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Nonlinear data assimilation using synchronization in a particle filter

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Current data assimilation methods still face problems in strongly nonlinear cases. A promising solution is a particle filter, which provides a representation of the model probability density function by a discrete set of particles. However, the basic particle filter does not work in high-dimensional cases. The performance can be improved by considering the proposal density freedom. A potential choice of proposal density might come from the synchronisation theory, in which one tries to synchronise the model with the true evolution of a system using one-way coupling via the observations. In practice, an extra term is added to the model equations that damps growth of instabilities on the synchronisation manifold. When only part of the system is observed synchronization can be achieved via a time embedding, similar to smoothers in data assimilation.

In this work, two new ideas are tested. First, ensemble-based time embedding, similar to an ensemble smoother or 4DEnsVar is used on each particle, avoiding the need for tangent-linear models and adjoint calculations. Tests were performed using Lorenz96 model for 20, 100 and 1000-dimension systems. Results show state-averaged synchronisation errors smaller than observation errors even in partly observed systems, suggesting that the scheme is a promising tool to steer model states to the truth. Next, we combine these efficient particles using an extension of the Implicit Equal-Weights Particle Filter, a particle filter that ensures equal weights for all particles, avoiding filter degeneracy by construction. Promising results will be shown on low- and high-dimensional Lorenz96 models, and the pros and cons of these new ideas will be discussed.