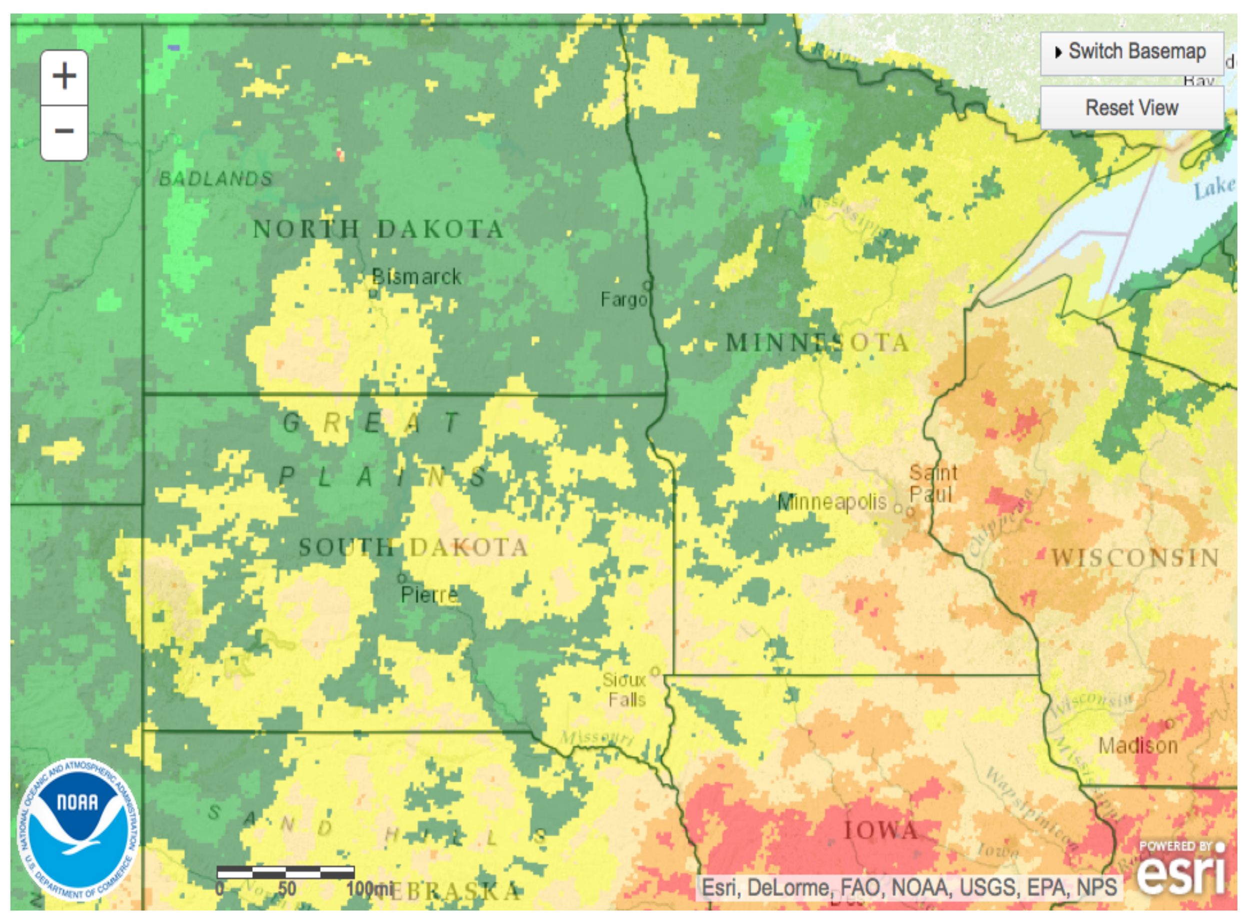
Modeling Range-Dependent Biases in Long-Term Radar-Based Precipitation Estimates

John W. Nielsen-Gammon and D. Brent McRoberts
Texas A&M University, College Station, Texas

