# Atmospheric Anomalies in 1997: Links to ENSO?


James E. Overland,[1] Nicholas A. Bond[2] and Jennifer Miletta Adams[2]

[1] *NOAA, Pacific Marine Environmental Laboratory*
*Seattle, WA 98115-0070, U.S.A.*
e-mail: overland@pmel.noaa.gov

[2] *University of Washington, JISAO*
*Seattle, WA 98195, U.S.A.*



## Abstract

In the summer of 1997, positive sea surface temperature anomalies (SSTA) of greater than 2°C extended across the Gulf of Alaska (GOA) and into the eastern Bering Sea (EBS). The SSTA in the EBS are at least in part due to atmospheric causes. Anomalously high 700-mb geopotential heights occurred over the region during April through August. This resulted in enhanced warming of the GOA and EBS due to increased insolation. The pattern of positive 700 mb height anomalies for April through August 1997 is similar to its counterpart formed by compositing the April through August anomalies that occurred during previous El Niños. The warming in the Bering Sea and North Pacific during summer 1997 appears to be due to the confluence of three factors: a decadal trend toward higher 700-mb heights, the El Niño, and a particularly strong blocking ridge weather pattern in May. As fall 1997 progressed, the SSTA in the EBS and non-coastal GOA dissipated due to increased storm activity, a winter signature of El Niño. More complete documentation is found at http://www.pmel.noaa.gov/~miletta/npac1997.html.


## Introduction

The intent of this abstract is to investigate whether the observed anomalies in the Eastern Bering Sea (EBS) occurred over a larger region and to investigate the relationship of the sea surface temperature anomalies (SSTA) to concurrent meteorological anomalies. The EBS is remote from tropical influences by direct oceanographic connection; however, indirect connections exist through the atmosphere. Recent studies suggest that there can be a midlatitude response to tropical SSTA in all seasons (Livezey et al., 1997; Trenberth et al., 1998). Because the midlatitude background circulation differs between winter and summer, the nature of the midlatitude response to the El Niño–Southern Oscillation (ENSO) also varies seasonally. The influence of ENSO at midlatitudes is believed to be related to an equatorward extension of the midlatitude Pacific jet stream and changes in mean flow/eddy feedback (Higgins and Mo, 1997; Straus and Shukla, 1997).

## Anomaly Fields in 1997

### Sea surface temperature

Monthly SSTA fields in the North Pacific for March through August 1997 are shown in Figure 1. The fields are taken from the National Centers for Environmental Prediction (NCEP) Reynolds analyses, which are based on a blending of satellite observations and *in situ* data (Reynolds and Smith, 1995). Positive (negative) anomalies equal to or greater than 1°C are drawn in shades of red (blue), with a contour interval of 1°C. The onset and intensification of the warm equatorial SSTA associated with El Niño are recognizable, with a 1°C positive anomaly near 180° in April and a large warm signal from May onward. In the EBS in March, the cold SSTA are –2°C. In April and May, the cold SSTA gradually give way to the warm anomalies extending westward from the GOA. May also shows the strongest warm SSTA off the west coast of North

America at subtropical latitudes. By June, strong warm SSTA stretch from the equator along the west coast, across the GOA, and into the Bering Sea. The extreme warm SSTA persist through August. The warm SSTA in the EBS in July and August are greater than 2°C. Local buoy observations (mooring site 2) showed SST anomalies greater than 2°C (Stabeno, personal communication). Based on the Reynolds analyses, the EBS showed remarkable SST warming of more than 12°C in a 5-month period, compared to a more typical value of 8°C. By November (not shown) the warm SSTA in the Bering Sea and non-coastal North Pacific had dissipated.

