North Pacific Climate Overview

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

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Summary. *The state of the North Pacific atmosphere-ocean system during 2014-2015 featured the continuance of 2013-2014* sea surface temperature (SST) *anomalies with some evolution in the pattern. This development can be attributed to the seasonal mean* sea level pressure (*SLP) and wind anomalies such as the cyclonic wind anomalies in the central Gulf of Alaska in fall 2015 and winter 2015, with a reversal to anticyclonic flow in the following spring and summer of 2015. The Bering Sea experienced the second consecutive winter of reduced sea ice, in what may turn out to be the early stage of an extended warm spell. The Pacific Decadal Oscillation (PDO) was positive during the past year, especially during the winter months. The climate models used for seasonal weather predictions are indicating strong El Niño conditions for the winter of 2015-16, and its usual impacts on the mid-latitude atmospheric circulation, which should serve to maintain a positive state for the PDO.*

1. SST and SLP Anomalies

The state of the North Pacific climate from autumn 2014 through summer 2015 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 (ESRL) at http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl.

The anomalies that occurred during the past year in the North Pacific beginning in autumn of 2014 reflect, to a large extent, the maintenance of conditions that developed during the previous year. In particular, two leading large-scale climate indices for the North Pacific, the Pacific Decadal Oscillation (PDO) and the North Pacific Gyre Oscillation (NPGO) were strongly positive and moderately negative (respectively). Following a transition in sign the year before. More detail on the evolution of the SST and SLP from a seasonal perspective is provided directly below.

The SST in the North Pacific during the autumn (Sep-Nov) of 2014 (Fig. 1a) included positive anomalies exceeding 1° C along the west coast of North America from Baja California to the Gulf of Alaska, and in the western Bering Sea. The pattern of anomalous SLP during autumn 2014 featured strongly negative anomalies in the NE Pacific with a peak amplitude greater than 5 mb near 40° N, 140°W. This SLP pattern implies anomalous downwelling in the coastal waters extending from Northern California through the Gulf of Alaska (GOA), and anomalous winds from the east across the Bering Sea. This period included a notable event and that is the most intense storm on record for the North Pacific as gauged by minimum barometric pressure. This storm originated as supertyphoon Nuri in the western North Pacific, underwent a transition to an extratropical cyclone, and reached its maximum strength as an extratropical cyclone with a central pressure of 924 mb in the Bering Sea. Extremely high, significant wave heights and hurricane-force winds accompanied this storm.

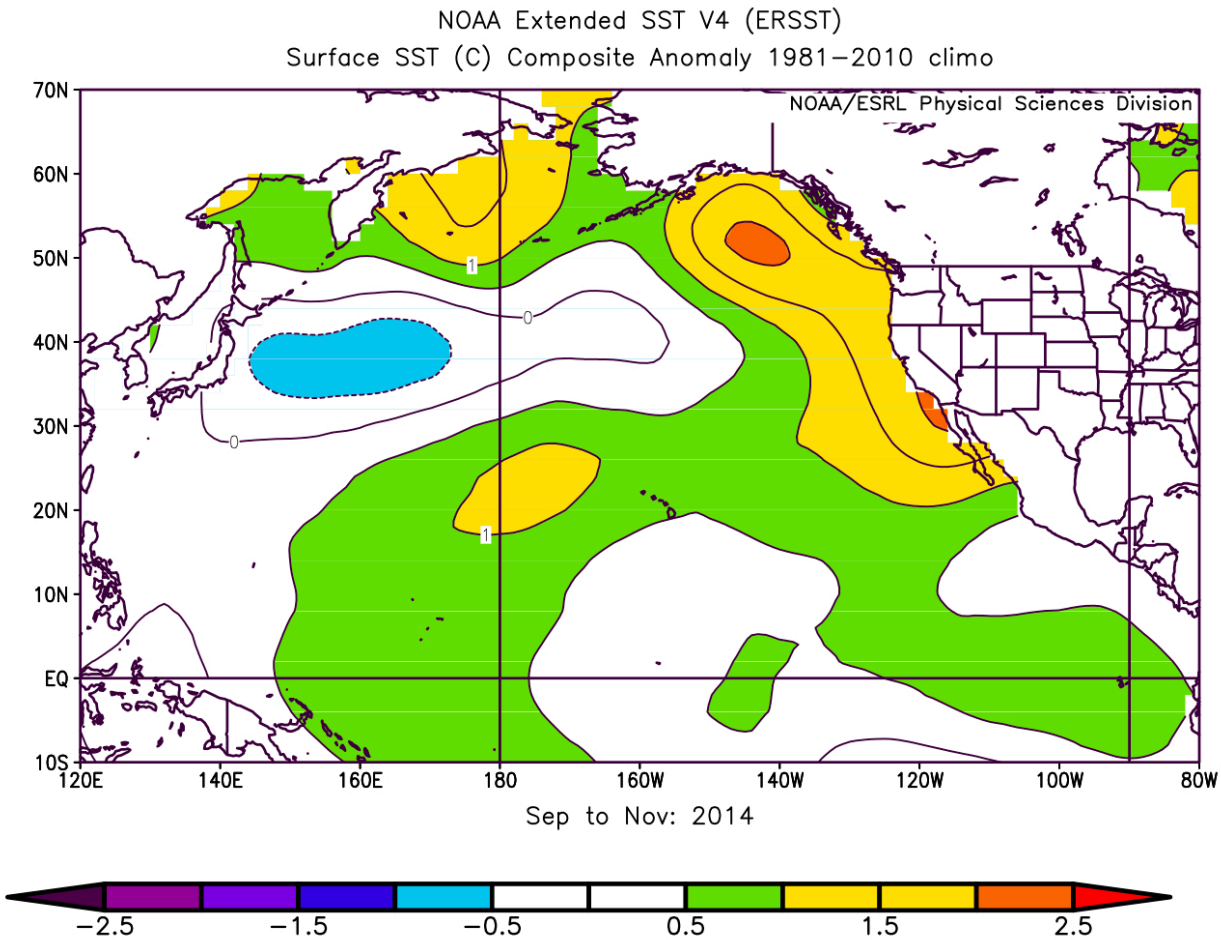

Figure 1a. SST anomalies for September-November 2014.

