The state of the eastern North Pacific since February 1999

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Dr. Howard Freeland is a research scientist in the Ocean Science and Productivity Division at the Institute of Ocean Sciences (Department of Fisheries and Oceans). His research interests include the climatic state of the ocean and low frequency variability. Presently he is responsible for the maintenance of Line P, a line of CTD stations that has been monitored for over 45 years between the mouth of the Juan de Fuca Strait and Ocean Station Papa at 50°N and 145°W (also known as WOCE Repeat Hydrography Line P6). Howard is also on the international science team for project ARGO which aims to deploy a global array of profiling ALACE floats to monitor the evolving state of the ocean. Examples of some products from a few profiling ALACE floats can be seen through his own web page at http://www.ios.bc.ca/ios/osap/people/freeland.htm. He is involved in various PICES activities as a member of the Physical Oceanography and Climate Committee, and Chairman of the newly formed Publication Committee.

In recent years we have witnessed some significant transitions in the climatic state of the Pacific Ocean. The 1997/98 El Niño ended in the spring of 1998, and we saw an immediate transition to moderate La Niña conditions that persisted into the spring of 1999. These events all originate in the equatorial Pacific and one useful indicator of this type of activity in the climate system is the Southern Oscillation Index, or SOI. Figure 1 shows daily values of the SOI. The solid blue line is a 30-day running mean representation. In this we see the transition in May 1998 from El Niño to La Niña-like conditions, and then in May 1999, a sharp transition back to normalcy. Of course, the SOI is only one measure of El Niño-like activity and is surely far from the whole story of activity on the equator. In fact, though this atmospheric index suggests that the equatorial Pacific has returned to normal, there is a large mass of water only about 40 metres subsurface on the equator that is substantially cooler than normal. Though conditions are normal at the surface, abnormal conditions are not far away and could be exposed very easily.

The panels of Figure 2 illustrate the evolution of temperature conditions in the eastern North Pacific Ocean during 1999. As the year progressed, the eastern North Pacific came more and more under the influence of cold anomalies. It is intriguing how these gradually penetrated into deeper waters along Line-P as the year progressed. These cold anomalies will not go away quickly, even though the La Niña forcing on the equator appears to have ended. So the consequences of La Niña will be with us for a substantial period yet.

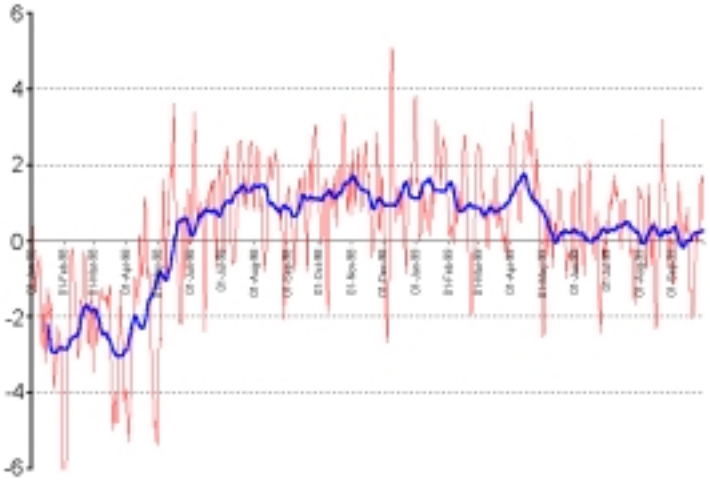

Fig. 1 The Southern Oscillation Index from January 1998 to present.

