North Pacific Climate Overview

N. Bond (UW/JISAO), J. Overland (NOAA/PMEL)
Contact: Nicholas.Bond@noaa.gov

Last updated: August 2009

Summary*. The North Pacific atmosphere-ocean system from fall 2008 through summer 2009 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 accompanying a weak Aleutian low during the past winter and spring. The consequences of the latter included relatively cold conditions and heavy sea ice for the Bering Sea, and mostly upwelling-favorable wind anomalies from the Gulf of Alaska to the Pacific Northwest. The summer of 2009 has featured a shift in the wind pattern and an overall moderation of coastal SSTs. The past winter included a La Nina of modest amplitude; the higher latitude response to the tropical Pacific was stronger than that during the past winter, even though the La Nina was weaker. El Nino conditions developed in the summer of 2009. There is a strong consensus of the available forecast models that this El Nino will persist, and probably strengthen, into 2010. This is liable to bring about a positive state for the PDO and relatively warm SSTs along the west coast of North America.*

1. SST and SLP Anomalies

The state of the North Pacific from autumn 2008 through summer 2009 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. From the perspective of the climate forcing, and basin-scale response, the year of 2008-09 bears quite a bit of resemblance to that of the previous year.

The autumn (SON) of 2008 featured positive SST anomalies in the central North Pacific, with maximum amplitudes exceeding 2° magnitude near 45° N, 160° E. Negative SST anomalies occurred along the west coast of North America from the Bering Sea to central California, and in the central and eastern subtropical North Pacific. The corresponding pattern of anomalous SLP included a moderate maxima (2-3 mb) over the Bering Sea,. Otherwise, relatively weak anomalies, and hence also near-normal winds prevailed over most of the North Pacific.

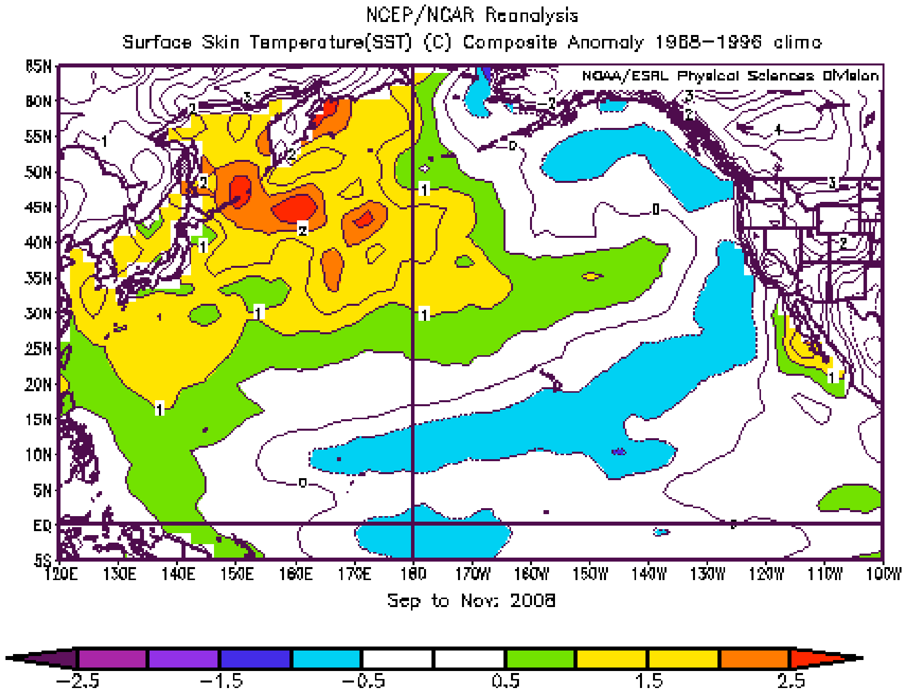

Figure 1a SST anomalies for September-November 2008.

