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Tackling Aliasing in Doppler Radar Data: A Single-band and Dual-band De-aliasing Strategy

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Outline

1. Description of the AGORA station
2. Understanding Aliasing in Doppler Cloud Radars
3. Methodology (De-aliasing)
   a) Mean velocity reference estimation.
      - Interactive bottom-up
      - Interpolated
      - External band
   b) Interpolated algorithm (IPA) for single band (SB) and dual-band (DB) mode
   c) Iterative bottom-up algorithm (IBUA)
   d) Time continuity correction
4. Preliminary results
   a) Case Study: De-aliasing of stratiform clouds
   b) Case Study: De-aliasing of convective clouds
5. Validation
6. Concluding Remarks
7. Next steps

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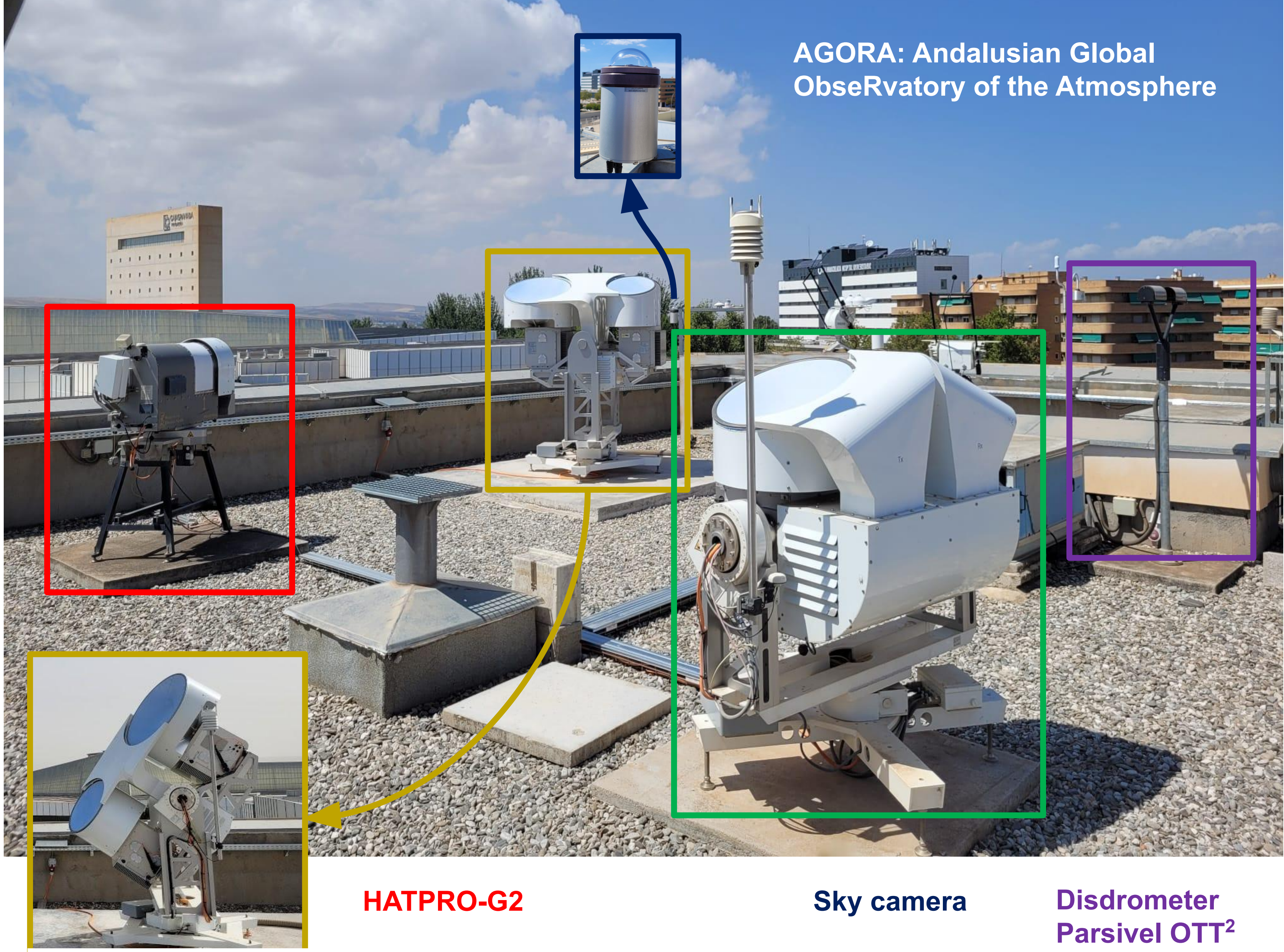
AGORA ACTRIS CCRES station (Granada Station)

Available in CLOUDNET

Cloudnet



Scanning capability

HATPRO-G2

RPG Dual frequency cloud radar (35,94GHz)

