR/CPR, Cal/Val of those data. For PMM, NICT will contribute of algorithm development of KuDPR. This study investigates creation and evaluation of precipitation particles falling velocity with simultaneous observations of the GPM and EarthCARE satellite’s radar.



# Method: falling velocity of precipitation particles

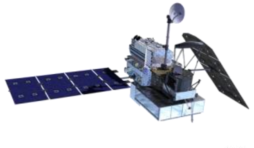
At nadir pointing, mean Doppler velocity is given as

Scattering property and spices

PSD parameters (as Gamma function)

$$V_{d,\mathrm{obs}} = \frac{\int_0^{D_{\max}} [w - V_t(D)]\,\sigma_{\mathrm{bk}}(D;\lambda)\,N(D;D_m,N_w,\mu)\,dD}{\int_0^{D_{\max}} \sigma_{\mathrm{bk}}(D;\lambda)\,N(D;D_m,N_w,\mu)\,dD}$$

CPR obs.



DPR estimates

$w$: Vertical wind
$V_t$: Falling velocity
$\sigma_{\mathrm{bk}}$: Backscattering coef.
$N$: PSD
$D$: Particle diameter
$\lambda$: Wavelength

$$V_{d,\mathrm{obs}} = w - \overline{V_{t,\lambda}}(D_m;\lambda) \qquad \text{where} \quad \overline{V_{t,\lambda}} = \frac{\int_0^{D_{\max}} V_t(D)\,\sigma_{\mathrm{bk}}(D;\lambda)\,N(D;D_m,N_w,\mu)\,dD}{\int_0^{D_{\max}} \sigma_{\mathrm{bk}}(D;\lambda)\,N(D;D_m,N_w,\mu)\,dD}$$

Vertical wind is

$$w = V_{d,\mathrm{obs}} + \overline{V_{t,\lambda}}(D_m;\lambda) \qquad \text{where} \quad D_m = \frac{\int_0^{D_{\max}} D^4 N(D)\,dD}{\int_0^{D_{\max}} D^3 N(D)\,dD}$$

# Method: falling velocity of precipitation particles

Scattering property is based on DPR algorithm (Seto et al., 2021)

$$\overline{V_{t,\lambda}} = \frac{\int_0^{D_{\max}} V_t(D)\sigma_{\mathrm{bk}}(D;\lambda)N(D;D_m,N_w,\mu)dD}{\int_0^{D_{\max}} \sigma_{\mathrm{bk}}(D;\lambda)N(D;D_m,N_w,\mu)dD}$$

Rain
Atlas and Ulbrich (1977)

Melting layer
Seto et al. (2021)

Snow
Magono and Nakamura (1965)

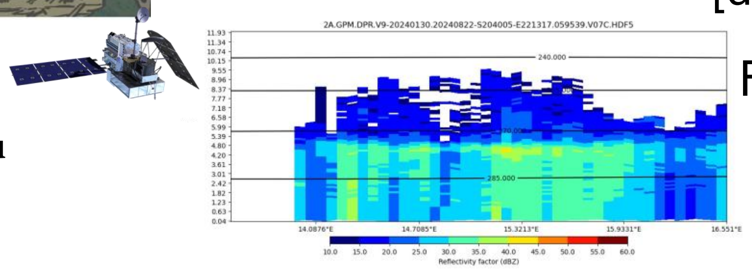
Pressure effect is also considered

Since Doppler velocity is weighted by backscattering coefficient, Vt becomes low at high-frequency

[dBZ]

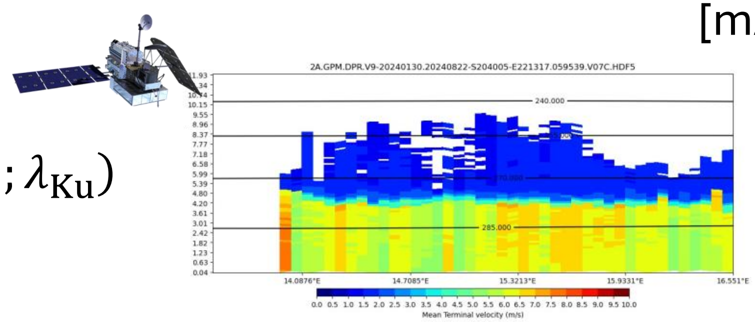
From $D_m$,$N_W$

$Z_{e,\mathrm{Ku}}$



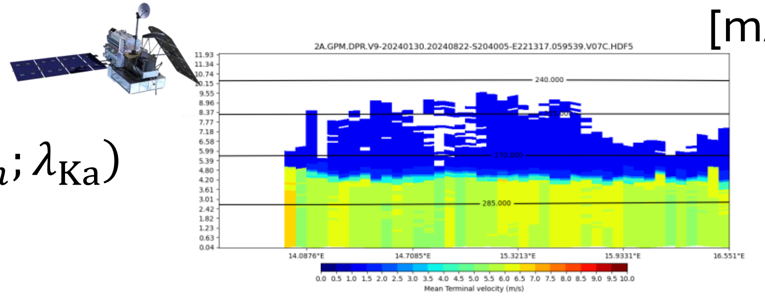

[m/s]

