McGill

EarthCARE C-APC processor

- Antenna Pointing Correction -

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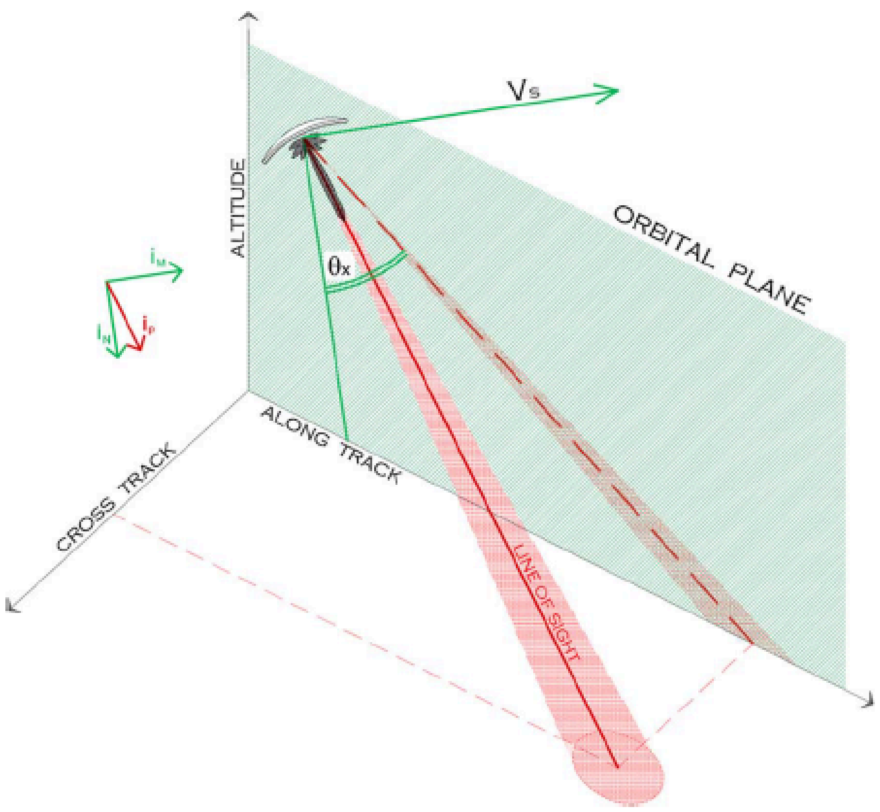
C-APC

The C-APC processor corrects the velocity bias introduced by the antenna mispointing

Normally, the AOCS (Attitude and Orbit Control System) data should be sufficient to remove any possible Doppler velocity bias. However, the possibility of having an uncharacterized amount of mispointing needs to be considered.

There are at least 2 sources associated to such a mispointing:

1) **Mispointing due to the altitude control system errors associated with the altitude sensors**
2) **Mispointing due to thermoelastic distortions of the platform and of the instrument**



Geometry of miss-pointing in quasi-nadir looking Doppler radar (Battaglia and Kollias, 2015)

$$\theta_X = \theta_{AOCS} + \theta_{mispointing}$$

The associated error is represented by the read shaded area

C-APC

Algorithm flowchart

- **A1** Correct ALL raw radar data for antenna pointing reported by the AOCS
- **A2** Correct **Earth's surface** raw radar data for NUBF
- **A3** Correct **Ice Clouds** raw radar data for NUBF and fall velocity bias
- **A4** Along-track integration of corrected raw radar data
- **A5** Produce Best Estimate of Antenna Pointing Characterization

The first step is to correct the Doppler velocities using the mispointing bias reported by the AOCS

After this, the algorithm relies in two different sources of **natural targets** to the find $\theta_{mispointing}$:

$$\theta_x = \theta_{AOCS} + \theta_{mispointing}$$

Earth's surface (Tanelli et al. 2005)
Ice clouds (Battaglia and Kollias, 2015)

Along-track integration is performed in order to reduce uncertainty and thus, enable the proper interpretation of velocity measurements

The last step of the algorithm is to produce the best estimate of θ_x using regression analysis

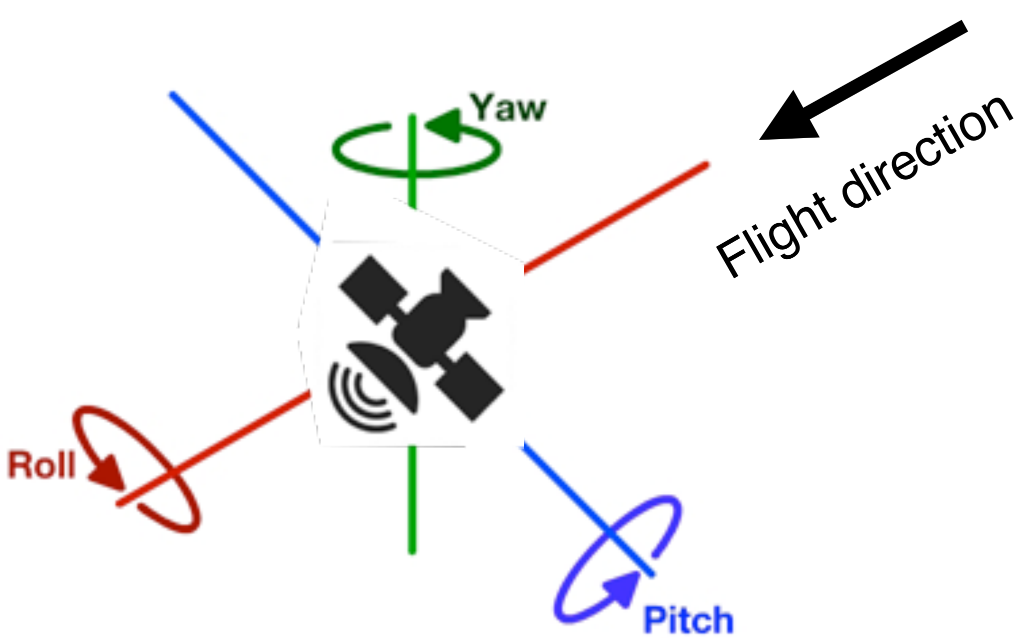
The final output is the best estimate of the corrected antenna mispointing velocity (along with other intermediary variables; lag-1 complex covariance, biases by method, etc.)

