On the use of “Bright Scatterers” for monitoring dual-polarization radars

and their meteorological applications, e.g.,

Lema melting hail attenuation June 28, 2021 @22:21 UTC

Albis wet radome attenuation: May 11 @10:05 UTC

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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** (and other REF points) (ERAD14)
2. Ext. pass. transponder to measure A, Φ of the Tx radar pulse (ERAD10)
3. Sun signals during op. weather scan program for pointing and relative CAL
4. Ext. active transp. for measuring RCS, Doppler, polarization (ICEAA2013)
5. Dedicated Sun-tracking (max. S/N) for absolute CAL of the Rx chain
6. Bright Scatterers, unique for low-sensitivity channel, day/night **(ERAD18)**

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.

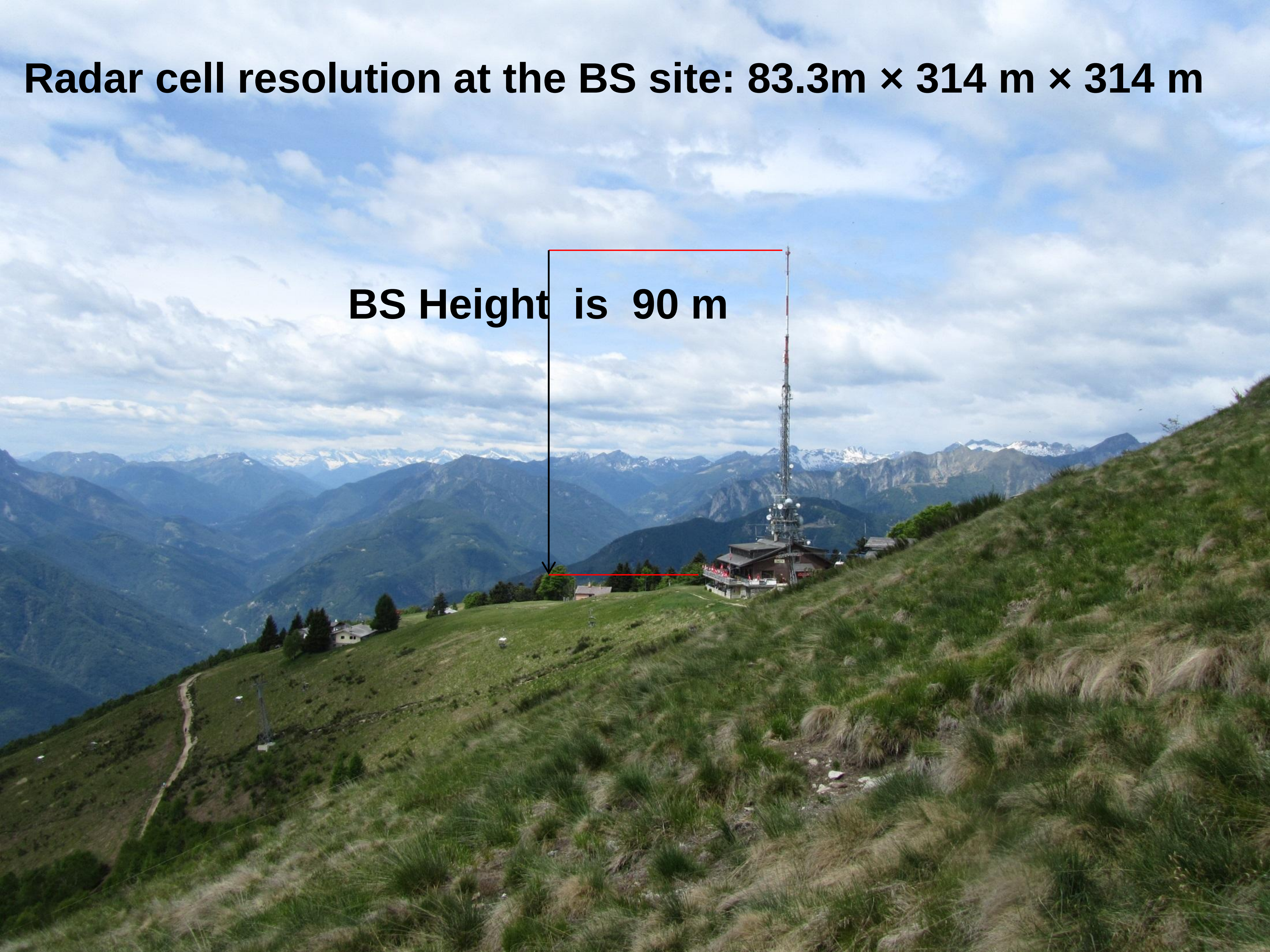
2. Gabella et al. (2010) An innovative instrumentation for checking EM performances of operational radar.

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., 2018: On the use of BS for monitoring dual-pol radars**. *Remote Sensing*


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

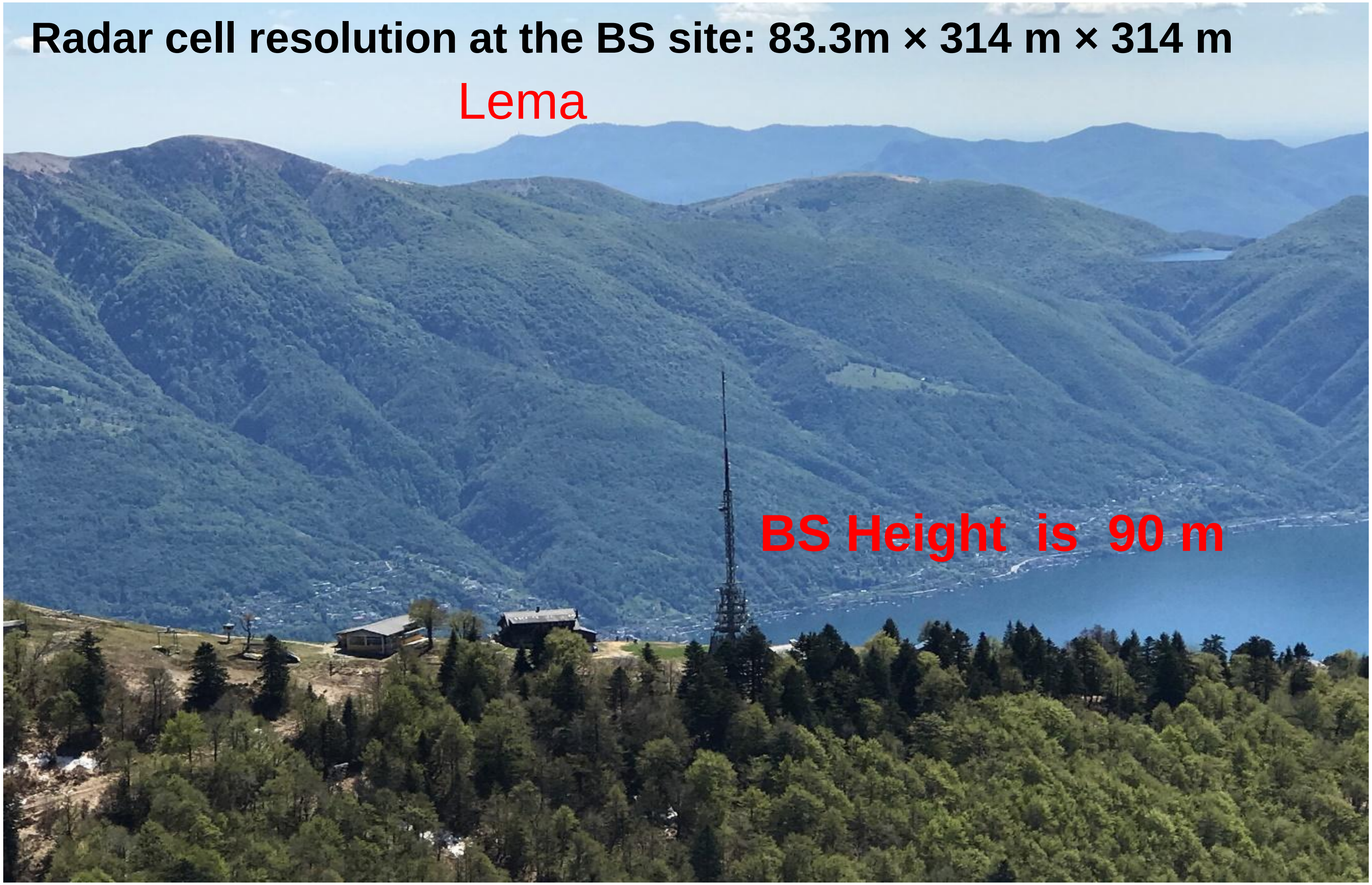
The Cimetta “BS” site in winter: view towards the M. Lema radar site

