Comparison between CPR observation modes

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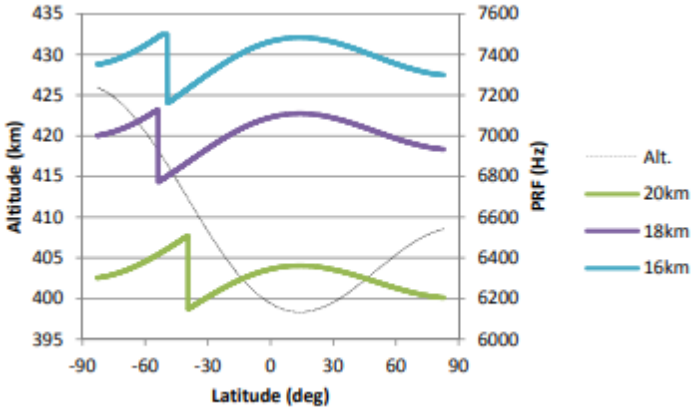
Introduction

■ CPR has three observation modes with different PRF values and maximum observation heights:

→ **16 km (Low), 18 km (Middle), and 20 km (High) modes**

PRF: 7150~7500Hz, 6800~7150Hz, 6100~6400Hz



■ There is a trade-off relationship between Doppler accuracy and observation height:

- High PRF (16 km mode) provides higher Doppler accuracy at the cost of lower observation height.
- Low PRF (20 km mode) provides higher observation height at the cost of lower Doppler accuracy.

*In the 16 km mode or 18 km mode, the number of pulse samples within the medium's decorrelation time increases, leading to better Doppler velocity measurement accuracy.

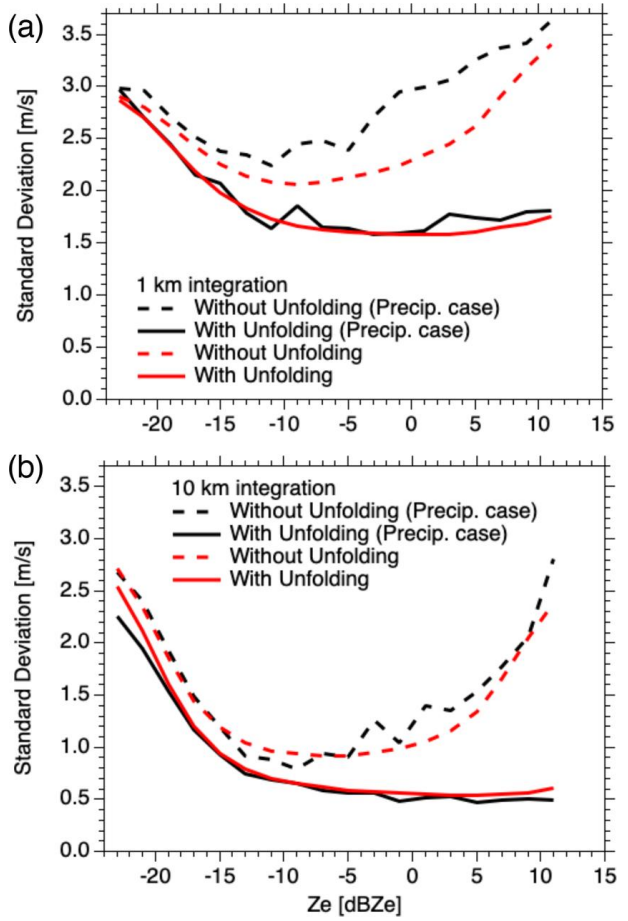
Currently, the 20 km mode (low PRF) is applied for latitudes < 60°, and the 16 km mode (high PRF) is used for latitudes ≥ 60° (Mix mode), because cloud top heights decrease with increasing latitude.

Introduction

■ Previous works evaluated Doppler data using simulation data (e.g., Hagihara et al., 2023; Tomiyama et al., 2020). This study presents results based on actual measurement data.

■ This study aims to elucidate Doppler measurement accuracy across the observation modes and determine which mode should be implemented in CPR observation.

■ This study proposes application of the 18 km mode into actual CPR operations to improve Doppler accuracy in latitudes < 60°, where the 20 km mode is currently employed. In addition, the potential risks associated with mirror image will be discussed.



