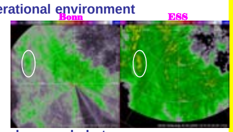
Monitoring polarimetric weather radar calibration

L. Borowska[1] and D. Zrnic[1]

(1) National Severe Storms Laboratory, USA
e-mail: lesya.borowska@noaa.gov, phone: 1405 325 6314

Motivation

- Calibration of either dual polarization or single polarization weather radars is difficult and time expensive in an operational environment
- Calibration of the weather radars is essential for accurate measurement of precipitation amounts



- Monitoring calibration of reflectivity factor Z_H and differential reflectivity Z_{DR} on polarimetric radars can help to avoid the unnecessary recalibrations

Experimental setup, data set and clutter detection

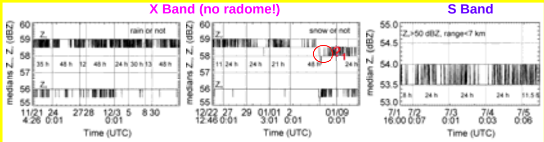
Parameter	X Band	S Band
Wavelength	3.21 cm	10.9 cm
Antenna beamwidth	1.06°	0.91°
Peak transmitter power	200 kW	750 kW
Pulse depth (variable) nominal	100 m	250 m
Pulse repetition time (variable) nominal	1 ms	3 ms

Parameter	X Band	S Band
Elevation angle	0.5°	0.5°
Min Z_H, dBZ	> 50	> 50
Max range, km	< 20	< 7

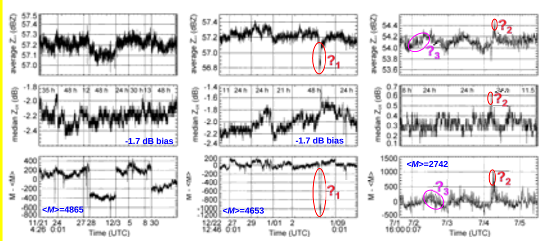
	X Band	S Band
Place	Bonn, Germany	Norman, OK, USA
Days, UTC	11/21/09 – 01/17/10	07/02/11 – 07/05/11
Total number of scans	4930 (410.9 h)	564 (91.5 h)
Type of precipitations	Clear air, rain, snow, rain+snow	Clear air, rain
Max Z_H, dBZ	47.9	50
Max R, mm h^{-1}	47	70

Median/Average Z and Z_{DR}; variations of the GC points

X Band (no radome!) | S Band



- The medians Z_H and Z_V vary within the quantization interval suggesting that monitoring of power calibration within 0.5dB would be viable.



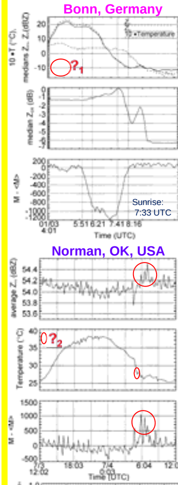
- The average values of Z_H have definite trends not seen in the median due to coarse quantization. Superposed to the slower variations are rapid fluctuations suggestive of noise.
- The median values of Z_{DR} are the stable and consistent average Z_H. The standard deviation of the medians are 0.09 dB for rainy days and 0.11 dB for days with snow at X Band; 0.07 dB for the clear air scans with several rainy scans at S Band. The medians of the median Z_{DR} are -0.5 dB (after bias correction) at X Band and 0.3 dB at S Band.
- In hot summer environment in Oklahoma the average Z_H and median Z_{DR} from the clutter have a diurnal periodicity. Therefore we can not use the average Z_H and the median Z_{DR} for routine automatic calibration monitoring at the end of volume scans. But if measurements are made at the same time (i.e., under similar environmental conditions) a check of calibration to within ~0.1 dB appears possible. In the cool regime like winter in Bonn no diurnal trend are evident as the refraction profile changes little throughout the day.
- The number M of clutter detection can serve a useful role in identifying times of the onset of change. Attribution of this change to a definite cause is difficult but the fact that such small change is detectable implies larger changes (~0.5 dB) should be easy to monitor.

Variations of Z and Z_{DR} from clutter

1) changes in transmitted power
2) changes in receiver transfer function (mainly gains)
3) antenna settling in elevation from scan to scan
4) differences in beam pointing (azimuth) at subsequent scans
5) variation of clutter reflection coefficient
6) refraction of the beam
7) changes in attenuation due to precipitation

Examples of influence

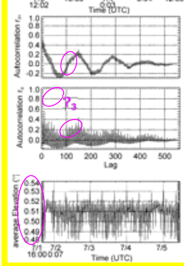
Bonn, Germany



Bonn: median values of Z_H, Z_V and Z_{DR} from snow obtained at 4.4° elevation between 5 km and 20 km from the radar; *M*-<*M*> obtained from the ground clutter

HYPOTHESIS: The relatively monotonic drop and rise in the number of detected points might have been caused by environmental conditions.
SPECULATION: Snow falling on the antenna and the antenna mounted receiver both of which are exposed to the environment. The significant snow started falling over and around the radar at 4:30 UTC. By 5:30 the uniform snow field broke in two small bands one of which crossed the radar at about 5:43 UTC. Perhaps wet snow was freezing on the dish and/or feed horn assembly both of which likely experienced increased radiative cooling. Then the sun caused warming of the dish and elimination of the ice/snow. Accumulation of ice precipitation on the dish and or feed can distort the antenna pattern and cause change in directivity.

Norman: ~ 4 to 7 UTC, July 4; the number of detections increased significantly (500 to 1000 more).
CAUSE: a storm moved over the radar at 4:00 UTC and stalled. At 5:00 it begun to dissipate rapidly, extinguished by precipitation embedded in a downdraft. The ensuing cool air (the sharp temperature drop after ~ 2.5 UTC) spread and created an inversion conducive to beam bending toward ground hence the increase in the number of detections and average Z_H. The rain came after many days of extremely hot dry weather and it could have influenced clutter reflectivity.



The autocorrelation coefficients of average Z_H show the diurnal periodicity and superposed higher frequency variations in the r_{ZH} plot. The high frequency variations have a period of approximately 50 min and are **caused by periodic variation of the antenna elevation angle**! Furthermore every volume scan begins at an azimuth angle on the average 66° larger than the previous one. Thus at the end of the fifth scan the antenna is positioned ~ 30° behind in azimuth from the first scan. For other scans relatively close to the batch of five the starting position of the antenna is further away from the first scan. This basic periodicity of five is highly correlated with the antenna elevation variations which are within 0.04° of the mean. Such small variations cause less than 0.1 dB change in the Z_H.

Conclusions

- **It is possible to use median and average values of ground clutter reflectivity and differential reflectivity to monitor polarimetric radar calibration!**
- **The effects of the environment on Z_{DR} are significant and might be difficult to routinely separate from the changes in the system.**

Nonetheless, monitoring Z_{DR} from clutter has merit on three accounts!

1) If changes are within tolerable limits (say 0.2 dB) unnecessary calibration work would be avoided regardless of the cause.

2) Changes correlated with signals from the environment such as temperature, presence of outflows, and storms indicate the system is most likely functioning properly and need not be tended for.

3) On days with similar environmental conditions one can use Z_{DR} quantitatively to estimate the system bias by choosing the time for calibration when conditions are most similar and stable.