North Pacific Climate Overview

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Last updated: August 2012

Summary. *The state of the North Pacific atmosphere-ocean system during 2011-2012 reflected the combination of a response to La Niña and intrinsic variability. The Aleutian low was weaker than usual in the winter of 2011-12, 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 continuation of a negative sense to the Pacific Decadal Oscillation (PDO). The ENSO indices for the tropical Pacific indicate a warming trend for the first half of 2012; the models used to forecast ENSO are indicating outcomes for the winter of 2012-13 ranging from near neutral to a weak-moderate El Niño.*

1. SST and SLP Anomalies

The state of the North Pacific from autumn 2011 through summer 2012 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 period of 1981-2010. The SST data are from NOAA's Extended Reconstructed SST analysis; the SLP data are from the NCEP/NCAR Reanalysis project. 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 2011-12 was dominated by the response to a weak-moderate La Niña that developed in late summer of 2011 and waned in spring 2012. The autumn (Sep-Nov) of 2011 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 in a band between 30° and 50°N. Cooler than normal SSTs occurred in the central and eastern tropical Pacific in association with the re-development of La Niña (Fig. 1a). The corresponding pattern of anomalous SLP included negative anomalies north of 50°N from eastern Siberia into central Canada and positive anomalies in the central north Pacific (Fig. 1b). This pattern corresponds with westerly wind anomalies from roughly 40° to 50°N across most of the North Pacific.

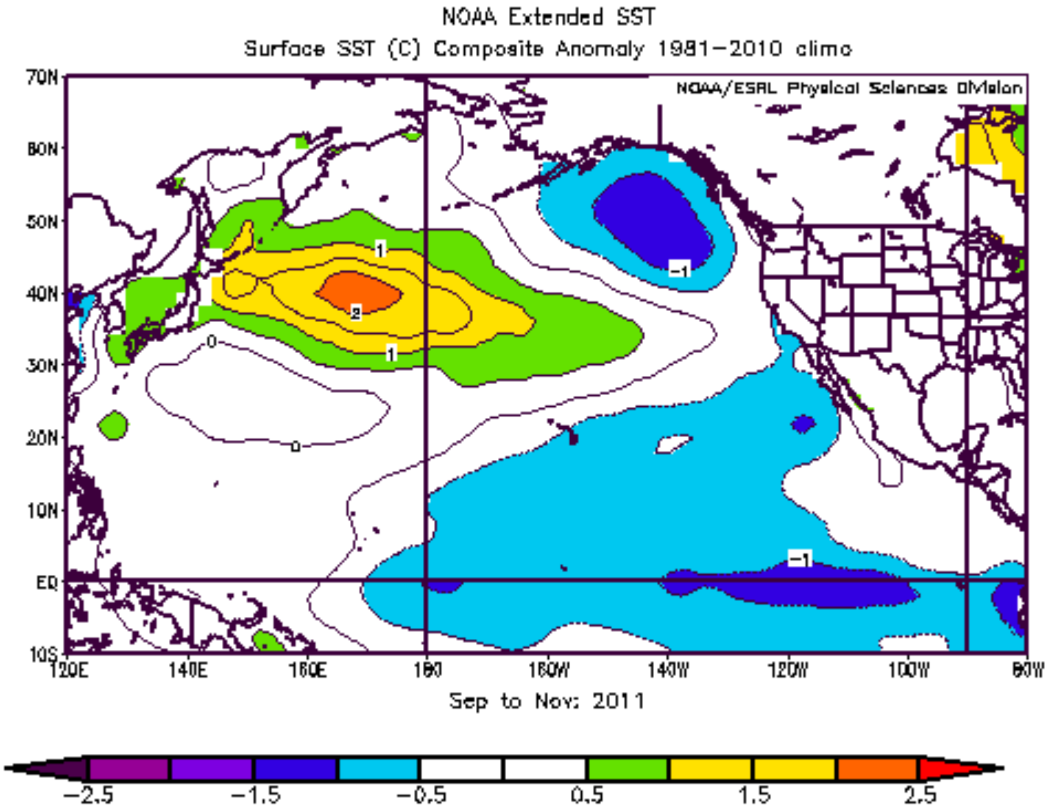

Figure 1a. SST anomalies for September-November, 2011.

