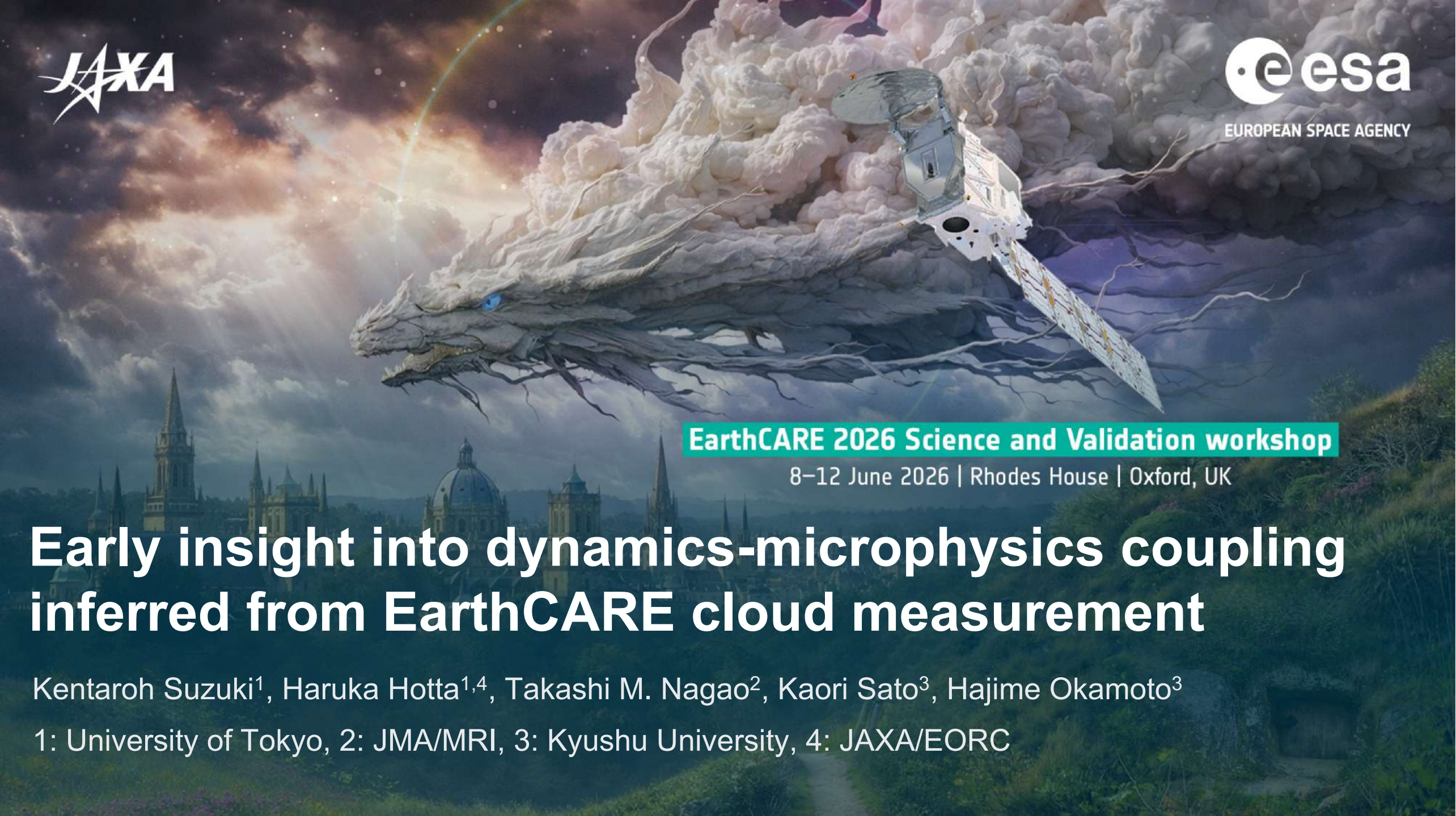
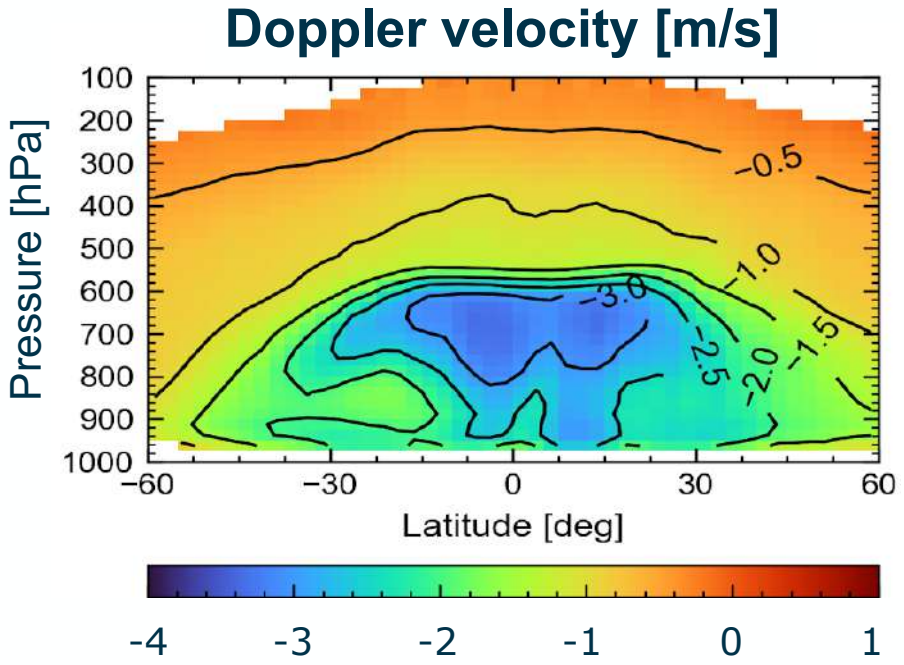


