Skillful Coupled Atmosphere-Ocean Data Assimilation — on a Laptop

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Abstract

A wide range of problems in weather and climate science depend upon dynamically consistent coupled states. For example, in climate science, direct ocean observations become increasingly sparse back in time prior to the 21st century, increasing the importance of effectively using atmospheric observations to inform on the state of the ocean. For weather, the S2S forecast problem depends upon consistent initialization of the coupled state, and operational assimilation systems typically employ weakly coupled assimilation (coupled model and uncoupled assimilation). Perhaps the main challenges to progress involve the computational burden of both the forecast and analysis steps, and the technical difficulty of developing and testing assimilation techniques in large, complex coupled modeling systems Here we use a low-dimensional linear emulator, trained on source datasets. This emulator has demonstrable skill on S2S timescales and allows fully coupled data assimilation using the unapproximated Kalman filter. Specifically, we use a linear inverse model (LIM), trained on data from the Climate Forecast System Reanalysis (CFSR), and observations also drawn from that dataset. We conduct a hierarchy of assimilation experiments, including uncoupled, weakly coupled, and strongly coupled cases. Results show a reduction in analysis error for the weakly and strongly coupled cases over the uncoupled case. Improvement is particularly large for midlatitude sea-surface temperature, where strongly coupled data assimilation reduces errors by over 10% compared to the weakly coupled case. The LIM framework facilitates decomposition of the dynamics into coupled and uncoupled subspaces, which are used to diagnose the sources of improvement.

Keywords: coupled data assimilation, Kalman filter

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