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A New Framework for Global Sensitivity Analysis for Environmental Modelling

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A New Framework for Global Sensitivity Analysis for Environmental Modelling

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Abstract: Global sensitivity analysis (GSA) is an effective tool for understanding the role and functioning of different model factors (e.g., model parameters, forcings, and boundary and initial conditions) in generating the model response. GSA can be helpful to improve the credibility and utility of environmental systems models, as these models are continually growing in complexity and dimensionality with continuous advances in understanding and computing power. However, conventional approaches to GSA suffer from (1) an ambiguous characterization of sensitivity, and (2) poor computational efficiency, particularly as the problem dimension grows. Here, we identify several important sensitivity-related characteristics of response surfaces that must be considered when investigating and interpreting the ''global sensitivity'' of a model response (e.g., a metric of model performance) to its parameters/factors. Accordingly, we present a new and general sensitivity and uncertainty analysis framework, Variogram Analysis of Response Surfaces (VARS), based on an analogy to 'variogram analysis', that characterizes a comprehensive spectrum of information on sensitivity. We prove, theoretically, that Morris (derivative-based) and Sobol (variance-based) methods and their extensions are special cases of VARS, and that their SA indices are contained within the VARS framework. We also present a practical strategy for the application of VARS to real-world problems, called STAR-VARS, including a new sampling strategy, called "star-based sampling". Our results across several case studies show the STAR-VARS approach to provide reliable and stable assessments of "global" sensitivity, while being at least 1-2 orders of magnitude more efficient than the benchmark Morris and Sobol approaches.

Keywords: Sensitivity analysis, Uncertainty analysis, Sobol, Morris, Variogram