North Pacific Climate Overview

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Summary. *The North Pacific atmosphere-ocean system from fall 2007 through summer 2008 featured relatively cool sea surface temperature (SST) along its northern flank extending from the Bering Sea through the Gulf of Alaska to off the coast of California. These SST anomalies were associated with a sea-level pressure (SLP) pattern that promoted enhanced westerly winds across most of the northern portion of the basin during fall through spring. The SLP anomaly pattern itself is consistent with the remote forcing from the tropical Pacific. In particular, a La Nina developed in late 2007, as signified by a negative sense for the NINO3.4 index. Two other climate indices commonly used to represent this system, the Pacific Decadal Oscillation for the ocean, and the North Pacific index (NPI) for the atmosphere, were negative and positive, respectively, for most of the last year. The Arctic Oscillation (AO) was also largely positive during the winter of 2008. Near-neutral ENSO conditions became established in the summer of 2008, and given the expectation that these conditions would persist into spring 2009, implies relatively low predictability 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 2007 through summer 2008 is summarized in terms of seasonal mean SST and sea level pressure (SLP) anomaly maps. 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 anomalies during the past year were substantial over large regions of the North Pacific.

The autumn (SON) of 2007 featured positive SST anomalies in the central North Pacific, with maximum amplitudes exceeding 2° magnitude near 35° N, 165° W, and negative SST anomalies in the eastern North Pacific. The SST was also colder than normal in the eastern equatorial Pacific in association with the development of La Nina. The corresponding pattern of anomalous SLP included a negative center (~-7 mb) over the Bering Sea, and a positive center (~3 mb) near 45° N, 150° W. The consequence of this pressure pattern was enhanced westerly winds across the entire North Pacific north of 45° N, and hence anomalous equatorward Ekman transports in the upper ocean, and upwelling-favorable wind anomalies in coastal regions from the south side of the Aleutian Islands to the Pacific Northwest.

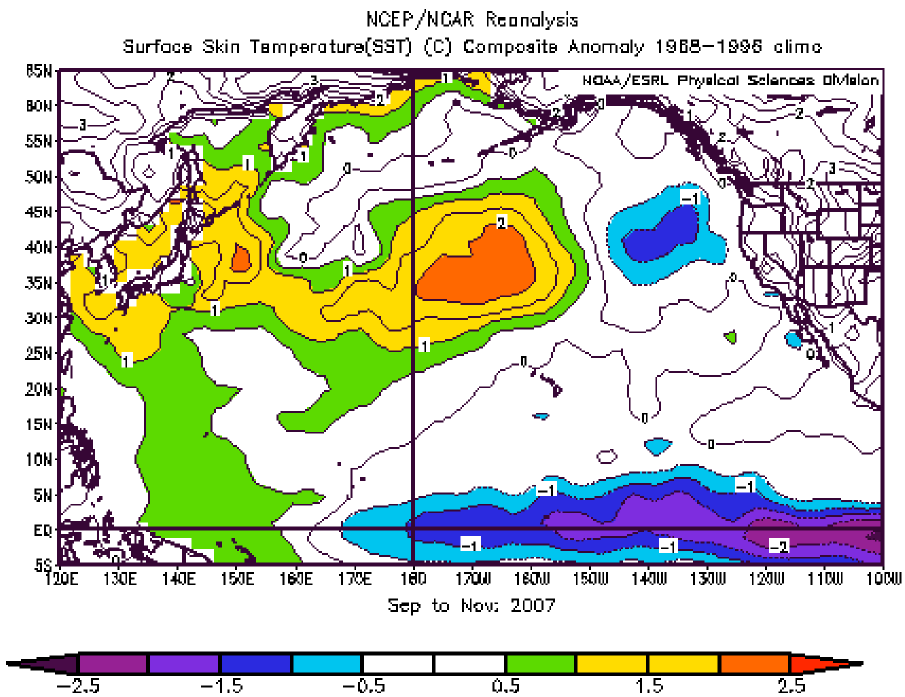

Figure 1a SST anomalies for September-November 2007.

