Analysis of Wave-like Cloud Structures Based on EarthCARE/CPR Observation（2）

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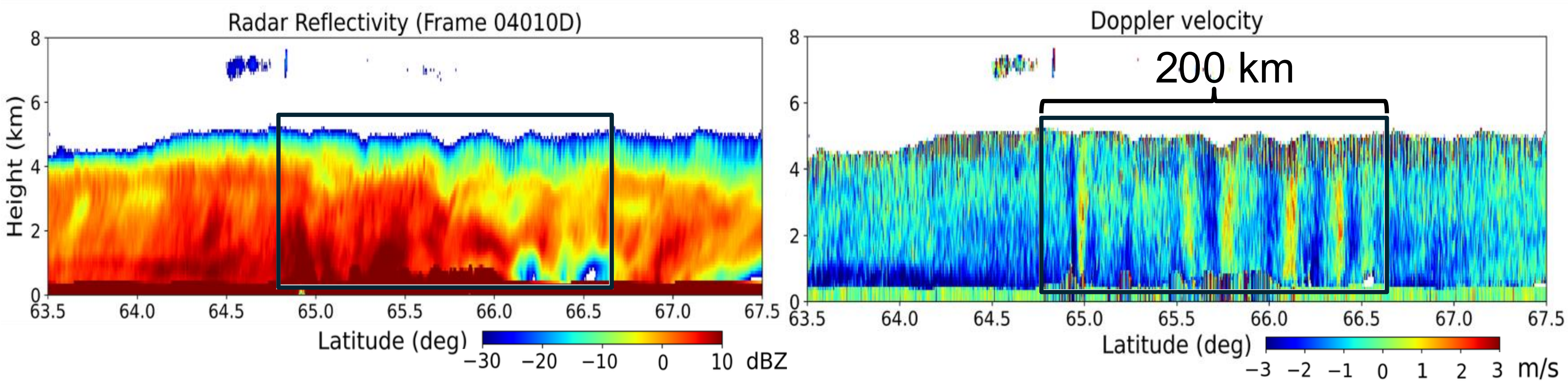
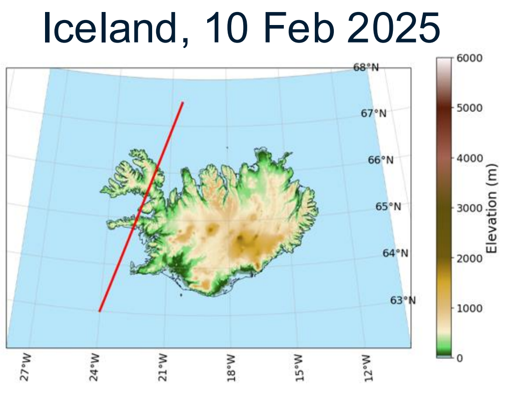
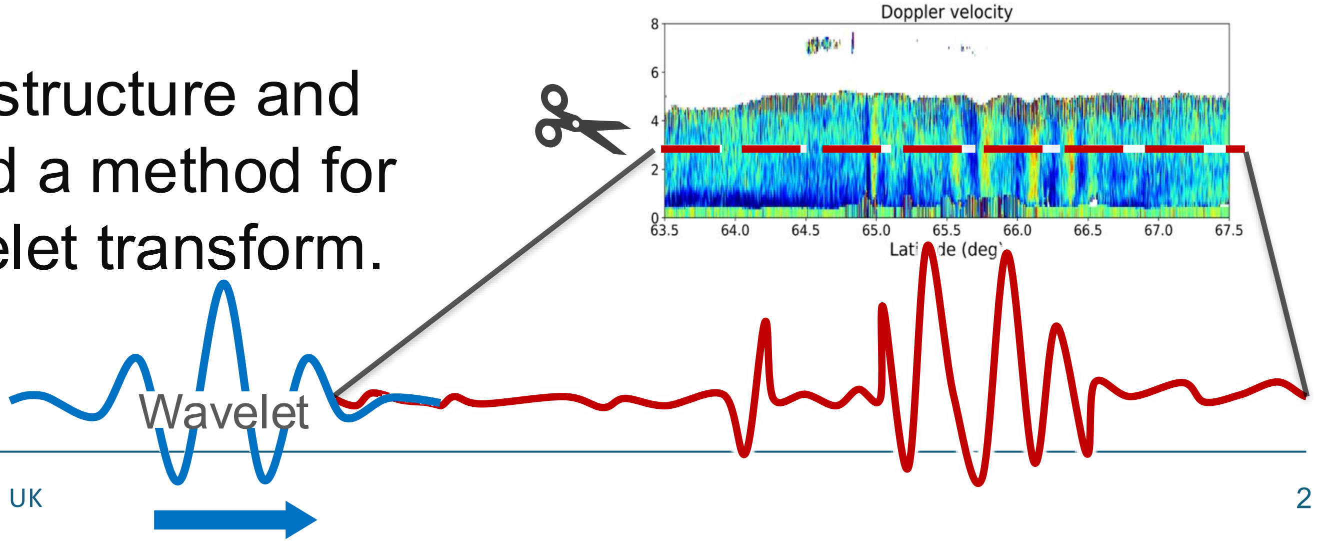
Review of last WS (Dec. 2025) (1)

- Wave structures in clouds are often observed by CPR.
- This type of wave structures has not been observed by previous satellites.





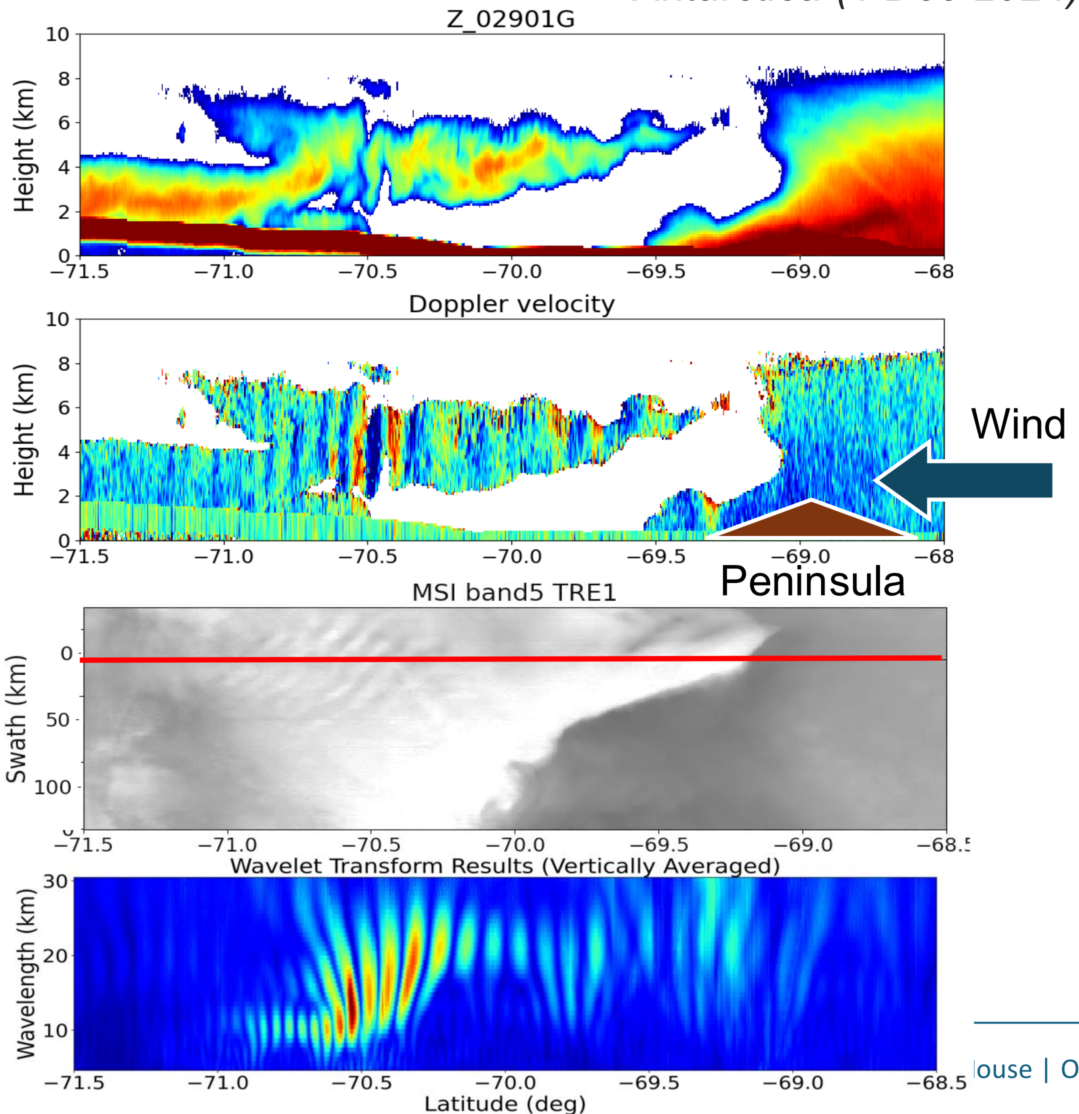
➢ To clarify the characteristics of wave structure and their global distribution, we developed a method for detecting wave structures using wavelet transform.



