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Multivariate Ensemble Sensitivity with Localization

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So far in the literature, covariance localization (tapering) has not been applied when performing ensemble sensitivity analysis. Sampling error in computing the sensitivities via lagged covariances leads to an over-estimation of the impact of a perturbation. Most commonly when computing sensitivities, the analysis covariance is approximated with the corresponding diagonal matrix. Two consequences follow: (1) the multi-variate sensitivity is approximated by a univariate sensitivity, and (2) sampling error in off-diagonal elements are obviated. It is unknown, however, how much information is lost by ignoring the off-diagonal elements in the full covariance. When forecasts depend on many details of the previous analysis, it is reasonable to expect that the diagonal approximation is too severe.

The purpose of this presentation is to clarify the effects of the diagonal approximation, and investigate the need for localization when off-diagonal elements are considered. Motivated by examples arising from sensitivities estimated within a cycling mesoscale ensemble data assimilation system, for easier interpretation we turn to the two-scale model first presented by Lorenz in 2005. We show that for most problems, an efficient matrix inversion is possible by finding a minimum-norm solution, and employing appropriate matrix factorization. Comparing the full inversion with off-diagonal elements, the fine-scale sensitivity estimates can be substantially different from those arising when the diagonal approximation is used. Localization on the sensitivity can be handled by an off-line empirical or Bayesian estimation technique. Because the sensitivity estimated from the full inversion is subject to sampling error, it is sensitive to the localization. The results show that compared to typical practices, more complete ensemble sensitivity formulations may be needed to draw robust inferences in general.