North Pacific Climate Overview

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Summary. *The state of the North Pacific atmosphere-ocean system during 2010-2011 reflected the typical response to La Niña. The Aleutian low was much weaker than usual in the winter of 2010-11, and the sea level pressure was higher than normal in the eastern portion of the basin for the year as a whole. Cooler than normal upper ocean temperatures prevailed in the eastern portion of the North Pacific and warmer than normal temperatures occurred in the west-central and then central portion of the basin. This pattern reflects a negative sense to the Pacific Decadal Oscillation (PDO). Near-normal conditions are present in the tropical Pacific at the current time; the models used to forecast ENSO are indicating outcomes for the winter of 2011-12 ranging from a neutral to a weak-moderate La Niña state.*

1. SST and SLP Anomalies

The state of the North Pacific from autumn 2010 through summer 2011 is summarized in terms of seasonal mean sea surface temperature (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 1981-2010, respectively. The SST data are from NOAA's Optimal Interpolation (OI) analysis; the SLP data are 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 climate forcing of the North Pacific during the year of 2010-11 was dominated by the response to La Niña. The autumn (Sep-Nov) of 2010 included weak to moderate negative SST anomalies in the northern and eastern North Pacific, and moderate to strong positive SST anomalies in the central and western North Pacific. Much cooler than normal SSTs occurred in the central and eastern tropical Pacific in association with La Niña (Fig. 1a). The corresponding pattern of anomalous SLP included negative anomalies in the Gulf of Alaska and weaker positive anomalies in the eastern sub-tropical and tropical Pacific (Fig. 1b). This pattern corresponds with westerly wind anomalies from roughly 30° to 50° N across the eastern North Pacific, and hence anomalous equatorward Ekman transports.

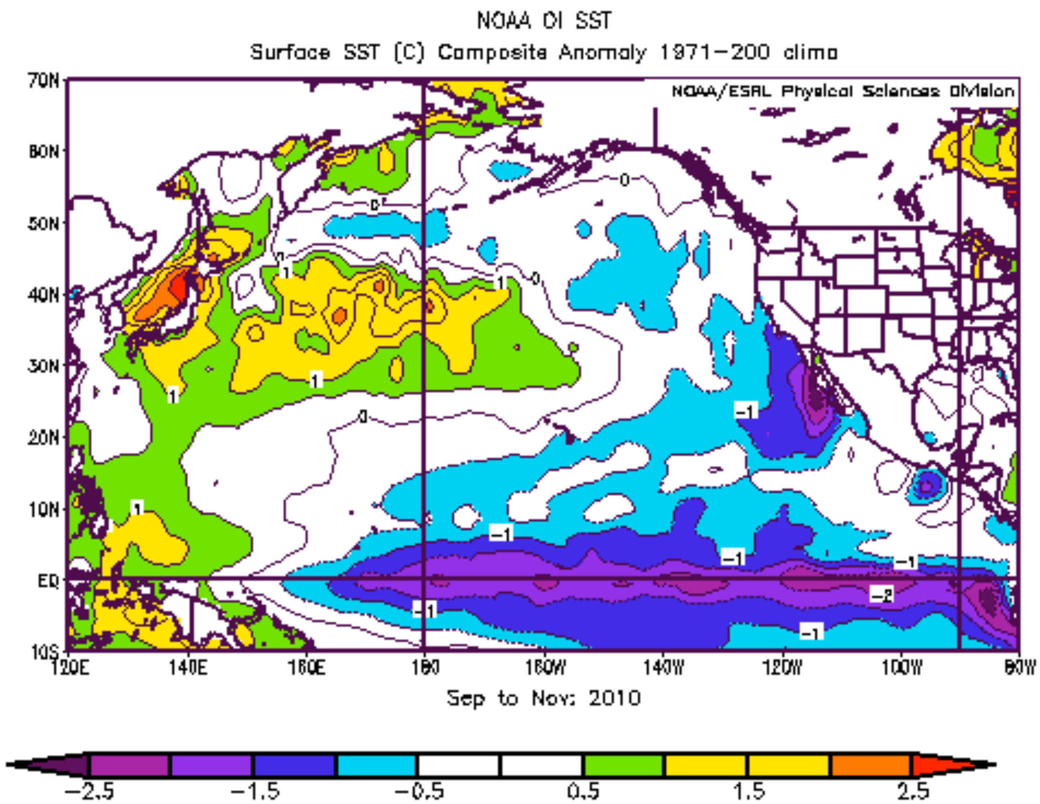

Figure 1a. SST anomalies for September-November, 2010.