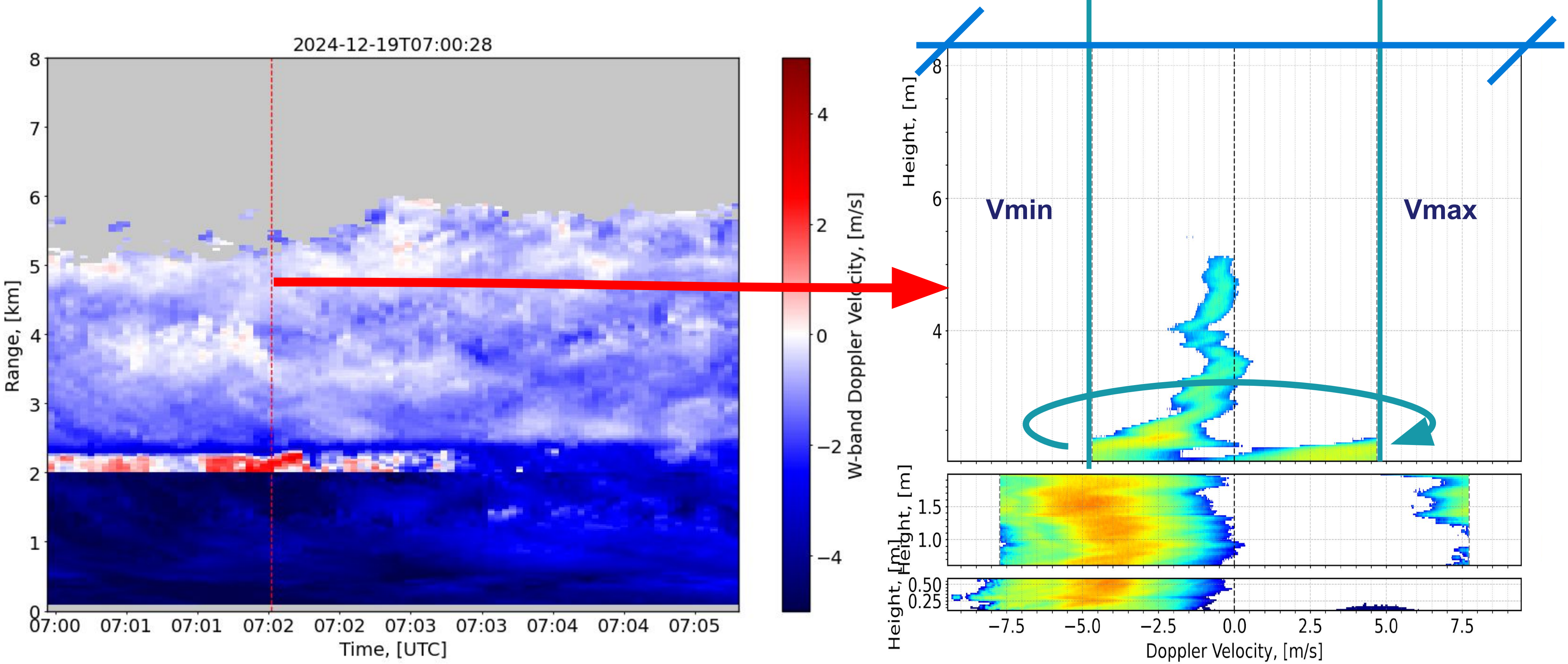
Sky camera

RPG 94-GHz Cloud radar

Disdrometer Parsivel OTT^2

Understanding Aliasing in Doppler Cloud Radars

Case study for W-band (19/12/2024)



Mean velocity reference estimation

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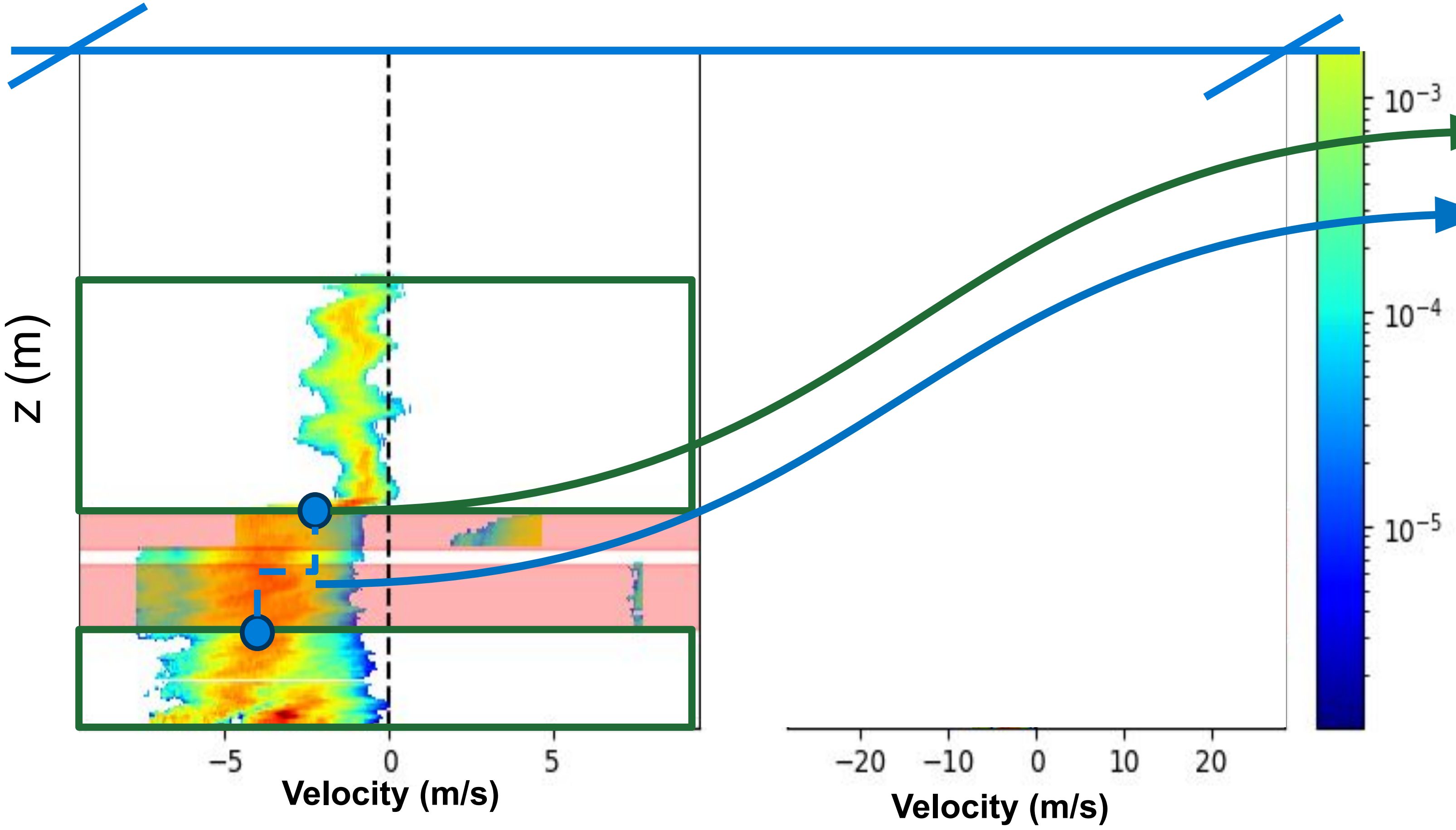
Iterative method: use the mean Doppler velocity of the bins below (in range) as an initial estimate for the Doppler velocity of the current bin

Interpolated method: fill in the aliased regions by interpolating the mean Doppler velocity from nearby non-aliased regions using nearest neighbor interpolation

External method: use the mean Doppler velocity profile from an external band with lower frequency as an initial estimate for the Doppler velocity

Methodology (De-aliasing)

Interpolated algorithm (IPA) for single band (SB) and dual-band (DB) mode



Retrieve velocity guess:

<u>Single-band mode:</u>

1. Calculate the mean doppler velocity when there is no data on both sides of the spectra
2. Extrapolate the mean velocity to aliasing areas (interpolated method)

<u>Dual-band mode:</u>

1. Use the doppler velocity profile from Ka-band (External method)

Shifting at each range bin "z":

$Vm \geq 0$: shift the left part of the spectra to the right

$Vm < 0$: shift the right part of the spectra to the left

Methodology (De-aliasing)

Iterative bottom-up algorithm (IBUA) by Tuomas Siipola (CLU)

Mean computation (Vectorized phase-based estimation)

