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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Background

Once-a-day measurements from shore stations are among the few records of low-frequency oceanographic variability. At several stations along the west coast of the United States, decades of temperature data have been collected by once-a-day "bucket" techniques (SIO, 1998). These are adequate for some analyses, if highly motivated volunteer observers are available (Reid et al., 1958; Roden, 1963; McGowan et al., 1998). However, it is difficult to find careful observers that will continue over the decades of measurement needed to monitor low-frequency ocean changes, e.g. local manifestations of climate change due to global warming. Consequently, it is important that automatically recording instruments be used in place of observers. In this case, the observer's role changes from daily operator of unsophisticated equipment to less frequent operator of sophisticated electronic equipment that requires careful calibration and monitoring. This Technical Memorandum is a report of the ability of conductivity and temperature measuring probes (CT-probes) to operate continuously in sub-littoral (2-5 m below lowest tide) conditions at Granite Canyon, California.

Value of the Granite Canyon sampling site

Records of once-a-day temperature measurements taken 5 to 30 times per month at the California Department of Fish and Game (CDF&G) Granite Canyon laboratory begin in 1971. Once-a-day salinity sample collection was initiated in 1986 (SIO, 1998). When long records are available, climate-scale changes in physical processes and resulting biological activity such as fish stock recruitment are more easily analyzed (Norton, 1987; Norton, 1999).

The Granite Canyon location, 11 km north of Pt. Sur, is on the unprotected central California coast. Measurements at this station are less influenced by local heat and water exchanges that may confound shore station measurements made in harbors and bays (SIO, 1998). Nearly constant wave action and vigorous wind-forced ocean transport at Granite Canyon (Breaker and Mooers, 1986) reduce the influence of local factors. Since there are no major rivers within 150 km of Granite Canyon, freshwater runoff would be expected to have only transitory influence on temperature and salinity measurements. Temperature measurements made at Granite Canyon may be representative of areas encompassing more than 4,000 km^2 of adjacent ocean (Breaker and Mooers, 1986; Breaker and Broenkow, 1994; Traganza et al., 1981).

The ocean record from Granite Canyon is especially important because both temperature and salinity measurements by standardized procedures are available. "Bucket" water samples are obtained and saved in "poly-seal" bottles at the same time sea temperature is measured. These water samples are shipped to Scripps Institution of Oceanography where salinity is measured using salinometers with accuracy between .01 and .004 psu. Regular data reports for Granite Canyon and other shore stations along the west coast of the United States are available from Scripps Institution of Oceanography (SIO, 1998).

Project goals

Since about 1992, greater requirements on and reassignment of CDF&G personnel at the Granite Canyon Laboratory have resulted in reduction in frequency of once-a-day "bucket" measurements. In March 1995 personnel from the Pacific Fisheries Environmental Laboratory (PFEL), in cooperation with the Real-Time Environmental Information Network and Analysis System (REINAS) experiment of University of California, Santa Cruz (Fernandez et al., 1996) and the CDF&G installed a Sea Bird Electronics (SBE)[1] Conductivity Temperature (CT) probe to obtain high temporal frequency measurements and to gain experience in using these instruments in collecting high-quality time series data at shore stations.

High-resolution records add dimension to existing data sets for this site. The effectiveness of the once-a-day "bucket" measurements in depicting the ocean environment can be assessed and the effects of missing intervals of daily sampling (mid-1990s to present) can also

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be examined for accuracy. High-resolution CT probe records provide continuous monitoring of the ocean environment and resolve a more extensive range of time scales than once-a-day "bucket" measurements. "Bucket" measurements at Granite Canyon are always made during daylight hours. The CT measurements allow the once-a-day measurements to be compared to measurements made throughout the daily cycle. Effects of tides and the daily solar cycle can also be assessed and analyzed as the higher frequency data become available.

Continuous high-resolution records are used by oceanographers and meteorologists in analyzing and predicting marine air-sea interactions such as those leading to the formation of marine fog (Norton and Schacher, 1980). The records may also find use in detecting and monitoring El Niño warming events (Norton et al., 1985; McGowan et al., 1998).

Electronic measurements allow the data to be transmitted, automatically processed and made available over the Internet via the REINAS network (Fernandez et al., 1996). Because of the sensitivity of temperature change at Granite Canyon to regional forcing mechanisms such as wind forced upwelling (Breaker and Mooers, 1986), real-time access to the data could be useful in directing pollution prevention and mitigation activities and possibly in ocean search and rescue operations.

Installation and maintenance

The CT-probe is installed inside a 0.203 m inside diameter pipe which extends to the bottom of a 10 by 20 m natural pool. The pipe is slotted with 5 by 20 cm openings and is one intake for the CDF&G laboratory sea water supply. Within pipe installation allows relatively easy access to the instrument and does not require SCUBA diving to insure secure installation. The sub-littoral pool is open to circulation at north and south ends. When ocean swell greater than one to two meters breaks over the westward rock barrier, mixing from the seaward side is continuous. The pool is 5 to 7 m deep and the installed CT remains more than 2.4 m below the sea surface (sub littoral). Bathymetry seaward of the sampling site slopes steeply from the littoral zone to more than 100 m within 2 - 3 km of shore. Access of ocean water is not impeded by bays, promontories or peninsulas. Sea breeze effects are minimized by the steep aerial topography shoreward of the site and winds generated by differential diurnal heating are channeled parallel to the coast. Changes in wind direction are frequently detected in the sea surface temperature within 12 hours. These temperature changes are similar to those found at sea in the area of Pt. Sur and along the central California coast (Breaker and Mooers, 1986). However, the fixed subsurface temperature data have important differences from surface "bucket" temperatures, as discussed below. Once-a-day “bucket” measurements are made within 3 - 4 m of the CT-probe location.

Positioning of the CT-probes inside the pump intake pipe of the CDF&G laboratory sea water supply system protects the probes from objects - rocks, kelp, driftwood, carcasses and other flotsam and jetsam - that may be tossed about by breaking waves that will occasionally exceed 6 m height. At the same time, the proximity to this turbulent environment promotes exchange of water with the open sea. However, installation at this location precludes attachment of chemical anti-fouling devices to the CT-probe. As a consequence bio-fouling in the salinity cell leads to loss of its utility after a few month’s deployment.

Four-lead cable connecting the CT to the power supply and data decoder (SBE "Opto" data and power interface box) ascends a cliff 30 m to a terminal box at the REINAS meteorological station, then 65 m to a building maintained by CDF&G. The cable is protected within a flexible plastic conduit with 0.5 cm wall thickness. This installation has been in place since February 1995. Initial problems with instrument grounding were solved by SBE and REINAS engineers. Recording of useful data began on March 31, 1995 with the model 1475 CT-probe. Appendix 1 lists all data files collected from March 27, 1995 to August 7, 1998.

Conductivity and temperature were measured with model 1475 and model 1441 SBE instruments. The model 1475 also records hydrostatic pressure in decibars (herein expressed as water depth in meters) at each measurement cycle. In either case, temperature and conductivity (converted to salinity with calibration data) were recorded 30 to 120 times an hour (0.5 to 2.0 min^{-1}). Data are stored internally by the CT and may also be monitored using SBE-provided software and the "Opto" interface box. Cooperation with the REINAS group allowed near real-time monitoring of CT output over an Internet connection.

Periodically (5 to 13 months), the instruments were exchanged and the out-of-service instrument was returned for factory calibration. The model 1475 probe was installed for over 8 months before temporary failure of salinity function. The model 1441 probe was deployed for more than 12 months during 1997 and 1998. However, in the latter case, significant degradation in salinity measurement was observed. Calibration and recalibration procedures are the major maintenance costs of the installation. Occasionally the deployed probe was retrieved and the salinity cell cleaned with medical swabs, Triton X100 detergent and alcohol. It appears from subsequent analysis that cleaning can be effective in restoring the original measuring properties of the salinity cell, depending on the nature and extent of biofouling.

REINAS, Internet accessibility to the CT-probe data

REINAS engineers helped with initial installation of the CT probe at Granite Canyon and arranged for near real-time Internet display and access to the CT data (Figure 1). REINAS is an engineering research and development program linking several local institutions. The goal of REINAS is to design, develop and test an operational prototype network for environmental data acquisition, management, and visualization (Figure 1).

The network gathers data in real-time from standard oceanographic and meteorological instruments (including the Granite Canyon CT-probe) plus continuous video and available satellite images (Fernandez et al., 1996). Demonstrations of REINAS capability in graphical display may be accessed on the Internet at:

http://csl.cse.ucsc.edu/projects/reinas/demos.html

Linking CT-probe data streams into the REINAS network allows the CT-probe to be monitored from any location with Internet access. The REINAS network provides a prototype of how data from a variety of sources might be collected, archived and made available in the future (Fernandez et al., 1996). However, it has not been possible to rely on the REINAS network as a sole data source because a limited amount of development programming has been done for each data collection node. REINAS conversions of the CT-probe hexadecimal data files are available only for the model 1475 CT and not for the CT lacking a pressure sensor (model 1441) during the period reported herein. In the current configuration the REINAS system stores data at the data collection node that are also transferred by radio or hard-wire link to the Computer Science Laboratory at the University of California at Santa Cruz (Fernandez et al., 1996).

Occasional radio link failure accompanying local power loss and storage disk malfunction has caused CT data to be lost and degradation of the REINAS data set. Fortunately, PFEL personnel have collected a complete series of data segments from the instruments by frequent downloading from CT data storage (Appendix 1). If, in the future, data segments are lost at a time when the REINAS system is fully functional, the data file may be obtained from the REINAS archive.

Graphic displays available through the REINAS Internet site for three data sensor channels can be produced on temporal scales ranging from hours to months. Temperature, salinity and depth channels may be displayed together or individually (Figure 1). When the model 1475 CT-probe is installed it is possible to check the status of each channel for accuracy and responsiveness. The addition of the CT-probe to the REINAS systems creates a valuable tool for monitoring the marine environment on the unprotected coast south of Monterey Bay.

Data processing

The data are stored internally by the CT-probes. Model 1475 CT, which records scan number, temperature, salinity and depth, will store 42810 data cycles and model number 1441 CT, which records scan number, temperature, salinity, will store 65213 data cycles.