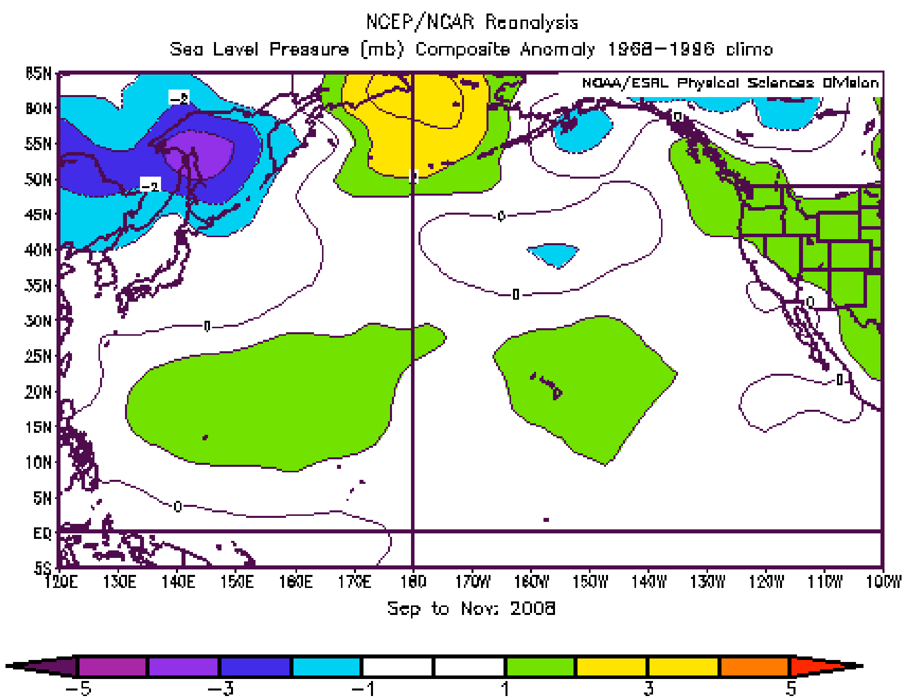

Figure 1b SLP anomalies for September-November 2008.

The pattern of anomalous SST during winter (DJF) of 2008-09 was similar to that during the fall of 2008. The primary changes that occurred over this interval were the development of cool conditions in the eastern Bering Sea, and a shift in the positive anomaly center to east of the dateline. There was also substantial cooling (relative to seasonal norms) in the eastern and central tropical Pacific in association with a return of weak La Nina conditions. The SLP during winter 2008-09 featured a large positive anomaly (~10 mb) in the northeastern Pacific. The sense and location of this anomaly is consistent with that which has occurred during past La Nina winters, but its magnitude is greater than ususal, particularly considering the modest intensity of La Nina. By way of comparison, the previous winter's La Nina was on the order of 50% stronger, but the atmospheric perturbation over the North Pacific, as gauged by the SLP, was about 30% weaker. This comparison of the two years illustrates that the linkage between ENSO and the midlatitude atmospheric circulation is subject to noise. Whatever the cause(s), the anomalous SLP pattern shown in Fig. 2b indicates anomalous westerlies in the mean across the northern portion of the basin from the dateline to southeast Alaska, and anomalous northerlies in the far eastern North Pacific.

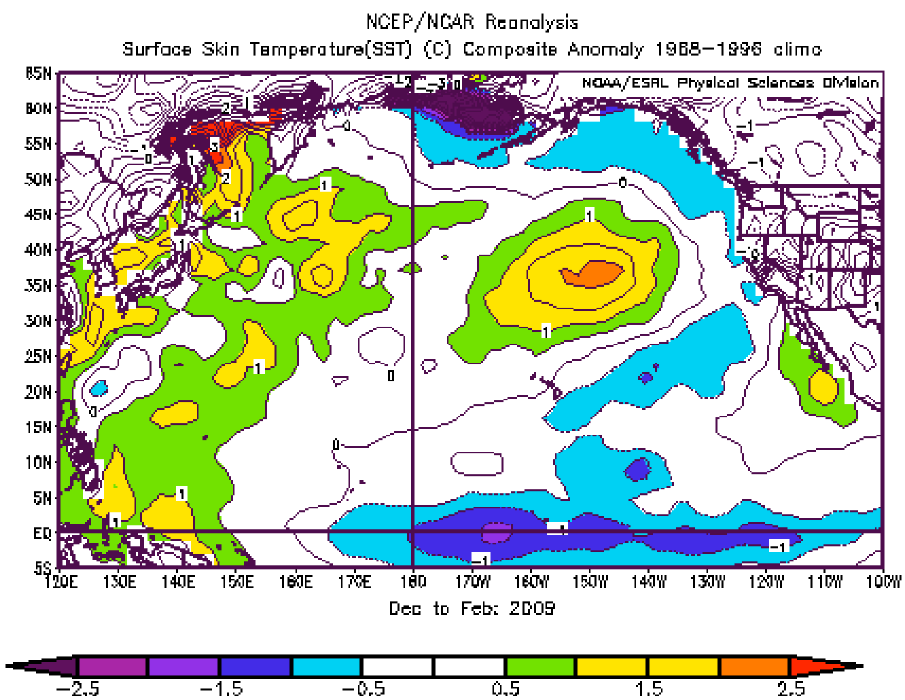

Figure 2a SST anomalies for December 2008-February 2009.

