Higher Order Ensemble Kalman Filtering

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In data assimilation, as in solving more general inverse problems, a key decision is how to represent the prior and posterior distributions. Methods such as the Kalman filter, extended Kalman filter, and variational filters work with a parametric family of distributions, whereas particle filters represent the distribution non-parametrically with a weighted set of representative samples. Ensemble transform methods such as the ensemble Kalman filter (EnKF), try to find a middle ground between the parametric and nonparametric extremes by using an ensemble of particles that is optimally chosen based on a parametric family. For example, the Unscented Kalman Filter (UKF) chooses optimal cubature nodes for a Gaussian approximation to the distribution. This can also be shown to be the maximum entropy approximation which matches the first two moments of the distribution. In this talk we generalize this approach to higher moments, (e.g. skewness, kurtosis, etc.) using a novel computationally feasible approximation to the CANDECOMP/PARAFAC (CP) tensor decomposition. This allows us to represent a distribution using a small ensemble of particles that capture the first four moments of the distribution (and generalizes to higher moments). Using rigorous error bounds, we can show weak convergence to the true distribution in the limit as the number of moments tends to infinity, a convergence result analogous to those of particle methods which take a limit as the number of particles tends to infinity. Finally, motivated by our higher order ensemble transform, we derive a higher order generalization of the Kalman equations based on a maximal entropy closure, generalizing the classical approach to these higher moments.

Joint work with Deanna Easley.