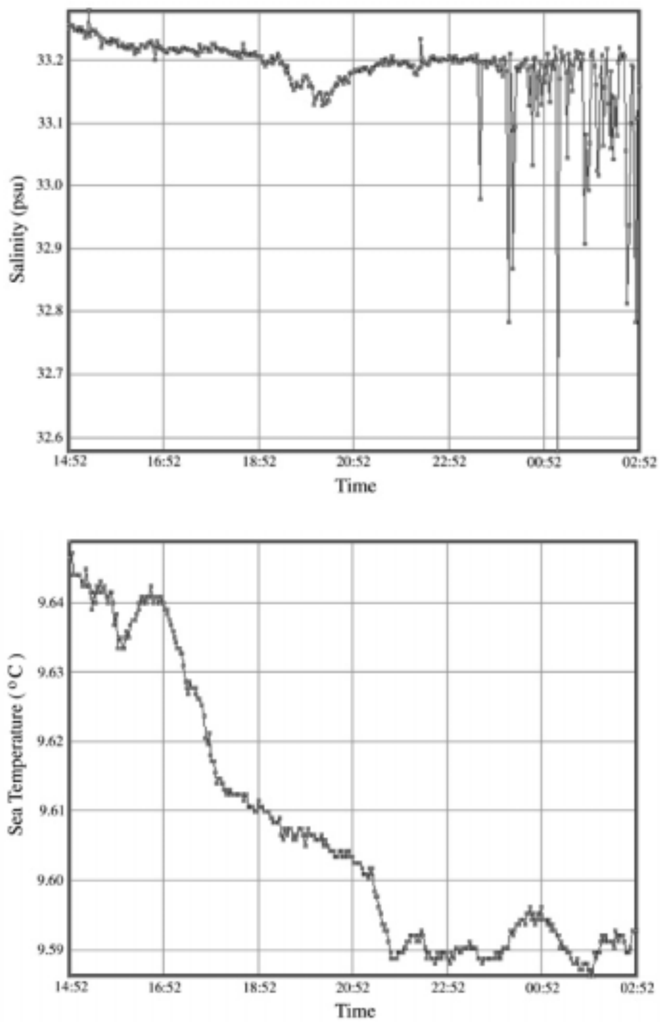

Figure 1. Twelve hours of CT-probe data obtained during an upwelling episode as displayed by the REINAS web page "Demonstration" option. Upper panel shows recorded salinity and the lower panel shows sea temperature for the 360 data points available. These data were sent from the Granite Canyon laboratory by radio link and then put on an Internet server at the University of California, Santa Cruz (Fernandez et al., 1996). Noise spiking to lower salinity shown after 2300 is discussed in the text.

Internally stored data files are periodically downloaded to a portable DOS-based computer by PFEL and CDF&G personnel. The data set from each download session is called a "segment." Segments vary in length from 3 to 70 days (Appendix 1).

Several factors go into making the segments different from one another. First, sensor response characteristics changed as deployment time increased. Second, the mechanical environment influenced the noisiness of some signals, particularly salinity. Third, the electrical environment varied from segment to segment as influenced by the 60 cycle/sec (Hz) power source and possibly radio frequency interference. These differences have been accommodated in developing processing techniques that can be applied uniformly to the entire data set.

The 41-month (1316 day) series sampled 30 hr^{-1} are cumbersome data sets within the available computing environment. The record for a single year may exceed 20 megabytes when date time data are included in each sample cycle. For this reason segments and samples of original data sets may be used in examples and Figures.

Preliminary processing (daily temperature)

SBE SEASOFT software was used to monitor data and present early results. When downloaded from the CT, the data are in hexadecimal form. One 12-character data word contains information about temperature, conductivity (16 characters to include depth in the model 1475) and scan number. The scan number is the measurement cycle number starting with 0000 for the first measurement cycle of the segment. Time and date information are added to header files at the beginning of each data collection sequence and before each 1000 scan cycles. Inaccuracies in CT time annotations were found to be less than 1-2 minutes. Header information is conveniently carried through all processing done by SEASOFT software. SEASOFT software adds additional information to the header as processing proceeds (SBE, 1993).

Hexadecimal files were first converted, using the SEASOFT DATCNV module, to ASCII files showing header information, scan number, temperature, salinity and depth (if available). Data were averaged into 24 hr intervals, centered on 1200 PST using SEASOFT BINAVG. SEASOFT BINAVG was also used to convert files of data sampled at 30 second intervals to 120 second spacing (see Appendix 1). In general there were few problems in this method of processing, aside from incrementing the date discrepancy caused by the leap day in 1996 and an occasional power fluctuation that caused the instrument to cease recording data and sometimes commence again. On one occasion, before March 1995, CT memory reached maximum capacity and recording stopped. In terms of internal data recorded, the instrument and SEASOFT software are well suited to preliminary processing of temperature and pressure when extensive corrections are not needed. After the SEASOFT conversion from hexadecimal to ASCII representation of temperature, salinity and depth, the largest part of the data presented in this report was processed using MATLAB (MATLAB, 1994).

Reduction of "noise" frequencies.

Noise (signal variance or energy at frequencies unrelated to the analysis) can be treated as either quasi-random or systematic. Quasi-random noise has apparently spurious positive and negative excursions: data streams are made more tractable by smoothing and filtering. Systematic noise (one-way spiking) will be modified but may not be removed by smoothing and filtering processes used routinely for quasi-random noise reduction. The noise encountered can be further classified into low-frequency (less than one hour in the present case) and higher frequency. Three approaches were taken in removing noise from the raw data series. First, higher frequency systematic noise in salinity data was reduced with a one way persistence filter (described below). Second, wide-banded quasi-random noise in temperature, salinity and pressure was reduced with a low-pass fast Fourier transform (fft) filter (cut off = 1 hr). Third, after data decimation from 30 to two samples per hour, low frequency systematic noise in salinity was reduced by comparison to once-a-day bucket sampling. Figures 2, 3 and 4 show before (upper) and after filtering (lower panels) for an April 1995 series.

High-frequency systematic noise reduction

Temperature and salinity data were frequently characterized by single datum one-way transients of more than 10 times the expected standard deviation. If these spurious data points are not removed, systematic offsets will be introduced into accepted smoothed series.

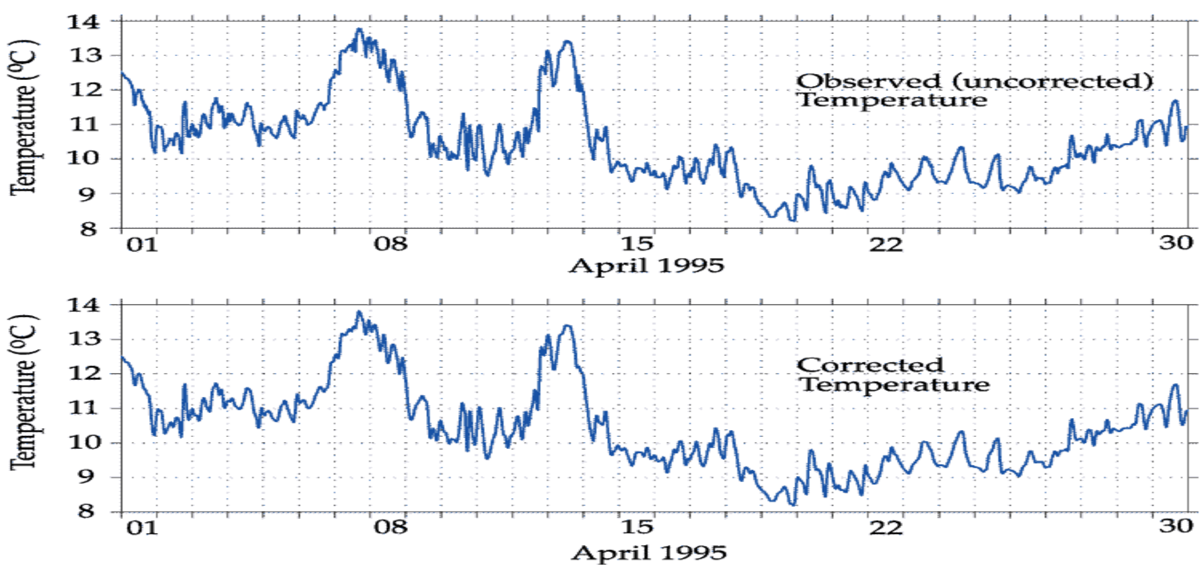

Figure 2. Processing of CT-probe temperature (upper panel) involved fast Fourier transform smoothing (see text) and decimation from 30 to 2 samples per hour. The upper panel shows observed 30 samples per hour data and the lower panel shows smoothed and decimated temperature data for April 1995. Similarity of traces suggest little need for additional processing.

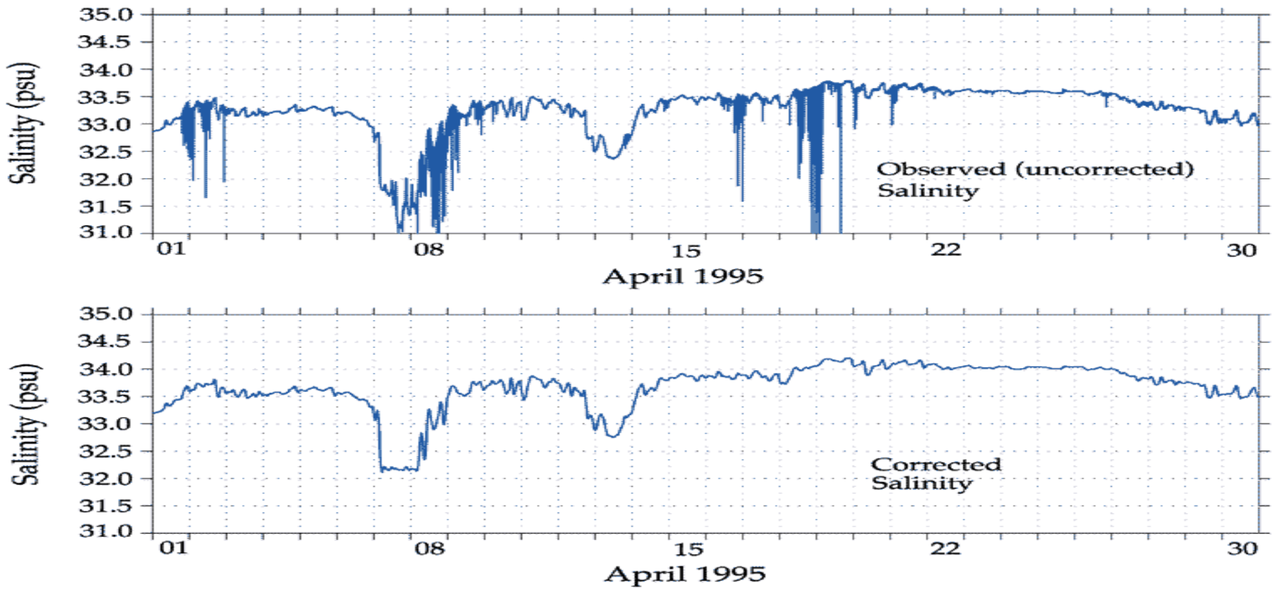

Figure 3. CT-probe salinity for April 1995. Systematic noise intervals occur near the 2nd, 8th and 18th of the month (upper panel). The lower panel shows the data after "step" filter, fft smoothing, decimation and low- frequency adjustment using bucket measurements. Note that the downward spiking noise is removed by filtering and the entire curve is displaced upward by the low frequency drift correction. The flat area during April 7th is a period where salinity values lower than 32.2 were adjusted to 32.2. See text for additional details.