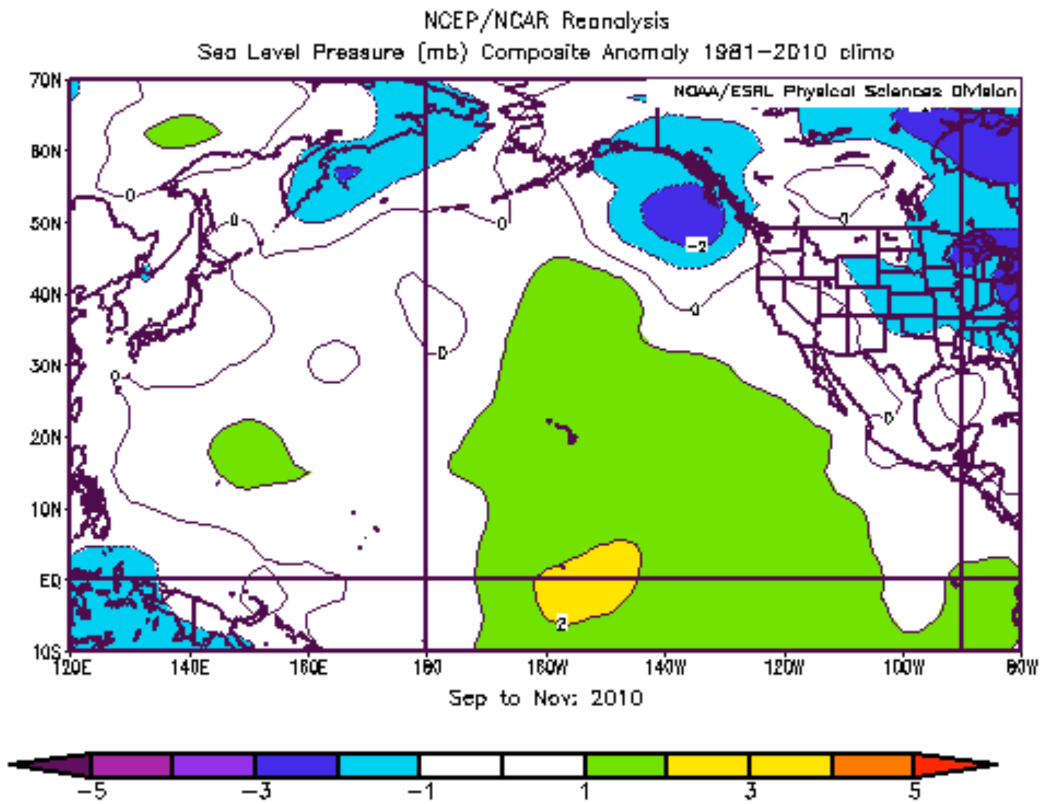

Figure 1b. SLP anomalies for September-November, 2010.

The pattern of anomalous SST during winter (Dec-Feb) of 2010-11 (Fig. 2a) resembled its counterpart during the previous fall. There was some modest cooling, relative to seasonal norms, in the eastern Bering Sea, and continuation of La Niña in the tropical Pacific. The anomalous SLP during winter 2010-11 was dominated by a large and intense high (>12 mb) centered near 50° N, 165° W (Fig. 2b). The seasonal average SLP near the center of this positive anomaly was the greatest since the winter of 1955-56 (which also featured La Niña). It is worth noting that the eastern North Pacific experienced SLP anomalies of comparable magnitude, but opposite sign, during the winter of 2009-10. This swing can be attributed, at least in part, to the transition from El Niño in 2009-10 to La Niña in 2010-11. The anomalous SLP pattern shown in Figure 2b indicates anomalous northwesterlies in the mean for the Gulf of Alaska and anomalous upwelling along the coast of North America from the Gulf of Alaska to California. The SLP pattern implies a suppression of storminess in the Aleutians and southwesterly wind anomalies across much of the Bering Sea. This is not a relatively warm pattern for the Bering Sea, since a weaker than normal Aleutian low means lesser than usual incursions of mild air of maritime origin.

