North Pacific Climate Overview

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Summary*. The state of the North Pacific atmosphere-ocean system during 2017-2018 was rather similar to that during 2016-17. Both winters featured La Niña and weaker than normal Aleutian lows (positive sea level pressure, SLP anomalies). The more prominent sea surface temperature (SST) anomalies during 2017-18 tended to be in the positive sense, with persistent warmth in the subtropical eastern North Pacific, increasing positive anomalies in the Bering Sea, and the expansion of warm waters off the east coast of Asia. The Pacific Decadal Oscillation (PDO) was slightly positive during the past year, with a decline to near zero in the summer of 2018. The climate models used for seasonal weather predictions are indicating about a 70% chance of a weak-moderate El Niño for the winter of 2018-19, and warmer than normal SSTs in both the western and eastern mid-latitude North Pacific in early 2019.*

1. SST and SLP Anomalies

The state of the North Pacific climate from autumn 2017 through summer 2018 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 Optimum Interpolation Sea Surface Temperature (OISST) 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 eastern portion of the North Pacific ocean experienced during 2014-16 one of the most extreme marine heat waves in the observational record (Scannell et al. 2016); the interval summarized here can be considered a transition period between that event and a more climatologically normal SST distribution on the basin-scale. More detail on the evolution of the SST and SLP from a seasonal perspective is provided directly below.

The SST during the autumn (Sep-Nov) of 2017 (Fig. 1a) was warmer than normal across almost the entire North Pacific Ocean. Greater positive (> 1°C) anomalies occurred in the Chukchi Sea and northwest Bering Sea in the northern and eastern Bering Sea, resulting in a delayed onset of sea ice the following winter. The SST anomalies were negative in the eastern equatorial Pacific in association with the development of La Niña. The SLP pattern during autumn 2017 featured prominent positive anomalies over the north central portion of the North Pacific Ocean, with the greatest departures from normal over the open ocean south of the western tip of the Alaska Peninsula. This SLP distribution implies an enhanced storm track along the east coast of Asia, and suppressed storminess from the Aleutians into the Gulf of Alaska (GOA).

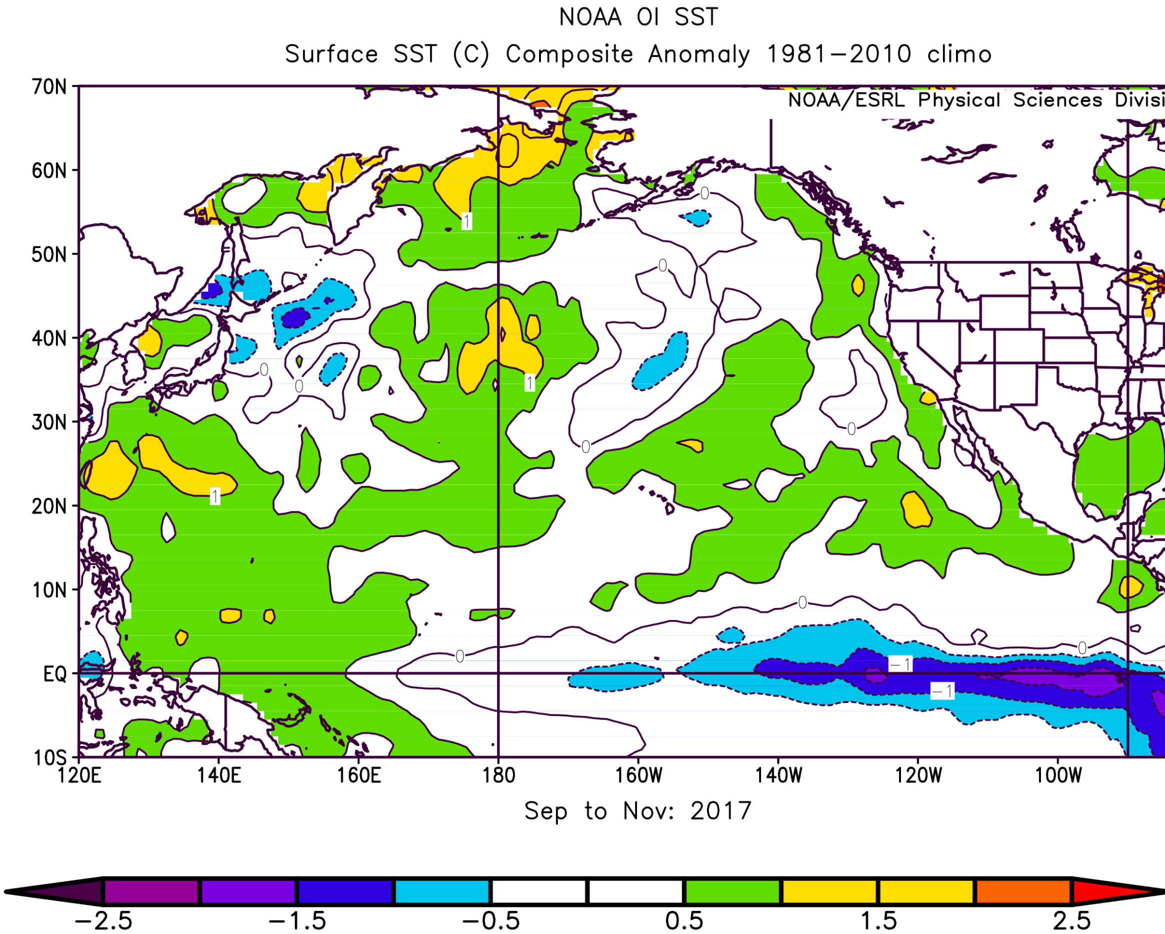

Figure 1a. SST anomalies (°C) for September-November 2017.

