Warm events in the California Current and Gulf of Alaska blob region: El Niño or not?

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Abstract

The El Niño – Southern Oscillation (ENSO) is a dominant mode of interannual climate variability throughout the Pacific. However, warm events occur in the extra-tropical California Current System (CCS) that are neither contemporaneous with a tropical El Niño nor mechanistically linked to ENSO. Likewise, not every tropical El Niño is reflected by a CCS warming. The paradigm that changes in the surface layer of the eastern equatorial Pacific propagate poleward along the coasts of North and South America does not completely account for CCS warmings. Atmospheric variations affecting winds that drive surface heat and momentum fluxes must be considered. These wind fluctuations result from local/regional pressure anomalies, which are only sometimes clearly related to remote forcing by atmospheric teleconnections. We document the history of El Niño and CCS warm events since 1950 and show how relationships between the ocean-atmosphere interactions forcing these events vary between events. The North Pacific warming known as "the Blob" is a notable example of a CCS warming that was not a result of El Niño generated teleconnections. The recent warming in the NE Pacific has persisted as the 2015-2016 El Niño develops. The coincidence of these two events in 2015 is now causing major changes in the California Current Ecosystem.

Introduction

Record high SST anomalies were observed in 2014 and 2015 in both the CCS and Gulf of Alaska warm blob regions (Figures 1 and 2). During this same period, the NINO3.4 index used to track ENSO rapidly increased to record-high levels late in 2015.

This analysis is focused on addressing three main questions:

1. To what extent have past warm and cold extremes in the California Current System (CCS) and Gulf of Alaska "warm blob" region been related to ENSO?
2. What are the patterns of atmospheric forcing on the NE Pacific associated with ENSO-teleconnections and regional-scale warm extremes in the CCS and Gulf of Alaska Blob regions?
3. To what extent have the exceptionally warm NE Pacific ocean temperatures in 2014-15 conformed to past patterns of co-variation between the Gulf of Alaska, the CCS, and ENSO?

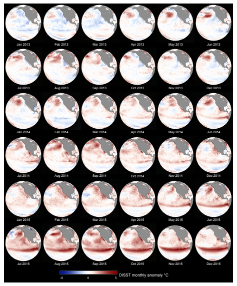
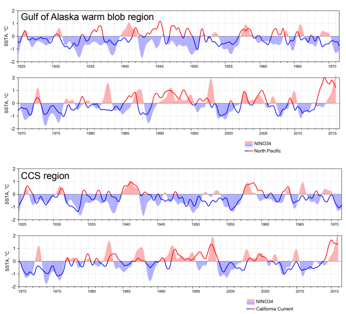


Figure 1: Monthly mean SST anomalies from January 2013-December 2015. Data are from NOAA OISST.v2, anomalies computed from the 1981-2010 climatology.



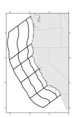


Figure 2: 12-month lowess smoothed monthly SST anomalies in the NINO34 (5N-5S, 170-120W), Gulf of Alaska Blob region (40-50N, 150-135W), and the US portion of the CCS (within 500km of the US West Coast, see map below), from 1920-2015. Data are from NOAA/NCEI ERSST.v4, anomalies computed from the 1981-2010 climatology.

Data and Methods

In order to address these questions, we developed time series for CCS and Blob region SST anomalies. We compare lead-lag correlations among the CCS, Blob, and NINO34 SST indices to identify relationships among these regions in the period from 1920-2015. We also develop composite atmospheric sea level pressure (SLP) anomaly maps in order to compare and contrast the spatial patterns of atmospheric forcing associated with warm extremes in each of the 3 regions. Composite SLP anomaly maps were based on the top 10 July-June average index values since 1949, excluding 2015, for each index using NCAR/NCEP reanalysis data.

Results

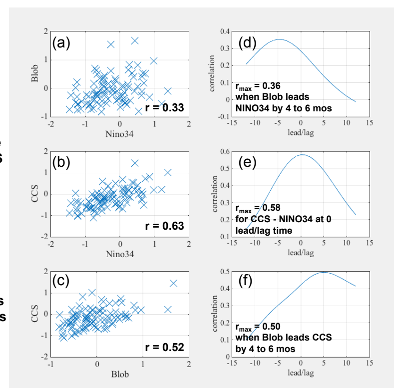
2014-15 had record high SST anomalies in the Blob and CCS regions (dating back to 1920), and these exceptionally warm temperatures developed about a year prior to the rapid increases in the NINO34 index (Figure 2). There is a weak correspondence between interannual variations in Blob and NINO34 region SST anomalies over the 1920-2015 period. In contrast, SST anomaly variations in the CCS and NINO34 regions are more coherent. However, there are notable cases where the CCS warming leads the NINO34 warming (1963, 2014-15), cases where it lags (1926, 1931, 1958, 1983, and 1992), cases where the warming is simultaneous (1940-41, 1997-98), and cases where there is no obvious correspondence at all (1967, 1969).