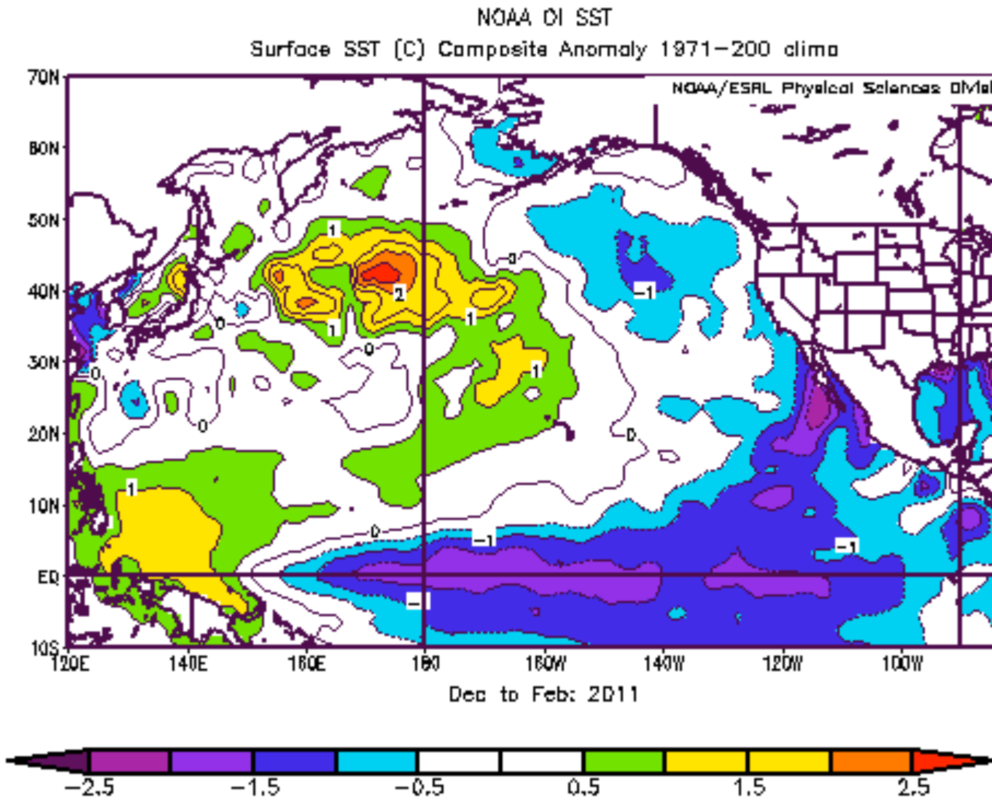

Figure 2a. SST anomalies for December 2010 - February 2011.

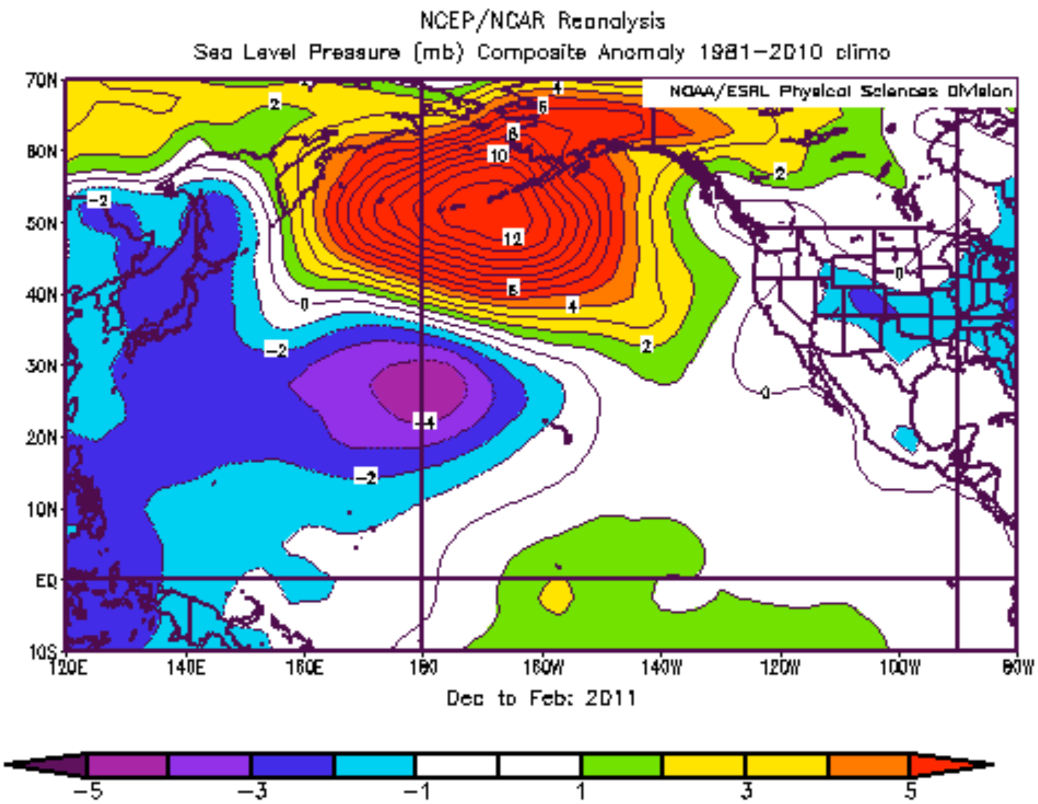

Figure 2b. SLP anomalies for December 2010 - February 2011.

The distribution of SST in spring (Mar-May) of 2011 (Fig. 3a) indicates a continuation of colder than normal temperatures in the eastern basin of the North Pacific and anomalous warmth in the central North Pacific. There was a marked decline in La Niña in the tropical Pacific. The concomitant SLP anomaly map (Fig. 3b) indicates a low-amplitude pattern with relatively low pressure extending from eastern Siberia across the northern Pacific into western and central North America, and high pressure in the eastern North Pacific. This pattern served to support anomalous easterlies for the Bering Sea shelf during the spring of 2011, and hence warming of this region relative to seasonal norms after a cold winter.

