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A Bayesian approach for estimating stable observation noise covariance

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We present a technique for optimizing covariance matrices for observation noise. The method of maximum likelihood has been widely used for the optimization under the assumption of linear system, but can be also extended even when the system is nonlinear (Ueno et al., 2010). Ueno et al. (2010) proposed a method of ensemble-based maximum likelihood, where the likelihood is approximated with the ensemble, and demonstrated that the method can estimate the parameters that describe the covariance for system noise and observation noise. Their procedure of maximizing the likelihood, however, requires huge computational costs; it requires assimilation runs many times that amount to the total number of combinations of the parameters. It means that the method of ensemble-based maximum likelihood may not work in practice where tens or more covariance parameters need to be optimized.

To overcome the difficulty, Ueno (2011) proposed an ef[U+FB01]cient algorithm for the maximum likelihood estimation of the observation noise covariance. The algorithm is based on the derivative of the ensemble-approximated likelihood with respect to the observation noise covariance, and forms an iterative updating procedure for estimating the optimal covariance parameters. The algorithm works with the ensemble-based [U+FB01]lters (such as EnKF and PF) in which the likelihood can be approximated with the ensemble. Since the algorithm does not require evaluating likelihood for every combination of the covariance parameters as done in Ueno et al. (2010), it can estimate many elements in the observation noise covariance matrix.

The method of Ueno (2011) is, however, constructed under the assumption that the observation noise covariance is independent between different observation times. This assumption may produce covariance that varies significantly with time, which is undesirable in some cases. To estimate covariance that stable with time, we extend the method by introducing prior information on the covariance to carry out a Bayesian estimation of the observation noise covariance, and construct another iterative algorithm.