On the use of individual “Bright Scatterers” for monitoring dual-polarization measurables:
operational scan program and stare mode observations

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MeteoSwiss guiding principles for radar monitoring is to combine several sources of information

1. **NS CAL signals inserted at LNA input** (+ other REF points) (**erad**2014)
2. Ext. pass. transponder to measure A, Φ of the Tx radar pulse (**erad**2010)
3. Sun signals during op. weather scan program for pointing and relative CAL
4. Ext. active transp. for measuring RCS, Doppler, polarization (ICEAA2013)
5. **Raster Sun-track (max. S/N)** for **absolute CAL** of **Rx** chains (**erad**2016)
6. **Bright Scatterers**, Q-Check low-sensitivity channel, day/night **(erad**2018**)**

1. Vollbracht et al. (2014) Absolute dual-pol radar CAL.: Temperature dependence and stability with focus on antenna-mounted receivers and noise source-generated reference signal.

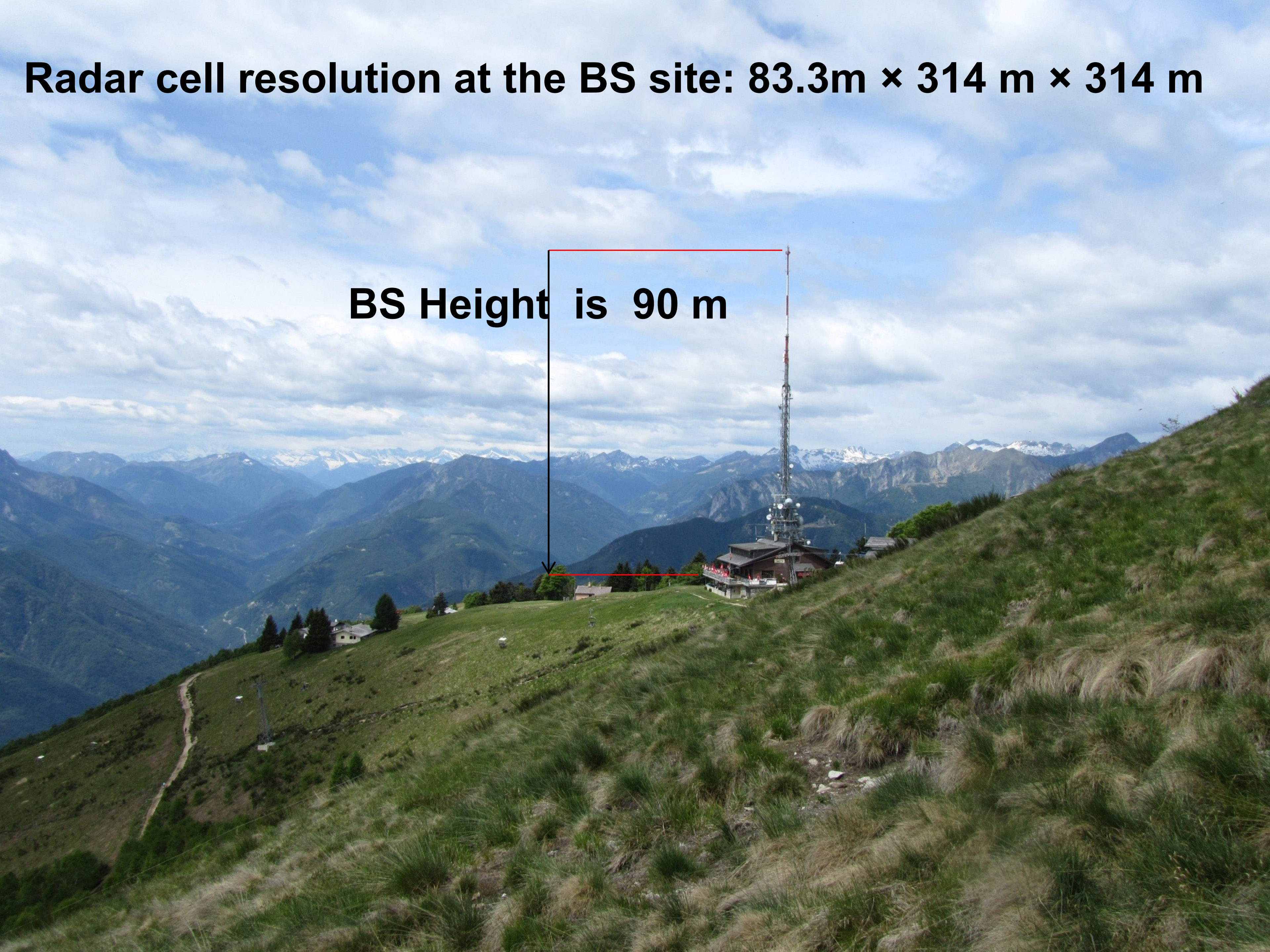
2. Gabella et al. (2010) An innovative instrumentation for checking EM performances of operational radar.

3. Huuskonen et al. JTECH2007, AMT2016; Holleman et al. JTECH2010, …; Gabella et al. *Atmos.* 2015

4. Gabella et al. (2013) Acceptance tests and monitoring of the next generation dual-pol. weather radar network in Switzerland. Proceed. of the 2013 IEEE Conf. on Electromagnetics in Adv. Appl.

5. **NCAR 80's, Gabella et al.** *Atmos.* 2016, **Gabella and Leuenberger**, *Sensors*, 2017

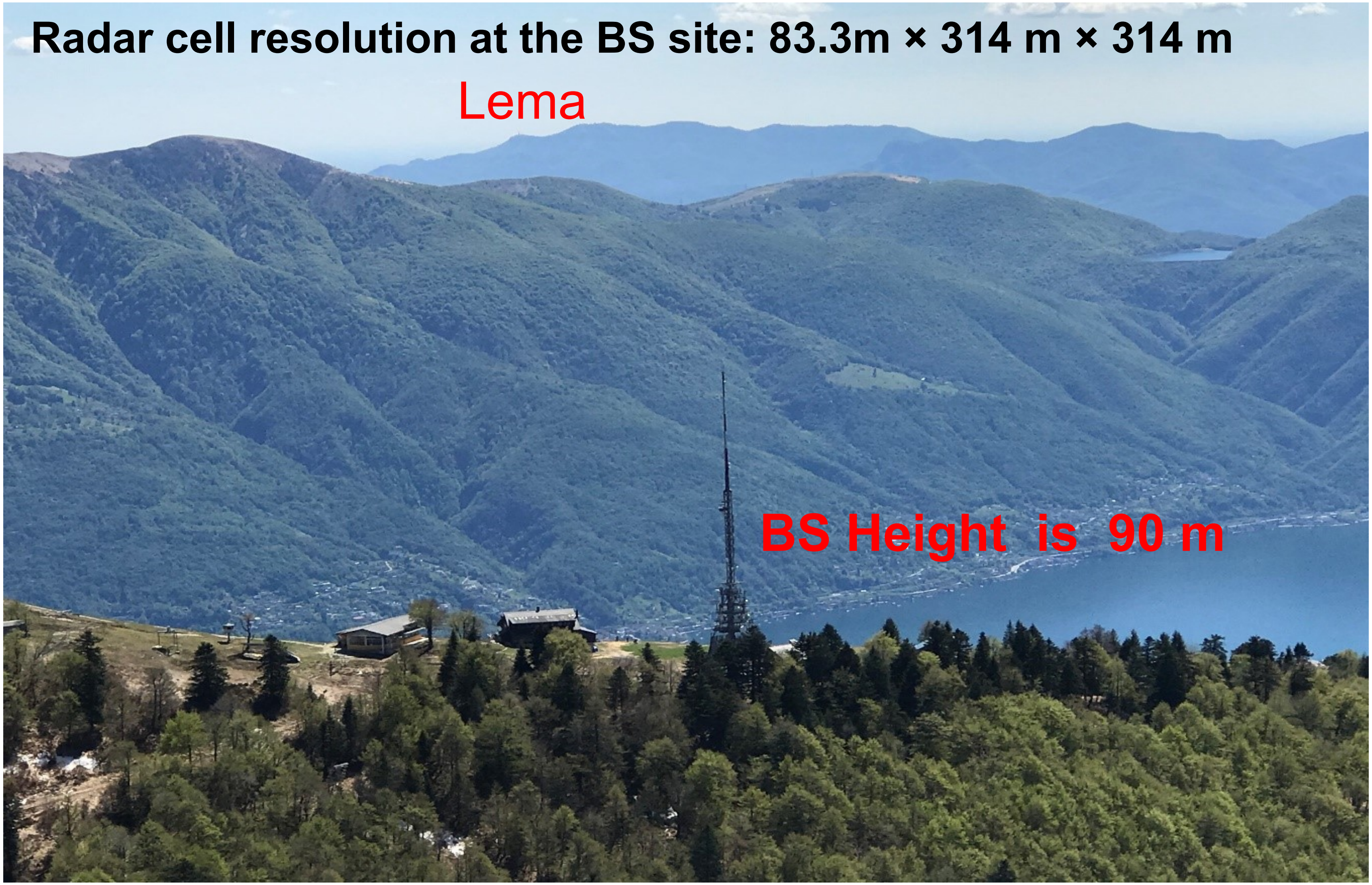
6 Gabella M., 2021: **Dual-pol signatures** of **BS before** and **after HardWare replacement**, *Remote Sensing*