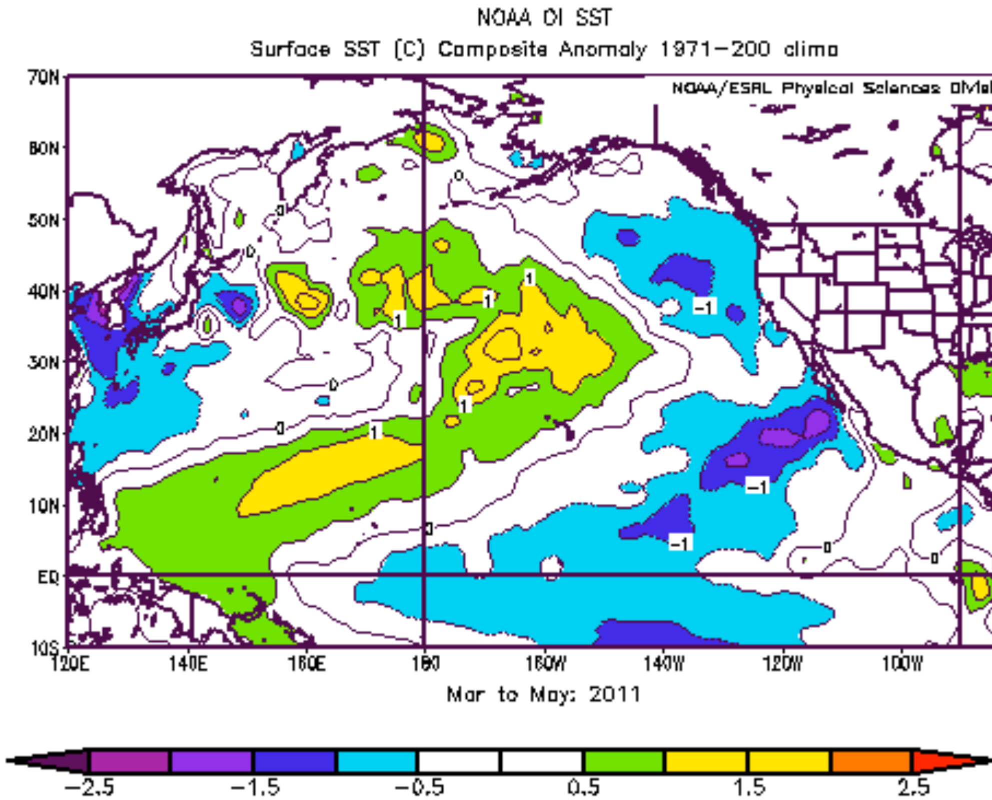

Figure 3a. SST anomalies for March – May, 2011.

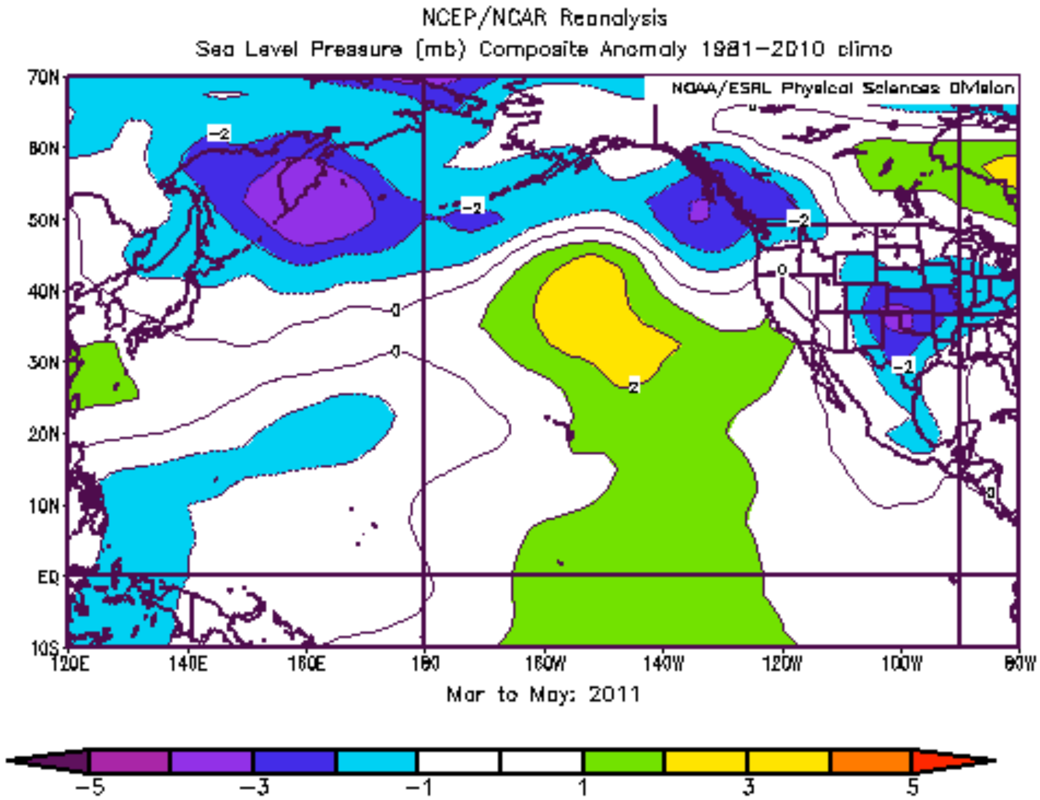

Figure 3b. SLP anomalies for March – May, 2011.

