News of the Northeast Pacific Ocean

by William Crawford

For a few months in late summer 2013, the west coast waters from Oregon to Alaska warmed by several degrees, bringing unusual marine life to the continental margin. This warm interval came after almost seven years of mainly cool sea surface temperature.

An unusually warm near-surface temperature within Canadian waters was observed in September off southwest Vancouver Island, as measured during the La Perouse survey by Fisheries and Oceans Canada (DFO). Figure 1 presents the temperature distribution, along with a map of station locations and a graph of individual profiles of ocean temperature. The individual profiles of temperature reveal waters as warm as 18°C. The zooplankton sampled during this cruise were dominated by gelatinous animals such as salps and doliolids. There were many *Corolla spectabilis* visible, swimming at the surface. These were last seen off the west coast in warm-water summers of 2005 and 1997. Cold water copepods and chaetognaths were almost completely absent from the samples in September 2013 until sampling reached northern Vancouver Island where the community structure returned to 'normal'. During another DFO survey in late summer, Pacific saury (*Cololabis saira*) were noted west of Vancouver Island. These fish have been caught in fisheries surveys in the past, but the numbers were higher in 2013. In addition, more albacore tuna (*Thunnus alalunga)* and juvenile sablefish (*Anoplopoma fimbria*) were observed near the coast than in previous summers. These three species of fish are associated with warmer waters than are normal for the Canadian west coast.

The warm episode in late summer 2013 contrasts with the prevailing conditions of the past few years. Since 2006, the ocean surface temperature along the North American west coast has been cooler than average, except for a brief interval during the 2009–2010 El Niño. The cool waters extend from the eastern Bering Sea south to the tip of Baja California, and are associated with a shift in the major atmospheric pressure systems of the Northeast Pacific. The close links between changes in air pressure and ocean temperature are surprisingly robust for this region and are described below.

Climatologists generally use a recent 30-year period to represent average atmospheric conditions, with the years 1981 to 2010 forming the most recent epoch. Average sea surface air pressure (SSP) and temperature (SST) are presented in Fig. 2 for this 30-year period. H and L in Fig. 2a denote the North Pacific High Pressure System and the Aleutian Low Pressure System, respectively. The former expands in area and increases in pressure in summer, whereas the latter expands in area and decreases in air pressure in winter. This seasonal change brings dry summers and wet winters to the North American west coast from Oregon to British Columbia.

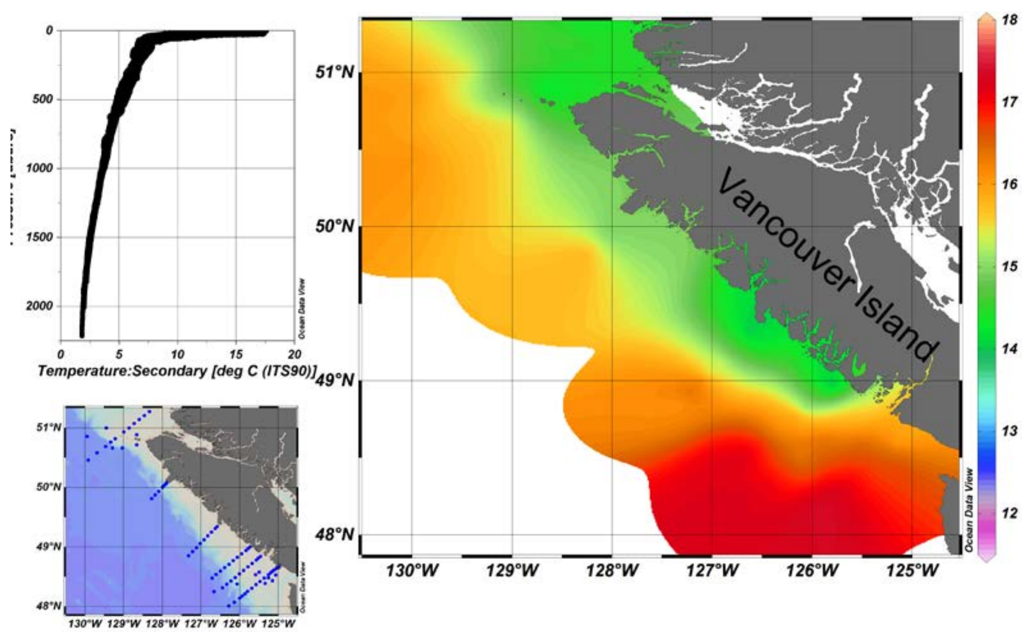

Fig. 1 Ocean conditions in September 2013 off the west coast of Canada. At right is a contour map of ocean temperature measured at the top of CTD profiles whose locations are shown at bottom left. Temperature profiles of sampling stations are presented at top left. Figure provided by Douglas Yelland, Fisheries and Oceans Canada.

