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Low-frequency variability and predictability in a new low-order, nonlinear, coupled ocean-atmosphere model

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We formulate and study a low-order, nonlinear, coupled ocean-atmosphere model. The model emphasizes the impact of radiative and heat fluxes and of the frictional coupling between the two fluid media on model behavior. This model version extends a previous 24-variable version by adding a dynamical equation for the passive advection of temperature in the ocean, along with an energy balance model.

The bifurcation analysis and the numerical integration of the model reveal the presence of low-frequency variability (LFV) concentrated near a long-periodic, attracting orbit. This orbit combines atmospheric and oceanic modes, and it arises for large values of the meridional gradient of radiative input and of frictional coupling. Chaotic behavior develops around this orbit as it loses its stability; this behavior is still dominated by LFV on the decadal and multi-decadal time scales that are typical of oceanic processes. Atmospheric diagnostics also reveals the presence of predominant low- and high-pressure zones, as well as of a subtropical jet; these features recall realistic climatological properties of the atmosphere over oceanic basins and downstream from the latter.

Finally, we perform a predictability analysis. Once the decadal-scale periodic orbits develop, the coupled model's short-term instabilities — as measured by its Lyapunov exponents — are drastically reduced, indicating the ocean's stabilizing role on atmospheric dynamics. On decadal time scales, the recurrence of the solution in a certain region of the invariant subspace associated with slow modes displays extended predictability up to several years.