Nonlinear Receivers and Impact on ZDR

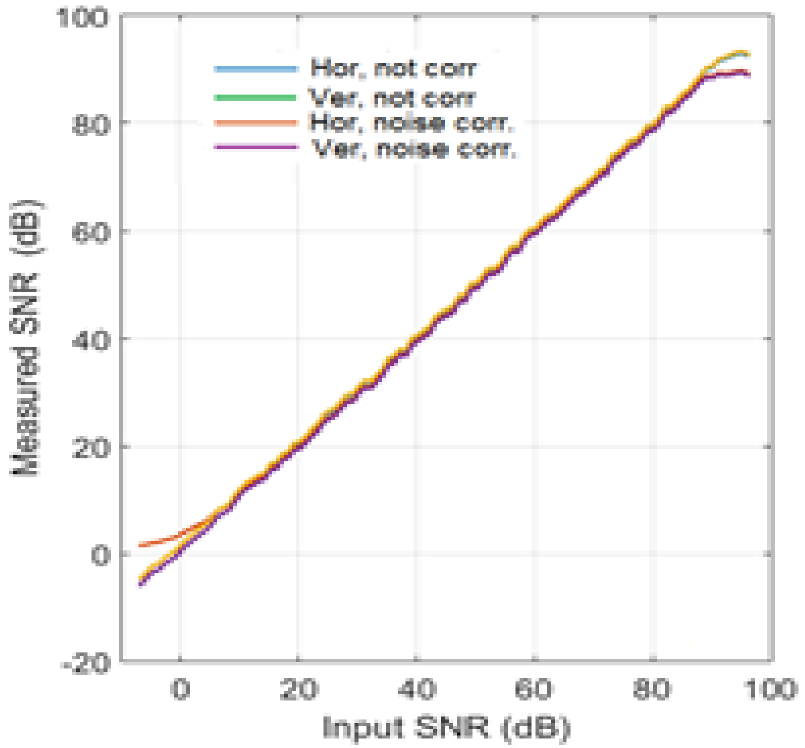
Tech Transfer SLA: FY22 Task 7

Valery Melnikov

Technical Advisory Committee , 25 March 2022

Contents

Part 1. Linearity of radar receivers



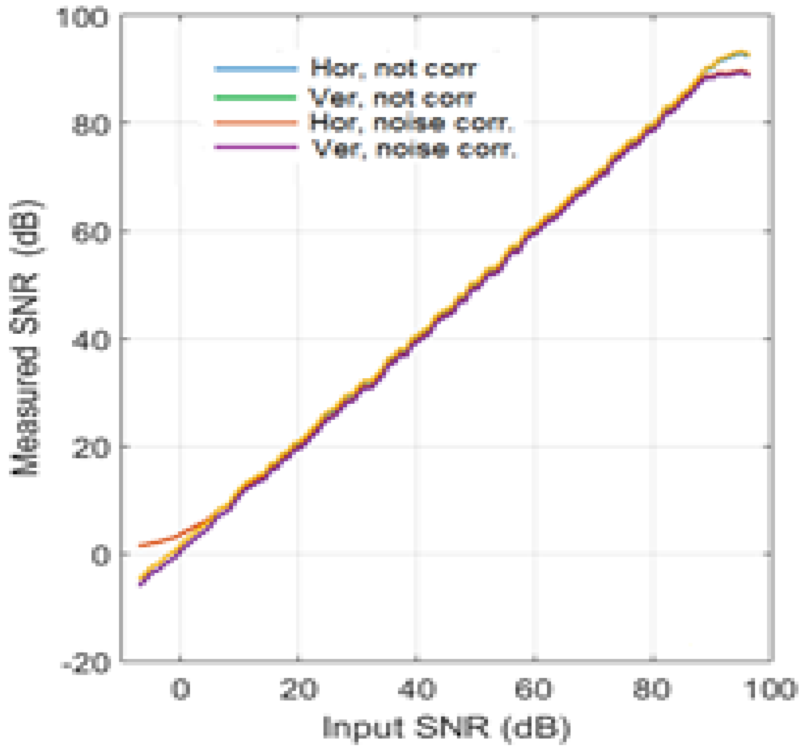
Signal-to-noise ratio (SNR) is a measure of the power scattered by a weather object.

Dynamic range of radar receivers

The manufacturer of the LNAs guarantees a linearity accuracy of 1 dB which is sufficient for Z measurements.

ZDR is the difference of responses in the Horizontal and Vertical channels.

Linear radar receivers



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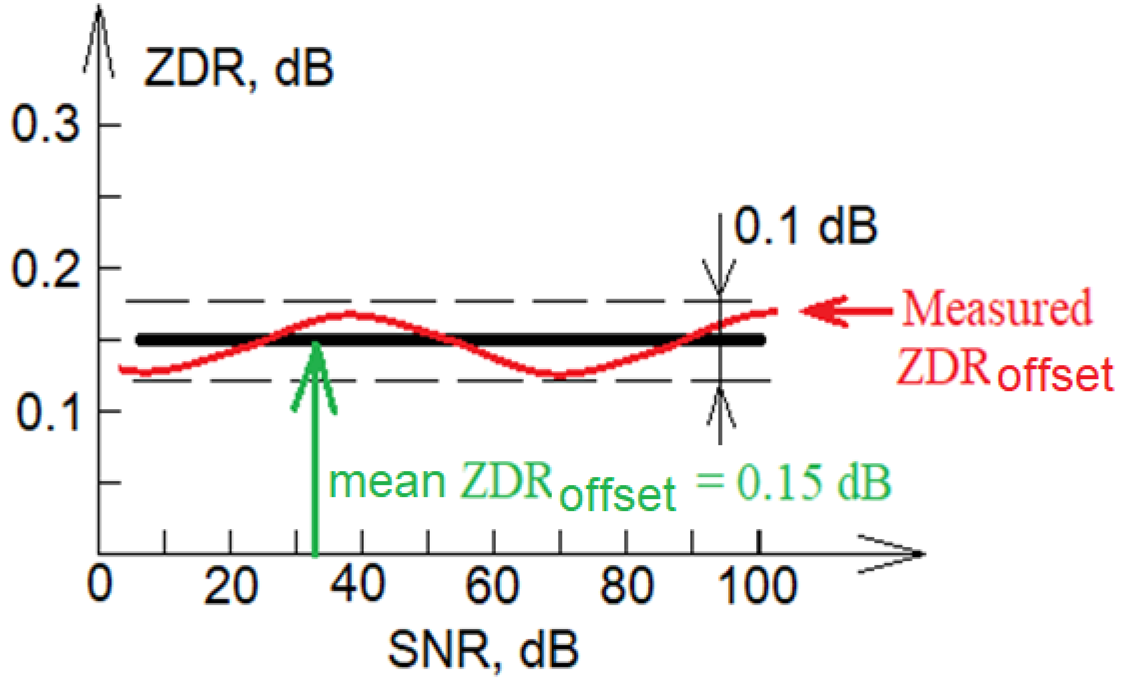
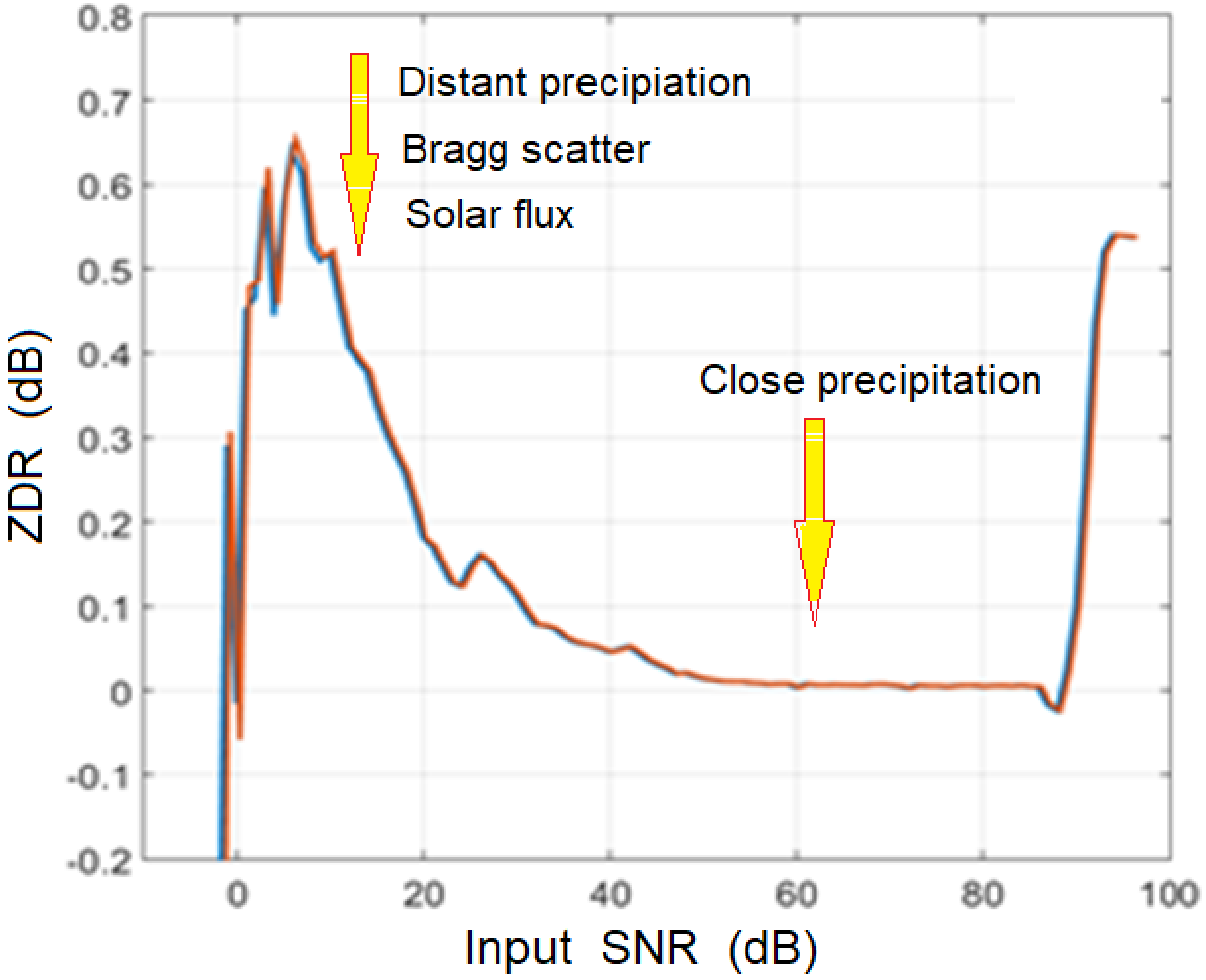
ZDR is the difference of responses in the Horizontal and Vertical channels.