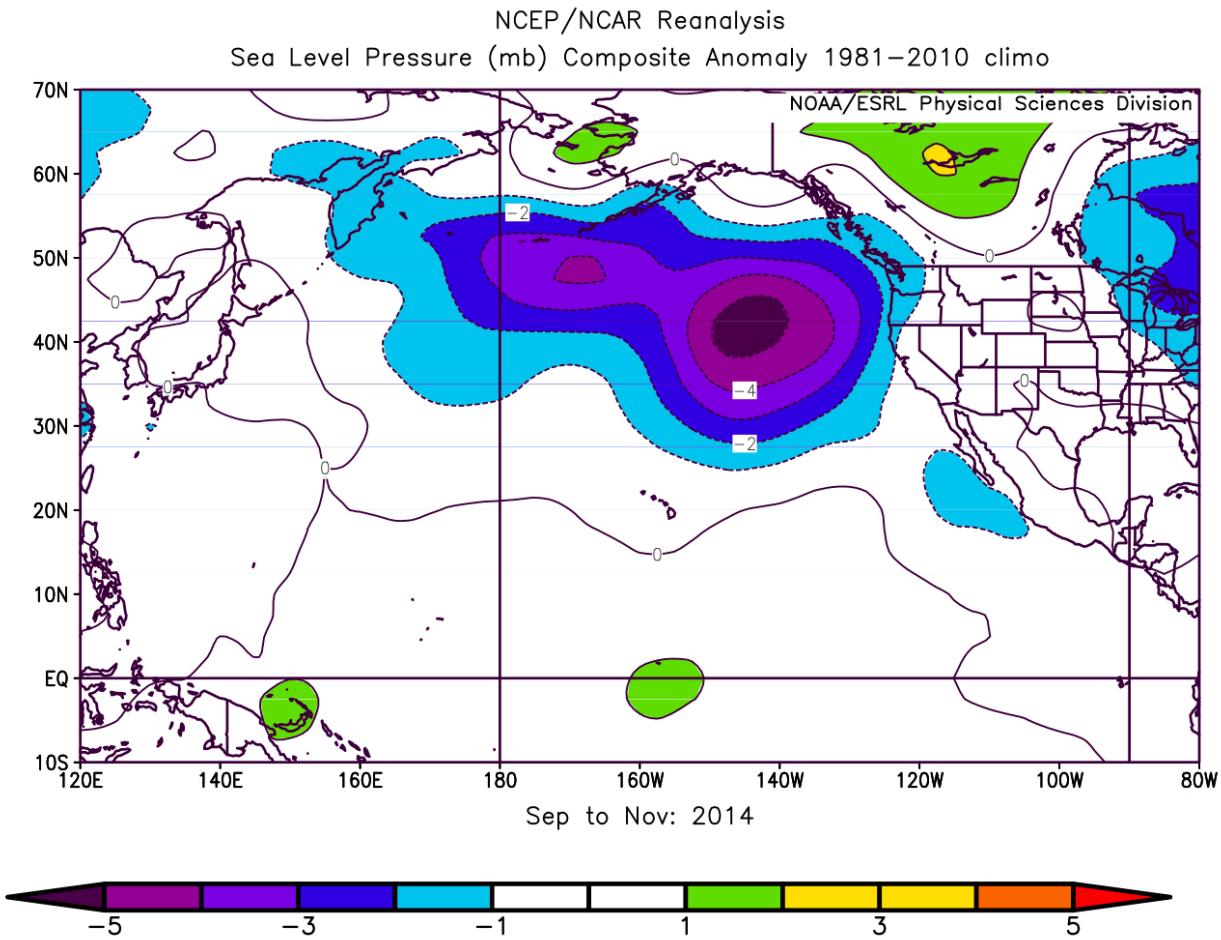

Figure 1b. SLP anomalies for September-November 2014.

The pattern of North Pacific SST during winter (Dec-Feb) of 2014-15 relative to the seasonal mean (Fig. 2a) essentially reflects persistence from the preceding autumn. The SLP also remained much lower than normal between Alaska and the Hawaiian Islands (Fig. 2b). At more northern latitudes, a band of higher than normal SLP extended to east Siberia, across Alaska and through western Canada, with a maximum positive anomaly over the western Bering Sea. This SLP distribution implies reduced storminess for the Bering Sea and for the west coast of North America from California to the Alaska Peninsula. There were regions of moderately enhanced wind speeds in the offshore portion of the eastern and northern Gulf of Alaska. The overall pressure pattern, and accompanying basin-scale atmospheric circulation, resulted in warmer than normal winter temperatures in western North America, with particularly prominent warm anomalies extending from the eastern tip of Siberia to the Alaska mainland. The lack of cold air over the Alaska interior meant fewer and weaker cold-air outbreaks over the Bering Sea shelf than usual.

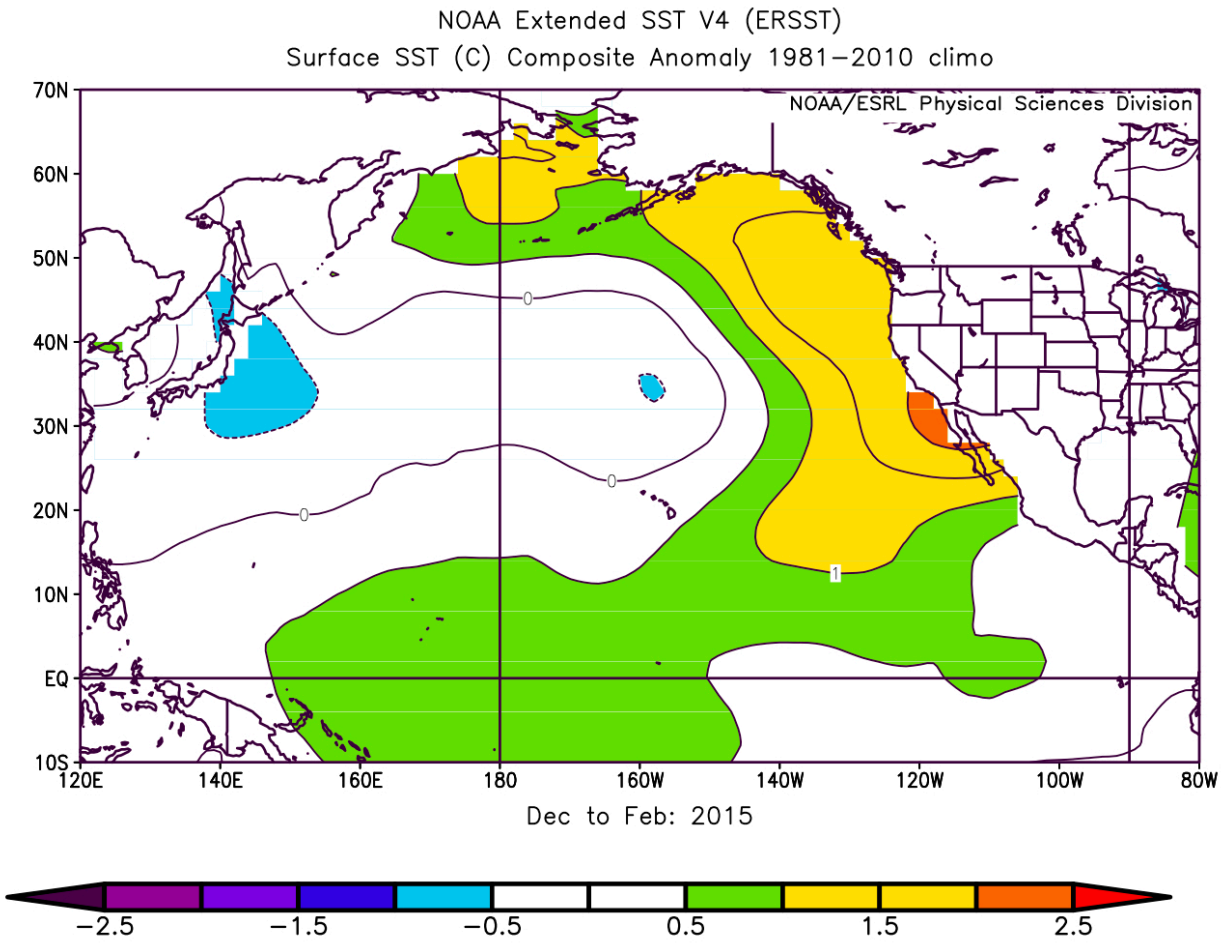

Figure 2a. SST anomalies for December 2014 - February 2015.