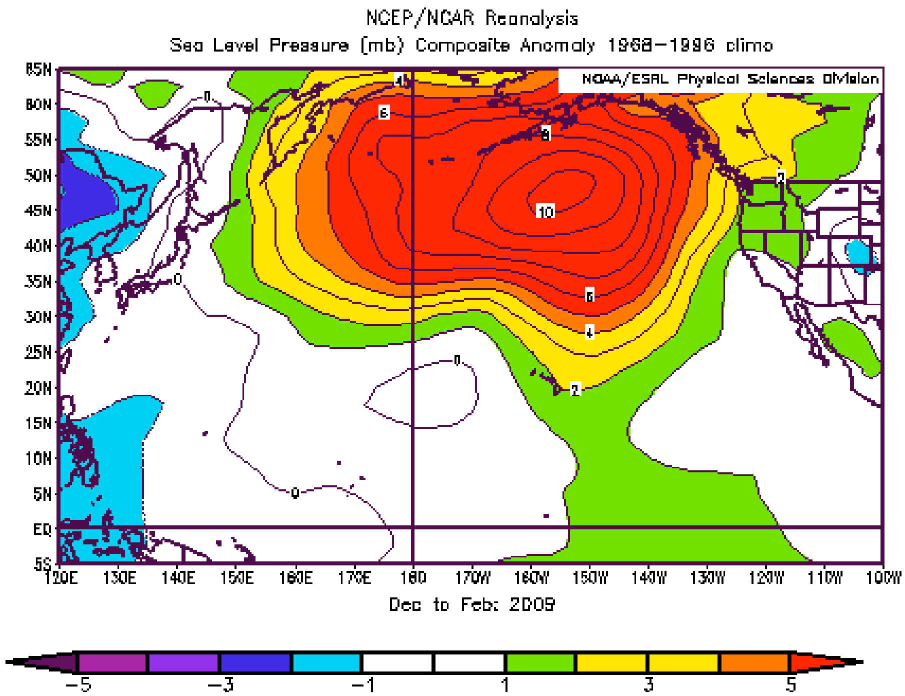

Figure 2b SLP anomalies for December 2008-February 2009.

The distribution of SST in spring (MAM) of 2009 (Fig. 3a) indicates an overall weakening of the positive anomalies in the central portion of the basin and cooling along the west coast of North America from Alaska to California. Only weak remnants of La Nina were present in the tropical Pacific. The concomitant SLP anomaly map (Fig.3b) indicates relatively high pressure over the Bering Sea and Gulf of Alaska and near normal pressure south of about 35° N. This pattern served to support relatively cool northerly winds and enhanced coastal upwelling for the Gulf of Alaska and Pacific Northwest.