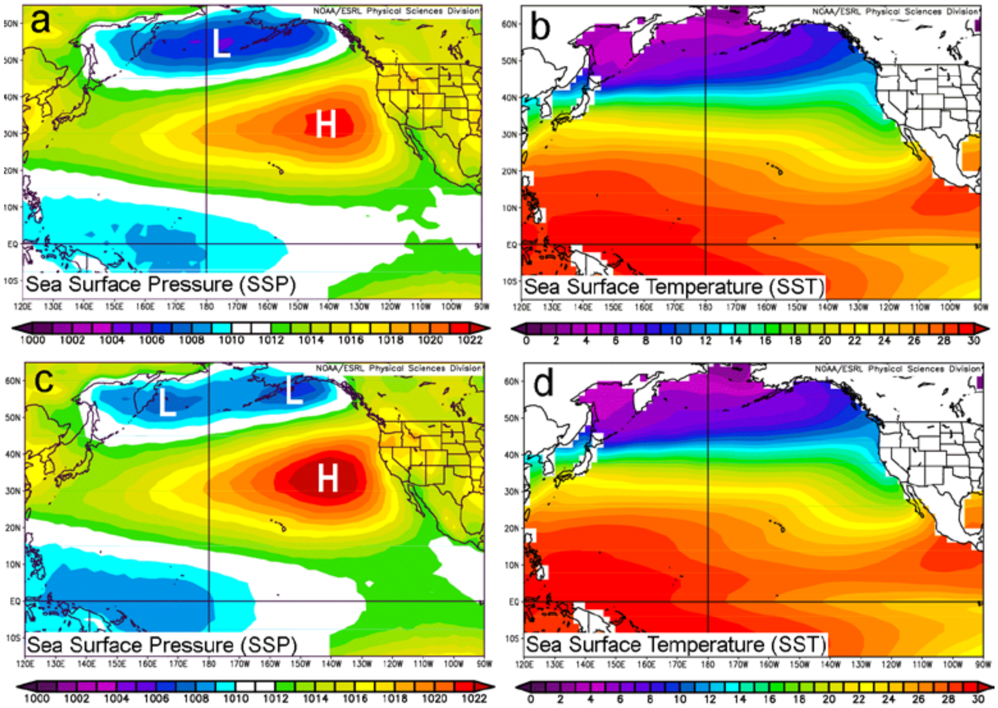

Fig. 2 (a) Sea surface air pressure (SSP, millibars) and (b) sea surface temperature (SST, degrees Celsius) for the North Pacific averaged over all months from January 1981 to December 2010. (c) Sea surface air pressure (SSP) and (d) sea surface temperature (SST) for the North Pacific averaged over all months from August 2006 to July 2013, except for the 1-year period of August 2009 to July 2010 during an El Niño event. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their website at http://www.esrl.noaa.gov/psd/.

Since 2006, the average air pressure distribution over the Northeast Pacific Ocean has shifted relative to average conditions, with a stronger North Pacific High (NPH) and weaker Aleutian Low (AL) after 2006. Comparison of Figs. 2a and 2c shows higher air pressure in the core of the NPH in 2006 to 2013. A bigger change can be seen in the AL, whose centre is weaker and shifted to the east in Fig 2c compared to Fig. 2a. Although SST changed along with the shifting sea surface pressure, the changes are not at first noticeable between Figs. 2b and 2d. A careful comparison reveals decreased SST along parts of the North American coast in 2006 to 2013, but the drop in temperature of a degree or so is difficult to observe when the full range is about 25°C.

