Physical Environment
Ecosystem Indicators and Trends Used by FOCI
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FOCI's scientists employ a number of climate, weather, and ocean indices and trends to help describe and ascribe the status of the ecosystem to various patterns or regimes. This document presents some of these with respect to current (2007) conditions. This section begins with an overview of North Pacific climate for 2007, including an examination of trends and tendencies in multidecadal and decadal climate regimes. Following this section are sections dealing explicitly with the western Gulf of Alaska and eastern Bering Sea.

North Pacific Climate Overview
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Summary. *The North Pacific atmosphere-ocean system was characterized by mostly modest anomalies of variable sign from autumn 2006 through summer 2007, with some minor exceptions. As a result, two indices commonly used to represent this system, the North Pacific index (NPI) for the atmosphere, and the Pacific Decadal Oscillation (PDO) for the ocean, also had weak amplitudes. A short-lived El Nino of weak-moderate intensity occurred in late 2006, but its effects appear to have been swamped by the combined effects of a positive state for the Arctic Oscillation in the winter of 2006-07 and the intrinsic variability of the North Pacific atmospheric system. While the basin-wide signals in the North Pacific were not prominent, there were some substantial regional events, including strong (weak) upwelling along the west coast of the U.S. in the summer of 2006 (2007), and the development of relatively cool SSTs from the Bering Sea shelf to south of mainland Alaska from winter into spring of 2007. La Nina conditions were developing in the summer of 2007, with probable consequences for the North Pacific climate system in the upcoming 6-9 months.*

1. SST and SLP Anomalies
The state of the North Pacific from autumn 2006 through summer 2007 is summarized in terms of seasonal mean sea surface temperature (SST) and sea level pressure (SLP) anomaly maps (Figures 15-18). These fields are observed reasonably well and can be used to represent the spatial distribution of air-sea interactions. The SST and SLP anomalies are relative to mean conditions over the periods of 1971-2000 and 1968-1986, respectively. The SST data is from NOAA's Optimal Interpolation (OI) analysis; the SLP data is from the NCEP/NCAR Reanalysis projects. Both data sets are made available by NOAA's Earth System Research Laboratory at http://www.cdc.noaa.gov/cgi-bin/Composites/printpage.pl As will be shown below, the basin-scale anomaly patterns during the past year tended to be of weak-moderate amplitude.

The autumn (September-November) of 2006 included positive SST anomalies of typically 0.5-1˚C magnitude in the western North Pacific and relatively cool SSTs in a narrow band along the U.S. west coast (Figure 15a). The corresponding pattern of anomalous SLP featured a band of relatively high pressure extending from the Sea of Okhotsk to the Gulf of Alaska and coastal British Columbia, with a peak magnitude of greater than 6 hPa near the dateline (Figure 15b). The sense of the overall pattern in the SLP was to drive anomalous easterly winds across most of the North Pacific between 30 and 50˚ N.

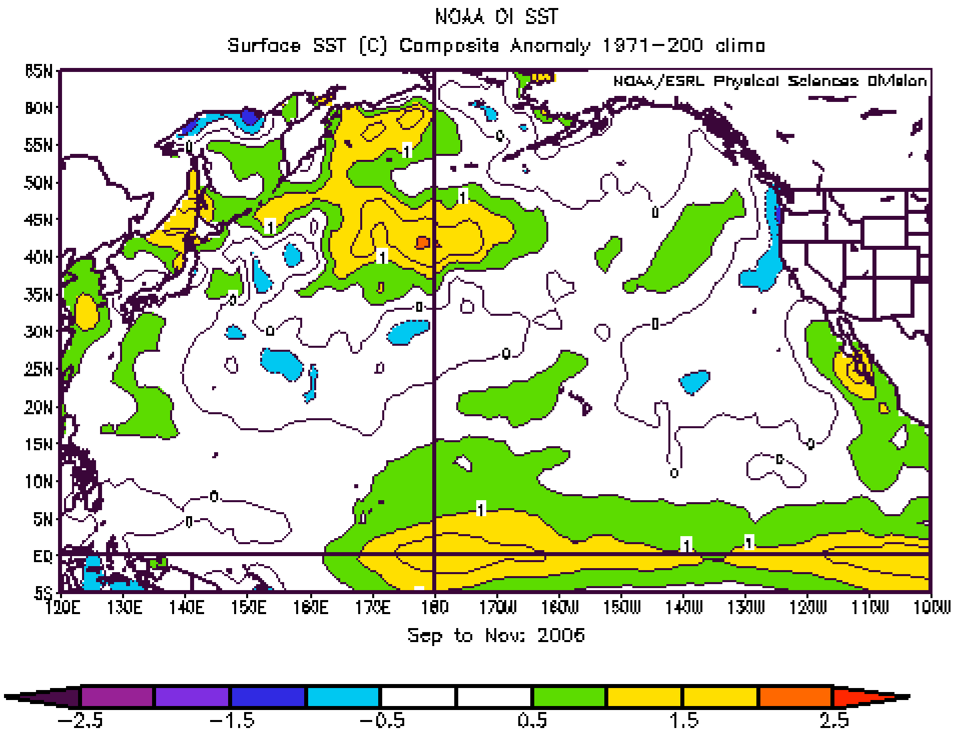

Figure 15a. SST anomalies for September-November 2006.

