Fourth Calibration and Monitoring Workshop

Long-term calibration of an X-band radar network in western Germany.

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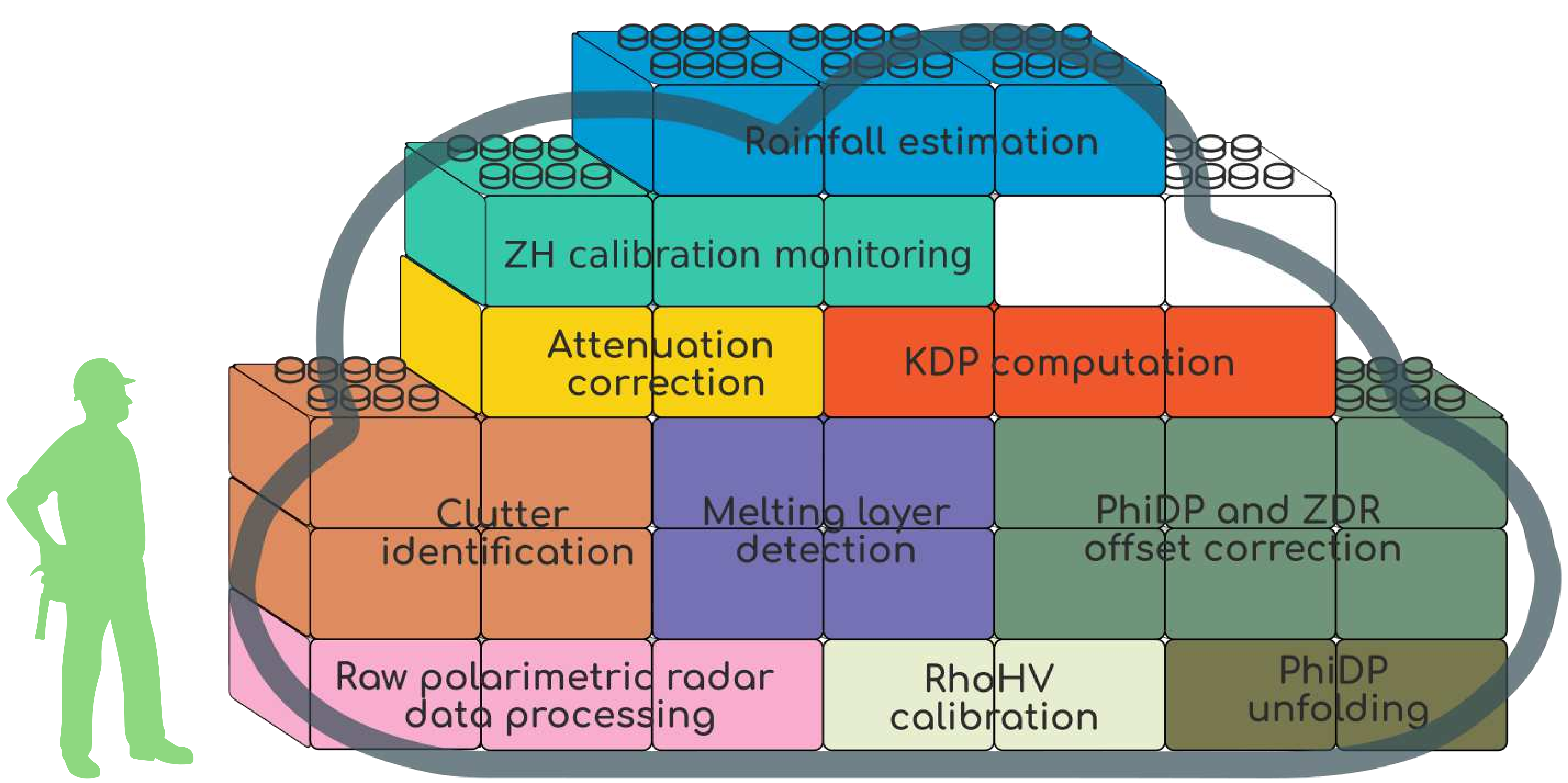
Project objectives

- This study is developed under the Digitales Geosystem -- Rheinisches Revier (DG-RR) project.
- It aims to provide a high-resolved, quality-assessed radar- based Quantitative Precipitation Estimation (QPE) and nowcasts exploiting the local polarimetric X-band radar network located in western Germany.
- To this end, we must monitor the calibration of two polarimetric X-band (wavelength ~3 cm) radars in Bonn (BoXPol) and Jülich (JuXPol).

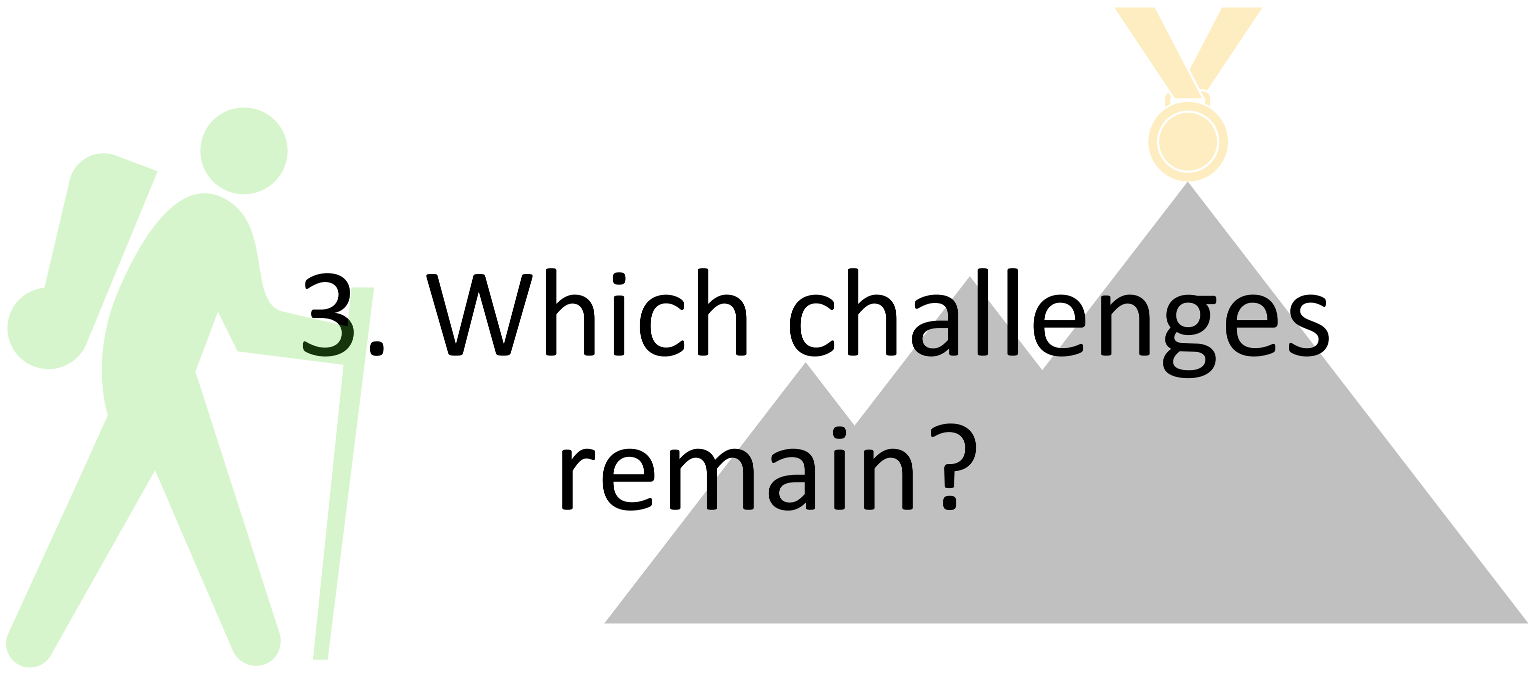
Talk outline



1. Radar processing chain

Why? How? Data?

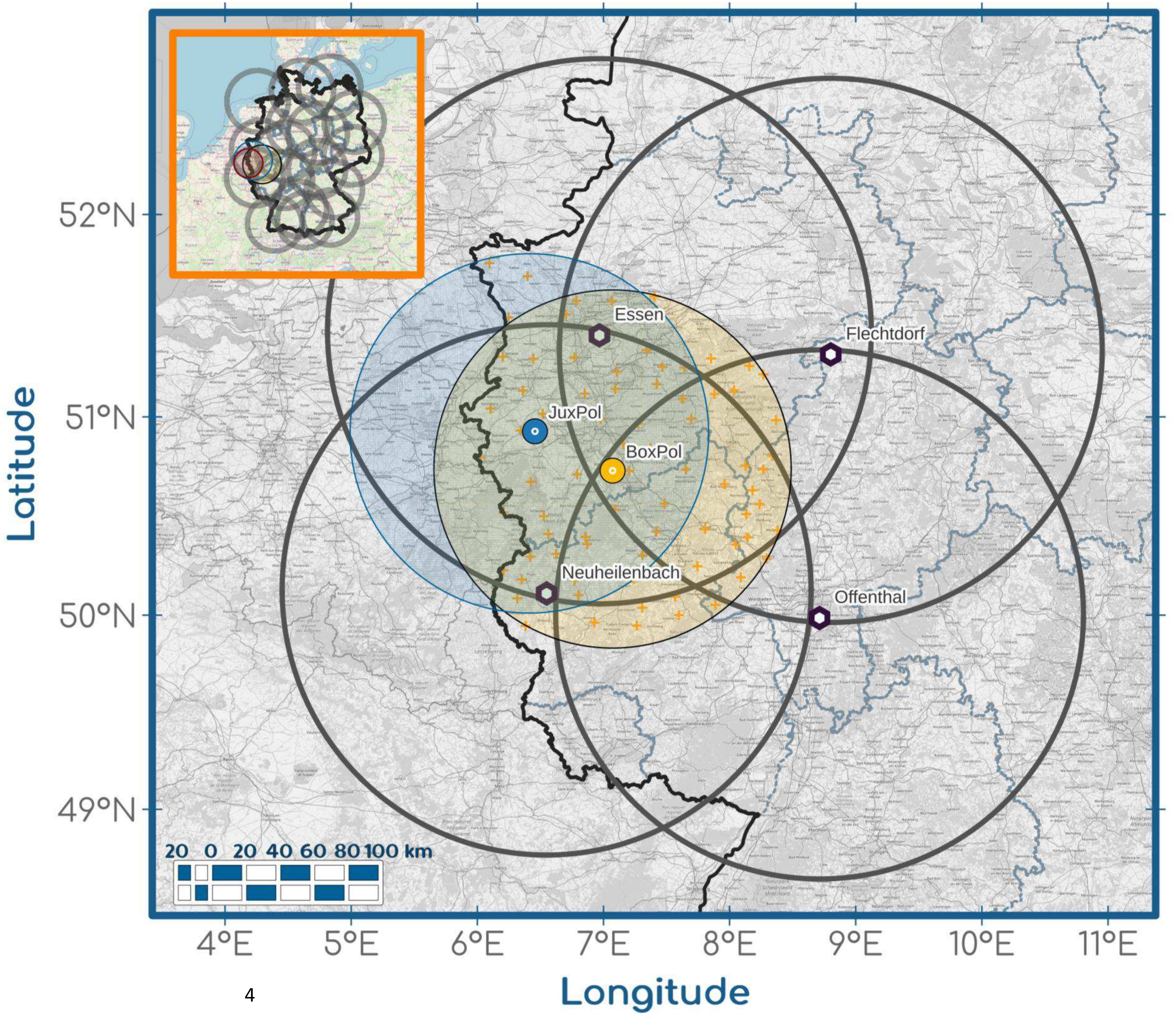
2. Which challenges did we overcome?



3. Which challenges remain?

Datasets

- Each X-band radar covers up to 150 km at 10 different elevation angles, monitoring the region with high spatial (~150 m) and temporal (~5 min) resolution.

