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The Blob Blog - Warm Northeast Pacific Ocean Conditions Continue (2016)

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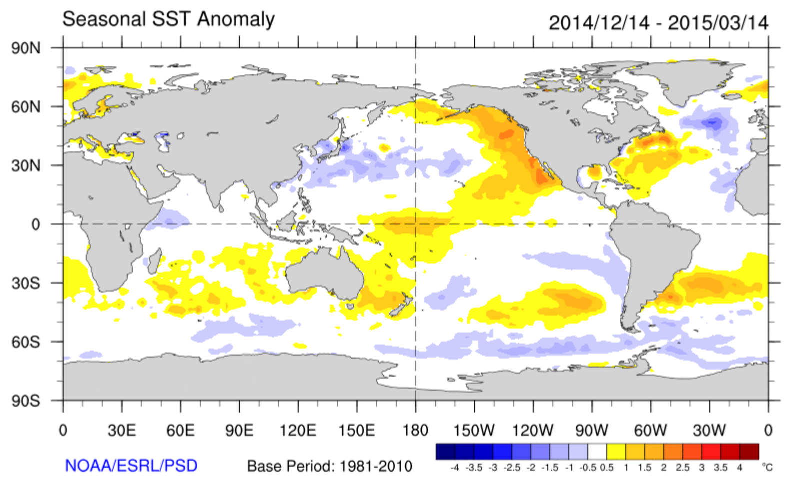

Figure 1. Sea surface temperature (SST) anomaly, December 2014 ? March, 2015.

The warm anomalous surface water conditions of the Northeast Pacific that became apparent in 2013 and continued through 2015, may seem to be disapating as surface temperatures return to normal. But a significant amount of heat remains at depth, so there is likely more life left in the Blob for 2016. A series of cold winter storms sweeping across the Gulf of Alaska this (2015-16) past November through January have effectively washed out the surface signature of the "Blob". These are the same storms that have been absent for nearly three years and allowed the Blob to develop in late 2013. Typically, a deep Alutian Low and winter storms in the Gulf of Alaska mix up cold nutrient rich waters from below, cooling the surface waters and supplying essential nutrients to the phytoplankton and the rest of the food chain. But in 2013 and 2014 the Alutian Low was weak and there was a near complete absence of major winter storms in the Gulf, resulting in one of the most significant Northeast Pacific oceanographic events on record. A number of on-going scientific workshops have been held to assess and discuss these extraordinary conditions.

The "Blob" (Nick Bond, UW) became apparent in December 2013 and was at it's peak by early February 2014. The entire Northeast Pacific (NEP) remained significantly warmer over the next 23 months, warmer by several degrees than at any time over the last few decades. In January 2014, the area and intensity of this warm anomaly had reached its maximum. Howard Freeland (Institute of Ocean Sciences) constructed a map of sea surface temperature anomaly (SSTa) for January 2014 (using the Reynolds SST data set) showing a region of warm temperature anomalies exceeding 4 standard deviations above the mean. He achieved the same result when using independent Argo profile data. The area exceeding 3 standard deviations covered an area of more than 1000 km^2. To put this in perspective, such an anomalous event would be expected less than once per millennium (<0.1%)! By the fall of 2014 this warm pool of surface water had shifted eastward from the central Gulf of Alaska, and by late 2014 and into early 2015, was blanketing the entire west coast of North America (Figure 1). Although the extent and the mechanisms, dynamics, and full consequence of the anomally are still being assessed, there is a growing consensus as to the dominant contributing factors that may have led to the development of these warm Northeast Pacific conditions, and a growing awareness of the significance (see for example Chris Mooney's piece in the Washington Post).

However, although the satellite data, which detect only the upper few metres of the ocean, might suggest the Blob is gone, there remains a tremendous amount of heat below the surface. Data from Argo floats in a large area of the Northeast Pacific and Station Papa (NEP - box) indicate that the heat signature of the Blob remains very much intact (December 2015). The same disappearing act occurred last year (January 2015), only to have the blob re-appear later in the spring (June 2015). So while the Godzilla El Nino begins to fade in 2016 and will likely be gone by June, I predict (January 2016) the Blob will live on for a while yet.