Hagihara et al. (2023)

Data

■ Data from the fixed 16 km and 18 km modes, analyzed for the period in November:
- 11/05 21:00:02～11/09 00:00:02: fixed 16 km mode (Low mode)
- 11/09 00:00:03～11/12 11:50:48: fixed 18 km mode (Middle mode)

■ Data from the Mix mode (analysis domain: 60S-60N) were also utilized to validate Doppler accuracy in the 20 km mode.
- 11/01 00:00:00～11/05 21:00:01: Mix mode (60S-60N; 20 km mode)

■ Data from ATLID were used to compare cloud top heights obtained from CPR and ATLID.

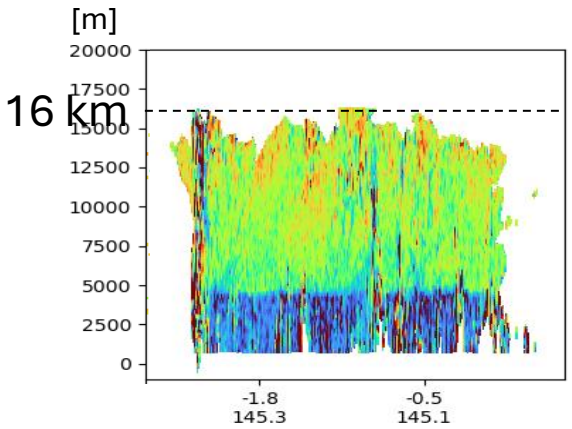
Sensor	Product	Period	Domain
CPR	L1b CPR_NOM vBa （Corrected by Dr. Aoki）	2024/11/01 ~2024/11/12	60S-60N (To compare the 20km mode in Mix mode)
ATLID	L1b ATL_NOM vAc L2a ATL_CLA vAa	2024/11/01 ~2024/11/12	Global

Case study of Doppler velocity measurement

■ Several cases were extracted to confirm the accuracy of Doppler measurements and cloud top heights.

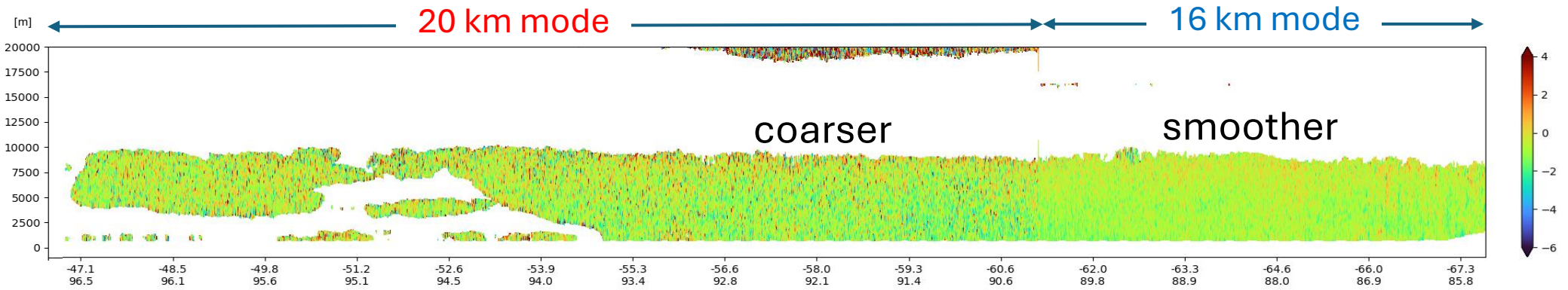
■ Regarding observation heights, there is a possibility that cloud tops higher than 16 km are slightly cut off in the 16 km mode.

(a) 11/7 2532A (16 km mode)



■ The 20 km mode has large spatial deviations of Doppler velocity, while the 16 km mode has smaller deviation of Doppler velocity, suggesting that the 16 km mode has higher accuracy of Doppler measurement.