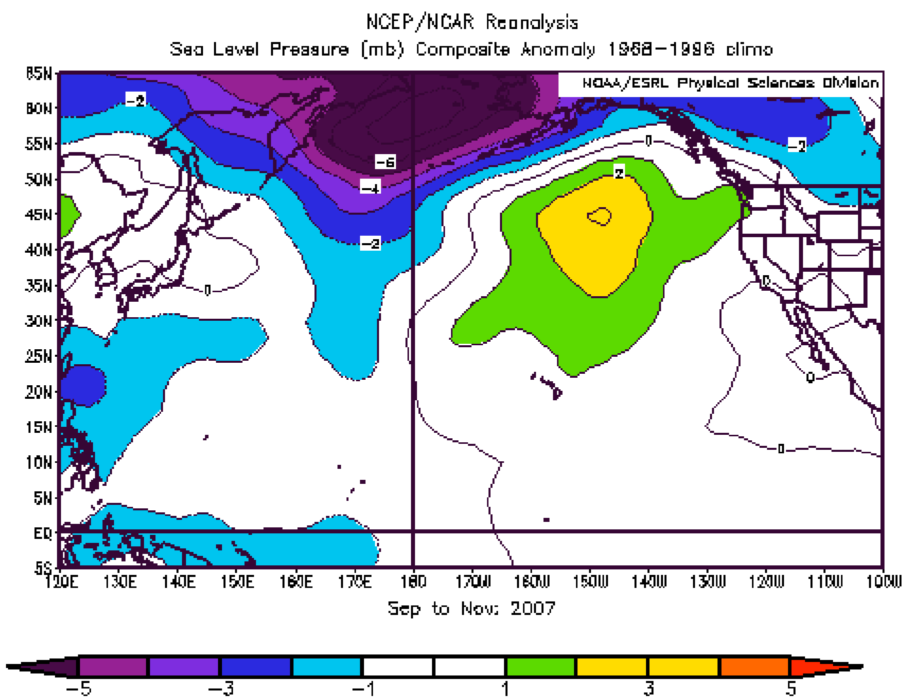

Figure 1b SLP anomalies for September-November 2007.

During the winter (DJF) of 2007-08, a band of positive SST anomalies was prominent from coast of southeast Asia cross the central North Pacific to north of the Hawaiian Islands. Negative SST anomalies extended from the northern Bering Sea across the Gulf of Alaska (GOA) to along the west coast of the lower 48 states. The signature of the moderately intense La Nina is evident in the equatorial Pacific. The SLP was consistent with La Nina, based on historical precedent, in particular with regards to the substantial positive anomalies (~7 mb) present over the eastern North Pacific. In conjunction with weakly negative SLP anomalies in the northern GOA, the wind anomalies were from the west to northwest across the North Pacific from the northern Bering Sea to California, which resulted in a rather cool winter from Alaska to the Pacific Northwest.

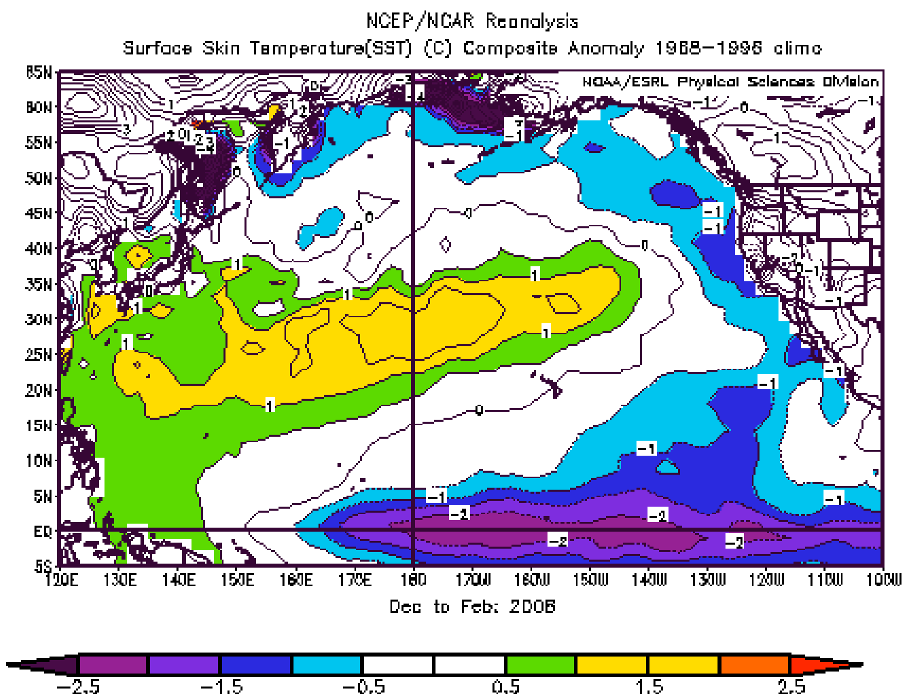

Figure 2a SST anomalies for December 2007-February 2008.