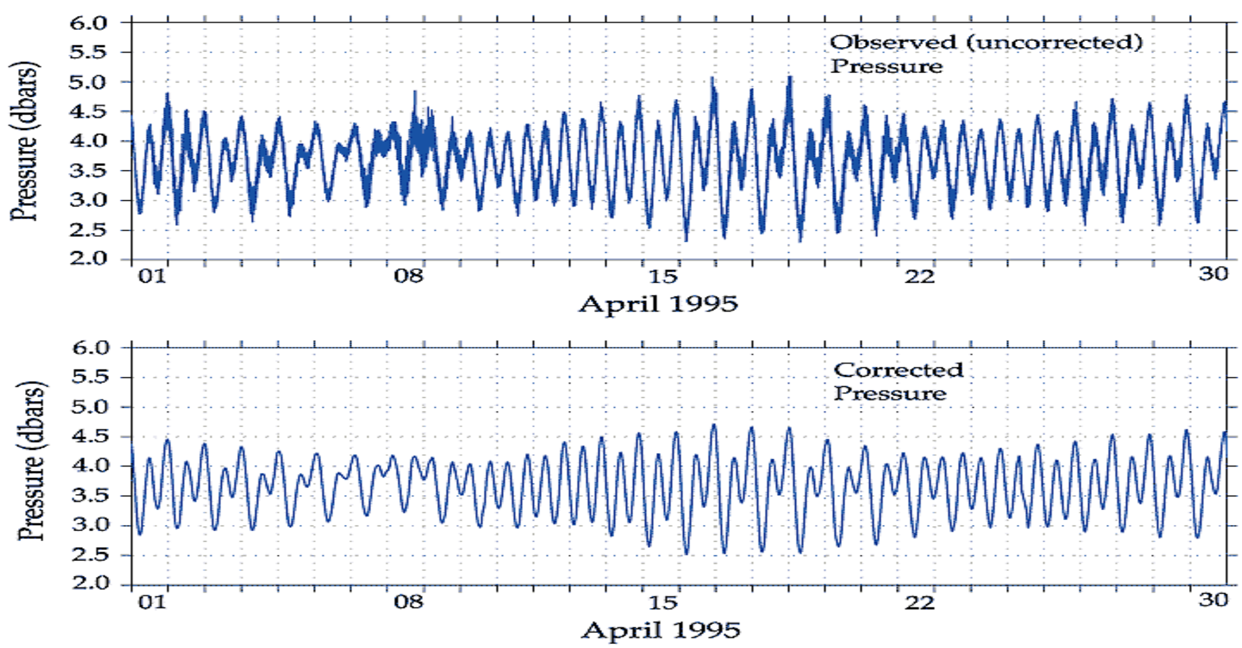

Figure 4. Processing steps converting observed (upper) to corrected (lower) pressure (dbar or depth in meters) were fft filtering and decimation. Sea swell is shown by a thickening of the line in the upper panel. Note that the line thickening in this figure corresponds to downward spiking in Figure 3, suggesting a connection between swell and noise in the salinity measurements.

These transients, lasting one to 10 times the two minute sampling rate, were most frequent in the salinity channel where they were toward lower salinity (Figures 1 and 3). Similar, but less frequent noise in the temperature channel was effectively eliminated by an fft filter (Figure 2).

When high-frequency oscillations due to sea swell increase in the pressure series, there is corresponding increase in downward spiking in the salinity channel (Figures 3 and 4). From this and on site observations, it is reasonable to conclude that one-way salinity spiking is caused by bubbles being formed and forced down to the level of the salinity sensor by breaking waves. Bubbles within the conductivity cell reduce conductivity (and calculated salinity) of the contained sea water volume (SBE, 1993).

A multi-pass "step" or persistence filter was developed to reduce systematic noise in the salinity data (spiking to lower values). This filter is based on the assumption that the coherent maximum values, shown in the upper panel of Figure 3, most accurately reflect salinity changes in the sub-littoral pool. The filter works from the earlier to later salinity values (S(1), S(2), ...S(n)....). Each sample, S(n), is compared to the values that precede and follow it. The temporal range of comparison and or replacement is the interval T. If the test value, Vt, is less than the test values derived from the data, then the mean or max of

...... S(n-2), S(n-1), S(n), S(n+1), S(n+2) ......

for interval, T, replaces the data value tested, S(n). The T and Vt values were adjusted empirically to permit minimum degradation of sample-to-sample variability in the 1995-1998 record. Comparison of upper and lower panels in Figure 3 shows that when the persistence filter procedure is combined with outlier removal and fft filtering, downward (and upward) spiking is significantly reduced. The five discrete test and replacement processes used are as described below. Each process was designed to meet specific noise reduction and down-stream processing requirements.

I. Salinity values exceeding 34 psu were replaced with the mean value of 140 samples equally spaced around the test value (T = 280 min). The wide replacement range was used to avoid data values (S(n)) characteristic of spiking to lower salinity. Data values above 34 psu were rare (<0.01%) and by coherence considerations were outliers in the CT data. The origin of high-frequency spiking to higher salinity is unknown. After process I two data sets were used in further processing: the series "sal", which is progressively modified through the next steps, and "rsal", which is the "raw" or unprocessed data set. Where possible, apparently bad values in "sal" were replaced with values derived from "rsal." These replacements counter the tendency for progressively aliasing the "sal" series through successive manipulations.

II. This process tests whether consecutive values differ by more than 0.2 psu (Vt). If (sal(n) - sal(n+1)) is more than Vt, then sal(n+1) is made equal to the maximum of "rsal" from n-3 to n+14 (T = 9 min.). This process removes most of the spiking to lower salinity (Figure 3). The process will not track precipitous value-to-value declines and increases unless adjusted to reach forward (n+14) for the maximum values of the "rsal" data series. The forward reach is minimized empirically. Vt might be increased to minimize the span of T, but this would leave larger negative offsets in "sal." In the worst case, there may be a 30-minute forward shift of signal segments, half the decimated data's Nyquist frequency.

III. This step flags outliers with a constant value. Records from once-a-day "bucket" measurements obtained during 1986 - 1997 show that salinity at this site is seldom less than 32.5 psu. To allow for exceptional salinity values, all values less than 32.2 psu were made equal to 32.2 psu.

An example of step III processing is shown for data from 7 - 8 April, 1995 (Figure 3). This process was added to flag values reasonably assumed to be incorrect and to keep persistent out-of range values (< 32.2 psu) from interfering with processing steps that depend on averaged "sal" values.

IV. This step modifies the "sal" series with three passes that detect steps in consecutive samples that increase "sal" more than 0.1 psu (Vt). If (sal (n+1) - sal(n)) is more than

Vt, then “sal” is replaced with the mean of 30 consecutive values distributed around sample number (n).

Process I was used for multi-point outlier groups. Step IV reduced the influence of one, two and three consecutive excursions to non coherently higher salinity, which represent less than 0.01% of the data set. If these positive excursions are not removed, they will be shifted to lower frequencies and by the maximizing steps that follow.

V. The final process aims at finer scale adjustment of values that are more than 0.03 psu (Vt) below the local mean. Here the mean of 7 points about sample n is compared to a value sal(n+1). If the value tested is more than Vt lower than the mean, it is given the maximum value of consecutive sample numbers, n, n+1, n+2 and n+3, of “rsal.” This process corrects some of the offset left by the relatively large value of Vt needed in process II (0.2 psu). A smaller Vt is needed in this step because the “sal” series has less noise after the preceding processes. Other filtering steps and sequences of steps may be as effective in reclaiming the salinity data as the ones discussed above.

Fast Fourier transform (fft) filter

An fft low-pass seventh-order Butterworth filter was developed and implemented in MATLAB (MATLAB, 1994). Allowable band pass attenuation was 3 decibels for frequencies lower than 0.333 hr-1. After filtering in the forward direction the filter was run through the once-filtered data in the reverse direction to produce zero-phase distortion. Forward-back filtering minimizes start-up and ending transients. These filtering processes remove quasi-random high and low spiking from each channel [e.g. swell signatures from the depth (pressure) channel]. This fft filter was used for all three channels (Figures 2, 3 and 4).

Tests made throughout the three-year sampling period and comparison of pre- and post- deployment factory calibration of the sensors indicate that the temperature and pressure sensors are accurate to within 0.01 °C and 0.01 m, respectively. Temperature and depth data were assumed to be accurate and received only fft filtering. The complete decimated temperature record is shown in Figure 5 along with the available bucket observations and an historical mean derived from "bucket" measurements.

Low-frequency systematic noise reduction in salinity data from independent “bucket” measurements

The CT-probe salinity data stream consistently drifted to lower values relative to “bucket” measurements as a consequence of the settling of algae and invertebrate larvae from the ambient plankton. As organisms settle and grow, the effective volume of the conductivity cell is reduced and the new cell geometry will result in recording of lower salinity because of decreased conductivity in the vicinity of the measuring electrodes (SBE, 1993). Stanton (Department of Oceanography, Naval Postgraduate School, 833 Dyer Rd, Monterey, CA) has observed that both the slope and intercept of the calibration curve will change as biological colonization occurs in the conductivity cell and in the vicinity of the electrodes. Therefore, correction is needed to insure proper interpretation of CT salinity records.