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

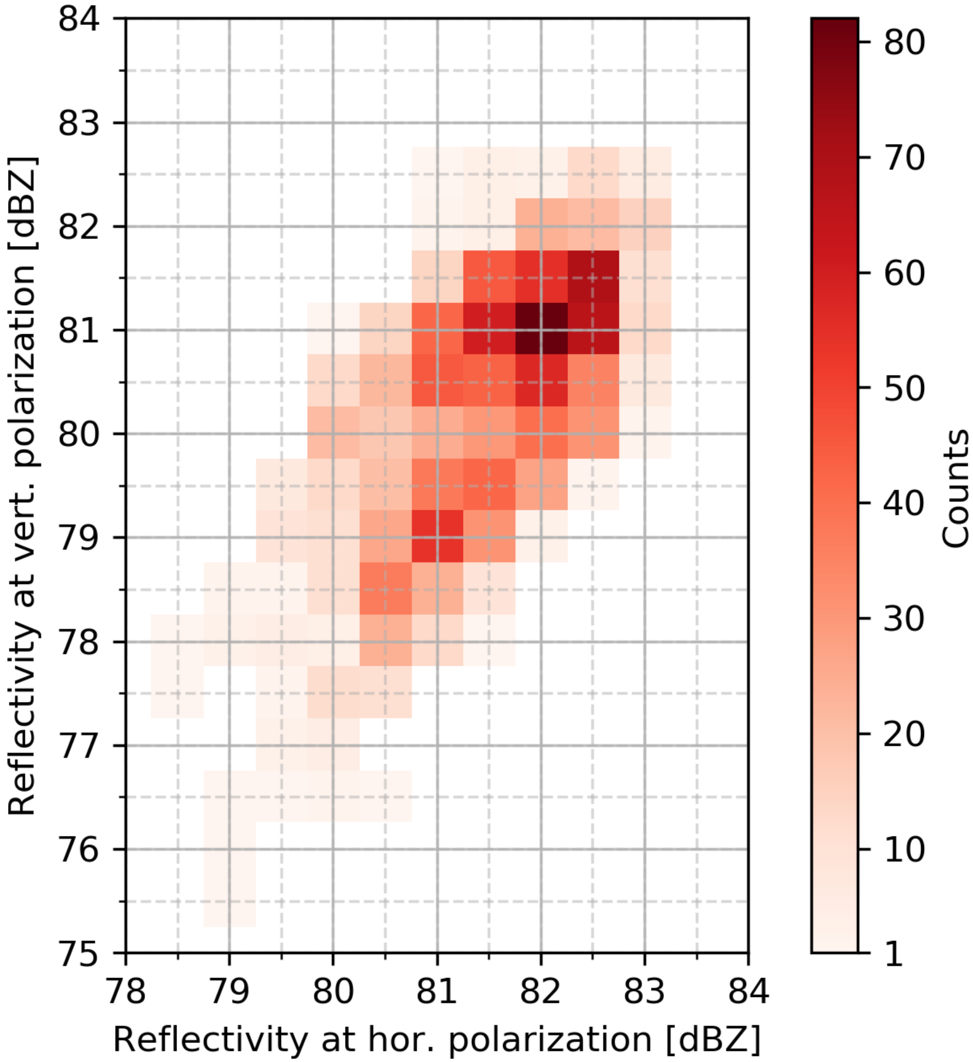
0 km
Lema radar site

Cimetta~18 km
Bright Scatterer

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



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**
Median{Z}	**81.5** dBz	**80.5**
Mean{Z}	**81.49**dBz	**80.27**
St. Dev.{Z}	±0.90 dBz	±1.21

Jan. 2015-17:
5 clear-sky days
1440 samples

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

Here it is 0.09 dB for H, –0.07 dB for V

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

Results: BS spectral/polarim. signatures

- The 2nd Doppler moment (spectrum width) is perfectly stable (31 days).
- The 1st Doppler moment (radial velocity) is very stable (31 days)

5-day 5-min clear-sky Jan. 2015 and 2017 data set (1440 samples)

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

Gabella M., 2018: “On the Use of Bright Scatterers for Monitoring Doppler, Dual-Polarization Weather Radars”, *Remote Sensing* doi:10.3390/rs10071007

Albis *BS polarimetric signatures **2019, 2021, 2020**

- The **copolar** correlation coefficient, ρ_{HV}, is as large
  0.9997±0.0002 (2019),0.9997±0.0001 (2021), **0.9993±0.0028** (2020)
- The **differential phase shift** ,Ψ_{dp}, is stable:
  $\sigma\{\Psi_{dp}\}$~**4.1**° (2019), 5.1° (2021), **7.0**° (2020)

*This particular BS ("Hammetschwand") is at Gate402 (~33.6 km) AZ196
4-day clear-sky normal refractivity data set (1152 samples) in **January**

Albis 2019 (*BS Gate402 AZ196) Albis 2021

	Hor.	Ver.
10 Log(Mean{z})	72.07dBz	75.68 dBz
Median{dBZ}	72.0 dBz	75.5 dBZ
Mean{dBZ}	71.97 dBz	75.62 dBZ
St. Dev.{dBZ}	±0.9 dBz	±0.7 dBz

	Hor.	Ver.
10 Log(Mean{z})	72.22 dBz	75.21
Median{dBZ}	**72.0** dBz	**75.0** dBz
Mean{dBZ}	**72.13** dBz	**75.15**
St. Dev.{dBZ}	±0.8 dBz	±0.7

