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Data assimilation approaches with iterative ensemble smoothers in coupled nonlinear multiscale models

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Iterative ensemble smoothers, originally developed for parameter estimation in petroleum applications, are effective data assimilation methods in coupled, unstable dynamical systems. In this study, we demonstrate this using a coupled multiscale model based on two Kuramoto-Sivashinsky equations with different spatial and temporal scales, representing two subsystems of an earth-system model. The cross-covariance between the variables of the two subsystems reflects how each subsystem influences the other, leading to unexpected structures that reveal interesting physics of the coupled system. The setup of the data assimilation allows simultaneous updating of both systems, leading to consistent estimates.

A comparative study illustrates the properties of iterative ensemble smoothers and assimilation updates over finite-length assimilation windows. We demonstrate the increased accuracy of the smoothers' solution compared to that of the standard ensemble Kalman filter and the fast convergence of the iterations related to the efficient handling of nonlinearities by the nonlinear space-time ensemble.

Localisation, whether distance-based or adapted to spatial correlations, can be used in iterative ensemble smoothers to effectively deal with limited ensemble sizes. We discuss the effects of the spatial distribution and temporal frequency of available observations and illustrate how data gaps in one of the two subsystems affect the coupled estimate. Looking forward, we present the possibilities and benefits of a potential implementation of this approach in coupled earth-system models.