Radar cell resolution at the BS site: 83.3m × 314 m × 314 m
BS Height is 90 m

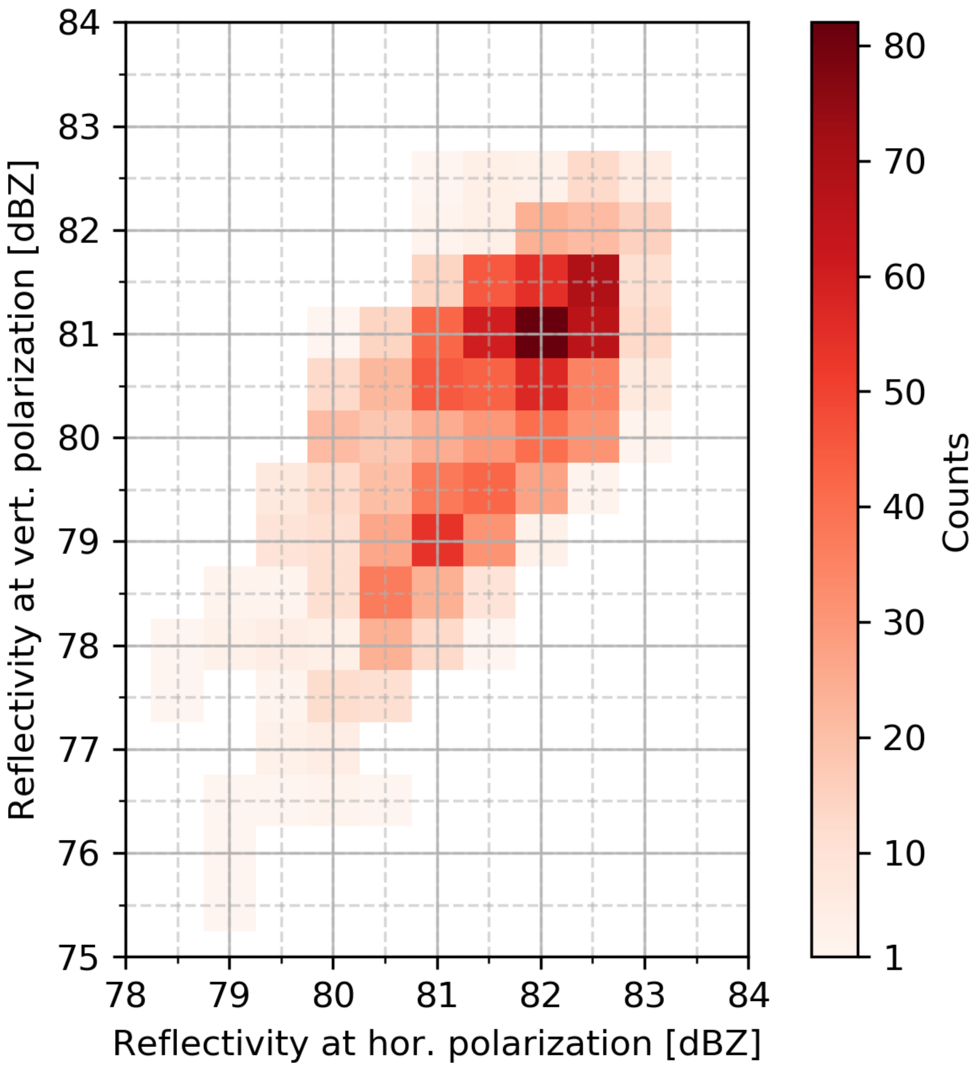
Radio link propagation: temporary installation of external passive and active calibrators and also … BS site!

0 km
Lema radar site

Cimetta~18 km
Bright Scatterer



81 dBZ (r~18 km), **RCS ~ 42.2** dBm^2, P_r ~ **-18.1** dBm



H-, V-pol. Reflectivity

	Hor.	Ver.
10 Log(Mean{z})	**81.59**dBz	**80.43**
Mean{Z}	**81.49** dBz	**80.27**
Median{Z}	**81.5** dBz	**80.5**
St. Dev.{Z}	±0.90 dBz	±1.21

10 Log(Mean/median) is expected to be:
- 1.6 dB for Rayleigh (Uniform Background);
- smaller for Ricean pdf (strong RCS in a UB)

In this case it is 0.09 dB for H, –0.07 dB for V

Jan. 2017
5 clear-sky days

10 Log(90%tile / Mean) is 0.9 dB, 1.1 dB (typ. ~3-4 dB)

Results: BS polarimetric signatures in Jan. 2017

- The **copolar** correlation coefficient, ρ_{HV}, very high and stable: 0.9968±0.0024 (median±spread) and **0.9962±0.0024** (**μ ±σ**, 5 days)
- The **differential phase delay** ,Ψ_{dp}, is quite stable → σ{Ψ_{dp}}~**4°**

5 clear-sky days in January 2017, 1440 samples, median Z_h~81.5 dBz , Z_v~80.5 dBZ

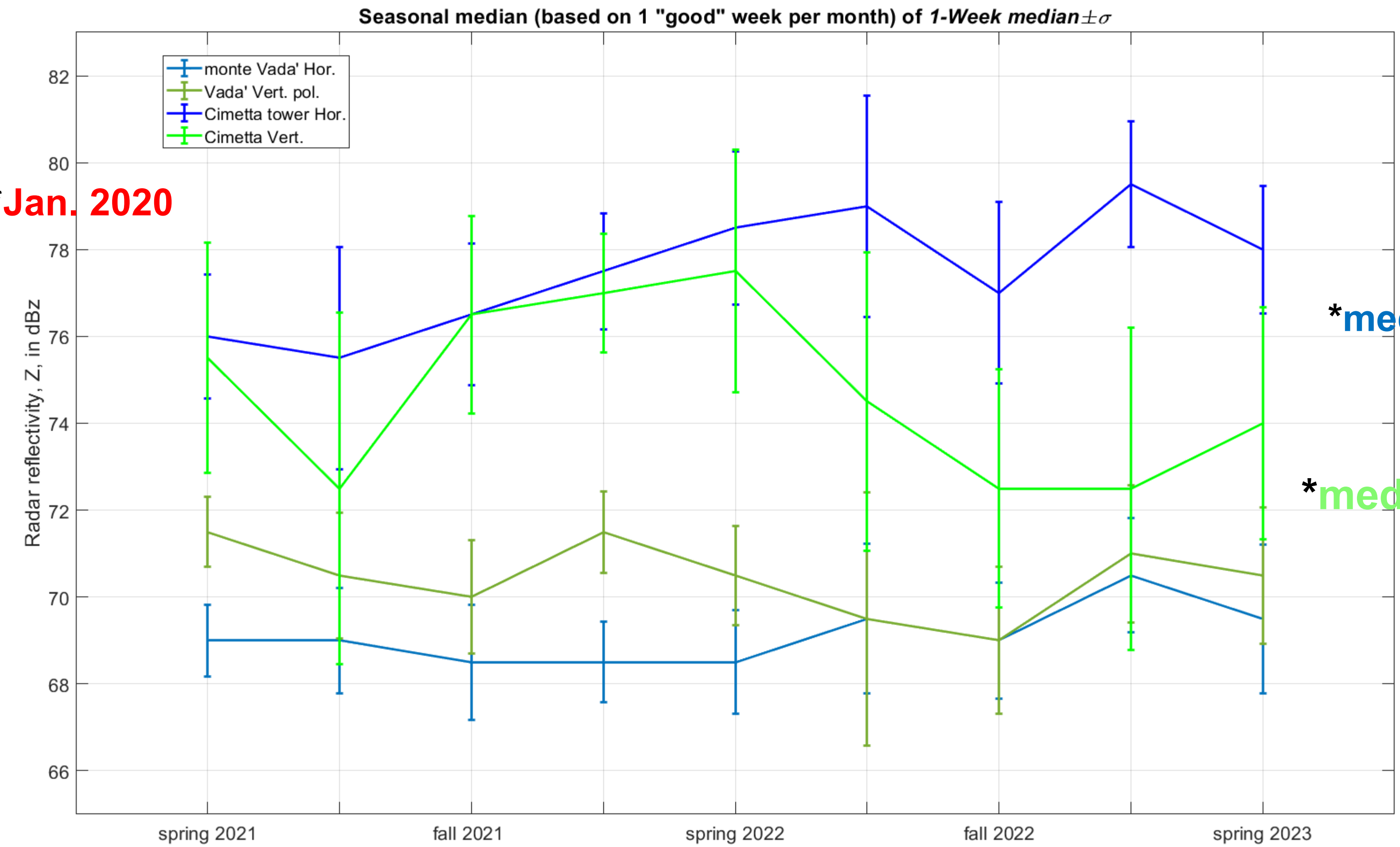
Gabella M., 2021: “On the spectral and polarimetric signatures of a Bright Scatterer **before** and **after** hardware replacement”, *Remote Sensing*, **13**, 12 pages

ρ_{HV}, was **0.9887±0.0317** (**μ ±σ**), while σ{Ψ_{dp}}~**29°, Jan. 2020, best day**

ρ_{HV}, was **0.9986±0.0007** (**μ ±σ**), while σ{Ψ_{dp}}~**3°, Jan. 2019, best day**

January 2020, “rhoHV-best-day”, median $\mathbf{Z_h}$~**76.5** dBz , $\mathbf{Z_v}$~**72.0** dBz

