Vertical Gradients of Ice Sedimentation Velocity from EarthCARE CPR as Indicators of Microphysical Processes

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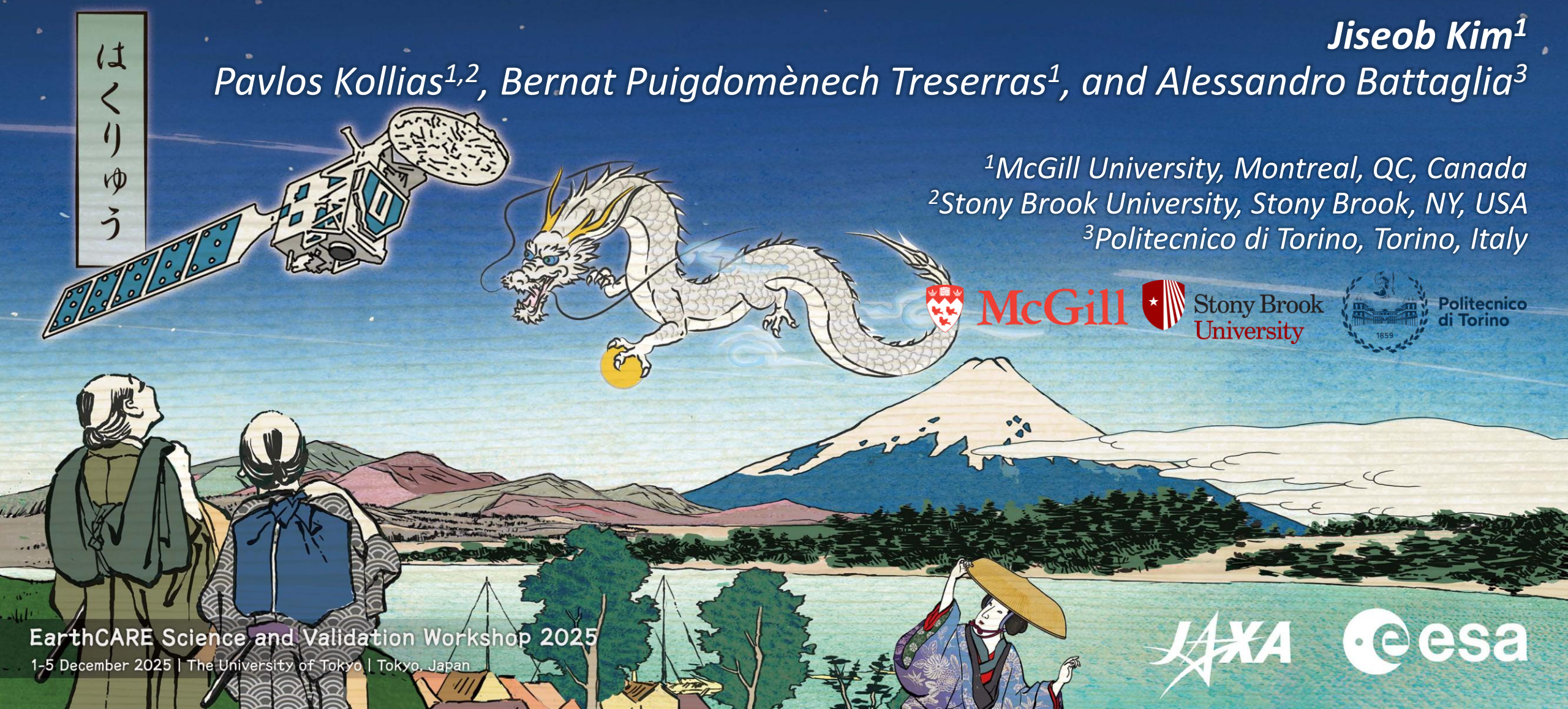

EarthCARE Science and Validation Workshop 2025
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Research background

