Unusual warming in the Gulf of Alaska

by Howard Freeland and Frank Whitney

In March 2014 there was something very unusual occurring in the Northeast (NE) Pacific that might have substantial consequences for biota in the Gulf of Alaska and southward into the subtropics. A quick examination of the Reynolds sea surface temperature (SST) data set shows considerably higher than normal temperatures in early 2014. Each month since November 1981, these data have been published by NOAA/NCEP (ftp://ftp.emc.ncep.noaa.gov/cmb/sst/oimonth_v2/) and represent the best estimate of the SST in the global oceans (see also Reynolds *et al*., 2007). A January mean state, including a field of standard deviations, for the N.E. Pacific was computed by averaging the SST fields for all Januaries from 1982 to 2013 inclusive. An anomaly field was then computed for January 2014 by subtracting the mean state and normalising by the field of standard deviations. Similar calculations were done for February 2014.

In January 2014 (Fig. 1a), we see SST departures of 4.5 standard deviations or ~3°C from the long-term mean, centered on 42°N 148°W. The anomaly field covers a large region of the N.E. Pacific in January 2014 and (not shown) a similar area in February, though the peak anomalies are slightly smaller. The black dots show the nominal locations of the stations comprising Line-P, for later reference. The authors of this article have never seen deviations from normal of 4.5 standard deviations before, despite extensive work with the Line-P data set. The warming event first appeared in November 2013, becoming strongest in January (Fig. 1a), and lasting into February 2014.

Something as extraordinary as a 4.5-sigma deviation requires corroboration, and for that purpose we examined Argo data, which are not ingested by the Reynolds data sets. The reason for this exclusion is that Argo floats sample during their ascent phase, and the CTD pump is turned off at a pressure of 4 decibars to avoid pumping surface films into the conductivity cell. In Figure 1b Argo data were interpolated to Ocean Station Papa (50°N and 145°W) and averaged over all Januaries from the start of the Argo program in the Gulf of Alaska in 2002 to the present time. The temperature, salinity and density (σ_t) are colored red, green and black, respectively, and the horizontal lines indicate the mean values computed from 2002 through 2013. The final point shows the recently observed values for January 2014, and the annotations indicate the value as a mean plus anomaly in standard deviations. The Argo data verify the very large temperature departures seen in Figure 1a, with an anomaly of 4.4 standard deviations from the mean in temperature, and similar large deviations in salinity. We note that high temperature anomalies coupled with low salinity anomalies both act to reduce density. Hence we see very large anomalies in surface density that must act to impede mixing near Station Papa, and likely over the entire region of SST anomaly.

To complete the description of the physical field, Figure 1c shows the distribution along Line-P of the temperature anomaly fields in January 2014. The temperature field has been computed using objective analysis to interpolate from all Argo profiles available in a 10-day window centred on the 15th day of January, and using a Gaussian covariance function with an *e*-folding scale of 400 km (see Bretherton *et al*., 1976, for a description of the methods). The mean state used to compute the temperature anomalies is from Marie Robert (Robert, 1994), which used all observations from 1956 to 1991. The section in Figure 1c shows the very strong warming and demonstrates that the event is primarily restricted to the upper 100 metres of the water column with possibly slight warming in deeper waters. The equivalent plot for salinity (not shown) has a similar behaviour with little influence below the top 100 metres.

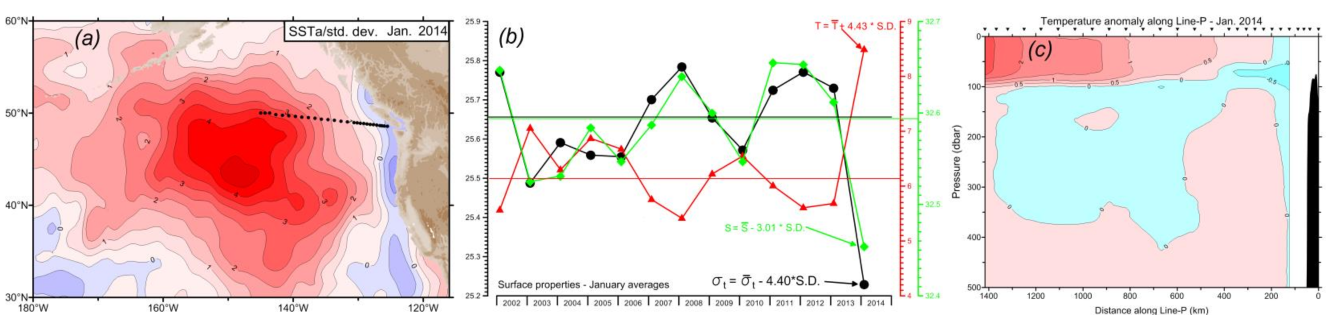

Fig. 1 Temperature and salinity in the N.E. Pacific in January 2014. Panel (a) shows the January 2014 SST anomalies (in standard deviations) from the 1982–2013 Reynolds NOAA/NCEP mean January state. Panel (b) shows January temperature (red), salinity (green) and density (σ_t; black) departures from the 2002–2013 mean state (horizontal lines) at Ocean Station Papa. Panel (c) shows temperature anomalies (°C) contoured versus depth and distance along Line-P in January 2014.