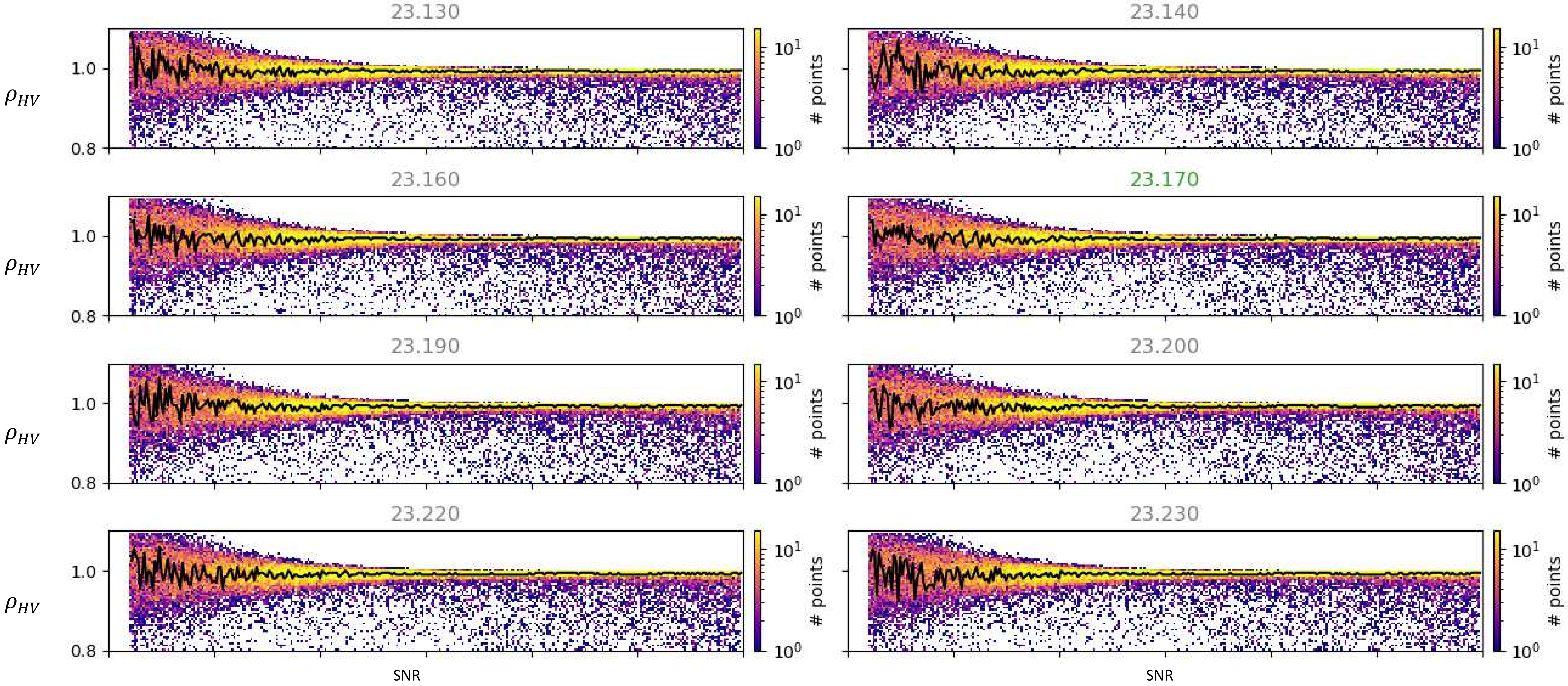


Radar processing chain

rhoHV correction

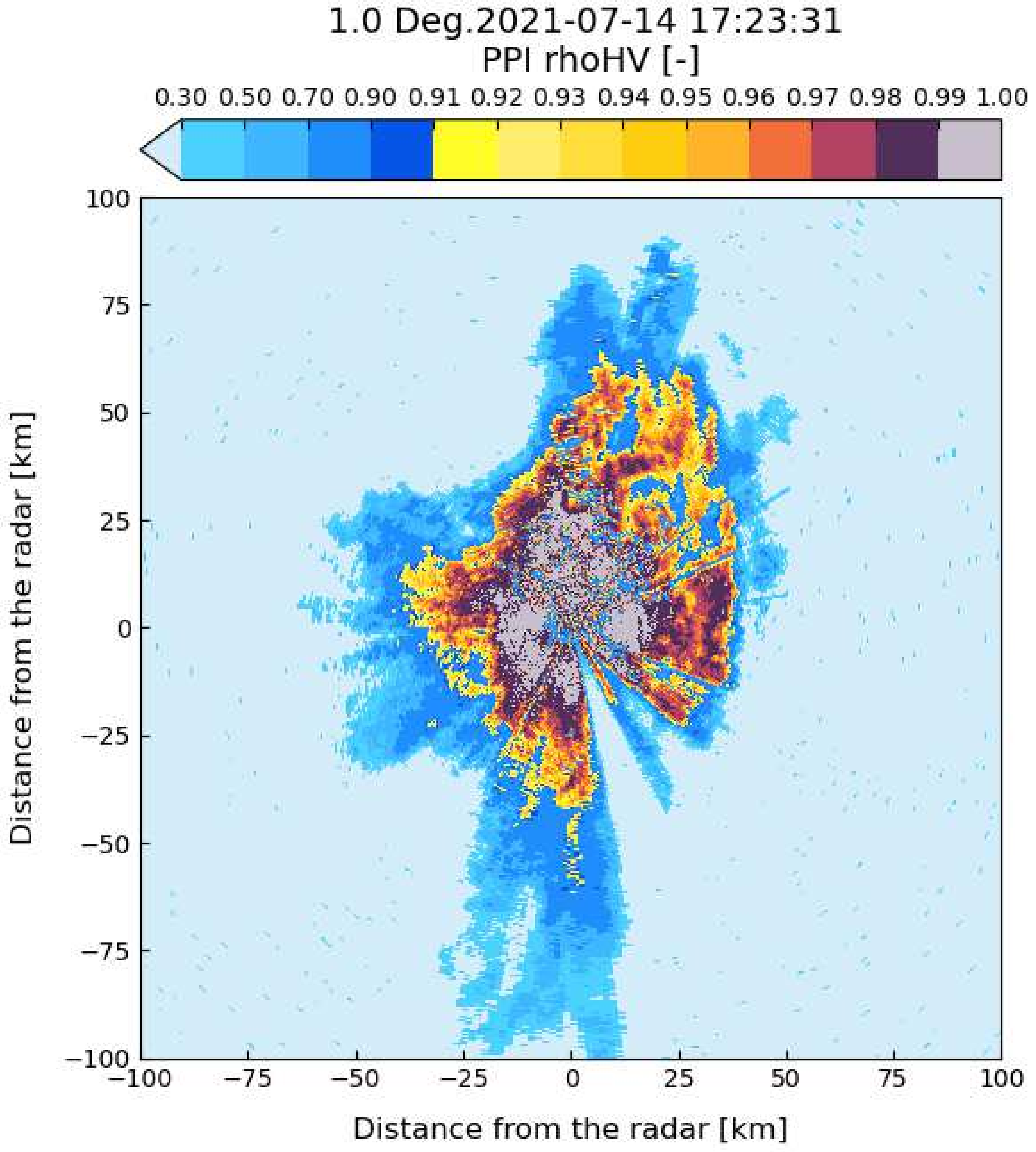
Consist on varying the radar constant (C) until a flat dependence of ρ_{HV} on SNR is achieved, as described in Ryzhkov and Zrnic, (2019).

$$SNR[dB] = Z_H[dBZ] - 20 * log_{10} * r[km] + C[dB]$$

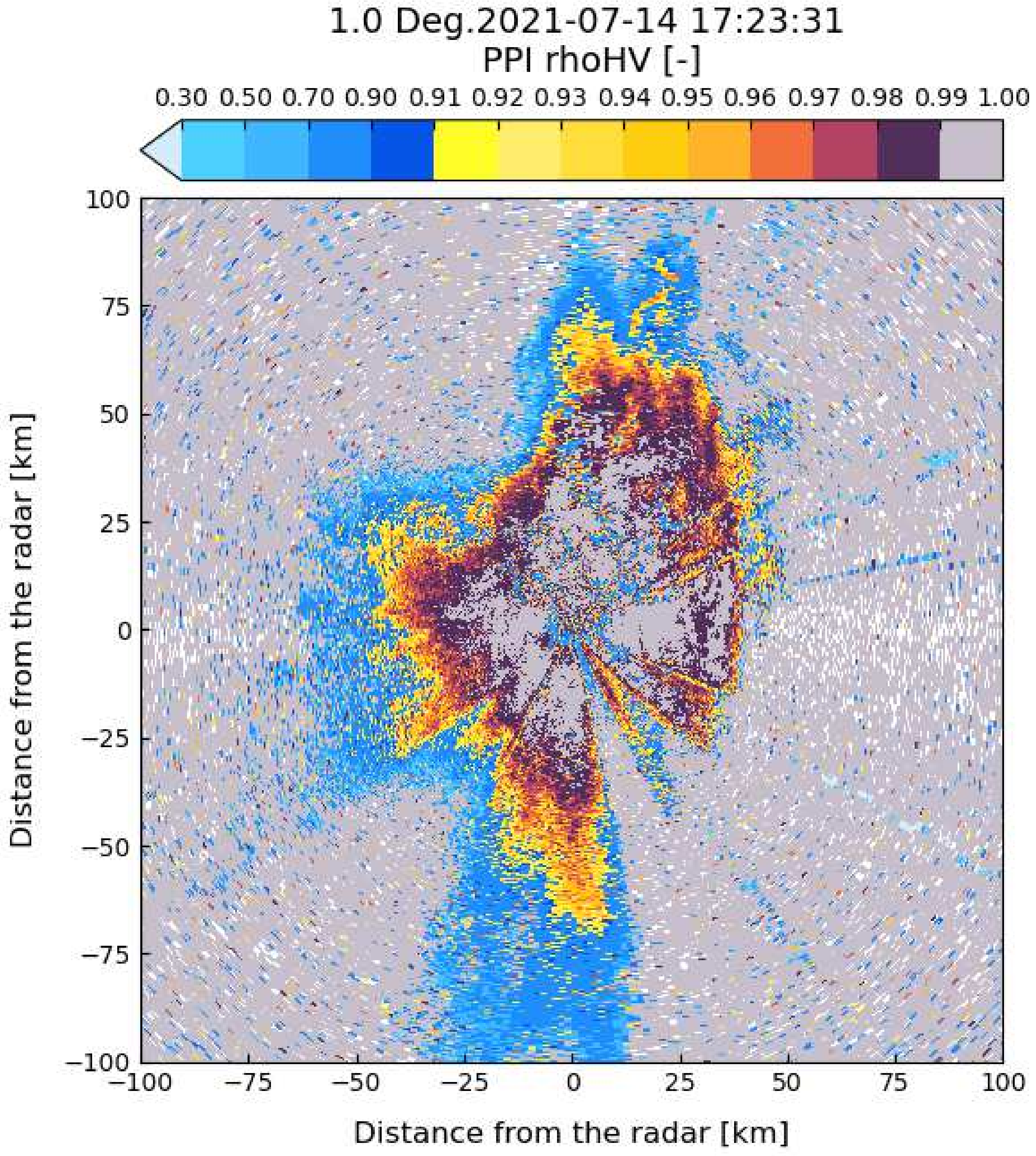


rhoHV correction

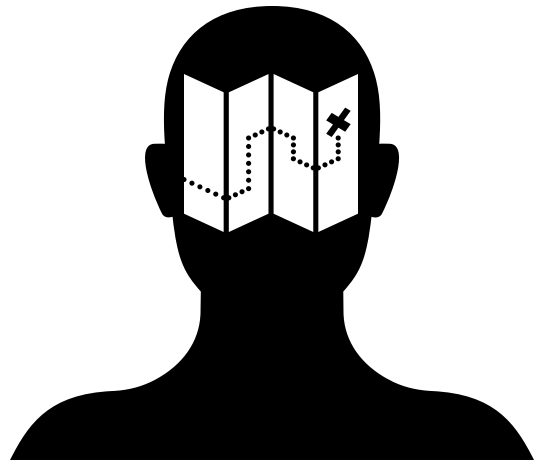
Results:



Raw ρ_{HV}



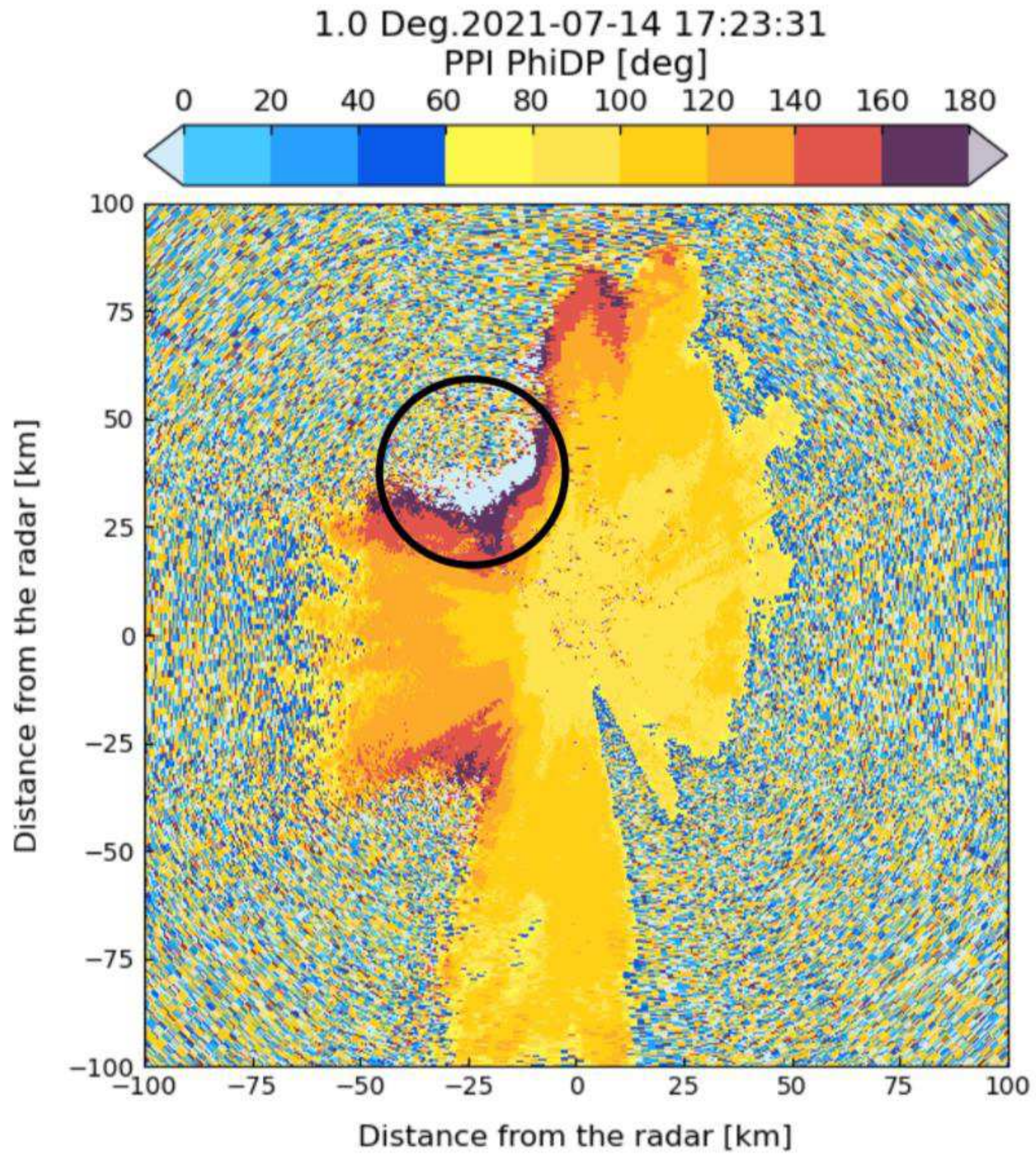
ρ_{HV} corrected



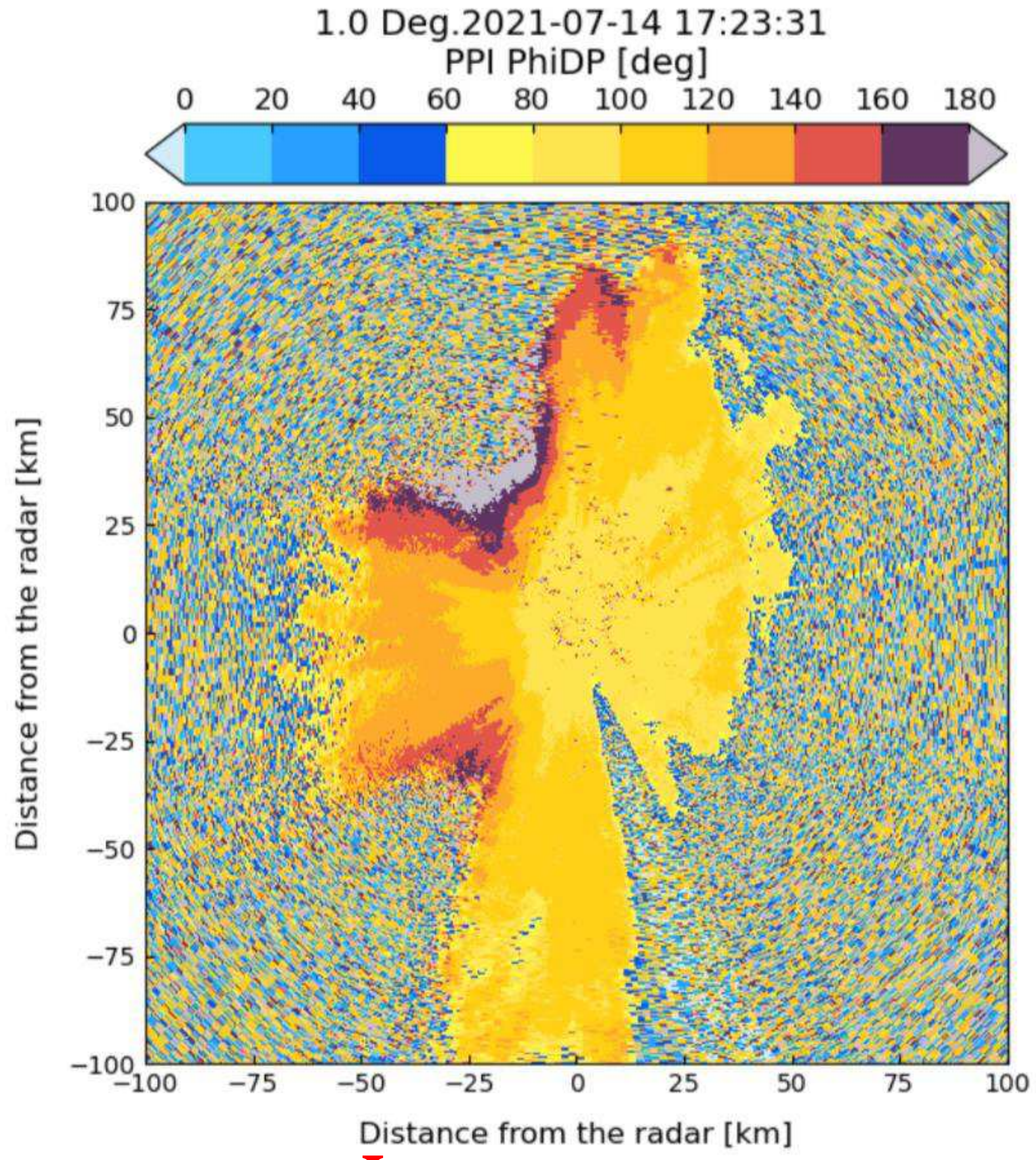
- Key challenges:
  - ☑ Do not overcorrect ρ_{HV}
  - ☑ Make it computationally cheap

PhiDP unfolding

Based on the standard deviation of Φ_{DP}, the Φ_{DP} slope and ρ_{HV}, as proposed by Wang et al., (2009).