$\overline{V_{t,\lambda}}(D_m;\lambda_{\mathrm{Ku}})$



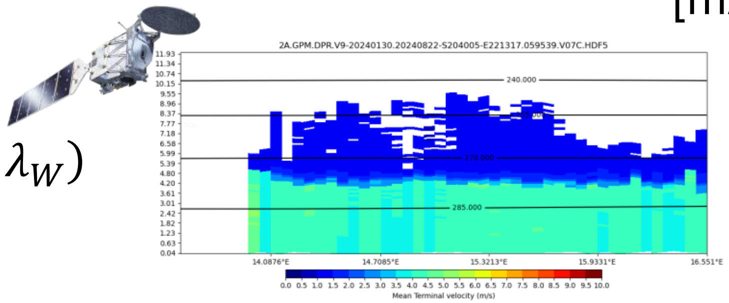

[m/s]

$\overline{V_{t,\lambda}}(D_m;\lambda_{\mathrm{Ka}})$



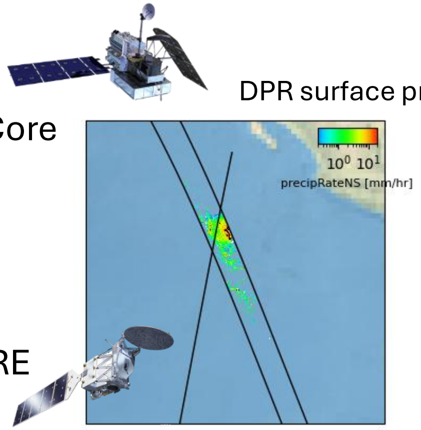

[m/s]

$\overline{V_{t,\lambda}}(D_m;\lambda_W)$



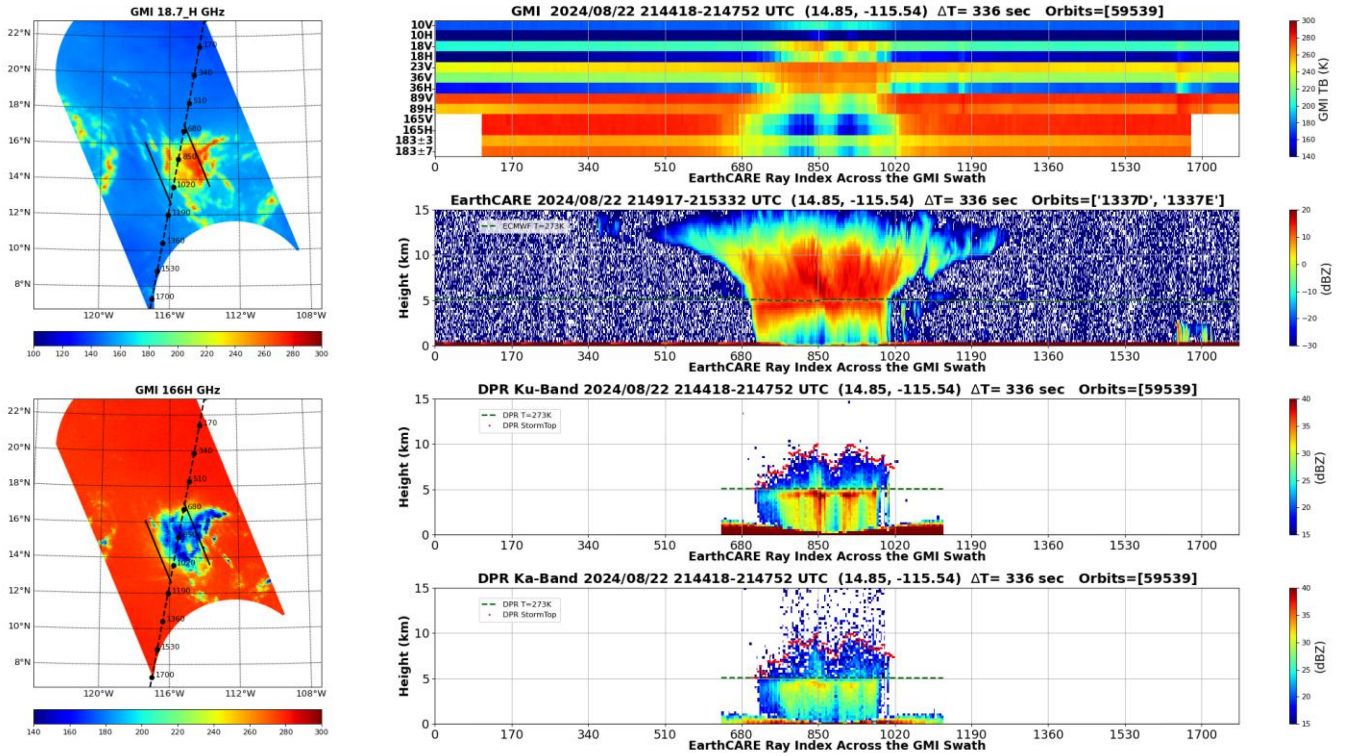
# Analyzed data & method

Handmade search algorithm




GPM-Core/EarthCARE cross event
(2024/08/22)

Very useful!

