The state of the eastern North Pacific in the second half of 1996

Howard Freeland
Ocean Science & Productivity Division,
Institute of Ocean Sciences,
P.O. Box 6000, Sidney, B.C.
CANADA V8L 4B2
E-mail: hjfree@ios.bc.ca

Dr. Howard Freeland is Head of the Ocean Science and Productivity Division at the Institute of Ocean Sciences (Department Fisheries and Ocean, Canada) and a memeber of PICES' Physical Oceanography and Climate Committee. His research interests include the climatic state of the ocean and low frequency variability. Dr. Freeland was the scientist primarily responsible for Canadian contribution to the WOCE Lines P15 & P1. Presently, he is accountable for maintenance of Line-P, a line of CTD stations that has been monitored for over 40 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 PR6). Last year he was the winner of the Applied Oceanography Prize awarded annually by the Canadian Meteorological and Oceanographic Society.

The General Features:

The diagram opposite (*Figure 1*) shows the major circulation features of the N.E. Pacific Ocean. This is highly schematic, and one should bear in mind that the amount of water entering this region along the subarctic boundary itself must vary, and further, the fraction of that water that splits into the southbound California Current and the northbound Alaska Current also must vary. Hence the volume fluxes associated with these currents are highly uncertain. Nevertheless, the dominant patterns are remarkably robust. Both surface and subsurface drifters placed anywhere between 35˚N and 45˚N between 140˚W and the dateline will eventually migrate towards the Americas. More southerly floats will always end up in the California Current system, and more northerly floats will always end up in the Alaska Current system. The latitude of the bifurcation in the eastward drift is not really known, though it is widely assumed to vary both seasonally and inter-annually. The dominance, and persistence, of the general eastward drift has a direct impact on the temperature field. In the more northerly regions of the Pacific Ocean the density of seawater is largely determined by the salinity with temperature having only a rather weak influence. Thus temperature fluctuations tend to be carried by the large scale background currents.

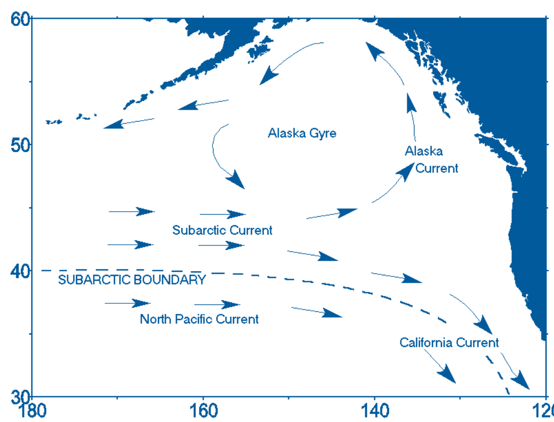

Fig. 1 *Cartoon of the general circulation of the N.E. Pacific Ocean showing the principal large-scale features.*

Sea Surface Temperature in 1996

Figure 2 shows plots of the temperature anomaly month-by-month through the second half of 1996. In all plots the contour interval is 0.5(C, the zero contour is indicated by a bold line, and negative contours (water colder than normal) are indicated by dashed lines. The maps are computed by taking a 1x1 degree grid of sea-surface