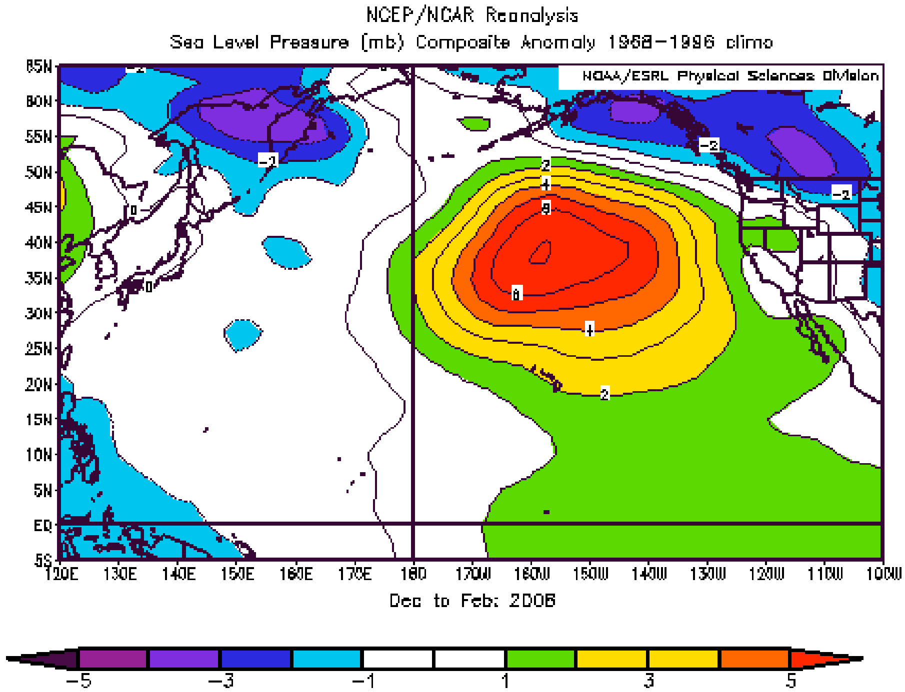

Figure 2b SLP anomalies for December 2007-February 2008.

The distribution of SST in spring (MAM) of 2008 (Fig. 3a) indicates some weakening of the band of positive SST anomalies extending from the western North Pacific to north of the Hawaiian Islands, and strengthening of the negative anomalies from the Bering Sea across the GOA to the coast of California. The equatorial Pacific showed the effects of a declining La Nina, with negative SST anomalies persisting near the dateline, and weak signals to the east. The concomitant SLP anomaly map (Fig.3b) shows positive anomalies in the western Bering Sea and west of Oregon, and negative center near 35° N and the dateline. This pattern favored the continuance of cool conditions over the southeast Bering Sea shelf, GOA and Pacific Northwest, and relatively low precipitation over California.

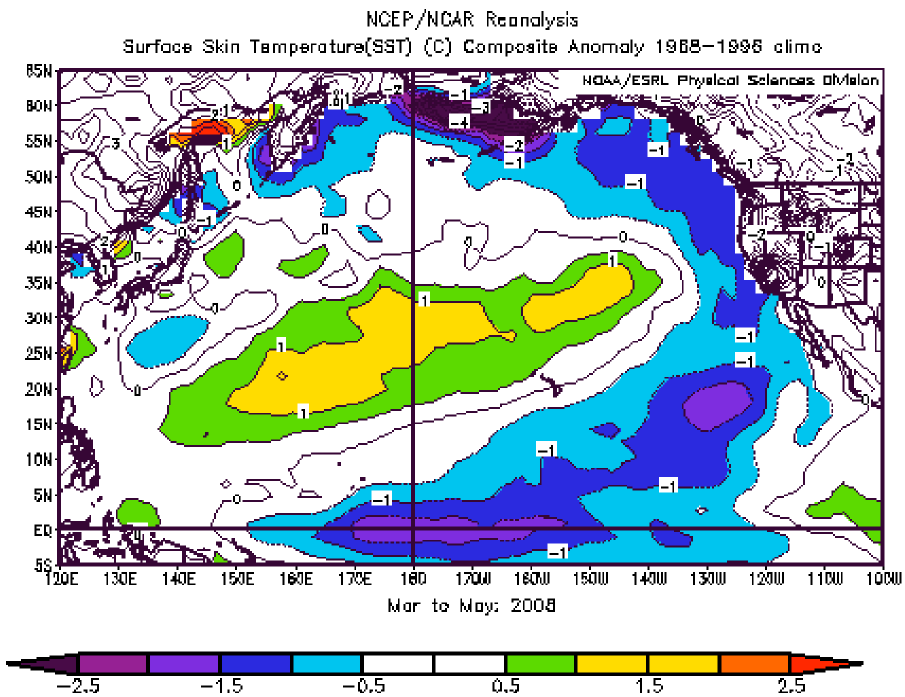

Figure 3a SST anomalies for March-May 2008.

