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A systematic approach to computer model evaluation, using a global aerosol model

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In this work a practical application of variance-based sensitivity analysis for model evaluation is presented. A global model of aerosol processes (GLOMAP) is used to illustrate how statistical methods can be used to better understand model behaviour and model diversity via a parametric sensitivity analysis. Complex models are commonly used in earth and environmental sciences and the current methods for constraining and reducing uncertainties in such models involve comparison to observational data. Here methods are proposed to better understand the computer model before introducing observational data and its associated uncertainties.
The first step to a parametric sensitivity analysis of a complex computer model is the construction of an experimental design giving model developers an opportunity to carefully consider all uncertain model parameters, often the first time since initial model development parameter uncertainties are reconsidered. The experiment is designed to explore model runs throughout the space of the uncertainty in the model parameters chosen by model developers. A Latin Hypercube design is chosen to investigate non-linear model behaviour that is undetected in the usual one-at-a-time model runs used to study uncertain parameter choices. Expert opinion is used to discount areas of the parameter uncertainty space and constrain the model at this early stage. An emulator is then used to carry out a parametric sensitivity analysis by estimating the model output throughout the uncertainty space conditional on the model output at the design points. A Gaussian process emulator is used here and the added uncertainty from using emulated output rather than GLOMAP output is quantified. The emulator is tested using verification data from additional GLOMAP runs. The full experiment has not yet been designed but the methods are illustrated here by following Spracklen (2005) in which a one-at-a-time sensitivity analysis was carried out. In this initial work the importance of considering the non-linear behaviour of the model is shown. The sensitivity analysis is shown to highlight the most important parameters causing uncertainty in the model output. The sensitivity of model output to each uncertain parameter depends upon the region, altitude and output of the study. It is clear which processes in the model need to be improved to reduce the uncertainty in model estimates. The full experiment will include more uncertain parameters but the methods will be applied as shown here.
The methods here will be applied across a range of global aerosol models to identify the important processes amongst models. The parameter sensitivities will be used to better understand why models produce diverse results when based on the same underlying physics: this will be done by focussing studies on the differences between the sensitive processes in different models. Model complexity will also be considered given information on parameter sensitivities. After individual models are better understood observation data can be introduced to the study and the sensitive parameters better constrained; this is not part of this initial work but is a wider aim of the project to reduce uncertainty and understand diversity in computer models.

Spracklen, D., Pringle, K., Carslaw, K., Chipperfield, M. and Mann, G. (2005). A global off-line model of size-resolved aerosol microphysics: II. Identification of key uncertainties, Atmos. Chem. Phys., 5: 3233–3250.