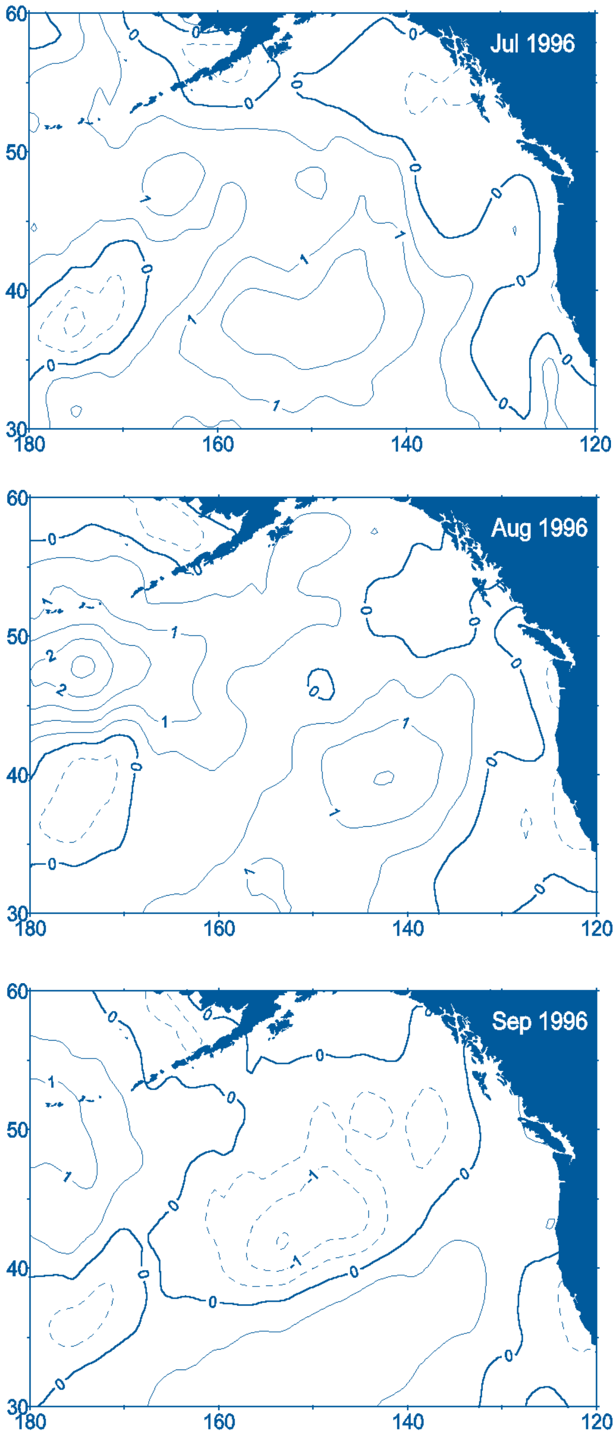

Fig. 2 Monthly mean temperature anomalies (deviations from normal) in the N.E. Pacific for July through December 1996. The contour interval is 0.5°C and negative anomalies are indicated by dashed lines

temperature for each month of 1996 and subtracting the average of grids computed for each month averaged over the years 1981 through 1996.

The maps indicate a remarkable general similarity. For every month of the year the ocean is cooler than normal in the Gulf of Alaska and in the bottom left of the maps. The ocean is warmer than normal off the Aleutians (top left corner) and in the California current system (bottom right corner). Thus, 1996 represents a significant departure from earlier years of the 1990s decade which were dominated by the direct influence of a series of El Niño events that were remarkable in their persistence, and then the long period necessary for the ocean to return to normal after this abnormal heating.

Though these four pools of warm and cold water were present in all months, the strength of the anomalies varied enormously. During March 1996, for example, anomalies were extremely weak over the entire N.E. Pacific. The negative anomalies appeared to be particularly weak during July and August 1996, but this may be more due to the absence of observations. (Objective mapping systems have a strong tendency to estimate the mean value, in this case, zero, when observations are sparse).

Off the coast of British Columbia we are fortunate to have an extensive network of buoys reporting data every hour onto the Global Telecommunications System. Also, for most of 1996 data from two profiling ALACE floats reported ocean conditions once every 5 days. Thus the data coverage of the region extending about 500 to 1000 km seaward of BC was well covered. The anomalies in this region rarely exceeded _ degree in either direction. This was not an artifact of the mapping procedures, rather it was real.

