The EarthCARE CPR L2A C-PRO data products: Post-launch updates and performance evaluation

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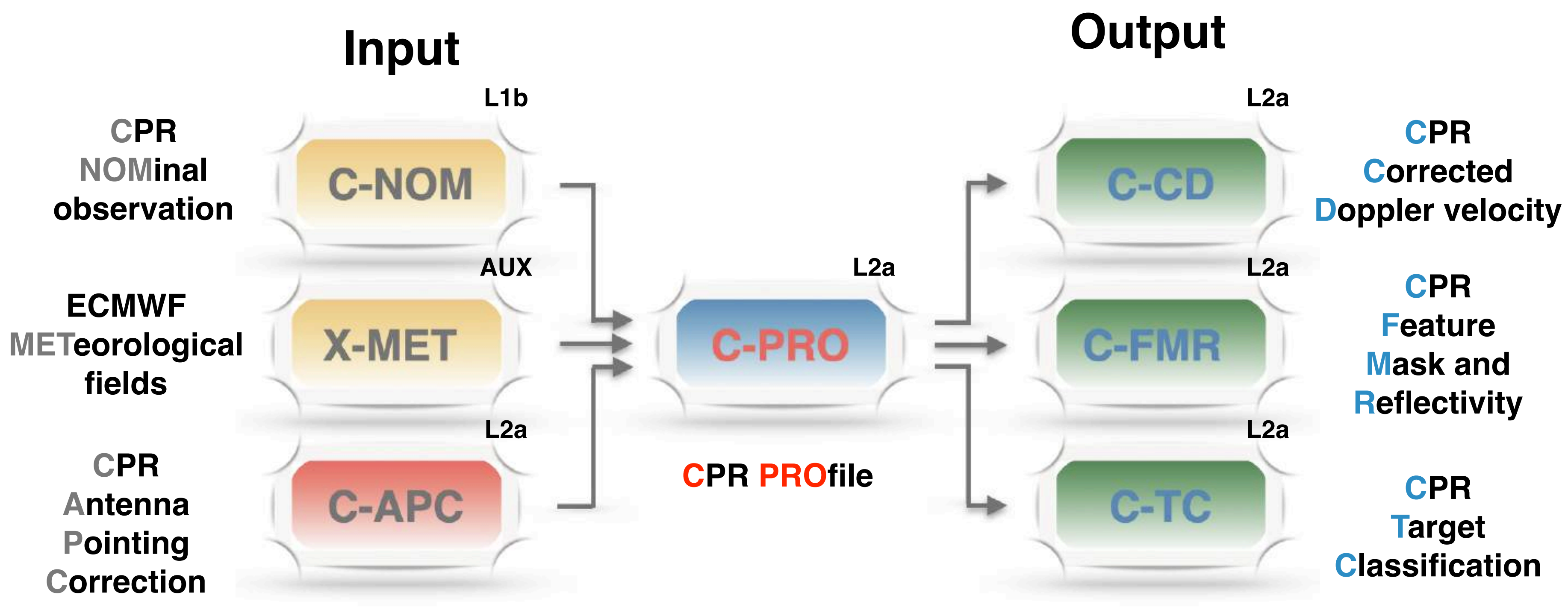
2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop
17 – 20 March 2025 I ESA-ESRIN I Frascati (Rome), Italy

Introduction

C-PRO

L2a CPR quality control processor



C-PRO list of algorithms

Radar reflectivity calibration
Gaseous attenuation correction
Second-trip echoes
Antenna mispointing correction
Path Integrated Attenuation estimation
Target classification
Clutter detection
Noise-floor estimation
Feature Mask
Multiple scattering detection
Non-Uniform Beam Filling correction
Doppler velocity unfolding
Sedimentation velocity
Stratiform/convective classification
Etc.

Introduction

C-PRO

L2a CPR quality control processor

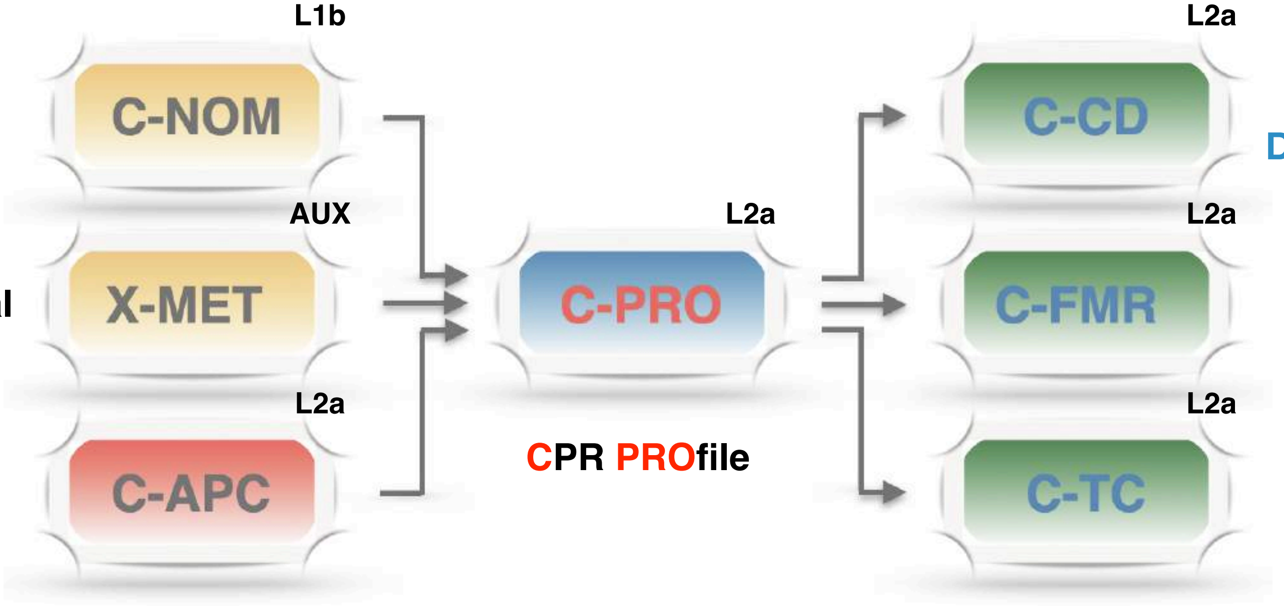
Input

CPR NOMinal observation

ECMWF METeorological fields

CPR Antenna Pointing Correction

Output



CPR PROfile

CPR Corrected Doppler velocity

CPR Feature Mask and Reflectivity

CPR Target Classification

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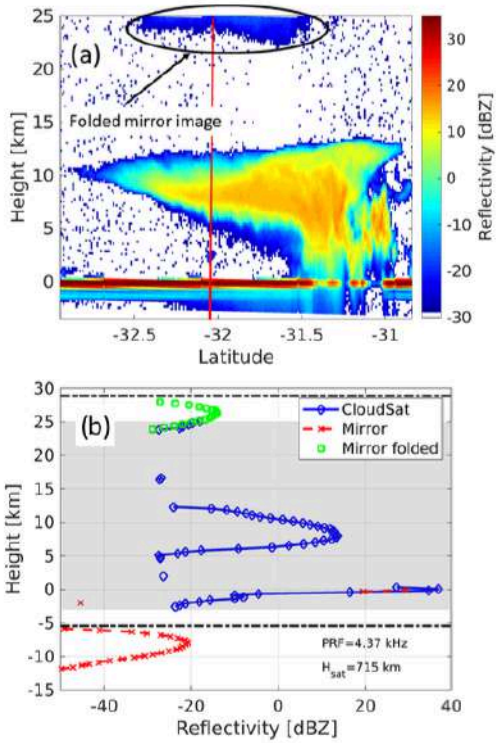
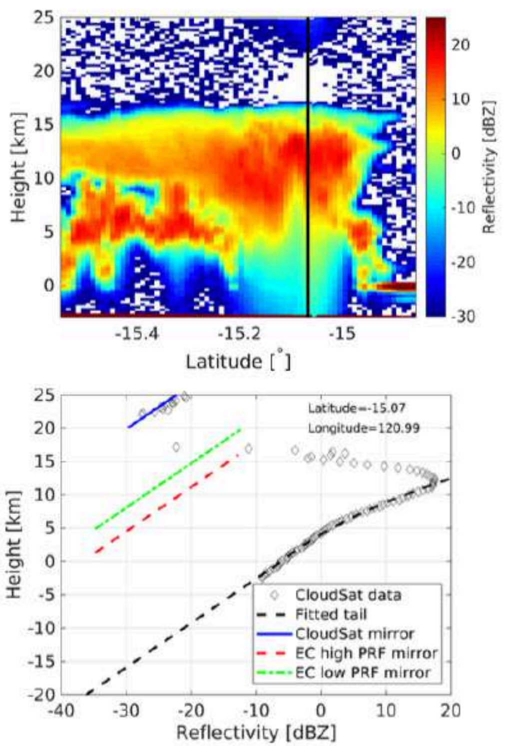
Reflectivity and Doppler Velocity

Second-trip Echoes

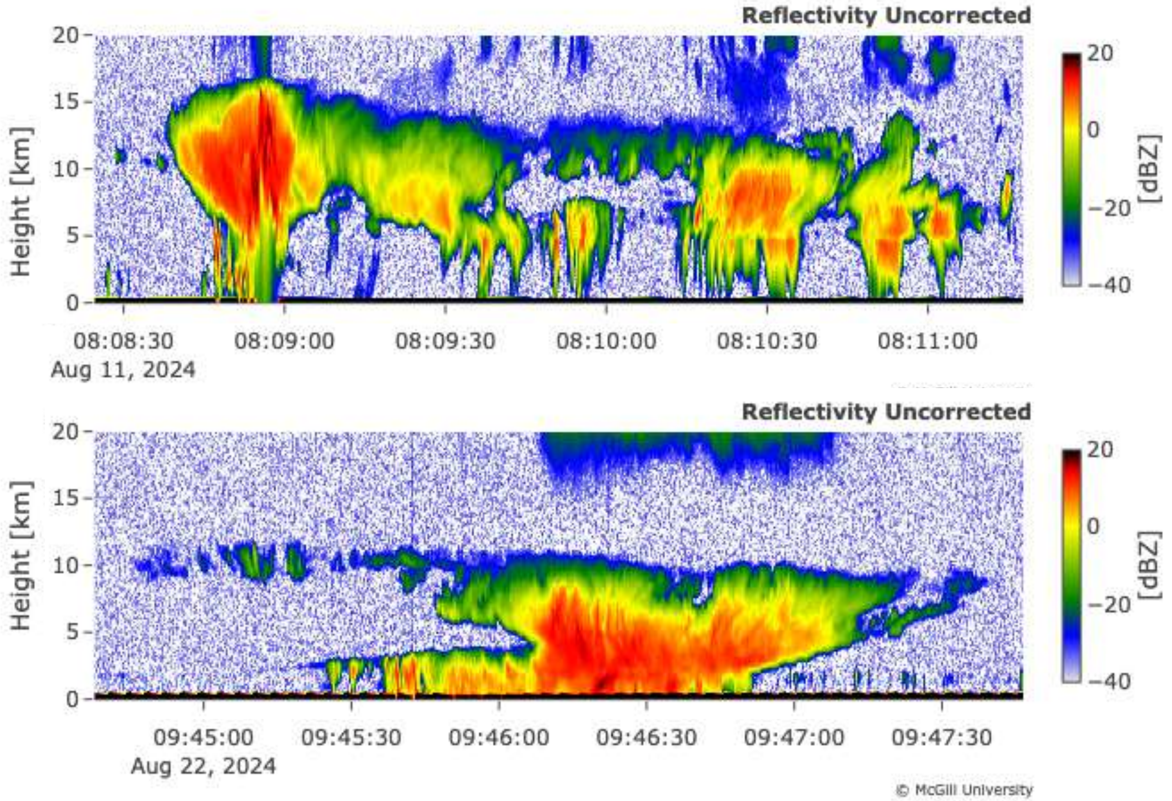
Mirror images



Multiple scattering tails



Examples



Impact of second-trip echoes for space-borne high-pulse-repetition-frequency nadir-looking W-band cloud radars
Alessandro Battaglia

