Comparison of Doppler velocity measurement across CPR observation modes

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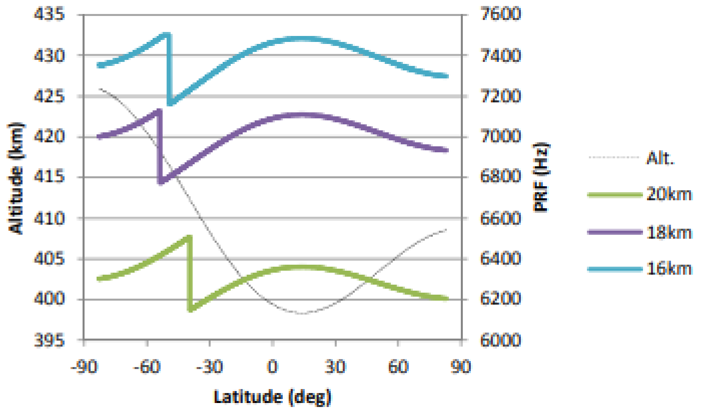
Introduction

- 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



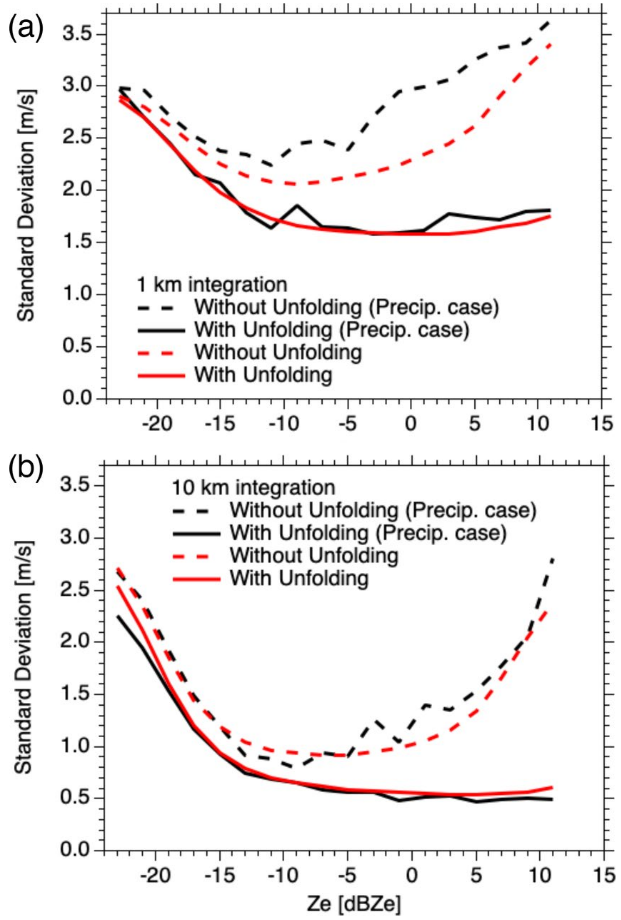
- There is a trade-off relationship between Doppler accuracy and observation height:
  - High PRF (16 km mode) provides higher Doppler accuracy at the cost of lower observation height.
  - Low PRF (20 km mode) provides higher observation height at the cost of lower Doppler accuracy.

*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.
- In the previous WS, we proposed implementation of the 18 km mode into actual CPR operations to improve Doppler accuracy in latitudes < 60°, where the 20 km mode is currently employed.
- This presentation builds on the previous WS by incorporating additional information on Doppler standard deviation, high-level cloud fraction, and mirror image, which further supports our proposals for the 18 km mode.



Hagihara et al. (2023)

Data

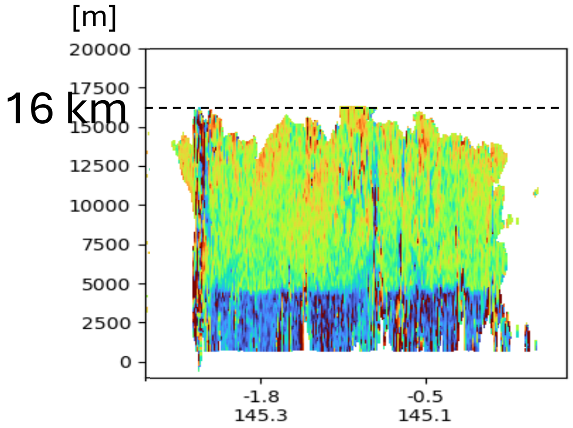
- For the analysis of Doppler velocity, data from the fixed 16 km and 18 km modes, were analyzed for the period in November:
  - 11/05 21:00:02〜11/09 00:00:02: globally fixed 16 km mode (Low mode)
  - 11/09 00:00:03〜11/12 11:50:48: globally fixed 18 km mode (Middle mode)
- Data from the Mix mode (analysis 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 vCa (Corrected by Dr. Aoki)	**Analysis on Doppler velocity**	2024/11/1 ~2024/11/12	60S-60N (To compare the 20km mode in Mix mode)
		Analysis on cloud fraction	2024/6/17 ~2025/2/15	Global
ATLID	L2a ATL_CLA vAa, vAb, vAc		2024/8/10 ~2025/2/28	Global

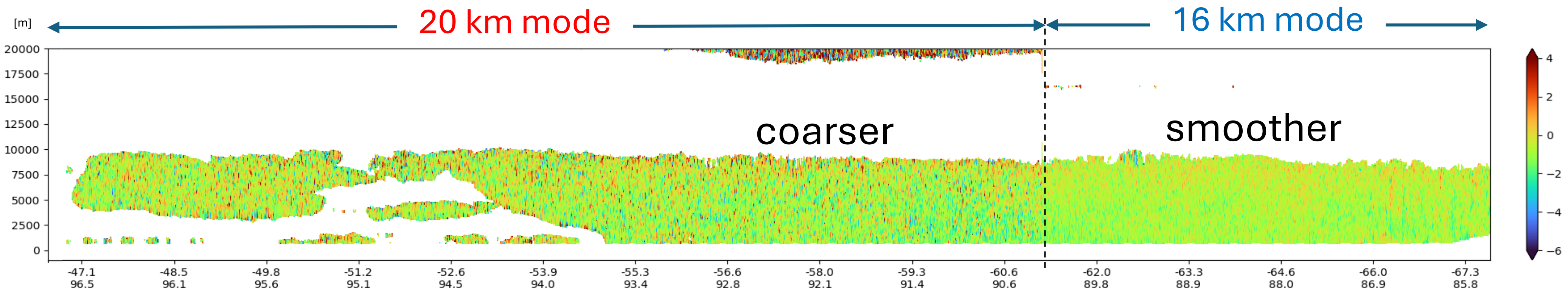
Case study of Doppler velocity measurement

- 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.
- 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.