Near Surface Conditions

A recent paper by Freeland et al. (H. Freeland, K. Denman, C.S. Wong, F. Whitney & R. Jacques. 1997. Evidence of Secular Change in the Northeast Pacific Ocean. Deep-Sea Research, *sub judice)* reports that over the history of the Line P/Station P observation program we have seen a steady decline in the thickness of the winter upper mixed layer. This is important because it is the deep mixing during the winter that ensures a substantial supply of nutrients in the ocean in early spring. Thus, we also see a decline in the nutrient concentrations of the upper 100 metres of the ocean at the end of winter.

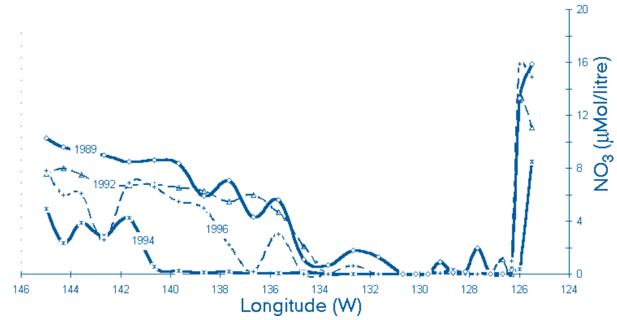

Fig. 3 Nitrate concentrations in late summer along Line-P for several recent years which show the extensive regions of zero-nitrate.

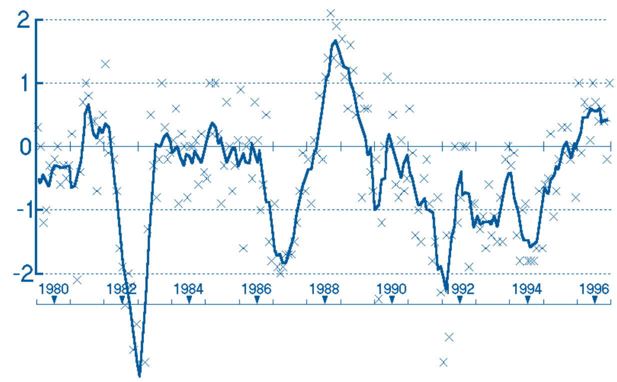

Fig. 4 The Southern Oscillation Index plotted against time from 1980 to Dec 1996. The X marks indicate actual observed monthly value, the solid line a 5-month running mean.

The problem here is that biological activity consumes dissolved nutrients at the same time (spring and summer) when mixing is weakest and so the re-supply rate is also least. The result is that, as shown in *Figure 3*, we have in recent years seen patches of water along Line P with zero dissolved nitrate. During the three most recent summers (1996 included) the nutrient depleted water has occupied most of the distance along Line-P from the continental slope to Station Papa. We do not know how far north or south of Line-P this nutrient depletion extends, but this is a high priority for future research.

The Large Scale

It is well known that large temperature variations do occur in the northern N. Pacific in response to events

(cont. on page 29)

Research and development

To support the above operational tasks, JMA has been conducting various oceanographic research activities, mainly through the Meteorological Research Institute (MRI). To investigate oceanic variations and to study the mechanism of the interaction between the ocean and the atmosphere which makes it possible to predict climate change, basic research is conducted on the development of numerical models of ocean general circulation and ocean ice model for the simulation and/ or prediction of the path of major currents (such as the Kuroshio), distribution of sea ice and sea surface temperature. A new ocean data assimilation system for the mid- and high-latitude regions is under development. Aiming at an operational forecast of ENSO, JMA is developing a coupled ocean-atmosphere general circulation model.

Furthermore, in the MRI, efforts are being made for developing methods for remote-sensing data analysis and for the application of the results to JMA's operational tasks. Recently, JMA has developed a method to derive sea surface dynamic heights from the TOPEX/POSEIDON altimetery data. JMA has also developed a method to determine sea surface current vectors from the obtained sea surface dynamic heights and sub-surface temperature distribution assuming the geostrophic balance (*Figure 3*).

