



Validation of CPR radar reflectivity and Doppler velocity with HALO aircraft observations

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EUROPEAN SPACE AGENCY

Introduction

PERCUSSION campaign with a focus on validation

Campaign period
09 Aug – 19 Nov 2024

Campaign locations

- ▶ Cape Verde / Sal: ITCZ, Aerosol
- ▶ Barbados: ITCZ, Convective organization
- ▶ Germany: Dedicated validation flights

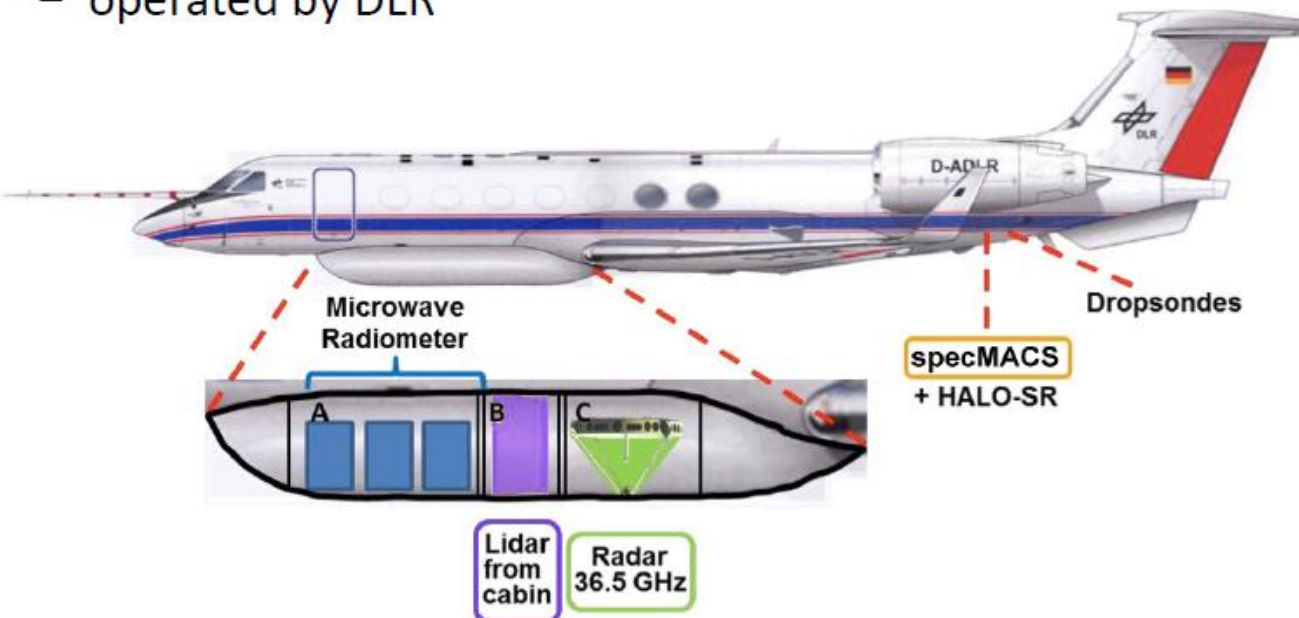
Campaign duration – 9 weeks

- ▶ 296 flight hours (incl. transfer and certification)
- ▶ 28 Scientific flights: 11 (Sal), 10 (Barbados), 7 (Germany)
- ▶ 33 EarthCARE / 4 PACE underpasses
- ▶ Embedded within the ORCESTRAS campaign:



HALO aircraft

- G550, max. alt 15 km / max. range: 8000 km
- In operation since 2012
- operated by DLR



Scientific Instruments

- HSRL-Lidar (WALES, 532 nm – Wirth et al. 2009)
- Cloud Radar (HAMP MIRA, 35 GHz – Ewald et al. 2019)
- Hyper-Spektral Imager (specMACS – Ewald et al. 2016)
- Microwave Radiometer (HAMP passive – Mech et al. 2014)

Specification of MIRA and CPR

	HAMP/MIRA	EarthCARE/CPR
Frequency	35.2 GHz	94.05 GHz
Pulse Power	30 kW	1.5 kW
Repetition rate	7.5 kHz	6.1-7.5 kHz
Antenna diameter	1 m	2.5 m
Beam width	0.6°	< 0.095°
Min. detect. Signal @10 km	-42 dBZ	< -35 dBZ

➤ Validate CPR radar reflectivity and Doppler velocity using HALO aircraft-borne MIRA with a Ka band.