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



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

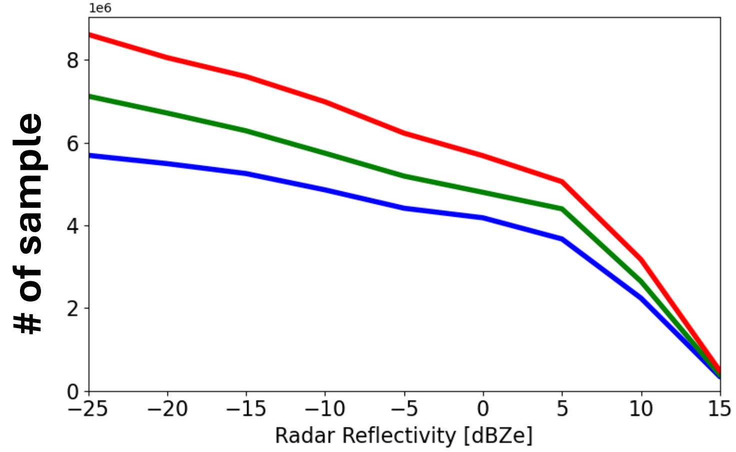


Comparisons of Doppler velocity measurements

- Calculated 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.

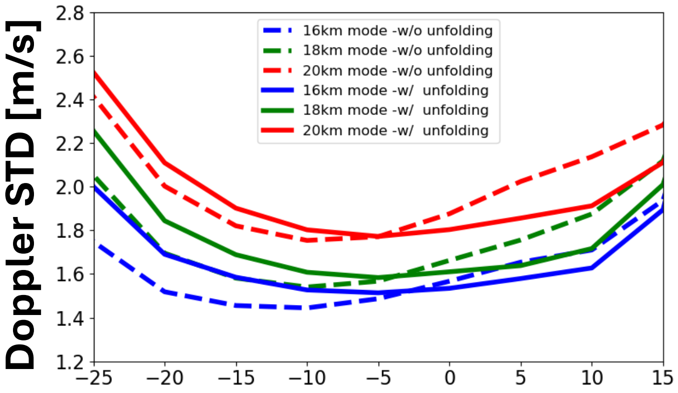
2024/11/1 ~ 2024/11/12



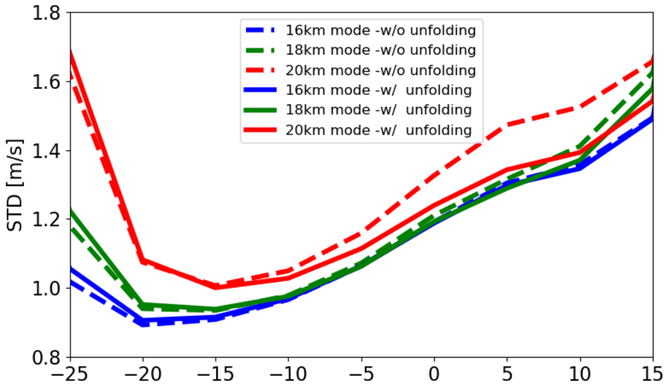
- The 18km and 20km modes captured clouds above 16 km, which disrupted a consistent comparison between the modes.
  ⇒Only clouds below 16 km were extracted to ensure the better analytical consistency between the modes.

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

500 m integration



10 km integration



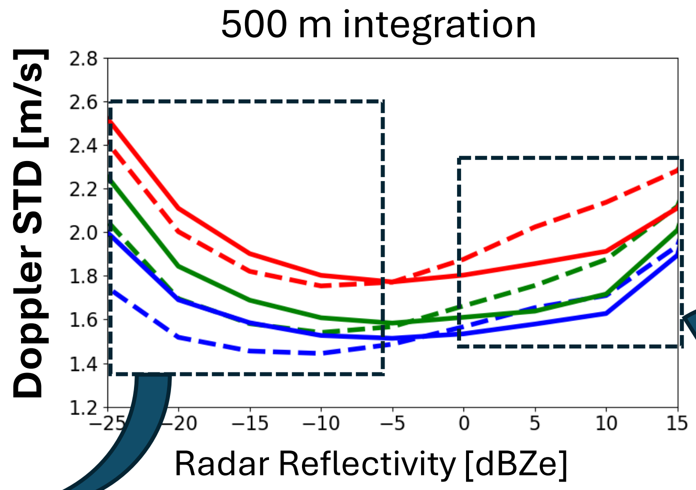
Radar Reflectivity [dBZe]

Dotted line: w/o unfolding
Solid line: w/ unfolding (> +3 m/s)

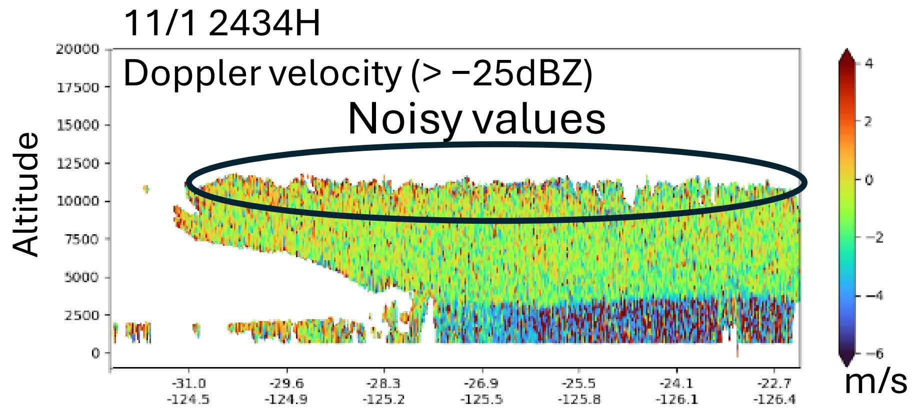
Comparisons of Doppler velocity measurements

- Calculated the standard deviation (STD) of the Doppler velocity for each radar reflectivity value
  Blue: 16km mode, Green: 18km mode, Red: 20km mode

This analysis uses data from Nov., when SPU-A was active. Due to the impact of its IQ offset, noisy Doppler values above +3 m/s remain in regions with low dBZ near the cloud boundaries.
⇒ STD appears to differ between the cases w/ and w/o unfolding corrections.



Dotted line: w/o unfolding
Solid line: w/ unfolding (> +3 m/s)



Since folding occurs in precipitation areas with high velocities, after applying the unfolding correction, Doppler values are generally smoothed to match the surrounding areas in regions with high dBZ (> 0 dBZ).
⇒ STD is smaller after the correction.