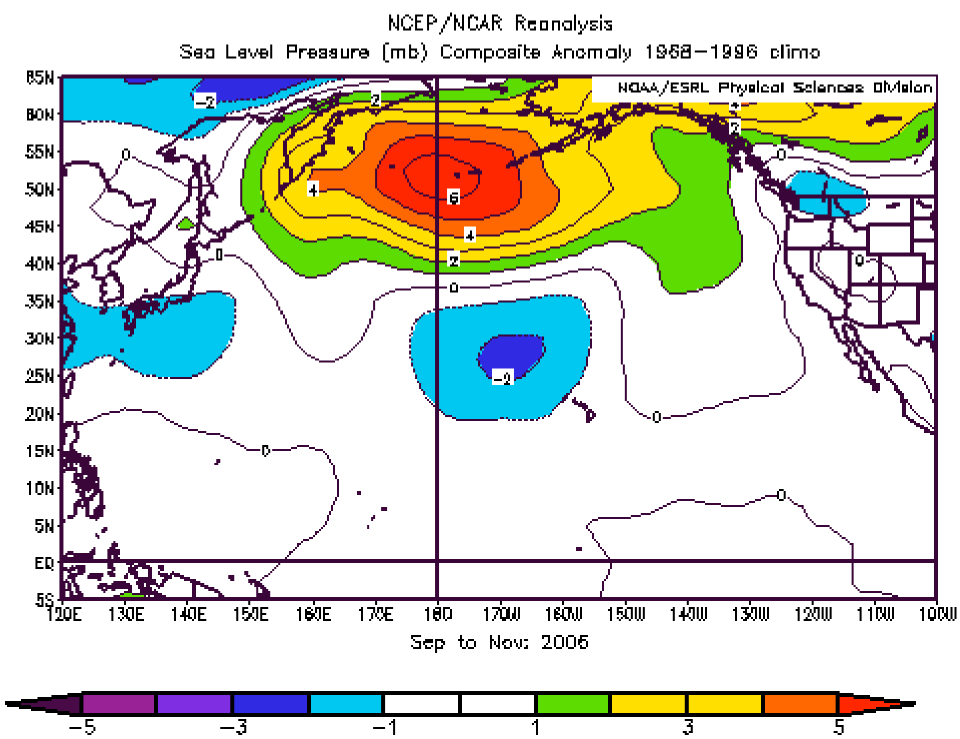

Figure 15b. SLP anomalies for September-November 2006.

During the following winter (December-February of 2006-07), the SST anomalies in the western North Pacific became weak, except for moderately positive values near and southeast of Japan (Figure 16a). This period was also marked by the development of weakly cooler SSTs in the eastern North Pacific in a broad band extending from Alaska to the subtropics. The wintertime SLP featured negative anomalies centered near Bering Strait and positive anomalies stretching across the entire Pacific from northern Japan to the western U.S (Figure 16b). The anomalous north-south gradient in SLP was accompanied by westerly wind anomalies (not shown), implying anomalous equatorward Ekman transports, which in turn, is broadly consistent with the observed cooling in seasonal mean SST anomalies in the North Pacific north of 40˚N.

