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Controllability, not chaos, key criterion for ocean state estimation

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In both atmospheric and oceanic models, the utility of the adjoint method of data assimilation (i.e., ‘‘4D-VAR”) over long time windows has been questioned due to the highly nonlinear or chaotic nature of the dynamical system. Much of the previous work has dealt with the initialization problem, finding the optimal initial conditions to reproduce a given set of observations: an extremely important task for numerical weather prediction. Ocean state estimation usually demands an additional task: finding the time-dependent boundary conditions, such as the highly-variable surface boundary conditions due to ocean-atmosphere interactions. In the ocean case, it is found that there is no limit to the time window of state estimation in a chaotic dynamical system, so long as the boundary conditions render the system controllable. Therefore, the adjoint method should not be automatically deemed useless in all cases where the dynamical system is highly nonlinear or chaotic, and instead, the key criterion is whether the system is controllable by the time-dependent boundary conditions.