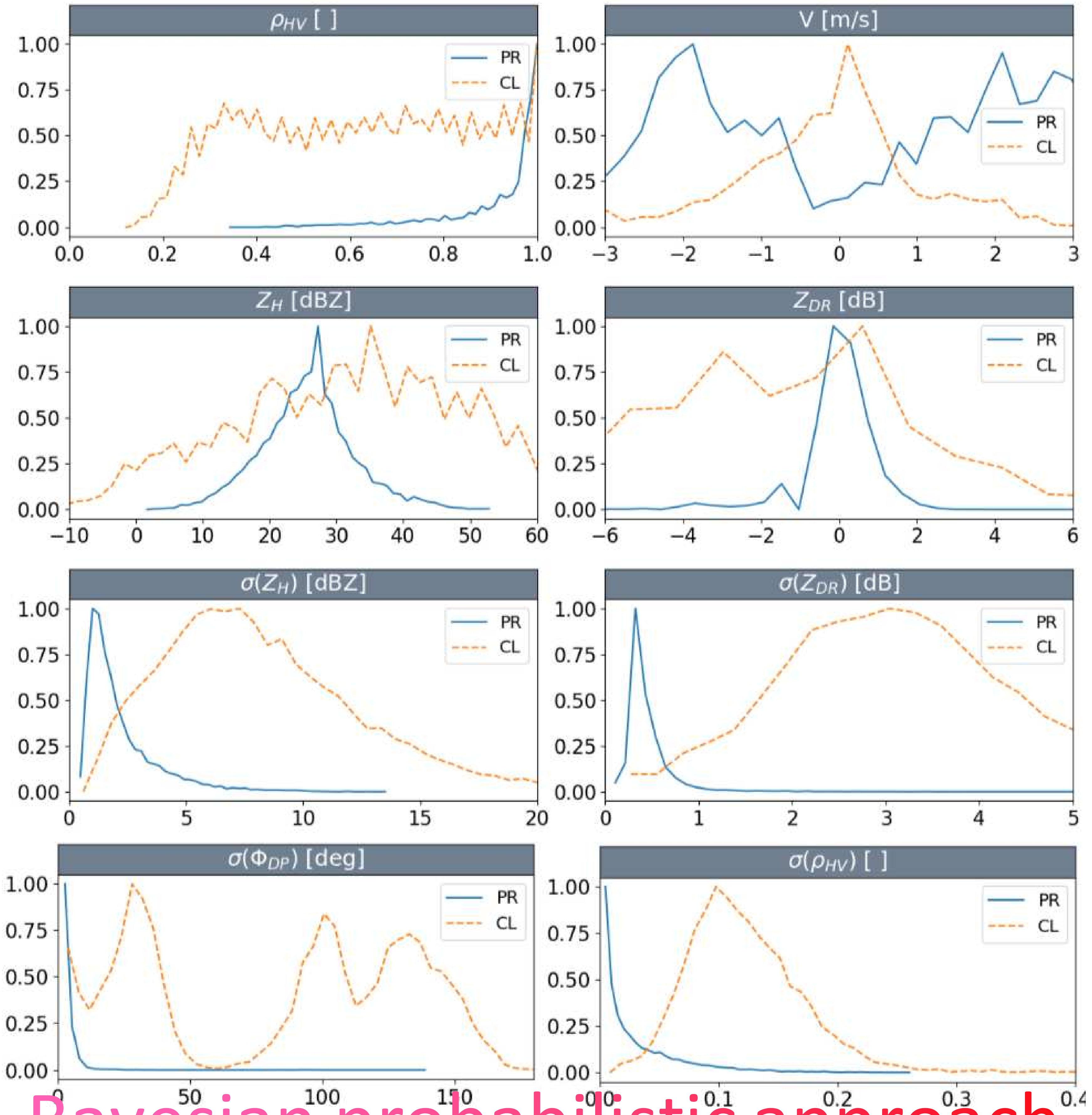
Folded Φ_{DP}



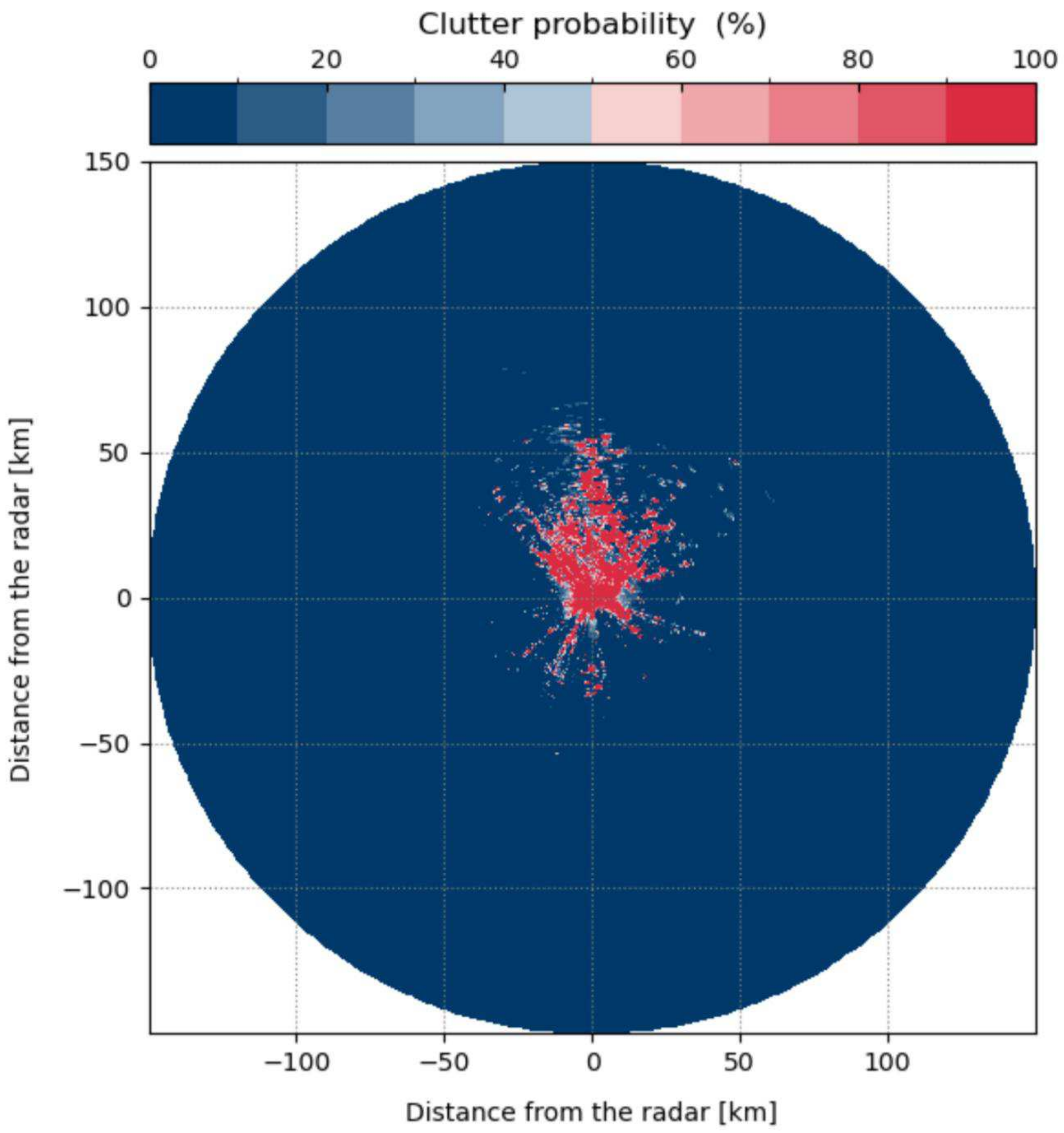
Φ_{DP} unfolded

Clutter ID

It's based on the study proposed by Rico-Ramirez and Cluckie (2008) designed to classify non-meteorological echoes (ground clutter, sea clutter, and anomalous propagation echoes)



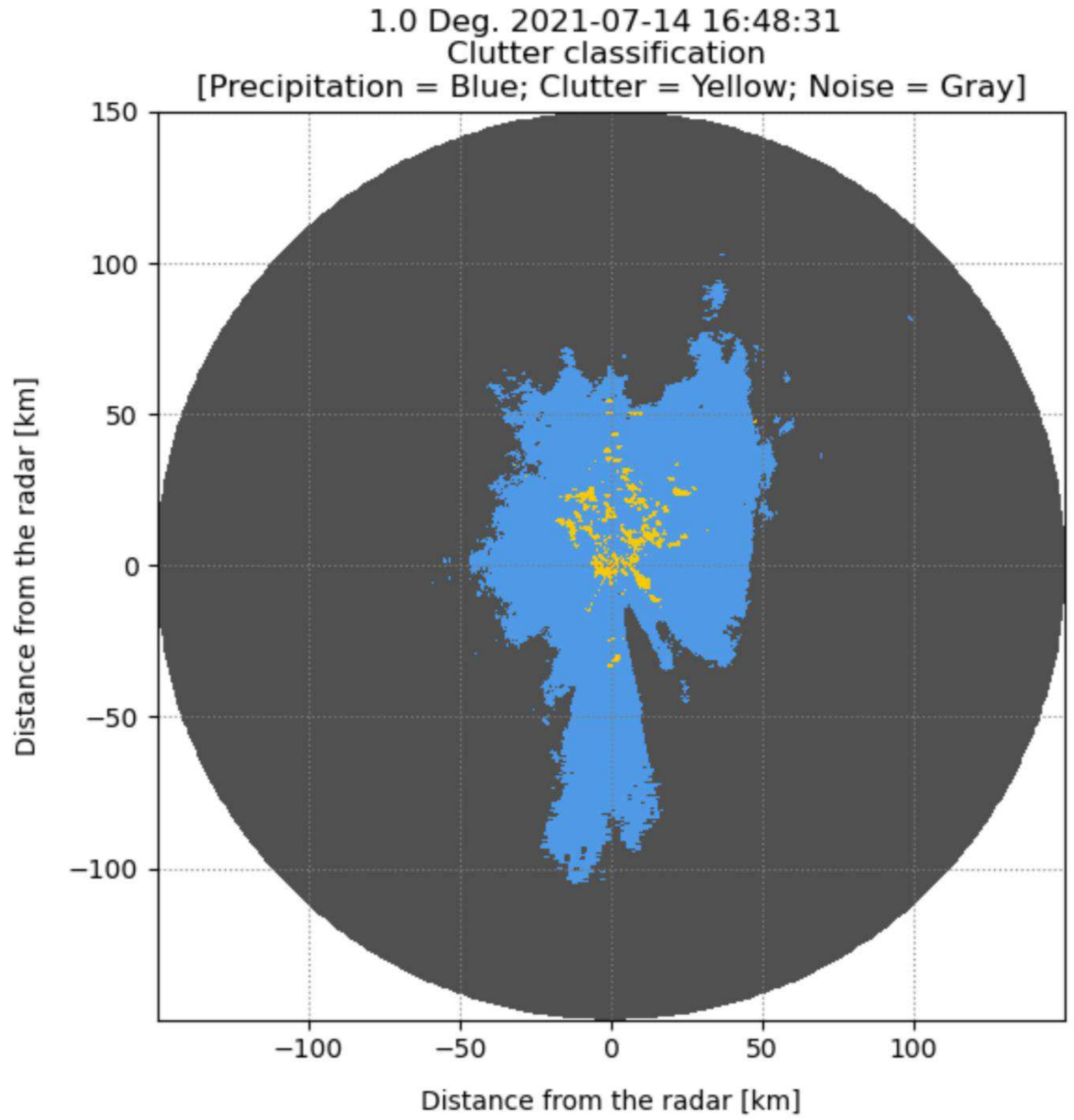
Bayesian probabilistic approach (MFS)

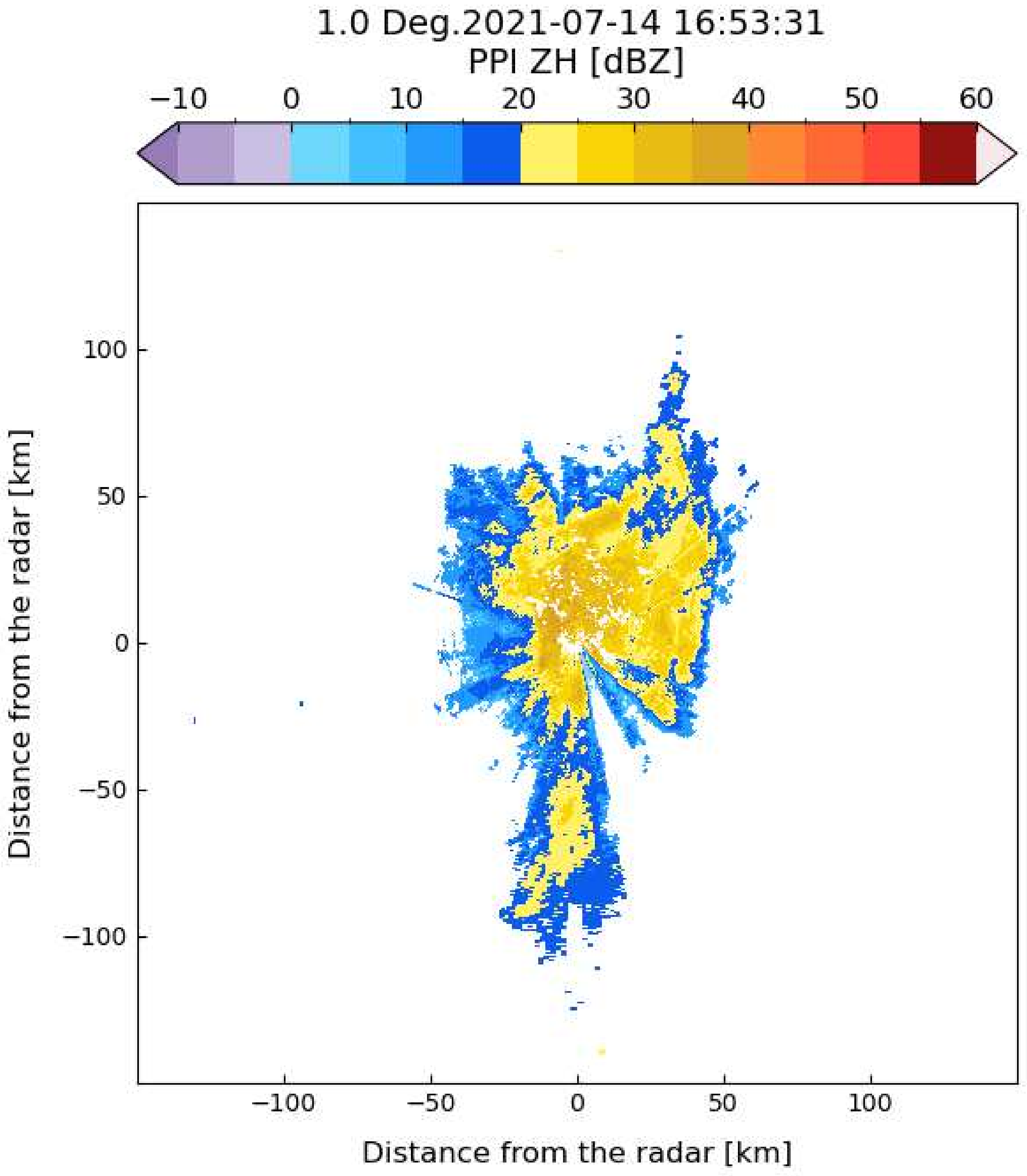


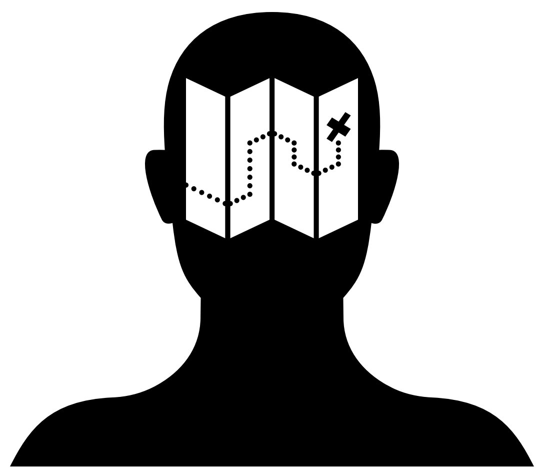
Dynamic clutter map

Clutter ID

Results:







Key challenges:

- Computation of the membership functions
- Use of scans with no rain to generate the clutter map