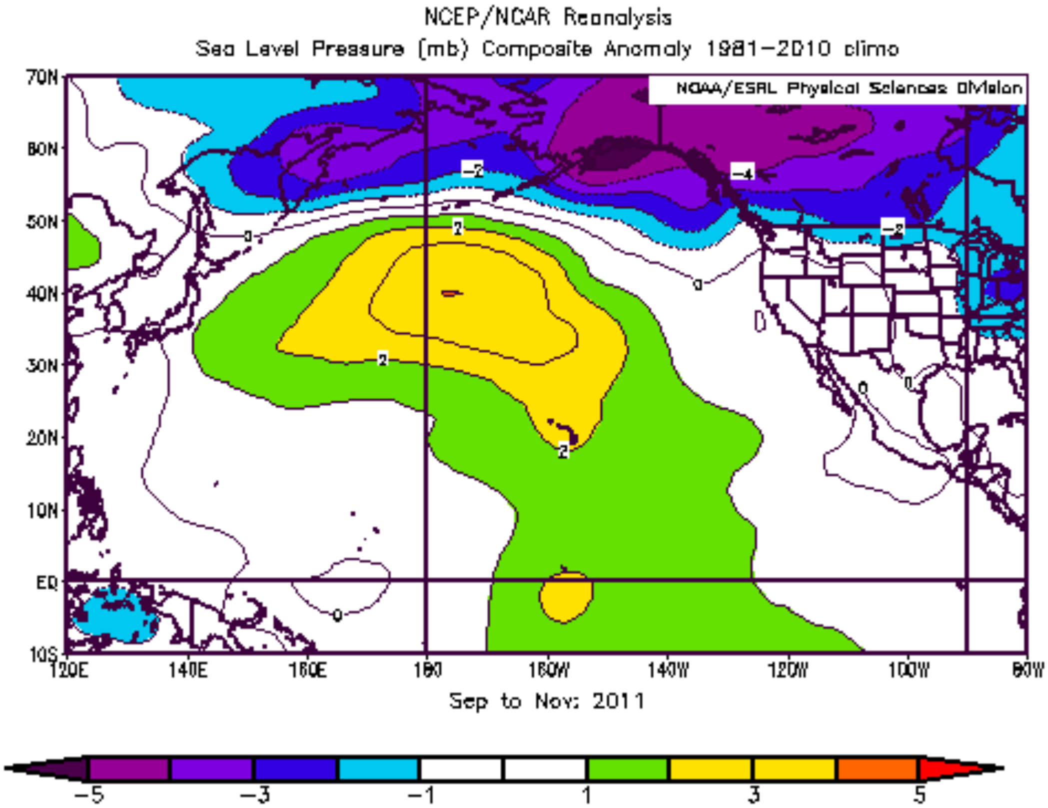

Figure 1b. SLP anomalies for September-November, 2011.

The pattern of anomalous SST during winter (Dec-Feb) of 2011-12 (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 2011-12 was dominated by a large high (>6 mb) centered near 40°N, 140°W (Fig. 2b). This anomaly was located well to the southeast of its usual location during La Niña.. The anomalous SLP pattern shown in Figure 2b indicates anomalous westerlies in the mean for the Bering Sea and Gulf of Alaska and anomalous upwelling along the coast of California. This promotes the delivery of cold air of Siberian origin to the Bering Sea and Gulf of Alaska; the higher than normal pressure west of California meant suppressed storminess in the far eastern North Pacific and below normal precipitation for the western US.

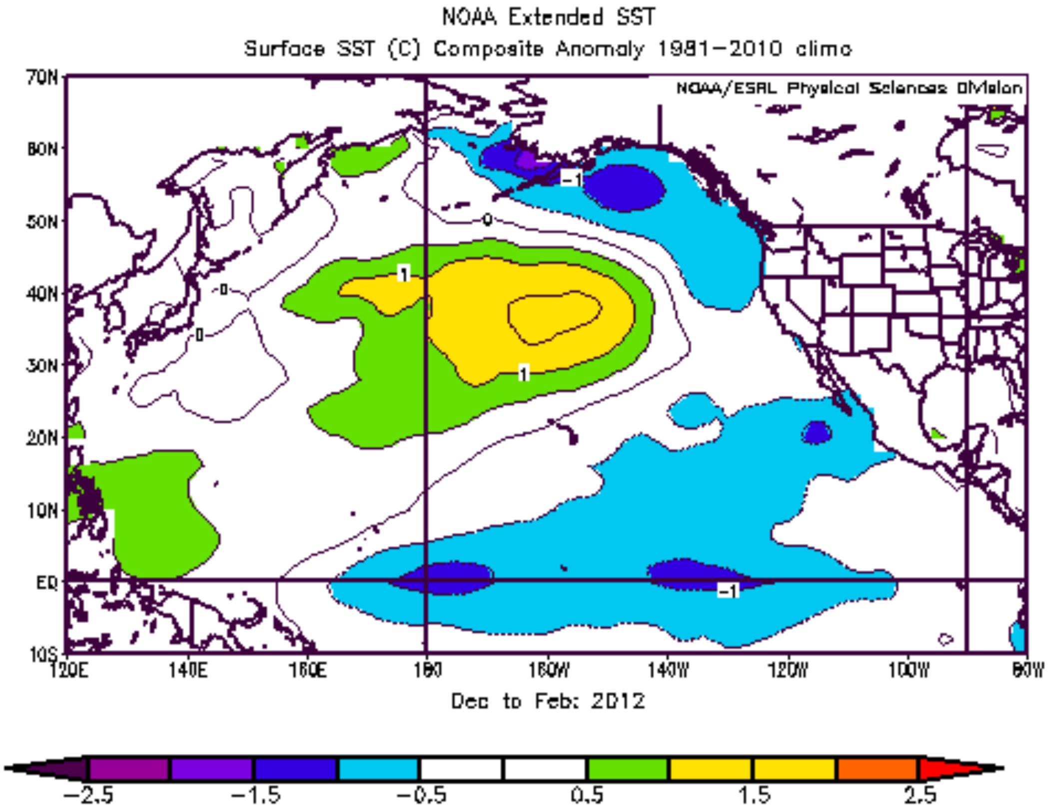

Figure 2a. SST anomalies for December 2011 - February 2012.

