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A Study on Mutil-Scale Background Error Covariances in 3D-Var Data Assimilation

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The construction of background error covariances is a key component of three-dimensional variational data assimilation. There are different scale background errors and interactions among them in the numerical weather Prediction. However, the influence of these errors and their interactions cannot be represented in the background error covariances statistics when estimated by the leading methods. So, it is necessary to construct background error covariances influenced by multi-scale interactions among errors.

With the NMC method, this article firstly estimates the background error covariances at given model-resolution scales. And then the information of errors whose scales are larger and smaller than the given ones is introduced respectively, using different nesting techniques, to estimate the corresponding covariances. The comparisons of three background error covariances statistics influenced by information of errors at different scales reveal that, the background error variances enhance particularly at large scales and higher levels when introducing the information of larger-scale errors by the lateral boundary condition provided by a lower-resolution model. On the other hand, the variances reduce at medium scales at the higher levels, while those show slight improvement at lower levels in the nested domain, especially at medium and small scales, when introducing the information of smaller-scale errors by nesting a higher-resolution model. In addition, the introduction of information of larger- (smaller-) scale errors leads to larger (smaller) horizontal and vertical correlation scales of background errors. Considering the multivariate correlations, the Ekman coupling increases (decreases) with the information of larger- (smaller-) scale errors included, whereas the geostrophic coupling in free atmosphere weakens in both situations.

The three covariances obtained in above work are used in a data assimilation and model forecast system respectively, and then the analysis-forecast cycles for a period of 1 month are conducted. Through the comparison of both analyses and forecasts from this system, it is found that the trends for variation in analysis increments with information of different scale errors introduced are consistent with those for variation in variances and correlations of background errors. In particular, introduction of smaller-scale errors leads to larger amplitude of analysis increments for winds at medium scales at the height of both high- and low- level jet. And analysis increments for both temperature and humidity are greater at the corresponding scales at middle and upper levels under this circumstance. These analysis increments improve the intensity of jet-convection system which includes jets at different levels and coupling between them associated with latent heat release, and these changes in analyses contribute to the better forecasts for winds and temperature in the corresponding areas. When smaller-scale errors are included, analysis increments for humidity enhance significantly at large scales at lower levels to moisten southern analyses. This humidification devotes to correcting dry bias there and eventually improves forecast skill of humidity. Moreover, inclusion of larger- (smaller-) scale errors is beneficial for forecast quality of heavy (light) precipitation at large (small) scales due to the amplification (diminution) of intensity and area in precipitation forecasts but tends to overestimate (underestimate) light (heavy) precipitation .