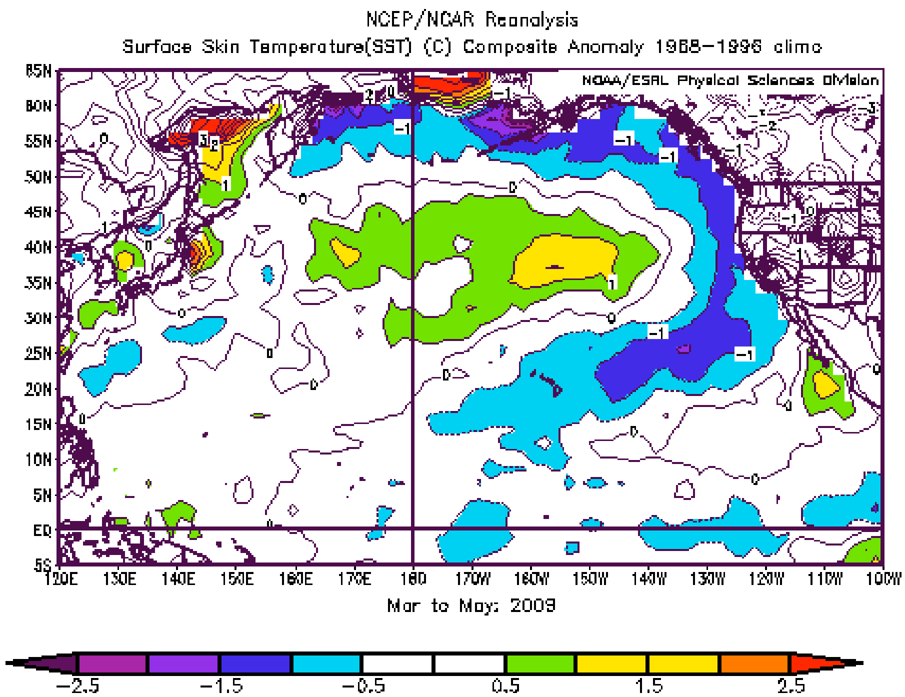

Figure 3a SST anomalies for March-May 2009.

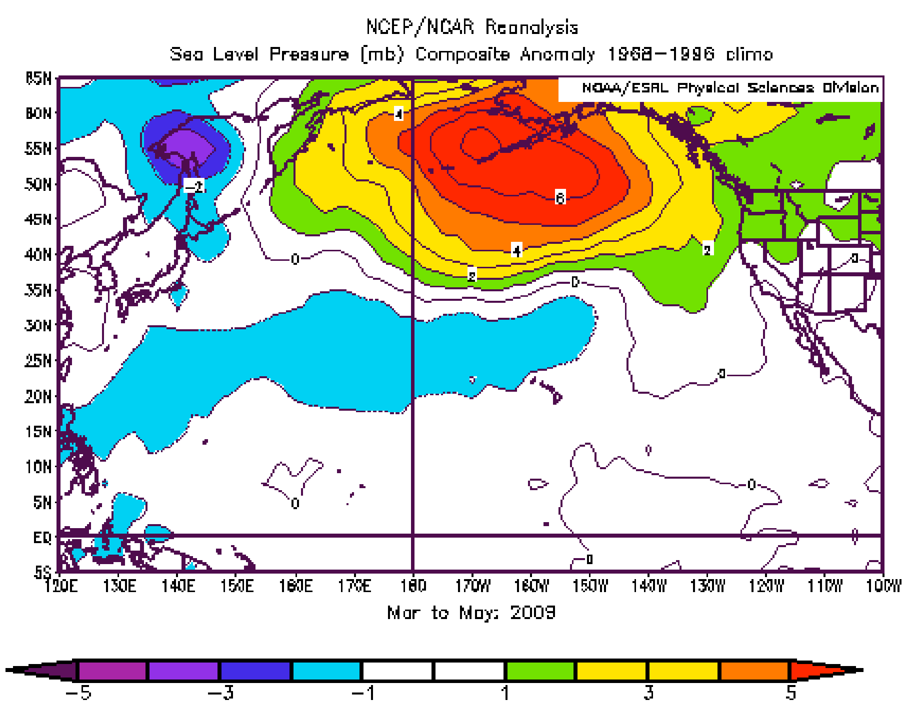

Figure 3b SLP anomalies for March-May 2009.

The pattern of anomalous SST in summer (JJA) 2009 included near-normal values along the west coast of North America from the Gulf of Alaska to California after a cooler than normal spring. Relatively cool SSTs persisted in the eastern Bering Sea. For the basin as a whole, the distribution of SST less resembled that characteristic of the negative state of the PDO. There were relatively warm SSTs in the tropical Pacific, especially east of about 130° W where temperatures were more than 1° C greater than normal.in association with a developing El Nino. The SLP distribution in summer 2009 featured anomalously low pressure in the central Pacific from about 25° N to Bering Strait. This anomaly represented a marked change from the higher than normal SLP in the central North Pacific observed over the previous two seasons. Less extensive SLP features included a negative anomaly off the coast of Northern California, and a weakly positive anomaly in the Gulf of Alaska. As a consequence, there was weaker than normal upwelling along the west coast of the lower 48 states, and slightly stronger than normal upwelling along the coast from the northeastern portion of the Gulf of Alaska to Vancouver Island.

