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On closure parameter estimation in chaotic systems

A. Solonen (1), J. Hakkarainen (2), A. Ilin (3), M. Laine (2), H. Haario (1), J. Tamminen (2), E. Oja (3), and H. Järvinen (2)

(1) Lappeenranta University of Technology, Department of Mathematics and Physics, Finland, (2) Finnish Meteorological Institute, Helsinki, Finland, (3) Aalto University, Helsinki, Finland

Many multi-scale dynamical models, such as numerical weather prediction (NWP) and climate models, contain so called closure parameters. These parameters usually appear in physical parameterizations of sub-grid scale processes, and they act as 'tuning handles' of the models. Currently, the values of these parameters are specified mostly manually, but the increasing complexity of the models calls for more algorithmic ways to perform the tuning. Traditionally, parameters of dynamical systems are estimated by directly comparing the model simulations to observed data using, for instance, a least squares type of approach. However, if the models are chaotic, the classical approach can be ineffective, since small errors in the initial conditions can lead to large, unpredictable deviations from the observations. In this presentation, three techniques for closure parameter estimation in chaotic systems are discussed: the summary statistics approach, off-line likelihood calculations using filtering methods and the state augmentation method.

The properties of the methods are studied using a stochastic version of the Lorenz 95 system. Our results indicate that the summary statistics approach, albeit relatively easy to implement and compute, can have problems in properly identifying the parameters, and may lead to biased estimates. The state augmentation approach can work well and converge fast, if properly tuned. A downside of the approach is that the 'static' model parameters are modeled as dynamical quantities, the parameter estimates change at every time step. The filter likelihood approach performed well in our tests. However, it may be computationally challenging to scale the method up to large scale NWP and climate models.