North Pacific Climate Overview

N. Bond (UW/JISAO), L. Guy (UW/JISAO)
Contact: Nicholas.Bond@noaa.gov
NOAA/PMEL, Building 3, 7600 Sand Point Way NE, Seattle, WA 98115-6349

Last updated: August 2010

Summary. *The North Pacific experienced mostly cooler than normal upper ocean temperatures in its eastern and northern portions from fall 2009 through summer 2010. These conditions can be attributed to the pre-existing state of the North Pacific and the basin-scale climate forcing during the past year. An El Niño occurred during the winter of 2009-10, and while the associated atmospheric circulation anomalies resembled those with past events, its effects do not appear to have persisted beyond spring 2010. La Niña began developing in the spring/summer of 2010 and is forecast to strengthen over the remainder of 2010. This should lead to a relatively weak Aleutian low, and a negative sense to the Pacific Decadal Oscillation (PDO) for the North Pacific atmosphere-ocean climate system into spring 2011.*

1. SST and SLP Anomalies

The state of the North Pacific from autumn 2009 through summer 2010 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.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl. In an overall sense, the year of 2009-10 featured prominent signals in the climate forcing of the North Pacific. This forcing was apparently on short enough time scales to produce a largely muted response in upper ocean temperatures.

The autumn (SON) of 2009 included negative SST anomalies in the eastern North Pacific, with the largest amplitudes exceeding 1° magnitude. Mostly positive SST anomalies prevailed in the western North Pacific. Warmer than normal SSTs occurred in the central and eastern tropical Pacific in association with the development of El Niño (Fig. 1a). The corresponding pattern of anomalous SLP included negative anomalies in the Gulf of Alaska and weaker positive anomalies stretching from eastern Siberia to north of the Hawaiian Islands (Fig. 1b). This pattern corresponds with both northerly wind anomalies over the Bering Sea, and hence relatively cool air temperatures (not shown), and westerly wind anomalies from roughly 35° to 50° N across the eastern North Pacific, and hence anomalous equatorward Ekman transports.

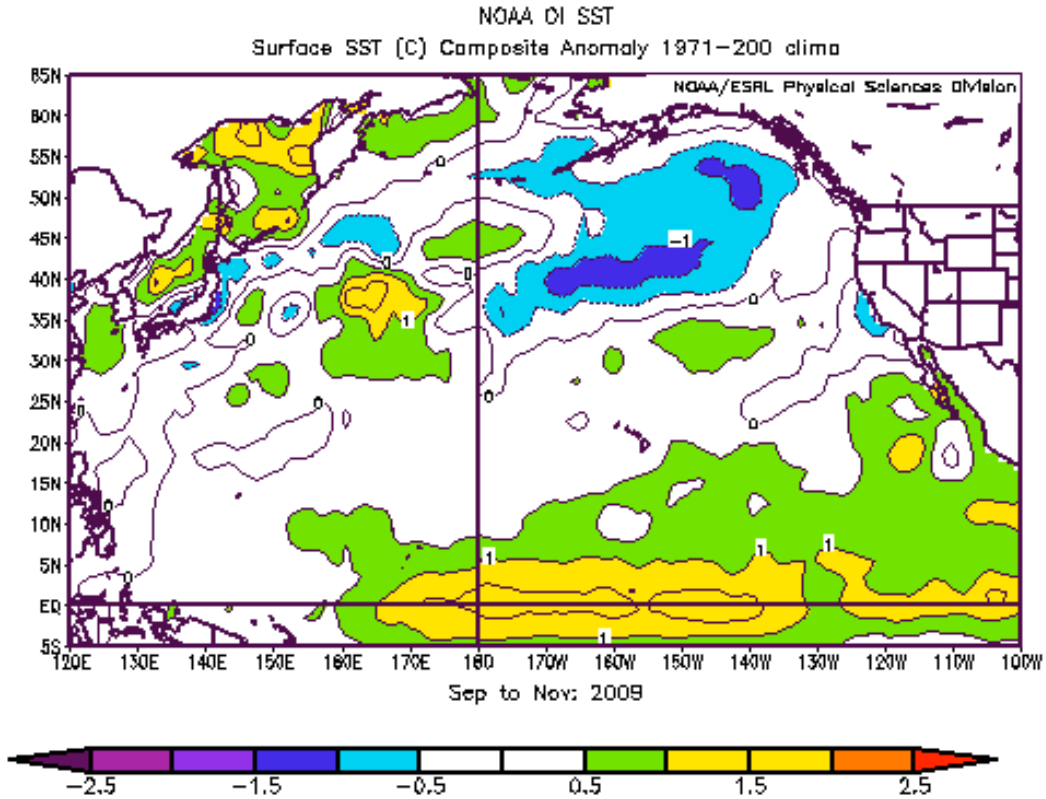

Figure 1a. SST anomalies for September-November 2009.