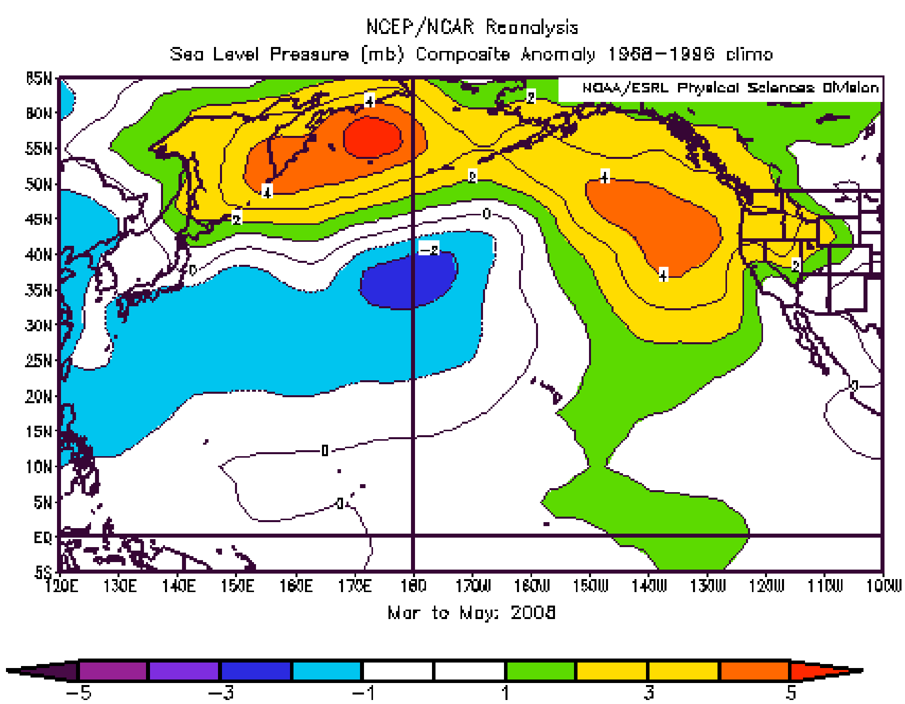

Figure 3b SLP anomalies for March-May 2008.

The pattern of anomalous SST in summer (JJA) 2008 features positive values over much of the central and western North Pacific, and negative anomalies in a semi-circle extending from the subtropical eastern Pacific to off the coast of the Pacific Northwest and into the eastern Bering Sea. La Nina was basically over, with just weak negative anomalies remaining near the dateline, and somewhat larger positive SST anomalies in the eastern equatorial Pacific. The SLP distribution for summer (Fig. 4b) included negative anomalies in the GOA and positive anomalies from the southern Bering Sea to about 35° N and just west of the dateline. This distribution favored anomalous winds from the north over the eastern Bering Sea, a relatively stormy GOA, and fairly typical upwelling along the west coast from Vancouver Island to San Francisco Bay.

