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A Point Estimate Method for the individual and collective assessment of sources of uncertainty in hydrological modelling

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Two important factors in decision-making related to flood and water resources management are the reliability of the information and the quickness with which such information can be processed. In fact, while in the case of flood warning management reliability and a fast response are essential, the ability to address separately, different sources of uncertainty is an important asset in models aimed at water resources management. Classical uncertainty analysis methods based on simulations and analysis of the error provide accurate information but are often limited by the computational demand and by the inability to discriminate between sources of uncertainty.

We present a new uncertainty estimation method, the Perturbance Moment Point Estimate Method (PMM), which is significantly less computationally demanding than Monte Carlo based methods, while offering an accuracy that is appropriate for practical hydrological applications. We also show how the use of Point Estimate Methods (PEMs) in general allows the analysis of the effects of individual sources of uncertainty without the need for additional simulations. We apply the method to analyze the uncertainty in the hydrologic response of the Brenta River (North-east Italy) to selected events. We focus on assessing the influence of parameter uncertainty, imperfect knowledge of the spatial distribution of rainfall, and instrumental error associated with rain-gauge observations on the estimated discharge, both collectively and individually.

Confirming a well-established result in the hydrologic literature, we see a significant influence of the parameters' uncertainty on the model results. The imperfect knowledge of the spatial distribution of rainfall has also a significant effect, pointing to the need for a more accurate assessment of this source of uncertainty and the potential benefit of reducing it, e.g. by an optimal design of the rain gauge network.

In addition, the uncertainty analysis of the hydrological model of the Brenta River emphasizes the importance of accounting for all sources of uncertainty, especially considering their interacting effects. In fact, comparison of the analyses of individual sources versus collective grouping shows at times synergistic and at times compensative effects. This further supports the notion that deterministic models cannot fully capture the behaviour of complex hydrologic systems and that traditional modelling should be adequately supported by uncertainty analysis both for scientific and practical applications.

In order to make informed management decisions, hydrologists and stakeholders should take advantage of reliable, and yet swift, methods to evaluate the uncertainty involved in hydrological modeling, particularly in emergency management situation when the computational time is an important factor. PEMs in general, and PMM in particular, are valuable and appealing tools in this regard, both in terms of computational time and in terms of detailed analysis. These properties are very useful in view of the deeper understanding that can be derived of the dominant hydrological processes.