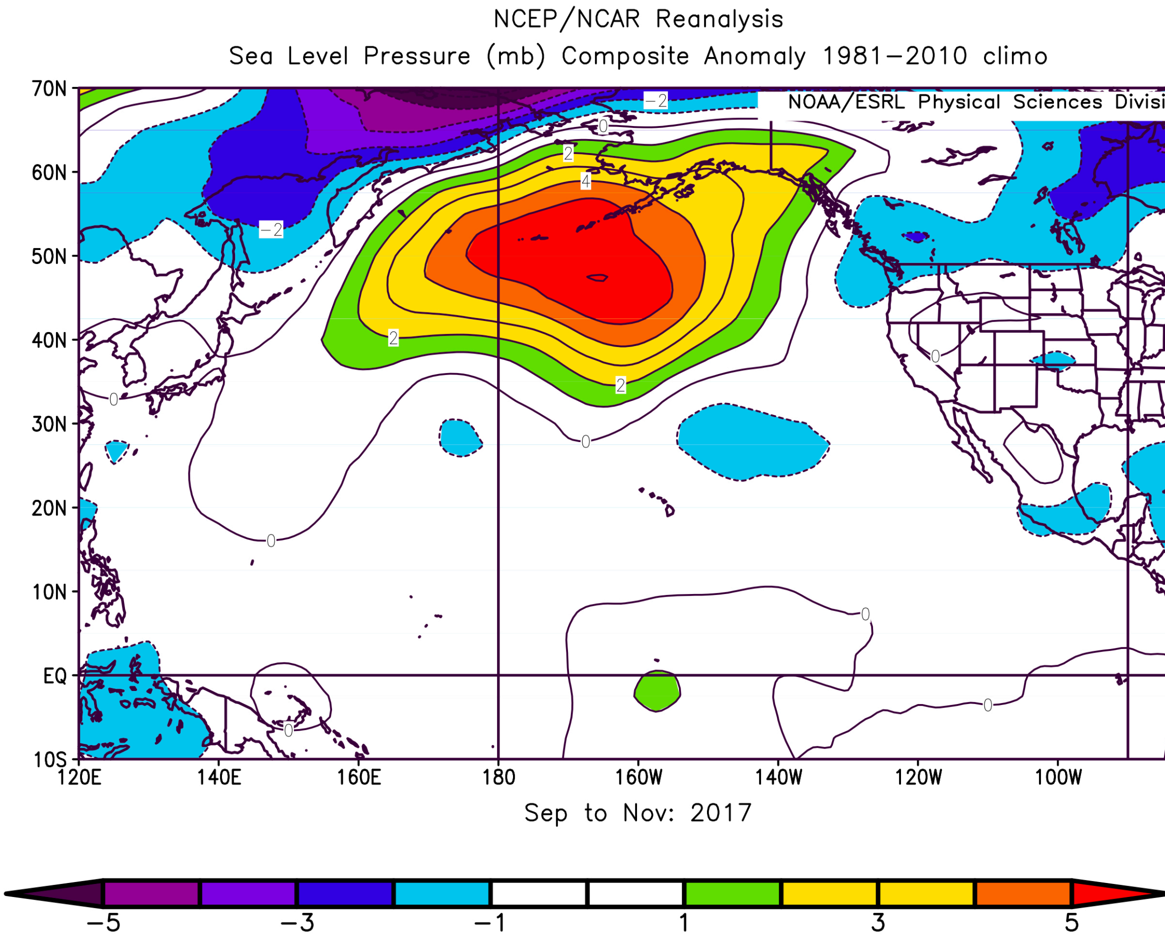

Figure 1b. SLP anomalies (hPa) for September-November 2017.

The North Pacific atmosphere-ocean system during winter (Dec-Feb) of 2017-18 reflected to large extent a continuation of the previous fall season. The distribution of SST anomalies (Fig. 2b) was quite similar, with some additional warming in the subtropical northeastern Pacific extending southwestward from southern California. The equatorial Pacific was characterized by weak/moderate La Niña conditions with the strongest negative SST anomalies well east of the dateline. The SLP during this period (Fig. 2b) featured an expansion of the pattern of the season before in terms of both magnitude and area, with substantial positive anomalies from about 160°E to western North America north of about 30°N. This relatively high SLP in combination with negative SLP anomalies over the East Siberian Sea resulted in a pressure pattern that supported extremely strong wind anomalies (~ 3 to 4 m s^{-1}) from the southwest across the Bering Sea.

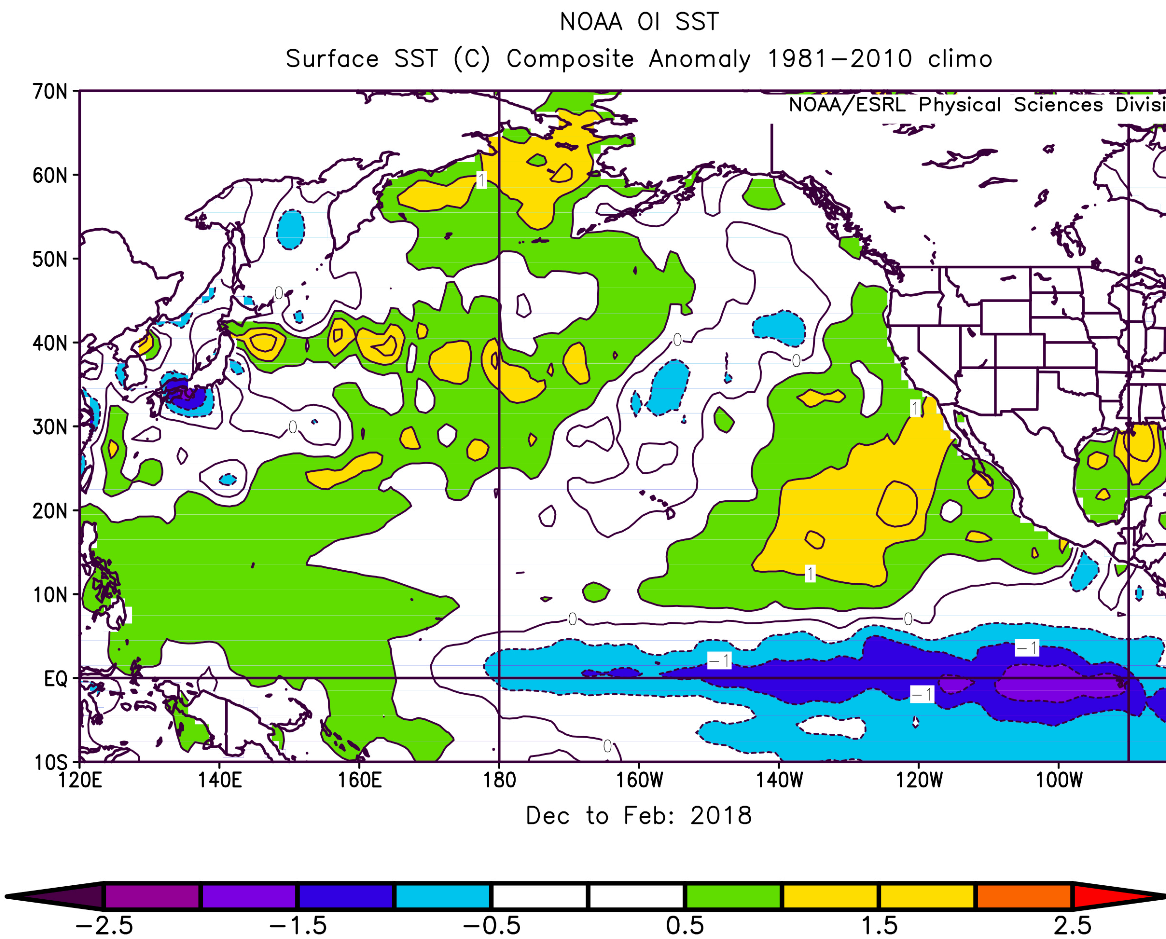

Figure 2a. SST anomalies for December 2017 - February 2018.