Methodology

- CPR L1b vDa data were used. Statistical analyses were conducted for all matchup cases with MIRA.
- For Doppler velocity, bias correction was applied using surface Doppler velocity. Folding correction was applied for values exceeding +3 m/s.
- For CPR data, spatial interpolation (nearest-neighbor) was applied to match the MIRA data spacing.
- For MIRA data, a 10 km moving average was applied to ensure consistency with the CPR 10 km integrated data.

Doppler velocity (IQ offset) correction

- The post-hoc IQ offset correction was applied by subtracting the real part of the noise covariance $Re(\hat{R}_{noise})$, which well represents the IQ bias, from the measured complex covariance \hat{R} :

$$R = \hat{R} - Re(\hat{R}_{noise}).$$

The noise region was defined as $Z < -40$ dB. Outliers were removed prior to calculating mean values.

Radar reflectivity (K-value) correction

- The radar reflectivity factor Z for both MIRA and CPR is defined as:

$$Z = \frac{\eta \lambda^4}{\pi^5 |K|^2} \quad (\eta: \text{radar reflectivity}, \lambda: \text{wavelength}, K: \text{normalizing dielectric factor})$$

- $|K|^2$ is 0.93 for MIRA, and 0.75 for CPR. \Rightarrow necessary to account for this difference

$$Z \propto |K|^{-2} \Rightarrow Z_W = Z_{Ka} + 10 \log_{10} \left(\frac{|K_{Ka}|^2}{|K_W|^2} \right) \text{ (dBZ)} \cong Z_{Ka} + 0.93 \text{ (dBZ)}$$

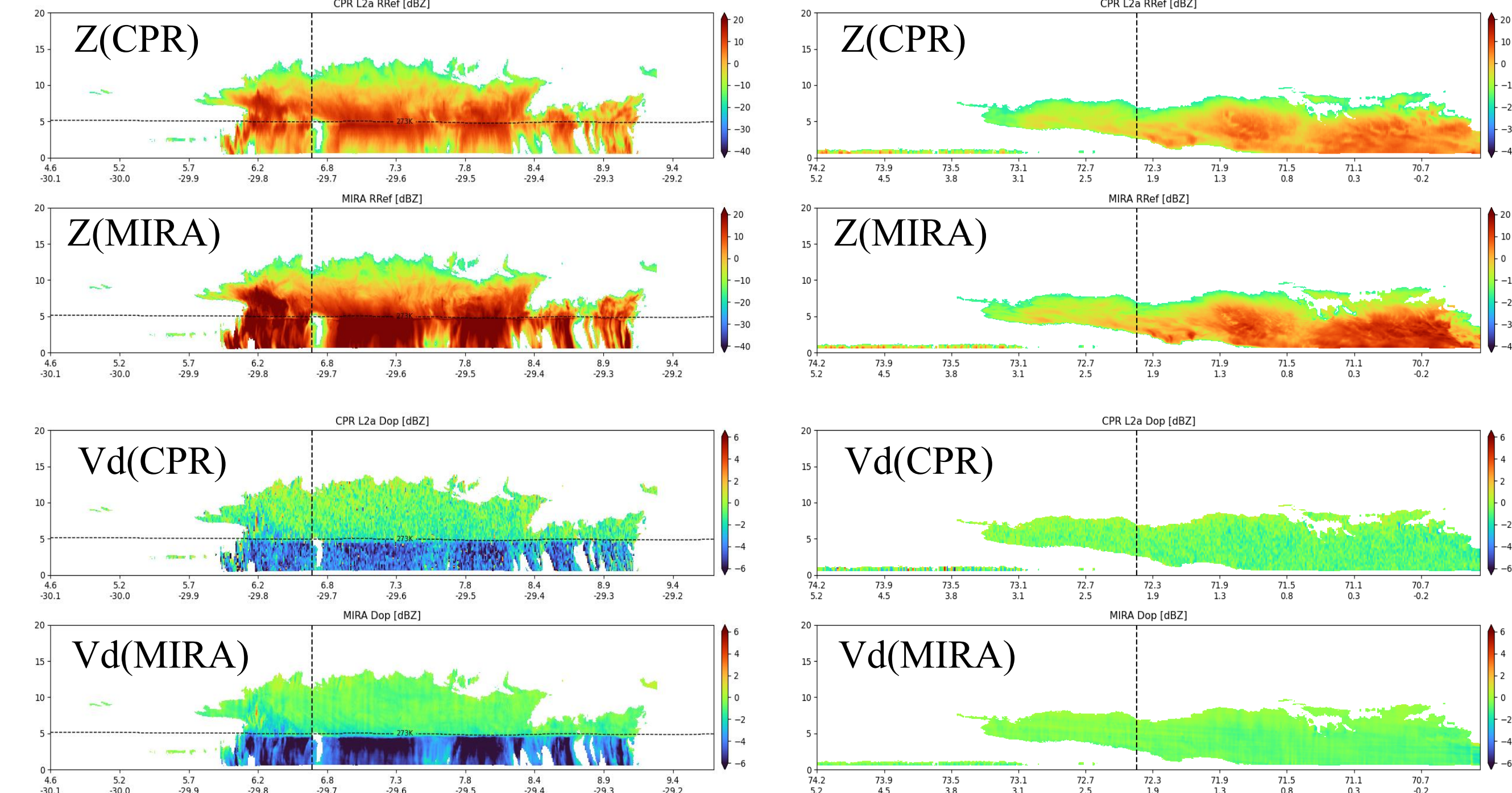
- Focused on regions below 253 K, where ice clouds are dominant and K -value is stable.