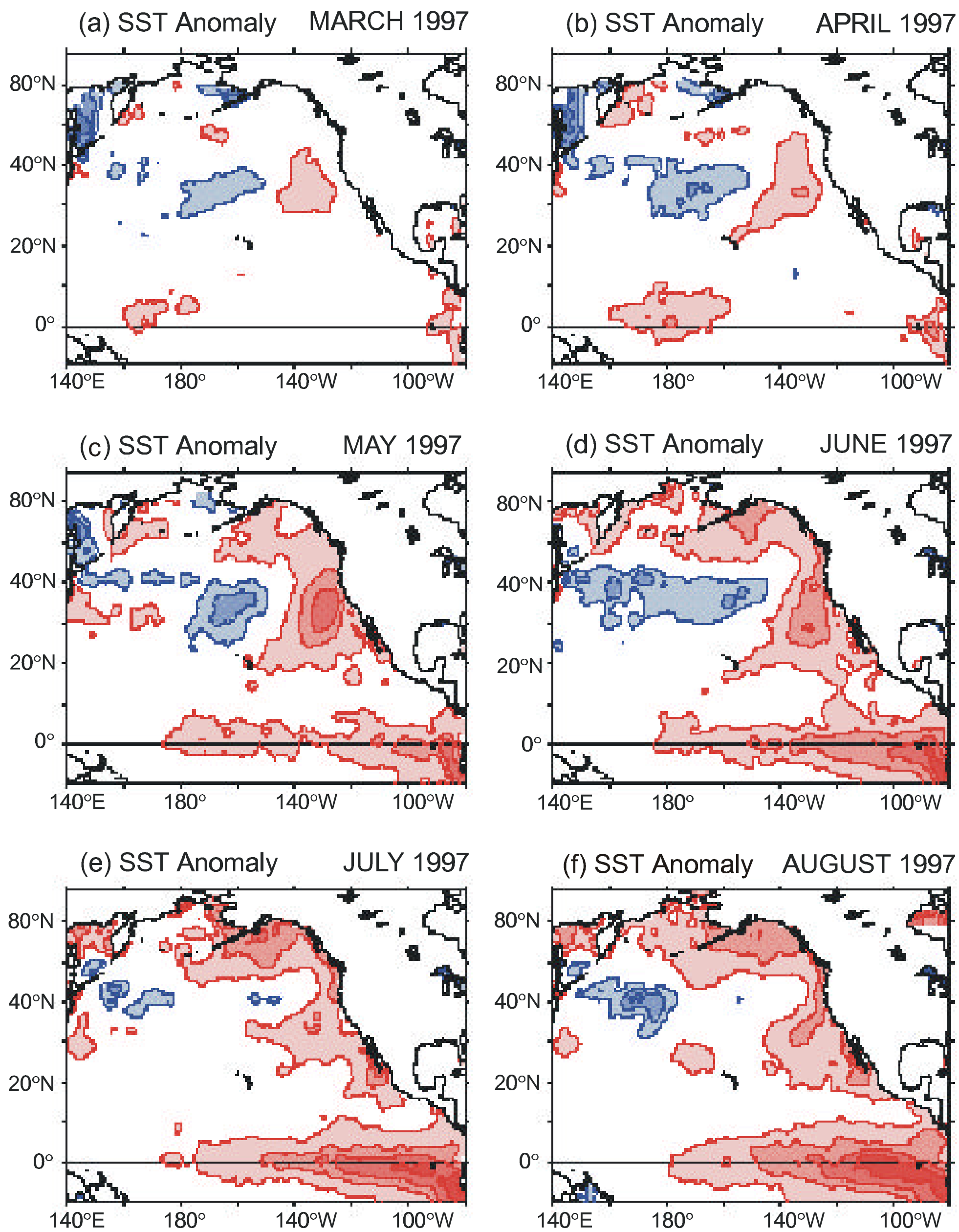


***Figure 1.*** *Monthly SST anomalies (SSTA) for the North Pacific for 1997. Positive (negative) anomalies equal to or greater than 1°C are drawn in shades of red (blue) with a contour interval of 1°C. Data are from NCEP analysis (Reynolds and Smith, 1995) and are a blend of satellite and in situ observations. Note the increase of the equatorial SST anomaly after April. Subarctic SSTA increase after May, first in the Gulf of Alaska and then in the Bering Sea.*

### 700-mb geopotential height

The 700-mb geopotential height anomalies for April–August are shown in Figure 2a. The 5-month mean anomaly pattern shows positive heights over the western Alaska and the EBS and negative heights across the Pacific centered at about 45°N. Time series of the 700-mb height (Figure 2b) at Mooring 2 site (cross location in Figure 2a) also shows the strong tendency for higher geopotential heights in the EBS; particularly prominent positive anomalies occurred in late May, late June, and mid-late August.