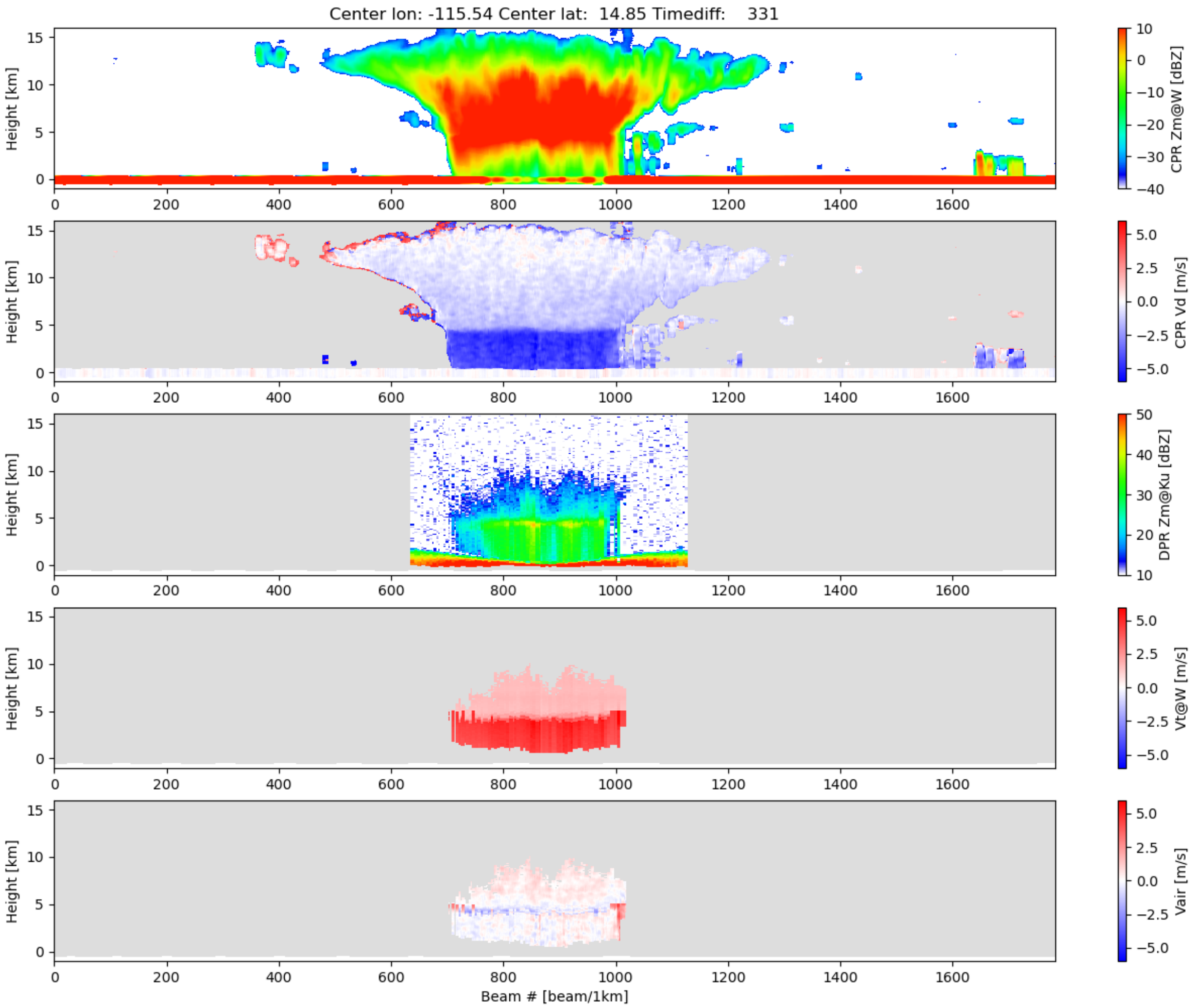



Data：GPM-EarthCARE coincidence datasets (Aoki et al. 2025, preprint)

Period: 2024/08-2025/09 (2845 events including no-precipitation case (for ±15 min))

# Case 1 (2024/08/22 21:49-21:53UTC Δt ~5 min)

DPR: 5.5 km x 5.5 km
CPR: 10 km x 0.8 km




CPR $Z_{m,W}$ [dBZ]

CPR $v_{d,W}$ [m/s]