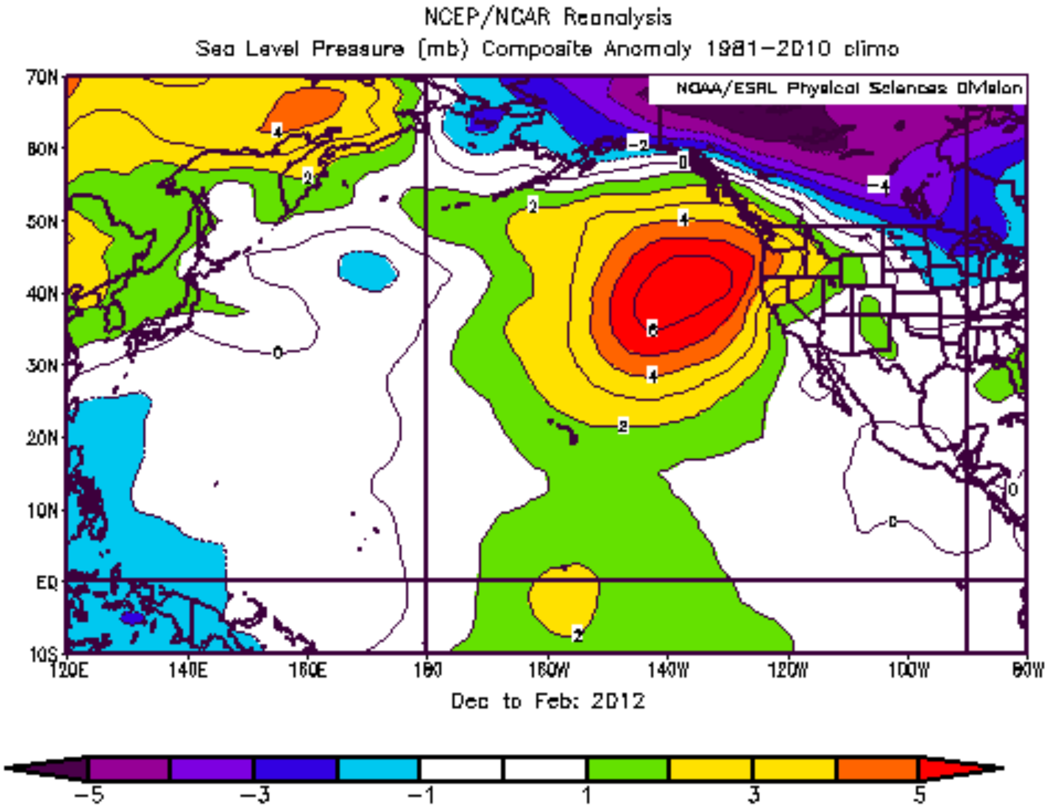

Figure 2b. SLP anomalies for December 2011 - February 2012.

The distribution of SST in spring (Mar-May) of 2012 (Fig. 3a) indicates a continuation of colder than normal temperatures in Alaskan waters and anomalous warmth in the central North Pacific. There was a marked decline in La Niña in the tropical Pacific, with positive anomalies developing in the far eastern portion of the coast of South America. The concomitant SLP anomaly map (Fig. 3b) indicates high pressure centered just south of the Aleutians, which is a more typical response to La Niña than was observed during the previous season. Anomalous low pressure extended from Alaska into western and central Canada. This set-up brought about an anomalous flow of cold air from the northwest across the Bering Sea and Gulf of Alaska, ultimately producing a cold and wet spring for the Pacific Northwest.

