Characterizing ENSO variability in the Equatorial Pacific: An OLR Perspective

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Abstract

Even after decades of interest in El Niño-Southern Oscillation (ENSO) phenomena, there remain questions of how best to identify the events most likely to cause global seasonal climate anomalies. By space-time averaging outgoing longwave radiation (OLR) over an eastern central Pacific (ECP) region, we identify an index that appears well suited for this purpose. This index exhibits strongly event like character; much more so than any commonly used ENSO index. Although the historical record for OLR is much shorter than for sea surface temperature (SST) or Southern-Oscillation Index (SOI,) OLR offers a direct connection to anomalous atmospheric heating, and results show that recognizably "ENSO-like", robust, mid-latitude atmospheric anomalies are driven from the tropics during the years identified as events by this ECP OLR index. This is not the case, in an average sense, for other years that have warm Niño 3.4 SST anomalies, but are not particularly distinctive from an ECP-OLR perspective. It is notable that the years distinguished by this OLR index are all commonly agreed to be "El Niño" years, and the relative sizes of OLR peaks in these years are consistent with commonly agreed relative sizes of "El Niño events." We suggest that warm-ENSO events distinguished by ECP-OLR be classified separately from others that may have warm-ENSO status based on some ENSO indices but are not distinct from an OLR perspective.

Introduction

The El Niño-Southern Oscillation phenomenon has become familiar around the world because substantial weather anomalies often occur during periods of extreme ``ENSO-state". The warm and cold phases of ENSO, generally referred to as El Niño and La Niña respectively, often bring anomalous regional seasonal rainfall and temperatures. Lists of years of extreme ENSO conditions have been composited and multi-month life cycles of ``El Niño events" and ``La Niña events", as well as associated seasonal weather anomalies, have been constructed and evaluated for the robustness of the characteristic marine surface and seasonal weather anomalies (see Ropelewski and Halpert 1987, 1996; Trenberth and Caron 2000; Harrison and Larkin 1998; Smith et al. 1999.) Such composites provide a statistical basis for seasonal weather forecasting in the affected regions, if the statistical linkages are sufficiently strong. The dynamical basis for such relationships is based on the fact that extremes of ENSO involve substantially anomalous patterns of deep tropical convection and, hence, of large scale anomalous atmospheric forcing, which can be expected to drive both tropical and extra-tropical atmospheric circulation anomalies.

Eastern Central Pacific OLR Anomaly

Motivation for examining the relationship between mid-latitude atmospheric anomalies and ECP OLR variability has been provided by results of statistical analysis of tropical OLR and global 500mb geopotential height variability that showed dominant patterns of OLR covariation in the ECP (not shown for brevity.) Significant correlation between OLR and two ENSO-related teleconnection indices known to influence climate over N. America (see Trenberth and Hurrel 1994 and Mo and Livezey 1986) also suggest the ECP as a tell-tale indicator of tropically-driven mid-latitude atmospheric circulation anomalies.

A distinct type of behavior is seen in OLR anomaly averaged over an eastern central region; most notably, four troughs stand out clearly from background variability (see Fig. 1.) Absolute OLR values during each of these events reaches (or nearly reaches) the deep-convective regime (OLR < 230 W m^{-2}) and their relative sizes are consistent with commonly agreed relative sizes of El Niño events (e.g. 1997-98 and 1982-83 larger than 1991-92 and 1986-87 events.)