ZDR/PhiDP offset correction

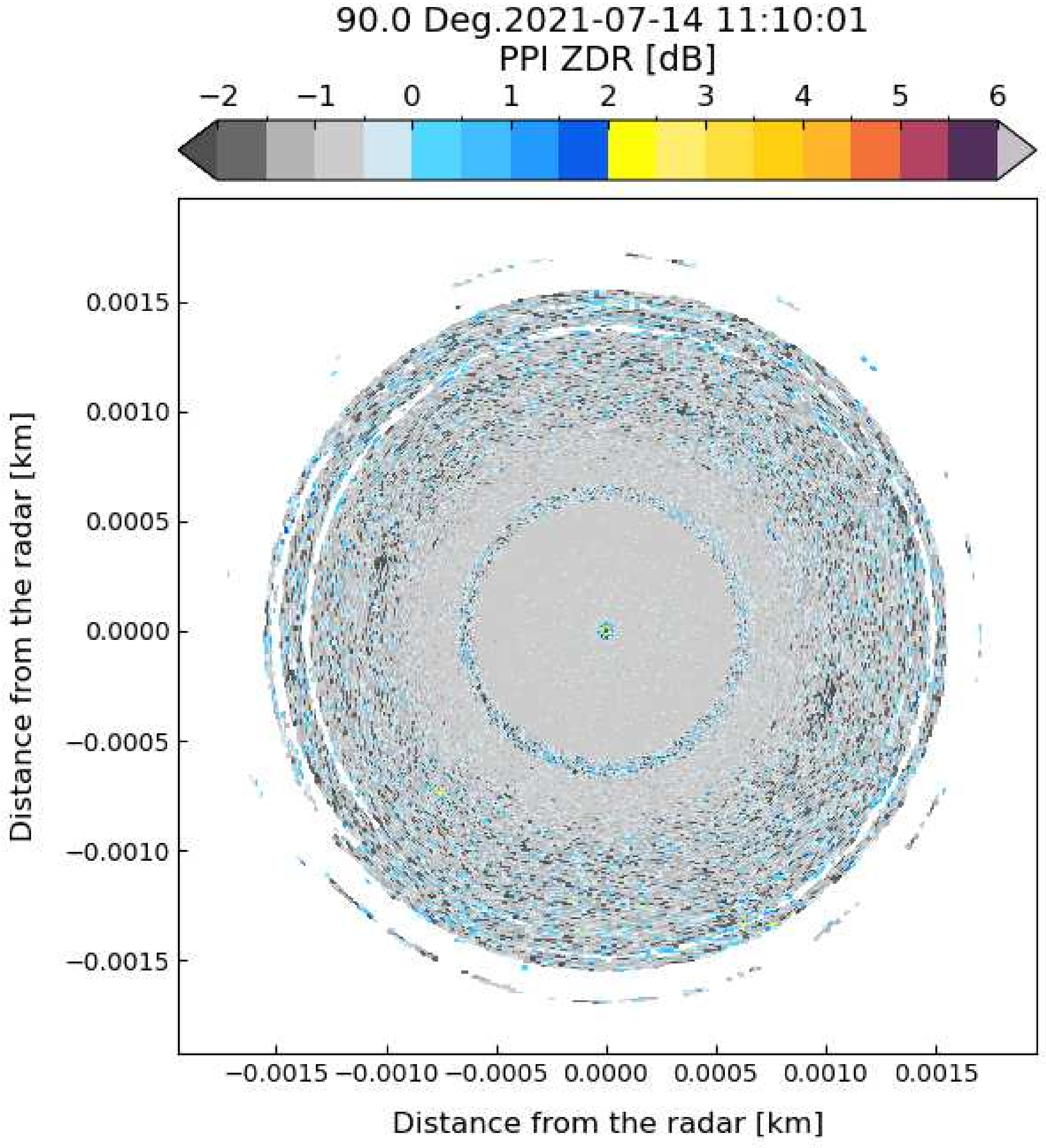
Using the birdbath method introduced by Gorgucci et al. (1999):

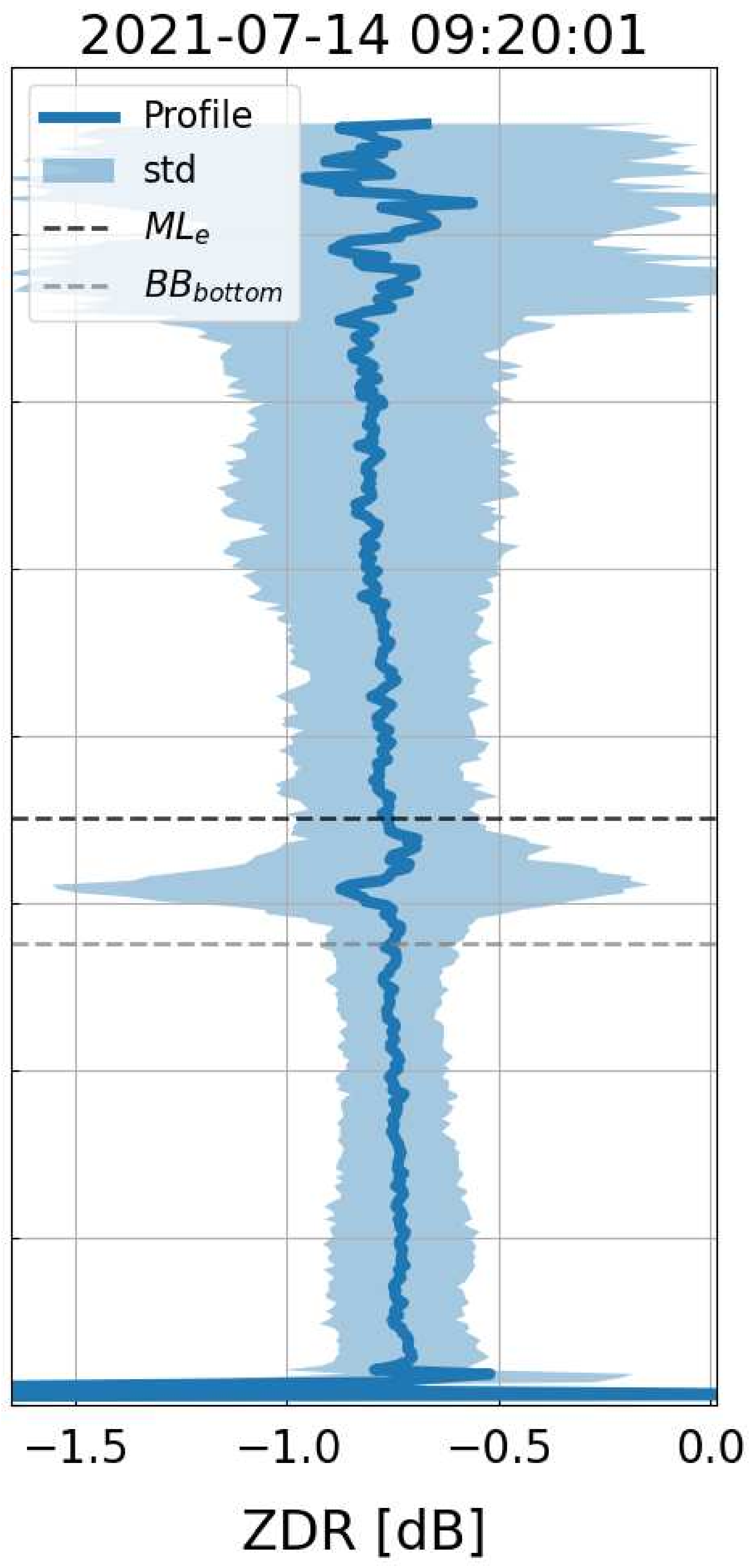
Thresholds related to light rain are set:

- VPs containing 2 or more consecutive bins of Z_{DR} in the rain region,

With corresponding values of:

- 5 dBZ < Z_H < 30 dBZ
- ρ_{HV} > 0.98

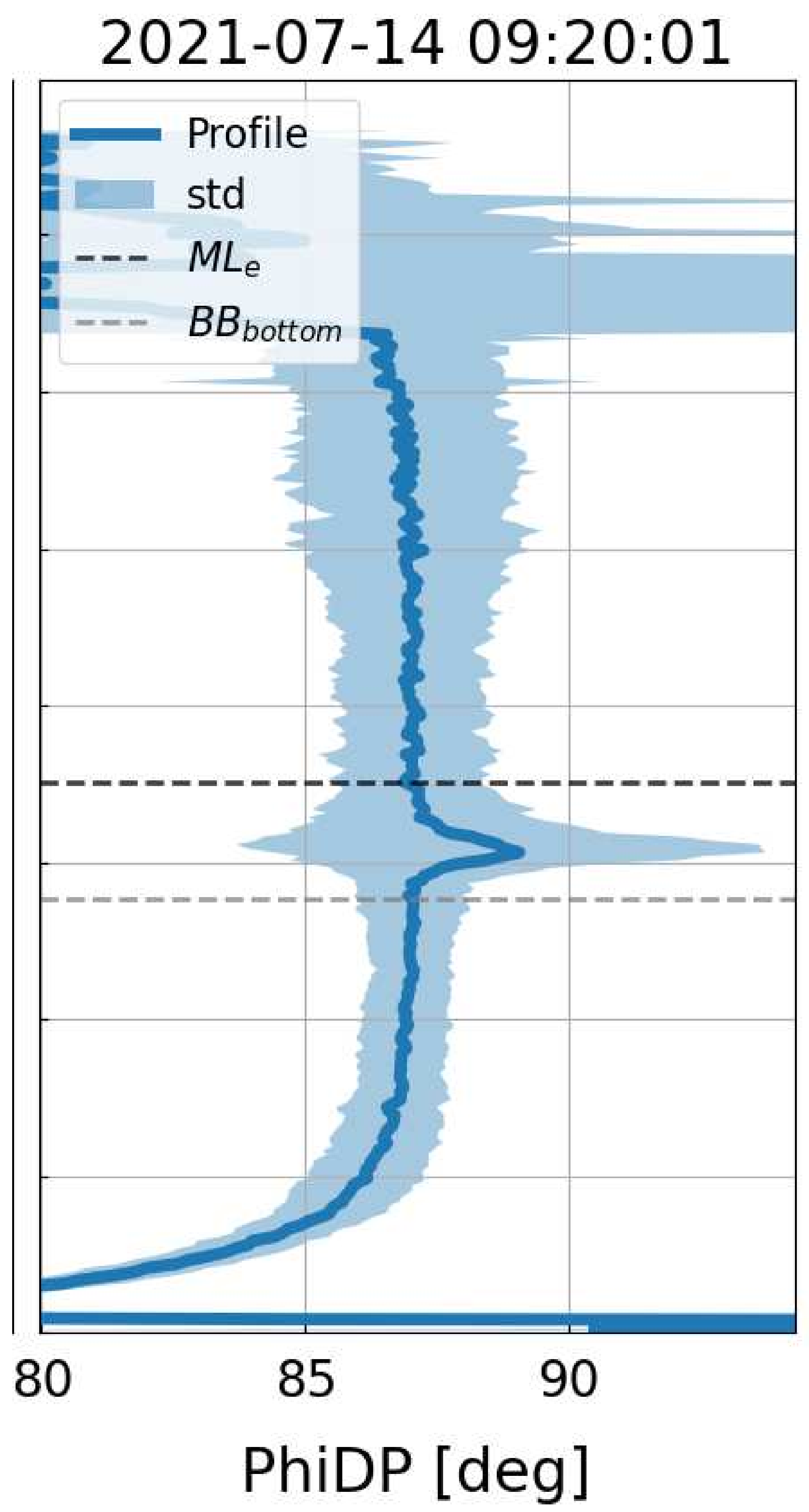


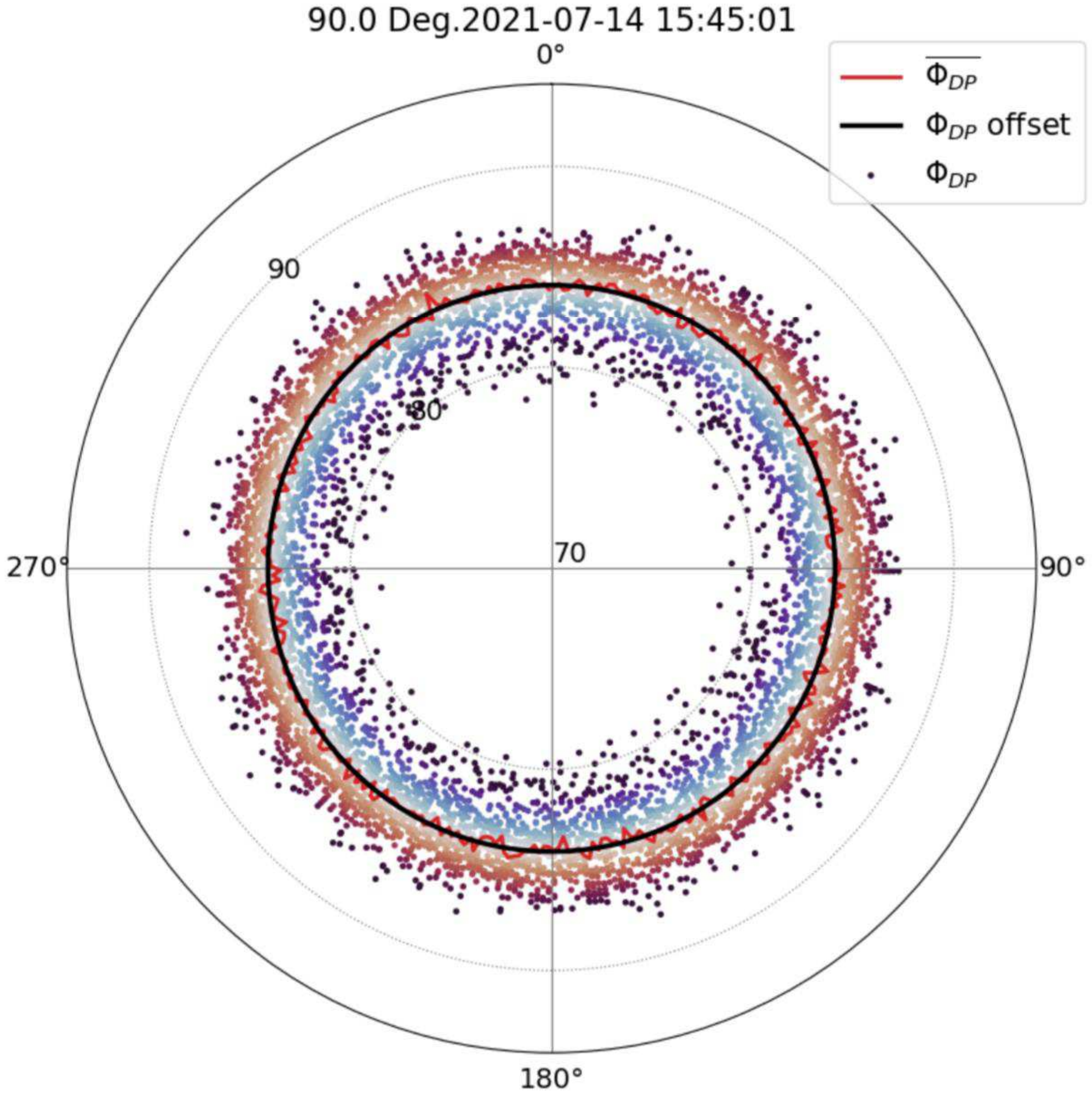


ZDR/PhiDP offset correction

Using the birdbath method introduced by Gorgucci et al. (1999):

- The computation of the Φ_{DP} offset using birdbath scans follows a similar procedure to that used for estimating the Z_{DR} offset, as proposed by Frech, (2013).