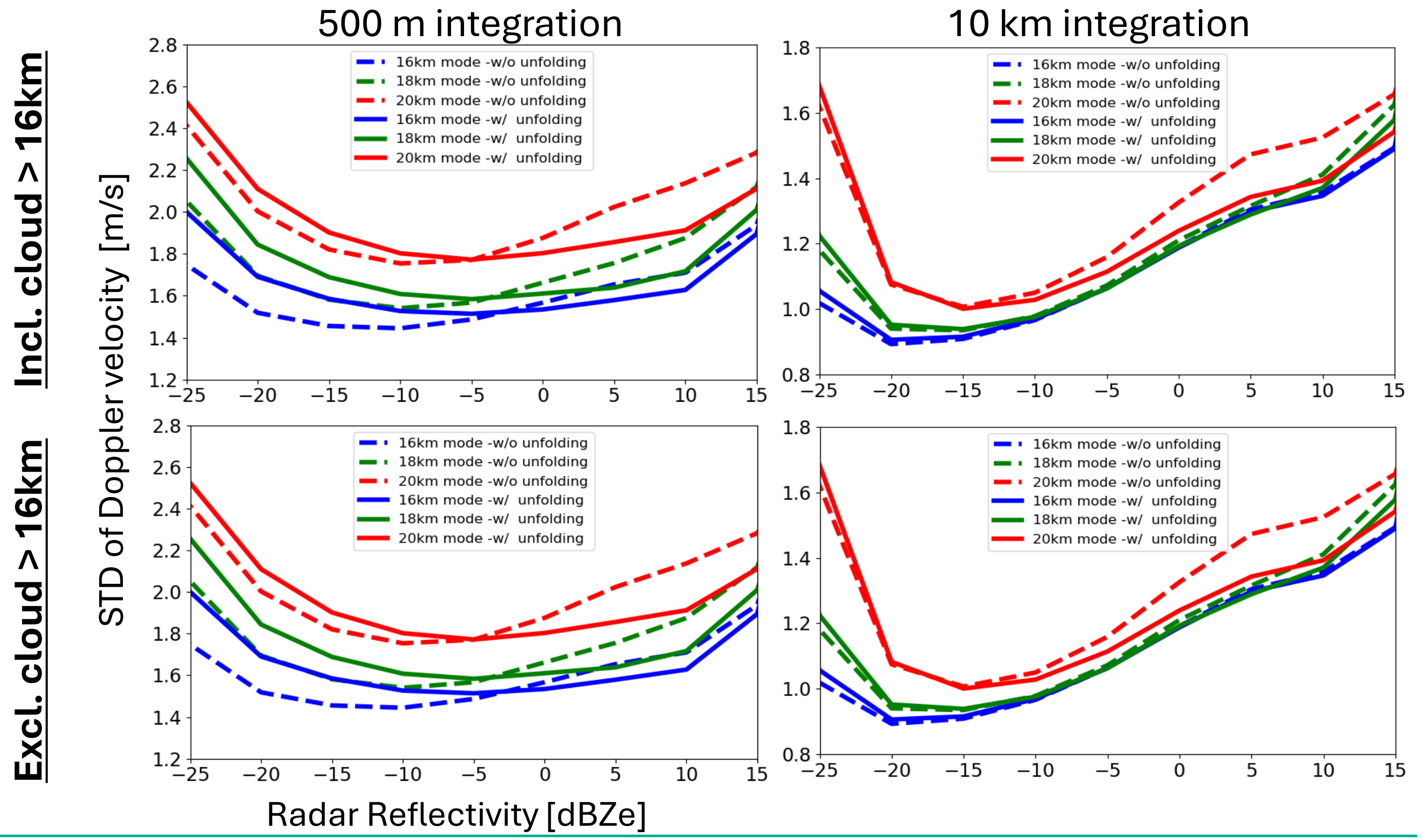
Comparisons of Doppler velocity measurements

- Calculated the standard deviation (STD) of the Doppler velocity for each radar reflectivity value
  Blue: 16km mode, Green: 18km mode, Red: 20km mode

Dotted line: w/o unfolding
Solid line: w/ unfolding

- We confirmed the difference between the two analysis methods, one including cloud above 16 km and the other excluding cloud above 16 km, to address the task raised in the previous WS.

- <u>The difference in the STDs of Doppler velocity between the two analysis methods is very small.</u>



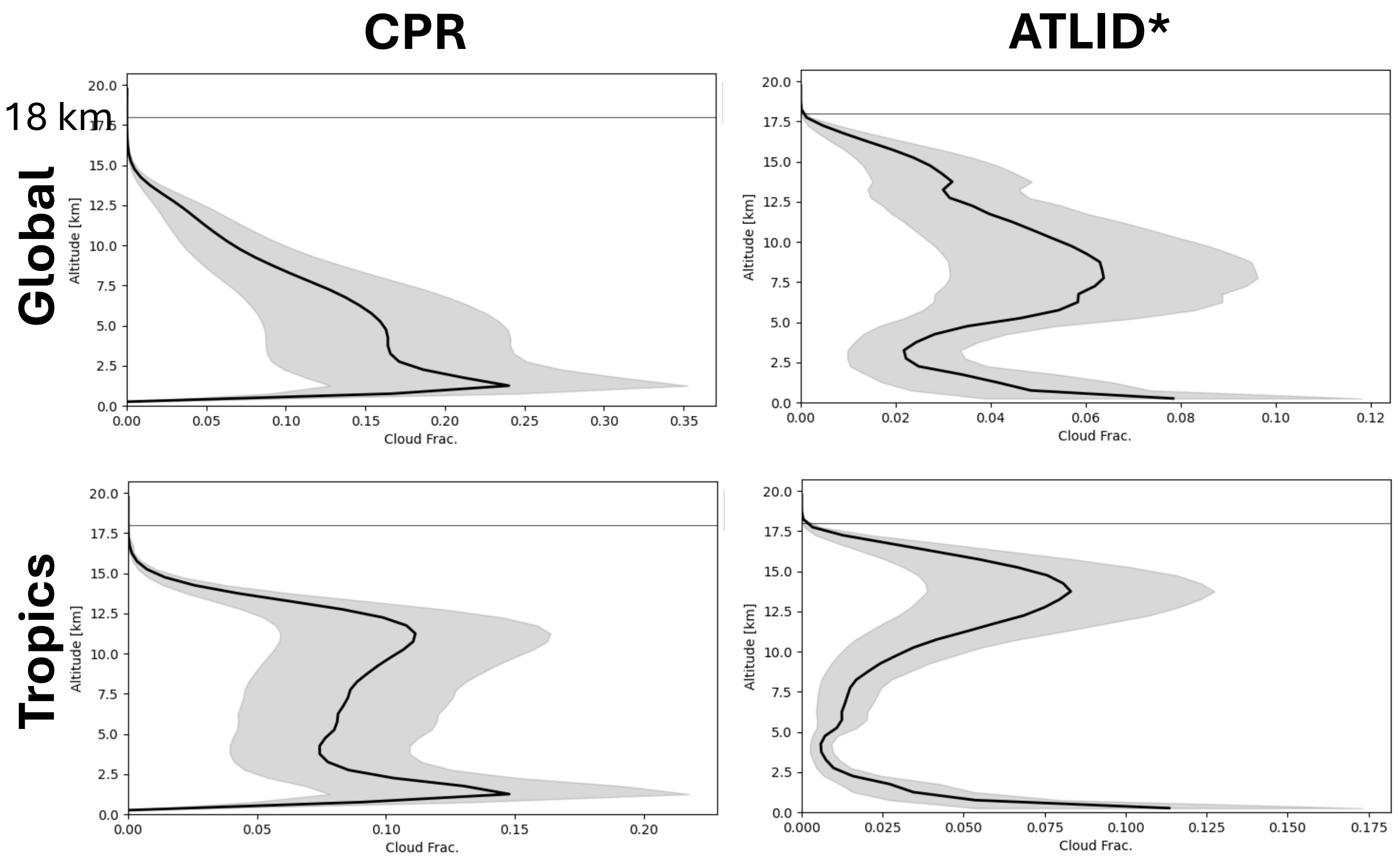
Analysis on high-level cloud fraction

- The calculated cloud fraction was derived from CPR L1b and ATLID L2a products.
- For CPR, the <u>cloud coverage above 16 km is only 0.022%</u>, which is why the STDs derived from the previous two methods were highly similar.
- <u>Clouds above 18 km were poorly detected</u> even by the ATLID, including in the tropics. This greatly supports the availability of the implementation of 18 km mode.