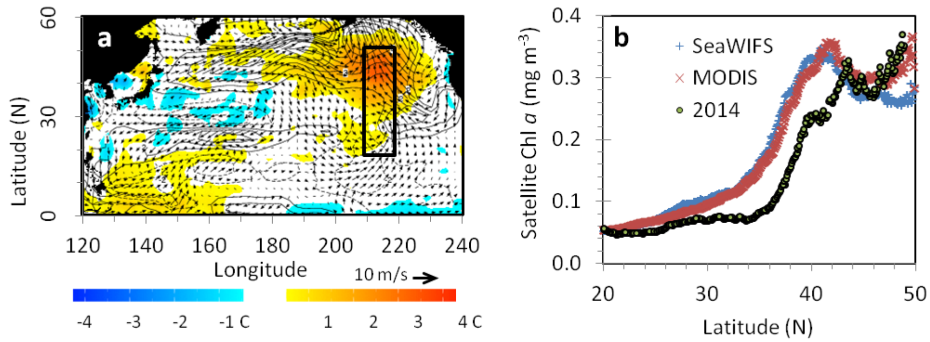

Fig.2 (a) Sea surface temperature (SST) and 1000 mbar wind anomalies for January 2014 in the North Pacific Ocean. SST anomaly (color bar) and wind speed (arrow) scales are shown at bottom; plots are generated by the International Research Institute for Climate and Society, Columbia University, NY on their website http://iridl.ldeo.columbia.edu using data from the NCEP/NCAR Reanalysis and the NOAA OISSTv2 dataset (Kalnay et al., 1996; Reynolds et al., 2007). The black rectangle outlines the region assessed in Panel b. (b)Average SeaWiFS and MODIS chlorophyll a for January, as well as January 2014 MODIS chlorophyll, are plotted against latitude for the region between 140–150°W (data from the Giovanni online data system, developed and maintained by the NASA GES DISC).

Wind anomalies (Fig. 2a) show the cause of the warm anomalies in the ocean's surface layer to be an unusual flow from the south as the North Pacific high pressure cell expanded northward. This pattern disrupted the path of the westerly winds that cross the subarctic Pacific, winds that normally transport nutrients from the subarctic North Pacific into the subtropics during winter (Ayers and Lozier, 2010; Whitney *et al*., 2013). In most years, a winter region of high productivity is created by this Ekman transport which reaches as far south as 30–32°N in the N.E. Pacific (Bograd *et al*., 2004). Named the Transition Zone Chlorophyll Front (TZCF), it is an important feeding area for migratory fish and seabirds (Block *et al*., 2011).

Without nutrients from the subarctic, the productivity of subtropical waters must decline. To assess impacts of the warm anomaly on ocean productivity, satellite chlorophyll between 140 and 150°W was averaged in 2 degree bins between 20 and 50°N. South of the warm anomaly between 22 and 40°N, January chlorophyll *a* was well below the SeaWiFS (1998–2010) and MODIS (2003–2014) averages in 2014 (Fig. 2b). Consequently, the TZCF (identified as 0.2 mg chl m^{-3}) was located 240 km north of its average location over the previous 16 years. Between 30–40°N, surface chlorophyll dropped to 60% of the average values. Top predators may be able to locate the chlorophyll front since they are accustomed to travelling great distances in their search for prey. However, weakened nutrient transport from the subarctic into the subtropics this past winter will dramatically reduce the productivity of the eastern subtropics over an area of ~17,000 km^2 (20° Longitude × 240 km northward displacement of the TZCF). One possible outcome might be a northward shift of the albacore tuna fishery in 2014.

References

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Dr. Howard Freeland (Howard.Freeland@dfo-mpo.gc.ca) is a scientist emeritus at the Institute of Ocean Sciences. Despite his retirement, he maintains a keen interest in the Argo program and ocean climate change. (In this picture he is seen launching yet another Argo float.)

Frank Whitney (whitneyf@shaw.ca) retired from Fisheries and Oceans Canada in 2006. He has remained interested in chemical processes impacting the productivity of the ocean, whether it is nutrient supply to surface waters or hypoxia at depth. Recent papers (J. Oceanogr. 67: 481–492; GRL 40: 1–6) summarized some of the trends he and colleagues observed over a span of 25 years or more in the subarctic Pacific. (In this photo, Frank is studying a common type of tube worm that barbecues quite nicely onboard ship.)