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Procedia Social and Behavioral Sciences 2 (2010) 7716–7717

Procedia
Social and Behavioral Sciences

Sixth International Conference on Sensitivity Analysis of Model Output

A comparative analysis of emulators for the sensitivity analysis of a land surface process model

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Abstract

Sophisticated mathematical models simulating land surface interaction processes are increasingly employed today in performing various types of scientific investigations and analysis, providing important assistance to scientists in better understanding the complicated physical phenomena that occur in nature. Sensitivity analysis (SA) in particular, is generally regarded nowadays as a key step in verifying the concept and relevance to real world of any mathematical model, before that is used for carrying out any kind of operation or analysis for which it has been developed.

The present work provides a comparative analysis of both Gaussian and Non-Gaussian process emulators for performing a global sensitivity analysis (GSA) to a land surface process model named SimSphere. Until today, only few SA studies have been conducted to this specific model, even more, GSA ones, and thus results from the work conducted here are expected to contribute decisively towards an all-inclusive assessment of its overall verification.

Keywords: sensitivity analysis; GEM-SA; DACE; SDP; SimSphere SVAT model

1. Main text

Surface–Vegetation–Atmospheric Transfer (SVAT) models form a special category of deterministic land surface process models which are able to provide in a vertical profile representations of the physical mechanisms controlling the physical interactions occurring in the soil/vegetation/atmosphere continuum (radiative, turbulent and water transfers). These models are able to provide access to a detailed description of soil and vegetation canopy processes and at a fine time resolution (typically less than an hour), which is in good agreement with the dynamic timescale of the atmospheric and surface processes (Sellers et al., 1996). One such SVAT model is the SimSphere model of Gillies et al. (1997), the current form of which has considerably evolved since its original development by Carlson and Boland (1978). The model is freely available from the Department of Meteorology of Pennsylvania State University, USA (https://courseware.e-education.psu.edu/ simsphere/).

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1877-0428
doi:10.1016/j.sbspro.2010.05.194

SimSphere is essentially a one-dimensional boundary layer model with a plant component. The model performs simulations over a 24-hour cycle, starting from a set of initial conditions given in the early morning and simulates the continuous evolving interaction between soil, plant and atmospheric layers. An extensive mathematical account of the different model components has been described by Taconet et al. (1986), and Olioso et al. (1996). Petropoulos et al. (2009a) in a review of the model use underlined that very few SA studies had been carried out to this model, most of which have been based on either empirical or on local sensitivity analysis (LSA) methods. Recognising the requirement for further SA to SimSphere using GSA methods, Petropoulos et al. (2009b) recently applied for the first time to SimSphere a GSA technique, based on a Gaussian process emulator, and they were able to quantitatively derive an estimate of the sensitivity of all the model inputs and of their interactions.

The objective of the present study is to perform to SimSphere a comparative analysis of different GSA methods, based on both Gaussian and Non-Gaussian processes emulators. A secondary objective is to investigate the effect of parameters such as the sampling method and sampling size selection to the determination of the training set of model simulations which are subsequently used to build the different emulators to execute the SA. For this purpose, GSA will be conducted on selected key land surface parameters simulated by SimSphere by employing the GEM-SA (O'Hagan, 2006) and DACE (http://www2.imm.dtu.dk/~hbn/dace/) Gaussian process emulators as well as the smoothing splines ANOVA emulators (Ratto et al., 2007, Storlie et el. 2009, Storlie and Helton RESS 2009). The present study will allow obtaining for the first time a direct appreciation of the effect of aspects such as the Gaussian assumption or the sampling method used for the emulators training to the sensitivity measures that will be derived with respect to the examined model, here, SimSphere. This work is also very timely, given that SimSphere is being considered to be combined with satellite data for the operational retrieval of soil moisture by National Polar-orbiting Operational Environmental Satellite System (NPOESS) from 2013 onwards, as proposed by Chauhan et al., (2003).

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