BS and **M**ountainous-**BS**: seasonality **of** Z_h **and** Z_v



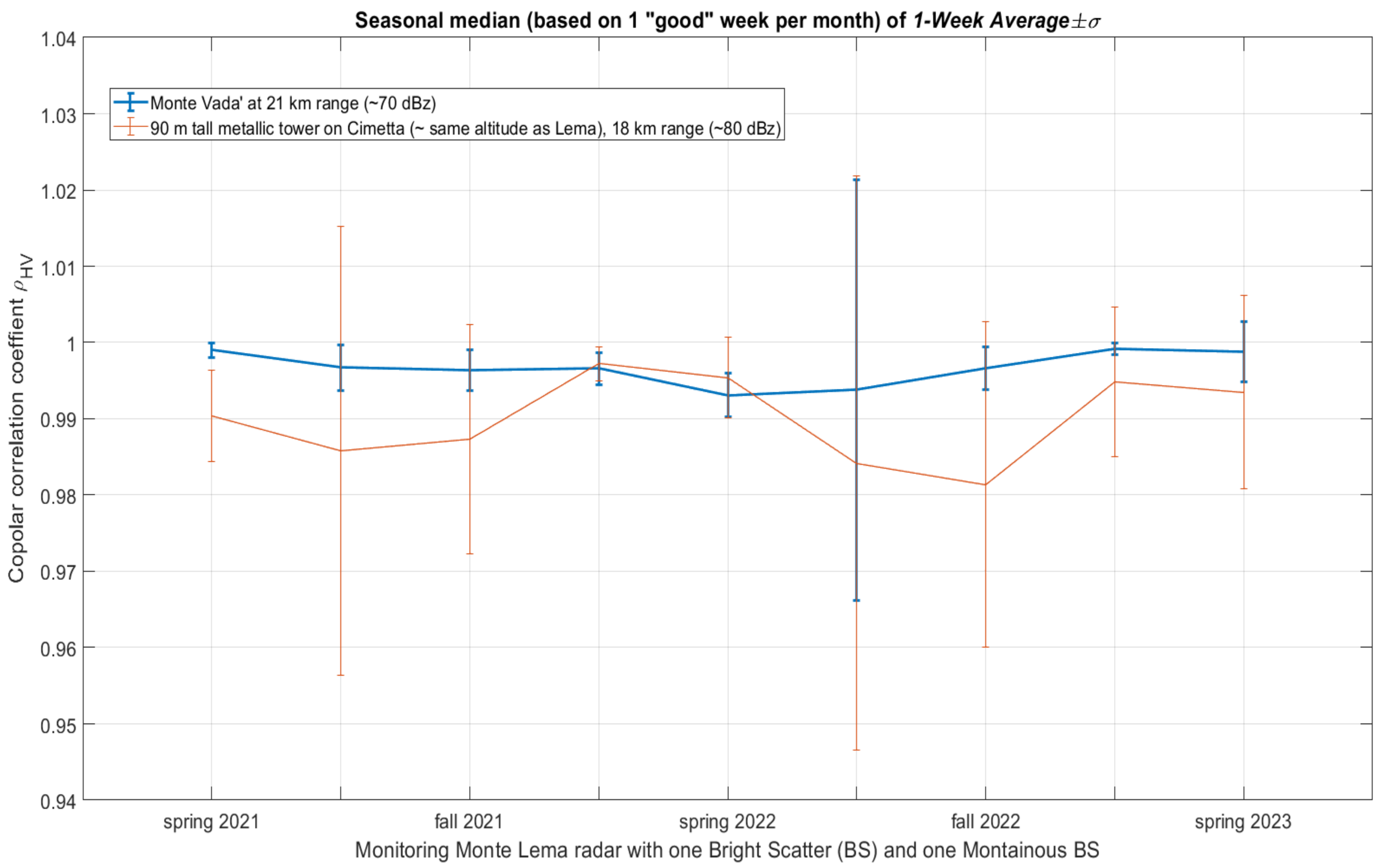
*Jan. 2020

*med. Z_h~76.5

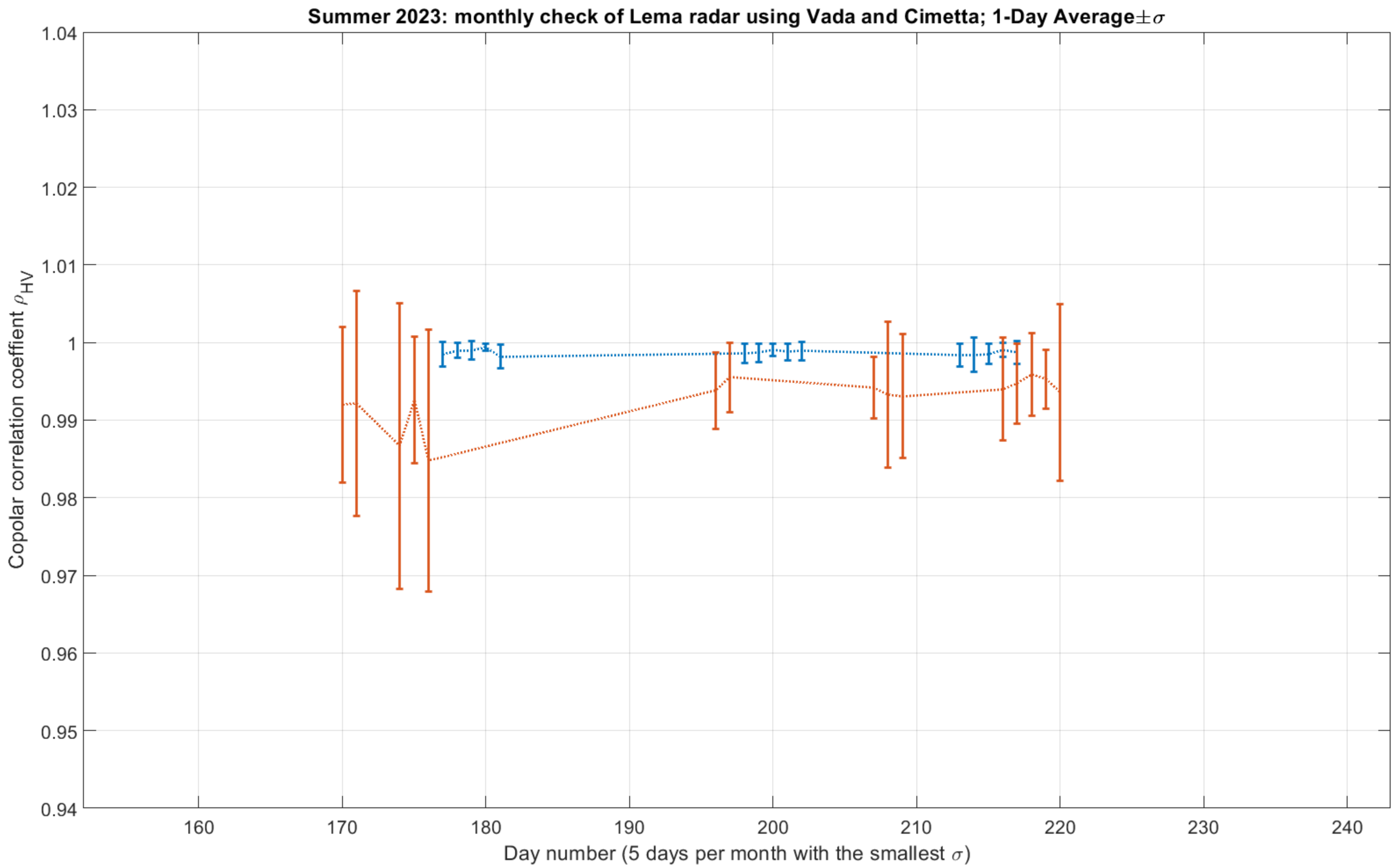
*med. Z_v~72 dBz

1-week dispersion and central location

Lema **BS** and **MBS**: seasonality of ρ_{HV} (1-week σ)

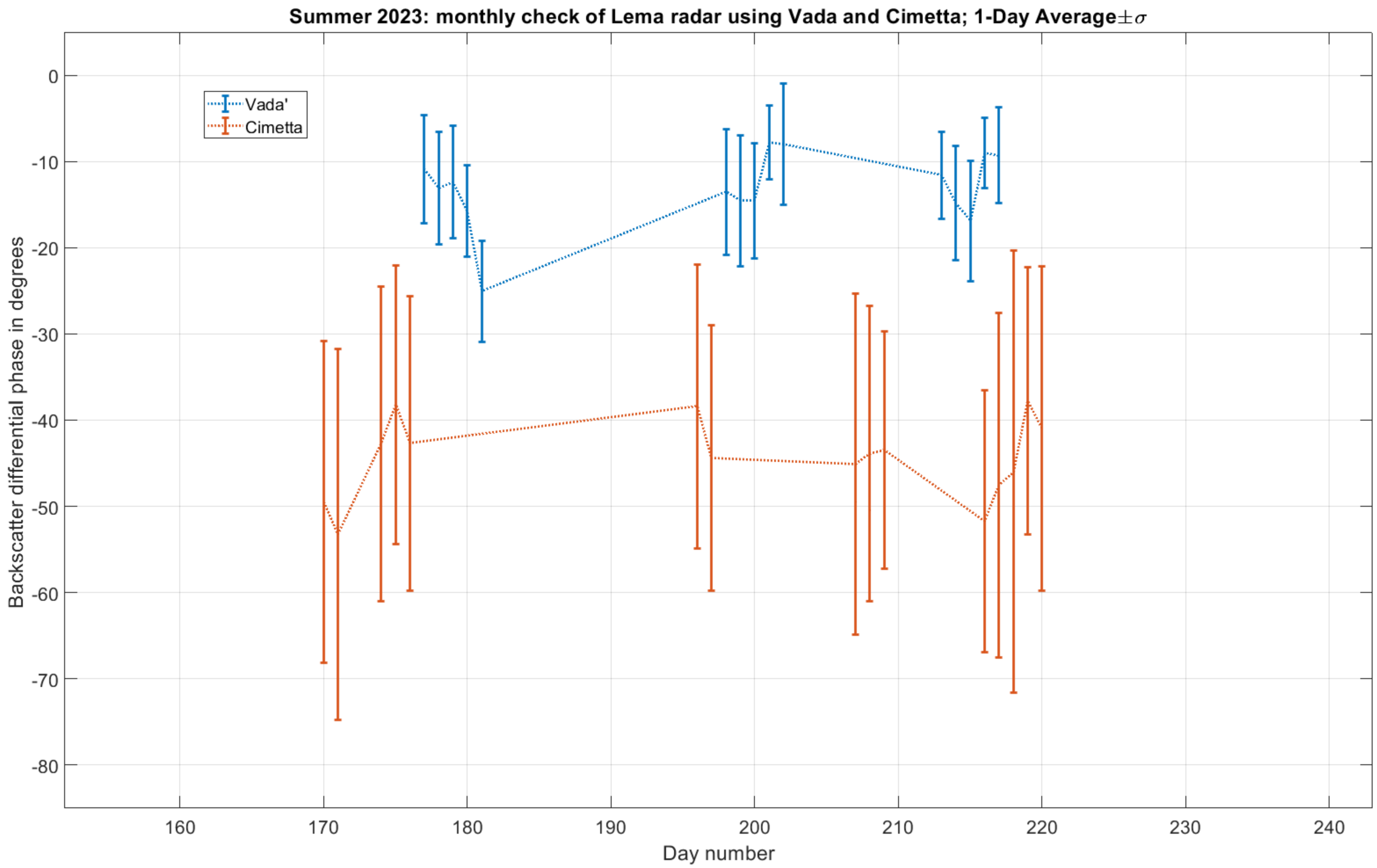


Lema **BS, MBS**: ρ_{HV} in **summer 2023** *(change of paradigm)*

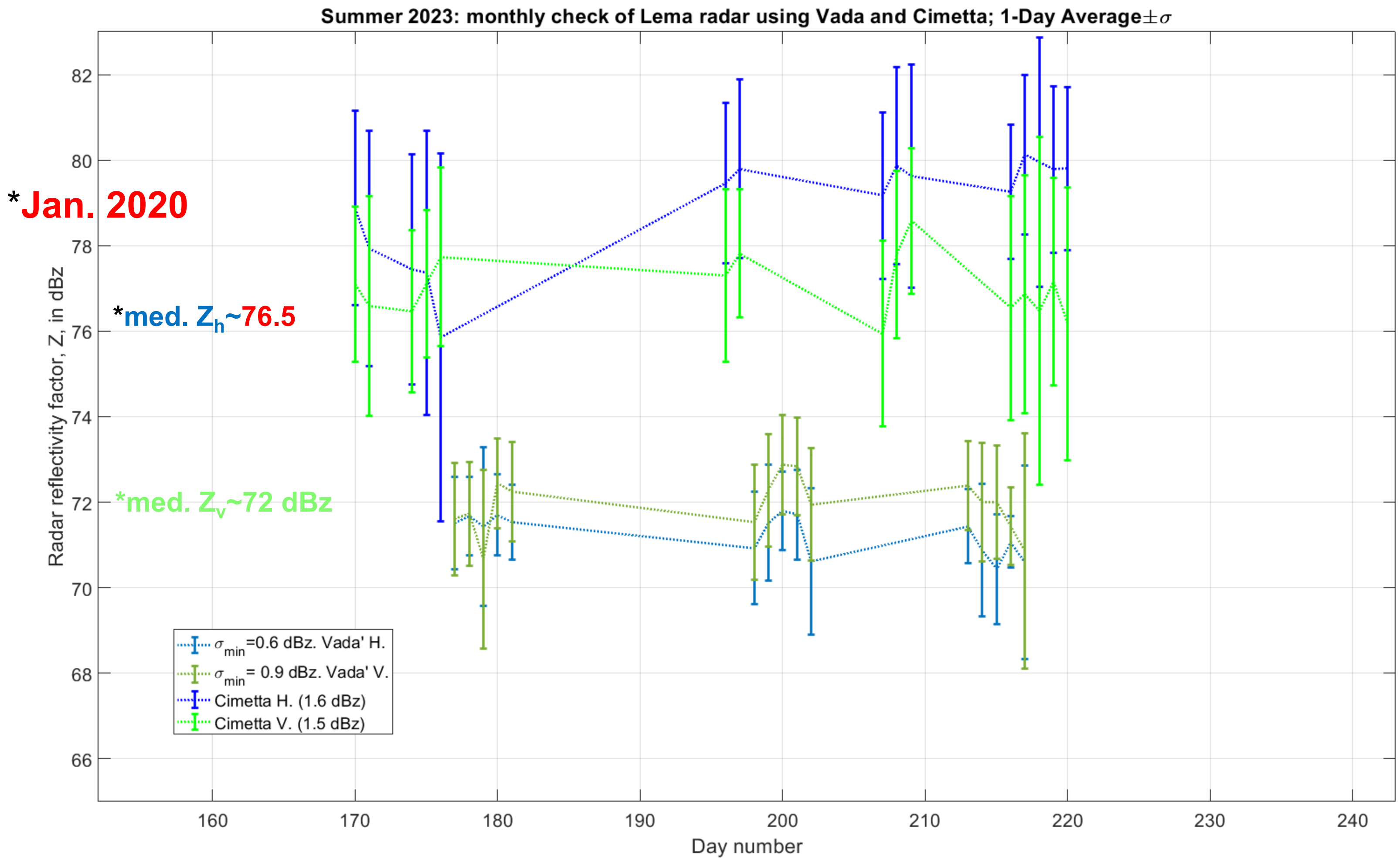


(5 "best ρ_{HV} σ_{daily}" days per month)