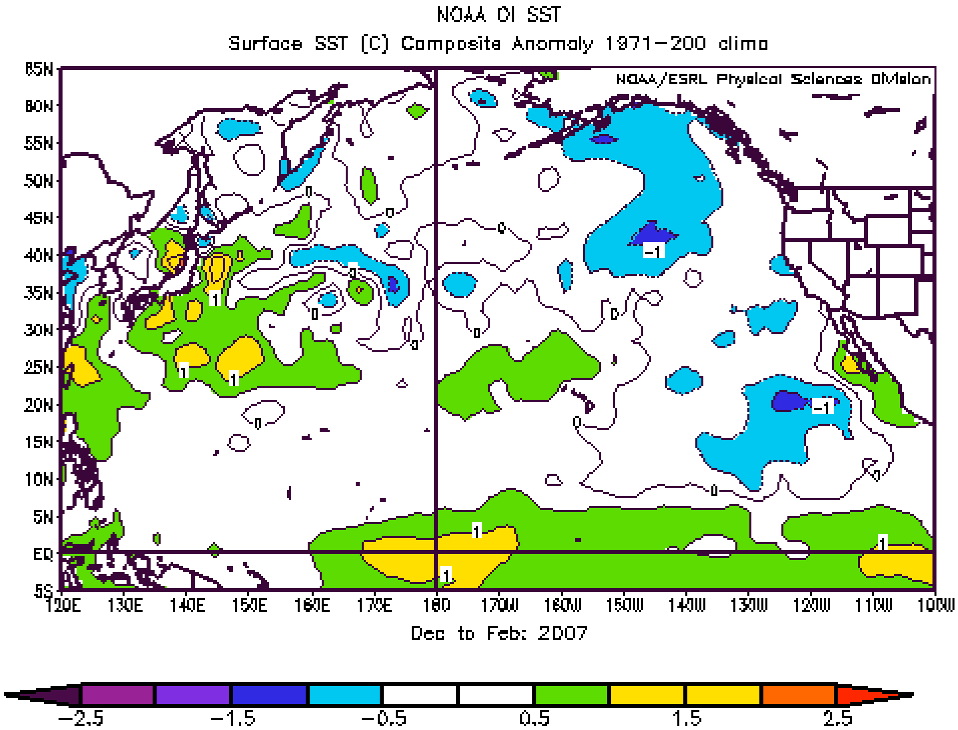

Figure 16a. SST anomalies for December 2006-February 2007.

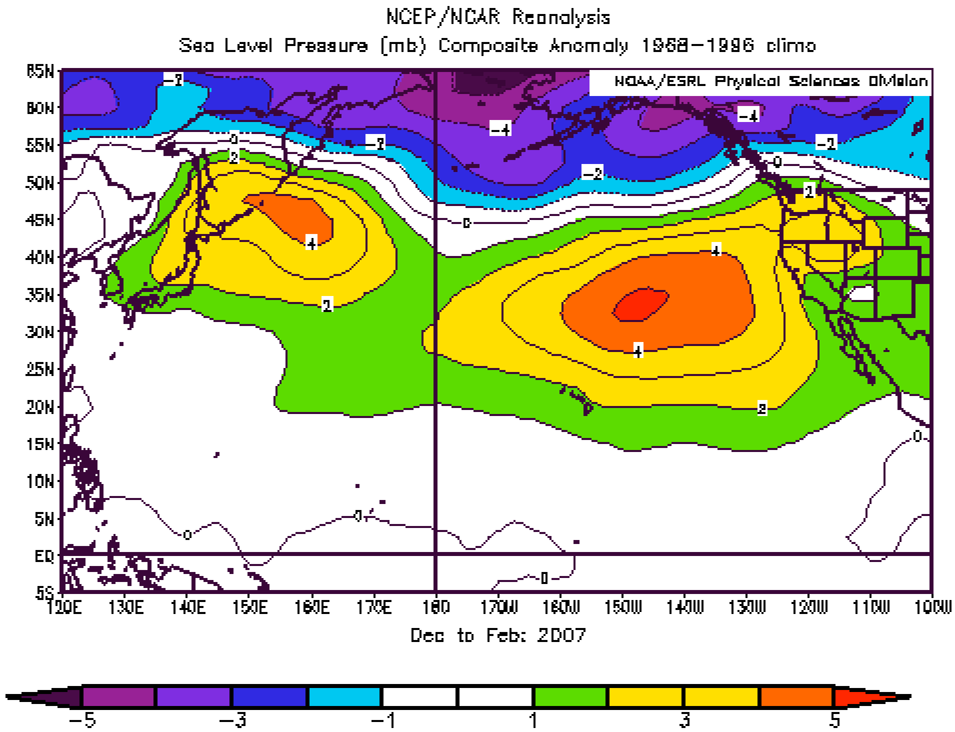

Figure 16b. SLP anomalies for December 2006-February 2007.

The distribution of SST in spring (March-May) of 2007 (Figure 17a) indicates continued cooling in the western North Pacific and warming in a band extending from the subtropical western North Pacific towards California. The concomitant SLP anomaly map (Figure 17b) shows a reversal from the previous season, specifically, an anomalous high over the Bering Sea and anomalous troughing from Japan into the Gulf of Alaska (Figure 17a). A secondary anomalous high was located off the coast of Oregon.