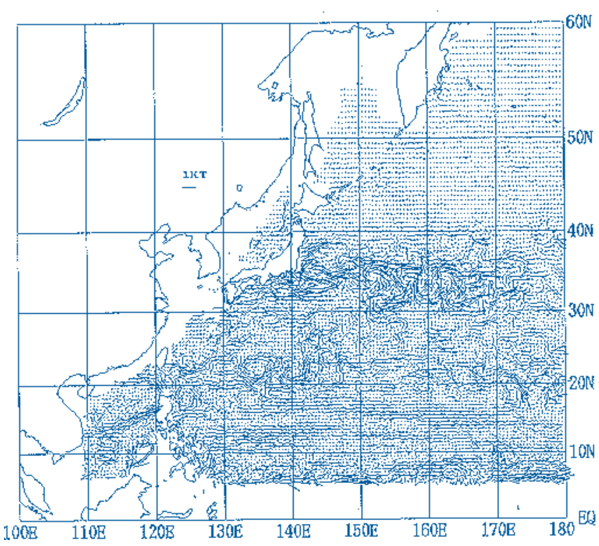

Fig. 3 Sea surface current vectors in the western N. Pacific (January 3, 1997). Vectors are derived from the sea surface dynamics heights from TOPEX/POSEIDON and sub-surface temperature distribution assuming the geostrophic relation.

(cont. from page 10)

occurring in the equatorial Pacific. Large scale pressure fluctuations originate on the equator, produce El Niño or its opposite the La Niña events, and these produce large responses in the extratropic regions. The early years of this decade were dominated (climatologically speaking) by a sequence of El Niño events without respite. The tendency towards or away from an El Niño is measured by the Southern Oscillation Index (hereinafter SOI) and this index is plotted in *Figure 4*. The SOI varied during 1996 between 0 and +0.8. This is on the La Niña side of normal, but the deviations from normal are weak. The SOI is usually reported in non-dimensional units, usually a normalized pressure difference divided by the standard deviation. Thus the peak value for 1996 is +1.0, or only one standard deviation above the long-term normal. The equatorial Pacific was close to the long-term climatic normal in 1996.

The Prospects for 1997 and 1998

In December of 1996 the SOI had the value +0.8. Also, other indicators were consistent with this value and indicated very cold conditions on the equator. Since El Niño and La Niña events, when they occur, usually start in the late fall of the year before (i.e., the 1983 El Niño started in Nov-Dec 1982) we can say with a very high level of certainty that there will be NO major climatic anomaly affecting the N. Pacific Ocean in 1997. Sea surface temperatures should not depart significantly from the climatic normals during 1997.

There are now about 15 computer models, each running on different principles, that attempt to predict the future of the equatorial Pacific and report their results monthly in the Experimental Log-Lead Forecast Bulletin published by the National Weather Service (National Centers for Environmental Prediction, and the Climate Prediction Center, NOAA, US Dept. of Commerce). Methods vary widely, some of the models are dynamical simulations, others are exclusively statistical. However, all agree that there will be no significant climate anomaly in the Pacific Ocean during 1997. Many of the models have been run for a long time and have developed an impressive track record, and the result is that it is believed that they have useful skill for forecasts 12 months in advance. So for the longer view, all of the dynamical models and most of the statistical models indicate that mild warming in the Niño-3 region should be evident by the end of 1997. In particular, the output of the new Scripps/MPI hybrid coupled atmosphere-ocean model suggests warming in the winter of 1997/98 sufficient to be called a moderate El Niño.