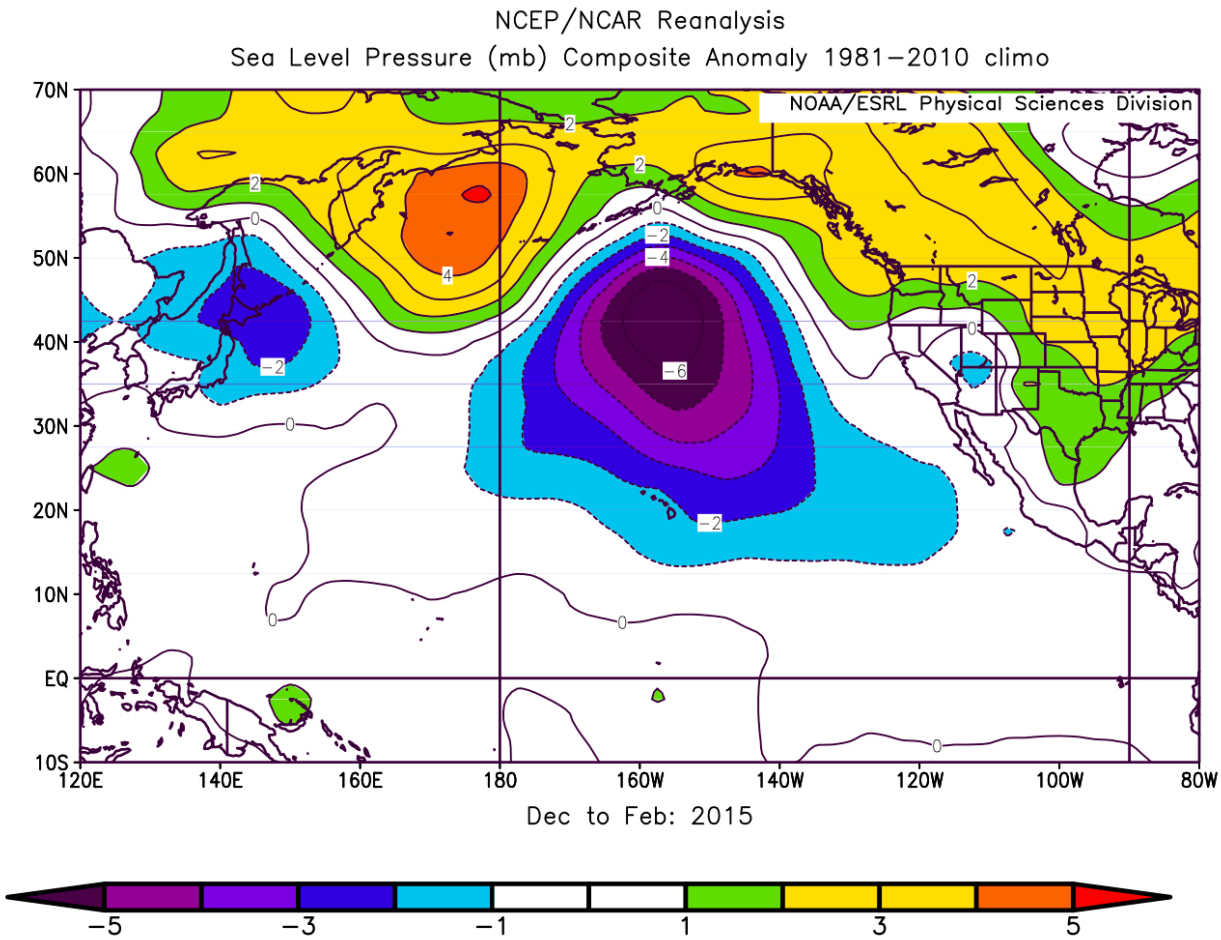

Figure 2b. SLP anomalies for December 2014 - February 2015.

The distribution of anomalous SST in the North Pacific during spring (Mar-May) of 2015 (Fig. 3a) resembled that of the season before, with an increase in the magnitude of the positive anomalies off the coast of the Pacific Northwest. The SST anomalies in the tropical Pacific also increased from the dateline to the coast of South America. The SLP anomaly pattern (Fig. 3b) for spring 2015 was substantially different than that for the previous winter. The most prominent features were a band of positive anomalies between roughly 30° and 50°N extending from the east coast of Asia to the west coast of North America, and anomalously low pressure to the north from the eastern tip of Siberia to the far northern portion of western Canada. This is typically a cold weather pattern for the southeast Bering Sea shelf. Nevertheless, the air temperatures at St. Paul Island were still above normal for this season as a whole, presumably in part because of the effects of warm ocean temperatures and reduced ice cover.