C-APC

A1 Correct ALL raw radar data for antenna pointing reported by the AOCS

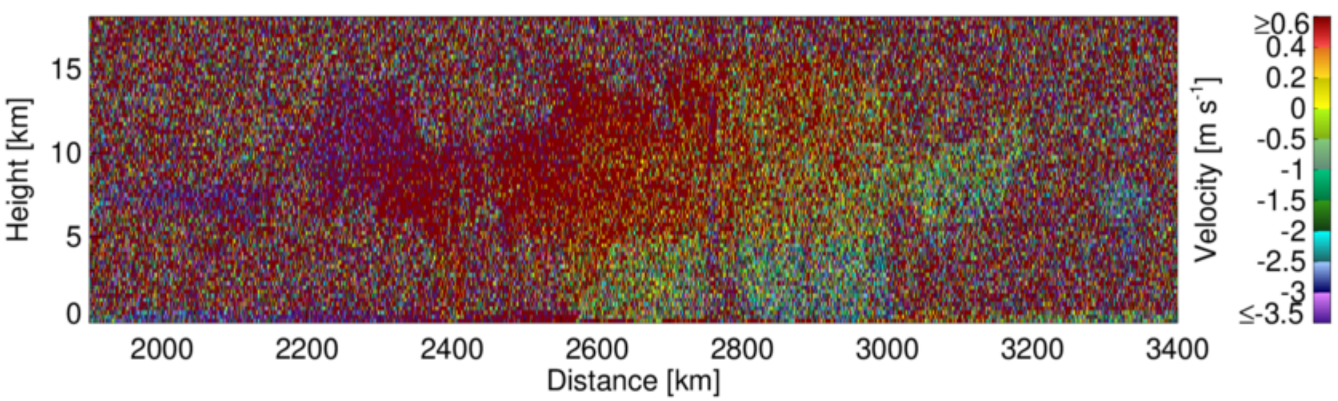
The first step is to correct the Doppler velocities using the mispointing bias reported by the AOCS

Spacecraft control

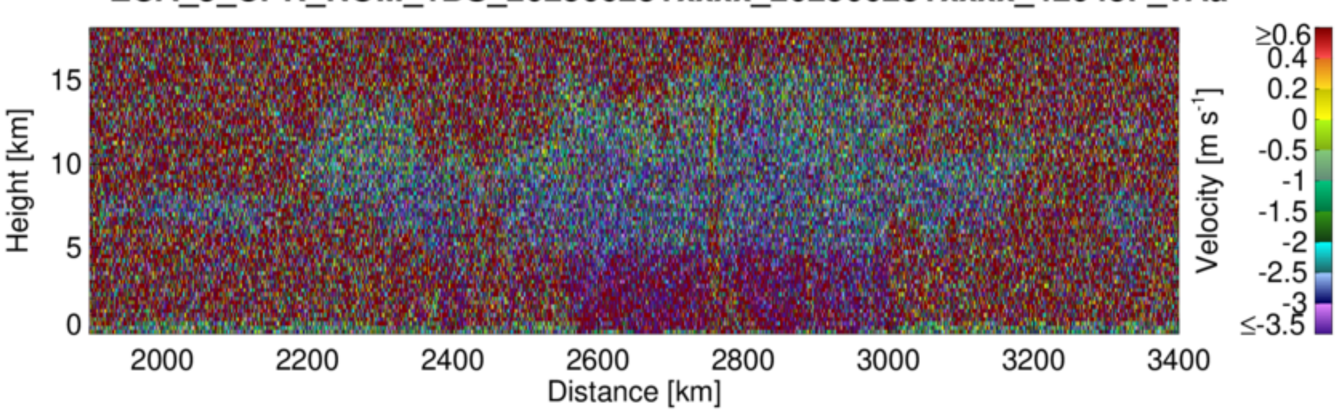


JAXA Doppler velocity (v2.6)