After several false starts, by the late spring of 2015 the NOAA El Nino prediction center announced that we were finally (after nearly a year of speculation) entering into an El Nino cycle. Although El Nino is now considered a rather global phenomina, it has a nucleus and primary signals in the western and central equatorial Pacific. The dynamics of an El Nino are related to a strong coupling between the atmosphere and upper ocean in the western equatorial Pacific. When the easterly trade winds slacken, the elevated warm surface waters in the western equatorial Pacific can surge eastward along the equator in a Kelvin wave and even pool off the west coast of Peru. The atmospheric low pressure over Indonisian can shift eastward, inducing draughts in Australia. There is hope that perhaps El Nino will kick the weather systems back into some form of normalicy, with rain and snow returing to the coastal mountains from California to BC. A weekly Sea Surface Temperature anomaly (SSTa) map from August 2015 shows that the blob split into two masses, one off Baha California and one off Washington State, while the El Nino signal remained bounded along the equator. Pacific huricanes developing in late August and early September (2015) over the eastern low-latitude Pacific, migrating northwest over the warm water regions, provided some of the strong winds and surface mixing necessary to start dispursing the warm conditions.

There is growing consensus that the warm ?blob? in the northeast Pacific, which was at its maximum in January 2014, was a result of a weak Aleutian Low and minimal storm activity over the Gulf off Alaska during the winter of 2013-14. The Blob did ot so much "come from somewhere", but was the result of reduced upper ocean colling in the winter of 2013-14. The ocean's response (dynamics) to a weak Aleutian Low are described below. What caused the Aleutian Low to be very weak (about half as intense as it typically is), and similarly caused the Jet Stream to shift west and support large meridional meanders affecting Alaska, California, Texas, and the eastern sea-board, is still under review. One possibility is that the reduced sea-ice cover in late 2012 delayed and weakened the Arctic Vortex which can result in a wavier Jet Stream, consistent with what has been seen in 2013-15 (see Jennifer Francis? work on these Arctic influences). There are indications (Walker and Bliss, 1932), that this may not be a new phenomenon/pattern, but the magnitude and scale of the 2013-2015 event has been extraordinary.

The surface waters of the ocean are strongly influenced by atmospheric pressure and surface wind conditions, heating from solar insolation, cooling from conduction and latent heat (evaporation), and buoyancy (salinity) variations associated with both precipitation and evaporation (Bond et al., 2015). In most regions of the ocean, seasonal variations follow regular transitions throughout the year. The Northeast Pacific has a number of dominant seasonal features, with several variations associated with both amplitude and spatial modulation on the primary patterns (i.e. the Pacific Decadal Oscillation and the North Pacific Gyre Oscillation). It is worth noting that the PDO and the NPGO represent large scale "patterns" associated with previous (based on data from the last several decades) conditions observed in the Northeast Pacific, and are the first two dominant empirical orthogonal function (EOS) modes of sea surface temperature anomaly and sea surface height, respectively.

Recently, Hartmann (et al., 2015) has analyzed data up to and including July 2014, and the third (or second, depending on the period of analysis) EOF mode (statistically independant from PDO and NPGO) of SSTa strongly resembles the recent warm patterns shown in Figure 1. However, these EOF "patterns" are not explicitly linked to any formal physics, dynamics, or set of processes that would have caused the pattern, and therefore they are helpful as a descriptive aid, but have minimal predictive skill. It has also been proposed that PDO and NPGO are linked with El Nino/La Nina southern oscillation (ENSO) events. However, the present warm north Pacific ocean conditions, starting in 2013 and continuing into 2015, may represent a new regime (Bond et al., 2015), with oceanic conditions seldom seen in the modern records. It is also quite safe to state that the anomalous Northeast Pacific warming that peaked in early 2014 is not causely a result of the equatorial El Nino/La Nina phenomena, but in fact, as suggested by Vimont (et al., 2003) could be a precursor to El Nino. Trying to figure out large scale atmosphere-ocean patterns and their teleconections is not new, with Walker and Bliss providing a formula for the North Pacific Oscillation (NPO) in their 1932 analysis.