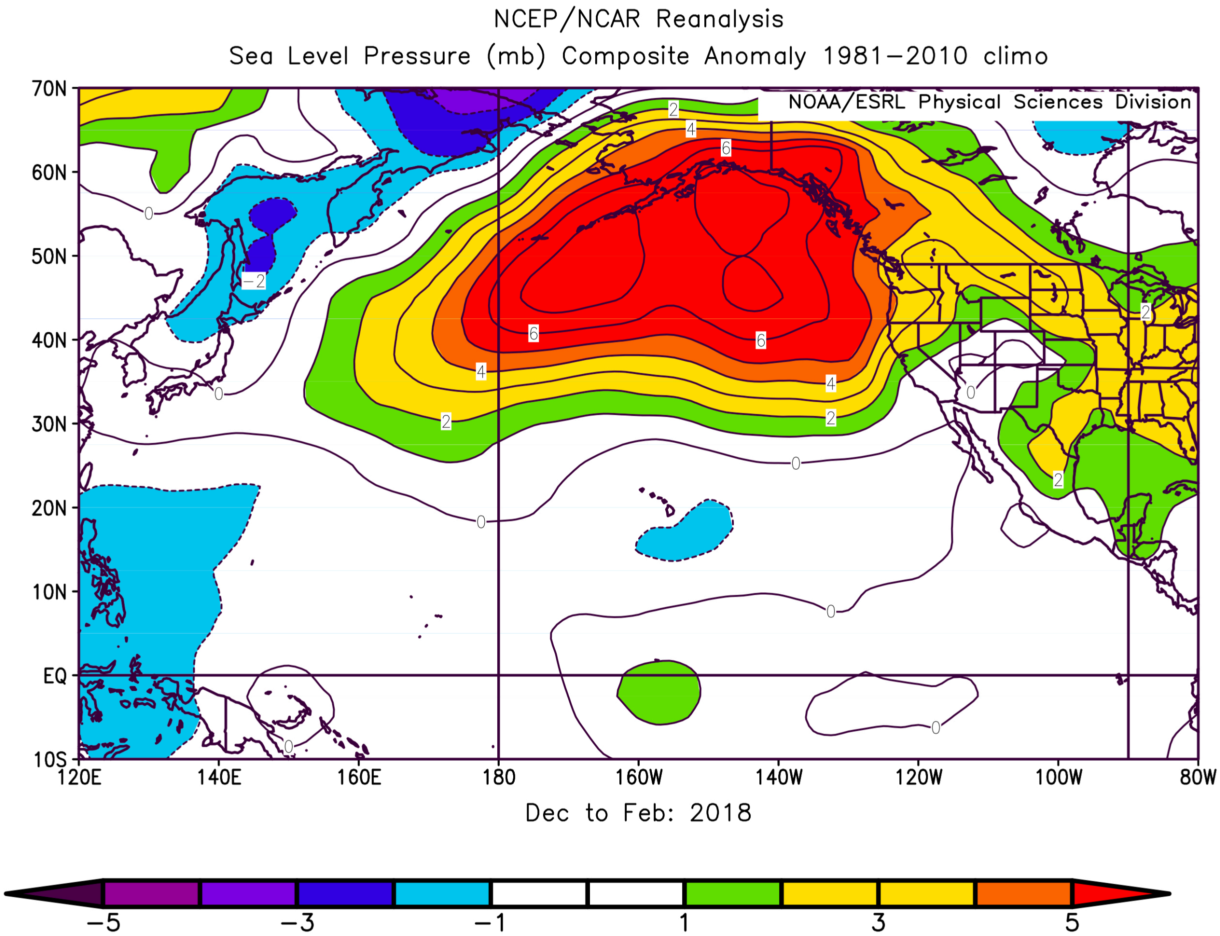

Figure 2b. SLP anomalies for December 2017 - February 2018.

The distribution of anomalous SST in the North Pacific during spring (Mar-May) of 2018 (Fig. 3a) was similar to that during the previous winter season. Exceptions were warming relative to seasonal normal in the eastern Bering Sea and in an east-west band from 25° to 40°N from Japan to the dateline. The SST anomalies in the tropical Pacific were of minor amplitude with the ending of La Niña. The SLP anomaly pattern (Fig. 3b) for spring 2018 featured bands of lower than normal pressure from eastern Siberia to northwestern Alaska and higher pressure from south of the Aleutian Islands to the GOA, resulting in another season of warm, southwesterly flow anomalies across the Bering Sea. The atmospheric circulation in the northeast Pacific promoted relatively upwelling-favorable winds in the coastal GOA.

