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COARE Seacat data: Calibrations and quality control procedures

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Abstract. An intensive set of quality analysis routines was applied to salinity data from twelve mooring sites of the Tropical Ocean-Atmosphere (TAO) Array within the western Pacific warm pool. Primary sources of error identified were 1) biological fouling and abrasive scouring of the conductivity cell, and 2) temperature/conductivity sensor response time mismatch in the presence of high-frequency temperature variability and low flush rate. Quality control methods included application of both pre-deployment and post-recovery calibrations, stability analysis among sensors, and comparison with CTD cast data. Corrections were applied by modeling error bias as linear or higher order polynomials. After correction, salinity data are believed to be accurate to within 0.02 psu in most cases.

1. Introduction

The western Pacific warm pool is a region with strong influence upon the El Niño/Southern Oscillation phenomena and thus world climate variations. The region is characterized by a warm surface mixed layer, high precipitation, intense westerly wind events, and strong ocean-atmosphere coupling. During the latter half of the 10-year Tropical Ocean Global Atmosphere (TOGA) program, the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) sought to describe and understand the processes at work in the coupled system of the western Pacific warm pool, and their influence on global climate (Webster and Lukas, 1992).

The large flux of fresh water into the warm pool from precipitation has a strong influence on the dynamics of the upper ocean. At times the depth of the mixed layer is determined as much by salinity as by temperature. During such times the mixed layer may be separated from the thermocline by a salt-stratified barrier layer that inhibits cooling of the mixed layer from below (Lukas, 1988; Godfrey and Lindstrom, 1989; Lukas and Lindstrom, 1991; Sprintall and McPhaden, 1994). Because the measurement of salinity is an important factor in understanding the processes active in ocean dynamics and the flux of energy between ocean and atmosphere in the warm pool, the objectives of the oceanographic component of COARE included the determination of salinity space-time structure as well as the net flux of salt and freshwater into the region.

Salinity measurements from moorings of the Tropical Ocean-Atmosphere (TAO) Array (Hayes *et al.*, 1991; McPhaden, 1993) in the warm pool were begun in November 1988 (Sprintall and McPhaden, 1994) and continue to the present. In preparation for COARE, the number of moorings from which salinity was measured was substantially increased through the cooperative efforts of the Pacific Marine Environmental Laboratory (PMEL), the University of Hawaii (UH), and L'Institut Français de Recherche Scientifique pour

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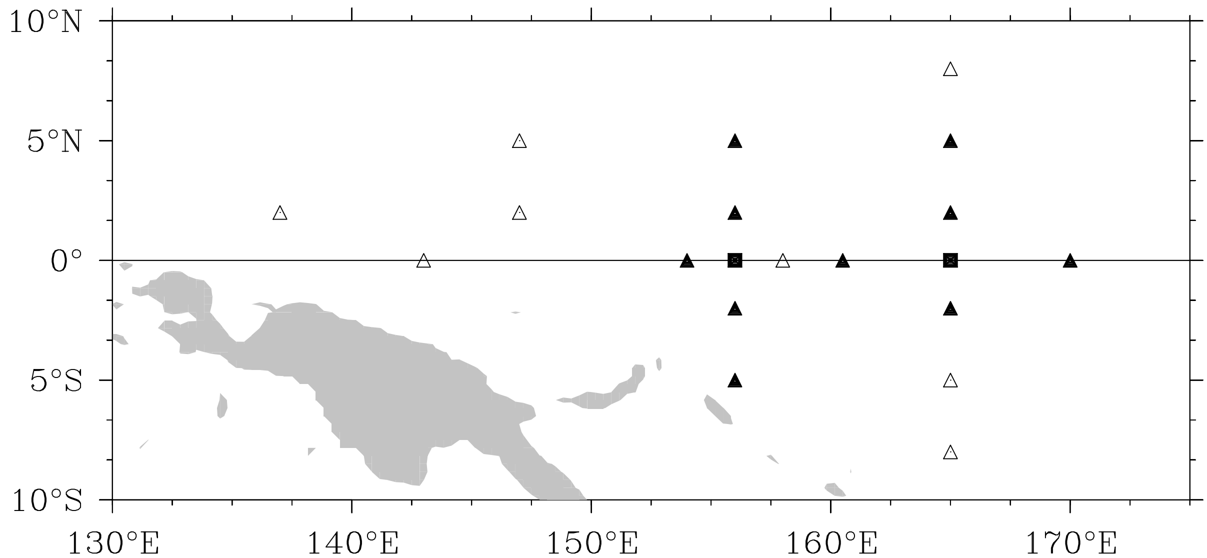

Figure 1: Location of TAO moorings in the western equatorial Pacific Ocean during COARE. ATLAS moorings from which Seacat data were obtained denoted by solid triangles. PROTEUS moorings with Seacat data denoted by solid squares. Atlas moorings without Seacat data denoted by open triangles.

le Développement en Coopération (ORSTOM), each of which contributed instruments, research-vessel time, and personnel. This memorandum will cover moorings deployed between fall 1991 and winter 1994, approximately 1 year before and after the COARE Intensive Observing Period (IOP), which was from November 1992 to February 1993. Mooring locations at which salinity measurements were made during this period are shown in Fig. 1. Data quality issues for TAO moored salinity measurements previous to the period covered by this memorandum were discussed by Sprintall and McPhaden (1994). Salinity measurements from TAO moorings continued after COARE will be quality controlled in a manner similar to those data described here.

The majority of measurements were made between 1 m and 100 m below the sea surface (Fig. 2). At two sites (0°, 156°E and 0°, 165°E) measurements were routinely made down to 200 m. Measurements were extended to 750 m at two moorings (2°S, 156°E and 2°S, 165°E) near TOPEX/POSEIDON crossover sites for verification of satellite altimetry measurements for 5–7 months concurrent with the IOP (Picaut *et al.*, 1995; Gourdeau *et al.*, 1995).

2. Instrumentation and Mooring Design

In the warm pool, vertical salinity differences in the upper 100 m, horizontal differences over the 200 km to 1000 km distance between moorings, and temporal differences over periods of hours to years are all order 1 psu. Salinity differences that define the vertical extent of the mixed layer may be of order 0.2 psu. Accurate determination of these signals requires moored salinity sensors with relatively high accuracy and small drift characteristics.

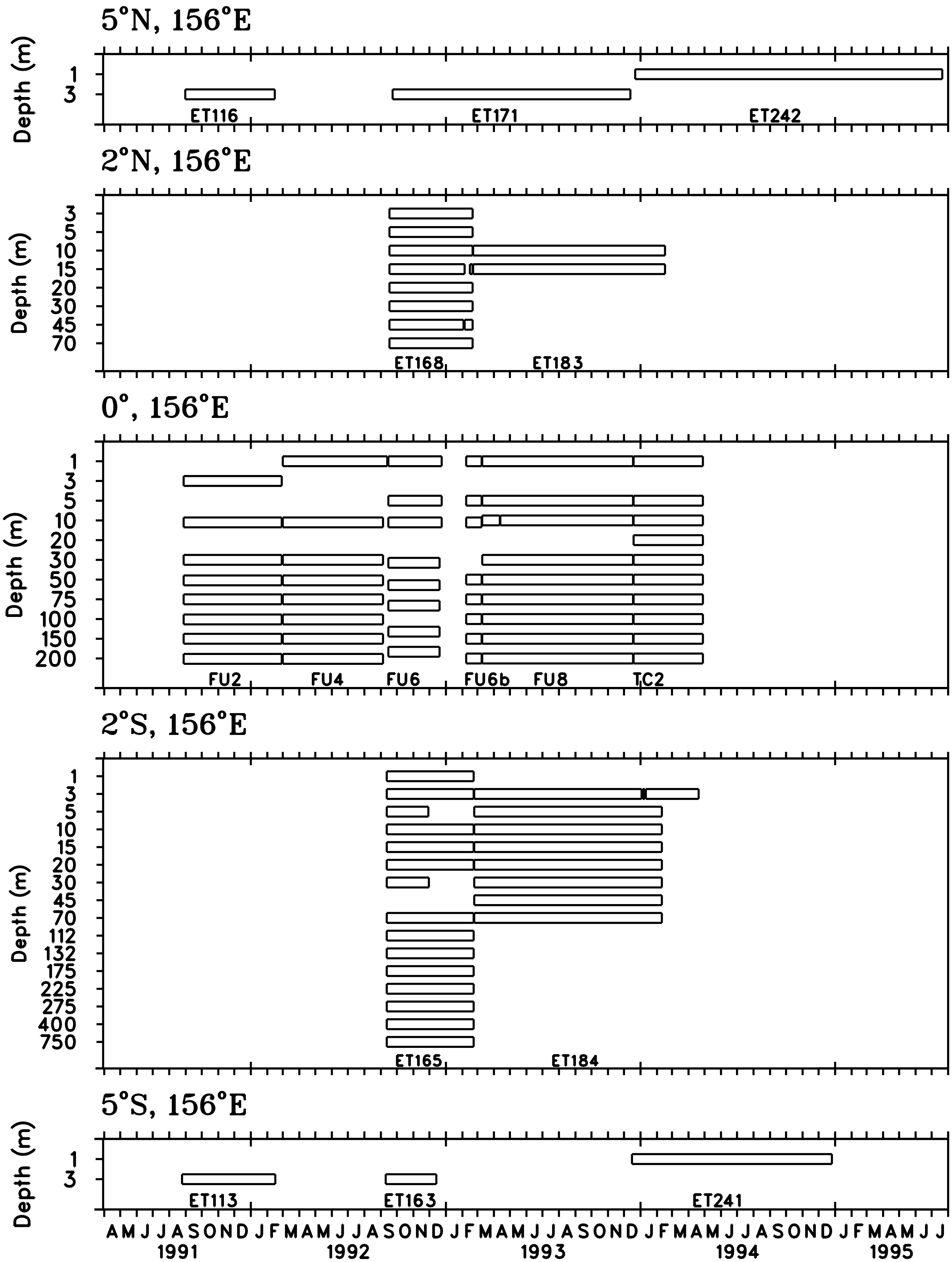

Figure 2a: Distribution of salinity data from moorings deployed along 156°E longitude. Mooring names are indicated along the time axis.

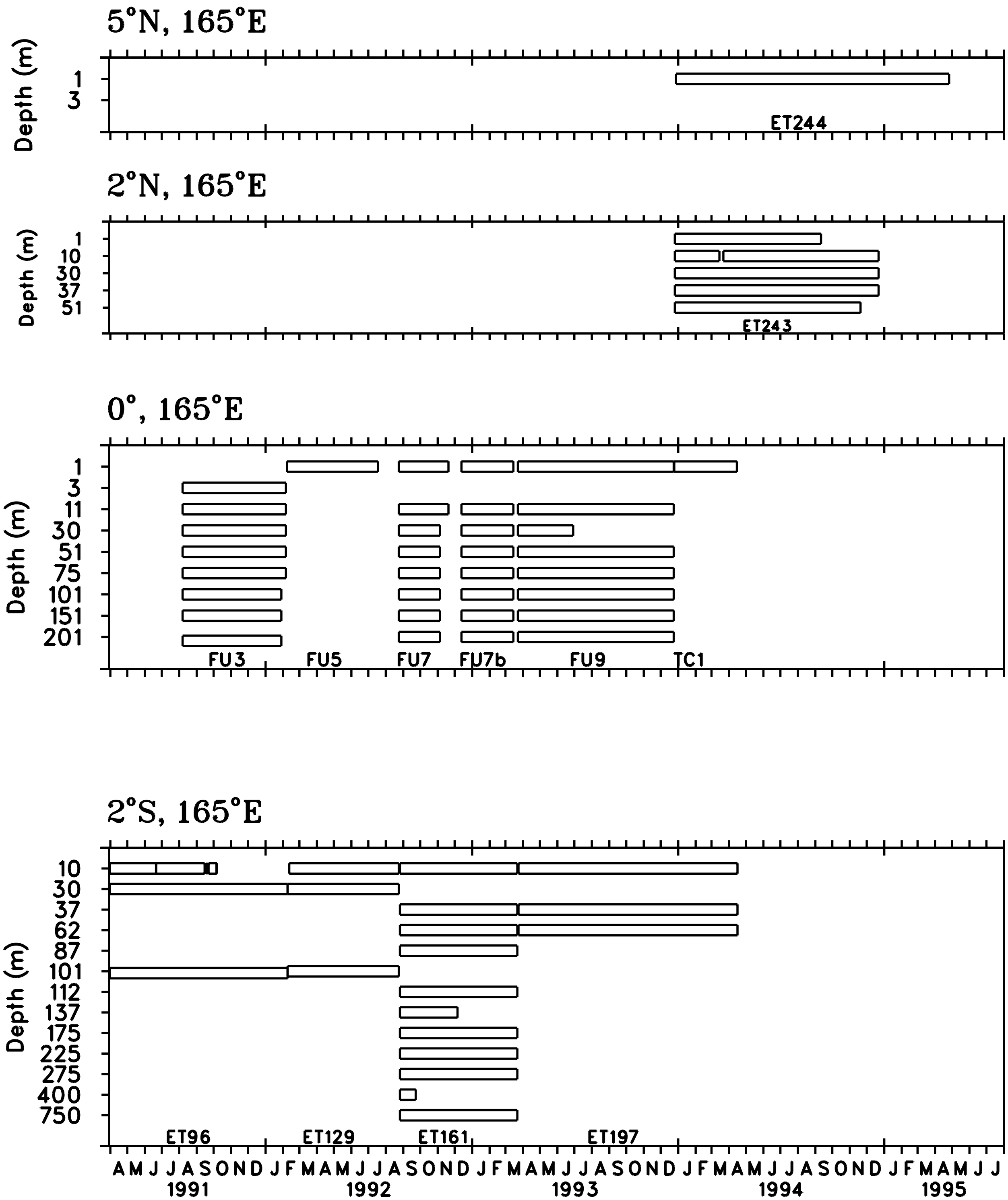

Figure 2b: Distribution of salinity data from moorings deployed along 165°E longitude. Mooring names are indicated along the time axis.

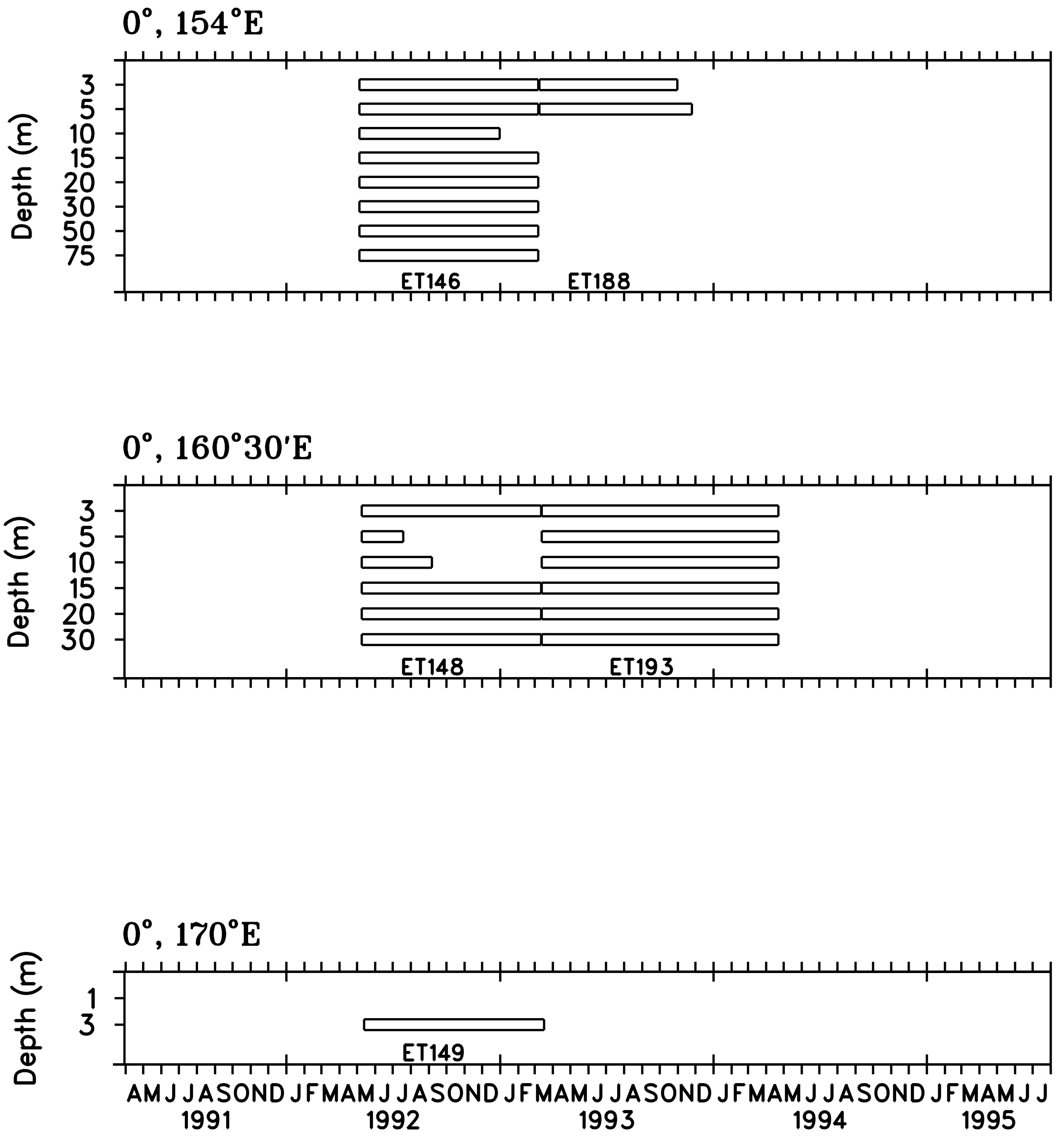

Figure 2c: Distribution of salinity data from moorings deployed near 0°, 154°E, 0°, 160°30′E, and 0°, 170°E. Mooring names are indicated along the time axis.

Conductivity and temperature data considered in this report were measured with Sea-Bird Electronics, Inc., Model SBE-16 Seacat Conductivity-Temperature recorders. The Seacat SBE-16 employs an internal-field conductivity cell with a range of 0 to 7 S m^{-1}, and a pressure-protected thermistor with a range of –5 to 35°C. The internal-field conductivity cell allows anti-foulant devices to be placed at both ends of the cell to reduce the effect of biological fouling on the cell. The conductivity cell has a nominal accuracy of 0.001 S m^{-1} $month^{-1}$, and a resolution of 0.0001 S m^{-1}; the thermistor has an accuracy of 0.01°C per 6 months and a resolution of 0.001°C. These accuracies and all other specifications cited here were provided by the manufacturer.

The sensors are interfaced to a Wein-bridge oscillator which generates temperature or conductivity dependent frequencies. The frequencies are digitized by counting integer and fractional cycles over a time interval of 0.125 seconds. The time base is determined by a precision temperature-compensated crystal oscillator. The Seacat interface circuit is corrected for electronic drift before each measurement by referencing stable Vishay resistors. The crystal oscillator has an accuracy of ±3 ppm over a temperature range of –5°C and 35°C and it ages less than ±2 ppm yr^{-1}.

The real-time clock in the Seacat is a 32,768 Hz watch crystal oscillator which is corrected for initial error, temperature-induced drift, and aging by the temperature-compensated crystal oscillator, yielding an accuracy of ±2.6 min yr^{-1}.

During COARE, Seacats were installed on several ATLAS (Autonomous Temperature Line Acquisition System) moorings. The upper section of an ATLAS mooring consists of a toroidal float with an instrumentation tower mounted on the upper side and a bridle mounted to the underside. Beneath the bridle, jacketed wire rope extends to a depth of (typically) 700 m. A 500-m-long, polyurethane-jacketed, double-armored, three-conductor cable with attached temperature and pressure sensors runs parallel to the wire rope. When Seacats are mounted on ATLAS moorings, they are mounted on either the bridle or on the wire rope section of the mooring line.

Usually the moorings were taut-line moorings, but at one site (5°S, 156°E) slack-line moorings were also deployed. For a taut-line mooring (Fig. 3), $\frac{3}{4}$" nylon line connects the wire rope to the acoustic release and the anchor. The nylon line, which stretches under tension, is adjusted to yield a scope of 0.985 (ratio of mooring length without tension to the water depth) which limits mooring excursions in both the horizontal and vertical. For a slack-line ATLAS mooring, a section of polyolefin line is included just above the anchor, and the mooring length is adjusted within the nylon section to a scope of 1.35.

At two sites (0°, 156°E and 0°, 165°E), Seacats were installed on taut-line PROTEUS (PRofile TElemetry of Upper ocean currentS) moorings (McPhaden *et al.*, 1991). The upper portion of a PROTEUS mooring consists of a toroidal float with an instrumentation tower and bridle attached. A downward-looking RDI Acoustic Doppler Current Profiler (ADCP) is mounted in the toroid. When Vector Averaging Current Meters (VACMs) are included in the mooring line, the wire rope is broken into sections with

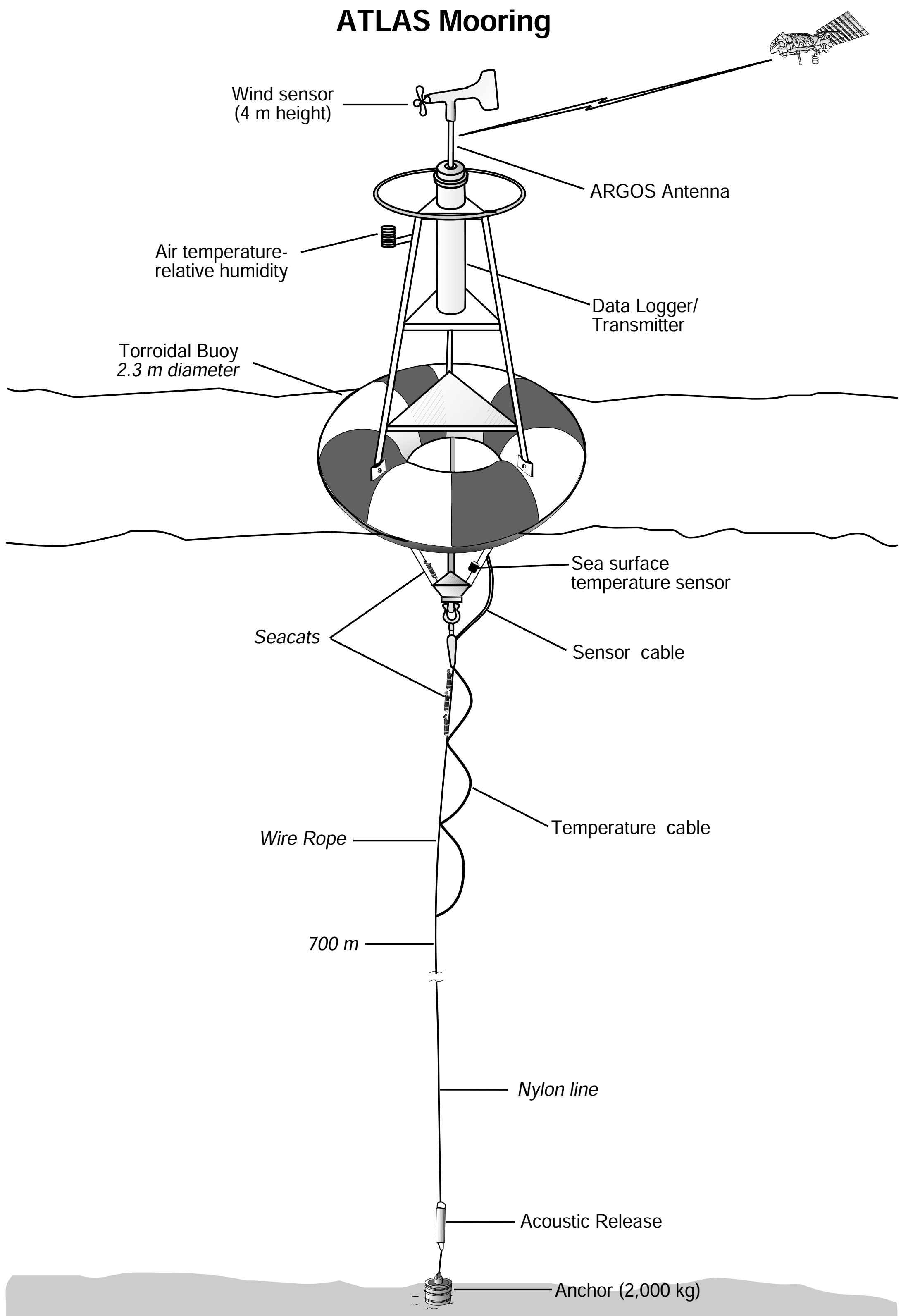

Figure 3: Schematic drawing of a taut-line ATLAS mooring. Number and placement of Seacats varied from site to site and, in some cases, from deployment to deployment at a given site.

the VACMs shackled between pieces. The deepest VACM is typically at 200 m. Seacats and MTRs (mini-Temperature Recorders, designed and built by PMEL) are mounted directly onto the wire rope. Fairings are typically placed on the upper portion of the wire rope to a depth of 250 m. The majority of the mooring length is made up of $\frac{3}{4}$" nylon line, which is adjusted to give an overall mooring scope of 0.985. The deepest part of the mooring consists of 32 glass balls, an acoustic release, and the anchor.

