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FACTORS AFFECTING RADAR PRECIPITATION ESTIMATES

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Foreword

Implementation of the WSR-88Ds in the West provides an important real-time dataset for forecasters to use. One aspect of these data is the generation of precipitation estimates from the reflectivity field. These estimates can be extremely useful in tracking areas of concern during widespread flooding, and can highlight areas of potential flash floods. However, like many derived datasets, errors can contaminate the estimates and reduce the forecaster's confidence when examining these data. This Technical Attachment categorizes the factors affecting the accuracy of radar precipitation estimates. Applying a subjective evaluation of these factors when using WSR-88D precipitation estimates can help determine the potential contamination which may exist in a product.

Factors Affecting Radar Precipitation Estimates

Various researchers have divided factors affecting radar precipitation estimates in anywhere from six (Austin 1987) to fourteen (Zawadzki 1984) different categories. The categories presented here contain most of the information given by them, but are organized from an operational evaluation standpoint. You should be able to subjectively evaluate each factor when examining a WSR-88D precipitation product, and determine the confidence which can be placed in the product.

Factor 1: Beam blockage

The blockage of the radar beam by mountains is a problem at all sites in the West. The subsequent reduction in reflectivity values will cause an underestimate in precipitation values.

The designers of the precipitation algorithm realized beam blockage was a serious problem and built special logic into the algorithm for dealing with terrain. Partial blockage is handled through the occultation data file. The occultation data file specifies how many dBz a specific radial of reflectivity should be increased to compensate for the partial blockage. Up to 4 dBz can be added when the blockage is 60% or less. When blockage is greater than 60%, the algorithm tries to use a higher scan angle. If the scan angle goes too high, no precipitation estimates are generated for that radial. The hybrid scan data file specifies which scan angle is used for every azimuth-range location, and helps the algorithm jump around to different angles within a volume scan.

The OSF has been systematically updating all occultation data and hybrid scan files for sites in Western Region. The reason for this effort is to increase the reliability of the precipitation algorithm in terrain. You should have or will soon have a hard copy of these data files for your site. Examine these files for your area of concern to determine how the algorithm is modifying the reflectivity data to compensate for your local terrain. High percentages of partial beam blockage (near 50%) or higher scan angles than normal should reduce your confidence in the precipitation estimate generated for an area.

Factor 2: Height of the beam

The lower the scan angle, generally the better the precipitation estimate. This statement is based on the fact that numerous atmospheric processes can occur from where the beam "illuminates" precipitation until the time that precipitation reaches the ground. Two examples illustrating these problems would be: (1) low-level growth of raindrops in fog or stratus, and (2) low-level evaporation of raindrops in dry air. Studies have shown that the first problem can cause an underestimate of up to 25% (Austin 1987). The second problem will obviously cause an overestimate of up to 100% if virga is occurring.

Higher elevation radars frequently have a pronounced problem with beam height during stratiform precipitation events. If the beam starts out at several thousand feet above a valley floor, the precipitation processes in a lower level cloud deck will be completely missed. An example of this problem is illustrated in WRTA 95-18.

As you know, the height of the beam is directly related to the distance from the radar. On the average, the higher the beam, the higher the probability the estimate will be underdone (Zawadzki 1984). Thus, locations further from the radar tend to be underestimated. This fact is apparent by examining almost any precipitation chart on the PUP. Precipitation amounts routinely drop off towards the 124 nm range.

One last concern when evaluating the height of the beam is anomalous propagation. During periods of superrefraction, lower scan angles will be contaminated with ground clutter. The WSR-88D algorithm tries to correct for these situations with the tilt test. The tilt test checks for continuity between the two lowest elevation scans. If the reflectivity field is reduced substantially from the 0.5 degree to the 1.5 degree scan, anomalous propagation is assumed and the 0.5 degree scan is discarded. For a higher elevation radar site observing a lower level stratiform precipitation event, the tilt test can ruin the precipitation estimates. An example of these conditions is given in WRTA 95-08.