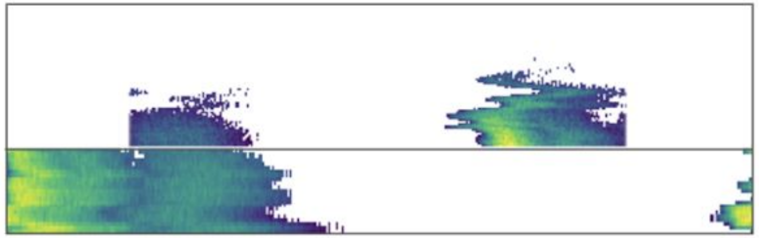
$$tau = 2 * np.pi$$

$$a = np.linspace(0, tau, n\_bins, endpoint = False)$$

$$b = np.sum(spec * np.\sin(a), axis = 1)$$

$$c = np.sum(spec * np.\cos(a), axis = 1)$$

$$mean = (np.\mathrm{atan2}(b, c) \; \% \; tau) \; / \; tau * n\_bins$$



Fix aliasing within chirp sequence

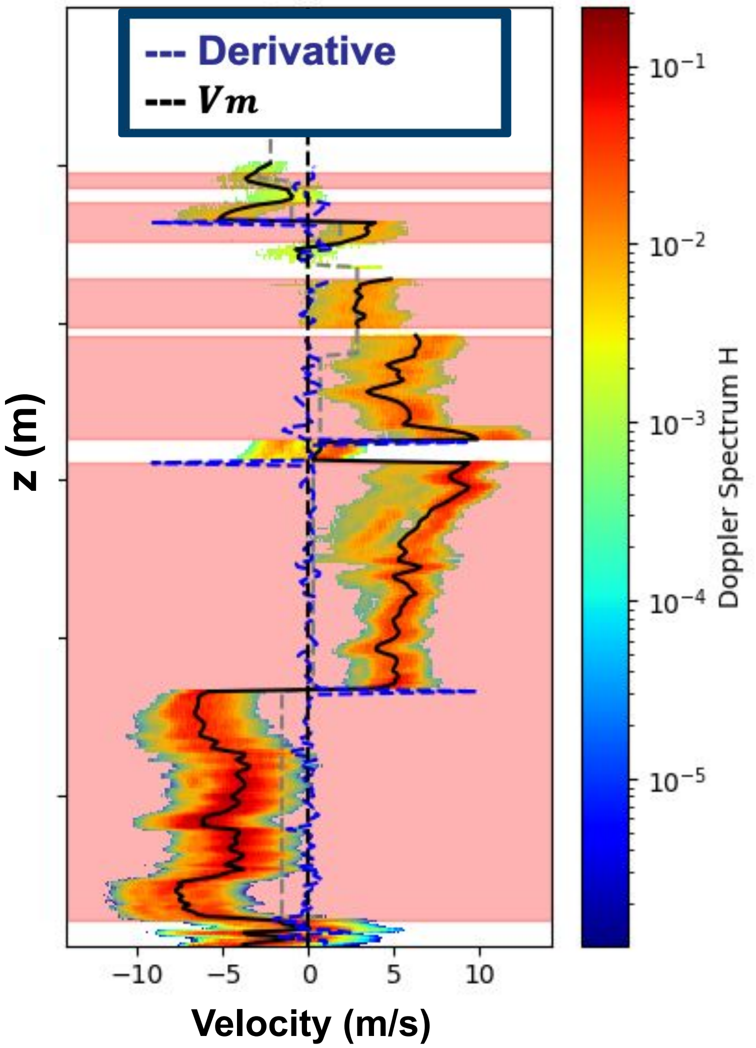
1. Shift on the circular mean at each range

Align chirp sequence

1. Assume not aliased at ground
2. Align means of the last and first ranges of adjoining chirp sequence ($n \, Vny$)

Time continuity correction

SB mode may need time continuity check
to dealiase convective clouds



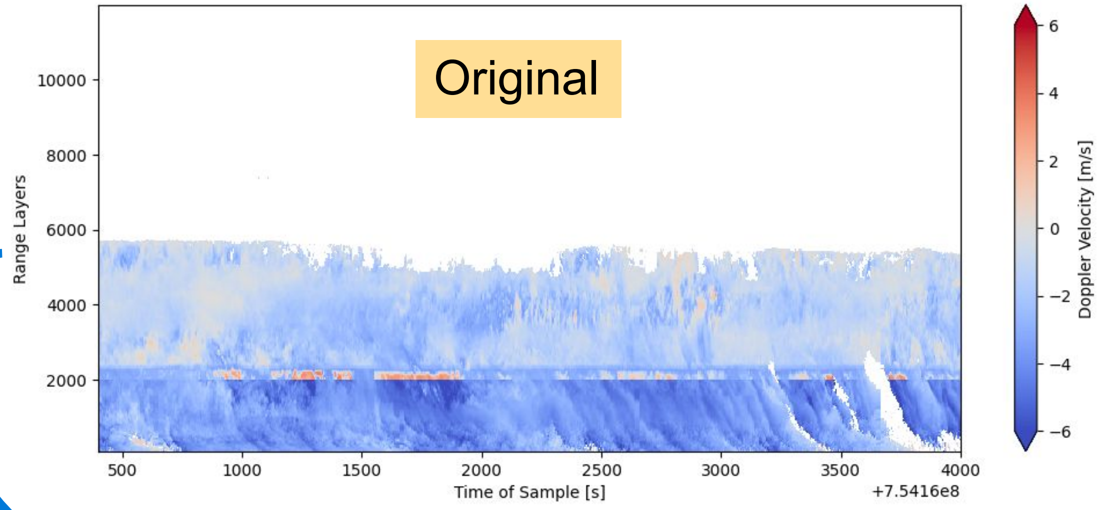
Inaccurate de-aliasing: Jumps of "n x Vn", where n = 0, ±1, ±2

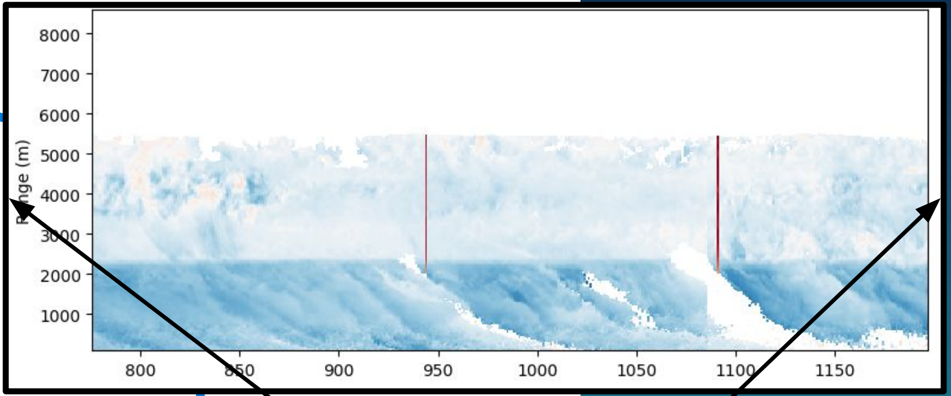
Correction:

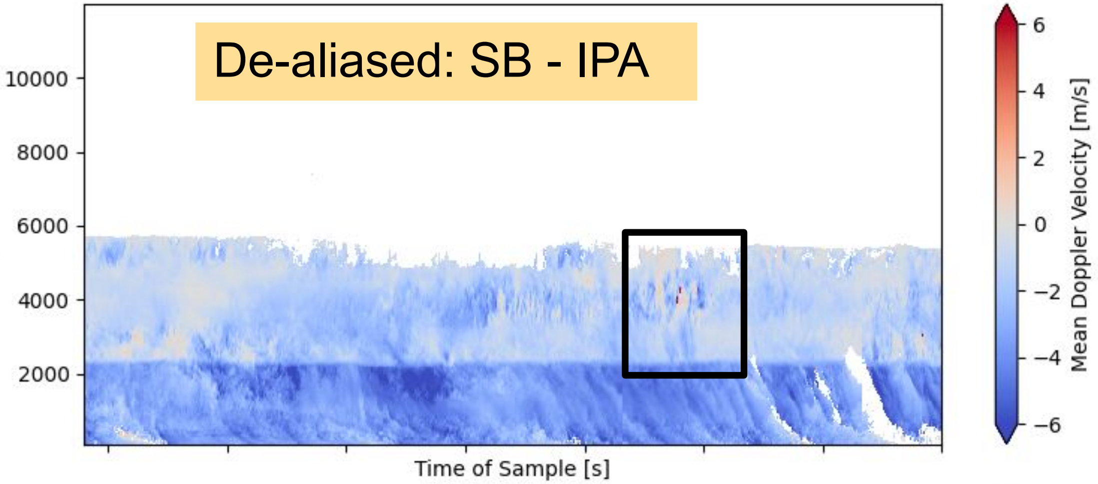
1) The corrected mean Doppler velocity is chosen so that the difference between the current velocity *Vm* and the reference *Vref* is minimized by adding or subtracting multiples of the Nyquist velocity.

