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Joint State and Parameter Estimation in Sequential Data Assimilation with Ensemble Kalman Filter and Meta-Model

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Two methods have become popular to jointly update states and parameters with Ensemble Kalman Filter (EnKF). In these methods, uncertainties with respect to the model states and parameters can be treated simultaneously. The two methods are: (1) SODA (Simultaneous Optimization and Data Assimilation), in which EnKF is combined with an optimization algorithm to update the model states and parameters separately; (2) Dual state parameter estimation (Dual), in which the model state vector of EnKF is augmented to include both model states and parameters in a new vector, which is updated during the assimilation. Because the SODA method is very CPU-intensive (especially for distributed models), it has not been applied widely. The Dual method has become a popular approach in recent applications. However, the disadvantage of the Dual method is that the model results are very sensitive to the sampling procedure of the high-dimensional parameter space and that the methodology performs only optimally for Gaussian distributions. Therefore, there is still potential to improve the joint state and parameter estimation with EnKF.

Here, a new efficient joint estimation method is proposed. The method consists of two steps: (1) State update: EnKF is used to assimilate the observations and update the model states vector; (2) Parameter update: a quadratic response surface regression method is used to fit a meta-model which describes the relationship between the model parameter ensemble members and the innovation vector of the EnKF. In addition, new model parameter ensemble members are generated and used as input to this meta-model to predict the new innovation vector. Finally the parameters which minimize the innovation vector are chosen as the updated parameters at the current time step. These two steps are carried out sequentially according to the availability of observation data.

The advantage of this new method is that a high dimensional parameter distribution space can be treated efficiently using the mean-model. This ensures the traversal of potential model parameter values and quick convergence. The Lorenz63 model was used to evaluate the new proposed joint estimation method. The results showed that the three model parameters could converge to the true parameter values in 700 model steps and the joint state and parameter estimation performed very well with this method.