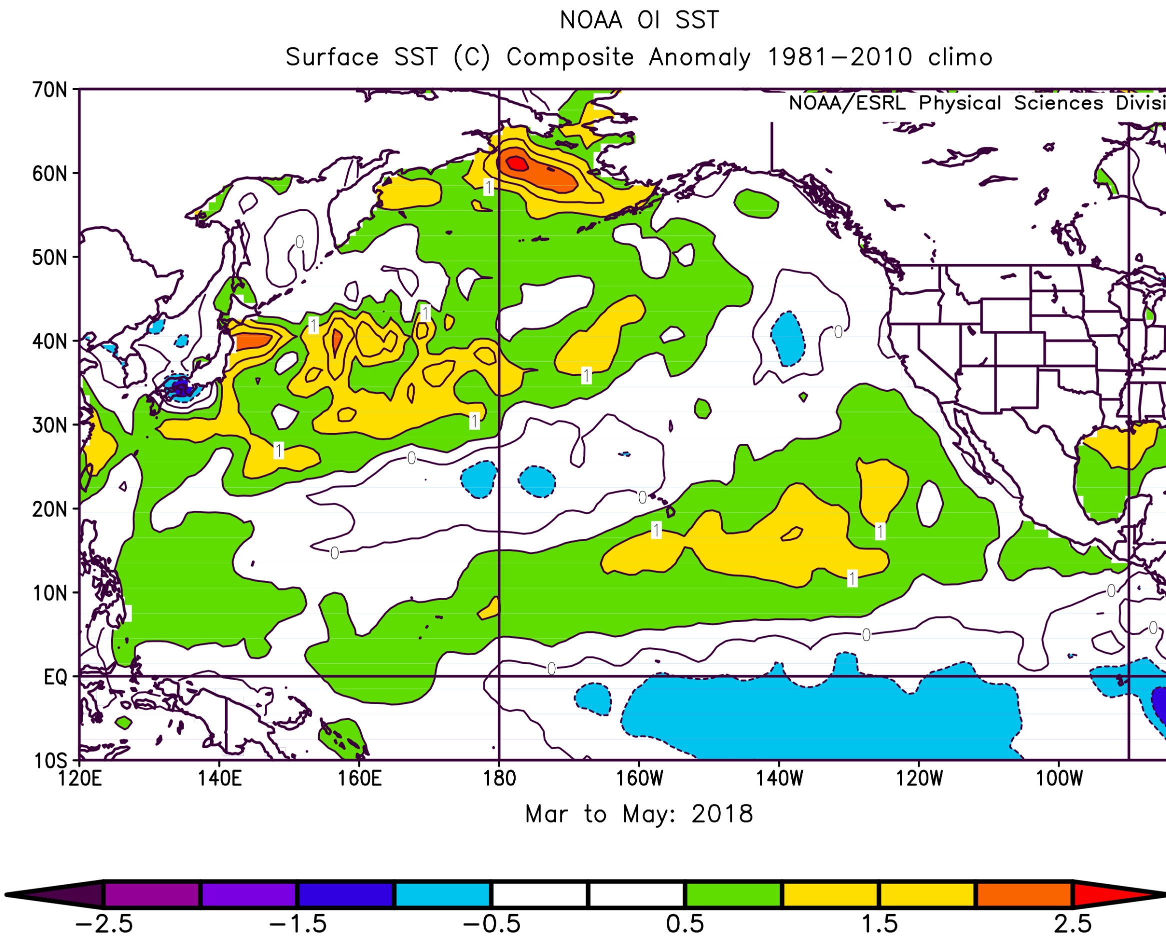

Figure 3a. SST anomalies for March – May 2018.

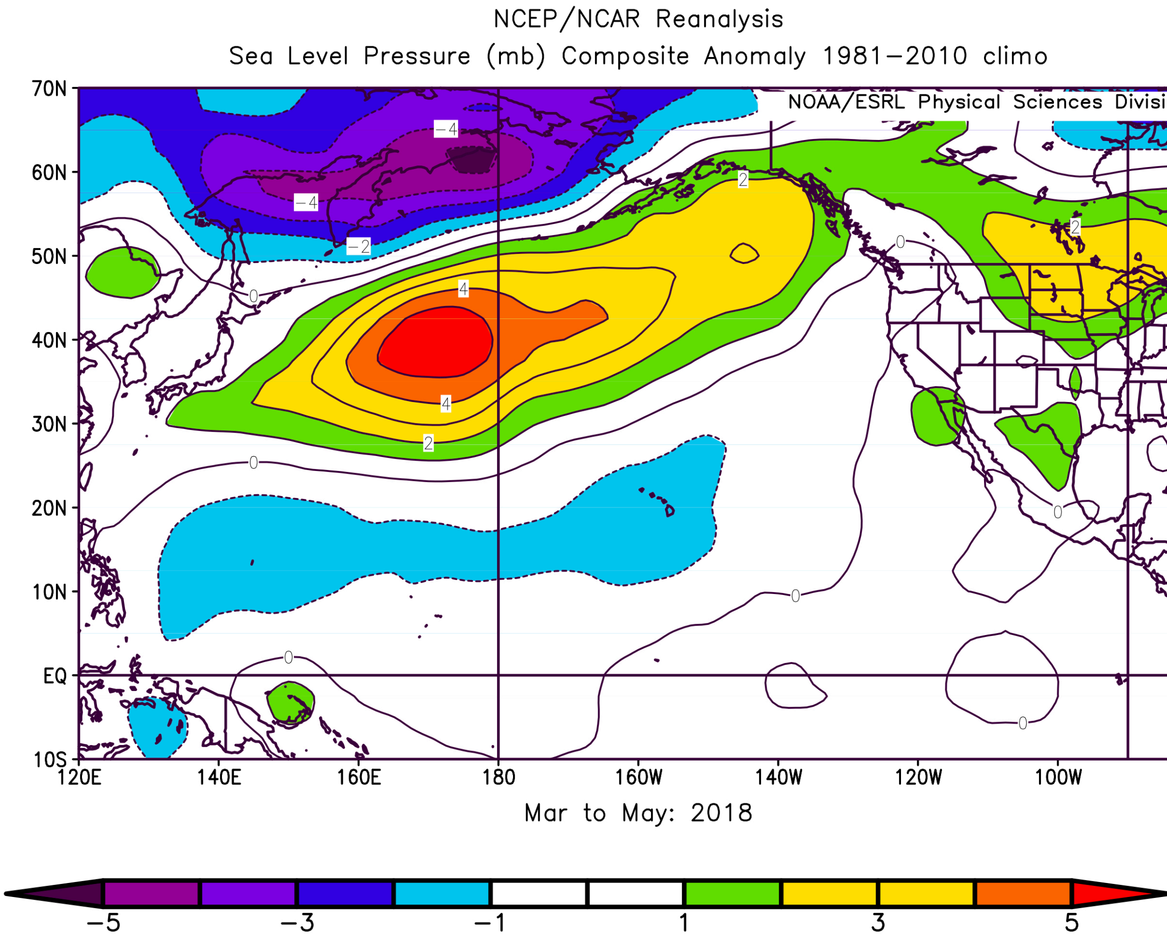

Figure 3b. SLP anomalies for March – May 2018.

The SST anomaly pattern in the North Pacific during summer (Jun-Aug) 2018 is shown in Figure 4a. Positive anomalies continued in a broad band extending from Japan to the southeastern GOA and from the northern Bering Sea into the Chukchi Sea. In the latter area, particularly strong positive temperature anomalies (exceeding 2˚C) developed in the vicinity of Bering Strait. Near normal SSTs were present along most of the west coast of North America from Vancouver Island to southern California. Warmth continued in the subtropical eastern North Pacific from Baja California to the equatorial Pacific east of the dateline, where temperatures were roughly 0.5˚ C above normal. The distribution of anomalous SLP (Fig. 4b) during summer 2018 included mostly just weak anomalies, which is typical for the season. A band of higher than normal pressure extended from the western North Pacific north of about 30˚ N into the GOA. Lower pressure extended from northwestern Canada across interior Alaska into the Bering Sea.