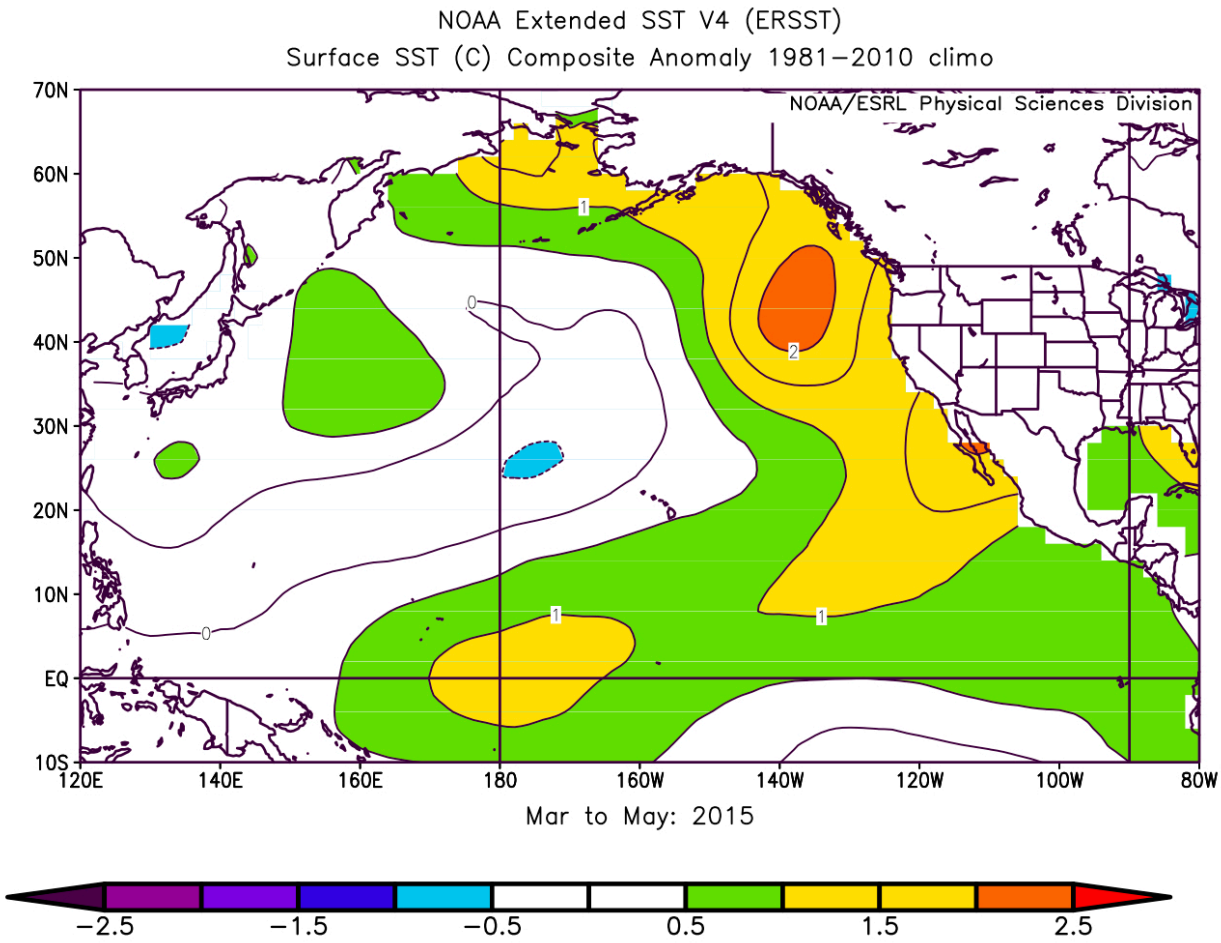

Figure 3a. SST anomalies for March – May 2015.

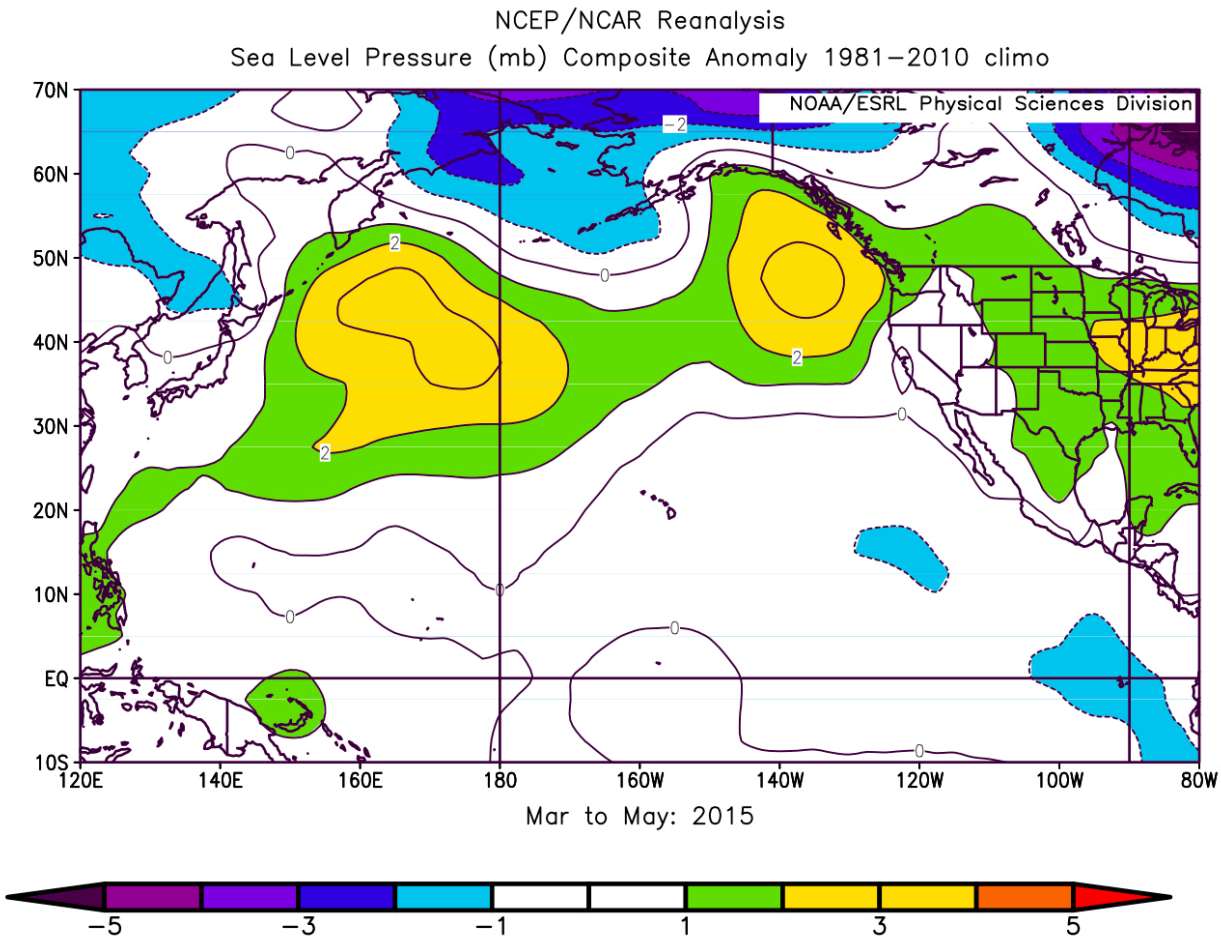

Figure 3b. SLP anomalies for March – May 2015.

The SST in summer (Jun-Aug) 2015 (Fig. 4a) was cooler than normal in a small region extending from the southern Sea of Okhotsk to the south of the Aleutian Islands, and then curving south to northwest of the Hawaiian Islands. The eastern portion of the North Pacific basin was quite warm, with prominent positive anomalies off the coast of the Pacific Northwest and in the eastern tropical Pacific. The latter feature is an indication of the El Nino that developed from spring into summer of 2015. The distribution of anomalous SLP (Fig. 4b) during summer 2015 included higher than normal SLP over the Gulf of Alaska; as shown in Fig. 4a there was surface warming under the central part of this SLP anomaly and a moderation of temperatures in the coastal zones of the western Gulf of Alaska and the Pacific Northwest due to anomalous upwelling favorable winds. Lower than normal SLP from the southern Sea of Okhotsk to north of the Hawaiian Islands implies enhanced storminess, which apparently served to slightly suppress the usual rate of summer warning in that portion of the North Pacific.