without velocity to beam direction correction



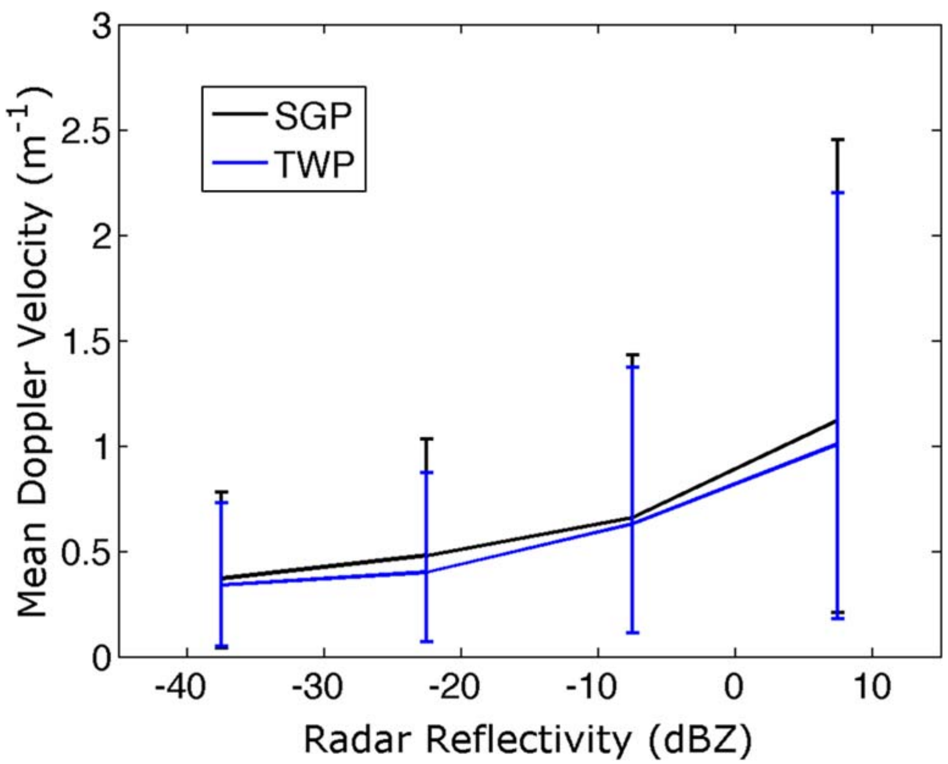
with velocity to beam direction correction



Climatology of Natural Targets

A2 Correct **Earth's surface** raw radar data for NUBF

A3 Correct **Ice Clouds** raw radar data for NUBF and fall velocity bias



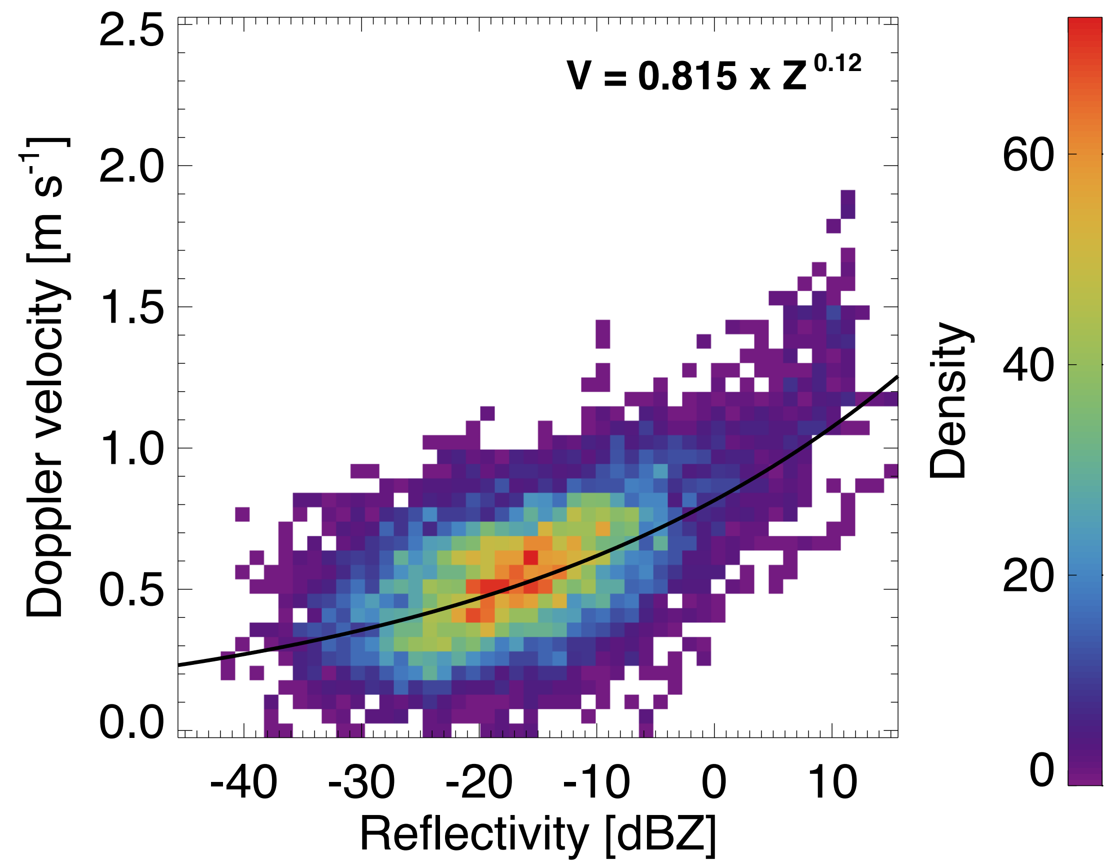
Mean Doppler velocity and standard deviation (indicated by the bars) as a function of radar reflectivity for cirrus clouds at the Southern Great Plains (SGP) and Tropical West Pacific (TWP) ARM sites.

Using Ice Clouds for Mitigating the EarthCARE Doppler Radar Mispointing [Battaglia and Kollias 2015]

Re-computed using the original dataset from

Climatology of High Cloud Dynamics Using Profiling ARM Doppler Radar Observations [Kalesse and Kollias 2013]

SGP site [01/Jan/1997 - 31/Dec/2010]