EarthCARE CPR: From Doppler velocity to sedimentation velocity

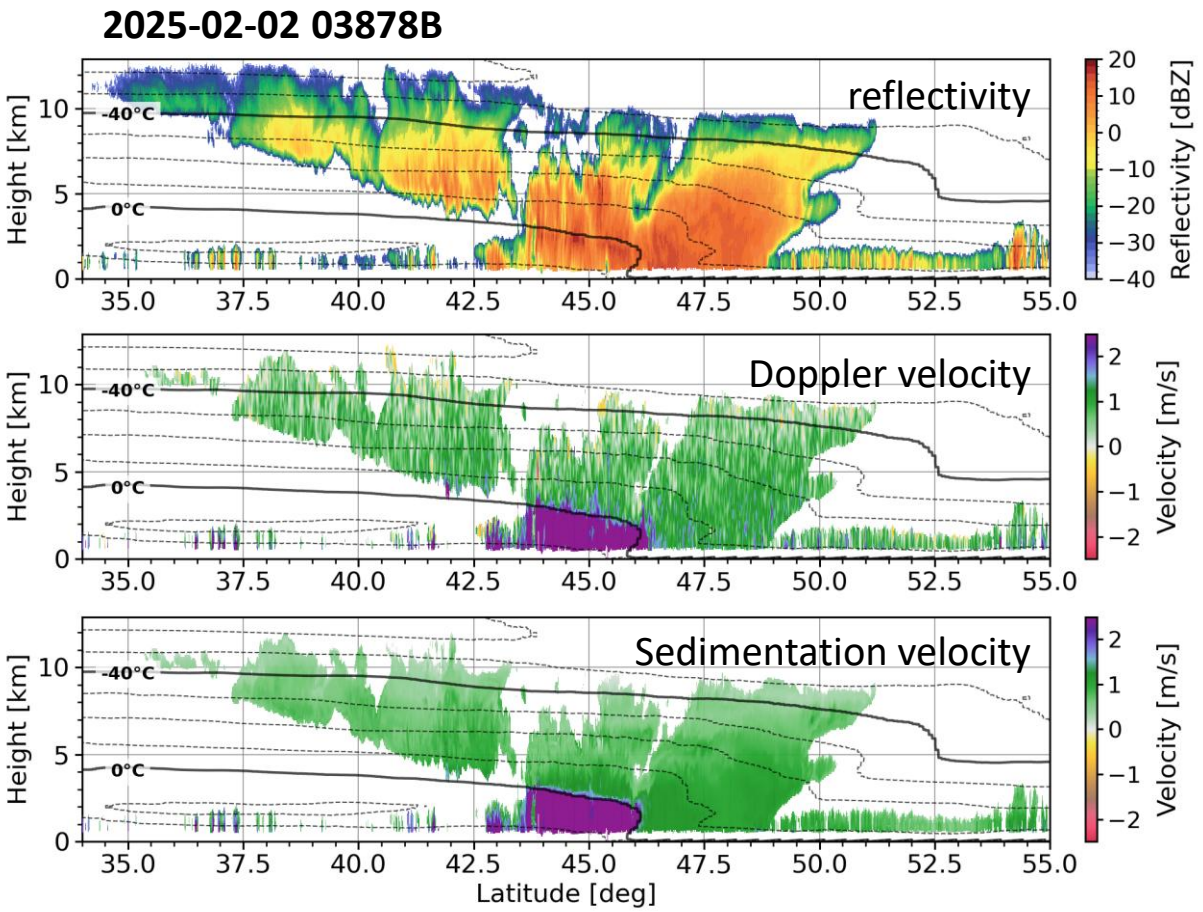
- Doppler velocity (V_D) is the sum of vertical air motion (w) and **hydrometeor sedimentation velocity (V_{sed})**:

$$\mathbf{V_D = V_{sed} + w}$$

(downward positive)

- **The ESA C-CD algorithm** (*recently updated by Bernat*) removes w by averaging Doppler velocities with similar (Z, T), weighting more heavily those that are more similar, have smaller standard error, and are closer in space.

- This produces **a coherent V_{sed} field** that preserves microphysical features. **We use this field for the gradient analysis in this study.**



Research background

The vertical gradients of ice sedimentation velocity ($\partial_z V_{sed}$)

: Here we focus on ice and mixed-phase clouds

Potential sources of vertical gradients ($\partial_z V$):