CldFrc > 18 km	CPR	ATLID
Global	0.012%	0.004%*
Tropics	0.003%	0.012%*

Vertical Distribution of Cloud Fraction

Shade: STD for the monthly mean values



2024/6/17 ~ 2025/2/15

2024/8/10 ~ 2025/2/28

*Cloud fraction above 12.5 km in the high latitudes was set to 0.

Impact of mirror image

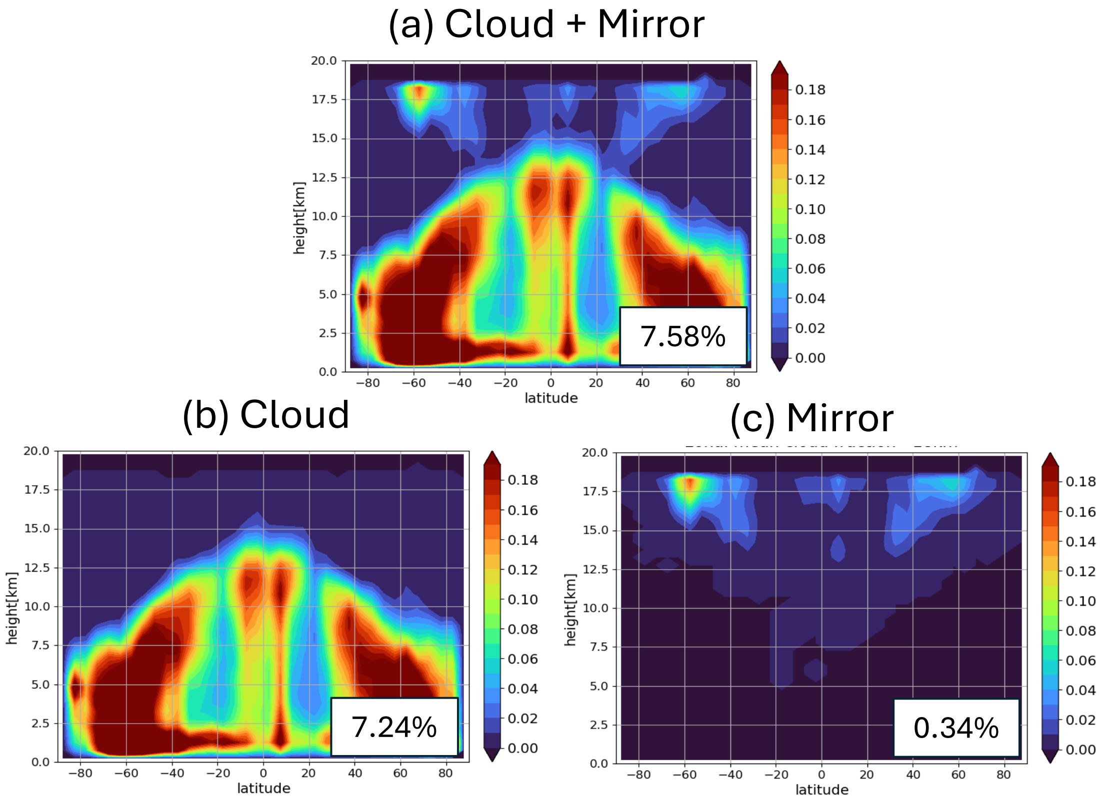
- It is pointed out that mirror image, which is a spurious cloud echo, tends to appear in the 18 km mode.
  *Reason: The 18 km mode has a PRF closer to that of the 16 km mode, which results in the distance from the observation upper limit of the mirror occurrence position in the 18 km mode being longer than in the 16 km and 20 km modes.

- Categorized cloud echoes into two types (real cloud echo and mirror image) 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.

- The peak in the tropics carries a risk of duplication b/w real cloud echoes and spurious mirror images. This issue can be addressed in the L2 algorithm. (Details will be provided by Aoki-san tomorrow.)

18 km mode



2024/11/9 ~ 2024/11/12

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 STD of Doppler velocity almost equal to that of the 16 km mode, likely due to the comparable PRF values used in both modes. Clouds above 16 km had minimal impact on the analysis of Doppler STD, because the cloud fraction above 16 km was very small (~0.022%).

- Comparison between CPR and ATLID data indicated that very few clouds were found above 18 km even by ATLID (~0.012% even in the tropics), suggesting that the 18 km mode can cover nearly all clouds.

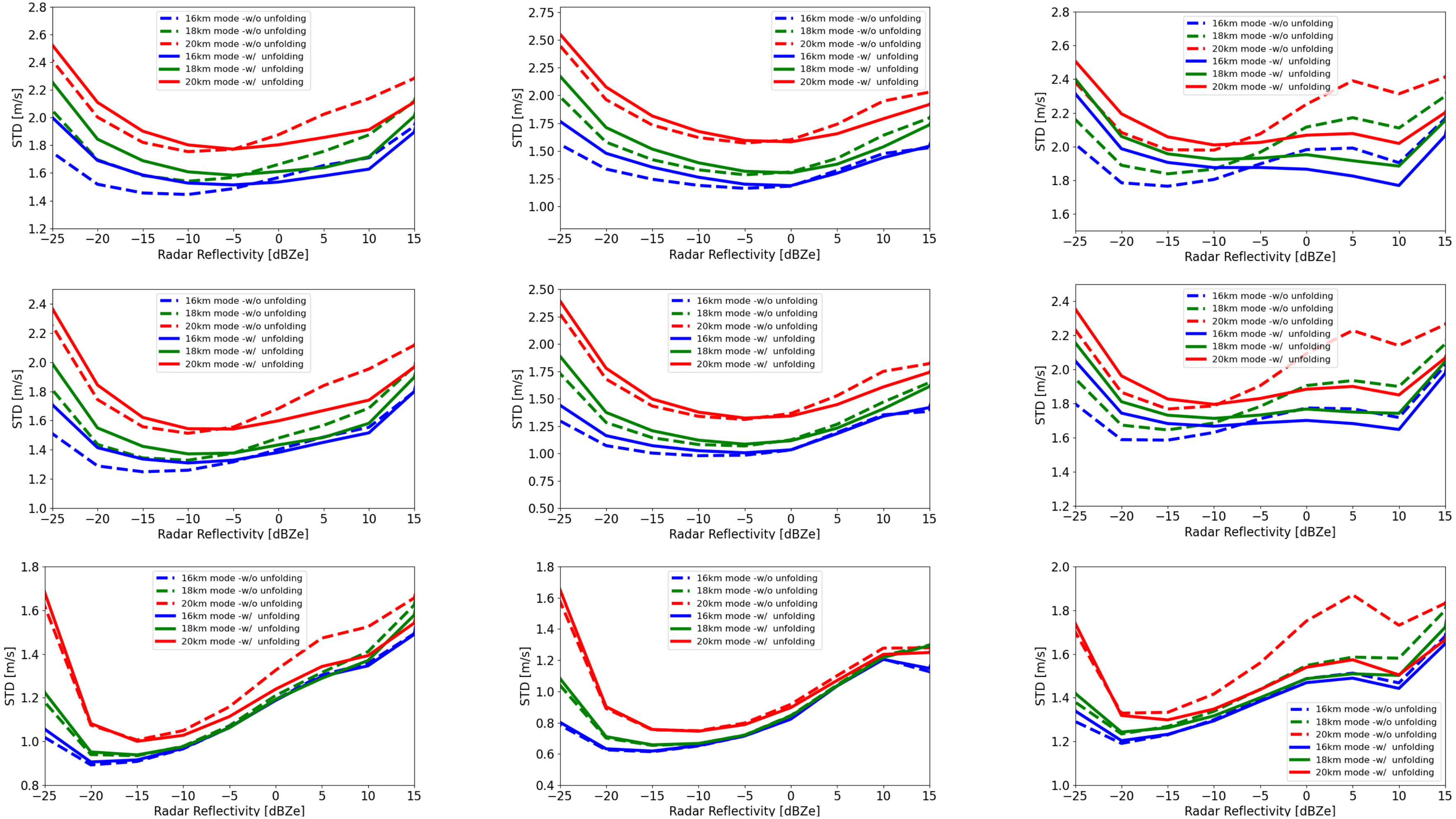
- There is an issue with mirror images that tend to appear in the 18 km mode. This issue can be mitigated in the L2 algorithm.