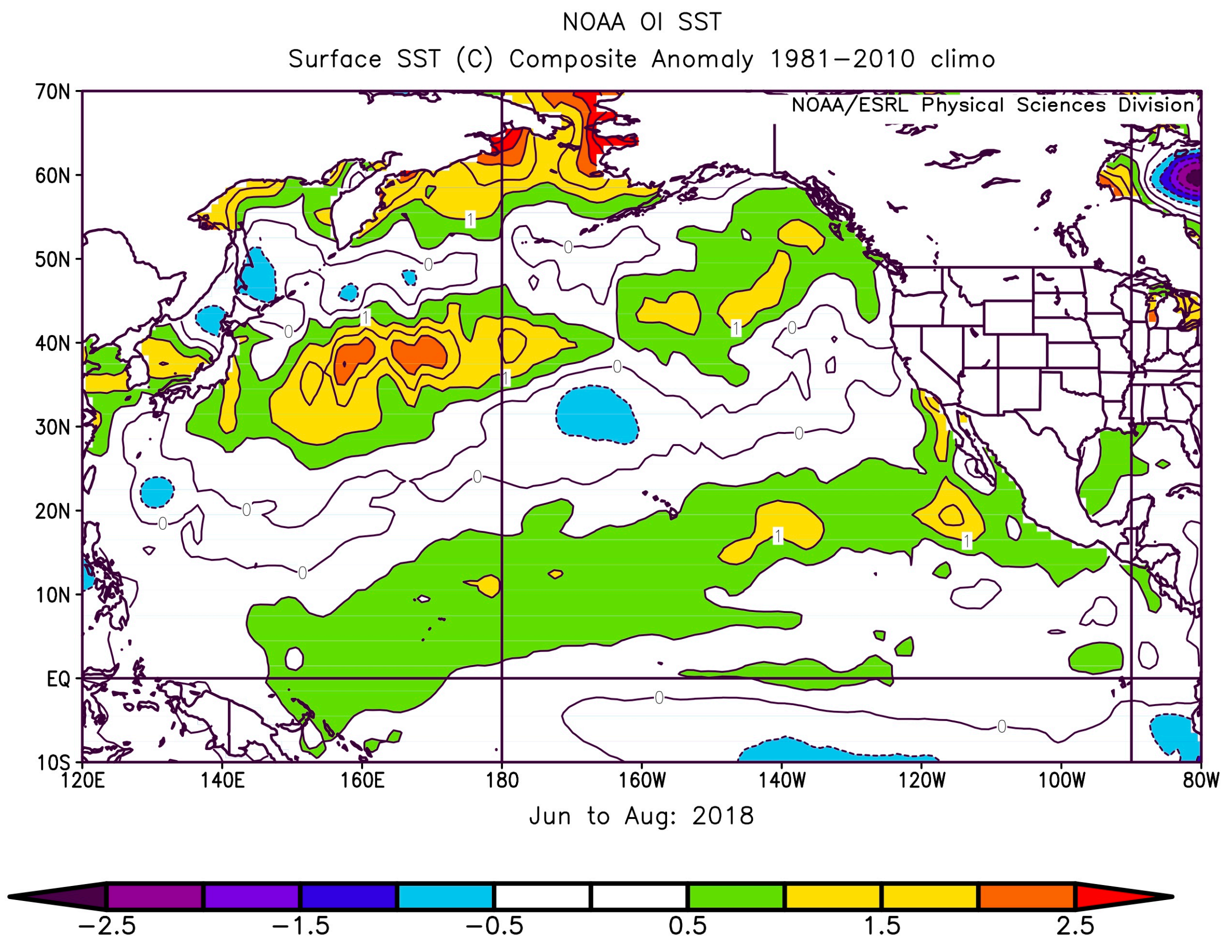

Figure 4a. SST anomalies for June – August 2018.

