Seasonal and long-term prediction of low flows in the Rhine Basin

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Abstract
The aim of this paper is to give information about a new project on the Rhine River. In this project we intent to identify appropriate low flow prediction models for the seasonal and long term by comparing uncertainties in low flows predicted by different pre-selected models.

Introduction
The study of low flow events may seem controversial for a low lying country like the Netherlands (Figure 1). However, low flow events in dry summers such as in 1969, 1976, 1985 and 2003 indicate the importance of considering these events in addition to flood events. Moreover, climate change is expected to increase the occurrence of low flows in the future. Therefore, the prediction of low flows for different lead times (seasonal term) and with climate change (long term) is of major importance. For the Rhine, there have been several attempts to predict low flows; however the results for longer lead times were mostly inaccurate and unreliable due to large uncertainties in weather predictions, model inputs and model structures.

The Dutch Water Service and the German Institute BfG are able to forecast low flows with a lead time of 4 days based on different hydrological and hydrodynamic models, e.g. FEWS, SOBEK, and WAVOS for the Rhine.

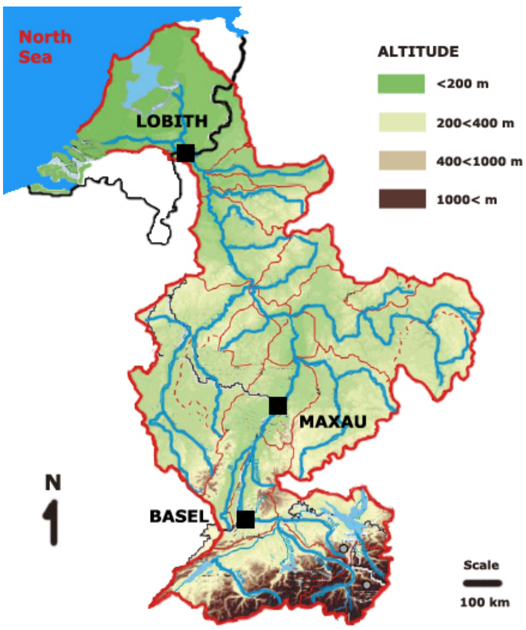

Figure 1. Rhine Basin

Seasonal predictions with a lead time of 2 weeks or 3 months do not exist (or exist without uncertainty quantification) although there is a high demand from different river-related functions (e.g. freight shipment, drinking water supply, and energy production).

Method
Hydrological models are usually compared based on their accuracy in simulating observed stream flow (Hurkmans et al. 2008; Te Linde et al. 2008). The uncertainties are usually not given with the results. Very few studies address model selection or applicability issues in seasonal predictions and climate change impact assessment. Klemes (1986) gave a plan for the systematic testing of applicability of hydrological models for impact assessment. Gleick (1986) reviewed different approaches for evaluating the regional hydrologic impacts of climate change and proposed a scheme for choosing an appropriate model. He indicated water balance models as more convenient for climate change studies. On the other hand, Klemes (1986) suggested models with a more physical basis that can be examined for different climate conditions such as dry and wet conditions.

In this study the uncertainty assessment in the model outcome will be used to determine the appropriate model (Figure 2) as the model output uncertainty integrates all other uncertainties related to input, parameters, and model structure. An appropriate low flow model is a model which produces output with the smallest uncertainty in low flows compared to other model alternatives. This uncertainty can also be compared with adequate uncertainty bands defined according to expert opinions to verify whether an appropriate low flow model also satisfies their requirements.

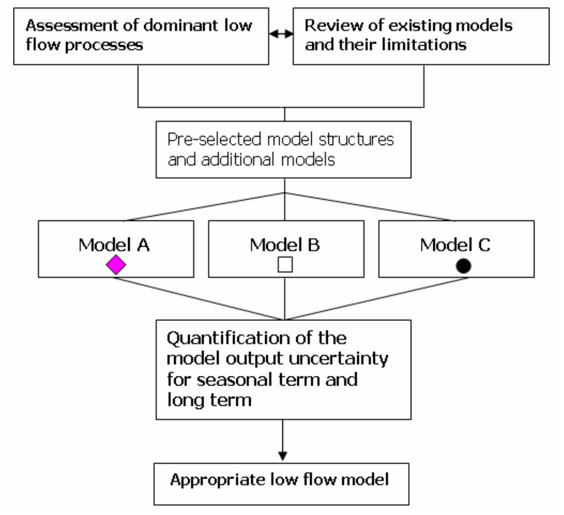

Figure 2. Preliminary research approach

The pre-selection of the models will be based on the identification of relevant low flow generating processes in the Rhine basin (for a particular lead time or climate impact assessment) and the availability of models incorporating these processes. Otherwise, additional models will be developed such as statistical and data driven models.

Results

The seasonal models are expected to produce more uncertainty than the current simulations for lead times of 1-4 days, since the uncertainty of the weather is much higher for longer lead times.

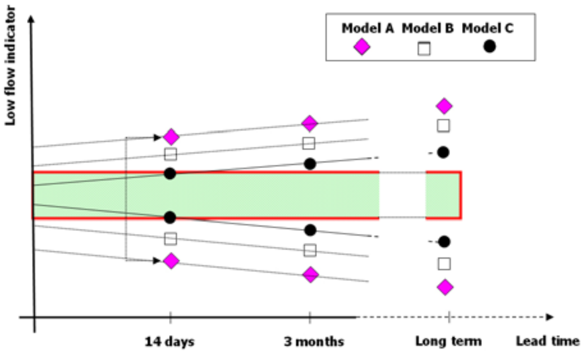

Figure 3. Identification of uncertainty bands at specific lead times for seasonal and long term low flow prediction.

Moreover the current hydrological models have been developed mostly for flood risk assessment which focuses more on fast overland flow processes than groundwater or base flow processes. These slower processes are usually represented by simple linear approaches. In consideration of these limitations and also other present model capabilities we intent to improve these models for longer lead times. We will present the uncertainty comparison of the prediction results like in Figure 3 to indicate the appropriate low flow model.

Discussion

We attended other scientific meetings and interviewed some experts about this new study which has a unique model evaluation scheme among the other classical simulation studies or model comparison approaches. The experts were asked for the most relevant low flow indicators in the Rhine basin. Moreover data availability and important spatial basin characteristics were also scrutinized. They underlined the groundwater relevance to low flow in the basin. The large area of the basin containing diverse regional processes and different seasonal behaviour within sub-basins will complicate the set-up and calibration of the models. The snow dominated upstream of Basel, the middle section of the basin in Germany and the Mosel River input need special attention in the modelling phase.

Conclusions

This projected study will shed a light on low flow aspects which is usually underexposed in hydrological modelling. It is important to improve and extend seasonal low flow predictions (including uncertainty) using appropriate models to support different river-related functions. The long term predictions will enable the assessment of the climate change impacts on low flows.

Acknowledgements

We acknowledge the financial support of the Dr. ir. Cornelis Lely Stichting (CLS), Project No. 20957310.

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