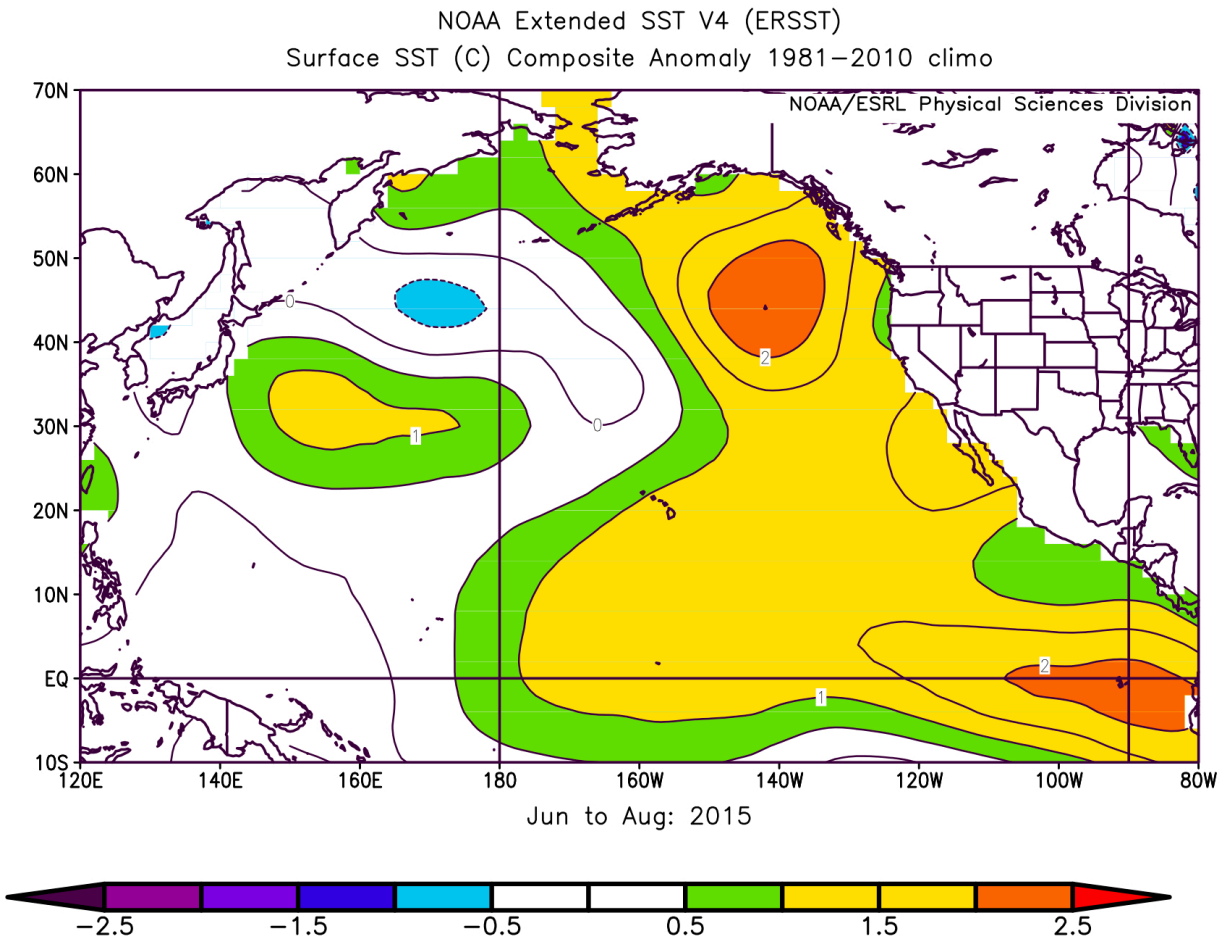

Figure 4a. SST anomalies for June – August 2015.

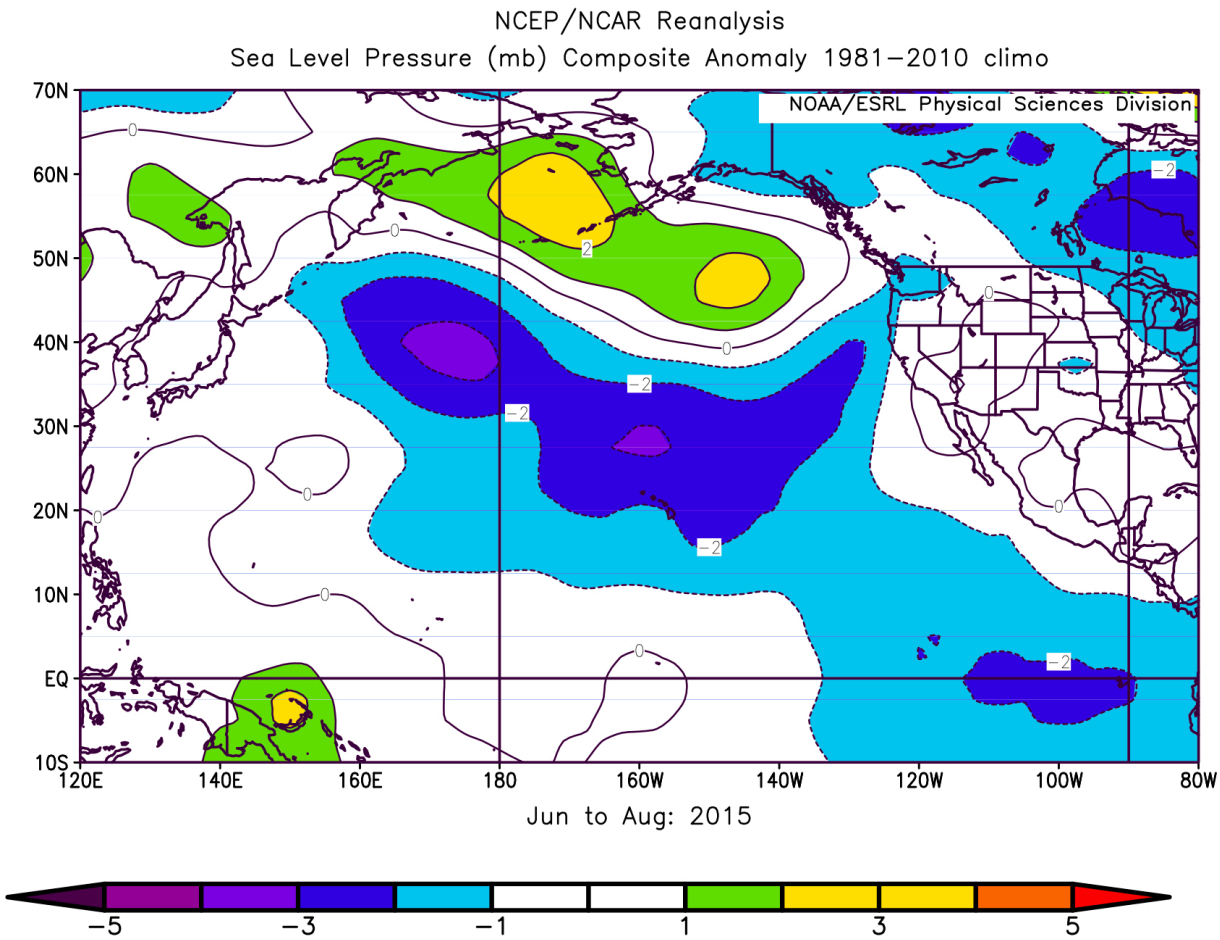

Figure 4b. SLP anomalies for June – August 2015.

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 2005 into summer 2015 are plotted in Figure 5.

