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Assimilation of Nonlinear Observations with the Maximum Likelihood Ensemble Filter

Saori Nakashita[1] and Takeshi Enomoto[2,3]
[1]Graduate School of Science, Kyoto University, Kyoto, Japan (nakashita@dpac.dpri.kyoto-u.ac.jp)
[2]Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto, Japan
[3]Japan Agency for Marine-Earth Science and Technology, Yokohama, Kanagawa, Japan

Satellite observations have been a growing source for data assimilation in the operational numerical weather prediction. Remotely sensed observations require a nonlinear observation operator. Most ensemble-based data assimilation methods are formulated for tangent linear observation operators, which are often substituted by nonlinear observation operators. By contrast, the Maximum Likelihood Ensemble Filter (MLEF), which has features of both variational and ensemble approaches, is formulated for linear and nonlinear operators in an identical form and can use non-differentiable observation operators.

In this study, we investigate the performance of MLEF and Ensemble Transform Kalman Filter (ETKF) with the tangent linear and nonlinear observation operators in assimilation experiments of nonlinear observations with a one-dimensional Burgers model.

The ETKF analysis with the nonlinear operator diverges when the observation error is small due to unrealistically large increments associated with the high order observation terms. The filter divergence can be avoided by localization of the extent of observation influence, but the analysis error is still larger than that of MLEF. In contrast, MLEF is found to be more stable and accurate without localization owing to the minimization of the cost function. Notably, MLEF can make an accurate analysis solution even without covariance inflation, eliminating the labor of parameter adjustment. In addition, the smaller observation error is, or the stronger observation nonlinearity is, MLEF with the nonlinear operators can assimilate observations more effectively than MLEF with the tangent linear operators. This result indicates that MLEF can incorporate nonlinear effects and evaluate the observation term in the cost function appropriately. These encouraging results imply that MLEF is suitable for assimilation of satellite observations with high nonlinearity.