4 clear-sky stand. Prop. days in Jan.: **1152 samples**

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

Here it is 0.07 dB for H, 0.18 dB for V

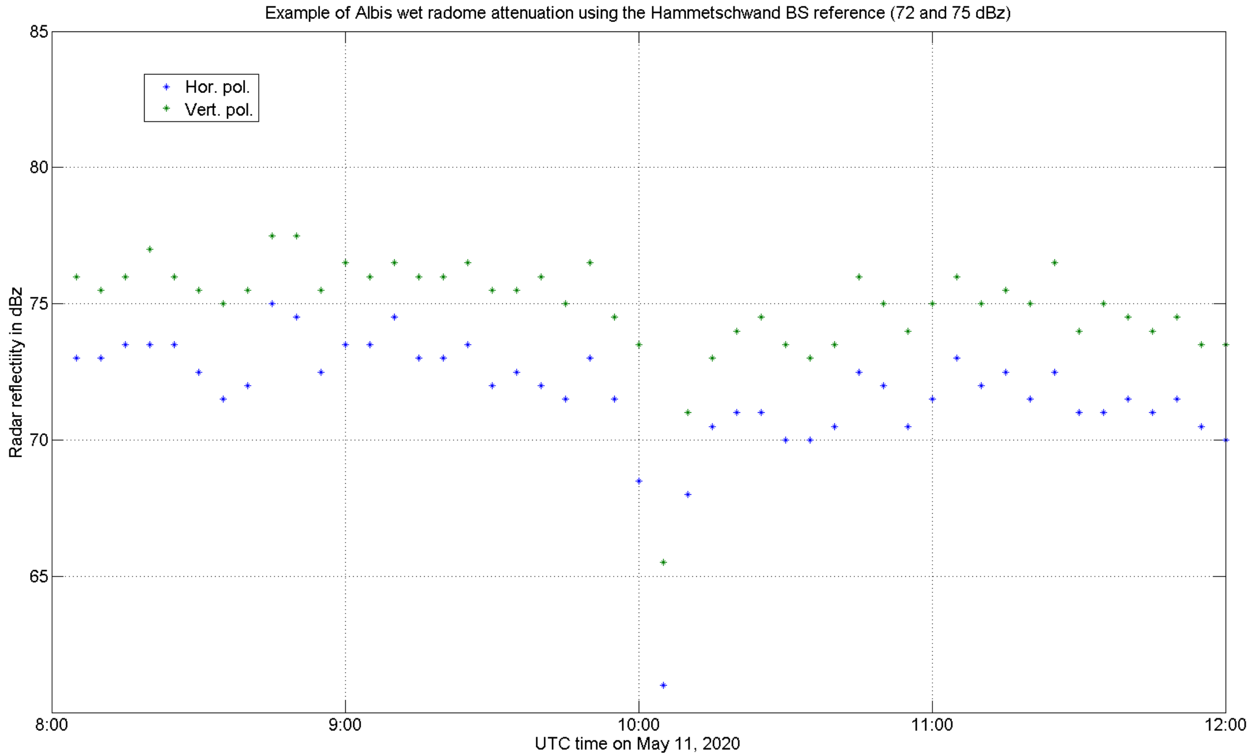
It is 0.22 dB for H, 0.21 dB for V

The Log(90%tile / Mean) is ~3-4 dB for most of typical GC

The Log(90%tile / Mean) is 0.9 dB for H, 0.8 dB for V

The Log(90%tile / Mean) is 0.8 dB for H, 0.8 dB for V

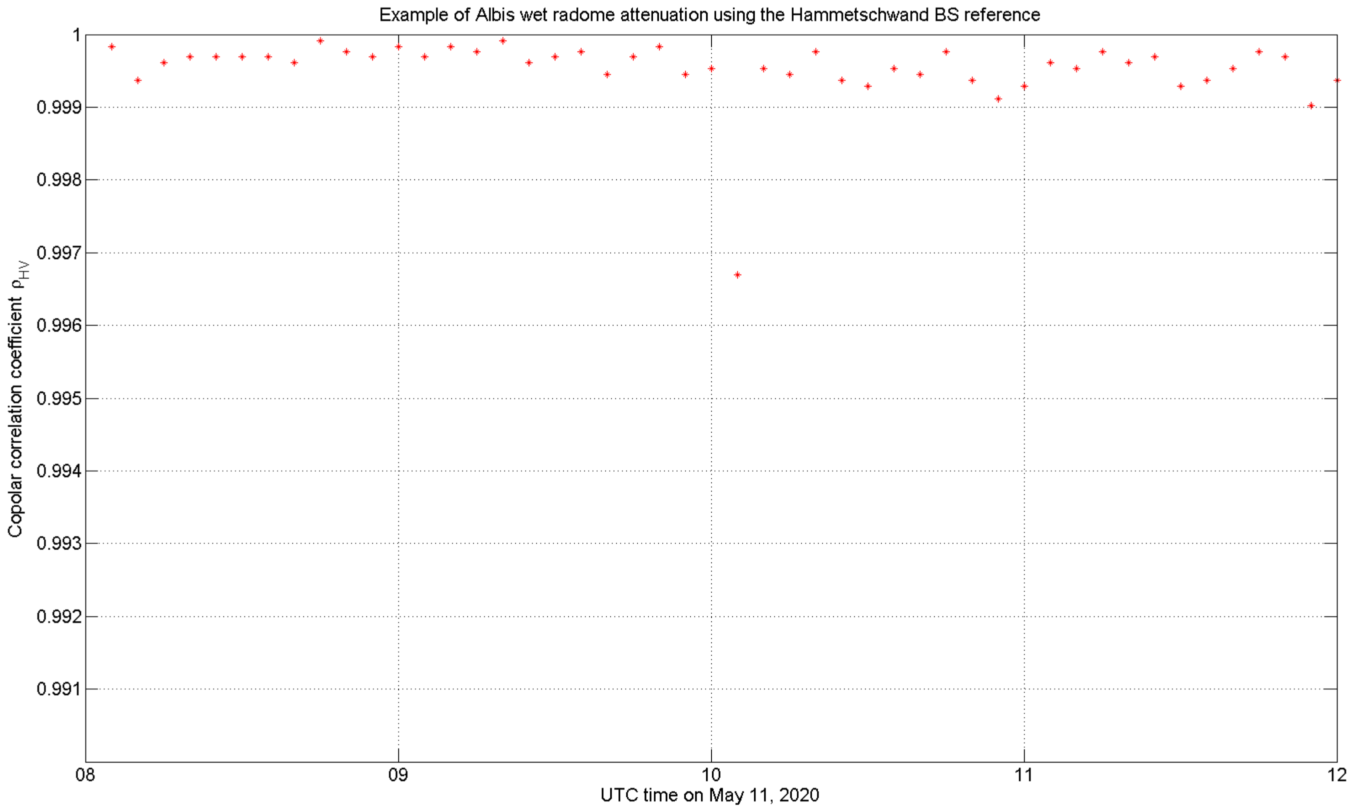
Albis *BS and wet-radome attenuation on 11.5.2020



The **increase in Noise** (median of 36 azimuthal values, 10˚-mean) is **1 dB** at 10:05

PIA is (see above) ~72-61= **11 dB** at **H**or. and ~75-65= **10 dB** at **Ver.** Pol.