3. Methods of Calibration and Quality Analysis

Each institution (PMEL, UH, ORSTOM) was responsible for the processing and quality analysis of data from the instruments which they contributed to the moored Seacat array. The principles used were generally the same (e.g., application of pre-deployment and post-recovery calibrations, stability analysis, and comparison to CTDs), although the exact methods used differed in some respects. For TOPEX/POSEIDON validation, ORSTOM interpolated some of their time series from their original sample intervals (10, 20, or 30 min) to 5-min intervals in a manner that took into account high-frequency variability measured by Seacats sampling at 5 min (Gourdeau *et al.*, 1995). In the present case, ORSTOM data were analyzed (by PMEL researchers) at their original sample interval to be consistent with the methods used on the PMEL and UH data.

The manufacturer has found that most Seacats drift toward lower conductivity values with time (Nordeen Larson, Sea-Bird Electronics, Inc., personal communication). This negative drift is primarily attributed to biological or geochemical fouling which decreases the effective cross-sectional area of the cell, and secondarily to fouling or loss of material on the electrode. Conversely, most Seacats deployed on TAO moorings drifted towards higher conductivity values. While the cause of this positive drift is not totally understood, it is suspected that abrasive scouring of the cell from strong, equatorial currents carrying high concentrations of plankton may be a factor. The manufacturer has reported that electron microscope photographs of cells deployed on TAO moorings have shown grooves running along the axis of the cell, which are not apparent on new cells. The first Seacats to be used on TAO moorings were configured with the conductivity cells in a horizontal orientation. In an attempt to reduce the flow rate through the cell (and presumably scouring of the cell) newer Seacats purchased by PMEL, as well as those purchased by UH and ORSTOM, were configured with vertically oriented conductivity cells. Unfortunately, conductivity drifts remained positive with either cell orientation, indicating that either flow rates were not significantly reduced by this change, or that the positive drifts were the result of some other process.

Biological growth and loss of material from the electrode are also factors in the drift of TAO moored sensors. When possible, instruments were calibrated after recovery in both an "as is" state and again after cleaning of the cell and replatinizing of the electrode. In most cases the second calibration indicated an even larger positive conductivity drift. It is assumed that negative drift, such as bio-fouling which was removed by the cleaning process, had partially compensated for the drift due to scouring. An attempt was made to minimize the effect of bio-fouling by installing anti-fouling plugs supplied by the manufacturer on the conductivity cells. It is thought that the anti-foulant is effective for a period of at least 3 months, typically 6 months, and perhaps longer in some cases (Nordeen Larson, Sea-Bird Electronics, Inc., personal communication). Our experience is generally consistent with this view. Differences between some sensor pairs placed within the mixed layer tended to be linear during the first months of a deployment, but increased nonlinearly thereafter (see discussion below on in situ stability analysis). This change in drift rates could be due to the depletion of the anti-foulant resulting in an increase in biologic growth rate on the cell.

A preliminary step in the processing of the data was to perform gross error checks. This process identified missing or obviously bad data. Once identified, these data points were either corrected or flagged as bad, depending on the length of time involved. Periods of bad or missing data of up to 6 hours in duration were filled by linearly interpolating between good data points before and after the bad or missing data. Longer periods of bad or missing data were flagged. Identification could often be automated by passing the data though a window (e.g., 10°C to 33°C for temperature, 29 psu to 36 psu for salinity) beyond which data values were not expected. In some cases the actual window limits were determined by the location of the instrument (i.e., at the surface, in the mixed layer, in the thermocline, etc). In addition to this automatically applied windowing technique, a subjective analysis was performed by plotting each time series and looking for spikes or other suspicious data. Once identified, comparisons to other time series from the same mooring, when available, were used to determine whether to manually correct the questionable values. In general, the amount of data affected by gross error checking was minimal, ranging from zero to order 10 samples per time series (order 0.1%). Time series with more significant rates of gross errors are noted in Appendix A.

The next step in quality analysis of salinity data was to apply both pre-deployment and post-recovery calibration coefficients in a linear, time-dependent combination so that pre-deployment calibrations predominate in the early portion of the time series and post-recovery calibrations predominate in the latter portion. This step removed a linear drift, the sources of which could be residual instability of the electronics, loss of material from the electrode, and/or abrasive scouring of the conductivity cell. In some cases this step was retracted if it appeared that the linear drift correction was inaccurate. Subsequent analysis included stability analysis (comparing instruments co-located in or near the mixed layer), comparison of moored Seacat and CTD data, and attachment of recovered Seacats onto the CTD frame for comparison. Details on each step of the analysis are given below. All methods of quality analysis could not be applied to all time series. Some instruments were damaged while on the mooring and thus could not be calibrated after recovery. Instruments located below the mixed layer and those which were singly located within the mixed layer could not have a vertical stability check performed (in other than a large scale sense, which would not identify the typically small rates of drift). Some deployments did not have sufficient CTD casts to make a meaningful comparison, and not all Seacats were attached to the CTD frame for comparison. Appendix A lists, by deployment, the particular methods used for each time series.

3.1 Pre-Deployment and Post-Recovery Calibrations

Prior to deployment and after recovery, the Seacats were sent by Sea-Bird Electronics, Inc. to the Northwest Regional Calibration Center for calibration. The instruments were calibrated in two baths with different salinities at several temperatures. Typically the salinity of one bath was 35 psu, and frequency outputs from the instruments in that bath were recorded at nominal temperatures of 31, 23, 15, 7, and –1°C. The typical salinity of the second bath was 15 psu, and measurements were made near 27, 19, 11, and 3°C. The temperatures of the baths were known to within 0.003°C and the salinities to within 0.003 psu (Andy Heard, Sea-Bird Electronics, Inc., personal communication). Frequency output for the dry conductivity cell in air was also measured.

The conductivity outputs measured during the post-recovery calibration of a Seacat are influenced by the handling of the instrument after it is recovered. Unfortunately, a method of handling doesn't exist that can be expected to preserve the conductivity cell in a state identical to that which it had upon recovery. Allowing the cells to dry after recovery, as PMEL researchers often did, allowed evaporative deposits (which may take some time to dissolve when re-immersed) and desiccation of the biota, both of which change cell geometry. The method followed by UH researchers, which was to keep the conductivity cell filled with distilled water, prevented the changes to cell geometry that drying would allow. However, keeping the cells in fresh water for weeks to months (often necessary for western Pacific cruises) may tend to rinse off or dilute the concentration of biota. Keeping cells in salt water would have allowed further biological fouling and chemical deposition to occur.

In spite of the uncertainties introduced by the inability to keep the Seacats in the same state they were upon recovery, applying the post-recovery conductivity calibrations as well as the pre-deployment calibrations generally improved data quality, in that drifts in the data were decreased. The 1-m and 5-m hourly salinities from mooring FU6 present an example of the improvement that can be made in data quality by applying both pre-deployment and post-recovery calibrations to salinity records (Fig. 4). A 6-week gap in the time series was caused by the mooring line having parted in December of 1992. The 1-m and 5-m Seacats were recovered within days of the mooring failure and the mooring was redeployed in February 1993 using the same Seacats. The majority of salinity differences between the 1-m and 5-m instruments, calculated using only the pre-deployment calibration values (Fig. 4a), were near zero when first deployed, but drifted to an offset of about 0.02 psu by the time the mooring line broke. When redeployed in February, the offset had not significantly changed from the December value. Even though these instruments were out of the water for weeks after the

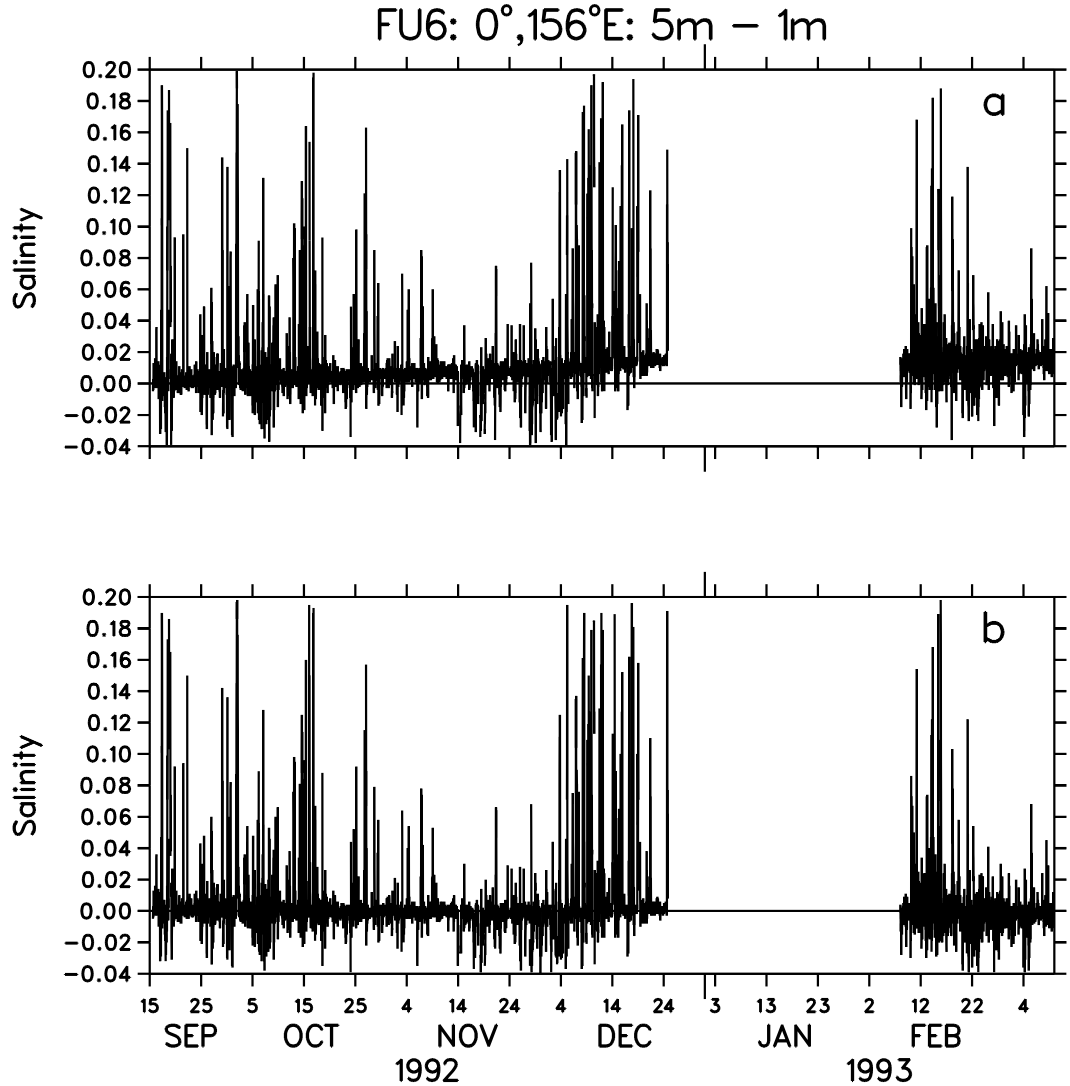

Figure 4: Salinity differences between 5-m and 1-m Seacats on FU6 deployment at 0°, 156°E. Salinity computed using (a) pre-deployment calibrations only and (b) a linear combination of pre-deployment and post-recovery calibrations.

mooring parted, and dry for months after the final recovery and before post-recovery calibrations were performed, application of linear drift corrections based on the pre-deployment and post-recovery calibration values removed the drift of the 5-m salinities relative to the 1-m values (Fig. 4b).

Salinity differences between pre-deployment and post-recovery calibrations were typically 0.06 psu or less for Seacats in the upper 100 m (Fig. 5) and were typically in the direction consistent with cell abrasion. Below 100 m, differences were smaller and of opposite sign.

While the above procedure often successfully removed apparent sensor drifts, in some cases its application resulted in increased instability. In these cases, only pre-deployment calibrations were applied to the data, after which other calibration methods (as described below) may have been performed.

Differences in temperature calibrations were typically 0.003°C or less,

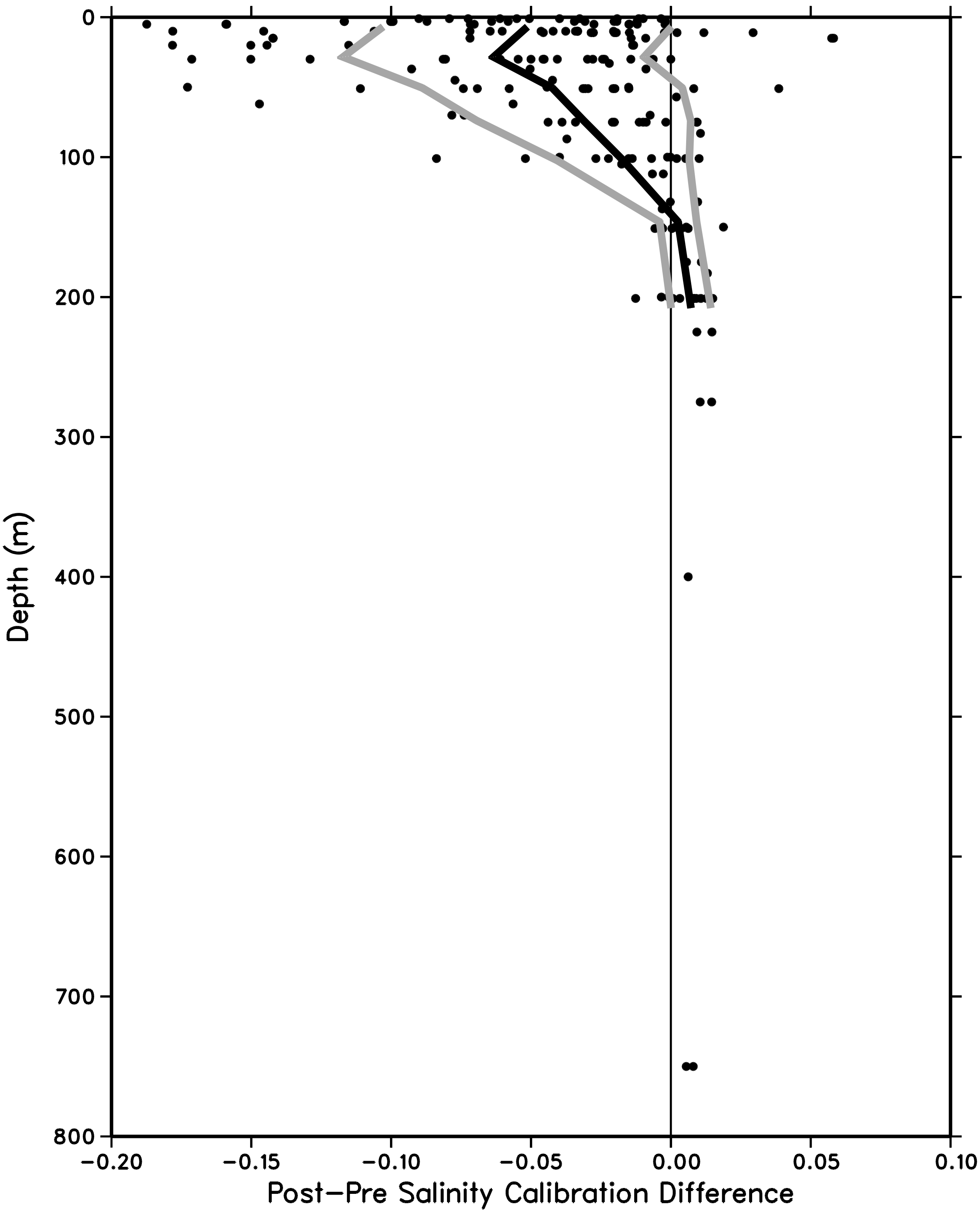

Figure 5: Differences between salinity values calculated using post-recovery conductivity calibrations minus values calculated using pre-deployment conductivity calibrations as a function of Seacat depth. Black line is the mean. Grey lines are the mean ± one standard deviation. Negative values indicate an instrumental drift towards higher salinities between pre-deployment and post-recovery calibrations.

which was comparable to the accuracy of the calibrations themselves. Linear temperature drift corrections based on both pre-deployment temperature calibrations and post-recovery calibrations were applied by UH researchers when available. Only pre-deployment calibrations were used for ORSTOM and PMEL temperature records.

3.2 In Situ Stability Analysis

Applying drift corrections based on pre-deployment and post-recovery calibrations did not correct all the questionable data. In the mixed layer, sustained periods of instability and trends in salinity or density differences between adjacent instruments could still be found in the data after correcting for linear calibration drift.

Problematic data were identified by PMEL researchers by examining time-series plots of the differences between adjacent instruments for temperature, salinity, and density. When large, sustained inversions were found in the plots of differences, further examination was needed to determine which instrument of the pair was in error. Often the biased instrument could be identified by comparison with data from a third instrument. When it was not possible to determine which record was in error, no correction was made.

Once the biased data were identified, they were corrected by modeling the bias for time-periods when the surface layer was well mixed or, at most, weakly stratified. These periods were determined using a stability criteria based on density differences among records with no apparent drift. When differences among these less questionable data were $\leq$0.02 kg m^{-3}, the surface layer was considered to be well mixed (to within the accuracy of the instruments) and the correction based on these data was considered a high-quality correction. When density differences for the less-questionable data were between 0.02 kg m^{-3} and 0.1 kg m^{-3}, the surface layer was considered to be weakly stratified and the resulting correction was considered to be of lower quality. When applied, criteria used for such corrections are noted in Appendix A.

For each time step where the well-mixed/weakly-stratified criterion was met, PMEL researchers modeled the error by calculating salinity as a linear function of depth from the less-questionable records. The error in the biased instrument was defined as the difference between its value and the linear fit at the depth in question. To generate an error time series for the entire record, a first-, second-, or higher-order polynomial function in time was fit to the estimated errors using least-squares regression techniques. The resulting relationship was subtracted from the measured data to obtain a corrected record at all times. In some cases, different sections of the record were modeled using different order polynomials.

An example of this method is shown in Fig. 6. Salinity differences between the 11-m and 1-m salinities from mooring FU4, after correction for calibration drift, were characterized by a small linear drift, with the 11-m record becoming relatively saltier, during the first 5 months of the record (Fig. 6a). In the last month of the record, the drift was non-linear and in the opposite direction, probably indicating a failure of an anti-foulant. The

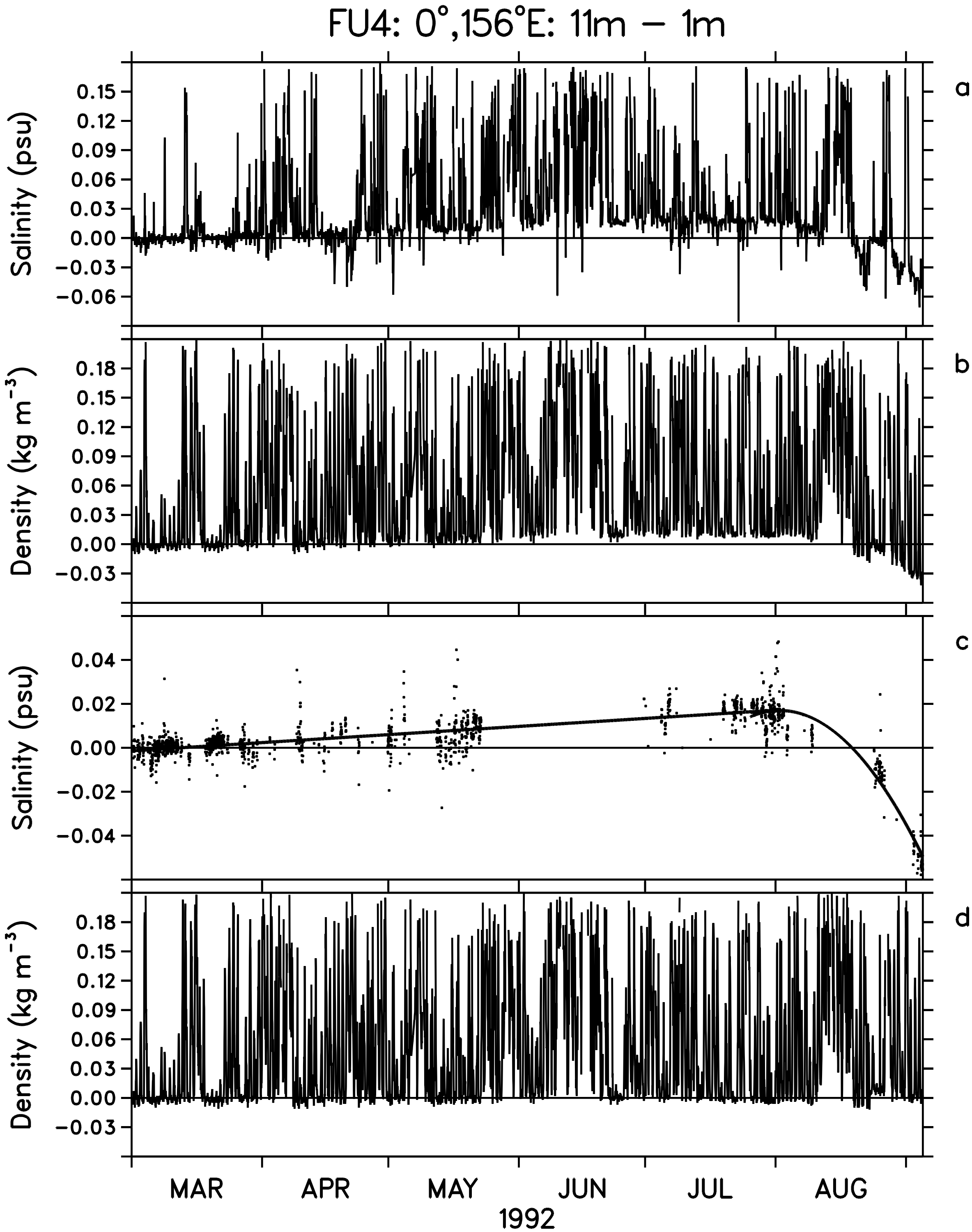

Figure 6: (a) Salinity and (b) density (sigma-theta) differences between 11-m and 1-m Seacats deployed at 0° 156°E. A linear combination of post-recovery and pre-deployment conductivity calibrations have been applied. (c) Salinity bias of 11-m data relative to 1-m and 30-m data (dots) has been modeled (solid line) as a linear function in time for the first 5 months and as a 2nd order polynomial for the last month. (d) Density differences after modeled bias has been removed.

relative salinity drift led to apparently unstable density differences between 11 m and 1 m in the last month of the mooring (Fig. 6b). Comparison with data from other depths identified the 11-m record as being in error. Using the stability correction scheme described above, a linear correction was modeled for the first 5 months, and a quadratic correction for the last month (Fig. 6c). After application of the modeled correction to the 11-m salinity, the trend towards increased stability in the first 5 months and the apparent instability in the last month was removed (Fig. 6d).