Second-trip Echoes

CPR_FMR_2A

$$10\log_{10}\left[P_r(r_m)\right] = 10\log_{10}\left[P_r(r_t)\right] - 4A_{\text{surface}\rightarrow\text{target}} + 10\log_{10}\left[\frac{(H_{sat}-H_t)^2\,\Gamma^4\sigma_0}{\sigma_0 H_{sat}^2 + 11.04\Gamma^2\frac{H_t^2}{\theta_{3\,\mathrm{dB}}^2}}\right]$$

Γ = Fresnel reflection coefficient
σ_0 = sigma-zero
θ = beam width
H_{sat} = satellite altitude
H_t = height

Adjust the attenuation using the actual signal to account for all different sources of uncertainty

Identification and mitigation

1) Model the mirror images and multiple scattering tails
2) Identification mask
3) Remove the echoes based on local-correlation conditions and second-derivatives
4) Suppression of echoes overlapping with the actual signal is not yet implemented

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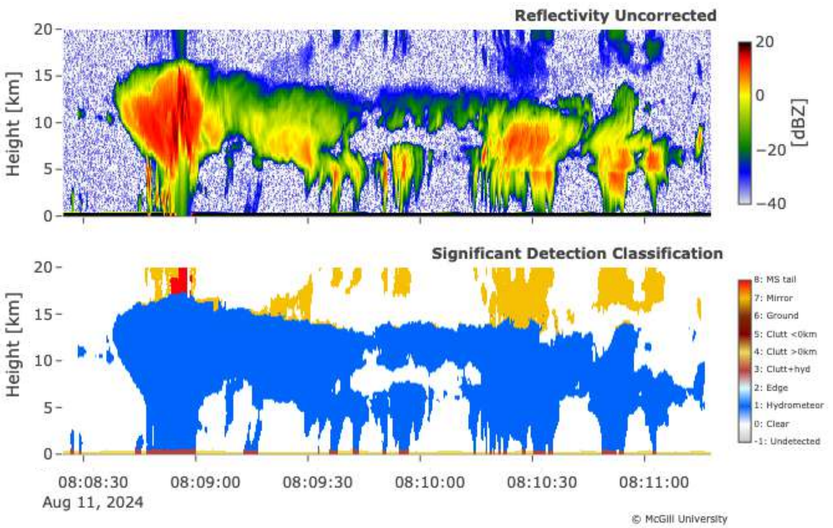

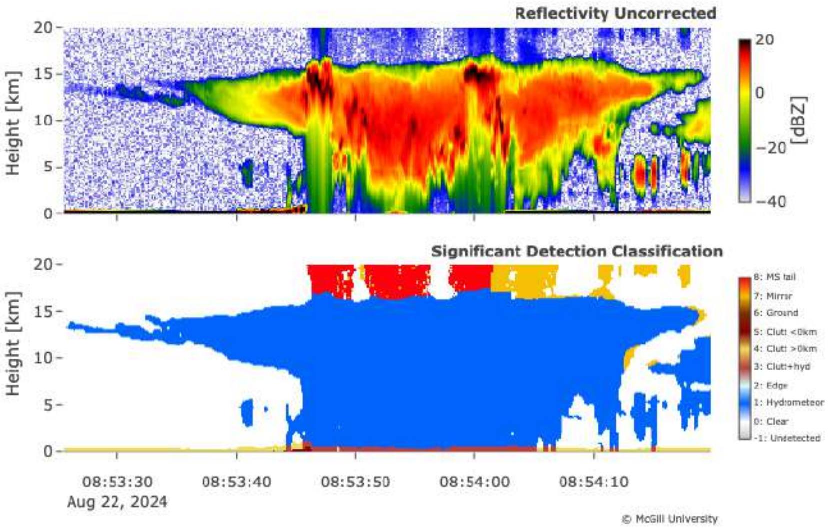

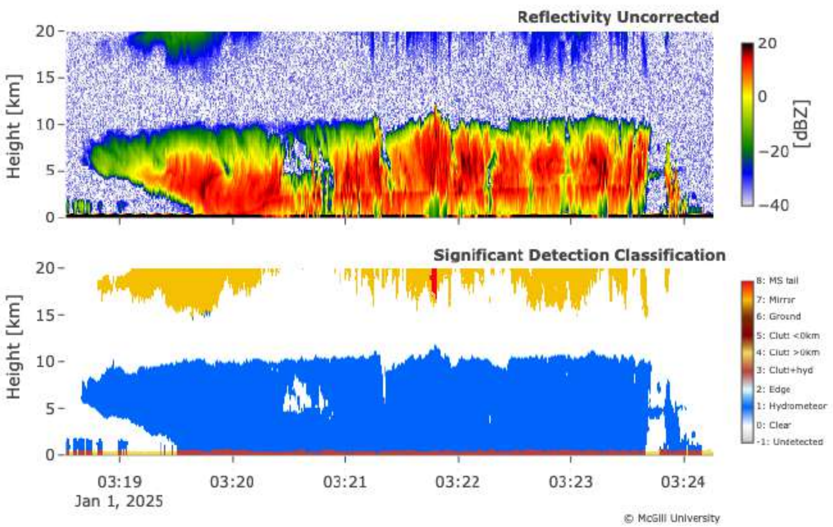

Second-trip Echoes

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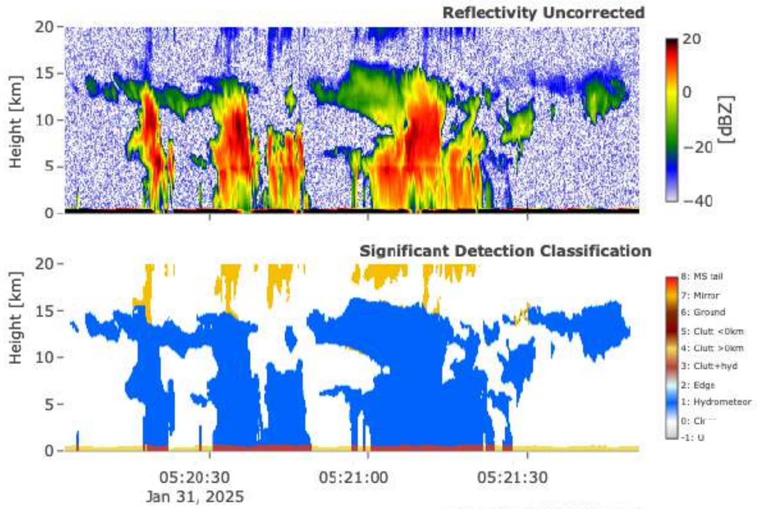
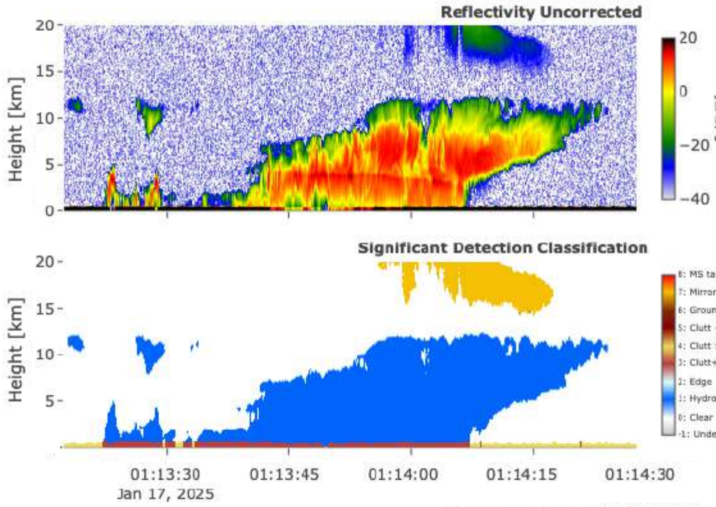
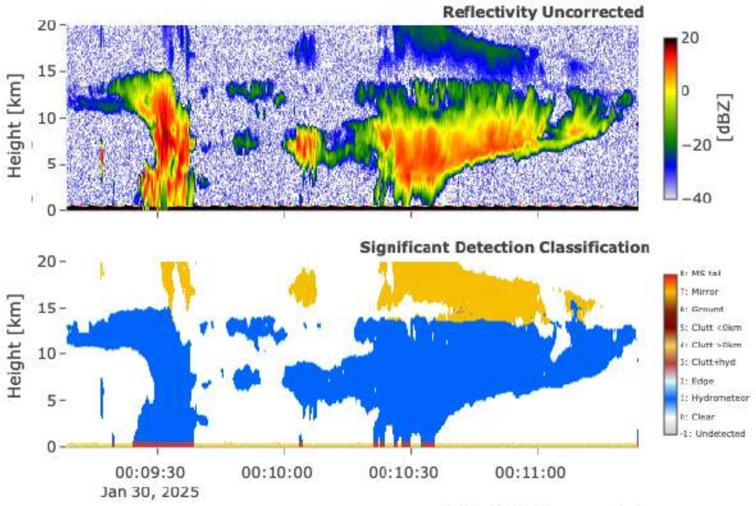
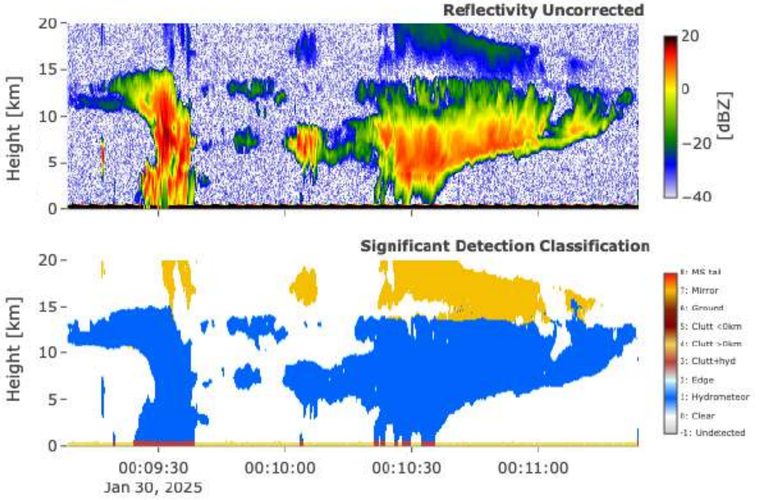
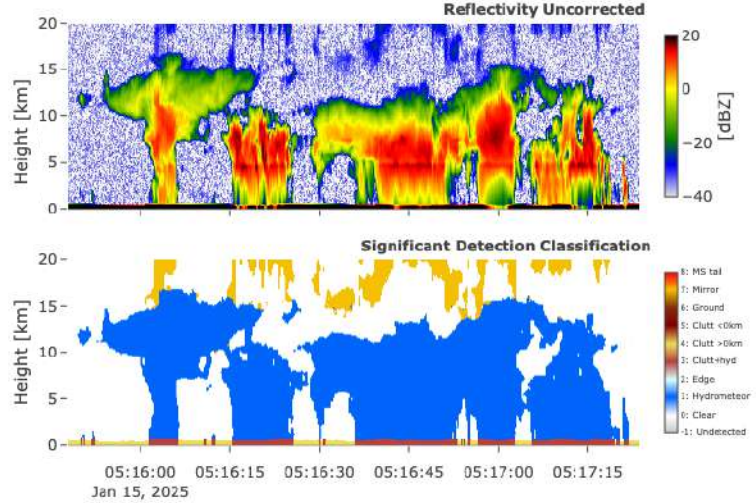
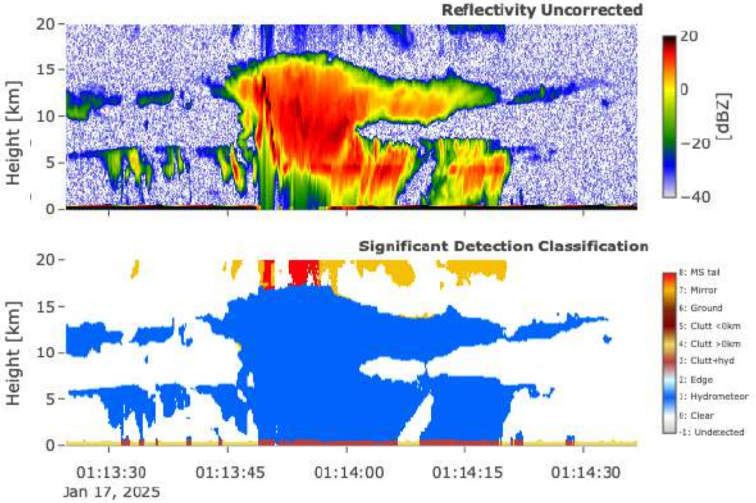








