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Maximum likelihood estimation of error covariances in ensemble-based filters and its application to a coupled atmosphere-ocean model

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We propose a method for estimating optimal error covariances in the context of sequential assimilation, including the case where both the system equation and the observation equation are nonlinear. When the system equation is nonlinear, ensemble-based filtering methods such as the ensemble Kalman filter (EnKF) are widely used to deal directly with the nonlinearity. The present approach for covariance optimization is a maximum likelihood estimation carried out by approximating the likelihood with the ensemble mean. Specifically, the likelihood is approximated as the sample mean of the likelihood of each member of the ensemble. To evaluate the sampling error of the proposed ensemble-approximated likelihood, we construct a method for examining the statistical significance using the bootstrap method without extra ensemble computation. We apply the proposed methods to an EnKF experiment where TOPEX/POSEIDON altimetry observations are assimilated into an intermediate coupled model, which is nonlinear, and estimate the optimal parameters that specify the covariances of the system noise and observation noise.