- **These results support the use of 18 km mode within the latitudes between 60S-60N for actual CPR operations.**

Supplemental Materials

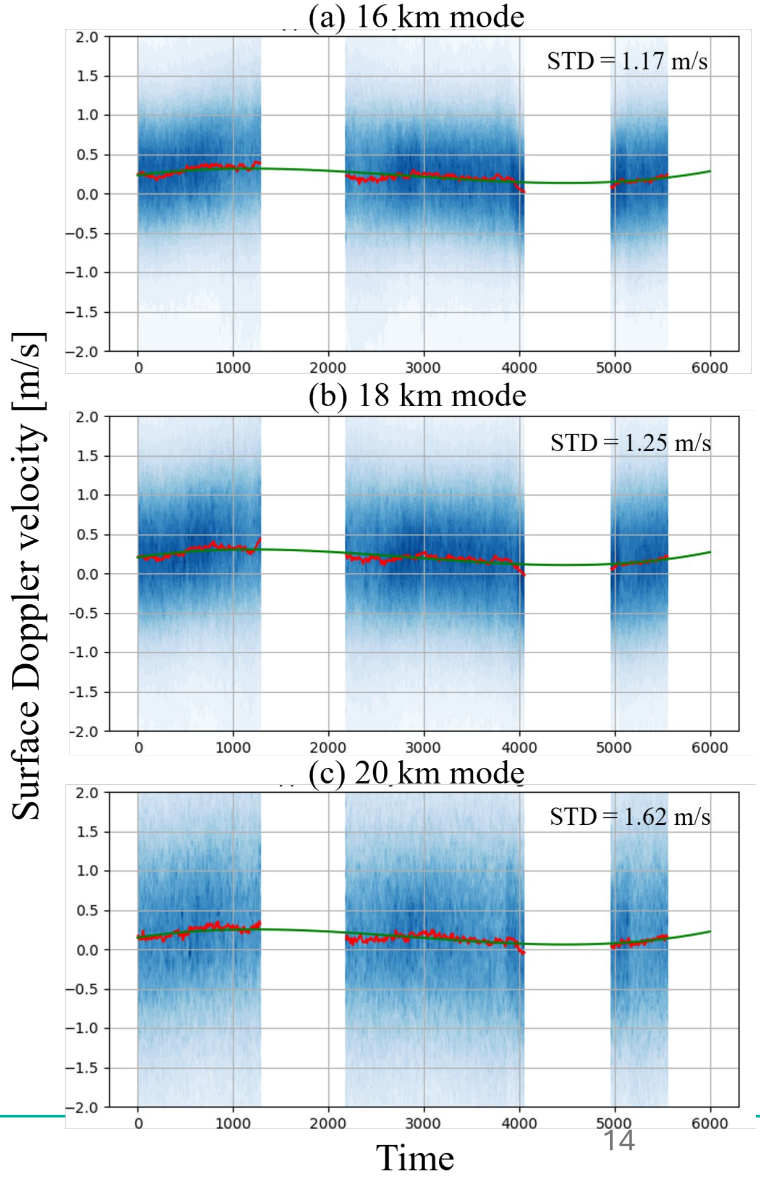
Regional analysis of STD of Doppler velocity

	Global	Mid Latitude (60S-30S, 30N-60N)	Tropics (30S-30N)
500 m intg.			
1 km intg.			
10 km intg.			



Measurement accuracy of surface Doppler velocity

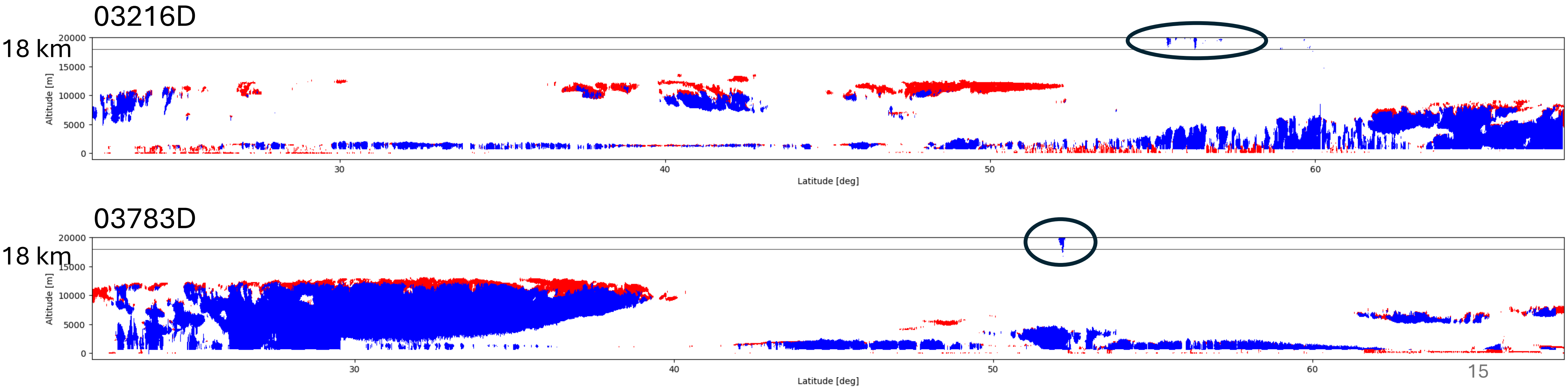
- Analyzed Doppler velocity at the surface and calculated standard deviations across the observation modes
- The horizontal axis represents time relative to the first ray in Frame A, with the time of the first ray set to 0. Analysis domain spans latitudes between 60S-60N, which explains the two margins 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.



Case study of mirror image

- Only a very small fraction of mirror images were mis-detected as real cloud echoes, contributing to the slight increase in real cloud fraction above 18 km.