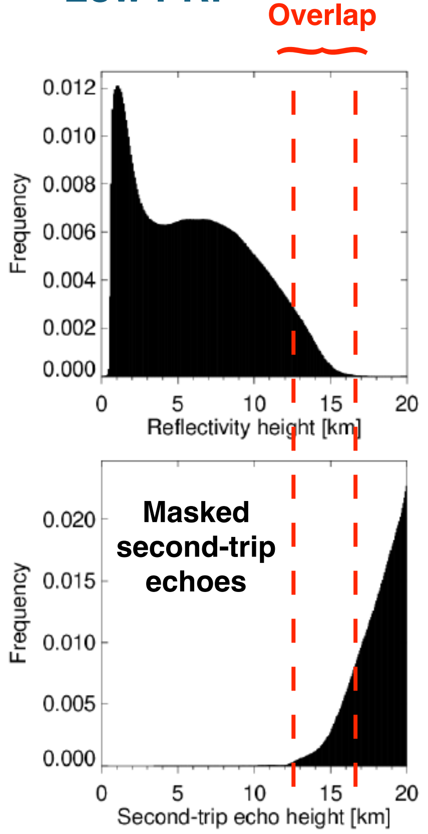




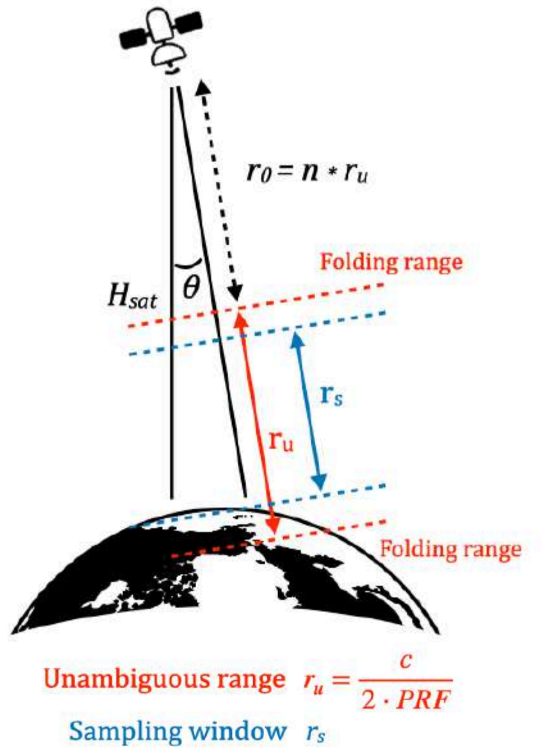
The PRF Dilemma

Higher PRF → increased overlap of second-trip echoes

Low PRF



The PRF determines the unambiguous range



The unambiguous range (r_u) is the maximum distance at which a target can be located to ensure that the backscattered power received corresponds to the latest transmitted pulse

The PRF Dilemma

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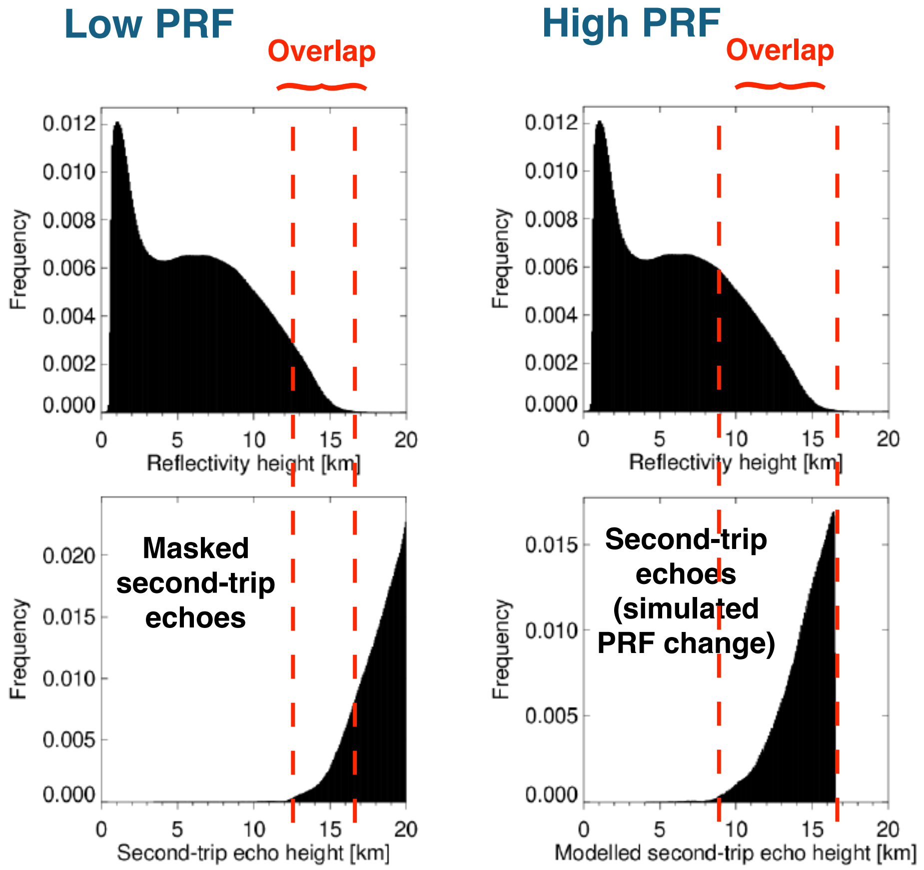

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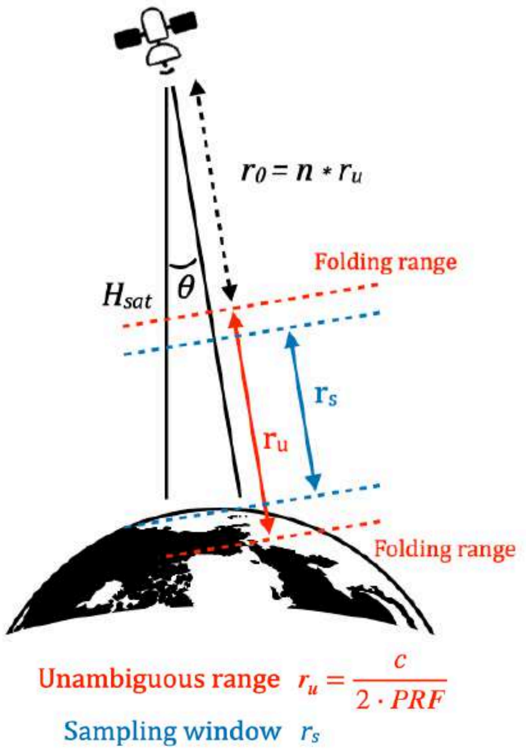