10 km integrated bias corrected Doppler velocity

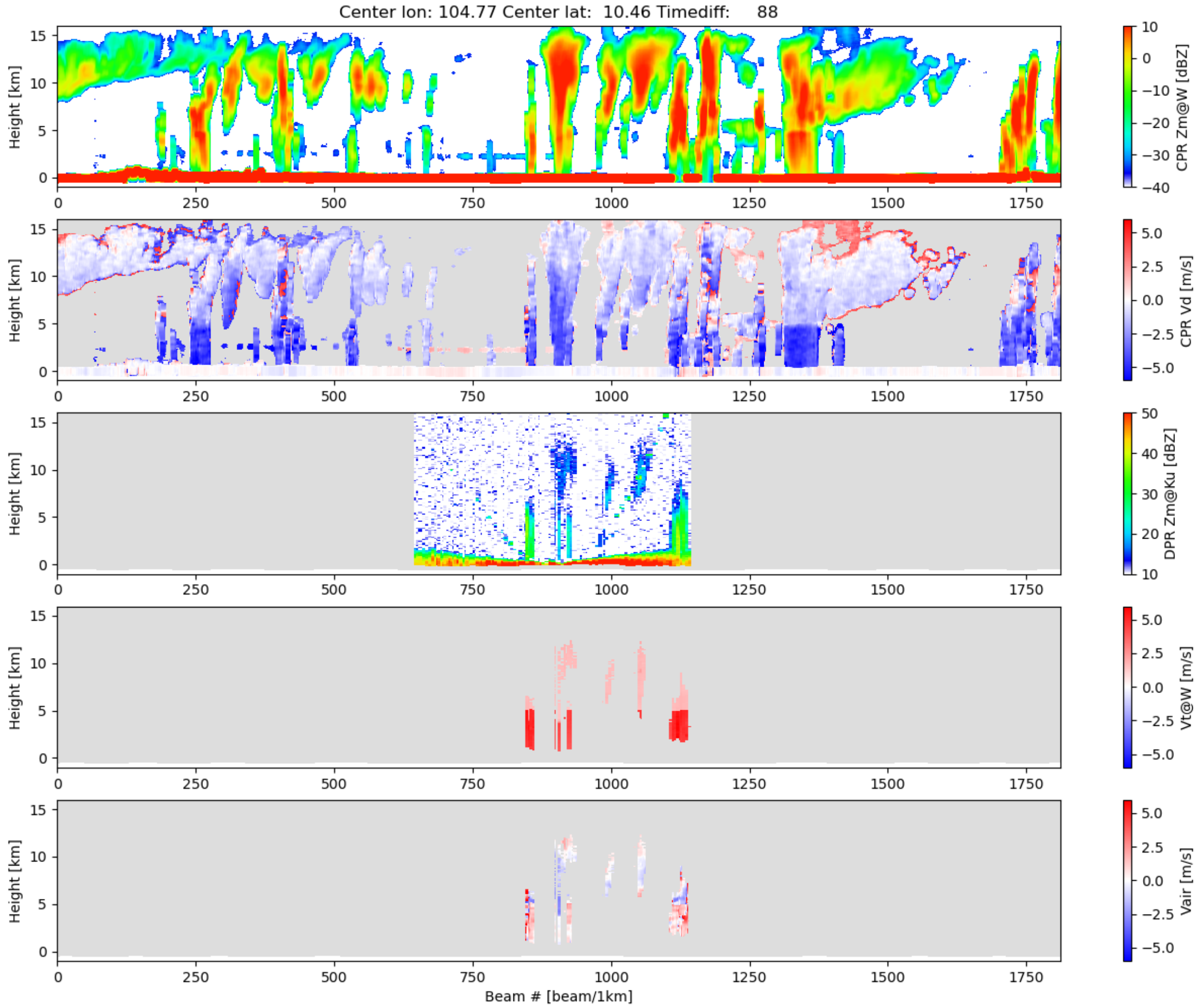
DPR $Z_{m,Ku}$ [dBZ]

$V_{t,w}$ from DPR's $D_m$ [m/s]

$w_{est}$ (= $V_{t,w}$ + $v_{d,w}$) [m/s]

# Case 2 (2024/08/23 07:05-07:10 Δt ~90 sec)

DPR: 5.5 km x 5.5 km
CPR: 10 km x 0.8 km




CPR $Z_{m,W}$ [dBZ]

CPR $v_{d,W}$ [m/s]

10 km integrated bias corrected Doppler velocity

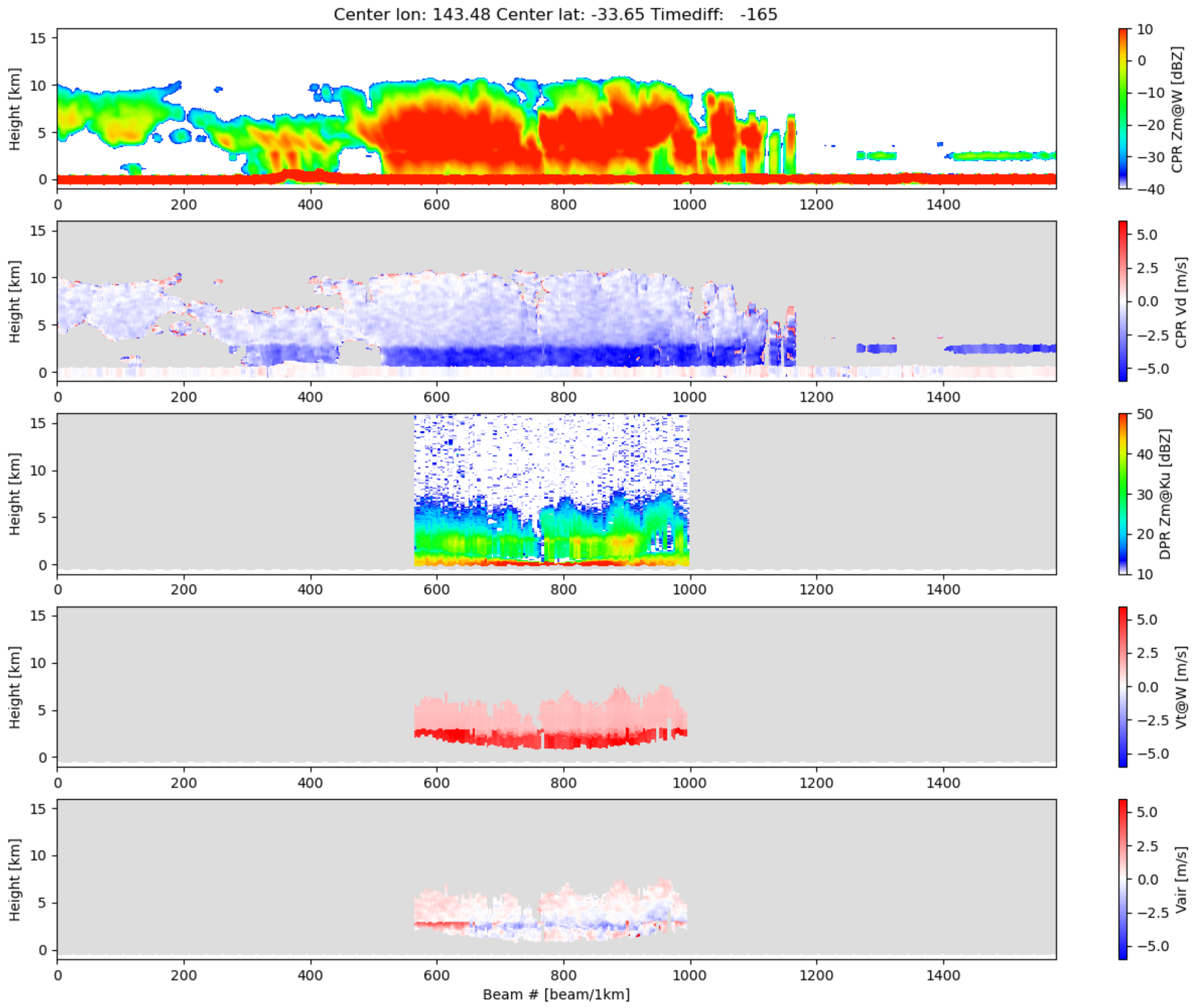
DPR $Z_{m,Ku}$ [dBZ]