Albis *BS and wet-radome attenuation on 11.5.2020



Daily **copolar** correlation coefficient, $\boldsymbol{\rho_{HV}}$, is typically **0.9993±0.0028**

~1 dB increase in Noise (median of 36 azimuthal values, 10°-mean) at 10:05

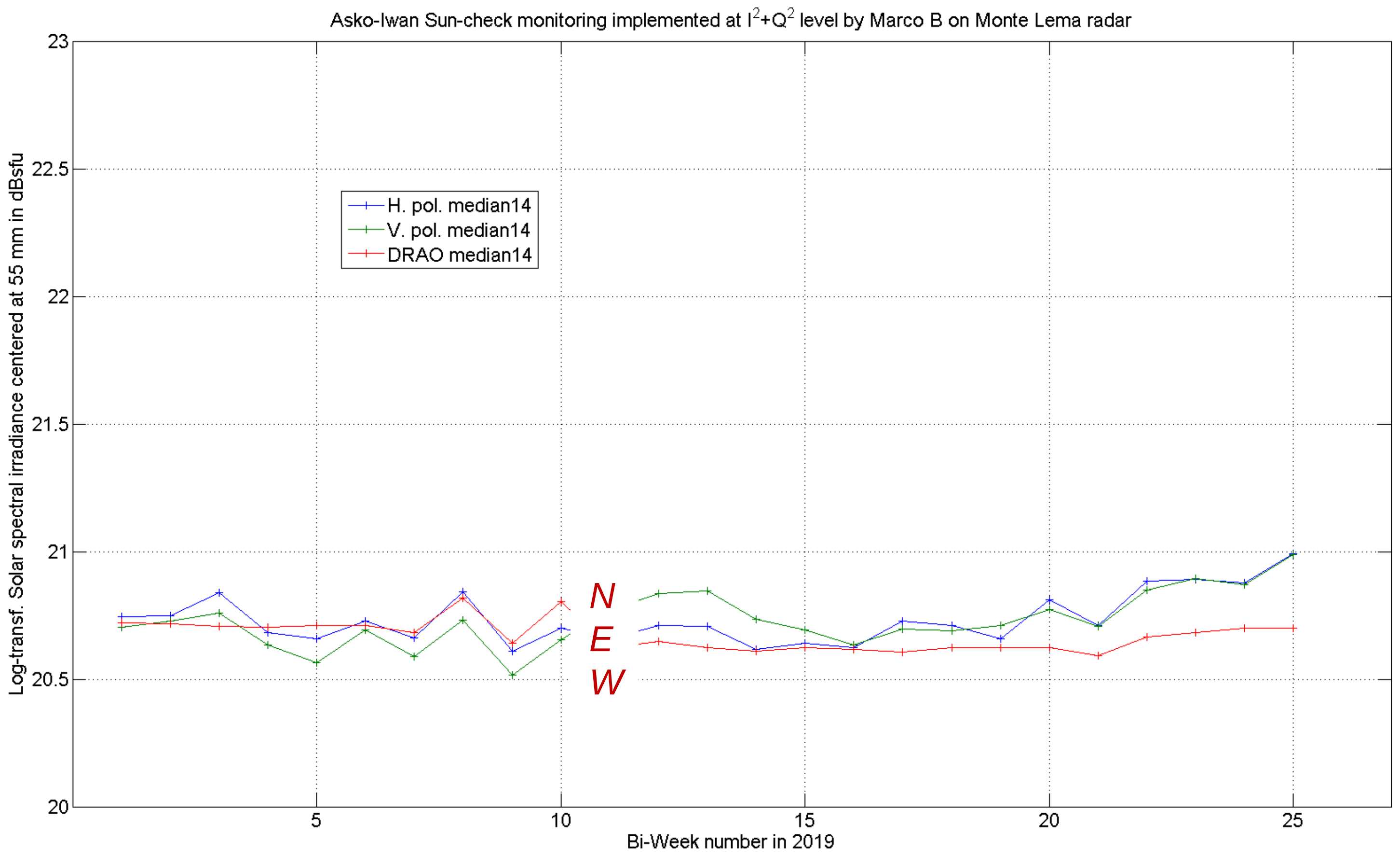
Lema: Worst/Best daily signatures in Jan. ‘19 vs ‘20

Worst 2020	Signature, site	Best 2020	Worst 2019	Best 2019
0.9594	**E{ρ_{HV}}, CIM**	**0.9887 <**	**0.9975**	0.9986
76.1°	**σ{Ψ_{dp}}, CIM**	**28.4° >**	**4.4°**	2.5°
0.0680	**σ{ρ_{HV}}, CIM**	**0.0310 >**	**0.0030**	0.0007
73.9 dBz	**E{Z_H}, CIM**	75.3 dBz<	81.5 dBz	82.5 dBz
71.3 dBz	**E{Z_V}, CIM**	72.2 dBZ<	80.2 dBz	81.5 dBz

Gabella M., 2021: “On the Spectral and Polarimetric Signatures of a Bright Scatterer before and after Hardware Replacement”, *Remote Sensing*

Monte **Vada'**, a unique MBS ~21 km west of Lema

Jan. 19	**Signature, site**			Jan. 2020
0.0007	**$\sigma\{\rho_{HV}\}$, CIM**			**0.0310**
0.0003	**$\sigma\{\rho_{HV}\}$, Vada'**			**0.0013**
2.5°	**$\sigma\{\Psi_{dp}\}$, CIM**			**28.4°**
2.0°	**$\sigma\{\Psi_{dp}\}$, Vada'**			**7.0°**
0.9986	**$E\{\rho_{HV}\}$, CIM**			**0.9887**
0.9998	**$E\{\rho_{HV}\}$, Vada'**			**0.9978**
81.5 dBz	**$E\{Z_V\}$, CIM**			72.2 dBZ
82.5 dBz	**$E\{Z_H\}$, CIM**			75.3 dBz
70.3 dBz	**$E\{Z_H\}$, Vada'**			68.0 dBz
71.4 dBz	**$E\{Z_V\}$, Vada'**			68.5 dBZ

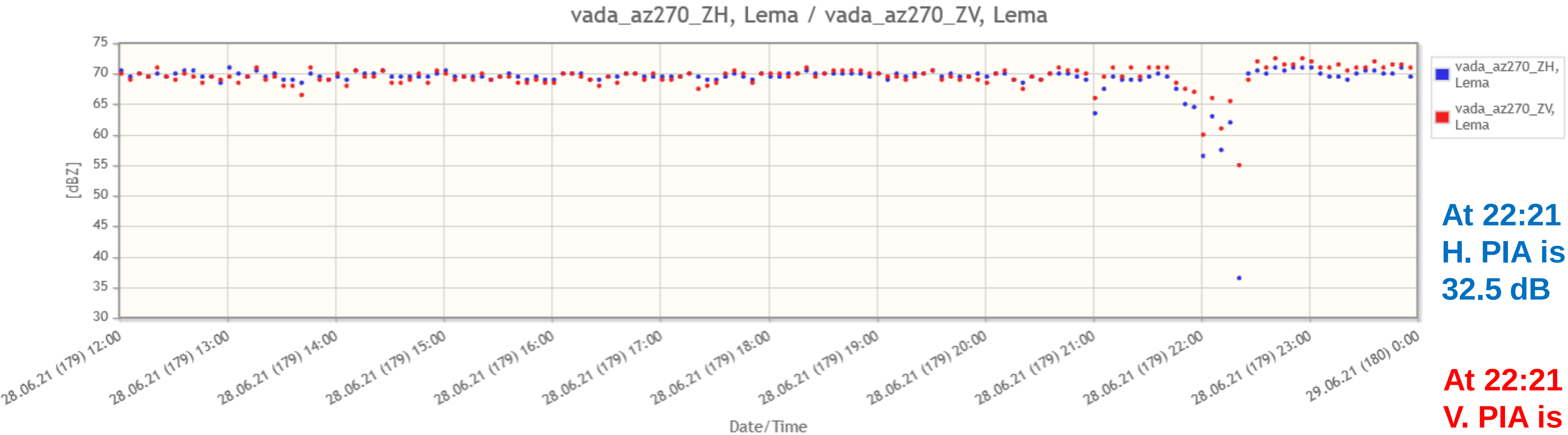

Asko-Iwan Sun-check monitoring implemented at I2+Q2 level by Marco B on Monte Lema radar
H. pol. median14
V. pol. median14
DRAO median14
Log-transf. Solar spectral irradiance centered at 55 mm in dBsfu
Bi-Week number in 2019
N
E
W
23
22.5
22
21.5
21
20.5
20
5
10
15
20
25