(1) Microphysical changes as particles fall

→ SIGNAL WE WANT

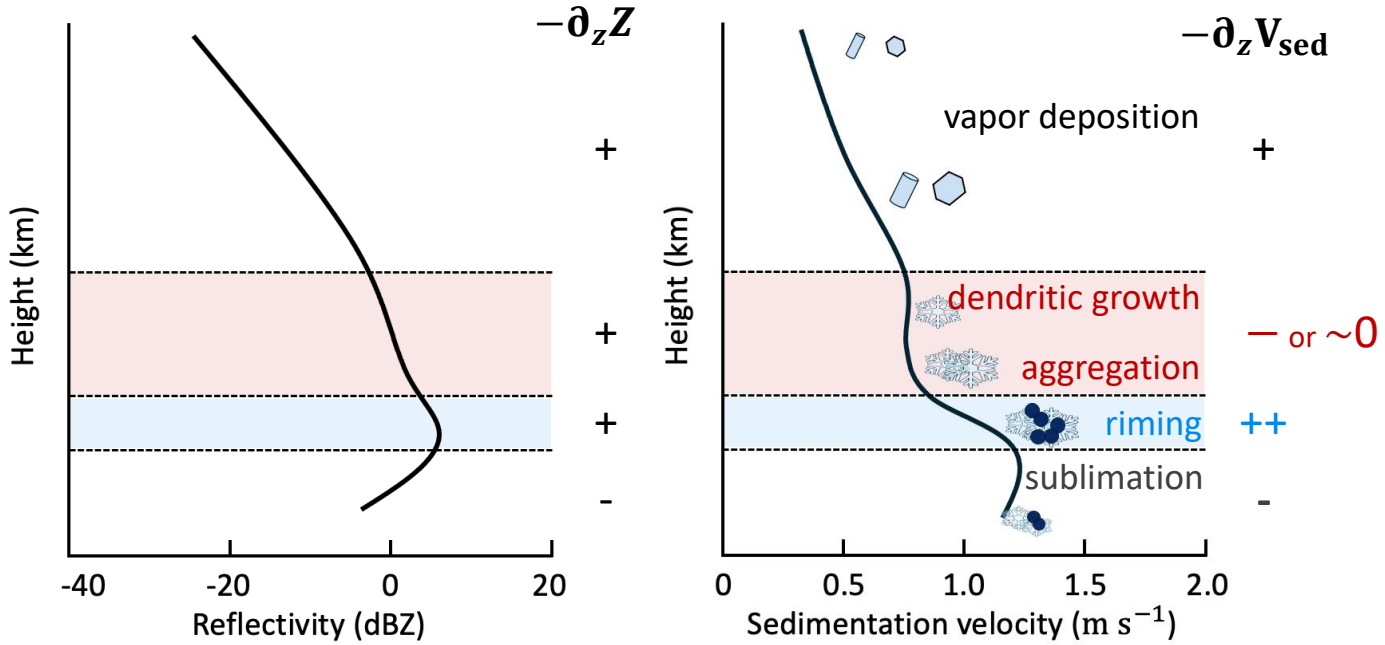
(2) Vertical air motion

→ largely removed in V_{sed}

(except in strongly convective clouds)

(3) Horizontal advection of falling hydrometeors

→ minimized by instantaneous satellite sampling



" For EarthCARE CPR, using V_{sed} greatly reduce (2) and instantaneous sampling are almost free from (3), **so $\partial_z V_{sed}$ mainly reflects microphysical changes**, except in strongly convective clouds. "

Vertical velocity gradient $\partial_z V_{sed}$

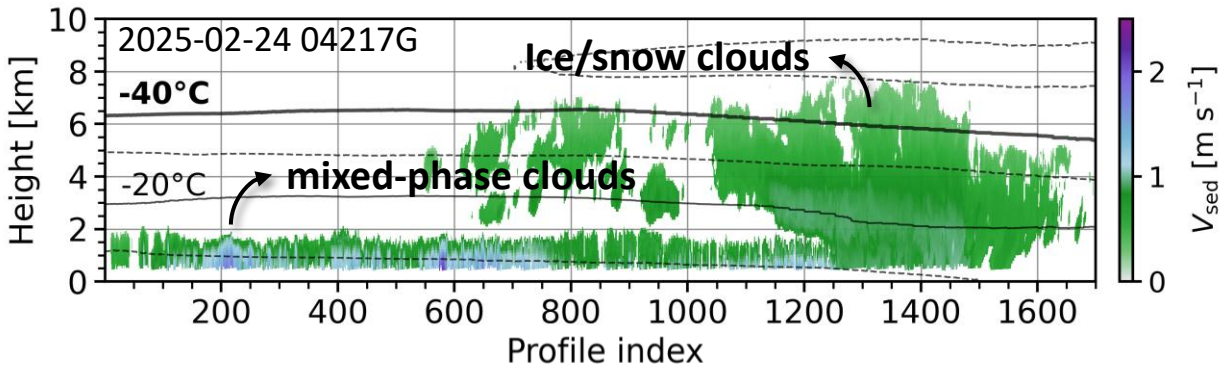
How to derive local vertical gradients of V_{sed}

- **Input field:** Air-density corrected sedimentation velocity V_{sed}
- **Vertical gradient**: At each center gate, fit a linear regression line to $V_{sed}(z)$

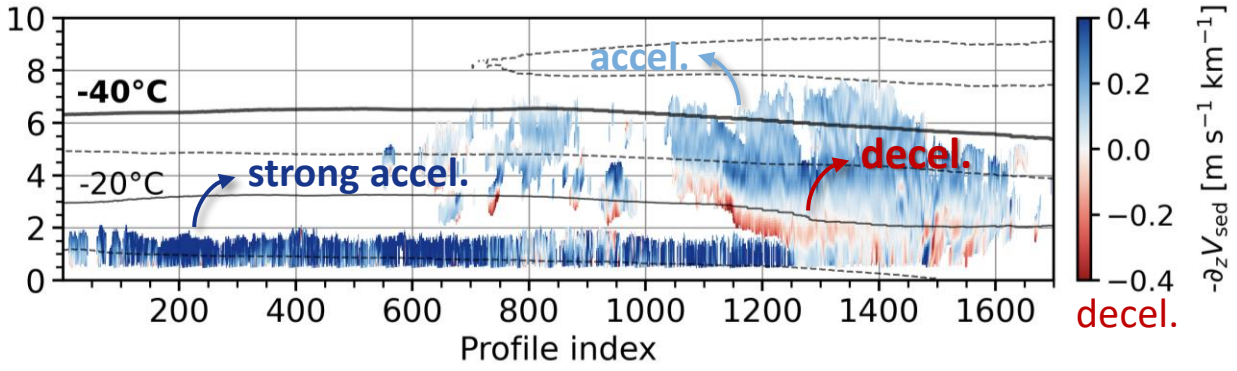
$$V_{sed}(z) \approx a\,z + b; \quad \partial_z V_{sed}(z) = a$$