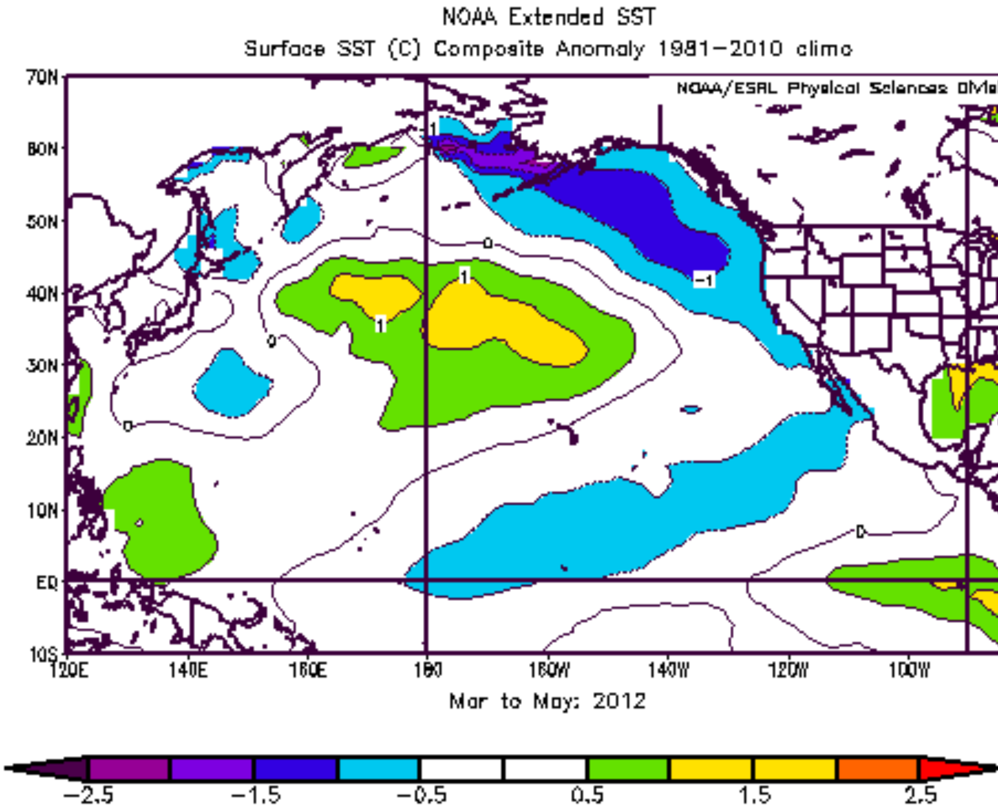

Figure 3a. SST anomalies for March – May, 2012.

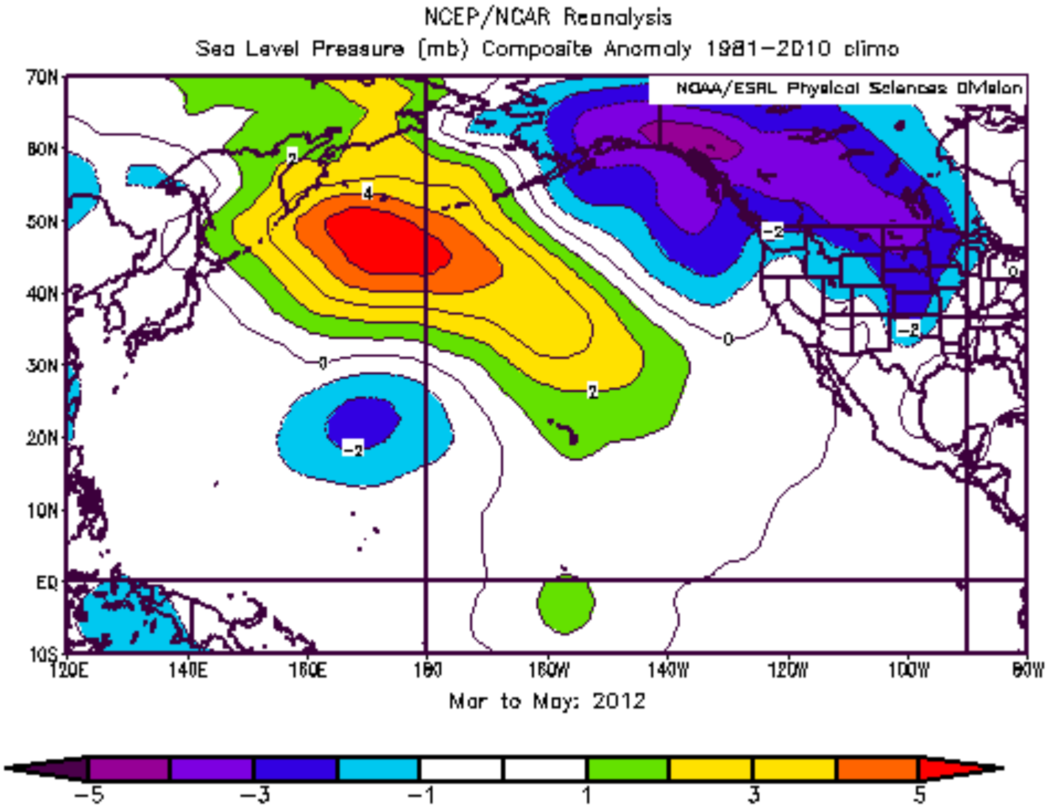

Figure 3b. SLP anomalies for March – May, 2012.