Linear ZDR response



To measure ZDR with an accuracy of 0.2 dB, a radar receiver should be linear to 0.1 dB

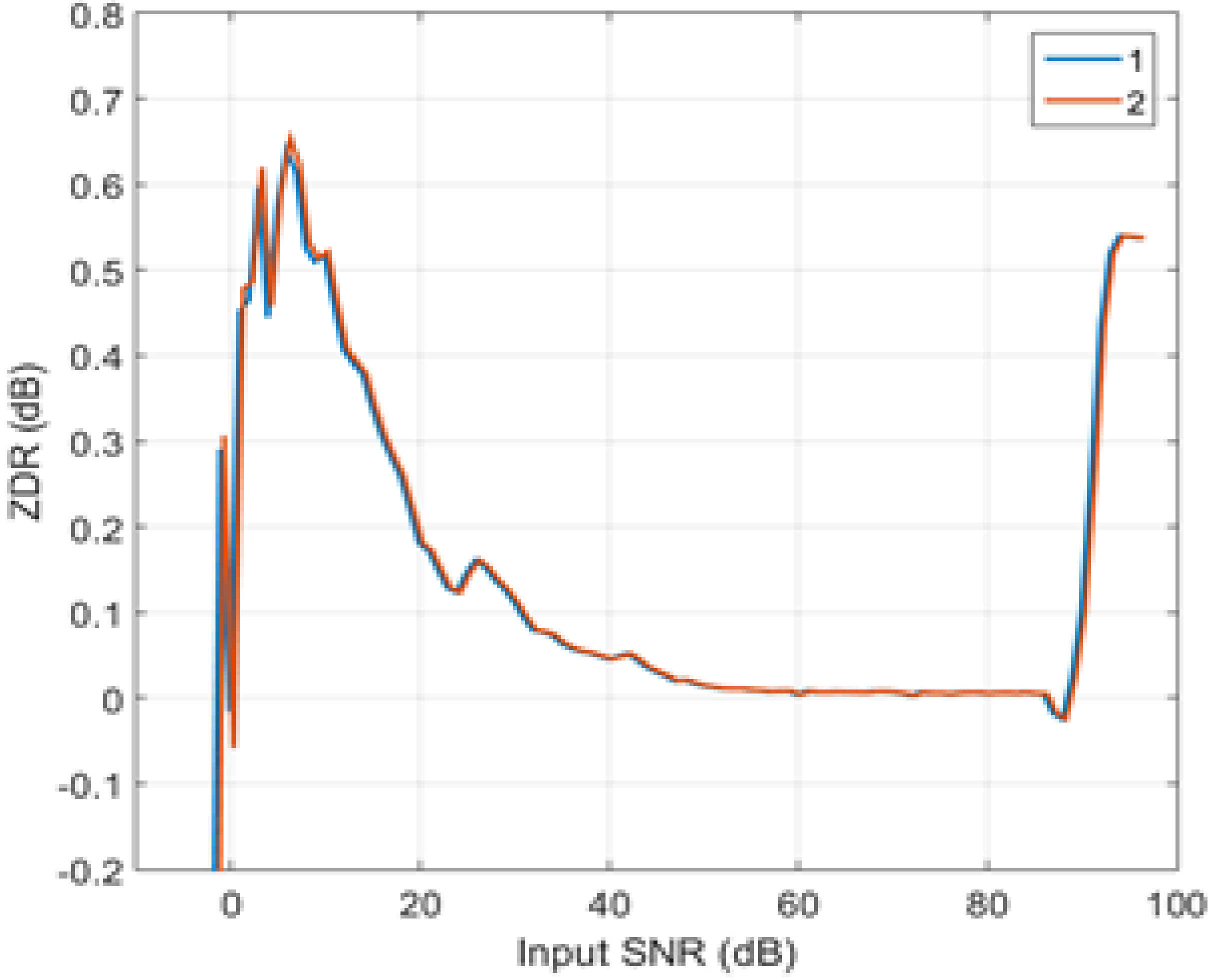
KOUN's receiver ZDR response



KOUN's receiver is not linear

ZDR measurements with a nonlinear receiver can result in different values from similar weather objects.

Part 2. Impact of nonlinear receiver on ZDR from clouds and precipitation



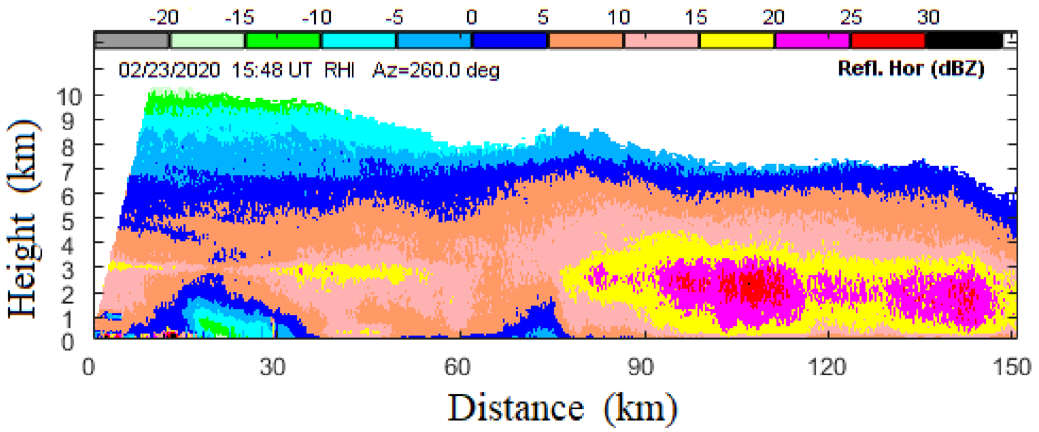
KOUN's receiver is not linear

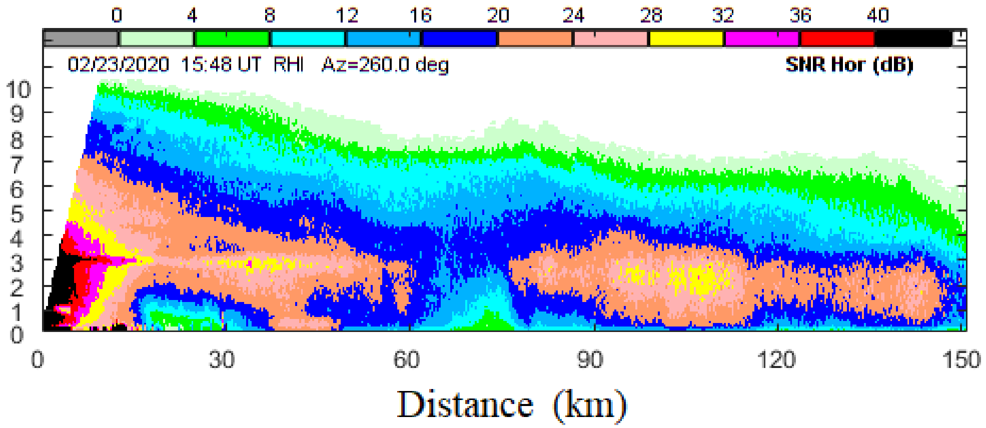
Analyze the SNR interval 2 – 20 dB

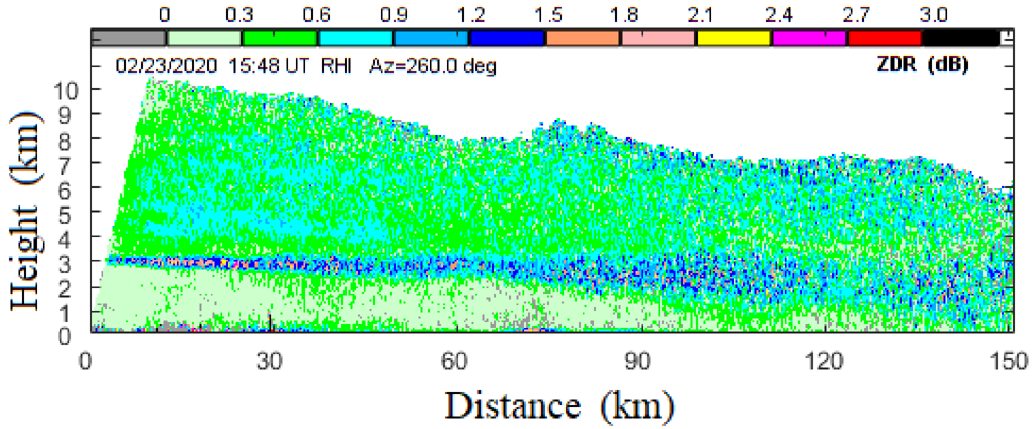
What should we expect to observe from weather?

An increase in ZDR with decreasing SNR.

How to collect data for the analysis?







Criteria for the data selection:

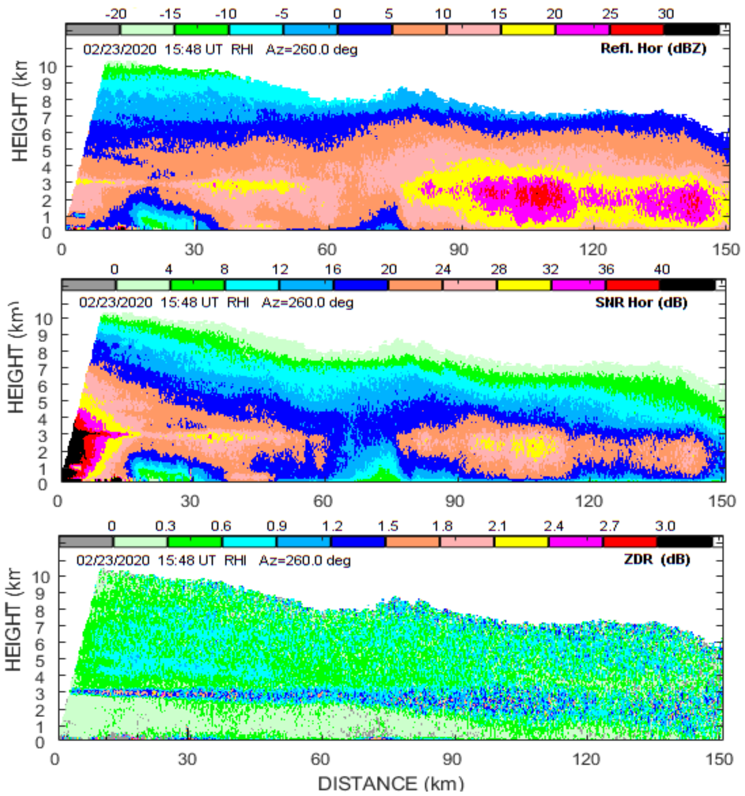
-Analyze stratiform precipitation/clouds

-Collect data above melting layers

-Stratiform clouds are good objects. Antenna elevation < 30 deg. No corrections for differential attenuation.

-Analyze data from numerous cases

Cases…



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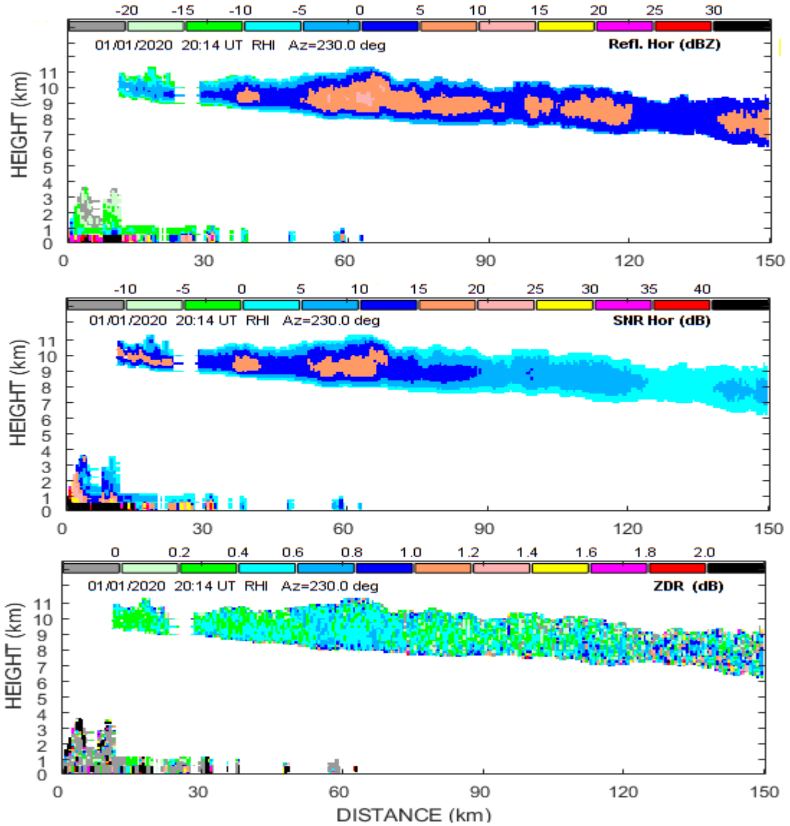
Refl. Hor (dBZ)
SNR Hor (dB)
ZDR (dB)
HEIGHT (km)
DISTANCE (km)