Early insight into dynamics-microphysics coupling inferred from EarthCARE cloud measurement

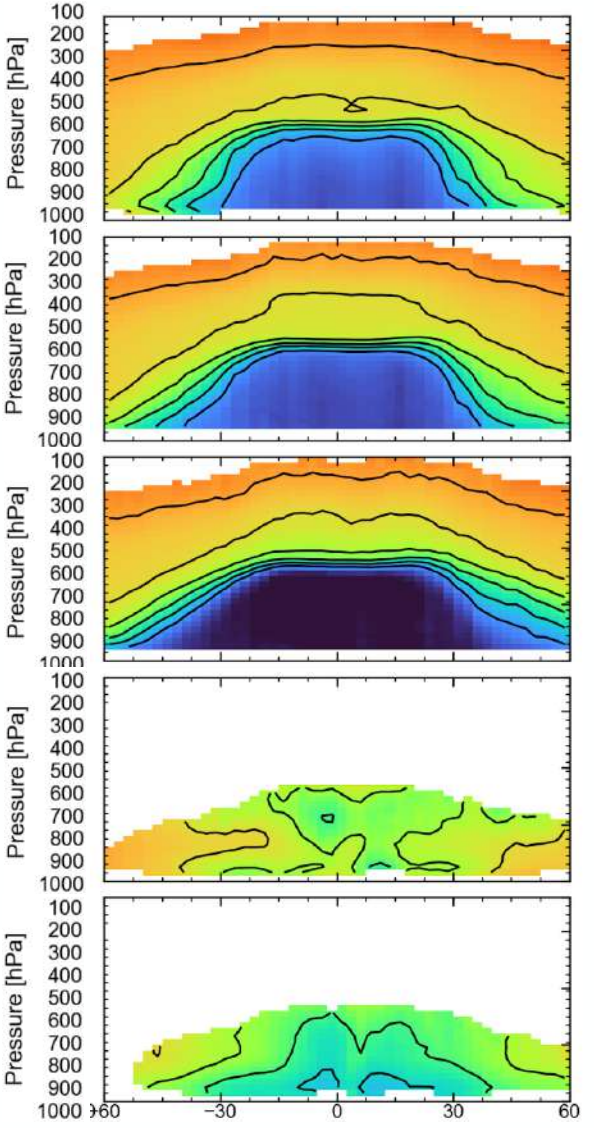
Kentaroh Suzuki[1], Haruka Hotta[1,4], Takashi M. Nagao[2], Kaori Sato[3], Hajime Okamoto[3]

1: University of Tokyo, 2: JMA/MRI, 3: Kyushu University, 4: JAXA/EORC

What can Doppler velocity tell us about?



- ✓ $V_d = w - V_t$ (Z_e-weighted)
  - w: Dynamics
  - V_t: Microphysics
- ✓ Z_e: Microphysics



