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Bayesian Integration of Radar Rainfall Data with Rain Gauge Measurements

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Accurate representation of the spatial and temporal distribution of rainfall intensity is crucial to development of robust calibrated hydrologic models. Rainfall data are commonly collected using rain gauges and Doppler radar. Rain gauge data are more accurate but they only yield information at point locations. Radar data provide continuous spatial information but they are less accurate. We present a Bayesian approach for integrating gauge and radar data to develop more accurate and continuous rainfall interpretation. In a Bayesian framework, the resulting probability distribution of rainfall intensity (posterior distribution) at a location at a time step is computed from a prior distribution and a likelihood function. Here, the prior distribution is estimated from the rain gauge data by applying geostatistical methods. The likelihood function is calculated based on the mismatch errors between the rainfall radar and rainfall gauge data where they overlap. We shortly discuss an earlier applied model based on a lognorm-transform of a Gaussian random field, but then focus on a novel non-parameteric approach. Therein, at each time step, a range of rainfall threshold levels is considered. For each threshold level, rain gauge and radar data are encoded into indicator values with 1 denoting rainfall intensity greater than the threshold level, 0 otherwise. Radar data are used to characterize the correlation structure of the indicator field. We study and compare several characterization approaches. Indicator Kriging using the resulting correlation model is applied to gauge indicator data to compute the prior estimate of the probability of exceeding the rainfall threshold. A fault table based on comparison of gauge and radar indicator values is used to compute the likelihood at each location. The resulting posterior estimate of the probability of exceeding the rainfall threshold is equal to the value of the posterior cumulative probability distribution function value.

We applied this Bayesian approach to the gauge and radar rainfall data collected between January 1, 1995 to June 30, 2003 in the Tampa Bay region in Florida, US. The inconsistency between the radar rainfall estimation and rain gauge point measurements were evaluated. Results show that Bayesian Integration of radar rainfall with rain gauge measurements using the proposed non-parametric threshold approach holds the potential to improve rainfall estimations. Posterior rainfall estimations obtained from Bayesian Integration show higher accuracy than rainfall estimations obtained from Kriging along and are consistent with all rain gauge data. We also have experimented with a Bayesian Integration based on the lognorm-transform of a Gaussian approach. Although the log-transformation approach is computationally more efficient than the proposed non-parametric approach, it can lead to unrealistically large rainfall. The non-parametric approach does not have this problem.