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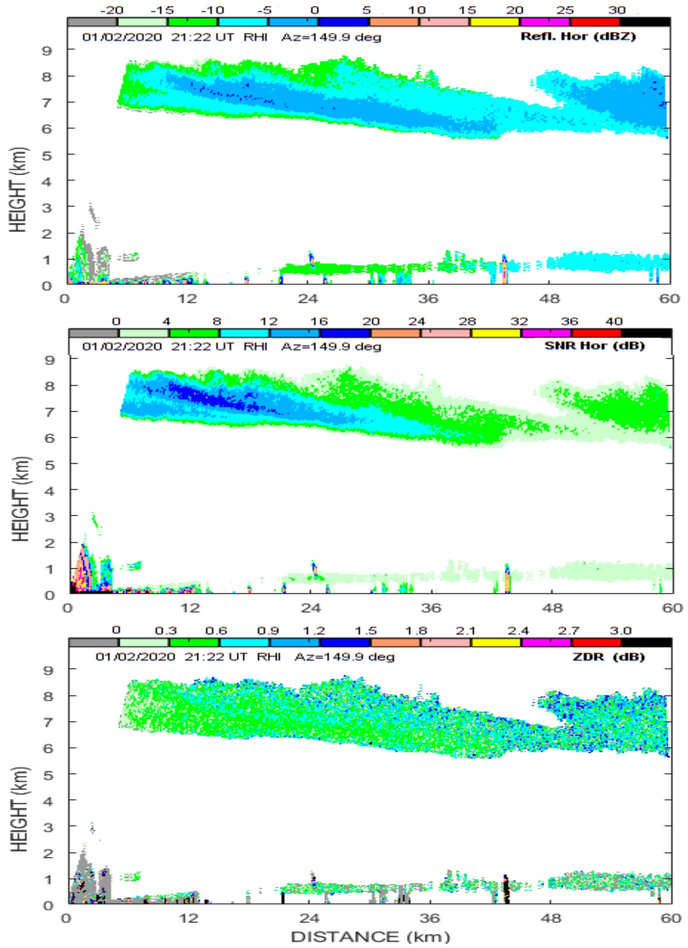
SNR Hor (dB)
ZDR (dB)
HEIGHT (km)
DISTANCE (km)



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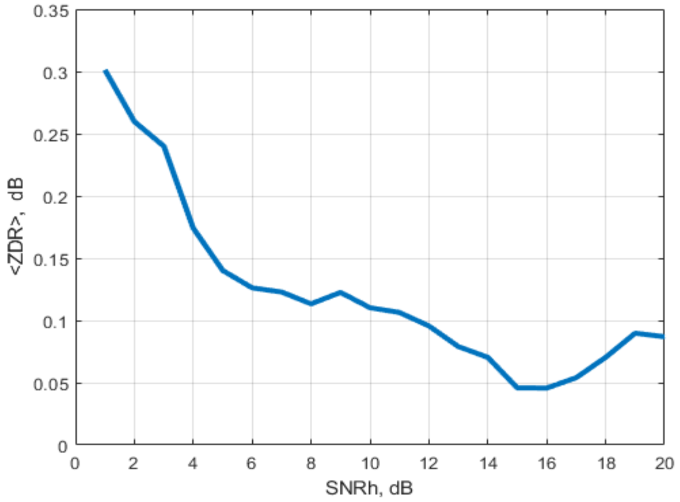
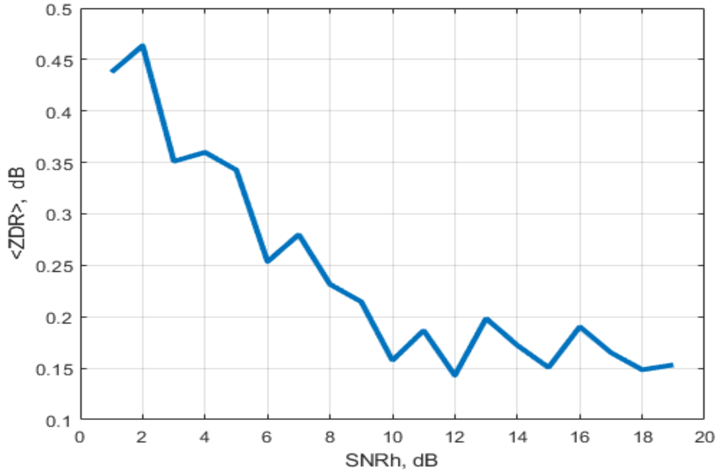
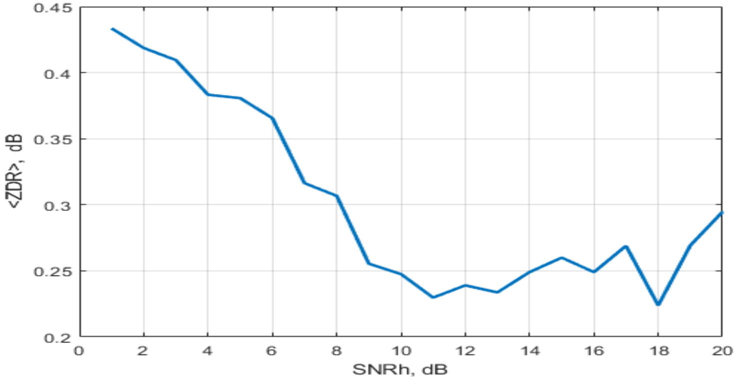
SNR Hor (dB)
ZDR (dB)
HEIGHT (km)
DISTANCE (km)



<ZDR>, dB
SNRh, dB

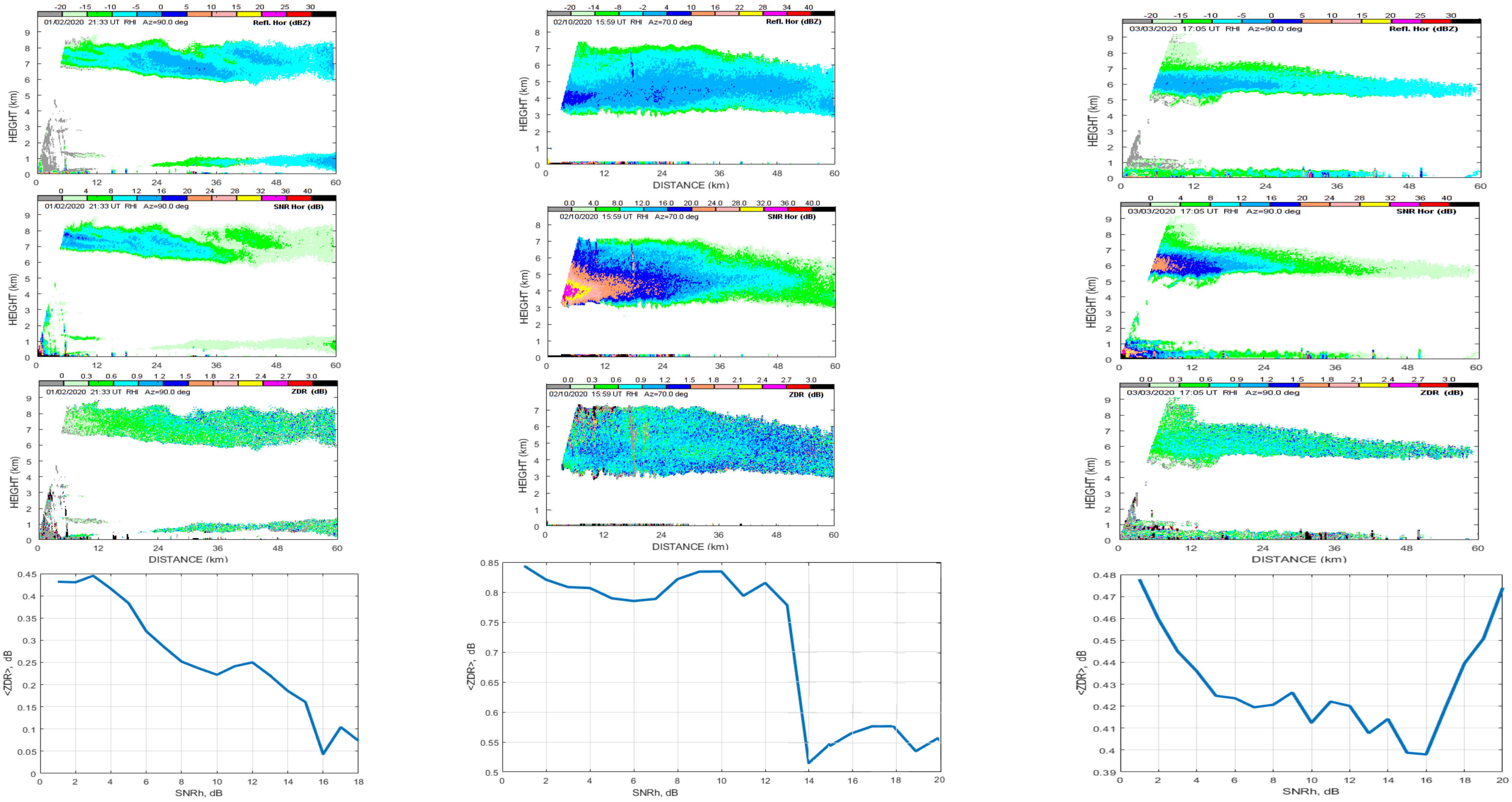


<ZDR>, dB
SNRh, dB



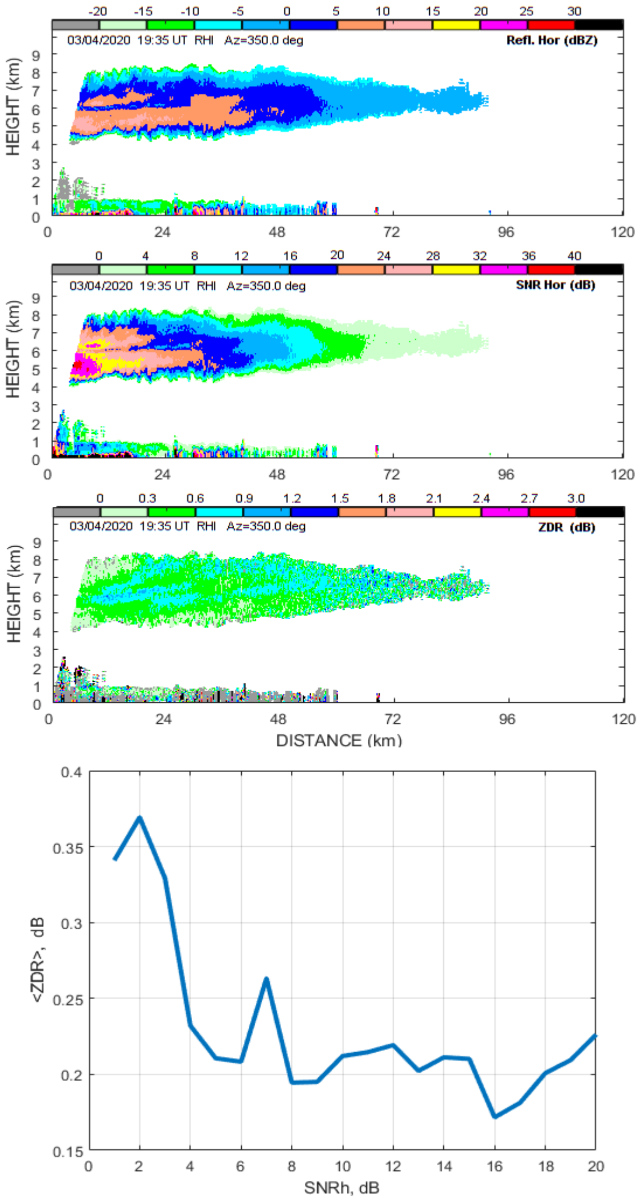
<ZDR>, dB
SNRh, dB

Cases …



01/02/2020 21:33 UT RHI Az=90.0 deg
Refl. Hor (dBZ)
SNR Hor (dB)
ZDR (dB)
02/10/2020 15:59 UT RHI Az=70.0 deg
Refl. Hor (dBZ)
SNR Hor (dB)
ZDR (dB)
03/03/2020 17:05 UT RHI Az=90.0 deg
Refl. Hor (dBZ)
SNR Hor (dB)
ZDR (dB)
HEIGHT (km)
DISTANCE (km)
<ZDR>, dB
SNRh, dB

