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# Optimal forcing of ENSO either side of the 1970's climate shift and its implications for predictability

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Inverse methods are used to investigate changes in the precursors to ENSO since the so-called 1970's climate shift. Linear Inverse Models (LIMs) constructed from tropical SST, thermocline depth and zonal wind stress anomalies from each of the periods 1958-1977 and 1978-1997, are able to reproduce the major observed characteristics of ENSO, including its amplitude, frequency and time evolution. Each LIM possesses low-frequency and biennial ENSO modes, the former being both the least damped and the mode responsible for strongest pseudoresonance, as quantified via calculation of the resolvent norm. Because these modes are damped ENSO variability is sustained in the stochastically forced LIMs by transiently growing perturbations. In each period two linear perturbations are identified that produce the most rapid growth of ENSO, with growth times of 7 and 15 months. Forced simulations confirm that ENSO variability occurs only through the growth of these two optimal structures. The structure of these optimal perturbations from each period differ significantly, and each of the optimal perturbations is found to be a skillful predictor of ENSO variability for their corresponding period, but not the alternate period, suggestive of both a change in the precursors of ENSO following the 1970s climate shift and of the existence of two initiation mechanisms in each period. Prior to the climate shift optimal linear ENSO growth over 7 months occurs through local Pacific sea surface temperature and thermocline anomalies, but afterwards involves large contributions from sea surface temperature anomalies in the Indian and south Atlantic. ENSO growth over 15 months also contain significant extra-Pacific components and which are inferred to initiate ENSO growth through remotely forced internal waves. Unlike the 7 month optimals, the 15 month optimal perturbations skillfully hindcast only a subset of ENSO events, with a marked asymmetry between hindcasts of El Niño and La Niña, implying that predictability out to 15 months is not always possible. Only the 7 month optimal perturbation deduced from the period 1958-1977 is able to skillfully hindcast ENSO amplitude from 1998 to the present. This precursor forecasts an intensification of La Niña over the first half of 2014. This result suggests that the initiation mechanism of ENSO events over recent decades may be more similar to that which governed prior to the 1970s, wherein the role of extra-Pacific teleconnections was less than occurred after 1977. Given that the period following the climate shift coincided with a marked increase in ENSO amplitude, our results suggest a possible relationship between ENSO strength and extra-Pacific forcing.