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Identifying riming through vertical gradients of EarthCARE CPR sedimentation velocity in stratiform clouds

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EarthCARE CPR sedimentation velocity

EarthCARE CPR: From Doppler velocity to sedimentation velocity

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

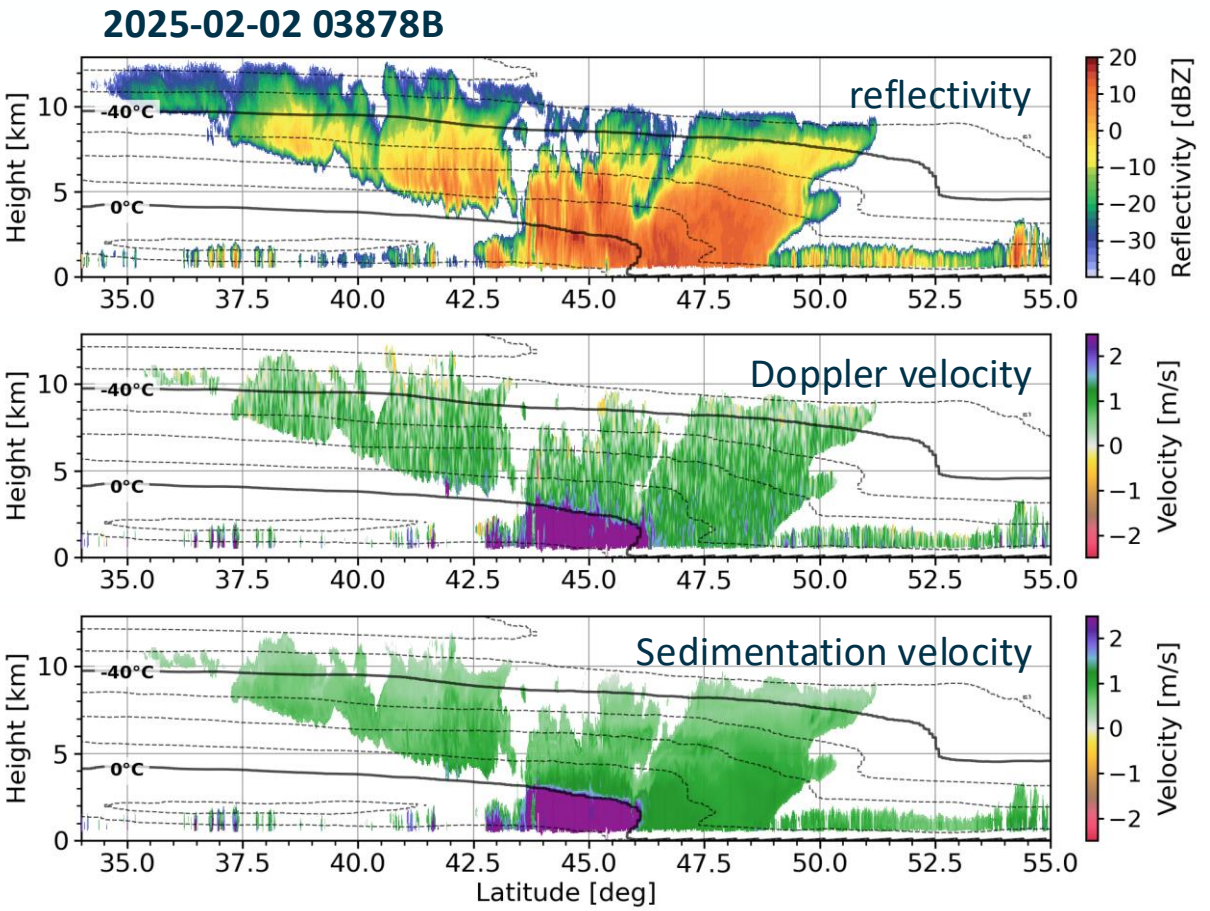
$$\boldsymbol{V_D = V_{sed} + V_{air}}$$

(downward positive)

- **The ESA C-CD algorithm** removes V_{air} by averaging Doppler velocities with similar (Z, T), weighting more heavily those that are more similar and are closer in space.