Cold
No Precip

Cold
Weak Precip

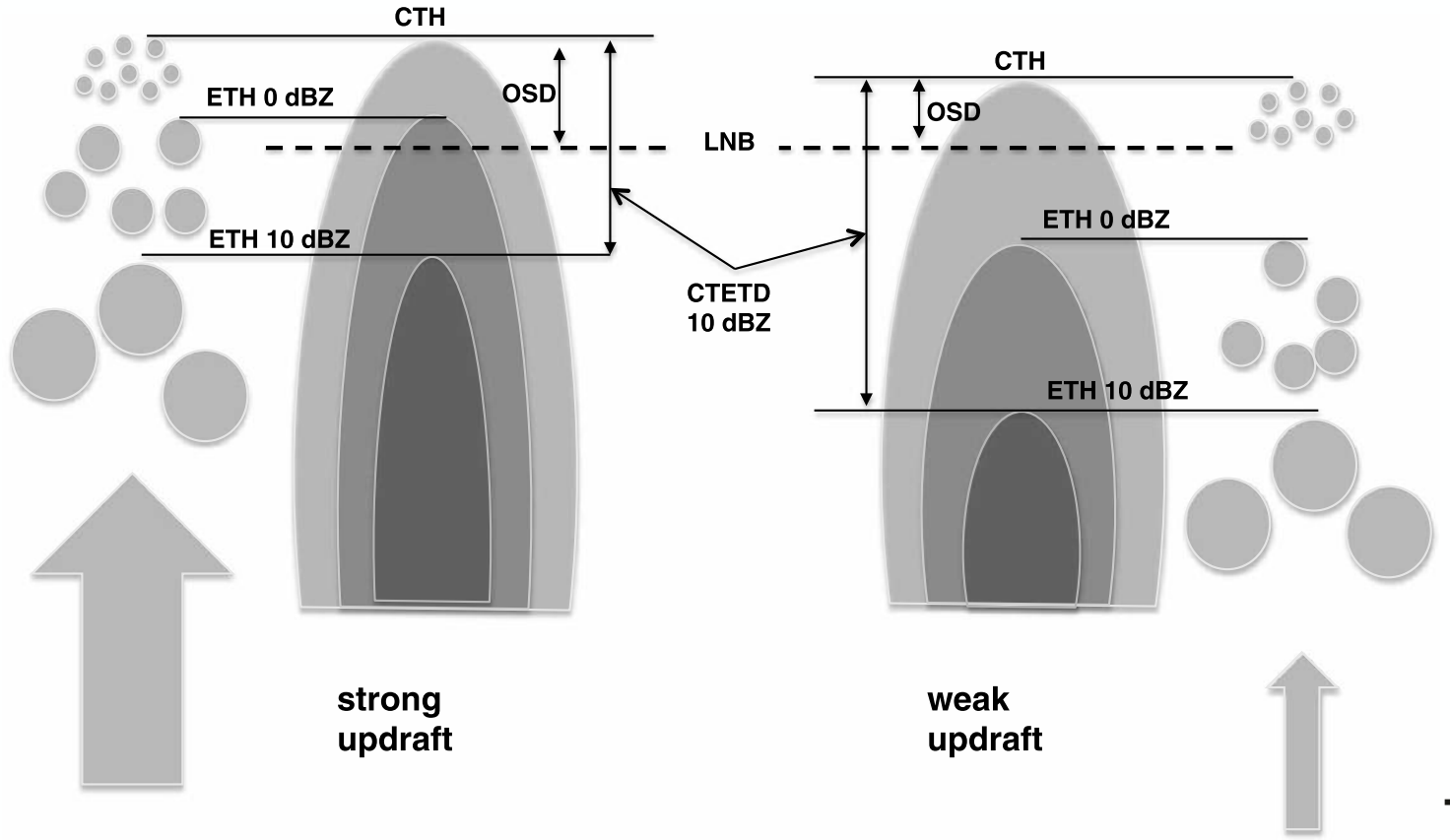
Cold
Strong Precip

Warm
No Precip

Warm
Precip

- DV varies regionally with ‘cloud type’ defined with reflectivity (e.g. precipitating/non-precipitating)
- Joint Z_e-V_d analysis offers a new insight into a coupling between dynamics and microphysics
- This is highlighted for deep convection and warm rain in this presentation

Dynamics-microphysics link in convection



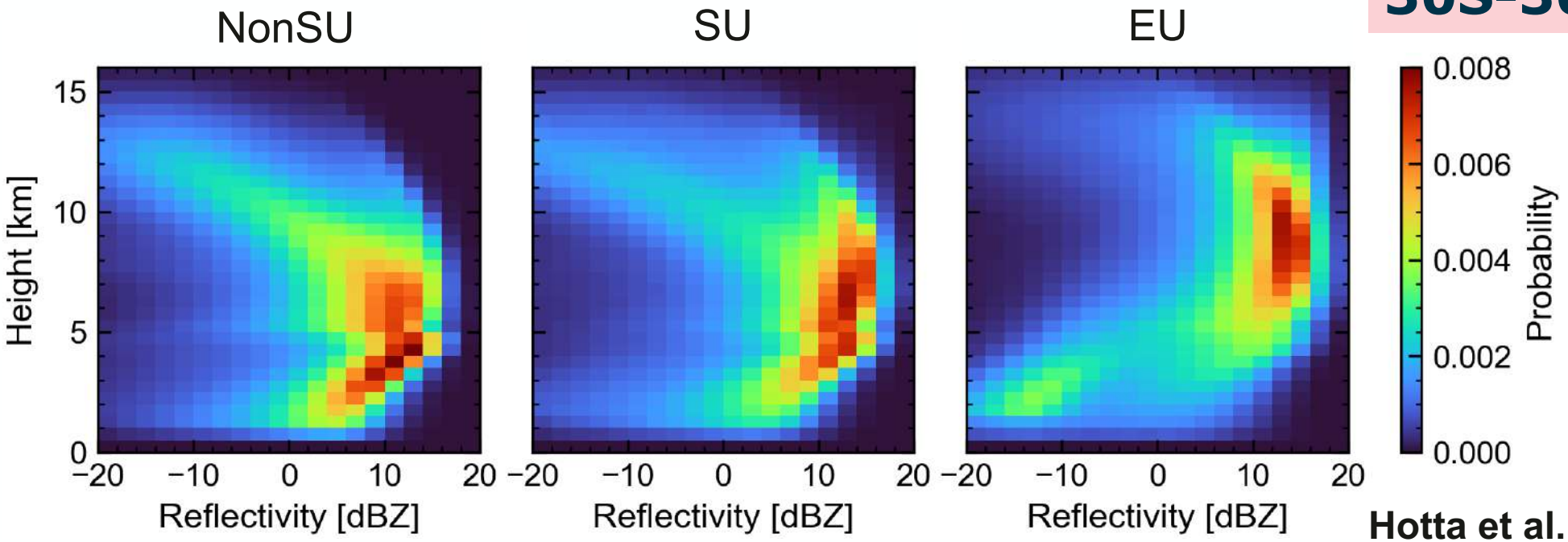
Takahashi & Luo (JGR '14)

- Strong updraft likely produces high Echo-Top Height (ETH): large particles lofted higher
- ETH has been proposed as an indirect proxy for convective intensity (e.g. Luo et al. '08)
- EarthCARE/Doppler offers a direct insight into this picture

How vertical structure varies with Doppler velocity?