Monte **Vada'**, a unique MBS ~21 km west of Lema

Jan. 19	**Signature, site**	13.4.2021	14.4.2021	Best Jan. 2020
0.0007	**$\sigma\{\rho_{HV}\}$, CIM**	**0.0035**	**0.0031**	**0.0310**
0.0003	**$\sigma\{\rho_{HV}\}$, Vada'**	**0.0008**	**0.0011**	**0.0013**
2.5°	**$\sigma\{\Psi_{dp}\}$, CIM**	**12.1°**	**6.5°**	**28.4°**
2.0°	**$\sigma\{\Psi_{dp}\}$, Vada'**	**7.5°**	**6.1°**	**7.0°**
0.9986	**$E\{\rho_{HV}\}$, CIM**	**0.9959**	**0.9966**	**0.9887**
0.9998	**$E\{\rho_{HV}\}$, Vada'**	**0.9992**	**0.9981**	**0.9978**
81.5 dBz	**$E\{Z_V\}$, CIM**	76.5±1.8 dBZ	76.0±2.2 dBz	72.2 dBZ
82.5 dBz	**$E\{Z_H\}$, CIM**	77.8±2.0 dBz	78.5±1.1 dBz	75.3 dBz
70.3 dBz	**$E\{Z_H\}$, Vada'**	68.4±0.5 dBz	**69.0±0.8 dBz**	68.0 dBz
71.4 dBz	**$E\{Z_V\}$, Vada'**	71.1±0.8 dBz	70.2±0.6 dBz	68.5 dBZ

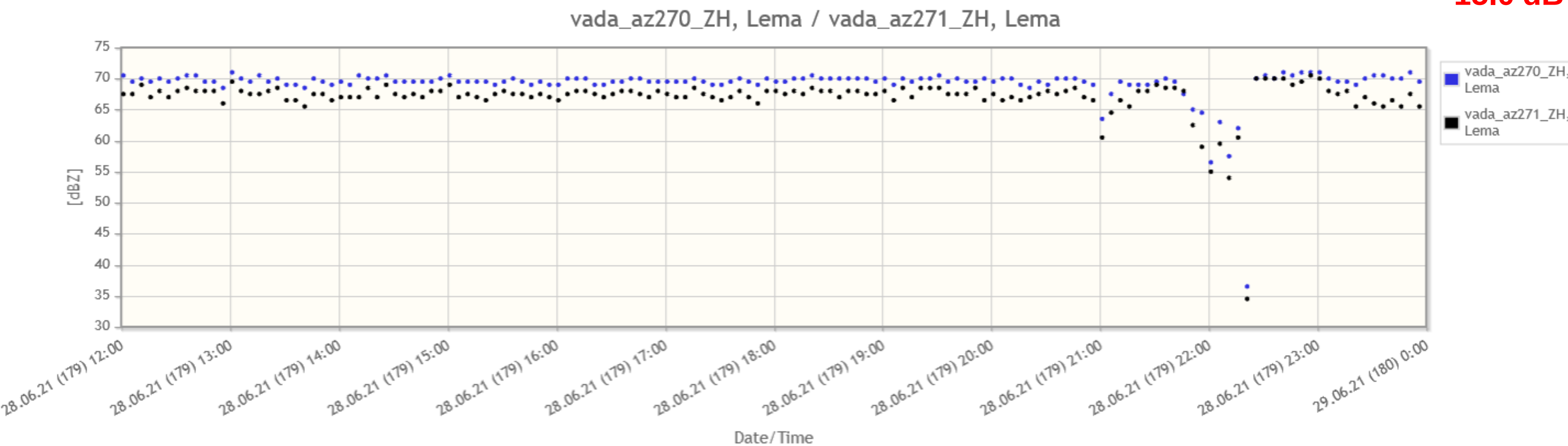
2 "good" days in spring 2021: **cs** and **light rain**