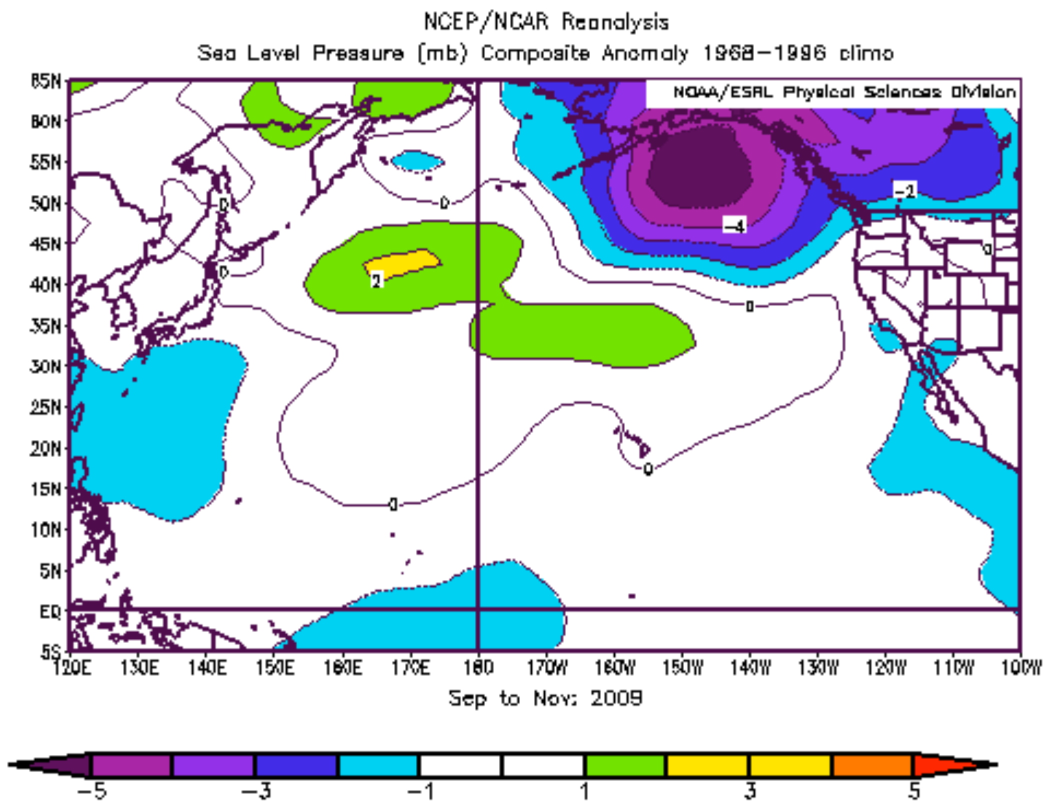

Figure 1b. SLP anomalies for September-November 2009.

The pattern of anomalous SST during winter (DJF) of 2009-10 was rather similar to that during the fall of 2009 (Fig. 2a). There was some modest cooling, relative to seasonal norms, in the northern Bering Sea, and continued warming in the central North Pacific due to El Niño. It bears noting that this particular El Niño featured its strongest SST anomalies in the central Pacific, rather than the eastern Pacific. This has been a tendency of recent El Niños. The causes and effects of the two different types of warm events are receiving increasing attention from the climate community. The SLP during winter 2009-10 was dominated by a large and very deep anomalous low centered near 45° N, 150° W (Fig. 2b). The location of this anomaly is almost identical to that which occurred during the winter of 2008-09 but of opposite sign. In both winters the SLP pattern was consistent with past ENSO events, but the magnitudes of the atmospheric responses were comparatively large, given both the La Niña of 2008-09 and the El Niño of 2009-10 were of no more than moderate intensity. The anomalous SLP pattern shown in Figure 2b indicates anomalous easterlies in the mean across the northern portion of the basin from southeast Alaska to the dateline, and anomalous downwelling along the coast of North America from California to the Alaska Peninsula. The SLP pattern implies northeasterly wind anomalies on the eastern Bering Sea shelf, which do not tend to be especially cold. It appears that the development of heavy ice on the Bering Sea shelf this winter into the following spring can be attributed in large part to the relatively low heat content of the water column going into the season (P. Stabeno, pers. comm.).