Cloud domain detected by CPR and ATLID



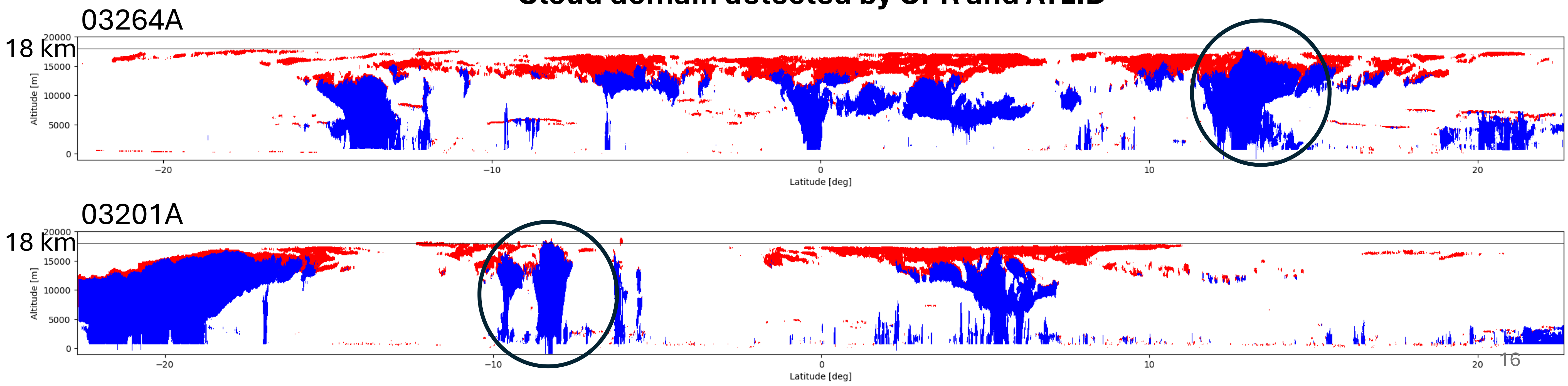
Red: ATLID (Feature Mask) Blue: CPR (Cloud Flag)

Case study of overshooting clouds

- The risk of implementing the 18 km mode was assessed in terms of very high-level clouds overshooting altitudes above 18 km, using a case study of tropical clouds.

- Some overshooting clouds were observed in the tropics, as indicated by CPR and ATLID data, but their occurrence is quite rare.

Cloud domain detected by CPR and ATLID



Red: ATLID (Feature Mask) **Blue: CPR (Cloud Flag)**

Vertical distribution of mirror image

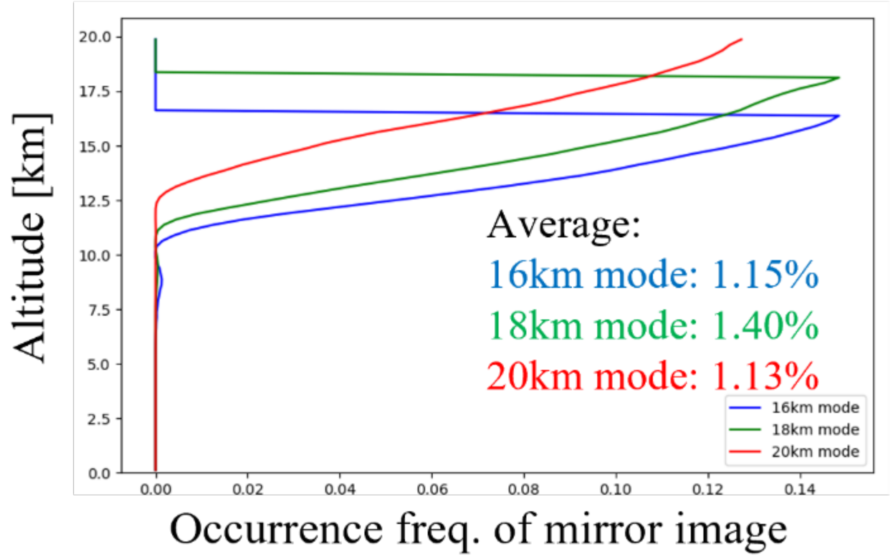
■ It is pointed out that mirror image, which is a spurious cloud echo, tends to appear in the 18 km mode.

*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.

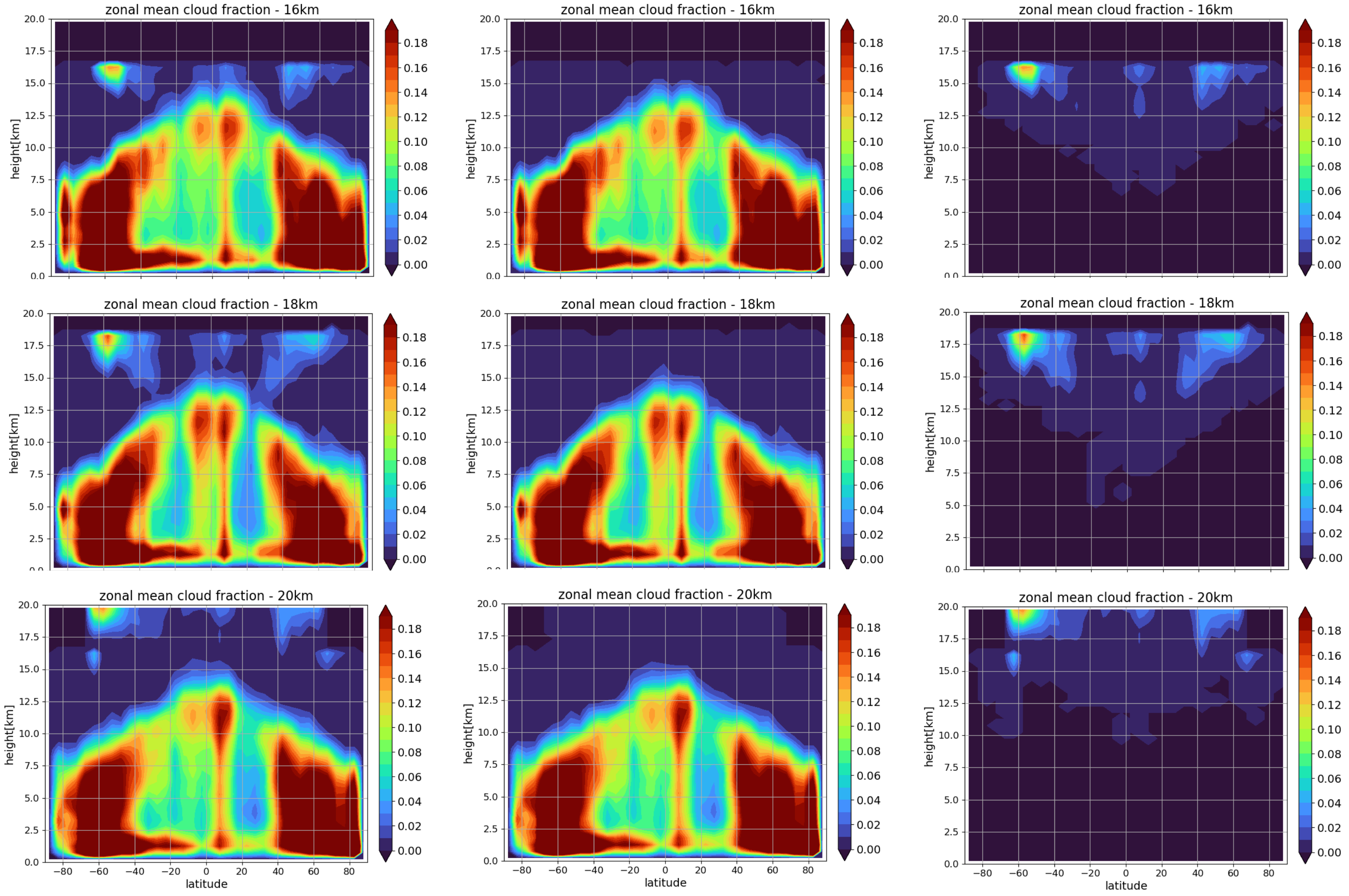
■ The vertical distribution of mirror image frequency in the 18 km mode is closer to that in the 16 km mode, rather than the 20 km mode, likely due to its PRF value.