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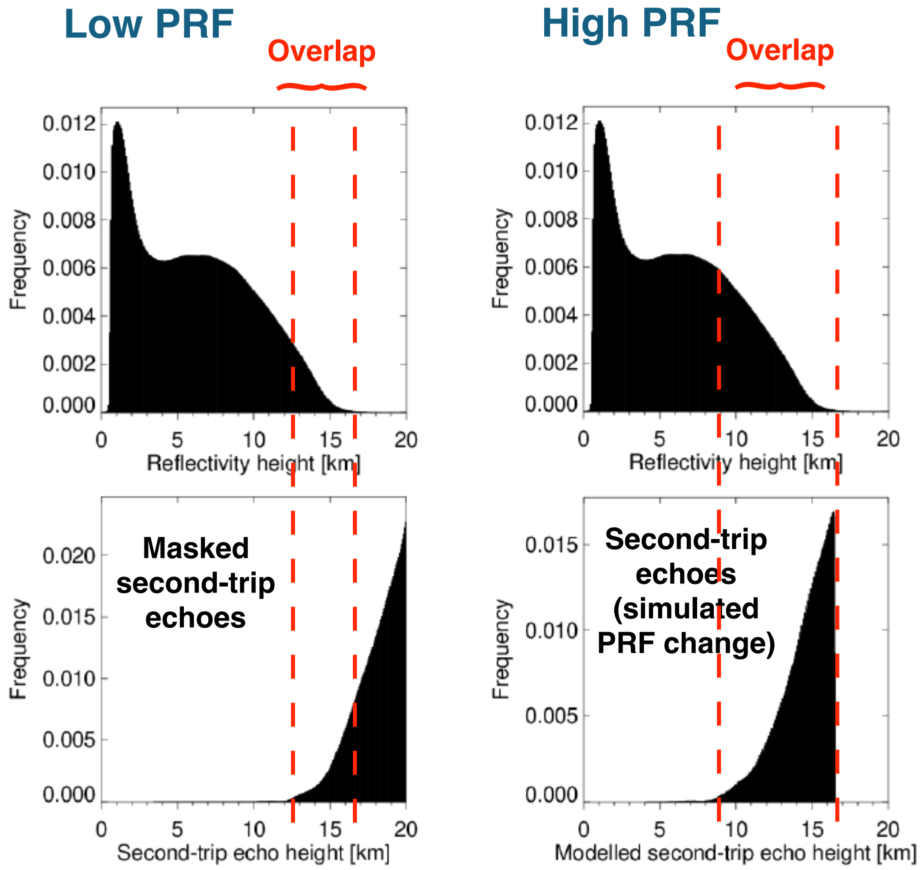
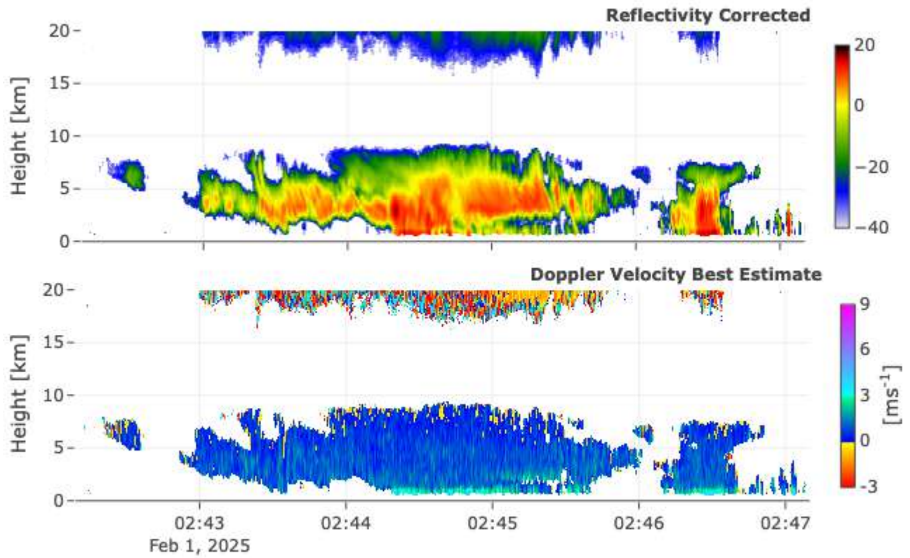
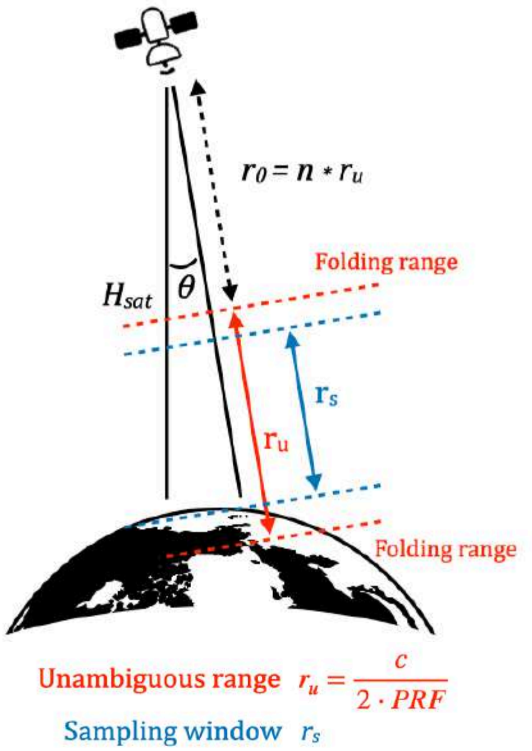




The Doppler velocity of all mirrors has an opposite sign → the impact of overlapping artifacts affects both Z and MDV

The PRF determines the unambiguous range



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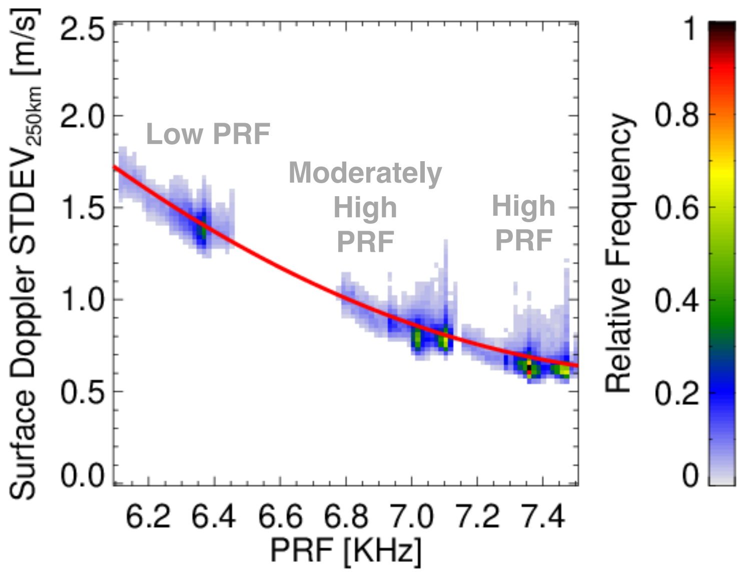
The PRF Dilemma

Higher PRF → better Doppler velocity measurements

High PRF Activity
November 6-12, 2024



The PRF Dilemma

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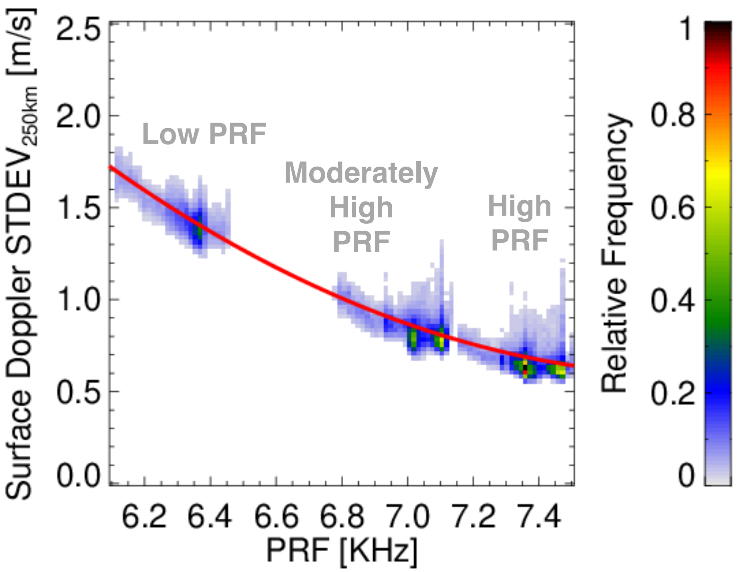
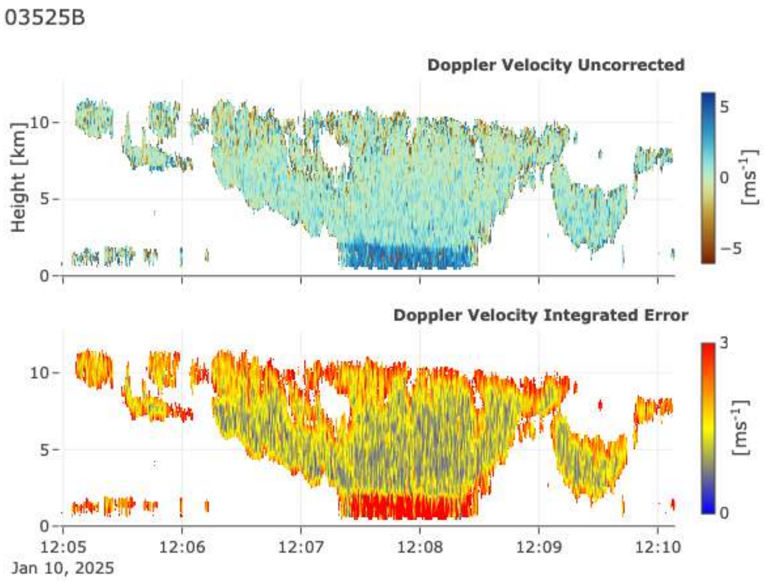
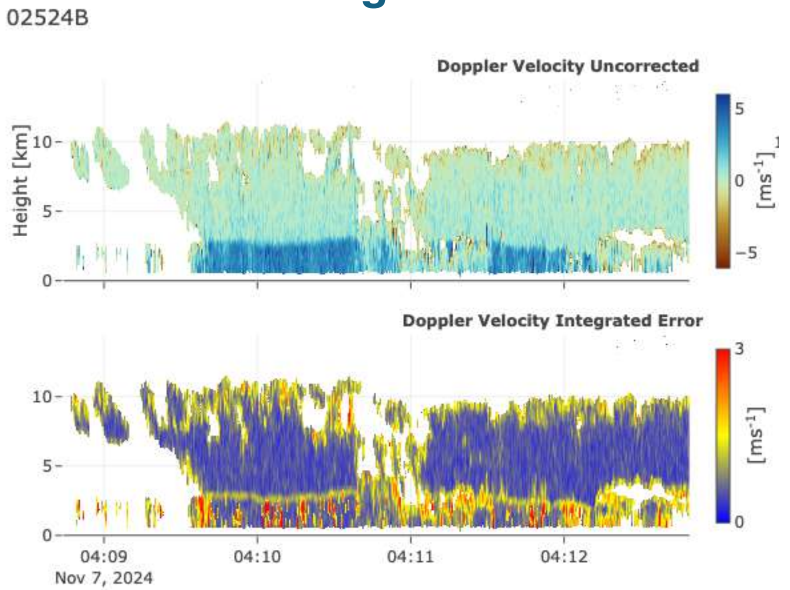