Herein, we use a correction to salinity based on the composite drift observed between electrode cleaning or refurbishing to recover 83% of the decimated salinity values. It is conservative to start with a linear approach and use the knowledge gained in this study to work toward more effective reclamation of CT-probe salinity series.

There were seven instances when the instrument was replaced with a refurbished CT or the conductivity cell of an in-place CT was cleaned. The composite slope of daily difference between CT measured salinity and “bucket” derived salinity (delta s) is shown in Figure 6. The day’s “bucket” measurements were taken to be between 0900 and 1300 hours and the day’s CT measurement was a mean of the measurements made during this interval.

In correcting the decimated salinity, each series was displaced (offset) by the intercept value of the individual linear fits to observed drift. Additional correction is added according to the composite linear fit shown in Figure 6. Calculations leading to Figure 6 measure time in days, but the slope was used to interpolate data corrections to 30 minute increments. Where concurrent “bucket” salinity corrections where not available, the average intercept was used with the composite linear fit (Figure 6). Those parts of the corrected salinity record that consistently diverged more than 0.3 psu from the “bucket” salinity were not “accepted” for further consideration in this report.

Note that fitting the composite of several drift sequences with any curve will have difficulties because individual drift sequences have different character. The fit is similar for first- (L = linear), second- (P2), and third-degree (P3) polynomials. Examination of Figure 6 shows that in the first 100 days the fit is balanced by different time dependent responses. For instance, the drift response for cases shown by triangles and circles will pull the fit down and the response shown by cases repre-sented by squares and asterisks pull the fit up. Consequently, none of the three fits provide an excellent match to observations in the 40 to 60 day range. Increasing dispersion (scatter) of points after the 80th day emphasizes the value of more frequent and more thorough salinity cell cleaning (Figure 6). There may also be seasonal and temperature related drift dependence that will become more evident as drift information is accumulated from the CT-probes deployed at the Granite Canyon site.

Comparison of sampling years

Comparison of the mean annual thermal cycle from historical "bucket" measurements, available "bucket" measurements and CT probe measurements allows several general observations. Regularity in the annual cycle is shown in the CT, and concurrent "bucket" sampling (Figure 5).

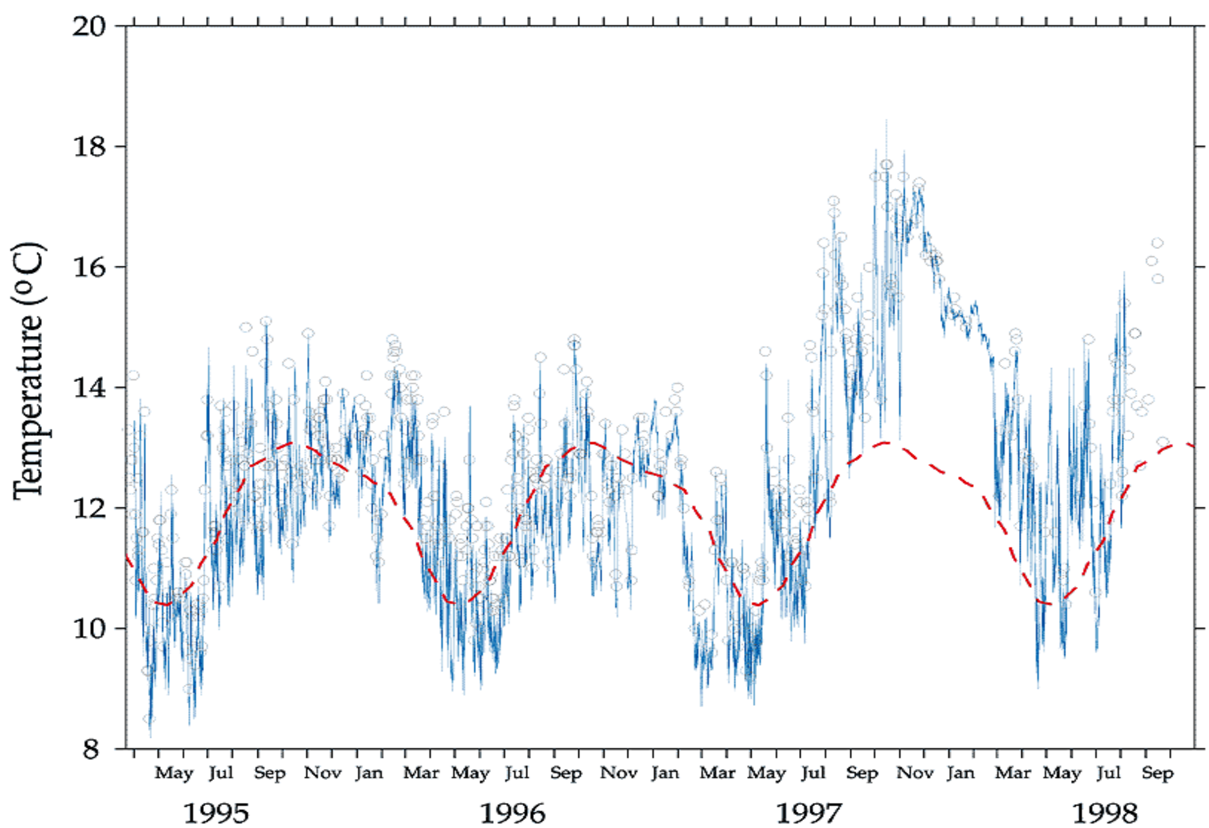

Figure 5. Temperature time series comparison of "bucket" (circles) and decimated CT series (fine line) for the period from March 1995 through August 1998. Temperature is in °C. The simple linear regression between the two sets of values (converted to 24 hr averages) gives an r of 0.89 to 0.95 depending on time period (r = 0.92 overall). "Bucket" measurements were made on about 40% of the days. Factory recalibration of CT-probes shows that the instruments maintain calibration within 0.01 °C during deployment. The heavy broken line gives a smoothed climatology based on monthly mean "bucket" measurements for 1973 - 1994 (SIO, 1998).

Interannual, annual and seasonal variability is clearly evident in magnitude and temporal position of maxima and minima shown in Figures 5, 7, 8 and 9. As would be expected, there is coherence between "bucket" and CT temperature measurements (correlation coefficient, r = 0.92). "Bucket" sampling appears adequate for low-frequency sampling. Higher frequency detail is apparent in CT data series.

Persistent differences between CT and "bucket" temperature measurements may be traced to the diurnal cycle. The average monthly "bucket" temperature is 0.4 - 0.5 °C above the monthly CT average. This difference may be primarily due to CT sampling throughout the diurnal cycle. "Bucket" temperatures are always made during daylight hours. Spectral analysis shows a spectral peak at 1 cycle per day (see below). Insolation of the sub-littoral pool and surrounding ocean probably causes day time "bucket" SSTs to be higher than 24-hr mean CT temperatures.

The 1997-1998 El Niño signal is shown by 2 - 4 °C positive temperature anomalies from October 1997 through June 1998 (Figures 5, 8). Lesser positive anomalies span from May 1997 through August 1998. The annual cycle was exaggerated and displaced: mean maxima occur in October and the 1997 maxima was in November. Minima for the climatological and measured temperatures during 1997 were in April and March, respectively. The difference between maxima and minima for 1997 was greater than the mean SST extreme and greater than that observed in the other two years of observation. CT and "bucket" measurements during the 1997 - 1998 winter (Figure 5) show that the amplitude of variations of 1-10 day period was 5% to 10% the amplitude of variation found in the rest of the record.

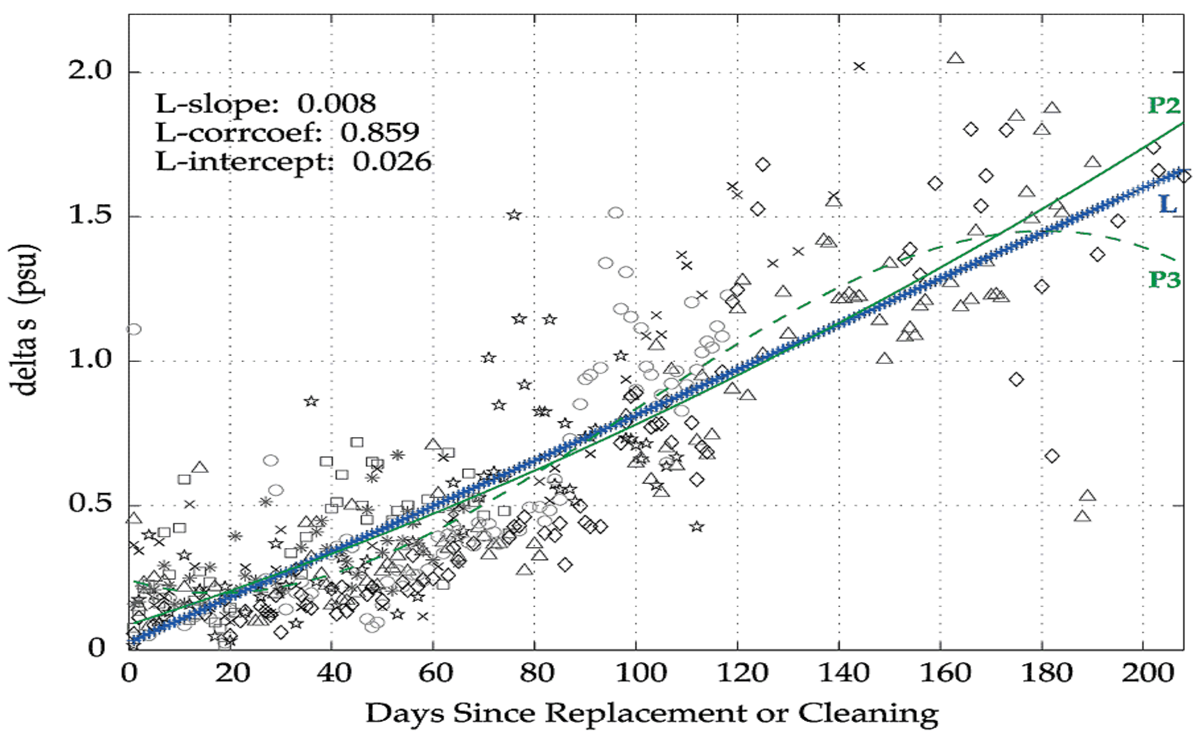

Figure 6. Differences between "bucket" salinity and average CT salinity (delta-s) plotted against the number of days after installation or cleaning (abscissa). Delta-s is the "bucket" salinity for day n minus average CT probe salinity between 0900 and 1300 hours for day n. Different symbols represent seven periods of salinity-cell drift monitoring. Points from all drift sequences, measured from replacement or cleaning were used in curve fitting. Delta-s points for the first (circles) and fifth drift series (squares) were displaced -0.29 and -0.70, respectively, to adjust for high intercept values. Derived low frequency corrections from the linear fit (L) were used to adjust the decimated CT-probe salinity to obtain the "corrected salinity." Second (P2) and third degree (P3) polynomial fits to these data are shown by the solid and broken lines, respectively.