UH researchers considered the upper water column to be well mixed during windy periods, defined as periods of sustained wind speeds over 8 m s^{-1}. Salinity records that looked suspicious because of lack of agreement with CTD casts taken near individual moorings were confirmed as erroneous by examining stability during windy periods. It was assumed that during well-mixed periods, density instabilities should not be present for more than 2–3% of the well-mixed times. A single instrument in the mixed layer, usually below 15 m to avoid biological fouling which seemed to most affect instruments near the surface, was selected and the mean differences between salinity data during well-mixed periods from that instrument and data from the other instruments in the mixed layer were calculated. Records with mean differences that suggested salinity and/or density instability in the mixed layer, and that also agreed poorly with CTD data, were regarded as questionable. The mean difference, for the well-mixed, windy periods, between data from an instrument regarded as good and data from the questionable instrument, was used as a correction. This correction was added to the questionable Seacat data beginning with the time of the first CTD/Seacat bias. For times when CTD data were not available for moorings, windy periods were used to both identify and correct suspicious data due to instability.

In contrast to well-mixed, windy periods, when instabilities are assumed to be rare, some short periods of increased instability (e.g., nighttime cooling) are to be expected, but should not dominate the time series. Identification of questionable salinity data was performed by UH researchers by looking for vertically adjacent records which displayed instability relative to each other for a high percentage of the deployment time, in a manner similar to the methods employed by PMEL. UH researchers considered data to be questionable if density instabilities were present for more that 10% of the mooring deployment time. If a time series plot or statistics of the density differences between two such records revealed a trend in salinity, steps were taken to identify and correct the record containing the salinity drift. Density differences with other nearby records were calculated and examined for corresponding trends. When the record containing the drift was identified, a correction was calculated based on an adjacent good record. The salinity differences were calculated between the good and the questionable records. The mean was removed; then all differences greater than ± 0.02 psu were removed. A linear regression was fit to the remaining values in order to compute a drift correction.

3.3 In Situ CTD Comparisons

An attempt was made to gather as many CTD casts as possible for in situ quality checks of Seacat salinities. From one to three CTD casts were made at the times of many of the mooring deployments and recoveries (e.g., Shinoda *et al.*, 1995). During the IOP the presence of several ships within the COARE Intensive Flux Array (centered at 2°S, 156°E) permitted additional casts to be made near a few moorings (e.g., Delcroix *et al.*, 1993). In some cases, comparisons provided a consistent picture, showing either that differences were small (0.01 psu or less) or that there was a bias in the Seacat measurement. In other cases, the comparisons were ambiguous, probably because of temporal and spatial variability in the salinity field. In regions of high vertical salinity gradient, slight depth offsets would lead to large salinity differences. Horizontal variations could also add uncertainty, since casts were typically made roughly a mile from the mooring. Rather than the actual time at each depth, processed CTD files recorded only the time when the instrument entered the water or when it reached the greatest depth (which could be an hour or more after the cast started). For this reason Seacat samples from a few sample intervals (ranging from 5 min to 60 min) near the cast time were often used in the analysis. In addition, salinity comparisons were made at fixed temperatures, rather than fixed depths, assuming small bias between Seacat and CTD temperature.

An example of a Seacat/CTD comparison follows for mooring FU2 which was placed near 0°, 156°E on 28 August 1991. Three CTDs were made within hours of deployment. Seacat/CTD salinity differences were large (up to 0.097 psu) in the upper 50 m, but inconsistent between casts and Seacat samples (e.g., differences ranged from –0.096 psu to 0.097 psu at 30 m; see Fig. 7a for an example of one of the three casts). The inconsistency of differences was due to a lack of a well-defined mixed layer. Two more casts were made 11 days later, at which time the upper ocean was well mixed to 60 m. (Figure 7b is an example of one of the two casts.) In this case Seacat/CTD differences were more stable between the two CTD casts and different Seacat samples. Mean differences at 3 m, 30 m, and 51 m were 0.010 psu or less for each cast. It was felt that given the uncertainties described above, differences of this magnitude were less than the accuracy of the method, and thus it was decided that the CTD and Seacats were not significantly different at these depths. Conversely, a fairly consistent Seacat/CTD difference with mean of 0.020 psu at 11 m was sufficiently large to determine that the Seacat at this depth was in error. The bias found from this CTD comparison was consistent with the bias found using the stability analysis method described above. The stability analysis method also showed that the 11-m Seacat bias was variable with time, and thus corrections were made using that method. Nevertheless, it was encouraging to find that the two methods gave a consistent estimate of bias in September.

In addition to using CTD comparison methods similar to those described above, UH researchers conducted CTD-Seacat intercomparison casts to aid in Seacat calibration. On several occasions, after mooring recoveries and prior to mooring deployments, Seacats were strapped to a CTD rosette, with

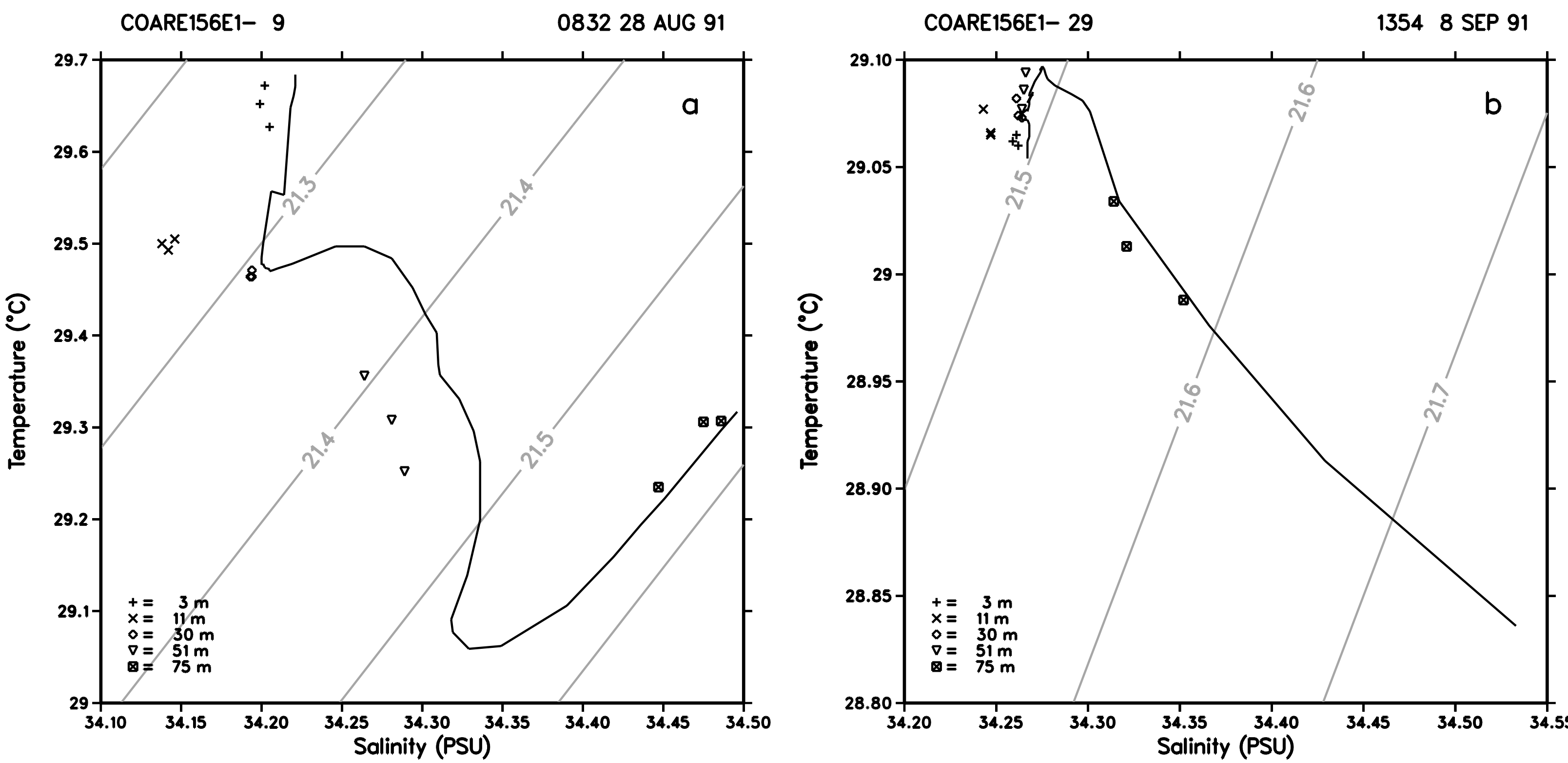

Figure 7: Temperature-salinity diagram of CTD cast (solid line) made near 0°, 156°E (a) on August 28, 1991 and (b) on 9 September 1991. Symbols represent Seacat measurements at approximately the same time as the CTD cast.

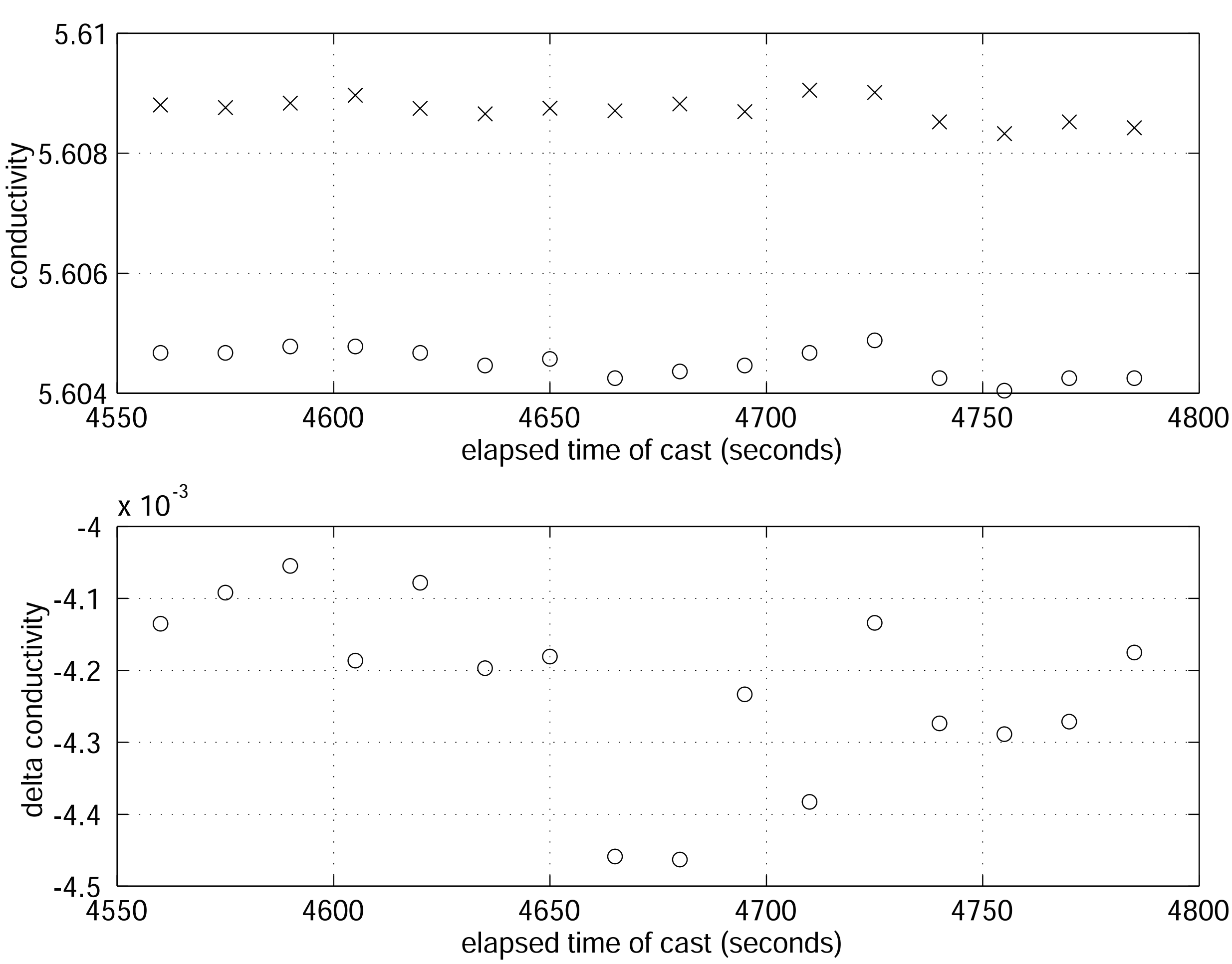

Figure 8: Conductivity readings recorded during a portion of an intercomparison cast involving a CTD (points marked with o's in top panel) and Seacat S/N 781 (points marked with x's in top panel). During this portion of the intercomparison cast, the CTD and Seacat were held at 30 m. The mean CTD–Seacat conductivity difference (bottom panel) is –0.00423 S m^{-1}.

the sensors placed roughly at the same vertical position. A CTD cast was then conducted with this instrument arrangement. During the cast, the CTD was held stationary at several depths for minutes at a time to obtain CTD-Seacat intercomparisons. After the CTD data were post-cruise calibrated and processed, mean and standard deviation statistics were determined for the CTD-Seacat temperature and conductivity differences during the times when the CTD was held vertically stationary.

When available, these intercomparisons were used to identify and correct questionable Seacat data in conjunction with the regular CTD comparisons as well as the windy period analyses and the stability analyses. If supported by CTD comparisons and/or well-mixed (windy) period and/or stability analyses, offset or drift corrections were made using the mean differences produced by the CTD-Seacat intercomparisons as a correction. For example, the ET 193 deployment (located at 0°, 160.5°E from March 1993 to April 1994) showed unstable density analyses during well-mixed (windy) periods. Intercomparison casts were taken before this deployment and upon using the corrections suggested by the intercomparison casts, the well-mixed (windy) periods showed stable density profiles. To illustrate, during an intercomparison cast, the Seacat placed at 30 m for ET 193 (Seacat S/N 781) showed a mean conductivity difference of –0.00423 S m^{-1} when held at 25 m during the intercomparison cast (Fig. 8). This mean difference was used to correct the 30-m Seacat (S/N 781) and similar differences were used to correct the other Seacats on this mooring to help produce stable density profiles during well-mixed (windy) periods observed by this mooring.

3.4 Salinity Spikes

Some salinity time series had a few positive spikes or periods of unusual high frequency variability. These spikes were most common at 1-m or 3-m time series and were distinct from negative salinity spikes due to rainfall. These spiky salinity periods were often correlated with strong daytime heating and high frequency variability in the temperature time series such as on November 3, 14, and 18, 1992, at 0°, 156°E (Fig. 9). On 19 November, when similar heating occurred, but without the high frequency variability, salinity variability was relatively small. Note that in the example shown the spikes are limited to less than 5 m depth. The strong diurnal heating was associated with days with low wind speed, during which a thin layer of surface water was heated in the presence of weak mixing. The high frequency variability in the temperature time series was perhaps due to small gusts of wind overturning the heated layer for short periods. A physical process generating positive salinity spikes of 0.4 psu or more exhibited here is unlikely. Using observed temperature and wind values in the bulk formula for latent heat flux, evaporative increases in salinity due to enhanced SST should have been much less than 0.1 psu. In addition, no source of such high salinity water was available immediately below the surface.

It is presumed that the source of much of this salinity noise was a mismatch in the response times of the temperature and conductivity sensors. The Seacat temperature time constant is 0.5 s, while the conductivity time constant is a function of the cell flush rate. Anti-fouling plugs and low wind speed (perhaps associated with calm seas and a low surface-current speed) would both tend to decrease the flush rate. Under these circumstances, the conductivity time constant would exceed 1 s (Nordeen Larson, Sea-Bird Electronics, Inc., personal communication).

These salinity spikes were corrected by PMEL researchers on a case-by-case basis. Identification and characterization of periods with erroneous spikes was aided by graphical computer software which displayed the temperature and salinity of the noisy instrument and, when available, rainfall and/or the salinity of an adjacent instrument located a few meters below the first. Methods of salinity correction included substitution of the adjacent instrument's data, linear interpolation (in time), or smoothing. Substitution was used when salinity at both levels was nearly identical during the nights

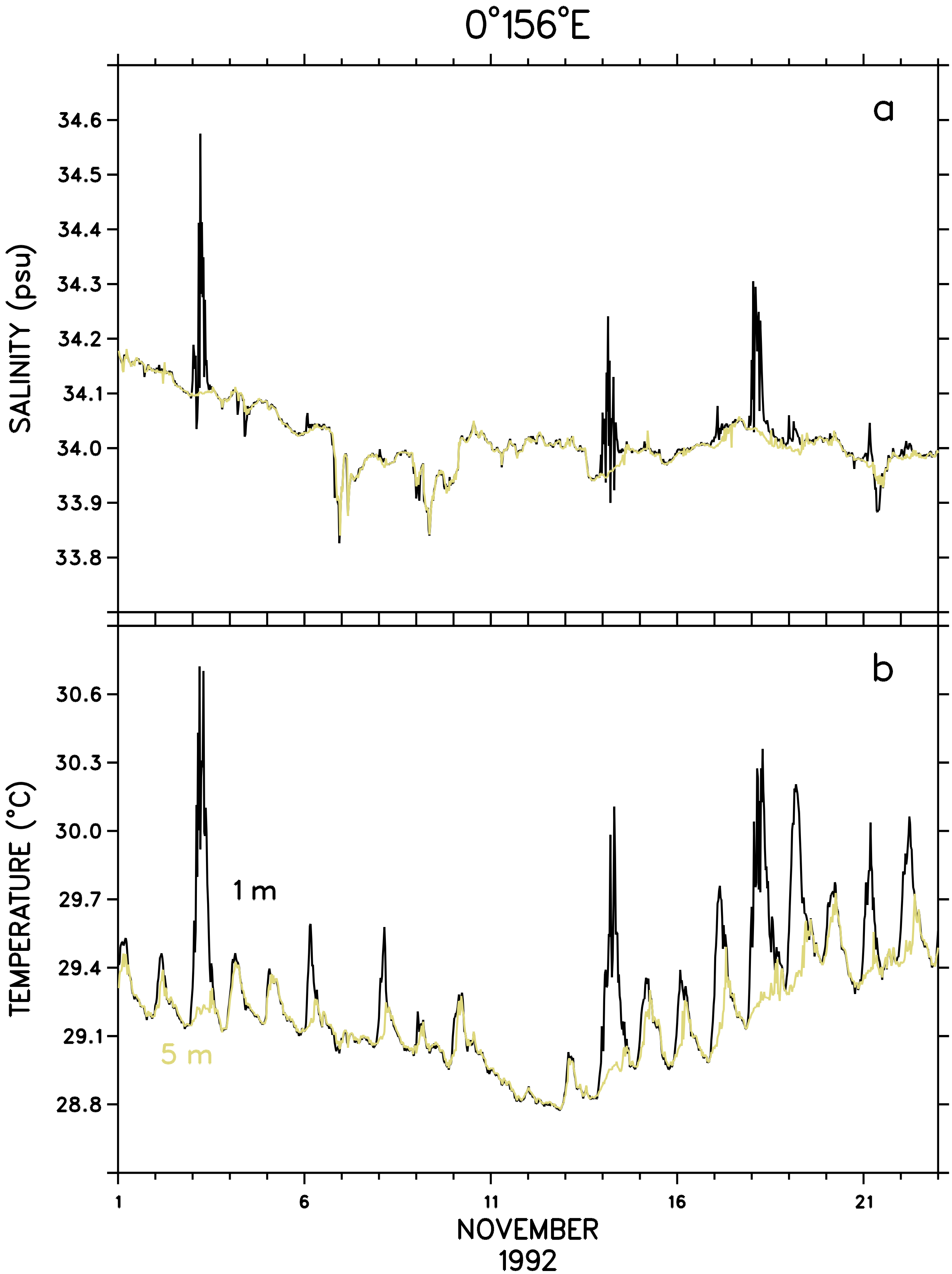

Figure 9: Seacat salinity and (b) temperature at 1 m (black) and 5 m (grey) at 0°, 156°E.

before and after the day with noisy salinity. When salinity at both levels differed at night, or when no adjacent time series was available, then a subjective choice of when and how to interpolate or smooth was made. When spiky data were identified, but no satisfactory correction could be made, the data were flagged as bad. Salinity data that were modified in these ways are identified by their quality index in the data archives. Time series modified in this manner are indicated in Appendix A. In some cases, surface salinity data were considered suspicious due to spikiness, but because no corroborating data (rainfall or nearby salinity) were available, no correction was attempted. These time series are also noted in Appendix A.

3.5 Remaining Inversions

Most density instability remaining in the corrected records involved near-surface (1-m or 3-m) time series and can be explained by nighttime cooling. Histograms of density differences, the time duration of inversions, and diurnal variation of inversions were examined to come to this conclusion. For example, remaining near-surface density inversions represented 16% of the 3–11 m data pairs from mooring FU2 (Fig. 10a), but the magnitudes of the great majority of these inversions were 0.01 kg m^{-3} or less (within the estimated accuracy of the instrument). Inversions between the 11-m and 30-m instruments represented less than 7% of data pairs and virtually none exceeded 0.01 kg m^{-3}. Moreover, the inversions between the 3-m and 11-m instruments were short-lived, and larger magnitude inversions were more likely to be short-lived. Sixty-one percent of all near-surface inversions were single (30-min) samples (Fig. 10b), and 91% of inversions with magnitude greater than 0.01 kg m^{-3} were single samples (Fig. 10c). A diurnal pattern to the remaining inversions also existed, with the greatest number of inversions occurring during the local night and early morning, and the smallest number occurring in the early afternoon (Fig. 10d). The inversions being near-surface, small, short-lived, and at night or early morning was consistent with nighttime, cooling-induced, small instabilities that were quickly mixed down.

Seacat records which, after correcting, still contained questionable instabilities are noted in Appendix A.