- Non-Strong Updraft (NonSU): Vd,max < 2.0m/s
- Strong Updraft (SU): Vd,max > 2.0m/s
- Extreme Updraft (EU) candidate: Folded Doppler profiles

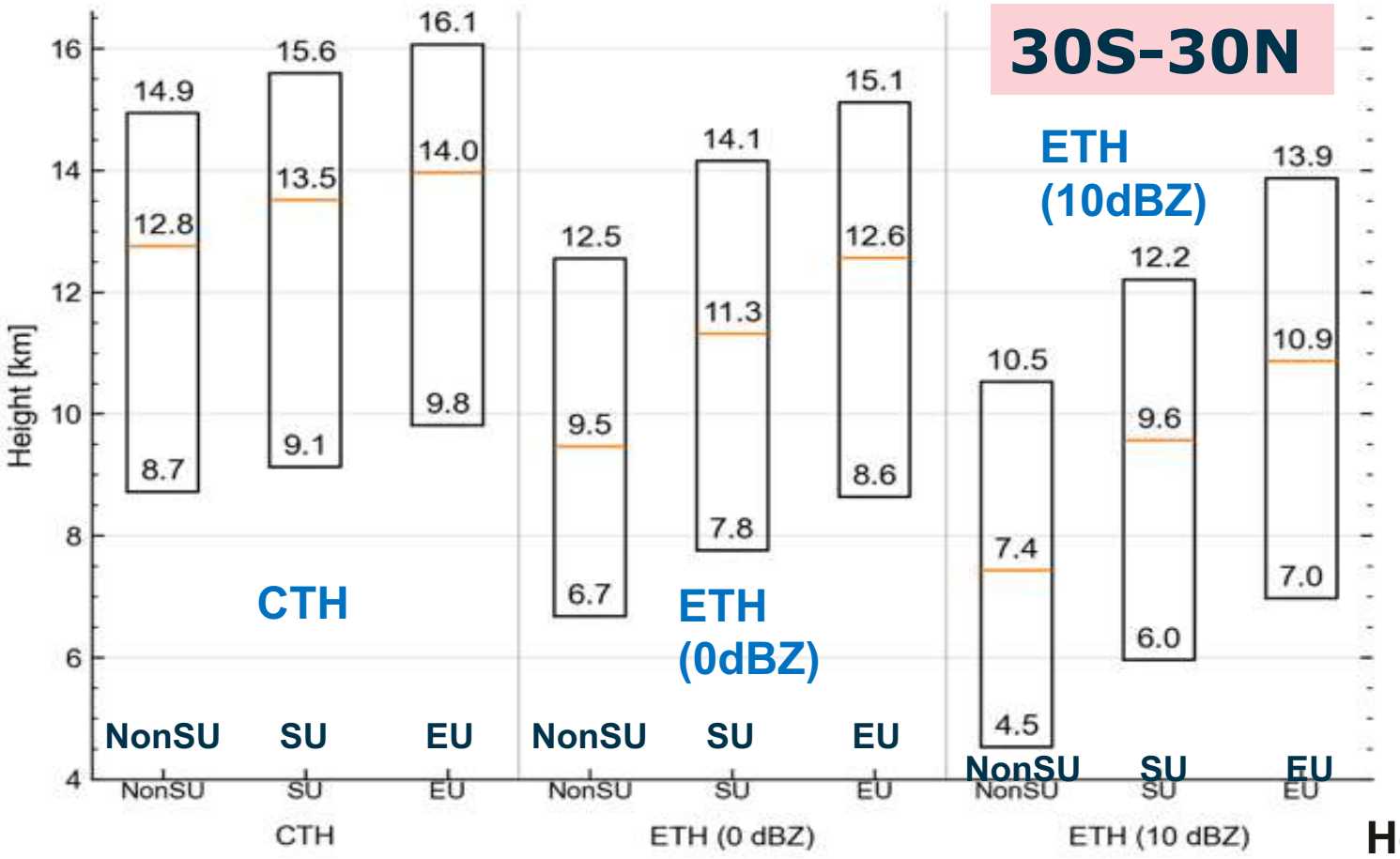
30S-30N

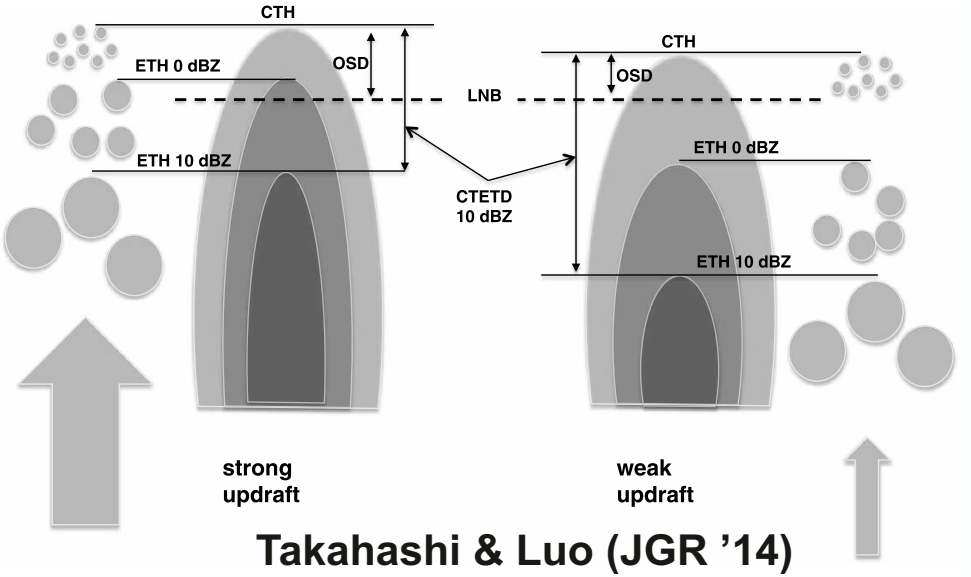


Hotta et al. (ACP revised)

