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# Quantifying the limits of oceanic decadal predictability

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Ocean General Circulation Models (OGCM), as part of coupled climate models, are now extensively used by the scientific community for decadal (or near-term) climate prediction. Understanding how far decadal predictions can reach in the future, and understanding the limits of decadal ocean predictability in particular, is critical for progress in this work. Here, we ask a simple but key question in this regard: What controls the error growth after the model initialization, *i.e.* the difference between the OGCM output and the subsequent data measurements in the ocean? To answer this question we conduct an optimization analysis of a realistic ocean GCM to find the bounds on the growth of model errors depending on the errors of the model initialization and the time delay. We find that that the even though the largest errors (in modeled temperature) develop in the upper 1000 m of the ocean, they originate in the deep ocean (especially in the Southern Ocean). An error of a few $10^{-2}$ K in the deep ocean will lead on a decadal timescale to a difference between the predicted and actual temperatures of the order of several degrees Kelvin in the upper ocean. In the ocean model we use, the transient error growth is maximal after about 14 years of integration, which can be interpreted as a decadal predictability barrier. An idealized model is developed to characterize the fundamental physical mechanisms involved in this sensitivity. Our analysis highlights the importance of the meridional temperature gradient in the upper ocean that enhances the sensitivity of the upper ocean to perturbations in the deep ocean through non-normal dynamics.