- This produces **a coherent V_{sed} field** that preserves microphysical features. **We use this field for riming detection.**

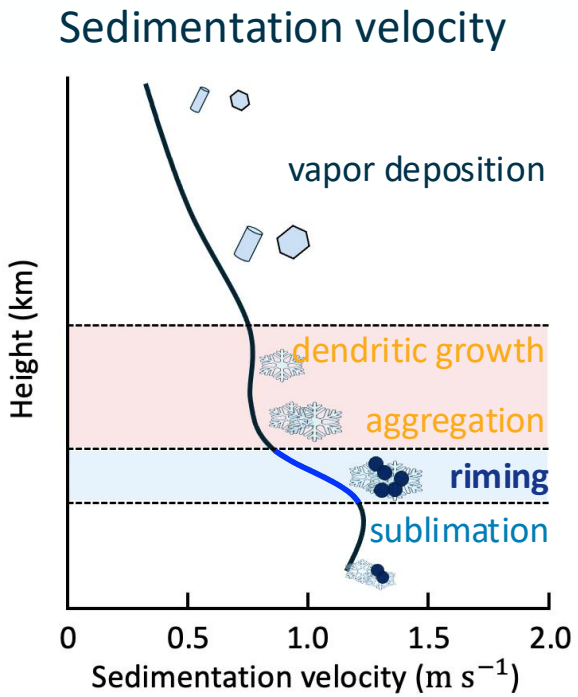
(Puigdomènech Treserras et al., 2026, in preparation)



Vertical gradient of sedimentation velocity: G_V

Vertical gradient of ice sedimentation velocity: $G_V \equiv -dV_{sed}/dz$

(Here we focus on ice and mixed-phase clouds)



Vertical gradient of sedimentation velocity (G_V)

0.1–0.2 m s^{-1} km^{-1}

~0 m s^{-1} km^{-1}

++ (accel.)

- (decel.)

Photos: Jiseob Kim
17 Jan 2026
Little Italy, Montreal, QC

Key idea: Rapid ice mass growth during **riming** produces a large positive G_V, providing a basis for riming detection

Evaluating riming detection against estimated SLW layers

1. **Define a conservative threshold from SLW-free ice/snow clouds**

   $G_V \geq 0.4\ \mathrm{m\ s^{-1}\ km^{-1}}$ (99% of SLW-free ice/snow clouds have $G_V < 0.4\ \mathrm{m\ s^{-1}\ km^{-1}}$)

2. **Test what this threshold captures in mixed-phase clouds**

   Use independently estimated SLW layers
   (PIA → SLWP → SLW layer depth)

   (1) Estimate SLWP from PIA

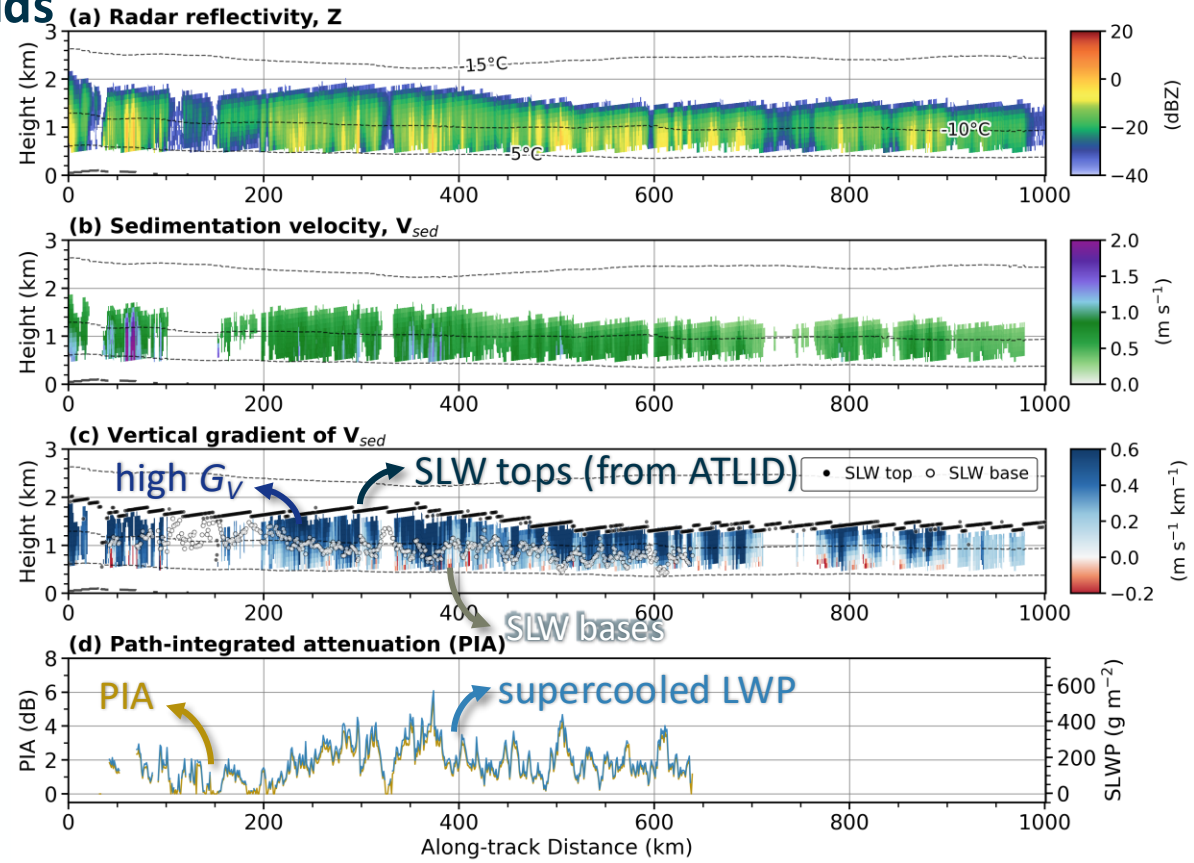
   $$\mathrm{PIA} \approx \alpha(\mathrm{T}) \cdot \mathrm{SLWP}$$

