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Score matching filters

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A widely popular group of data assimilation methods in meteorological and geophysical sciences is formed by filters based on Monte-Carlo approximation of the traditional Kalman filter, e.g. E nsemble Kalman filter (EnKF), Ensemble square-root filter and others. Due to the computational cost, ensemble size is usually small compared to the dimension of the state vector. Traditional EnKF implicitly uses the sample covariance which is a poor estimate of the background covariance matrix - singular and contaminated by spurious correlations.

We focus on modelling the background covariance matrix by means of a linear model for its inverse. This is particularly useful in Gauss-Markov random fields (GMRF), where the inverse covariance matrix has a banded structure. The parameters of the model are estimated by the score matching method which provides estimators in a closed form, cheap to compute. The resulting estimate is a key component of the proposed ensemble filtering algorithms. Under the assumption that the state vector is a GMRF in every time-step, the Score matching filter with Gaussian resampling (SMF-GR) gives in every time-step a consistent (in the large ensemble limit) estimator of mean and covariance matrix of the forecast and analysis distribution. Further, we propose a filtering method called Score matching ensemble filter (SMEF), based on regularization of the EnKF. This filter performs well even for non-Gaussian systems with non-linear dynamics. The performance of both filters is illustrated on a simple linear convection model and Lorenz-96.