The pattern of anomalous SST in summer (Jun-Aug) 2012 (Fig. 4a) featured the continued warming of the eastern tropical Pacific relative to seasonal norms. Negative anomalies persisted in a horseshoe pattern extending form the Bering Sea to the west coast of the US and curving back towards the southwest to the dateline. Warm water remained in the central North Pacific in a band stretching from north of the Hawaiian Islands to the Sea of Japan. This pattern represents a negative expression of the Pacific Decadal Oscillation (PDO), as further discussed below. The distribution of anomalous SLP (Fig. 4b) included positive anomalies stretching from Japan to the southeastern Bering Sea and then south into the central-eastern North Pacific. Relatively low pressure occurred from far eastern Siberia across Alaska across Canada. The gradients in the SLP anomalies, and hence anomalous winds, were weak in many regions, e.g., along the west coast of North America. This is typical for the summer season, when atmospheric circulation anomalies tend to be lower in amplitude compared to other times of the year.

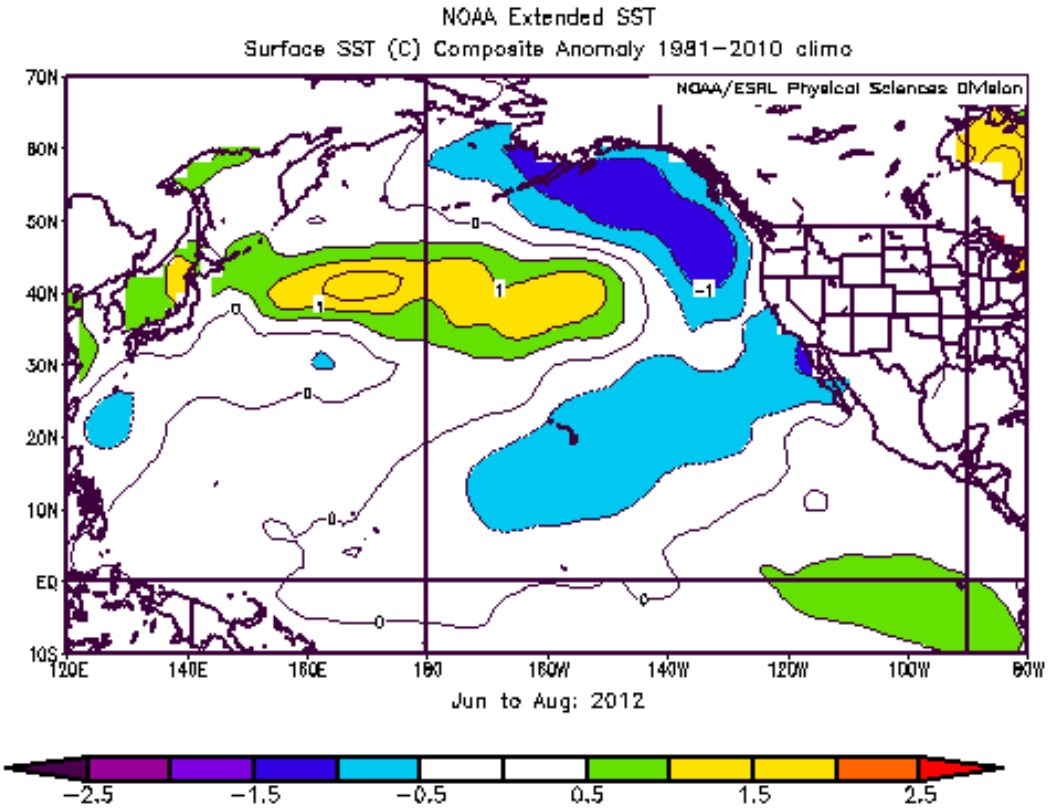

Figure 4a. SST anomalies for June – August, 2012.