Result (Imura et al., in prep.)

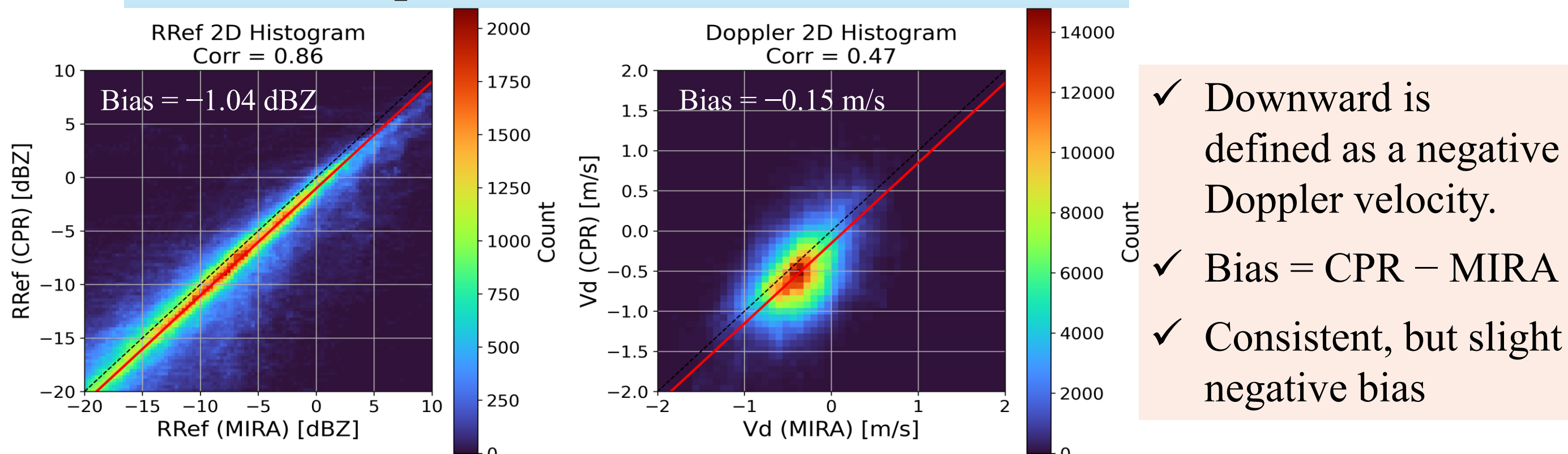
Case study

Case 1 (18 Aug. 2024)
Tropical convective system

Case 2 (14 Nov. 2024)
Arctic stratiform clouds

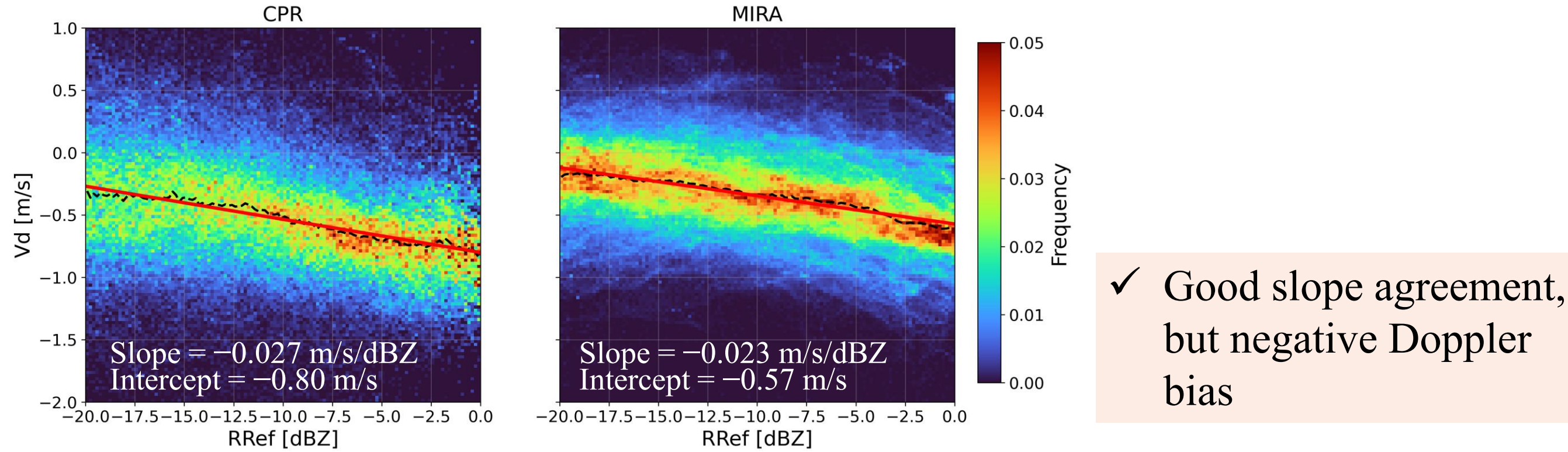


