Recent trends in the subarctic NE Pacific: Cooling of 2006 continues into 2007

by William Crawford and Patrick Cummins

Ocean temperatures at 10 m depth in the eastern Gulf of Alaska cooled by several degrees from winter 2006 to winter 2007, with coastal waters of the NE gulf cooling the most. This decline followed a period of extremely high temperatures in the region in the summers of 2004 and 2005. Above-normal temperatures appeared to persist into 2007 only in the Strait of Georgia in the SE region of **Figure 1**.

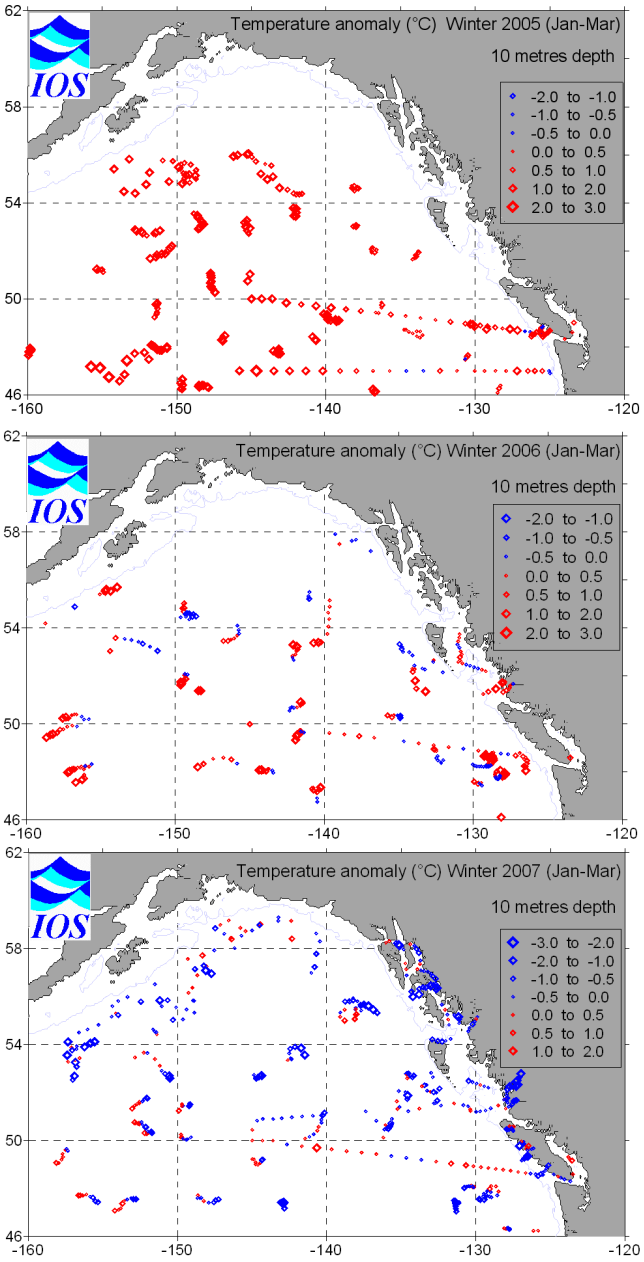

Fig. 1 Anomalies of winter temperature at 10 m depth in the Gulf of Alaska in 2005 (top), 2006 (middle) and 2007 (bottom). Symbols denote negative (blue) and positive (red) anomalies in degrees Celsius. Each symbol represents a single observation from a research vessel, or an Argo profiler.

Temperatures there often lag those in oceanic waters by several months to a year. Much of the cooling from Oregon to British Columbia might be attributed to major storms and southerly storm tracks of late 2006 that cooled oceanic surface waters. Cooling earlier in 2006 is believed to be associated with a shift in atmospheric circulation patterns. Impacts of continuing cooling in late 2006 and into 2007 are pointed out in a recent overview (DFO Ocean Status Report 2007/001; http://sci.info.pac.dfo.ca/PSARC/OSR's/OSR.htm). It notes that cooling in the last half of 2006 along the West Coast was accompanied by more boreal copepods on the Oregon continental shelf. Dr. William Peterson of the U.S. National Marine Fisheries Service reports that preliminary indications from samples collected in the winter and early spring of 2007 are that the copepod community is dominated by cool water species, *Pseudocalanus mimus* and *Calanus marshallae*. *Neocalanus plumchrus/flemingerii* also appeared to be unusually abundant in the spring of 2007.

