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State and parameter estimation for a coupled ocean–atmosphere model

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The El-Nino/Southern-Oscillation (ENSO) phenomenon dominates interannual climate variability and plays, therefore, a key role in seasonal-to-interannual prediction. Much is known by now about the main physical mechanisms that give rise to and modulate ENSO, but the values of several parameters that enter these mechanisms are very poorly known. We apply the Extended Kalman Filter (EKF) to estimate both the model state and its parameters in an intermediate, nonlinear, coupled ocean–atmosphere model of ENSO. The coupled model consists of an upper-ocean, reduced-gravity model of the Tropical Pacific and a steady-state atmospheric response to the sea surface temperature (SST). The model errors are assumed to be mainly in the atmospheric wind stress, and assimilated data are equatorial Pacific SSTs. Model behavior is very sensitive to two key parameters: (i) the ocean-atmosphere coupling coefficient between SST and wind stress anomalies, which measures the degree of nonlinearity; and (ii) the surface-layer coefficient, which determines the period of the model's self-sustained oscillation. Depending on the values of these parameters, the spatio-temporal pattern of model solutions is either that of a delayed oscillator or of a westward-propagating mode. Estimation of these parameters is tested first on synthetic data and allows us to recover the delayed-oscillator mode starting from model parameter values that correspond to the westward-propagating case. Assimilation of SST data from the NCEP-2 Reanalysis shows that the parameters can vary on fairly short time scales and switch between values that approximate the two distinct modes of ENSO behavior. Rapid adjustments of these parameters occur, in particular, during strong ENSO events. To achieve robust parameter estimates over the whole assimilation interval, we apply estimation in a loop-like manner, using the previous parameter

estimates in the next forward estimation; convergence of the loop is achieved after just two iterations. Ways to apply EKF parameter estimation efficiently to state-of-the-art coupled ocean–atmosphere GCMs will be discussed.