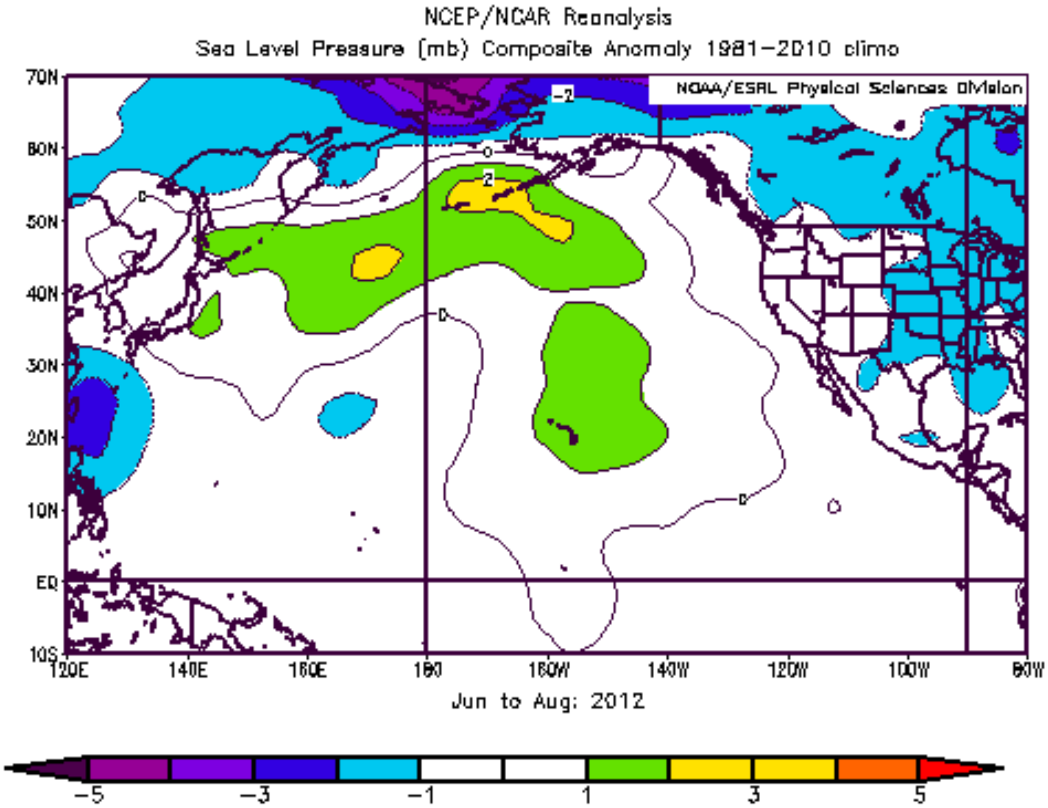

Figure 4b. SLP anomalies for June – August, 2012.

2. Climate Indices

Climate indices provide a complementary perspective on the North Pacific atmosphere-ocean climate system to the SST and SLP anomaly maps 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, Pacific Decadal Oscillation (PDO) index (the leading mode of North Pacific SST variability), North Pacific Index (NPI), North Pacific Gyre Oscillation (NPGO) and Arctic Oscillation (AO). The time series of these indices from 2002 through spring 2012 are plotted in Figure 5.

The state of the North Pacific atmosphere-ocean system reflected the influences of ENSO during 2011-12. The Aleutian Low tends to be weaker during La Niña winters, and while this was the case to an extent, the SLP anomalies during the past year (Fig. 2b) featured a positive anomaly center displaced to the southeast from its average location near 50°N, 160°W. Note that while ENSO is dominated by year-to-year variability it also varies on multi-year time scales. In particular, it was in a predominantly positive state from 2002 through 2005, and a negative state from late 2007 through early 2012, with La Niña present during four of the last five winters. As of summer 2012, recent warming in the tropical Pacific has transitioned ENSO into a positive state. The projections of the dynamical and statistical models used to forecast ENSO are discussed in the last section of this overview.

The PDO has manifested a largely downward trend since the winter of 2002-03. This reflects a multi-year shift from relatively warm to cool water in an arc extending from the Bering Sea through the Gulf of Alaska to along the west coast of North America, and SST anomalies of the opposite sign in the western and central North Pacific. There has been a return towards a more neutral state since late 2011, at least in part due to the influence of ENSO on the PDO through the former's impacts on the atmospheric circulation over the North Pacific. The potential predictability of the PDO appears to be largely associated with its connection to ENSO.