The pattern of anomalous SST in summer (Jun-Aug) 2011 (Fig. 4a) featured the development of substantial negative values in the eastern Bering Sea, a strengthening of cold temperatures off the west coast of the lower 48 states and in the eastern sub-tropical Pacific, and continued cool conditions in the eastern Bering Sea. There was also a strengthening of warm SST anomalies to north of the Hawaiian Islands. The overall pattern projects rather strongly on the negative phase of the Pacific Decadal Oscillation (PDO). Near-neutral ENSO conditions prevailed in the tropical Pacific. The distribution of anomalous SLP (Fig. 4b) included strongly negative and positive centers in the northern Bering Sea and southern Gulf of Alaska, respectively. The former anomaly helped cause the anomalous cooling of the Bering Sea due to enhanced storminess and westerly winds (equatorward Ekman transports). The circulation around the anomalous high in the southern Gulf of Alaska produced stronger than normal northwesterlies over much of the far eastern North Pacific.

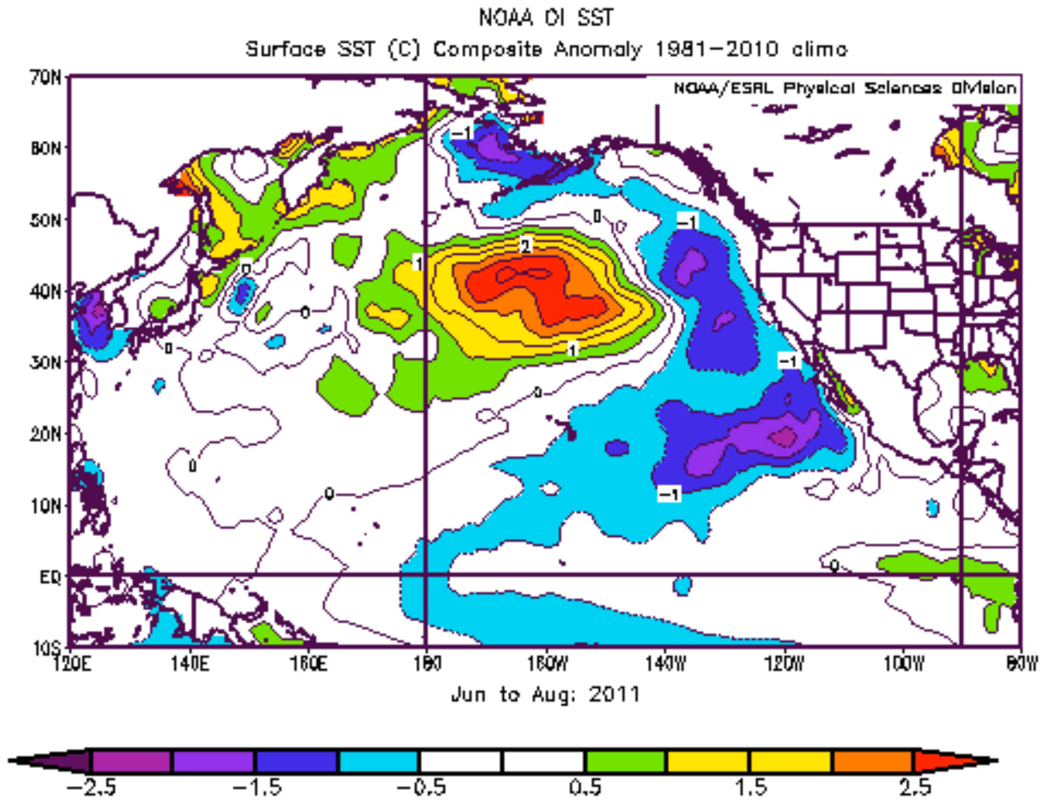

Figure 4a. SST anomalies for June – August, 2011.