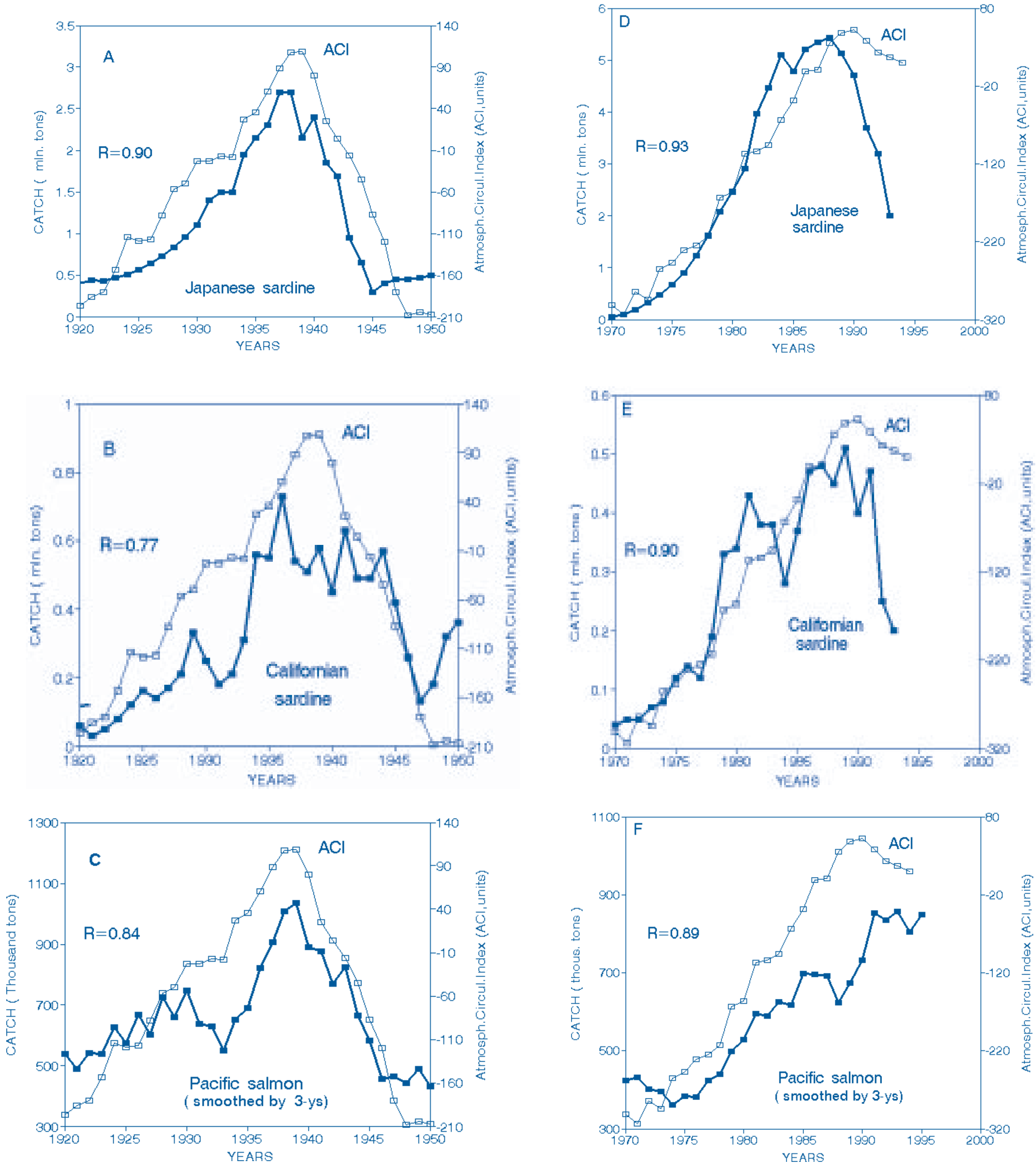

Fig. 6 *Relationship between salmon and sardine catch and Atmospheric Circulation Index (ACI) trend in the Northern Pacific for the periods of 1920-1950 (A, B, C) and 1970-1993 (D, E, F).*
A-Japanese sardine. B-Californian sardine. C-Pacific salmon.
D-Japanese sardine. E-Californian sardine. F-Pacific salmon.