   $\alpha(\mathrm{T})$: liquid absorption coefficient

   (2) Estimate effective SLW layer depth (h)

   $$h \approx \sqrt{\frac{2 \cdot \mathrm{SLWP}}{f_{ad}\Gamma_{ad}}}$$

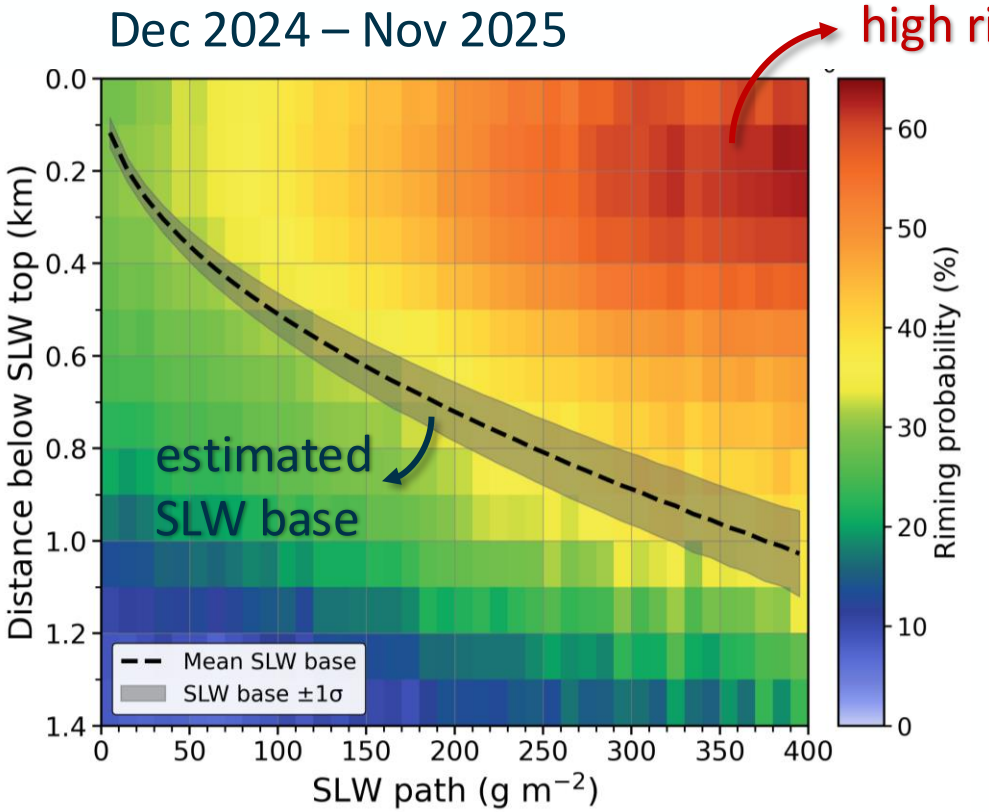
   f_{ad}: 0.85 (adiabaticity)
   Γ_{ad}: adiabatic rate of LWC