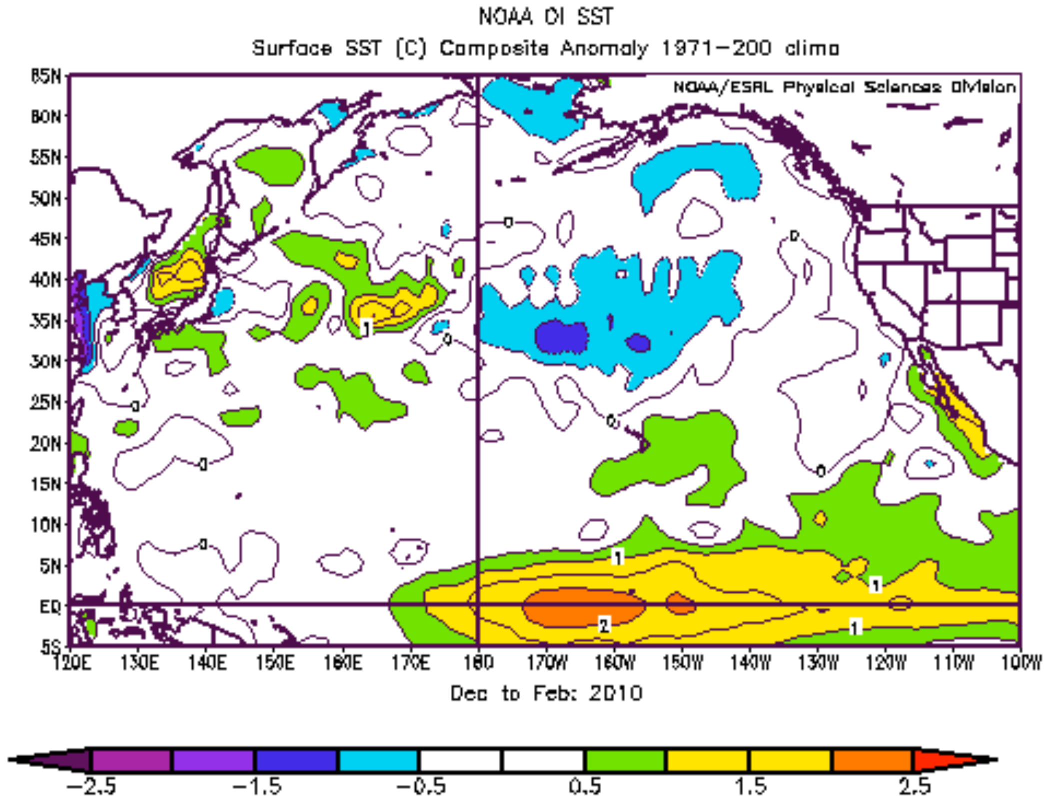

Figure 2a. SST anomalies for December 2009-February 2010.

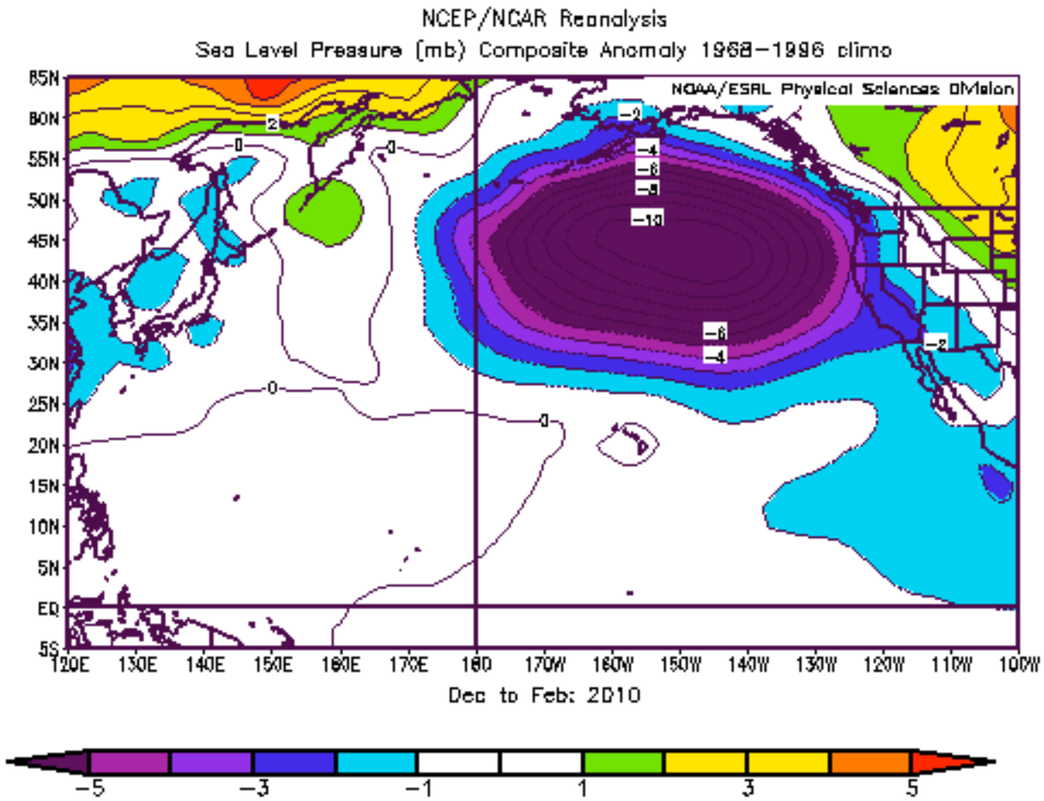

Figure 2b. SLP anomalies for December 2009-February 2010.

