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Treatment of Nonlinearity in An Observation Space 4D-Var System

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In variational data assimilation, the generally smooth nonlinearity of large scale atmospheric processes is usually handled by iterative processes (using the so called outer loops), where sequences of linearized least-squares problems (linearized around a basic state) converge to the non-linear one. There are two minimization algorithms that are typically used in atmospheric community, namely the model space based algorithm and the observation space based algorithm, to find the solution respectively. Although they are mathematical equivalent to each other, the two algorithms can be quite different in implementation. The duality of the two algorithms can be found in Courtier (1997). The use of additional outer loops to treat the nonlinearity in the data assimilation system has been proven to be beneficial in the model space 4D-Var systems. However, there is very little research that shows the impact of the additional outer loops on the performance of the observation space based 4D-Var. In this study, we will first present two strategies to treat the nonlinearity in NAVDAS-AR (NRL Atmospheric Variational Data Assimilation System - Accelerated Representer), an observation space based operational 4D-Var system. We will then show the impact of additional outer loops on the analysis and forecasts. We will also discuss the issue of using additional outer loops in the weak constraint 4D-Var.