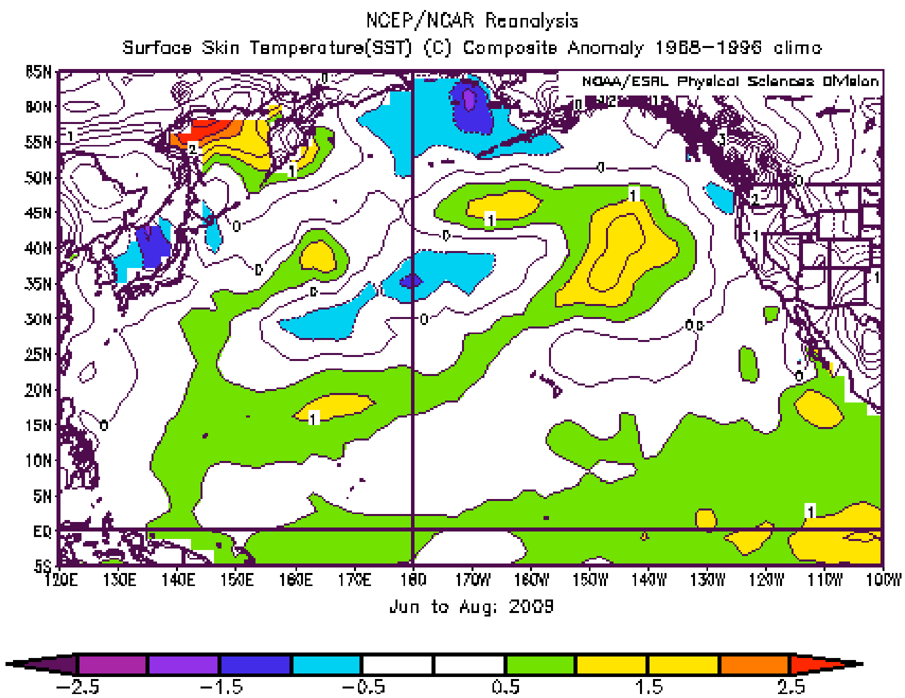

Figure 4a SST anomalies for June-August 2009.

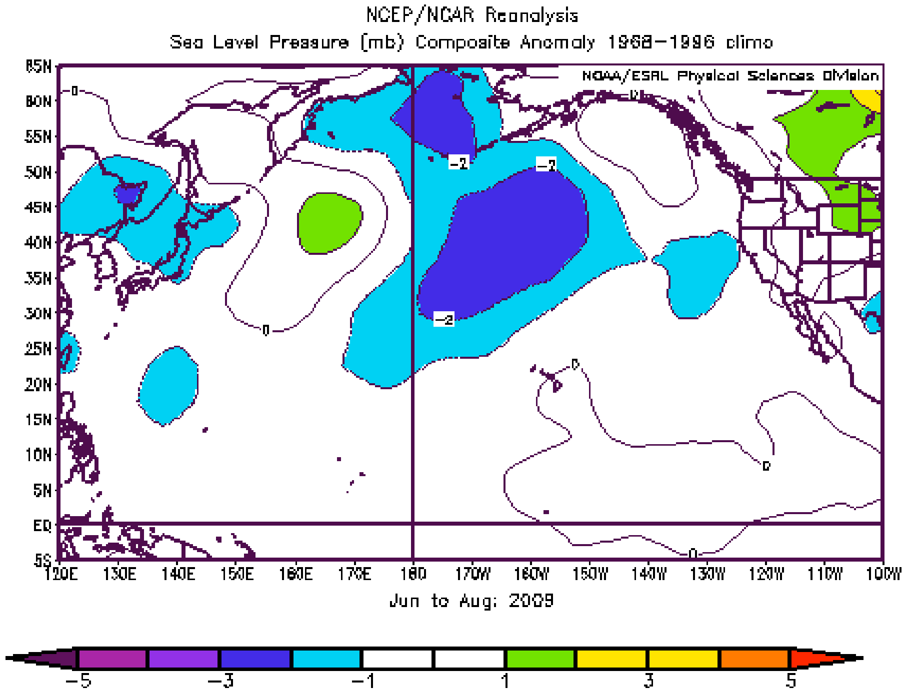

Figure 4b SLP anomalies for June-August 2009.

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 probably played an important role in determining the state of the North Pacific climate during 2008-09. As mentioned above, while the La Nina was actually stronger in 2007-08 than during the past year, as encapsulated by the NINO3.4 index (Fig. 5), the concomitant SLP anomalies were stronger in the more recent winter.   The tropical Pacific underwent a transition during spring 2009 and is now characterized by weak-moderate El Nino conditions, and there is a strong consensus of the dynamical and statistical models used to forecast ENSO that this El Nino will strengthen into the winter of 2009-10.

