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Variational Bayesian methods in data assimilation.

D. Cornford (1), M. Opper (2) and I. Roulstone (3)

(1) SEAS, Aston University (d.cornford@aston.ac.uk), (2) ECS, Southampton University (mo@ecs.soton.ac.uk), (3) SEPS, University of Surrey (I.Roulstone@surrey.ac.uk)

Current research in data assimilation is largely focussed on two related methods, 4D VAR and the ensemble Kalman filter. In this paper we define a new method, based on a variational Bayesian methods. In the Variational Inference for Stochastic Dynamic Environmental Models (VISDEM) project we are developing a novel approach to performing fully probabilistic data assimilation for realistically sized problems. 4D VAR simplifies the data assimilation problem to that of seeking an (approximate) maximum a-posteriori probability estimate of the state, given the observations and the model. This point estimate of the state thus loses any probabilistic information. The ensemble Kalman filter approximates the state probability distribution using a very small number of samples. The small number of samples (with respect to the dimension of the state vector) works when the model is largely linear (as does the incremental version of 4D VAR) but will suffer from sampling introduced errors in other cases. In our work we introduce an approximation widely used in the machine learning community, based on relative entropy, or Kullback-Leibler distance, often referred to as variational Bayesian inference. The key idea is to approximate the true posterior distribution of the state given the observations, P, by some parameterised approximation, Q. While we cannot evaluate P directly, we can minimise the KL distance between P and Q, by adjusting the parameters in Q. In this way we seek the Q that best (in the relative entropy sense) fits the true posterior P. In this talk we describe the application of the method to the case where Q is a constrained space-time Gaussian process, with compact spatial support and describe how this renders the problem computationally tractable. We discuss the benefits of the VISDEM approach and show how this can be used to estimate hyper-parameters in the model, such as parameters within the unknown stochastic forcing. In this work we treat the model as being stochastic from inception, and pay careful attention to error processes. Thus we could also be seen as defining a novel method for solving the Fokker-Planck equation for the model state.