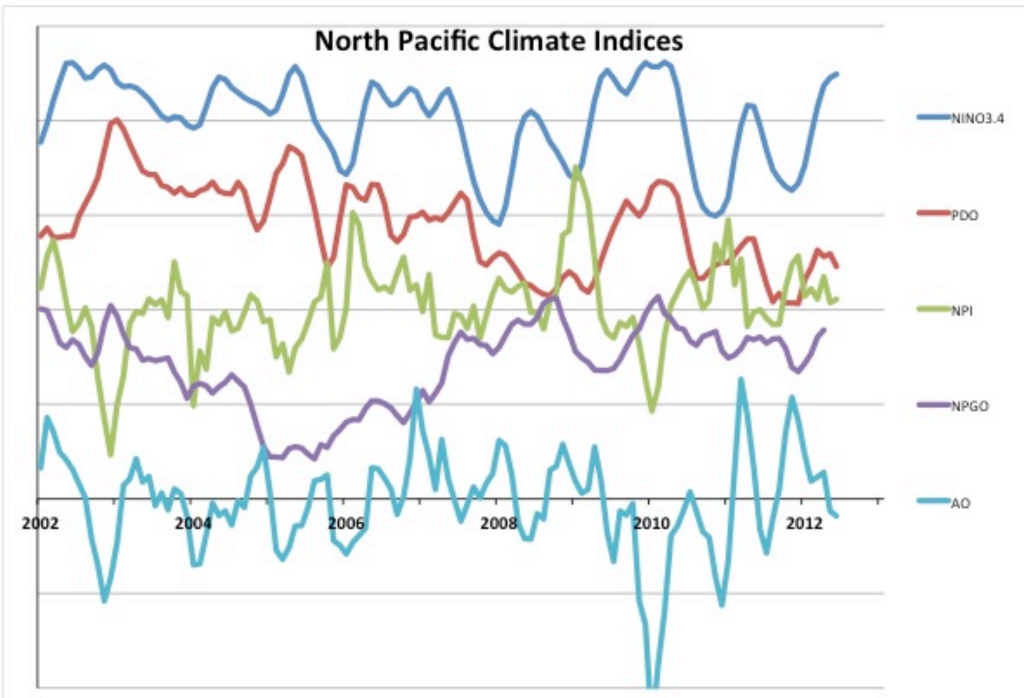

Figure 5. Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 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 prominence of its short-term variability can be attributed to the nature of the North Pacific atmospheric circulation, which undergoes substantial fluctuations on short time scales (days) as well as years to decades. Note the negative correspondence with the NINO3.4 index in general. That being said, the NPI had a rather muted response to ENSO during the past La Niña.

The North Pacific Gyre Oscillation (NPGO) represents the second leading mode of variability for the North Pacific, and has been shown to relate to chemical and biological properties in the Gulf of Alaska and the southern portion of the California Current (DiLorenzo et al. 2008). 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. It has been suggested that the NPGO may influence ENSO through its association with the strength of the trade winds in the sub-tropical eastern Pacific, but the mechanisms behind this potential linkage are poorly understood.

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. The overall sense of the AO was positive during the winter of 2011-12 and since has been in a near neutral state. There are no reliable forecast tools at present for seasonal prediction of the AO, but there is some tendency for it to be in a negative state during El Niño.

3. Regional Highlights

a. **West Coast of Lower 48** – This region experienced conditions during 2011-2012 that mostly resembled those during past periods of La Niña and negative PDO. The waters near the coast tended to be mostly 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, except for during fall 2011 (B. Peterson, NOAA/NWFSC). There was a rather late start to the upwelling in spring 2012. For the summer of 2012, the winds have tended to be more upwelling favorable than usual south of about 40°N, and near normal to the north. Additional information on the state of the California Current system is available at www.pacoos.org and http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/bb-midyear-update.cfm.

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 increased markedly from summer into fall of 2011, and after declining over the course of the winter, again increased from spring into summer 2012. These changes from season to season are consistent with the winds, as can be deduced from the SLP anomaly patterns shown in Figs. 1b-4b. The mixed layer depths in the Gulf were shallower than usual during the winter of 2011-2012 but by early summer 2012 were near their seasonal norms.

c. **Alaska Peninsula and Aleutian Islands** – Westerly wind anomalies have prevailed in this region for much of the past year. Anomalies in this sense tend to suppress the northward transport through Unimak Pass and perhaps also the Aleutian North Slope Current. A possible implication is a reduced supply of nutrients onto the southern Bering Sea shelf, but the importance of this mechanism is poorly known.

d. **Bering Sea** – The Bering Sea shelf experienced another relatively heavy ice year, especially in terms of maximum ice extent. The weather was punctuated by periods of unusually frigid temperatures at around the first of the year, the end of January and much of March. Westerly wind anomalies occurred during spring, which resulted in a late ice retreat from the southern shelf, but not to extent of some recent years, notably 2010. Unlike a year ago, the summer of 2012 has been relatively calm. This has resulted in a relatively thin (~10 m) mixed layer that rapidly warmed in June through July, especially in the north. The water at depth is still cold and the onset of the fall storms should result in rapid cooling near the surface. The combination of El Niño expected this winter and a continuation of reduced ice cover in the central Arctic (more on this below) should yield a lighter ice year for the Bering in 2013.

e. Arctic – The tendency for reduced sea ice cover in the Arctic during the summer has continued into 2012. The distribution of the arctic in sea ice in early August 2012 differs somewhat from recent years. Specifically, high ice concentrations have persisted in the Chukchi and in the western portion of the Beaufort Sea. The extent to which this ice will melt back during the remainder of summer depends on the weather of August and September. If the ice pack retreats to well north of Alaska, as it has in recent summers, there should again be a delay the development of ice in marginal seas such as the Bering Sea during the following cold season.

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. These projections of 3-month average anomalies indicate systematic declines in the magnitudes of the cold anomalies in the northeastern and southeastern portions of the basin, and of the warm anomaly centered near 40°N and the dateline. Changes of this nature imply a transition to a near neutral state for the PDO and are consistent with the changes in SST anomalies that have occurred during previous El Niños. Note that for the tropical Pacific itself, that the CFS is predicting some increase in the intensity of the warm anomalies, i.e., the development of a weak-moderate El Niño over the remainder of 2012. A slow decrease in the amplitude of El Niño is forecast during late winter 2013. The CFS is also forecasting a stronger than normal Aleutian Low, that is, negative SLP anomalies, for the winter of 2012-13 (not shown). The scenario described here resembles that of three years ago. A moderate El Niño developed over the summer and fall of 2009 after the back-to-back La Niñas of 2007-08 and 2008-09; the presently developing El Niño event is occurring with similar precursor conditions. The CFS forecasts for late 2009 through summer 2010 were reasonably accurate; there is the expectation that the present CFS forecasts will also have value. The CFS predictions for El Niño are supported by the consensus of the predictions from a variety of dynamical and statistical approaches used by modeling centers towards forecasting ENSO. Based on not just the SST predictions shown in Figure 6, but also other forecast fields, it is likely that there will be a warming of Alaskan waters over the next 2-3 seasons, relative to the mostly cooler than normal temperatures that have prevailed over the last 5 years.