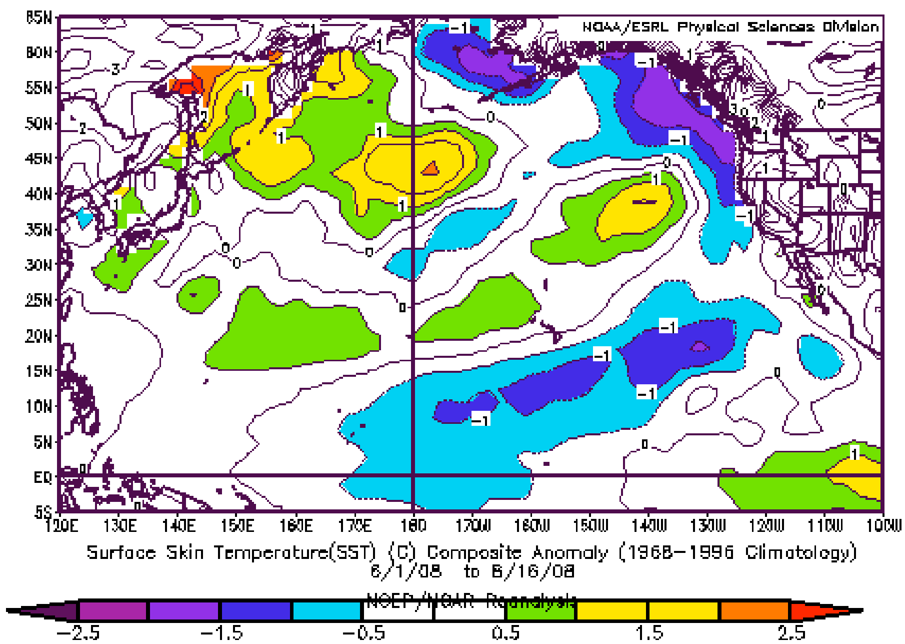

Figure 4a SST anomalies for June-August 2008.

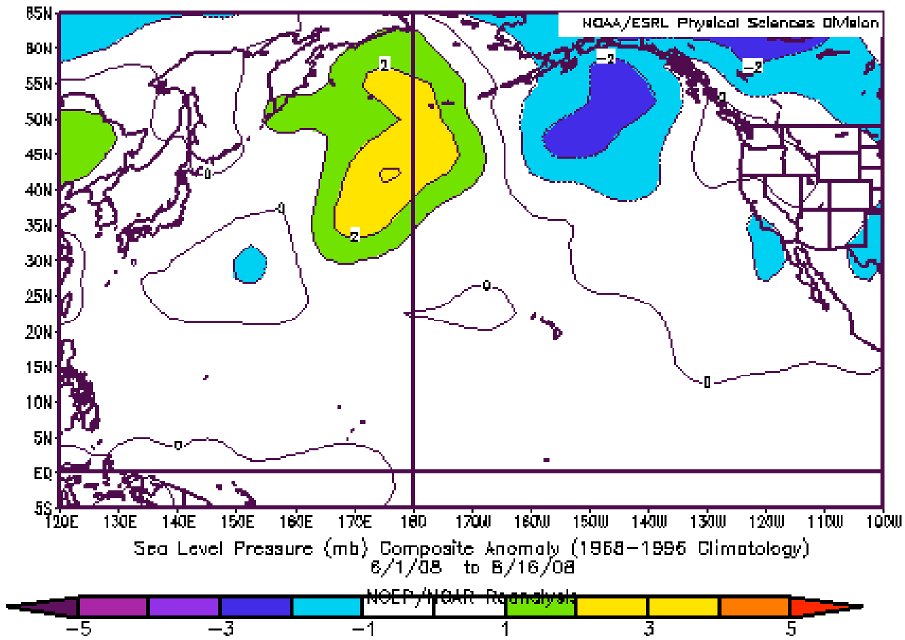

Figure 4b SLP anomalies for June-August 2008.

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 appears to have been an important driver of the North Pacific climate during 2007-08. The NINO3.4 index (Fig. 5) bottomed out at a value of about -2.2 during early 2008; this metric (along with others) indicates that the recent La Nina was slightly stronger than the events of 1998-99 and 1999-2000 but somewhat weaker than that of 1988-89. The SLP anomaly pattern in the eastern North Pacific, in particular the relatively high pressure centered near 40° N, 160° W, resembles its counterparts during the last four La Nina winters (1975-76, 1988-89, 1998-99, and 1999-2000). The NINO3.4 index has trended positive since early 2008 and at the time of writing of this report, is indicating a near neutral state for ENSO going into autumn 2008.

Negative values of the PDO developed in 2007 and have persisted into 2008 (Fig. 5). This transition in the PDO is also consistent with past La Ninas. The last time the PDO was as significantly negative for as long was in association with the La Nina of 1999-2000. It is highly uncertain whether the PDO will remain negative for an extended period since the return to a neutral ENSO state implies low predictability in the atmospheric circulation over the North Pacific, and hence relatively large uncertainty in the atmospheric forcing of the PDO over the near term.

