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Rigorous Exploration of Complex Environmental Models to Advance Scientific Understanding

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Environmental models are central for advancing science by increasingly serving as a digital twin of the earth and its components. They allow us to conduct experiments to test hypotheses and understand dominant processes that are infeasible to do in the real world. To foster our knowledge, we build increasingly complex models hoping that they become more complete and realistic images of the real world. However, we believe that our scientific progress is slowed down as methods for the rigorous exploration of these models, in the face of unavoidable data- and epistemic-uncertainties, do not evolve in a similar manner.

Based on an extensive literature review, we show that even though methods for such rigorous exploration of model responses, e.g., global sensitivity analysis methods, are well established, there is an upper boundary to which level of model complexity they are applied today. Still, we claim that the potential for their utilization in a wider context is significant.

We argue here that a key issue to consider in this context is the framing of the sensitivity analysis problem. We show, using published examples, how problem framing defines the outcome of a sensitivity analysis in the context of scientific advancement. Without appropriate framing, sensitivity analysis of complex models reduces to a diagnostic analysis of the model, with only limited transferability of the conclusions to the real-world system.