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Characterizing Pacific Ocean Regime Shifts

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The Pacific Decadal Oscillation (PDO), the dominant year-round pattern of monthly North Pacific sea surface temperature (SST) variability, and the related basin-wide Interdecadal Pacific Oscillation (IPO), undergoes relatively rapid changes in phase every few decades or so. Such "regime shifts", which have been related to many regional and global climate impacts including variations in the global mean temperature and the recent warming hiatus, are often thought to represent sudden nonlinear changes between relatively stable climate states. We suggest instead that these regime shifts could result from a linear superposition of different key Pacific physical processes, which operate on different timescales to drive similar PDO/IPO-like SST anomaly patterns. The combination of these processes can be represented by a low-order multivariate autoregressive model (multivariate Ornstein–Uhlenbeck process) known as a linear inverse model (LIM), empirically determined from the zero- and one-season lag covariance of observed seasonal Pacific SST anomalies. In the LIM, variations in the superposition of randomly forced processes alone can result in both Pacific regime shifts and a PDO power spectrum resembling 1/f noise. Key aspects of observed Pacific regime shifts since 1890, including the dominant pattern, its amplitude, and the probability distribution of regime durations (time intervals between phase changes) can all be reproduced by this simple LIM.

Moreover, the LIM captures details of Pacific regime shifts significantly better than do all the CMIP5 coupled GCM simulations of the 20th century, perhaps because Pacific variability simulated by these models is often based on a different balance of processes than in nature. This is illustrated by a LIM constructed from one historical run of the NCAR CESM (one of the CMIP5 models), which is also able to reproduce the regime shift behavior found within a 40-member ensemble of the same model even as its regime behavior exhibits typically larger amplitudes and shorter durations than observations.