Comparison of Doppler Velocity Errors in Mid-Latitudes Frame B

Low PRF



High PRF



A higher PRF increases the sampling rate, improving Doppler velocity estimation

The PRF Dilemma

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Higher PRF → increased overlap of second-trip echoes

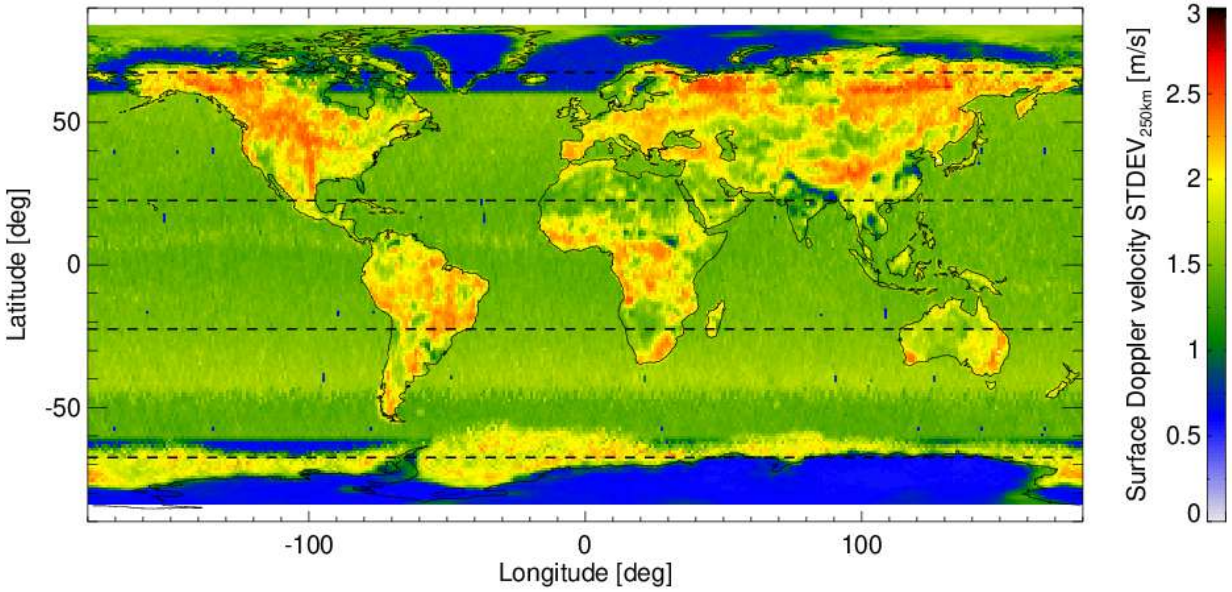
→ better Doppler velocity measurements

The importance of developing robust techniques to remove second-trip echoes

Doppler Velocity

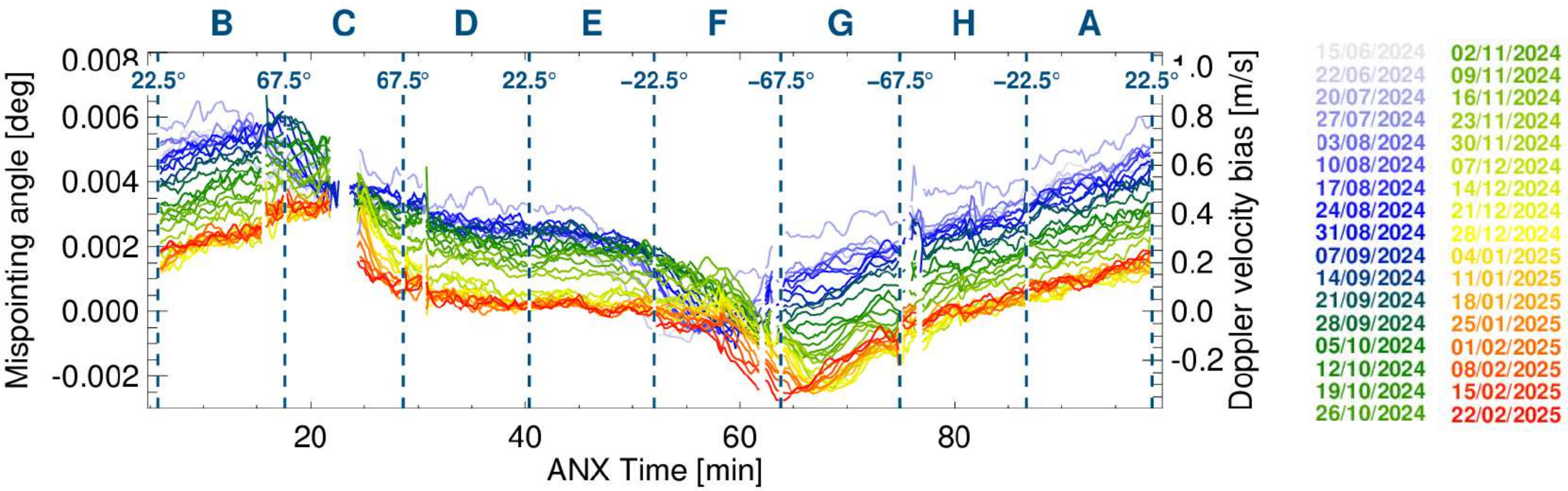
Using Surface Doppler Velocity to Identify Potential CPR Antenna Mispointing

- The surface, as a high-SNR measurement, can provide reliable information to assess the CPR antenna mispointing
- No induced Doppler effects (vertical motion at nadir) are expected from surfaces like the ocean or snow-covered land
- Any departure from the expected 0 m/s velocity indicates a potential antenna mispointing
- At the velocity of the satellite, small mispointing can cause significant line-of-sight Doppler velocity contamination:
- **0.01°$_{(7.6km/s)}$ → 1.32m/s**



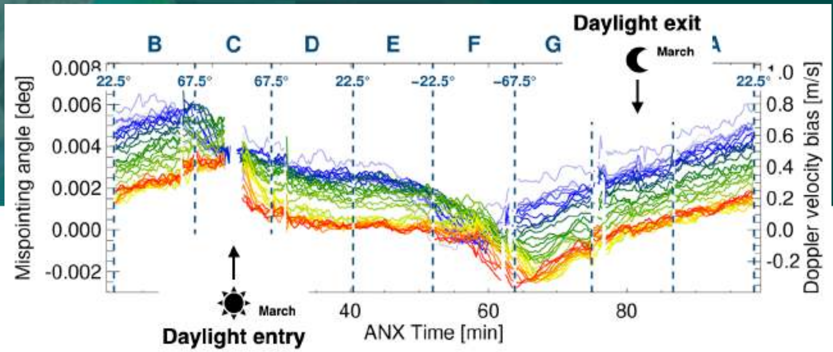
CPR Antenna Mispointing Correction

Weekly Averaged CPR Antenna Mispointing Angles



Surface Doppler velocity observations reveal mispointing trends influenced by solar illumination cycles and thermoelastic distortions on the CPR antenna

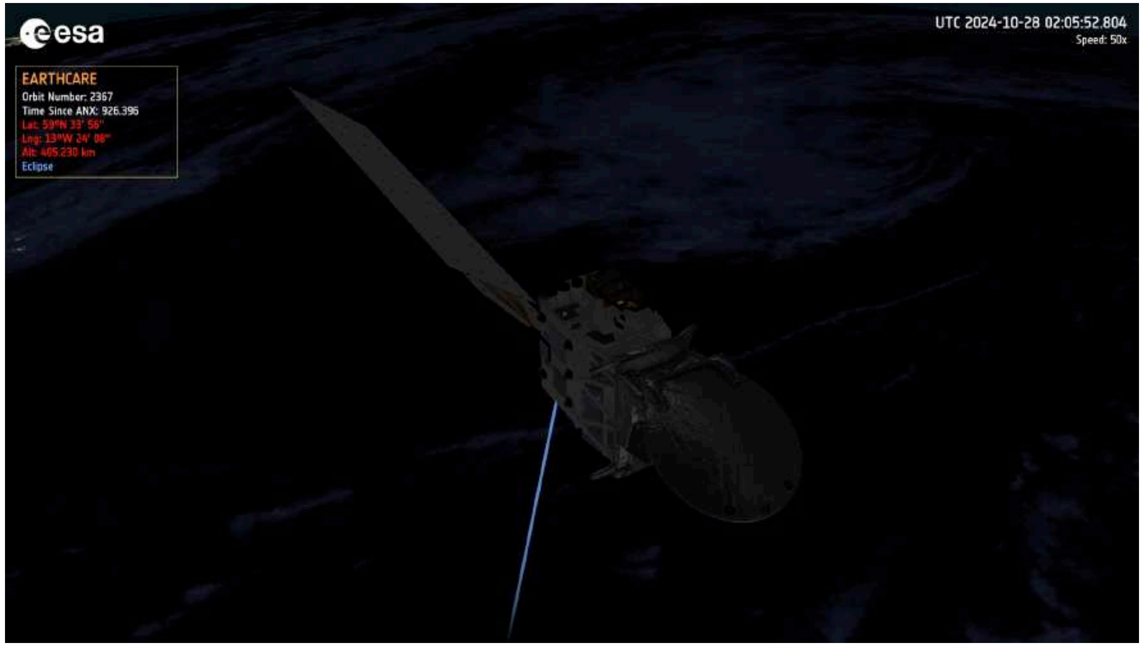
CPR Antenna Mispointing Correction



EarthCARE's Orientation Relative to Sunlight

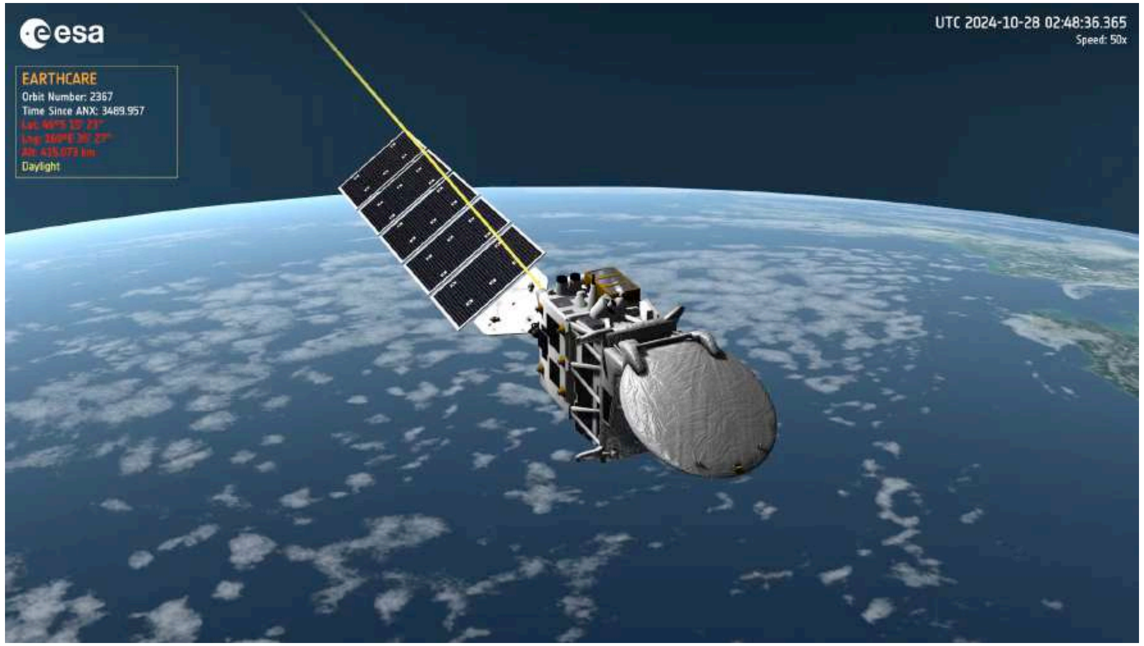
Daylight entry

Direct solar illumination causes a rapid mispointing shift at daylight entry



Daylight exit

A second shift occurs a few moments before exit, as sunlight is partially blocked by the spacecraft