The Z-V relationship $V = 0.815 \times Z^{0.12}$ is used in **C-APC**

The Mispointing Harmonic

A4 Along-track integration of corrected raw radar data

A5 Produce Best Estimate of Antenna Pointing Characterization

In the first approximation, the CPR mispointing uncertainty can be parametrized in the form:

$$\theta_{\text{mispointing}} \approx \mu + A \cdot \cos(ft + \phi) + e$$

$$e = a_0 + a_1 ft + a_2 ft^2 + a_3 ft^3 + a_4 ft^4$$

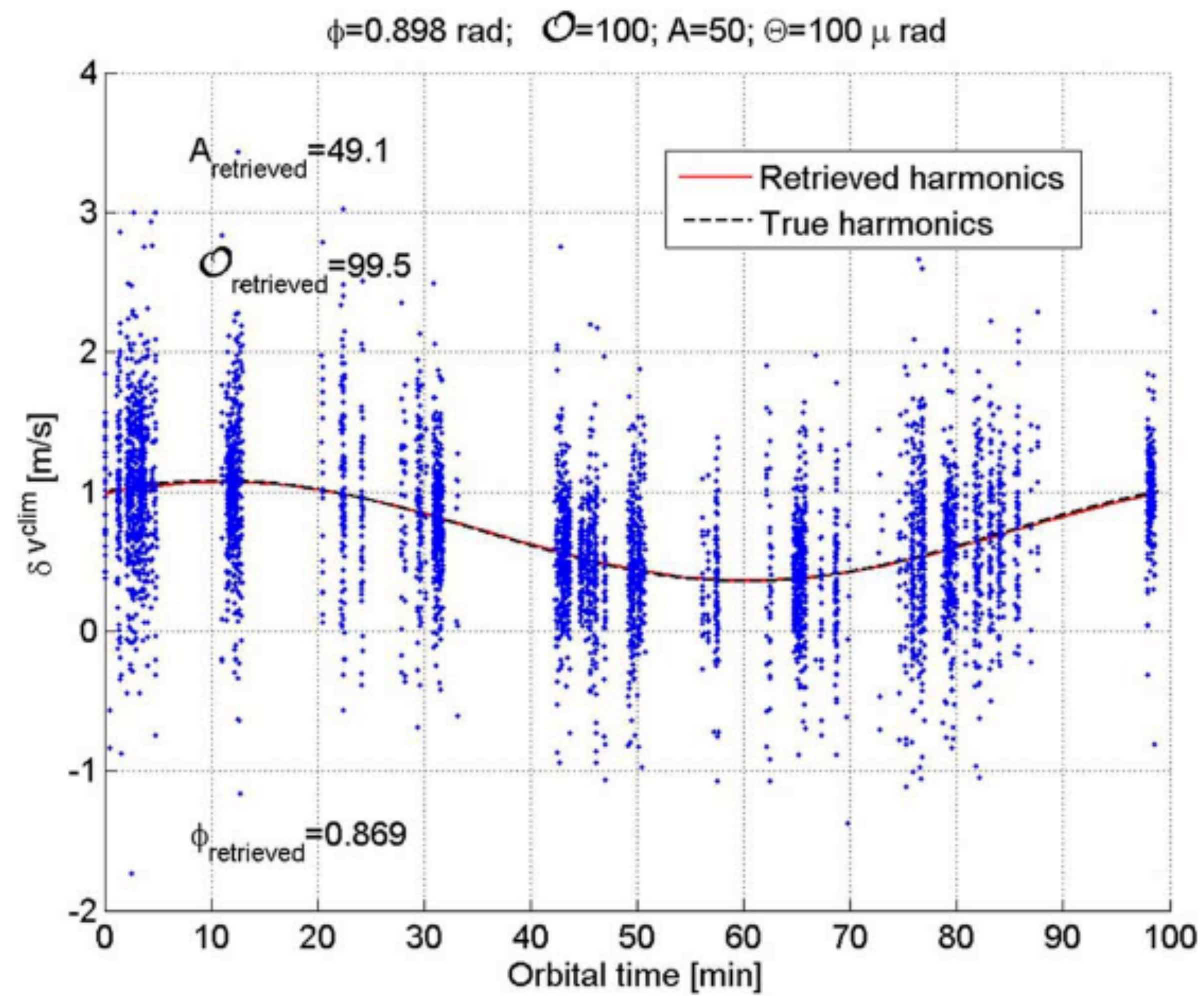
μ = mean of the series
A = amplitude of variation
Φ = horizontal offset (phase)
ft = frequency
a_x = residual polynomial coefficients

where $$ft = \frac{2\pi \cdot (t - t_0)}{T_{\text{orb}}}$$

t_0 = reference time
T_{orb} = satellite orbital period

μ, **A**, **Φ** and **a_0 … a_n** are the unknowns computed by C-APC
t_0 is the first element of the time series ingested by C-APC
T_{orb} can be retrieved from the TLE files and it's defined as a configurable parameter in C-APC

The Mispointing Harmonic



Example of retrieval for the low-frequency component of the mispointing

Using Ice Clouds for Mitigating the EarthCARE
Doppler Radar Mispointing [Battaglia and Kollias 2015]