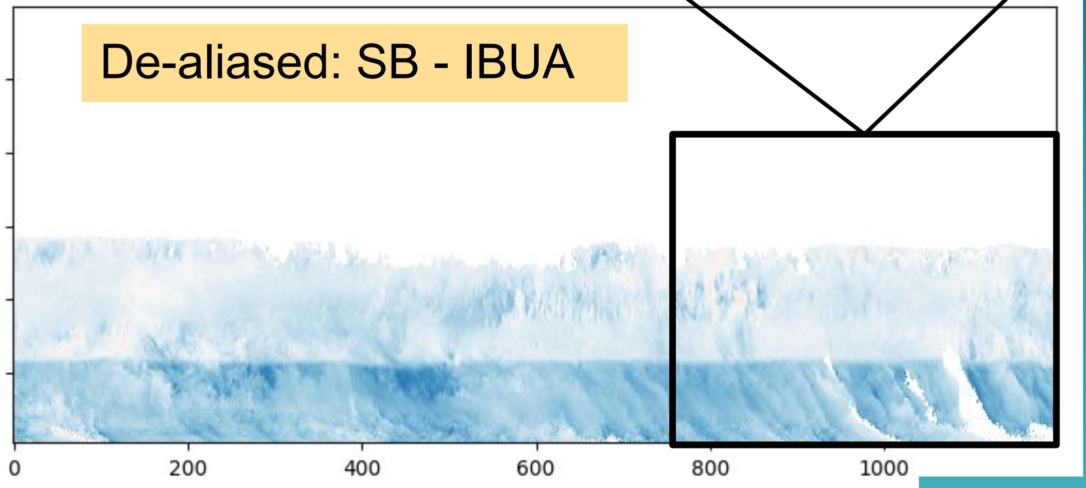
2) If the velocity change exceeds one Nyquist velocity, use the dealiased Doppler velocity profile from the previous time step as the reference (*Vref)*

Case Study: De-aliasing under low-complexity conditions (stratiform) clouds W-band (NEBULA W) 19/12/2024





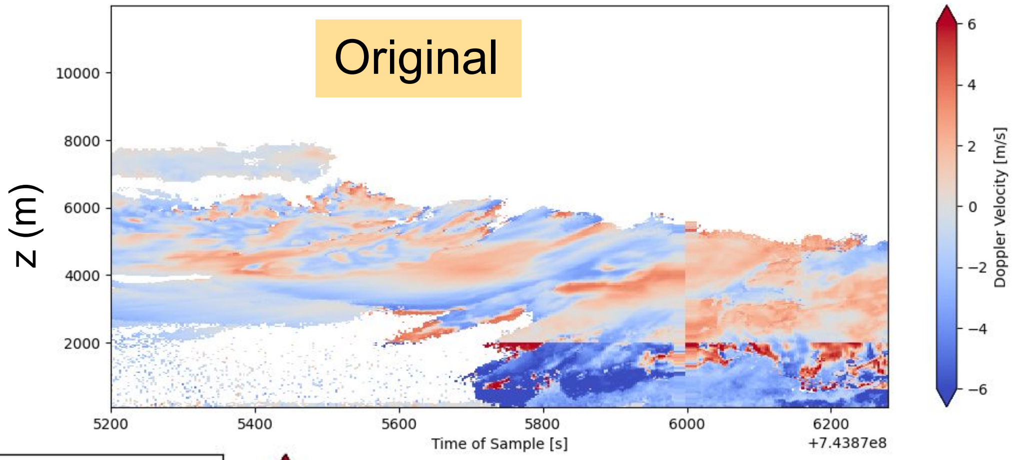




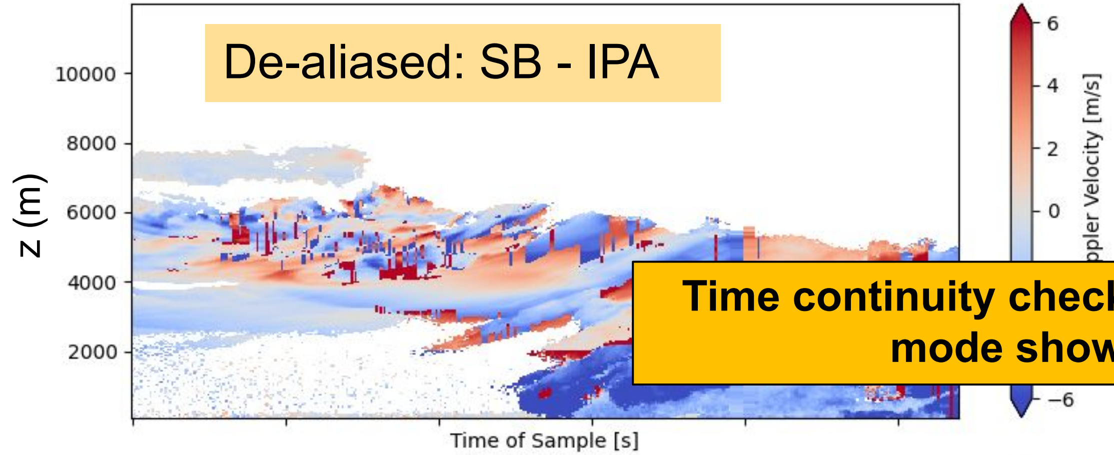
Both algorithms works quite well for stratiform clouds

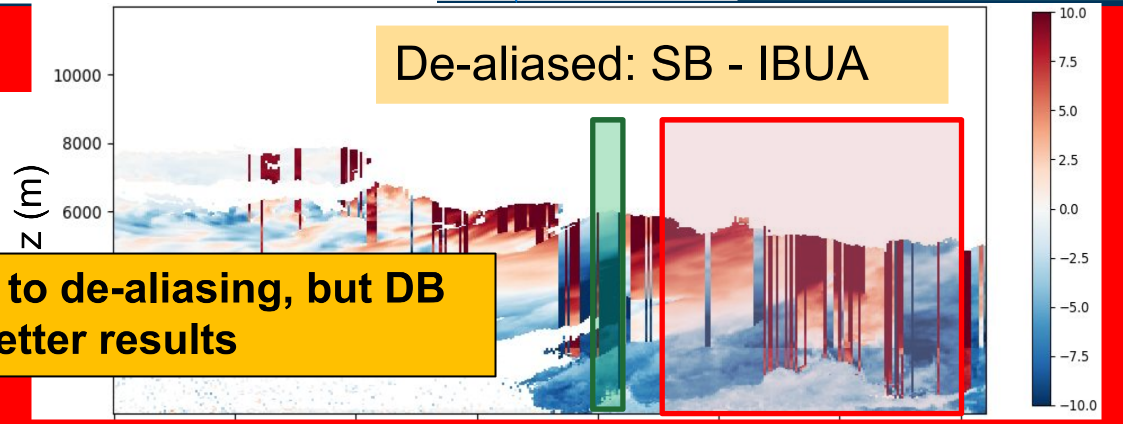
Case Study: De-aliasing under high-complexity conditions (convective clouds)

