A reduced rank data assimilation for airborne measurements of a tsunami

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Our experiments have suggested that a large tsunami can possibly be observed by airborne platforms equipped with a high precision nadir pointing radar altimeter. However, the use of multiple airborne radars is necessary to ensure the applicability of the proposed tsunami observing system for a real-time tsunami forecasting. This can be achieved by attaching the radar on commercial airplanes, considering the viable spatiotemporal coverage of commercial airplane routes in our study area that is located around the Nankai Trough, south of Japan. Assuming that the tsunami signal has been successfully isolated from other oceanic phenomena, a data assimilation is needed to bridge the observation with a model, so that we can numerically spread the observed information throughout the areas of interest. With a considerable number of airplanes, this possible new type of tsunami observation should provide high-resolution data, which is desired but may raise some complexities as well. The large dataset due to the moving observation and the vast number of airplanes requires an efficient data assimilation method to satisfy operational constraints of a typical tsunami forecasting system.

Here we develop a reduced rank approach applied to the standard tsunami data assimilation based on the optimal interpolation. The rank reduction scheme works by decomposing the background error covariance matrix using the Eigen decomposition. The assimilation is then performed using the reduced covariance matrix obtained from a reconstruction of leading eigenvalues with the corresponding eigenvectors. Note that the background error covariance matrix does not depend on measurements, and therefore can be computed and decomposed in advance and stored. Together with the observation error covariance matrix, the background error covariance matrix will characterize the spread of information through the resulted gain matrix. In the standard optimal interpolation, the gain matrix is dependent on observations-to-grids and observations-to-observations distance using a normalized Gaussian kernel and is assumed to be constant. This assumption is no longer valid for the moving observations, as the said distances vary over time. Therefore, the rank reduction approach is necessary to minimize the computational burden, because we have to compute the gain matrix at every assimilation cycle.

In this study, we demonstrate that the rank reduction scheme for the background error covariance matrix can lead to a substantial reduction of computing times without a significant loss of accuracy. Using 200 airplanes, the computing time and accuracy of the full rank matrix are 4.4 min and 98%, respectively. For the same number of airplanes, the reduced rank approach requires only 0.8 min of computing time with a slightly reduced accuracy of 94%.

Keywords: Tsunami forecasting, Airborne observations, Reduced rank data assimilation