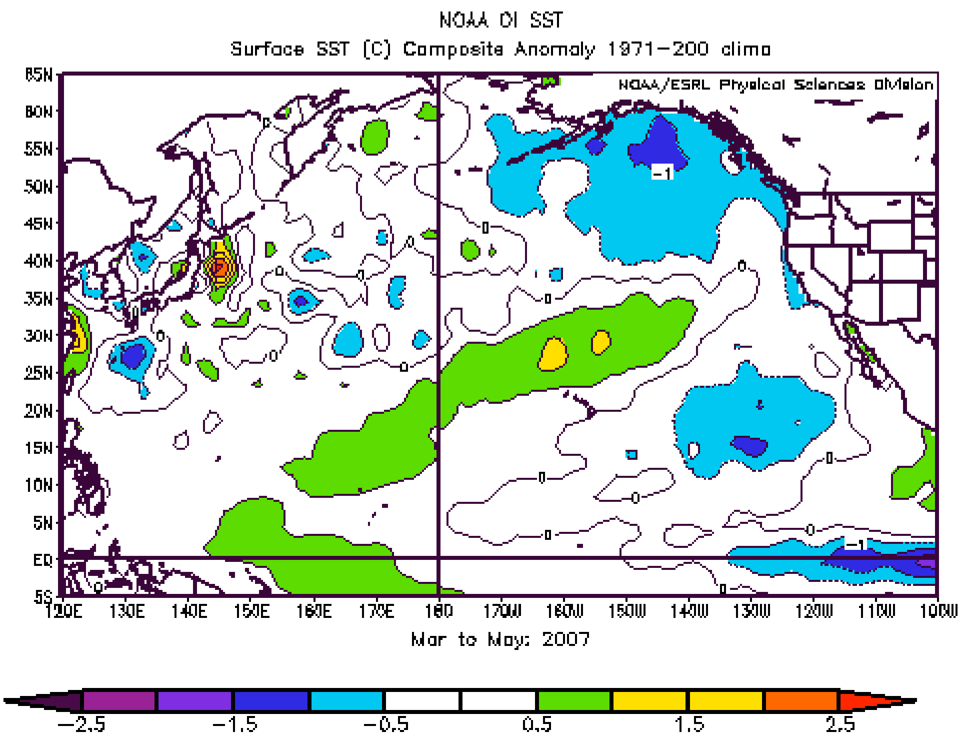

Figure 17a. SST anomalies for March-May 2007.

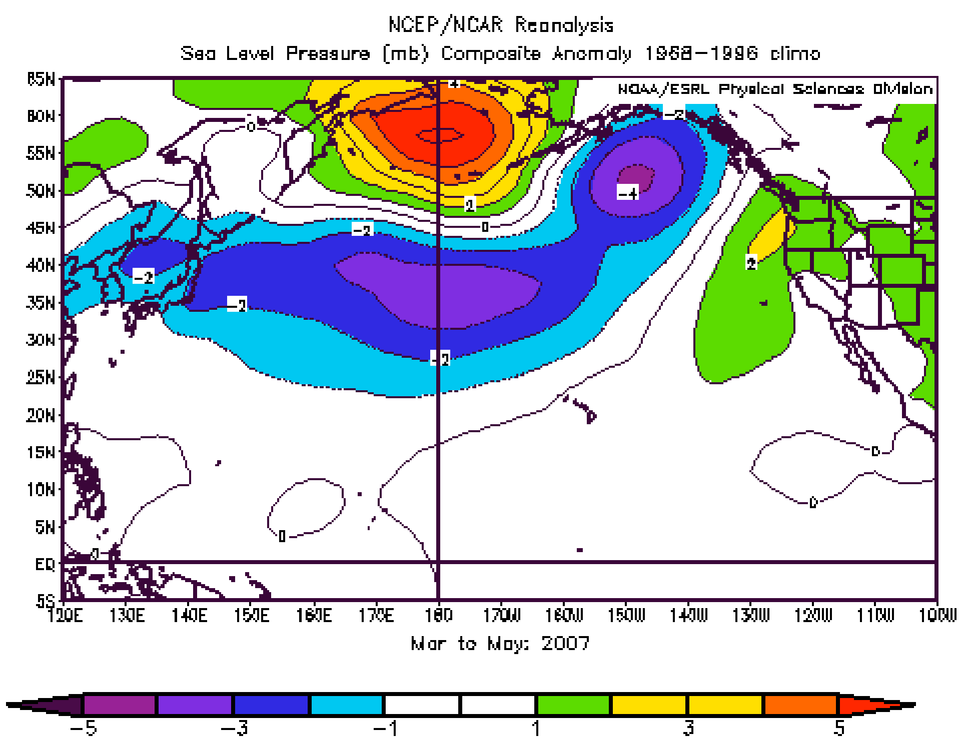

Figure 17b. SLP anomalies for March-May 2007.

The pattern of anomalous SST in summer (June-August) 2007 includes positive values in the western and northern portions of the Bering Sea, negative values in the western North Pacific centered near 35˚ N and in the eastern North Pacific south of Alaska centered near 40˚ N, a continuation of the positive anomalies from the western subtropical North Pacific towards California, and finally, negative anomalies in the eastern subtropical North Pacific (Figure 18a). The magnitudes of these anomalies were generally larger than during the previous spring, which is not unusual in that the summertime oceanic mixed layer is shallow, and hence relatively sensitive to the surface heat fluxes (which are dominated by the shortwave radiation component). The SLP distribution for summer (Figure 18b) indicates the maintenance of relatively high pressure over the Bering Sea, and low pressure anomalies in the northwestern portion of the North Pacific basin and off the coast of the Pacific Northwest.