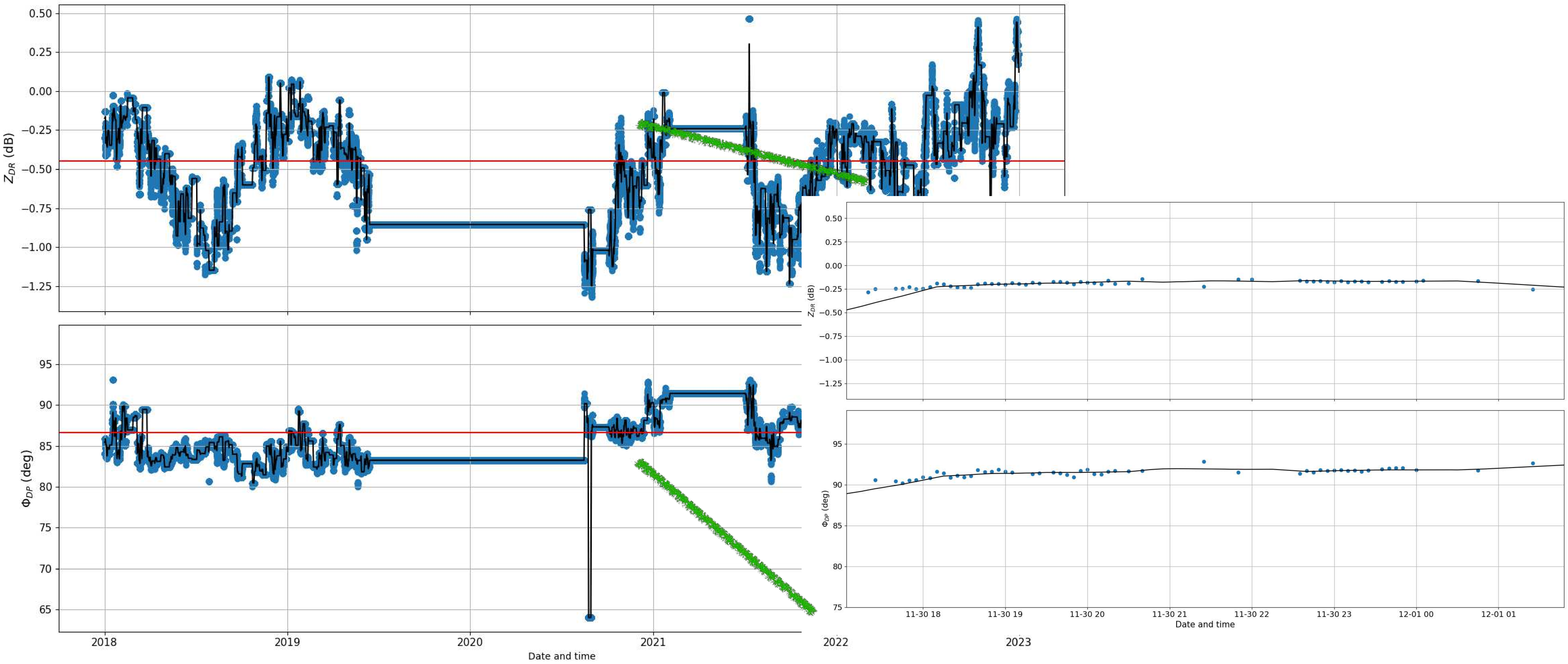




ZDR/PhiDP offset correction

Results:

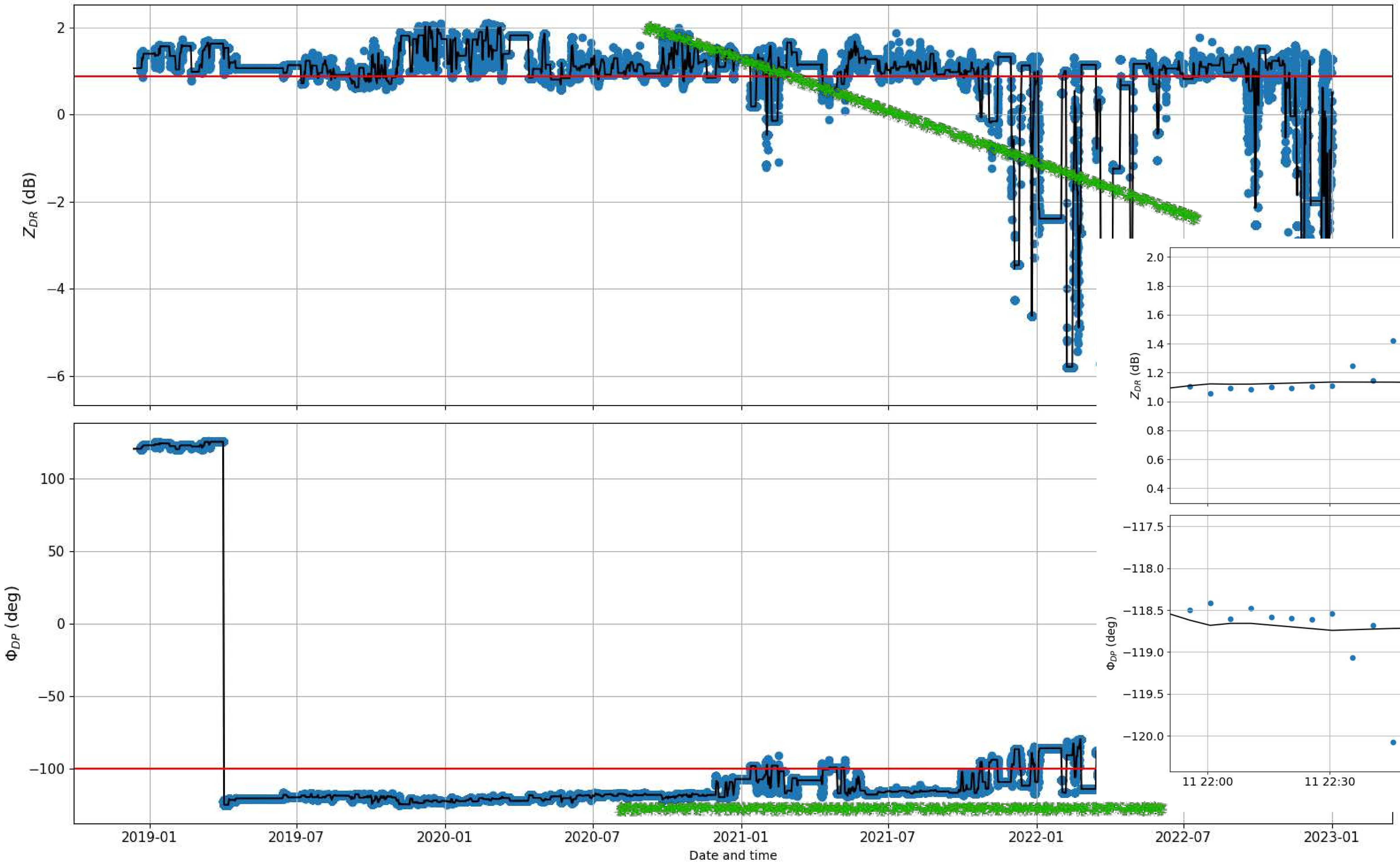
BoXPol

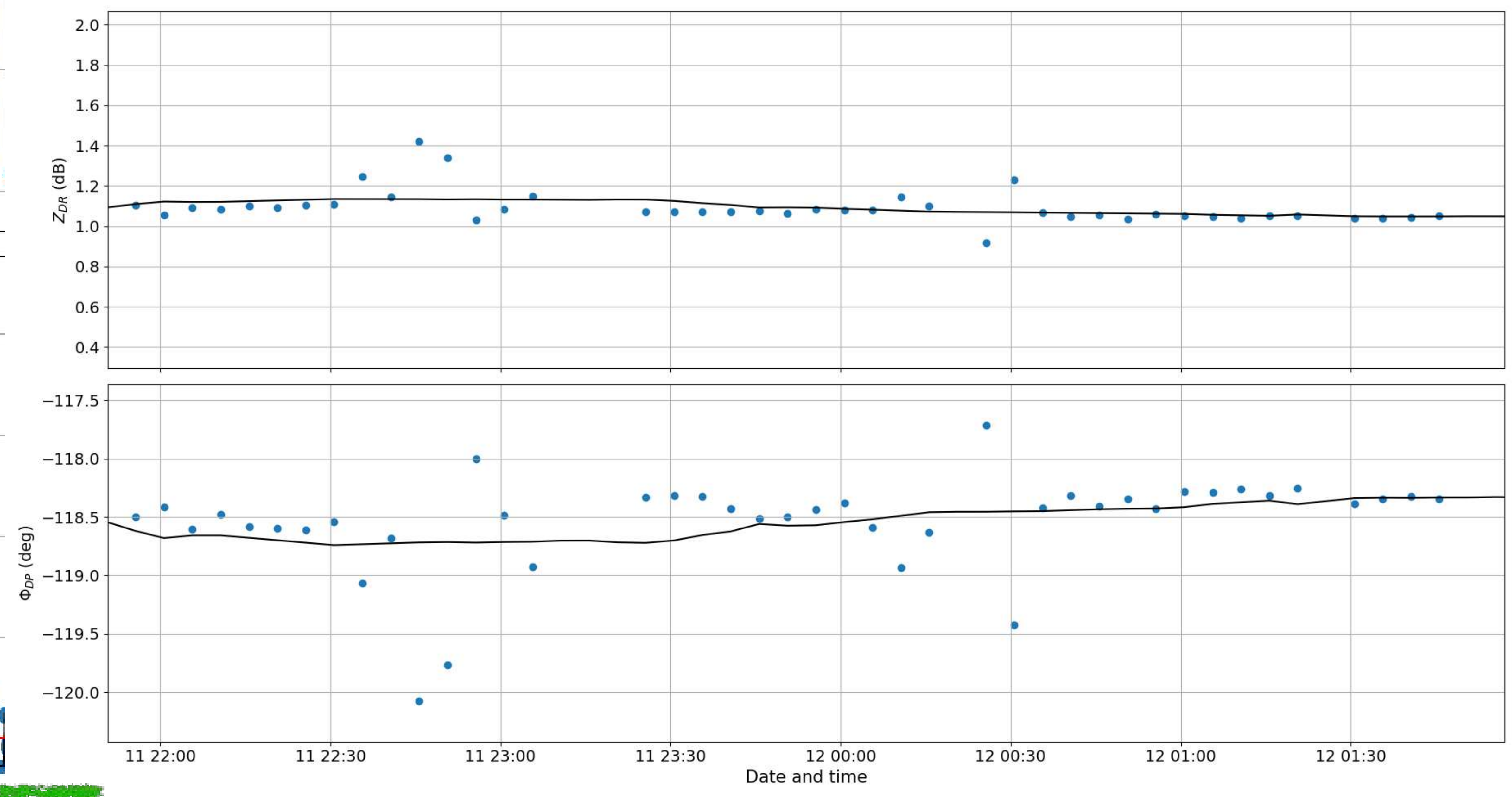


ZDR/PhiDP offset correction

Results:

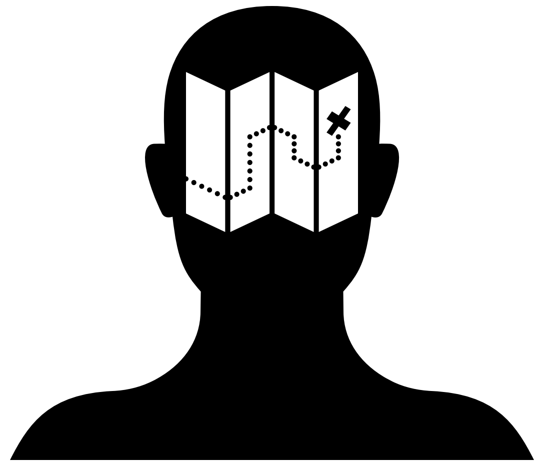
JuXPol



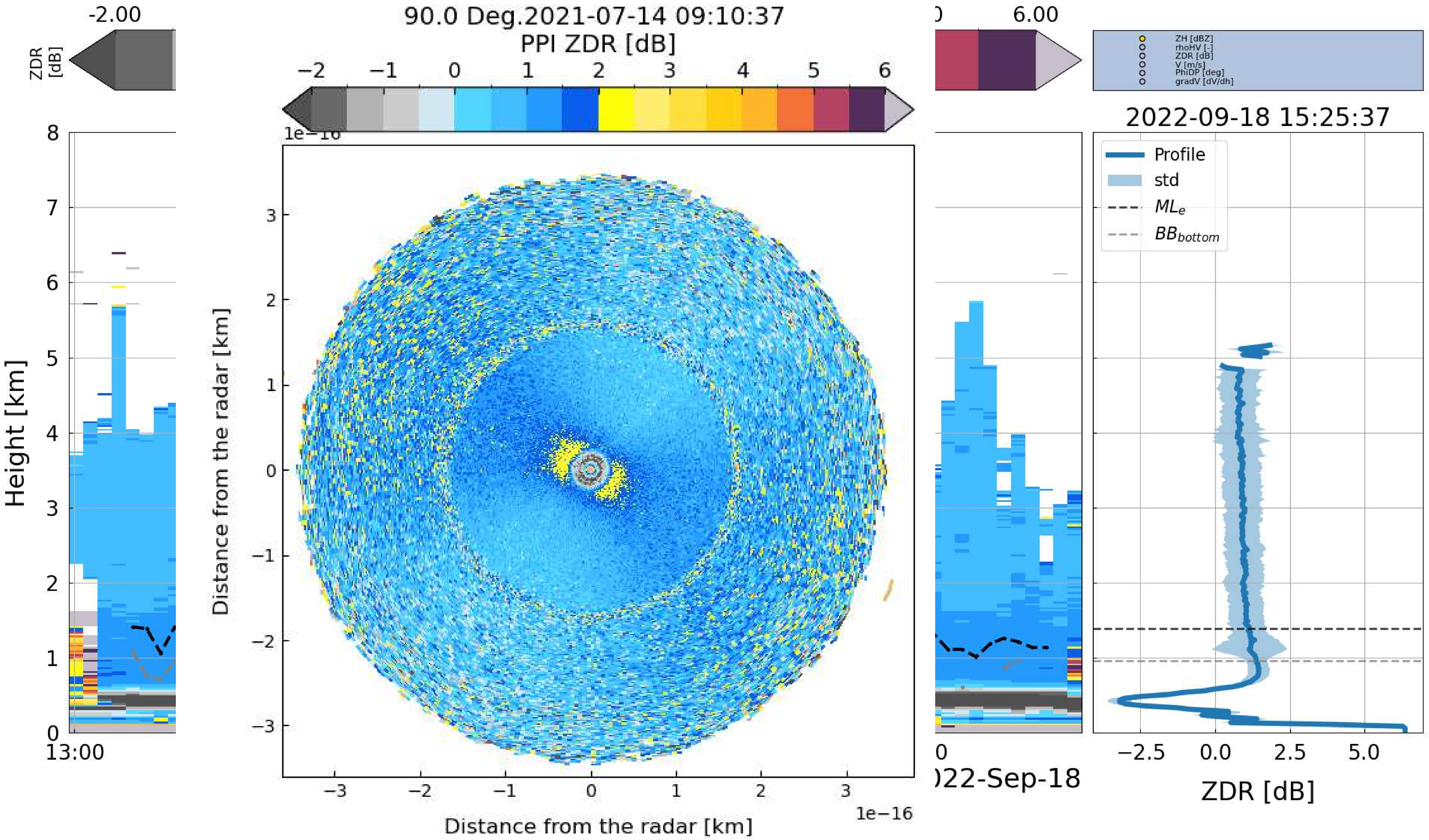


ZDR/PhiDP offset correction

Using the birdbath method introduced by Gorgucci et al. (1999):



- Key challenges:
  - Melting layer detection
  - Detection of spurious echoes in the birdbaths scans



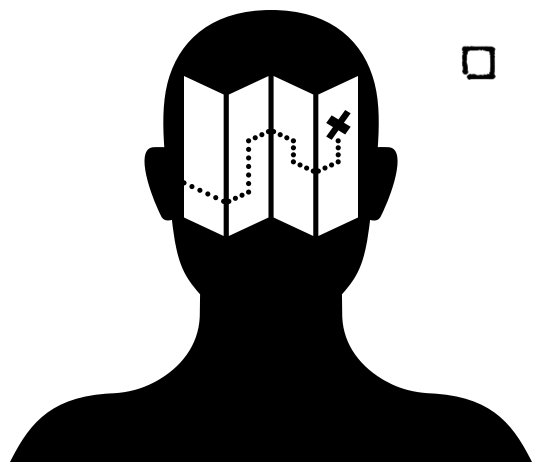
Attenuation correction

Horizontal reflectivity is corrected for attenuation using a ray-wise optimised attenuation method proposed by Rico-Ramirez, M. A. (2012).