3.6 Errors Induced by Depth Excursions

Temperature and salinity data from Seacats on both taut-line and slack-line moorings are subject to errors resulting from vertical displacement of sensors from their nominal depths. Most Seacats were mounted on taut-line moorings, which minimize vertical excursions of the mooring line. However, even taut-line moorings respond in some degree to surface wind forcing and to surface and sub-surface currents. Relative displacements, which are zero at the surface, increase monotonically with depth. McCarty *et al.* (1997) show that mooring-motion-induced errors in taut-line ATLAS temperature records were largest in the upper thermocline, with root mean square (RMS) values of 0.15°C to 0.45°C. Errors below 200 m in the western Pacific ranged

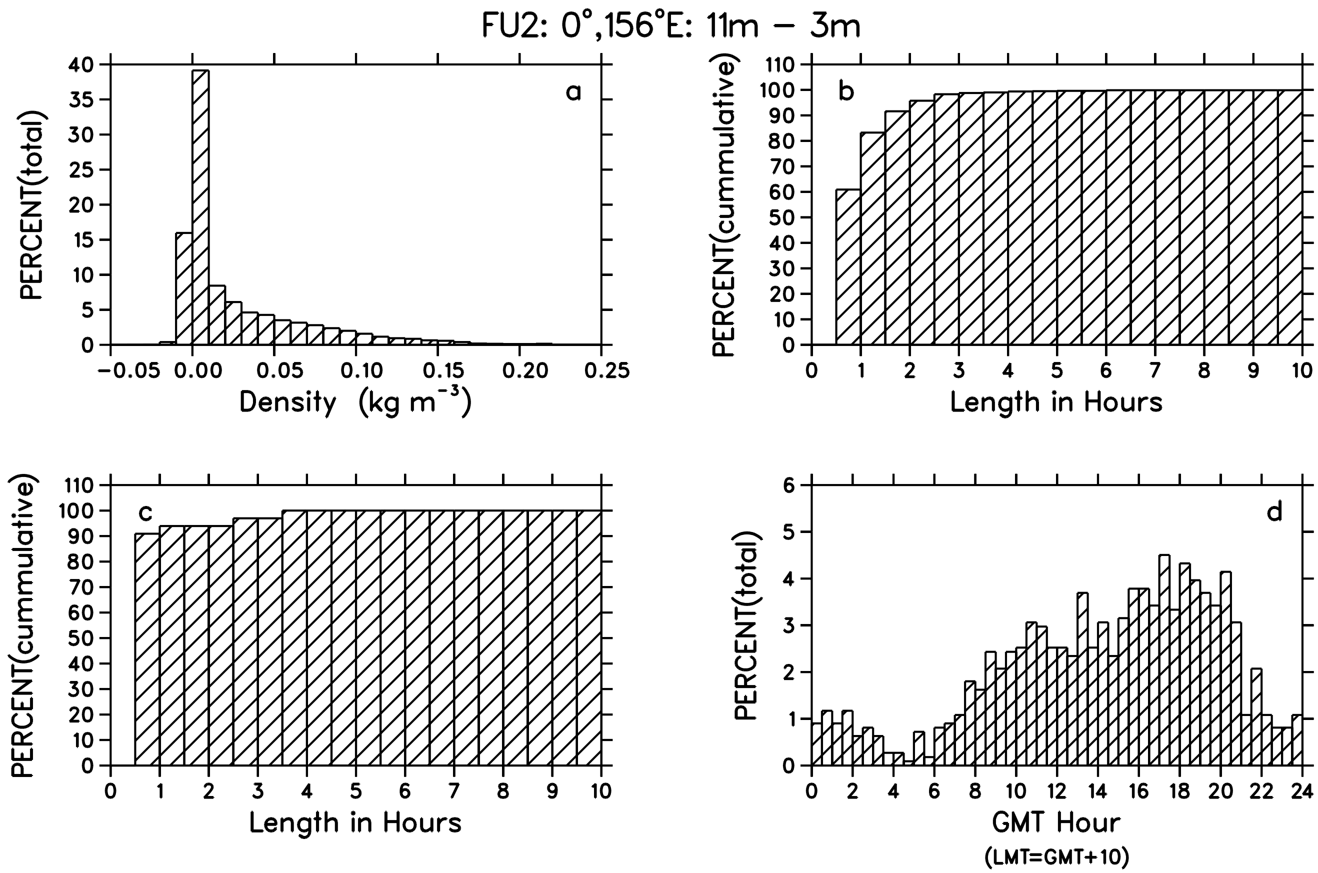

Figure 10: (a) Distribution of 11-m minus 3-m density (sigma-theta) differences at 0°, 156°E. (b) Cumulative distribution of duration (hours) of all instabilities. (c) Cumulative distribution of duration for instabilities $\geq$0.01 kg m^{-3}. (d) Diurnal distribution of all instabilities. Nighttime hours (1800 to 0600 local) are 0800 to 2000 GMT.

from 0.02°C to 0.15°C. Errors in the mixed layer were negligible on both taut-line and slack-line moorings.

The induced errors in the Seacat temperature records are assumed to be similar in magnitude to the errors induced in the records from ATLAS temperature sensors. Salinity errors due to vertical excursions of the Seacats are expected to be small, because the salinity gradients are for the most part weak. Also, most Seacats were located in the upper 100 m to 200 m of the mooring line, where vertical excursions were small. No Seacats were deployed below 3 m on slack-line moorings. In the surface mixed layer, salinity errors should be negligible for both taut-line and slack-line moorings. In the upper thermocline, a typical mean value for vertical displacement of the 200 m depth of a taut-line ATLAS buoy was 2.5 m. Assuming a salinity gradient of 1 psu per 100 m, an error due to mooring-line motion of 0.025 psu could be expected in a Seacat salinity record from 200 m.

Correction of either the salinity or temperature records for depth excursions was not attempted.

4. Summary

After application of the quality analysis routines described above, the COARE array of Seacats deployed on TAO moorings has produced a high-quality salinity data set that may be used to describe the structure of the salinity field in both time and space. In addition, these data may be used to investigate the salinity balance of the region (Cronin and McPhaden, 1997). Errors in the data, due primarily to cell abrasion and biological fouling, have been corrected using an intensive set of analysis methods that required sensor calibration before and after use, coincident CTDs, and the placement of multiple sensors within the mixed layer. The sign of the corrections was generally such that salinity values were lower after correction (Fig. 11). Most corrections were near zero at the beginning of a deployment and increased in magnitude with time. Consequently, longer deployments typically had larger corrections than shorter deployments. In a few cases, corrections near the beginning of the record are not near zero because: 1) pre-deployment calibration was many months before deployment (significant only for UH processed data), 2) CTDs at the time of deployment indicated an offset, or 3) the instrument was redeployed shortly after recovery, with no laboratory calibration in between. A few time series have sharp jumps in the corrections which were the result of either: 1) stability analysis indicating a sharp offset in salinity, 2) or stability analysis indicating a specific correction for only a portion of the record (this might occur if the thickness of the mixed layer changed). In some cases, salinity data after these sharp offsets in the corrections occurred are considered to be questionable and of lower quality than other data in general. These cases are identified in Appendix A. The largest correction was 0.435 psu, but corrections of this magnitude occurred in only a few cases and generally only during the last month or two of a year-long deployment. The vast majority of the 173 time series processed had much smaller corrections. The RMS of all maximum corrections was

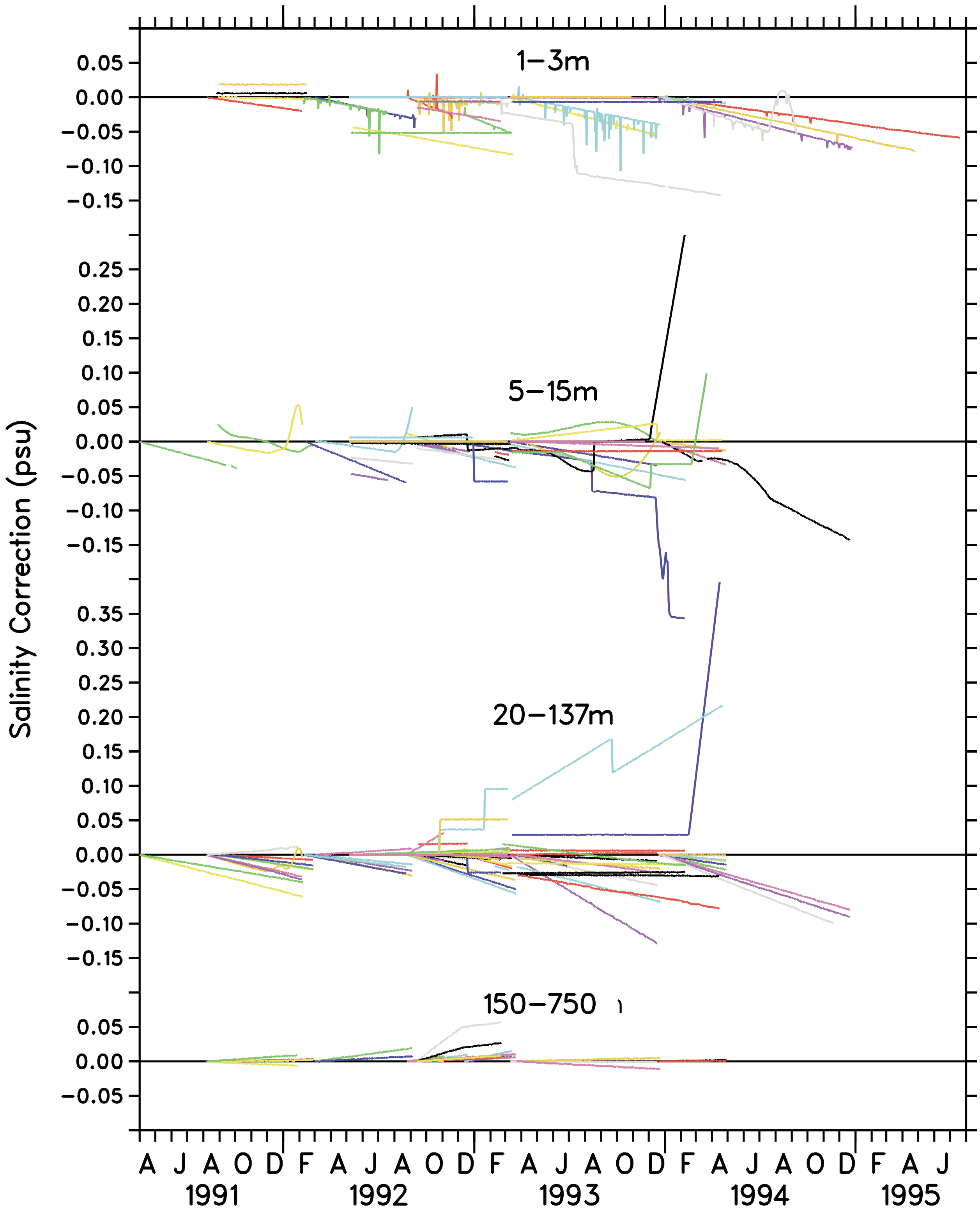

Figure 11: Daily mean salinity differences between quality controlled salinity time series minus time series based on pre-deployment calibrations. Negative values imply that the data were fresher after correction.

0.062 psu. Corrections for instruments placed at 150 m and below were significantly smaller than those above, with a tendency towards higher salinity after correction.

In addition to these long-term drift corrections, the effect of despiking several near-surface salinity time series is also shown in Fig. 11. The differences shown are those of daily averaged data. The magnitude of changes to individual data points was at times much larger. For most time series the largest individiual spike removed ranged between 0.2 and 0.8 psu. For one particularly noisy 1-m time series (FU8) the largest individual spike removed was 1.8 psu.

Given the uncertainties inherent in the calibration of moored conductivity sensors, as discussed above, a precise, absolute accuracy of these salinity measurements cannot be given, but intercomparison of Seacat salinities and comparisons to CTD salinities have led to the conclusion that the corrected data are accurate to within 0.02 psu or less in the majority of cases. Instances when this level of accuracy was not met would include times when there were insufficient co-located instruments or CTDs to perform intercomparisons, times when well-mixed conditions were not sufficiently present, and times when salinity spiking near the surface was large and adequate correction methods were unavailable.

Daily mean values of salinity and density (sigma-theta) are displayed in Appendix B. Hourly mean temperature, salinity and density are available on the World Wide Web at `http://www.pmel.noaa.gov/coare/coare-seacat-deliv.html`.

5. Acknowledgments

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Appendix A

This appendix contains details of salinity quality analysis for each Seacat time series. Pages are ordered from west (0° 154°E) to east (0° 170°E) and from north to south along longitudes with multiple mooring sites. Each page contains a table which lists mooring name, latitude, longitude, deployment and recovery dates, Seacat serial numbers (S/N), sample rates (ΔT) and depths of the instruments. In addition, the tables indicate what type of processing was used. For temperature, they indicate whether pre-deployment calibrations were used exclusively, or a linear combination of pre-deployment and post-recovery calibrations. These entries are found for salinity as well, plus entries indicating adjustments made based upon stability analysis, CTD comparisons (with either moored Seacats or Seacats attached to the CTD), and a column showing the maximum long-term salinity drift (ΔS) between the time series generated using only pre-deployment calibrations and the final version of the time series.

In addition to the tables, any other pertinent facts are listed below the tables. These may include: moorings parting and drifting, Seacats going to the bottom, instrument failures for incomplete records, order of polynomials used and other necessary details for stability corrections, and the details of CTD-based corrections.

Mooring ET146

Latitude: 0° 0.2′S **Longitude:** 153° 59.2′E
Deployment Period: 5 May 1992–7 March 1993

Depth (m)	S/N	ΔT (min)	Temperature Pre	Temperature Pre/Post	Salinity Pre	Salinity Pre/Post	Salinity Stability	Salinity CTD	ΔS (psu)
3	804	10		•	•				0.0
5	803	10		•	•		•		–0.058
10	799	10		•	•		•	•	0.006
15	801	10		•	•				0.0
20	802	10		•	•				0.0
30	784	60		•	•		•		0.096
50	781	60		•	•		•		0.051
75	736	60		•	•				0.0

The 3 m Seacat (S/N 804) drifted towards fresher values starting on 19 October 1992. The drift was of order –0.25 psu. As it is unclear how to best correct for this drift, the 3 m salinity data recorded after 19 October 1992 remain uncorrected and should be considered highly suspect.

A jump of 0.058 psu was detected through the use of stability analyses in the 5 m Seacat (S/N 803) salinity data which seemed to affect all salinity points after 31 December 1992. These points were corrected with an offset correction of –0.058 psu but should be considered suspect. Furthermore, a salinity drift of order –0.15 psu/month started on 30 August 1992. Thus, all salinity points for the 5 m Seacat recorded after 30 August 1992 should be considered highly suspect as it is not clear how to correct for this drift.

The 10 m Seacat (S/N 799) became very unstable and began to record inaccurate readings (a severe drift caused salinities less than 33 psu to be recorded) starting on 10 January 1993 so data after this day were eliminated. The conductivity cell for the 10 m Seacat was found to have corrosion damage when it returned to the factory for recalibration so this could have been a source for the inaccurate and unstable readings. A CTD cast taken just after the deployment of this mooring as well as stability analyses and analyses performed during well-mixed times suggested that all salinity data from this instrument required an adjustment of 0.006 psu.

Stability analyses showed a drift in the 15 m Seacat (S/N 801) salinities beginning on 28 November 1992. Salinities from this instrument began to drift to saltier (larger) values at this time. As it is difficult to determine how to correct for this drift, all 15 m salinity points after 28 November 1992 should be considered highly suspect.

Two drops in salinity were detected using stability analyses for the 30 m Seacat (S/N 784). Sustained drops in salinity were seen on both 26 October 1992 and 21 January 1993. Offset corrections were applied to the onset of each drop and the corrections were continued from that point through the rest of the deployment. Salinity points after the 26 October 1992 drop were corrected by 0.037 psu and points after the 21 January 1993 drop were corrected by 0.059 psu. All these corrected salinity points should be considered suspect.

Stability analyses show a salinity drop in the 50 m Seacat (S/N 781) salinity data on 27 October 1992. An offset correction of 0.051 psu was applied to this drop and all salinity points recorded after its onset. Hence, all salinity points recorded after 27 October 1992 for the 50 m Seacat should be considered suspect.

Quality analysis was performed at the University of Hawaii.

Mooring ET188

Latitude: 0° 1.1′N **Longitude:** 153° 59.5′E
Deployment Period: 7 March 1993–25 November 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	800	10		•	•				0.0
5	797	10		•	•				0.0

This mooring was heavily vandalized. The mooring line parted somewhere below 500 m and the mooring was set adrift starting on 20 April 1993. Data recorded after 20 April 1993 had a constantly changing location associated with them. On 16 November 1993, the mooring line was again severed and all equipment below 9 meters was lost.

The 3 m Seacat (S/N 800) began to record wild readings (negative temperature, negative salinity) on 31 October 1993 until the instrument was recovered. These data were eliminated from the record.

Salinity data from the 3 and 5 m Seacats (S/N 800 and S/N 797) should be considered highly suspect from 22 June 1993 until the end of the deployment. One of the Seacats experienced a large change in salinity (on order of > 0.3 psu) on 22 June and salinities remained offset between the two sensors until the end of the deployment. As it is difficult to determine which sensor was responsible for the salinity offset, salinity data from both Seacats (S/N 800 and S/N 797) should be considered highly suspect from 22 June 1993 until the end of the deployment.

Quality analysis was performed at the University of Hawaii.

Mooring ET116

Latitude: 5° 0.0′N **Longitude:** 156° 1.0′E
Deployment Period: 31 August 1991–18 September 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	800	10		•	•			•	0.019

Seacat S/N 800 failed on 15 February 1992 due to a bad battery pack.

All salinity data from Seacat S/N 800 was offset corrected by 0.019 psu after two near-mooring CTD casts, taken one week after deployment, showed the instrument to be recording salinities which were 0.019 psu too low.

Quality analysis was performed at the University of Hawaii.

Mooring ET171

Latitude: 5° 0.5′N **Longitude:** 156° 0.2′E
Deployment Period: 23 September 1992–21 December 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	1096	10		•	•			•	0.0

Seacat S/N 1096 filled its memory before recovery.

Five near-mooring CTD casts conducted during the course of this mooring deployment were used to verify the salinity of Seacat S/N 1096. The five near-mooring CTD casts were always at least within 0.02 psu of the Seacat and at times, the CTD and Seacat S/N 1096 compared even more favorably. Hence, no adjustments were made to the Seacat salinities.

Quality analysis was performed at the University of Hawaii.

Mooring ET242

Latitude: 4° 59.8′N **Longitude:** 156° 3.7′E
Deployment Period: 22 December 1993–21 July 1995

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	622	60	•			•			–0.060

This was a longer than normal (19 month) deployment. Based upon the performance of other Seacats deployed for long periods, it could be expected that salinity drift could be very non-linear toward the latter portion of the time series. Since this mooring had only one Seacat, no stability analysis could be performed. Comparisons were made to a CTD cast at deployment and one in April 1994 and no clear evidence of Seacat bias was found.

The 1 m record had 9 days with periods of noisy salinity. These periods were despiked using linear interpolation. A total of 14 hours of salinity data were modified (0.1% of the total). The largest salinity spike removed was an upward spike of 0.224 psu. In addition, the 1 m temperature data contained several spikes, affecting 8 days of the record. Temperature data were despiked using linear interpolation. Twelve hours of temperature data were modified.

There were a large number of downward spikes in the last 3 months of the time series. By comparison, the number of downward salinity spikes in May to July 1995 was noticeably larger than the number occurring in the corresponding period of 1994. Without a rain gauge or adjacent Seacats on the mooring, it was impossible to distinguish instrumental error from rain events. The data for May to July 1995 should be used with caution.

Quality analysis was performed at PMEL.

Mooring ET168

Latitude: 2° 0.2′N **Longitude:** 156° 1.3′E
Deployment Period: 17 September 1992–20 February 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	1091	10	•		•		•		–0.006
5	1102	10		•	•				0.0
10	1086	10		•	•		•		–0.005
15	1095	10		•	•				0.0
20	1100	10	•		•		•		–0.007
30	1089	10	•		•				0.0
45	1098	10		•	•				0.0
70	1101	10		•	•				0.0

A boat tied off and then moved this mooring 2 miles to the northwest of its original position on 3 February 1993. From this day forward, wild and unstable readings were seen for the 3, 5, 10, and 45 m Seacats. These data from 3 February 1993 until the end of the deployment should be considered suspect. Upon recovery, the Seacats were found with connector plugs and anti-foulant caps missing as well as having electronics connectors, mounting brackets, and handles broken. These events most likely occurred when the mooring was towed and thus caused the wild and unstable salinity readings. The mooring was also found with a fishing net tangled within it down to 65 m. The entanglement of this net could have been related to the mooring being dragged.

A –0.0063 psu offset was applied to the 3 m Seacat (S/N 1091) salinity data as determined by the 3–5 m salinity differences.

The 10 m Seacat (S/N 1086) was corrected by a 2.9×10^{-5} psu/day linear drift correction as determined by the salinity differences between the 10 and 15 m Seacats.

The 15 m Seacat (S/N 1095) has a 10-day period of missing data near the end of the deployment which was due to an instrument malfunction.

Beginning on 15 October 1992 a -6.17×10^{-5} psu/day linear drift correction was applied to the 20 m Seacat (S/N 1100) salinity data as determined by the 15–20 m salinity differences. After the linear drift correction was made, an overall offset correction of 0.0012 psu was applied to the 20 m Seacat (S/N 1100) salinity data as determined by the 15–20 m salinity differences.

Quality analysis was performed at the University of Hawaii.

Mooring ET183

Latitude: 2° 0.1′N **Longitude:** 156° 0.3′E
Deployment Period: 21 February 1993–27 April 1994

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
10	1098	10		•	•				0.0
15	1101	10		•	•				0.0

The mooring line parted and all instruments fell to the bottom on 16 February 1994. As a result, the instruments at 3 and 5 m (Seacats S/N 1091 and S/N 1089) were lost at sea. The 20 m Seacat (S/N 1100) failed during deployment and only returned 17 hours of data.

Density stability analysis showed that density became unstable between the 10 and 15 m Seacats (S/N 1098 and S/N 1101) beginning on 25 November 1993. The unstable trend was long and sustained and originated due to a drift in the salinity data between the 10 and 15 m Seacats starting on 12 September 1993. As there is not enough information available to determine which Seacat was drifting, all salinity points from both the 10 and 15 m Seacats (S/N 1098 and S/N 1101) should be considered suspect from 12 September 1993 until the end of the deployment.

Quality analysis was performed at the University of Hawaii.

Mooring FU2

Latitude: 0° 0.9′S **Longitude:** 155° 24.2′E
Deployment Period: 28 August 1991–28 February 1992

Depth (m)	S/N	ΔT (min)	Temperature Pre	Temperature Pre/Post	Salinity Pre	Salinity Pre/Post	Salinity Stability	Salinity CTD	ΔS (psu)
3	741	30	•			•			–0.003
11	737	30	•			•	•	•	–0.015
30	744	30	•			•			–0.008
51	740	30	•			•			–0.023
75	742	30	•			•			–0.022
101	739	30	•			•			–0.016
150	745	30	•			•			0.004
201	743	30	•			•			0.003

Temperature and current meter records from this mooring indicate that it was pulled upon (presumably by fishermen) for about 12 hours on 18 February 1992. All time series have been linearly interpolated (in time) during this period.

After application of post-deployment calibrations, the 11 m salinity had a non-linear bias when compared to the 3 m and 30 m time series. A 4th order polynomial was fit to the bias from the start of the time series through 2 February 1992. A 3rd order polynomial was fit to the bias from 3 February 1992 to the end of the time series.

At the time of deployment the upper water column was not well mixed, making comparison to 3 CTD casts taken at that time of little value for comparison to Seacats. Two CTD casts in September indicated small (<0.01 psu) differences with the exception of the 11 m Seacat. Differences at 11 m were comparable to those indicated by the Seacat stability analysis given above.

Quality analysis was performed at PMEL.

Mooring FU4

Latitude: 0° 0.3′N **Longitude:** 155° 58.8′E
Deployment Period: 1 March 1992–13 September 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	294	30	•			•			–0.033
11	173	30	•			•	•		0.053
30	170	30	•			•			–0.015
51	292	30	•			•			–0.031
75	169	30	•			•			0.010
101	291	30	•			•			–0.024
150	167	30	•			•			0.020
201	293	30	•			•			0.008

This mooring broke in the nylon and was adrift from 20 April 1992 to 6 May 1992. It was redeployed on 7 May 1992. Data were linearly interpolated (in time) for the 21 hours between recovery and redeployment. On 5 September 1992 the buoy was unshackled from the mooring line (presumably by fishermen), and the majority of the mooring fell to the ocean floor. The buoy, with the 1 m Seacat attached, drifted until recovered on 13 September.

The 1 m record had 15 days with periods of noisy salinity. These periods were despiked by either linear interpolation or smoothing. A total of 106 hours of salinity data were modified (2.2% of total). The largest salinity spike removed was an upward spike of 0.273 psu.

After application of post-deployment calibrations, the 11 m salinity had a bias when compared to the 1 m and 30 m time series. A linear fit to the bias was applied from the start of the time series to 1 August 1992 and a 2^{nd} order polynomial was fit thereafter.

Salinity differences with CTD casts taken near the mooring shortly after deployment were small (<0.01 psu). Two CTDs taken in May when the mooring was redeployed did not have data above 20 m and the data below did not provide a good Seacat/CTD comparison. No casts were taken at recovery since the mooring was on the bottom.

Quality analysis was performed at PMEL.

Mooring FU6

Latitude: 0° 0.1′S **Longitude:** 156° 2.3′E
Deployment Period: 15 September 1992–24 December 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	386	30	•			•			–0.008
5	172	30	•			•			–0.021
11	745	30	•			•			–0.016
33	171	30	•			•			–0.016
57	741	30	•			•	•	•	0.017
83	737	30	•			•			0.008
132	740	30	•			•			0.007
183	744	30	•			•			0.010

A snag in the mooring line between 30 m and 50 m resulted in Seacats intended for 51 m and below being 18 m higher. The mooring parted at 30 m on 20 December. The drifting surface portion of the mooring was recovered on 24 December.