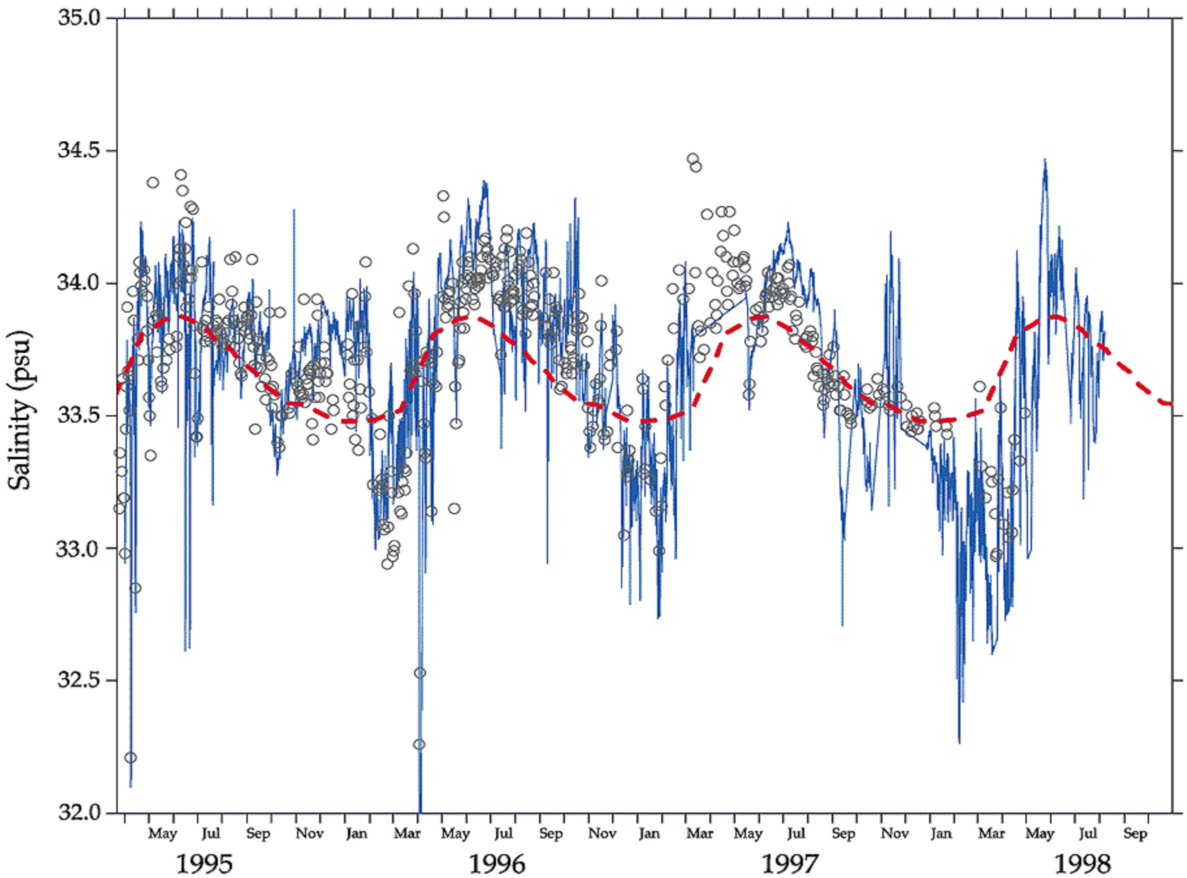

Figure 7. Comparison of "accepted" CT salinity (line) and "bucket" salinity (symbols). The interval compared is the same as for Figure 5. The corrected CT salinity is deleted where it consistently diverged more than 0.30 psu from the "bucket" salinity. These divergent intervals are shown by straight lines connecting areas of normal variability. Eighty-three percent of the decimated values have been retained in the set of "accepted" salinity (line). The heavy broken curve shows historical annual cycles from monthly means of "bucket" sampling during 1973-1994 (SIO, 1998).

During 1997, the spring transition was the earliest observed during the 1995-1998 CT observations. 1996 was the coolest year of CT observations (Figures 5, 8 and 9).

Power spectra

An example of power spectral analysis on 30 sample hr^{-1} temperature data during 90 days in 1995 is shown in Figure 10. The panels show identical spectra plotted against linear (upper) and logarithmic (lower) scales.

A large portion of the energy is in the lowest frequencies, indicating strong seasonal forcing. Beginning at the low-frequency end of Figure 10 (left), the most energetic peak is found around 0.001 cycles per hour (cph) or about a 42-day cycle. This maxima may be aliased because the short data sequence analyzed. There is a triplet of peaks from about 0.0026 to 0.005 cph (16- to 8-day cycles). Next, maxima are shown for 5.2- and 3.0- day cycles (0.008 and 0.014 cph, respectively). Three to 16-day cycles are evident in Figures 5 and 8. The peaks at 0.038 and 0.042 cph occur at diurnal lunar tide and the diurnal solar cycles, respectively. The relative strength of these signals suggest that the solar diurnal cycle was more important than the diurnal tides. The importance of the solar cycle is also indicated by the general difference in daily temperature between "bucket" and CT-probe temperatures.

Another series of maxima appear between .07 and .09 cycles per hour. These may be harmonics of the maxima around 0.04 cph.

The higher frequency peak at 0.084 cph appears related to the semi-diurnal tides (Figure 10). Several of these maximum frequencies are shown in the power spectra of salinity data from the same period (not shown).

Central California ocean seasons

The CT-probe data from Granite Canyon show the three oceanic seasons reported by Skogsberg (1936) and Skogsberg and Phelps (1946). These relationships were further discussed by Sverdrup et al. (1942) in a general description of California coastal oceanography and by Breaker and Broenkow (1994) and Breaker and Mooers (1986) in their discussions of interannual variability off the central California coast. Present terminology follows Skogsberg and Phelps (1946). The upwelling season is characterized by lower temperatures and higher salinity (Figures 5, 7, 8 and 9). It is the low temperature part of the year that may last from mid-February (julian day or jd ~ 048) to late August (jd ~237).The oceanic season is from late August (jd ~ 238) to mid-November (jd ~ 319). In the mean this period has the highest temperatures as shown by Figures 5, 7, 8 and 9.

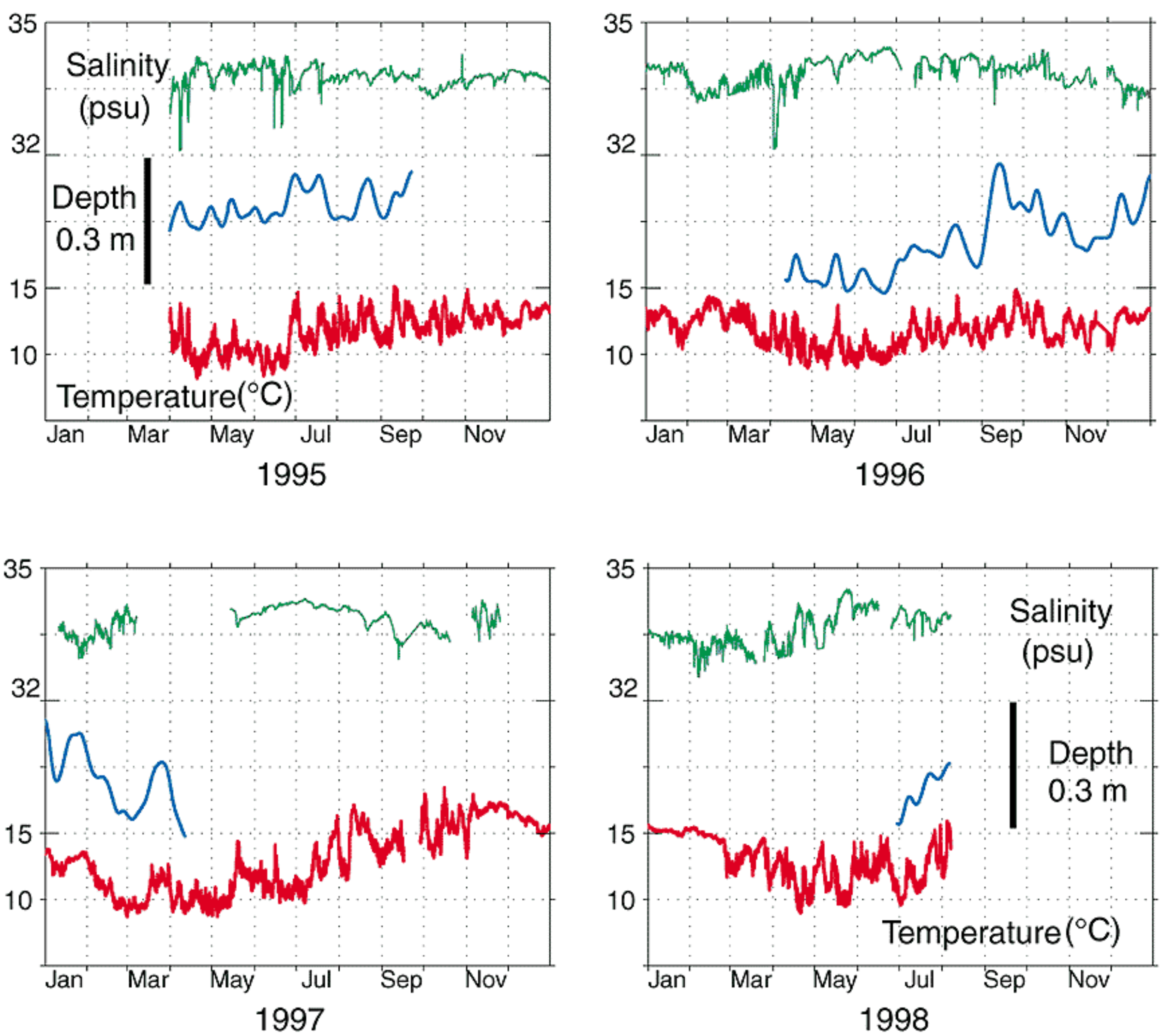

Figure 8. Comparison of pressure, accepted salinity (32-35 psu) and corrected temperature (5 - 15 °C) for the four years of observation. Pressure (depth) is on a relative scale with total range of 0.3 m. Low frequency events are conspicuous in each of the three parameters during each of the four years. All data segments have been smoothed by fft filtering.

