Bayesian and information-theoretic scores for model selection and similarity analysis

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ABSTRACT

Environmental modeling involves the simplification of physical processes through numerical approximations with the goal of reproducing natural systems and predicting their behavior in current or future scenarios. Due to incomplete knowledge of the real system, more than one model exists to reproduce the same phenomenon. Therefore, the modeler is met with the challenge of selecting one model out of the many possible options. Bayesian inference, through the use of Bayesian model evidence (BME), has traditionally provided a framework with which to compare competing models, considering both parameter and conceptual uncertainty. BME, however, has two main limitations. First, it allows to judge models based solely on its prior predictive capabilities, disregarding the updating of prior knowledge through the observation data, which is the main objective of Bayesian inference. Second, it cannot be used to compare models which depend on different data sets due to bias injected through the likelihood function. When using BME, one would have to either ignore models with different data sets, or remove observation data such that all models depend on the same set. In either case, this results in a loss of information with which to make decisions. This thesis proposes the use of information-theoretic scores, such as expected log-predictive density, relative entropy (or Kullback-Leibler divergence) and information entropy, to provide additional information on both the posterior and the amount of information gained through the observation data. This methodology was applied to both Bayesian model selection and model similarity analysis, and tested using three controlled model comparison setups, two based on simple analytical models and one based on numerical groundwater models. The results showed how the information-theoretic scores complement BME by providing a full picture with regards to the Bayesian inference analysis. Additionally, the results shows how both relative and information entropy can be used to compare models with different data sets, avoiding any loss of information, which leads to a more informed model selection decision.

Keywords: Bayesian model selection, Bayesian model similarity, information theory, information entropy, relative entropy, model calibration