Northeast Pacific Dynamics

To see how and why this warm anomaly may have developed, we first review some of the dominant weather and ocean dynamics of the Northeast Pacific, and then explore the conditions in 2013 that may have contributed to the warming. During the winter months (December-February), the atmosphere in the Gulf of Alaska is dominated by the Aleutian Low (Figure 2), representing a large cyclonic (counter clockwise in the northern hemisphere) atmospheric circulation around a low sea level pressure field. In the summer (June-August), the North Pacific High develops, which is an anti-cyclonic (clockwise, northern hemisphere) atmospheric circulation around a relative high in the sea level pressure (Figure 3).

The ocean responds in a number of key ways under the influence of strong persistent atmospheric winds. The surface waters are influenced by the wind stress associated with the wind and the Coriolis force, which tends to move the upper layers of the ocean to the right (in the northern hemisphere) of the wind direction in a process called Ekman transport. The displacement of the surface waters laterally away from the center of the atmospheric low introduces a sub-surface pressure gradient in the ocean that drives a deeper ocean circulation forced by the surface slope of the ocean and Coriolis, in a balance known as Geostrophy. The net effect is that surface waters tend to vacate a region of low atmospheric pressure and, alternately accumulate in a region of high atmospheric pressure (Ekman Pumping), with deeper currents flowing in the same cyclonic or anti-cyclonic direction as the atmospheric winds.

The combination of the atmospheric winds and oceanic response in the Northeast Pacific is such that during a typical winter, surface waters in the Gulf of Alaska are thinned due to this lateral transport and also mixed vertically by the strength of the winds, which brings to the surface cooler nutrient rich waters. In a typical summer, surface waters are warmed and tend to accumulate and converge in the central Gulf of Alaska, with enhanced upwelling along the coastal margin, which results in a thin coastal band of cool nutrient rich surface water that stretches from North Vancouver Island to California. In addition to the temperature of the surface waters, high rainfall along the coastal margins from Oregon to Alaska introduces significant volumes of fresh water, which tends to keep the entire Northeast Pacific one of the freshest ocean regions on the planet.

Variations on a Theme: The Warm Blob

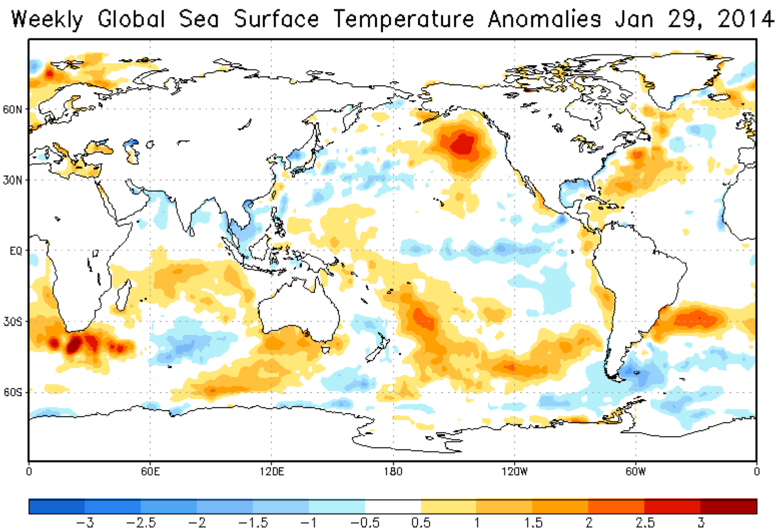

Figure 7. Sea Surface Temperature (SST) anomaly, 29 January 2014.

Several variations to these more typical conditions seemed to have conspired to contribute to the development of the anomalously warm surface waters of the Northeast Pacific in 2014. Starting as early as the winter of 2013, the Aleutian Low had become particularly weak, in that both the intensity and extent of the low atmospheric sea surface pressure were significantly diminished (Figures 4 and 5). This had at least three significant consequences. First, the weaker winds (Figure 3.9 of Newlin and Gregg 2014) resulted in weaker Ekman export of the surface waters from the Gulf of Alaska and weaker advection of cold water transport from the northwest towards the southeast. Second, the combination of weak mean winds and fewer storms limited the vertical mixing, which failed to mix the warm surface waters downward and the cool nutrient rich water upward. Thirdly, the weaker Aleutian Low to the west was accompanied by a persistent North Pacific High over western North America, which acted as a ridge to block storms and reduced the strength of westerly winds which further export nutrient rich waters from the Gulf of Alaska (Whitney, 2015). Consequently, by early summer of 2013, the surface waters of the Northeast Pacific were already slightly warmer than usual, and would become warmer yet through the summer of 2013, under typical North Pacific High conditions. A similar weak Aleutian Low and North Pacific High ridge persisted in the fall and winter of 2013-14 (Figure 6), so that by early 2014, the surface waters of the Northeast Pacific (Gulf of Alaska) had become anonymously warm, exceeding in spatial extent and magnitude any prior record from at least the last 50 years (Figure 7, shown above).