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



Occurrence of categorized cloud types

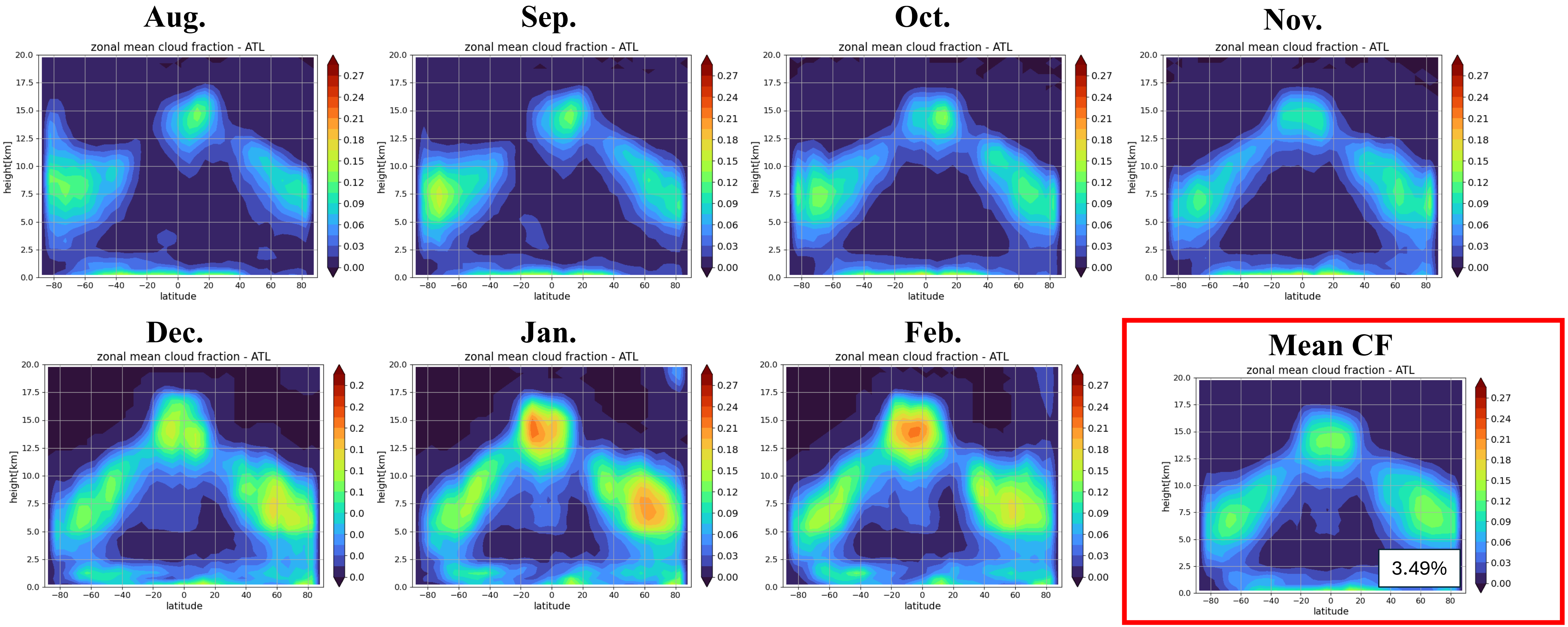
	Cloud+Mirror	Cloud	Mirror
16 km mode			
18 km mode			
20 km mode			



2024/11/1 ~ 2024/11/12

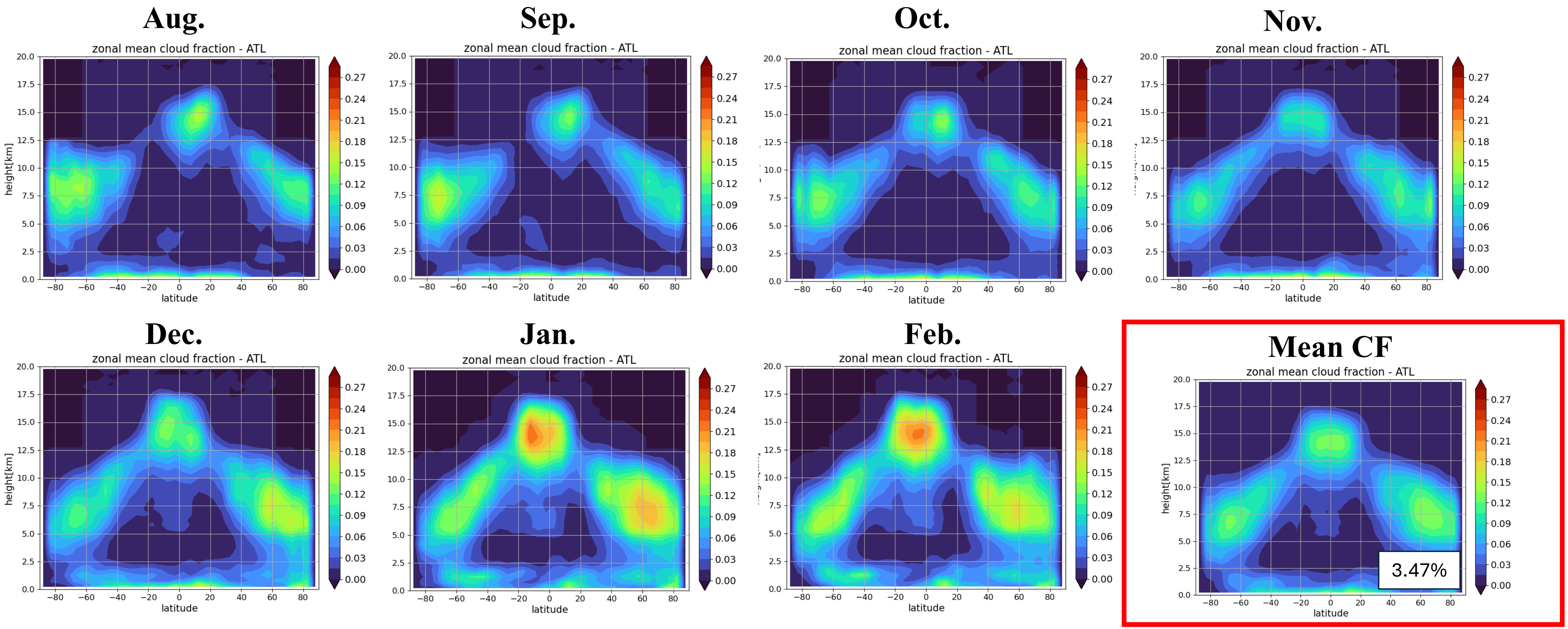
Cloud fraction by ATLID

Cloud fraction above 12.5 km in the high latitudes (>60S, >60N) was not set to 0.