Review of last WS (Dec. 2025) (2)

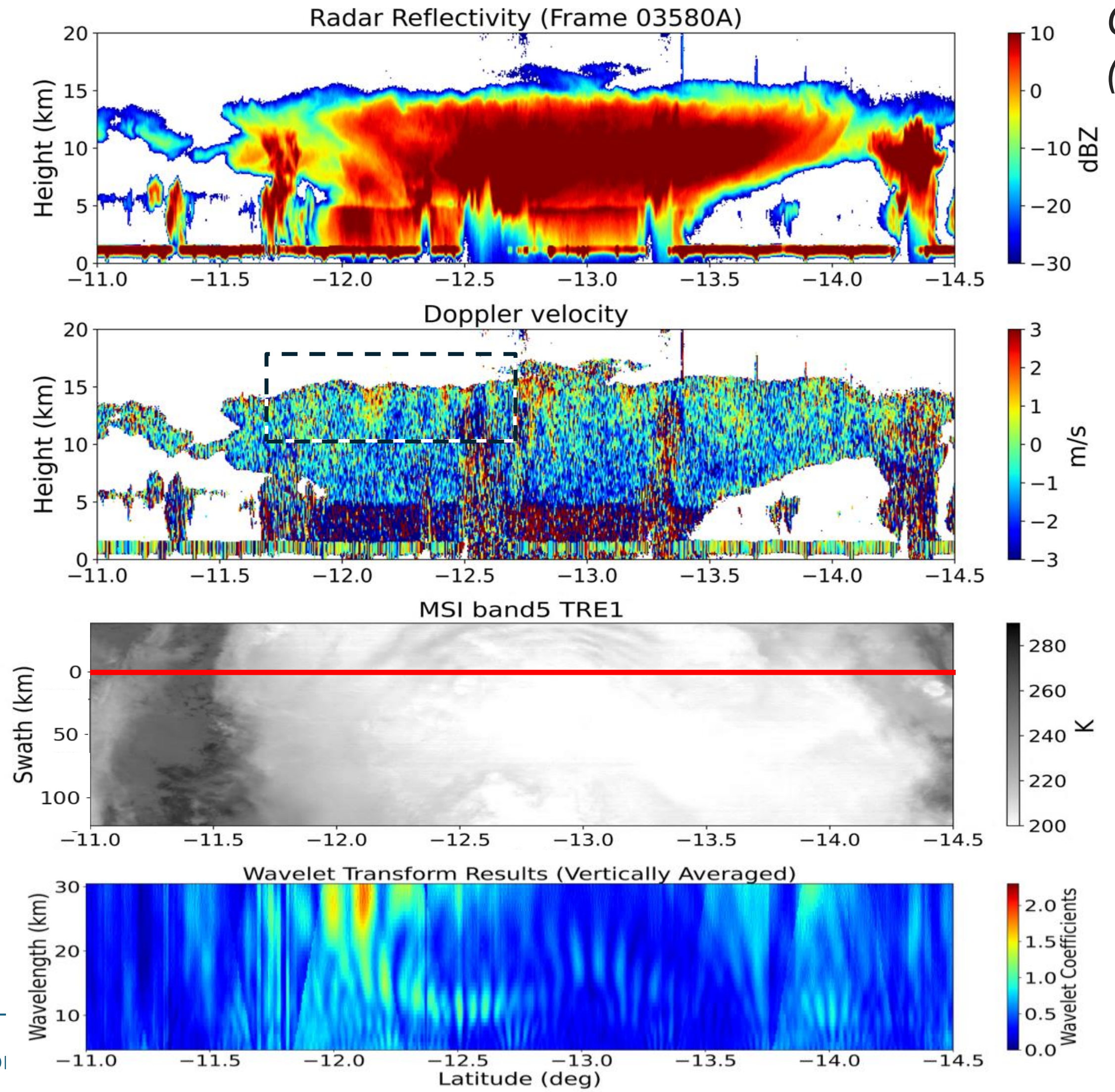
Mountain wave

Antarctica (1 Dec 2024)



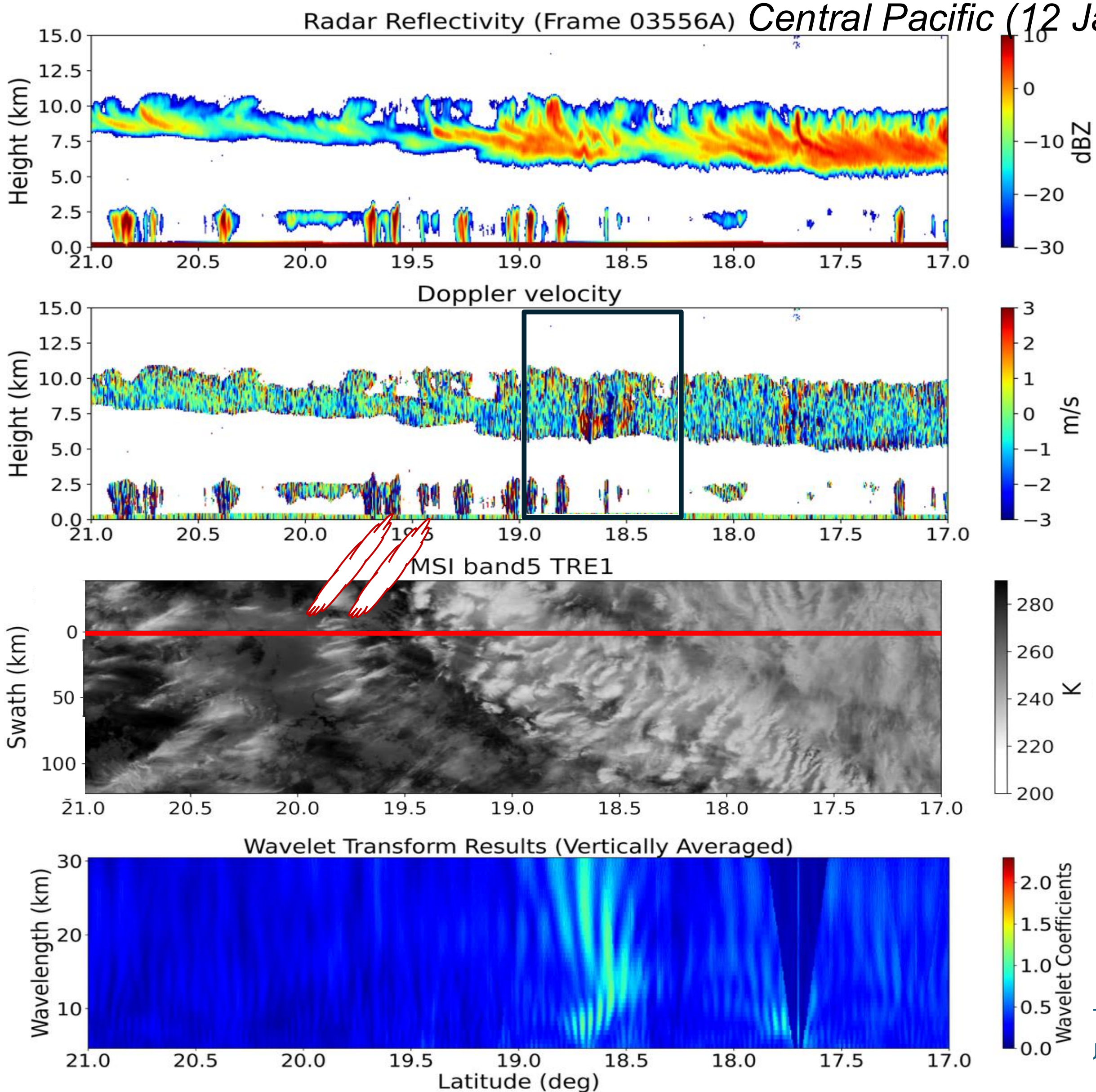
Gravity wave caused by deep convection

Central Africa (14 Jan 2025)