### Solar radiation

The net short wave anomalies from the NCEP reanalyses at the surface for April–August 1997 are shown in Figure 3. In the 5-month mean, an extra 5–10 W m$^{-2}$ was available to warm the ocean in the central and eastern Bering Sea with the greatest anomalous heating over Bristol Bay. The time series in Figure 3b shows that the positive flux anomalies at the Mooring 2 site were about 30 W m$^{-2}$ from mid-May through mid-July. Assuming a typical mixed layer depth of 20 m, this amount of anomalous heat would increase the SST by 2°C.

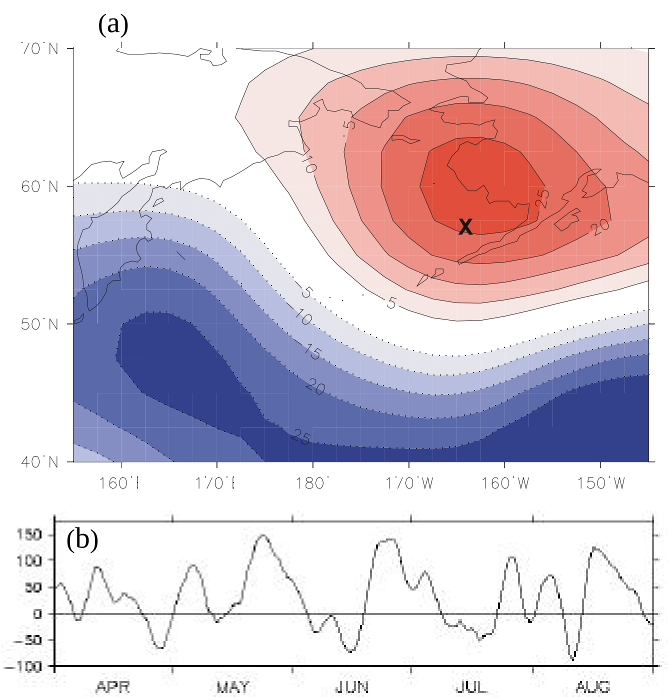


*Figure 2.* *Geopotential height anomalies in meters at 700 mb for spring and summer of 1997. (a) Five-month (April–August) mean anomaly. (b) Time series of daily anomalies at 57°N, 164°W (mooring site 2, x on Figure 2a) for the same 5-month period, smoothed with a 5-day running mean. There are seven peaks of high geopotential height.*

## Link to the Tropical Pacific?

### Historical composites

In this section we examine covariability between equatorial SSTA and midlatitude atmospheric circulation in all spring/summer months with a strong El Niño signal. This is reasonable because the midlatitude atmospheric circulation responds relatively quickly, on time scales of a few weeks or less, to tropical Pacific anomalies. As a measure of equatorial SSTA we use the NINO3 index greater than 1.3 for SSTA between 5°N–5°S and 150°–90°W, available from NCEP. The range of years considered is 1958–1996, limited by the NCEP reanalyses data set.

The atmospheric circulation for the North Pacific during the months of May and August 1997 best resembled that which occurred for previous El Niños. The overall similarity on a seasonal basis is shown in Figure 4 which compares the April–August mean 700-mb height field for 1997 and El Niño composites. The 700-mb height anomaly pattern is an amplified version of the ENSO composite. The influence of the ENSO on northern hemisphere atmospheric conditions is most apparent