(b) 11/1 2432F (MIX mode)

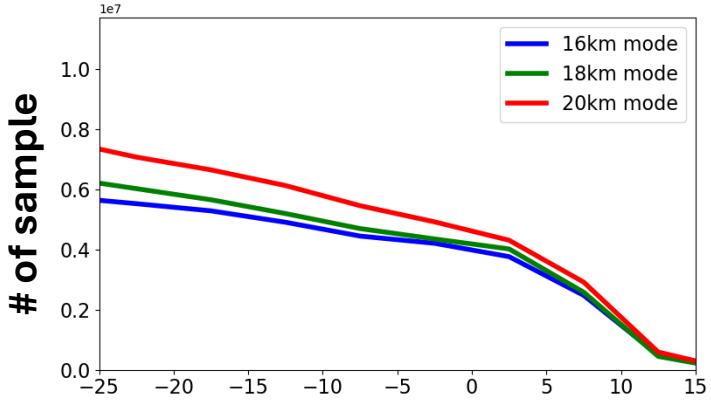


Comparisons of Doppler velocity measurements

■ Calculate the standard deviation (STD) of the Doppler velocity for each radar reflectivity value

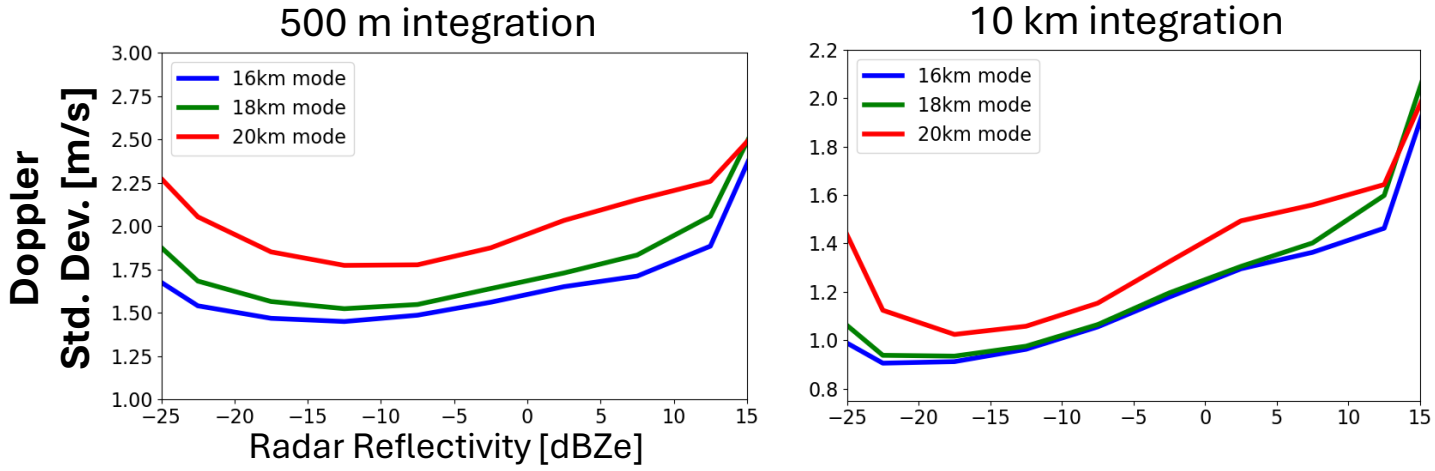
Blue: 16km mode, Green: 18km mode, Red: 20km mode

■ There are only minor differences in the sample numbers between the modes, which facilitates reasonable discussion in terms of Doppler accuracy.



■ The increase in STD with higher radar reflectivity is likely due to rain echoes with large spatial variation in velocity.

■ The STD of Doppler velocity for the 16km and 18km modes is very similar and lower than that for the 20km mode.



Measurement accuracy of surface Doppler velocity

■ Analyzed Doppler velocity at the surface and calculated standard deviations across the observation modes

■ The horizontal axis represents time relative to the first ray in Frame A, with the time of the first ray set to 0. Analysis domain spans latitudes between 60S-60N, which explains the two margins in the histogram.

