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A two-step particle Smoother for large-scale Problems

P.J. van Leeuwen

IMAU, Utrecht University, Princetonplein 5, 3584 CC Utrecht, Netherlands
(p.j.vanleeuwen@phys.uu.nl)

A problem with filters in general is that the solution is discontinues at observations. Fixed-interval and fixed-lag smoothers, like 4D-VAR, do not have this problem in the smoother interval (although they do have the same problem at the the end points of the time interval). However, these smoothers usually make use of the adjoint of the forward model, which is difficult to construct, and, since the adjoint is a linear operator, requires a linearization of the problem which might hamper convergence. Particle methods do not need linearizations, but particle smoothers needs a prohibitively large number of particles to prevent collapse of the particle ensemble. A way to strongly reduce the ensemble size is to do local updating of the particle filter, i.e. a different weighting is applied in different areas of the computational domain. Disadvantage is the need to 'glue' different particles together to obtain particles that are close to the observations in all areas of the domain. And the solution is still discontinues at the observation time.

A new method is presented in which a smooth solution in time is obtained while at the same time the efficiency gain by local updating is incorporated. It is a two-step procedure in which first the particle filter with local updating is constructed, using random forcing of the model between observations. Then the local weights are used to weight the random forcings locally between the observation times. In this way a set of random forcings is obtained that tend to lead the particles close to the observations in all areas of the domain. By ensuring that the generation procedure of the random forcing is repeatable, no random forcing fields have to be stored.

A disadvantage of the method is that the ensemble of particles has to be run twice. Advantages are that the local weighting ensures that the particles are efficient, reducing the size of the ensemble, and in this method balances are not distroyed. In fact, the only approximation made with regard to the general nonlinear smoother is in the ensemble size, and adjoint integrations are not needed.

The feasibility of the method is illustrated using a large-scale multi-layer primitive equation model of the ocean in which highly nonlinear areas are present.