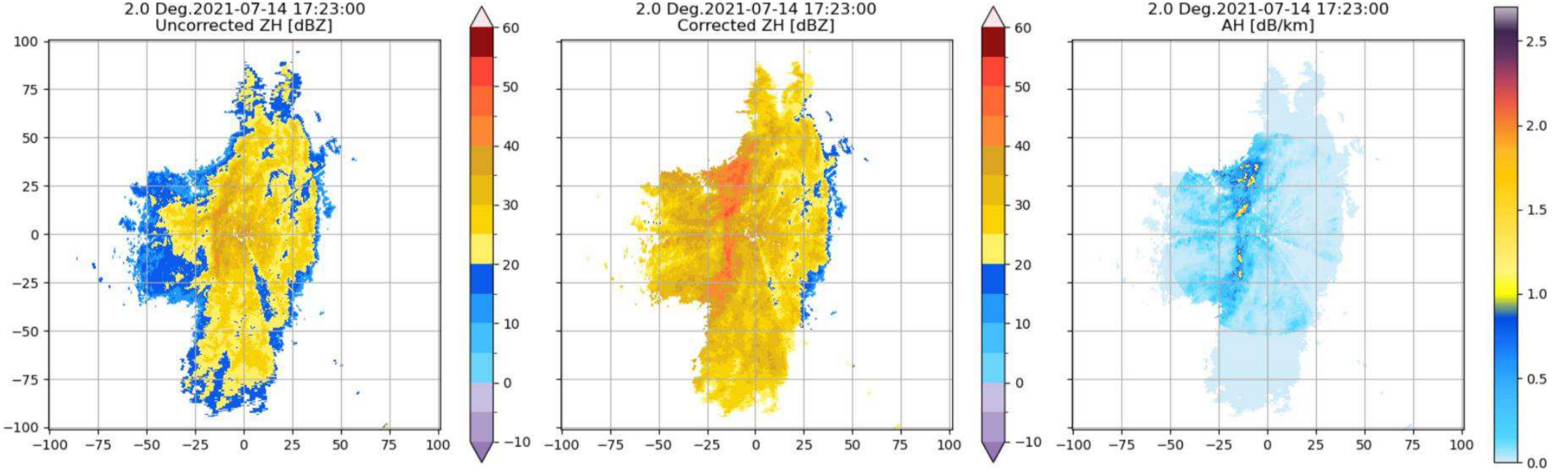
$$A_h(r) = \frac{[Z_{hh(m)}(r)]^{b}\left(A_f^{-b} - 1\right)}{I(r_0 : r_m) + \left(A_f^{-b} - 1\right) I(r : r_m)}$$

where $\log A_f = -0.1\alpha\Delta\Phi_{DP}(r_0 : r_m)$

$$\phi_{DP(C)}(b, \alpha, r) = 2\int_{r_0}^{r} \frac{A_h(s, b)}{\alpha} ds$$



- Key challenges:
  - Assumes an isotropic melting layer height.
  - Only valid in the rain region.

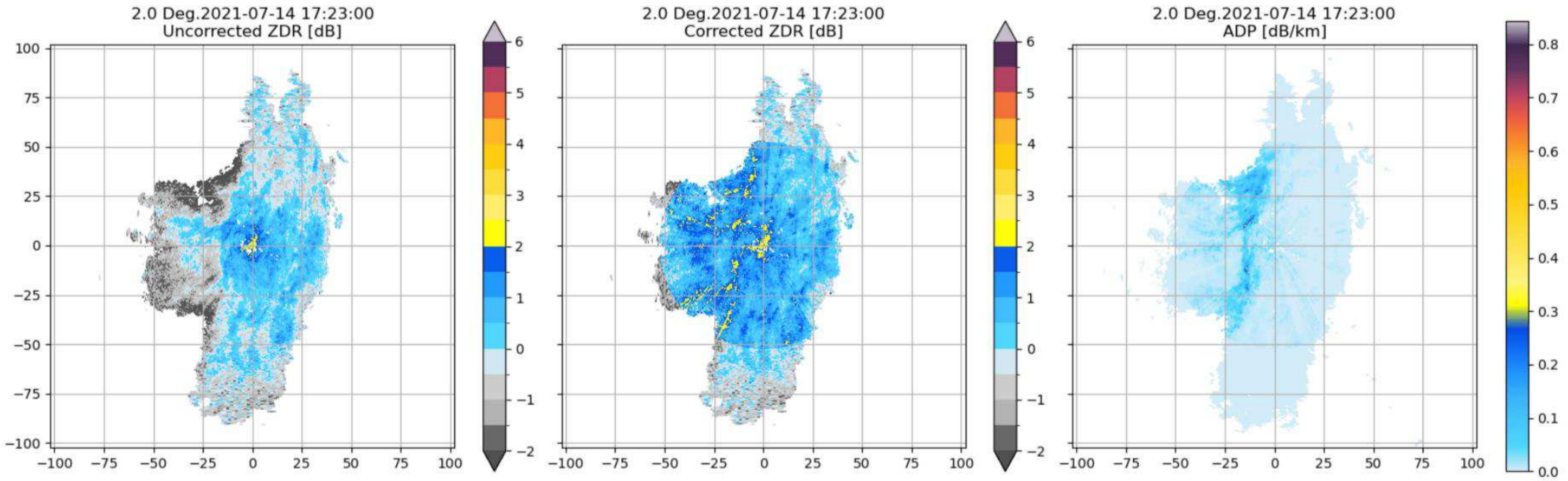


Differential attenuation correction

Differential horizontal reflectivity is corrected for differential attenuation using a ray-wise optimised attenuation method adapted from Bringi et al. (2001).

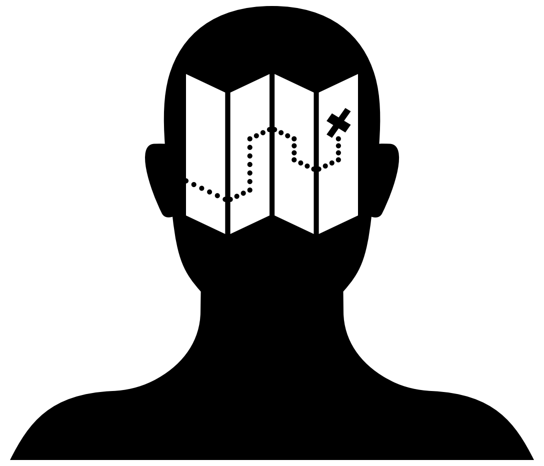
$$\gamma_{\mathrm{opt}} = \frac{1}{\alpha_{\mathrm{opt}}} \frac{|Z'_{\mathrm{DR}}(r_0) - Z_{\mathrm{DR}}(r_0)|}{\phi_{\mathrm{DP}}(r_0) - \phi_{\mathrm{DP}}(r_1)}$$

$$A_{\mathrm{DP}}(r) = \gamma A^{d}_{\mathrm{H}}(r)$$

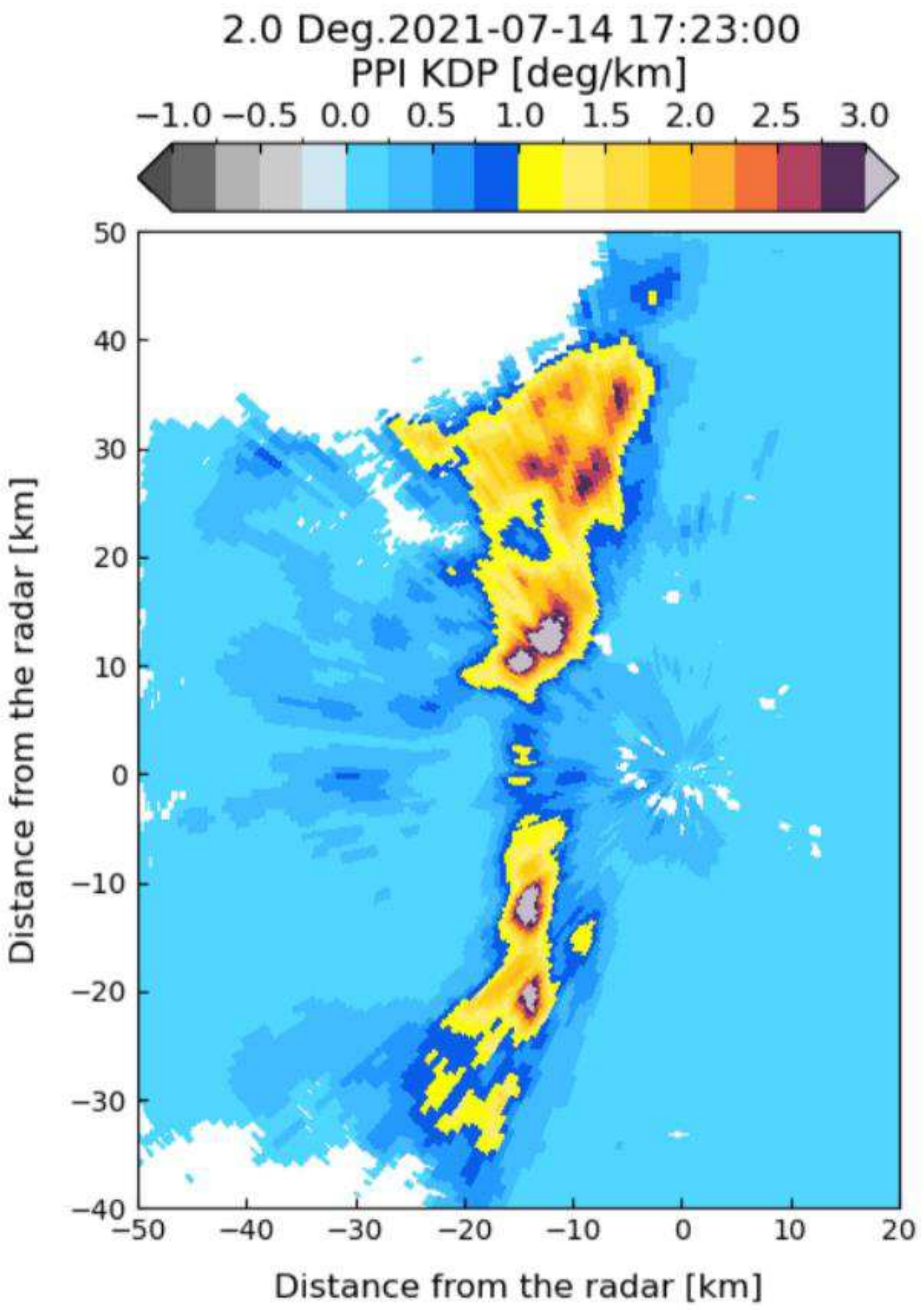


KDP computation

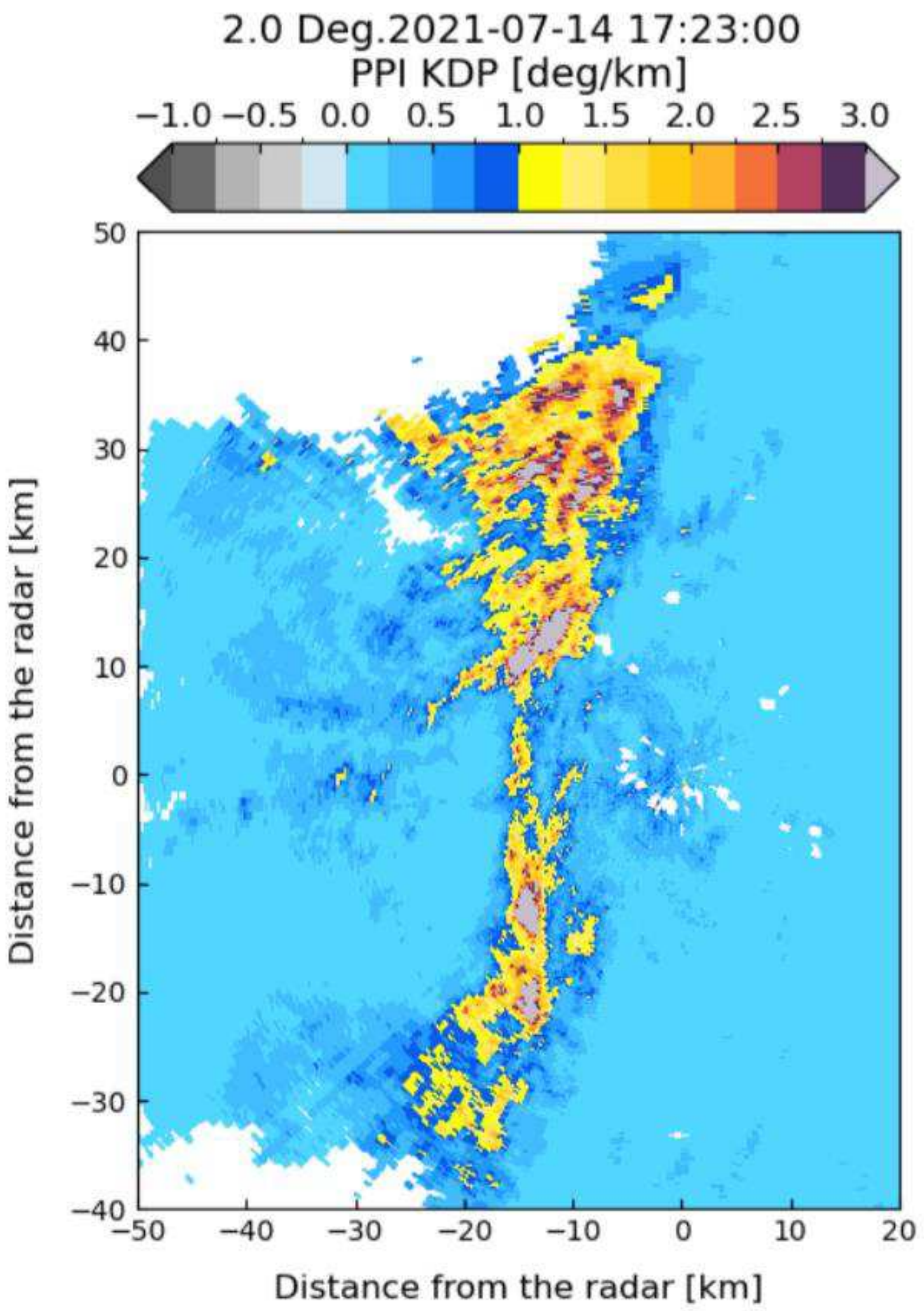
We compute K_{DP} using the method proposed by Vulpiani et at. (2012) but also from AH.



- Key challenges:
  - Φ_{DP} processing/smoothing.
  - Choosing a reliable window size .



K_{DP}
Vulpiani et al. (2012)



$$A_H = \alpha K_{DP}^{c} \Rightarrow K_{DP} = A_H / \alpha$$

* parameter c is close to unity for X-band radars

ZH calibration

We combine the relative calibration adjustment (RCA) method (Silberstein et al., 2008) and the method proposed by Diederich et al. (2015a).