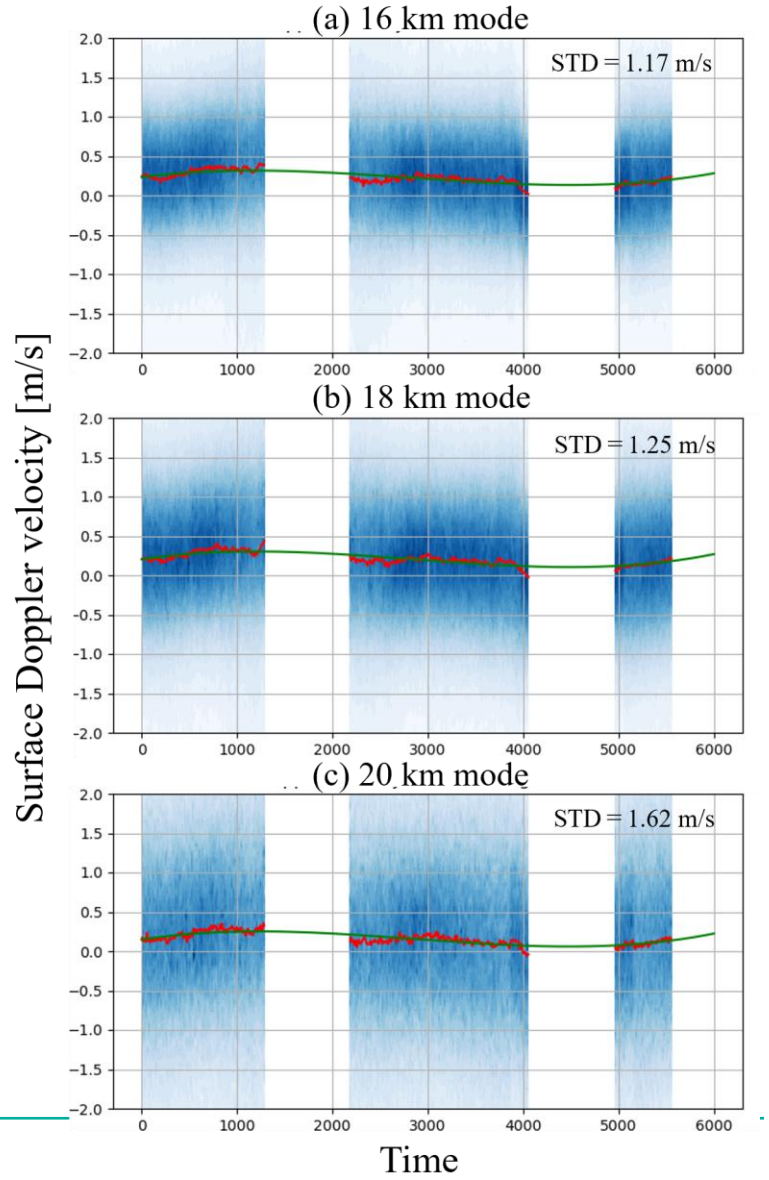
Blue: Surface Doppler velocity

Red line: Mean value of surface Doppler velocity

Green line: Fitted values using a cubic function

■ There are positive surface Doppler biases and sinusoidal patterns in all modes, likely due to the absence of antenna thermal distortion correction.

■ Consistent with previous results, the standard deviation of surface Doppler biases for the 16km and 18km modes are relatively similar and lower than that for the 20km mode.



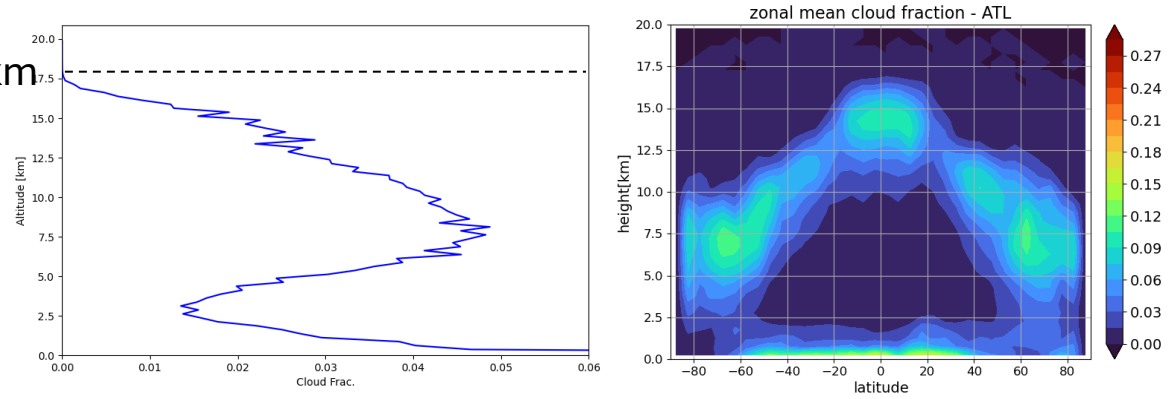
Comparison between CPR and ATLID

■ The figure below shows the overlaps of cloud areas derived from ATLID (red) and CPR (blue).

