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An Ensemble-based Weak-constraint 4DVar

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The perfect model assumption in the strong-constraint four-dimensional variational data assimilation (4DVar) method potentially limits its further application. It is necessary that weak constraint (imperfect model assumption) 4DVar algorithms will be required to properly combine the background forecast with high resolution observations in longer data assimilation windows. On the other hand, the 4DVar still faces numerous challenges in coding, maintaining and updating the adjoint or tangent linear model of the forecast model. A new ensemble-based weak-constraint 4DVar (referred to as EnWC4DVar) method is proposed to account for and estimate model error by taking the four-dimensional (4D) state as the control variable and calculating the covariances of the background error from the 4D ensemble forecasts. Its computational costs are further reduced significantly through ensemble reconstructing by the proper orthogonal decomposition technique. The adjoint model is also avoided in this new approach. Moreover, it doesn't need a linear approximation in the forward model and observation operator. Assimilation experiments in soil moisture assimilation show this new approach moderately outperforms another ensemble-based strong-constraint 4DVar (referred to as EnSC4DVar) method with assimilation errors and computational costs can be reduced only a fraction of the latter. Another assimilation experiment using the Lorenz model shows that it performs almost same as the EnSC4DVar if the model is perfect.