Cases…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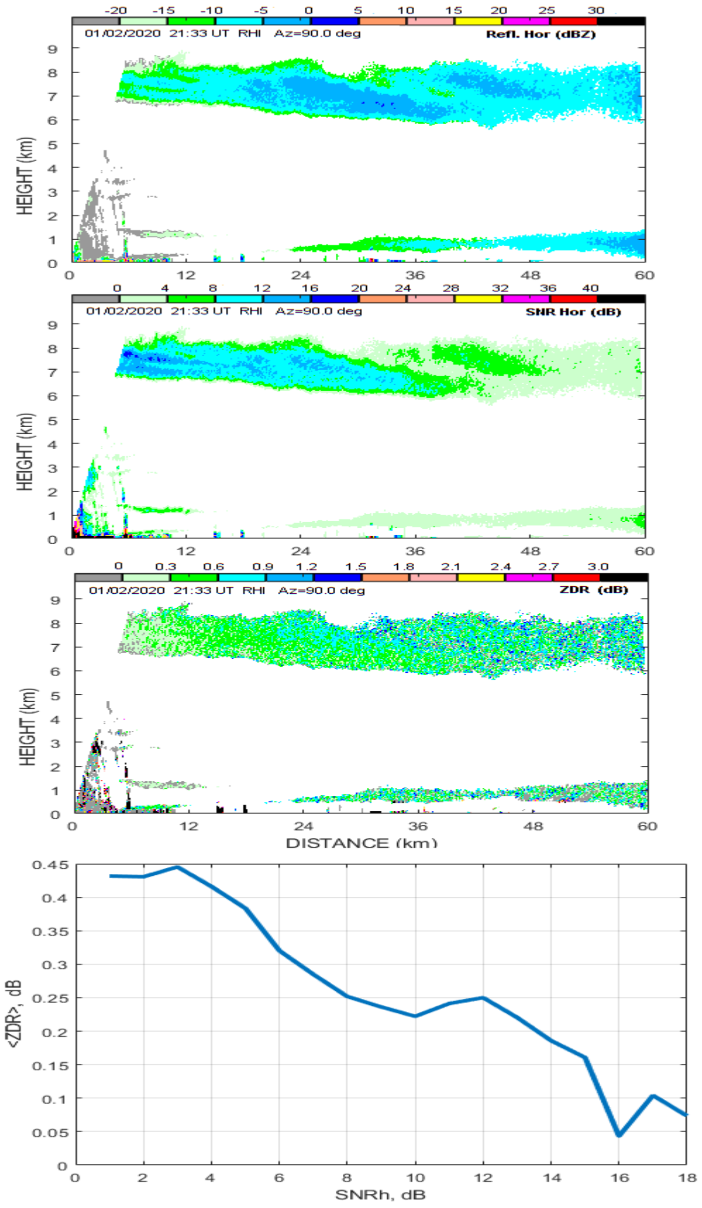
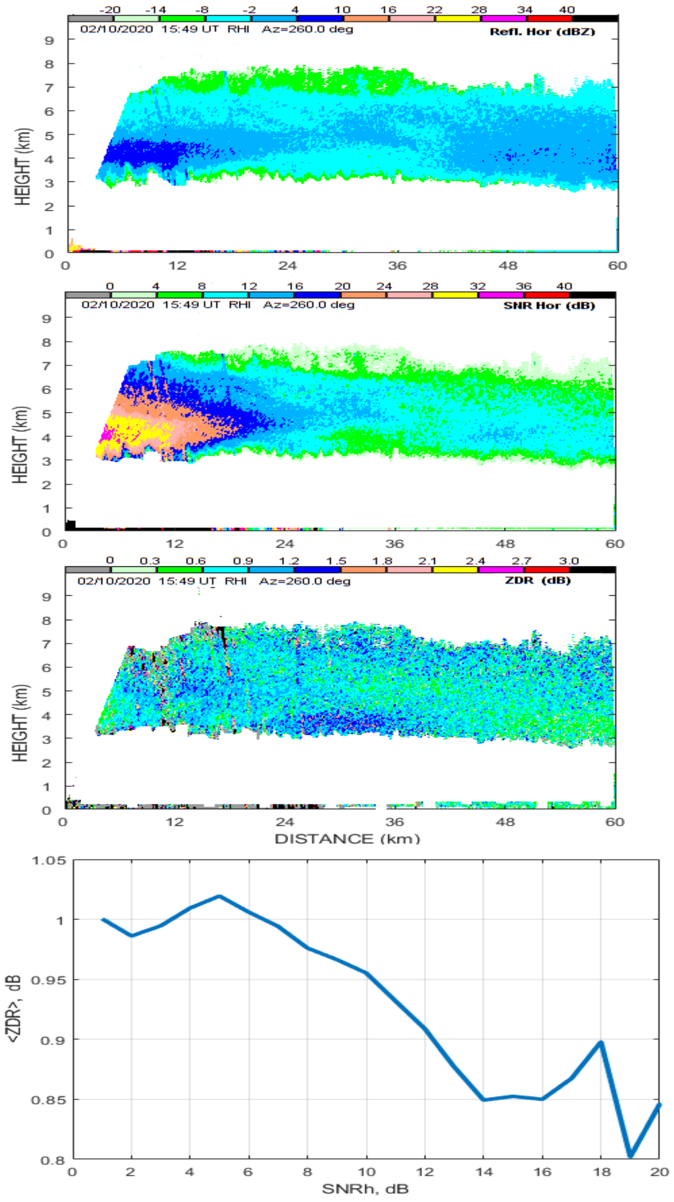
SNR Hor (dB)
ZDR (dB)
HEIGHT (km)
DISTANCE (km)
<ZDR>, dB
SNRh, dB


01/02/2020 21:33 UT RHI Az=90.0 deg
Refl. Hor (dBZ)
SNR Hor (dB)
ZDR (dB)
HEIGHT (km)
DISTANCE (km)
<ZDR>, dB
SNRh, dB


02/10/2020 15:49 UT RHI Az=260.0 deg
Refl. Hor (dBZ)
SNR Hor (dB)
ZDR (dB)
HEIGHT (km)
DISTANCE (km)
<ZDR>, dB
SNRh, dB

Conclusions on part 1

- Nonlinear ZDR receiver responses can affect ZDR calibration and consequently ZDR values from precipitation, Bragg scatter, and solar flux.

- Analyzed weather data exhibit an increase in the ZDR values with decreasing SNR. Such a dependence is expected from the measured KOUN's receiver response.

- It is hard to compare this increase with the KOUN's nonlinear receiver response quantitatively because the weather data are not completely uniform and variations in ZDR values from weather can contribute to the observed dependence.

Part 3. Temperature dependence of the system ZDR offset

The RocStar radar data have been provided by Don Rinderknecht (ROC)

System ZDR offset is obtained by WSR-88Ds from measured radar performance parameters at the end of each VCP.

Obtained ZDR offset is used to calculate ZDR values during the next VCP.

It has been noticed that the ZDR offsets depend on ambient temperature:
- How strong is this dependence?
- What system components contribute to this dependence?

The systems are supposed to compensate for this dependence:
-How perfect is this compensation? Do measured ZDR values from weather depend on temperature?

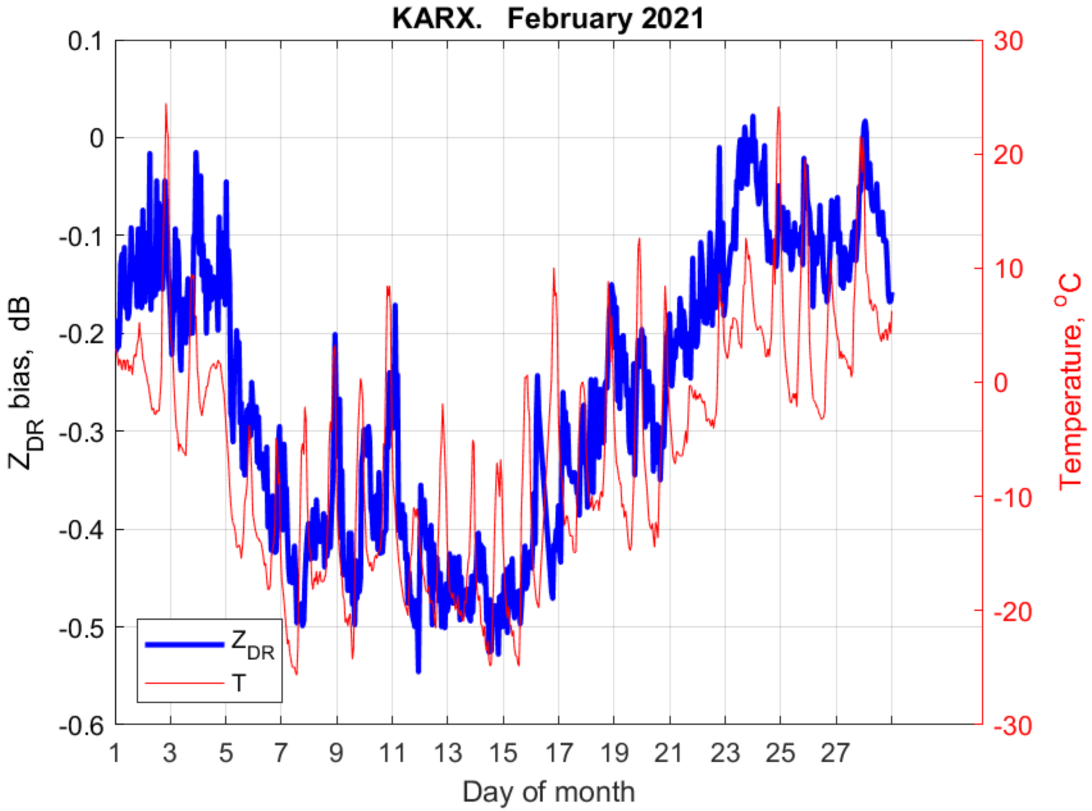
Temperature dependence of the system ZDR offset

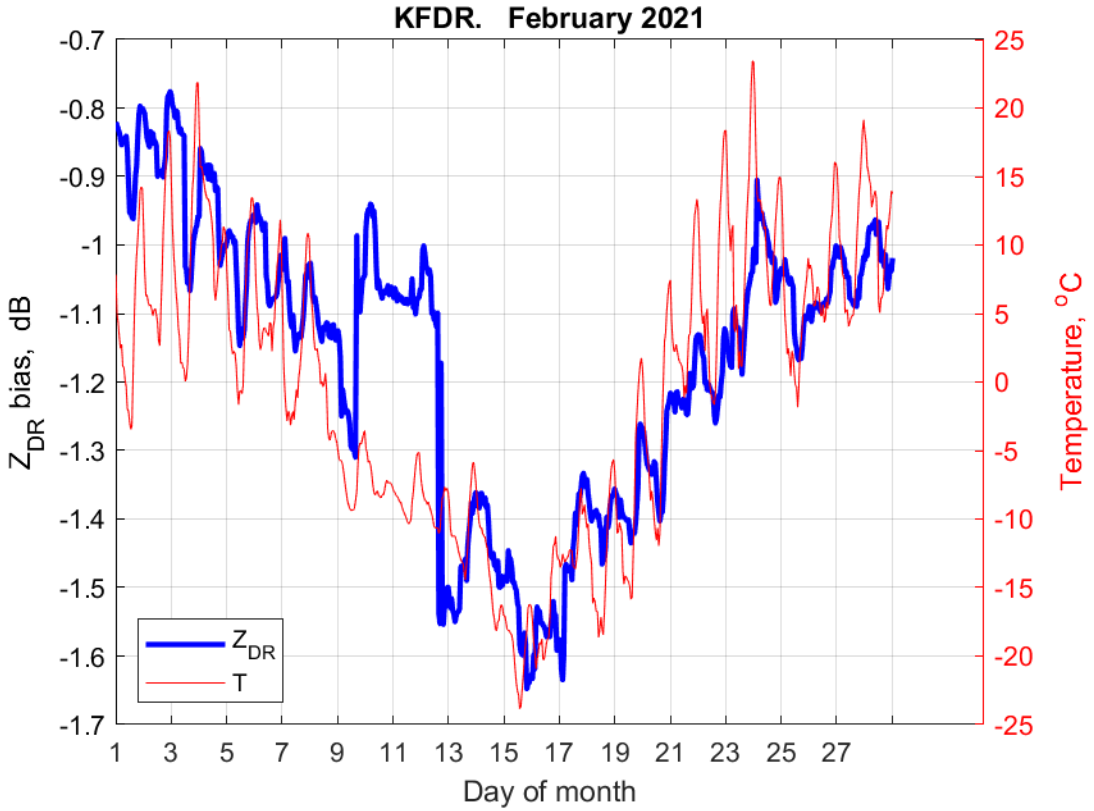
Four types of temperature dependencies are seen in the data from 144 systems (CONUS locations)

- No dependence (ZDR offset does not exhibit a temperature dependence. 21% of the systems)
- Strong correlation (ZDR offset decreases with temperature drops. 38%)
- Anti-correlation (ZDR offset increases with temperature drops, 3%)
- Mixed correlations (ZDR offset can sometimes decrease and sometimes increase with temperature drops, 31%).