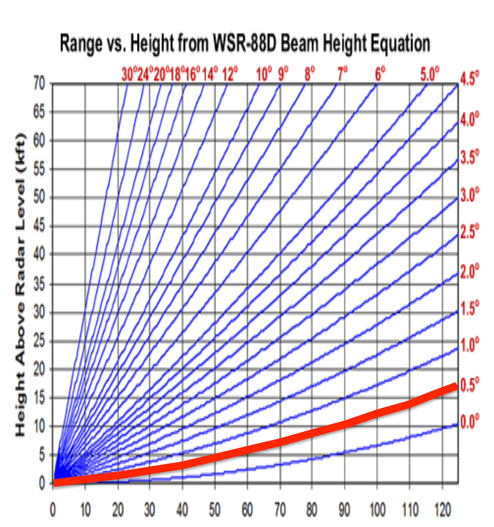
Context

Comprehensive gridded precipitation datasets are used in a wide range of applications, such as drought monitoring and land surface modeling. In most locations, the best spatial resolution is provided by analyses that rely heavily on radar-based precipitation estimates. Ordinarily, such estimates are calibrated against rain gauge data, but such calibration rarely takes into account the known structural characteristics of radar-estimated precipitation errors.

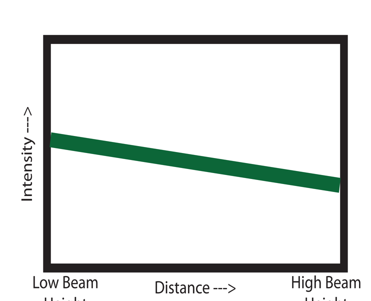
This range-dependent adjustment is step 2 of a 3-step process. Step 1 identifies and adjusts instances of beam blockage (see Poster #560, this Thursday). Step 3 is standard Kriging against gauge data, using results from Steps 1 and 2 as the first guess.



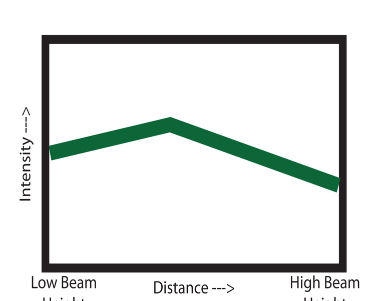
Common range-dependent error patterns arising from vertical variations of reflectivity