The North Pacific atmosphere-ocean climate system has undergone substantial change over the past two years. The ENSO has transitioned from a near-neutral (slightly positive) state late in 2014 to strongly positive (~ +2) at the time of this report (note that the indices shown in Fig. 5 are updated through July or August and have been smoothed with three-month running means). The PDO sharply increased late in 2014, and then moderated during spring 2015. The PDO value of 2.5 during December 2014 was the largest during a winter month in the record extending back to 1900. Changes in the PDO typically lag those in ENSO by a few months due to the North Pacific oceanic response to atmospheric teleconnection patterns emanating from the tropical Pacific, but over the past two years the changes in the PDO have mostly led and surpassed ENSO. The NPI was negative during the fall and early winter (implying a strong and often displaced Aleutian Low, as indicated in Figs. 2a and 2b). This development occurred

relatively independent of ENSO, at least as gauged by the NINO3.4 index. The generally negative values of the NPI are consistent with the positive trend in the PDO.

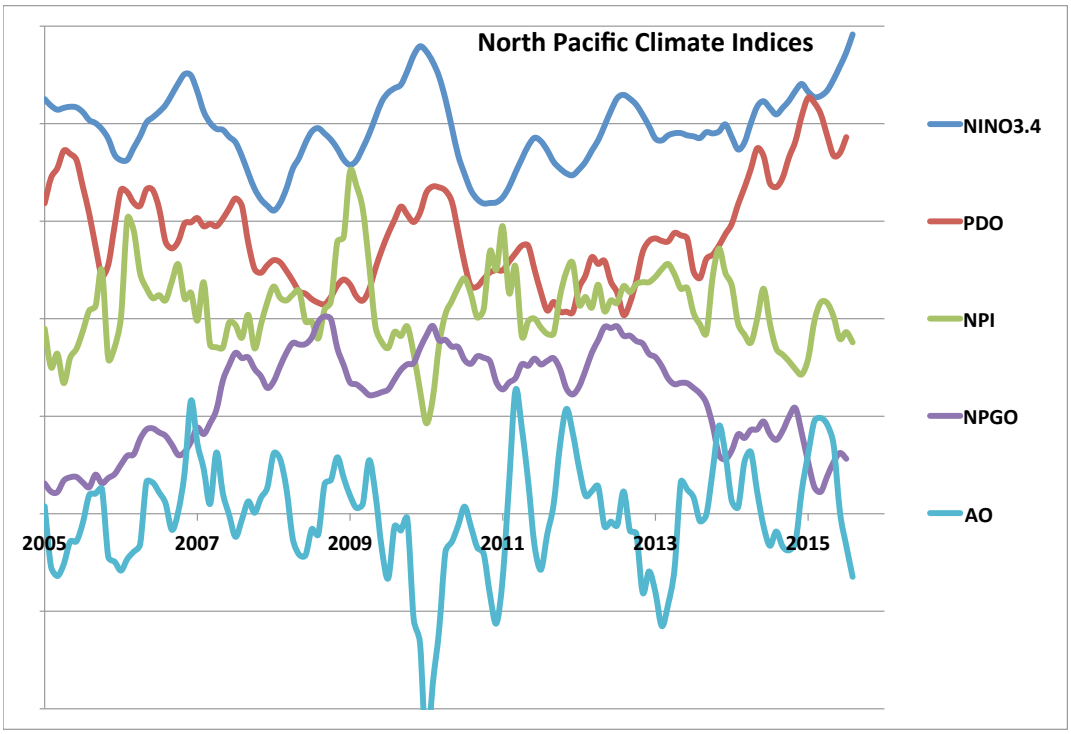

Figure 5. Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices. Each time series represents monthly values that are normalized and then smoothed with the application of three-month running means. The distance between the horizontal grid lines represents 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 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 northeastern Pacific, in particular the Gulf of Alaska. The NPGO has undergone a general decrease from a strongly positive state in 2012 to negative in 2015. A negative sense of this index implies a reduced west wind drift and projects on weaker than normal flows in both the Alaska Current portion of the Subarctic Gyre and the California Current. There is tentative evidence that the NPGO, and in particular its atmospheric counterpart the North Pacific Oscillation (NPO), can impact ENSO through its association with the strength of tradewinds in the eastern subtropical Pacific. The climate community is taking great interest in the recent conditions in the North Pacific and it is possible that the strength of the fluctuations, i.e., the signals, are great enough to gain better understanding of the interactions between extratropical and tropical modes of variability in the Pacific. 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. The AO was negative late in 2014, strongly positive during the early part of 2015, and then negative during the summer of 2015. It does not appear that the variations in the AO have been closely related to conditions in the vicinity of Alaska during the last few years.

3. Regional Highlights

a. **West Coast of Lower 48** – This region continues to be impacted by warm (in some cases record) upper ocean temperatures. The winter featured suppressed precipitation in California and warm air temperatures along the entire coast. The lack of winter snowpack and relatively warm and dry weather in spring and summer led to rivers and streams running extremely low and warm, with detrimental effects on many returning adult salmon runs. The spring and summer included relatively robust upwelling in the northern portion of this domain and hence a thin strip of water of moderate temperatures in the immediate vicinity of the coast. Nevertheless, the proportion of northern, lipid-rich copepods was relatively low in sampling carried out on the Newport, OR line and therefore it is expected that conditions will favor species adapted to warmer water and associated prey. The wind anomalies were mostly downwelling favorable south of roughly Cape Mendocino during spring and summer, which served to maintain the warm waters. The effects of the highly unusual atmospheric and oceanic conditions on the marine ecosystem are receiving considerable attention from the research community. Additional information on the state of the California Current system is available at http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/index.cfm.
b. **Gulf of Alaska** –The upper ocean in this region remained fresher than usual with a relatively strong pycnocline, in the continuation of conditions first seen in early 2014. The sub-arctic front was farther north than usual, which is consistent with the poleward surface currents shown in the Ocean Surface Currents – Papa Trajectory Index section (Stockhausen and Ingraham). The coastal wind anomalies were generally downwelling favorable during fall and winter but switched to more upwelling favorable during the spring and summer, resulting in more moderate SST anomalies along the coast as compared with the much warmer than normal water offshore by summer 2015.
c. **Alaska Peninsula and Aleutian Islands** – Some of the abnormally warm water that developed in the NE Pacific during early 2014 appears to have made it to the Aleutians and through the eastern Aleutian passes into the Bering Sea, presumably during the winter when the local winds were favorable for northward transports. During the period from fall 2014 to summer 2015, upper ocean temperature anomalies in the western Aleutians cooled from above normal to near normal. These anomalies remained general above normal along the arc of the eastern Aleutian Islands and Alaska Peninsula.

d. **Bering Sea** –The Bering Sea shelf experienced weather during the past cold season of 2014-15 in an overall sense that was quite similar to 2013-14. For the period of October 2014 through March 2015, mean air temperatures were 1-2° C warmer than normal on the southern portion of the shelf and about 3° C warmer than normal in the north. The warm weather can be attributed mostly to relatively warm and moist air aloft over the Bering Sea shelf due to an atmospheric circulation that suppressed the development of extremely cold air masses over Alaska, the usual source of the lower-atmospheric flow for the Bering Sea shelf. The relative warmth of the water in the south prevented ice from reaching as far as south as usual even though there were periods of sustained northerly winds late in the cold season, such as during the middle part of April 2015. The consequence was a cold pool that did not extend much south of 59° N. The weather during summer of 2015 tended to be warm, with a typical amount of storminess.

e. **Arctic** – The timing of the onset of ice in the Chukchi and coastal portion of the Beaufort Sea during fall 2014 was comparable to that of most recent years. Air temperatures in these regions were systematically higher than normal from fall 2014 through spring 2015. It remained relatively warm in the Chukchi Sea through the summer of 2015, but temperatures were near normal in the Beaufort Sea where the ice was slow to retreat, with a band of ice just off the coast east of Barrow that persisted through late summer. This can be attributed to westerly wind anomalies along the northern coast of Alaska and hence southward Ekman transports, and a lack of warm water from the Mackenzie River plume, which instead advected eastward towards the Canadian Archipelago. This contrasts with the norm for the last decade or so, which has included anomalous winds from the east. For the Arctic as a whole, the area of sea ice cover at the end of the 2015 melt season is liable to resemble that of 2011, which represented the 3rd lowest value in the observational record.

