Geophysical Research Abstracts
Vol. 15, EGU2013-4528, 2013
EGU General Assembly 2013

Comparative test on several forms of background error covariance in 3DVar

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The background error covariance matrix (Hereinafter referred to as B matrix) plays an important role in the three-dimensional variational (3DVar) data assimilation method. However, it is difficult to get B matrix accurately because true atmospheric state is unknown. Therefore, some methods were developed to estimate B matrix (e.g. NMC method, innovation analysis method, recursive filters, and ensemble method such as EnKF). Prior to further development and application of these methods, the function of several B matrixes estimated by these methods in 3Dvar is worth studying and evaluating.
For this reason, NCEP reanalysis data and forecast data are used to test the effectiveness of the several B matrixes with VAF (Huang, 1999) method. Here the NCEP analysis is treated as the truth and in this case the forecast error is known. The data from 2006 to 2007 is used as the samples to estimate B matrix and the data in 2008 is used to verify the assimilation effects. The 48h and 24h forecast valid at the same time is used to estimate B matrix with NMC method. B matrix can be represented by a correlation part (a non-diagonal matrix) and a variance part (a diagonal matrix of variances). Gaussian filter function as an approximate approach is used to represent the variation of correlation coefficients with distance in numerous 3DVar systems. On the basis of the assumption, the following several forms of B matrixes are designed and test with VAF in the comparative experiments: (1) error variance and the characteristic lengths are fixed and setted to their mean value averaged over the analysis domain; (2) similar to (1), but the mean characteristic lengths reduce to 50 percent for the height and 60 percent for the temperature of the original; (3) similar to (2), but error variance calculated directly by the historical data is space-dependent; (4) error variance and characteristic lengths are all calculated directly by the historical data; (5) B matrix is estimated directly by the historical data; (6) similar to (5), but a localization process is performed; (7) B matrix is estimated by NMC method but error variance is reduced by 1.7 times in order that the value is close to that calculated from the true forecast error samples; (8) similar to (7), but the localization similar to (6) is performed.
Experimental results with the different B matrixes show that for the Gaussian-type B matrix the characteristic lengths calculated from the true error samples don't bring a good analysis results. However, the reduced characteristic lengths (about half of the original one) can lead to a good analysis. If the B matrix estimated directly from the historical data is used in 3DVar, the assimilation effect can not reach to the best. The better assimilation results are generated with the application of reduced characteristic length and localization. Even so, it hasn't obvious advantage compared with Gaussian-type B matrix with the optimal characteristic length. It implies that the Gaussian-type B matrix, widely used for operational 3DVar system, can get a good analysis with the appropriate characteristic lengths. The crucial problem is how to determine the appropriate characteristic lengths.

(This work is supported by the National Natural Science Foundation of China (41275102, 40875063), and the Fundamental Research Funds for the Central Universities (lzujbky-2010-9))