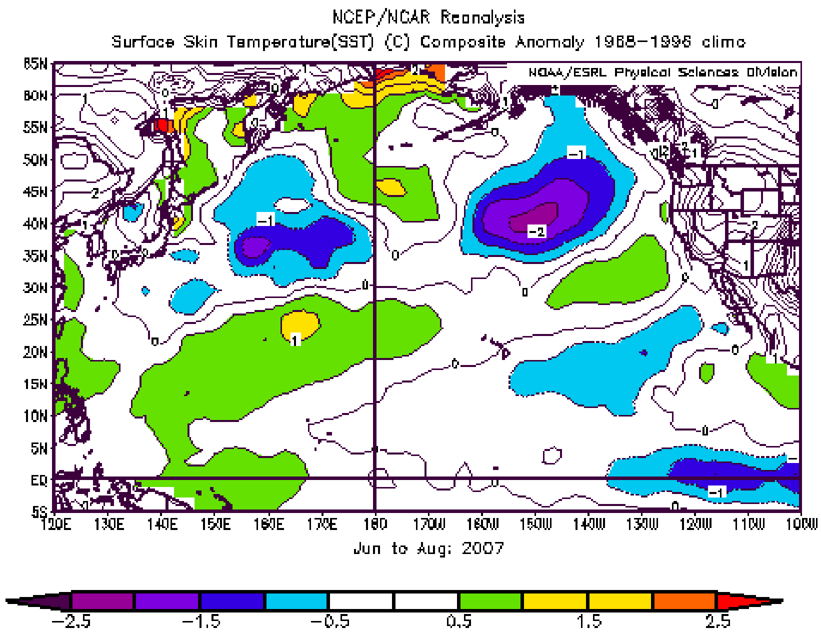

Figure 18a. SST anomalies for June-August 2007.

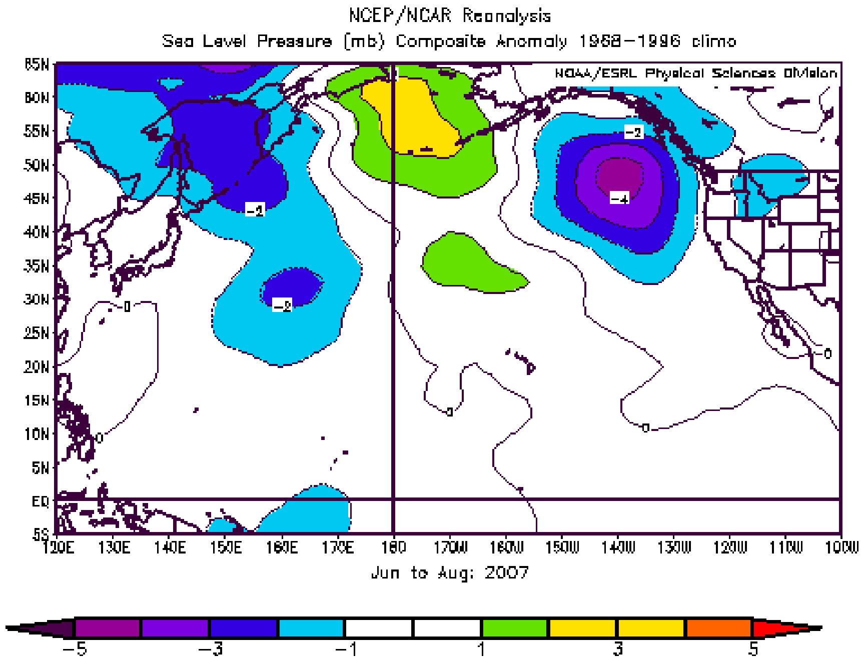

Figure 18b. SLP anomalies for June-August 2007.

2. Climate Indices

The SST and SLP anomaly maps for the North Pacific presented above can be placed in the context of the overall climate system through consideration of climate indices. For the present purposes we focus on four indices: the NINO3.4 index to characterize the state of the El Nino/Southern Oscillation (ENSO) phenomenon, the Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), and two atmospheric indices, the North Pacific index (NPI) and Arctic Oscillation (AO).

ENSO underwent substantial evolution over the last year (Figure 19). Over most of 2006, the trend in the NINO3.4 index was positive, resulting in weak-moderate El Nino conditions near the end of 2006. But this was a short-lived event in that neutral conditions returned by early spring 2007. A cooling trend resumed in summer 2007 after a short period of small change; as will be discussed below it now appears probable at least a weak La Nina will form by the fall/winter of 2007-08. As shown in Figure 19, the El Nino of late 2006 was of lower amplitude than the 2002-03 event, and stronger at its peak, but of shorter duration, than the warm conditions that occurred in the winter of 2004-05. An important point here is that the observed SST and SLP anomalies that occurred in the North Pacific during the fall through winter of 2006-07 bear little resemblance to the canonical patterns associated with previous El Ninos.

The PDO was of rather modest amplitude over the last year (Figure 19). It transitioned from moderately positive in early 2006 to moderately negative in the summer/early fall of 2006 and has slowly increased to weakly positive values during the summer of 2007. In general, the SST anomalies for the North Pacific have not projected strongly on the spatial pattern associated with the PDO since 2000, with the exception of the period of the El Nino winter of 2002-03.