The distribution of SST in spring (MAM) of 2010 indicates a continuation of temperatures that are colder than normal in the eastern basin of the North Pacific and warmer than normal in the western basin, strengthening of the negative anomalies in the Bering Sea, and a weakening of the El Niño signal in the tropical Pacific (Fig. 3a). The concomitant SLP anomaly map (Fig. 3b) indicates relatively low pressure extending from far eastern Siberia into western Canada, and high pressure from the Sea of Okhotsk to north of the Hawaiian Islands. This pattern served to support the flow of relatively cold air off Siberia across the Bering Sea, and hence contributed to the extensive ice that occurred on the Bering Sea shelf during the spring of 2010.

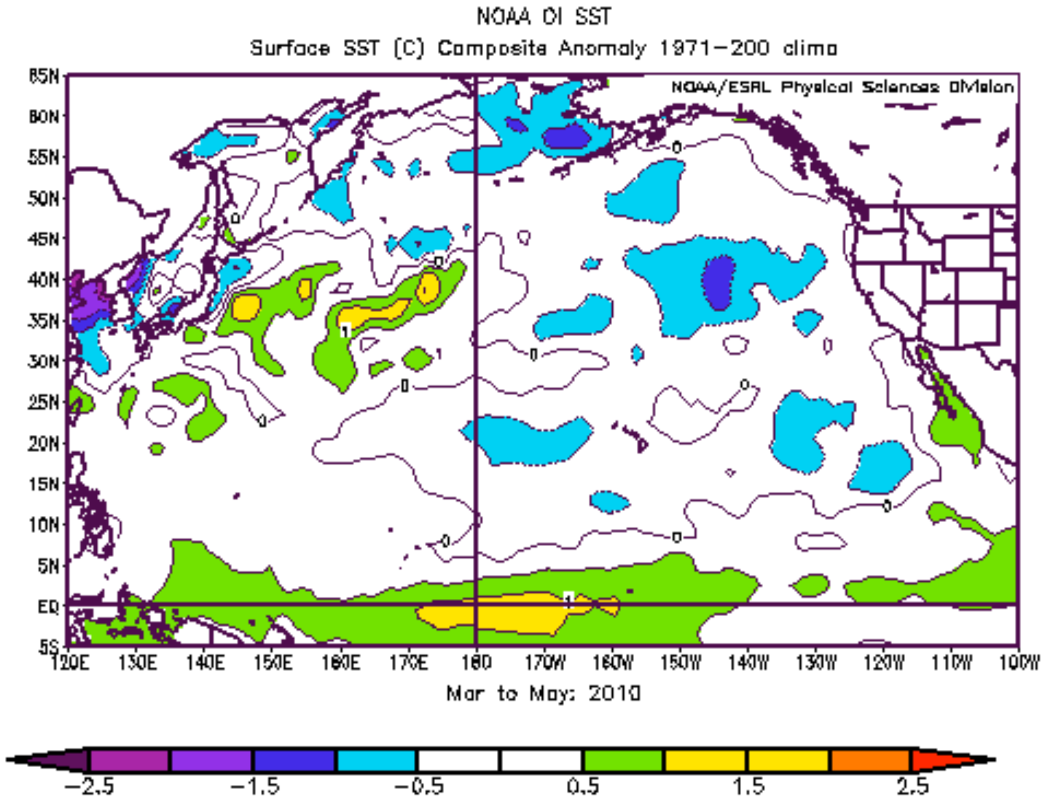

Figure 3a. SST anomalies for March-May 2010.