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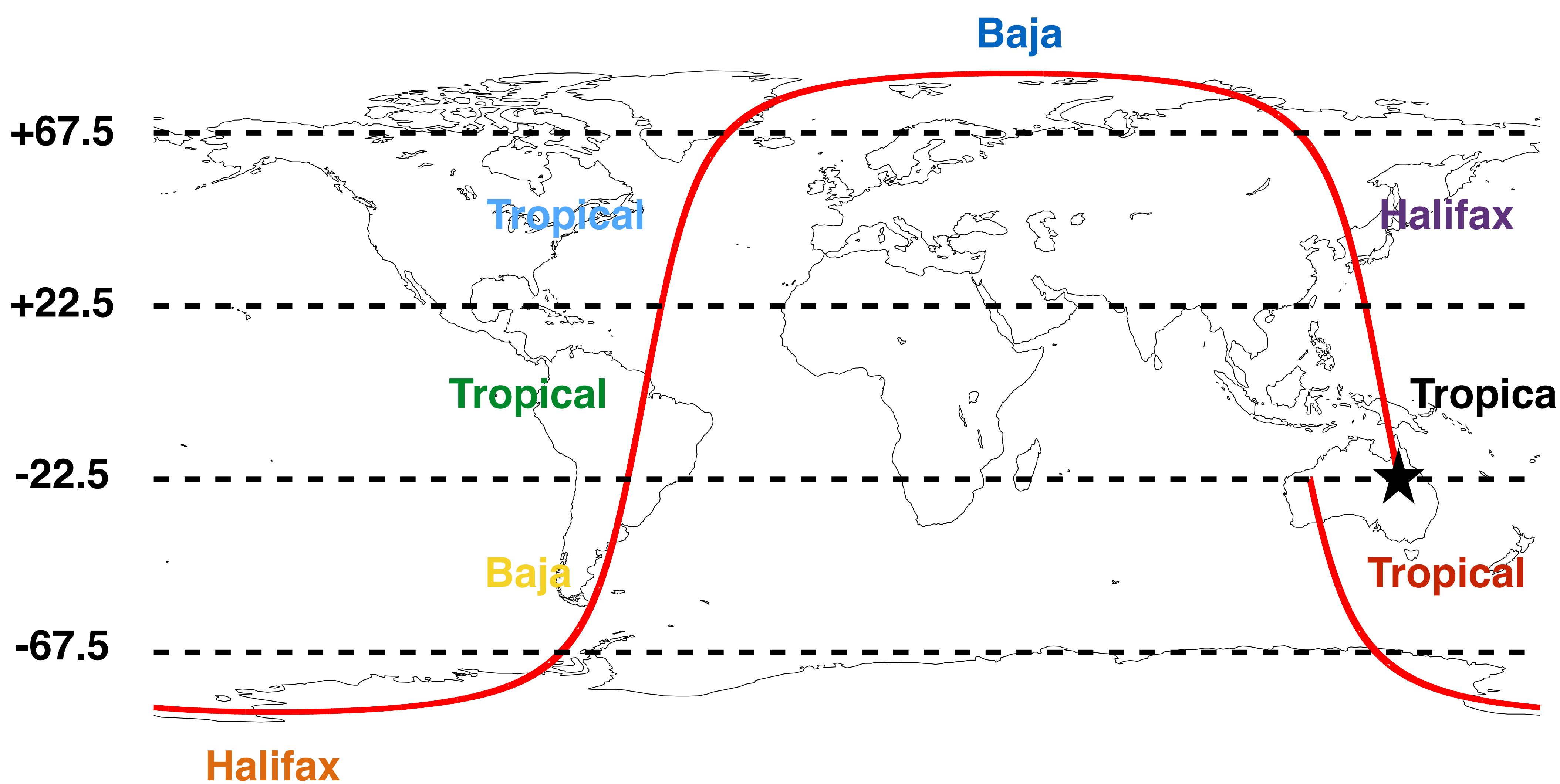
Test data

C-NOM

The test data is created simulating a full EarthCare orbit combining the 3 ECCC scenes
A total of **8 frames** has been used