The relationship between shifting SSP and SST is more easily seen in their anomalies, although changes can be difficult to understand at first. Figure 3 presents sea surface pressure anomaly (SSPA in Fig. 3a) and sea surface temperature anomaly (SSTA in Fig. 3b) for the same years as for Figs. 2c and 2d. There was an anomalously positive SSPA centred over the Aleutian Islands and extending far to the south in the Gulf of Alaska in 2006 to 2013, as shown in Fig. 3a. In contrast, SSPA was negative over most of North America. The presence of these two opposite-sign anomalies created an east–west gradient in air pressure that set up an anomalous wind that blew along the direction of the black arrow in Fig. 3a, generally from the north. (Anomalous wind from the north could actually

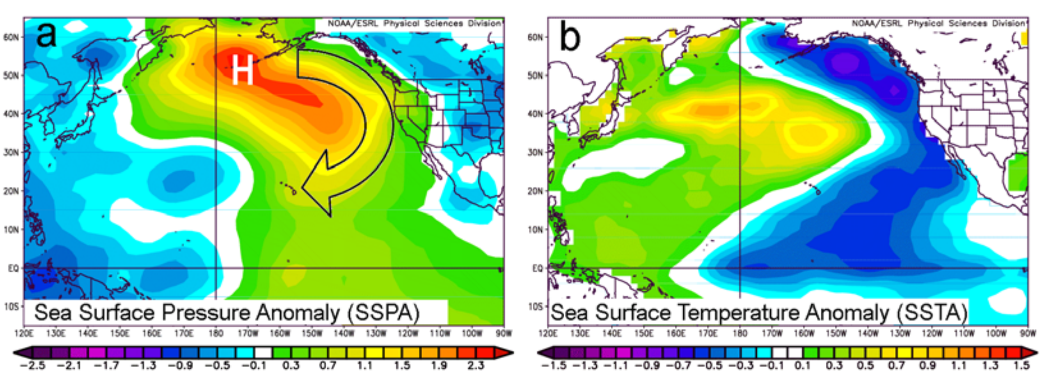

Fig. 3 (a) Sea surface air pressure anomaly (SSPA, millibars) and (b) sea surface temperature anomaly (SSTA, degrees Celsius) for the North Pacific Ocean, averaged over all months from August 2006 to July 2013, except for the 1-year period of August 2009 to July 2010 during an El Niño event. The black arrow in (a) represents anomalous winds due to the anomalous SSPA. The Equator and 180ºW lines are show in black. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their website at http://www.esrl.noaa.gov/psd/.

be due to weaker wind from the south. It is this interpretation that often confuses.) The arrow in Fig. 3a extends all along the eastern side of the positive SSPA, representing a cold wind anomaly in the direction of upwelling along the west coast of North America. The combination of cool wind and increased coastal upwelling (or weaker downwelling) drove the negative SSTA observed in the eastern Gulf of Alaska in Fig. 3b. In addition, the broad centre of the high SSPA of Fig. 3a is a region of enhanced Ekman convergence, which led to positive SSTA for this region in Fig. 3b.

This pattern of Fig. 3 was interrupted from August to October 2013, when a shift in air pressure and wind brought high ocean temperature to west coast waters, and also to adjacent waters offshore. This event is represented in Fig. 4. The yellow arrow in Fig. 4a shows the direction of the wind anomaly, blowing counterclockwise around the low pressure anomaly, carrying warm air from the south, and blowing along the coast in direction to force coastal downwelling. Both factors lead to positive SSTA in waters of the Gulf of Alaska, as shown in Fig. 4b, between the centre of the negative SSPA and the coast. This air pressure pattern persisted for only a few months, but it was able to reverse the pattern of positive and negative SSTA of Fig. 3d that persisted until July 2013. Although the SSTA image of Fig. 4b lags the SSPA image by several weeks, the actual lag of temperature anomaly relative to pressure anomaly can vary considerably, depending on the strength of the pressure field and accompanying winds, and distance to the continental margin.

The sudden warming along the coast was captured by the daily sampling program of Fisheries and Oceans Canada at its coastal stations. Time series of surface temperature are shown in Fig. 5 for Langara Island and Amphitrite Point along the Canadian west coast. These locations are plotted in Fig. 4b, with Amphitrite Point located on the west coast of Vancouver Island and Langara Island to the north.