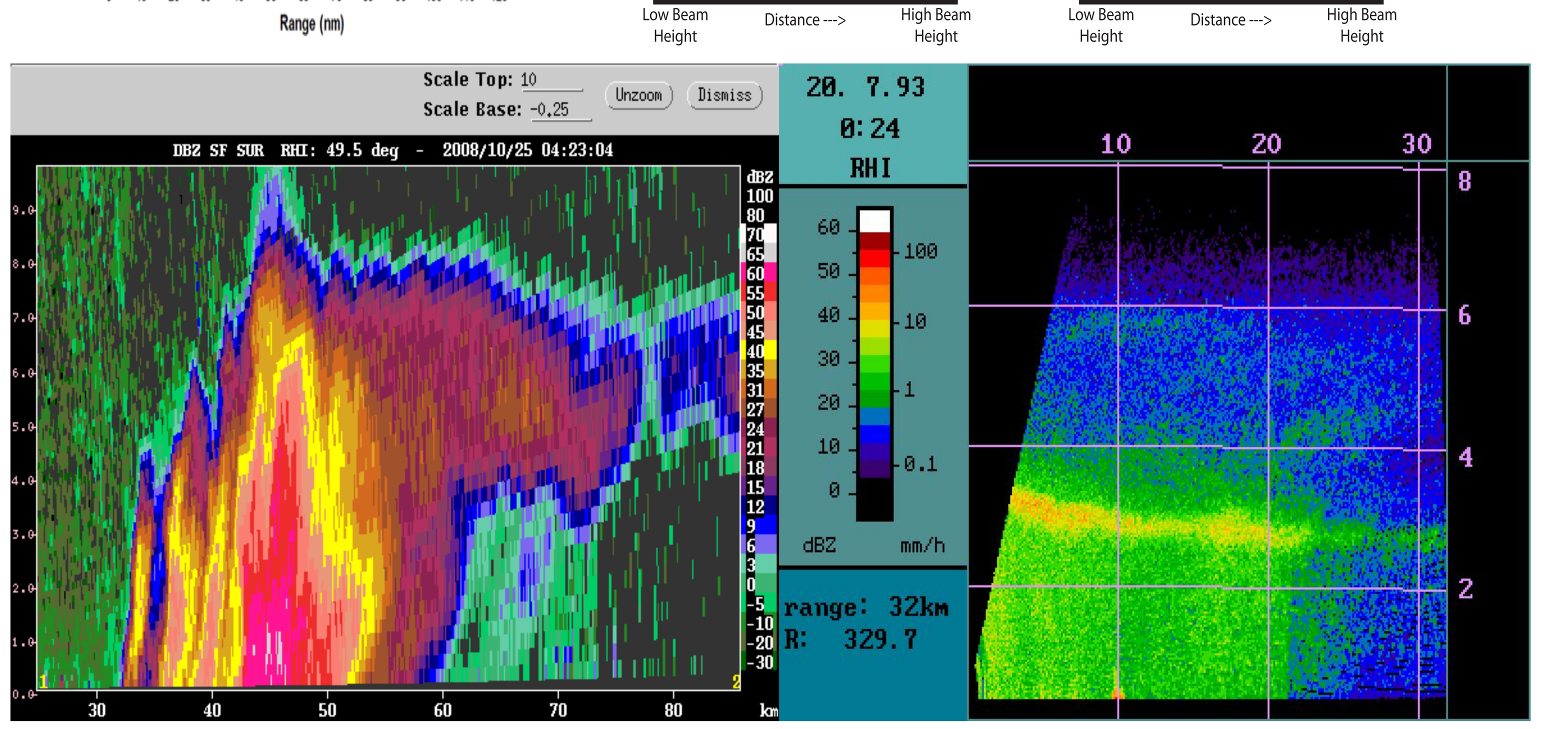


Mode N: Simple structure

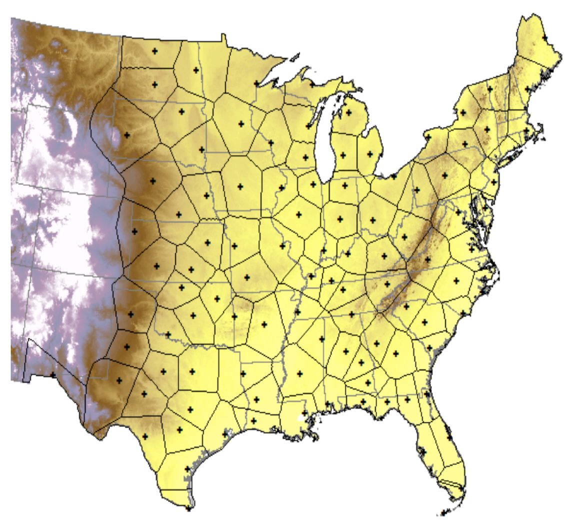


Mode Y: Bright band or low-level evaporation





Left image: UCAR/RAP (2008). Right image: Doswell and Kracmar (1996)



Starting Point: Assign gridded (5x5 km) Stage IV precipitation estimates east of Rockies to nearest radar. Operate on long-term accumulated precipitation estimates (1-36 months)

Definition: Bias = (obs – truth) / truth

Model 1: For a given radar, find grid cells collocated with nearly complete rain gauge data. Assume gauge data is unbiased. Calculate gauge-radar differences. Fit mode N or mode Y using Sen's weighted slope method.

Model 2 (novel): For a given radar, compute departure from normal rainfall at each grid point. Average all departures from normal within range bands with equal numbers of data points. Fit mode N or mode Y to range band averages. Calibrate using median of gauge-radar differences.

Model 1 assumption: Gauges provide unbiased measures of precipitation but are subject to random errors.

Model 1 advantage: Bias estimates are based entirely on independent data.

Model 1 disadvantage: Gauge data may be sparse and (particulary for frozen precipitation) unreliable.

Model 2 assumptions: PRISM rainfall climatology is accurate; long-term precipitation departures from climatology are mostly uniform or planar.