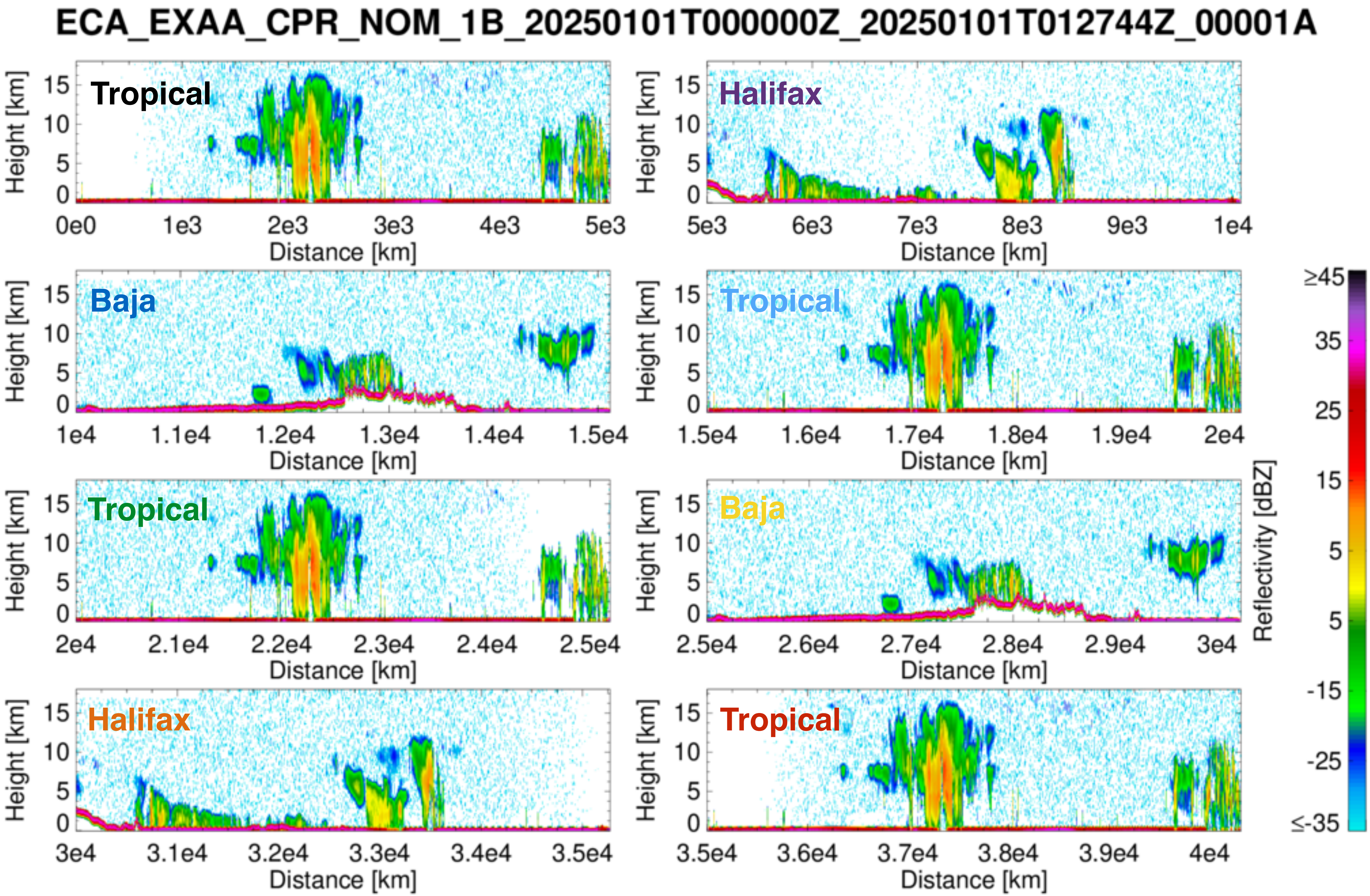
★ **Start**

Flight direction

Tropical + Halifax + Baja + Tropical + Tropical + Baja + Halifax + Tropical ←

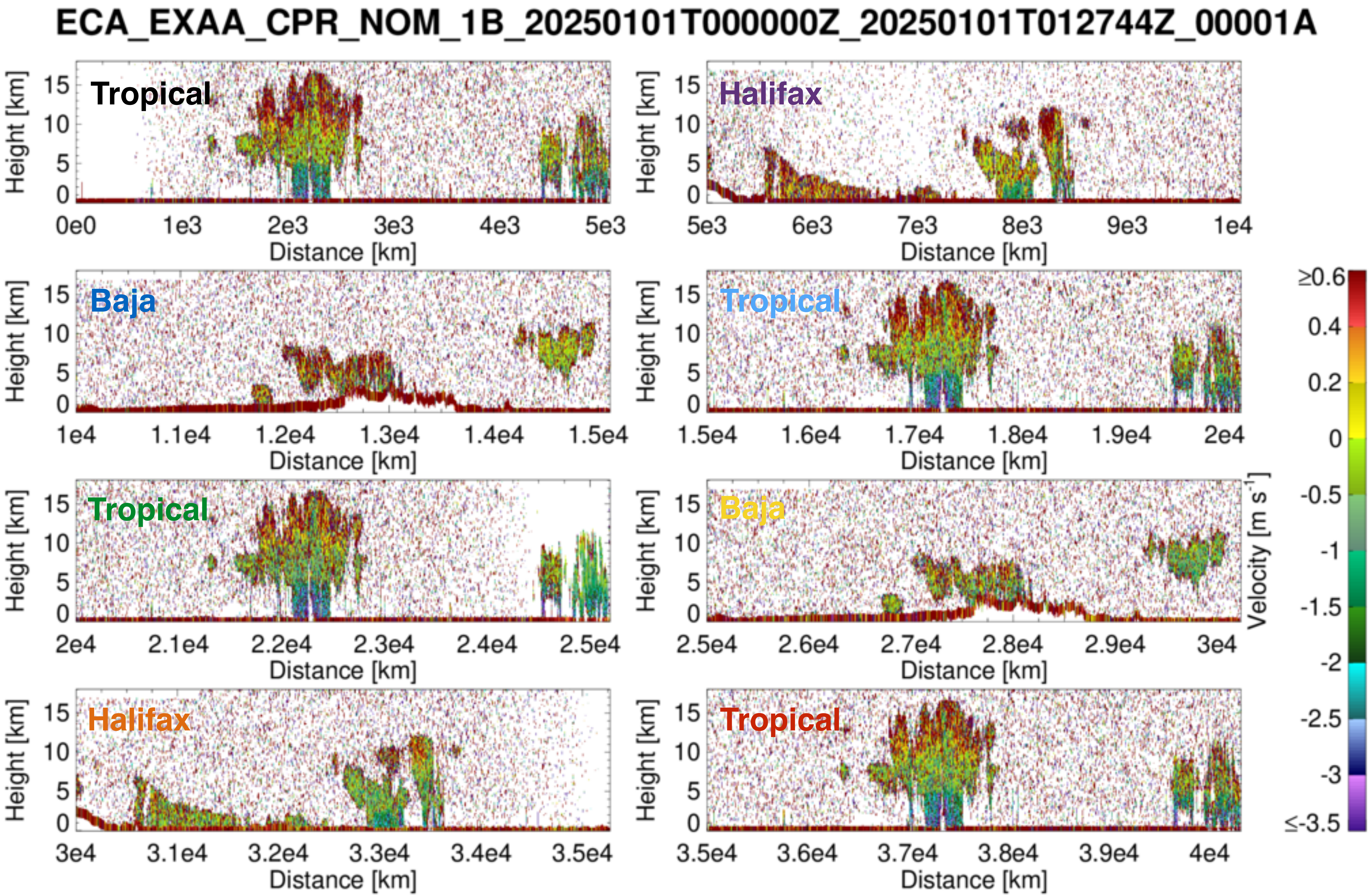