The PDO underwent a general decline from early 2003 to early 2009 and since then, has trended positive. Note the correspondence between the PDO and ENSO as indicated by NINO3.4; the correlation coefficient between the NINO3.4 and PDO indices is ~0.6 over the period of record. Given the expectation of El Nino over the upcoming fall and winter, it is also probable that the PDO will revert back to a positive state. On the other hand, while the sense of the PDO tends to match that associated with ENSO, the magnitudes of the PDO's extrema do not correspond tightly with those with ENSO. The key here is the strength of the Aleutian low (the stronger the low the more positive the PDO) and there are factors other than ENSO that help determine the strength, and position, of the Aleutian low.

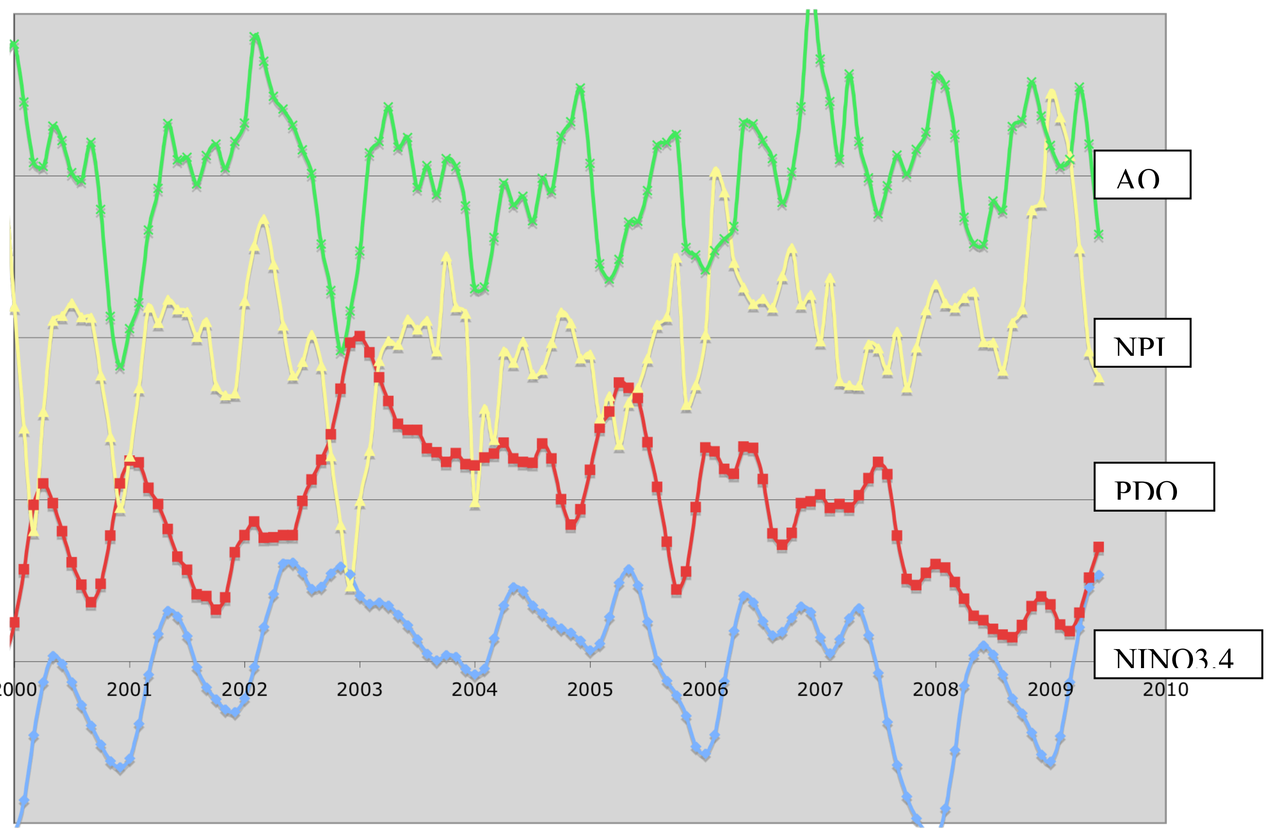

Figure 5 Time series of the NINO3.4 (blue), PDO (red), NPI (yellow), and AO (green) indices. Each time series represents monthly values that are normalized and then smoothed with the application of 3-month running means. The distance between the horizontal grid lines represents 2 standard deviations. 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 NPI was strongly positive from late 2008 through 2009 (Fig. 5), as also indicated by the SLP anomaly maps of Figs. 2b and 3b. While the NPI has certainly trended strongly negative during 2009, and the remote effects of ENSO make it probable that this trend will continue into 2010, the intrinsic variability of the middle to higher latitude atmospheric circulation precludes making any definitive projections for the future state of the NPI.

