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Consequences of the Hawkmoth Effect: Explicit subjective judgements about uncertain model-system relationships improve policy relevance of climate model output

E.L. Thompson and L.A. Smith

ABSTRACT

The Earth's climate is a complex many-dimensional dynamical system with feedbacks, nonlinearities, and long time scale internal variability. The Hawkmoth Effect is a description of structural instability in dynamical systems (sensitivity to the mathematical structure of a model), analogous to the manner in which the better-known Butterfly Effect describes dynamical instability (sensitivity to initial conditions). The Hawkmoth Effect can be paraphrased in the following way: "You can be arbitrarily close to the correct equations (model structure), but still not be close to the correct solutions (future trajectories)". Here we illustrate the possible consequences for model-based climate research, drawing together a number of observations about modelling, data assimilation, climate model calibration, and numerical solution of partial differential equations. We contrast and then synthesise this with the statistical/stochastic modelling viewpoint and the sophisticated Bayesian frameworks that have been proposed to interpret model output. We conclude that the primary uncertainties in long term climate projections may well be the implicit subjective assumptions that dynamical modelling is appropriate and adequate for the predictive task, and that the Hawkmoth Effect will not be experienced. Good Bayesian practice involves quantification of such prior assumptions. The likelihood that model runs are adequate for predictive purpose will vary with the space and time scales of the task, and is necessarily quantified outside the limitations of the modelling framework; thus, intermodel diversity alone may not be informative about the probability of adequacy, nor about the timescales on which this assumption may become invalid. Intuition based on the underlying physics of the situation is, fortunately, likely to be of use, and expert elicitation frameworks exist for quantifying such judgements. Acknowledging and explicitly incorporating these subjective probabilities into research output, as the IPCC have already begun to do, will continue to improve the internal consistency, relevance and usefulness of climate science as a support for policy and make it more robust to anti-scientific attack.

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