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Evaluation of oceanic surface observation for reproducing the upper ocean structure in ECHAM5/MPI-OM

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Better constraints of initial conditions from data assimilation are necessary for climate simulations and predictions, and they are particularly important for the ocean due to its long climate memory; as such, ocean data assimilation (ODA) is regarded as an effective tool for seasonal to decadal predictions. In this work, an ODA system is established for a coupled climate model (ECHAM5/MPI-OM), which can assimilate all available oceanic observations using an ensemble optimal interpolation approach. To validate and isolate the performance of different surface observations in reproducing air-sea climate variations in the model, a set of observing system simulation experiments (OSSEs) was performed over 150 model years. Generally, assimilating sea surface temperature, sea surface salinity, and sea surface height (SSH) can reasonably reproduce the climate variability and vertical structure of the upper ocean, and assimilating SSH achieves the best results compared to the true states. For the El Niño–Southern Oscillation (ENSO), assimilating different surface observations captures true aspects of ENSO well, but assimilating SSH can further enhance the accuracy of ENSO-related feedback processes in the coupled model, leading to a more reasonable ENSO evolution and air-sea interaction over the tropical Pacific. For ocean heat content, there are still limitations in reproducing the long time-scale variability in the North Atlantic, even if SSH has been taken into consideration. These results demonstrate the effectiveness of assimilating surface observations in capturing the interannual signal and, to some extent, the decadal signal but still highlight the necessity of assimilating profile data to reproduce specific decadal variability.