- The basis for the RCA technique is that any variation in ground clutter reflectivity is caused by a change in radar calibration constant provided that the elevation and azimuth pointing accuracy does not change.
- By determining a baseline for the clutter reflectivity distribution $\left(Z_c^{ref}\right)$, we can determine the relative calibration offset (RCA):

$$RCA = Z_c^{ref} - Z_c^{95}$$

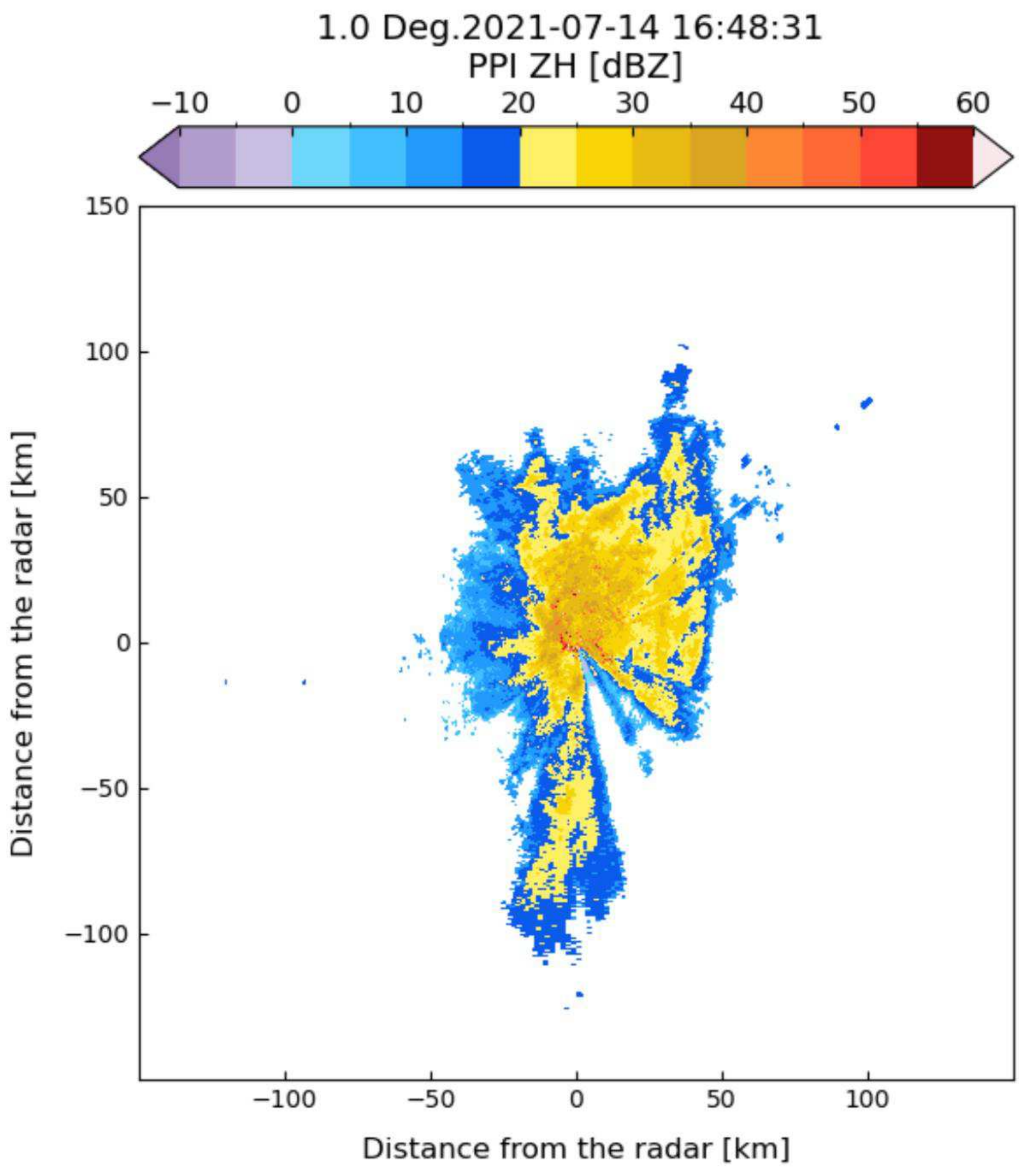
where Z_c^{95} is the 95th percentile of the ground clutter reflectivity distribution.

- Diederich et al. (2015a) propose comparing reflectivity at horizontal polarisation derived from specific attenuation with reflectivity corrected for attenuation.

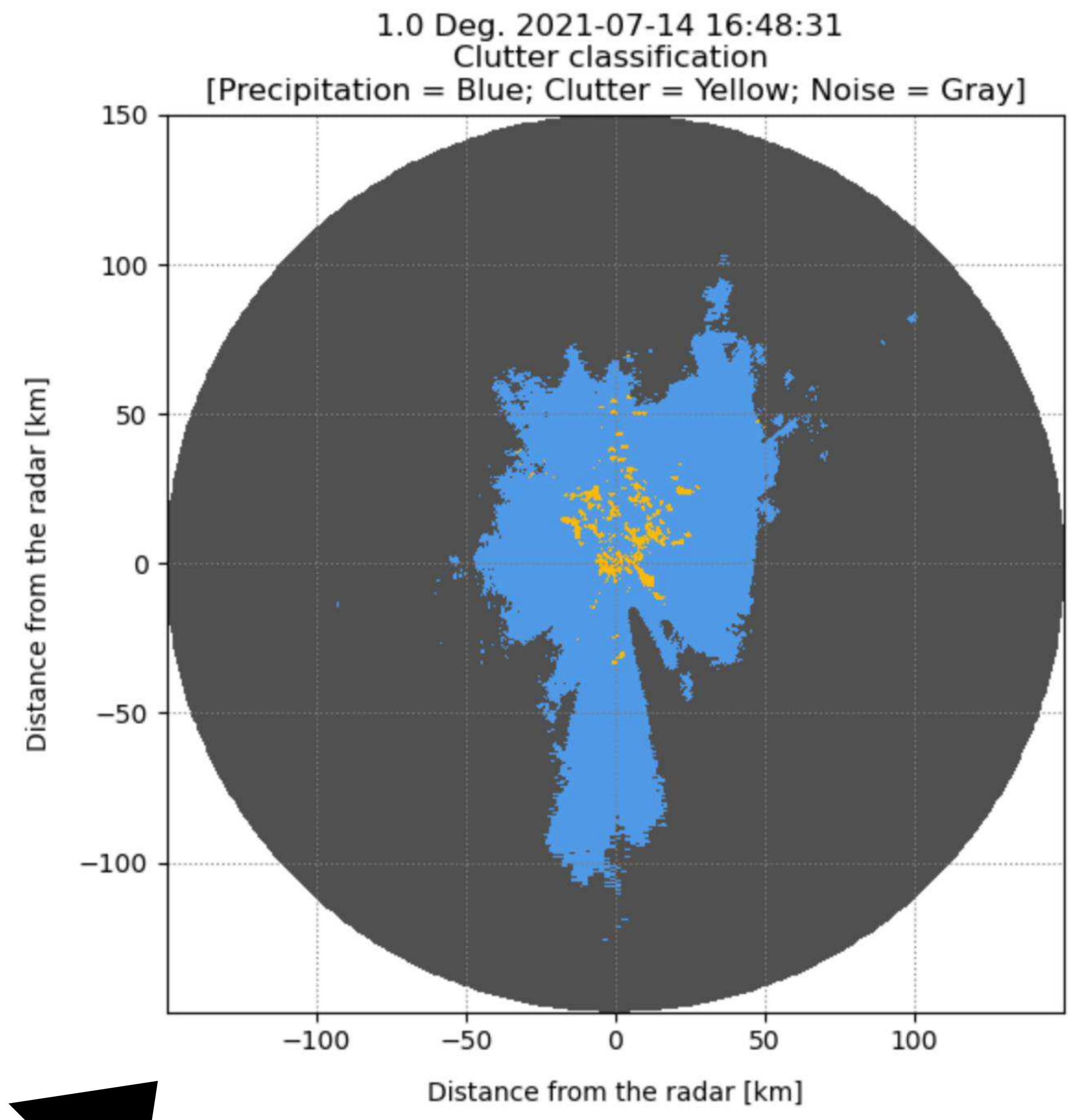
$$BA = 10 \times log_{10} \frac{\sum 10^{0.1[Z_H(A_H)]}}{\sum 10^{0.1[Z_H + IA_H)]}}$$

ZH calibration

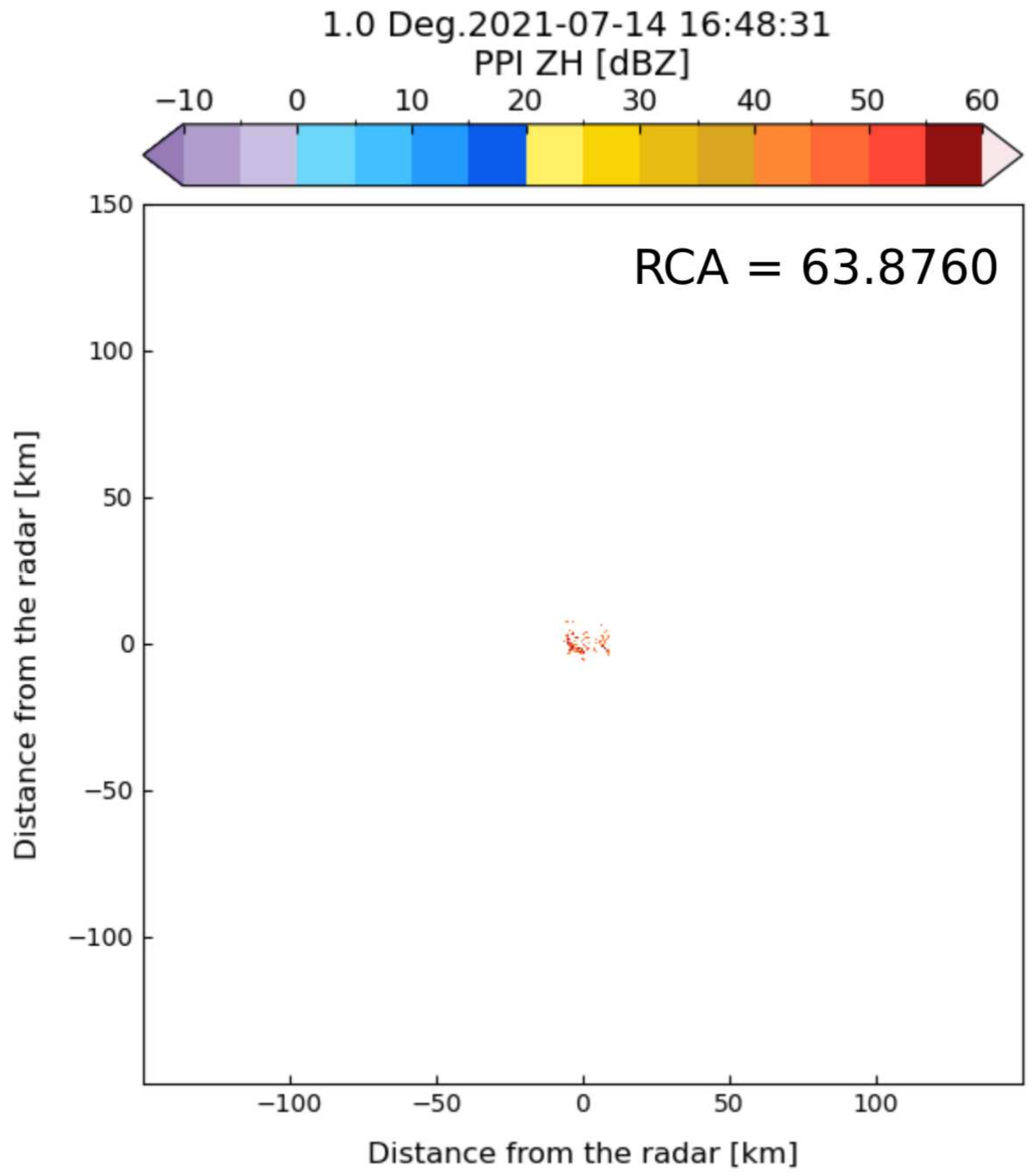
Results: RCA method (Silberstein et al., 2008)



Raw Z_H



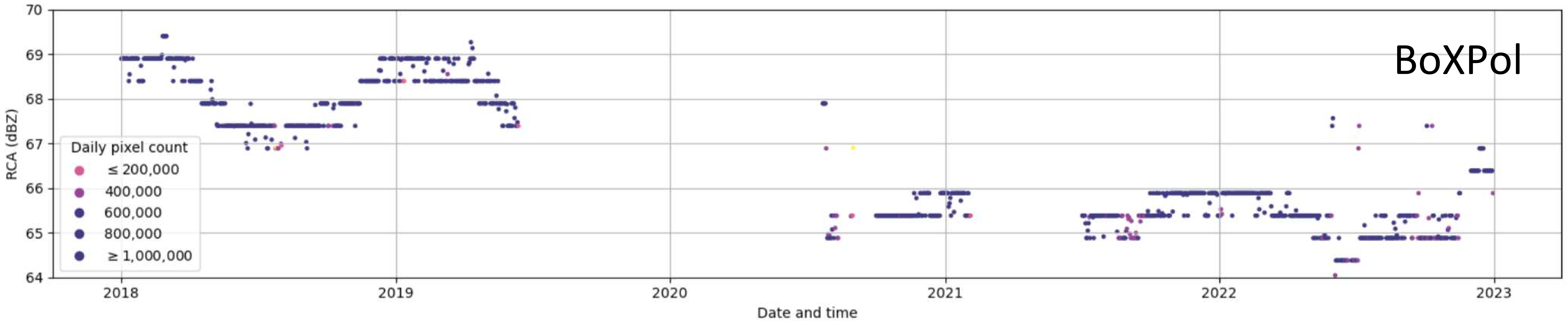
Clutter ID

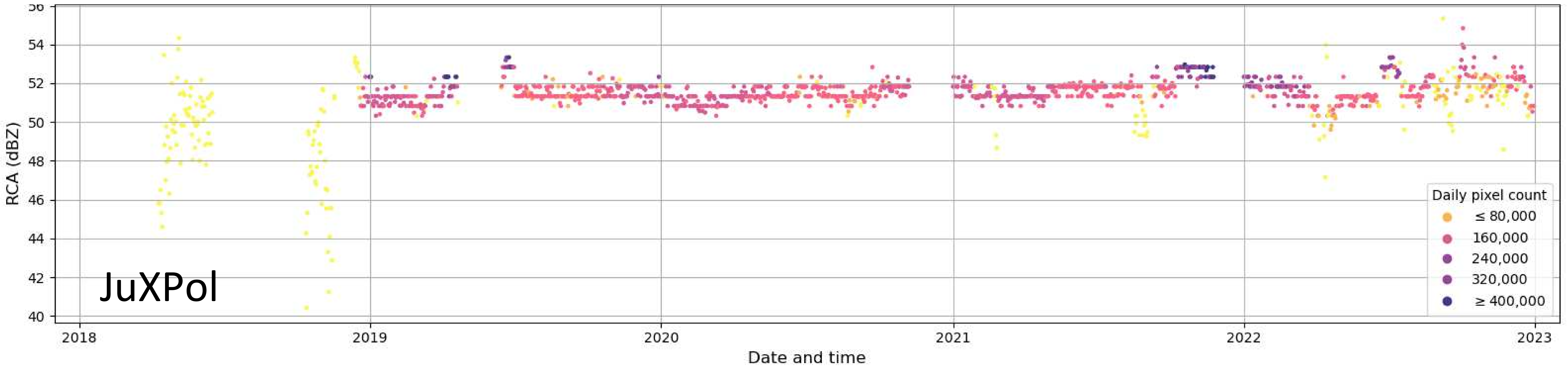


- Use only clutter pixels within a range of 10 km
- Frequency map pixel > 80%
- ZH > 40 dBZ