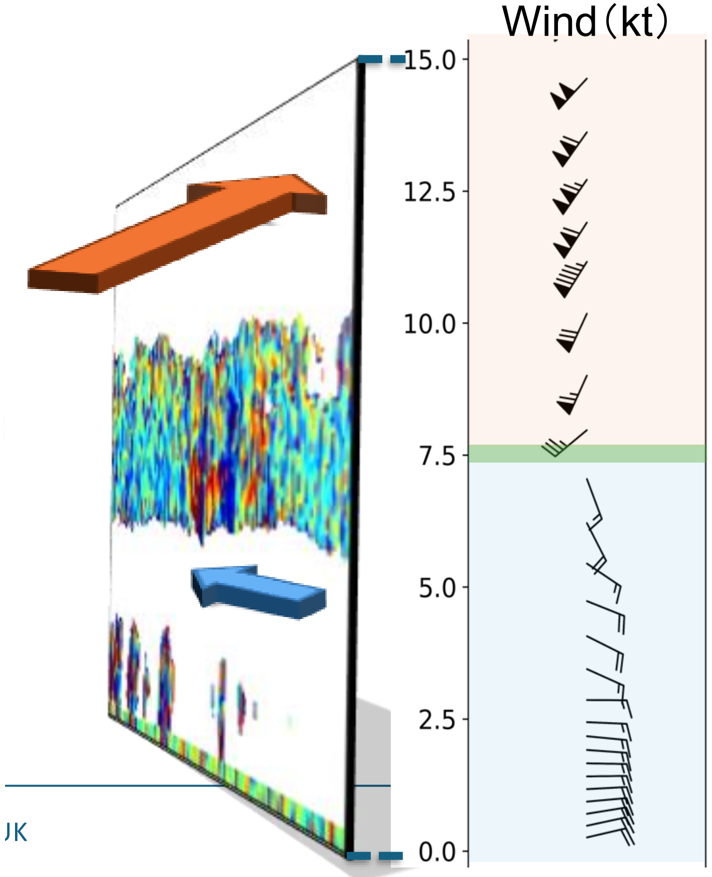


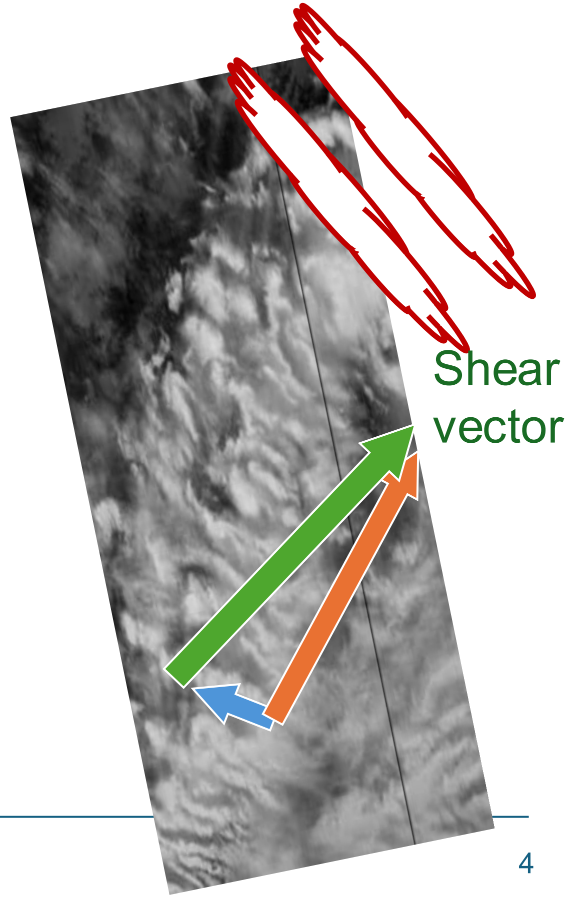
Kelvin-Helmholtz wave (KH wave)

Central Pacific (12 Jan 2025)

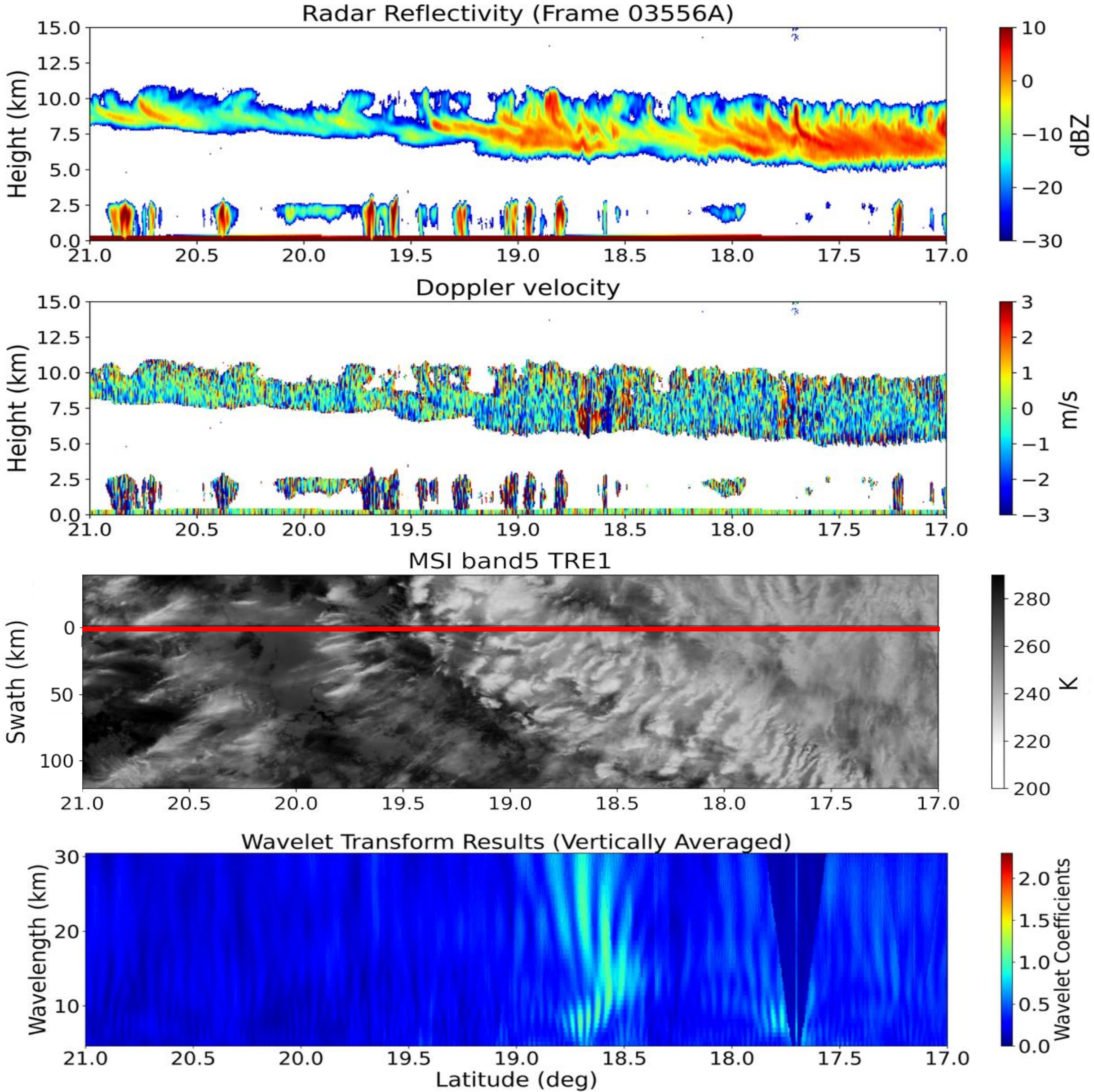


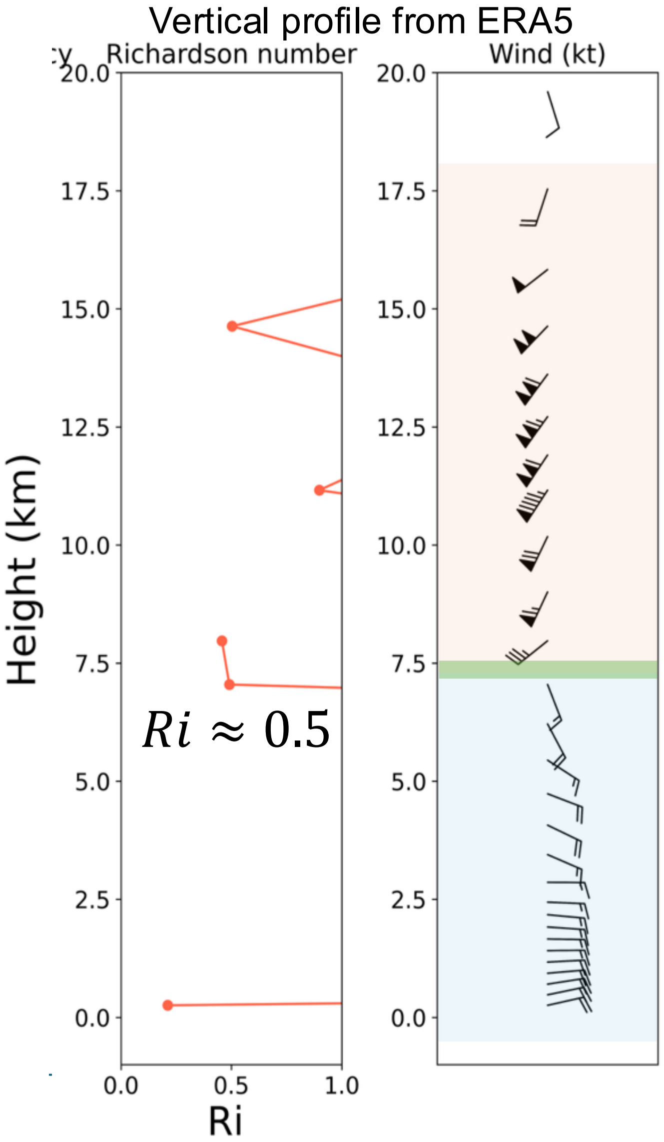
- **Strong wind shear** was present at the wave altitude and the shear vector is **perpendicular to cloud bands**.