The 1 m record had 17 days with periods of noisy salinity. These periods were despiked by either linear interpolation, substitution of the 5 m value or smoothing. A total of 84.5 hours of salinity data were modified (3.5% of total). The largest salinity spike removed was an upward spike of 0.474 psu.

There were four long-lived episodes of instability between the 33 m and 57 m instruments in October and November. Comparison with the 83 m instrument indicated that the 57 m instrument had a bias of about 0.015 psu. The water column was well stratified during the first and last months of the record, so no indication of bias was found at those times. Sixteen CTD's from Hakuho Maru during one of the November episodes confirmed the estimate of bias. A constant adjustment of 0.015 psu was made to the entire 57 m record. This adjustment resulted in a few ($<1\%$) small (≤ 0.005 kg m^{-3}) instabilities between 57 m and 83 m, but these were short lived and mostly during the night.

Quality analysis was performed at PMEL.

Mooring FU6b

Latitude: 0° 0.5′N **Longitude:** 156° 0.2′E
Deployment Period: 8 February 1993–9 March 1993

Depth (m)	S/N	ΔT (min)	Temperature Pre	Temperature Pre/Post	Salinity Pre	Salinity Pre/Post	Salinity Stability	Salinity CTD	ΔS (psu)
1	386	5	•			•			–0.011
5	172	5	•			•			–0.028
11	745	5	•			•			–0.020
50	171	5	•			•			–0.023
75	741	5	•			•			0.003
100	737	5	•			•			0.011
150	740	5	•			•			0.010
200	744	5	•			•			0.014

These Seacats were redeployed from the recovered FU6 mooring. Instruments at 50 m and below had spent the previous month and a half on the sea floor.

Because of the short duration of this deployment, the sample rate was increased to 5 minutes between samples.

The 1 m record had 7 days with periods of noisy salinity. These periods were despiked by either linear interpolation or substitution of the 5 m value. A total of 32.3 hours of salinity data were modified (4.5% of total). The largest salinity spike removed was an upward spike of 0.357 psu.

The Seacat at 75 m had been adjusted by 0.015 psu during the previous deployment, but the density gradient during the FU6b deployment was such that no instability at 75 m was indicated. The mean differences between 24 CTDs from RV *Natsushima* and all Seacats between 5 and 75 m were $\leq$0.006 psu or less.

Quality analysis was performed at PMEL.

Mooring FU8

Latitude: 0° 0.3′N **Longitude:** 156° 1.1′E
Deployment Period: 10 March 1993–18 December 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	874	30	•			•			–0.056
5	1210	30	•			•	•		0.028
10	292	30	•			•			–0.036
30	291	30	•			•			–0.130
50	293	30	•			•			–0.045
75	170	30	•			•			–0.010
100	167	30	•			•			0.003
150	169	30	•			•			–0.001
200	294	30	•			•			–0.002

The 1 m Seacat (S/N 874) salinity time series was quite noisy, especially in the first half of the record. The noise was not related to unusually warm days and high frequency temperature variability, as were some other surface records. A 7-pt Hanning filter was applied to the complete salinity time series, because of their relative ubiquity. While removing much of the noise, to some degree this smoothing also decreased the magnitude of downward salinity spikes related to rain events. The largest salinity spike removed was a downward spike of 1.769 psu.

After application of post-deployment calibrations, the 5 m salinity had a bias when compared to the 1 m, 10 m and 30 m time series. A 3rd order polynomial fit to the bias was applied to the entire record.

Four CTD casts were taken at the time of deployment, but large cast-to-cast differences and instability in the upper portions of the casts made Seacat/CTD comparisons difficult. There was a general tendency for the Seacats in the mixed layer (after adjustment at 5 m described above) to be lower than the CTD by 0.015 to 0.020 psu, but no adjustment was made to the Seacats since the CTDs were so inconsistent among themselves. One cast was made at the time of recovery, but did not provide any data for a useful comparison to the Seacats.

Quality analysis was performed at PMEL.

Mooring TC2

Latitude: 0° 0.4′N **Longitude:** 156° 1.8′E
Deployment Period: 19 December 1993–29 April 1994

Depth (m)	S/N	ΔT (min)	Temperature Pre	Temperature Pre/Post	Salinity Pre	Salinity Pre/Post	Salinity Stability	Salinity CTD	ΔS (psu)
1	744	30	•			•			–0.009
5	745	30	•			•			–0.014
10	970	30	•			•			–0.034
20	1107	30	•			•			–0.010
30	1110	30	•			•			–0.023
50	1111	30	•			•			–0.015
75	1242	30	•			•			–0.008
100	1244	30	•			•			–0.002
150	1245	30	•			•			0.003
200	1116	30	•			•			0.002

This mooring was dragged 6 nm on 24 March 1994. Data at 75 m and below were interpolated for 10.5 hours while the mooring was moving because it was apparent that they were above their nominal depths during this time. Because instruments above 75 m were in the mixed layer during this time, they did not appear to be affected by the movement of the mooring.

During the first 2 months after deployment, the 1 m Seacat (S/N 744) salinity, and to a lesser degree temperature, had a lot of high-frequency noise. This noise resulted in some relatively large (some greater than 0.1 kg m^{-3}) instabilities between the 1 m and 5 m density time series. Later in the record there were some salinity spikes associated with unusually warm days and high frequency temperature variability, and also some salinity spikes not associated with temperature variability. To minimize all types of salinity errors, a 7-pt Hanning filter was applied to the complete salinity time series. While removing much of the error, some residual error remained, and to some degree this smoothing also decreased the magnitude of downward salinity spikes related to rain events. The largest salinity spike removed was a downward spike of 0.843 psu.

No significant biases were apparent after application of the post-deployment calibrations, but the number of density instabilities between the 1 m and 5 m was higher than for most near-surface time series, even after the 1 m time series was smoothed. Instabilities less than 0.01 kg m^{-3} were 25% of the total record. Furthermore, unlike most cases, the number of instabilities did not decrease monotonically with depth. The percentage of instabilities less than 0.01 kg m^{-3} were 6% between 5 m and 10 m, and 17% between 10 m and 20 m. This implies that there was a small (<0.01 psu) bias in the 5 m salinity, but differences of this magnitude are considered within the accuracy of the instruments and therefore no adjustment was made.

Quality analysis was performed at PMEL.

Mooring ET165

Latitude: 1° 59.2′S **Longitude:** 155° 53.8′E
Deployment Period: 12 September 1992–22 February 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	623	30	•			•	•		–0.009
3	1099	5		•		•			–0.035
5	1097	5		•		•	•		–0.009
10	1090	5		•		•			–0.026
15	1088	5	•			•	•	•	–0.014
20	1093	5		•	•		•	•	–0.028
30	1085	5		•	•				0.000
70	1092	5		•	•				0.000
112	969	5	•			•			–0.008
132	970	5	•			•			–0.002
175	971	5	•			•			0.007
225	1112	5	•			•		•	0.058
275	1113	5	•			•		•	0.027
400	1116	10	•			•			0.007
750	1117	10	•			•			0.009

Stability analysis showed that the 1 m Seacat values are too salty relative to the 3 m and 10 m records. (The 5 m record was excluded from the stability analysis because it was short.) The 1 m salinity data were corrected by a constant offset of –0.005 psu. The 1 m record had 15 days with periods of noisy salinity. These periods were despiked by linear interpolation in time or substitution of the 3 m time series. A total of 58 hours of salinity data were modified (1.4% of total).

Seacats at 5 and 30 m (S/N 1097 and S/N 1088) have short data records (data ends in mid-November 1992) due to bad battery packs.

A stability analysis showed a small drift (on order 0.008 psu) for the 5 m Seacat (S/N 1097) for the entire deployment. Even after correcting this drift, a significant number of inversions remained between 3 m and 5 m Seacats. As no further determinations could be made regarding the calibration of the 5 m salinity data, data for this instrument should be treated with caution if the data are used in cases where an accuracy of ±0.01 psu or better is required.

Three analyses conducted during well-mixed periods suggested that after 19 December 1992, the 15 and 20 m Seacats (S/N 1088 and S/N 1099) needed corrections of –0.024 and –0.028 psu, respectively, as their readings appeared anomalously high compared to the 10 m Seacat (S/N 1090). Eleven near-mooring CTD casts helped to support this conclusion as they also showed offsets of approximately these same amounts for the 15 and 20 m Seacats. Thus, the salinity data for the 15 and 20 m Seacats (S/N 1088 and S/N 1099) were corrected after 19 December 1992 but should be treated with caution.

The 30 m Seacat (S/N 1085) showed an anomalous drop in salinity (on order 0.02 psu) on 31 October 1992. After this date, salinity data from this instrument were widely varying and, at times, less than the 20 m Seacat data. As neither a cause nor correction can be determined, caution must be used when analyzing the 30 m salinity data after 31 October 1992.

After application of linear corrections for post-deployment calibration, Seacat data at 225 m (S/N 1112) and 275 m (S/N 1113) had mean biases of –0.042 and –0.012 psu, respectively, relative to 17 CTDs taken between 8 December 1992 and 12 February 1993. No Seacat bias was indicated when compared to 3 CTDs taken between 12 September and 26 September 1992. A linear adjustment was applied between the time of deployment and 8 December 1992, increasing from zero to the means listed above. Thereafter a constant adjustment equal to the mean bias was applied.

Quality analysis was performed on the 3 m through 70 m Seacats at the University of Hawaii. ORSTOM performed the initial quality analysis on the remainder of instruments during TOPEX/POSEIDON validation. PMEL performed a consistency check on the combined data set and made adjustments to the 225 m and 275 m salinity based on CTD comparisons.

Mooring ET184

Latitude: 1° 58.7′S **Longitude:** 156° 20.2′E
Deployment Period: 23 February 1993–30 April 1994

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	1099	10		•		•	•	•	–0.126
5	1090	10		•		•	•	•	–0.260
10	965	10	•			•		•	–0.056
15	1088	10	•			•	•	•	–0.301
20	1093	10		•	•			•	–0.028
30	966	10		•	•			•	0.006
45	1092	10		•	•			•	–0.012
70	967	10		•		•		•	–0.017

Mooring parted between 3 m and 5 m on 10 February 1994.

A near-mooring CTD cast conducted immediately after the deployment of this mooring showed the Seacat salinities to be offset from the CTD. Hence, the Seacat salinities were corrected through the information provided by the near-mooring CTD cast. Corrections of 0.013, 0.014, –0.001, –0.024, –0.028, 0.006, –0.012, and –0.020 psu were made to the 3, 5, 10, 15, 20, 30, 45, and 70 m Seacats respectively (S/N's 1099, 1090, 965, 1088, 1093, 966, 1092, and 967) according to the offsets between the Seacats and the near-mooring CTD cast.

Stability analysis suggests that the 3 m Seacat (S/N 1099) salinity record had a fast and anomalous increase from 8 July 1993 through 17 July 1993. After 17 July, the 3 m salinity appears to remain offset by 0.070 psu. Although a correction was applied to the anomalous salinity increase, caution should be used when examining salinity data from the 3 m Seacat (S/N 1099) after 8 July 1993.

A sharp increase in salinity was seen for the 5 m Seacat (S/N 1090) during a stability analysis. It appears that the sharp increase in salinity of 0.042 psu occurred on 14 August 1993 and left the salinity data offset by that amount until the salinity data started to drift even more on 15 December 1993. This drift increased the salinity data until 13 January 1994 when it appeared to reach a constant offset of 0.173 psu. Corrections have been applied to the 5 m Seacat (S/N 1090) salinity data from 14 August 1993 until the mooring sank, but these data should be treated with caution.

The 15 m Seacat (S/N 1088) showed two salinity drifts during stability analysis. The first drift showed a steady increase in salinity from the beginning of the deployment until 18 August 1993 when the pattern of the drift could no longer be determined (although it did reach a maximum increase of 0.043 psu). The second drift seen for the 15 m Seacat began 11 December 1993 and continued until the mooring sank, at which point the drift had reached an increase of 0.301 psu. Corrections were made for these drifts but caution should be used when examining the 15 m Seacat (S/N 1088) salinity data from the beginning of the deployment until August 18, 1993 and from 11 December 1993 until the end of the record.

Quality analysis was performed at the University of Hawaii.

Mooring ET113

Latitude: 4° 58.8′S **Longitude:** 156° 0.0′E
Deployment Period: 25 August 1991–11 September 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	797	10		•	•			•	0.006

Seacat S/N 797 failed on 16 February 1992 due to a bad battery pack.

All salinity data from Seacat S/N 797 was offset corrected by 0.006 psu after a near-mooring CTD cast conducted 1.5 hours after deployment showed the instrument to be recording salinities which were 0.006 psu low.

Quality analysis was performed at the University of Hawaii.

Mooring ET163

Latitude: 4° 58.9′S **Longitude:** 156° 1.4′E
Deployment Period: 10 September 1992–16 December 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	1094	10		•	•				0.0

ET163 was a slack-line mooring.

Seacat S/N 1094 failed on 14 December 1992. Data recorded after 24 November 1992 were eliminated as they were completely unrealistic.

Two near-mooring CTD casts were made for this mooring while Seacat S/N 1094 was functioning. However, neither CTD cast compared well with the CTD. As it was difficult to determine a clear way to correct the Seacat data according to the CTD, they were left uncorrected. It should be noted though, that since there were no corrections made, the CTD casts do suggest that the salinity data for Seacat S/N1094 could be inaccurate by more than 0.05 psu.

Quality analysis was performed at the University of Hawaii.

Mooring ET241

Latitude: 5° 0.1′S **Longitude:** 156° 1.7′E
Deployment Period: 16 December 1993–26 December 1994

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	623	60	•			•			–0.073

ET241 was a slack-line mooring.

Since this mooring had only one Seacat, no stability analysis could be performed. There were no CTD data available at the Seacat depth.

The 1 m record had 19 days with periods of noisy salinity. These periods were despiked using linear interpolation. A total of 33 hours of salinity data were modified (0.4% of the total). Without a rain gauge or adjacent Seacats on the mooring, it was impossible to distinguish downward (fresher) salinity spikes due to instrumental error, from real data; no attempt was made to adjust downward spikes. The largest salinity spike removed was an upward spike of 0.381 psu.

Quality analysis was performed at PMEL.

Mooring ET148

Latitude: 0° 1.6′S **Longitude:** 160° 32.8′E
Deployment Period: 9 May 1992–12 March 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	787	60	•		•		•		–0.052
5	791	60		•		•			–0.060
10	792	60		•		•			–0.032
15	793	60		•		•			–0.003
20	794	60		•	•				0.0
30	795	60		•	•				0.009

The 3 m Seacat (S/N 787) was lost at sea after this deployment so it does not have a post-deployment temperature or conductivity calibration. Stability analyses performed after the other Seacats were calibrated suggested that the 3 m Seacat (S/N 787) was recording salinities which were 0.052 psu too salty from the beginning of the deployment. Thus, an offset correction was made. Furthermore, stability analyses showed that the 3 m Seacat (S/N 787) started to drift to extremely fresh values starting on 20 August 1992. The drift appeared to become as large as 0.25 psu by December 1992. This drift could be due to biological fouling of the conductivity cell, but it is difficult to model as it is unknown if the drift continued beyond December 1992. Thus, all salinity data recorded after the drift began on 20 August 1992 should be considered suspect

The time-series for the Seacat at 5 m (S/N 791) only lasted 73 days (until 19 July 1992) due to a battery connection problem.

The time-series for the Seacat at 10 m (S/N 792) lasted for only 120 days (until 6 September 1992) for an unknown reason. The batteries were still in good condition upon retrieval so it did not appear to be a battery connection problem. However, a “rollover” problem did induce errors in the time-series for the 10 m Seacat (S/N 792) as 134 unrealistic temperature and conductivity values were introduced into the record.

Quality analysis was performed at the University of Hawaii.

Mooring ET193

Latitude: 0° 1.1′S **Longitude:** 160° 33.9′E
Deployment Period: 13 March 1993–22 April 1994

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	804	10		•	•			•	–0.007
5	803	10		•	•			•	–0.015
10	802	10		•	•		•	•	0.026
15	801	10		•	•		•	•	0.241
20	784	60		•	•		•	•	0.435
30	781	60		•	•		•	•	0.217

Intercomparison casts were made for these Seacats prior to this deployment and conductivity offset corrections were applied to the Seacat data in accordance with the offsets suggested by the intercomparison casts.

The 10 m Seacat (S/N 802) was found to be recording a mean density inversion compared to other Seacats through stability analyses. The mean inversion seemed to be caused by a drift in the 10 m Seacat salinities so a linear salinity drift correction of 9.1×10^{-5} psu per day was applied from the beginning of the deployment until 17 December 1993. After 17 December 1993, the 10 m Seacat (S/N 802) salinity data became widely varying until the end of the deployment. The 10 m salinity data during this period have times when they were fresher than the 5 m salinity data and then saltier than the 20 and 30 m salinity data. As there are no clues as to how to correct these data (no near-mooring CTD casts and no well-mixed period analyses available) the 10 m salinity data (Seacat S/N 802) should be considered highly suspect from 17 December 1993 until the end of the deployment.

A linear salinity drift correction of 0.0045 psu per day was applied to the 15 m Seacat (S/N 801) from 21 February 1994 until the end of the deployment as stability analyses showed this sensor to be drifting near the end of the deployment. After the linear salinity drift correction was applied to these points, a salinity offset correction was applied to the 15 m Seacat (S/N 801) as stability analyses and analyses conducted under well-mixed conditions showed the 15 m data to be too fresh from the beginning of the deployment until 17 June 1993. Thus, a salinity offset correction of 0.0177 psu (based on 10 and 15 m salinity differences) for these points was applied. After 17 June 1993, the 10 and 15 m salinity differences showed another drift in the 15 m Seacat (S/N 801) salinity data so another linear drift correction was applied. The linear drift correction was applied directly to the 15 m salinity data from 17 June 1993 until 5 December 1993 at a rate of –0.0003 psu per day.

Through stability analyses, the 20 m Seacat (S/N 784) was found to be recording salinities which were too fresh due to probable instrument drift. Thus, a linear salinity drift correction of 0.0062 psu per day was applied to the 20 m Seacat data from 16 February 1994 until the end of the deployment.

Stability analyses showed a drift in the 30 m Seacat (S/N 781) salinity data so a linear salinity drift correction of 0.0005 psu per day was applied to the 30 m salinity data for the entire deployment. After the linear drift correction for the 30 m Seacat (S/N 781) salinity data, the 30 m data appeared to be offset from the 20 m Seacat (S/N 784) salinity so an offset correction of 0.0238 psu from the beginning of the deployment until 22 September 1993 was applied. This correction was based on the median value of the 20 and 30 m salinity differences. An additional salinity offset correction of 0.0263 psu was applied to the 30 m Seacat (S/N 781) salinity data from the beginning of the deployment until 22 September 1993 as two analyses during well-mixed periods suggested that the 30 m Seacat was recording salinities which were 0.0263 psu (the mean difference from the two well-mixed periods) too fresh during this time period.

Quality analysis was performed at the University of Hawaii.

Mooring ET244

Latitude: 5° 1.8′N **Longitude:** 165° 0.2′E
Deployment Period: 28 December 1993–26 April 1995

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	624	60	•			•			–0.079

Since this mooring had only one Seacat, no stability analysis could be performed. A comparison was made to 1 CTD cast and no clear evidence of Seacat bias was found.

There were several periods in the ET244 1 m record where high frequency variability in the salinity record appeared to be related to high frequency variability in the temperature record. However, without rain data or additional salinity records, it was impossible to dismiss downward salinity spikes as noise, and consequently, very little despiking was performed. Five days of data were despiked by linear interpolation or by applying a 5-hour long (five-point) Hanning filter. Only 0.3% of the salinity data were modified by despiking procedures. The largest salinity spike removed was an upward spike of 0.310 psu.

Quality analysis was performed at PMEL.

Mooring ET243

Latitude: 2° 0.2′N **Longitude:** 164° 59.2′E
Deployment Period: 26 December 1993–22 December 1994

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	968	30	•			•	•		–0.058
10	969	30	•			•	•		–0.144
30	1112	30	•			•			–0.081
37	1113	30	•			•			–0.092
51	1243	30	•			•			–0.102

Both temperature and salinity data from the 1 m instrument were bad after 11 September 1994.

The 1 m record had 54 days with periods of noisy salinity. These periods were despiked by linear interpolation, substitution of the 10 m salinity data, or application of a seven-point (3.5 hour) Hanning filter. A total of 258 hours of data were modified (4% of the record). The largest salinity spike removed was an upward spike of 0.557 psu.

The 10 m record had a period of noisy temperature that extended from 15 March 1994 to 22 March 1994. Temperature and salinity data for that time period are flagged.

There was a prolonged period of pronounced instability between the 1 m and 10 m instruments which began in mid March and persisted to mid July. Comparison with the 30 m and 37 m instruments indicated the 10 m instrument had a bias during the mid-March to mid-July time period. The bias was modeled as a second-order polynomial which crossed 0.0 psu on 6 March 1994 and again on 22 July 1994 and which attained a maximum value of 0.025 psu from 8 to 20 May 1994. The 10 m salinity data between 18:00 6 March 1994 and 17:00 22 July 1994 were adjusted by the modeled bias. After mid-July, bias was apparent in the 1 m record (see below). Comparing the 10 m data to the deeper data, there is some suggestion that the 10 m values after late August are too fresh, but without 1 m data the possibility of real stratification can not be eliminated.

After mid July, an extremely pronounced and persistent stratification developed between 1 m and 10 m and lasted until a few days before the 1 m salinity measurements failed. Comparison with the 30 m and 37 m data indicated that the 1 m record had a large bias during this time period. The bias of the 1 m data was calculated for the periods when the water column between 10 m and 37 m was weakly stratified and then modeled as a second order polynomial. The modeled bias is 0.0 on 20 July 94 and reached a maximum value of 0.066 on 16 August 1994. The 1 m salinity between 3:00 20 July 1994 through 05:00 11 September 1994 was adjusted by the modeled bias. This is not considered a high quality correction.

The 51 m time series ended about 1 month before the mooring was recovered, but no failure mode was determined for the instrument. Between 37 m (30 m) and 51 m there were several long-lasting, instability episodes, at times reaching magnitudes >0.05 kg m^{-3}. Seven (five) of the instability events lasted longer than 12 hours. In two cases the events lasted longer than a day. This may indicate a bias in the 51 m record. No attempt was made to correct the 51 m record, because the 51 m Seacat was infrequently in the mixed layer, and because there were no instruments below for comparison. The problematic instability events begin on 21 July 94. All 51 m data after this point should be considered questionable.

Quality analysis was performed at PMEL.

Mooring FU3

Latitude: 0° 0.6′N **Longitude:** 165° 0.8′E
Deployment Period: 7 August 1991–7 February 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	738	30	•			•			–0.020
11	174	30	•			•	•	•	0.054
30	168	30	•			•	•	•	–0.025
51	171	30	•			•			–0.032
75	386	30	•			•			–0.037
101	26	15	•			•			0.013
151	27	15	•			•			–0.008
201	172	30	•			•			0.010

The mooring parted between 75 m and 100 m on 29 January 1992. The lower portion of the mooring dropped to the ocean bottom, but was later recovered. The upper portion drifted for 9 days, after which it was also recovered.

Both the 11 m and 30 m Seacat salinity time series drifted, relative to the 3 m and 51 m instruments, beginning on 5 November 1991. Because the drift rates were complicated, 4^{th} order polynomials were fit for November–December, and for January to recovery. Three CTDs taken on 26 January 1992 confirmed that the adjustments made to the 11 m and 30 m Seacats were necessary.

Quality analysis was performed at PMEL.

Mooring FU5

Latitude: 0° 1.7′N **Longitude:** 164° 51.5′E
Deployment Period: 8 February 1992–12 August 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	874	15	•			•			–0.021

Mooring FU5 was vandalized. Seacats from 11 m to 151 m were lost and the Seacat at 201 m was damaged and returned no data.

