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Hydrological model selection under uncertainty: a Bayesian alternative

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The evaluation and comparison of hydrological models has long been a challenge to the practicing hydrological community. No single model can be identified as ideal over the range of possible hydrological situations. Assessing the relative performance of competing model structures in a specific catchment given the uncertainties in the modeling process can be difficult in practice. This is highlighted by the common difficulties in obtaining a unique set of values for the model parameters. Bayesian statistical inference, with computations carried out via Markov Chain Monte Carlo (MCMC) methods, offer an efficient alternative to traditional calibration techniques, allowing for the combination of any pre-existing knowledge about individual models and their respective parameters with the available catchment data to assess the parameter uncertainty.

Bayesian statistical inference can also provide a framework to evaluate the evidence in favour of a model, given a group of competing models. The methodology allows for model uncertainty to be taken into account. In comparing two models, the traditional approach requires calculation of the Bayes Factor, which is the posterior probability ratio of the models (assuming equal prior probabilities).

Calculation of Bayes factors is complicated by the computational effort required, particularly for high dimensional models. Markov chain Monte Carlo (MCMC) methods can provide an analytical solution to calculating the marginal likelihood of a model in relation to Bayes factors. Difficulties arise in calculating the marginal likelihood when full conditional densities are not available, but a method may be developed whereby the MCMC chains produced by an adaptive Metropolis sampling algorithm can be

used to directly estimate the marginal likelihood of a model. However widespread use of the method relies on finding an MCMC technique which may be easily applied to hydrological models.

This study develops a model selection framework based on calculating Bayes Factors by estimating the marginal likelihood of a model. The framework uses an adaptive Metropolis algorithm to calculate the models posterior odds. The adaptive algorithm offers a relatively simple basis for assessing parameter uncertainty in hydrological modeling studies. It also has characteristics that are well suited to model parameters with a high degree of correlation and interdependence, as is often evident in hydrological models. The study builds on previous work in which the parameters of the Australian Water Balance Model (AWBM) were estimated using computations carried out via Markov chain Monte Carlo methods. To assess the model selection method in a controlled setting, artificial runoff data were created corresponding to a known model configuration. These data were used to evaluate the accuracy of the model selection method and its sensitivity to the size of the sample being used. An application of the Bayesian model identification methodology to daily streamflow data from selected Australian catchments concludes our study. Model comparison via the Bayes factor also provides a formal comparison of the performance of models which assume different error structures, and this is illustrated in the study.