- **Window:** Use **an 11-gate (~1 km) vertical window** for the fit to balance noise and over-smoothing.
  Near cloud edges, gradually shorten the window from 11 down to 6 gates.
  *we exclude the 5 gates above the 0°C isotherm or melting top to avoid melting particles

(air-density corrected) Sedimentation velocity



Vertical velocity gradient

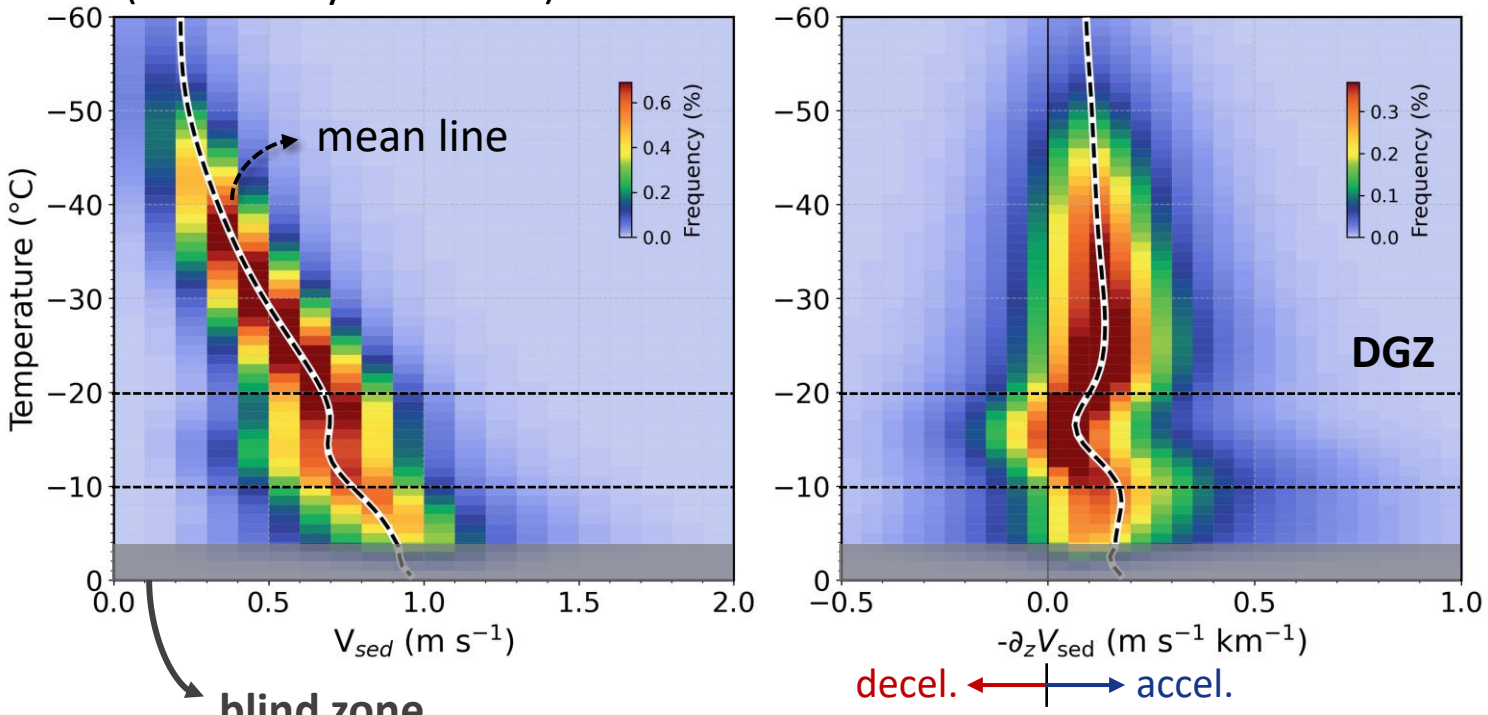


Dendritic growth zone

Dec 2024 – Oct 2025 (~11 months)

Sedimentation velocity
(air-density corrected)