The 1 m record had 76 days with periods of noisy salinity. These periods were despiked by either linear interpolation or smoothing. A total of 294 hours of salinity data were modified (8% of total). The largest salinity spike removed was an upward spike of 0.547 psu.

Quality analysis was performed at PMEL.

Mooring FU7

Latitude: 0° 0.6′N **Longitude:** 164° 59.2′E
Deployment Period: 24 August 1992–20 November 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	876	30	•			•			–0.026
11	743	30	•			•	•		–0.010
30	27	30	•		•				N/A
51	738	30	•			•			0.033
75	742	30	•			•			–0.009
101	168	30	•			•			0.002
151	26	30	•			•			0.002
201	739	30	•			•			0.008

Mooring FU7 parted above the 30 m Seacat on 5 November 1992. The drifting surface portion of the mooring was recovered on 20 November.

The 1 m record had 7 days with periods of noisy salinity. These periods were despiked by either linear interpolation, or substitution of the 11 m value. A total of 46 hours of salinity data were modified (2.2% of total). The largest salinity spike removed was a downward spike of 0.358 psu.

The 11 m Seacat appeared to have a salinity bias when compared to 1 m and 30 m instruments, but corrections based on the 1 m and 30 m time series appeared to overcorrect the bias relative to 1 m. This may have been because of problems with the 30 m instrument (see below). A small, linear (–.012 psu to 0.000 psu) correction was applied, based on the 1 m and 11 m differences. Three CTDs taken at deployment confirmed the need for the correction at that time.

The 30 m Seacat conductivity cell was found to be cracked when post-calibrated. Only pre-deployment calibrations were used since the time when the cell cracked is unknown. This time series is probably less accurate than most time series in this data base.

Quality analysis was performed at PMEL.

Mooring FU7b

Latitude: 0° 0.0′N **Longitude:** 165° 0.4′E
Deployment Period: 13 December 1992–15 March 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	876	30	•			•			–0.053
11	743	30	•			•	•		–0.014
30	1212	30	•			•			–0.005
51	1243	30	•			•			–0.021
75	1211	30	•			•			–0.017
101	1245	30	•			•			0.007
151	1242	30	•			•			0.009
201	1244	30	•			•			0.016

Mooring FU7b parted deep in the mooring line and drifted for its entire deployment period.

Seacats at 1 m and 11 m were recovered from mooring FU7 and deployed without calibration between use.

The 1 m record had 5 days with periods of noisy salinity. These periods were despiked by linear interpolation in time. A total of 34 hours of salinity data were modified (1.5% of total). The largest salinity spike removed was an upward spike of 0.385 psu.

A small (–0.007 psu) salinity correction was computed and applied to the 11 m Seacat based on the 1 m and 30 m time series.

No CTD's were available for this mooring.

Quality analysis was performed at PMEL.

Mooring FU9

Latitude: 0° 0.1′N **Longitude:** 165° 0.1′E
Deployment Period: 23 March 1993–24 December 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	742	30	•			•			–0.040
11	26	30	•			•	•		–0.052
30	173	30	•			•			–0.017
51	1211	30	•			•			–0.069
75	1212	30	•			•			–0.021
101	738	30	•			•			–0.029
151	739	30	•			•			0.006
201	168	30	•			•			–0.012

The 1 m record had 35 days with periods of noisy salinity. These periods were despiked by linear interpolation in time, or substitution of the 11 m salinity time series. A total of 271 hours of salinity data were modified (4.1% of total). The largest salinity spike removed was an upward spike of 0.481 psu.

The 1 m and 11 m salinity and sigma-theta records exhibited several problems relative to one another. From the beginning of the deployment until mid-September there was a trend from slight instability to pronounced stratification. From late September to the end of the deployment there were two prolonged instability episodes separated by a period of pronounced stratification from mid-October to mid-March. Comparison of the 1 m and 11 m records to deeper records indicated that the 11 m instrument was the instrument in error. The bias was calculated for times between 23 March and 23 August 1993 when the well-mixed criterion was met. The bias was modeled by a second-order polynomial which crossed 0.0 on 12 April 1993, and reached a maximum of 0.0139 psu on 10 August 1993.

For the latter half of the 11 m record, a second bias model was required. Bias was calculated for weakly stratified times between 15 July and 24 December 1993. The bias was modeled by a second-order polynomial, which crossed the first bias model on 10 August 1993, reached a maximum value of 0.032 psu on 24 September 1993, crossed 0.0 on 22 November 1993, and was –0.0440 psu at the end of the deployment. The 11 m record was adjusted by the first polynomial between 23 March and 10 August 1993, and adjusted by the second polynomial between 10 August and 24 December 1993. The 11 m data after 10 August 1993 should be used with caution; the adjustment for that time period is not considered a high-quality correction, and it introduces long-lasting (up to 17 hours), large (as much as 0.04 kg m^{-3}) instabilities between 1 m and 11 m during the period of late September to mid-October.

The 30 m salinity exhibited a large, sharp jump (~0.4 psu) on 29 June 1993. Post-recovery calibration of the instrument did not reveal any problem with the instrument and the drift of the conductivity cell was typical. The salinity data were judged to be uncorrectable after the jump, and were omitted from the 30 m record.

Quality analysis was performed at PMEL.

Mooring TC1

Latitude: 0° 0.1′N **Longitude:** 165° 1.7′E
Deployment Period: 25 December 1993–17 December 1994

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
1	876	60	•		•				0.000

Mooring TC1 was not recovered, but during a visit to the site on 15 April 1994, data up to that point were recovered from the 1 m Seacat. Since no instruments were recovered, no post-deployment calibrations exist. No data were recovered from subsurface Seacats, so no stability analysis could be performed. There were no CTD data available at the 1 m Seacat depth.

The TC1 1 m record had 9 days with periods of noisy salinity. These periods were despiked by linear interpolation. A total of 32 hours of data were modified (1.2% of the record). The largest salinity spike removed was an upward spike of 0.327 psu. One point (1 hour) in the temperature record was also despiked by linear interpolation.

Quality analysis was performed at PMEL.

Mooring ET96

Latitude: 1° 58.8′S **Longitude:** 164° 52.8′E
Deployment Period: 31 March 1991–9 February 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
10	622	30	•			•			–0.039
30	623	30	•			•			–0.061
102	624	30	•			•			–0.041

There are no obvious instability problems between Seacats. There were five CTD casts taken at this site during the deployment. No significant differences between CTD values and Seacat data could be identified.

The 10 m salinity and temperature records end on 7 October 1991 and had a 9-hour period of noisy values on 21 June 1991. All 10 m data for that time period are flagged. There were also a few short gaps (32 points in all, no gap longer than 6 hours) which were filled by linear interpolation.

ORSTOM performed the initial quality analysis on these instruments. PMEL later applied their own quality analysis as a consistency check, flagged the noisy period on 21 June 1991, and filled the short gaps.

Mooring ET129

Latitude: 1° 59.8′S **Longitude:** 164° 41.9′E
Deployment Period: 9 February 1992–25 August 1992

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
10	965	10	•			•			–0.060
30	966	10	•			•			–0.028
101	967	10	•			•			–0.018

The 10 m salinity and temperature records do not begin until 12 February 1992. There were no obvious instability problems between Seacat depths. No CTD casts were taken at this site during this deployment.

ORSTOM performed the initial quality analysis on these instruments. PMEL later applied their own quality analysis as a consistency check.

Mooring ET161

Latitude: 1° 59.4′S **Longitude:** 164° 24.9′E
Deployment Period: 26 August 1992–22 March 1993

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
10	1106	5	•			•			–0.038
37	1107	5	•			•			–0.054
62	1108	5	•			•			–0.057
87	1109	5	•			•			–0.038
112	1111	5	•			•			–0.004
137	1110	5	•			•			–0.004
175	968	5	•			•			0.013
225	622	20	•			•			0.010
275	624	20	•			•			0.011
400	1114	10	•			•			0.000
750	1115	10	•			•			0.006

The 400 m salinity and temperature records end on 23 September 1992; the 137 m records end on 6 December 1992.

There were no obvious instability problems between Seacat depths. Only one CTD cast was taken at this site during this deployment. No significant Seacat bias could be identified by comparison with the CTD data.

ORSTOM performed the initial quality analysis on these instruments. PMEL later applied their own quality analysis as a consistency check.

Mooring ET197

Latitude: 1° 57.5′S **Longitude:** 164° 22.7′E
Deployment Period: 24 March 1993–16 April 1994

			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
10	799	10		•		•			–0.011
37	793	60		•		•		•	–0.032
62	794	60		•		•		•	–0.079

Linear conductivity drift corrections of -4×10^{-6}, -1×10^{-6} and -1.8×10^{-5} S/m per day were applied to the Seacats at 10, 37, and 62 m respectively (S/N 799, S/N 793, and S/N 794). These corrections were established by comparisons of pre-deployment and post-deployment conductivity calibrations.

Conductivity offset corrections of 0.004219 and 0.004379 S/m were applied to the 37 and 62 m Seacats (S/N 793 and S/N 794). These offsets were determined through both CTD intercomparison and near-mooring casts.

Quality analysis was performed at the University of Hawaii.

Mooring ET149

Latitude: 0° 2.5′N **Longitude:** 169° 59.5′E
Deployment Period: 12 May 1992–17 March 1993

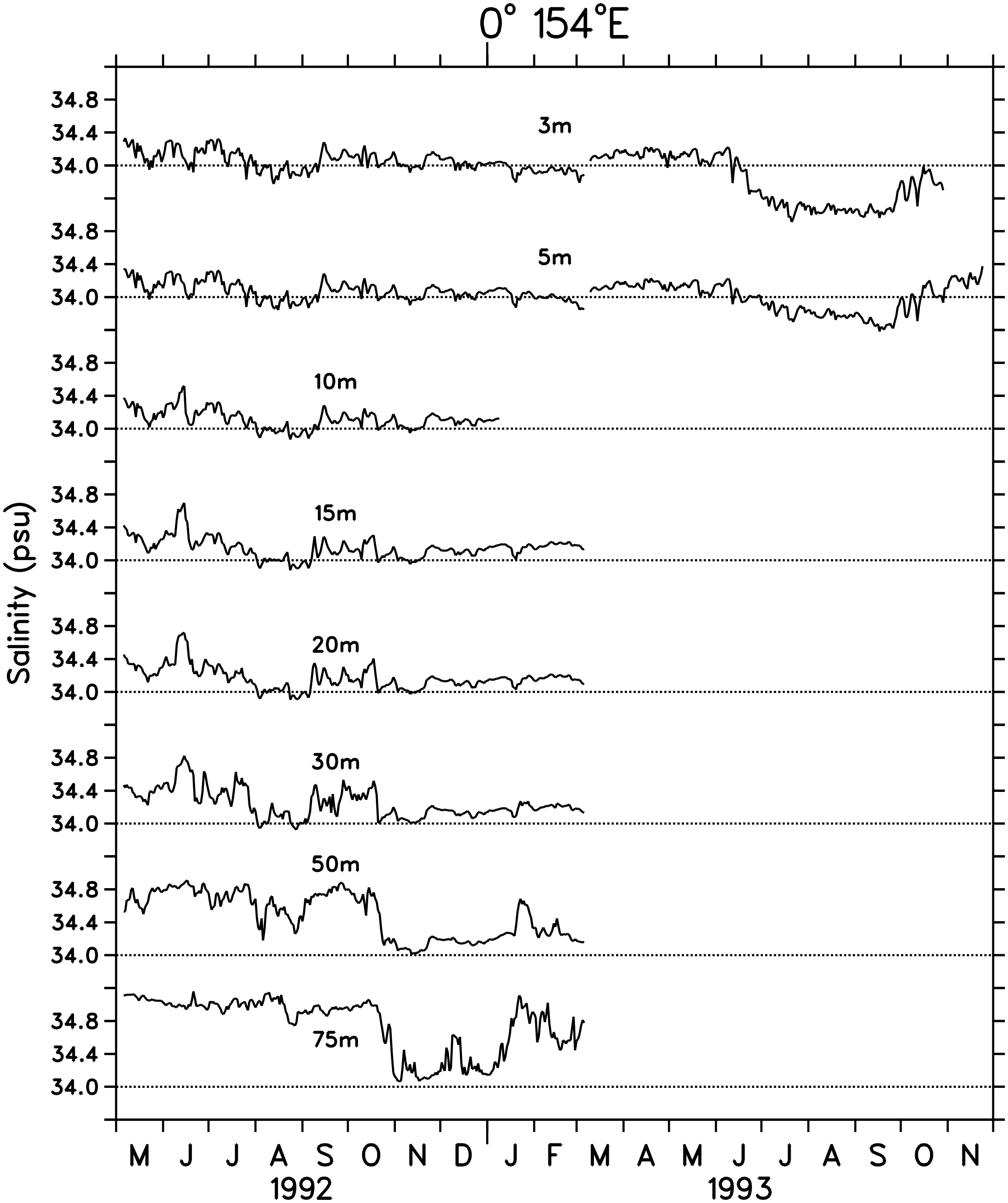
			Temperature		Salinity				
Depth (m)	S/N	ΔT (min)	Pre	Pre/Post	Pre	Pre/Post	Stability	CTD	ΔS (psu)
3	783	60		•		•		•	–0.083

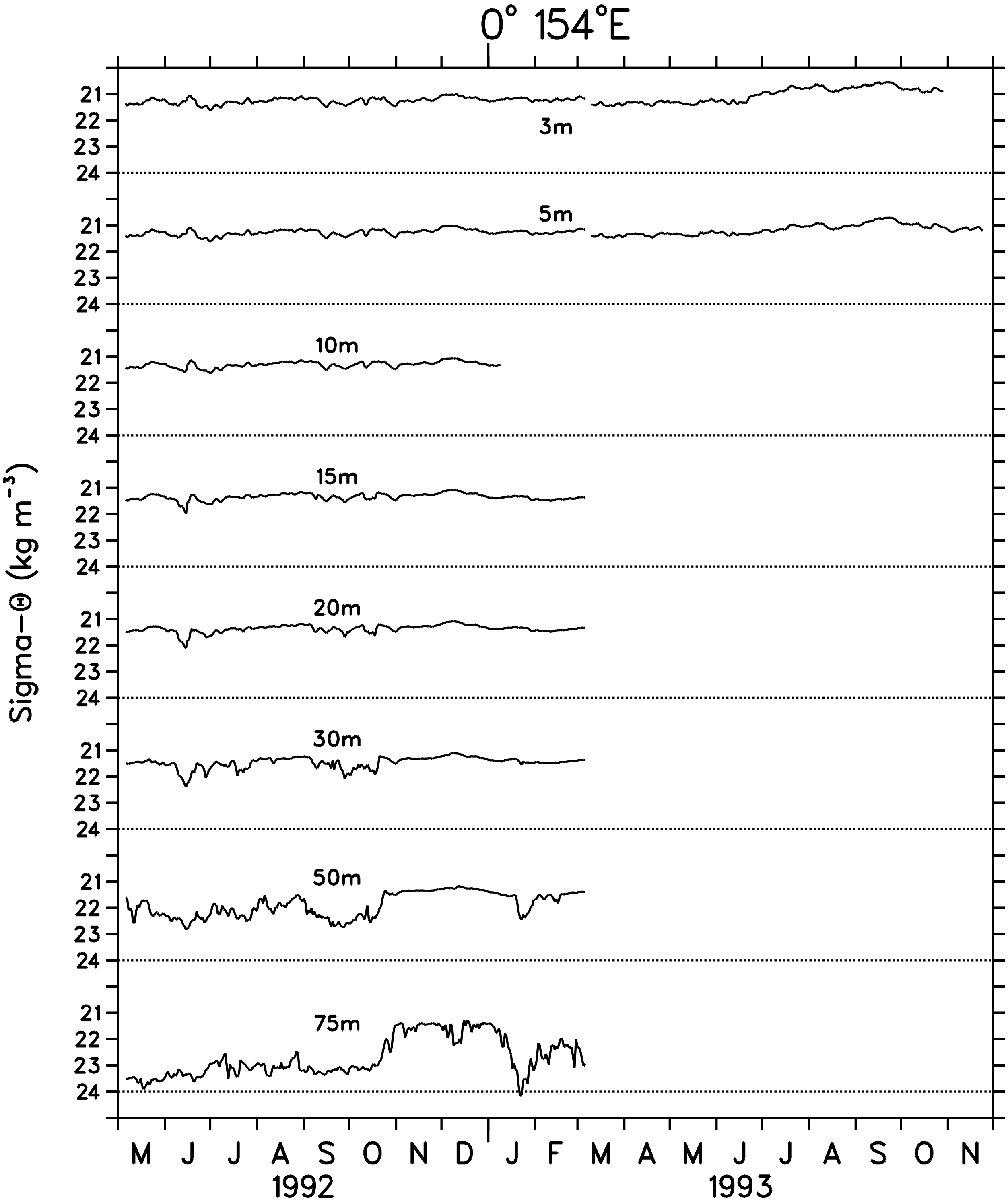
A near-mooring CTD cast conducted at the end of this deployment suggested that a -1.87×10^{-5} S/m per day linear conductivity drift correction (established by comparison of pre-deployment and post-deployment conductivity calibrations) be used to allow salinity data from Seacat S/N 783 to better match the CTD.

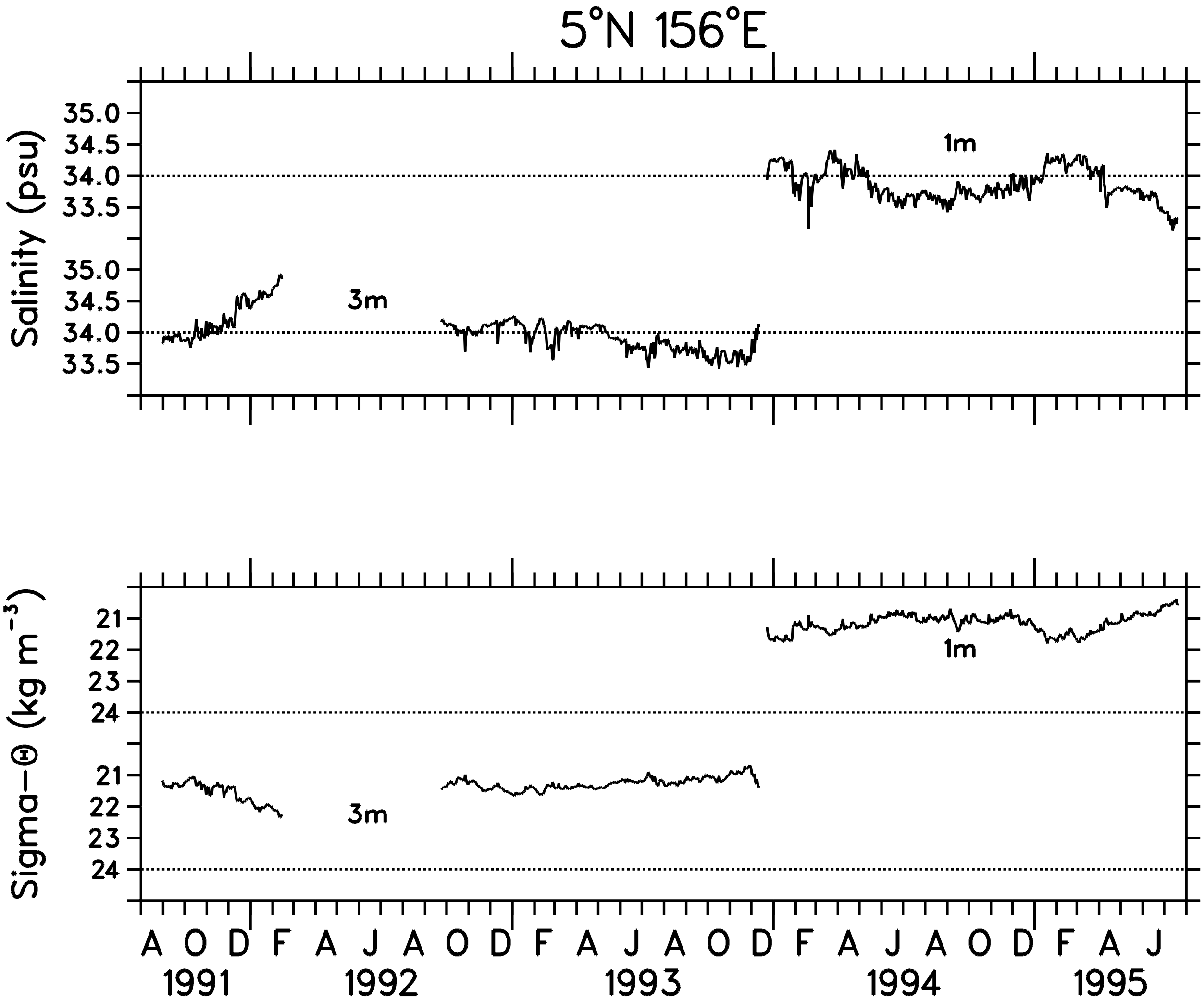
Quality analysis was performed at the University of Hawaii.