1-to-1 comparison between CPR and MIRA



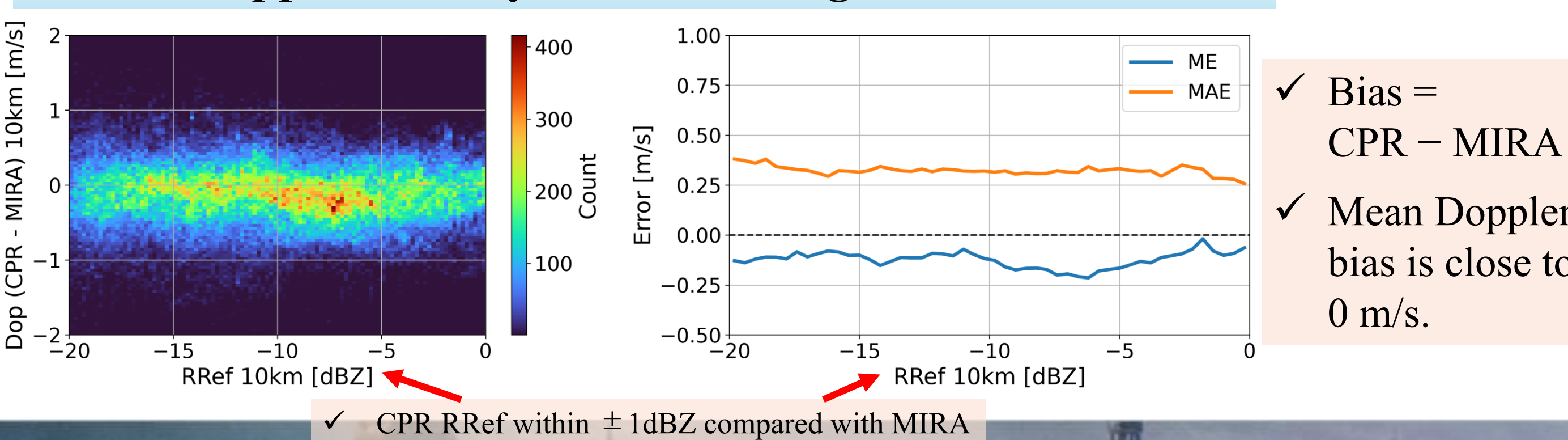
- ✓ Downward is defined as a negative Doppler velocity.
- ✓ Bias = CPR – MIRA
- ✓ Consistent, but slight negative bias