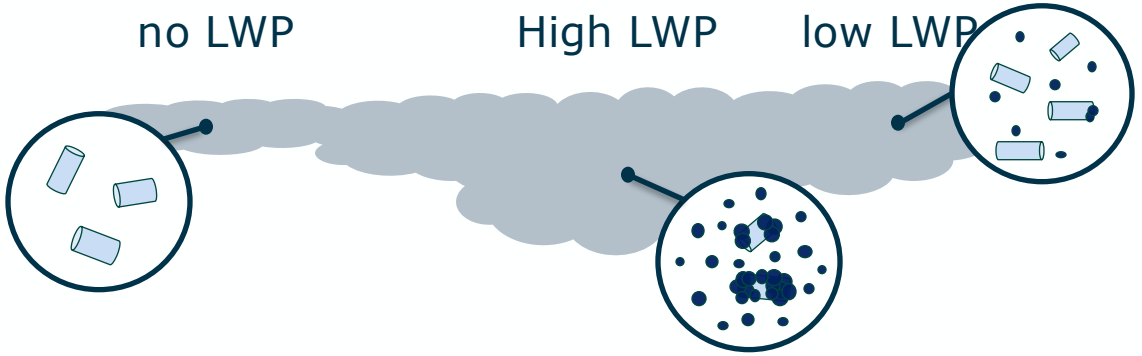
Evaluating riming detection against estimated SLW layers

Evaluation cloud regime:

Shallow mixed-phase clouds (single-layer, CTH ≤ 2.5 km) where SLW layer and SLWP can be estimated

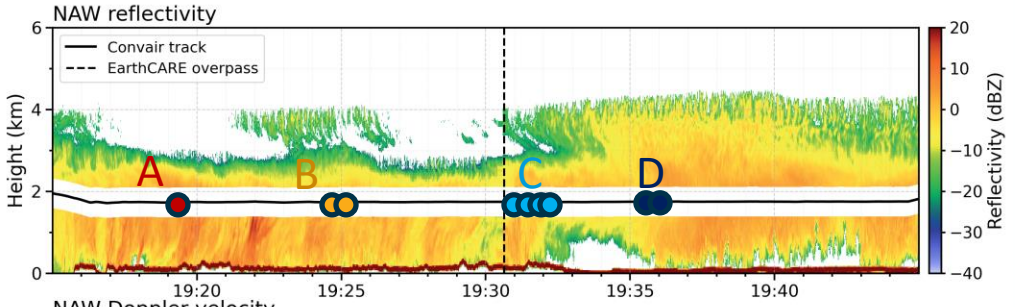


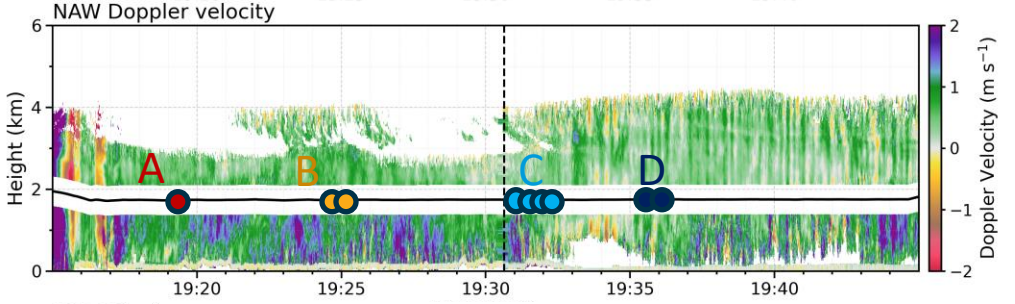
(Kim et al., 2026, in preparation)