$V_{t,w}$ from DPR's $D_m$ [m/s]

$w_{est}$ (= $V_{t,w}$ + $v_{d,w}$) [m/s]

# Case 3 (2024/08/23 07:05-07:10 Δt ~3 min)

DPR: 5.5 km x 5.5 km
CPR: 10 km x 0.8 km




CPR $Z_{m,W}$ [dBZ]

CPR $v_{d,W}$ [m/s]

10 km integrated bias corrected Doppler velocity

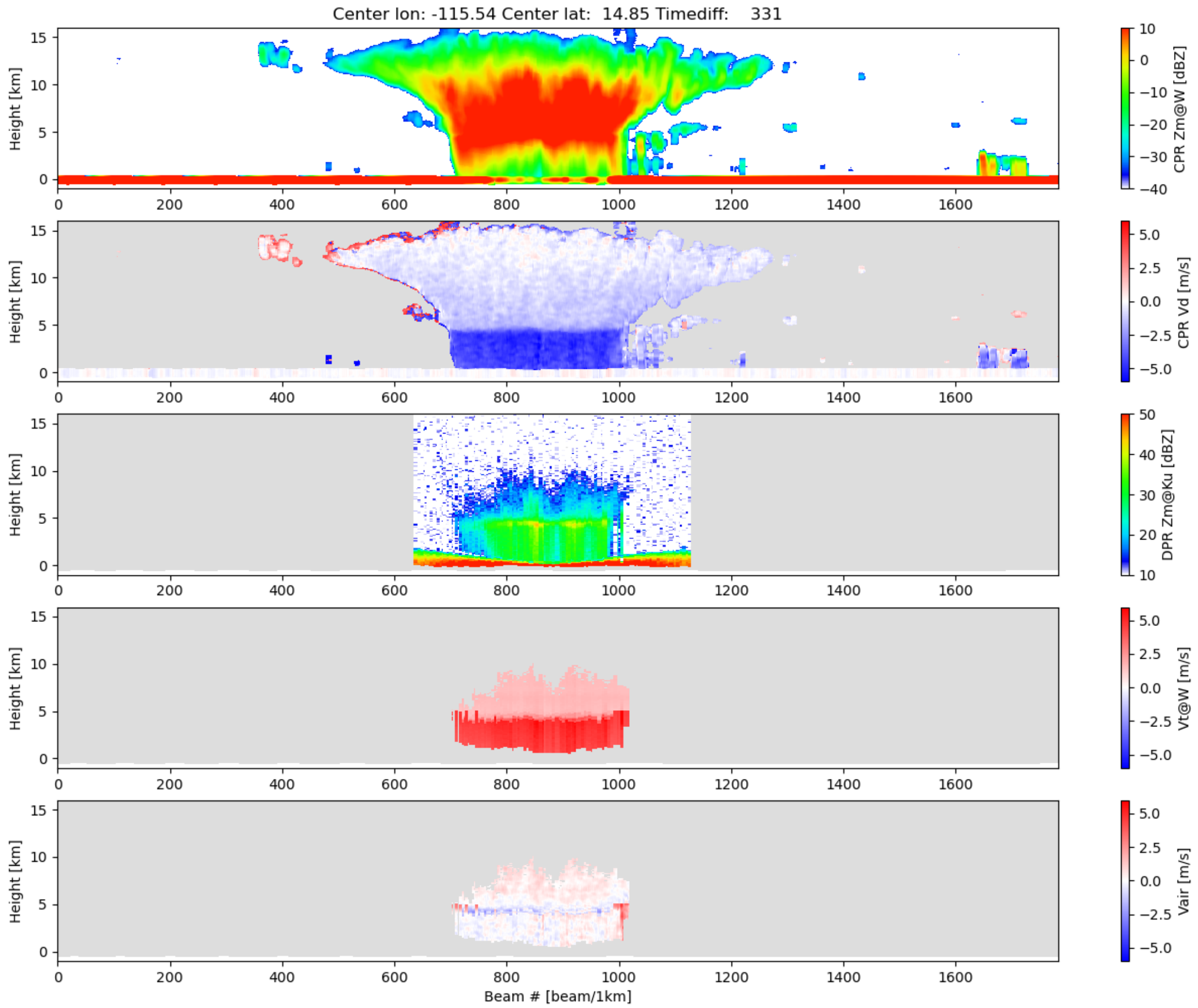
DPR $Z_{m,Ku}$ [dBZ]