■ There is a moderate cloud fraction between 16 km and 18 km, but very few clouds extending above 18 km.

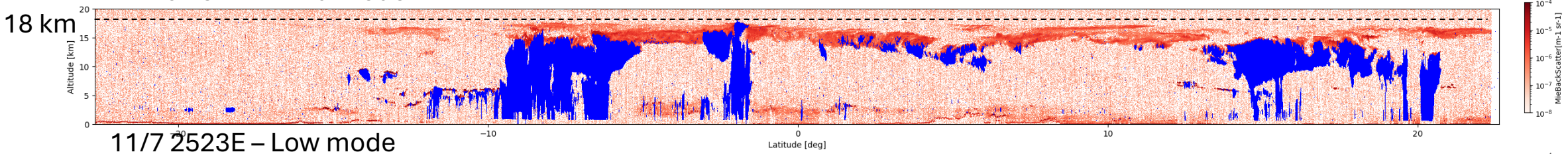
⇒ This suggests that almost all clouds can be detected by the 18 km mode, and supports the use of the 18 km mode that enables higher performance of Doppler velocity measurement.

Cloud Fraction from ATLID (derived from feature mask)

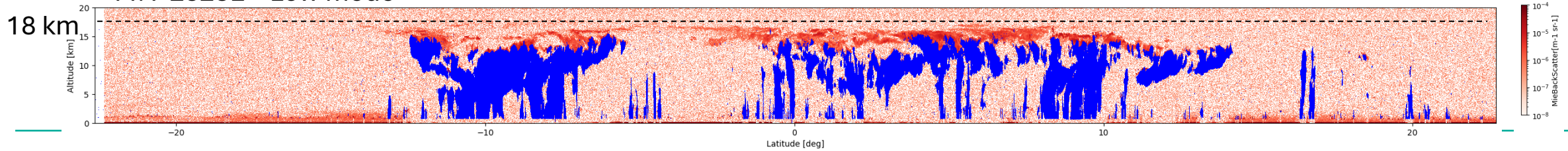


- Red: Mie Attenuated Backscatter (by ATLID)
- Blue: Cloud domains identified by cloud flag provided by Dr. Aoki

11/10 2572A – Mid mode



11/7 2523E – Low mode



Analysis on Mirror image

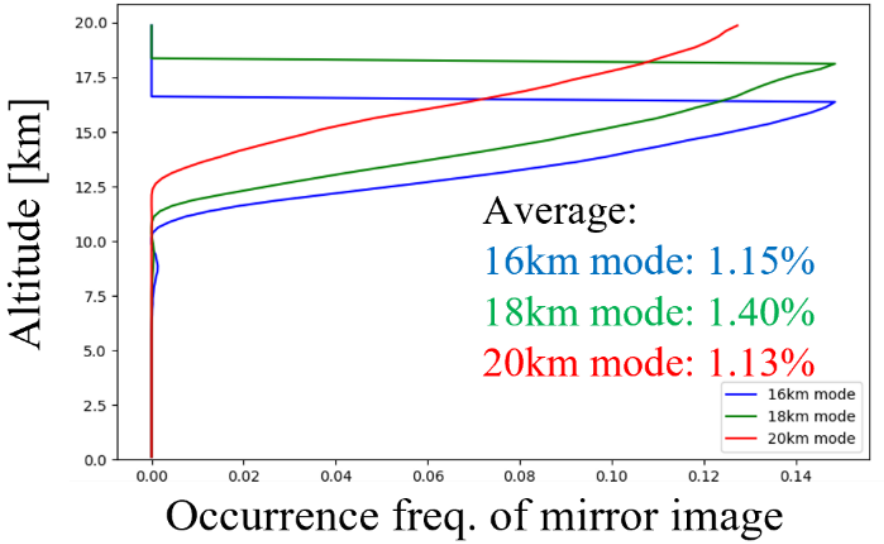
■ It is pointed out that mirror image, which is a spurious cloud echo, tends to appear in the 18 km mode.