Test data

C-NOM radar Reflectivity Factor



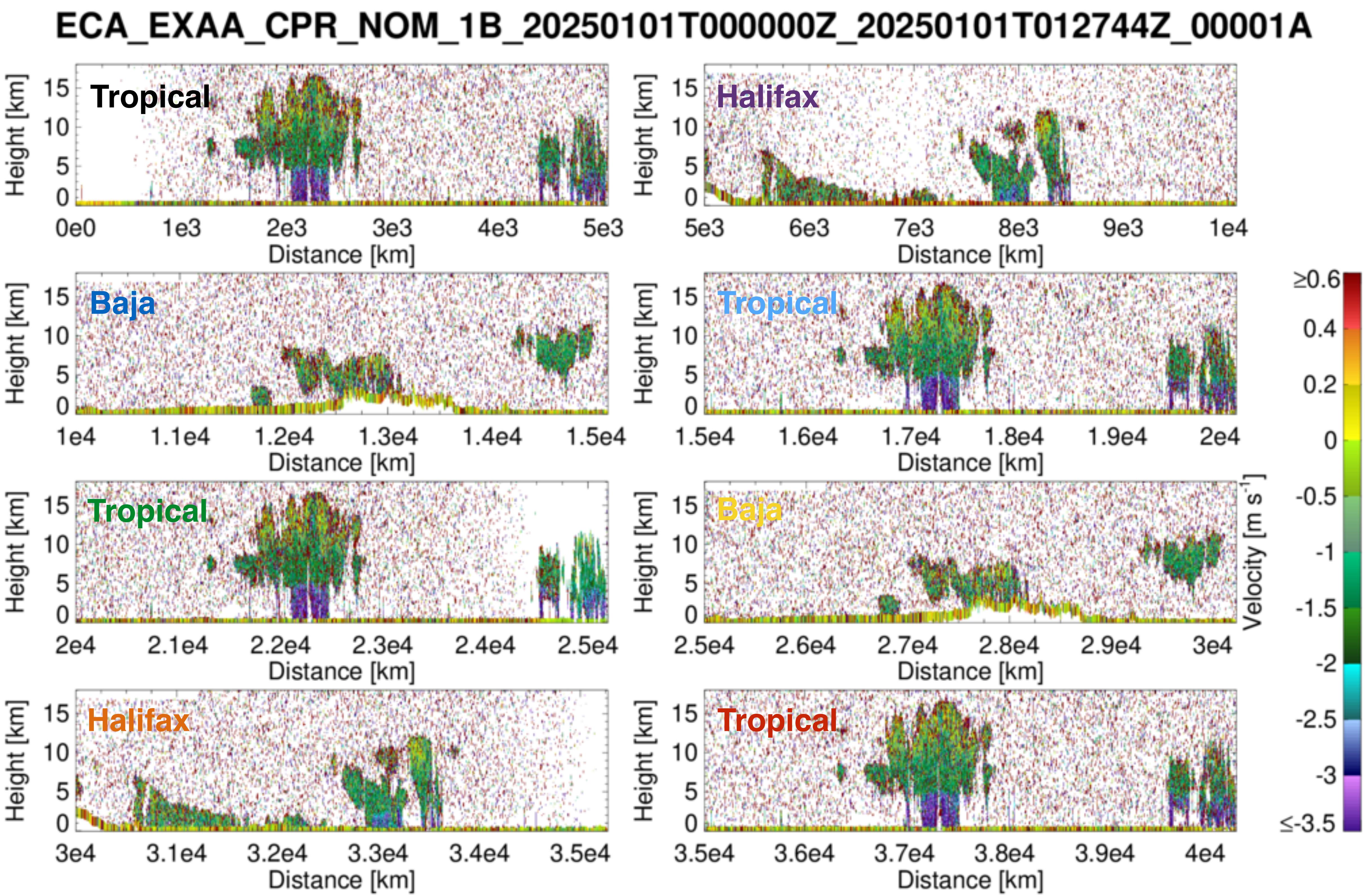
Test data

C-NOM Doppler velocity **with antenna mispointing**



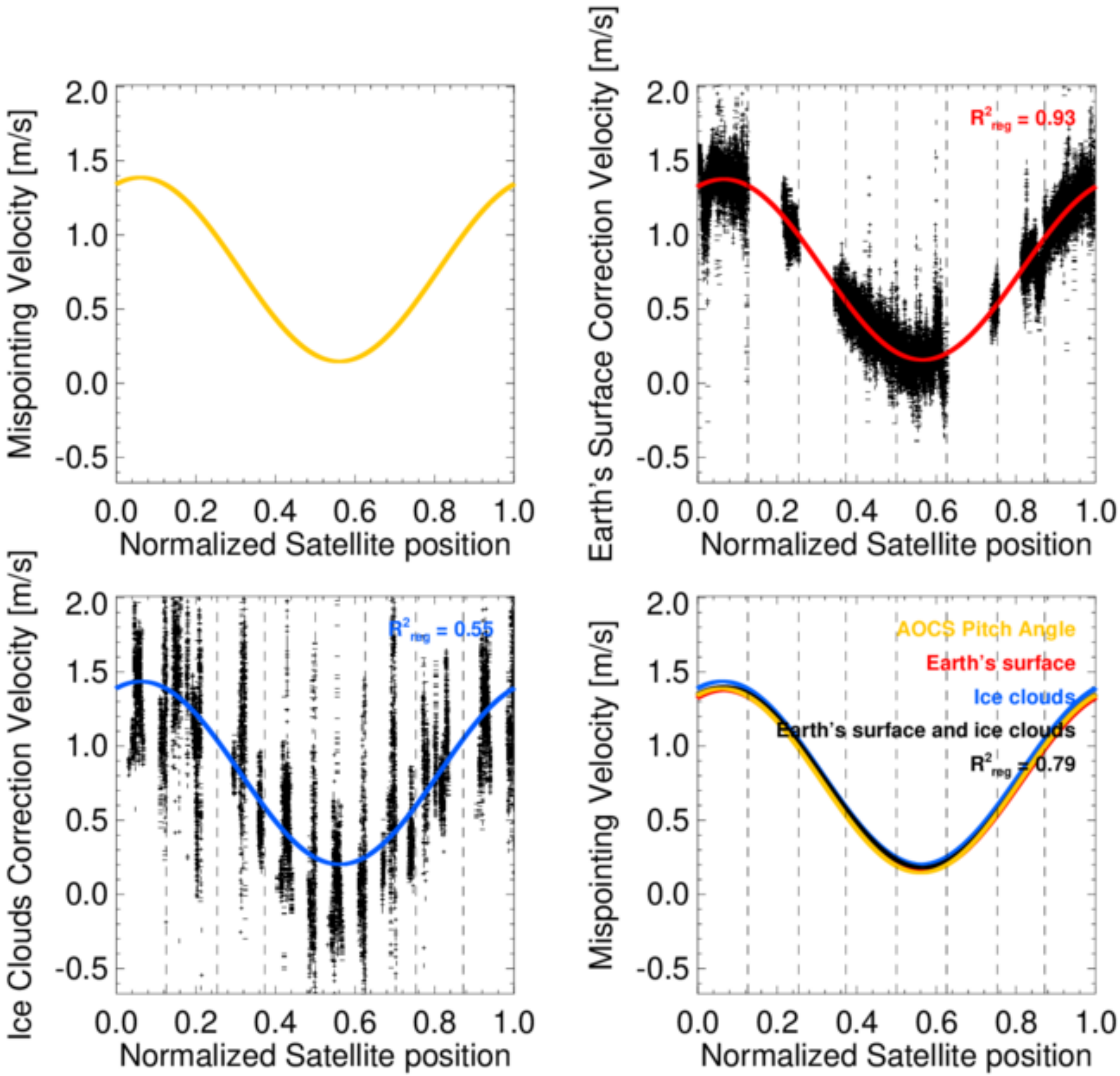
Test data