- Vertical reflectivity profiles differ systematically among Doppler-based convection regimes
- More intensive-updraft clouds tend to have larger reflectivity in upper layer

How echo-top heights vary with Doppler velocity?





Takahashi & Luo (JGR '14)

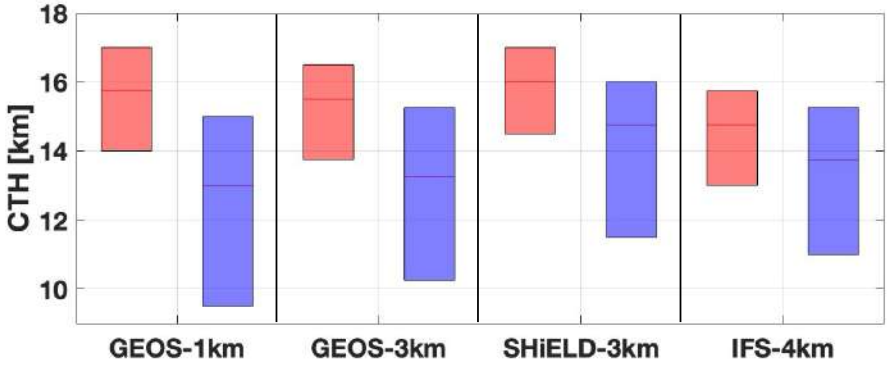
- NonSU: Vd,max < 2.0m/s
- SU: Vd,max > 2.0m/s
- EU: Folded Doppler profiles

Hotta et al. (ACP revised)

- Clouds with more intense upward velocity have systematically higher echo-top heights
- This characteristic is more pronounced for ETH with larger reflectivity threshold

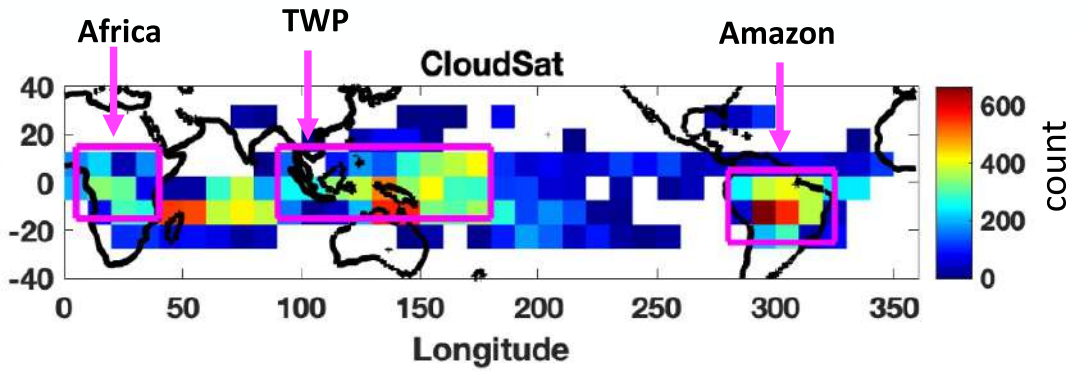
Echo-top heights in global km-scale models