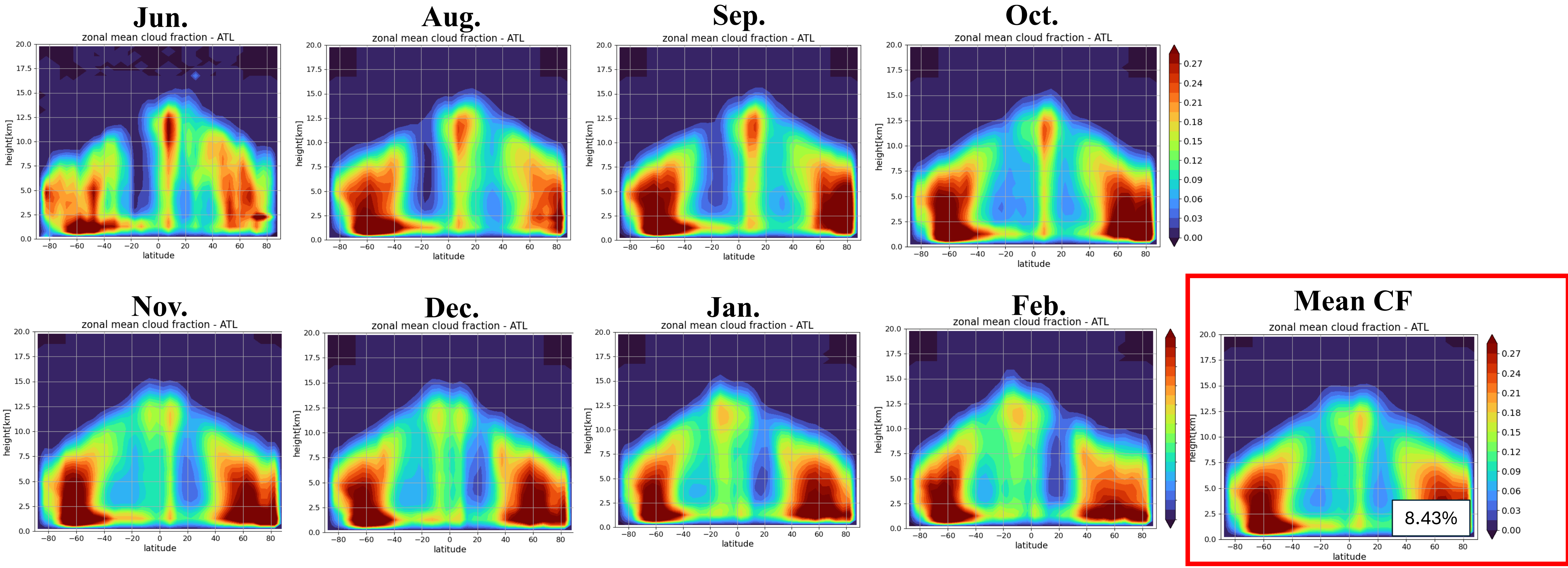


Cloud fraction by ATLID

Cloud fraction above 12.5 km in the high latitudes (>60S, >60N) was set to 0.

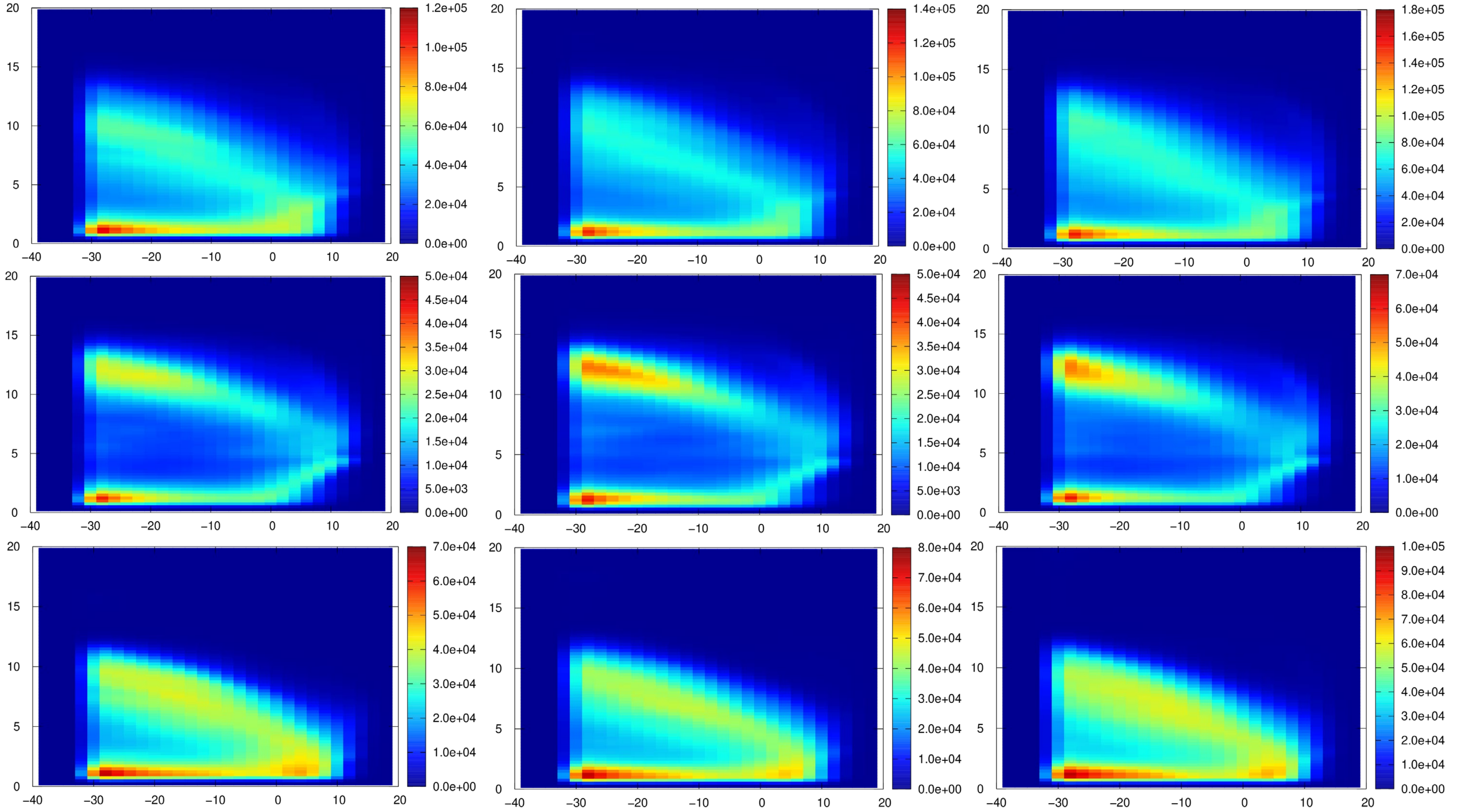


Cloud fraction by CPR



CFAD

	16 km mode	18 km mode	20 km mode
60S-60N			
Tropics (30S-30N)			
Mid Latitude (60S-30S, 30N-60N)			



2024/11/1 ~ 2024/11/12