9 sites: The temperature radome sensor was not working in February 2021.

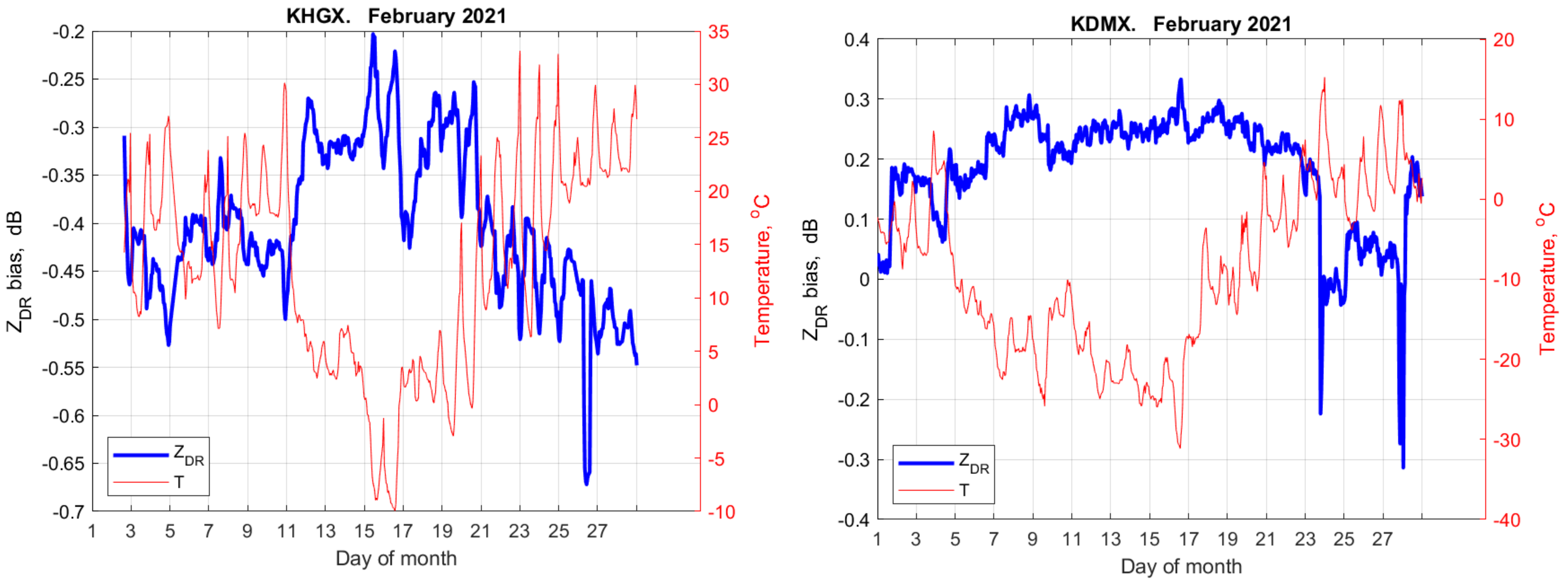
Temperature dependence of the system ZDR offset: Correlation





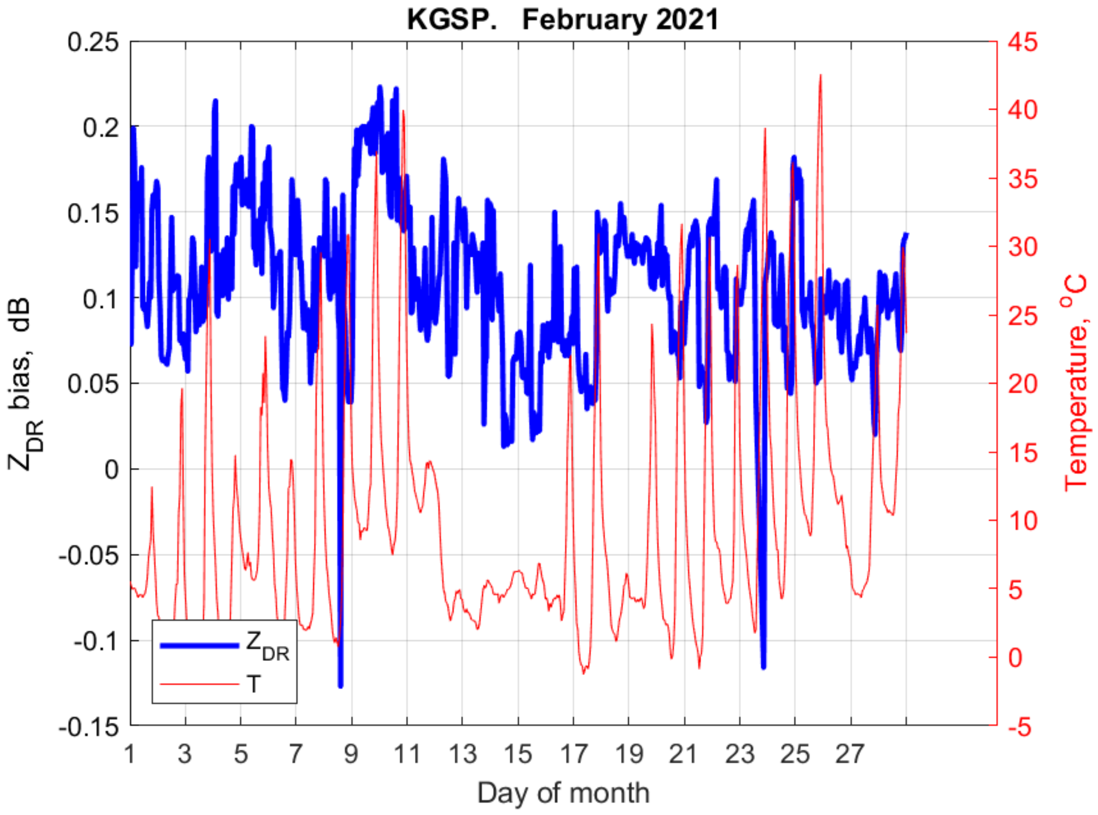
Strong correlation between the radome temperature and system ZDR. This dependence is exhibited by 55 sites, 38%

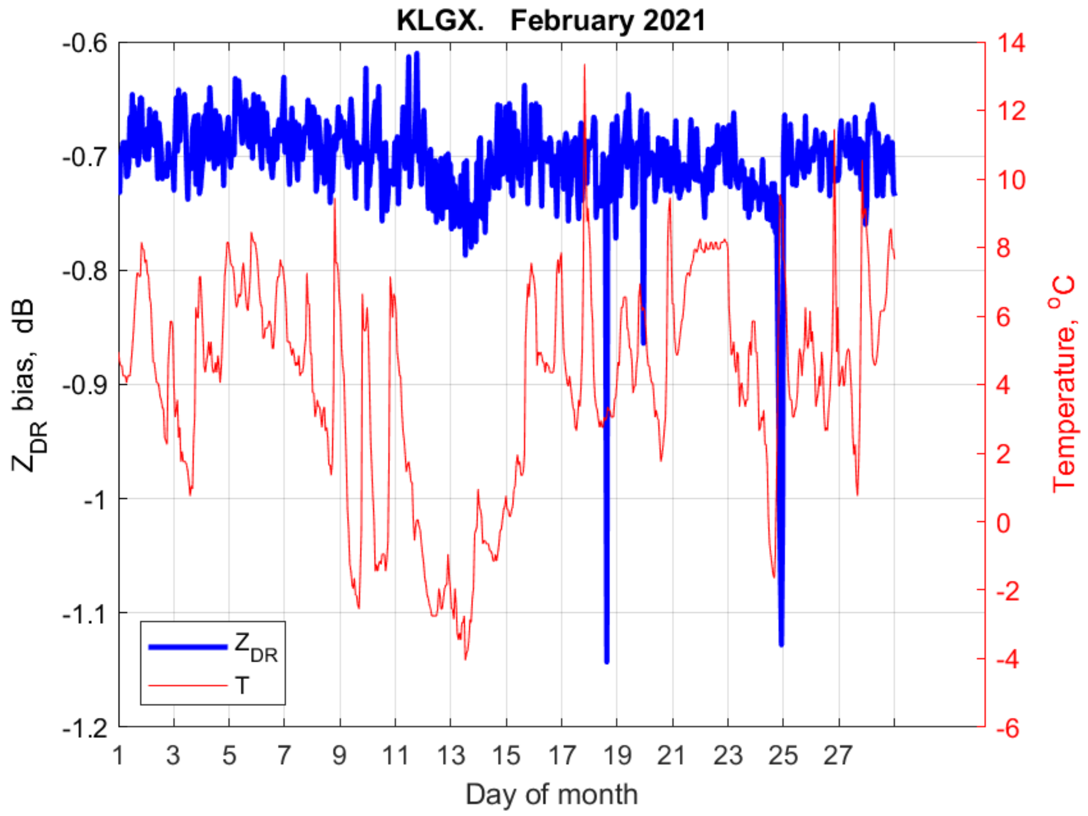
Temperature dependence of the ZDR offset: anti-correlation



Anti-correlation between the radome temperature and system ZDR, 5 sites, 3%

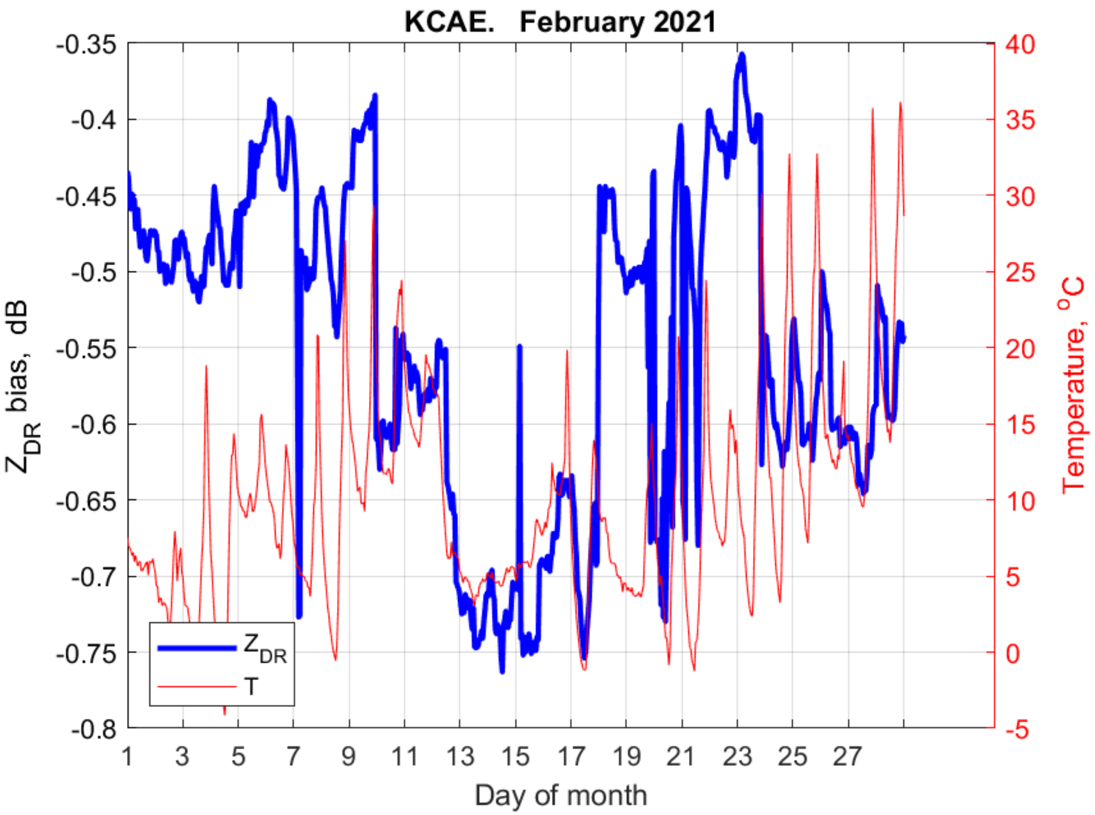
Temperature dependence of the ZDR offset: no impact