C-NOM Doppler velocity **after antenna mispointing correction**

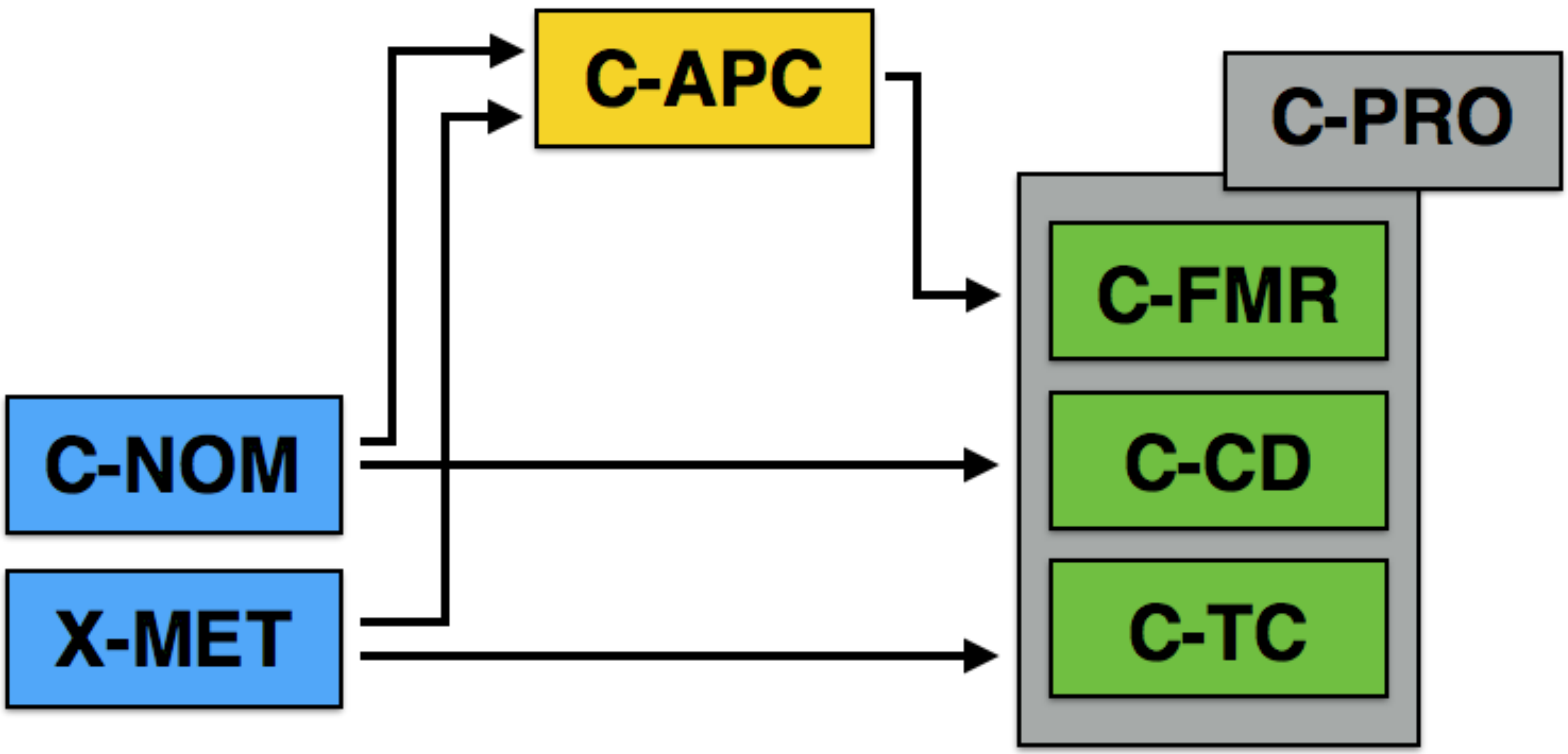


Test data

Results



C-APC / C-PRO interface



C-APC and its relationship to C-PRO