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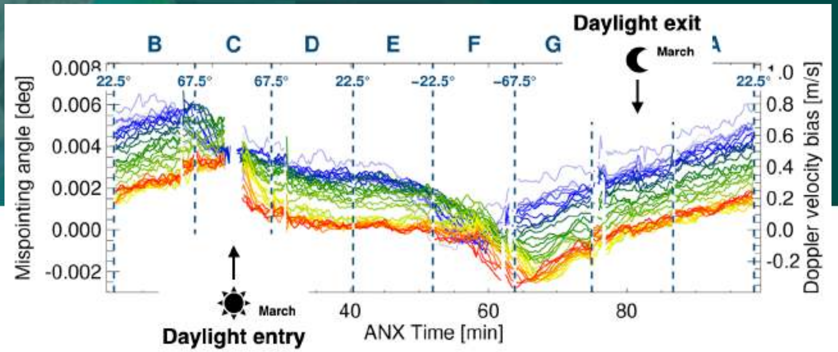

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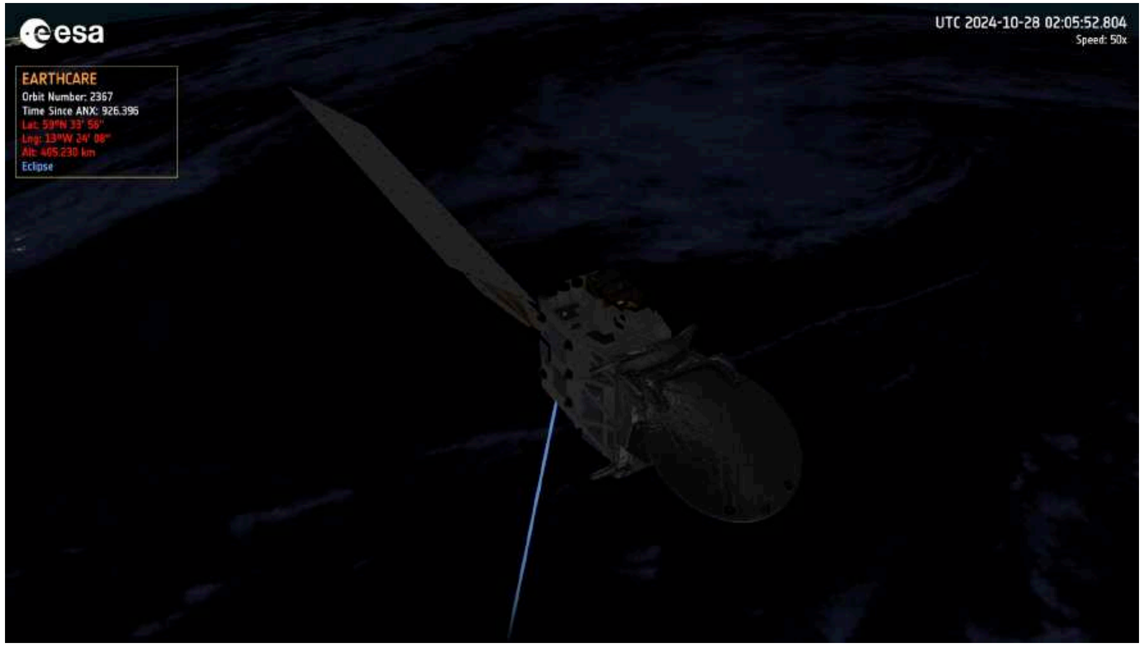

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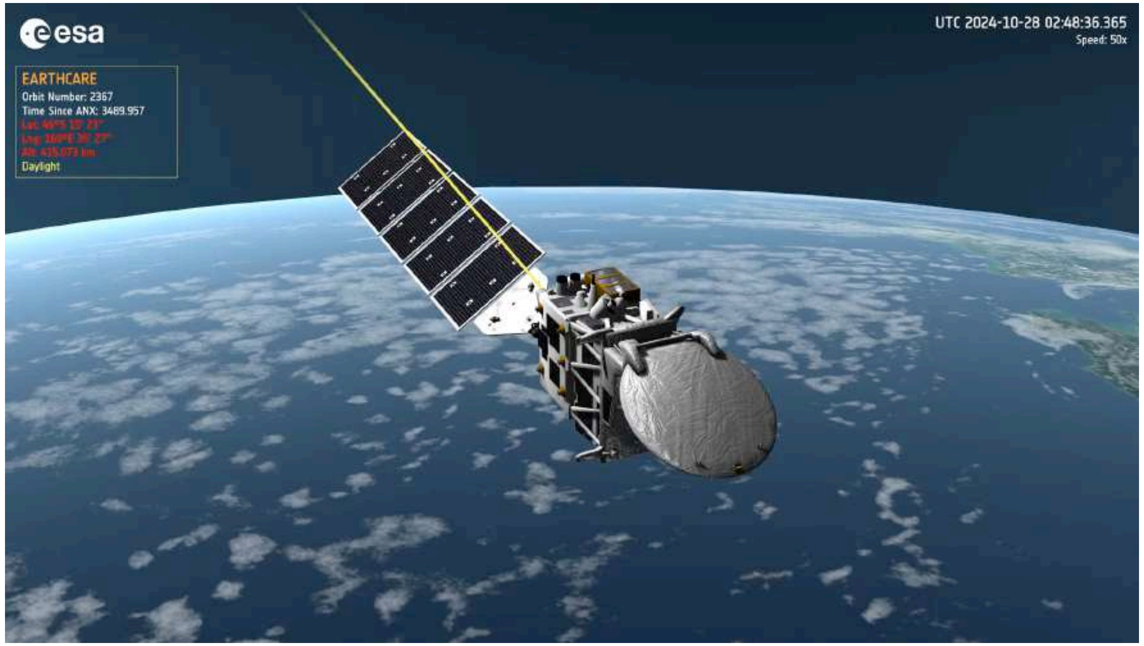
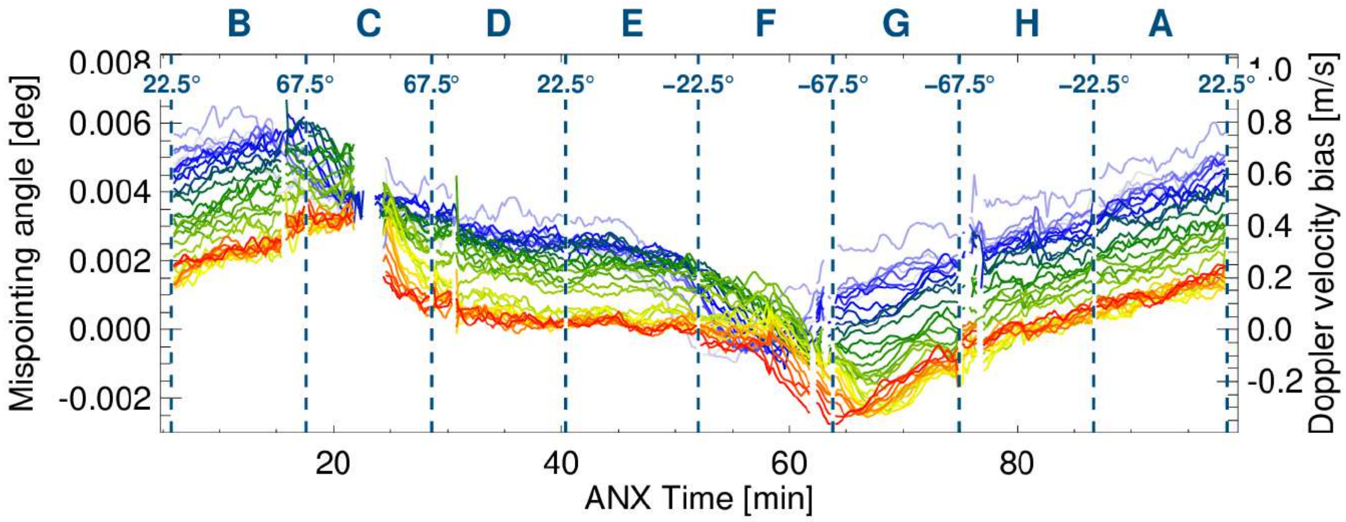


CPR Antenna Mispointing Correction

CPR Antenna Mispointing Parametrization

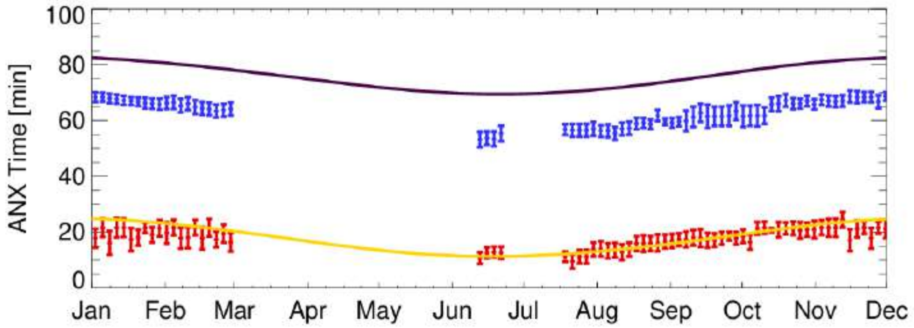
New antenna mispointing correction implemented in C-PRO (baseline **AC**)