Factor 3: Melting and frozen precipitation

Water coated ice particles greatly increase the return in a reflectivity field. This increase in reflectivity is commonly referred to as a bright band, and generally occurs just below the freezing level. Precipitation estimates will be greatly overestimated when this phenomena occurs. For stratiform events with a constant horizontal freezing level, the reflectivity field will exhibit a circular or arc shaped maxima. If the freezing level is sloped in the horizontal, a elliptical maxima is seen. The best strategy for dealing with a bright band is to recognize that one exists, and mentally reduce amounts in those areas. The Office of Hydrology is doing some work to automatically eliminate bright band contamination, but any positive results are likely 2-3 years away.

Hail causes an affect similar to the bright band, since water coated ice particles are again present. The WSR-88D precipitation algorithm had substantial problems with hail contamination when it was first implemented. To overcome these problems, the maximum reflectivity used in the algorithm was limited to 53 dBz. This cutoff value eliminates strong hail contamination, but some over estimate in these areas still occurs.

Entirely frozen precipitation (snow) is always underestimated. Energy returned from snow is substantially less than from liquid targets. In a snow situation, most sites discard the precipitation estimates and force the WSR-88D into clear-air mode to gain the added detail. The OSF is currently working with the Bureau of Reclamation to develop a snow accumulation algorithm. This work is just beginning, so the implementation of any results would be 4-5 years away.

Factor 4: Beam filling

Like many other phenomena observed by a radar (e.g., a tornado vortex signature), beam filling problems can "blur" details useful in making a forecast decision. If an intense but small area of precipitation is occurring at an extended range, this precipitation may only partially fill the beam. Thus, the precipitation is averaged over the entire beam width and an underestimate occurs.

The extent of the error occurring through these effects depends upon: (1) size, (2) intensity and (3) distance from the radar of the precipitation echo. When these conditions are occurring, the estimated precipitation is always underdone and can range from 6% to 40% (Zawadzki, 1984).

Factor 5: Air motions and precipitation

As mentioned in factor 2, precipitation observed aloft can be modified before it hits the ground. Air motions are a primary consideration in this process, and can be classified into two categories: (1) vertical and (2) horizontal motions. The presence of an updraft or downdraft changes the fall speed of the rain relative to the surface. Hence, the rainfall rate either decreases or increases respectively, and is considered a second order effect in the sense that the vertical motion may slightly amplify other errors. For most situations, the vertical air motion errors can be ignored.

On the other hand, horizontal air motions can produce errors up to 100%. Forecasters should be aware of strong lower level wind fields in an area, and mentally adjust the precipitation rates accordingly. Air motion errors will be greatest when close to the radar. At extended ranges, the sampling area is large enough that any advection of rain still lands inside the area. Closer to the radar, advection of precipitation may completely move it into the next sample volume.

Factor 6: Calibration discrepancies

Minor variations in reflectivity values can noticeably change the precipitation estimates. Figure 1 (Urell, 1995) describes this relationship. Notice that a 1 dBz change can translate to a variation of 16-18% rainfall rate error when reflectivity values are near 45 dBz. Current calibration practices provide a 2 dBz specification window; thus a potential error of 30% may be present, dependent upon your actual radar hardware. This type of error is difficult for a forecaster to discover. When coverage from two radars overlap, estimates from each can be compared; however, other errors may still mask the calibration differences, so an engineering solution is required. The OSF is currently examining methods to reduce this specification window, and improvements are likely within the next year or two.

Summary

The above factors can dramatically affect the quality of precipitation estimates produced by the WSR-88D. Many of these factors vary from day-to-day, so a forecaster must still understand how the algorithm works to rapidly evaluate the precipitation estimate quality. This Technical Attachment tries to outline the major factors affecting quality to streamline the evaluation process.

Overall, the best precipitation estimates are produced from valley location radars during deep convection. Thick stratiform precipitation events can also be estimated well, if the freezing level is well above the beam.