Kelvin-Helmholtz wave (KH wave)





Richardson number (Ri)

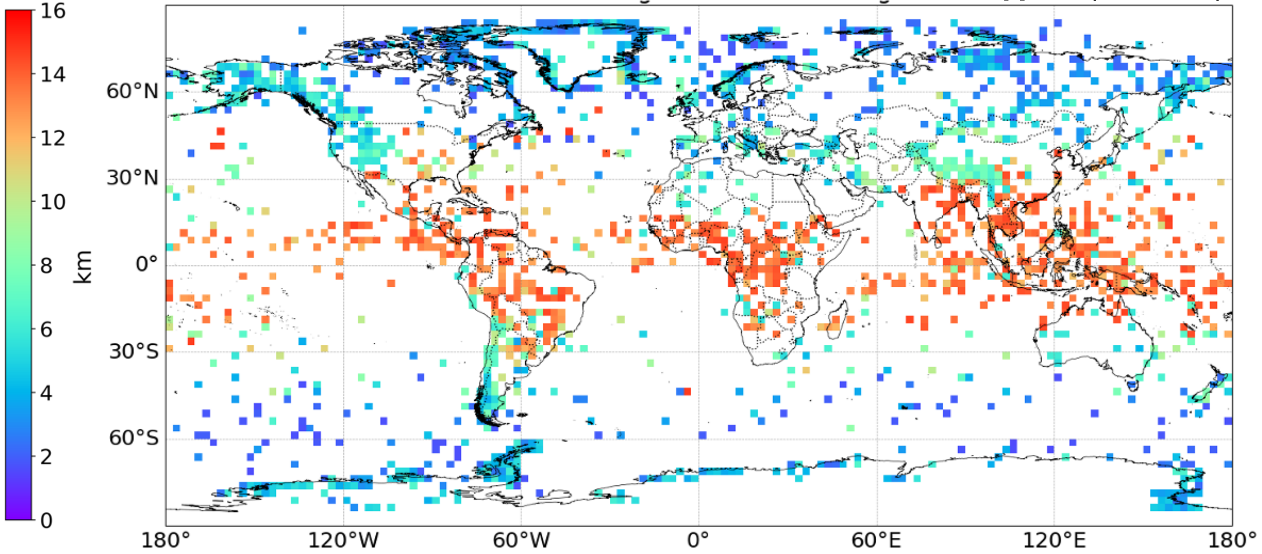
$$Ri = \frac{N^2}{\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial v}{\partial z}\right)^2}$$

In theory, KH waves develop in layers with $Ri < 0.25$. However, when calculated using ERA5 data, threshold of $Ri < 1$ ismore appropriate.

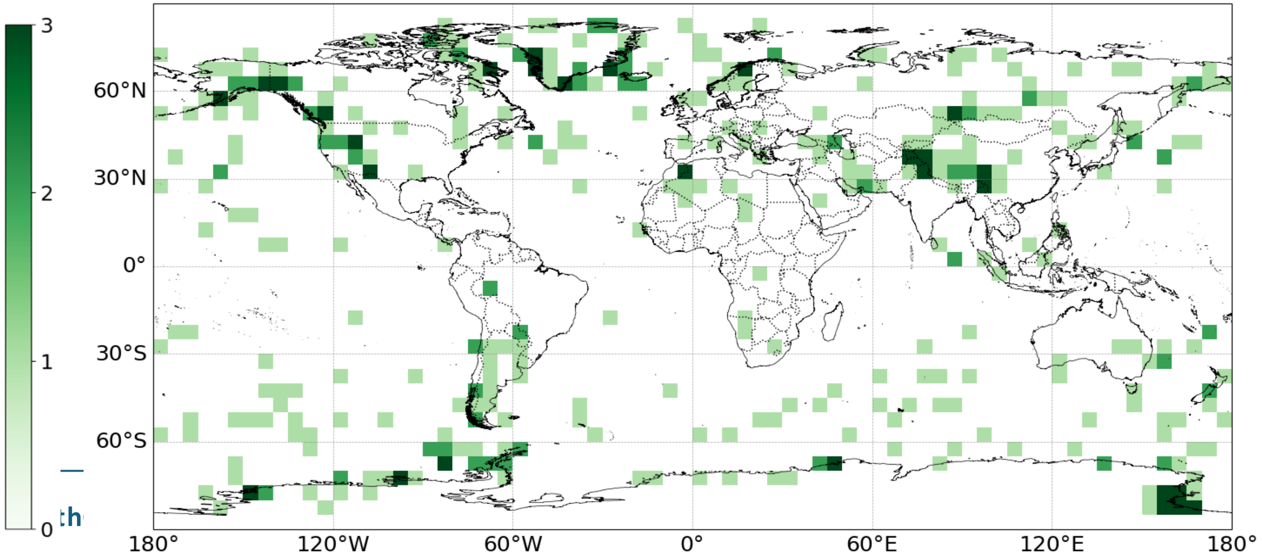
(Shao et al., 2023)

Global Distribution of Detected Waves

Distribution of Mean Wave-Center Height (Annual)



Distribution of Wave Occurrence in Layers with Ri < 1 (Annual)



- High latitudes
- Areas of steep terrain
- Lower troposphere

⇨ **Mountain waves**

- ITCZ (Intertropical Convergence Zone)
- Tropical continents
- Upper troposphere

