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Input uncertainty in catchment models: an evaluation of the suitability of multiplicative rainfall error models using high resolution raingauge and radar data

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This paper presents an investigation of rainfall error models used in rainfall-runoff model calibration and prediction. A growing number of studies now specify an error model for rainfall input, usually simple in form due to computational constraints during parameter estimation. Such rainfall error models have not typically been validated against experimental evidence. If the data uncertainty hypotheses and assumptions are unsupported, the interactions between input and structural model error may significantly contaminate the inference and lead to unreliable parameter estimates and model predictions. It is therefore important that the data error models should be developed using data analysis that is independent from the hydrological model calibration, to bring genuine independent information into the inference.

In this study we use data from the 50 km2 Mahurangi catchment in Northland, New Zealand, where there is detailed space-time information on rainfall from both a dense tipping bucket raingauge network (13 stations) and X-band radar rainfall estimates. This high resolution data is used to provide insights on the suitability of the common multiplicative rainfall error model for use at varying spatial and temporal scales of hydrological models. We first present an analysis of the spatial variability and uncertainty in rainfall when considered solely as a binary (wet/dry) process. This type of analysis is a crucial check on the assumptions underlying multiplicative rainfall error models, since the latter cannot account for rain events with only partial catchment cover that are hence not recorded by a rain gauge. Secondly, we examine the consistency of rainfall quantities over the catchment; based both on complete rainfall records and also for individual storm events when correct estimation of rainfall is most crucial. This allows us to estimate the statistical distributions of rainfall multipliers and test if these could form the basis of an adequate rainfall error model and put multipliers into the context of events.

Results highlight some important results for understanding rainfall uncertainty and deriving data-based probabilistic error models for use in hydrological calibration. In the Mahurangi catchment, multiplicative error appears to be a suitable formulation for correcting mean catchment rainfall values during high-rainfall periods (e.g. intensities over 1 mm/hour); or for longer timesteps at any rainfall intensity (timestep 1 day or greater). We suggest that the effect of timestep on multiplier suitability is regulated by catchment size: specifically the time required for typical raincells to cross the catchment could be used as a first estimate of critical timestep.

The standard distribution used for rainfall multipliers, the lognormal, provided a relatively close fit to the empirical multiplier distributions. However the empirical distributions have greater excess kurtosis and positive skew than the lognormal. Since heavy rainfall events display multiplier distributions differing most significantly from the lognormal, a skewed and heavier-tailed distribution to be used for times of high rainfall would more faithfully reproduce the observed error characteristics. Lastly, the high resolution of the data available demonstrated the time/space complexity of rainfall behaviour that cannot be corrected by a simple multiplicative error on measured rainfall. A hydrological model that aims to capture the full effects of rainfall variability would need an additional mechanism, such as a distribution function approach to rainfall input; or a blurred threshold for processes such as infiltration excess.