References

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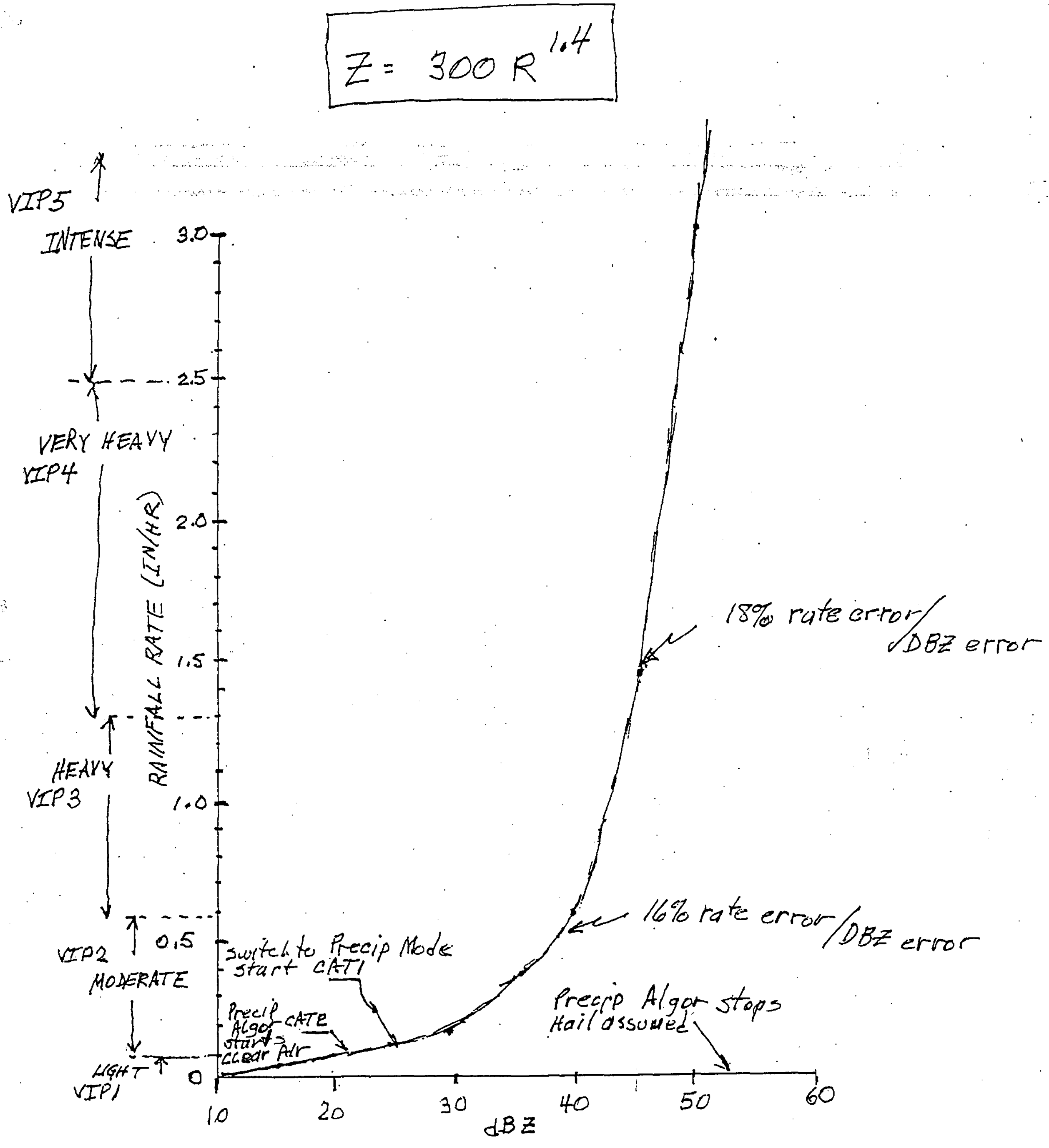

Figure 1 - Reflectivity versus rainfall rate for $Z = 300R^{1.4}$. Notice dramatic rise in rainfall rate from 40 to 45 dBz. (Urell, 1995)