In the left column of Figure 3 scatterplots of the annual mean (July-June) indices provide more insights into relationships between interannual SST variations between these regions. The weakest correlations are between the Blob and NINO34 indices (r=0.33, Fig. 3a), the strongest correlations are between the CCS and NINO34 indices (r=0.63, Fig. 3b), with intermediate level correlations between the CCS and Blob indices (r=0.52, Fig. 3c).

In the right column of Figure 3 lead/lag correlations between the monthly lowess smoothed SST indices highlight tendencies for temporal offsets in SST variations between the 3 study regions. Notably, maximum correlations exist when the Blob index leads NINO34 and the CCS by 4 to 6 months, while the CCS-NINO34 correlation maximum exists at zero lead/lag.

Composite SLP anomaly maps for the top 10 warm years in each region, respectively, are shown in Figure 4. Warm blob events in the Gulf of Alaska are associated with a bulls-eye of anomalously high SLP centered in the Gulf of Alaska, and broader regions of low SLP anomalies over the Aleutians and in the subtropical eastern and central Pacific. Warm events in the CCS are associated with low SLP anomalies between the Hawaiian Islands and the mainland of North America.

Figure 3: Using July-June annual mean time series for NINO34, CCS, and Blob regions for 1921-2015, we show scatter-plots for (a) the Blob versus NINO34, (b) CCS versus NINO34, and (c) CCS versus the Blob. Curves in the right column show lead/lag correlations between the lowess smoothed monthly time series for (d) the Blob and NINO34, (e) CCS and NINO34, and (f) CCS and the Blob. Peak correlation values and associated lead/lag times are indicated on each plot.



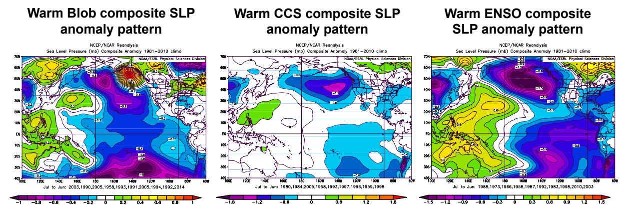


Figure 4: Composite SLP anomalies for the top 10 warm years (based on July-June averages) between 1949 and 2014 for the Gulf of Alaska Blob region (left), the CCS (center), and NINO34 regions (right). Maps were generated using the NOAA/ESRL Physical Sciences Division web-page http://www.esrl.noaa.gov/psd.

As shown in many previous studies, the composite SLP pattern for warm phases of ENSO includes low SLP anomalies throughout the eastern Pacific, with one center between Hawaii, the Aleutians, and West Coast of North America, another in the eastern tropical Pacific, and high SLP anomalies in the tropical IndoPacific region.

Discussion and Conclusions

- Record warming in the Gulf of Alaska blob region and in the CCS in 2014-15 preceded the rapid development of the 2015-16 ENSO event by about a year.
- Over the 1920-2015 period, there is a strong tendency for covarying SST in the CCS and NINO34 regions, but on an interannual time scale the two regions share only about 1/3 of their SST variance.
- There is a weaker tendency for covariation between Blob region SST variations and those in the CCS or NINO34 regions, with Blob region SSTa tending to lead both NINO34 and CCS indices by about 5 months.

The tendency for Blob region SST variations to lead those in the NINO34 region has been noted in previous studies focused on mid-latitude pre-cursors to tropical ENSO variability through the "seasonal footprinting mechanism" (Vimont et al. 2001) or the "meridional mode" (Chiang and Vimont 2004) where large-scale SLP anomalies in the northeast Pacific drive surface flux anomalies that cause SST variations in both the Gulf of Alaska and tropical Pacific. Under the right conditions, the tropical anomalies initiate positive feedbacks between tropical SST and surface wind stress anomalies that lead to a tropical El Niño event months later.

Two basic mechanisms for SST variations in CCS are (1) tropical-origin coastally-trapped Kelvin waves caused by changes in the zonal-wind anomalies near the equator (e.g. Pares-Sierra and O'Brien 1980), and (2) regional-scale atmospheric forcing in the NE Pacific that causes variations in wind-driven surface fluxes, Ekman transports, turbulent mixing, and upwelling that combined cause regional-scale variations in NE Pacific SST (Johnstone and Mantua 2014). Tropical El Niño events favor both mechanisms, especially during boreal winter months when ENSO-related atmospheric teleconnections to the North Pacific and tropical wind anomalies tend to peak.

The composite SLP anomaly pattern we identify here as associated with warm events in the Gulf of Alaska is quite similar to that identified by Bond et al. (2015) as responsible for the initiation of the Blob in 2013-14. Likewise, our composite SLP anomaly for CCS warm periods is similar to the SLP anomaly pattern shown by Johnstone and Mantua (2014) as best correlated with SST variations in the NE Pacific Arc that includes the CCS in a broader regional pattern.

References

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