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Sensitivity analysis of a spatio-temporal hydrological model for pesticide transfers

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Pesticide use is a major issue in sustainable agriculture and water quality. Therefore, it is important to have the knowledge and the tools to best estimate the risks associated with their use and propose appropriate corrective actions. The PESHMELBA model developped by [2] aims at simulating processes involved in water and pesticide transfers at the watershed scale, in order to compare scenarios of the landscape management and its impact on the river quality. An important step in the journey to PESHMELBA's operational use is performing a thorough study on the model uncertainties. A sensitivity analysis can help trace the output uncertainties back to its input parameters, verify the model consistency with respect to the physical processes and enhance the understanding of the modeled behaviour. However, the application of global sensitivity analysis (GSA) to spatio-temporal environmental models can be very challenging and dependent on the particular case studied. No universal methodology exists for performing GSA on spatio-temporal models. Additionally, GSA methods have not yet been applied to distributed pesticide transfer models.

In the case of the PESHMELBA model, the sensitivity analysis is particularly challenging. PESHMELBA is made up of coupled code units that represent interacting physical processes simulating pesticide transfers and fate. Each code unit can be characterized by its own resolution method and its own time step. This leads to a very heterogeneous final structure, which is hard to analyse. Additionally, the PESHMELBA model is a distributed model - the resolution is performed on each spatial unit individually. Then, interactions between spatial units are integrated. The spatial aspect adds another layer of difficulty to the sensitivity analysis, as spatial interactions should be taken into account to interpret the results. Both the integration of various physical processes as distinct code units and the spatial distribution of the model contribute to drastically increasing the number of input parameters. Indeed, in the case studied, PESHMELBA counts 145 input parameters. The exploration of such a high dimensional input space is challenging as it implies time consuming model evaluations.

In this study, we propose a novel GSA methodology for the PESHMELBA model, taking into account both its high dimensionality and spatio-temporal aspect. Two solutions were taken to deal with the high dimensionality of the input space: (a) screening and (b) estimating sensitivity indices via metamodels. The proposed methodology can be separated in two conceptual steps. The first step deals with the temporal aspect of the outputs, by studying each spatial unit independently. Thus, for one spatial unit at a time, sensitivity indices are obtained for its whole output dynamics. This is done by calculating sensitivity indices on the sum of scores of the functional outputs principal components [1]. In the second step, the spatial aspect is considered. The sensitivity indices obtained for each spatial unit are aggregated to the watershed scale by means of vector projections [3]. To sum up, the proposed methodology consists in: (i) screening via the elementary effect method on the principal components of the functional outputs, (ii) calculating sensitivity indices of one spatial unit at-a-time through metamodels (polynomial chaos expansion or random forest) and (iii) aggregating the sensitivity indices to a watershed scale.

Two different PESHMELBA outputs were studied, surface moisture series and pesticide mass series. The methodology was successfully applied to surface moisture series and proved its potential for improving knowledge on model behavior. The method is promising but still needs to be improved as results were less satisfactory for pesticide mass series due to the complexity of the physical processes simulated and the non-linear interactions between them.

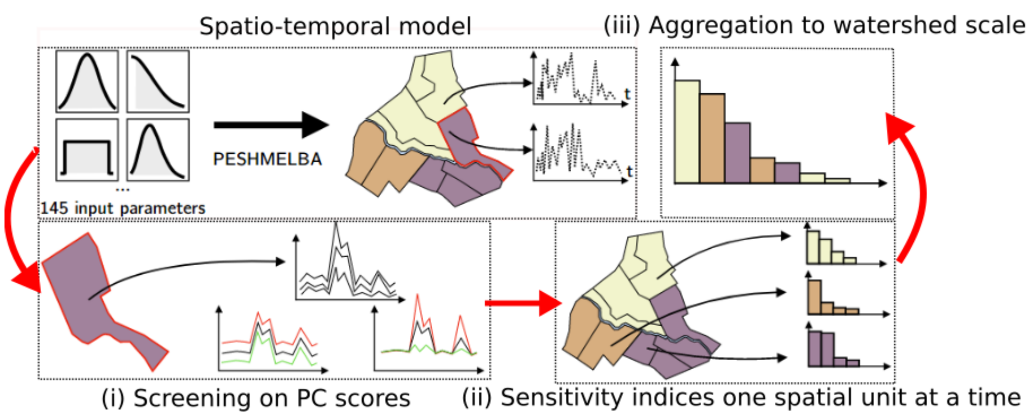

Figure 1: Schema of the proposed methodology.

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