Dissolved Gas Measurements at Stn. P4 during the 97–98 El Niño

Craig McNeil, David Farmer and Mark Trevorrow
Institute of Ocean Sciences
Sidney, B.C., Canada
e-mail: mcneilc@dfo-mpo.gc.ca

Preliminary results and interpretation of measurements obtained at the N.E. Pacific El Niño monitoring station P4 during September 1997 to May 1998 are presented. Station P4 is situated in the vicinity of 48° 39' N and 126° 40' W approximately 75 km west of Vancouver Island, British Columbia, Canada in a water depth of approximately 1,300 m. An instrument package, consisting of a SBE16 DO CTD and an upward-looking sonar, was deployed on a subsurface mooring at a mean depth of ~20 m. Time series measurements, recorded with a 1-h sampling period, include total dissolved air pressure or gas tension, dissolved oxygen and nitrogen concentrations, fluorescence, water temperature and salinity, and acoustical back-scatter intensity.

Data Overview

Figure 1 displays a summary of the data. The instrument package remained at around 20 m depth for the majority of the deployment, although it was drawn down to depths in excess of 50 m for a short period during a storm on year day 415. Water temperatures in November 1997 (year day 280) were around 15°C. Water temperature at 20 m depth continued to cool until mid-January 1998 (year day 380). Dissolved oxygen, measured by a Beckman probe on the SBE16, appeared super-saturated by approximately 20–30% for the first 25–30 days of the deployment and then remained reasonably stable, close to saturation. Winkler calibration samples are indicated. The initial decline in dissolved oxygen concentration is suspect and probably associated with a calibration change during what appears to be a ‘settling in’ period of the sensor. This is apparent by comparing the dissolved oxygen sensor measurements with the gas tension signal as follows.

Gas tension is the dissolved air pressure. The signal is approximately 20% pO_2 (dissolved) and 80% pN_2 (dissolved). As dissolved N_2 is relatively biologically inert, the sensor responds, like an oxygen sensor, to variations in dissolved oxygen concentration. The accuracy of the gas tension measurement, however, is remarkable. Its absolute error is ± 0.01% yr^{-1} (the error bar is thinner than the plotted line). Unfortunately it stopped working on day 450 due to a pressure housing leak, but not before the spring bloom.

A bloom event is identified during mid-March, lasting approximately 10 days. The bloom is reflected in the dissolved oxygen measurements, the gas tension measurements and the fluorometer measurements, providing three completely independent means of determining the timing, duration and size of the bloom. We used a WETLABS WETStar fluorometer. The calibrations appear good (*cf.*, bottle sample). The fall bloom and spring bloom periods are identified. The spring bloom occurs shortly after a storm. The bloom appears to be triggered by a very calm period when there is no significant surface wave activity or bubble plume penetration (to be discussed). Peak Chl levels of ~ 4 $\mu g\ l^{-1}$ were recorded.

The meteorological and wave measurements we use are from the Environment Canada buoy # 46206 located at 48° 50' N and 125° 60' W. Shown also for comparison is a time series of the power at the inertial period (f_1) of the CTD pressure period, which serves as a crude indicator of storm activity. Bubble cloud penetration depth is measured using an upward-looking sonar at 200 kHz, located at the top of the mooring with an unobscured view of the surface.

These data may be compared with historical measurements and differences interpreted in terms of the impact of the El-Niño on N.E. Pacific productivity.

Historical Measurements

Figure 2 displays CTD casts taken during January, February and March 1998 at Stn. P4. The effect of the El Niño is clearly seen in the unusually warm and saltier surface waters, reaching peak levels sometime during February. Note that the surface waters at 150 m are changing temperature by 3°C during January to March.

Our data are presented in Figure 3 and compared with the historical annual average at Stn. P4 and indicate the waters at 20 m depth are approximately 3°C warmer than usual and saltier by approximately 0.5. Shown as error bars on the historical data are the standard deviations.

