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Nonlinear sensitivity analysis for small model ensembles

Leonid Ivanov (1), Robin T. Tokmakian (2), Curtis A. Collins (2), and Tetyana Margolina (2)

(1) Moss Landing Marine Laboratories, Moss Landing, United States (lmivanov@nps.edu), (2) Naval Postgraduate School, Monterey, United States

A new technique for nonlinear sensitivity analysis of geophysical models for small size ensembles of model outputs has been developed. It utilizes probability weighted moments to reconstruct uni- and multi-modal distribution functions for model outputs and sensitivity metrics without hypothesis on smallness of perturbations inserted in the model. Sobol-Saltelli sensitivity indices and cumulative distribution functions if perturbations are random, and a Hartley-like measure if perturbations are represented in form of fuzzy sets (i.e. are non-random) were used as sensitivity metrics.

The general theory was generalized for the case when sub-ensembles produced by different numerical models had opposite features due to different solutions reproduced by different models. In this case nonlinear sensitivity analysis in small multi-modal ensembles was re-formulated as a multi-criteria problem with optimal solution on Paretto optimal.

Our calculations demonstrated that robust estimates of the sensitivity metrics are always possible for 50-100 term ensembles. Calculations were often successful for ensembles with 20-30 terms only. Uni-modal distributions can be also reconstructed for 8-20 term ensembles. Lorenz 63 model (a few degrees of freedom) and the ocean component of the Community Climate System Model (CCSM3) (several thousand degrees of freedom) are used to illustrate the sensitivity analysis based on the developed approach.