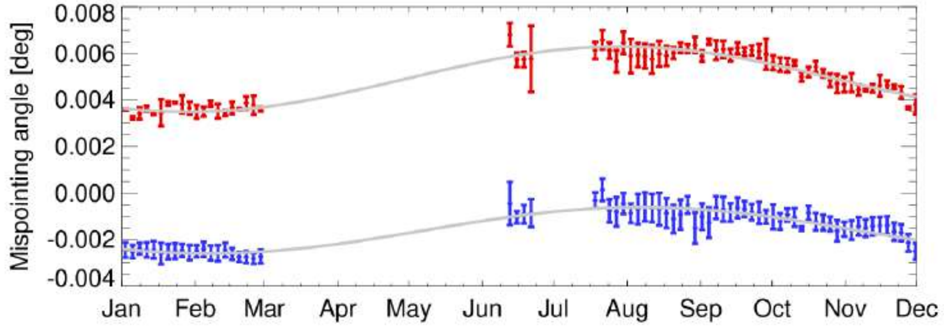
We use the 'climatological' parameterization and then adjust the fit on an orbit-to-orbit basis minimizing the residuals relative to the input surface observations

The parametrization allows to correct the CPR data to within 5-7 cm/s, the 90th percentile is below 0.00077º (~10 cm/s) precision - tested over 3K orbits

Time and Amplitude Shifts



ANX Time corresponding to the min/max mispointing values
SC daylight entry
SC daylight exit



Min/max mispointing values
Fitted harmonics

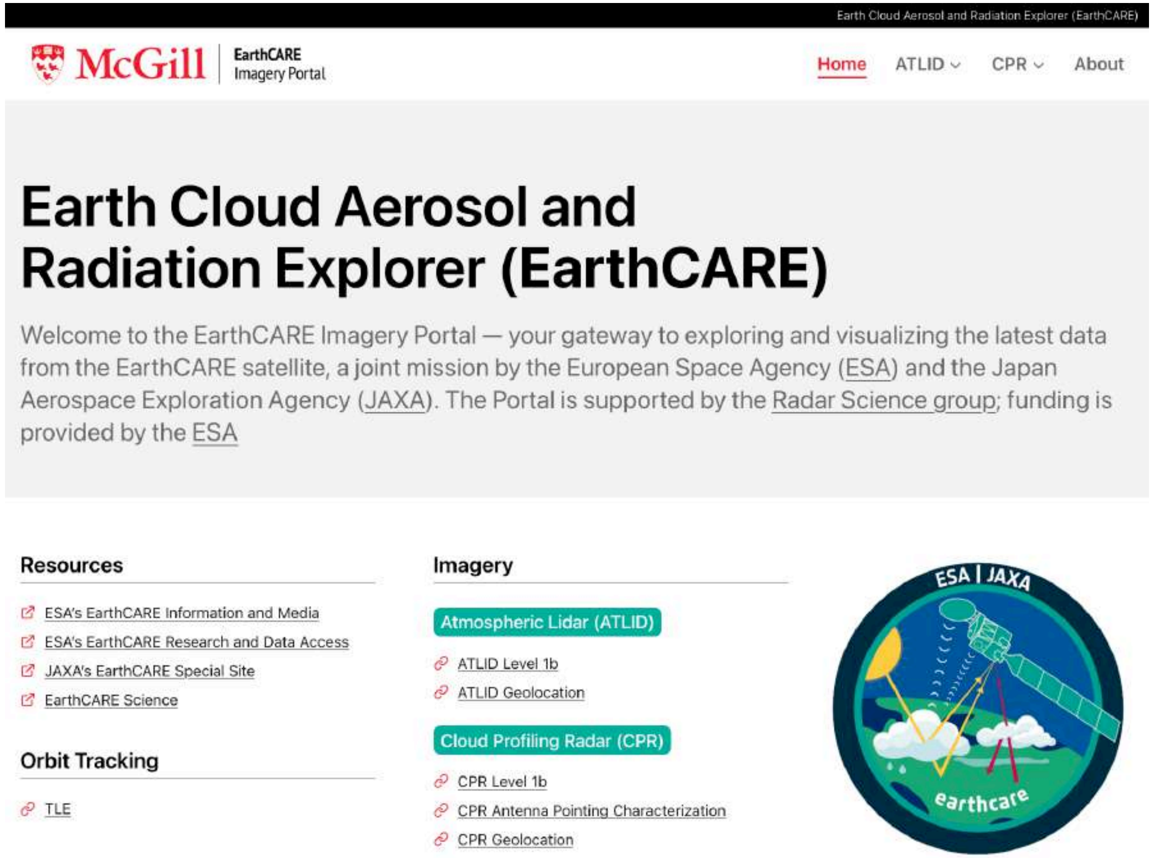
Want to learn more? Our manuscript is coming out soon!

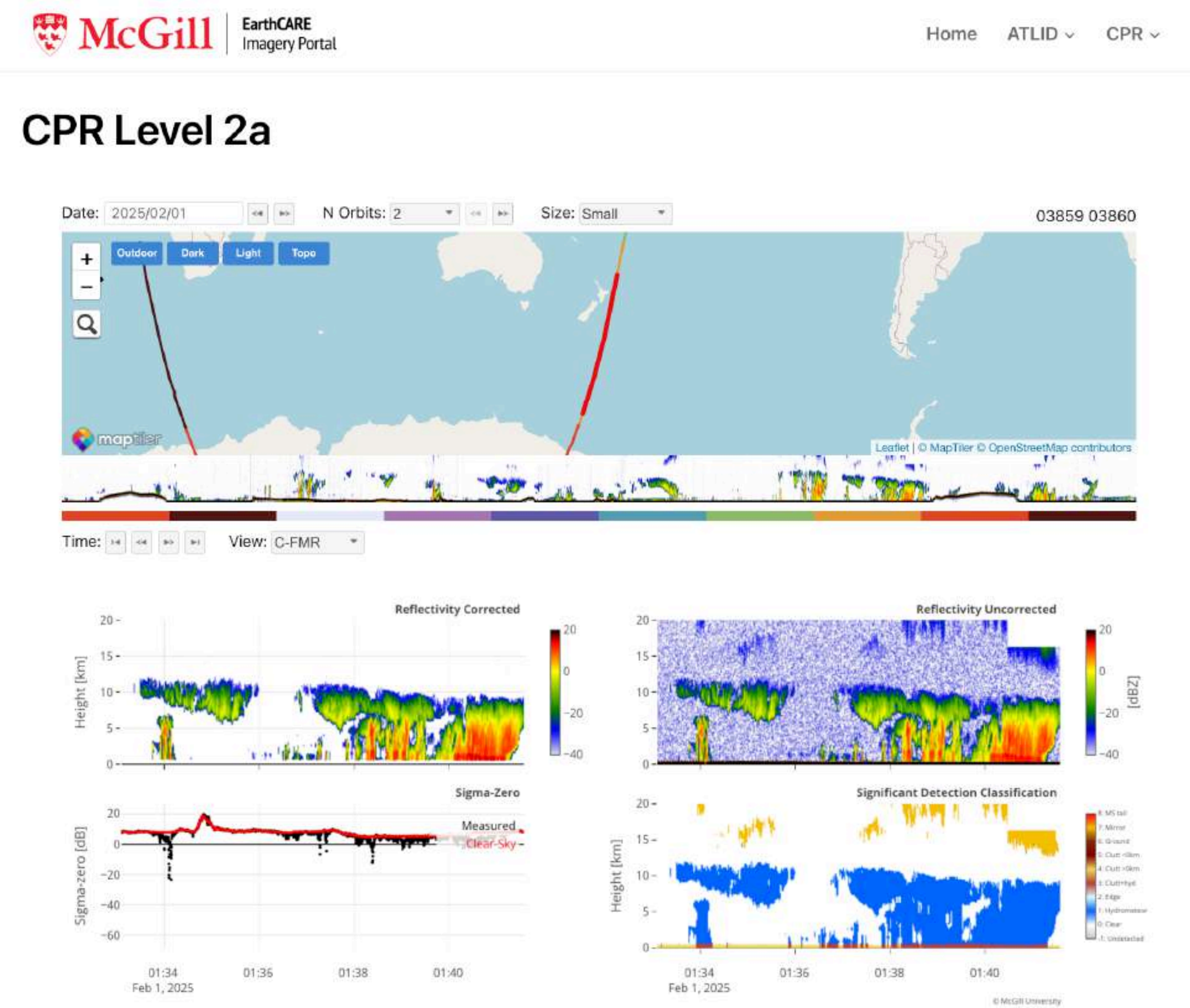
EarthCARE's Cloud Profiling Radar Antenna Pointing Correction using Surface Doppler Measurements

Bernat Puigdomènech Treserras, Pavlos Kollias, Alessandro Battaglia, Simone Tanelli and Hirotaka Nakatsuka

McGill EarthCARE Imagery Portal

https://web.meteo.mcgill.ca/EarthCARE/



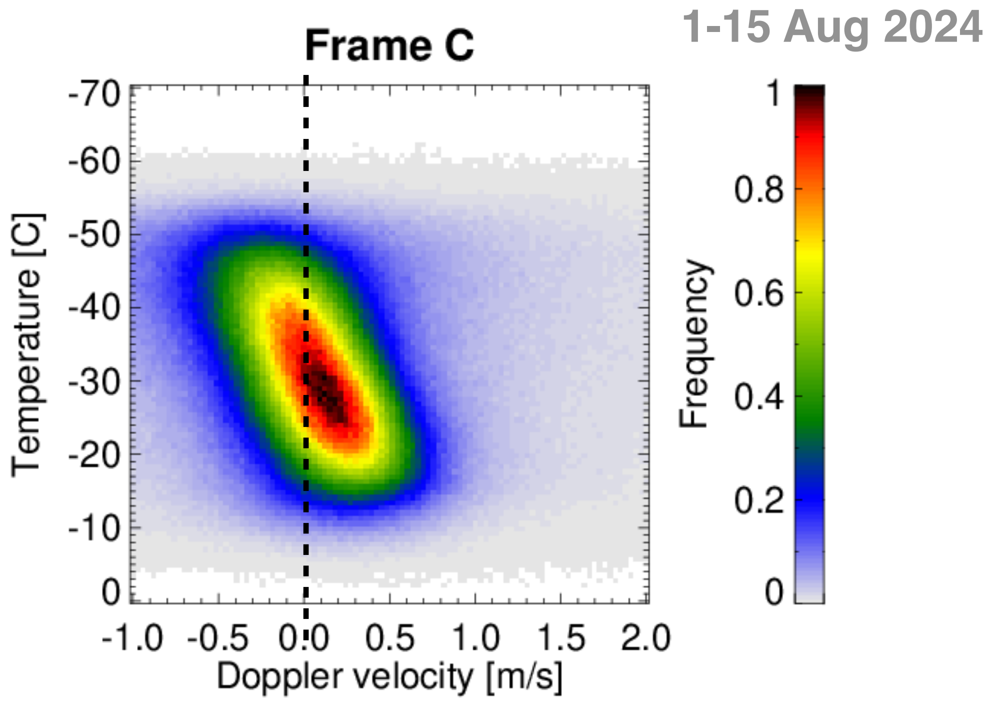


CPR Antenna Mispointing Correction

Validation Using Ice Clouds

New antenna mispointing correction implemented in C-PRO (baseline **AC**)