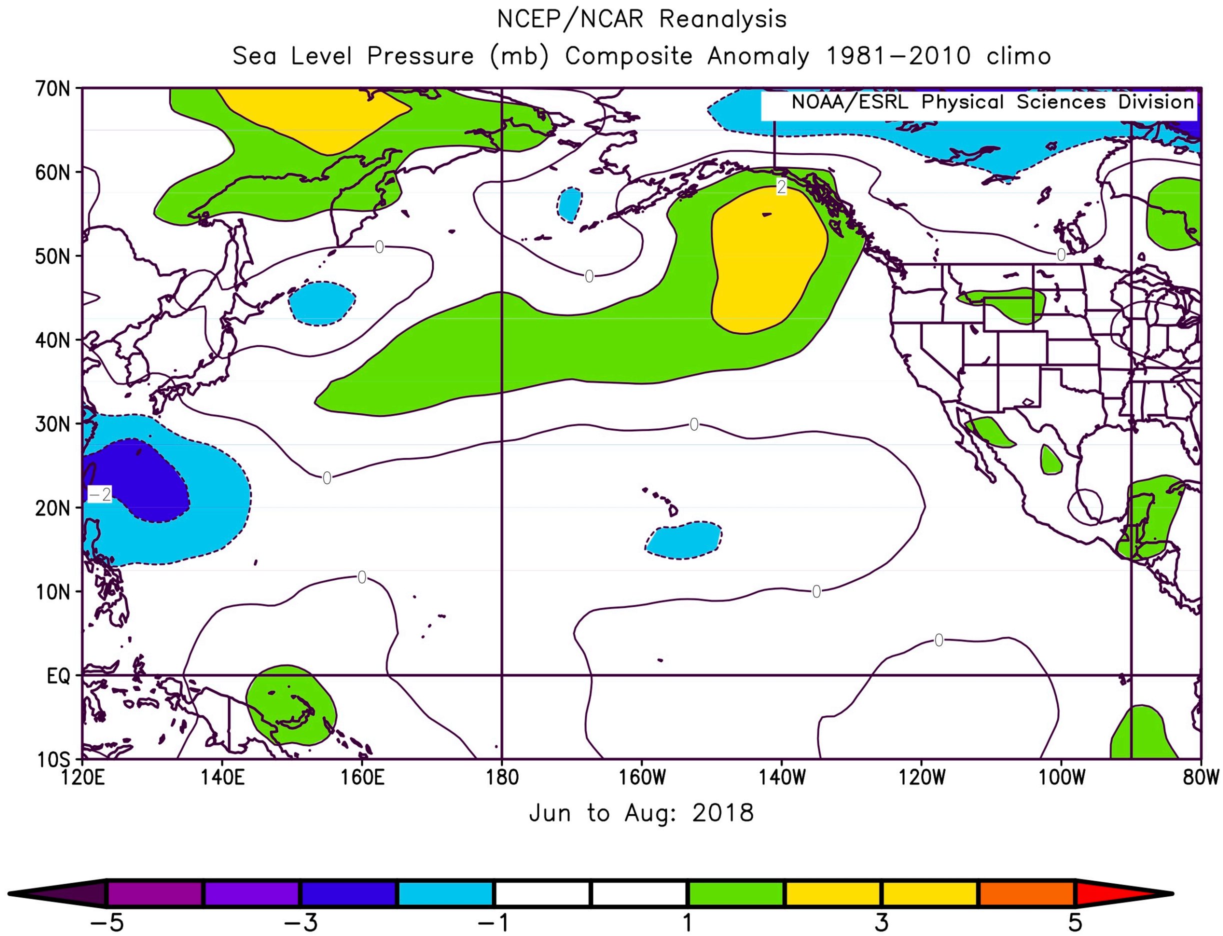

Figure 4b. SLP anomalies for June – August 2018.

2. Climate Indices

Climate indices provide an alternative means of characterizing the state of the North Pacific atmosphere-ocean system. The focus here is on five commonly used indices: the NINO3.4 index for 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 2008 into spring/summer 2018 are plotted in Figure 5.

The North Pacific atmosphere-ocean climate system was mostly on the warm side during 2017-18. This was despite the second fall/winter in a row with a negative value for the NINO3.4 index in association with a weak/moderate La Niña event . The positive state of the PDO (indicating warmer than normal SST along the west coast of North America and cooler than normal in the central and western North Pacific) that began in early 2014 ended in 2017. This decline is consistent with the typical remote effects of ENSO, and in particular the transition from a strong El Niño in 2015-16 to the following two episodes of La Niña. The SST anomaly distribution during spring and summer of 2018 has a minimal projection on the characteristic pattern of the PDO. The NPI was strongly positive from fall 2017 into 2018 due to the relatively high SLP in the region of the Aleutian low. A positive sense for the NPI commonly accompanies La Niña, its magnitude from late 2017 into 2018 was greater than might be expected.

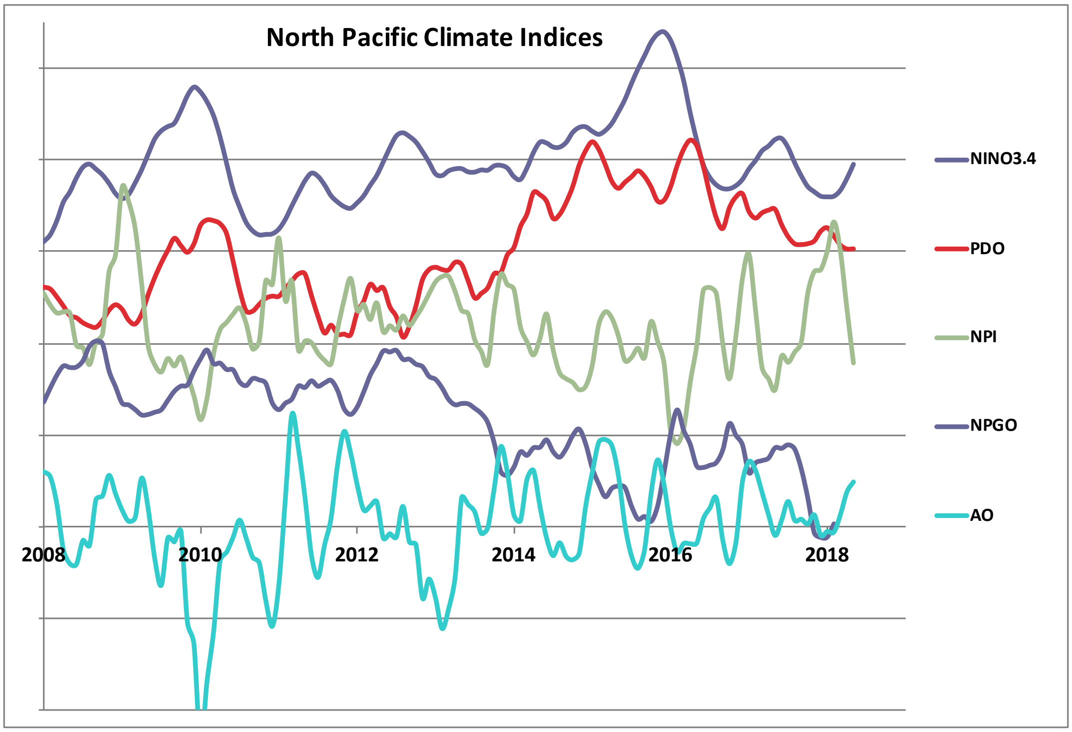

Figure 5. Time series of the NINO3.4 (blue), PDO (red), NPI (green), NPGO (purple), and AO (turquoise) indices for 2008-2018. Each time series represents monthly values that are normalized using a climatology based on the years of 1981-2010, and then smoothed with the application of three-month running 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 NPGO became strongly negative in 2017, and stayed negative into 2018 (February is the latest month for which this index is available). This index has undergone an overall decline from positive values during the period of 2008 to 2012. 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 Ocean at a latitude of roughly 45°N. It was in a near-neutral state during the last half of 2017 with a transition to a positive state in spring 2018 that has continued into summer. A consequence has been relatively low pressure in the Arctic during early summer.