BS, MBS: backscattering phase shift, δ, in **summer 2023**



Lema BS and **MBS**: radar reflectivity, Z, in **summer 2023**



(5 "best ρ_{HV} σ" days per month)

Albis "**very-low-σ**" *BS in **2019, 2021**

- The **copolar** correlation coefficient, ρ_{HV}, is as large

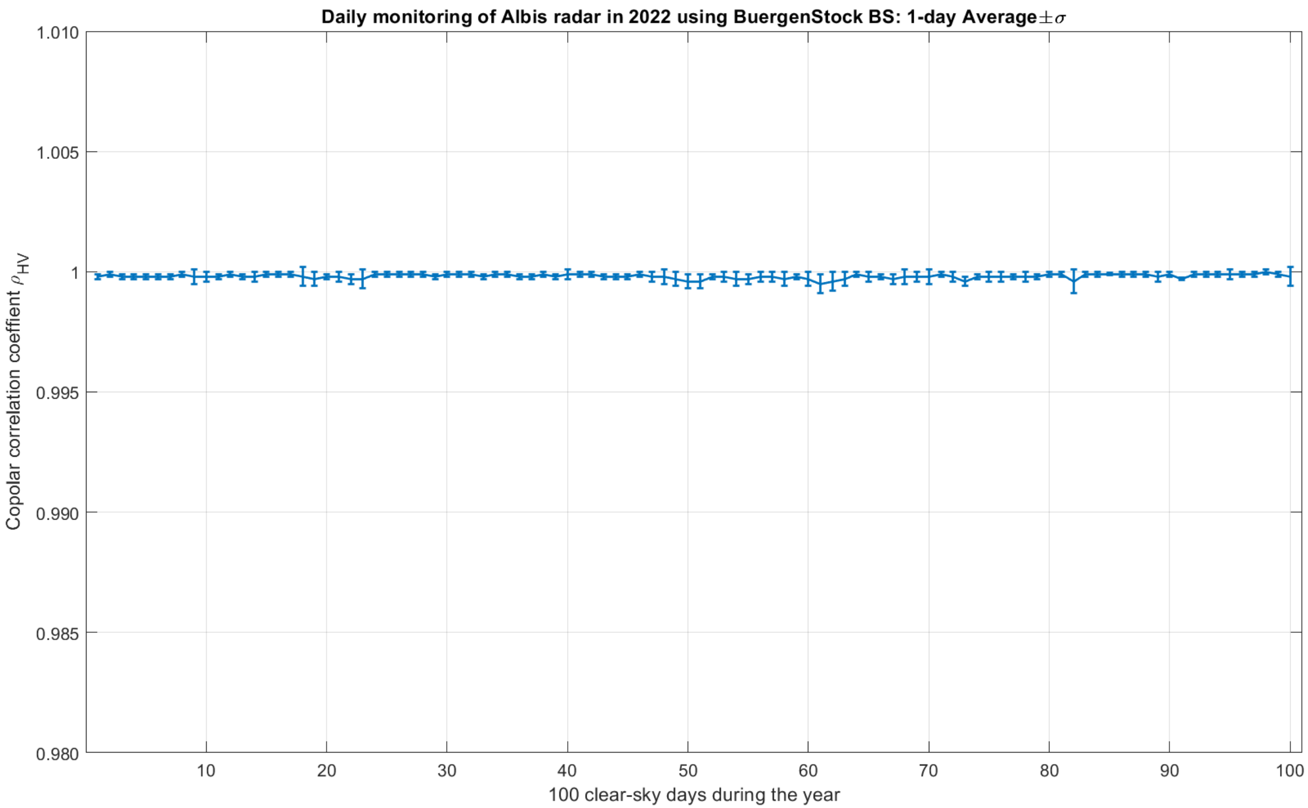
  0.9997±0.0002 (2019), **0.9997±0.0001** (2021)
- The **differential phase shift** , Ψ_{dp}, actually backscattering phase shift, δ is stable: $\sigma\{\Psi_{dp}\}$~**4.1°** (2019), **5.1°** (2021),

This *BS (Buergenstock / Hammetschwand) is at Gate402 (~33.6 km) AZ197

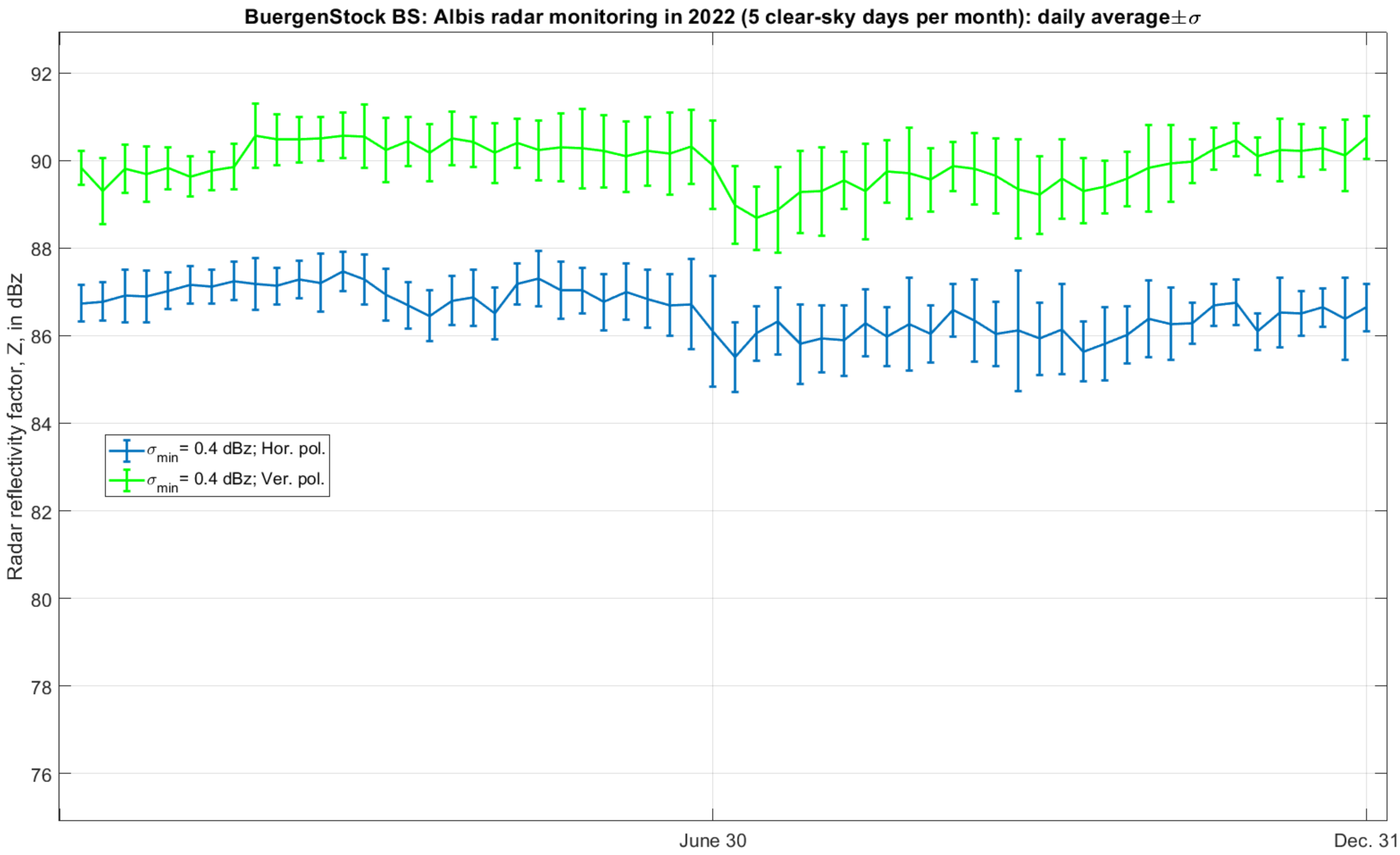
4-day clear-sky normal refractivity data set (1152 samples) in **January**

median Z_h~86.5 dBz , Z_v~90 dBz ; **σ as small as 0.5 dBz** for both pol.