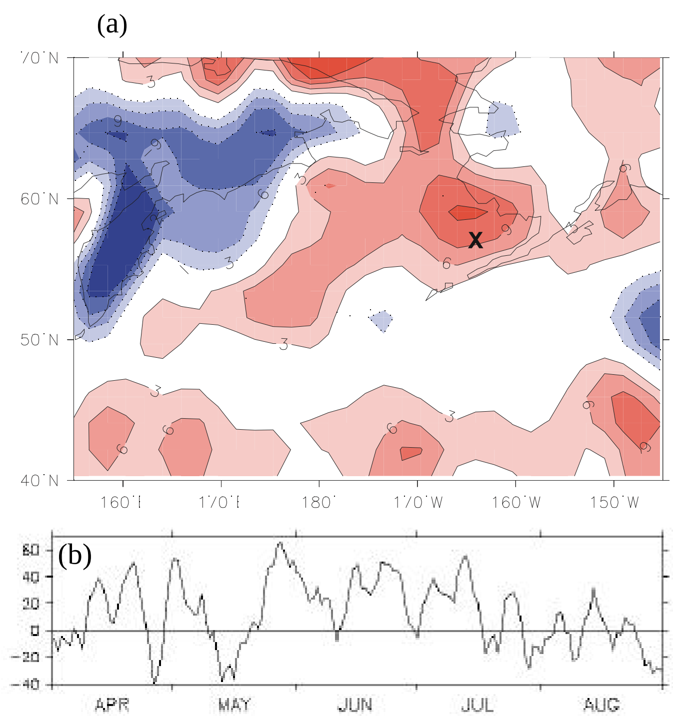


*Figure 3.* *Net shortwave radiative flux anomalies at the surface in W m$^{-2}$ for spring and summer of 1997. Positive values are downward, implying a surface warming. (a) Five-month (April–August) mean anomaly. (b) Time series of daily anomalies at 57°N, 164°W for the same 5-month period, smoothed with a 5-day running mean. There is anomalous heating centered on the EBS from late May through early June.*

on a seasonal time scale. As suggested by Figure 4, the El Niño of 1997 during April and May had an effect on the North Pacific, yet the tropical SSTA were only ~1°C. These modest anomalies must be considered in light of the seasonal cycle of the tropical Pacific. Since central and eastern tropical Pacific SSTs are warmest during the boreal spring, relatively minor warming can cause the SST to exceed the 27°C threshold for deep cumulus convection. It is these anomalies in deep convection and the associated upper-tropospheric zonal wind anomalies that have repercussions on the global atmospheric circulation.

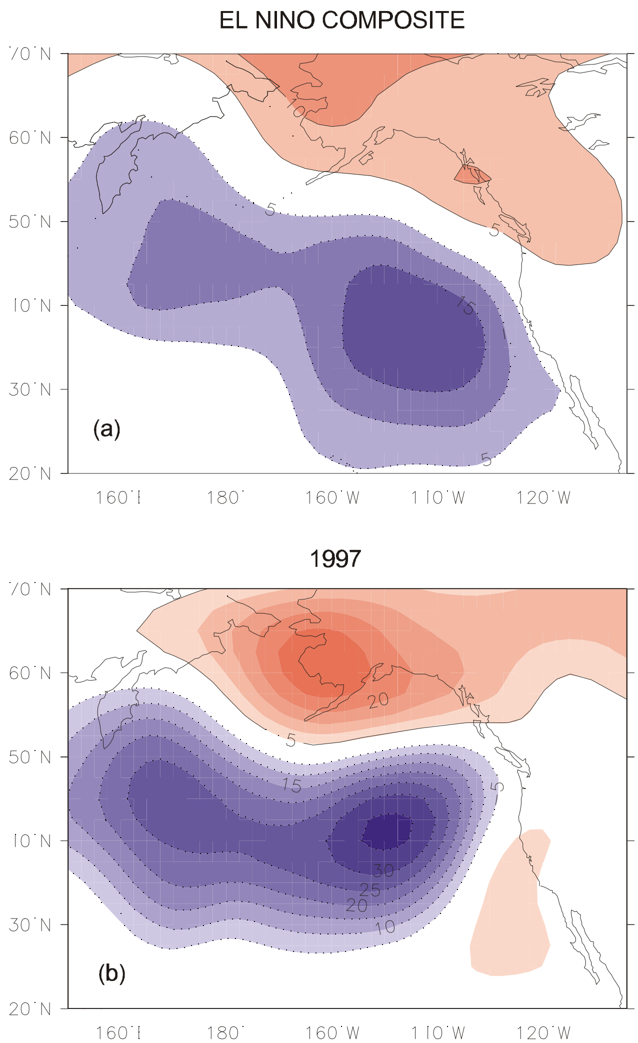


***Figure 4.*** *April–August 700 mb geopotential height fields. (a) Composite for months with a strong El Niño signal and (b) April–August 1997.*

## Summary

The warm SSTA in the EBS and GOA during the spring and summer of 1997 were partly related to concurrent large-scale atmospheric anomalies. The principal processes involved in producing the warm SSTA were enhanced warm-air advection and insolation as revealed by the anomalous distributions of low-level temperature, geopotential height, relative humidity, and cloud cover.