*Reason: The 18 km mode has a PRF closer to that of the 16 km mode, which results in the distance from the observation upper limit of the mirror occurrence position in the 18 km mode being longer than in the 16 km and 20 km modes.

■ Categorized cloud echoes into three types (real cloud echo, mirror image, and multiple scattering tail) and evaluated the occurrence frequency of mirror image across the observation modes.

■ The vertical distribution of mirror image frequency in the 18 km mode is closer to that in the 16 km mode, rather than the 20 km mode, likely due to its PRF value.

■ The average occurrence frequency of mirror images is slightly higher in the 18 km mode compared to the other modes.



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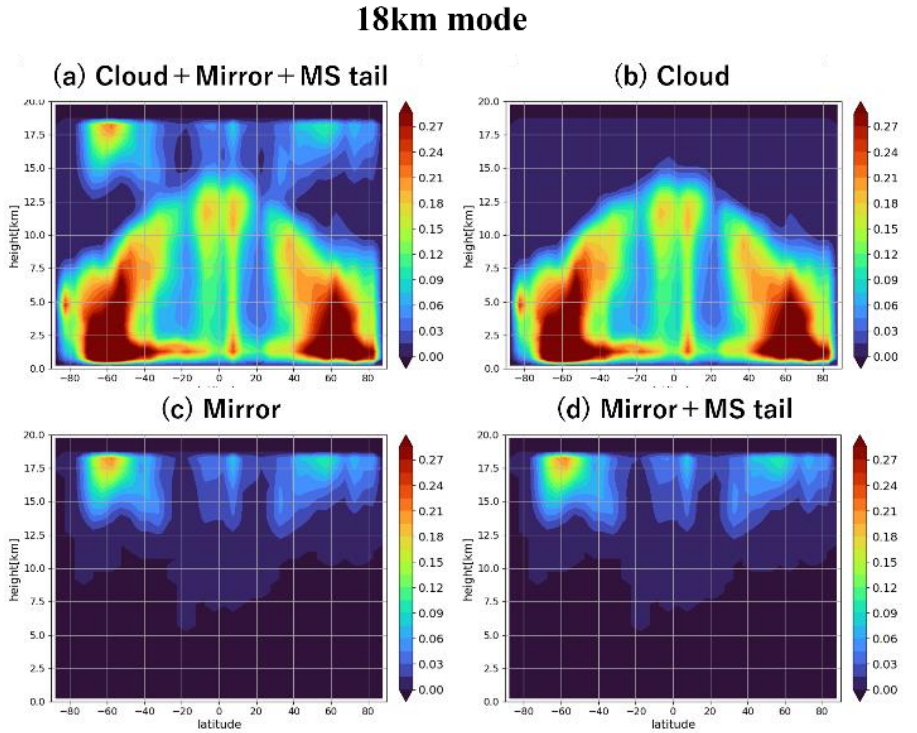
■ Categorized cloud echoes into three types (real cloud echo, mirror image, and multiple scattering tail) and evaluated the occurrence frequency of mirror image across the observation modes.

■ There are three peaks in the occurrence frequency of mirror images at high altitudes: in the northern and southern high latitudes, and in the tropics.

■ There is a risk that mirror image overlaps with real cloud echoes, particularly in the tropics where high-level clouds are present.

■ This issue will be addressed and mitigated in the L2 algorithm in the future.



Summary

■ This study focused on three CPR observation modes with different PRF values: 16 km, 18 km, and 20 km modes, and investigated the differences in performance of Doppler velocity measurement across latitudes between 60S-60N, where the 20 km mode is currently used.

■ The 18 km mode provides small standard deviation of Doppler velocity almost equal to that of the 16 km mode. The performance of the 16 km and 18 km modes is similar, likely due to the comparable PRF values used in both modes.

■ Compared cloud top heights obtained by CPR and ATLID. Very few clouds were found above 18 km even by ATLID, suggesting that the 18 km mode can cover nearly all clouds. These results support the use of 18 km mode within the latitudes between 60S-60N for actual CPR operations.

■ However, there is an issue with mirror images that tend to appear in the 18 km mode. This issue will be mitigated in the L2 algorithm in the future.