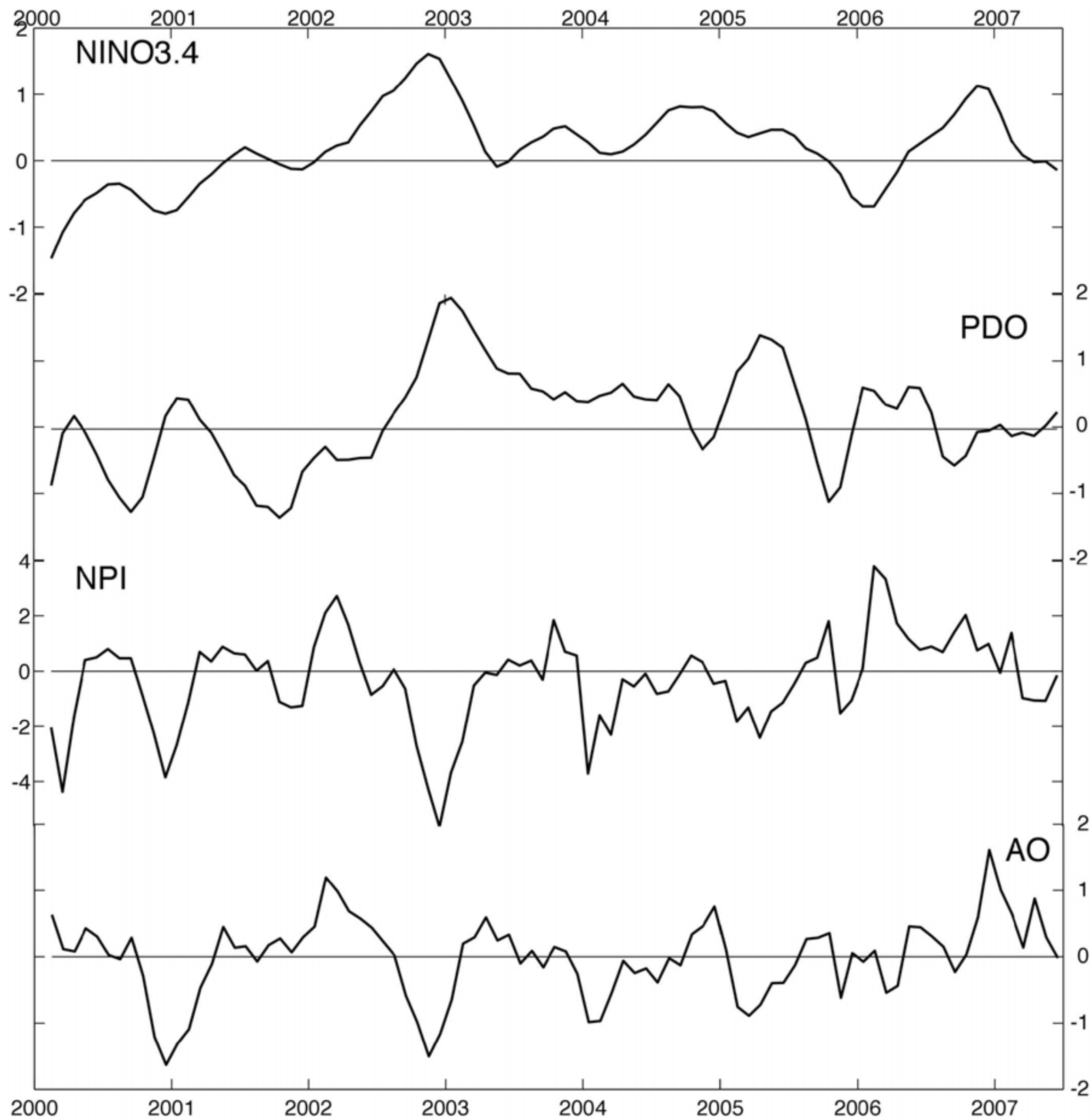

Figure 19. Time series of the NINO3.4, PDO, NPI, and AO indices. Each time series represents monthly values smoothed by 3-month running means. More information on these indices is available from NOAA's Earth Systems Laboratory at http://www.cdc.noaa.gov/ClimateIndices/.

The NPI is one of several measures used to characterize the strength of the Aleutian low. The time series of the NPI with the annual cycle removed (Figure 19) indicates positive values in early 2006 (i.e., high SLP anomalies in the central North Pacific and hence a weak Aleutian low), with an overall declining trend until late spring of 2007. The lack of a strong signal in the NPI since early 2006 is consistent with the SLP anomaly maps presented above, which indicate mostly dipole patterns bracketing, rather than colocated with the position of the mean Aleutian low (with the exception of fall 2006; Figure 15b). The NPI tends to be negative (positive) during El Ninos (La Ninas), but the time series of the NPI and NINO3.4 indices since 2000 show that deviations from this relationship are not uncommon, further illustrating the complexity of the climate variability of the North Pacific.

