Geophysical Research Abstracts
Vol. 18, EGU2016-12664, 2016
EGU General Assembly 2016

Exploring synchronisation in nonlinear data assimilation

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Present-day data assimilation methods are based on linearizations and face serious problems in strongly nonlinear cases such as convection. A promising solution to this problem is a particle filter, which provides a representation of the model probability density function (pdf) by a discrete set of model states, or particles. The basic particle filter uses Bayes's theorem directly, but does not work in high-dimensional cases. The performance can be improved by considering the proposal density freedom. This allows one to change the model equations to bring the particles closer to the observations, resulting in very efficient update schemes at observation times, but extending these schemes between observation times is computationally expensive. Simple solutions like nudging have been shown to be not powerful enough.

A potential solution might be synchronization, in which one tries to synchronise the model of a system with the true evolution of the system via the observations. In practice this means that an extra term is added to the model equations that hampers growth of instabilities on the synchronization manifold. Especially the delayed versions, where observations are allowed to influence the state in the past have shown some remarkable successes. Unfortunately, all efforts ignore errors in the observations, and as soon as these are introduced the performance degrades considerably.

There is a close connection between time-delayed synchronization and a Kalman Smoother, which does allow for observational (and other) errors. In this presentation we will explore this connection to the full, with a view to extend synchronization to more realistic settings. Specifically performance of the spread of information from observed to unobserved variables is studied in detail. The results indicate that this extended synchronisation is a promising tool to steer the model states towards the observations efficiently. If time permits, we will show initial results of embedding the new synchronization method into a particle filter.