Time and Space Observation Error Correlation of Doppler Radar Radial Winds

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Rapid progress in remote sensing technologies including radar meteorology has brought us increasingly high-resolution and high-frequency observational data. The huge amount of detailed information of the atmospheric state contained in these data is expected to have a great potential to improve weather predictions. It is particularly important to effectively utilize the dense observations in numerical weather prediction in order to enhance accuracy in forecasting high-impact severe weather events, often involved with small scale phenomena in space and time.

However, data assimilation schemes to incorporate observational information into NWP is not necessarily sophisticated enough to appropriately handle these data. In particular, the spatial and temporal correlations of observation error become strong in dense observational data. Conventional data assimilation schemes are based on an assumption that the observation error correlation is negligible, allowing simple implementation and reduced computational cost. In order to meet this assumption, a severe thinning is usually applied to observations, discarding considerable part of the information contained in the data. Thus, it is an important issue to develop a methodology to appropriately handle correlated observational information in data assimilation.

Weather radar provides one of the important remote sensing observations, serving as a source of detailed information on the atmospheric situation. The Japan Meteorological Agency (JMA) operates the weather radar network consisting of 20 C-band Doppler radars and the aviation weather observation system including 9 C-band airport weather Doppler radars. Radial wind data from these radars, along with reflectivity and precipitation data, are assimilated in initializing the 5km-operational limited-area model, called the Meso-scale Model (MSM, JMA (2019)). In the data assimilation system, called the Meso-scale Analysis (MA), the four-dimensional variational (4D-Var) scheme based on JNoVA (JMA Nonhydrostatic model-based Variational Data Assimilation; Honda et al. 2005) is adopted. The observation errors of radial winds, along with those of other observations, are assumed to be uncorrelated each other. To meet this assumption, the radial wind data are averaged over 5 km by 5.625 deg. cells to form super observations, and further thinned to 20 km in the pre-processing.

This study investigates the properties of the observational error correlation of radial winds in the context of its handling in MA. The diagnosis uses the methodology proposed by Desroziers (2005), estimating the error correlation from statistics of observation-minus-background and observation-minus-analysis residuals. This methodology has previously been applied to estimate observational error correlation of radial winds by Watterlot et al. (2012) and Waller et al. (2016) on their operational three-dimensional variational data assimilation system. As discussed in Watterlot et al. (2012), Waller et al. 2016a and 2016b etc., this methodology is only valid when the analysis update, determined from observation- and background-error covariances used in the assimilation, is consistent with the true error covariances. However, under this limitation, it is widely used to obtain results indicative of the properties of the observation error correlation.

The 3-hourly 4D-Var data assimilation cycles were performed over a period from 1 to 8 July 2018 to generate statistical samples. The optimization of the 4D-Var runs at a horizontal grid spacing of 15 km, generating the analysis increments to be added to the first guess at a resolution of 5 km. The super observation scheme and thinning are applied to the radial velocity data as in the operational configuration. Only observations at the hour are assimilated. On the other hand, the diagnosis uses all the super observations available at every cell (5 km by 5.625 deg.) and every 10 minutes to probe the detailed structure of the error correlation.

The left figure displays the diagnosed observation error correlations along the beam for the weather Doppler radar at Sapporo (43.14N, 141.01E) at the elevation angle of 1.1 deg. and averaged over all the azimuth angles. The diagnosed correlation shows some width around the diagonal. Although the result is noisy because of a limited number of statistical samples, the correlation distance looks to increase with range. This increase is consistent with the result by Waller et al. (2016b) shown to be likely to result from larger measurement volumes at far ranges. Consideration of the time correlation also is important in 4D-Var data assimilation. The right figure displays the diagnosed time correlation of the observation error at the range of 75 km. The statistics shows a broad width increasing with time.

Because of the uncertainties in this diagnosis, further investigations are required to evaluate influence from the limited number of statistical samples, and the assumption posed in the diagnosis, etc. However, these results suggest a possibility that observation error correlation can become important in extensive use of radial wind observations. Future work will include investigation of an appropriate handling of observation error correlation in data assimilation system.

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