The AO signifies the strength of the polar vortex, with positive values signifying anomalously low pressure over the Arctic and high pressure over the Pacific and Atlantic at a latitude of roughly 45° N, and hence anomalously westerly winds across the northern portion of the Pacific and Alaska. The AO includes considerable energy on daily to decadal time scales; the time series of the three-month running mean plotted in Figure 19 shows it was in a mostly negative state in early 2006 and was strongly positive for a brief period in the middle of the 2006-07 winter. At this time, the AO and EL Nino may have been working at cross-purposes in terms of their individual effects on the strength (and position) of the Aleutian low, which might help explain the lack of the usual, monopole-type SLP anomaly pattern. The AO trended downward during 2007 to a near-neutral state by summer. If this trend continues, the atmospheric circulation for the Northern Hemisphere will be less zonally symmetric than usual and instead feature relatively high-amplitude waves and meridional flow. Further discussion of the year ahead is provided in Sec. 4.

3. Regional Highlights

a. **West Coast of Lower 48** – During the summer of 2006, strong and especially persistent upwelling-favorable winds occurred from Vancouver Island south to central California. The oceanic response included a tongue of relatively cold water along the coast (as shown earlier in Figure 15a), and a region of hypoxia on the shelf extending from Oregon north into Washington farther than ever found before. Particularly unusual was the lack of relaxation events in the upwelling winds during the summer of 2006; the implications of this are uncertain but it is suspected that it was disruptive to organisms that rely on these events for retention in the coastal domain. On the other hand, the summer of 2007 brought relatively weak upwelling to the same region. By way of comparison, there was also weak upwelling in 2005, but during that particular year it was a case of delayed onset of upwelling in spring, rather than weak upwelling in summer. The delayed onset of upwelling in 2005 had substantial impacts on the coastal ecosystem; the ecosystem's response to anomalous winds in 2007 is unknown at the time of this writing.

b. **Gulf of Alaska** – Significant anomalies in the forcing of the Gulf of Alaska during the last year occurred in the winter of 2006-07 and the spring of 2007. The former period featured anomalous southwesterly winds, which given the prevailing seasonal winds, meant enhanced wind mixing and enhanced positive wind stress curl and hence upward Ekman pumping. The net effect was relatively shallow mixed layer depths in the central Gulf, and deep mixed layer depths close to the coast, at the end of winter of 2007 as compared with the previous year, based on data from ARGO profiling floats (http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/argo/Mixlayer_e.htm). During spring 2007, anomalously low SLP was present in the central Gulf of Alaska, which promotes anomalous downwelling in the coastal zone, and a relatively strong Alaska Coastal Current (ACC). It bears noting that the scarcity of sub-surface data for the shelf regions of the Gulf of Alaska precludes making definitive statements about the actual state of the ACC during 2007.

c. **Alaska Peninsula and Aleutian Islands** – This region experienced westerly wind anomalies during the winter of 2006-07 in association with the SLP anomaly dipole shown in Figure 16b, and a reversal to easterly wind anomalies during the spring of 2007. Westerly winds act to suppress the poleward flow of warm Pacific water through the Aleutian passes (especially Unimak Pass), while easterly winds enhance these transports. This mechanism is apt to have played a role in the anomalously cold conditions that occurred in the southern Bering Sea from winter into early spring (Figure 16a), and in the relatively strong warming from spring into summer that followed.

d. **Bering Sea** – The Bering Sea experienced a relatively cold winter and spring. There was a pronounced warming in late spring to the extent that upper ocean temperatures were above normal by the middle of summer. This anomalous warming can be attributed to the relatively high SLP for the region (Figures 17b and 18b) and fewer storms than normal and hence less wind mixing of cold water from depth, and presumably, reduced cloudiness and hence greater solar heating. Considering that a substantial cold pool was also present, the thermal stratification on the Bering Sea shelf was also relatively large. A more complete treatment of the Bering Sea, with a focus on the winter of 2006-07 in the context of the climate record, is provided later in this document.

e. **Arctic** – The summer of 2007 featured a noteworthy milestone: a record low total area of sea ice in the Arctic. The data from the National Snow and Ice Data Center (NSIDC) are preliminary, but suggest a sea ice coverage as little as about 3 million square kilometers at the end of August 2007 as compared with a previous low value of about 4 million square kilometers in 2005. The lack of sea ice can be attributed to a combination of long-term trends and the weather/circulation of the last year. In particular, the predominantly positive state to the AO during the winter of 2006-07 helped bring about positive air temperature anomalies of about 3˚ C in much of the Arctic (not shown). It is interesting that the anomalous melting of Arctic sea ice in the summer of 2007 was largely confined to the month of June. This month featured anomalously high SLP over the Arctic, with especially prominent positive anomalies over Greenland and extending from the north coast of Alaska to over the North Pole. This circulation pattern both suppresses clouds and hence enhances melting by shortwave radiation, and promotes the export of ice down Fram Strait.