W-band (NEBULA) 28/07/2024

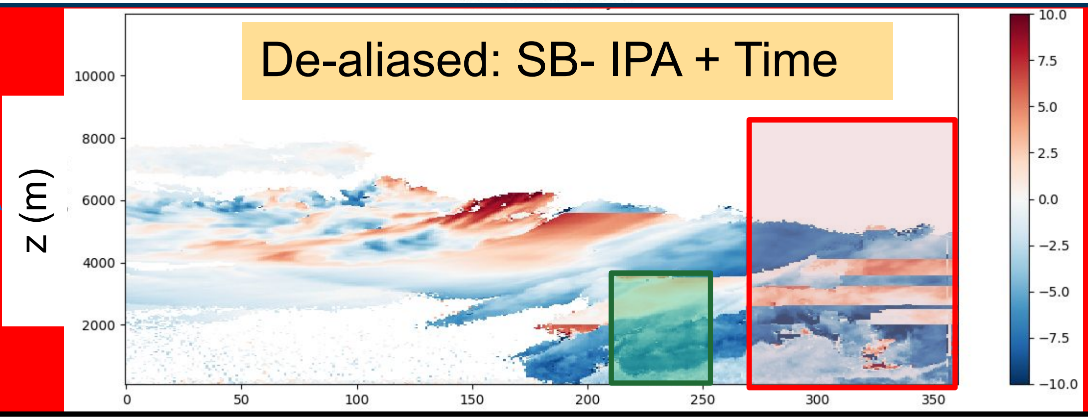


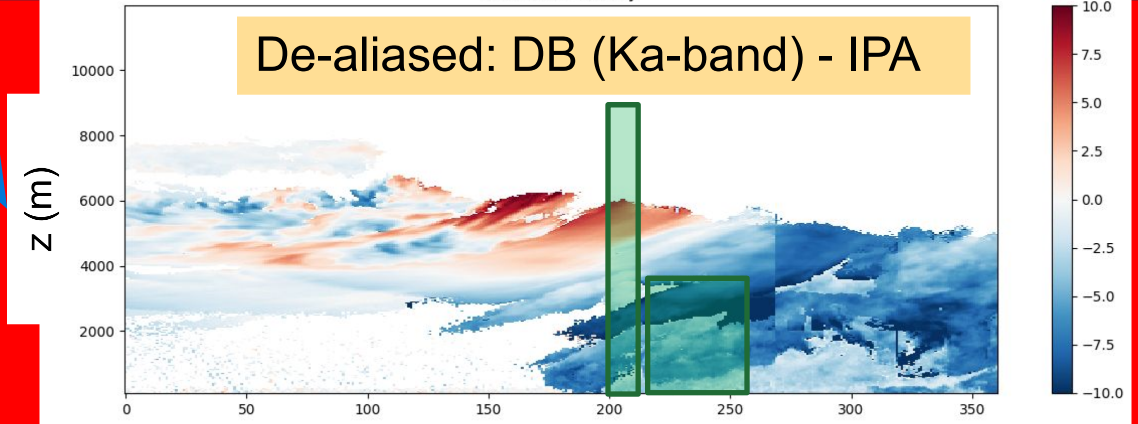
- Can propagate errors in range
- Sometimes it may get the real values in sharp changes in speed





Time continuity check can help to de-aliasing, but DB mode shows much better results





- Can propagate errors in time
- It is smooth and may look right without a reference (Ka-band)

Validation DDV_{Ka-W}: Methodology

$$DDV_{Ka-W} = V_{Ka} - V_W$$

Max DDV for liquid droplets = -2.2 m/s (Courtier et al 2024)

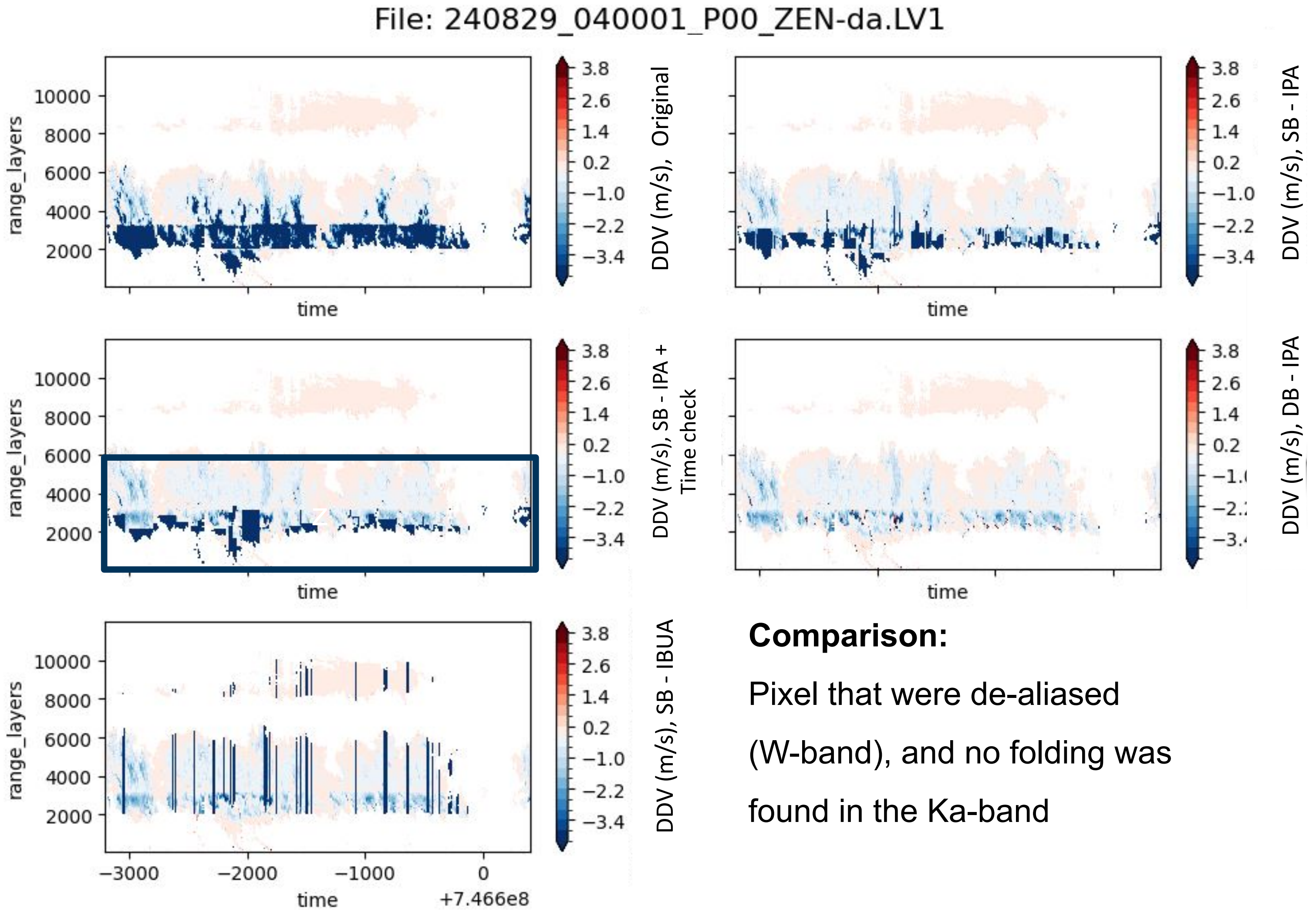
However, 3 m/s seems to be a better indicator of erroneous corrections