⇨ **Gravity waves caused by deep convection**

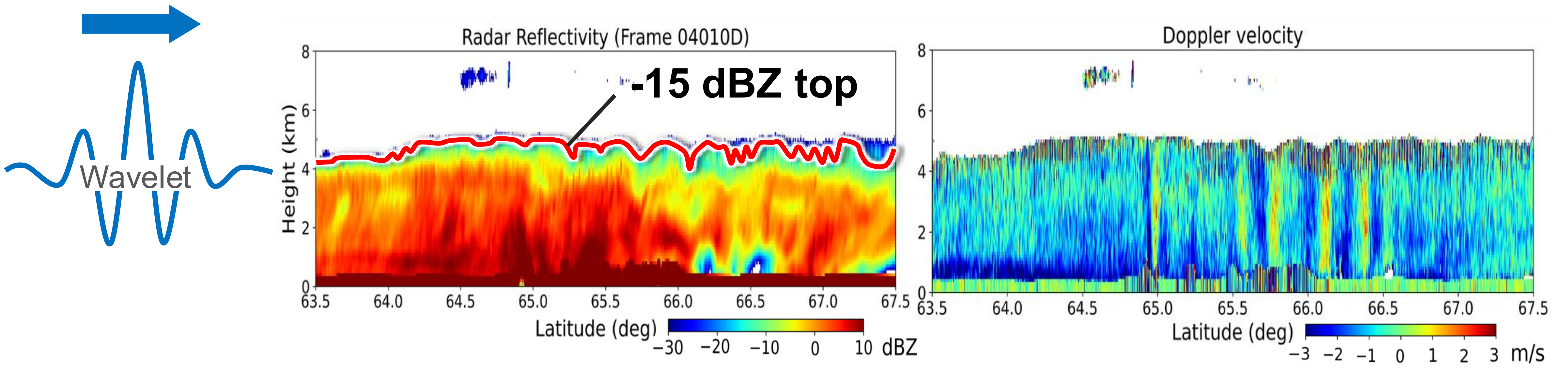
- Layers with $Ri < 1.$

⇨ **KH waves**

Wave Detection Using the Reflectivity Data

- Apply the wavelet analysis to reflectivity data

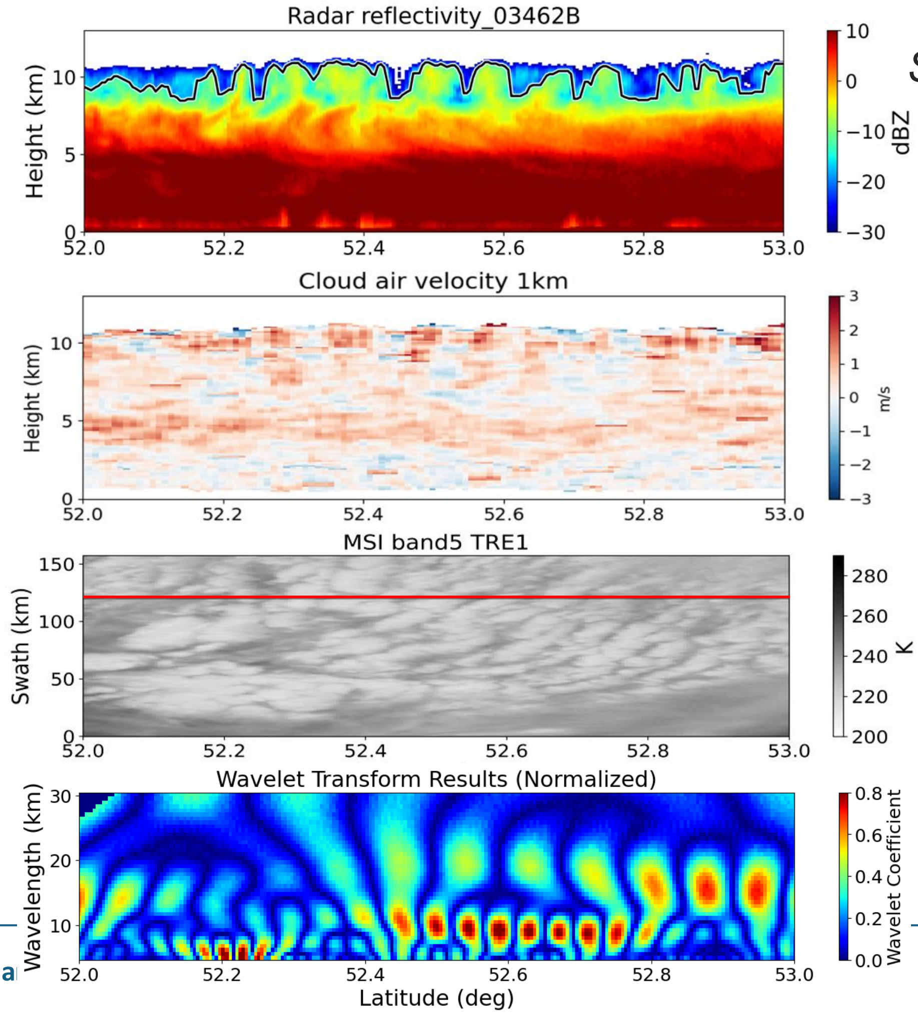
⇨ Focusing on cloud top, detect wave structures by applying wavelet transform to **-15dBZ reflectivity height**.



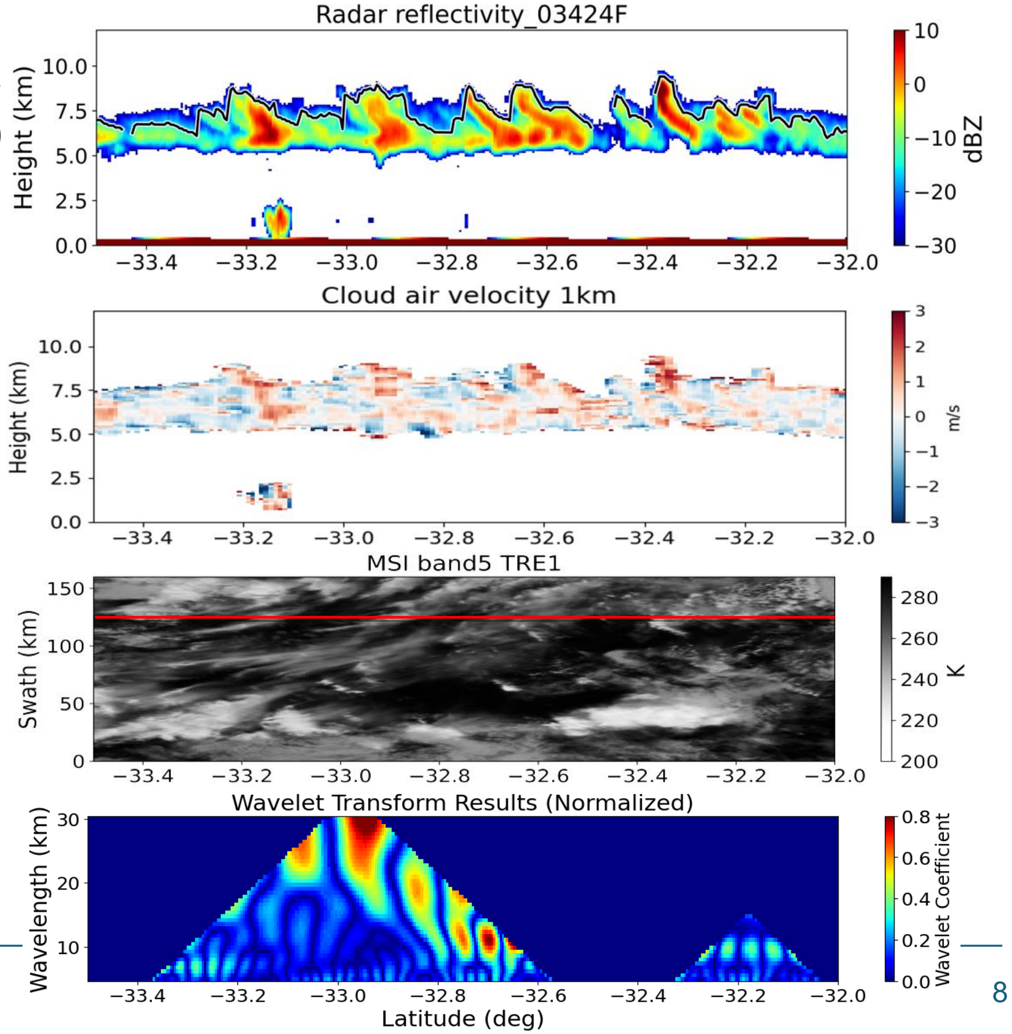
Wave Detection Using the −15 dBZ Height

Results : Most of the detected structures appeared to be generated by convection.
Gravity waves or KH waves were rarely detected.

Western Pacific
(6 Jan 2025)



South Pacific
(4 Jan 2025)



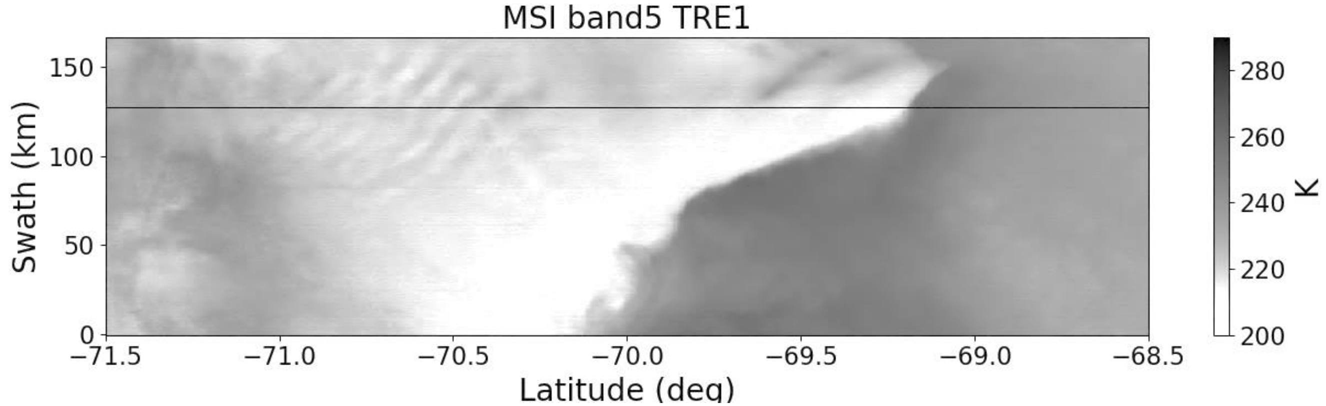
Next Step…

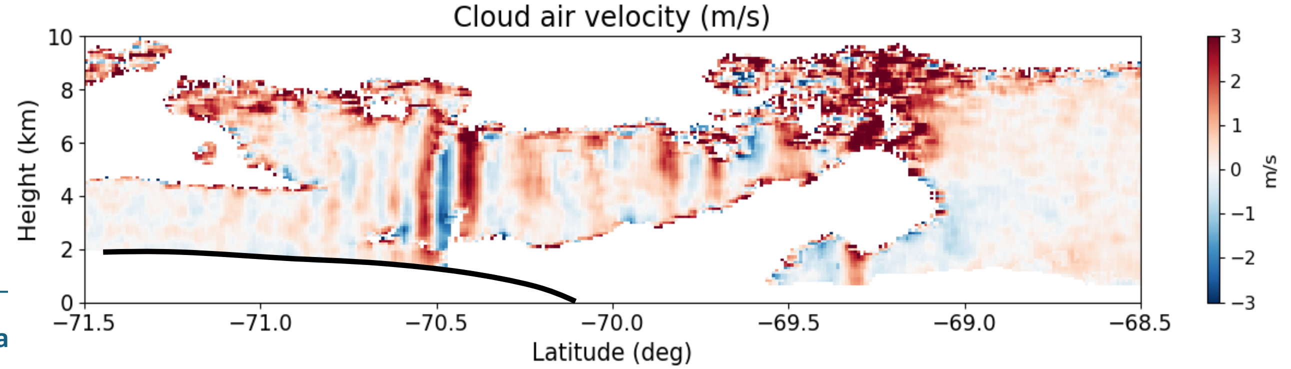
Evaluation of global 1-km simulation (NICAM)

EarthCARE and NICAM are complementary each other.