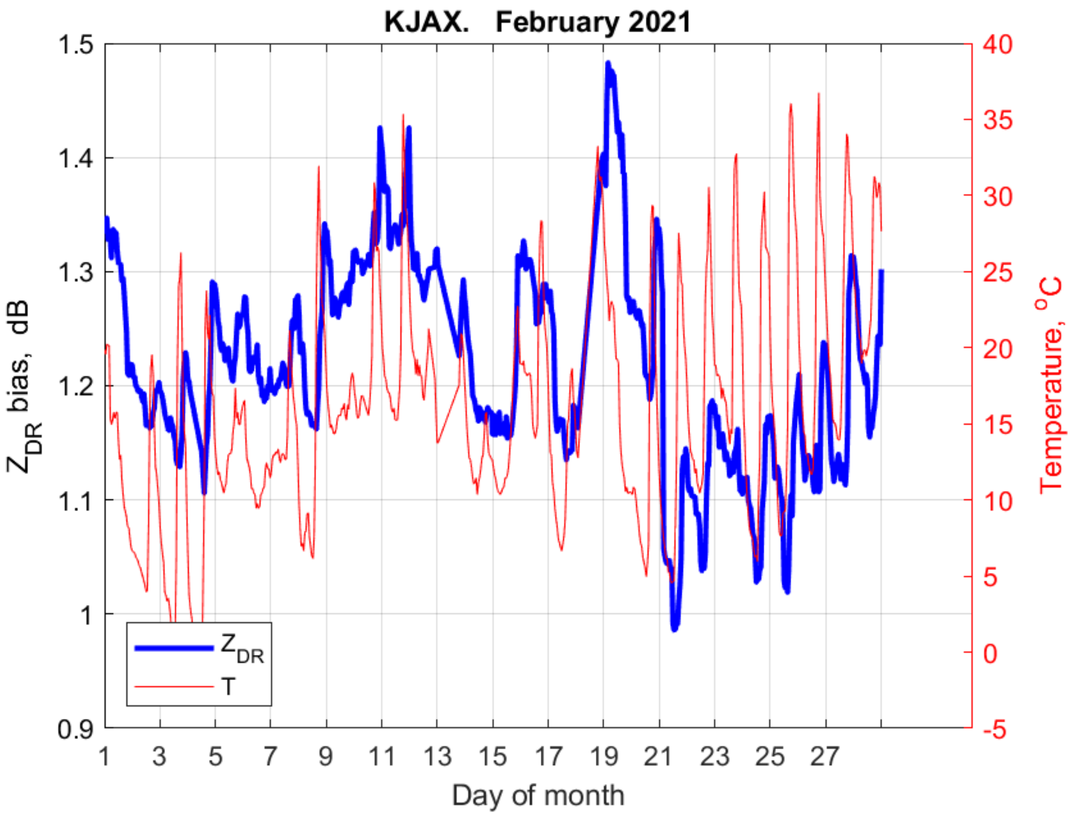




No dependency of the ZDR offset on temperature, 30 sites, 21%. Large temperature variations are not seen at some sites (i.e.,KLGX (on right)).

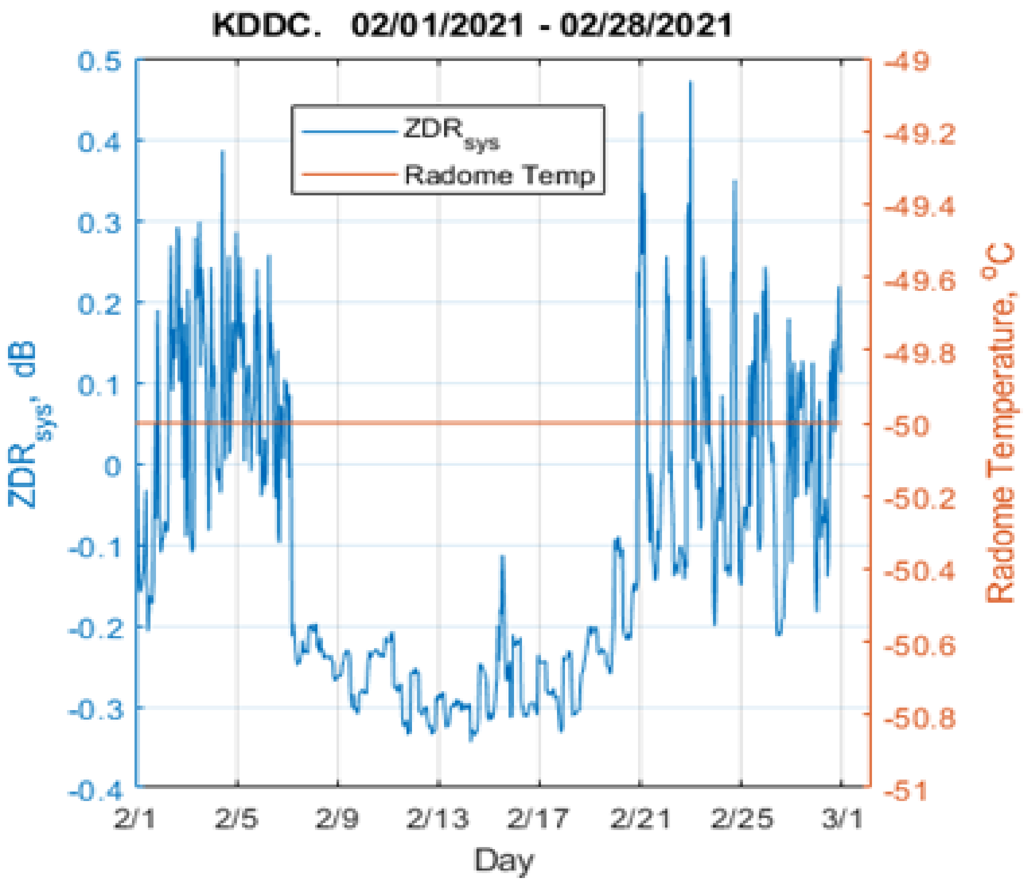
Temperature dependence of the ZDR offset: undetermined