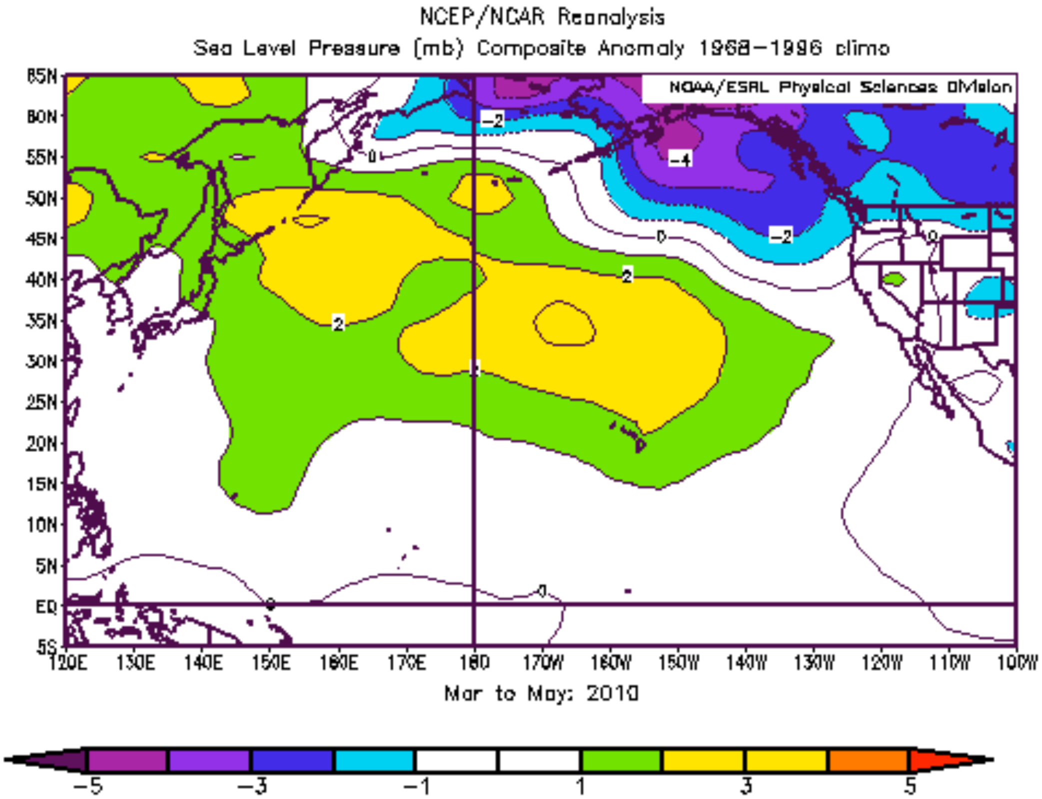

Figure 3b. SLP anomalies for March-May 2010.

The pattern of anomalous SST in summer (JJA) 2010 (Fig. 4a) included the development of substantial negative values along much of the west coast of North America, and continued cool conditions in the eastern Bering Sea. Relatively warm SSTs developed north of the Hawaiian Islands. The overall pattern resembles that associated with the negative phase of the Pacific Decadal Oscillation (PDO). This is consistent with the rapid development of cool SSTs in the central and eastern tropical Pacific, i.e., La Niña. It is also consistent with the field of anomalous SLP (Fig. 4b). The relatively high pressure in the northeastern portion of the basin supports anomalous upwelling along the entire coast of North America; the warming in the central part of the basin is consistent with suppressed cloudiness/enhanced insolation in the vicinity of the pressure center itself, and anomalous poleward Ekman transports on its southern and western flanks.

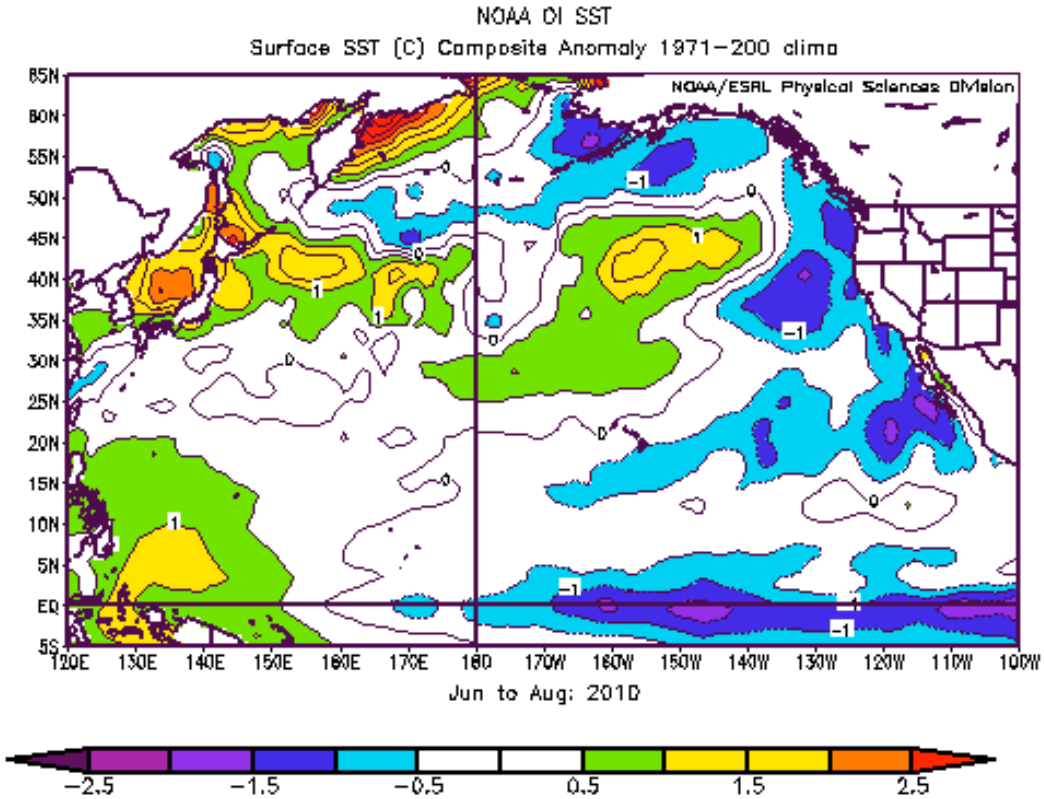

Figure 4a. SST anomalies for June-August 2010.