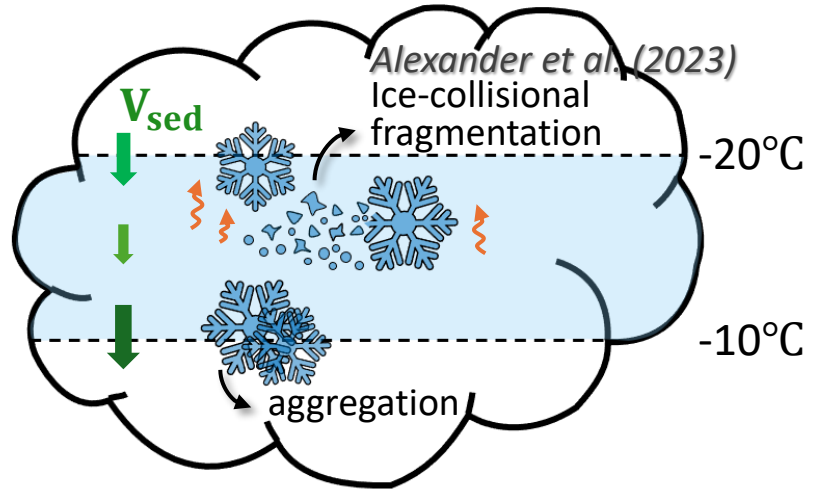
Vertical velocity gradient



blind zone

: exclude 5 gates above the melting tops / 0℃ isotherm

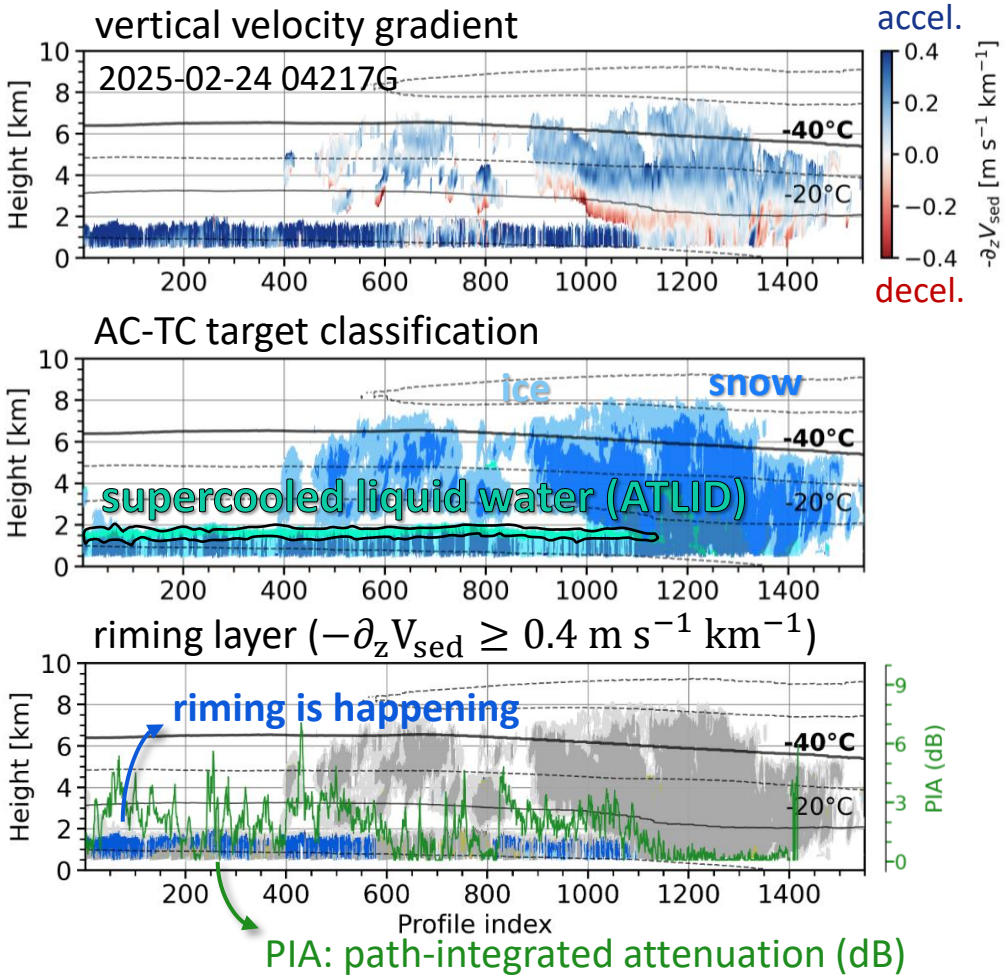
Dendritic growth zone (DGZ)