Cloud-top height

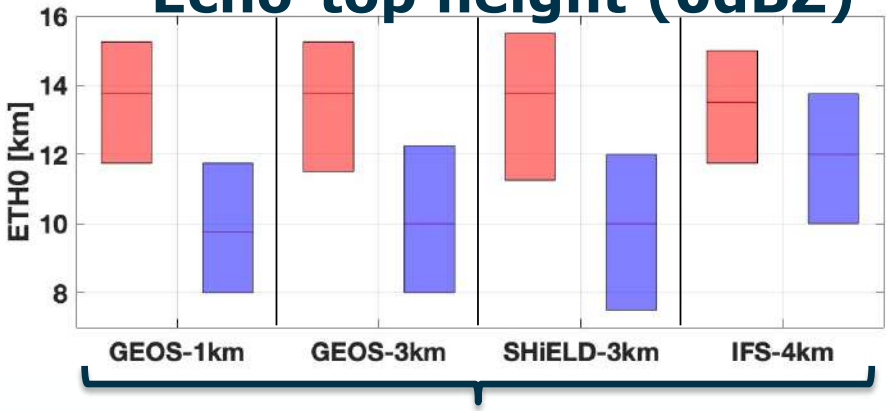


Updraft clouds

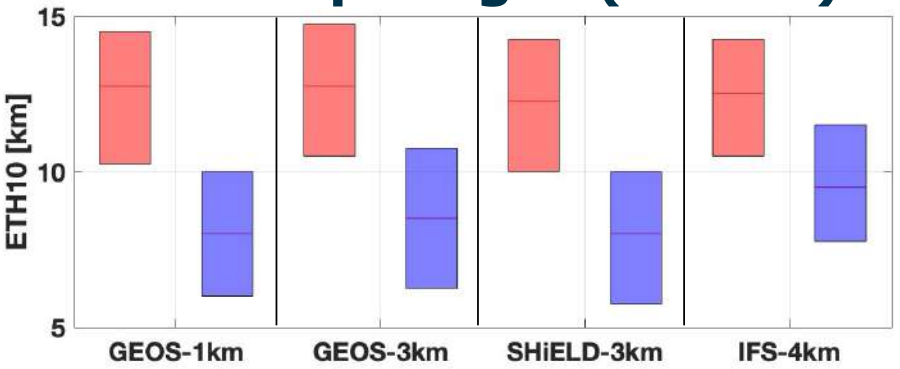
Non-updraft clouds



Echo-top height (0dBZ)



Echo-top height (10dBZ)



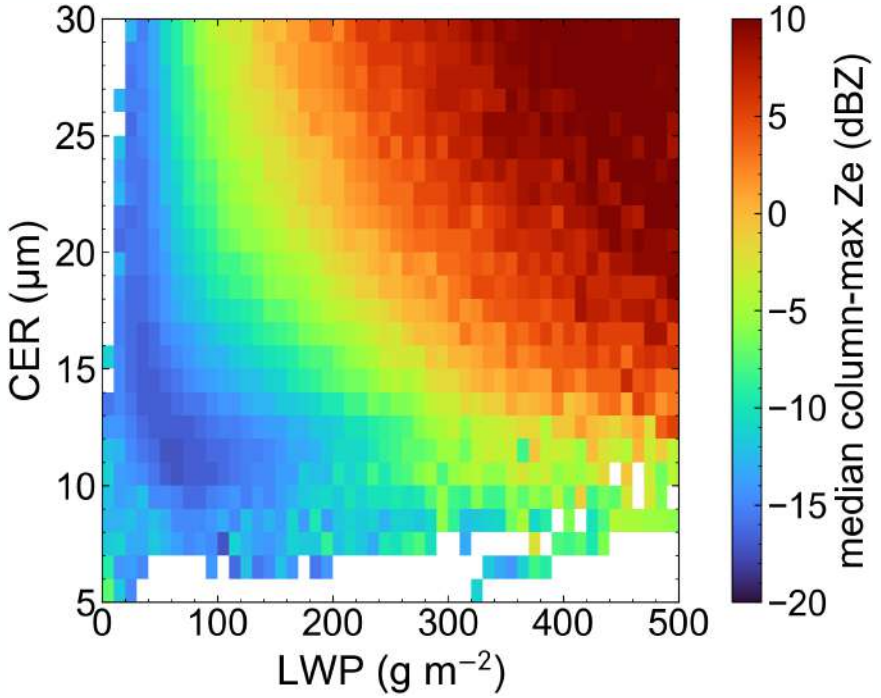
DYAMOND models

Takahashi et al. (JGR ’25)

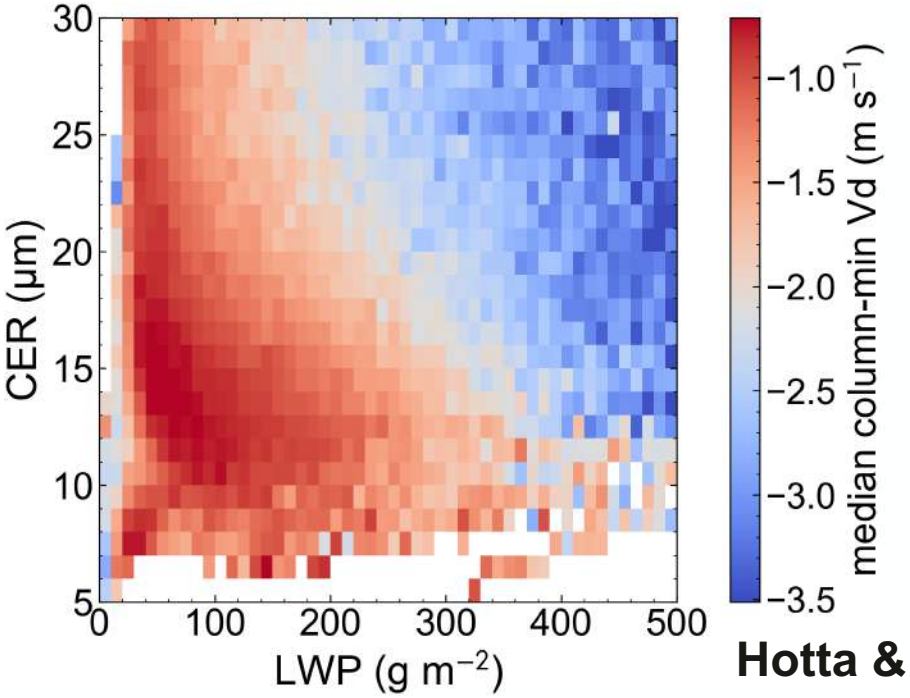
- Echo-top heights differ b/w updraft & non-updraft clouds in global km-scale models
- Qualitatively consistent with EarthCARE, providing a quantitative constraint on the model

How about warm rain process?