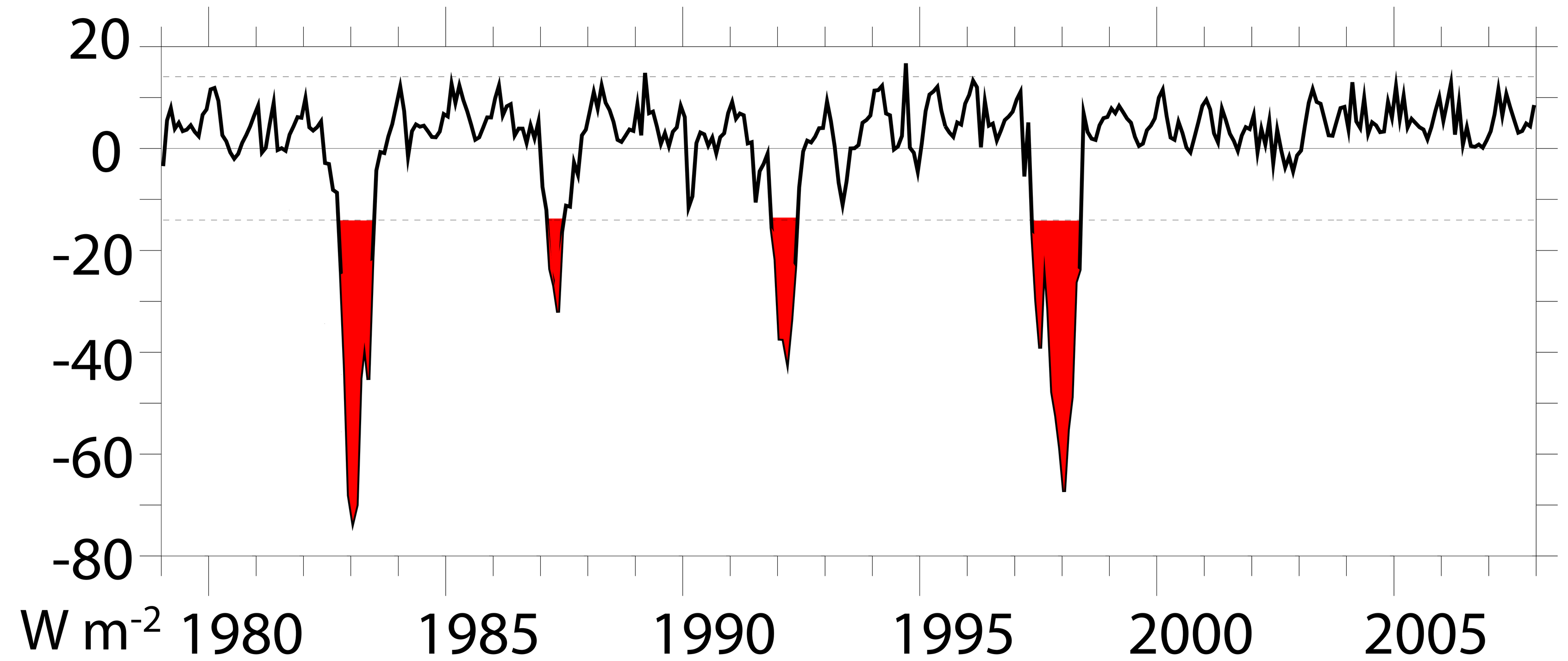

Fig. 1 Monthly OLR anomaly, averaged over 160°W-125°W, 2°S-2°N. Red shading for values below -1 standard deviation. Data from NOAA "Interpolated" daily OLR.

Distribution of ECP OLR

The distribution of ECP OLR (Fig. 2a) is rather event-like, with a relatively large negative (i.e. convective region) tail that substantially exceeds the expectations for a continuously distributed variable (e.g. expected, 95% and 5% limit values for a Gaussian-distributed variable with equivalent mean and standard deviation are shown by middle, upper and lower hash marks, respectively, in Fig. 2) Thus, this OLR index is consistent with the conventional conception that anomalous conditions during "El Niño events" are distinct from background variability. The distribution of the commonly used Niño 3.4 SSTA index is shown for comparison (Fig. 2b.) In this case, none of the bins contain values that are very different (90% confidence level) from those expected for a Gaussian system. This is also true for for SOI and the OLR index recommended by Chelliah and Arkin (1992; not shown.) Thus, distinguishing events by considering only Niño 3.4 SSTA (or other Gaussian-like ENSO indices) will necessarily lead to ambiguity. This can explain some confusion caused recently by efforts to classify ENSO-state based solely on marine variables (see Larkin and Harrison 2005a, b.)