Albis "**very-low-σ**" BS: daily μ±**σ** of ρ_{HV} in **2022**

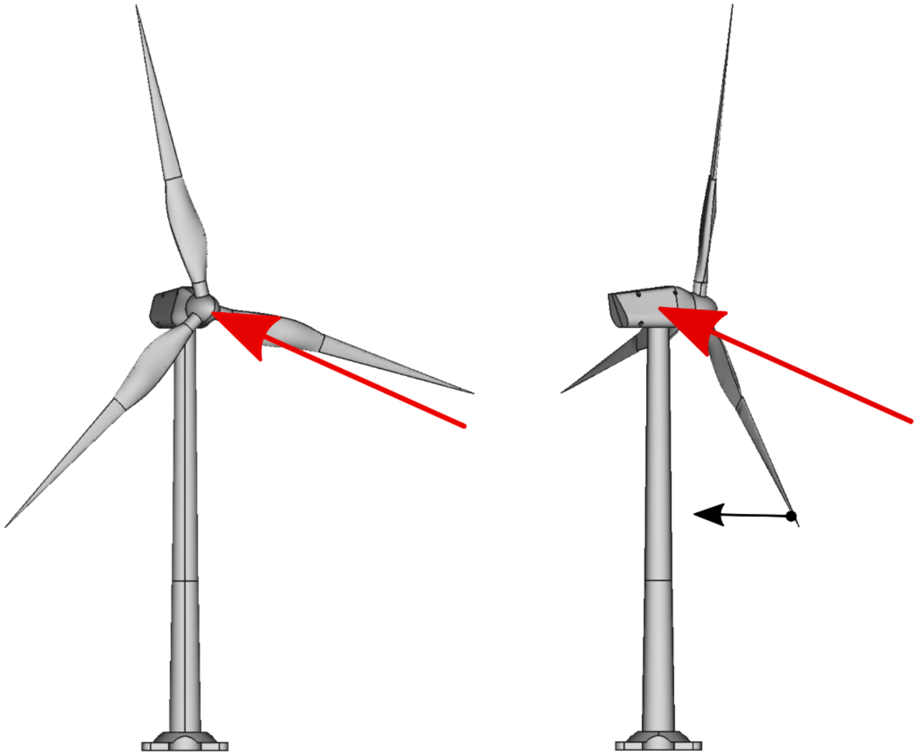


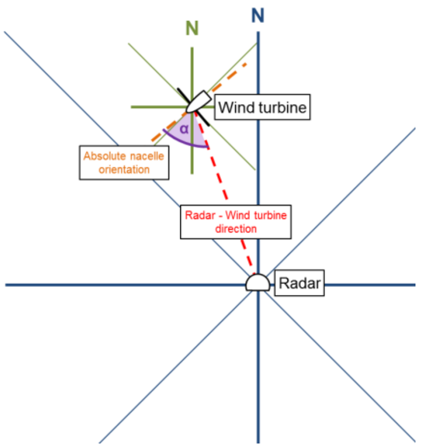
Albis Buergenstock BS: daily μ±**σ** of Z in **2022**



Tbc, e.g., 4 days in Jan. 2019 and 2021 median Z_h~86.5 dBz , Z_v~90 dBz ; **σ~0.5 dBz**

Wind **T**urbine **rotation / blade pitch angle** / orientation





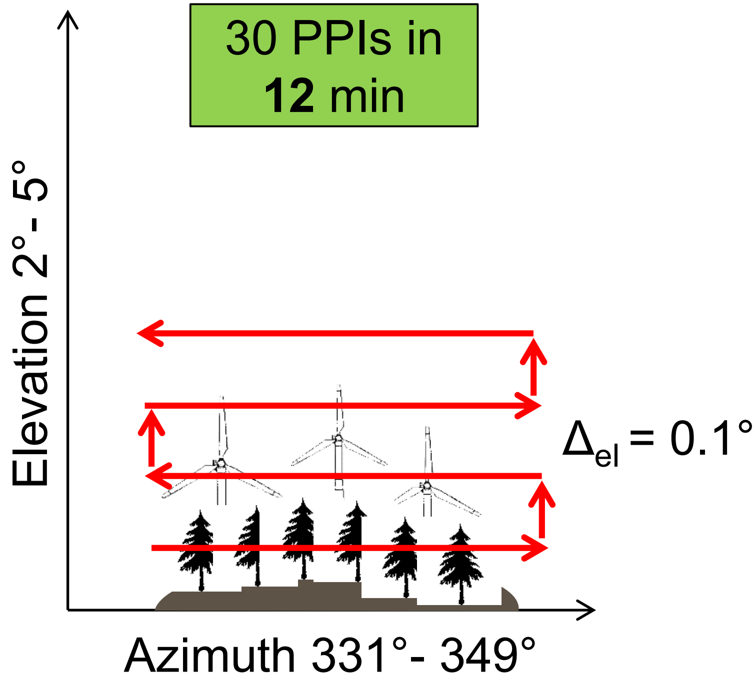
Convention:

0° → Facing towards radar

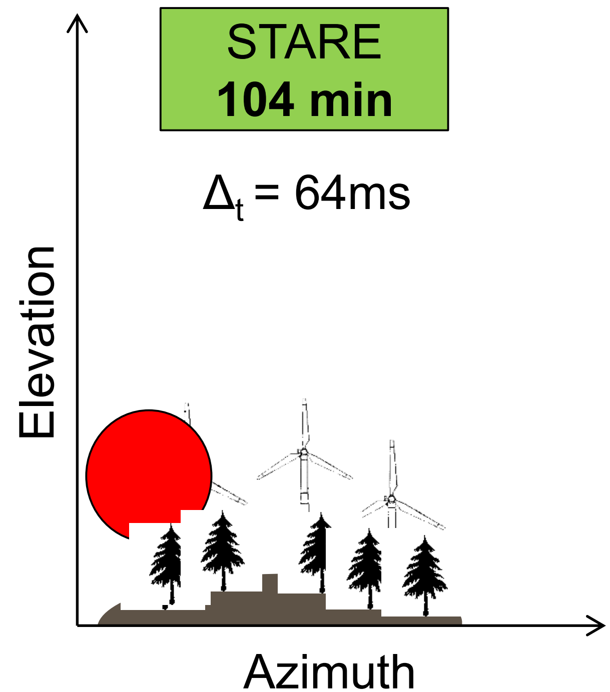
180° → Facing away from radar

Scan strategy: ~100 min stare mode in 2020

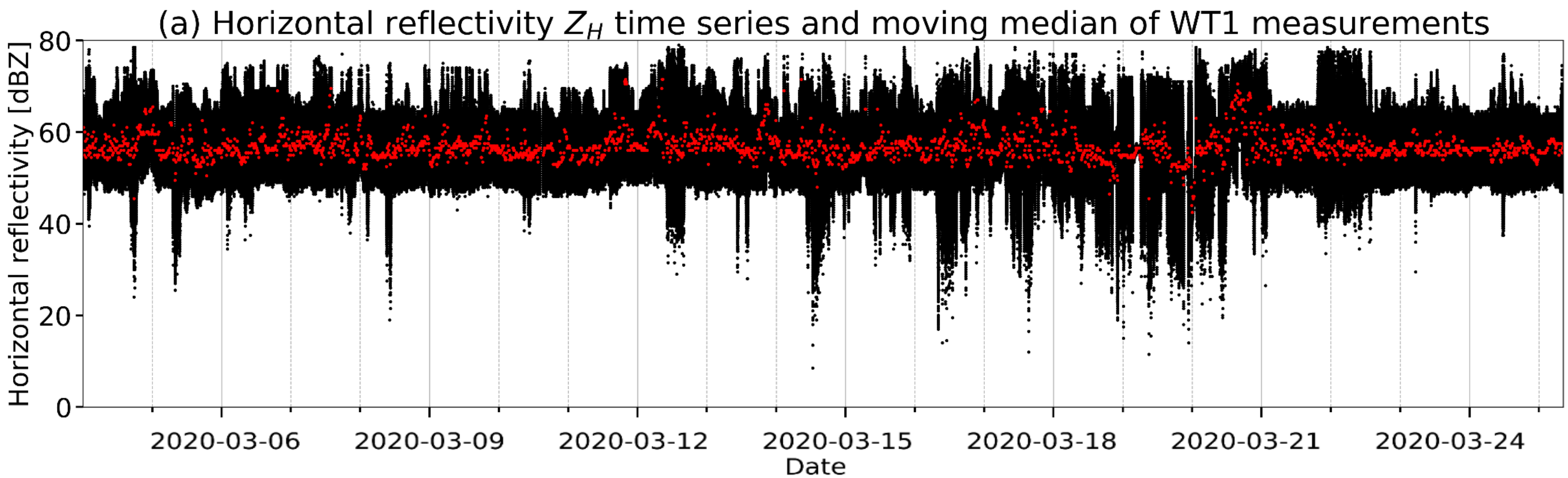
e.g., from **16:54** to **18:06** UTC



e.g., from **17:08 to 18:52 UTC**



Dual-pol signatures backscattered by a (quasi-)**still W**ind **T**urbine acquired (**64 ms**) by an X-band radar in **stare mode**

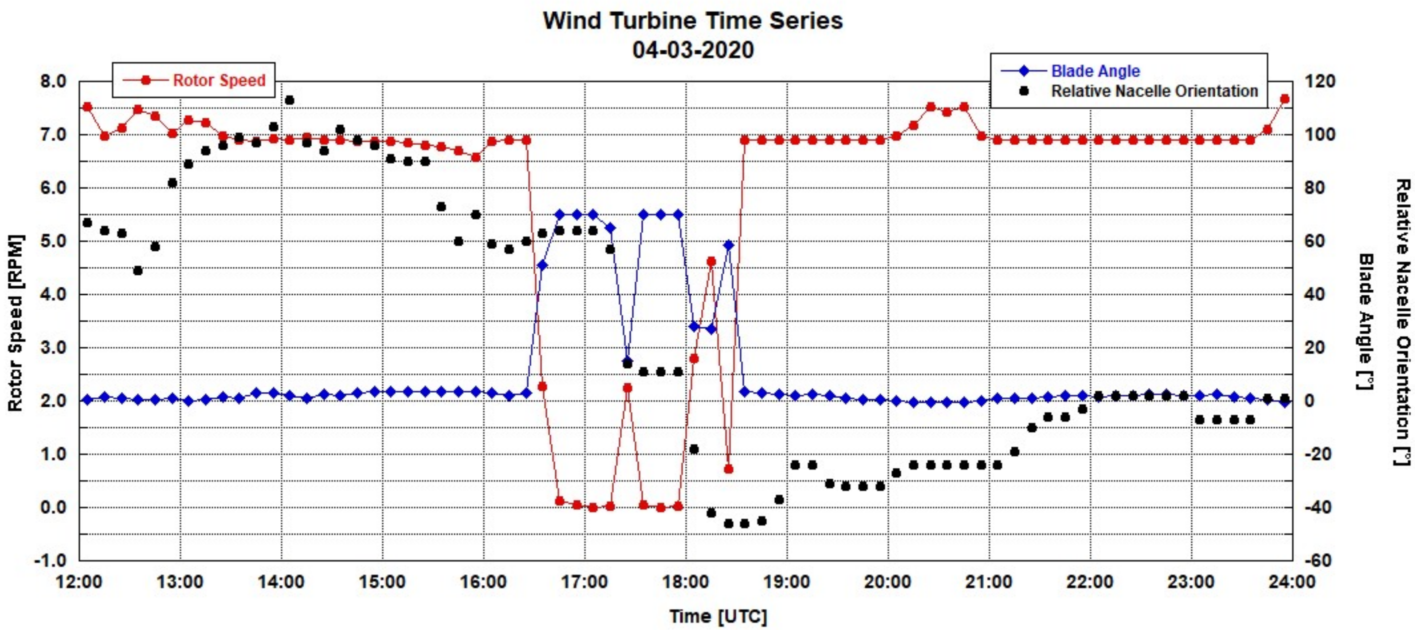


- **64 ms** reflectivity data in **black**, **600 s** moving median in **red**
- PRF 2000 Hz, data from 128 I-Q pulses
- 600 s WT metadata available (rotor speed, **blade pitch angle**, orientation)
- Max Z_h reaches 78.5 dBz