Column-max reflectivity



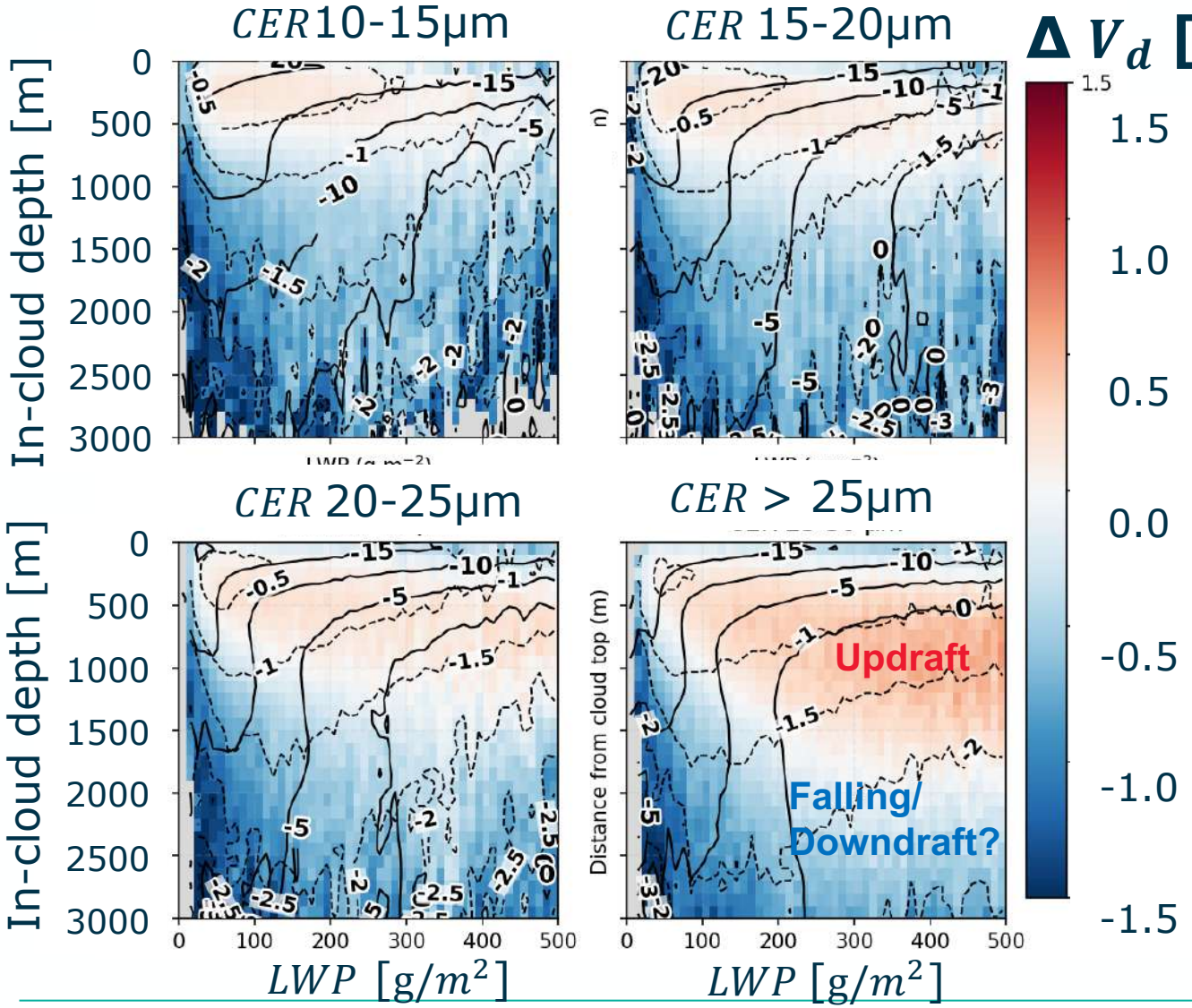
Column-min Doppler velocity



Hotta & Suzuki (In prep.)

- Synergistic analysis of CPR observables (Z_e, V_d) & MSI retrievals (CER, LWP)
- ”Dynamical context” added to the warm rain process fingerprint
  - Cloud-to-rain transition occurs systematically with CER & LWP
  - Precipitating clouds are associated with larger negative V_d

Insight into dynamics-microphysics link in warm rain



Δ V_d [m/s]

Solid curve: Z_e-contour
Dashed curve: V_d-contour
Color shade: ΔV_d [m/s]

$$\Delta V_d = V_d - V_{d,median}\,(Z_e)$$

- Small LWP (< 30g/m^2): ΔV_d is negative overall
- Moderate to Large LWP:
  - $\Delta V_d > 0$ in upper layer
  - $\Delta V_d < 0$ in lower layer
- The positive-ΔV_d layer is thicker for large CER: Active condensation growth with strong updraft?

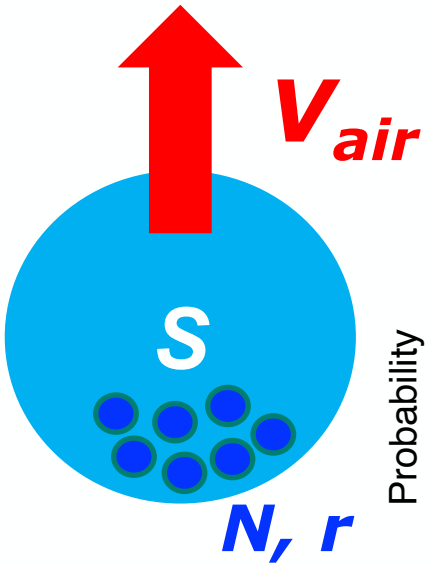
Hotta & Suzuki (In prep.)