Sea surface temperatures (SSTs) at Amphitrite Point on the west coast of Vancouver Island were 1 to 2°C below the long-term average from May to early June 2007 (**Fig. 2**), and boreal copepods were abundant in the region in May 2007, evidence of the continuing impact of this cool ocean.

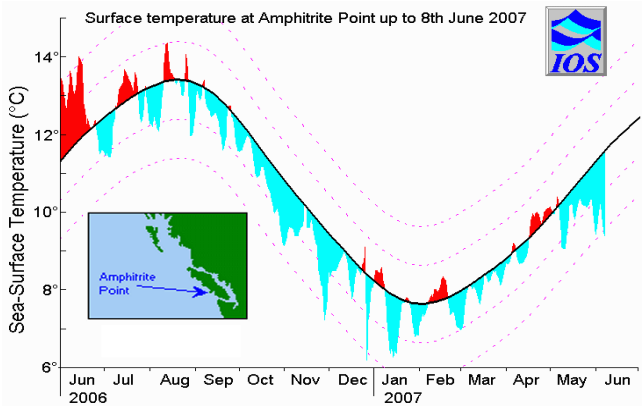

Fig. 2 Sea surface temperature at Amphitrite Point on the west coast of Vancouver Island. The solid black curve denotes the long-term annual cycle; red and blue show measured temperatures above and below the annual cycle. (Image provided by H. Freeland. Updates are available at http://www-sci.pac.dfo-mpo.gc.ca/osap/projects/sst/default_e.htm#)

Sea surface height (SSH) anomalies measured by satellite altimetry over the NE Pacific registered changes in the upper ocean. These anomalies provide a vertically integrated measure of upper ocean variability with greater "inertia" than rapidly fluctuating SSTs. Contour plots of SSH anomalies averaged at quarterly intervals (**Fig. 3**) indicate that between the first and second quarters of 2006 (winter to spring), SSH in the NE Pacific was dominated by a pattern that is related to the cold phase of the Pacific Decadal Oscillation (PDO). It consists of below-average