Without Antenna Pointing Correction



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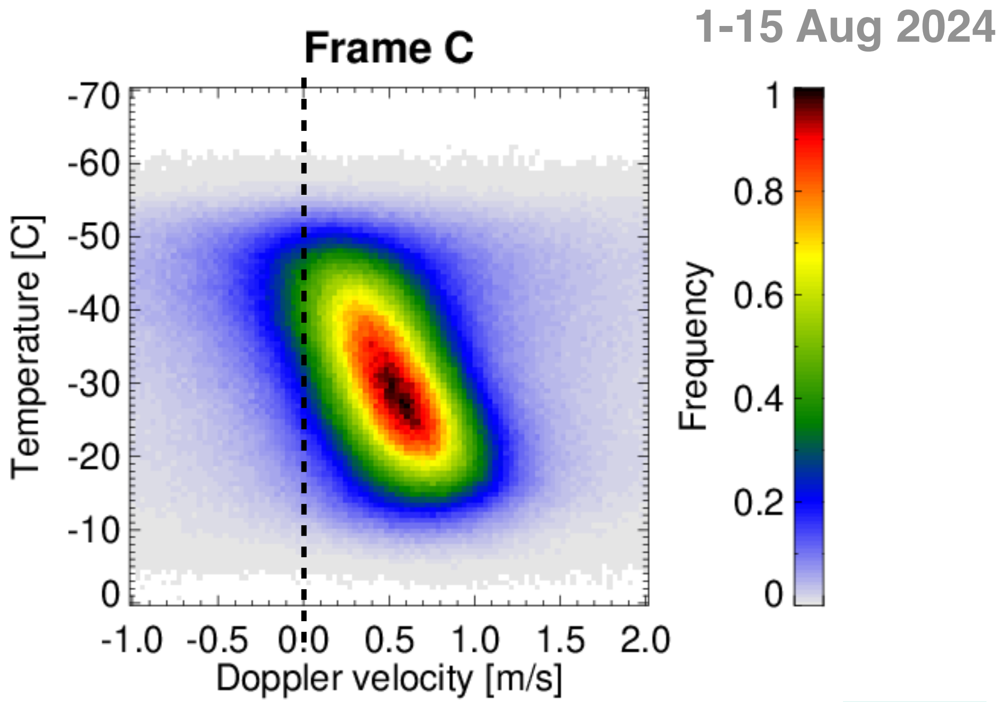

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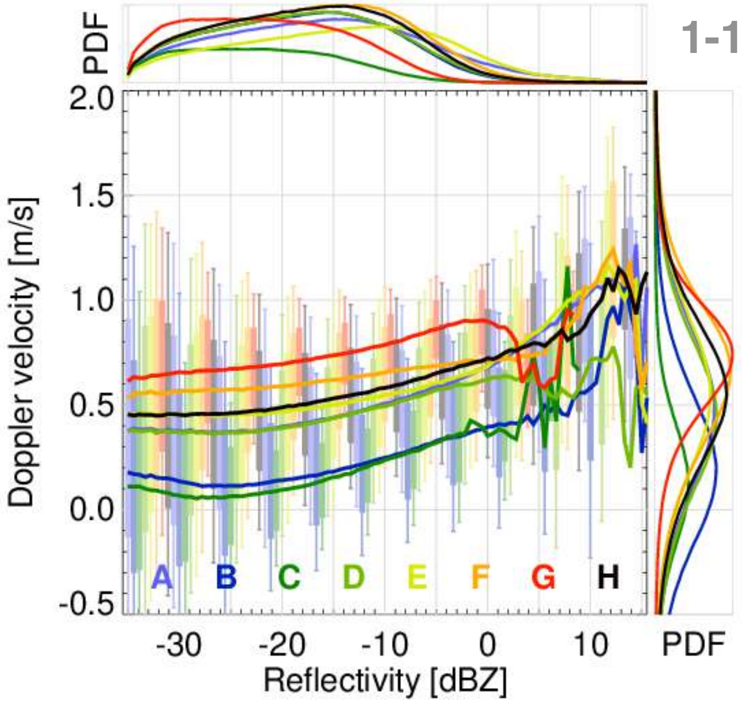

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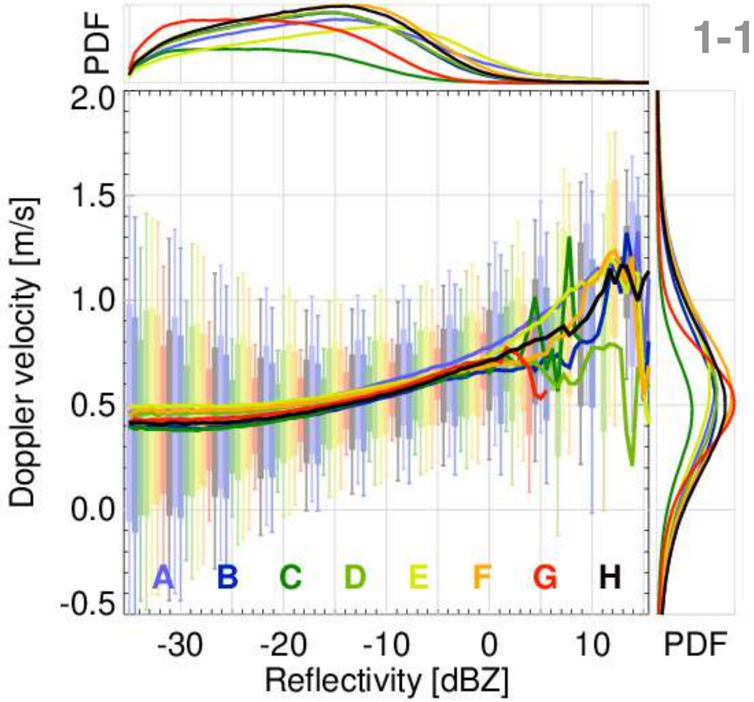
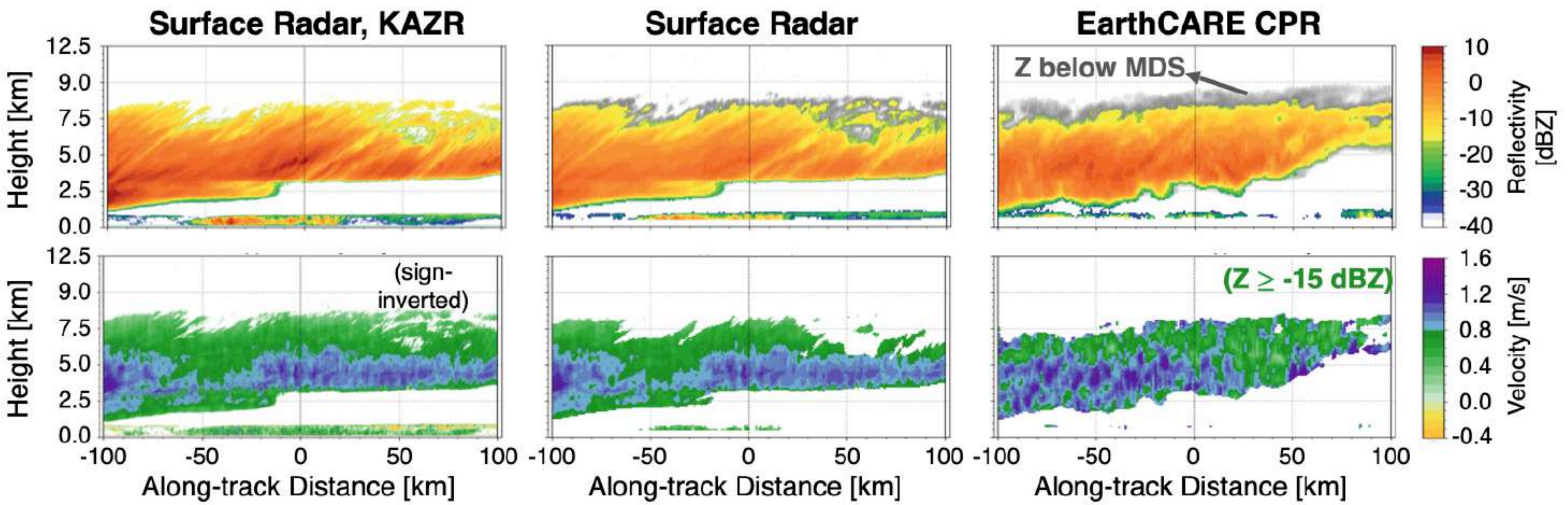
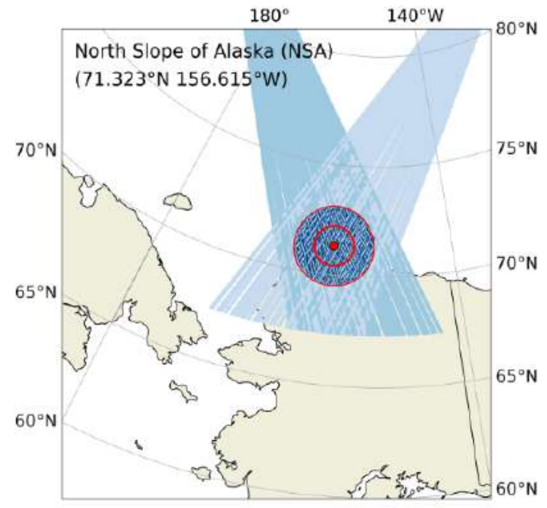


Evaluation using campaign data

- Observation Period: Jun 12, 2024 – Feb 15, 2025 (~8 months)
- Instrument Simulator: Orbital-Radar Tool (*Pfitzenmaier et al., 2024*), adjusting surface radar data to match CPR
- Data Filtering: Applying the same minimum detectable signal (MDS)
- Spatial Window: Within a 100 km radius of each site location
- Reflectivity Calibration: -1.9 dB (KAZR, NSA) and -0.7 dB (FMWC, Neumayer), derived following *Kollias et al. (2019)*





EarthCARE C-frame

counts (1 month):
within **100 km**: 12-15 times
within **200 km**: 26-31 times