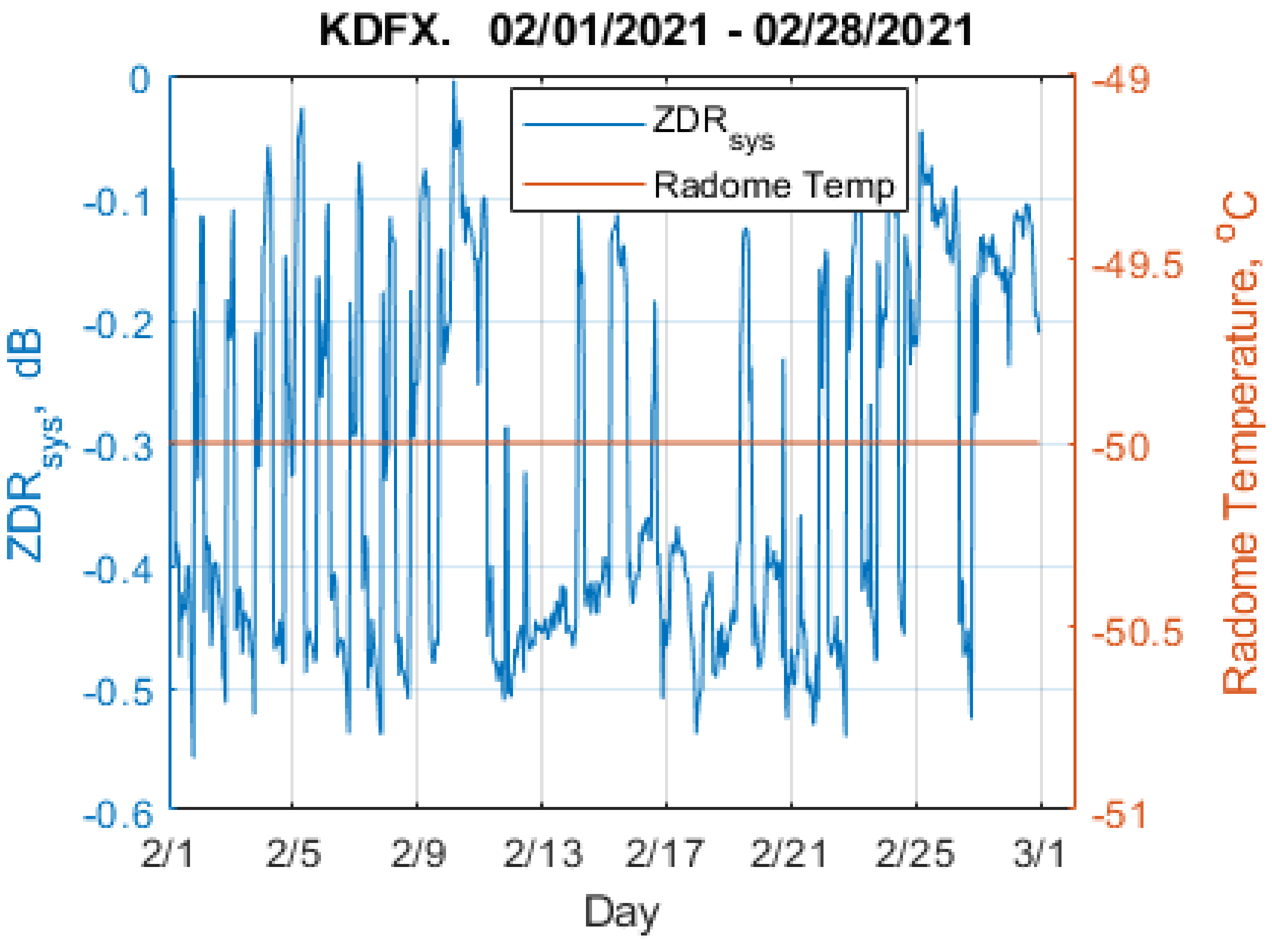




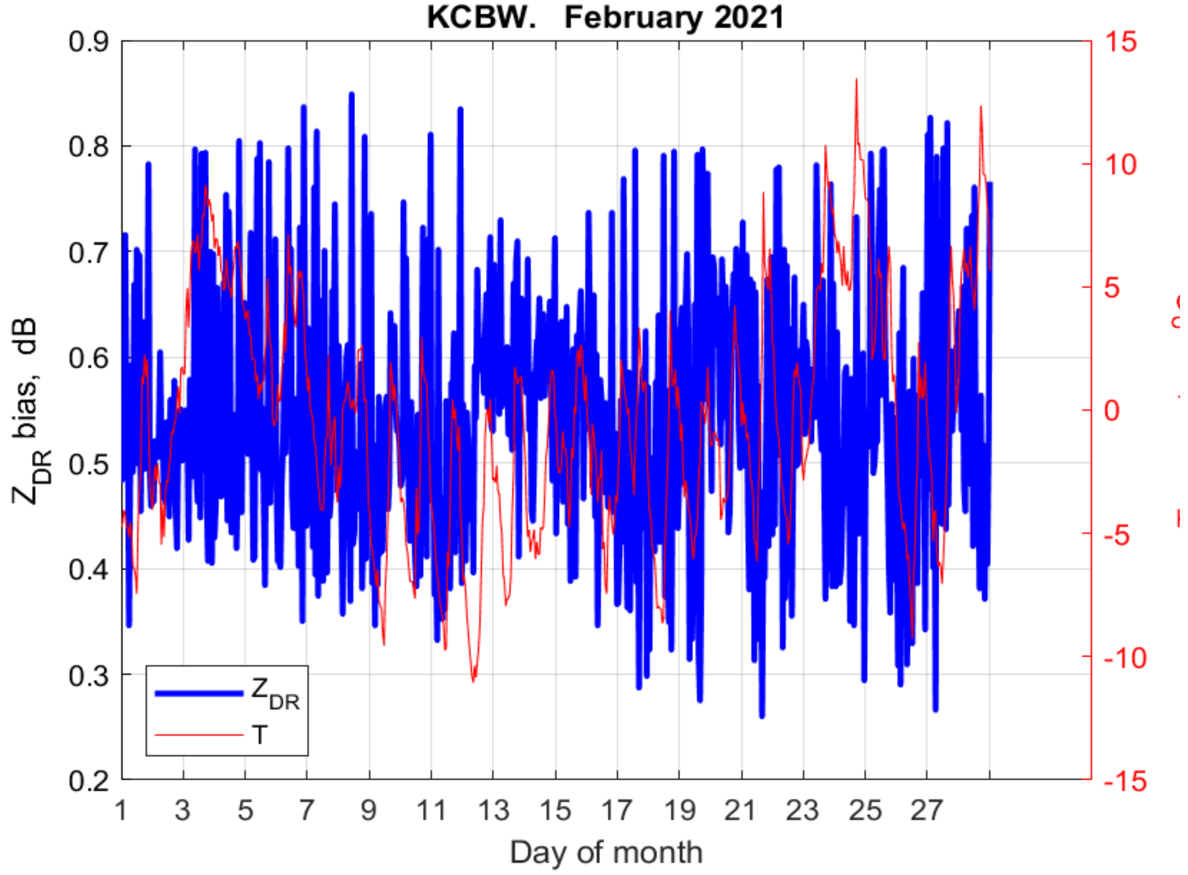
45 sites, 17%.

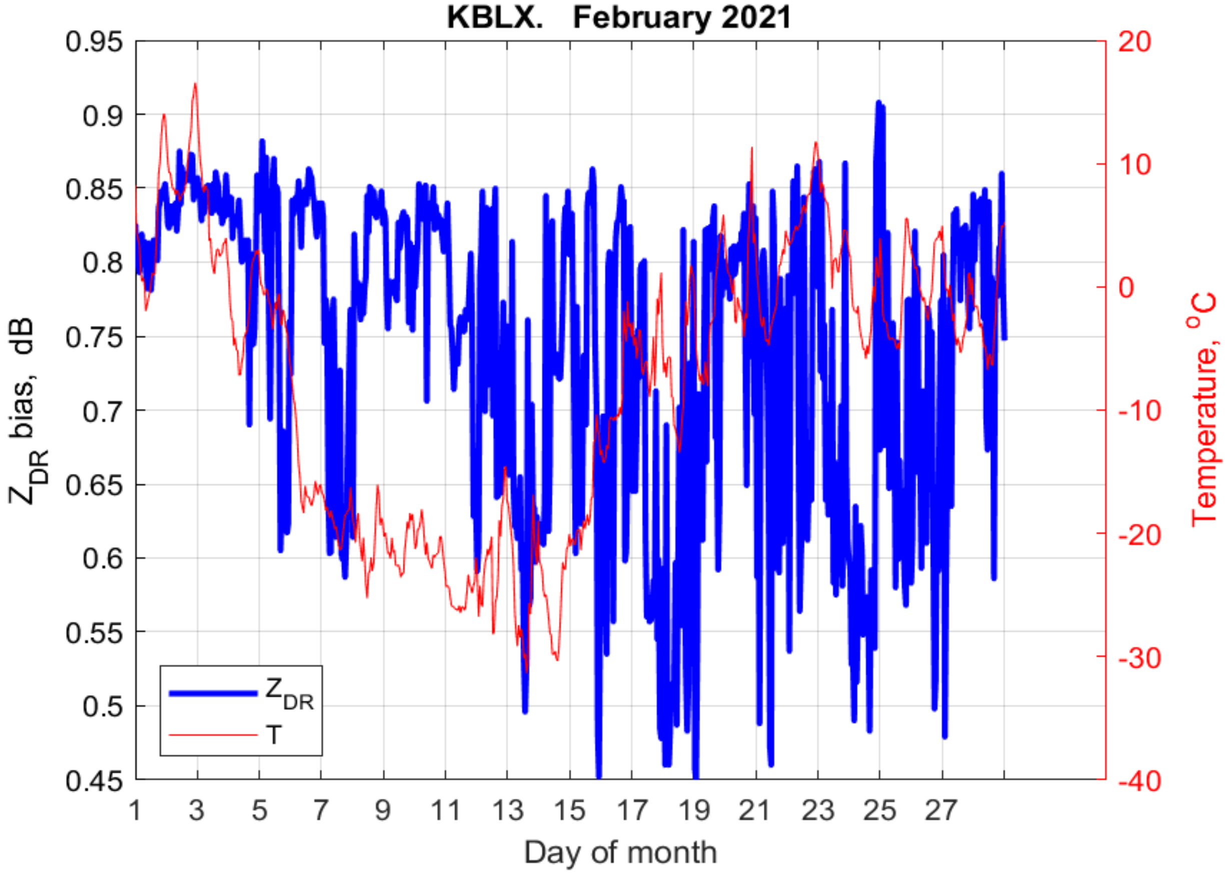
Not working radome temperature sensors: 9 sites, 6%.





Strong time variations of the ZDR offsets





The amplitudes of variations may exceed 0.5 dB, which lead to visual changes in ZDR fields from VCP to VCP

Conclusions

- ZDR measured with a nonlinear receiver depends on SNR from weather objects.
- An SNR interval 2-30 dB typically exhibits nonlinearity. This is the interval where signals from distant precipitation, Bragg scatter, and solar flux (used for ZDR calibration) are measured.
- Nonlinear receivers may impact ZDR calibration using light rain, snow, and Bragg scatter.
- The system ZDR offset depends on temperature. This dependence is caused by the receivers. It is not clear how well the systems tolerate this dependence (ongoing work, 2022 Tech Transfer SLA Task 7).

Future work

- The manufacturer of the radar receivers (Vaisala/Sigmet) admits its nonlinearity in discussions with ROC engineers (Feb – March 2022). Further discussions with Vaisala on mitigating the impacts of nonlinear ZDR responses are desirable.

- To correct for the nonlinear receiver responses, an RDA software procedure can/should be designed.

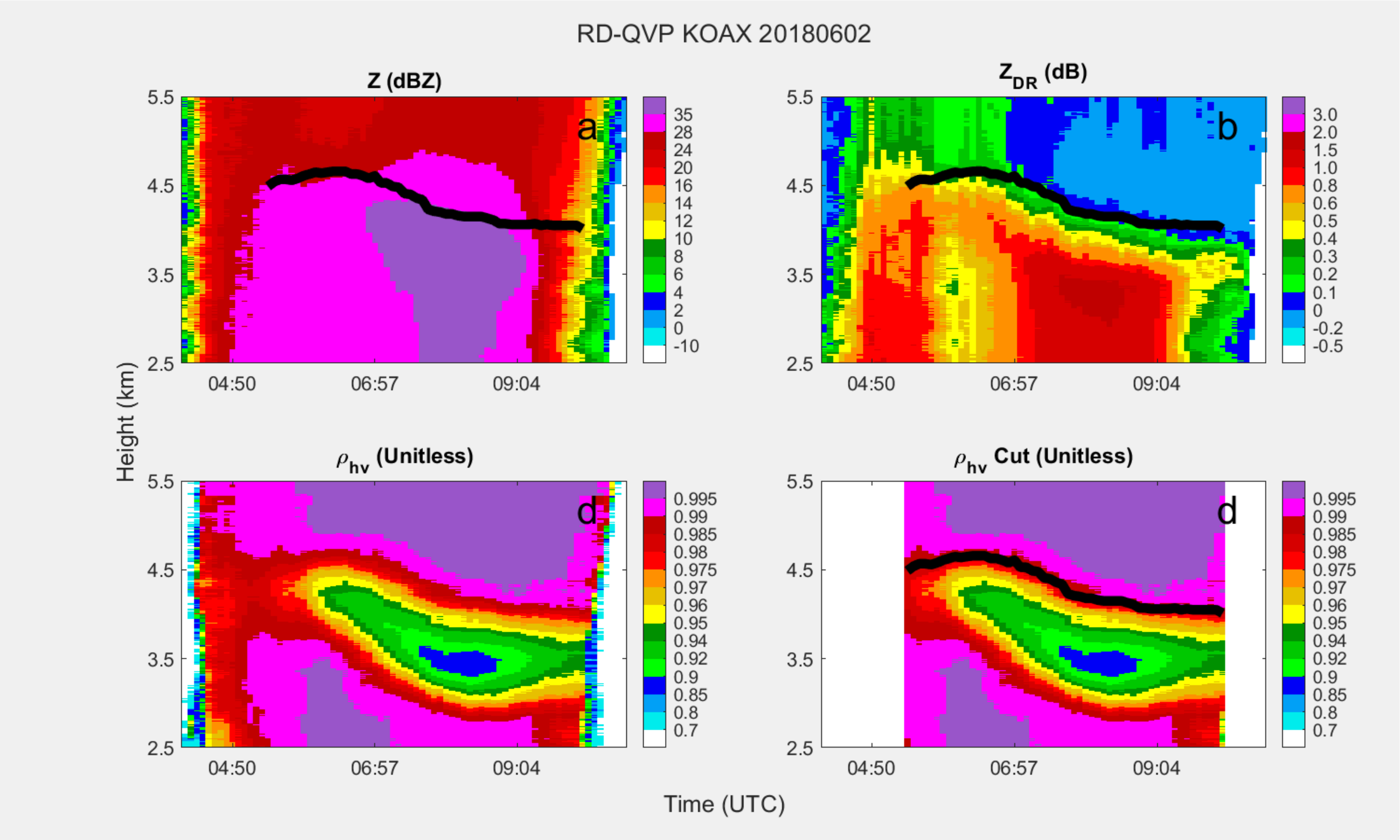
- Temperature dependence of the system ZDR offset should be analyzed (ongoing, 2022 Tech Transfer SLA Task 7).

- The source of fast temporal variations in the ZDR offset needs to be found. The variations should be reduced/eliminated.