4. Seasonal Projections from NCEP

Seasonal projections from the NCEP coupled forecast system model (CFS03) for SST are shown in Figure 20. The SST anomaly maps indicate the development of a weak-moderate La Nina by the fall of 2007. This result agrees with the consensus ENSO forecast (not shown) from the host of dynamical and statistical models in present use. This model also suggests relatively cold SSTs in the Gulf of Alaska and Bering Sea from late 2007 into 2008, with a weakening of these anomalies in spring 2008. The corresponding atmospheric anomalies (not shown) include lower than normal pressure over the Bering Sea in the fall of 2007, and positive pressure anomalies south of mainland Alaska in early 2008. The latter anomalies are consistent with La Nina, based on the historical record. If these model results are correct, there will be westerly wind anomalies across much of the North Pacific from fall 2007 into spring 2008. It should be noted that these kinds of forecast models have more skill in the tropical Pacific, where the atmosphere-ocean system is relatively deterministic, than in the North Pacific, where it is more chaotic and hence inherently less predictable.

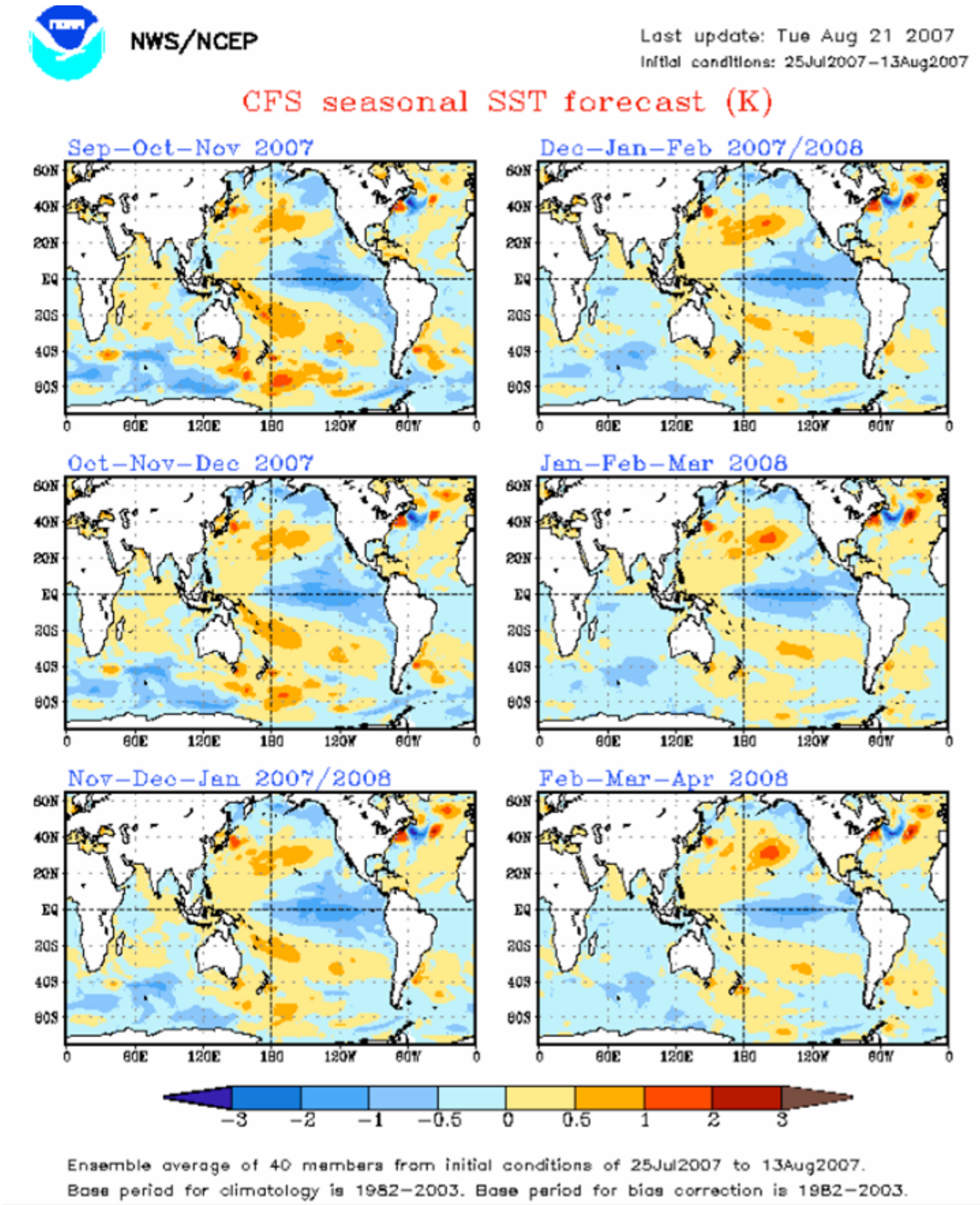

Figure 20. Seasonal forecast of SST anomalies from the NCEP coupled forecast system model.