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# Evaluating Quantitative Precipitation Estimate Uncertainty in Complex Terrain for Use in Quantitative Precipitation Forecast Validation

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As numerical weather prediction models provide quantitative precipitation forecasts (QPF) at higher and higher spatial and temporal resolution, gridded quantitative precipitation estimates (QPE) will be needed at comparable resolutions for validation. While there are many sub-hourly to hourly QPE datasets currently available at spatial resolutions under 10km, all are subject to various sources of uncertainty depending on the observational platform, leading us to wonder, "what is the truth?". Determining accurate QPE is especially difficult in complex terrain, where radar beam blockage, reduced gauge placement, and regions of rapid orographic precipitation enhancement or suppression compound intrinsic uncertainties.

In this study we develop a methodology to estimate QPE uncertainty over a region of Northern California, USA, which includes the complex terrain of the Sierra Nevada, as well as the less prominent Coastal Range, separated by the Central Valley. We examine a variety of high resolution (hourly, 10km or less) satellite, radar, and gauge-based QPE products, including multi-sensor QPE, and select candidate products based on their ability to capture climatological precipitation patterns. Using one of those products (Gauge Corrected Multi-Radar Multi-Sensor (MRMS)) as a 'reference', we use the distribution of rainfall estimates from the other products under similar conditions (e.g. elevation, season, rainfall intensity) to estimate the probability that the true precipitation falls within some range of precipitation amounts.

We then evaluate model precipitation forecasts using this range of probable precipitation amounts. Forecast precipitation is compared to the reference dataset on a point-by-point basis, but, in contrast to traditional gridpoint validation, the distribution of observed QPE under similar conditions is also considered. In this way, we can determine whether the forecast precipitation falls within a selected range of the QPE distribution (a good forecast), falls outside the selected range, but within the tails of the distribution (forecast was possible, but unlikely), or lies outside of the distribution (bad forecast).