$V_{t,w}$ from DPR's $D_m$ [m/s]

$w_{est}$ (= $V_{t,w}$ + $v_{d,w}$) [m/s]

# Case 4 (2025/02/05 15:36-15:40 Δt ~60 sec)

DPR: 5.5 km x 5.5 km
CPR: 10 km x 0.8 km




CPR $Z_{m,W}$ [dBZ]

CPR $v_{d,W}$ [m/s]

10 km integrated bias corrected Doppler velocity

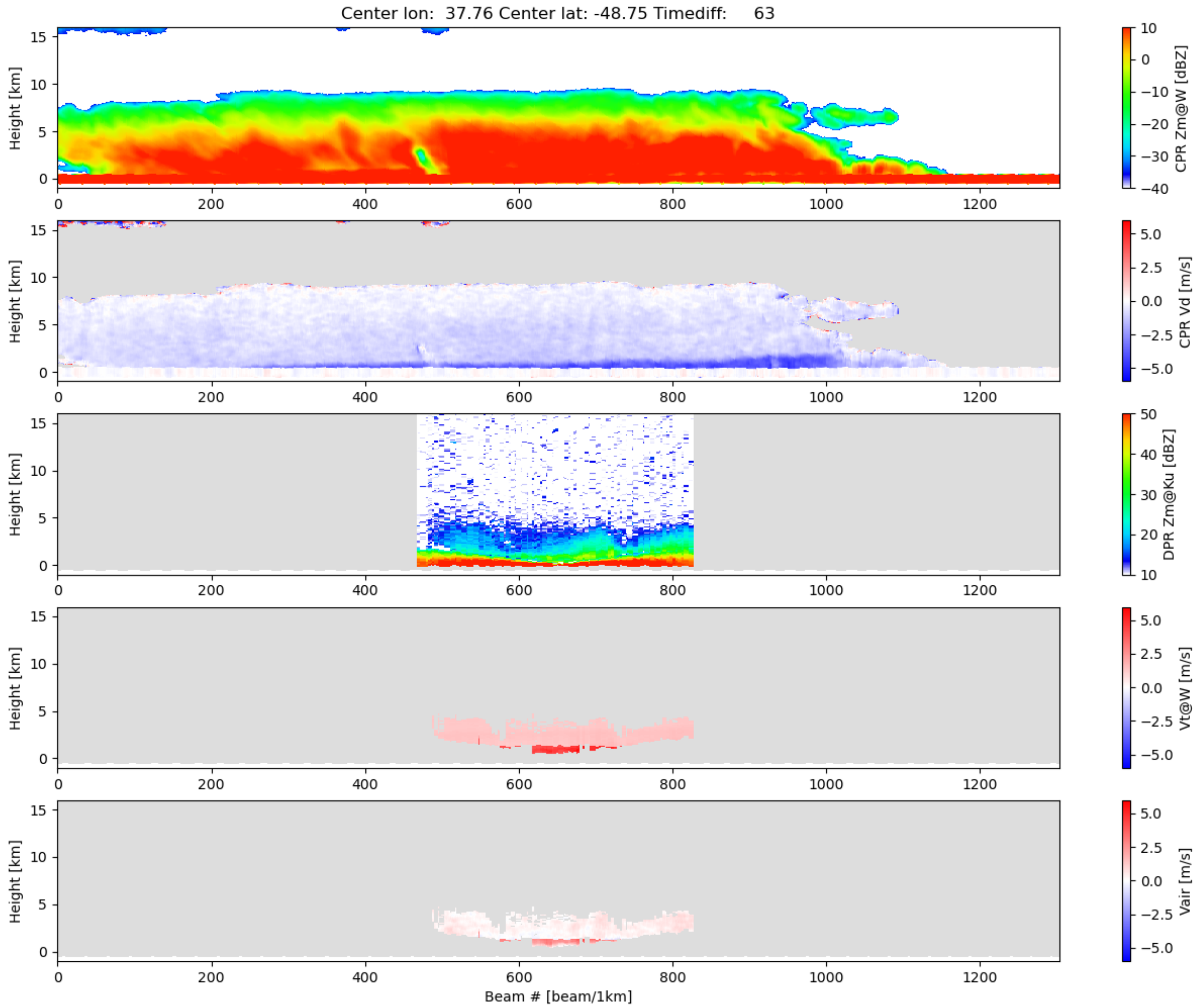
DPR $Z_{m,Ku}$ [dBZ]

$V_{t,w}$ from DPR's $D_m$ [m/s]

$w_{est}$ (= $V_{t,w}$ + $v_{d,w}$) [m/s]

# Case 5 (2025/07/13 23:56-23:59 Δt ~60 sec)

DPR: 5.5 km x 5.5 km
CPR: 10 km x 0.8 km




CPR $Z_{m,W}$ [dBZ]

CPR $v_{d,W}$ [m/s]

