Monitoring polarimetric weather radar calibration

L. Borowska1 and D. Zrnic1

(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 Zr and differential reflectivity Zdr on polarimetric radars can help to avoid the unnecessary recalibrations

Variations of Z and Zdr from clutter

1) Changes in transmitted power
2) Changes in receiver transfer function (mainly gains)
3) Antenna setting 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: median values of Zr, Zdr, and Zhp from snow obtained at 4.4° elevation between 5 km and 20 km from the radar. 8:45 to 9:45 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 4:00 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 began 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 Zr. The rain came after many days of extremely hot dry weather and it could have influenced clutter reflectivity.

Experimental setup, data set and clutter detection

Parameter X Band S Band

<table>
<thead>
<tr>
<th>Parameter</th>
<th>X Band</th>
<th>S Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>3.21 cm</td>
<td>10.7 cm</td>
</tr>
<tr>
<td>Antenna beamwidth</td>
<td>1.03°</td>
<td>0.93°</td>
</tr>
<tr>
<td>Peak transmitter power</td>
<td>200 kW</td>
<td>500 kW</td>
</tr>
<tr>
<td>Pulse depth (variable)</td>
<td>100 m</td>
<td>200 m</td>
</tr>
<tr>
<td>Pulse repetition time (variable)</td>
<td>1 ms</td>
<td>3 ms</td>
</tr>
</tbody>
</table>

Median/Average Z and Zdr variations of the GC points

- The medians Zr and Zdr vary within the quantization interval suggesting that monitoring of power calibration within 0.5 dB would be viable.
- The median values of Zr are the stable and consistent average Zr. The standard deviation of the medians are 0.05 dB for rainy days and 0.11 dB for days with snow at X Band, 0.07 dB for the clear on scans with several rainy scans at S Band. The medians of the median Zr 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 Zr and median Zr from the clutter have a diurnal periodicity. Therefore we can not use the average Zr and the median Zr 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 cold regimes like winter in Bonn no diurnal trend are evident as the refraction profile changes little throughout the day.

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 Zr are significant and might be difficult to routinely separate from the changes in the system. Nonetheless, monitoring Zdr from clutter has merit on three accounts:
  1) If changes are within tolerable limits (say 0.2 dB) uncalibrated 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 Zdr quantitatively to estimate the system bias by choosing the time for calibration when conditions are most similar and stable.

Median/Average Z and Zdr variations of the GC points

- The average values of Zr have definite trends not seen in the median due to coarse quantization. Superposed to the slower variations are rapid fluctuations suggestive of noise.
- The average values of ground clutter reflectivity and differential reflectivity to monitor polarimetric radar calibration! The effects of the environment on Zdr are significant and might be difficult to routinely separate from the changes in the system. Nonetheless, monitoring Zdr from clutter has merit on three accounts: 1) If changes are within tolerable limits (say 0.2 dB) uncalibrated 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 Zdr quantitatively to estimate the system bias by choosing the time for calibration when conditions are most similar and stable.