A New Framework for Comprehensive, Robust, and Efficient Global Sensitivity Analysis

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Global sensitivity analysis (GSA) is a systems theoretic approach to characterizing the overall (average) sensitivity of one or more model responses across the factor space, by attributing the variability of those responses to different controlling (but uncertain) factors (e.g., model parameters, forcings, and boundary and initial conditions). GSA can be very helpful to improve the credibility and utility of Earth and Environmental System Models (EESMs), 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.

References:

Razavi, S., and Gupta, H. V., A new framework for comprehensive, robust, and efficient global sensitivity analysis: I. Theory, Water Resources Research, 51 (2016) doi:10.1002/2015WR017558.

Razavi, S., and Gupta, H. V., A new framework for comprehensive, robust, and efficient global sensitivity analysis: II. Application, Water Resources Research, 51 (2016) doi:10.1002/2015WR017559.

Razavi, S., and H. V. Gupta, What do we mean by sensitivity analysis? The need for comprehensive characterization of "global" sensitivity in Earth and Environmental systems models, Water Resources Research, 51, 3070–3092 (2015) doi:10.1002/2014WR016527.