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 mostly positive state from late 2006 through spring 2009, and recently shifted to a negative phase. The response of the atmospheric circulation in the North Pacific to ENSO tends to be enhanced (suppressed) during periods of a negative (positive) state in the AO (Bond and Harrison, Intl. J. Climatol., 2006). There is little predictability in the AO, but if it does remain mostly negative over the next two seasons, then it is likely that the upcoming El Nino will have relatively dramatic impacts on North Pacific air-sea interactions.

3. Regional Highlights

a. **West Coast of Lower 48** – The focus here is on the upwelling that occurred during the last year. The winter and spring featured stronger than normal upwelling, particularly in the north. This is consistent with observations of a relatively high abundance of species that prosper in cool conditions, including sub-arctic zooplankton, from northern California to Oregon, and presumably, to the north. The winds, relative to their seasonal norms, shifted abruptly in late spring, resulting in anomalous downwelling in central and southern California, especially in June. These conditions are suspected to be a contributing cause of very high sea lion pup mortality in the Southern California Bight, and poor conditions in general for the other piscivores of the region such as cormorants.

b. **Gulf of Alaska** – The coastal Gulf of Alaska remained relatively cool during the past year. The data from Argo profiling floats, available at http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/argo/Gak_e.htm, reveals a relatively weak and broad Alaska Current off the coast of SE Alaska, as compared with 2008. This region also had relatively shallow mixed layer depths in the winter and spring of 2009, as would be expected during periods of higher than normal SLP and hence suppressed storminess. Based on the winds along the northern Gulf of Alaska coast, the Alaska Coastal Current (ACC) on the shelf was probably relatively weak during the winter and spring, returning to near-normal transports in the summer. 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 the review period.

c. **Alaska Peninsula and Aleutian Islands** – The eastern portion of this region experienced suppressed storminess during winter and spring; the sense of the wind anomalies since late 2008 is from the east to southeast, which is associated with enhanced transports through Unimak and the other shallow passes in the eastern Aleutians. The western Aleutians experienced southerly wind anomalies early in the period and northerly wind anomalies during the past summer. The SST here was warm during the latter part of 2008, cooling to near normal by summer 2009 relative to seasonal norms.

d. **Bering Sea** – The third in a series of notably cold winters occurred in the Bering Sea. This is consistent with a weaker than normal Aleutian low, in that when the Aleutian low is intense there is a greater frequency of cyclonic storms of maritime origin, versus migratory anticyclones of continental or Arctic origin. An important consequence of the extensive sea ice on the Bering

Sea shelf during the past winter and spring was that it effectively left behind a prominent cold pool of water of less than 2° C on the middle shelf.. The offshore extent of the cold pool during 2009 is comparable, but not quite to that which was observed in 2008. The SLP pattern over the Bering Sea has favored somewhat greater than normal wind speeds over the shelf during the summer of 2009, but at the time of the writing of this report, the extent to which this has been manifested in the mixing of nutrients from depth, and hence sustained primary production, is unknown.

e. **Arctic** – The past year was marked by some continuation in a recovery from a record low total area of sea ice in the Arctic in early fall 2007. At the time of writing, the sea ice cover for the Arctic as a whole was about 1 x 10^6 km^2 greater than that at the same time during 2007, but still 1.3 x 10^6 km^2 less than the 1979-2000 average. From an Alaskan perspective, it is interesting that the ice edge in the Beaufort Sea is presently near its long-term climatological position. The melt season will continue for another 5-6 weeks, and it is uncertain how the minimum ice extent will compare with past summers. The SLP pattern during winter and spring featured anomalously low values in the central Arctic in association with a positive state of the AO. A decidedly different SLP distribution prevailed in the summer of 2009 during which substantially higher than normal pressure occurred in the Arctic, especially in its western half.