Method:

if $DDV_{ka\text{-}W}$ >= -3: accurate correction.

Otherwise: erroneous correction

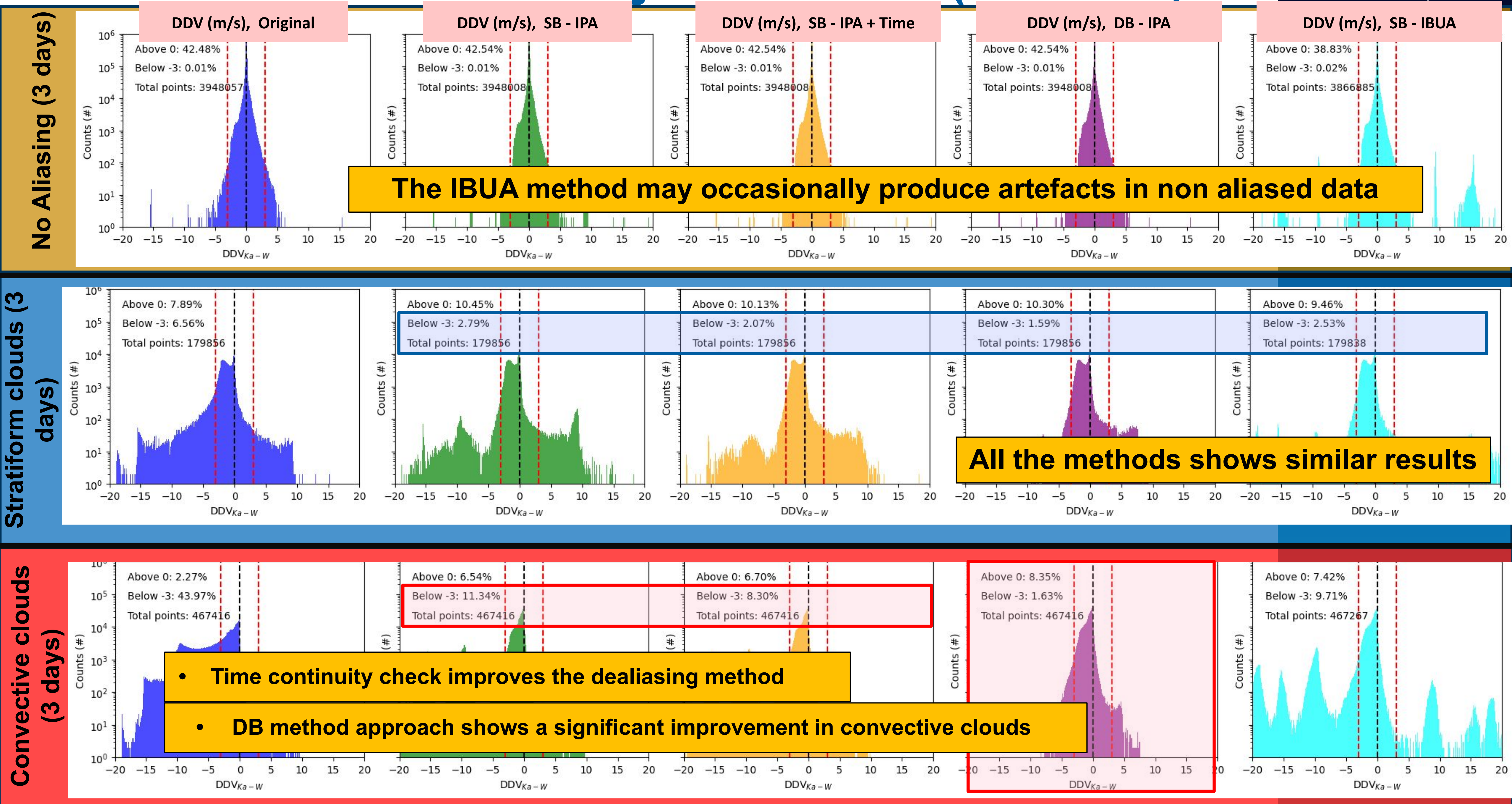
DDV_{Ka-W} for each original profile and each method



Comparison:

Pixel that were de-aliased (W-band), and no folding was found in the Ka-band

9 days validation (Granada)



Concluding Remarks

1. This work has successfully assessed four dealiasing algorithms:
   - Spatio-temporal continuity check
   - Case studies: stratiform and convective
2. Accurate dealiasing achieved with all three single-band methods for stratiform clouds.
3. SB mode algorithms performs quite well (IBUA is the fastest one)
4. In convective clouds, time continuity check improve de-aliasing performance
5. These are cases where the Ka-band becomes essential.
6. Deep convective cloud: the use of Ka-band doppler velocity spectra becomes essential

Next steps

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- Apply time continuity check to SB – IBUA approach (CLU)
- Standard formulation to retrieve polarimetric variables
- Retrieving of spectral correlation coefficient and LDR (comparable to RPG LV1)
- Moments calculation

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Thank you !