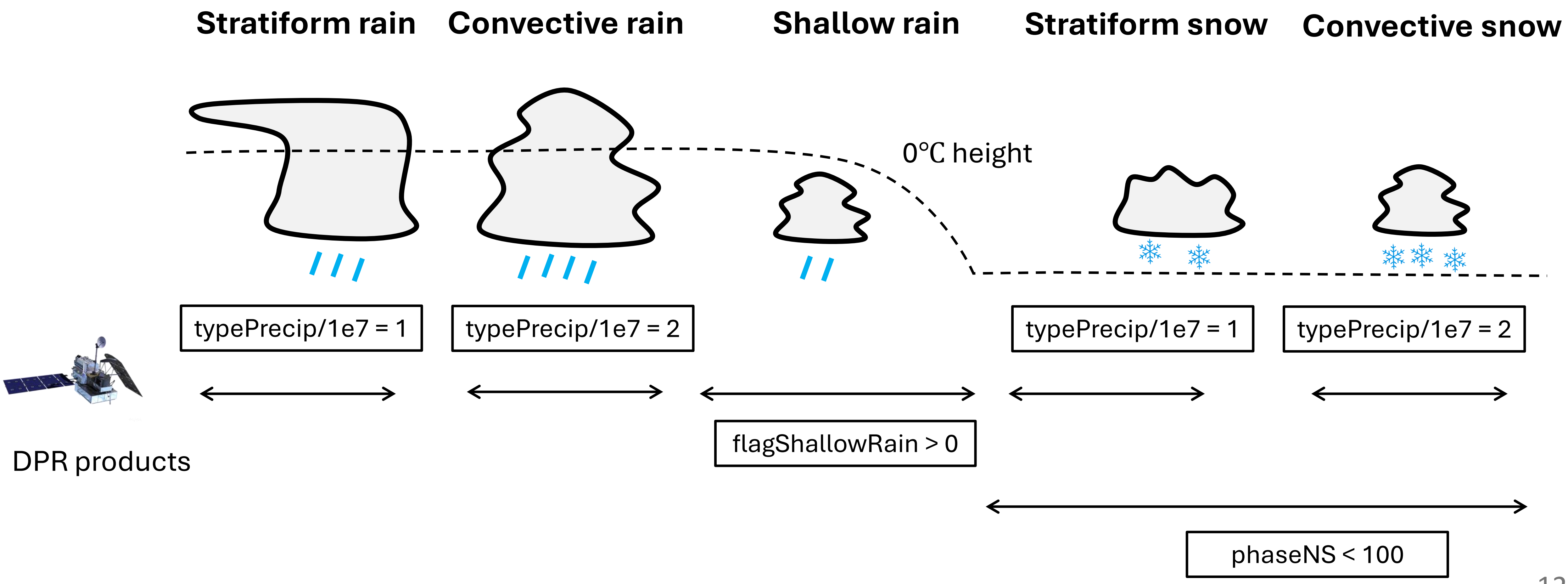
10 km integrated bias corrected Doppler velocity

DPR $Z_{m,Ku}$ [dBZ]

$V_{t,w}$ from DPR's $D_m$ [m/s]

$w_{est}$ (= $V_{t,w}$ + $v_{d,w}$) [m/s]

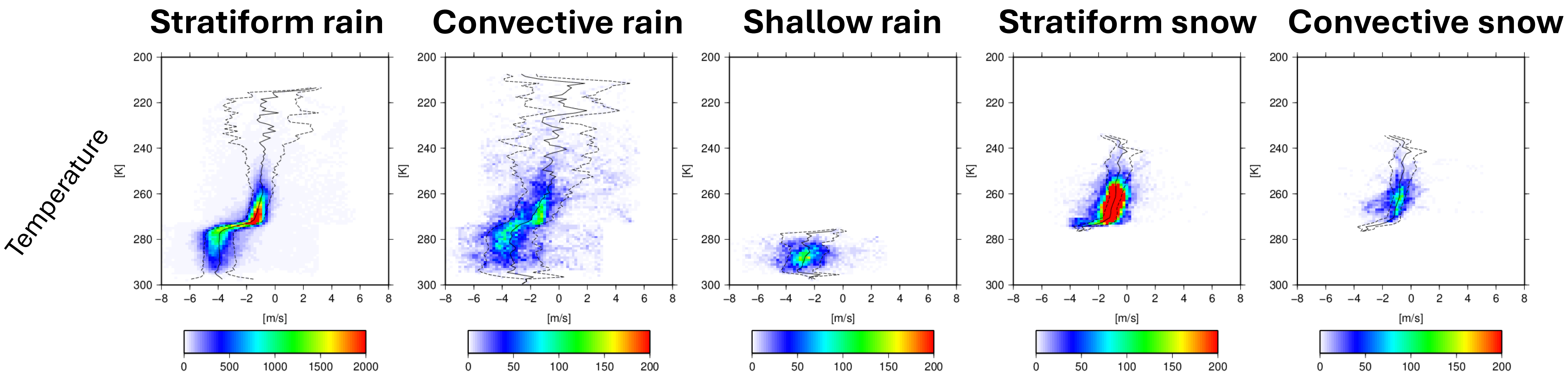
# Statistical analysis with DPR's type classification



# Statistical evaluation (± 300 sec)

$V_{d,\mathrm{obs}}$ 

Color: frequency
Solid: mean
Dash: ±1 stdv



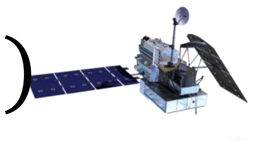

CFED (Contoured frequency by the temperature diagrams)