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 increasingly positive SST anomalies in the equatorial Pacific. This model's forecast of El Nino is on the high side, but within the envelope of ENSO forecasts (not shown) from the host of dynamical and statistical models in present use. The CFS03 model indicates an overall warming along the west coast of North America. Specifically, by late winter/early spring of 2010, it projects near normal temperatures on the eastern Bering Sea shelf, and significantly warmer than normal temperatures in the northeastern portion of the North Pacific, particularly off the coast of southeast Alaska. It turns out that the forecasts made by this model last year at this time reproduced the basin-wide pattern of the seasonal mean SST anomalies that were observed, but with an overall warm bias. In particular this atmosphere-ocean model did not forecast conditions promoting extremely heavy sea ice on the eastern Bering Sea shelf. Nevertheless, the favorable track record for this model over the last two years, and the extra North Pacific predictability associated with El Nino indicates it can provide useful guidance through at least the winter of 2009-10.

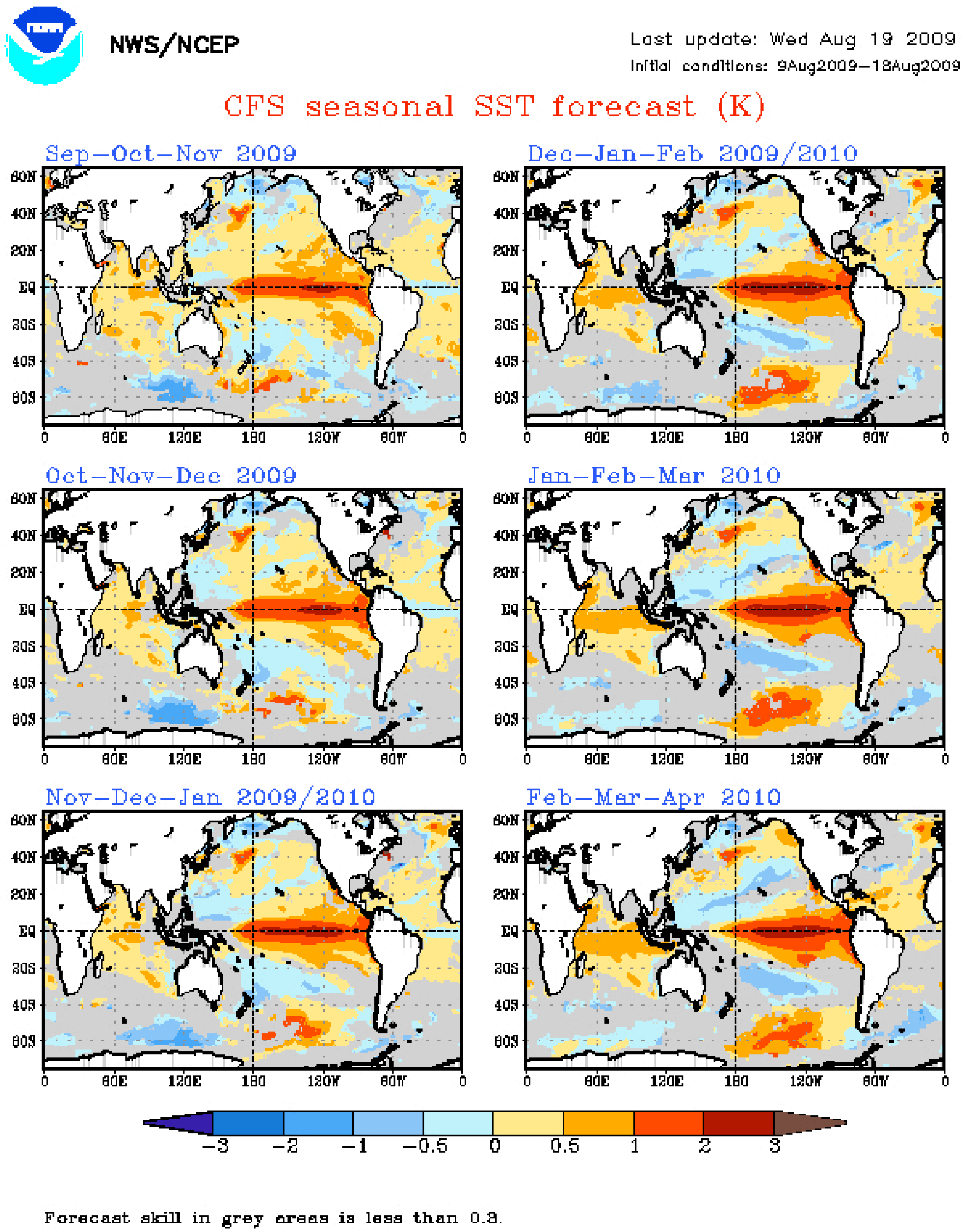

Figure 6. Seasonal forecast of SST anomalies from the NCEP coupled forecast system model.