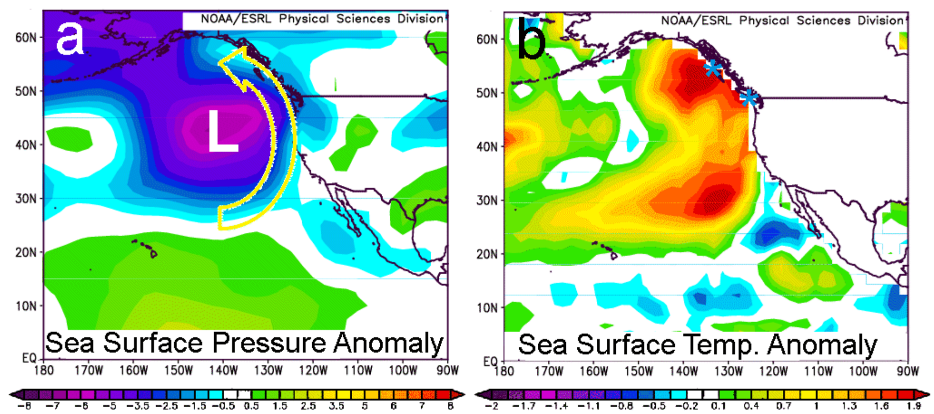

Fig. 4 *(a) Sea surface air pressure anomaly (SSPA, millibars) averaged from August 21 to September 12, 2013. (b) Sea surface temperature anomaly (SSTA, degrees Celsius) for the Northeast Pacific Ocean, averaged from September 5 to September 26, 2013. The yellow arrow in (a) represents anomalous wind due to the SSPA. The reference period for the anomaly is January 1981 to December 2010. Blue stars in (b) show positions of lighthouse stations where temperature is sampled daily. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their website at http://www.esrl.noaa.gov/psd/.*

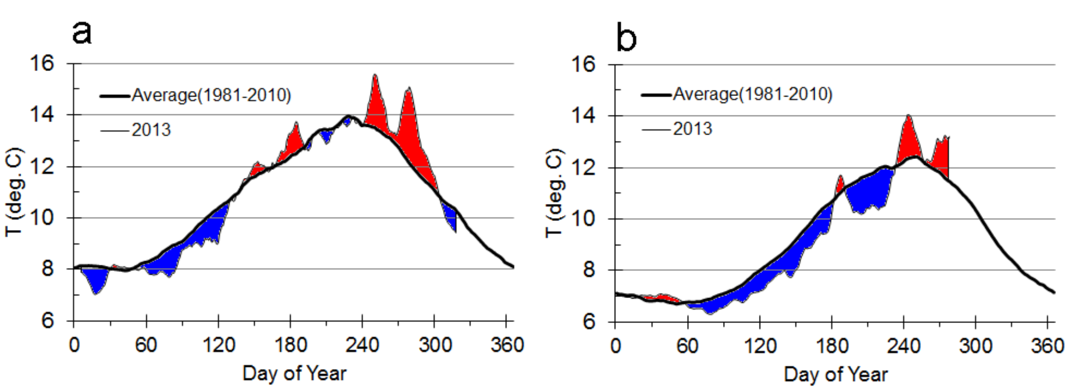

Fig. 5 *Time series of sea surface temperature measured at shore at (a) Amphitrite Point and (b) Langara Island. The thick line is the average temperature for 1981 to 2010. The thin line is the temperature measured in 2013. Red and blue shading shows the magnitude of positive and negative temperature anomalies. Both time series have been passed through an 11-day low-pass running-mean filter. Day 240 is August 28 and day 300 is October 27. Water samples have been collected and recorded daily at these stations for almost 80 years, mainly by lighthouse keepers. Additional information and data are found at http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/lighthouses-phares/index-eng.html.*

The warmest days were on September 6 and August 30 at Amphitrite and Langara, respectively, and were by far the warmest periods of the year. The second warm period followed by 28 days at both stations. Although each event lasted only a few weeks, and the two warm events lasted for just over two months, observers on Canadian research vessels saw a significant influx of warm-water species as noted earlier. It is impressive that shifts in air pressure can lead quickly to changes in sea surface temperature. This reliable temperature response is likely to be more common in eastern boundary regions, where prevailing currents are much weaker than on the western sides of oceans, and along the continental shelf where coastal upwelling and downwelling lag the changes in wind direction by a day or so.

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