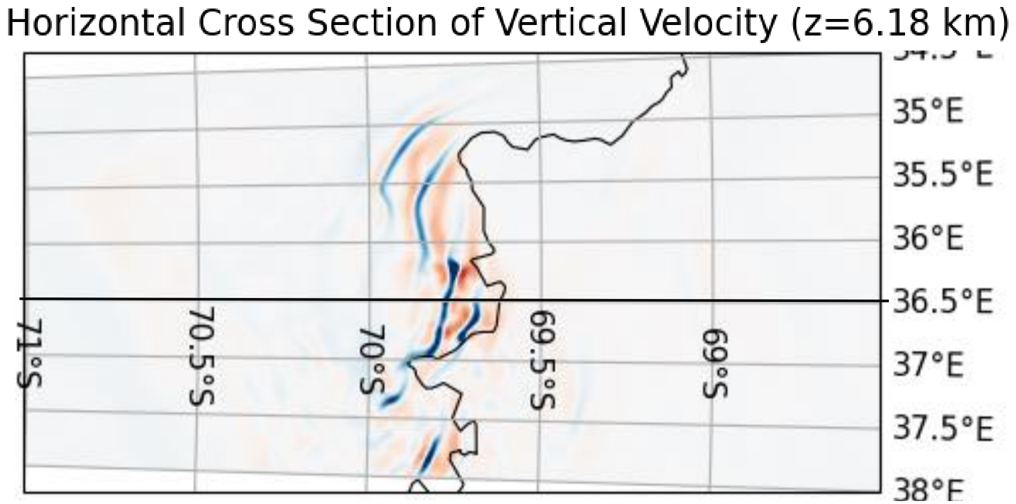
- EarthCARE : Actual observation
- NICAM : 3D structure of waves

