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Ensemble Kalman filtering in presence of inequality constraints

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Kalman filtering is presence of constraints is an active area of research. Based on the Gaussian assumption for the probability-density functions, it looks hard to bring in extra constraints in the formalism. On the other hand, in geophysical systems we often encounter constraints related to e.g. the underlying physics or chemistry, which are violated by the Gaussian assumption. For instance, concentrations are always non-negative, model layers have non-negative thickness, and sea-ice concentration is between 0 and 1. Several methods to bring inequality constraints into the Kalman-filter formalism have been proposed. One of them is probability density function (pdf) truncation, in which the Gaussian mass from the non-allowed part of the variables is just equally distributed over the pdf where the variables are alolwed, as proposed by Shimada et al. 1998. However, a problem with this method is that the probability that e.g. the sea-ice concentration is zero, is zero!

The new method proposed here does not have this drawback. It assumes that the probability-density function is a truncated Gaussian, but the truncated mass is not distributed equally over all allowed values of the variables, but put into a delta distribution at the truncation point. This delta distribution can easily be handled with in Bayes theorem, leading to posterior probability density functions that are also truncated Gaussians with delta distributions at the truncation location. In this way a much better representation of the system is obtained, while still keeping most of the benefits of the Kalman-filter formalism. In the full Kalman filter the formalism is prohibitively expensive in large-scale systems, but efficient implementation is possible in ensemble variants of the kalman filter. Applications to low-dimensional systems and large-scale systems will be discussed.