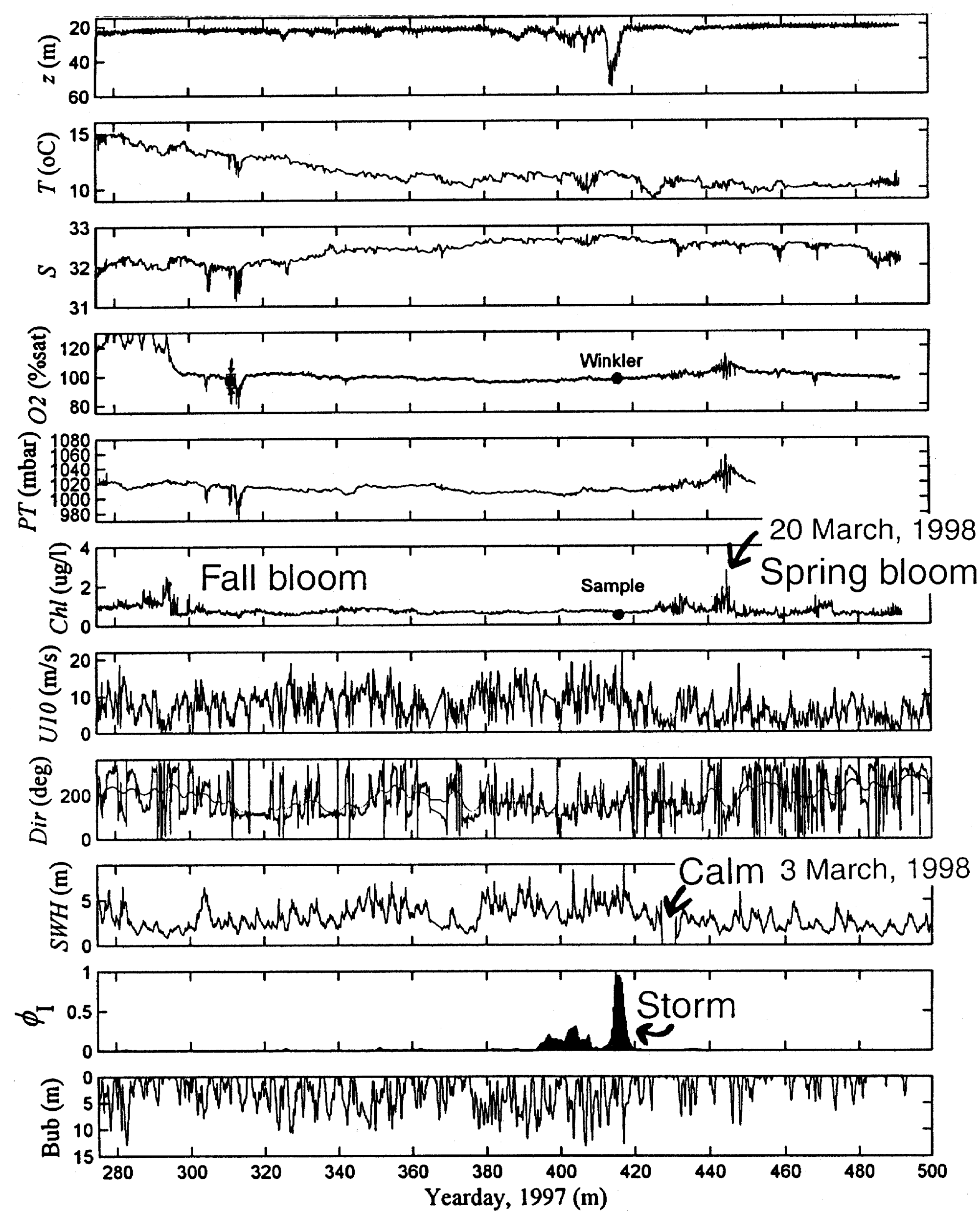

Figure 1. *Data recorded during September 1997 to April 1998 at Stn. P4, showing: instrument depth; water temperature and salinity; dissolved oxygen saturation level; total gas tension; chlorophyll concentration; wind speed, direction and significant wave height from a MET buoy 50 km away; energy in the inertial frequency band from the CTD pressure record at 30 m depth; bubble cloud penetration depth from an upward-looking sonar.*