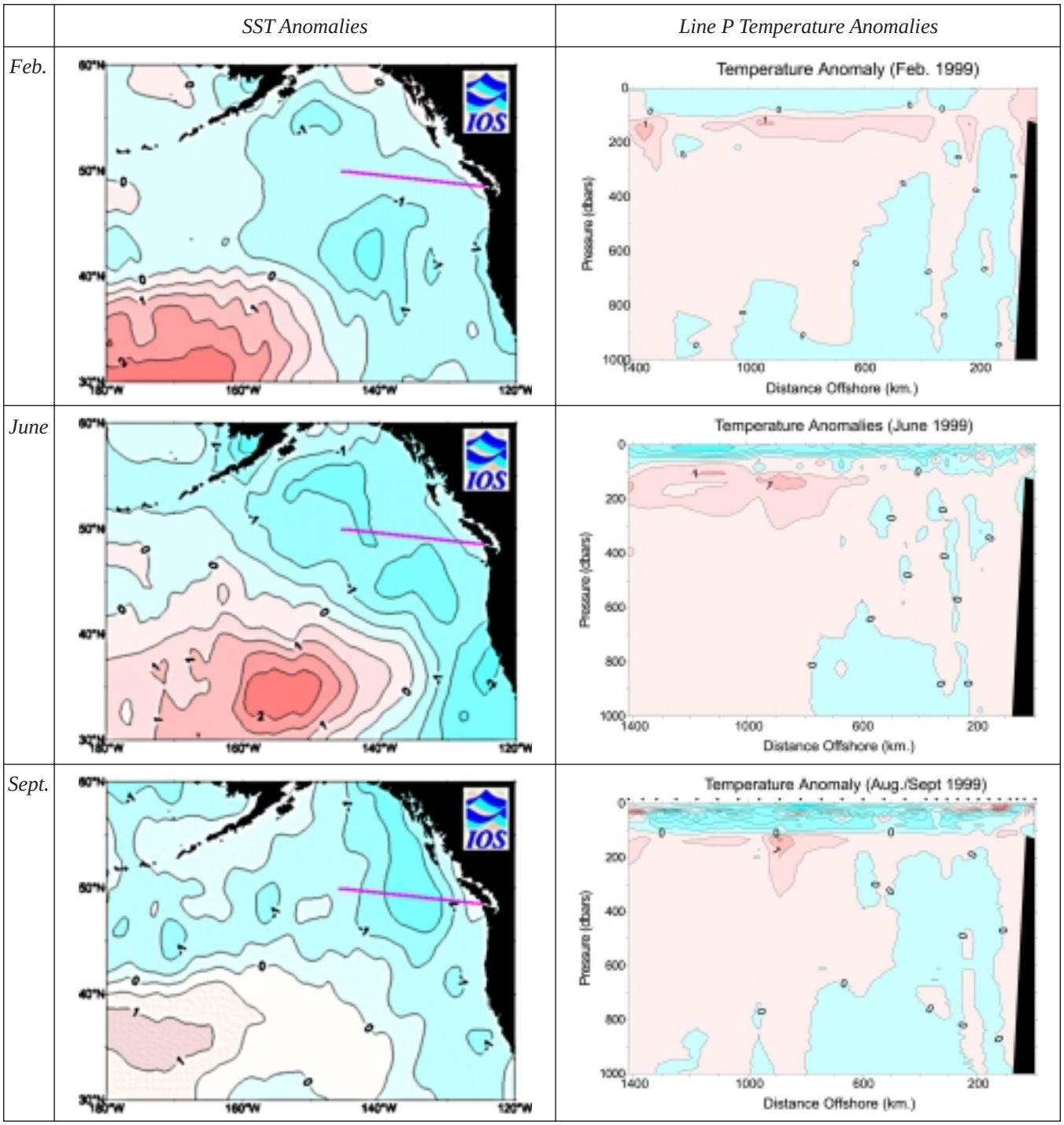

Fig.2 Sea surface temperature anomalies and temperature anomalies along Line-P for 3 representative months in 1999.

Another intriguing feature is the apparent intrusion of a warm water mass into the vicinity of Station Papa, showing in the June and September anomaly plots of Figure 2, between 600 and 1400 km offshore. It is a pity that we cannot sample more frequently along Line-P, but in this case we have data from a profiling ALACE float that has remained for more than $2^1/_2$ years. The *in situ* temperature field is shown here in Figure 3. The three near-surface warm epochs that show up clearly identify the summers of 1997, 1998 and 1999. Beneath the 1999 surface warm period, we see the abrupt arrival of this warm water mass at about the time that the El Niño conditions in the eastern North Pacific were replaced by La Niña conditions.