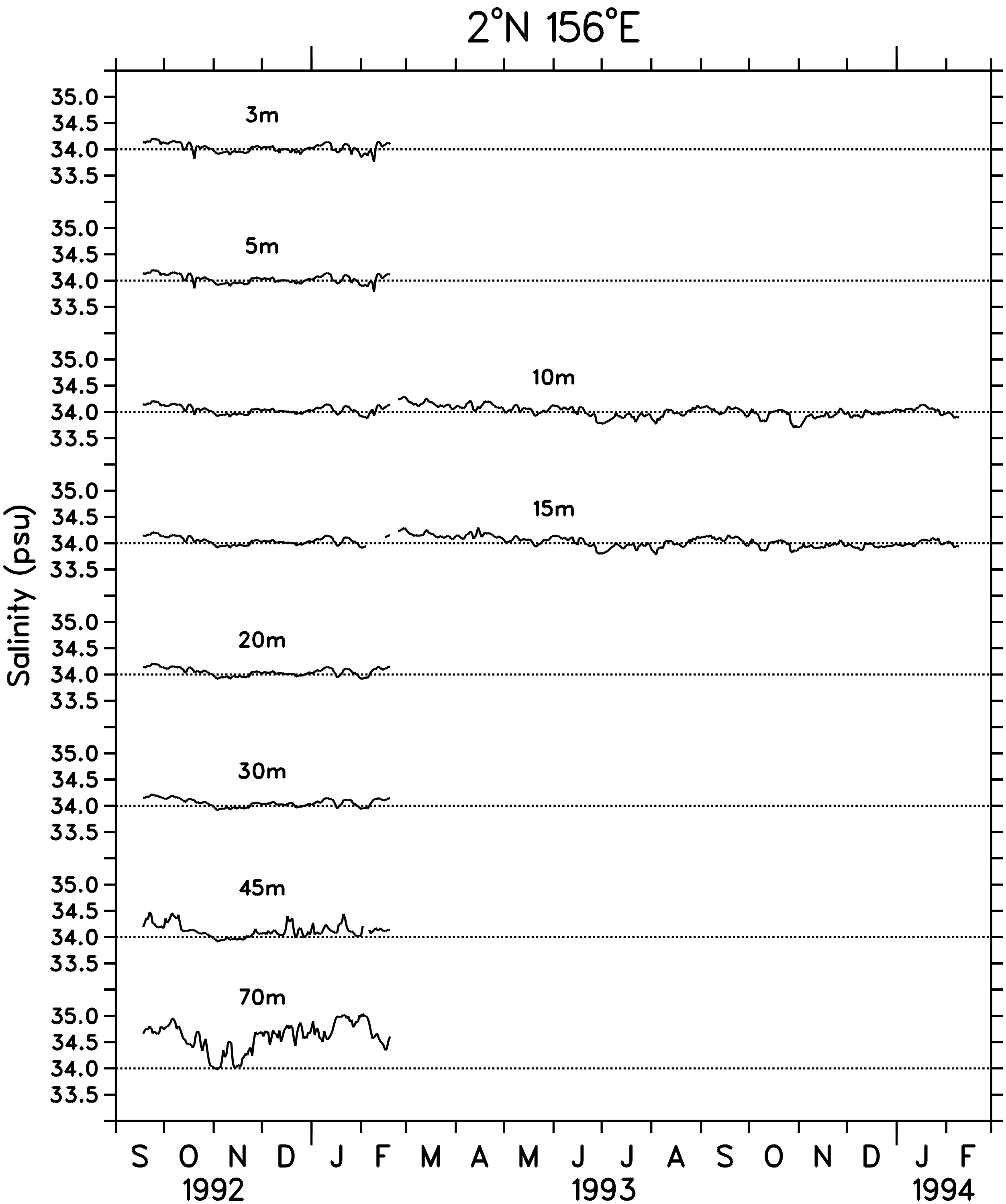
Appendix B

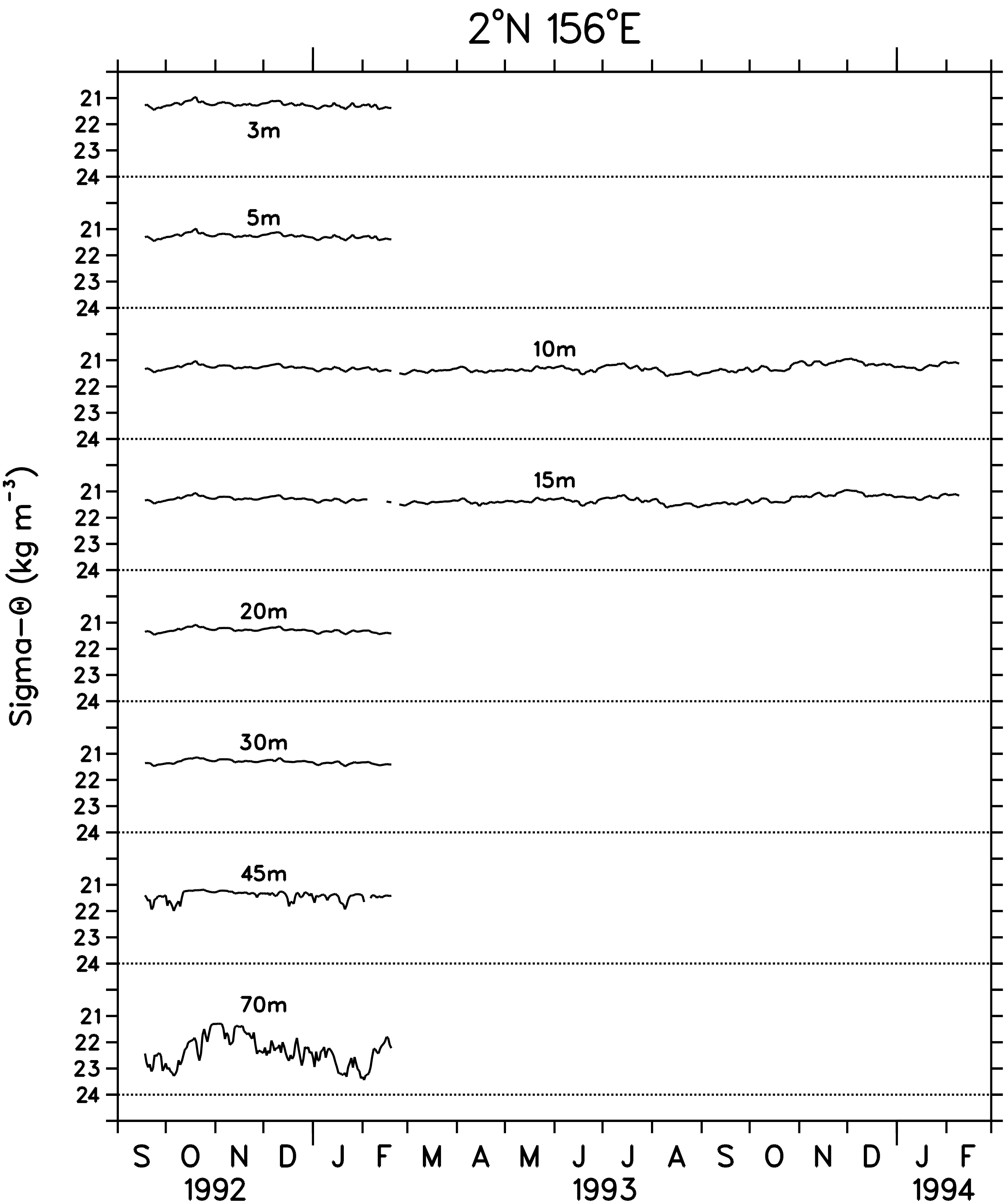
Time series plots of daily averaged salinity and density (sigma-theta). Plots are organized by site from west (0° 154°E) to east (0° 170°E) and from north to south along longitudes with multiple mooring sites. Most sites have one page with all salinity time series and one page with all density time series. Sites which had instruments at only one or two depths have both salinity and density plotted on the same page. Sites which had many instruments have two pages for salinity and two pages for density. Plotting scales have been chosen at each site which clearly display the data for that site, but scales may change from site to site. Most plots have one panel per instrument depth. At some sites, instrument depths changed from one mooring to the next. If time series from more than one depth are plotted in one panel, they are identified by greytone differences.

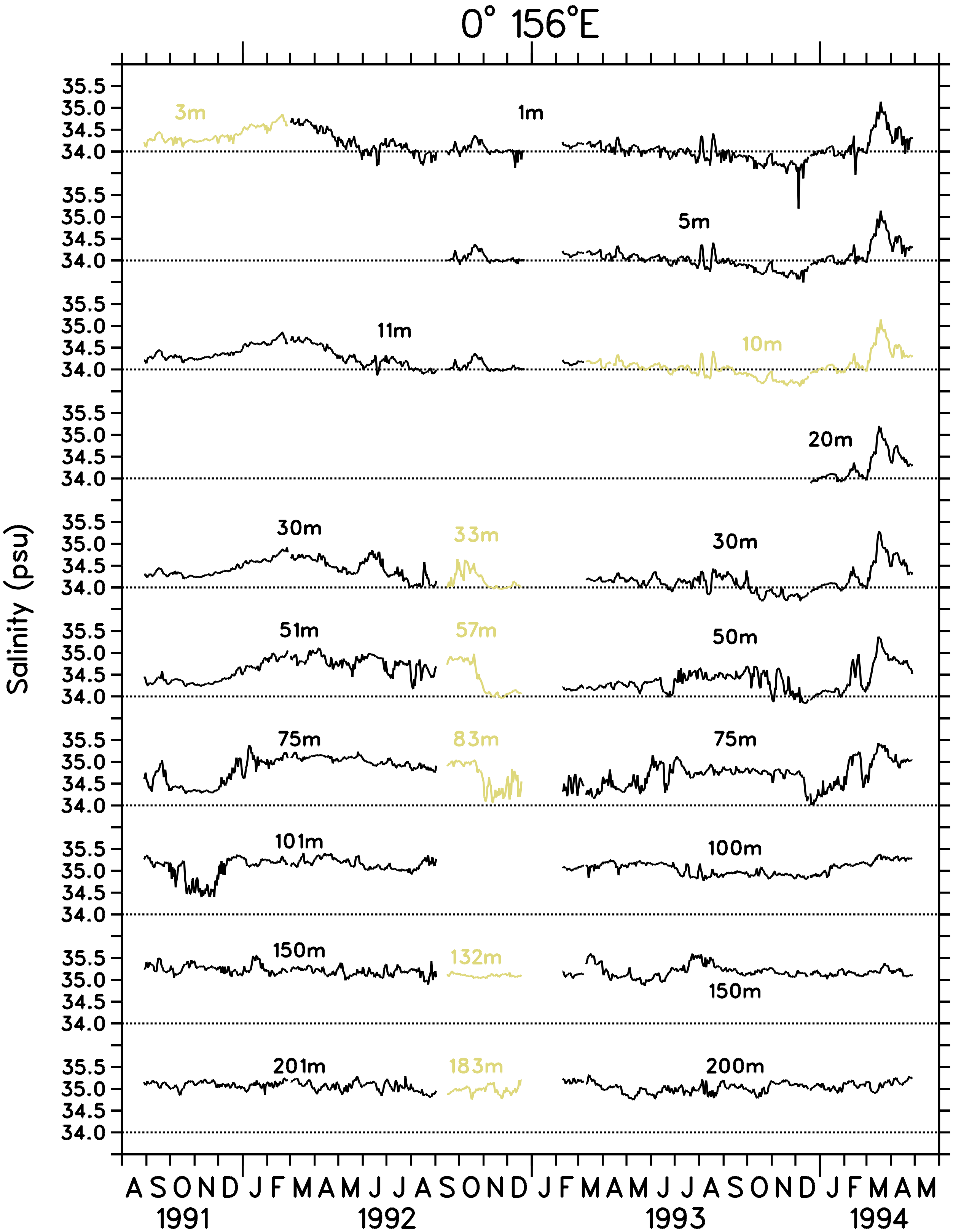

0° 154°E
Salinity (psu)
34.8
34.4
34.0
3m
5m
10m
15m
20m
30m
50m
75m
M J J A S O N D J F M A M J J A S O N
1992
1993

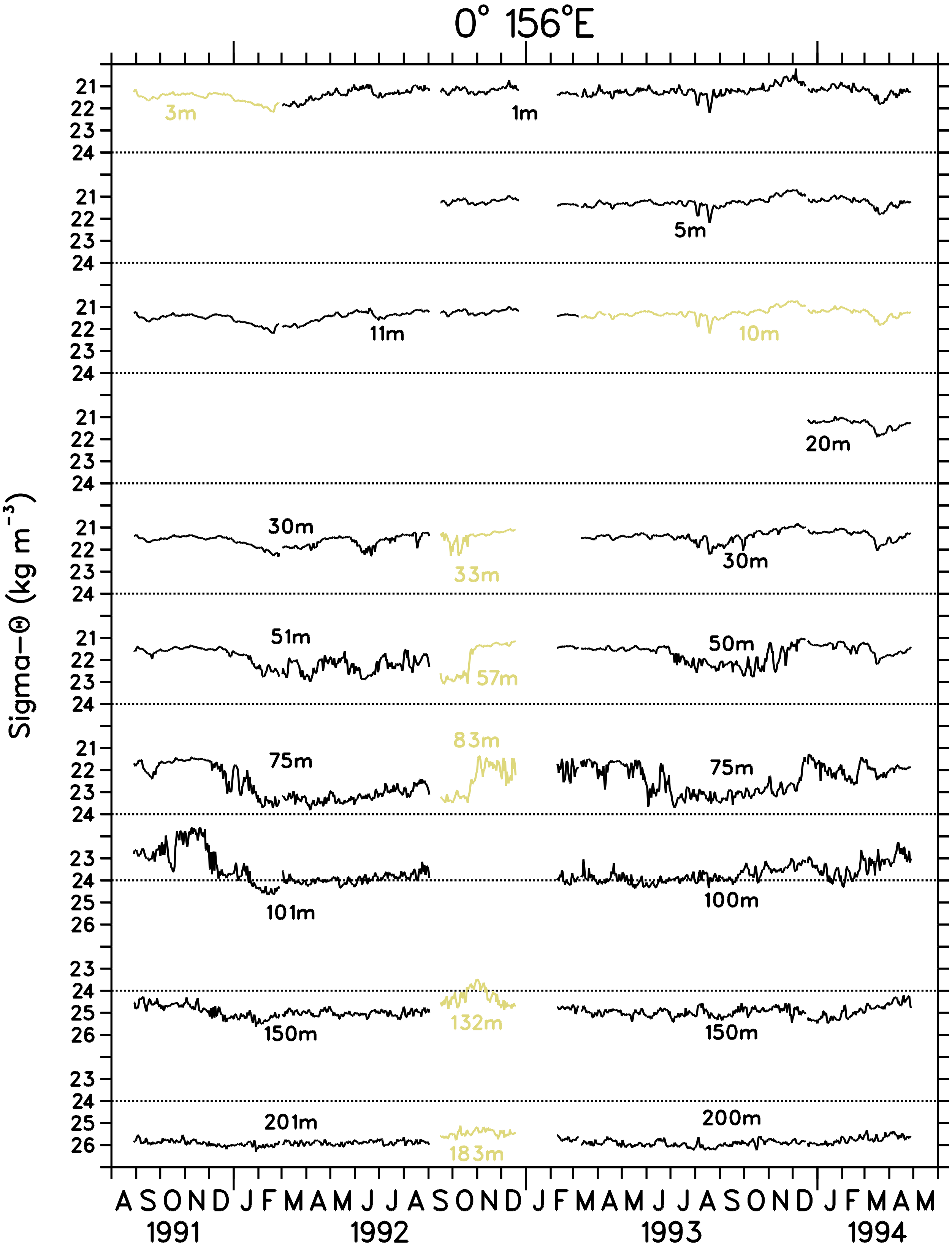

0° 154°E
Sigma−Θ (kg m⁻³)
21
22
23
24
3m
5m
10m
15m
20m
30m
50m
75m
M J J A S O N D J F M A M J J A S O N
1992
1993


5°N 156°E
Salinity (psu)
35.0
34.5
34.0
33.5
1m
3m
Sigma−Θ (kg m^{-3})
21
22
23
24
A O D F A J A O D F A J A O D F A J A O D F A J
1991
1992
1993
1994
1995

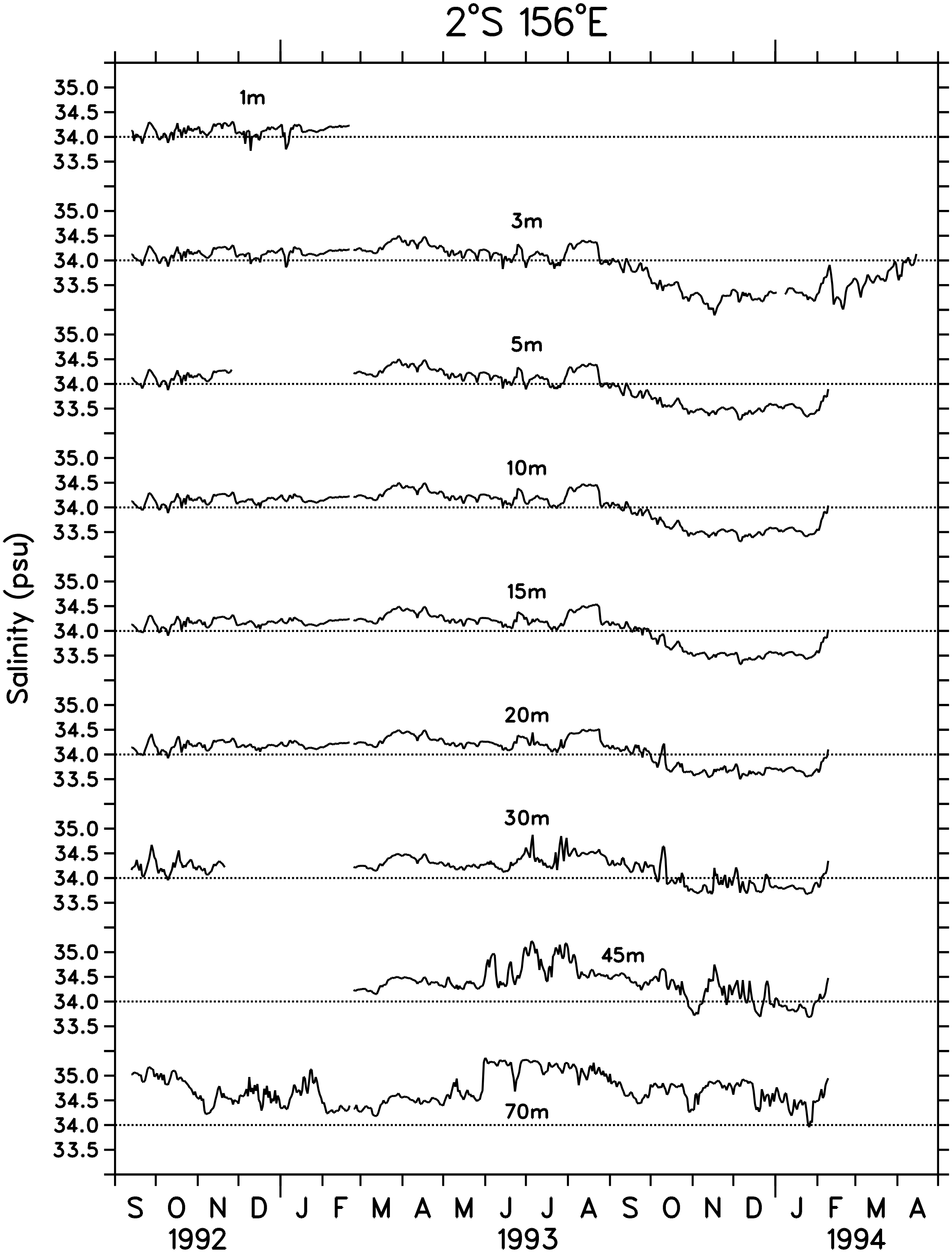

2°N 156°E
Salinity (psu)
35.0
34.5
34.0
33.5
3m
5m
10m
15m
20m
30m
45m
70m
S O N D J F M A M J J A S O N D J F
1992
1993
1994

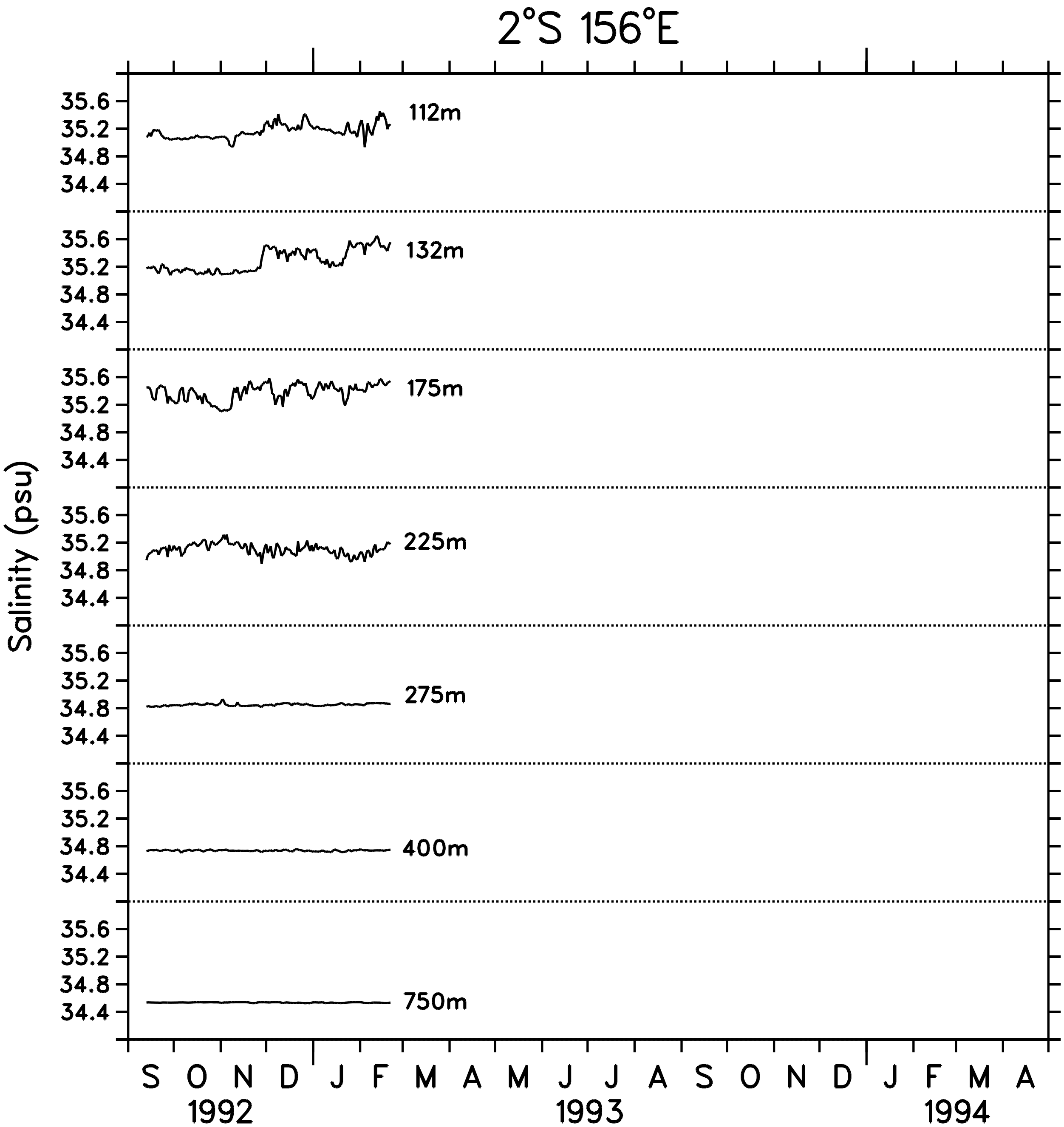

2°N 156°E
Sigma-Θ (kg m^{-3})
21
22
23
24
3m
5m
10m
15m
20m
30m
45m
70m
S O N D J F M A M J J A S O N D J F
1992
1993
1994

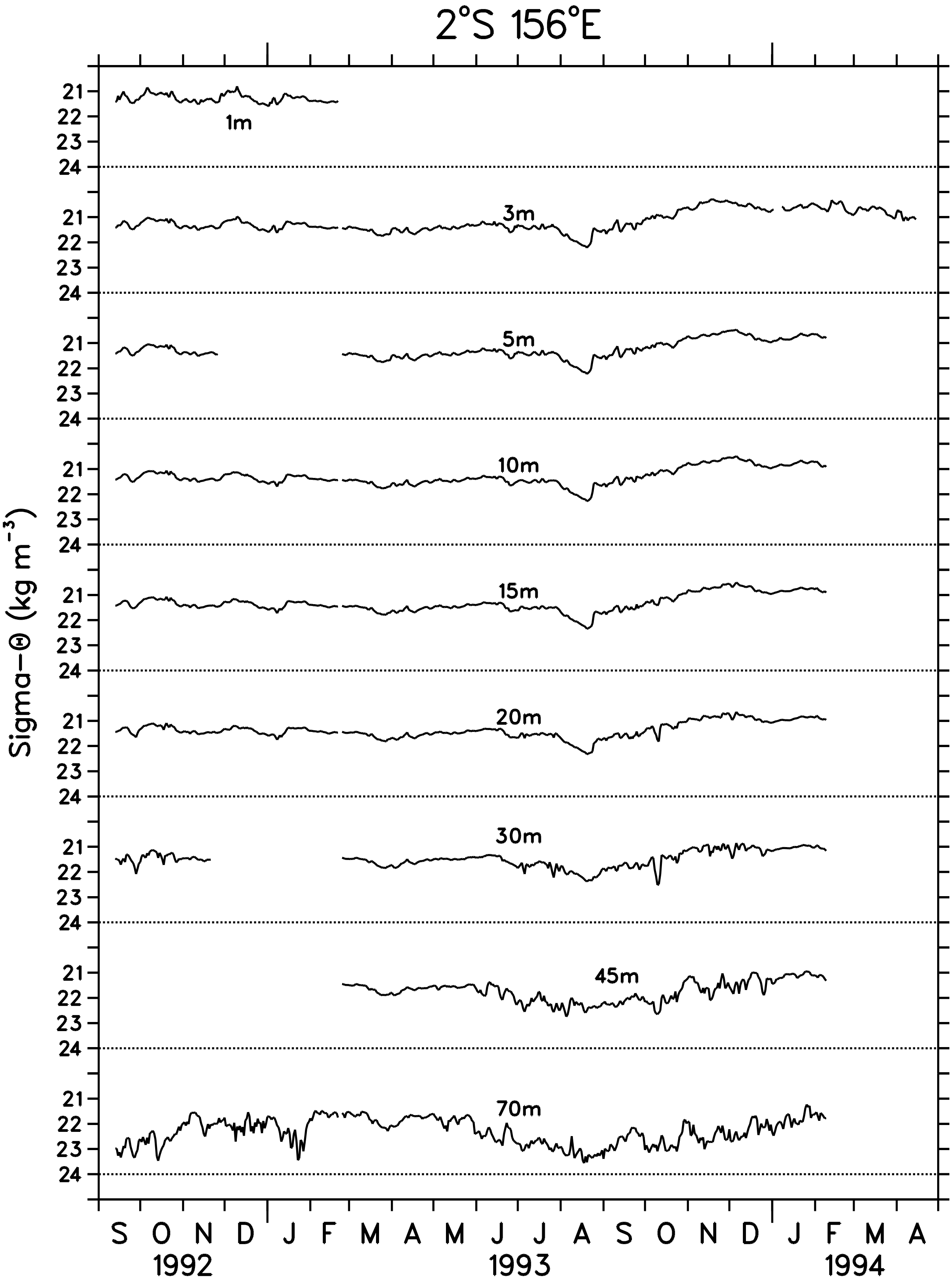

0° 156°E
Salinity (psu)
35.5
35.0
34.5
34.0
3m
1m
5m
11m
10m
20m
30m
33m
30m
51m
57m
50m
75m
83m
75m
101m
100m
150m
132m
150m
201m
183m
200m
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
1991
1992
1993
1994