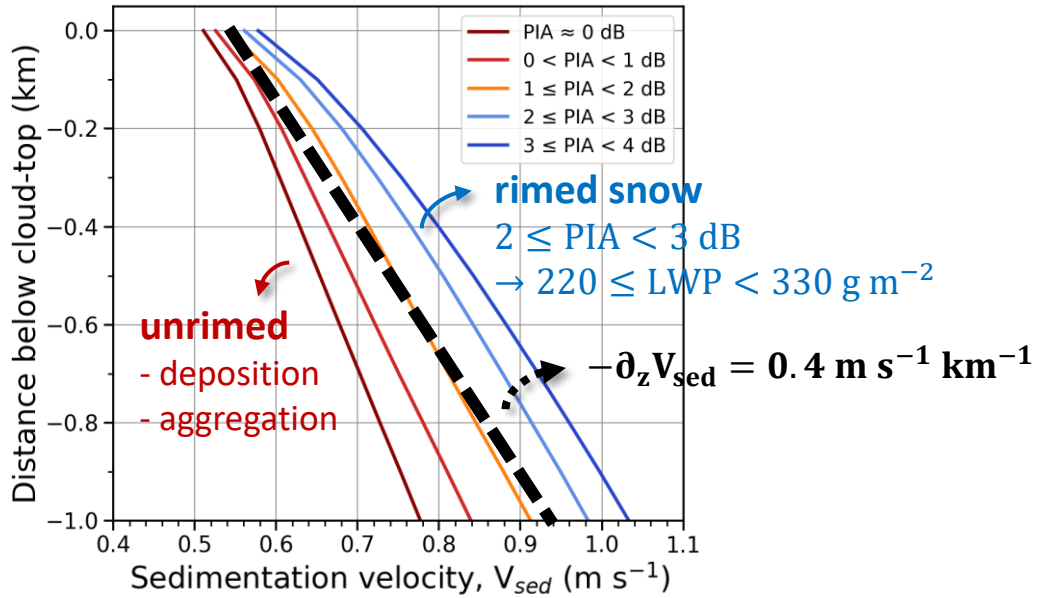
updraft from latent-heat release
(dendritic depositional growth)
von Terzi et al. (2022)

Detecting riming with $\partial_z V_{sed}$

Riming layer: $-\partial_z V_{sed} \geq 0.4\ \mathrm{m\ s^{-1}\ km^{-1}}$ (strong acceleration of fall speed)



Low-level mixed phase clouds
- Single layer (CTH ≤ 2.5 km)
- All subzero
- Dec 2024 – Oct 2025



For PIA ≥ 2 dB, our gradient criterion ($-\partial_z V_{sed} \geq 0.4\ \mathrm{m\ s^{-1}\ km^{-1}}$) captures riming in ~81% of the profiles

