‘spup’ – an R package for uncertainty propagation analysis in spatial environmental modelling

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Abstract

Computer models have become a crucial tool in engineering and environmental sciences for simulating the behaviour of complex static and dynamic systems. However, while many models are deterministic, the uncertainty in their predictions needs to be estimated before they are used for decision support. Currently, advances in uncertainty propagation and assessment have been paralleled by a growing number of software tools for uncertainty analysis, but none has gained recognition for a universal applicability and being able to deal with case studies with spatial models and spatial model inputs. Due to the growing popularity and applicability of the open source R programming language we undertook a project to develop an R package that facilitates uncertainty propagation analysis in spatial environmental modelling. In particular, the ‘spup’ package provides functions for examining the uncertainty propagation starting from input data and model parameters, via the environmental model onto model predictions. The functions include uncertainty model specification, stochastic simulation and propagation of uncertainty using Monte Carlo (MC) techniques, as well as several uncertainty visualization functions. Uncertain environmental variables are represented in the package as objects whose attribute values may be uncertain and described by probability distributions. Both numerical and categorical data types are handled. Spatial auto-correlation within an attribute and cross-correlation between attributes is also accommodated for. For uncertainty propagation the package has implemented the MC approach with efficient sampling algorithms, i.e. stratified random sampling and Latin hypercube sampling. The design includes facilitation of parallel computing to speed up MC computation. The MC realizations may be used as an input to the environmental models called from R, or externally. Selected visualization methods that are understandable by non-experts with limited background in statistics can be used to summarize and visualize uncertainty about the measured input, model parameters and output of the uncertainty propagation. We demonstrate that the ’spup’ package is an effective and easy tool to apply and can be used in multi-disciplinary research and model-based decision support.