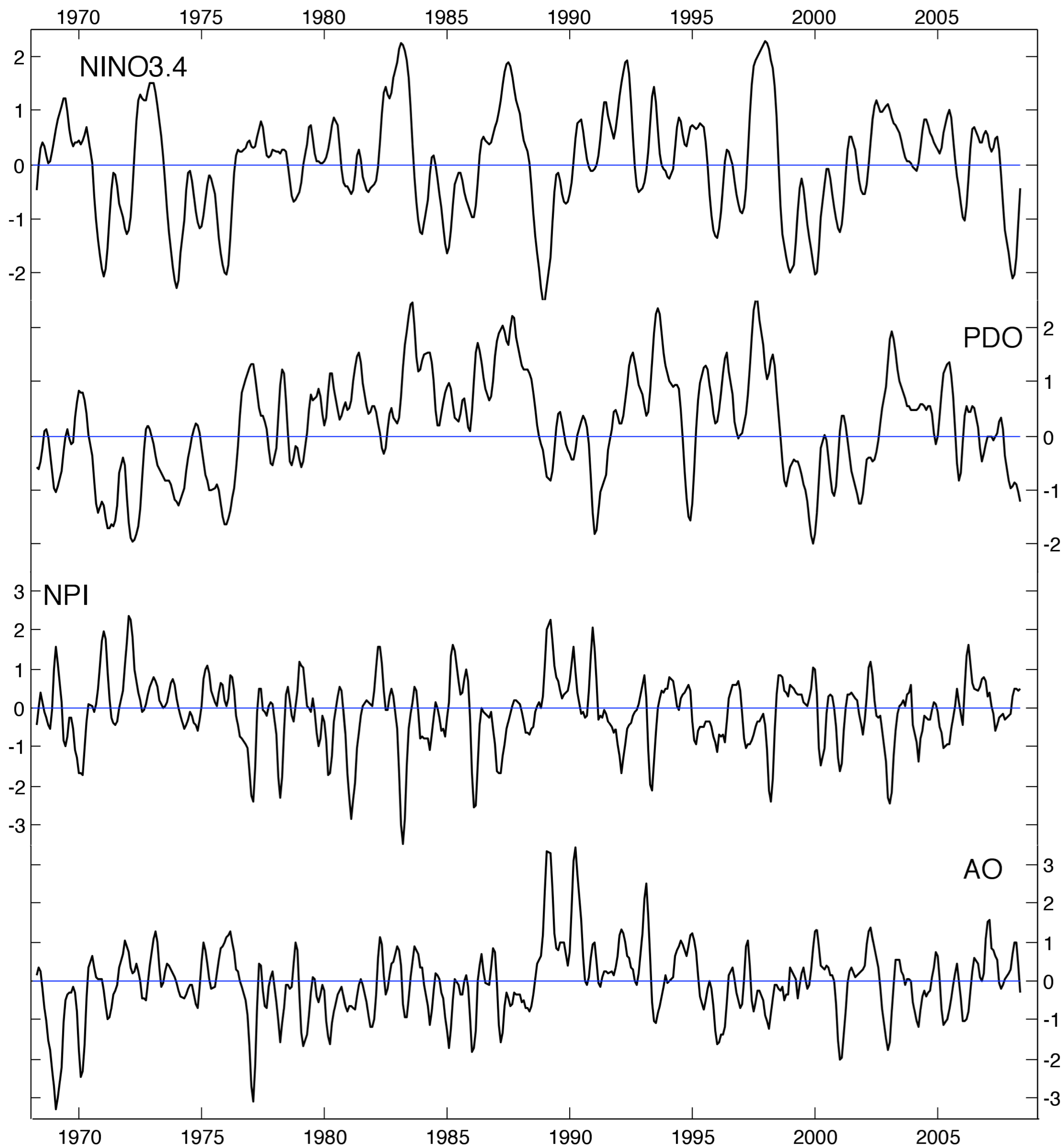

Figure 5 Time series of the NINO3.4, PDO, NPI, and AO indices. Each time series represents monthly values that are normalized and then smoothed by 3-month running means applied twice. More information on these indices is available from NOAA's Earth Systems Laboratory at http://www.cdc.noaa.gov/ClimateIndices/.

The NPI is one of several measures used to characterize the strength of the Aleutian low. The positive state of the NPI since late 2007 (Fig. 5) is consistent with the historical record in that the Aleutian low tends to be weak, and sometimes split into two centers, in association with La Nina, especially during winter. Therefore, while the NPI reflects the influence of the tropical Pacific on the higher latitude atmospheric circulation, it does not necessarily indicate any long-lasting shift in the climate 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. The AO includes considerable energy on daily to decadal time scales; the time series of the three-month running mean plotted in Fig. 5 shows it was in a positive state during late 2007 into early 2008 and since has become negative. It is interesting that the last 5 La Nina winters have been accompanied by a positive state for the AO; the previous six La Nina events all coincided with a negative sense to the AO. This distinction is meaningful in that La Nina winters feature westerly wind anomalies across the North Pacific north of 45° N when the AO is positive, and northwesterly wind anomalies during La Ninas when the AO is negative.