3. Regional Highlights

a. **West Coast of Lower 48** – This region experienced generally warmer than normal ocean temperatures from late 2017 into 2018 followed by cooling in the north relative to seasonal norms, and continued warmth south of Pt. Conception . The winter of 2017-18 was wetter and slightly cooler than normal in the Pacific Northwest, and relatively warm and dry in California. The abundant snowpack in the Pacific Northwest melted rapidly in May in association with unusually warm weather. The coastal wind anomalies were upwelling-favorable for the states of Oregon and Washington during the late spring and early summer raising concerns about hypoxia developing to a greater extent than usual. Many streams in the Pacific Northwest had above normal temperatures due to the combination of low flows and hot air temperatures. Mostly upwelling-favorable wind anomalies occurred along the northern and central portions of California. Strong downwelling-favorable winds developed in early summer in the Southern California Bight, resulting in a thin layer of very warm water in the immediate vicinity of the coast. The SST at the Scripps Pier in La Jolla, Ca observed the warmest SST (25.9°C) in its entire historical record extending back to 1916. There were sightings of large assemblages of pyrosomes in the coastal waters of the Pacific Northwest for the second year in a row.

b. **Gulf of Alaska** –The weather of the coastal GOA featured warmer than normal air temperatures from late fall 2017 into winter and then again in the following summer of 2018. There was generally less precipitation than usual in the coastal watersheds of the eastern GOA from winter into summer 2018. The freshwater runoff in this region appears to have been enhanced during the winter of 2017/18 and suppressed during the spring of 2018. The GOA coastal winds anomalies were in a clockwise sense during the winter of 2017/18; they were still in the downwelling-favorable sense, but to a lesser extent than normal. These winds were reflected in the surface currents estimated with NOAA's Ocean Surface Current Simulator (OSCURS), which tended to indicate relatively weak south to north flow in the eastern GOA. More on this subject is provided in the Ocean Surface Currents – PAPA Trajectory Index section of the Gulf of Alaska Ecosystem Status Report.

c. **Alaska Peninsula and Aleutian Islands** – The weather of this region included suppressed storminess during the fall of 2017 and the following winter of 2017/18. The regional wind anomalies were from the southwest in an overall sense. Based on synthetic data from NOAA's Global Ocean Data Assimilation System (GODAS), the Alaska Stream appears to have been relatively diffuse, as opposed to concentrated into a narrower, high velocity flow, on the south side of the eastern Aleutian Islands. The eddy activity in this region was on the low side (see the Eddies in the Aleutian Islands section of the Aleutian Islands Marine Ecosystem Status Report).

d. **Bering Sea** –The Bering Sea had the least amount of sea ice in the observational record back to 1979. This can be attributed to the delayed start of winter (Being Strait was still open on 1 January) and then very mild temperatures with strong winds from the southwest, particularly in February 2018. An important consequence was a cold pool in summer 2018 of exceedingly small areal extent. The weather during summer 2018 was stormier than usual on the southeast Bering Sea shelf; at the time of this writing it is unknown if those conditions helped sustain primary production into later into the warm season than usual. In the region of the M2 mooring the thermal stratification during summer 2018 was somewhat less than observed during recent years; the vertically integrated heat content was the second greatest on record, topped by 2016.

e. **Arctic** – The winter of 2017/18 was relatively warm in the Arctic, and included an extreme "heat wave" (for the season) in the central Arctic during February. The Arctic's maximum ice extent in mid-March 2018 was the 2^{nd} lowest on record. On the other hand, the decline in sea ice coverage during the late spring and early summer of 2018 was on the slow side, primarily in association with relatively low SLP in the central Arctic and cool and cloudy weather. The west winds accompanying this circulation pattern helped maintain a wide band of ice near the coast east of Pt. Barrow. Relatively rapid losses in sea ice concentrations and coverage occurred here in late July 2018. The edge of the pack ice in the Chukchi Sea was well north of its usual position during the summer of 2018. At the time of this writing, it appears that the minimum ice extent for the Arctic as a whole will be well below of climatological norms, but more akin to the years of 2013 and 2014 rather than the extreme minimum ice cover year of 2012.

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 climate 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/.

First, the projections from a year ago are reviewed qualitatively. From an overall perspective, the SST forecasts were essentially correct with respect to their basin-scale patterns of negative and positive SST anomalies. The NMME forecasts included underprediction of the magnitudes of some of the more prominent anomalies. In particular, Alaskan waters generally ended up warmer than forecast, especially the Bering Sea shelf during late winter and early spring 2018, when there was much less sea ice than suggested by the model forecasts made during September 2017.

These NMME forecasts of three-month average SST anomalies indicate a continuation of warm conditions across virtually all of the North Pacific through the end of the year (Oct-Dec 2018) with a reduction in the longitudinal extent of cooler than normal temperatures offshore of the Pacific Northwest (Fig. 6a). The magnitude of the positive anomalies is projected to be greatest (exceeding 1°C) north of the Kuroshio Extension in the western North Pacific and in the northern portion of the Bering Sea. Positive SST anomalies are projected in the central and eastern equatorial Pacific. The ensemble model average is strong enough to constitute El Niño of weak to moderate magnitude. As of early September 2018, 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 about a 70% chance of El Niño, and otherwise equatorial SSTs in the neutral category. The overall pattern of SST anomalies across the North Pacific is maintained through the 3-month periods of December 2018 – February 2019 (Fig. 6b) and February – April 2019 (Fig. 6c). There is moderate but by no means a complete consensus among the models that the Aleutian low will be deeper than normal (negative SLP anomalies) during the latter portion of the winter of 2018-2019. This is a common remote response to El Nino, and tends to result in relatively warm late winter and early spring weather for Alaska that is liable to be enhanced by the effects of the warmth of the waters surrounding Alaska. For the period of February – April 2019, the models are projecting little noticeable decline in the magnitude of the equatorial Pacific temperature anomalies even though El Niño often weakens during the boreal spring. The positive SST anomalies along the west coast of North America that are indicated in Fig. 6c commonly occur after El Niño winters. The PDO has also generally been positive during these kinds of periods in the past, but the predicted warmth in both the western and eastern portions of the mid-latitude

North Pacific does not resemble the characteristic pattern of the PDO. An important implication is that the PDO is liable to be ill-suited for characterizing the state of the North Pacific in early 2019.

