A General Ensemble Filtering Framework Using Quantiles

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Abstract

Ensemble Kalman filters are commonly used for data assimilation for numerical weather prediction and climate applications. These methods fit a normal distribution to the prior ensemble estimate and use Bayes' rule with a normal likelihood to generate a sample from a normal posterior. A novel efficient algorithm that allows use of arbitrary continuous priors and likelihoods is presented. The key innovation is to select posterior ensemble members with the same quantiles with respect to the continuous posterior distribution as the prior ensemble had with respect to the prior continuous distribution. This is a generalization of previously documented square root ensemble Kalman filters for normal distributions. It also generalizes non-parametric ensemble filters such as the rank histogram filter. Examples using continuous priors that are gamma, inverse gamma, beta and a sum of normal kernels are presented. These examples are useful for physical variables that are bounded on one or both sides such as the concentration of a pollutant, relative humidity, or fractional sea ice coverage. They are also useful for variables that have multimodal or other non-normal distributions. The method can be extended to directly estimate the marginal distributions of state variables, mostly eliminating the linear constraints imposed by traditional ensemble methods that use a Kalman gain (regression).

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