Statistics > Applications

Parameter Tuning for a Multi-Fidelity Dynamical Model of the Magnetosphere

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Geomagnetic storms play a critical role in space weather physics with the potential for far reaching economic impacts including power grid outages, air traffic re-routing, satellite damage and GPS disruption. The LFM-MIX is a state-of-the-art coupled magnetospheric-ionospheric model capable of simulating geomagnetic storms. Imbedded in this model are physical equations for turning the magnetohydrodynamic state parameters into energy and flux of electrons entering the ionosphere, involving a set of input parameters. The exact values of these input parameters in the model are unknown, and we seek to quantify the uncertainty about these parameters when model output is compared to observations. The model is available at different fidelities: a lower fidelity which is faster to run, and a higher fidelity but more computationally intense version. Model output and observational data are large spatio-temporal systems; the traditional design and analysis of computer experiments is unable to cope with such large datasets that involve multiple fidelities of model output. We develop an approach to this inverse problem for large spatio-temporal datasets that incorporates two different versions of the physical model. After an initial design, we propose a sequential design based on expected improvement. For the LFM-MIX, the additional run suggested by expected improvement diminishes posterior uncertainty by ruling out a posterior mode and shrinking the width of the posterior distribution. We also illustrate our approach using the Lorenz `96 system of equations for a simplified atmosphere, using known input parameters. For the Lorenz '96 system, after performing sequential runs based on expected improvement, the posterior mode converges to the true value and the posterior variability is reduced.

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