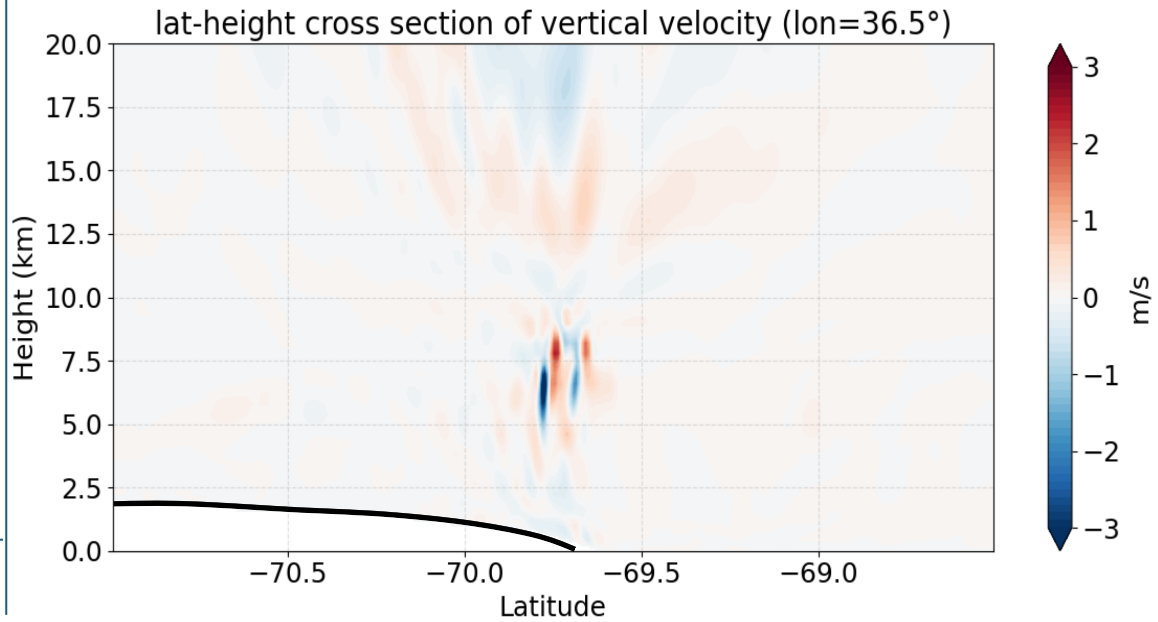
EarthCARE *Antarctica (1 Dec 2024)*





NICAM *Antarctica(Jun 2024) 870 m resolution*

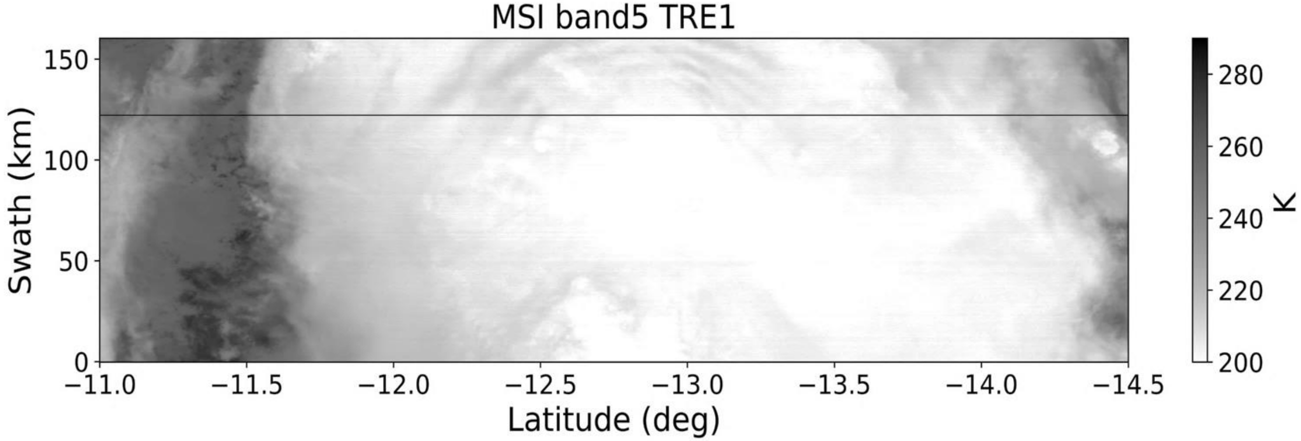


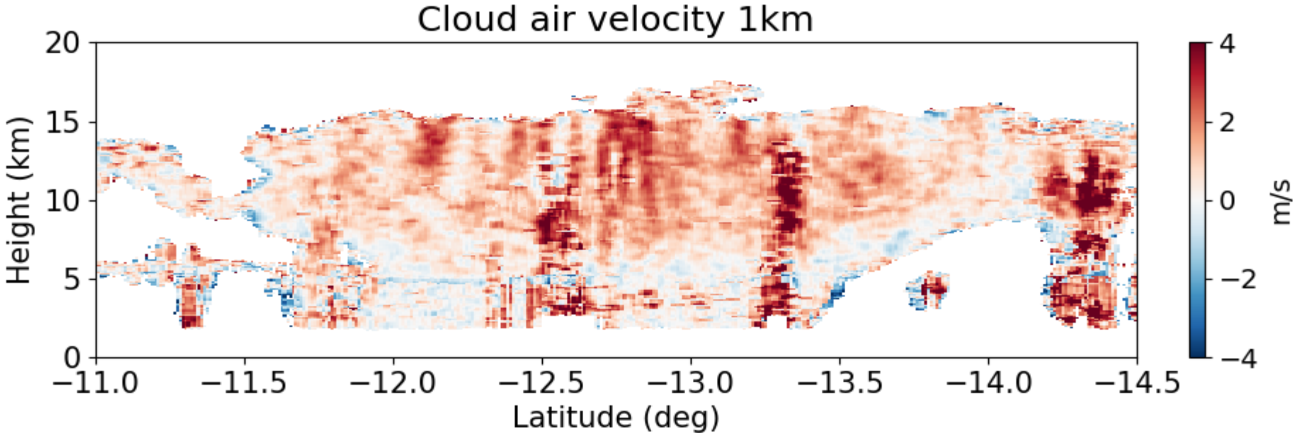


Ea

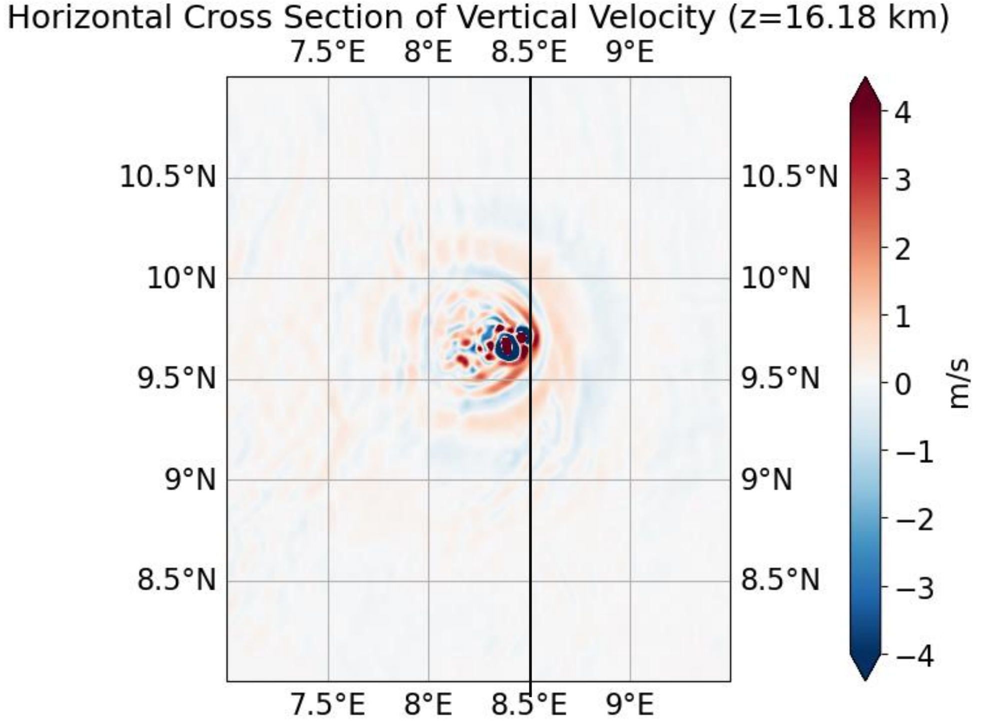
Deep Convection Case

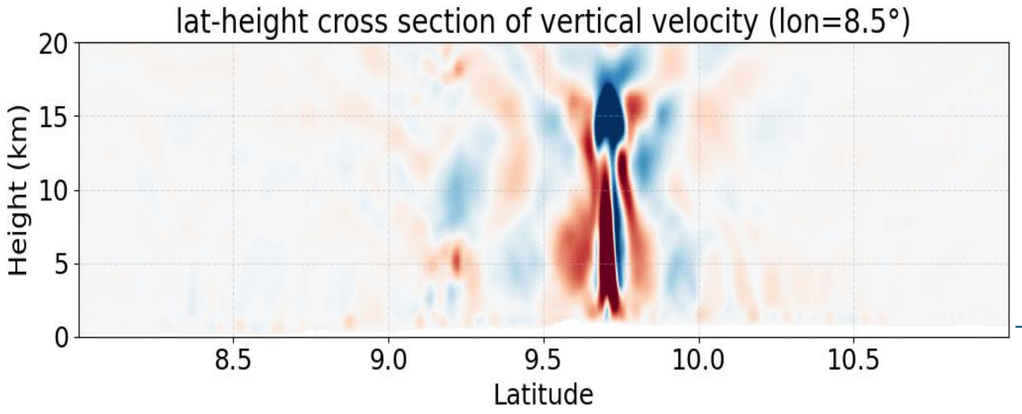
EarthCARE *Angola/Central Africa (14 Jan 2025)*





NICAM *Nigeria/West Africa (Jun 2024) 870 m resolution*





Summary & Future Work

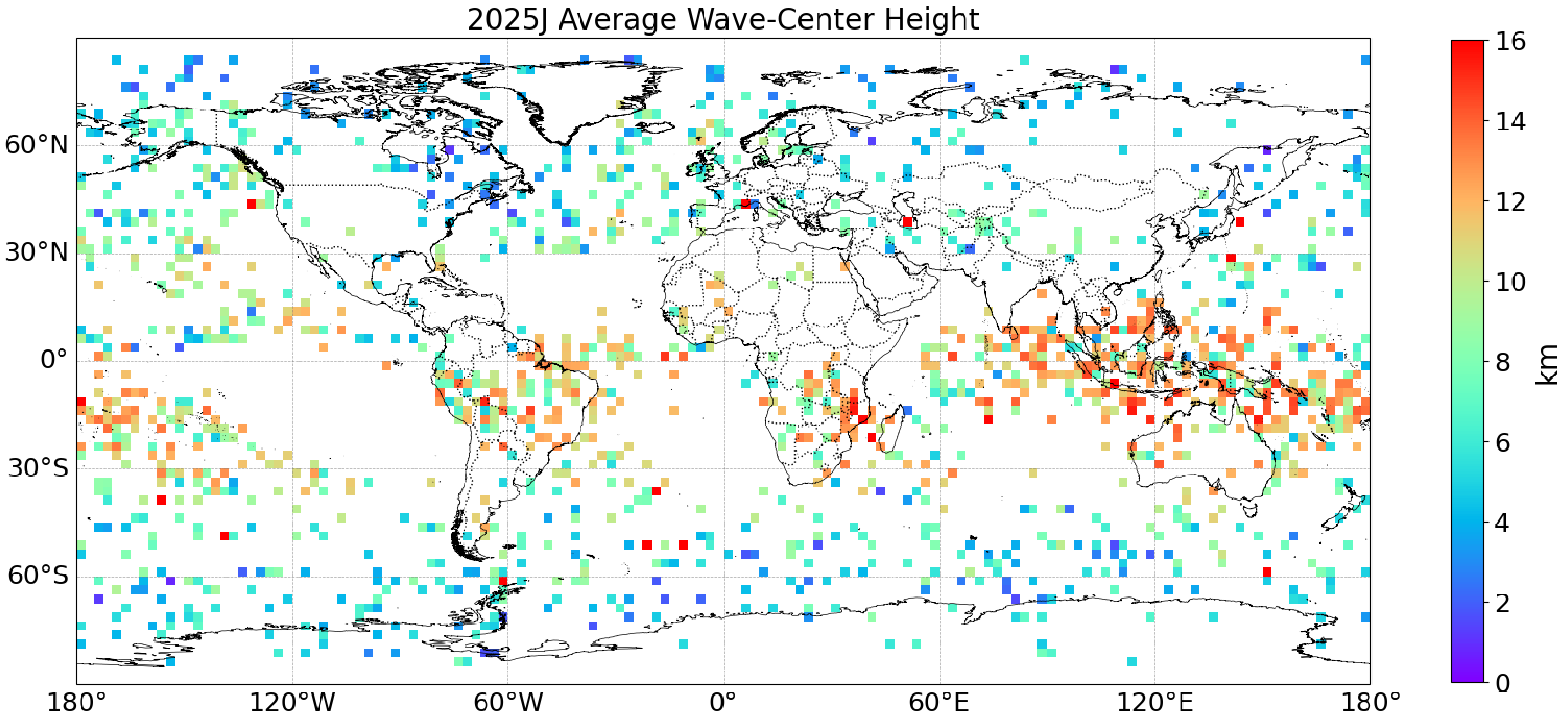
- To investigate wave structures observed by the CPR, we detected waves using wavelet transform.
- **Mountain waves**, **Gravity waves generated by deep convection**, and **KH waves** are detected and their distributions were estimated.
- Wavelet analysis of cloud-top reflectivity (-15 dBZ height) did not detect these waves.

＜Future Work＞

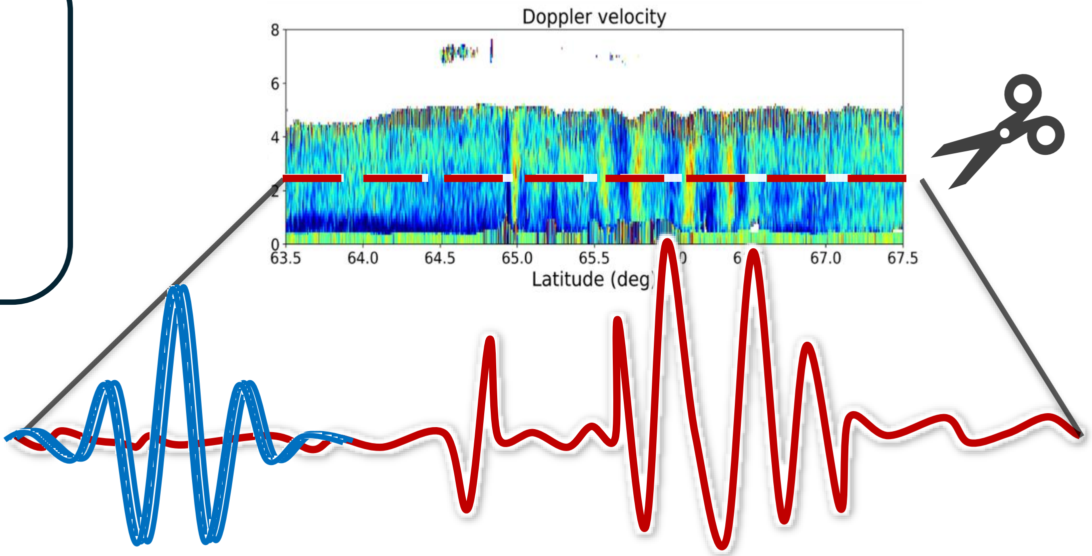
- **Evaluation of NICAM by through comparison with EarthCARE**
  - ➢ Assessment of overestimation and underestimation of wave activity
- **Understanding observed waves by comparing NICAM**
  - ➢ Investigation of wave generation mechanisms using 3D information.
  - ➢ Clarifying which part of a wave phenomenon is captured by EarthCARE.
  - ➢ Assessment of orbital sampling biases in wave observations.
  - ➢ Estimation of wave impacts on the stratosphere.

Wave Detection Using the −15 dBZ Height

Global Distribution of Detected Waves



Data : CPR Level-1b data
Period : December 2024 – November 2025
Altitude range : 0–16 km



① Data screening.（exclude noise）

② Frequency analysis at each altitude.

- Wavelet transform was applied along flight direction for each altitude.
- Detected wavelength was set 5–30 km.