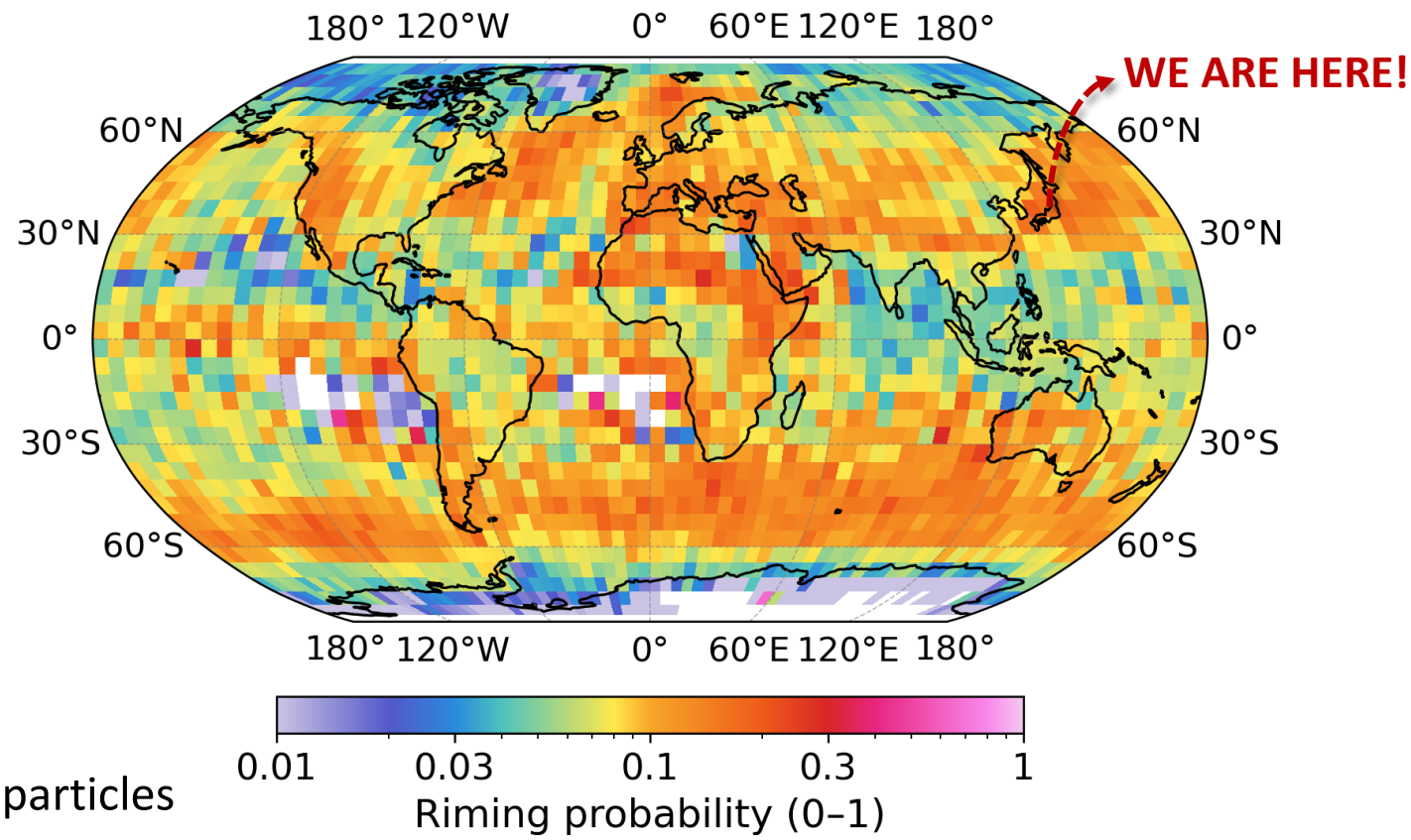
Global riming probability

Riming probability (0 - 1)

$$P_{rime} = \frac{\sum_i \text{riming gate}_i}{\sum_i \text{valid gate}_i}$$

(only gates with $-20°C \leq T \leq -5°C$)

Dec 2024 – Oct 2025 (~11 months)



Shows where active riming layers are detected, with ice and supercooled liquid coexisting and V_{sed} increasing rapidly downward.

This is not a map of supercooled liquid or rimed particles

Summary and future work

Summary

- EarthCARE CPR provides, for the first time, global measurements of the sedimentation velocity ($\mathrm{V_{sed}}$) of hydrometeors
- The vertical gradient of $\mathrm{V_{sed}}$ ($\partial_z \mathrm{V_{sed}}$) is a useful indicator of hydrometeor growth and decay processes (e.g., sublimation, vapor deposition, aggregation, dendritic growth, and riming).
- Strong gradients ($-\partial_z \mathrm{V_{sed}} \geq 0.4\ \mathrm{m\ s^{-1}\ km^{-1}}$) reliably capture active riming layer, enabling the first global map of riming occurrence

Future work

- We plan to constraint the mass-size relation of rimed particles to improve the microphysical retrieval algorithm

Thank you

for listening to my presentation

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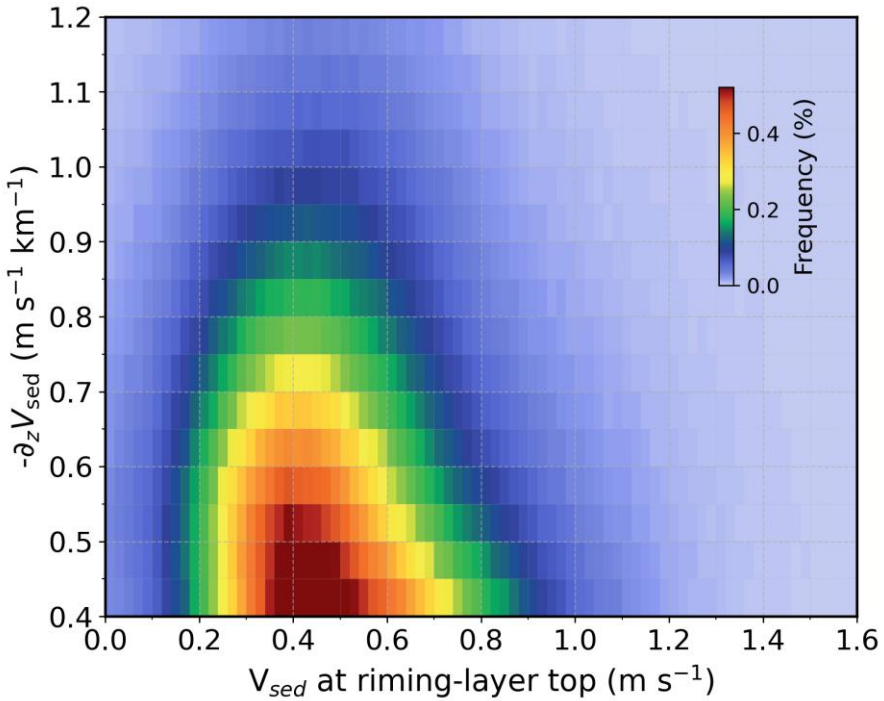
JAXA esa