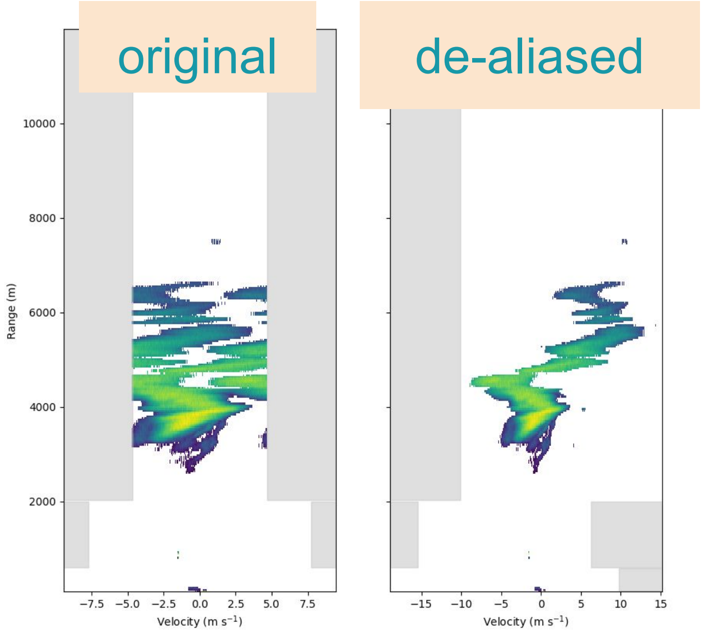
Backup slides

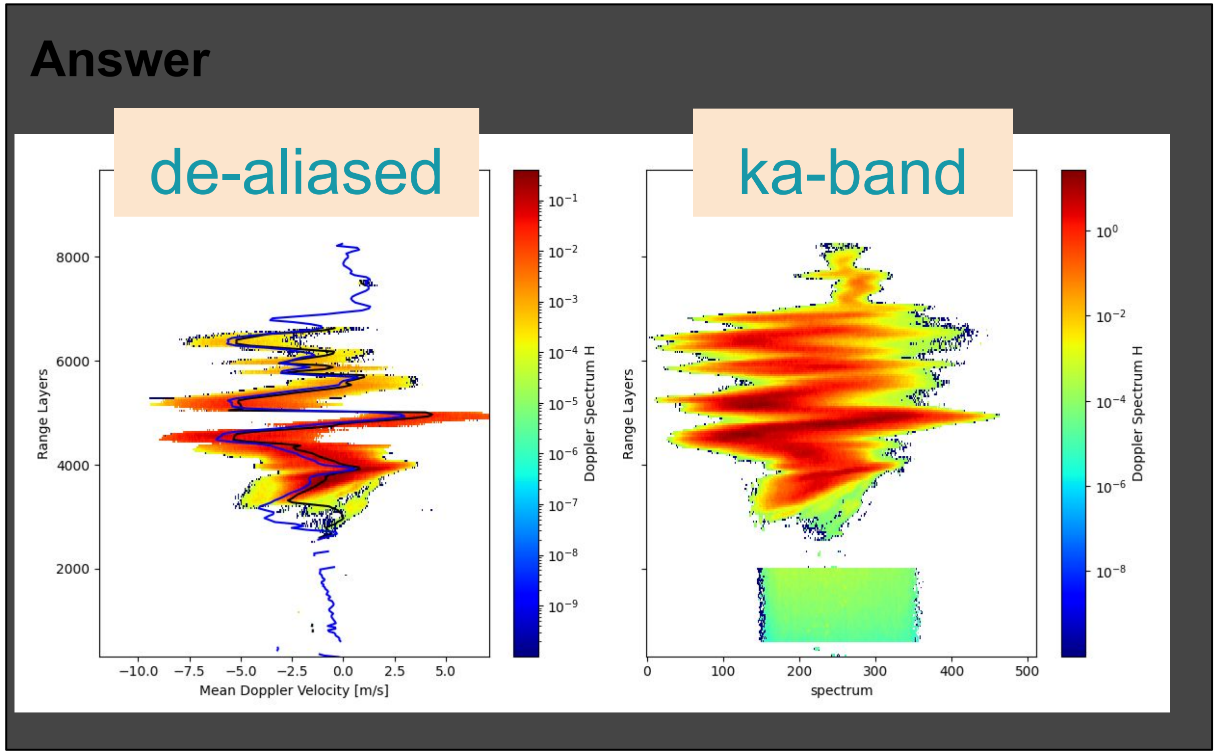
Coherence in Range:

Considerations: works quite well for most cases but can give bad results when data have **gaps** (attenuation or multilayer) or **two regimes**.

GAPS:

Difficult case





Consequences: Some parts of the spectra are more than one nyquist shifted in the wrong direction.

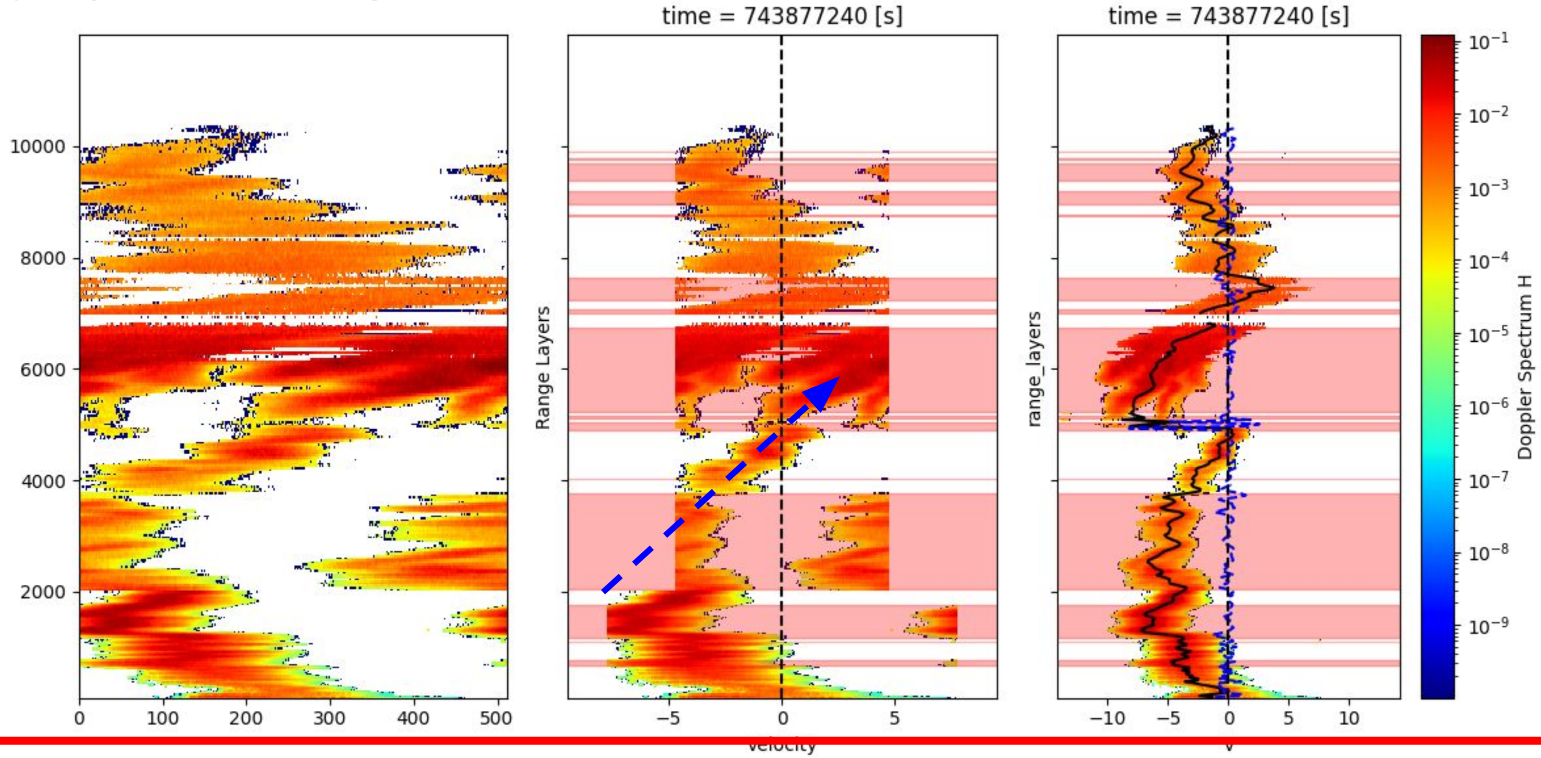
Solution: Baseline (something close to the truth): Ka-band or the closest profile with no folding or **correctly** de-aliased

Coherence in Range:

Considerations: works quite well for most cases but can give bad results when data have **gaps** (attenuation or multilayer) or **two regimes**.