Z-Vd relationship



- ✓ Good slope agreement, but negative Doppler bias

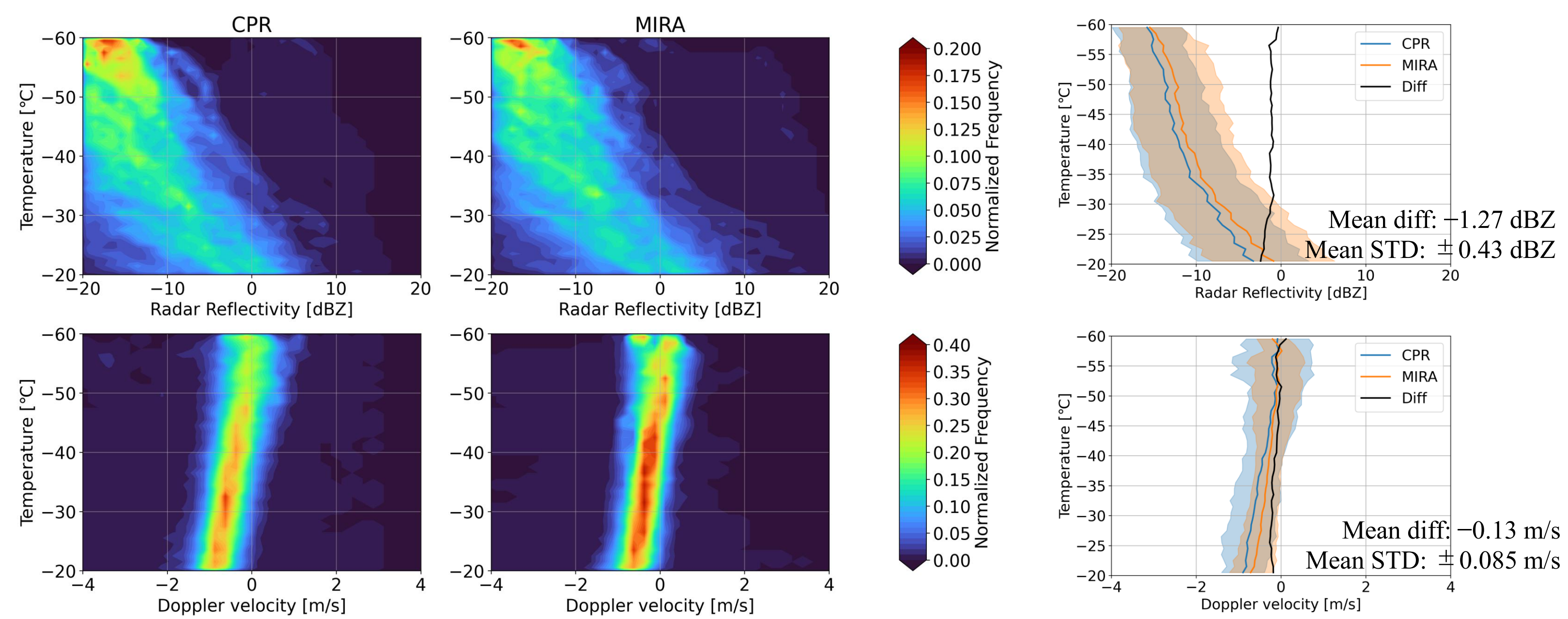
Doppler velocity bias of CPR against MIRA



- ✓ Bias = CPR – MIRA
- ✓ Mean Doppler bias is close to 0 m/s.