12-hour Vada' radar Reflectivity evolution on June 28, 2021



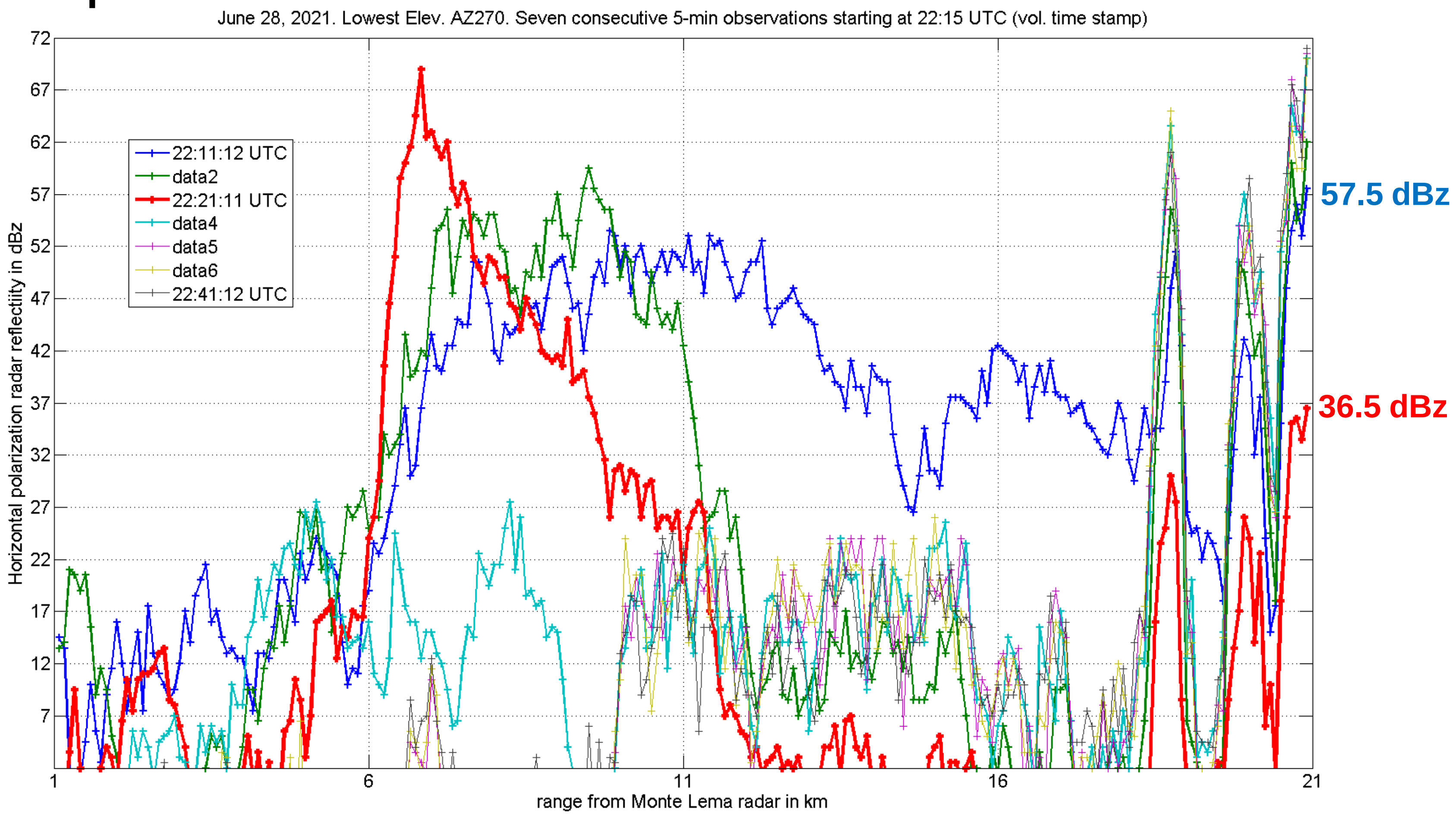
At 22:21 H. PIA is 32.5 dB

At 22:21 V. PIA is 15.0 dB



Lema A-scope

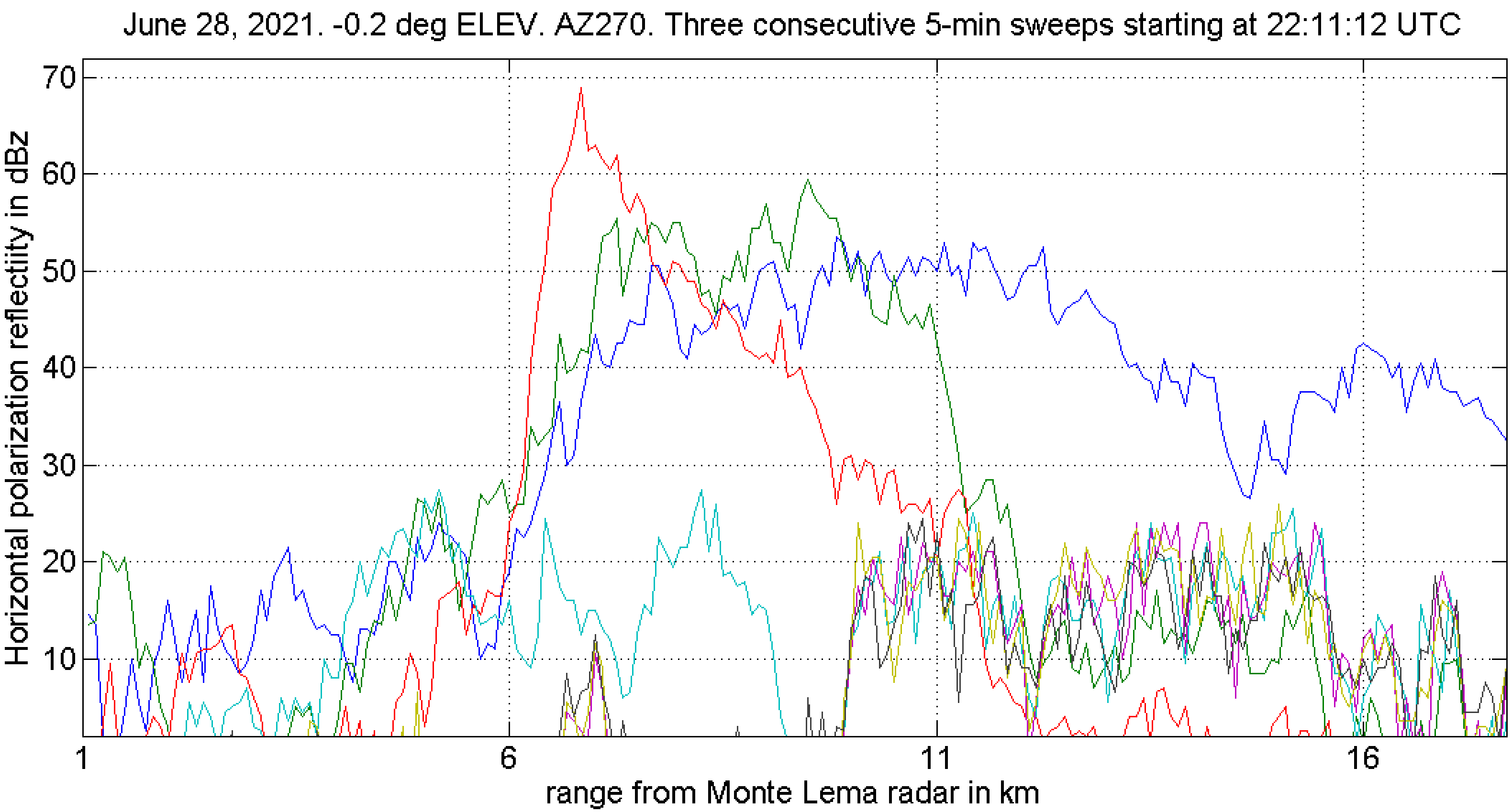
PIA at 22:21 UTC is 69.0-36.5 = 32.5 dB



