Effective Assimilation of Altimetry Observations with the CFS-LETKF System

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Abstract

Past studies about the altimetry observation assimilation with the ensemble Kalman filter (EnKF) mainly focus on the assimilation of sea level anomaly (SLA) observations, and they usually show neutral impact on the improvement of the ocean analysis for two reasons: (1) the value of SLA observations, which are calculated by removing the mean dynamic topography (MDT) from the observed Altimetry Absolute Dynamic topography (ADT), is highly dependent on the selection of the MDT. (2) When assimilating SLA observations with the EnKF, no vertical localization is applied to the SLA observations so that the analysis in the deeper ocean are usually degraded due to the sampling errors arising from the small ensemble size.

In this study, we investigate the impact of *direct assimilation of the altimetry* ADT observations, rather than the SLA, within the atmosphere-ocean coupled data assimilation system CFS-LETKF. A simple online constant bias correction is applied to remove the observed global positive bias of the ADT observations to ensure the successful assimilation of the ADT observations. From the balance operator used in the ECMWF NEMOVAR, we show the complexity of assimilating ADT since they are nonlocal observations. Assimilating nonlocal observations in the EnKF system is a nontrivial problem because of the ambiguity about where to set the locations of these ADT observations. We then explored several localization strategies for the ADT observations: (1) Assimilating ADT observations with no vertical localization, (2) localizing the ADT observations at the ocean surface, (3) localizing the ADT observations at the thermocline depth, and (4) only assimilating those ADT observations which have high correlations with each model variables since EnKFs underestimate small correlations more severely than high correlations (we call this method the correlation threshold method). This correlation threshold method automatically sets the depth of the localization at the level with the maximum state-observation correlation, so ADT observations are effectively localized at different levels for different model variables (i.e., temperature, salinity and U/V-currents).

The verification against the independent ocean profiles shows that without vertical localization, the ocean temperature and salinity analysis in the top 900m are improved, while the analysis in the deeper layers are degraded globally. Localizing the ADT observations near the thermocline not only leads to reduced positive impact on the top 500m in the ocean, but also results in degraded temperature and salinity analysis in the Southern Hemisphere. By contrast, the temperature and salinity analysis obtained with the *correlation threshold method* not only show reduced RMSE in the top 900m, but also no degradation in the deep layer. In addition, the largest temperature improvements in the Tropics take place at a shallow level while they appear in a deeper layer in the Northern Hemisphere, and are absent in the Southern Hemisphere, all of which are consistent with what could be expected from ocean dynamics.