Focus on 32 minutes on March 4, still WT (Z_h= 78.5 dBz, 4 times, twice consecutive)

P1 17:08-17:10 UTC: **0.0 RPM average rotor speed**

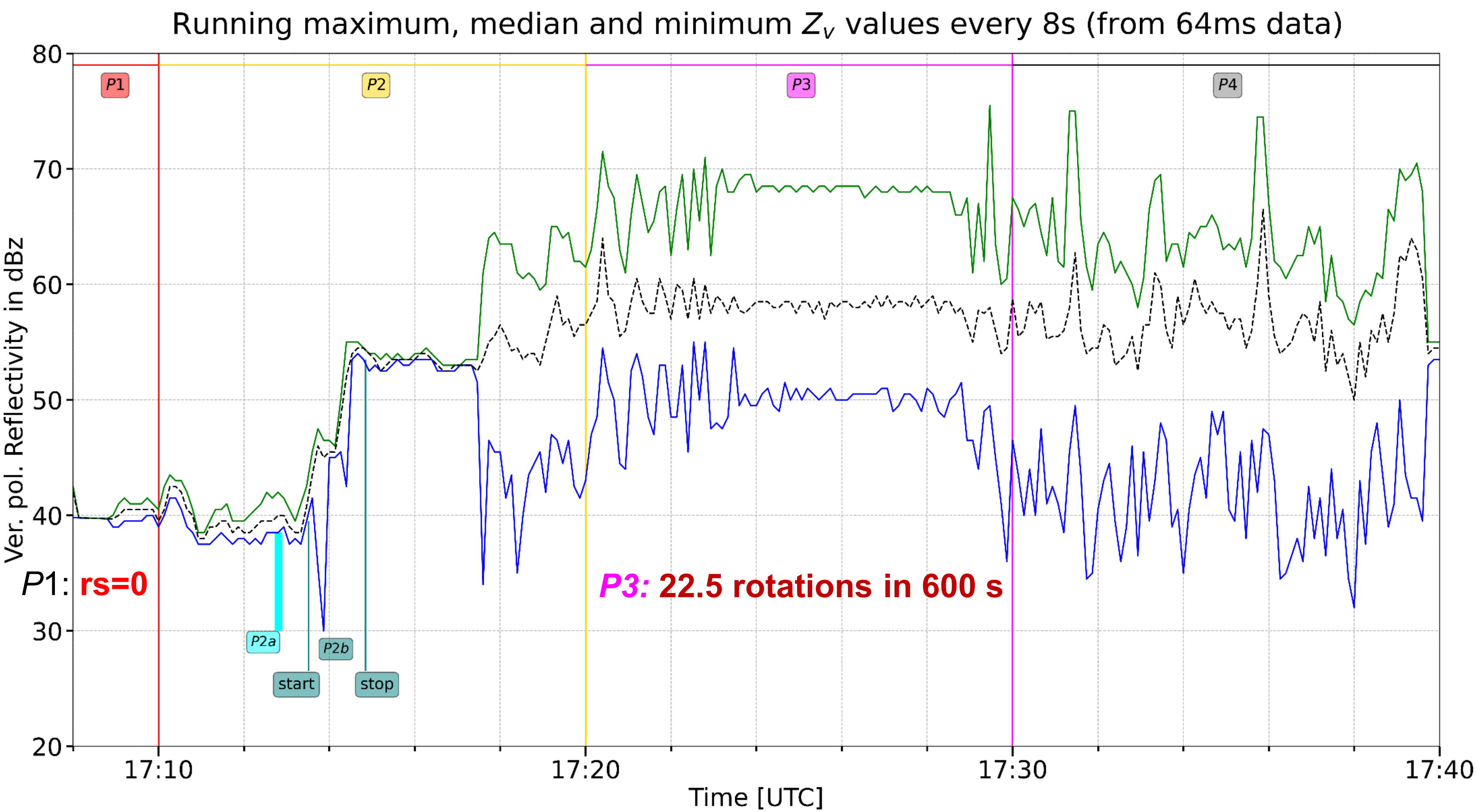
P2 17:10-17:20 UTC: **72° rotation**; ***P4*** 17:30-17:40 UTC: **216° rotation**



P3 17:08-17:10 UTC: **22.5 rotations in 600 s**

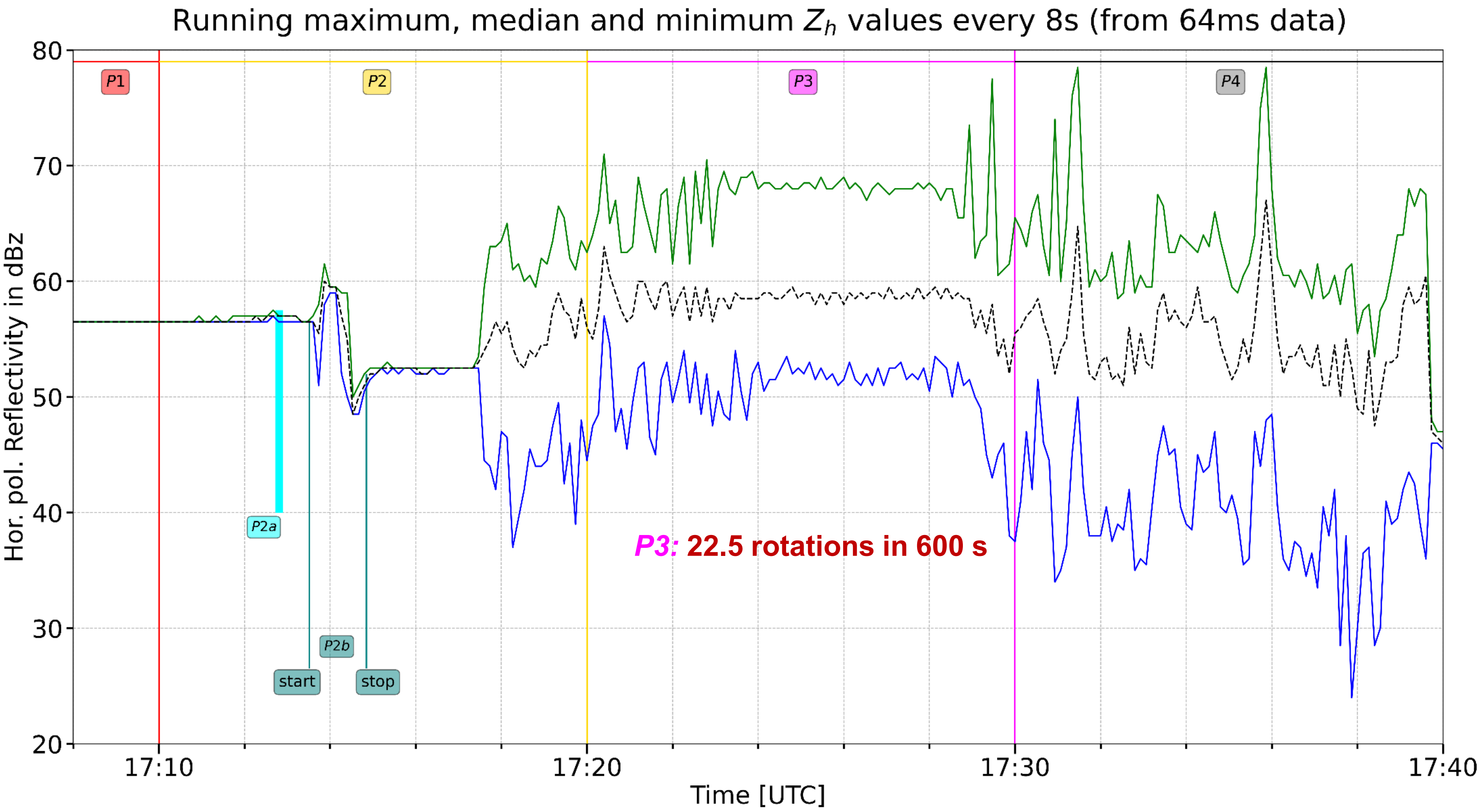
Focus on 32 minutes on **March 4**, still WT (Z_h= 78.5 dBz, 4 times)

32 minutes on **March 4**, **still**, quasi-still WT and ~20 rotations in ~4 min: Z_v