Supersaturation: Crosspoint b/w dynamics & microphysics

$$\frac{dS}{dt} = \omega - \eta S$$

$$\omega = Q_1(p,T)V_{air}$$

$$\eta = Q_2(p,T)N\bar{r}$$

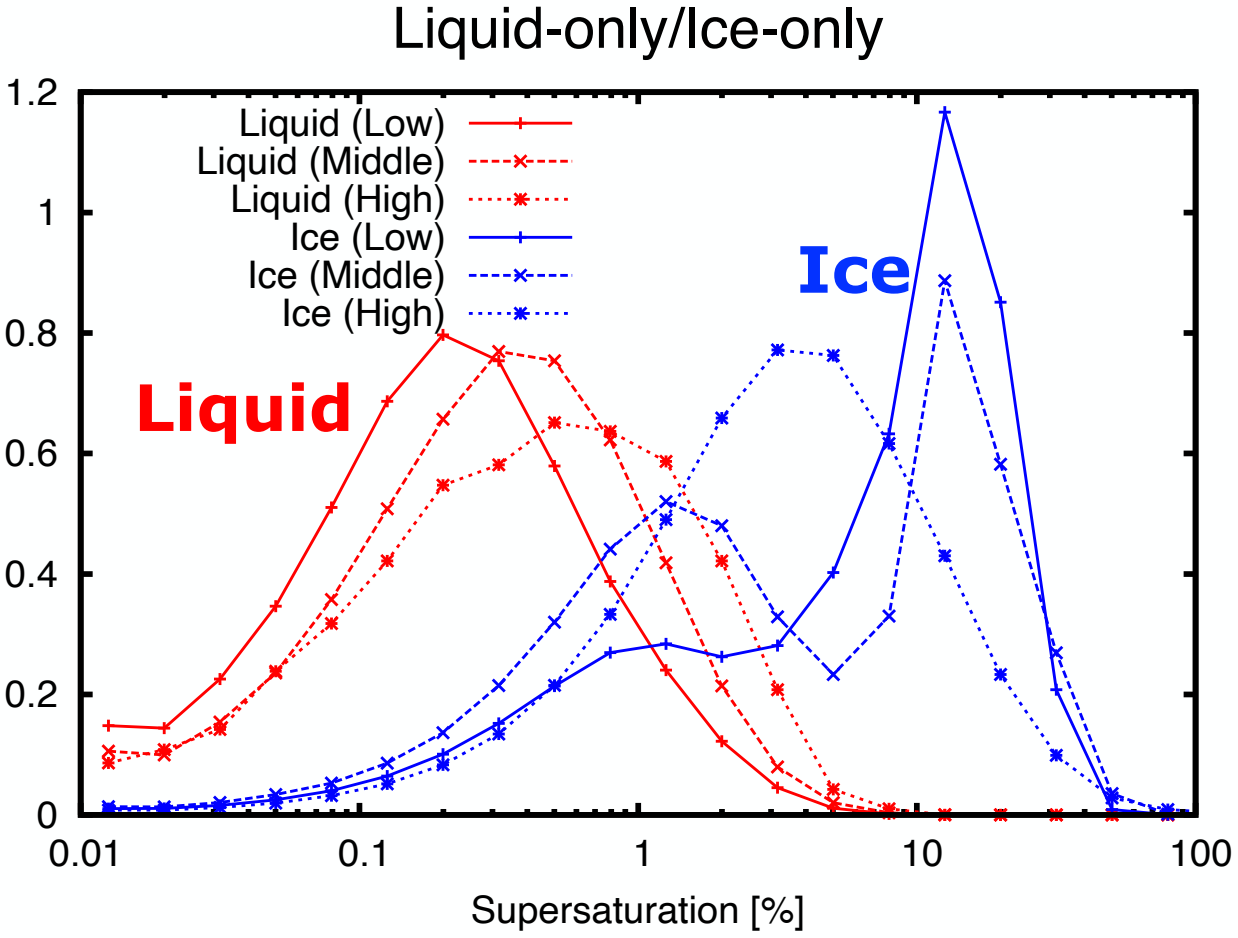


(Assuming spherical particles)

$$S \approx \frac{Q_1(p,T)}{Q_2(p,T)}\boxed{\frac{V_{air}}{N\bar{r}}}$$

Dynamics

Microphysics



Suzuki et al. (In prep.)

Measured by EarthCARE

Summary

- EarthCARE cloud measurements have started to be used to explore dynamics-microphysics coupling for deep convection and warm rain processes
- Deep convection:
  - Echo-tops are found to be higher with stronger updraft, implying that precipitation-sized particles are lofted higher by intense updraft
  - Traditional proxy for convective intensity is ‘validated’ with Doppler velocity
- Warm rain process:
  - Rain with larger negative Vd occurs with increasing CER & LWP
  - Detailed Vd variability hints at particle growth process coupled with dynamics
- The dynamics-microphysics interaction may also be manifested as supersaturation