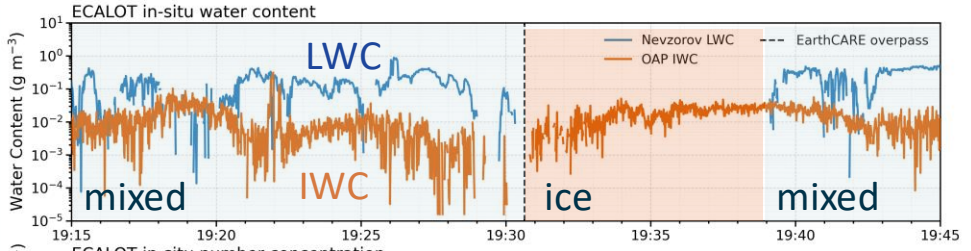


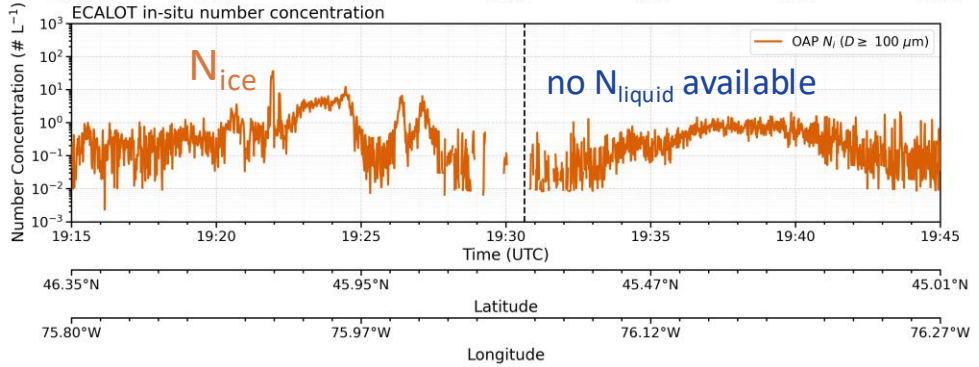
- G_V-based riming detections are concentrated within the estimated SLW layer
- Detected riming occurrence increases with SLWP, exceeding ~50% for SLWP ≥ 200 g m^{-2}

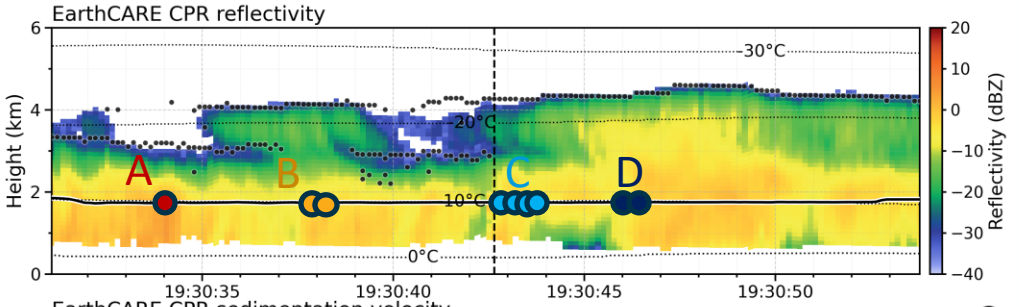
Comparing CPR riming detections with “ECALOT” aircraft observations (2025-03-25, Northwest of Ottawa, QC)