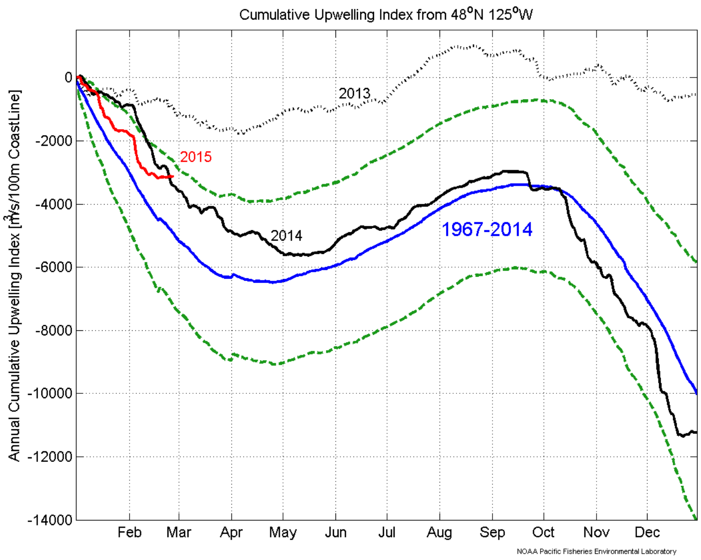

Figure 8. Cumulative upwelling index from 48N 125W, from 1967 through to 2015.

As a proxy to demonstrate how anomalous the Northeast Pacific winds were in 2013, which contributed to the development of the warm conditions, we present the up-welling index from the west coast of Vancouver Island. When the Aleutian Low is present (winter), the winds along the west coast of Vancouver Island blow northward (south wind), pushing surface waters towards the coast and depressing the deeper cool nutrient rich waters (downwelling). When the North Pacific High develops (summer) the winds are primarily southward (north wind), and Ekman transport pushes warm surface water off-shore, elevating the deeper nutirent rich waters (upwelling). The Bakun upwelling index is a measure of the net volume transport of surface water per unit length of coastline and is derived directly from the along-shore component of the wind. Shown here (Figure 8, on the right) is a plot of the cumulative upwelling index for the last 46 years. In a typical year, there is a net downwelling (negative upwelling) of the order 10,000 m^3/100m of coastline, representing the dominance of the Aleutian Low from late September through to May each year. The Aleutian Low was so weak throughout 2013, that the net downwelling for the entire year was only 500 m^3/100m of coastline, representing the weakest downwelling winds in the 46 year record (5% of the typical 46 year mean). So in a real sense, the weak Aleutian Low and light winds of 2013 were the remarkable conditions that led to the warm surface waters of early 2014.

Warm Waters Come Ashore

Figure 10. Seawater temperature at 100m depth for Folger Passage (Deep).

The North Pacific High was re-established in the summer of 2014 (Figure 9), with upwelling favourable winds along the west coast of North America. Upwelling along the west coast from Hecate Strait to northern California in the summer of 2014 resulted in typical summer condition along the coast, with cool nutrient rich waters along the shore. In the Pacific Northwest, we experienced one of the longest summers in recent memory, demonstrated by garden tomato harvests in Victoria BC from mid-June through to early November (personal experience). By the late summer of 2014, the warm surface water anomaly in the Gulf of Alaska began to deform and shift eastward towards the west coast of North America. By September 2014, warm surface waters were being detected along the central and north coasts of British Columbia (Peter Chandler, personal communications) and extending south as far as California. By early October, the warm waters had reached the entrance to Barkley Sound, where Ocean Networks Canada?s Folger Passage (see map) installation continuously monitors all water properties. By early November (Oceans 2.0 Plotting Utility and Figure 10, shown here on the left) coastal water temperatures at 100m depth had reached record highs, nearly 2 degrees warmer than any previous observation. Warm surface waters were even detected encroaching into Juan de Fuca Strait and the Salish Sea (Doug Yelland/Marie Robert, Line-P, personal communications), against the prevailing esturaine circulation.

