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Combining meteorological ensemble prediction, data assimilation and hydrological multimodel to reduce and untangle sources of uncertainty

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Hydrological ensemble prediction systems offer the possibility to dynamically assess forecast uncertainty. An ensemble may be issued wherever the uncertainty is situated along the meteorological chain. We commonly identify three main sources of uncertainty: meteorological forcing, hydrological initial conditions, and structural and parameter uncertainty. To address these uncertainties, different techniques have been developed. Meteorological ensemble prediction systems gained in popularity among researchers and operational forecasters as it allows to account for forcing uncertainties. Many data assimilation techniques have been applied to hydrology to reinitialize model states in order to issue more accurate and sharper predictive density functions. At last, multimodel simulation allows to get away from the quest of single best parameter and structure pitfall.

The knowledge about these individual techniques is getting extensive and many individual applications can be found in the literature. Even though they proved to improve upon traditional forecasting, they frequently fail to issue fully reliable hydrological forecast as all sources of uncertainty are not tackled. Therefore, an improvement can be obtained in combining them, as it provides a more comprehensive handling of errors. Moreover, using these techniques separately or in combination allows to issue more reliable forecasts but also to identify explicitly the amount of total uncertainty that each technique accounts for. At the end, these sources of error can be characterized in terms of magnitude and lead time influence.

As these techniques are frequently used alone, they are usually tuned to perform individually. To reach optimal performance, they should be set jointly. Among them, the data assimilation technique offers a large flexibility in its setting and therefore requires a proper setting considering the other ensemble techniques used. This question is also raised for the hydrological model selection as their performance is influenced by the updating procedure.

This study evaluates performance in terms of accuracy and reliability of an ensemble initially composed of 20 lumped hydrological models chosen for their structural and conceptual diversity. The multimodel ensemble is coupled with either perfect forecast or the ECMWF probabilistic meteorological weather forecast and tested on more than 2 years of a 10-day ahead forecasts and 38 catchments under important nival influence. Ensemble Kalman filter is used to reinitialize state variables prior to the forecasting step. A thorough investigation to reach an optimal framework for initial conditions uncertainty handling is performed and a guideline to optimize the use of Ensemble Kalman filter for a hydrological multimodel and meteorological ensemble is suggested.

Results show that even if the multimodel ensemble, the meteorological ensemble, and the data assimilation are efficient, they do not individually allow to have a reliable and accurate predictive distribution for all lead times, and forecast can be improved by combining them according to others properties. Using alternatively the three aforementioned techniques enable to quantify and untangle the different sources of errors in the hydrometerological modeling chain.