Nested particle filter algorithm for data assimilation in parallel computing systems

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The particle filter (PF) is an ensemble-based algorithm which is applicable to general data assimilation problems with nonlinear dynamical system models. The PF is a rather simple algorithm which provides an approximation of a posterior probability density function by resampling a forecast ensemble. However, the PF requires a large ensemble size in order to achieve sufficient accuracy of the estimation especially for high-dimensional models. This means that we need to run a simulation model extraordinarily many times. Parallel computing offers one potential solution which could enable us to use the sufficiently large ensemble size.

When we implement the PF in a parallel computing system, especially in a distributed computing system consisting of multiple nodes, one major problem is that resampling procedures requires much network traffic between nodes. This network traffic could be crucial especially when we use high-dimensional models. In this study, we assume that internal traffics in each node are much faster than inter-node traffics. Then, we consider a bi-level scheme which reduces inter-node network traffics. In this scheme, resampling procedures are performed locally in each node and inter-node communications are considered separately. An ensemble subset assigned to each node offers an approximation of a probability density function with a smaller ensemble size. If we assign a weight to each node according to an average of likelihoods in members of the ensemble subset, the whole ensemble also offers an approximation of a probability density function as a whole. Inter-node communications are determined by comparing the weights among the multiple nodes. We performed some experiments in which this bi-level scheme was applied to the 40-dimensional Lorenz 96 model. We then discuss the efficiency of this scheme in comparison with the normal scheme.