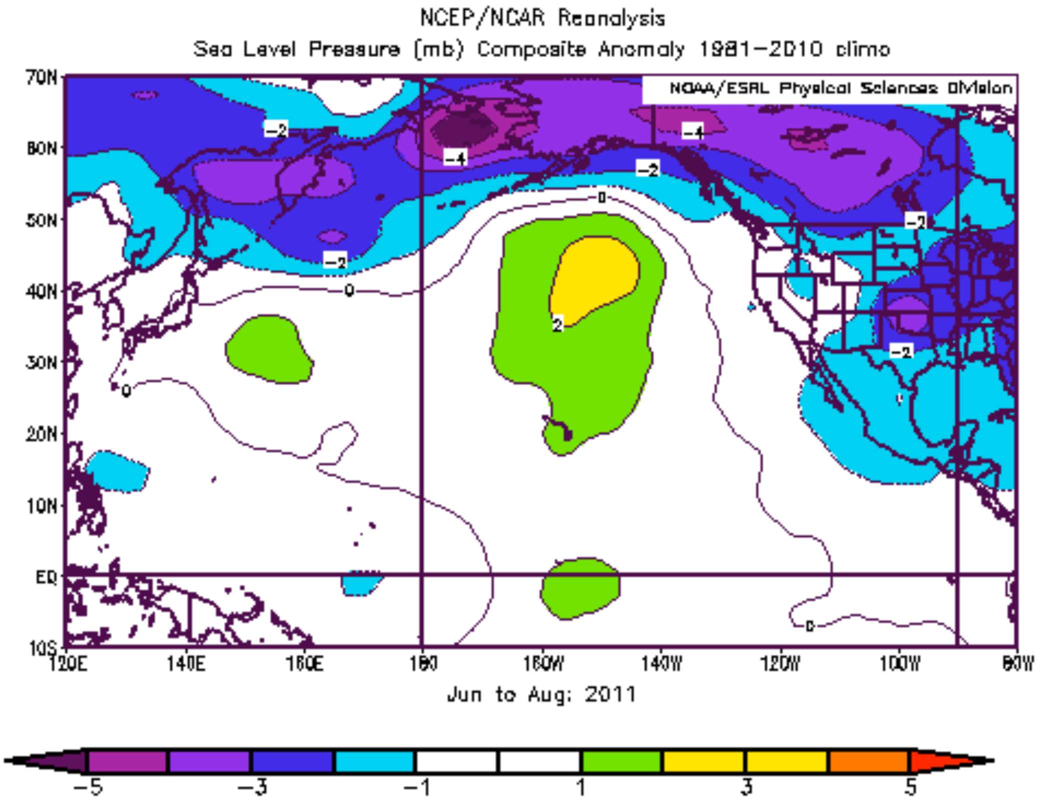

Figure 4b. SLP anomalies for June – August, 2011.

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 five 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 three atmospheric indices, the North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2001 through early 2011 are plotted in Figure 5.

The state of the North Pacific atmosphere-ocean system reflected the influences of ENSO during 2010-11. The Aleutian Low tends to be weaker during La Niña winters, and 2010-11 was no exception, as evidenced by the strongly positive SLP anomalies shown in Figure 2b. It is worth noting that the degree of activity in the ENSO cycle varies on multi-year time scales. The ENSO cycle was relatively weak during the first half of the 2000s while it was in a predominantly positive phase; the fluctuations between significantly positive (El Niño) and negative values (La Niña) have been more prominent during the past 5-6 years. The projections of the dynamical and statistical models used to forecast ENSO are discussed in the last section of this overview.

The PDO became negative during spring of 2010 and reached a minimum of about -1.3 in early fall 2010. It exhibited an increasing trend from late 2010 through the spring of 2011. This trend reversed again in summer 2011. It is an open question whether this latest tendency will continue, or whether the PDO will return to a more neutral state. The PDO is related to ENSO through the effects of the latter on the atmospheric circulation over the North Pacific and hence air-sea interactions, and ultimately, SST patterns. The potential predictability of the PDO appears to be largely associated with its connection to ENSO.