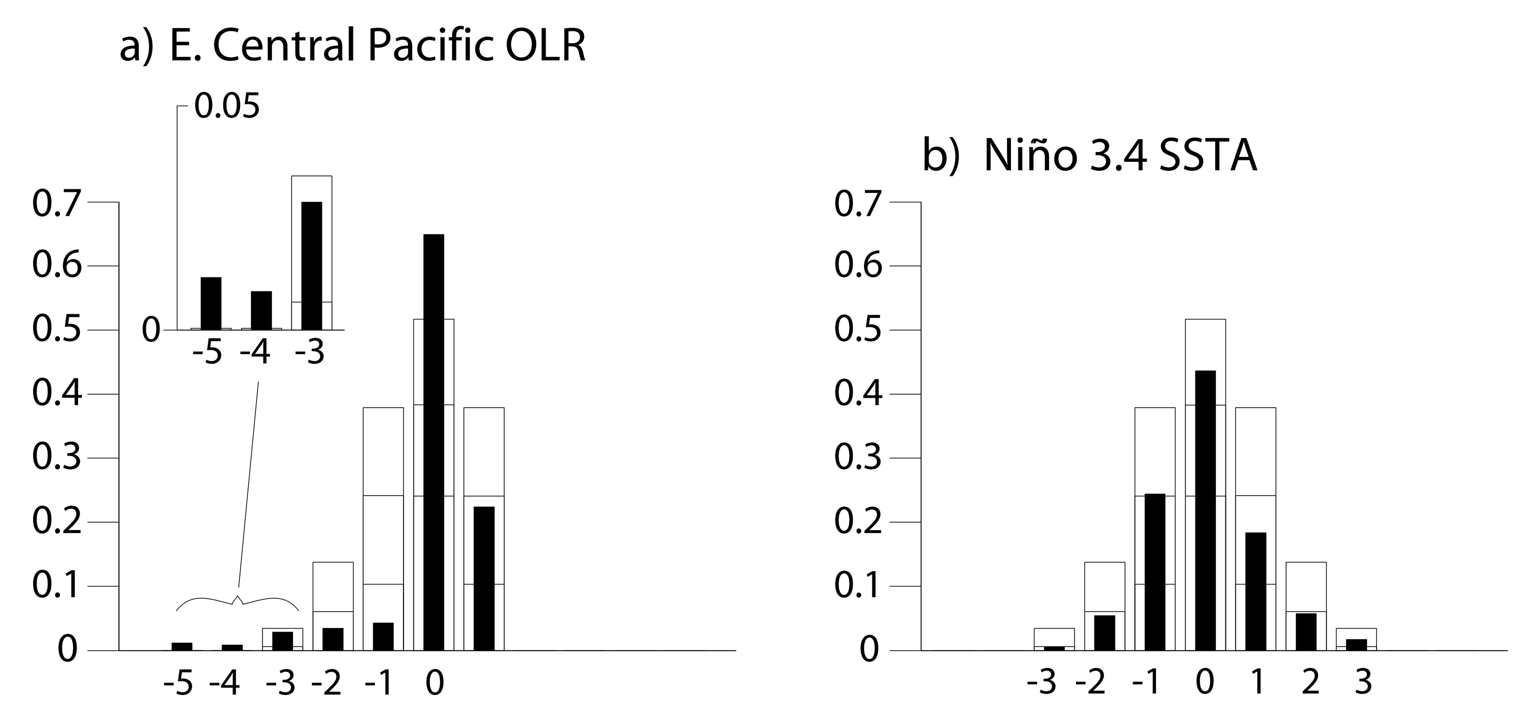

Fig. 2 Distribution of eastern central Pacific OLR anomaly values shown in Fig. 1 (a) and monthly averaged Niño 3.4 SSTA (b.) Base periods are the same (1979-2007) in each case. Bin spacing (x-axis) is 1-standard deviation, centered at -1, 0, 1, etc. Y-axis gives fraction of values falling in each bin. Hash marks for high (95%,) most likely and low (5%) expectations for a commensurate Gaussian-distributed variable.

Mid-latitude atmospheric anomalies during OLR-events

Geopotential height anomaly (500mb) averaged over December-January-February (DJF) periods distinguished by OLR events shows evidence of substantial tropically driven mid-latitude atmospheric circulation anomalies. For example, a wave train of alternating positive and negative anomaly is seen emanating from the tropical Pacific and extending eastward and poleward (Fig. 3a.) This anomaly pattern is largely consistent with previous, well known ENSO teleconnection patterns (e.g. Wallace and Gutzler 1981;) note, for example, the large (80m) negative anomaly centered in the northern Pacific, with contours running parallel to the North American coastline, indicative of a substantial deflection of the jet stream in this region, and significant positive anomaly over much of north central N. America. Results for other years in the period considered, with event-status based on Niño 3.4 SSTA but not on ECP OLR, do not show this type of behavior (see Fig. 3b.)