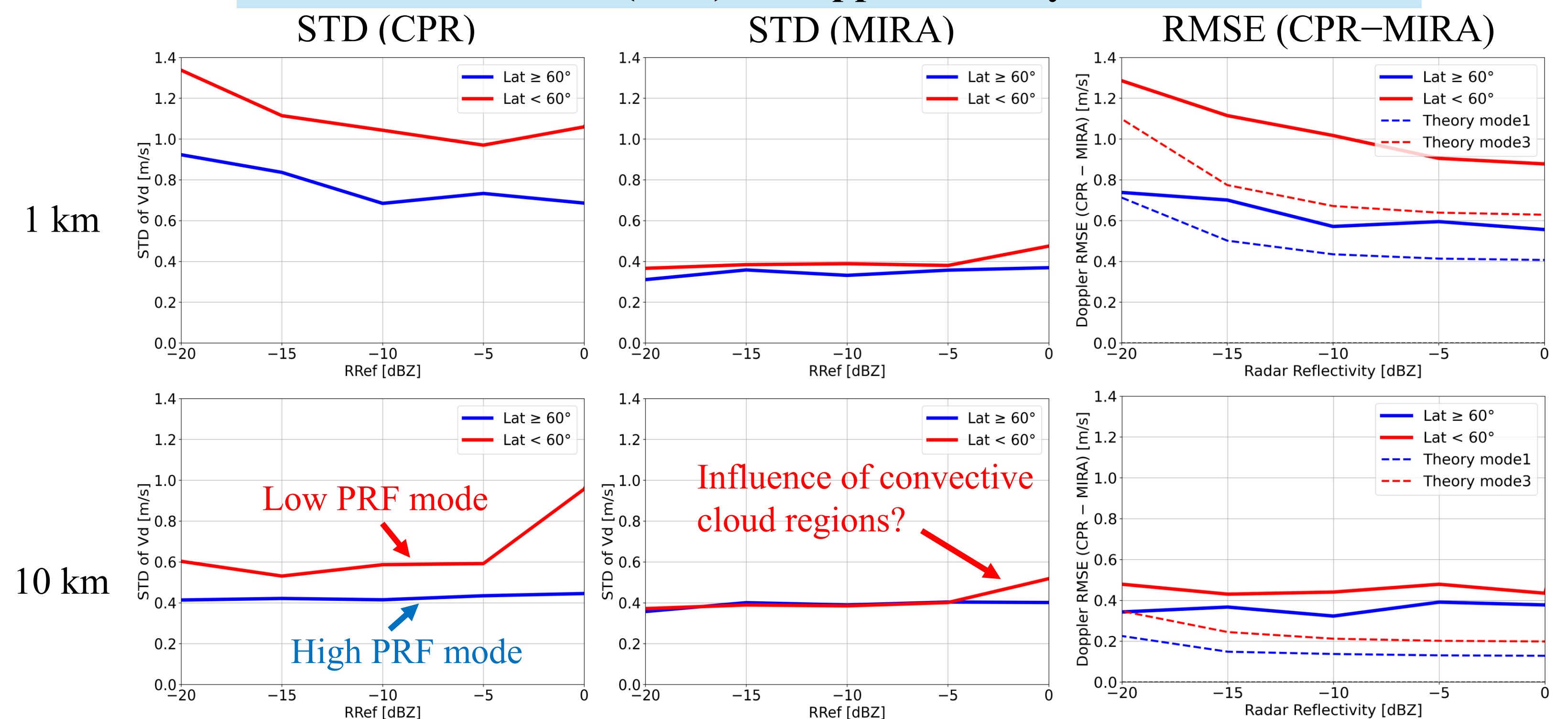
✓ CPR RRef within ± 1dBZ compared with MIRA

Contoured Frequency by tEmperature Diagram (CFED) (> -20 dBZ)



✓ CPR well captures microphysical characteristics

Standard deviation (STD) of Doppler velocity as a function of Z



- Doppler velocity = (Velocity from random error within beam width) + (Velocity from natural variability)
- Assuming MIRA random error is very small, the RMSEs can be purely interpreted as the Doppler random error of CPR.

Conclusion, future work, and acknowledgement

- It is found that CPR qualitatively and quantitatively captures radar reflectivity and Doppler velocity well through direct comparison with HAMP/MIRA.
- To gain more robust insight into CPR observational performance, future studies should incorporate comparisons with other aircraft-borne radars, such as CRS onboard NASA's aircraft, as well as ground-based radars. Future work will also focus on validating CPR L2 products using additional cloud-related variables, such as liquid/ice water content and effective radius.
- Acknowledgement: We would like to thank Prof. K. Nakamura for proposing the method of IQ offset correction.

EarthCARE 2026 Science and Validation workshop

8–12 June 2026 | Rhodes House | Oxford, UK