



The University of Chicago
Department of Statistics

SPECIAL STATISTICS COLLOQUIUM

LEONARD A. SMITH
London School of Economics

Real-World Challenges to Data Assimilation and Uncertainty Quantification in Big Nonlinear Models

TUESDAY, November 22, 2011, at 12:00 PM
110 Eckhart Hall, 5734 S. University Avenue

ABSTRACT

The use of nonlinear simulation models is becoming more and more common. Most operational modelling is for either a weather-like application or a climate-like application. Weather-like applications are data rich in the sense that the forecasts are made fairly often and thus a large forecast-verification archive is available, while in climate-like applications the operational lifetime of a model is often much less than the lead time of the forecast. Operational models tend to be big in the sense that they evolve in million+ dimensional state spaces; their underlying equations are nonlinear and the models are imperfect. This talk focuses on how to initialise such models (data assimilation) and how the choice of initialization method can impact the interpretation of the ensembles of simulations produced (uncertainty quantification). No prior knowledge either of nonlinear dynamics or operational forecasting is assumed.

Traditional ideas from the theory of nonlinear dynamical systems, specifically the notions of attractors, manifolds, effective exponential divergence and shadowing, will be introduced in the context of low-dimensional models. The role of (sets of) indistinguishable states in probabilistic forecasting of chaotic systems will also be presented. With this background, data assimilation in real-world models will then be considered. The relative strengths of the Ensemble Kalman Filter, 4-D Variational methods and a new method based on gradient descent in a sequence will be contrasted. The stated aim of data assimilation in operational models will be shown to be at best murky, due to the mixture of observational uncertainty and model inadequacy. A measure of information content for modern weather and seasonal forecasts will be introduced, but for climate model forecasts the information content remains unclear. A major challenge in both contexts is to identify the lead times at which these forecasts become misinformative and then communicate this to decision makers.

The central aims of the talk are to present a new approach to data assimilation and thereby motivate wider consideration of nonlinear dynamics throughout operational modelling.

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