3. Regional Highlights

a. **West Coast of Lower 48** – The fall of 2007 represented a return of relatively strong northerly (upwelling-favorable) winds, after a summer of extremely low upwelling. The upwelling remained greater than normal through the winter in general, and then was near its seasonal norms from late spring through summer 2008. The precipitation was generally slightly above normal in Washington and Oregon, with high mountain snowpacks, and slightly below normal in California, with the latter being particularly dry in spring 2008. The combination of enhanced upwelling and the remote forcing by La Nina in terms of coastally-trapped oceanic phenomena, resulted in cooling of coastal SSTs, relative to their seasonal norms, from fall 2007 until spring 2008. The ecosystem's response to this combination of local and remote forcing is unknown, but based on prior experience and limited sampling, it should be expected that the spring/summer of 2008 included average to above average primary production, and a relative preponderance of sub-arctic versus sub-tropical zooplankton.

b. **Gulf of Alaska** – The data from Argo profiling floats, available at http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/argo/Gak_e.htm, can be used to characterize upper ocean conditions in the Gulf of Alaska. As might be expected based on the prevalence of westerly wind anomalies over the last year, the Argo data shows an increase in the North Pacific Current (West Wind Drift) in the eastern North Pacific. Since the flow in the California Current System has also been stronger, while the flow in the coastal Gulf of Alaska has changed little, the proportion of the flow across the Pacific entering the Gulf has been lower than normal. The mixed layer depths in the Gulf of Alaska appear to have been near normal during most of the last year. The air temperature in the coastal Gulf was on the cool side during the spring and summer of 2008, which probably implies somewhat delayed snowmelt, and depressed glacial melt. Since the precipitation was close to normal, in an overall sense, presumably the runoff of freshwater onto the shelf was also relatively low. 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 Alaska Coastal Current (ACC) during 2008.

c. **Alaska Peninsula and Aleutian Islands** – This region experienced westerly wind anomalies from the fall of 2007 through early 2008 as implied by the SLP anomaly maps of Figs. 1b and 2b. 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. The SST anomalies themselves were negative in the vicinity of the Alaska Peninsula and near normal to the west along the Aleutian Island chain.

d. **Bering Sea** – The Bering Sea has been relatively cool since the winter of 2007-08. The extremely low ice extent in the central Arctic going into the fall of 2007 probably helped delay the development of seasonal sea ice in the northern Bering Sea early in the winter, but once the weather conditions become favorable for ice, near the end of 2007, there was rapid ice growth and advance of the ice pack southward. SSTs remained cool in the eastern Bering Sea through summer 2008 due to a combination of relatively inclement weather (less insolation and more wind mixing) and northerly wind anomalies. More detail on physical conditions in the Bering Sea during last year is provided in the following section.

e. **Arctic** – The past year was marked by some recovery from a record low total area of sea ice in the Arctic in early fall 2007. At the time of the writing of this report, the sea ice is relatively thin and in low concentrations over much of the Arctic, and it is possible that there will be very rapid melting and ultimately, a minimum ice extent in 2008 not much different from that in 2007. The circulation in the central Arctic has not been as favorable for the export of ice in 2008 as it was in 2007, but there is very little thick, multi-year ice, and so the region is susceptible to continued low ice extent.

4. Seasonal Projections from NCEP

Seasonal projections from the NCEP coupled forecast system model (CFS03) for SST are shown in Fig. 6. The SST anomaly maps indicate the persistence of cool SSTs in the equatorial Pacific. This result is within the envelope of ENSO forecasts (not shown) from the host of dynamical and statistical models in present use, which indicate near-neutral conditions through spring 2009 in a consensus sense. The CFS03 model indicates the maintenance of relatively cold SSTs in the North Pacific from the Bering Sea, across the Gulf of Alaska to the west coast of the lower 48 states through fall, with subsequent weakening. By spring 2009, the only signal emerging above the climate "noise" is relatively cool SSTs in the Gulf of Alaska. The corresponding atmospheric anomalies (not shown) include lower than normal pressure over Alaska and higher than normal pressure in the eastern sub-tropical Pacific. This pattern is consistent with a cool Gulf of Alaska, and a weaker tendency for a cool Pacific Northwest. The latter signal is barely above the noise, but may serve to counteract the slow warming trend in association with climate change. It is noteworthy that the equivalent forecasts made one year ago were largely correct on the basin-scale. The previous forecasts had the benefit of the relatively systematic effects of La Nina; for the upcoming year this source of predictability is lacking. That being said, the coupled model forecasts do have some skill, and should be considered in making projections at least through the winter of 2008-09.