4. Seasonal Projections from the National Multi-Model Ensemble (NMME)

Seasonal projections of SST from the National Multi-Model Ensemble (NMME) are shown in Figures 6a-c. An ensemble approach incorporating different models is particularly appropriate for seasonal and longer-term simulations; the NMME represents the average of eight models. The uncertainties and errors in the predictions from any single climate model can be substantial. More detail on the NMME, and projections of other variables, are available at the following website: http://www.cpc.ncep.noaa.gov/products/NMME/.

These NMME forecasts of 3-month average SST anomalies indicate a continuation of warm conditions in the eastern North Pacific through the end of the year (Oct-Dec 2015) with a smaller region of slightly cooler water than normal in the central North Pacific (Fig. 6a). This overall pattern is maintained, with some strengthening of the central North Pacific cold anomaly, through the 3-month periods of December 2015 – February 2016 (Fig. 6b) and February – April 2016 (Fig. 6c). These SST patterns project onto a positive sense for the PDO, which represents a continuation of the present phase that began in 2014. All three 3-month periods feature strong to very strong El Nino conditions in the tropical Pacific. At the time of this writing (late summer 2015) the probabilistic forecast provided by NOAA's Climate Prediction Center (CPC) in collaboration with the International Research Institute for Climate and Society (IRI) for the upcoming fall through winter indicates El Niño with unusually high confidence. These same models also agree that there will be a marked weakening of the El Nino in early 2016, as is usually the case, since El Ninos rarely last longer than a calendar year. It bears noting that this El Nino is already in the moderate-strong category and apt to strengthen over the next 2 months. It is therefore likely to have teleconnections to the high-latitude North Pacific that have occurred with past El Ninos, notably a deeper than normal Aleutian low during winter. Among the other consequences of the projected weather during the upcoming fall and winter is a continuation into spring 2016 of considerably warmer than normal SSTs along the entire west coast of North America from Mexico to the eastern Bering Sea shelf.

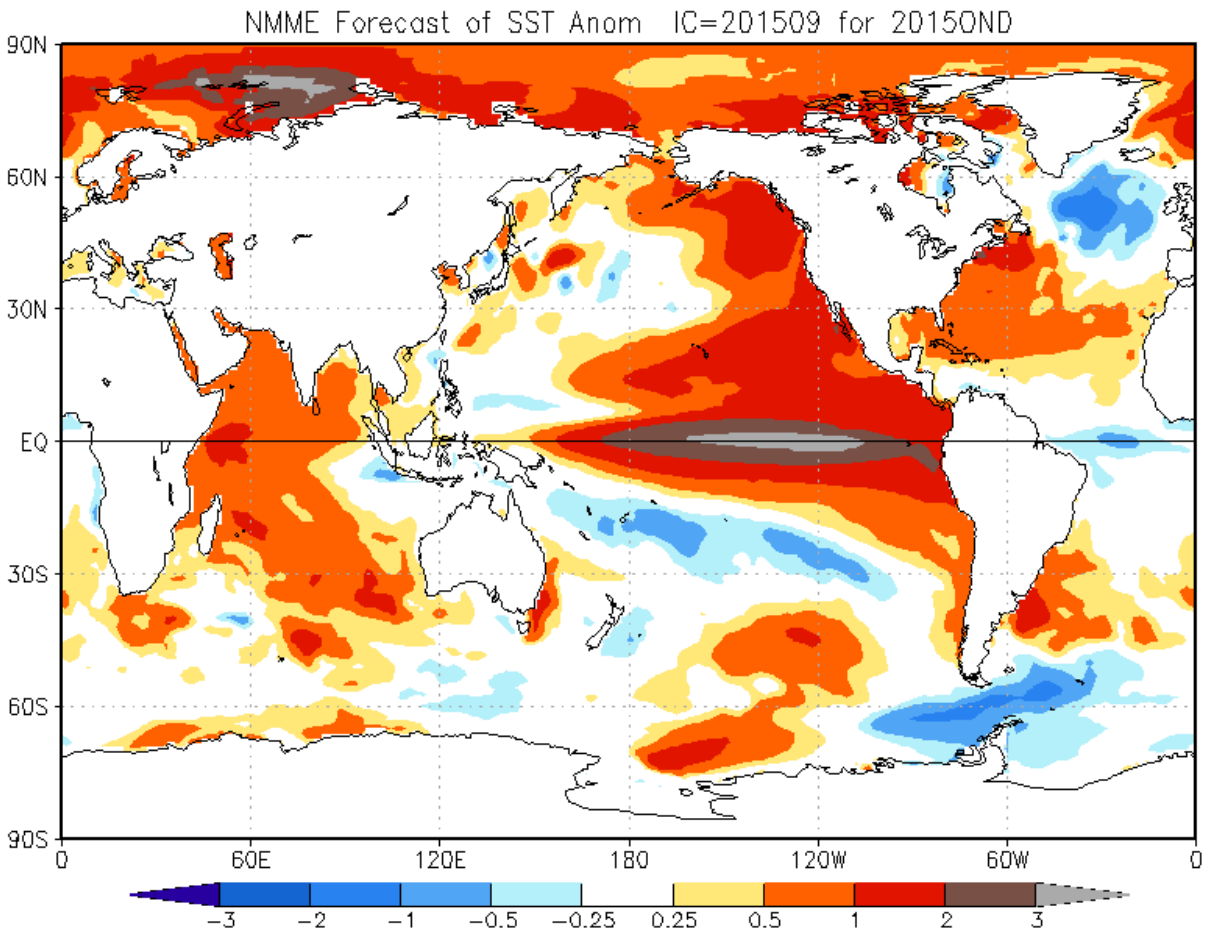

Figure 6a Predicted SST anomalies for October-December 2015 (1 month lead) from the National Multi-Model Ensemble (NMME) of coupled atmosphere-ocean climate models. See text for details.