Two regimes:

Difficult case

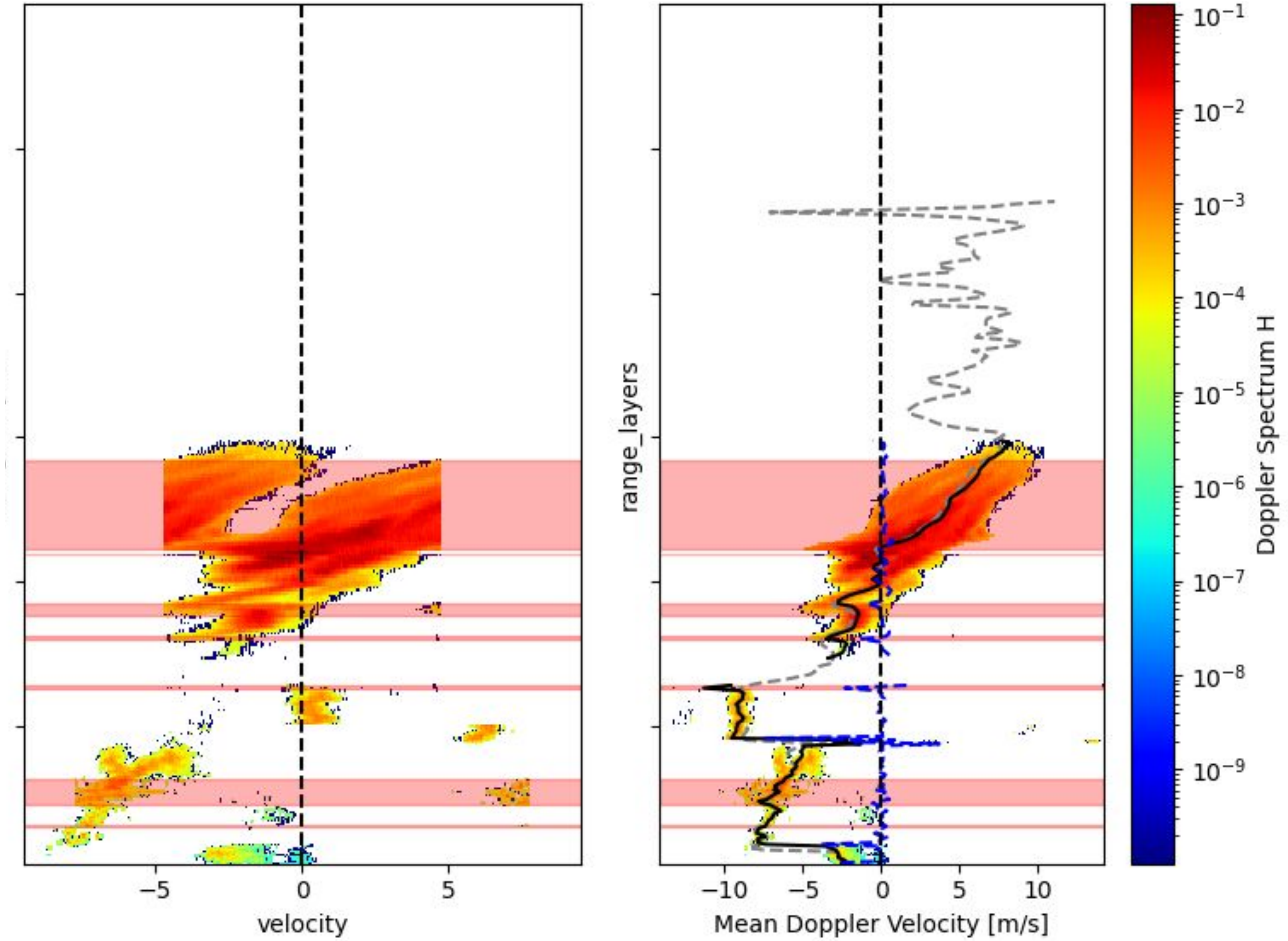


Consequences: Some parts of the spectra are more than one nyquist shifted in the wrong direction.

Solution: Baseline (something close to the truth): Ka-band or the closest profile with no folding or **correctly** de-aliased

N > 2:

Considerations:

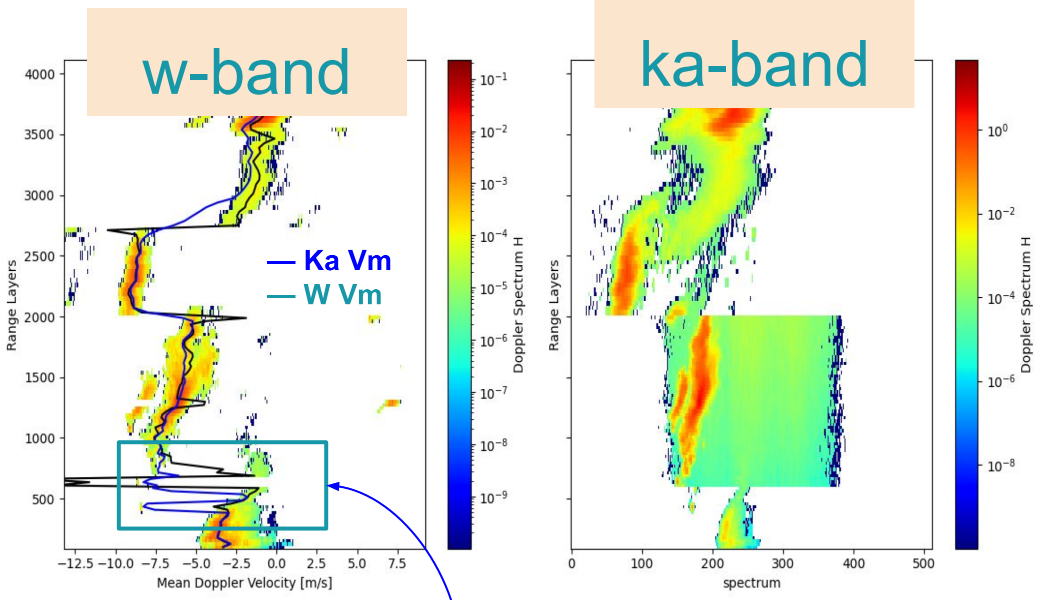


Two regimes:

Difficult case

Consequences: Solution:

Ka-band as reference can also cause some minor issues due to better sensibility



Difference in mean doppler velocity: Ka-band can see more

Possible solution: range coherence verification
(Difficult to know each part of the spectra is the truth)

In general, Ka-band gives much better results in complicated cases