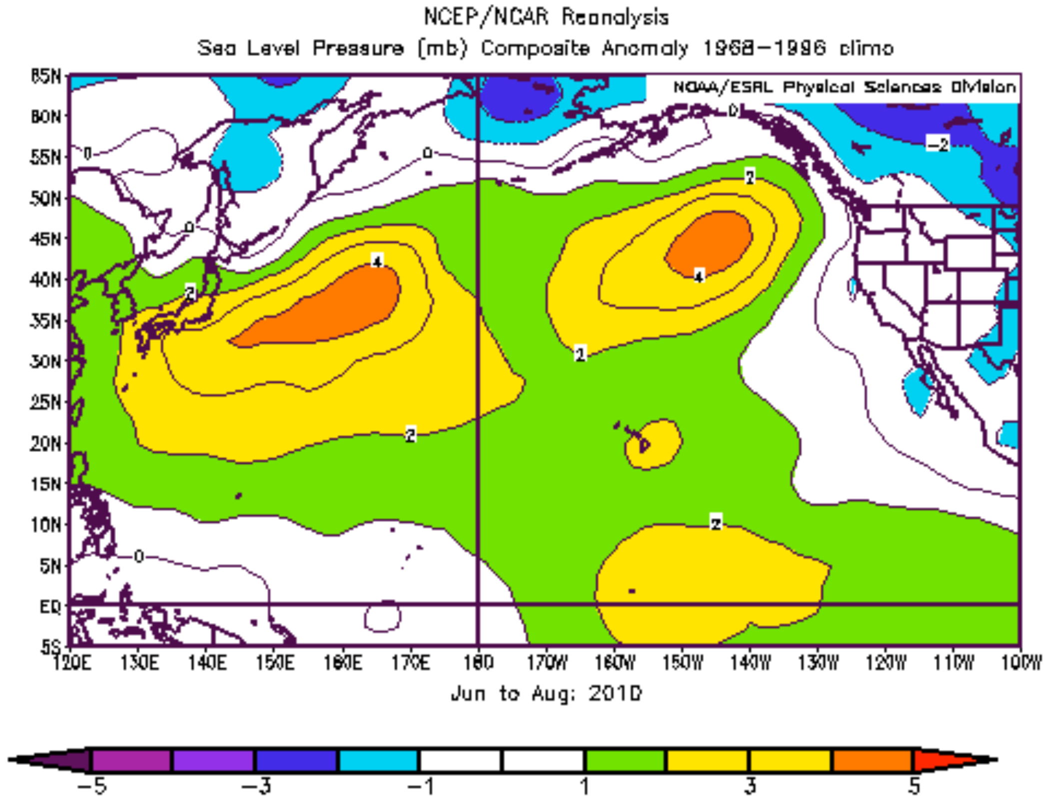

Figure 4b. SLP anomalies for June-August 2010.

2. Climate Indices

There is a small set of climate indices that can provide useful context for the SST and SLP anomaly maps for the North Pacific presented above. The focus here is on four commonly used indices: the NINO3.4 index to characterize the state of the El Niño/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). The time series of these indices from 2001 through the early summer of 2010 are plotted in Figure 5.

As mentioned above, ENSO appears to have had an important influence on the North Pacific climate during 2009-10. In particular, a deeper and southeastward displaced Aleutian low during winter tends to accompany El Niño, as was observed in 2009-10. The transition from El Niño to La Niña that occurred from spring into summer of 2010 was also accompanied by the development of typical SLP and wind anomalies. While most of the variability in ENSO is on temporal scales of a few years, it also exhibits some power on longer time scales. ENSO was predominantly positive during the first half of the 2000s and has oscillated between negative and positive during the past five years. The projections of the dynamical and statistical models used to forecast ENSO are discussed in the last section of this overview.

The PDO underwent a marked increase over the course of 2009 into early 2010 and since then, has trended negative. The PDO, to a significant extent, responds to ENSO (Newman et al. 2003); the correlation coefficient between the NINO3.4 and PDO indices is about 0.5 over the period of record. While ENSO has some predictability, it is important to recognize that the atmospheric circulation over the North Pacific has considerable variability from sources (intrinsic and perhaps forced) other than ENSO. In particular, it is presently not feasible to project the magnitude of the PDO, nor the details in the SST of the North Pacific on regional scales.

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 three-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.esrl.noaa.gov/psd/data/climateindices/.

The NPI is an appropriate means for characterizing the strength of the Aleutian low. The NPI underwent a tremendous swing from about 3 positive standard deviations during the winter of 2008-09 to about negative 2 standard deviations during the winter of 2009-10 (Fig. 5). The magnitude of this transition has only been exceeded twice since 1968, with one of those instances being associated with the intense El Niño of 1982-83. The La Niña that is developing at the time of the writing of this overview suggests another sizable swing to a positive state for the NPI, as the trend in the index itself is demonstrating.