The diagrams constituting Figure 2 offer a very broad-brush picture of conditions in the eastern North Pacific. When we look at the details off the coast of British Columbia, the monitoring time series indicate occasions when SST

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anomalies dropped to 3.5˚C below normal, and the lighthouse observing sites reported the lowest SST anomalies observed in 65 years.

At Ocean Station Papa we have previously reported observations of the mixed-layer depth, and the influence of climate change on that depth. Over the last 50 years, mid-winter mixed-layer depth has systematically declined, as shown in Figure 4. During the abnormally warm winter of 1997/98, we observed (in February 1998, letter B on Fig. 4) the lowest mixed-layer depth in the history of Line-P observations. The previous low value immediately followed the 1982/83 El Niño (A on Fig. 4). SST anomalies reached record lows during the winter of 1998/99, and this reduced the stability of the upper water column. The result was that the mixed layer was substantially deeper at the start of 1999 (C on Fig. 4), though only reaching the long-term average. The progressive reduction in mixed-layer has led to a progressive reduction in the supply of nutrients to the upper ocean during the deep mixing periods. This culminated in 1998, which was preceded by a winter with the lowest mixed-layer depths on record, and so the weakest mid-winter supply of nitrate to the upper ocean. Observations by Frank Whitney show that in 1999, following relatively normal mixed layers in the previous winter, the nitrate concentrations had returned close to the long-term mean conditions.

The continuation of cold conditions in the eastern North Pacific suggests that we will see an ample supply of nitrate injected into the upper layers of the ocean during the winter of 1999/2000.

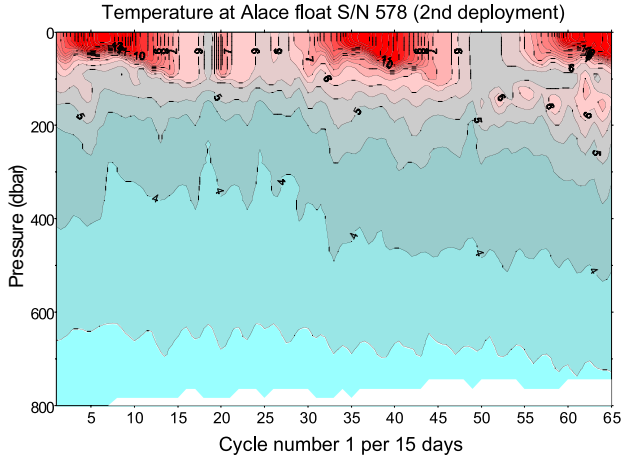

Fig. 3 Temperature measured at a profiling ALACE float which has so far spent 2.7 years near Ocean Station Papa.

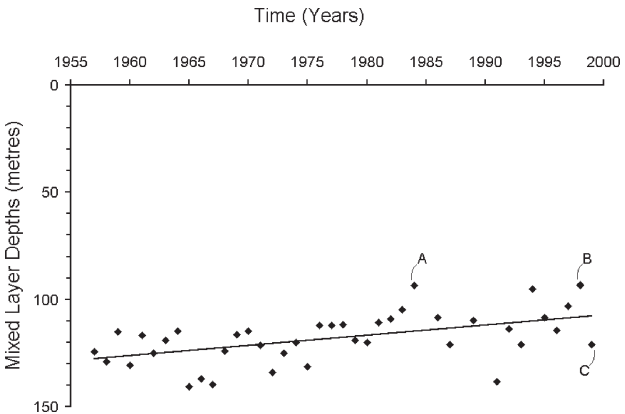

Fig. 4 Mid-winter mixed layer depth at Ocean Station Papa, from 1956 to present.