Rainfall: -4 m/s
Shallow rain: -3 m/s

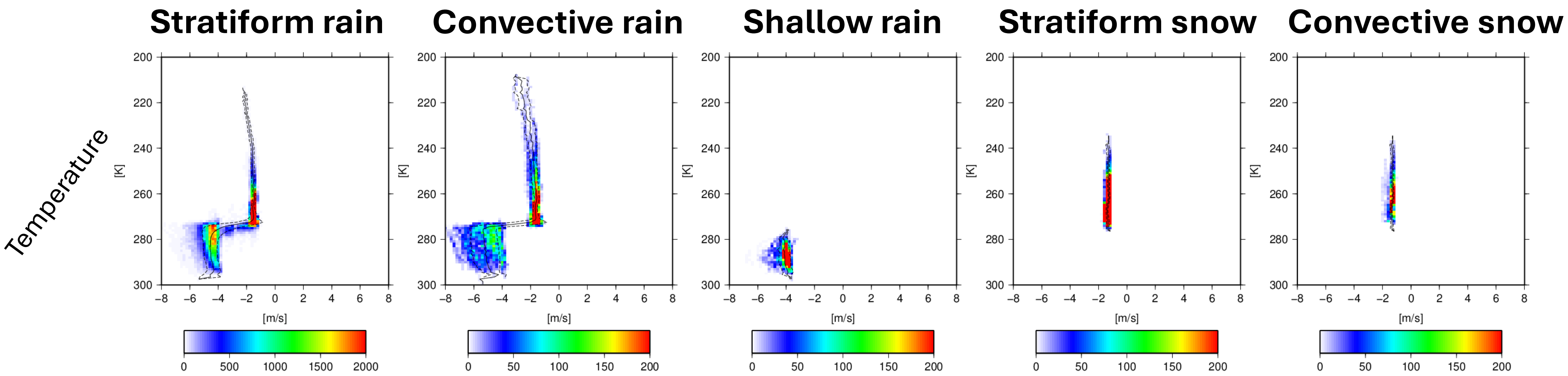
Snow: -1 m/s

# Statistical evaluation (± 300 sec)

$$-\overline{V_{t,\lambda}}(D_m;\lambda_W)$$



Color: frequency
Solid: mean
Dash: ±1 stdv

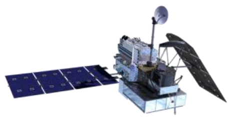



CFED (Contoured frequency by the temperature diagrams)

Estimation of rainfall is -4 m/s
→ Discrepancy for shallow rain

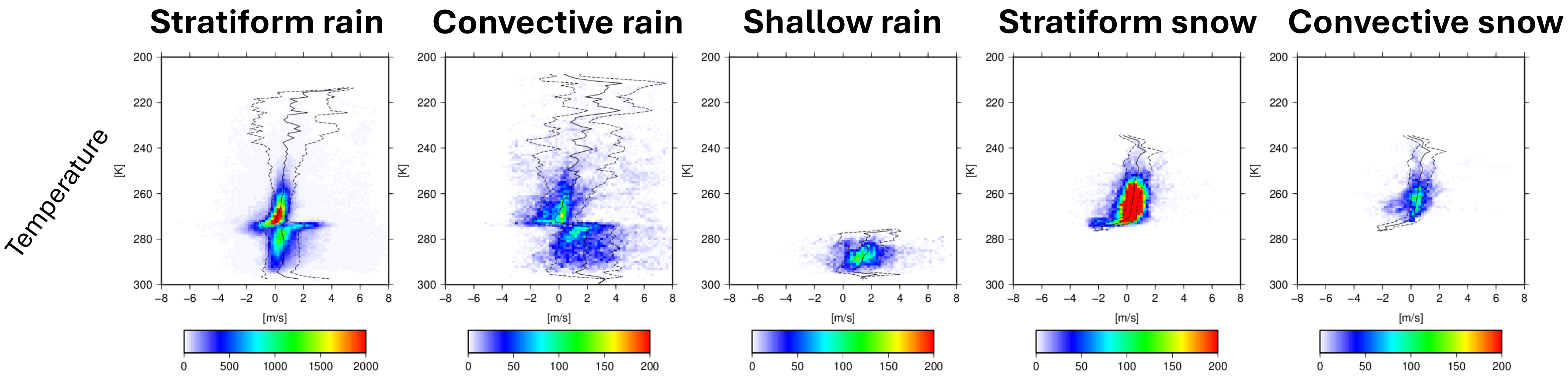
Temperature dependency is not obtained from estimation of snow

# Statistical evaluation (± 300 sec)



$$w = \overline{V_{t,\lambda}}(D_m; \lambda_W) + V_{d,\mathrm{obs}}$$

Color: frequency
Solid: mean
Dash: ±1 stdv




CFED (Contoured frequency by the temperature diagrams)

Improvement of treatment for melting layer is required
For convective rain, detailed analysis is also required.
For shallow rain, improvement of Vt estimation is required.

Improvement of modeling for snowfall is also required.

# Summary and next step

- To realize observation of vertical air motion in intense precipitating clouds in PMM era, synergistic use of GPM/EarthCARE satellite's radars is conducted.
  - Database of precipitation particle falling velocity is constructed using legacy of DPR/CPR algorithm development

- Future task
  - Revision of scattering model/PSD for solid precipitation and treatment of melting layer in DPR algorithm are required to estimate Vt accurately.
  - To evaluate noon uniformity in radar beam (e.g. rain cell for small scale), velocity bias due to the non-uniform beam filling should be considered.