③ Wave identification using the criteria.

- Amplitude exceeds 0.5 m/s. Vertical and horizontal extents exceed 2 km.

Wave Detection Method Using Doppler Velocity Data

Data: CPR (Level 1b) data from December 2024 to November 2025.

Data screening

The following regions were excluded from the analysis:

- Weak cloud regions with Z < -30 dBZ, which have low data reliability.
- Regions below the 0°C layer, or regions with Z > 10 dBZ and t underlying regions where velocity folding in precipitation may lead to f detections.
- Near-surface regions below 500 m above ground to avoid contamina from surface clutter.
- Regions above 16 km altitude at 60°S–60°N and above 14 km altitud > 60 °N and < 60 °S to avoid second trip mirror image.

Wave Detection Method Using Doppler Velocity Data

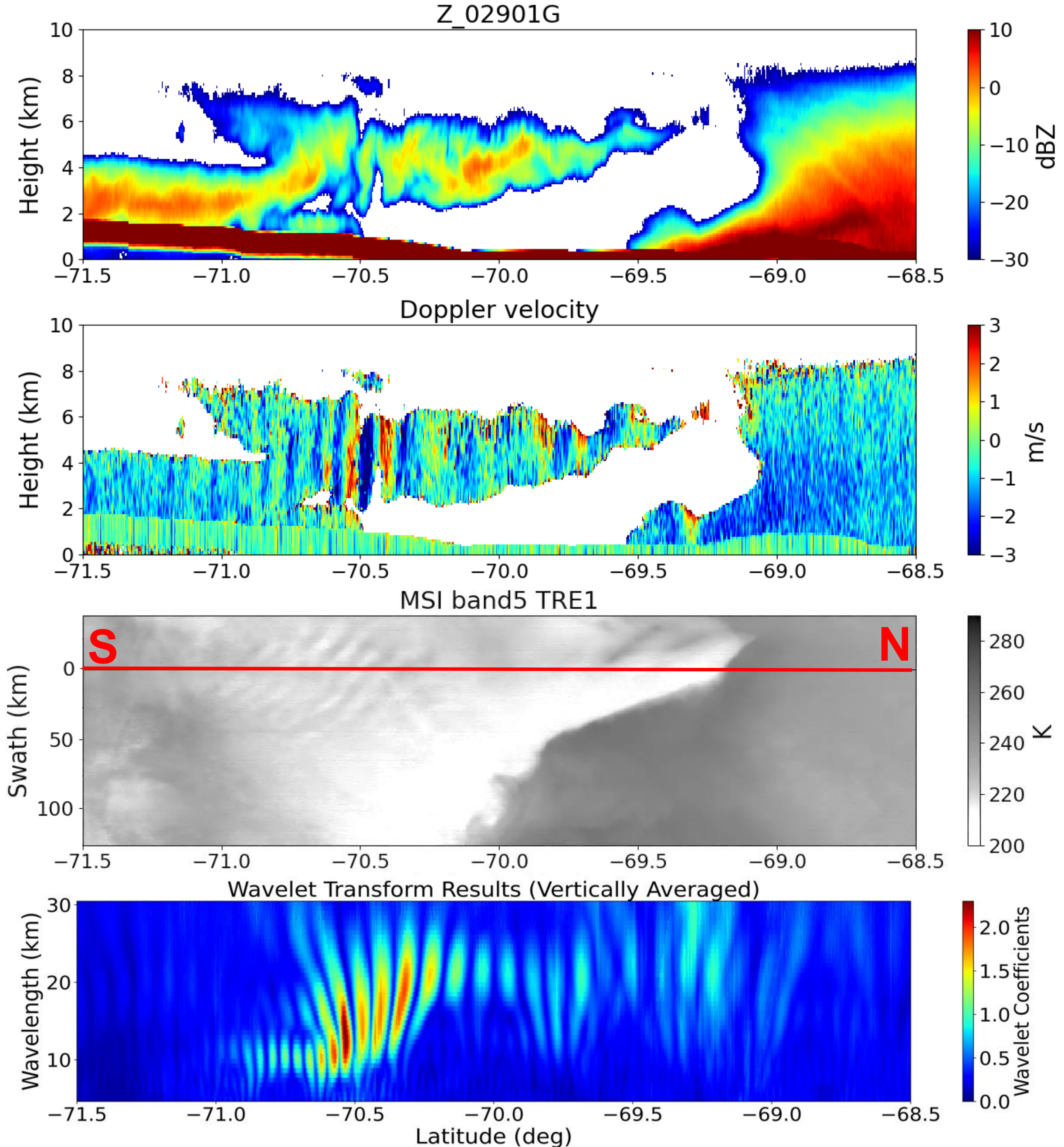
Wavelet transform

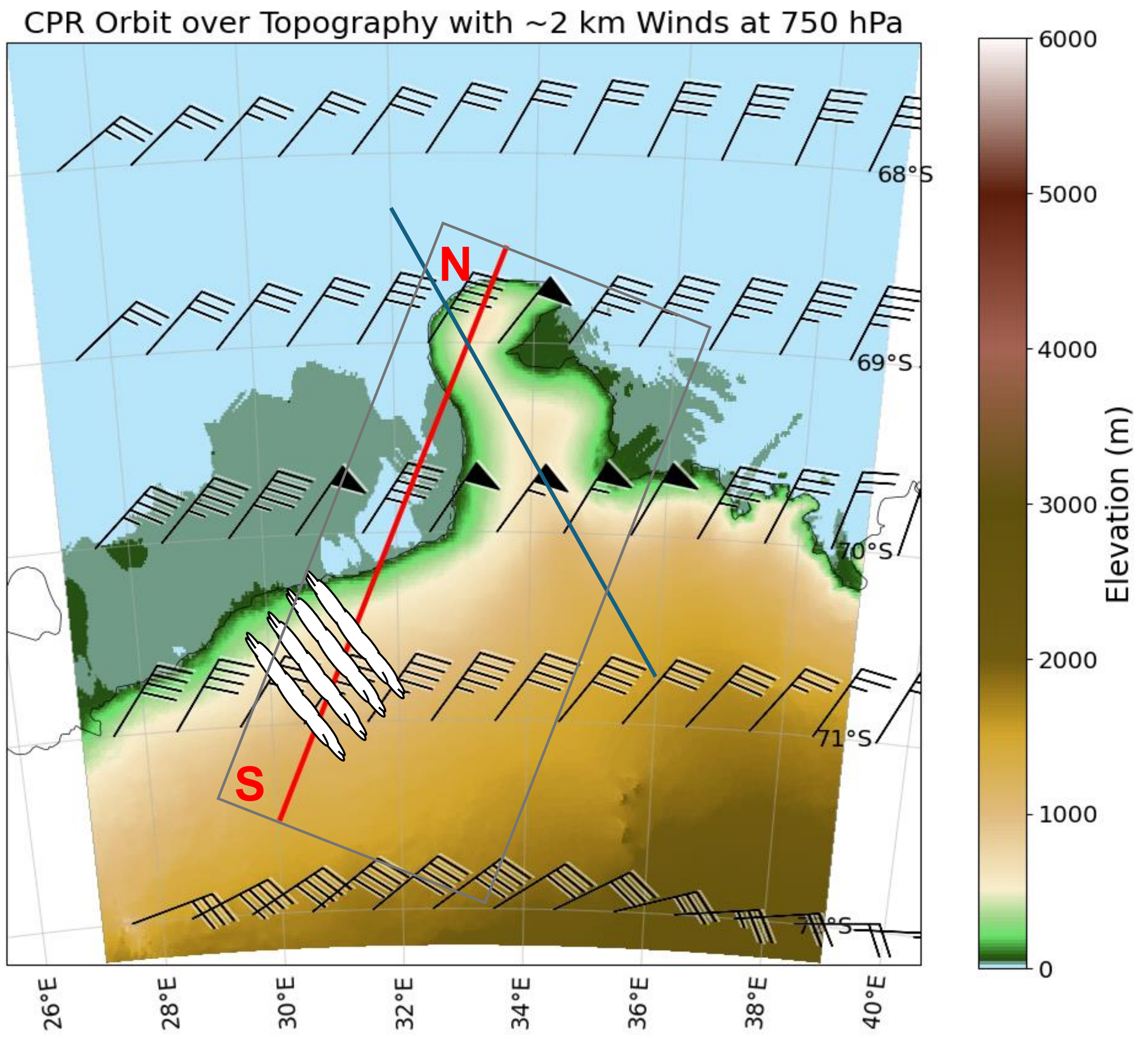
- Morlet wavelet was used to apply along flight direction for each altitude.
- Wavelength range was set 5–30 km.
- Calculation was skipped if invalid data were included within the analysis window.

Criteria to determine wave.

- Amplitude exceeds 0.5 m/s.
- Vertical and horizontal extents exceed 2 km.

Mountain Wave





Wave Detection Using the −15 dBZ Contour

Hypothesis : Clouds containing waves, Z should also exhibit wave structures through the generation and dissipation of cloud particles.

Analysis : Detect wave structures by applying wavelet transform to -15dBZ reflectivity contour.