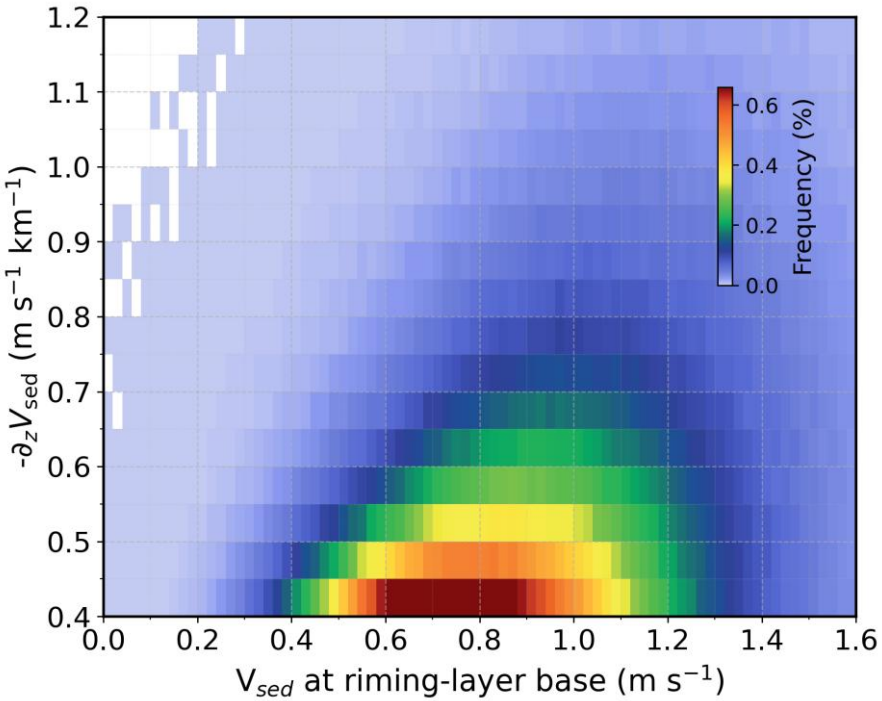
Supplementary slides

Dec 2024 – Oct 2025 (~11 months)

riming layer top



riming layer base



Supplementary slides

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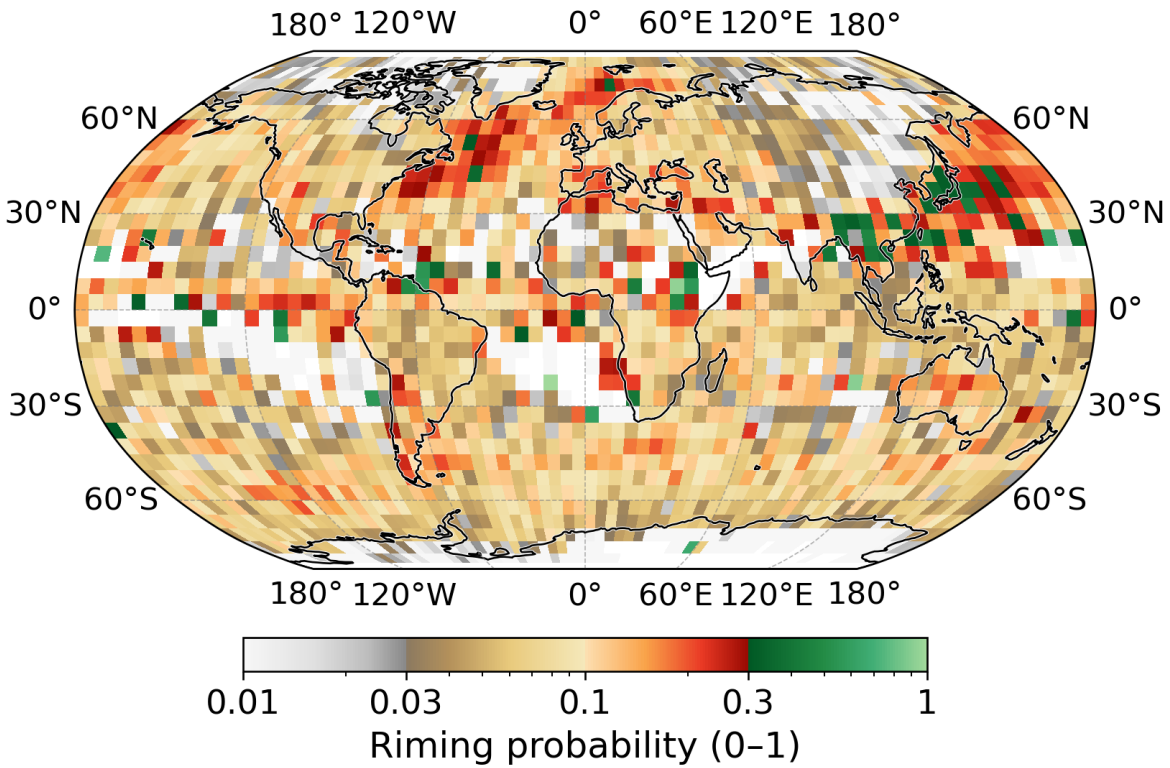

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