The atmospheric circulation anomalies for the EBS and GOA during spring and summer of 1997 appear to represent a particularly strong manifestation of the effect of ENSO. Support for a connection to the tropical Pacific during this time of year is provided by the GCM results of Livezey et al. (1997). A particularly prominent role for the tropical Pacific should be expected because local ENSO forcing, i.e., tropical Pacific SST, Outward Long-wave Radiation (OLR), and 200-mb zonal wind anomalies during the spring and summer of 1997, were exceptionally large by historical standards.

The warming in the Bering Sea and North Pacific during summer 1997 appears to be due to the confluence of three factors: a decadal trend toward higher 700-mb geopotential heights as noted in the time series of the spring teleconnection or NP pattern (Figure 5), the atmospheric ENSO connection (Figure 4), and a particularly strong blocking ridge weather pattern in May. Thus natural within-year variability coincided with interannual and decadal variability to produce extremely anomalous sea temperature conditions in the Bering Sea.

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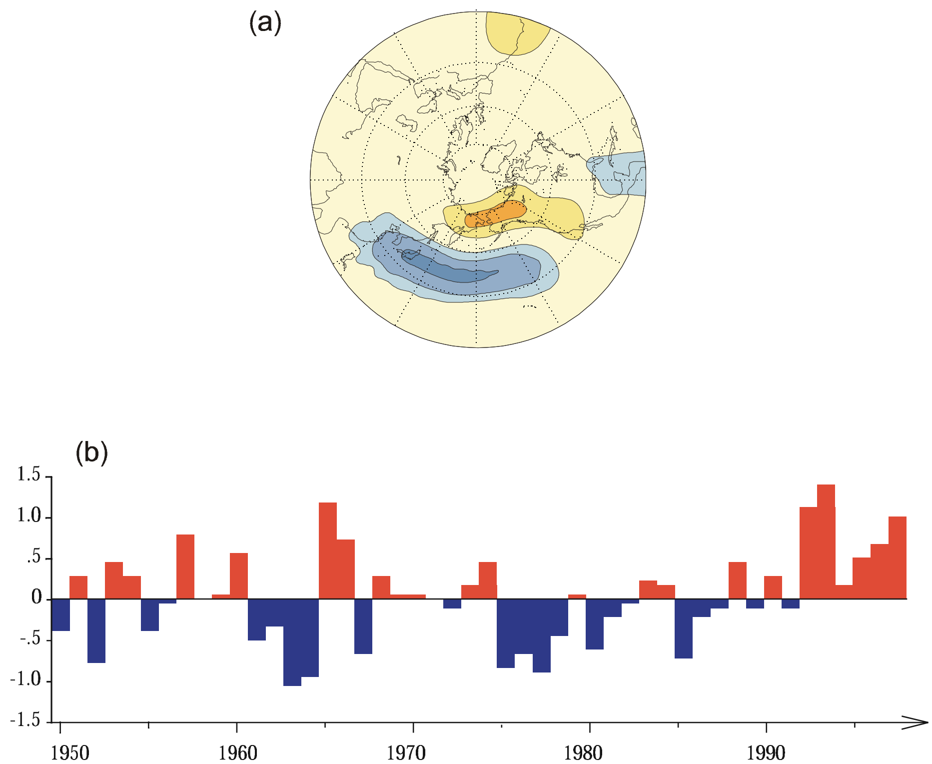


***Figure 5.*** *The prominent teleconnection for spring/summer in the North Pacific is (a) the "North Pacific" (NP) pattern. It has a north/south out of phase relationship for 700-mb heights (Bell and Halpert, 1995). There has been a regime of higher 700-mb heights over the Bering Sea and Alaska since 1989, a positive NP signal. (b) Time series of March–July mean NP amplitudes.*

## References

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