The oceanic season is a transitional period from a regime when the subtropical atmospheric high pressure system is well-developed and coastal winds from the northwest are common to a period when the Aleutian low atmospheric pressure system has greater influence (Skogsberg and Phelps, 1946; Bakun, 1973; Norton et al, 1985; Norton et al., 1994). Figure 5 shows short periods of elevated ocean temperatures occurring between late July (jd ~ 210) and late October (jd ~ 300) of 1995, 1996 and 1997. These are the periods of highest daily temperature during 1995 and 1996, but in the 1997 El Niño year this warming period is early and is seen as a local maximum rather than an annual maximum.

The Davidson current season from mid-November until mid February (jd ~ 320 until jd ~ 47), is characterized by northward coastal current and deepening of the coastal thermostructure (Skogsberg, 1936, Reid et al., 1958; Breaker and Mooers, 1986). Figures 5, 7 and 8 show relatively high temperatures and low salinity during this period, when upwelling events of 2-10 day duration may occur. The Davidson current season ends when the spring transition becomes evident (Figure 9).

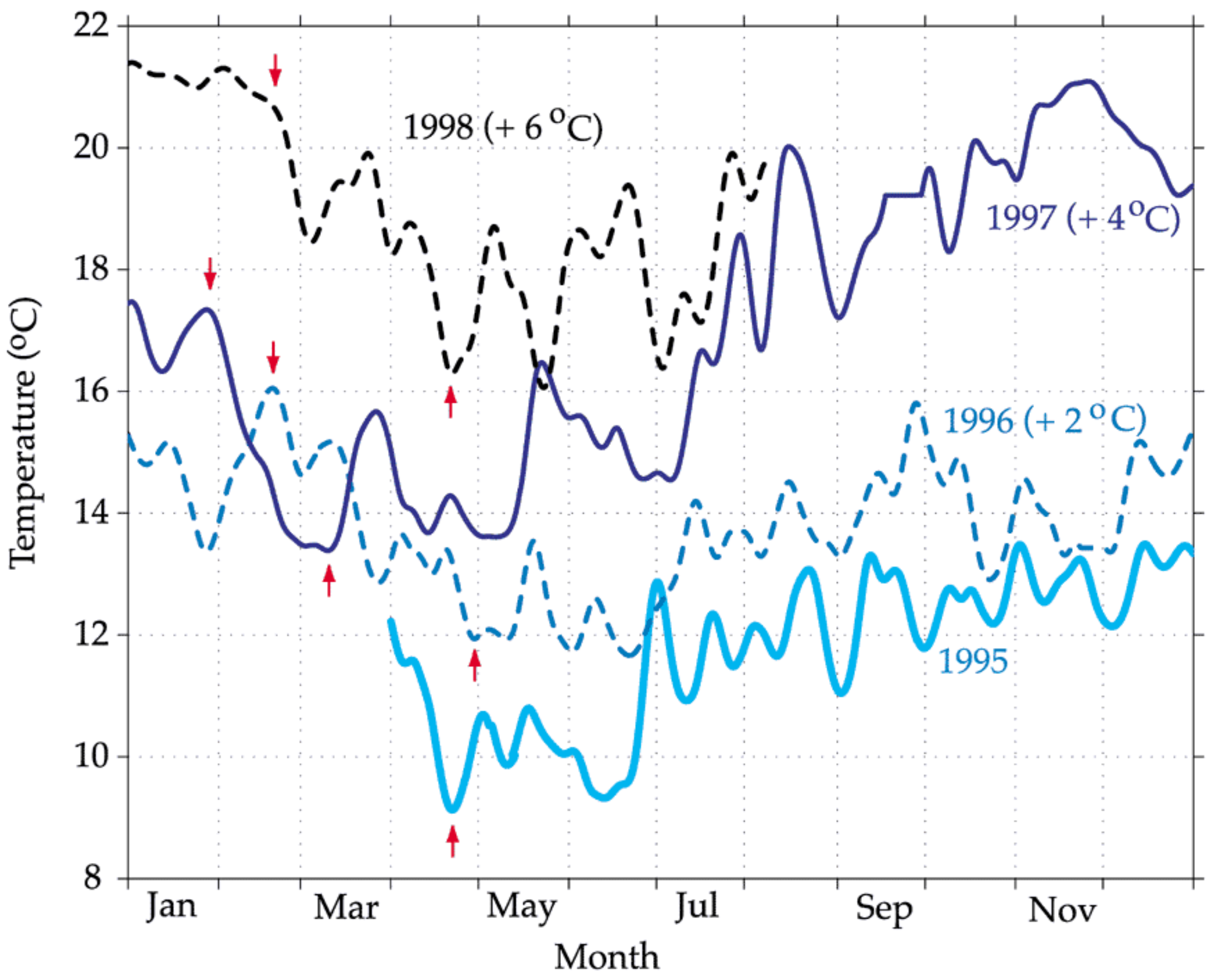

Figure 9. Spring transitions for 1996, 1997, 1998 and partially for 1995 are compared using temperature series that have been smoothed by an fft filter to show low frequency events (see text). The year's traces are successively offset 2°C upward. Downward pointing arrows show the apparent beginning of the spring transitions and the upward arrows show the approximate end of these events.

During El Niño years (Figure 5, 8), the greatest positive temperature anomalies and sometimes the warmest annual temperatures are found during the Davidson current period (Norton et al., 1985; Breaker and Mooers, 1986; Norto-nand McLain, 1994). An interesting feature of the Granite Canyon SST series is that the lowest temperatures occur during the spring upwelling season in common with offshore temperatures (Skogsberg, 1936; Robinson, 1960). The coolest temperatures at more protected shore stations occur in the winter Davidson current season (SIO, 1998; Norton, personal observations at Monterey Wharf 2.).

Temperature/salinity relationships

Interpretation of time series from shore station measurements is facilitated by an understanding of the source of the water measured. A well-tested method of obtaining this information is to examine temperature/salinity (T/S) relationships (Sverdrup et al., 1942; Lynn and Simpson, 1987; Norton and Crooke, 1994). T/S relationships may be visualized by plotting data pairs with increasing temperature on the ordinate and increasing salinity on the abscissa (Figure 11). In the present case the depth is fixed and a representation of water source is obtained from the position of the data points (Sverdrup et al., 1942).

The importance of coastal upwelling in determining the overall shape of the T/S scatter is indicated by the convergence of values in the lower part of the graph near 34.1 psu and 8-10 °C. This represents the water brought to the surface during extreme upwelling conditions. The triangular shape is similar to that seen in an assembly of T/S points from vertical sampling (Sverdrup et al., 1942).

The low salinity, left margin, of the cluster indicates increase of temperature concomitant with decrease of salinity. This relationship reflects dominant on-offshore water movement off the central California coast. When there is upwelling, surface water is pushed offshore and cooler, higher salinity water comes to the surface. When upwelling episodes end, the on-offshore slope characteristic of upwelling is relaxed and warmer, less saline water from offshore enters the littoral zone. These relationships are shown in Figure 8. For instance, the two temperature maxima shown in July 1995 correspond to two minima in the accepted salinity series. In Figure 11 the points on the right of the cluster suggest processes that change temperature as much as 5 °C while the salinity remains greater than 34 psu.

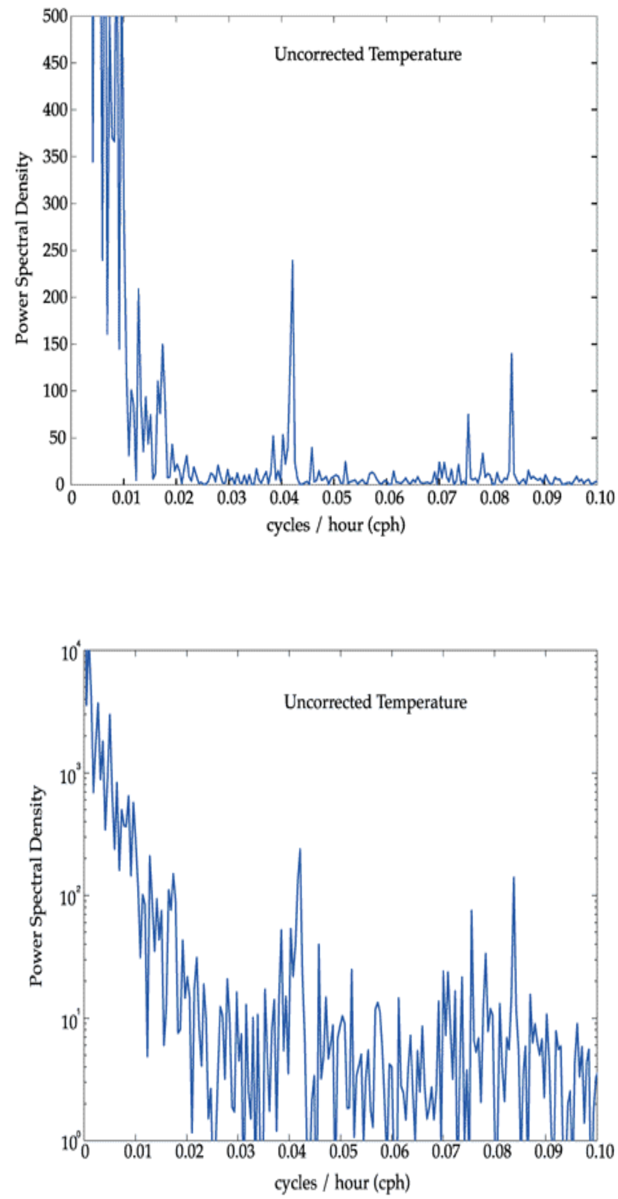

Figure 10. Two presentations of temperature power spectra. The upper panel shows variability, or power, plotted on a linear scale. The lower panel is identical except for a logarithmic ordinate. This is an fft transform of 90 days of 30 per hour temperature data obtained during March, April, May and June 1995. The solar diurnal frequency is shown by the peak at 0.042 cycles per hour.

