Selecting the optimal spatial detail and process complexity for modeling environmental systems

S. Van Hoey**Fout!** , I. Nopens**Fout!**, G. Engelen**Fout!**, H. Van der Kwast**Fout!**,

J. De Kok[1], P. Seuntjens**Fout!**

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Abstract

When modeling environmental systems, one can choose between different formulations and spatial conceptualisations. As a result, a wide variety of models have been developed for analyzing the properties and behaviour of such systems when triggered by events. Roughly, this variety is characterized by different levels of spatial detail and process complexity. A trade-off exists between the required level of complexity, the accepted level of uncertainty, the data-availability and the performance of the model. As a result, the choices regarding the complexity are not necessarily straightforward or transparent and are highly dependent on the objective of the modeling exercise.

The spatial complexity can vary from lumped models in which all data and parameters are averaged over a given area, up to a high-resolution spatially-explicit model operating at many small entities. Lumped models give rise to uncertainty due to the spatial aggregation, while distributed models suffer from uncertainty owing to data variability and measurement errors. The process complexity depends on the model structure and the complexity of the different equations used. Processes can be represented by means of a single empirical (transfer) function (black box), a conceptualization or a description of the underlying physics using the governing equations (mechanistic - grey/white box). Physically-based equations are assumed to be the best representation of the phenomena, but require a lot of good quality data for proper calibration and, hence may give rise to overparameterisation, and consequently, uncertainty. Empirical equations, on the other hand, can not be extrapolated to other situations without significantly increasing the uncertainty. It is recognised that there is no general model structure for all scales used and goals set forth. Hence, the model structure and process descriptions must be consistent with the spatial resolution of the model.

The aim of this study is to create a systematic methodology that helps in selecting the most appropriate combination of spatial detail and process complexity as function of the specific conditions of the system, the available data and the objectives of the study. The latter depend on existing environmental policies and regulation, the assessment of management practices, scenario-analysis, etc.

The presented methodology will be tested for a case-study in order to compare different model formulations and spatial resolutions corresponding to selected model objectives for hydrological modeling. Sensitivity analysis of a model of the catchment will be used to identify dominant processes and to gain an insight into possible simplifications of the model relative to different spatial resolutions. By varying the attributes of the catchment, the input data and the spatial resolution of the model, different options in setting up a simplified model are assessed.

mechanistic model

Affiliation:

[1]Flemish Institute for Technological Research (VITO), Boeretang 200, 2400 Mol, Belgium

[2]Ghent University, Department of Applied Mathematics, Biometrics and Process Control, Belgium

[3]Ghent University, Department of Soil Management, Belgium

[4]University of Antwerp, Belgium

Email:
stijn.vanhoey@vito.be
Ingmar.Nopens@biomath.ugent.be
guy.engelen@vito.be
hans.vanderkwast@vito.be
Jean-Luc.DeKok@vito.be
piet.seuntjens@vito.be

Phone +32 (0)9 264 5935