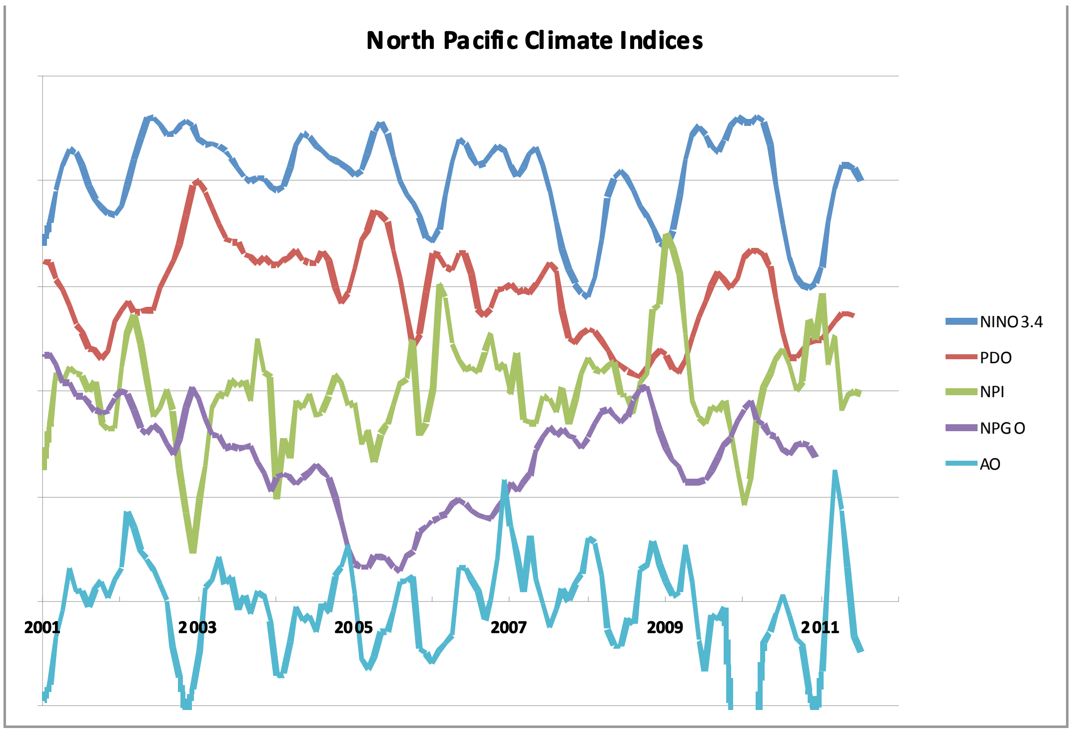

Figure 5. Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 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 a commonly used measure of the strength of the Aleutian Low. The NPI has undergone large swings from positive to negative and then back to positive over the last three years. Note the negative correspondence with the NINO3.4 index in general; over the last few years this relationship appears to have been especially tight.

The climate community has been paying increasing attention to another mode of variability in the North Pacific termed the North Pacific Gyre Oscillation (NPGO). It has been shown to relate to chemical and biological properties in the Gulf of Alaska and the CalCOFI survey area (DiLorenzo et al. 2008). It underwent a significant transition from strongly negative in the early 1990s to strongly positive in the early 2000s in concert with the so-called "Victoria" pattern in SST (Bond et al. 2003). It has been in a positive state since 2007, which projects on stronger than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current.

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 has a weakly positive correlation with sea ice extent in the Bering Sea. During periods of positive AO, cold air outbreaks to mid-latitudes are suppressed. The AO had a record negative value during the winter of 2009-10; it was also strongly negative during the early portion of the winter of 2010-11 and then switched to positive during the early portion of 2011. It became weakly negative during late spring 2011. 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 experienced a typical response to La Niña during 2010-11. The waters near the coast tended to be cool, with varying salinity, relative to normal. The cooler waters were accompanied by a greater preponderance of sub-arctic than sub-tropical zooplankton than usual (B. Peterson, NOAA/NWFSC). With regards to the winds, the winter of 2010-11 brought anomalous upwelling off of Washington and Oregon and near-normal wind forcing along California. This pattern reversed for the spring and early summer 2011 during which upwelling was somewhat stronger than normal off California and weaker than normal to the north. The copious precipitation along the west coast during the winter and spring produced anomalously high freshwater discharges. More details on the state of the California Current system are available at www.pacoos.org.
b. **Gulf of Alaska** –The data from Argo profiling floats, available at http://www.pac.dfo-mpo.gc.ca/science/oceans/Argo/Alaska-Argo-eng.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 declined considerably over the last 18 months since its peak in the winter of 2009-10. This change is presumably due, at least in part, to the anomalous northerly and northwesterly winds over the interval. The mixed layer depths in the Gulf have been near their seasonal norms.
c. **Alaska Peninsula and Aleutian Islands** – Westerly wind anomalies have prevailed in this region during the past year, except during spring 2011. These anomalies have served to suppress the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current. The wind anomalies during spring 2011 were weak, but since they were easterly they would have acted to enhance upwelling during that season along the north side of the Alaska Peninsula and Aleutian Islands.
d. **Bering Sea** – The Bering Sea shelf experienced another relatively heavy ice year, but not as extreme as those of 2008-09 and 2009-10. The weather during early winter was quite cold, but the late winter was a bit warmer than normal and the winds during the spring did not feature the same northerlies that delayed the retreat of the ice in 2010. As noted above, the summer of 2011

has been relatively stormy. The upper ocean is also relatively cold in the eastern Bering Sea and if these conditions persist into fall, they would promote the relatively early development of sea ice during the winter of 2011-12. A confounding factor is the state of the Arctic, which is summarized briefly below.

e. **Arctic** – The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2011. The areal coverage in July 2011 was even less than in July 2007, and hence the lowest in the historical record. The idea that reduced sea ice cover in the fall may have systematic impacts on the hemispheric atmospheric circulation during early winter is consistent with the strongly negative AO state that occurred in December 2010. It has become clear that the reduced ice cover at the end of the melt season tends to delay the development of ice in marginal seas such as the Bering Sea during the following cold season. Nevertheless, it is unclear how much the maximum ice extent in these marginal seas depends on previous conditions in the central Arctic.