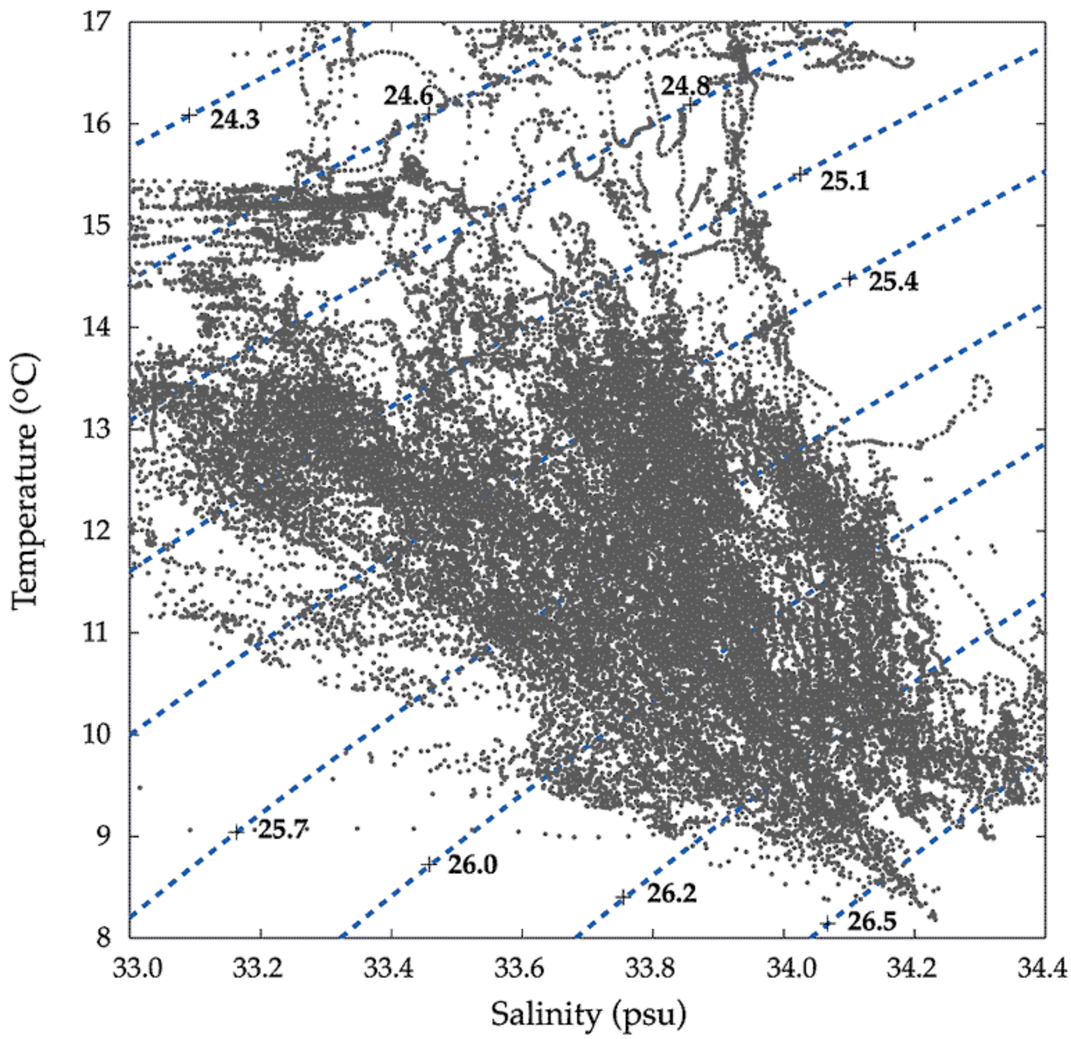

Figure 11. Plot of decimated data pairs of temperature and corresponding accepted salinity (T/S plot). Temperature increases on the ordinate and salinity increases on the abscissa. Curved dotted, diagonal lines show water density as sigma-t.

Comparison to other environmental measurements

CT-probe temperature was found to be correlated with other environmental measurements from the central California coast. CT temperature at Granite Canyon was correlated (r = 0.62) with the standard upwelling index at 36°N (Bakun, 1973; Schwing et al., 1996). Daily averaged CT temperature was correlated (r = 0.63 and 0.55, respectively), with SST from the Cape San Martin and Monterey Bay NOAA, National Data Buoy Center buoys, suggesting significant relationships. The relationships hold when the annual cycle is removed from the comparison. These comparisons with buoys moored 70 km to the south and 50 km to the north, respectively, show physical coherence between SST at Granite Canyon and other locations along the central California coast, confirming earlier results of Robinson (1960) and Breaker and Mooers (1986).

Conclusions and prospectus

Aside from the fact that it is better to have measurements every day, a series of pooled measurements provides a better representation of environmental changes than single daily measurements. We are currently obtaining 720 measurements per day. These pooled measurements (by averaging or smoothing) are better representations of daily temperature and pressure. When sampling does not include complete solar and tidal cycles, the observation of lower frequency events may be biased. The solar cycle varies from day-to-day and the extent of solar heating and the extent of mixing at the time of a single measurement will vary. The tidal cycle will also be aliased into the data when measurements are made at a fixed time each day. In addition, the high temporal resolution CT-Probe measurements allow analyses of daily and higher frequency ocean events at Granite Canyon.

Continuous records such as the ones available from Granite Canyon can provide background for all physical and biological oceanographic studies conducted along the central California coast. It may be possible to distinguish between different types of coastal ocean forcing using comparison of salinity, temperature and sea level time series to standard upwelling index products (Bakun, 1973), locally measured wind forcing (Fernandez et al., 1996), ocean dynamic topography, large-scale indices (Norton and McLain, 1994) and buoy data. Additional studies may allow changes that occur in the adjacent ocean volume to be interpreted as temporal variation at Granite Canyon. Continuous, high-resolution data are important in advancing these efforts. Near-real-time access to the data enhances its value in pollution control, sampling trip planning, bio-toxin monitoring, physical modeling and interpretation of ecological changes.

Deployment of additional CT-probes at other locations on the central coast would also enhance the utility of the Granite Canyon installation, particularly if each installation has near-real-time access. Addition of dissolved oxygen and fluorescence sensors to the CT-probe would improve its utility in biological studies.

Marine plants and animals are sensitive to temperature and major bio-geographic divisions correspond to regions of 1 - 4 °C temperature change (Brinton, 1981; Fields et al., 1993). At a fixed shore station these discontinuities may be measured temporally rather than spatially. Micro-nutrient increase and consequently biological productivity along the central California coast corresponds to decreased ocean temperature with such regularity that the primary (planktonic) productivity can be assessed by an analysis of ocean temperature changes (Traganza et al., 1981). Macro-algae (kelp) growth and proliferation on the central California coast will be a function of temperature changes reflecting nutrient variability. Important ecological processes involving several commercial and recreationally important species are linked to seasonal and interannual variability in kelp forest production (Zimmerman and Kremer, 1984; Tegner and Dayton, 1987; Roughgarden et al., 1988).

An ongoing program combining daily measurements and continuous CT-probe recording will optimize both recording methods. The CT salinity sensor must be kept free of contaminants to maintain calibration. Because settling of algae and invertebrate larval stages from the ambient plankton is continuous, necessary cleanliness of the salinity cell and electrodes is seldom possible for an installed instrument. Therefore, correction is needed to insure proper interpretation of CT salinity records. Once-a-day salinity measurements (as done in the past) allow continuous calibration of CT salinity and they allow rapid changes in CT calibration to be detected (Figure 7). The highest quality records will be obtained when daily salinity measurements are available.

Current plans call for CDF&G personnel to maintain the CT probe system at Granite Canyon, with PFEL serving in a data processing and advisory capacity. CDF&G knowledge of the relationship between species survivorship and oceanic conditions will lead to a more ecological approach to management of marine resources as mandated by California Assembly Bill AB1241.

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We would not have been able to complete this report without the help of Connie Fey of the Marine Life Research Group, Scripps Institution of Oceanography, who provided the shore station data needed to validate CT-probe functioning. George Boehlert, Director of the Pacific Fisheries Environmental Laboratory, provided the support necessary to install the instruments, collect and process the data and assemble this report. Art Stroud and Steven Cummings of the Pacific Fisheries Environmental Laboratory were extremely helpful in providing information and assistance in using computing and graphing equipment and programs. Mike Donnelin and Scott Clark of the California Department of Fish and Game have efficiently taken control of CT-probe operation.

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Appendix 1

DATA FILES FROM GRANITE CANYON CT (1995-1998)

This table lists downloaded segments for the March 1995 through August 1998 period, along with the filenames used for the downloaded segments and the intervals covered by the segments. From 13 February through 16 March several download segments were made during testing and trouble shooting. These early segments contain only short sections of useful information and are not considered in this report.

- 1995 -

DOWNLOAD DATE	SAMPLING INTERVAL	INSTRUMENT MODEL NUMBER	BEGIN DATE AND TIME (PST)	END DATE AND TIME (PST)	DOWNLOAD FILE NAME	PROCESS NAMES
27 March 95	(30 sec)	1475	March 16, '95 1608	March 27, '95 0948	jgn1400.hex	J15.CNV jgn1404.cnv gc_ctd_1.1995
4 Apr. 95	(30 sec)	1475	March 27 1137	April 4 1339	J1500.hex	J154A.CNV gn1504.cnv gc_ctd_2.1995
10 Apr. 95	(30 sec)	1475	April 4 1439	April 10 1451	JGN1600.hex	J1610A.CNV jgn1604.cnv gc_ctd_3.1995

- Begin analyzed record on March 31, 1995 (jd=90) -

25 Apr. 95	(30 sec)	1475	April 10 1606	April 25 0918	jgn1700.hex	Jgn1700.cnv jgn1704.cnv gc_ctd_4.1995
3 May 95	(30 sec)	1475	April 25 1213	May 3 1401	jgn1800.hex	JGN1800.cnv jgn1804.cnv gc_ctd_5.1995
11 May 95	(30 sec)	1475	May 3 1453	May 11 1231	JGN1900.hex	jgn1904.cnv gc_ctd_6.1995
19 May 95	(30 sec)	1475	May 11 1343	May 19 1441	JGN2000.hex	jgn2004.cnv gc_ctd_7.1995
30 May 95	(30 sec)	1475	May 19 1551	May 30 1449	JGN2100.hex	jgn2104.cnv gc_ctd_8.1995
8 June 95	(30 sec)	1475	May 30 1631	June 8 1115	JGN2200.hex	jgn2204.cnv gc_ctd_9.1995