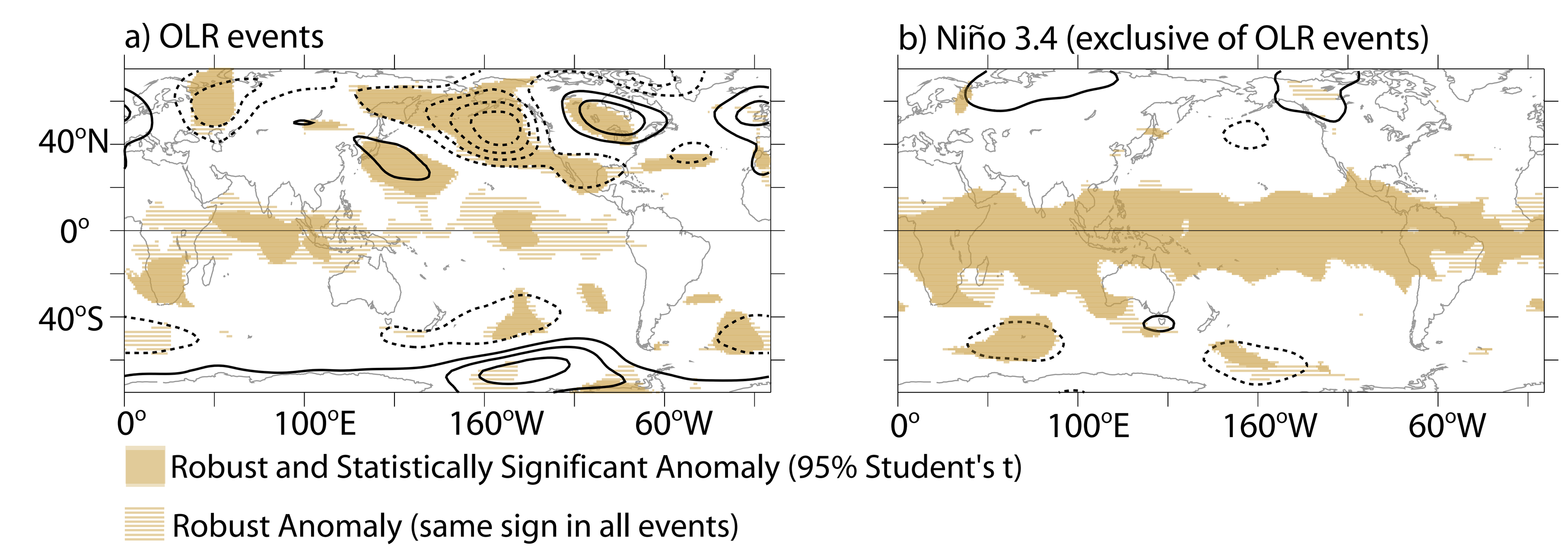

Fig. 3 a) DJF geopotential height anomaly (500mb) during years distinguished by ECP OLR events (1982-83, 1986-87, 1991-92, 1997-98.) Contour interval is 20m. Zero contour is omitted. Data from NCEP/NCAR reanalysis. b) Same as (a,) except for years meeting NOAA Climate Prediction Center "historical El Niño" definition (1979-2007 base period,) but not distinguished by OLR (1987-88, 1994-95, 2002-03, 2004-05.)

Conclusions

An OLR-based warm-ENSO index is identified that clearly distinguishes the most commonly agreed upon "El Niño" events from background variability and is consistent with the commonly agreed relative sizes of these events.

Anomalous atmospheric heating conditions and geopotential height anomalies observed during these years show evidence of robust tropically-driven mid-latitude atmospheric anomalies. The case for tropically-driven mid-latitude atmospheric anomalies in years not distinguished by OLR is less clear.

The timing of the OLR events discussed here is often early enough to be useful to ENSO-related seasonal forecast efforts.

We suggest that years that are not particularly distinctive from an OLR perspective should be classified as different from the OLR-distinguished El Niño years.