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# A drift-free climate prediction system using ocean assimilation approach in the Community Earth System Model

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Performance and predictability in a newly developed decadal climate prediction system are examined using the low-resolution Community Earth System Model (CESM). In this system, we assimilate 3-dimensional ocean temperature and salinity data into the ocean component of the fully coupled global climate model CESM. The resulting simulation then serves as a basis for ensemble hindcast experiments. Instead of assimilating direct observations, we assimilate temperature and salinity anomalies obtained from the ECMWF Ocean Reanalysis Version 4 (ORA-S4). Anomalies are calculated relative to the sum of the ORA-S4 climatology and an estimate of the externally forced signal. The latter is obtained from a Singular Value Decomposition of the ORA-S4 temperature and salinity data and an ensemble mean of historical 20th Century forced simulations conducted with the CESM. The resulting anomalies are added to the model simulated climatology and externally forced signal, and then assimilated back into the ocean component of CESM using the incremental analysis update technique.

To identify key sources of predictability, determine the role of surface and sub-surface data assimilation, and assess the fidelity of the data assimilation system, we also conduct a series of perfect model experiments. These experiments reveal the importance upper ocean temperature and salinity anomaly assimilation in reducing surface sea surface temperature (SST) biases. However, to reduce biases in the sea surface height (SSH), data assimilation below 300 m in the ocean is necessary, in particular for high latitude regions. Moreover, by assimilating deeper ocean data in the perfect modeling framework, we see a considerable improvement in reproducing decadal climate variability associated with the Atlantic Meridional Overturning Circulation (AMOC) and in the North Pacific region. The perfect model experiments clearly emphasize the key role of combined 3-dimensional ocean temperature and salinity anomaly assimilation in reproducing mean state and model trajectories.

Applying this knowledge to our ORA-S4/CESM prediction system, we conducted an ensemble of ocean assimilation simulations with the fully coupled CESM covering the period 1960-2014. From these simulations, we branched off a 10-member ensemble of decadal hindcasts. As a result of applying the balanced ocean anomalies to the ocean model and accounting for the externally forced signal, our hindcasts show only very little drift and initialization shocks. This new prediction system exhibits multi-year predictive skills for decadal climate variations of the AMOC, the Pacific Oscillation, and the North Pacific Gyre Oscillation. This system also demonstrates multi-year predictive skills of climate, drought and wildfire probability over the southwestern North America.