# Nonlinear data assimilation with 4DEnVar using iterative weather forecast model

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En4DVar and 4DEnVar are two popular ensemble-based variational data assimilation methods for the numerical weather prediction. Although the ensemble-based forecast error covariance can be reflected in the analyses of both methods, En4DVar calculates the gradient of the cost function with the adjoint of tangent linear forecast model, which requires large development and computational costs. Such costs are generally not required in 4DEnVar because 4DEnVar does not use the tangent linear forecast model. However, 4DEnVar analyses are generally worse than those of adjoint-based En4DVar probably because 4DEnVar does not iteratively calculate the nonlinear forecast model. In this study, therefore, we developed 4DEnVar with iterative nonlinear forecast model (hereafter, 4DEnVar-IF). In 4DEnVar-IF, the nonlinear forecast model is iteratively calculated to gain the non-quadratic cost function and its gradient in each iteration. The 4DEnVar-IF applied to the Lorenz63 model showed that the 4DEnVar-IF analysis can be better than those of En4DVar and general 4DEnVar when nonlinearity is strong and ensemble perturbations are appropriate. Moreover, we also applied 4DEnVar-IF to JMA nonhydrostatic model-based 4DVar data assimilation (JNoVA) system. The single-observation assimilation experiments with JNoVA showed that 4DEnVar-IF can make the cost function smaller than En4DVar when the assimilated observation has the strong nonlinearity as like potential temperature associated with cloud microphysics. In the assimilation experiment of multiple real observations with 4DEnVar-IF of the small localization scale, however, the minimization of the cost function was not sufficiently succeeded. As a next step, we will develop the localization and hybrid of forecast error covariance matrix.

Keywords: data assimilation, ensemble forecast, nonlinear, 4DEnVar