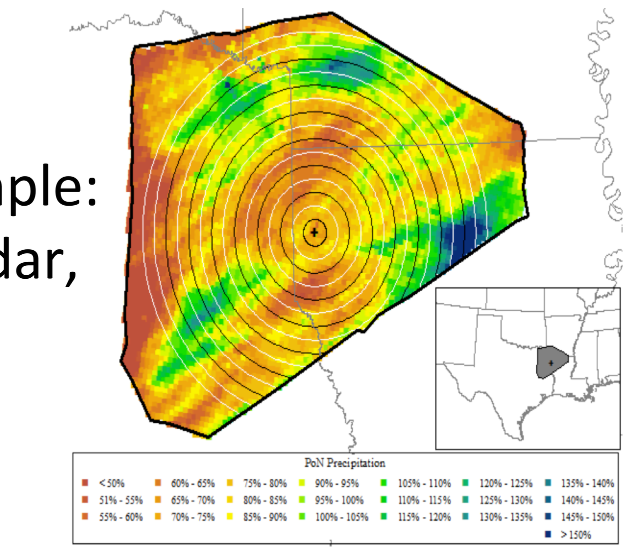
Model 2 advantage: Data are spatially and temporally complete and are geographically homogeneous.

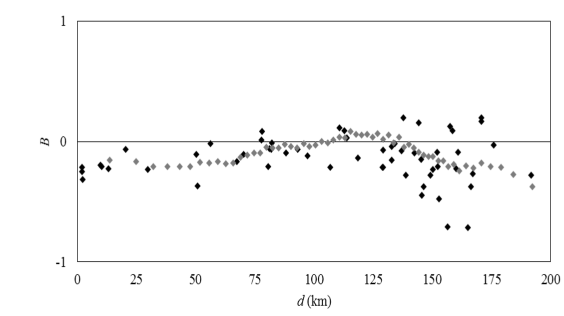
Model 2 disadvantage: Gauge data is still needed for absolute calibration.

Last Step: merge Model 1 and Model 2 into a single optimal model of radar-based precipitation biases for each radar, as follows:

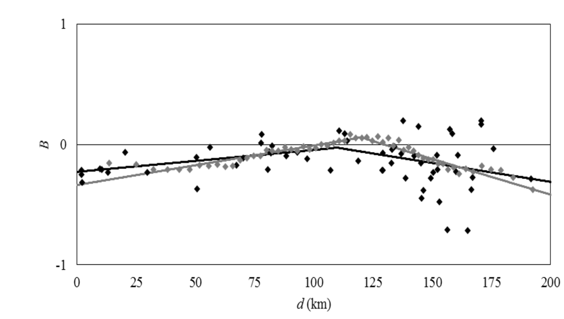
1) Estimate uncertainty associated with each model. Use conventional uncertainty estimates for Model 1. For Model 2, determine uncertainty using an empirical calibration as a function of scatter and slope.
2) If modes for the two Models differ, choose mode from model with smallest uncertainty.
3) Merge model parameters using maximum likelihood estimators.

Complex example: Shreveport radar, Dec. 2012

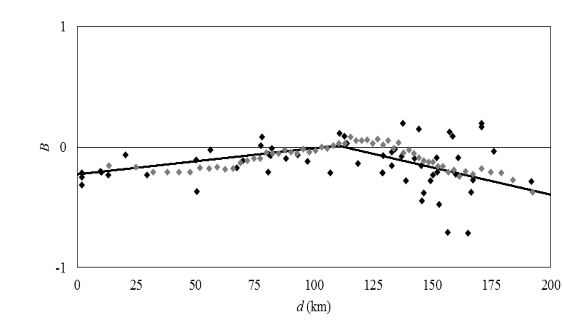




Radar-gauge pair bias estimates (black diamonds)
Calibrated departure from normal bias estimates (gray diamonds)



Model 1 fit to black diamonds (black line)
Model 2 fit to gray diamonds (gray line)



Final maximum likelihood merged model of radar-estimated precipitation biases

Validation and Conclusion

Cross-validation tests were applied to all radars east of the Rockies, using four different accumulation periods ranging from 1-36 months and four different ending times, for 16 validation cases in all. Correcting the Stage IV precipitation estimates for range-dependent and mean-field biases reduced the RMS difference between rain gauge and Stage IV precipitation estimates by 20% to 57%.

We conclude that adjusting for range-dependent biases in this way is intrinsically useful and provides a superior first guess field for subsequent gauge-based bias adjustments.

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