

Particle Filters for Numerical Weather Forecasting

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With ever increasing model resolution, complexity of physical parameterisations, and complexity of observation operators the data-assimilation problem becomes more and more nonlinear. Traditional data-assimilation methods like 4DVar and Ensemble Kalman Filters rely on Gaussian assumptions for the prior that are often not justifiable. Modern extensions to hybrid formulations do not solve this problem. Fully nonlinear data-assimilation methods are available, but typically prohibitively expensive in high-dimensional settings. Perhaps most promising are particle filters, although the so-called ‘curse of dimensionality’ leads to degenerate filters and has hampered their use in the geosciences [1,2].

Recently a breakthrough in efficient particle filters [3, see also e.g. 4] has led to successful applications in systems of dimensions up to 65,000 [5]. Moreover, the formulation is such that degeneracy will not occur by construction, removing one of the barriers of widespread application of particle filters in the geosciences.

In this paper I will discuss what needs to be done to make particle filters useful for the real job, numerical weather forecasting, based on experience implementations in large-scale ocean models, coastal ocean models, and climate models. For instance, the importance of allowing for errors in the model equations (they are present and substantial, after all), and how to implement them will be discussed. Also, the practical advantages of using particle filters will be addressed. Specifically the fact that the quality of the initialization does not depend on the quality of the error covariances of the model state will be highlighted. This point should not be underestimated. Tens (hundreds?) of man/woman years have gone into developing accurate and efficient coding of the background error covariance in 4DVar. Ensemble Kalman filters rely on estimates of state covariances from a relatively small ensemble, and suffer from ad hoc modifications such as localization and inflation. Particle filters do not have this problem, and activity can be redirected to where it is most badly needed, the model errors. This would have the additional advantage of making data-assimilation a much more useful tool for model improvement.

References

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