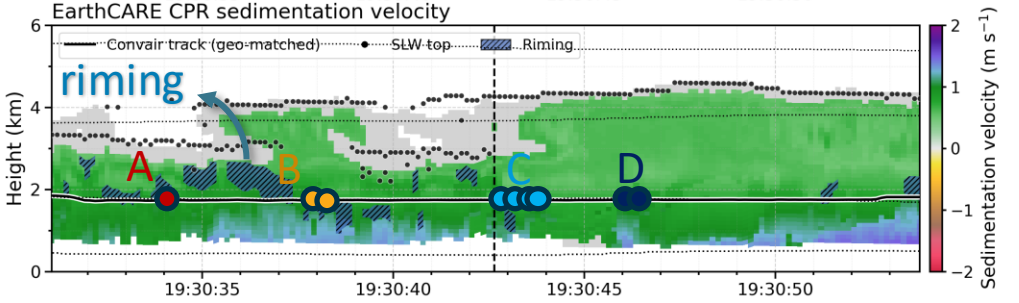


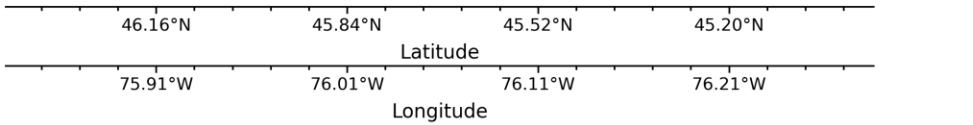


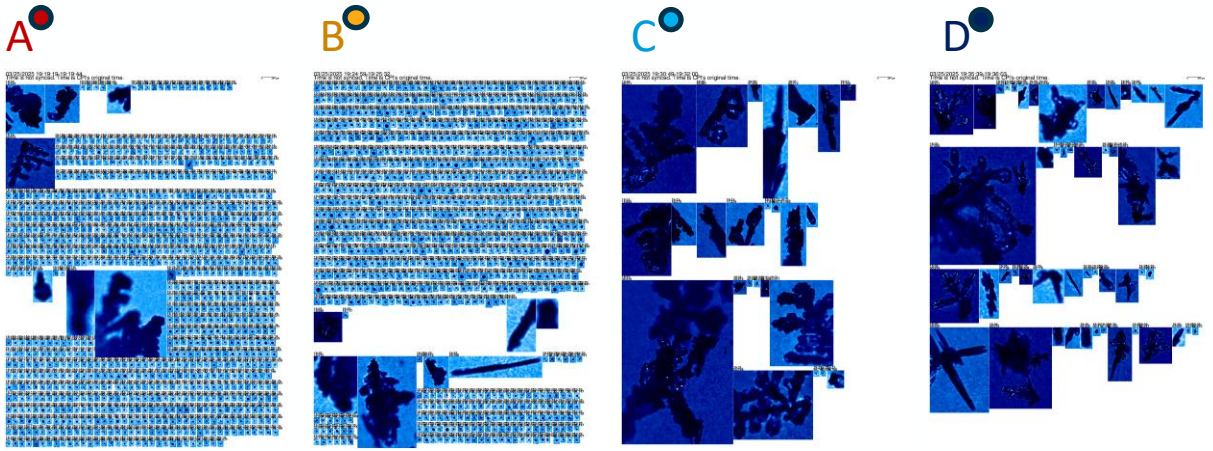




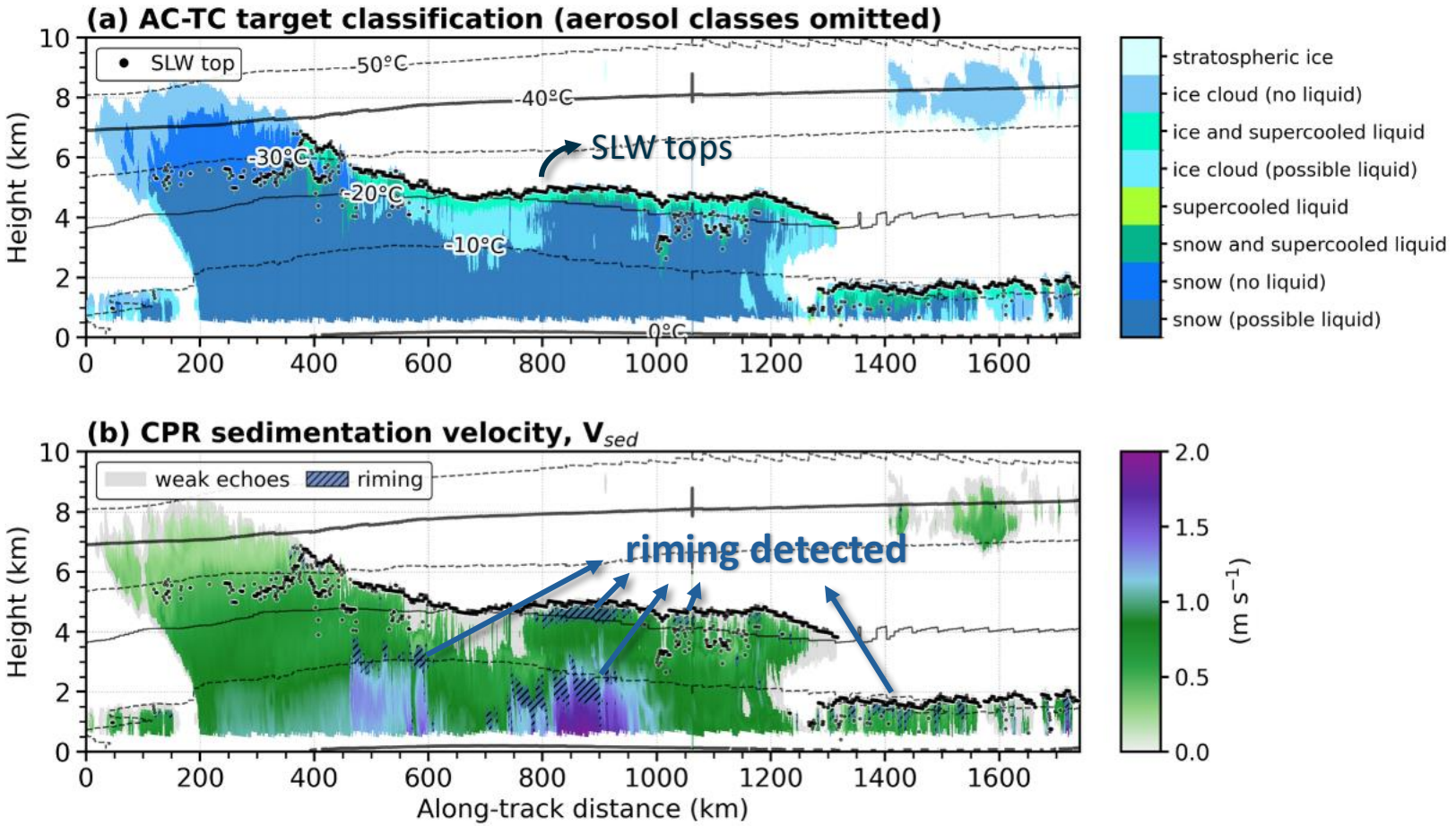






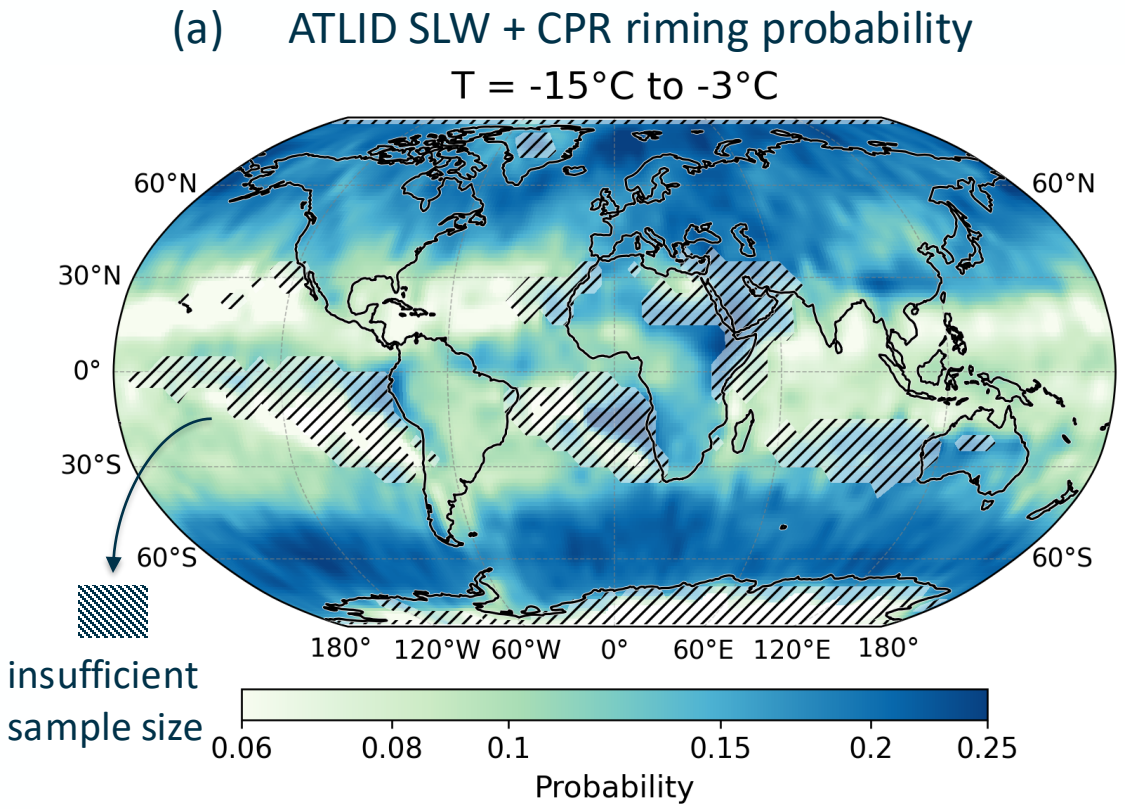


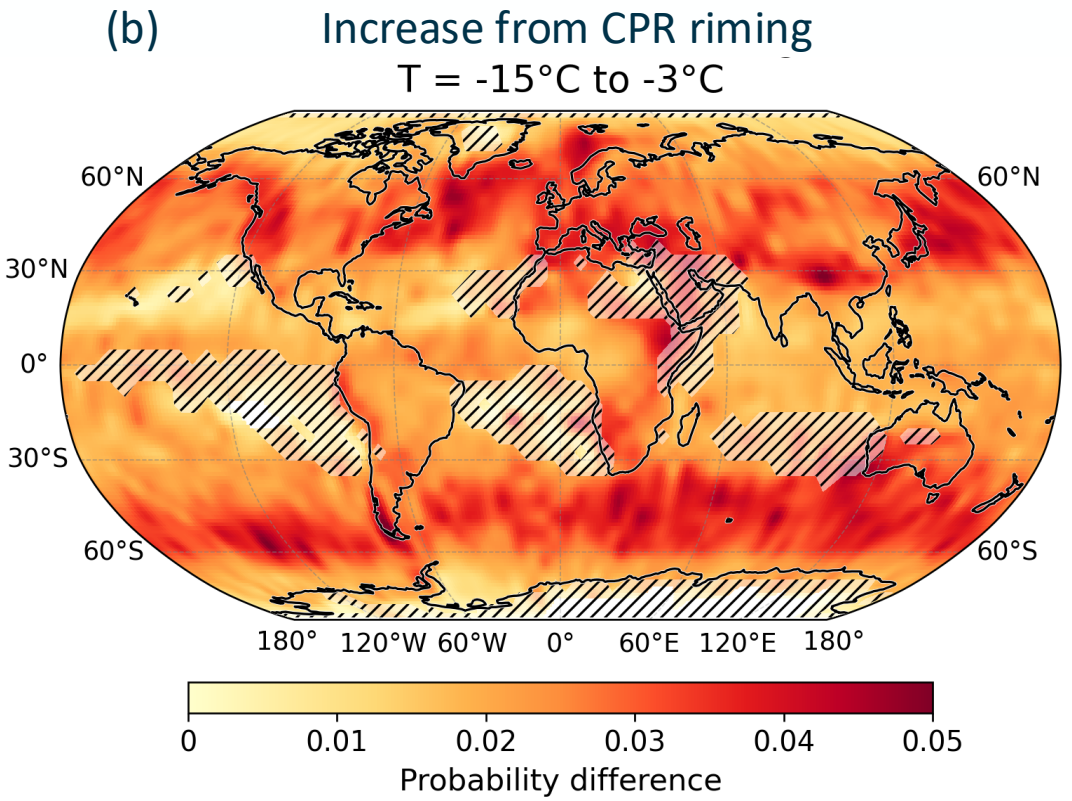
Riming in a deeper mixed-phase system



CPR G_V-based riming detection captures **embedded riming inside deep clouds** where ATLID cannot penetrate

Riming as an indicator of embedded SLW layers





ATLID and CPR can provide **complementary views** of supercooled liquid environments

Summary and future work

Summary

- EarthCARE CPR provides, for the first time, near-global measurements of the sedimentation velocity (V_{sed}) of hydrometeors
- Strong positive vertical gradient G_V ($\geq 0.4\ \mathrm{m\ s^{-1}\ km^{-1}}$) reliably capture active riming layer and provides complementary information on embedded SLW layers where ATLID cannot penetrate

Future work

- Investigate which environments favor or suppress riming and other ice growth processes
- Evaluate the representation of riming processes in numerical weather and climate models
- Constrain the mass-size relation of rimed particles to improve the EarthCARE microphysical retrievals

Thank you for your attention

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