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Estimating the full posterior pdf with particle filters

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The majority of data assimilation schemes rely on linearity assumptions. However as the resolution and complexity of both the numerical models and observations increases, these linearity assumptions become less appropriate. A need is arising for fully non-linear data assimilation schemes, such as particle filters. Recently, new particle filter schemes have been generated that explore the freedom in proposal densities and that are quite effective in estimating the mean of the posterior probability density function (pdf), even in very high dimensional systems. However, in non-linear data assimilation the solution to the data assimilation problem is the full posterior pdf. At the same time we can only afford a limited number of particles. Here we concentrate on the equivalent weights particle filter in conjunction with a 65,000 dimensional Barotropic Vorticity model. Specifically we test the ability of the scheme to represent the posterior in three important areas.

In many actual geophysical applications, observations will be sparse and may well be unevenly distributed. We discuss the effect of changing the frequency, number and distribution of the observed variables on the ensemble representation of the posterior pdf. Specifically we show that the filter has remarkably good convergence in marginal and joint pdfs with ensemble size, and the rank histograms are quite flat, even with low observation numbers and low observation frequencies. Only when the observation frequency is much larger than the typical decorrelation time scale of the system do we see underdispersive ensembles when using 32 particles.

The second area attempts to replicate the realistic situation of using a geophysical model designed without a full understanding of the error statistics of the truth. This is done by using deliberately erroneous error statistics in the ensemble equations compared to those used to generate the truth. Specifically we consider changes in the correlation length-scales and variances in the model error statistics. Again the filter is remarkably successful in generating correct posterior pdfs, although rank histograms tend to point to under- or overdispersive ensembles. One of the interesting results is that when we overestimate the model error amplitude the ensemble is underdispersive. We present an explanation for this counter-intuitive phenomenon.

Finally we show that the computational effort involved in the equivalent-weights particle filter is comparable to running a simple resampling particle filter with the same number of particles.