The AO represents a measure of 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. It is closely related to the North Atlantic Oscillation (NAO). The AO mostly decreased over the course of 2009, bottoming out in January 2010 with a record negative value of almost 5 standard deviations. The response of the atmospheric circulation in the North Pacific to ENSO tends to be enhanced during periods of a negative state and suppressed during periods of a positive state in the AO (Bond and Harrison 2006). The unusually strong response in the Aleutian low, as reflected in the NPI, to the moderate El Niño of the winter of 2009-10 may reflect another instance of this interaction between ENSO and the AO in terms of the climate forcing of the North Pacific. There are no reliable forecast tools at present for seasonal prediction of the AO and so it is unknown how it may impact the North Pacific during the upcoming year.

3. Regional Highlights

a. **West Coast of Lower 48 –** This region appears to have experienced a relatively modest response to the El Niño of 2009-10. There was a period of highly anomalous southerly, downwelling-favorable, winds along the coast of Oregon and Washington during the winter, and a rather late spring transition to upwelling-favorable winds for the coast as a whole. Since the spring transition, upwelling has generally been stronger than normal. The climate forcing is reflected in the coastal SST, which was near normal during the winter and spring, but cooler than normal during the summer of 2010. The physical conditions are consistent with lower-trophic level species populations, which included low levels of krill and somewhat high numbers of sub-tropical copepods in spring 2010, but also a recent tendency towards typical values.

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, are useful for diagnosing the sub-surface physical properties of this region. Based on the gradient in dynamic height from Argo, the poleward branch of the Alaska Current in the southeastern portion of the Gulf was considerably greater than normal in the winter of 2009-10, presumably at least in part due to the anomalous southerly winds during this season. The strength of this branch of the Alaska Current has since declined to about its mean over the last decade. The mixed layer depths in the Gulf were relatively shallow during the winter, as might be expected with anomalously strong upward Ekman pumping. During the summer of 2010 they have been observed to be somewhat deeper than normal.

c. **Alaska Peninsula and Aleutian Islands –** The winds in this region impact the upwelling along the arc of the Alaska Peninsula and Aleutian Islands, and the flow of Pacific water through Unimak Pass into the Bering Sea (Stabeno et al. 2002). The winter of 2009-10 featured strong easterly wind anomalies, which probably promoted northward transport through Unimak Pass and enhanced the Aleutian North Slope Current. The sense of the wind anomalies switched to anomalous westerly during the spring and summer of 2010 for the Alaska Peninsula and eastern Aleutian Islands. This would tend to produce suppressed upwelling on their north sides and enhanced upwelling to their south.

d. **Bering Sea –** The Bering Sea shelf experienced a relatively heavy ice year in 2010. It is rare for this region to have greater than normal ice extent during El Niño years. The especially low heat content on the shelf going into the fall of 2009 is likely to have been an important contributing factor, as mentioned above. Two notable advances occurred in the ice cover due to episodic weather events, specifically a severe cold snap near the end of February into March, and a period of strong northerlies (but not unusually cold temperatures) from late April through the middle of May 2010. The summer of 2010 has generally been a bit stormier than usual.

e. **Arctic** – The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2010. The areal coverage in July 2010 was the second lowest in the historical record (the record low for July was in 2007). There is now very little multi-year ice in the Arctic (R. Lindsay, pers. comm.). There is some tentative evidence that reduced sea ice cover in the fall, through its impacts on low-level air temperatures, may impact the hemispheric atmospheric circulation (Overland and Wang 2010). In particular, low ice cover in fall tends to be followed by a negative sense to the AO in the following winter. Current research is investigating whether this mechanism represents a reliable source of predictability.

4. Seasonal Projections from the National Centers for Environmental Prediction (NCEP)

Seasonal projections from the NCEP coupled atmosphere-ocean forecast system model (CFS) for SST are shown in Figure 6. The SST anomaly maps indicate negative SST anomalies in the equatorial Pacific from fall 2010 into spring 2011, with the event's peak near the first of the year. This forecast is in agreement with the vast majority of the forecasts from other models run operationally and experimentally at a variety of US and international centers. As a group, the dynamical models such as CFS tend to indicate a stronger La Niña than their statistical/empirical model counterparts. In light of the present conditions in the tropical Pacific, in particular the anomalously low vertically integrated heat content and the combination of easterly wind anomalies and suppressed deep cumulus convection in the central Pacific, it can be anticipated with a high degree of certainty that La Niña conditions will prevail through the remainder of 2010 into 2011. A La Niña generally brings cool upper ocean conditions along the west coast of North America, and for Alaska waters. The CFS model is indicating the likelihood of a weaker Aleutian low than normal, as typically occurs during La Niña. The model has a good track record at predicting the broad patterns in the anomalous atmospheric circulation in winter. On the regional scale, however, the weather is more difficult to forecast reliably. For example, some of the individual runs of the ensemble of CFS simulations are indicating a storm track into the western Bering Sea that generally brings more mild air of maritime origin into the Bering Sea. Consequently, the evidence for continued cold in the Bering Sea, at least from this particular forecast model, is not that strong. The Bering Sea is one of the few regions that has been relatively cold in recent years, and it will be interesting to see if this La Niña will help keep it cold there, or whether it warms like much of the rest of the globe.