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. On the hemispheric scale, these projections resemble those made a year ago. Of special note is the prediction of relatively cold SSTs in the tropical Pacific of a magnitude commensurate with a weak-moderate La Niña. Earlier predictions by the CFS model (made before June 2011), and many of the current predictions from the other statistical and numerical models used for ENSO forecasts, were indicating a near-neutral state for ENSO during the winter of 2011-12. Present conditions in the tropical Pacific support the possibility of the development of La Niña, but it is too early to make any reliable predictions for the upcoming winter except that the probability of El Niño is lower than usual. If the CFS model projections are correct, and this model does have a reasonably good track record over the last 5 years or so, the Aleutian low will be weaker than normal (not shown). If this comes to pass, the relatively cold upper ocean temperatures in the northeastern Pacific that stretch from the Bering Sea through the Gulf of Alaska to off the coast of California, and a negative sense to the PDO, can be anticipated to persist well into 2012, as shown in the SST projections of Figure 6.

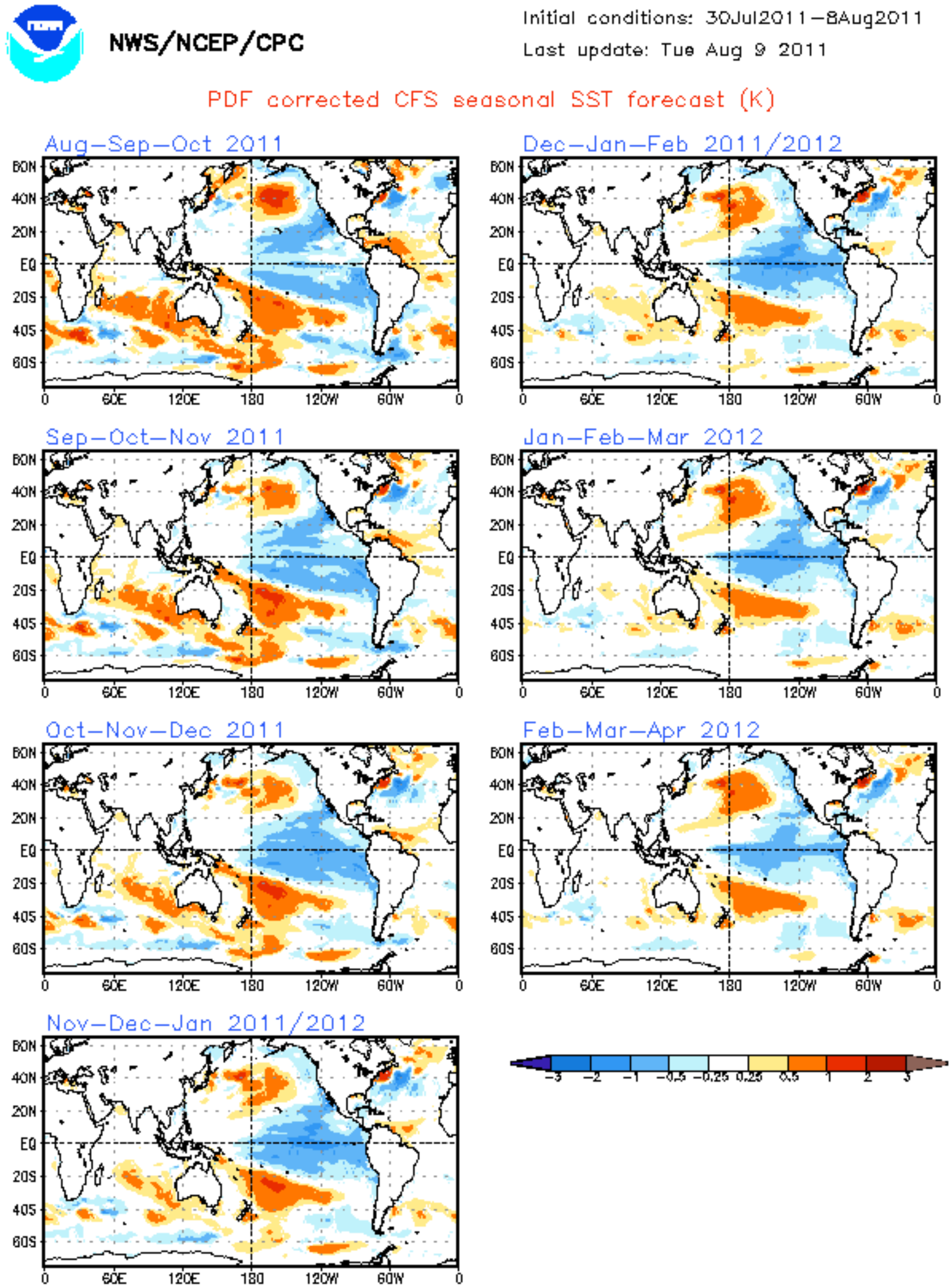

Figure 6. Seasonal forecast of SST anomalies from the NCEP coupled forecast system model for August 2011 through April 2012.

5. Literature Cited

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