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Skill and cost-loss analysis of a probabilistic nutrient ensemble prediction

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Model uncertainty can be divided into two main sources. The stochastic uncertainty is linked to forcing data (e.g. precipitation rates in the case of a rainfall-runoff model) and eventual free parameters (e.g. recession coefficients in a rainfall-runoff model). The structural uncertainty comes from the simplification made in the description of the natural system through mathematical equations. This uncertainty is especially typical of the hydro-biogeochemical models that are nowadays used to predict nutrient loads at the catchment scale. Most of these modelling concepts are rather conceptual and therefore provide highly uncertain predictions.

Over the last years, great progresses have been made in the analysis of the stochastic uncertainty, most frequently based on parameter value or range estimation techniques, either in a deterministic (e.g. SCE-UA) or a probabilistic (e.g. Markov-Chain Monte Carlo) way. However, the structural uncertainty has remained hardly quantifiable so far. Moreover, whilst it has become quite frequent to use multi-model predictions in atmospheric and hydrological sciences to tackle this problem, only few published studies have presented results of ensemble nutrient flux predictions. Ensembles of predictions have been treated in two main different ways in hydrological sciences. Deterministic approaches have been based on different model averaging techniques in order to obtain a new 'best' prediction. On the other hand a probabilistic approach has also frequently been adopted in order to provide the model users with confidence intervals in the case of extreme events prevention notably. Probabilistic ensembles would be especially helpful to quantify the risk of meeting drinking water thresholds for example.

With the aim to demonstrate the advantage of using even a simple probabilistic ensemble, we have applied 4 different catchment scale hydro-biogeochemical models (LASCAM, CHIMP, SWAT and HBV-N-D) over the Ellen Brook catchment in south-west Western Australia. The capability of each model to correctly predict the exceedance of total nitrogen (TN) concentration was evaluated with skill assessments and cost-loss analyses over a calibration and a validation period. The ensemble of the 4 model predictions was extended to a set of different probabilistic thresholds. In the case of the Ellen Brook, we could demonstrate that taking into account alternatively 2, 3 or 4 models in a probabilistic way increased the skill of the prediction of high TN concentration from 2 to 51% compared to the single deterministic predictions. Accordingly, the economic value of the probabilistic ensemble was most of the time higher than for any of the single models.

These first results, obtained with one of the simplest possible probabilistic ensemble of hydro-biogeochemical predictions, should encourage scientists in this domain to consider ensemble modelling has a viable alternative to provide more reliable predictions.