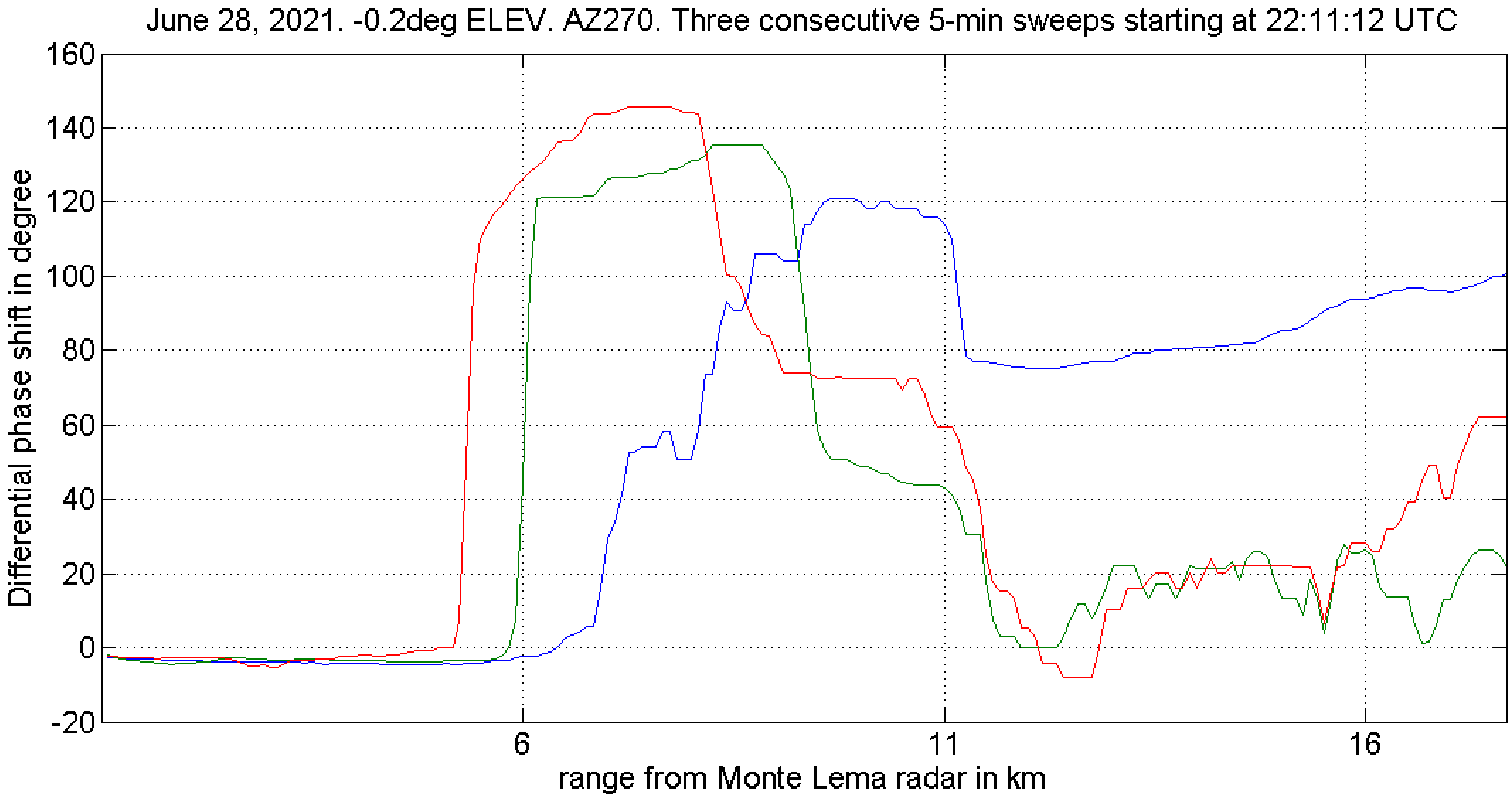
MBS as a Surface Reference target for estimating Path Integral Attenuation

E{Z_H}=69.0±0.8 dBZ M. Vada'

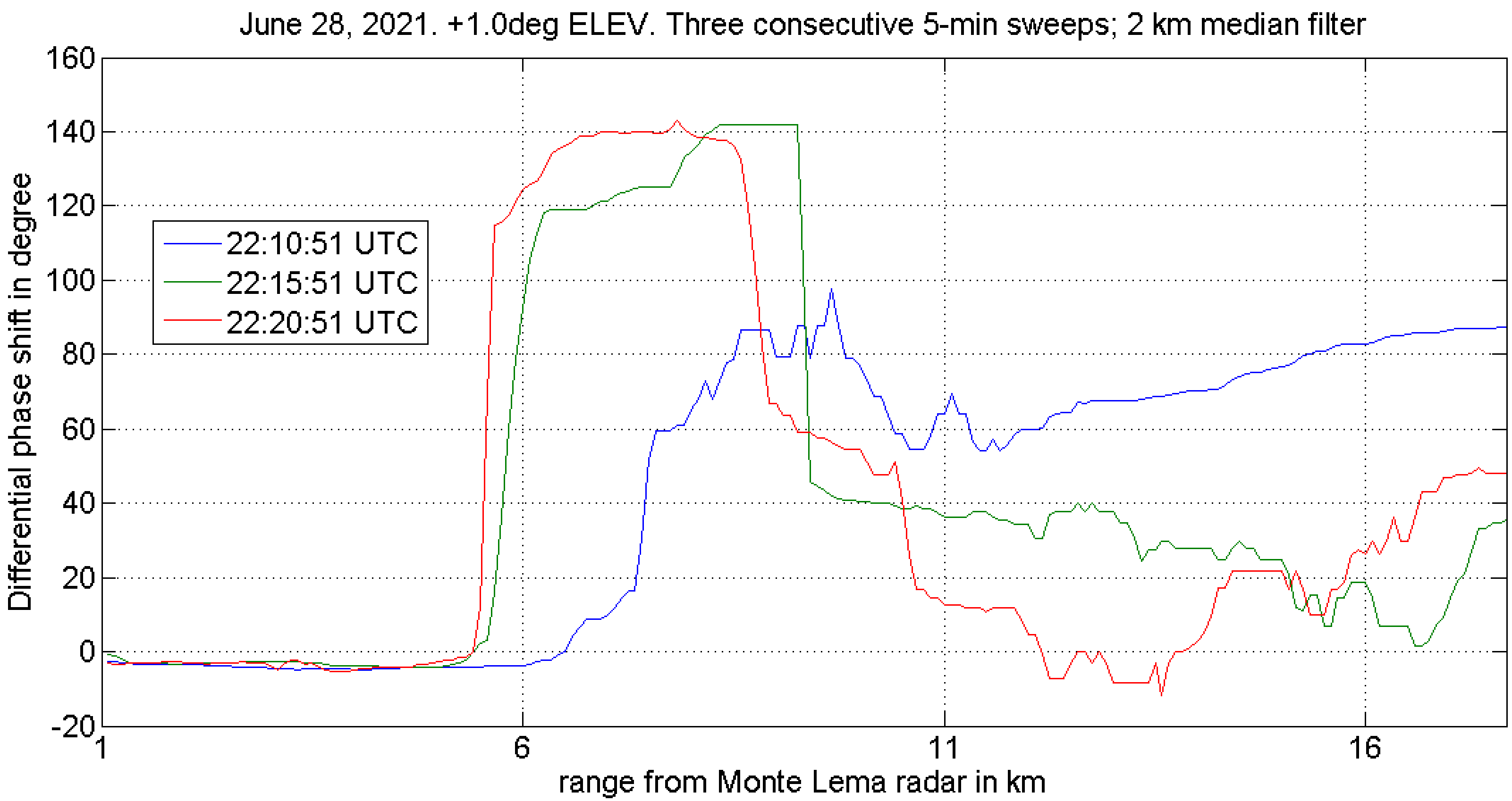
Lema A-scope: Z_H at 22:11:12 UTC, 22:16:11 UTC, at 22:21:11 UTC