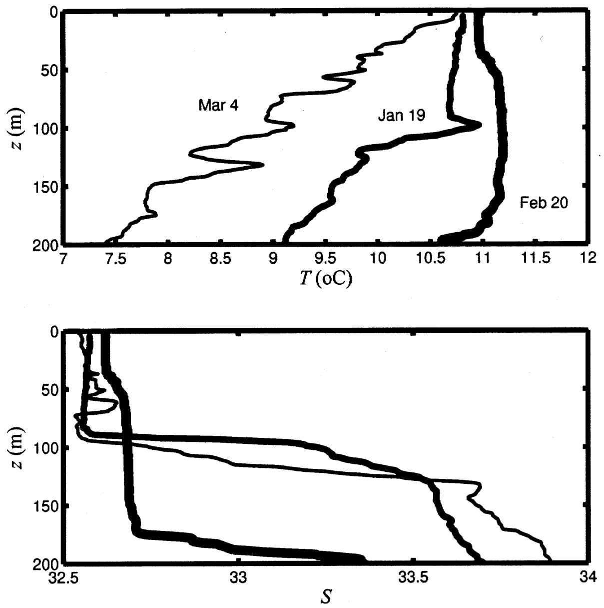

Figure 2. *CTD measurements at Stn. P4 during 1998 (from IOS, Sidney, B.C.).*

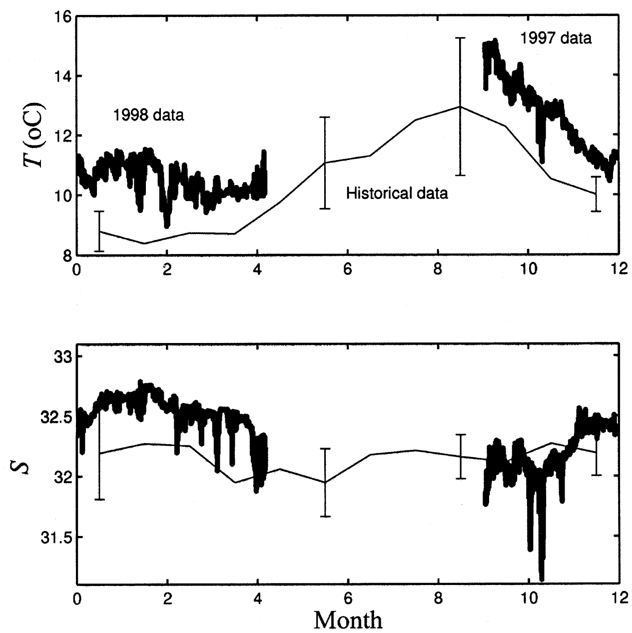

Figure 3. *Temperature and salinity time series at Stn. P4. Bold line shows data collected during September 1997 to April 1998, thin line shows historical annual average and standard deviations from records during 1959–1990 (Tabata and Weichselbaumer, 1992).*

Primary Production Estimates

What is the primary production rate derived from these data? There are two preliminary comparisons to make:

1. daily change in Chl concentrations,
2. daily change in dissolved O_2 concentrations.

Assuming a C:Chl ratio by weight of 60 and the observed change in Chl (inferred from fluorescence changes) of say 1 ug l^{-1} day^{-1}, we calculate a primary production rate of 1.2 gC m^{-2} day^{-1} assuming a 20-m layer depth. Such an estimate is crude as it does not account for daily redistribution of the biomass, changes in the fluorescence with time of day or grazing by zooplankton.

Similar calculations can be made using the observed dissolved oxygen changes. Again, we neglect redistribution of oxygenated water and biomass and assume that mixing extends to h = 20 m depth. From the observed daily saturation level change in dissolved oxygen of $\Delta s = 20\%$, and the mean dissolved oxygen solubility, b = 280 mmol m^{-3}, we may estimate the productivity as $hb\Delta s/\Delta t$ (McNeil and Farmer, 1995). This leads to a net production rate of 1.12 molO_2 m^{-2} day^{-1}. Using a photosynthetic quotient, PQ = O_2:CO_2, of 1.2 (typically in the range of 1.1–1.2; Kirk, 1983) would imply a carbon production rate of 0.93 mol CO_2 m^{-2} day^{-1}, or 11 gC m^{-2} day^{-1}. This is a factor of ten times more than that derived from the change in fluorescence.

The above analysis indicates the levels of uncertainty associated with these kinds of estimates. We do, however, expect the estimate derived from fluorescence to be less than that derived from oxygen as fluorescence is typically quenched during the day as a result of light exposure (Denman and Gargett, 1988). The magnitude of this effect is not known for these data. It would, therefore, be inappropriate to combine the above results to infer a C:Chl ratio. We note once again that dissolved oxygen has been measured by two independent methods and both methods provide the same result giving credibility to this production estimate during the bloom of 11 gC m^{-2} day^{-1}.

Questions to be Addressed

Several questions have been identified by this preliminary look at the data:

– How will primary production estimates from these data compare with sediment trap data at the site?

– Is the timing of the spring bloom, or the magnitude of the spring bloom, different from non El Niño years?

– Is the export efficiency of carbon from the upper ocean different between El Niño and non El Niño years?

We invite other investigators to help address these questions through correspondence and data comparison.

Acknowledgements We thank Frank Whitney, Howard Freeland, Ken Denman and Angelica Peña for discussions and use of their data, and Kevin Bartlett for assistance with data collection and processing.

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