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Understanding earth system models: how Global Sensitivity Analysis can help

Francesca Pianosi and Thorsten Wagener
University of Bristol, Department of Civil Engineering, Bristol, United Kingdom

Computer models are an essential element of earth system sciences, underpinning our understanding of systems functioning and influencing the planning and management of socio-economic-environmental systems. Even when these models represent a relatively low number of physical processes and variables, earth system models can exhibit a complicated behaviour because of the high level of interactions between their simulated variables. As the level of these interactions increases, we quickly lose the ability to anticipate and interpret the model's behaviour and hence the opportunity to check whether the model gives the right response for the right reasons. Moreover, even if internally consistent, an earth system model will always produce uncertain predictions because it is often forced by uncertain inputs (due to measurement errors, pre-processing uncertainties, scarcity of measurements, etc.). Lack of transparency about the scope of validity, limitations and the main sources of uncertainty of earth system models can be a strong limitation to their effective use for both scientific and decision-making purposes.

Global Sensitivity Analysis (GSA) is a set of statistical analysis techniques to investigate the complex behaviour of earth system models in a structured, transparent and comprehensive way. In this presentation, we will use a range of examples across earth system sciences (with a focus on hydrology) to demonstrate how GSA is a fundamental element in advancing the construction and use of earth system models, including: verifying the consistency of the model's behaviour with our conceptual understanding of the system functioning; identifying the main sources of output uncertainty so to focus efforts for uncertainty reduction; finding tipping points in forcing inputs that, if crossed, would bring the system to specific conditions we want to avoid.