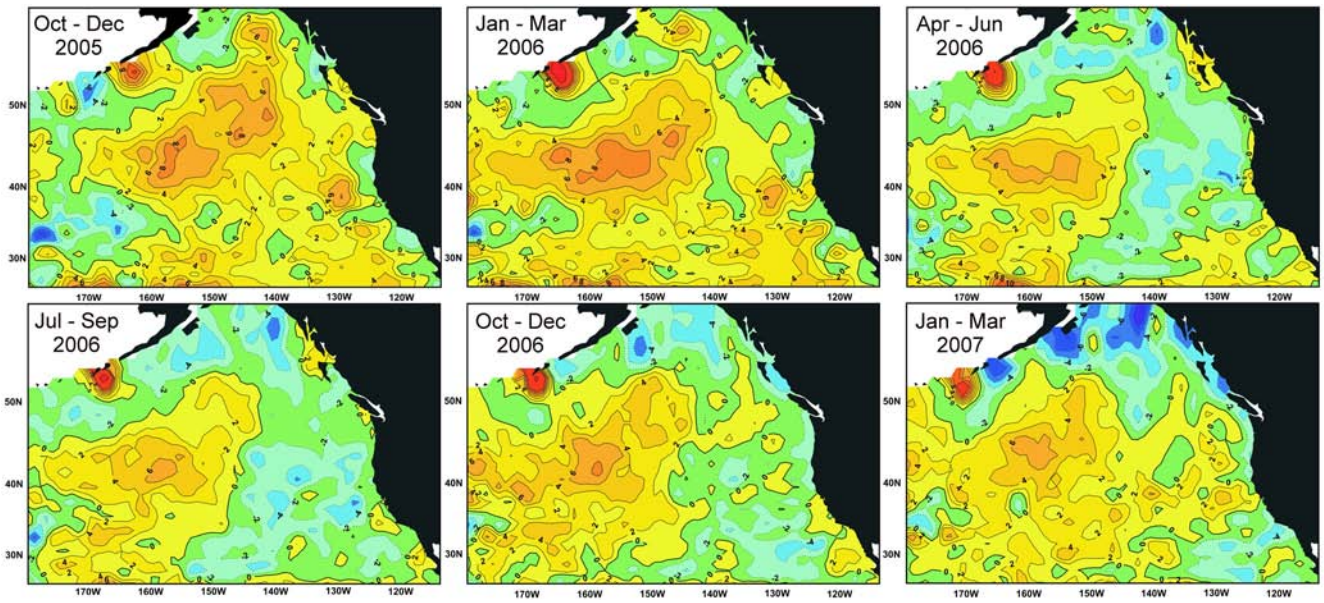

Fig. 3 Sea surface height (SSH) anomalies at 3-month intervals. Contour interval is 2 cm, with yellow-orange-red denoting positive values and blue-green denoting negative values. The anomalies in SSH were constructed by removing monthly means computed from 14 years of satellite altimeter data (TOPEX/Poseidon and Jason-1, 1993–2006), gridded at a resolution of 1 degree.

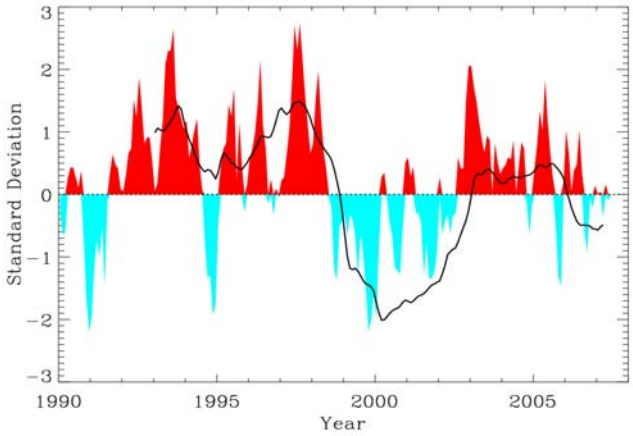

Fig. 4 The solid red/blue curve gives the recent history of the PDO index (obtained from http://jisao.washington.edu/pdo/PDO.latest). The solid black line is the first principal component of SSH over the NE Pacific.

sea level in a broad horseshoe-shaped pattern around the perimeter of the Gulf of Alaska, and extending into the central Pacific out to 205°E (155°W). The pattern in **Figure 3** is similar to a period of 4 years of La Niña-like anomalies that occurred in 1999–2002. While the pattern has persisted through the fourth quarter of 2006, it may be starting to break down in the first quarter of 2007 (**Fig. 3**, last panel). An index based on the first principal component of SSH over the NE Pacific (Cummins *et al.*, *Geophys. Res. Lett*., 2005, 32, L17607) shifted to negative values in 2006. This change was similar to, but not as strong as, the shift that occurred in 1999 (**Fig. 4**). SSH anomalies in the winter of 2007 (**Fig. 3**, last panel) were especially low in the northern Gulf of Alaska, usually an indicator of less heat in the water column. The large, slowly propagating positive SSH anomaly located directly south of the Aleutian Island chain (**Fig. 3**) is likely associated with a mesoscale eddy in the Alaskan Stream.

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Bill (crawfordb@pac.dfo-mpo.gc.ca) conducts research into the movement water masses in the Gulf of Alaska and their impacts on marine biota. He co-chairs the Fisheries and Oceanography Working Group that prepares the annual "State of the Ocean Report" for Canada's Pacific Region. Bill is the senior Canadian delegate to the International Association of Physical Sciences of the Ocean. He also serves as the Canadian member of the Pacific Panel of CLIVAR and the PICES CFAME Task Team.

Patrick (cumminsp@dfo-mpo.gc.ca) has developed relatively simple models to interpret ocean change as revealed by satellite altimeter data. Of particular interest to him is an understanding of the influence of the Pacific Decadal Oscillation over the NE Pacific and developing indices that may be useful to monitor climatic changes. Patrick is co-editor of Atmosphere–Ocean, *the research journal of the Canadian Meteorological and Oceanographic Society (CMOS).*