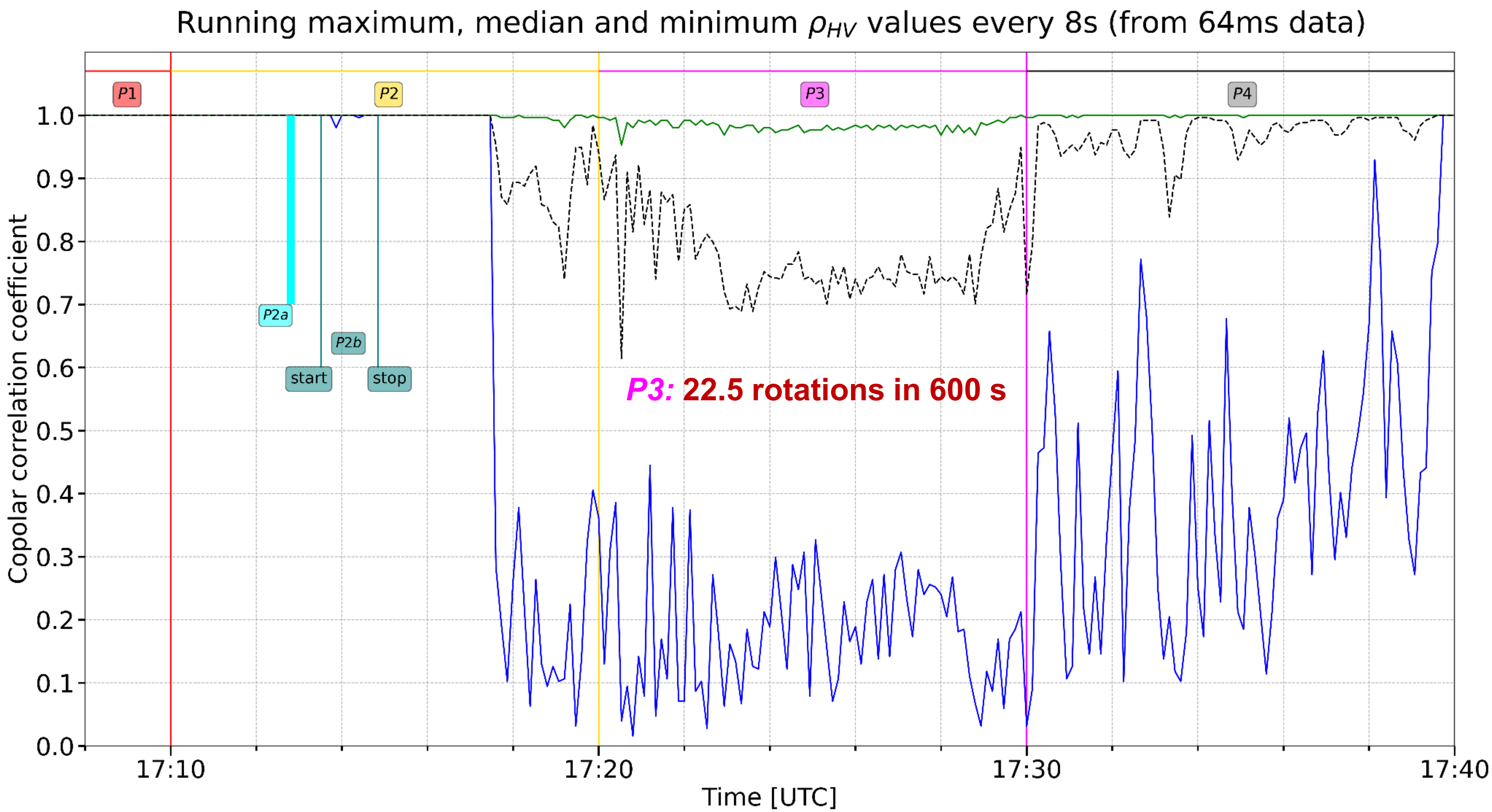


P2: **72° rotation**; *P4*: **216° rotation**

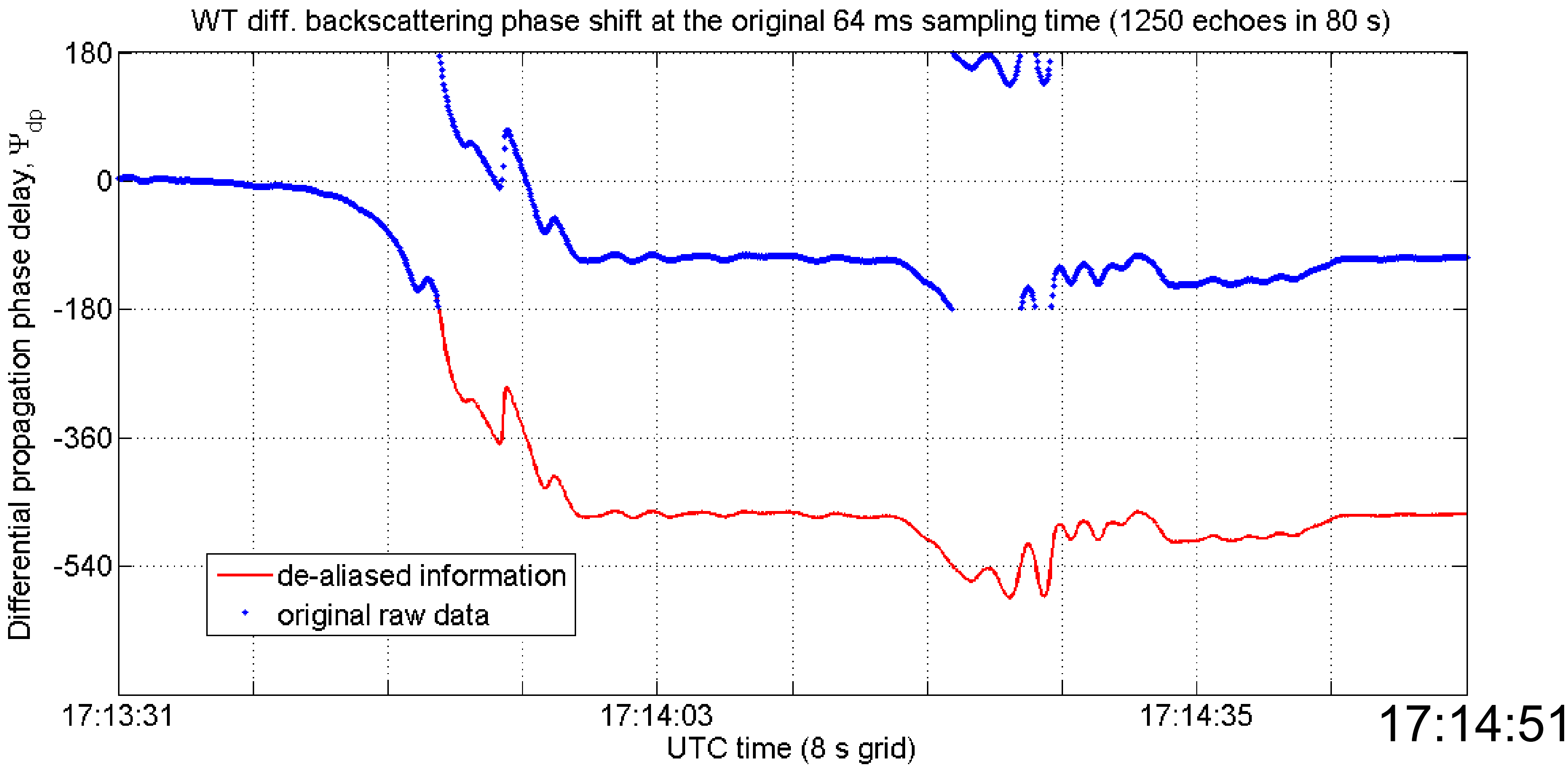
32 minutes on **March 4**, **still**, quasi-still WT ~20 rotations in ~4 min)



Copolar corrcoeff between **Horiz.** and **Vert. polarization**, ρ_{HV}

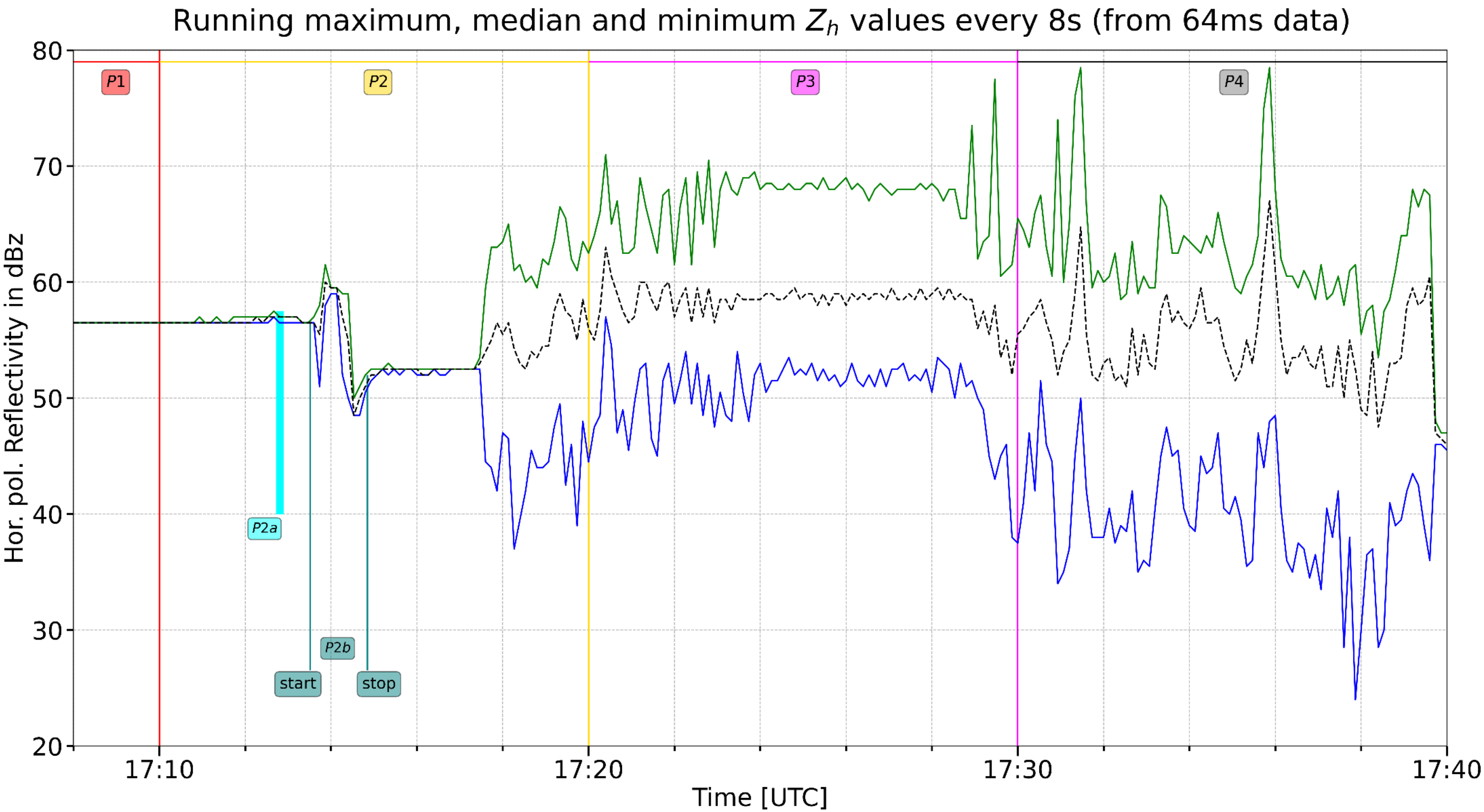


Sub-Period ***P2b*, 80 s**, backscatter differential phase shift



$$\Psi_{dp} = \Psi_0 + \Phi_{dp} + \delta_{co} \sim \delta_{co}$$ in this specific case

32 minutes on **March 4**, **still**, quasi-still WT (plus 20 rotations in ~6 min)