- Change in sampling rate (30 sec. to 120 sec) -

15 June 95	(120 sec) or (720/day)	1475	June 8 1251	June 15 1455	jgn2300.hex	jgn2300.cnv gc_ctd_10.1995
5 July 95	(120 sec)	1475	June 15 1522	July 5 1306	jgn2400.hex	jgn2400.cnv gc_ctd_11.1995
20 July 95	(120 sec)	1475	July 5 1351	July 20 0945	jgn2500.hex	jgn2500.cnv gc_ctd_12.1995

DOWNLOAD DATE	SAMPLING INTERVAL	INSTRUMENT MODEL NUMBER	BEGIN DATE AND TIME (PST)	END DATE AND TIME (PST)	DOWNLOAD FILE NAME	PROCESS NAMES
20 July 95	(120 sec)	1475	---	---	jgn2600.hex	jgn2600.cnv (Note: monitor cleaning of con-ductivity cell; 1-2 hour record not included)

- Conductivity cell cleaned -

8 Aug. 95	(120 sec)	1475	July 20 1213	August 8 1337	jgn2700.hex	jgn2700.cnv gc_ctd_13.1995
28 Aug. 95	(120 sec)	1475	August 8 1421	August 28 1527	jgn2800.hex	jgn2800.cnv gc_ctd_14.1995
7 Sept. 95	(120 sec)	1475	28 August 1614	7 September 1540	jgn2900.hex	JGN2900.CNV gc_ctd_15.1995
13 Sept. 95	(120 sec)	1475	7 September 1704	13 September 1258	jgn3100.hex	---
13 Sept. 95	(15 sec)	1441	13 September 1350	13 September 1415	JGN3200.hex	JGN3200.CNV (Note: 1441 clock time test# 1441 not included in fi-nal data)
27 Sept. 95	(120 sec)	1475	7 September 1704	27 September 0945	jgn3300.hex	JGN3300.CNV gc_ctd_16.ctd (Note: counter uneven / cycle drop out is 1258 to 1441 on 13 Sept.)

- Remove model number 1475 CTD-probe / Install model number 1441 CT-probe -

27 Sept. 95	(15 sec)	1441	September 1235	September 1357	jgn3400.hex	JGN3400.CNV (Note: install / check; not included in final data)
6 Oct. 95	(120 sec)	1441	27 September 1412	October 6 1226	JGN3500.hex	JGN3500.CNV gc_ctd_17.1995
20 Oct. 95	(120 sec)	1441	October 6 1329	October 20 1427	jgn3600.hex	JGN3600.CNV gc_ctd_18.1995
3 Nov. 95	(120 sec)	1441	October 20 1511	November 3 1114	JGN3700.hex JGN3800.hex (Note: 600 b/no error)	jgn3700.cnv jgn3800.cnv gc_ctd_19.1995
18 Nov. 95	(120 sec)	1441	November 3 1253	November 18 1239	jgn3900.hex	jgn3900.cnv gc_ctd_20.1995

DOWNLOAD DATE	SAMPLING INTERVAL	INSTRUMENT MODEL NUMBER	BEGIN DATE AND TIME (PST)	END DATE AND TIME (PST)	DOWNLOAD FILE NAME	PROCESS NAMES
3 Dec. 95	(120 sec)	1441	November 18 1323	December 3 1337	jgn4000.hex	jgn4000.cnv gc_ctd_21.1995
15 Dec. 95	(120 sec)	1441	December 3 1428	December 15 1642	jgn4100.hex	jgn4100.cnv gc_ctd_22.1995
31 Dec. 95	(120 sec)	1441	December 15 1716	December 31 1404	jgn4200.hex	JGN4200.CNV gc_ctd_23.1995

- 1996 -

12 Jan. 96	(120 sec)	1441	December 15 1717	January 11 1049	JGN4400.hex	JGN4400.CNV gc_ctd_1 (Note: file contains data gap from last upload)
3 Feb. 96	(120 sec)	1441	January 12 1501	February 3 1648	JGN4300.hex	JGN4300.CNV gc_ctd_2 (Note: file numbers not sequential)
5 Mar. 96	(120 sec)	1441	February 3 1755	March 5 1549	jgn4500.hex	JGN4500.CNV gc_ctd_3 (Note: CT record date incorrect due to 29 day (leap year) February)
22 Mar. 96	(120 sec)	1441	March 5 1718	March 22 1513	03-22-96.hex	03-22-96.CNV gc_ctd_4
5 April 96	(120 sec)	1441	March 22 1625	April 5 1316	04-05-96.hex	04-05-96.CNV gc_ctd_5

- Remove model number 1441 CT-probe / install model number 1475 CTD-probe -

30 April 96	(120 sec)	1475	April 5 1631	April 30 1541	04-30-96.hex	04-30-96.CNV gc_ctd_6 (Note: record includes data dropout)
24 May 96	(120 sec)	1475	April 30 1710	May 24 1341	05-24-96.hex	05-24-96.CNV gc_ctd_7
15 June 96	(120 sec)	1475	May 24 1504	June 15 1411	06-15-96.hex	06-15-96.cnv gc_ctd_8
4 July 96	(120 sec)	1475	June 1 1524	July 4 0946	07-04-96.hex	07-15-96.cnv gc_ctd_9

DOWNLOAD DATE	SAMPLING INTERVAL	INSTRUMENT MODEL NUMBER	BEGIN DATE AND TIME (PST)	END DATE AND TIME (PST)	DOWNLOAD FILE NAME	PROCESS NAMES
1 Aug. 96	(120 sec)	1475	July 7 1056	August 1 1244	08-01-96.hex	08-01-96.CNV gc_ctd_10

- Cleaning of conductivity cell not entirely effective -

2 Sep. 96	(120 sec)	1475	August 1 1510	September 2 1514	09-02-96.hex	09-02-96.CNV gc_ctd_11
30 Sep. 96	(120 sec)	1475	September 2 1657	September 30 1426	09-30-96.hex	09-30-96.CNV gc_ctd_12
18 Oct. 96	(120 sec)	1475	September 30 1613	October 18 1022	10-18-96.hex	10-18-96.CNV gc_ctd_13

- Clean conductivity cell -

22 Nov. 96	---	---	---	---	---	Note: Unable to establish communications; Opto box non-functional.

13-27 November: data lost from jd=318 (683) to jd=331 (696);
Opto interface box damaged by power surge

29 Nov. 96	(120 sec)	1475	October 18 11:44:46	---	bust.hex	11-29-96.CNV gc_ctd_14 (Note: record lost, logging stopped on 12th)
28 Dec. 96	(120 sec)	1475	November 29 1802	December 28 1540	12-28-96.hex [28dc.96]	12-26-98.CNV gc_ctd_15 (Note: replace Opto interface box)

- 1997 -

20 Jan. 97	(120 sec)	1475	Dec. 28, '96 1721	Jan. 20, '97 1542	20JN97.hex	01-20-97.cnv gc_ctd_1.1997
13 Feb. 97	(120 sec)	1475	Dec. 28, '96 1720	Feb. 13, '97 1745	2-13-97.hex	02-13-97.cnv gc_ctd_2.1997 (Note: file 02-13-97.cnv contains above record)
12 Mar. 97	(120 sec)	1475	February 13 2034	March 12 0906	03-12-97.hex	03-12-97.cnv gc_ctd_3.1997

DOWNLOAD DATE	SAMPLING INTERVAL	INSTRUMENT MODEL NUMBER	BEGIN DATE AND TIME (PST)	END DATE AND TIME (PST)	DOWNLOAD FILE NAME	PROCESS NAMES
17 April 97	(120 sec)	1475	March 12 1048	April 17 1647	041797.hex	041797.cnv gc_ctd_4.1997
14 May 97	(120 sec)	1475	April 17 1905	May 17 0814	05-14-97.hex	05-14-97.cnv gc_ctd_5.1997

- Remove model number 1475 CTD-probe / install model number 1441 CT-probe -

5 June 97	(120 sec)	1441	May 14 1157	June 5 1514	06-05-97.hex	06-05-97.cnv gc_ctd_6.1997 (Note: second start at 18th record)
1 July 97	(120 sec)	1441	June 5 1626	July 1 1451	07-01-97.hex	07-01-97.cnv gc_ctd_7.1997
5 Aug. 97	(120 sec)	1441	July 1 1608	August 5 1440	08-05-97.hex	08-05-97.cnv gc_ctd_8.1997
20 Aug. 97	(120 sec)	1441	August 5 1303	August 20 1445	08-20-97.hex	08-20-97.cnv gc_ctd_9.1997
28 Sept. 97	(120 sec)	1441	September 28 1427	August 20 1543	09.28.97.hex	09-28-97.cnv gc_ctd_10.1997
8 Nov. 97	(120 sec)	1441	September 28 1731	November 8 1524	110897g.hex	110897G.cnv gc_ctd_11.1997
27 Dec. 97	(120 sec)	1441	November 8 1753	December 27 1546	12-27-97.hex 12.hex	12.CNV gc_ctd_12.1997

- 1998 -

2 March 98	(120 sec)	1441	December 27 1810	March 2 1230	gc980302.hex	gc980302.cnv gc_ctd-1.1998
3 May 98	(120 sec)	1441	March 2 1534	May 3 1435	03d05m98.hex	03d05m98.cnv gc_ctd_2.1998
6 June 98	(120 sec)	1441	May 3 1707	June 6 1732	06d06m98.hex	gc_ctd_3.1998 06d06m98.cnv
16 June 98	(120 sec)	1441	June 6 1900	June 16 1107	16d06m98.hex	16d06m98.cnv gc_ctd_4.1998

- Remove model number 1441 CT-probe / install model number 1475 CTD-probe -
- CDF&G takes control of equipment and “field” work -

23 June 98	(120 sec)	1475	June 16 1535	June 23 1013	23d06m98.hex	23d06m98.cnv gc_ctd_5.1998
13 July 98	(120 sec)	1475	June 23 1104	July 13 1332	13d07m98.hex	13d07m98.cnv gs_ctd_6.1998
7 Aug. 98	(120 sec)	1475	June 13 1605	Aug. 7 1005	07d08m98.hex	07d08m98.cnv gc_ctd_7.1998