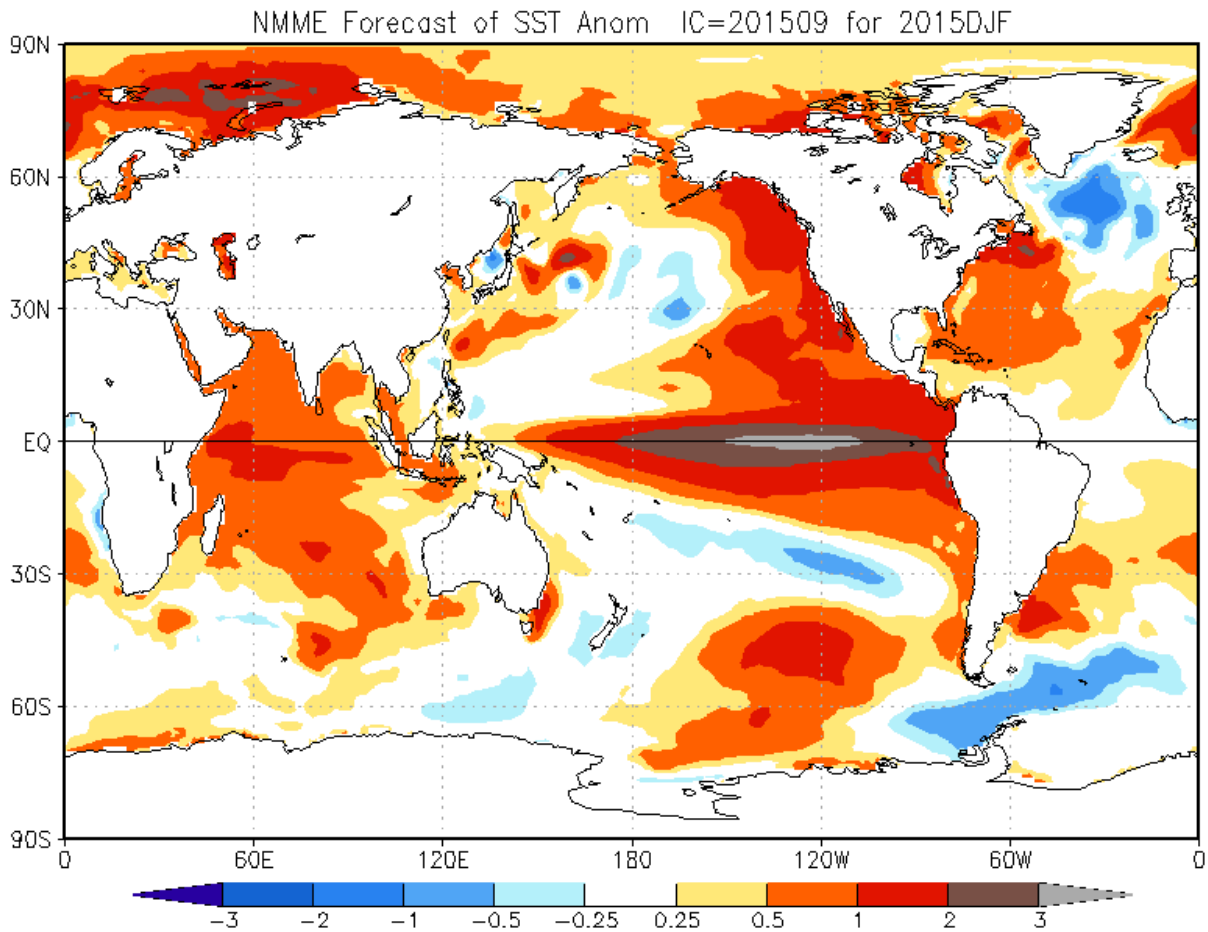

Figure 6b As in Fig. 6a, but for December 2015-February 2016 (3 month lead).

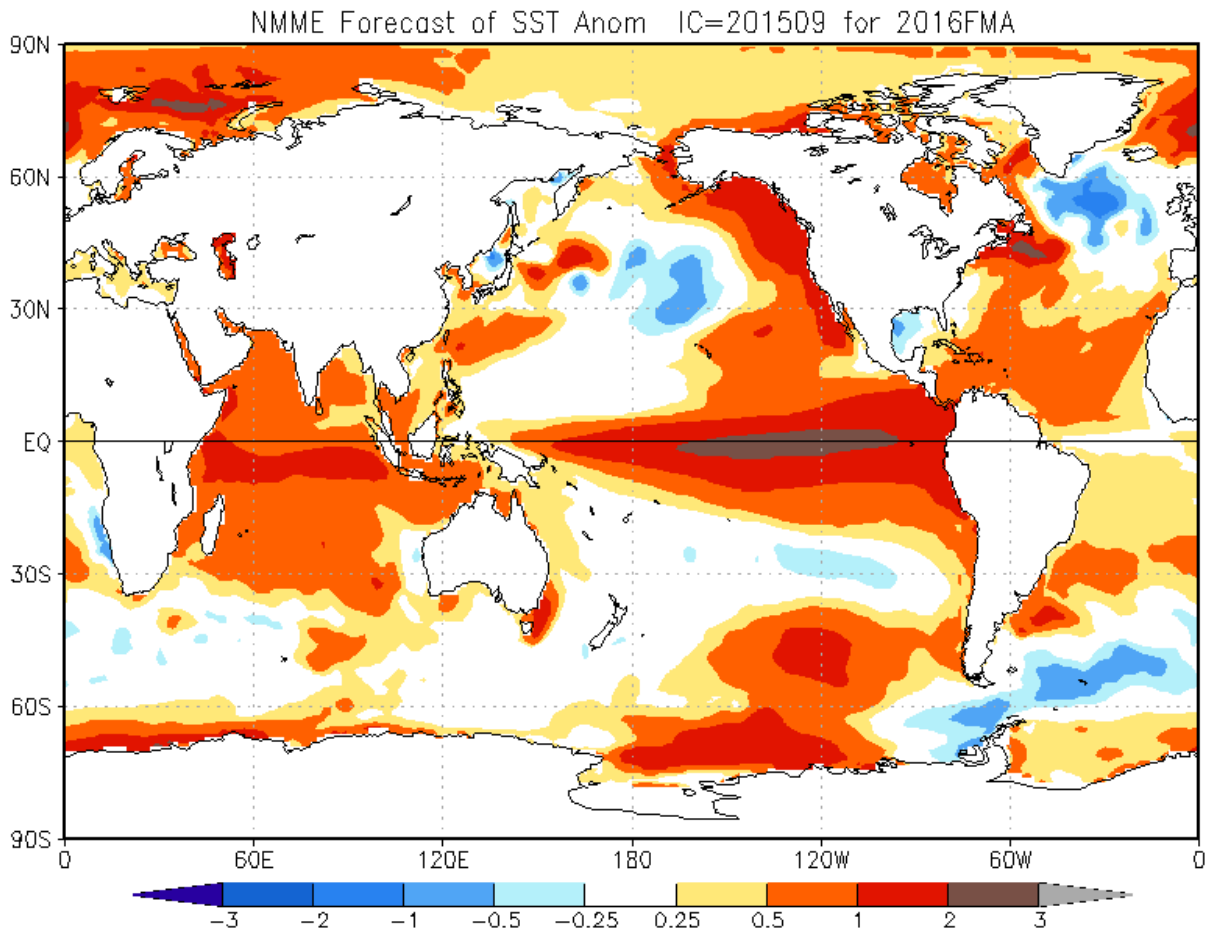

Figure 6c. As in Fig. 6a, but for February-April 2016 (5 month lead).