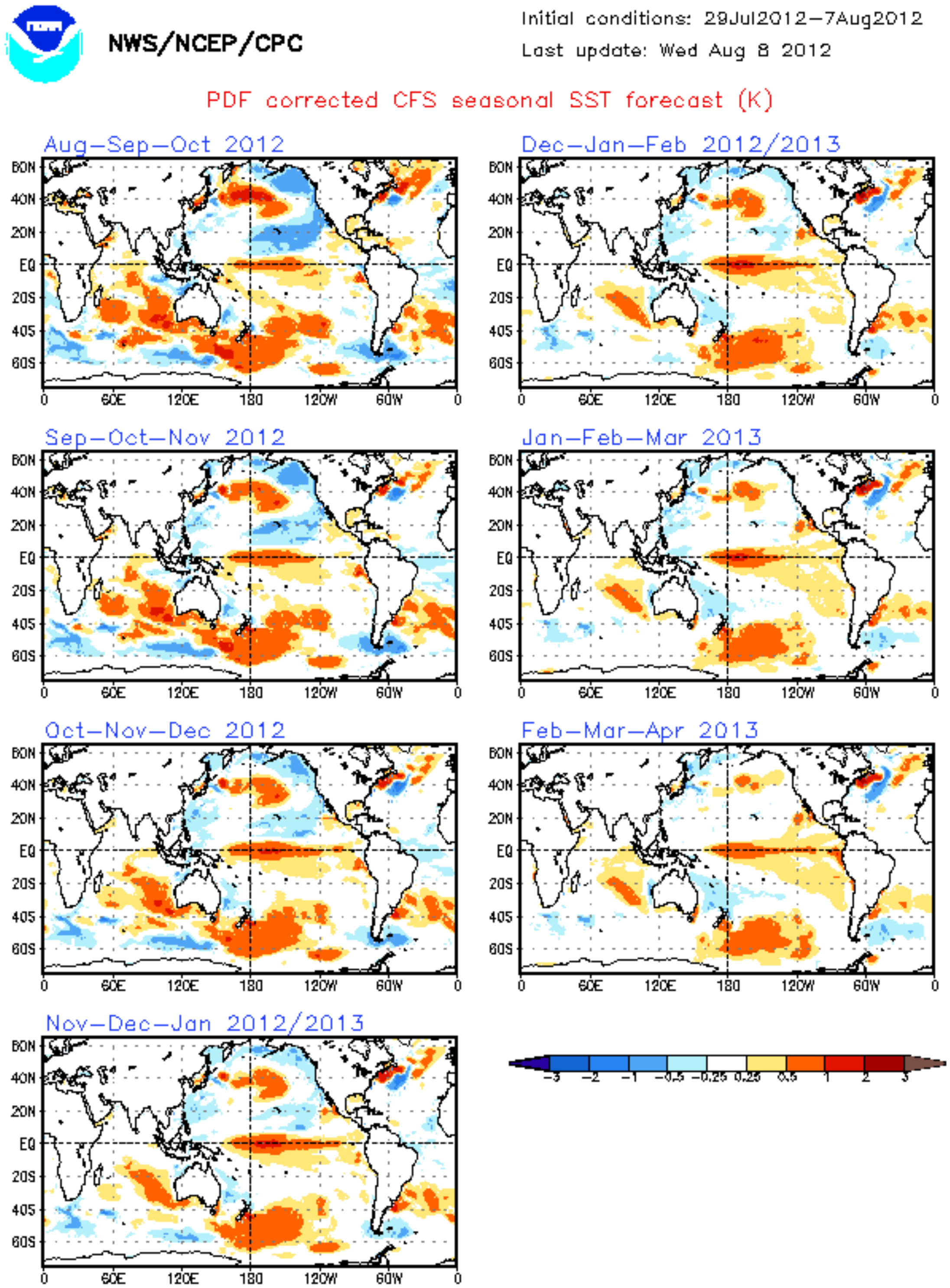

Figure 6. Seasonal forecast of SST anomalies from the NCEP Coupled Forecast System (CFS) model for August 2012 through April 2013.

5. Literature Cited

Di Lorenzo E., Schneider N., Cobb K. M., Chhak, K, Franks P. J. S., Miller A. J., McWilliams J. C., Bograd S. J., Arango H., Curchister E., Powell T. M. and P. Rivere (2008): North Pacific Gyre Oscillation links ocean climate and ecosystem change. Geophys. Res. Lett., 35, L08607, doi:10.1029/2007GL032838.