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A 4D-Localized Particle Filter Method for Regional Data Assimilation at DWD

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Nonlinear ensemble data assimilation methods like particle filters aim to improve the numerical weather prediction and the uncertainty quantification in a non-Gaussian setting. The localized adaptive particle filter (LAPF), introduced by R. Potthast, A. Walter and A. Rhodin in 2019, overcomes filter collapse in a high-dimensional framework. This particle filter was further developed by Walter et al. (2021) to the local mixture coefficients particle filter (LMCPF) which was tested within the global ICON model. In the LMCPF method the background distribution is approximated by Gaussian mixtures. After a classical resampling step, Bayes' formula is carried out explicitly under the assumption of a Gaussian distributed observation error. Furthermore, the particle uncertainty can be adjusted which affects the strength of the shift of the particles toward the observation. Lastly, Gaussian resampling is employed to increase the ensemble variability. All steps are carried out in ensemble space and observation localization is applied in the method.

Following a study of Kotsuki et al. (2021), we recently substituted the approximated particle weights in the LMCPF method with the exact Gaussian mixture weights which leads to an increase of the effective ensemble. Using the exact weights, Kotsuki et al. (2021) detected an improvement of the stability of the LMCPF method with respect to the inflation parameters within the SPEEDY model.

Furthermore, we explore the potential of the LMCPF with the exact particle weights in the kilometre-scale ensemble data assimilation (KENDA) system with the limited area mode of the ICON model (ICON-LAM) and compare the particle filter method to the localized ensemble transform Kalman filter (LETKF) which is operationally used at the German Meteorological Service (DWD). Both methods describe four-dimensional data assimilation schemes if the observation operators are applied during the model forward integration at the exact observation times and not only at analysis time. This leads to four-dimensional background error covariance matrices at times and locations of the observations which are employed to derive the analysis ensemble.

In addition to a mathematical introduction of the LMCPF method, we present experimental results for the LMCPF in comparison with the LETKF method in KENDA used at DWD for the ICON-LAM model. Moreover, we discover the improvements of the LMCPF with exact particle weights over the method with approximated weights.