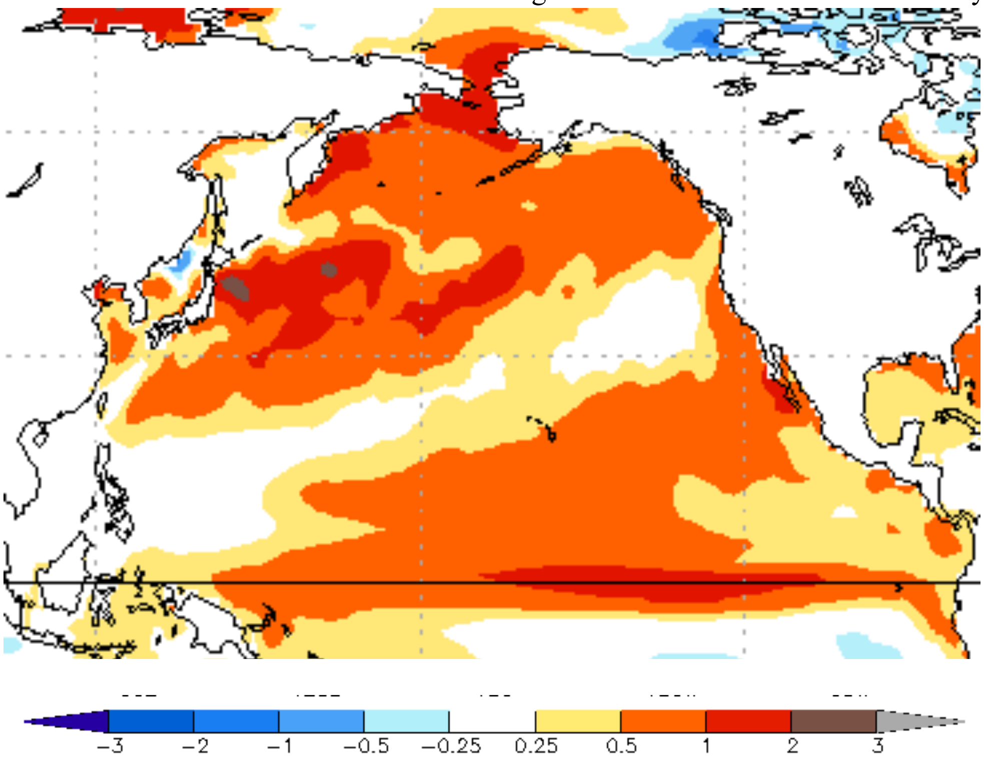

Figure 6a Predicted SST anomalies (°C) for October-December 2018 (1 month lead) from the National Multi-Model Ensemble (NMME) of coupled atmosphere-ocean climate models. See text for details.

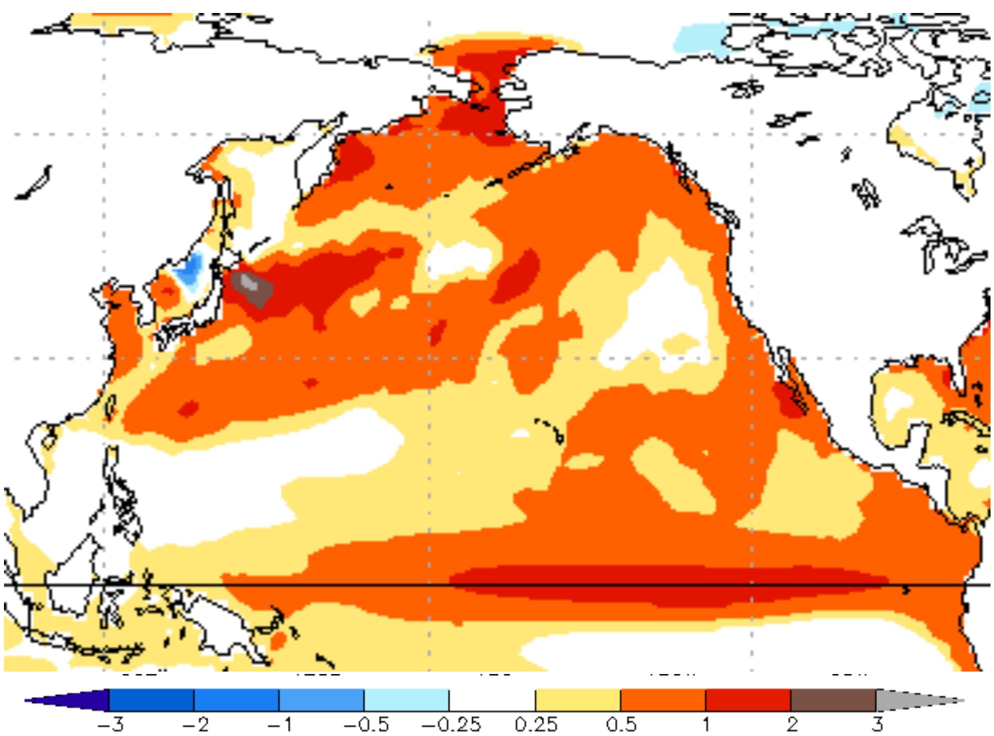

Figure 6b As in Fig. 6a, but for December 2018-February 2019 (3 month lead).

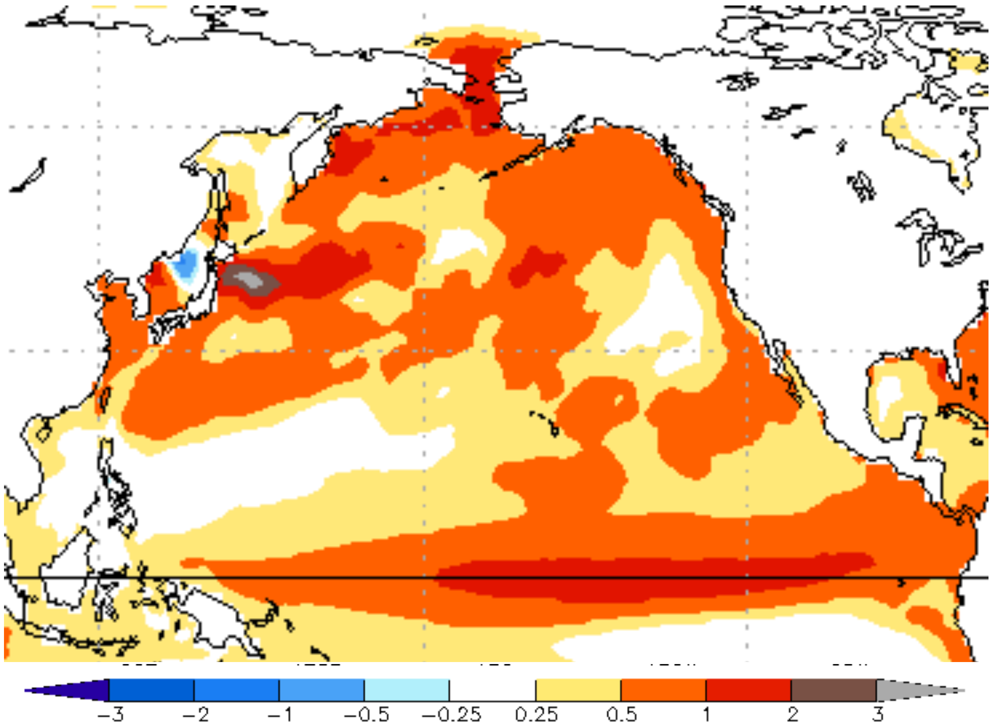

Figure 6c. As in Fig. 6a, but for February-April 2019 (5 month lead).