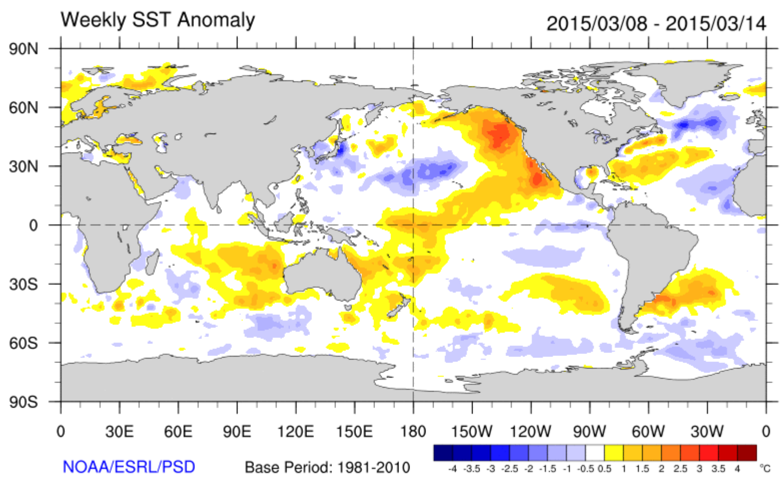

Figure 11. One week mean sea surface temperature anomaly 8-14 March 2015.

By early 2015, the finges of the warm pool of water in the Northeast Pacific had spread to fully occupy the entire west coast of North America (Figure 11, show here on the right). The Aleutian Low in the early winter of 2015 was slightly smaller than usual and slightly shifted to the southeast (Figure 12). Mild conditions along the west coast of North America persisted for over 18 months (October 2013 - March 2015). The larger weather patterns and jet stream were also anomalous over most of North America in this same period (Figure 13), with prolonged draught conditions in California, two anomalously warm winters in Alaska, and two cold winters in the continental Northeast of North America.

There are few long-range forecasts that indicate where and how this warm water will continue to influence the Northeast Pacific, and it will remain an active story that will continue to unfold through 2016. How will the warm deep waters further influence the ecosystem, and how long will the deep (200m) heat content of the Blob survive remain open explorations. The short and long-term impacts on marine ecology are now being assessed, as the most recent samples and data continue to get analyzed, but they are likely to be significant, as the warm waters represent a reduced cooling from below which is also were the nutirent reside. The low nutrients in the Gulf of Alaska in 2014 and much of 2015, have reduced the net primary and secondary production, and left much of the Gulf malnurished.

This is very much a work in progress (and I will continue to edit and expand this story), so if you have any questions or comments, please send them to Richard Dewey, the Associate Director, Science with Ocean Networks Canada.

Links and Sources

1. Warm Waters in the Gulf of Alaska, February 2014 (pdf)
2. Nicholas Bond's (et al) March 2015 assessment, originator of the "blob" tag. (pdf)
3. Walker and Bliss, 1932 (pdf)
4. Dennis Hartmann's analysis, including a third EOF mode resembling the recent warm conditions.

(pdf)

5. NOAA's Earth System Research Laboratory Sea Surface Temperature Map Room
6. Summer/Winter surface atmospheric pressure and current comparisons, from
7. Jennifer Galloway's 2010 paper. (pdf)
8. The Pacific Decadal Oscillation (PDO)
9. North Pacific Gyre Oscillation (NPGO)
10. Coriolis Effect
11. Ekman Transport
12. Geostrophic Current
13. Ekman Pumping and Suction: Introduction
14. Mixed Layer
15. Slope Base Study Site (PN1A)
16. Salinity Introduction (NASA)
17. Wind Driven Surface Currents: Upwelling and Downwelling
18. Data from BC Lighthouses
19. Temperature and Salinity Time Series from Folger Passage (Free login required)
20. NOAA Earth System Research Laboratory Atmospheric Variables Plotting Page

Key Words: The Blob, Northeast Pacific warming, warm Pacific, warm north Pacific, warm Pacific Ocean, Aleutian Low, North Pacific High

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