Lema A-scope: Ψ_{dp} at 22:11:12 UTC, 22:16:11 UTC, at 22:21:11 UTC



Lema A-scope: Ψ_{dp}

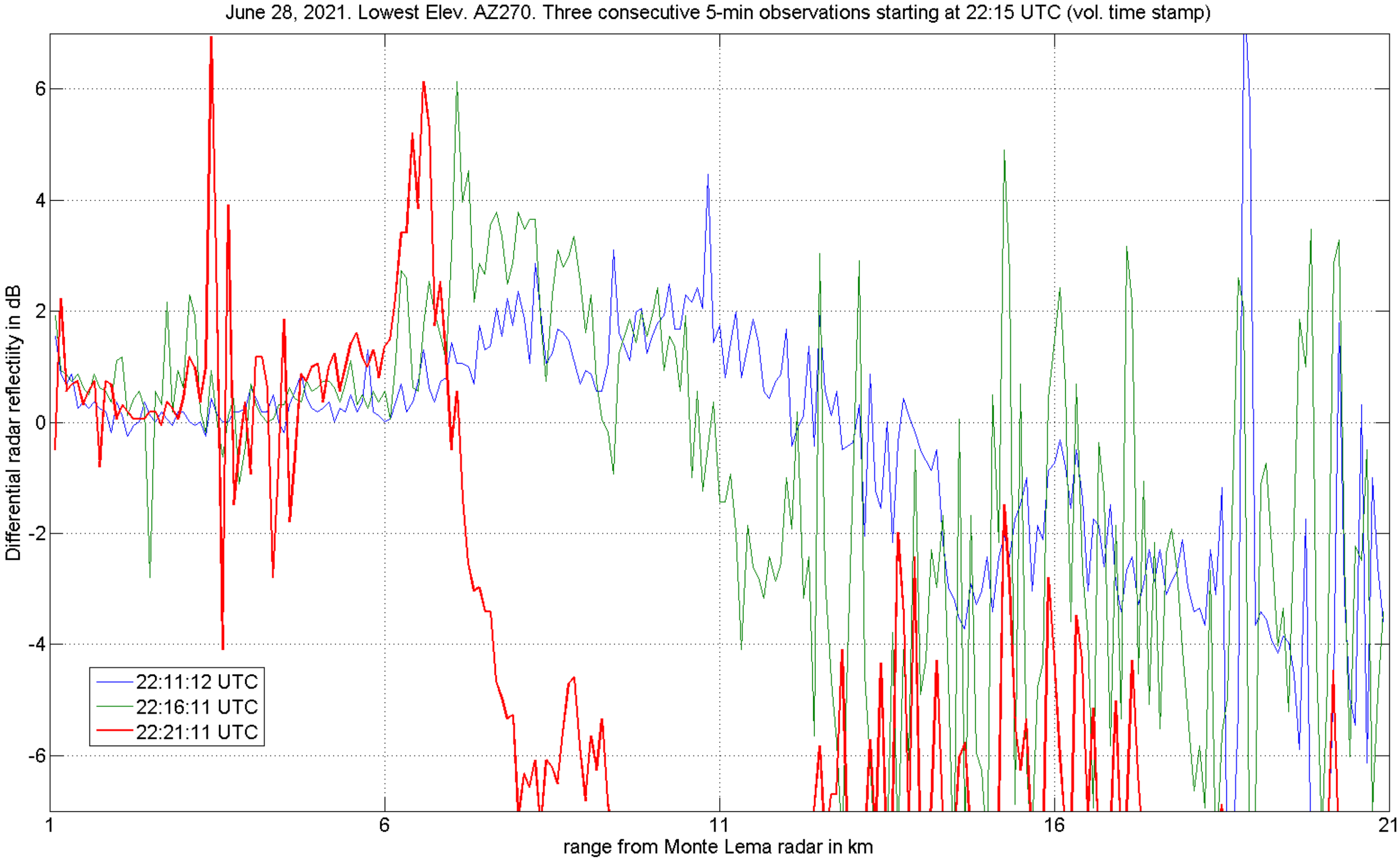


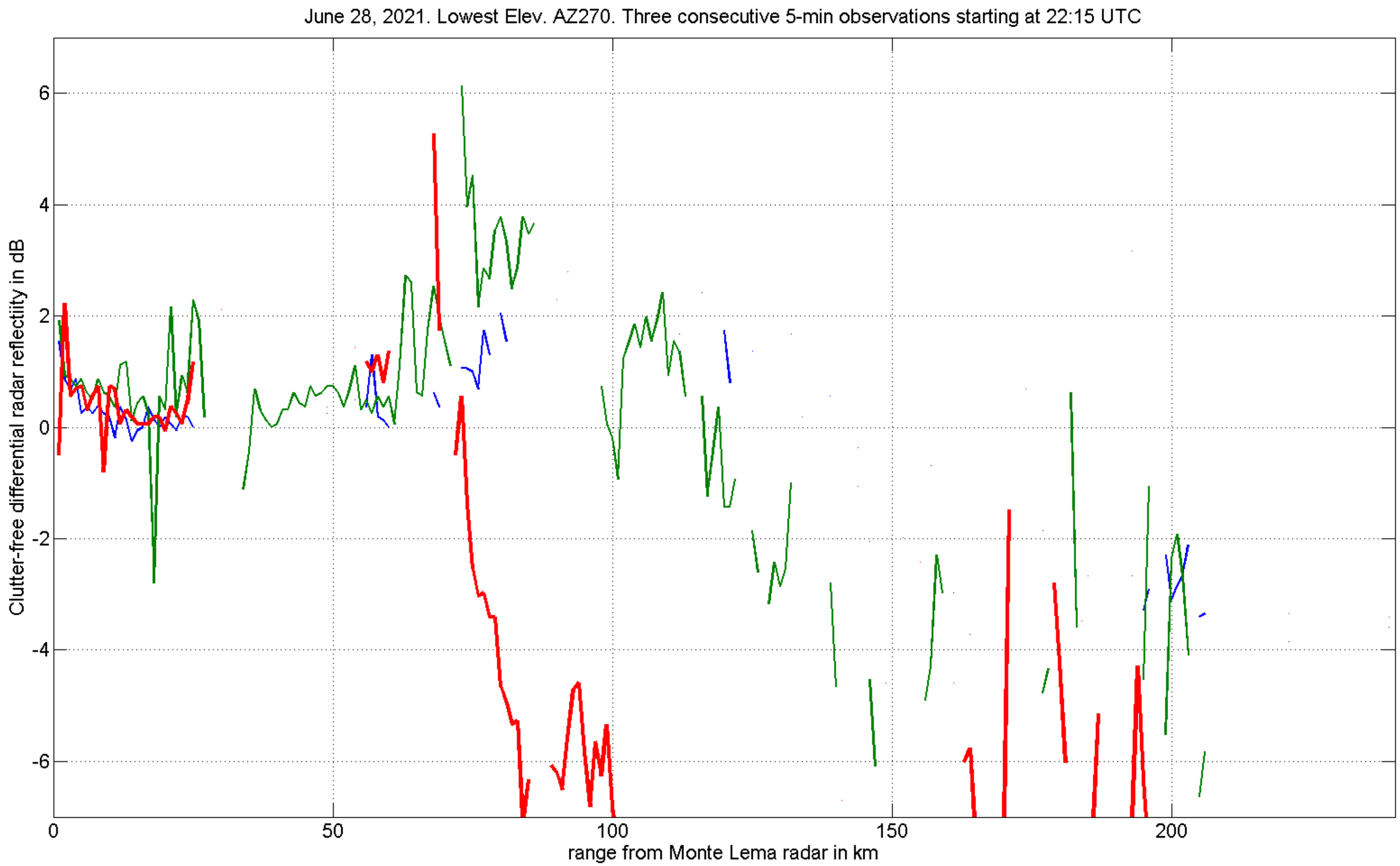
Summary, conclusions and open points

- Worthwhile to identify "BS": → near-range, large RCS, perpendicularly hit by the main lobe beam axis, which is at (almost) MAX Gain
- The unique backscattered signals by Bright Scatters can be used to monitor and quality-check the low sensitivity channel of operational dual-polarization weather radars
- The BS (and the MBS in case of Lema) looks promising also as far as meteorological applications are concerned: e.g, PIA retrieval with high angular and temporal resolution
- Why do the BS polarimetric signatures depend on the CU? --> the PHASE of the low-sensitivity channel LNAs??


THANK YOU

Lema A-scope: Z_{dr}





At 22:21 H PIA is 32.5 dB

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