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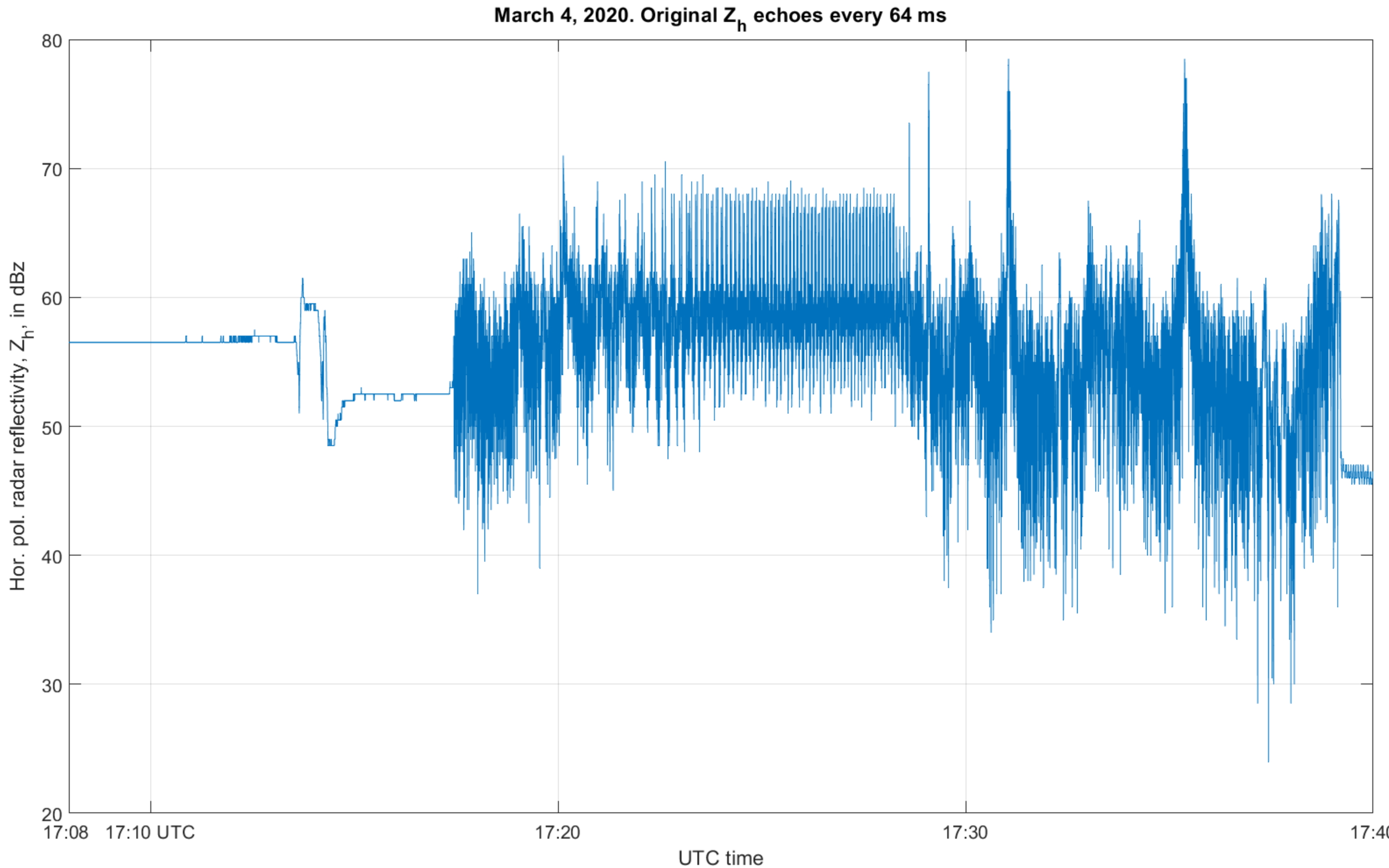
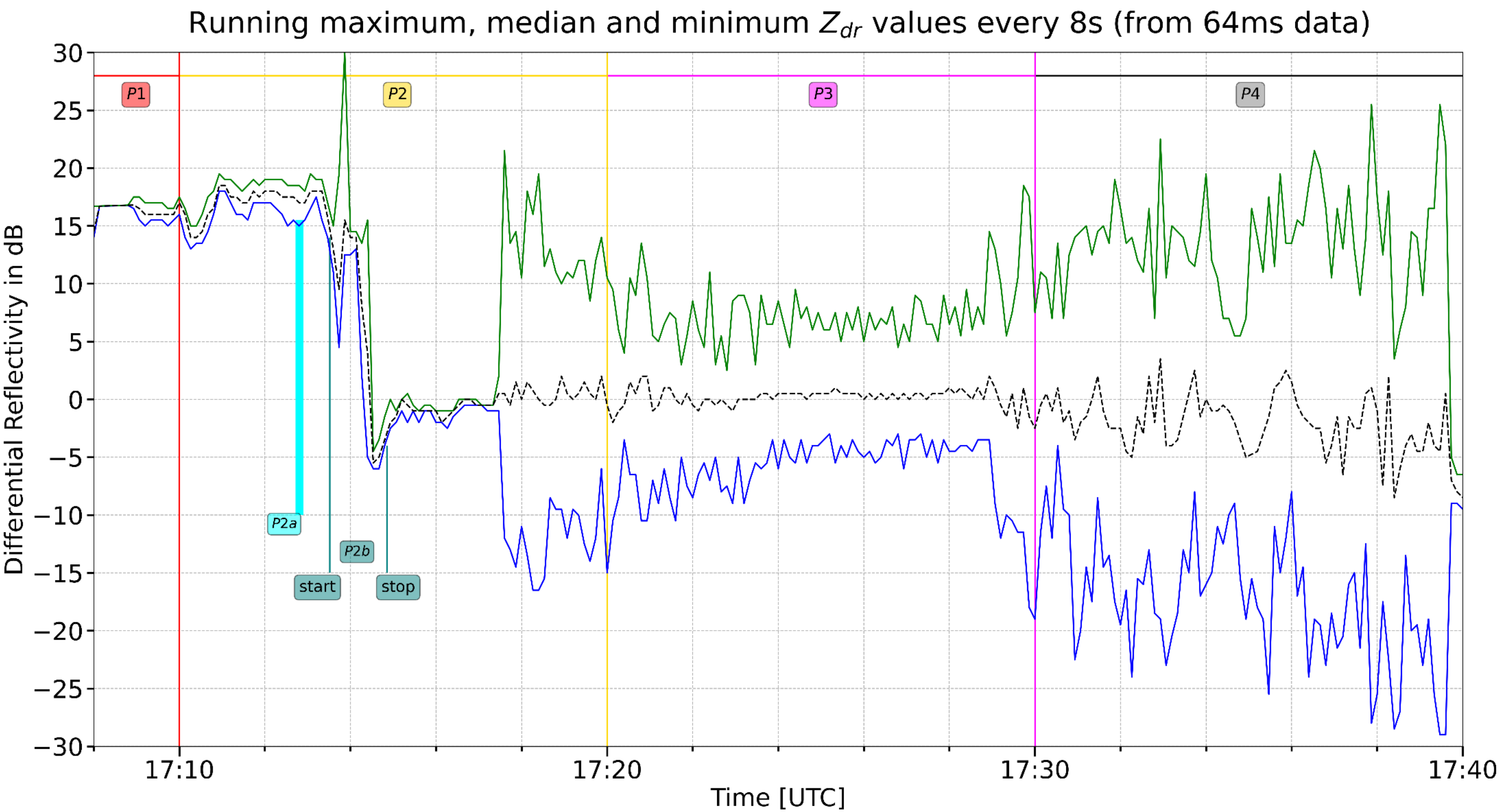
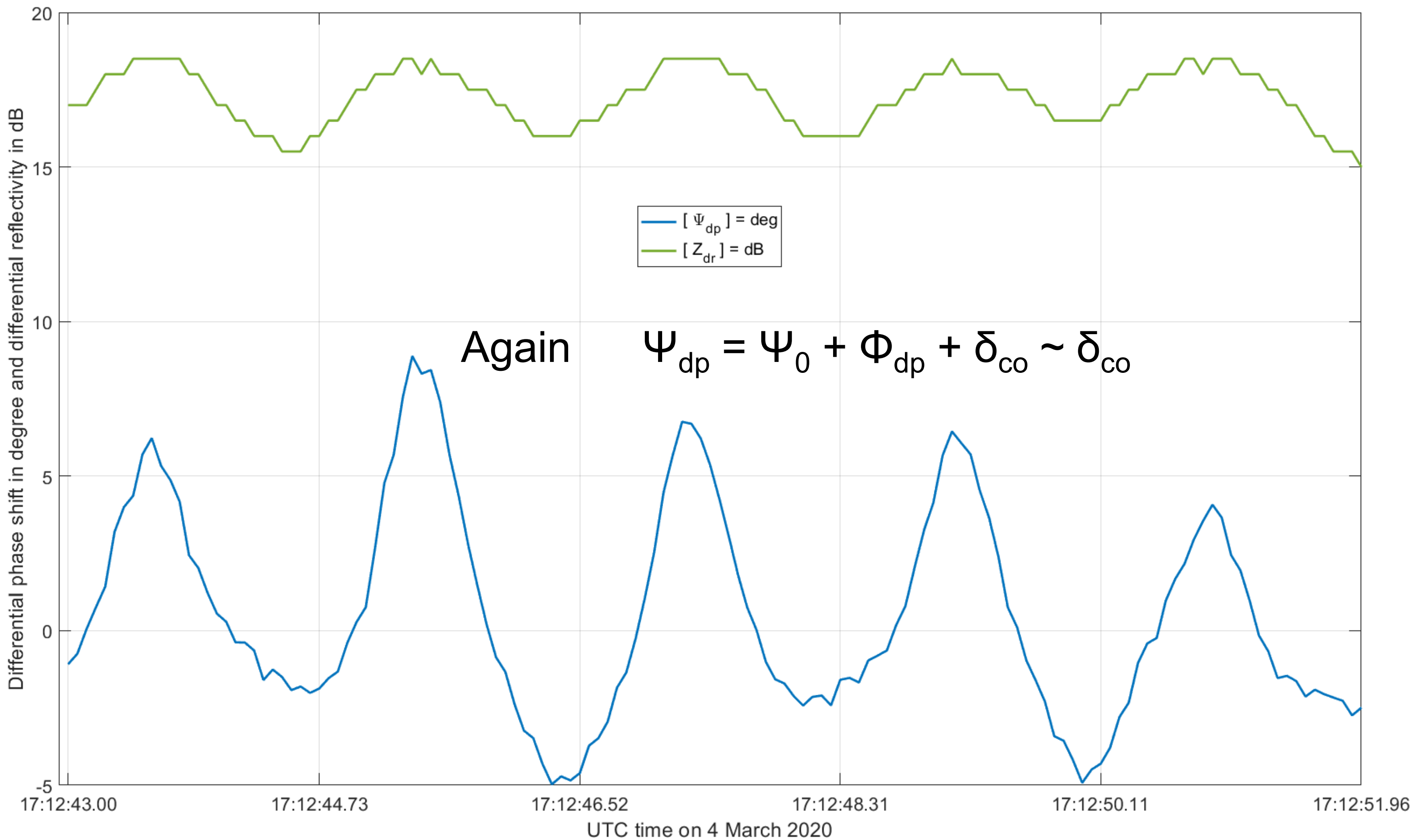

March 4, 2020. Original Z_h echoes every 64 ms
Hor. pol. radar reflectivity, Z_h, in dBz
80
70
60
50
40
30
20
17:08
17:10 UTC
17:20
17:30
17:40
UTC time

32 minutes on **March 4**, **still**, quasi-still WT and ~20 rotations in ~4 min: Z_{dr}



Sub-Period ***P2a*** (1.73×5 s): diff. reflectivity, backscattering diff. phase shift



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Summary, conclusions and open points

- Worthwhile to identify "Bright Scatterers" → "near-range", large RCS, perpendicularly hit by the main lobe beam axis.
- Still WT acts a BS. Using stare mode, dispersion tends to ZERO (ρ_{HV}, both H and V Z, Z_{dr}, Ψ_{dp}~δ_{co} , …), ρ_{HV} → 1!
- Backscattered signals by BSs can used to monitor and quality-check the low sensitivity channel of operational dual-pol weather radars.
- Do the BS polarimetric and spectral signatures depend on every single CAL. Unit? --> the PHASE of the low-sensitivity channel LNAs??
- BSs looks promising also as far as meteorological applications are concerned: e.g, accurate estiomation of Path Integrated Attenuation with high angular and temporal resolution

THANK YOU

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