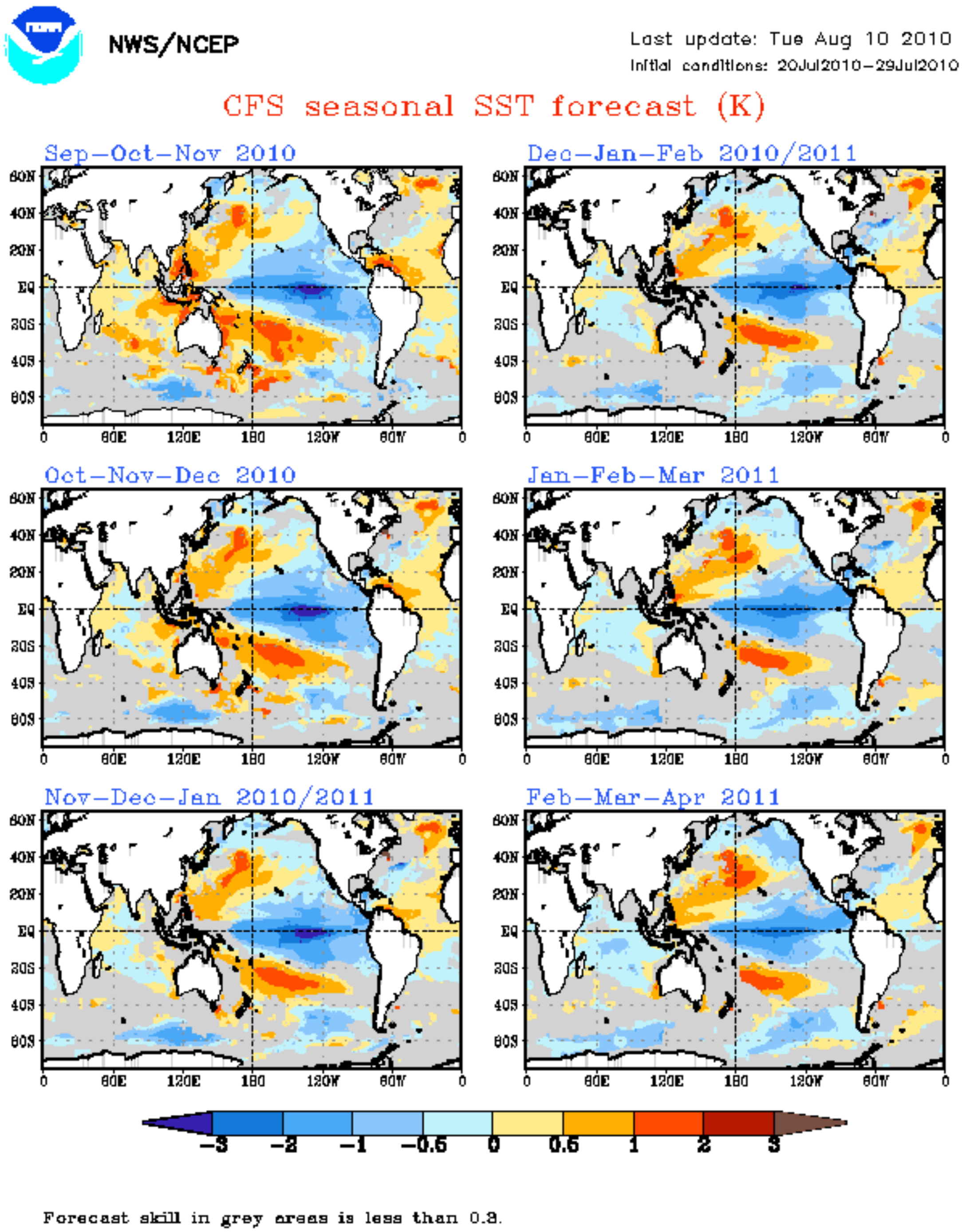

Figure 6. Seasonal forecast of SST anomalies from the NCEP coupled forecast system model.

5. Literature Cited

Bond, N. A., and D. E. Harrison, 2006: ENSO's effect on Alaska during opposite phases of the Arctic Oscillation. Intl. J. Climatol. 26:1821-1841.

Newman, M., G.P. Compo and M.A. Alexander, 2003: ENSO-forced variability of the Pacific Decadal Oscillation. J. Climate, 16, 3853-3857.

Overland, J.E., and M. Wang, 2010: Large-scale atmospheric circulation changes are associated with the recent loss of Arctic sea ice. Tellus, 62A, 1–9.

Stabeno, P.J., R.K. Reed and J.M. Napp, 2002: Transport through Unimak Pass, Alaska. Deep-Sea Res. II, 49, 5919-5930.