Calibration of Differential Reflectivity Using Dry Aggregated Snow Above the Melting Layer

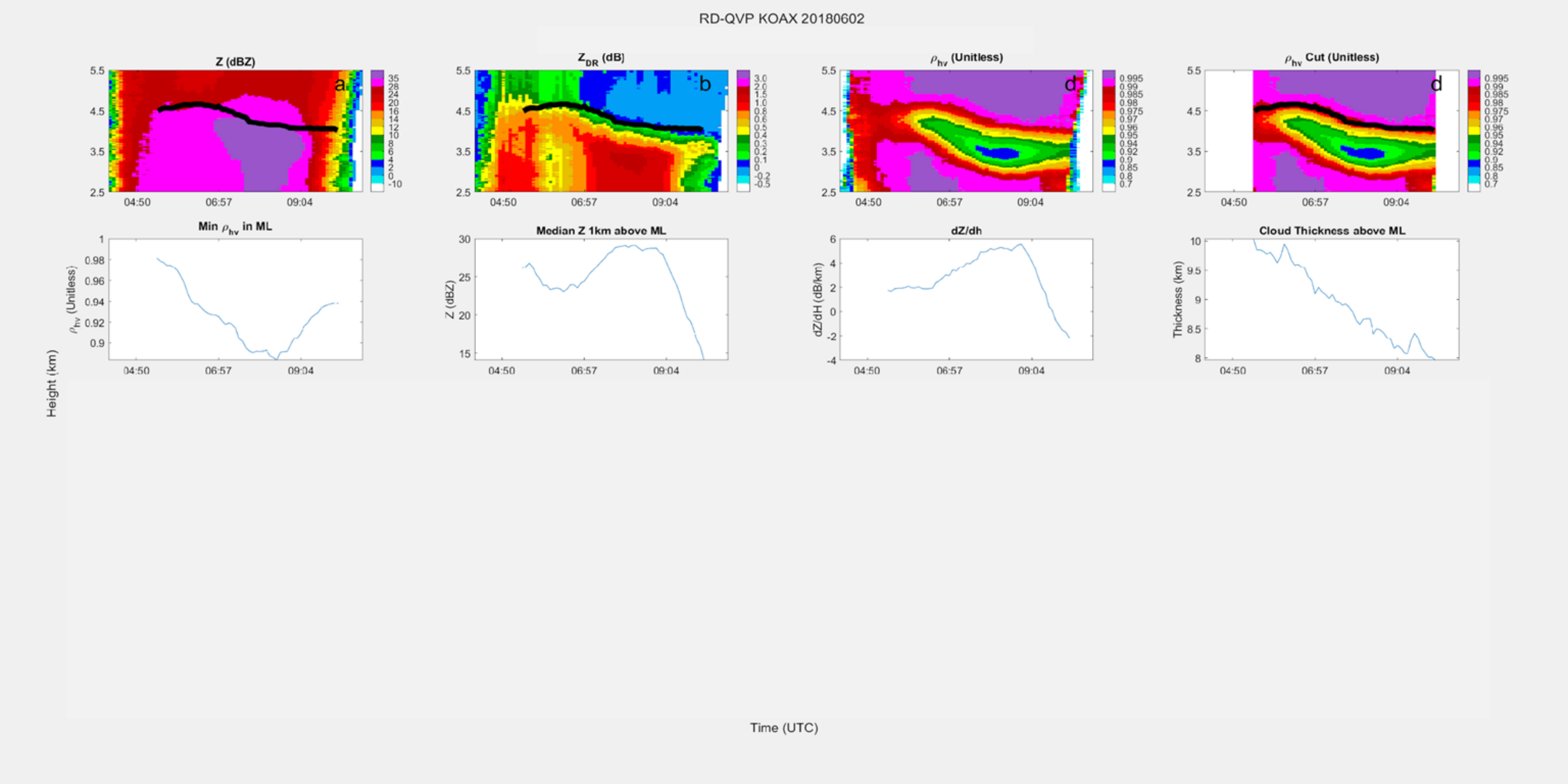
Alexander Ryzhkov, Jiaxi Hu, and John Krause (CIWRO / NSSL)

Step 1: Determine Melting Layer (ML) Top for every QVP



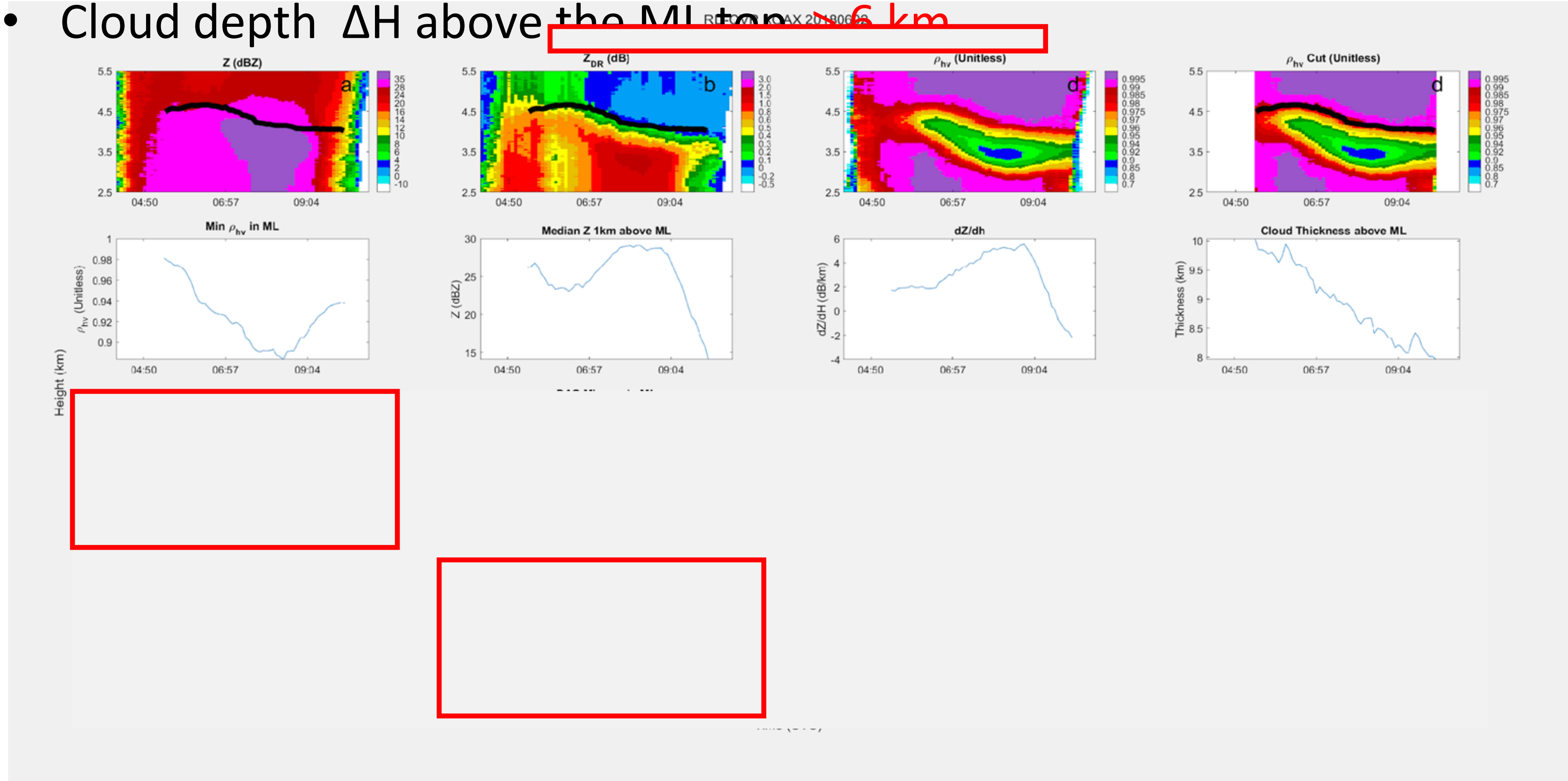
Step 2: Calculate four relevant parameters of each QVP:

- Minimal ρ_{hv} within the ML
- Median value of Z within 1 km above the ML
- Vertical gradient of reflectivity dZ/dh in a 3-km layer above the ML
- Cloud depth ΔH above the ML top



Step 3: Identify QVPs with Dry Aggregated Snow (DAS) above the ML with

- Minimal ρ_{hv} within the ML < 0.95
- Median value of Z within 1 km above the ML > 15 dBZ
- Vertical gradient of reflectivity dZ/dh in a 3-km layer above the ML > 3 dB/km
- Cloud depth ΔH above the ML top > 6 km



Final steps

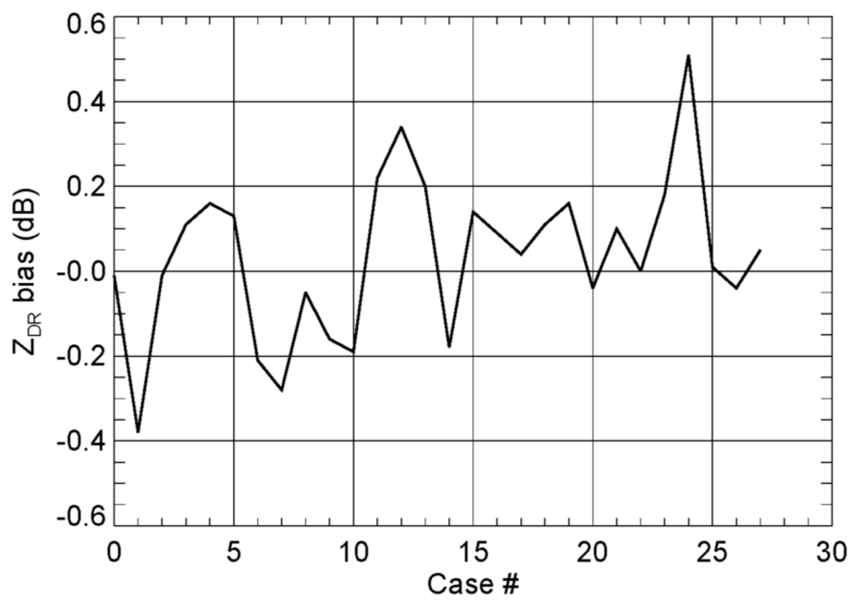
Step 4: Calculate median value of Z_{DR} in a 1-km layer in DAS above the ML for each DAS QVP (DAS Z_{DR})

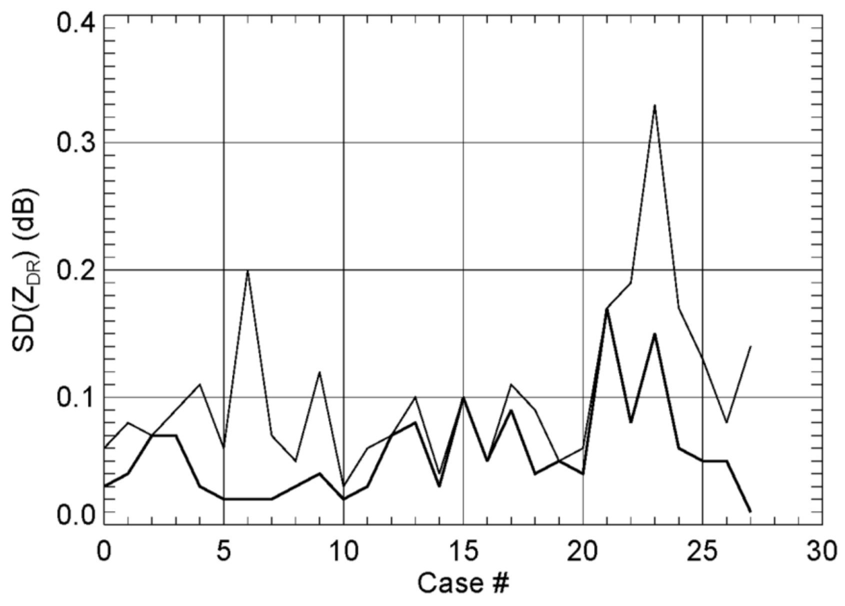
Step 5: Calculate median value of DAS Z_{DR} over the whole QVP duration period <DAS Z_{DR}>

Step 6: Calculate the bias of Z_{DR} as the difference <DAS Z_{DR} > – 0.15 dB

Step 7: Estimate the standard deviation of DAS Z_{DR} (DAS SD(Z_{DR}) as the measure of stability of the estimated Z_{DR} bias

Summary of all storms





For about 20% of cases the Z_{DR} bias exceeds 0.2 dB which is consistent with the statistics of the Z_{DR} bias across the whole WSR-88D fleet

Thick line is for DAS $SD(Z_{DR})$
$SD(Z_{DR})$ = 0.10 dB
DAS $SD(Z_{DR})$ = 0.055 dB

The accuracy of the Z_{DR} bias estimation is 0.05 – 0.06 dB