ZH calibration

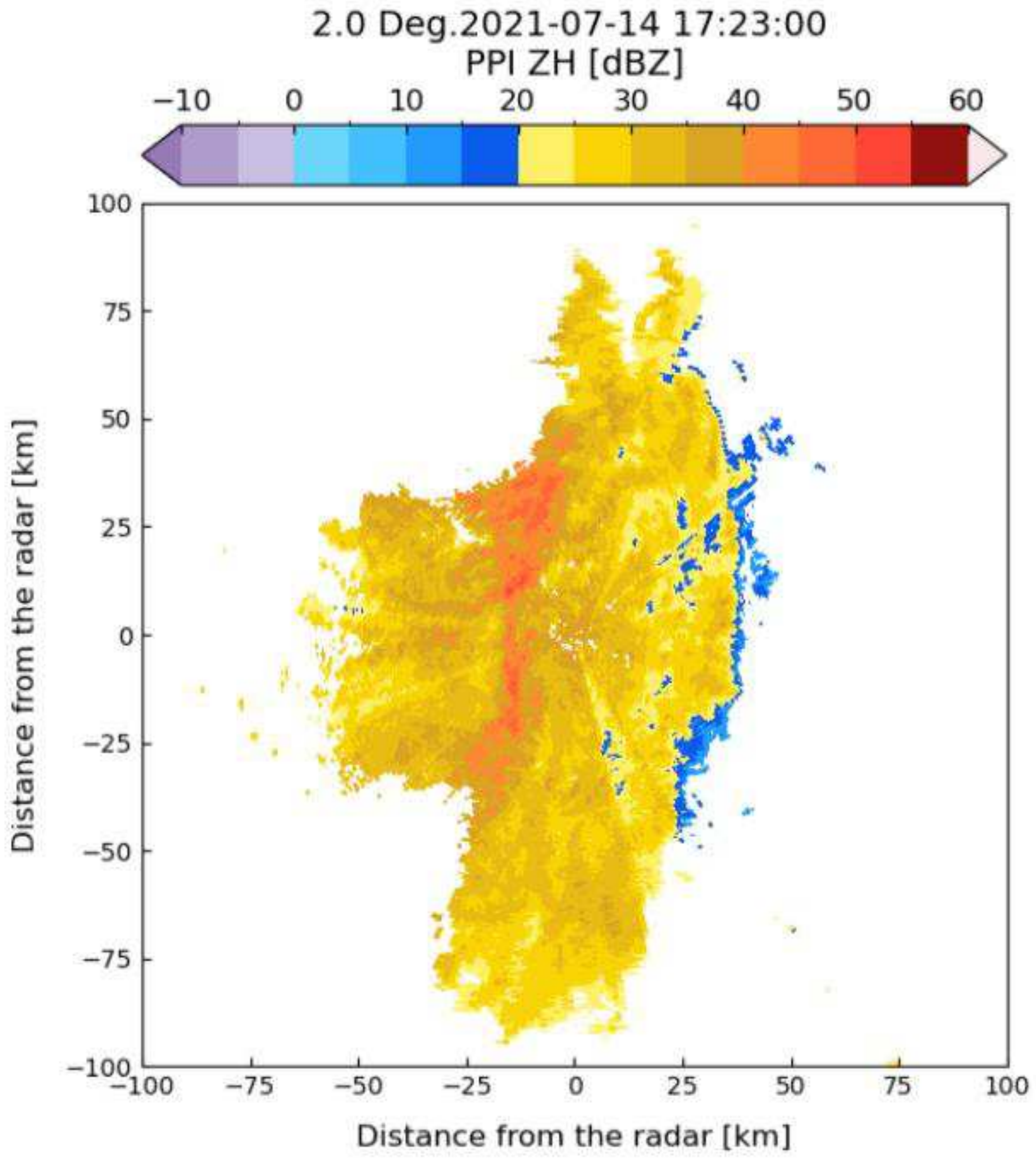
Results: RCA method (Silberstein et al., 2008)



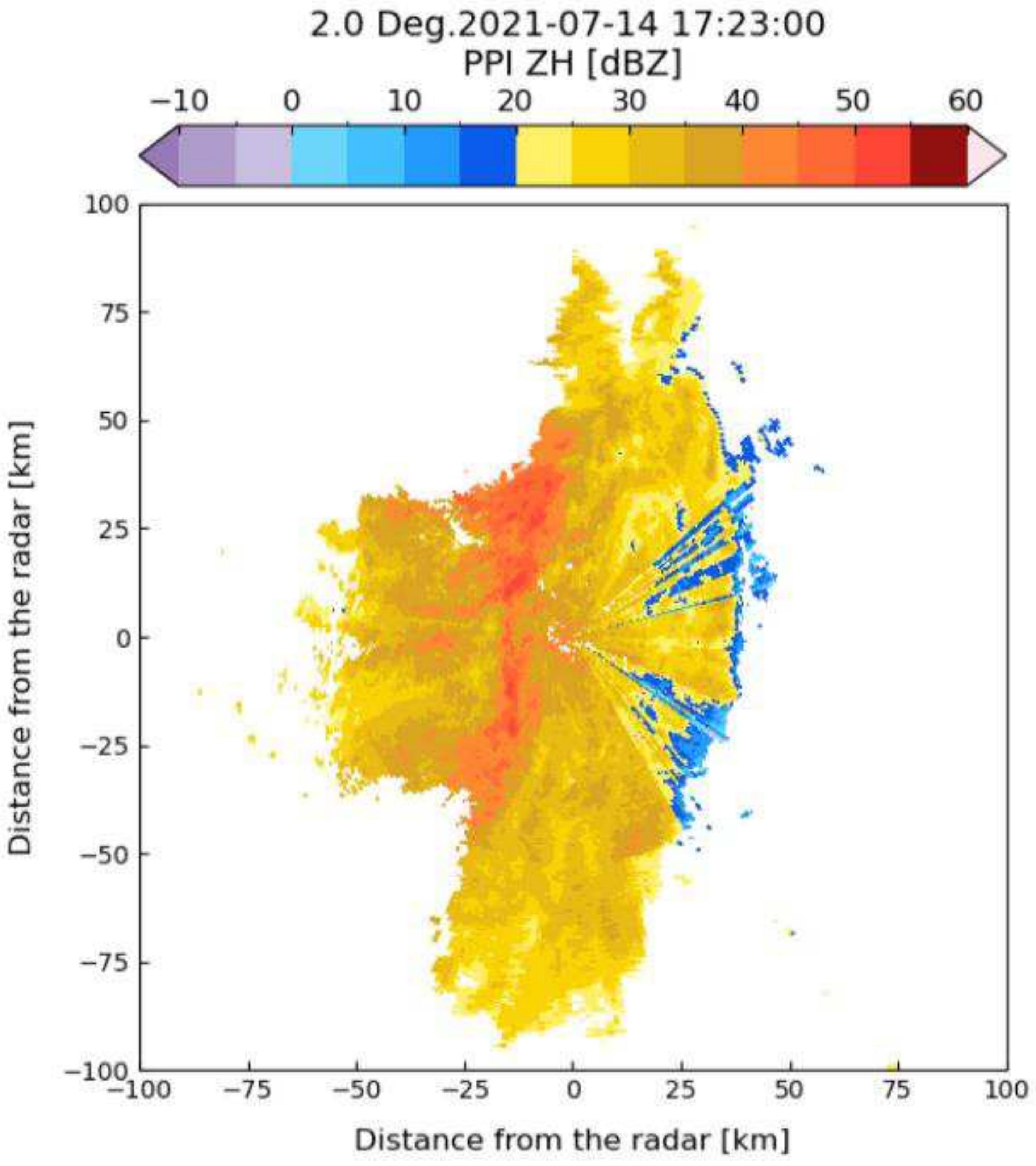


ZH calibration

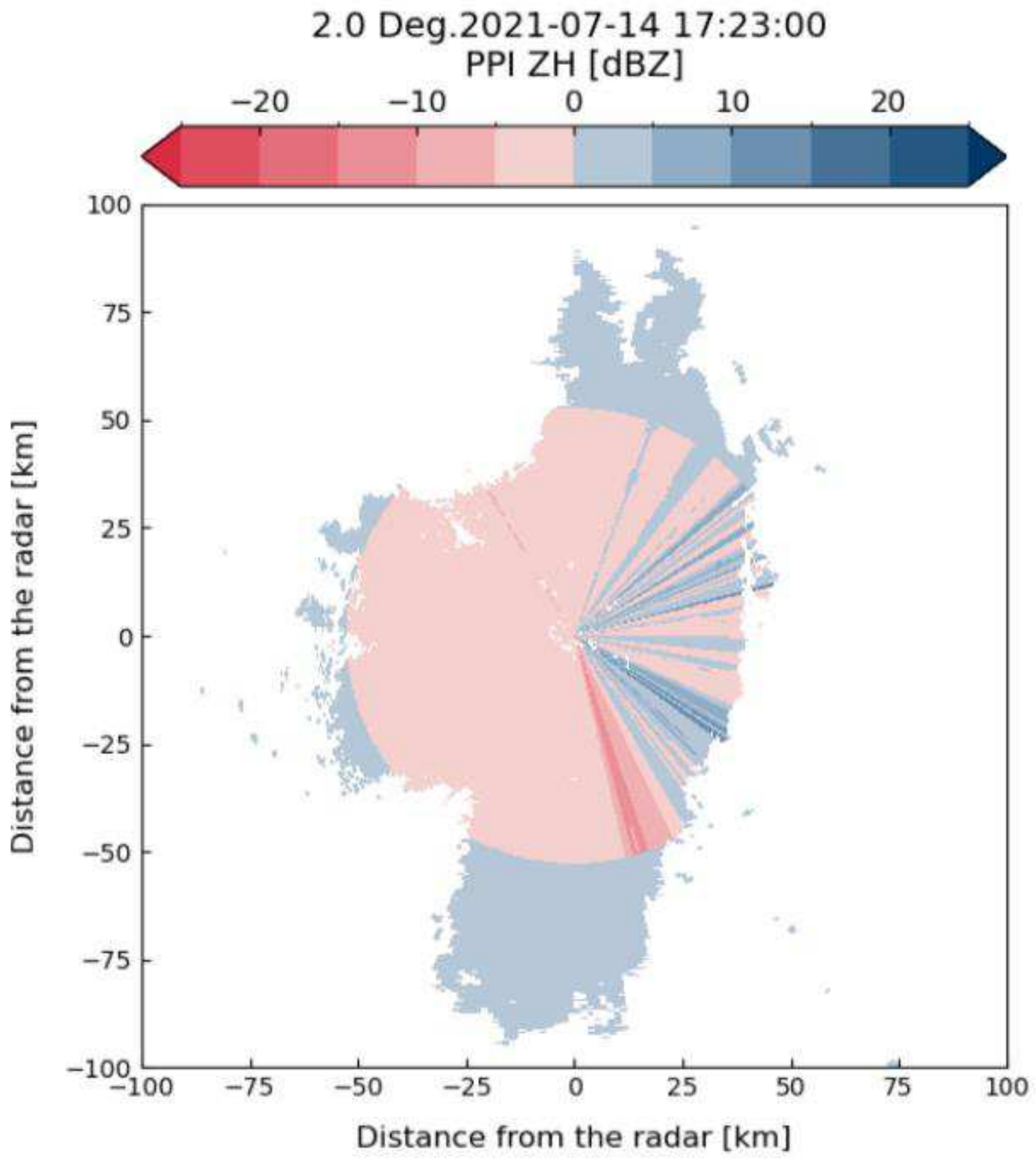
Results: ZH from AH



ZH corrected for attenuation



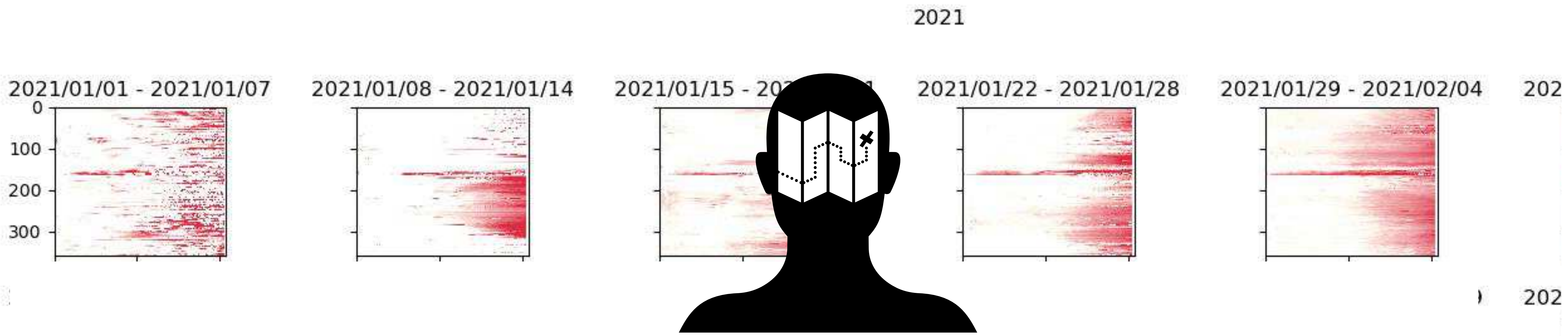
$$A_H = 1.15 \times 10^{-4}(Z_H^{0.78})$$



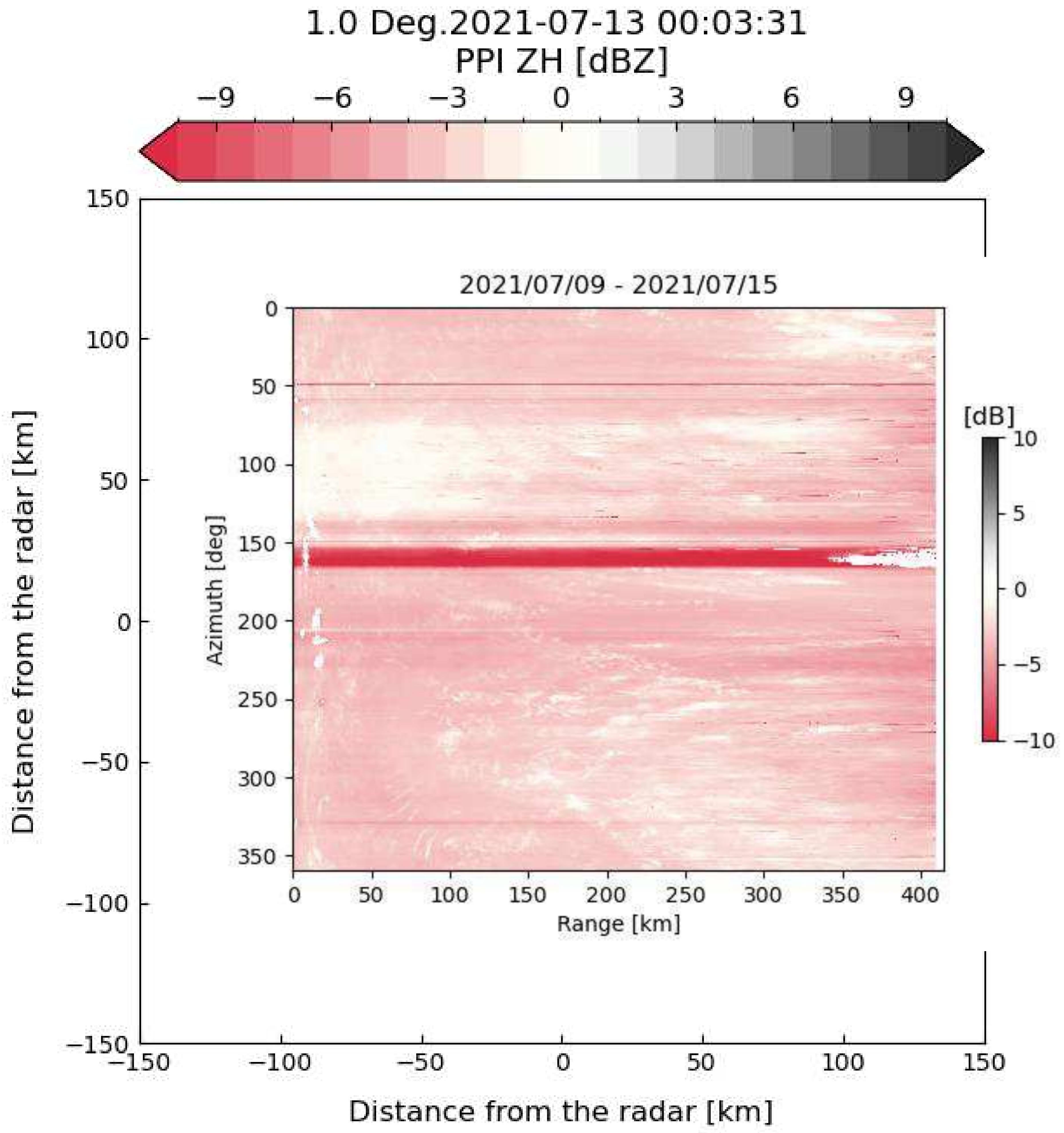
$$BA = 10 \times log_{10} \frac{\sum 10^{0.1[Z_H(A_H)]}}{\sum 10^{0.1[Z_H+IA_H)]}}$$

ZH calibration

Results:



- Key challenges:
  - Averaging over a sufficiently large spatial–temporal domain to mitigate the effect of the DSD variability and temperature-dependency assumptions.
  - Thresholds to mitigate the influence of backscatter differential phase shift and light rain.



Conclusions and Outlook

- The calibration of two X-band radars is constantly monitored using robust polarimetric-based techniques.
- Combining the RCA and ZH(AH) methods shows encouraging results. This method could enable monitoring the calibration of the radar reflectivity based solely on data collected by the radar itself.
- Future work will focus on the validation of the radar QPE.
- The described methods are (or will be soon) available in tools, such as Towerpy or wradlib!

Towerpy: An open-source toolbox for processing polarimetric weather radar data

References

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Thank you for your attention!