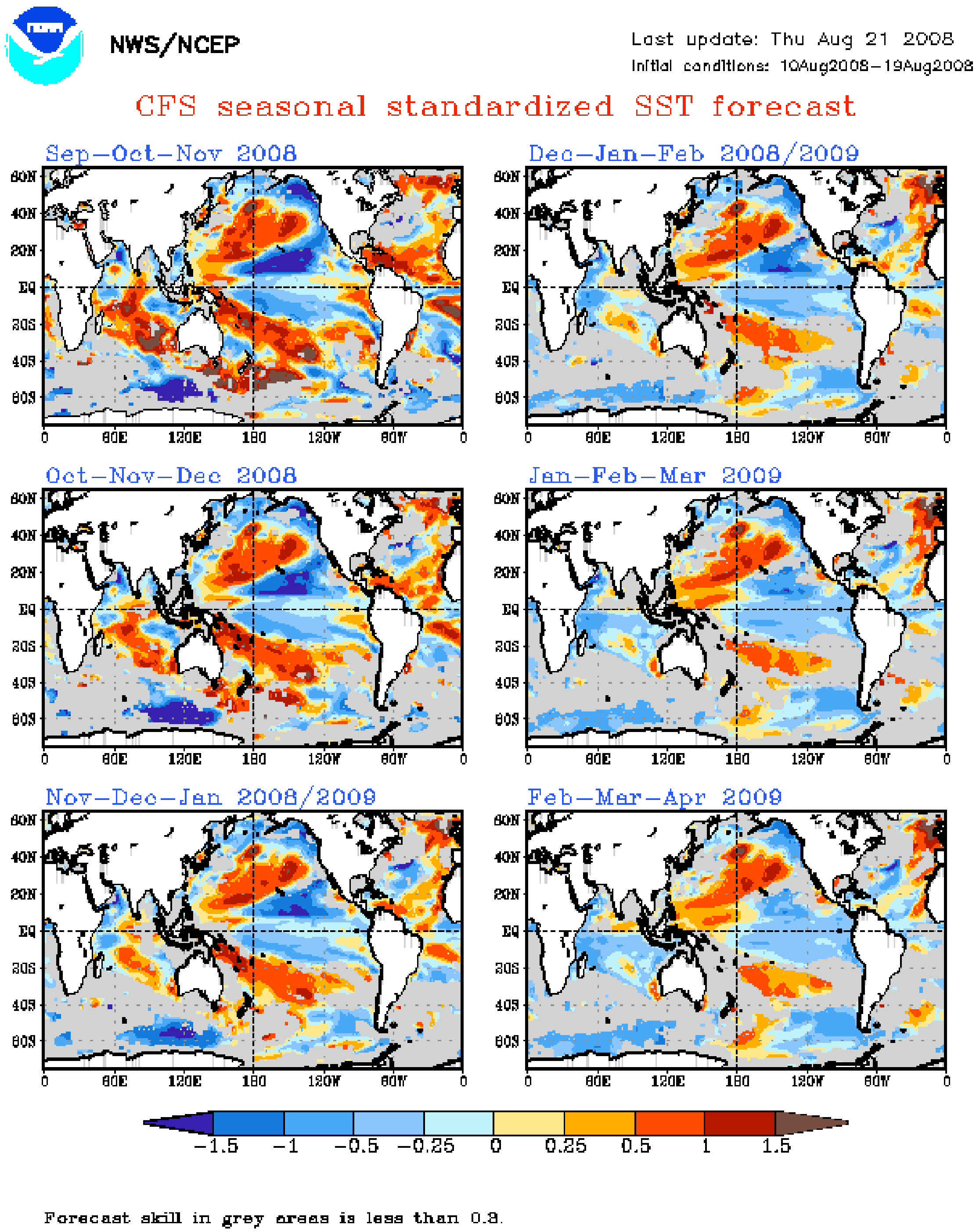

Figure 6. Seasonal forecast of SST anomalies from the NCEP coupled forecast system model.