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Application of mass and positivity constraint for radar data assimilation with a localized ensemble transform Kalman filter

Tijana Janjic and Heiner Lange
Hans Ertel Centre for Weather Research, DWD, Munich (Tijana.Janjic-Pfander@dwd.de)

Data assimilation on convective scales needs to capture fast changing processes and many scales of motion that are resolved in high resolution models. Therefore, it is beneficial for the data assimilation algorithm to have time evolving error covariances as represented through an ensemble. Results from previous studies show that Ensemble Kalman Filter (EnKF) techniques can be applied for the convective scale data assimilation, in both real data experiments (Dowell et al. 2004) as well as in observing system simulation experiments (e.g. Snyder and Zhang 2003; Zhang et al. 2004). Observations such as radar reflectivity or cloud products are important for prediction on these scales, but difficult to assimilate with the EnKF due to background errors which are non-Gaussian in nature. To deal with the non-Gaussianity in an EnKF framework, we propose the use of physically based constraints in the analysis step to weakly constrain the solution and therefore change the analysis error statistics.

We suggest modifications to the localized ensemble transform Kalman filter (LETKF) in order to approximately preserve two a priori chosen physical properties of positivity and total mass. The benefit on prediction is illustrated in an idealized setup (Lange and Craig, 2013). This setup uses the non-hydrostatic COSMO model with a 2 km horizontal resolution, and the LETKF as implemented in KENDA (Km-scale Ensemble Data Assimilation) system of German Weather Service (Reich et al. 2011). Random perturbations of temperature and vertical wind in statically unstable conditions initiate convective systems with lifetimes over six hours. Simulated observations of radar data are drawn from a true run and are assimilated with the LETKF in order to analyze the location and intensity of the storms in the ensemble members. Due to the Gaussian assumptions that underline the LETKF algorithm, the analyses of water species will become negative in some grid points of the COSMO model. These values are set to zero currently in KENDA after the LETKF analysis step, in order not to give the numerical model unphysical values. The tests done within this setup show that such a procedure introduces a wet bias in the analysis ensemble with respect to the true, that increases in time due to the cycled data assimilation. As will be shown, weak constraints on mass and positivity alleviate the problem.