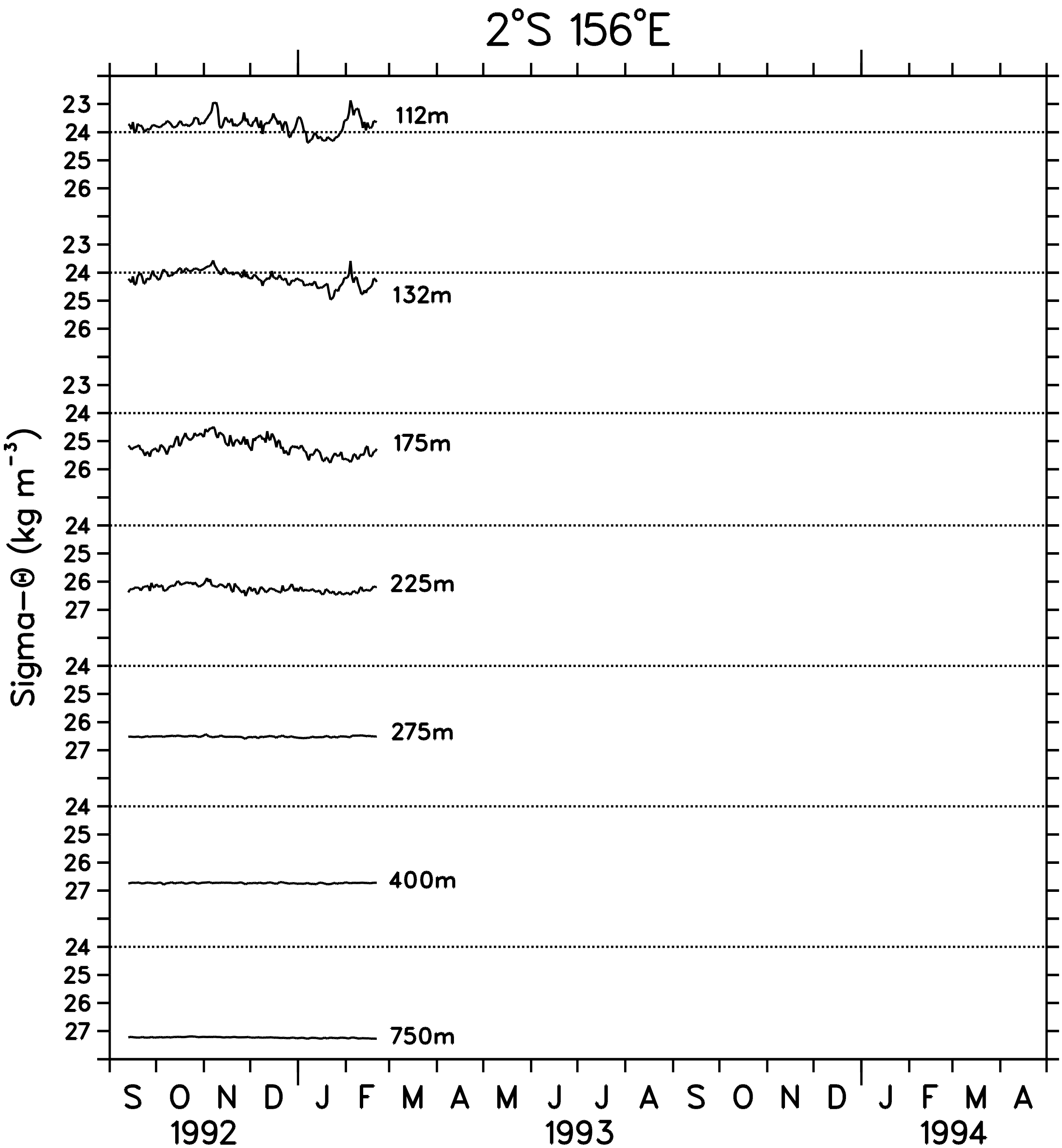


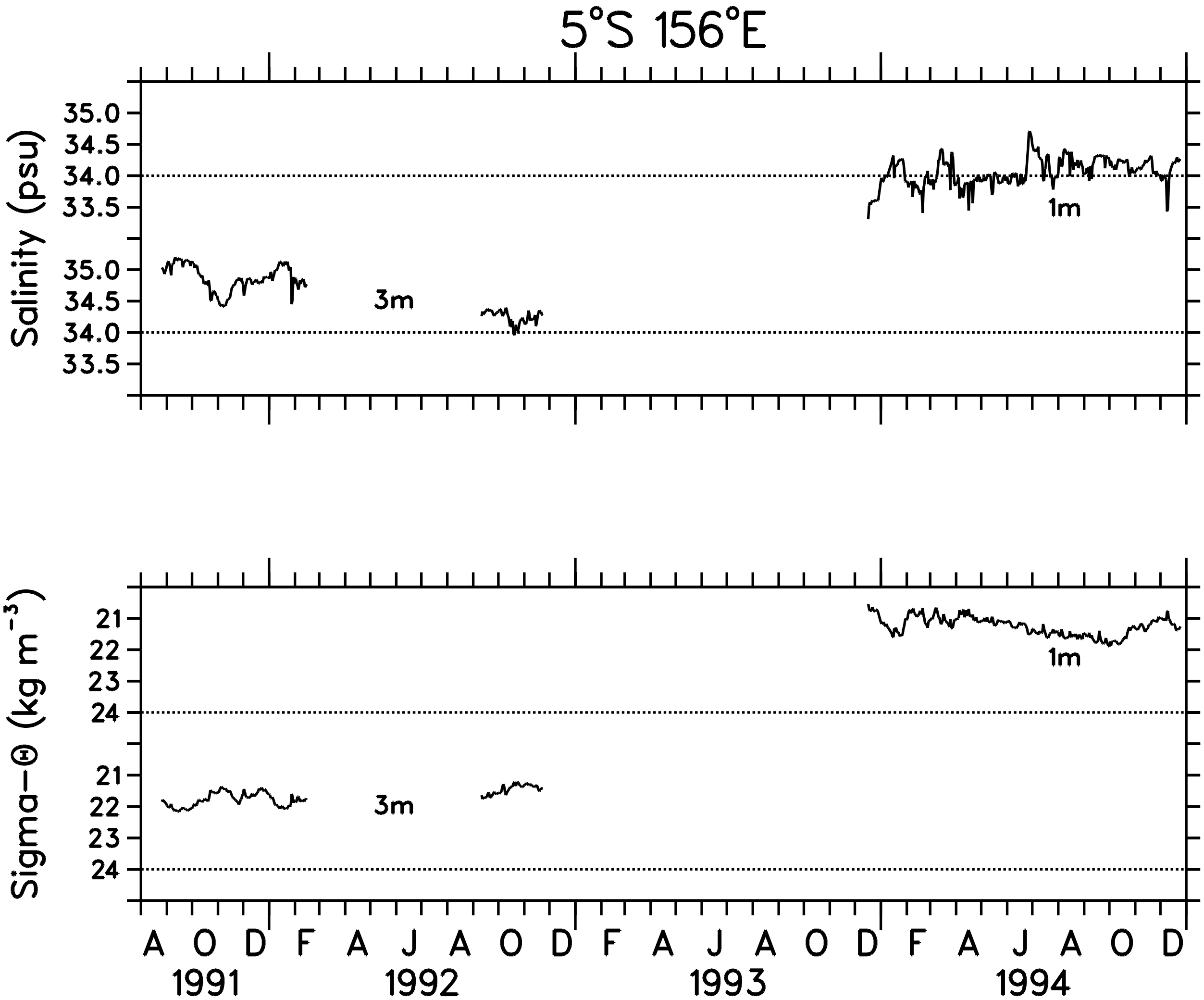
0° 156°E
Sigma−Θ (kg m⁻³)
3m
1m
5m
11m
10m
20m
30m
33m
30m
51m
57m
50m
83m
75m
75m
101m
100m
132m
150m
150m
201m
183m
200m
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
1991
1992
1993
1994

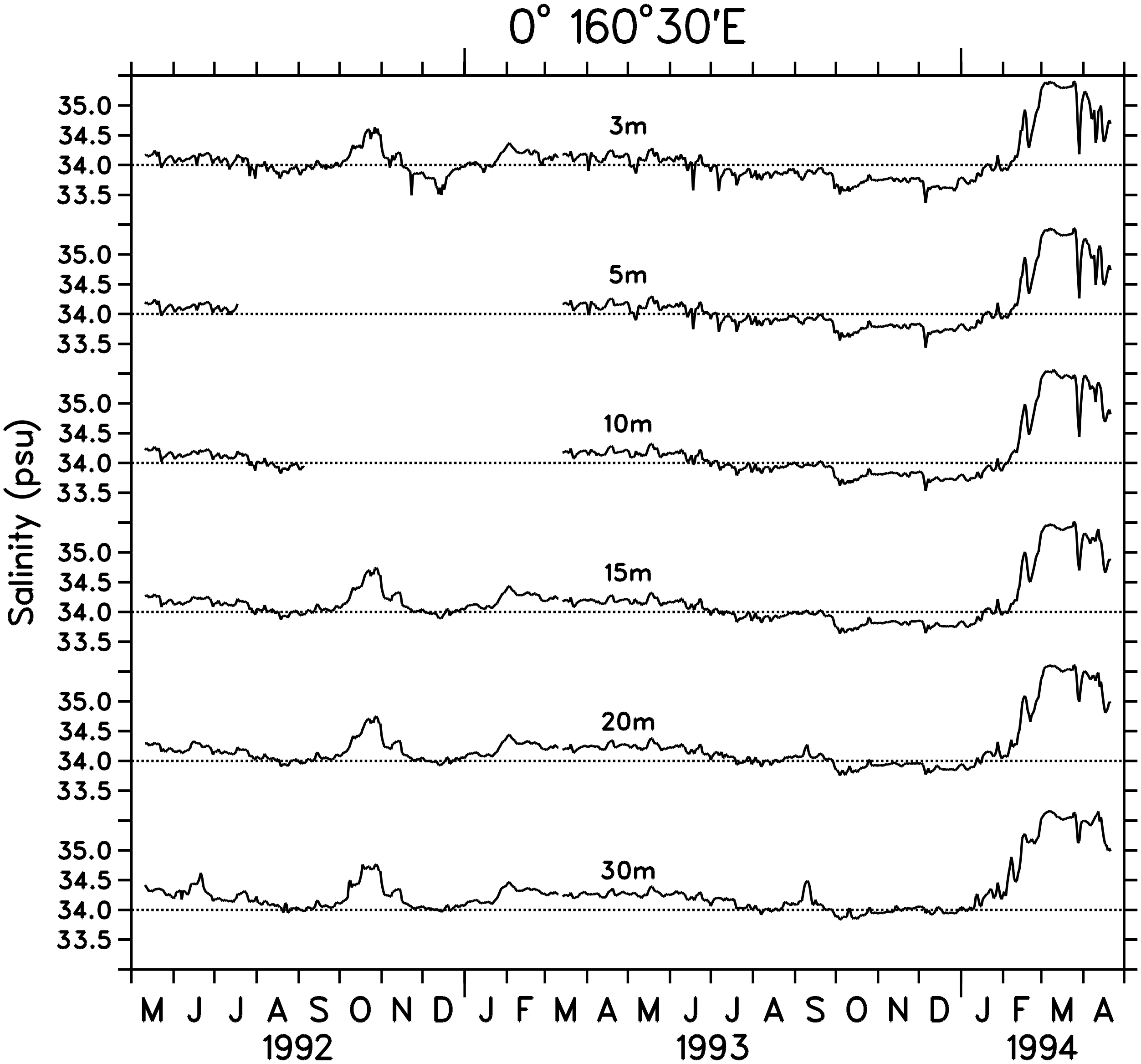

2°S 156°E
Salinity (psu)
35.0
34.5
34.0
33.5
1m
3m
5m
10m
15m
20m
30m
45m
70m
S O N D J F M A M J J A S O N D J F M A
1992
1993
1994

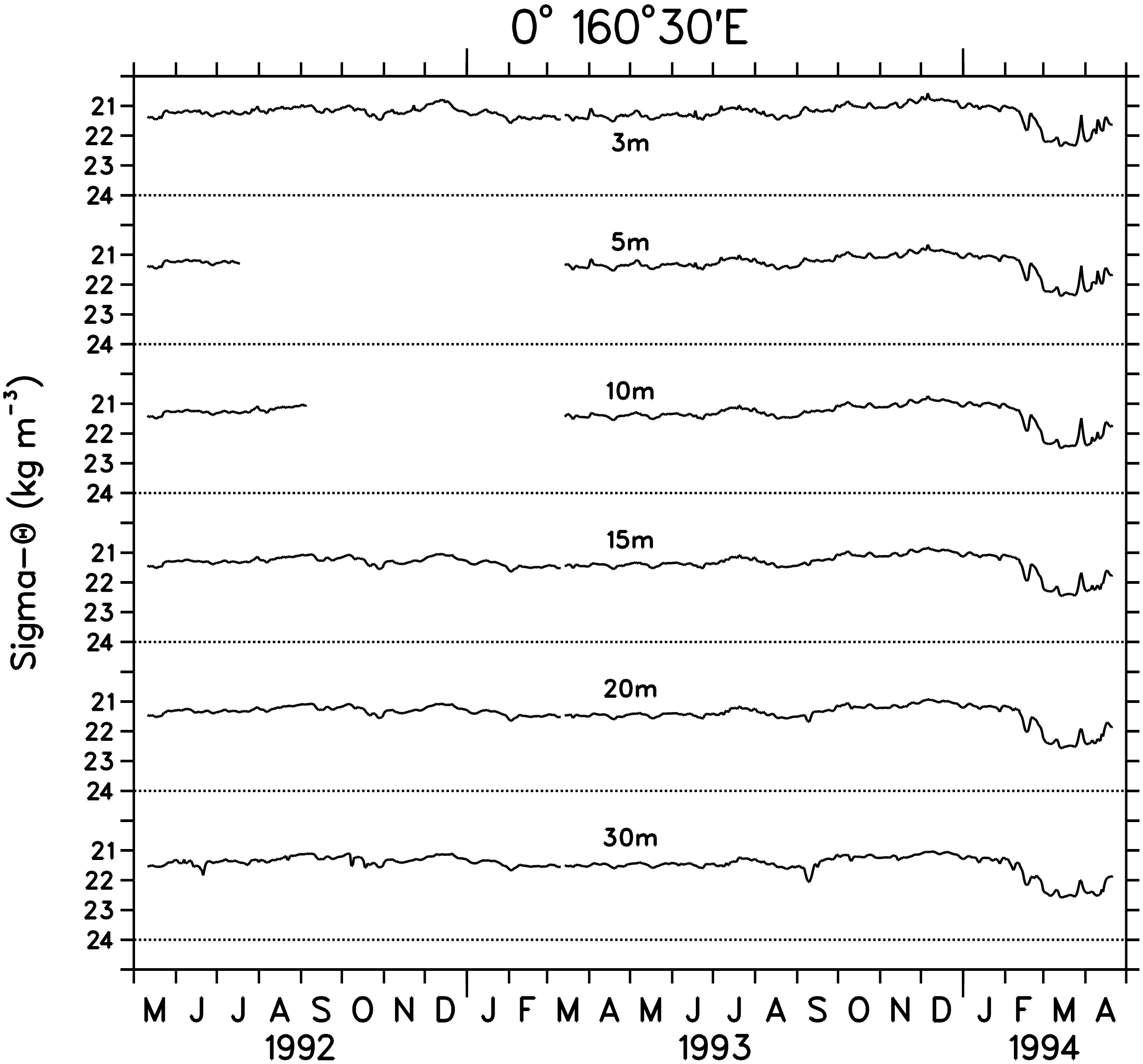

2°S 156°E
Salinity (psu)
35.6
35.2
34.8
34.4
112m
132m
175m
225m
275m
400m
750m
S O N D J F M A M J J A S O N D J F M A
1992
1993
1994

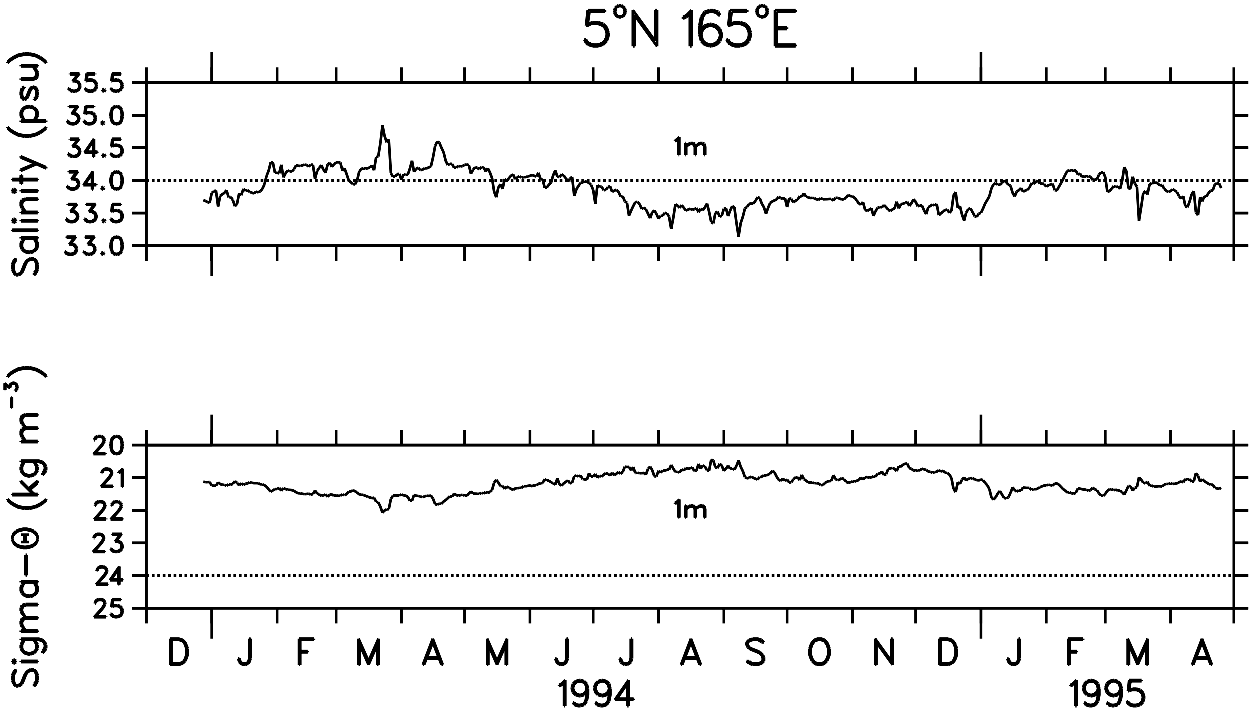

2°S 156°E
Sigma–Θ (kg m^{-3})
21
22
23
24
1m
3m
5m
10m
15m
20m
30m
45m
70m
S O N D J F M A M J J A S O N D J F M A
1992
1993
1994

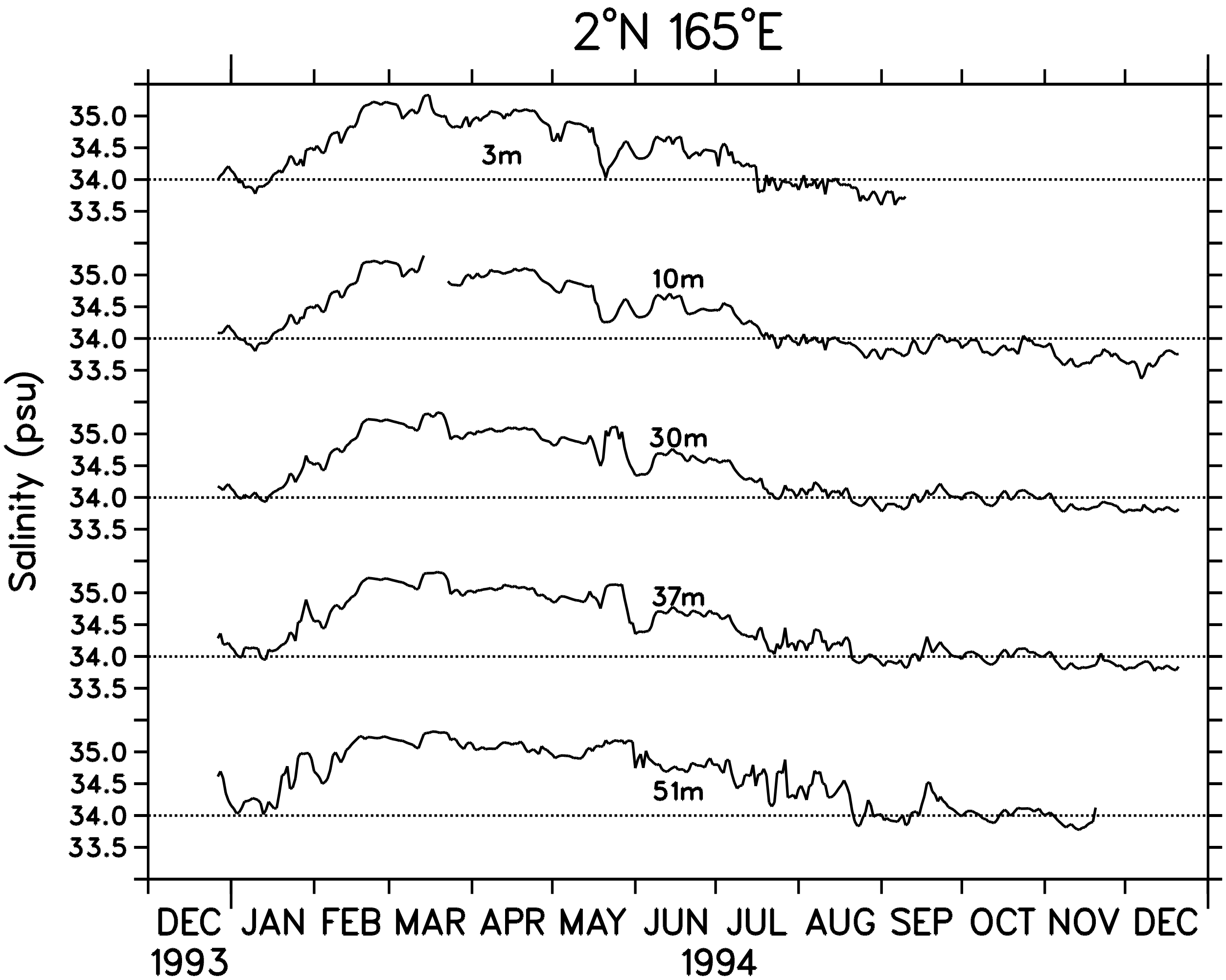

2°S 156°E
Sigma−Θ (kg m^{-3})
23
24
25
26
27
112m
132m
175m
225m
275m
400m
750m
S O N D J F M A M J J A S O N D J F M A
1992
1993
1994

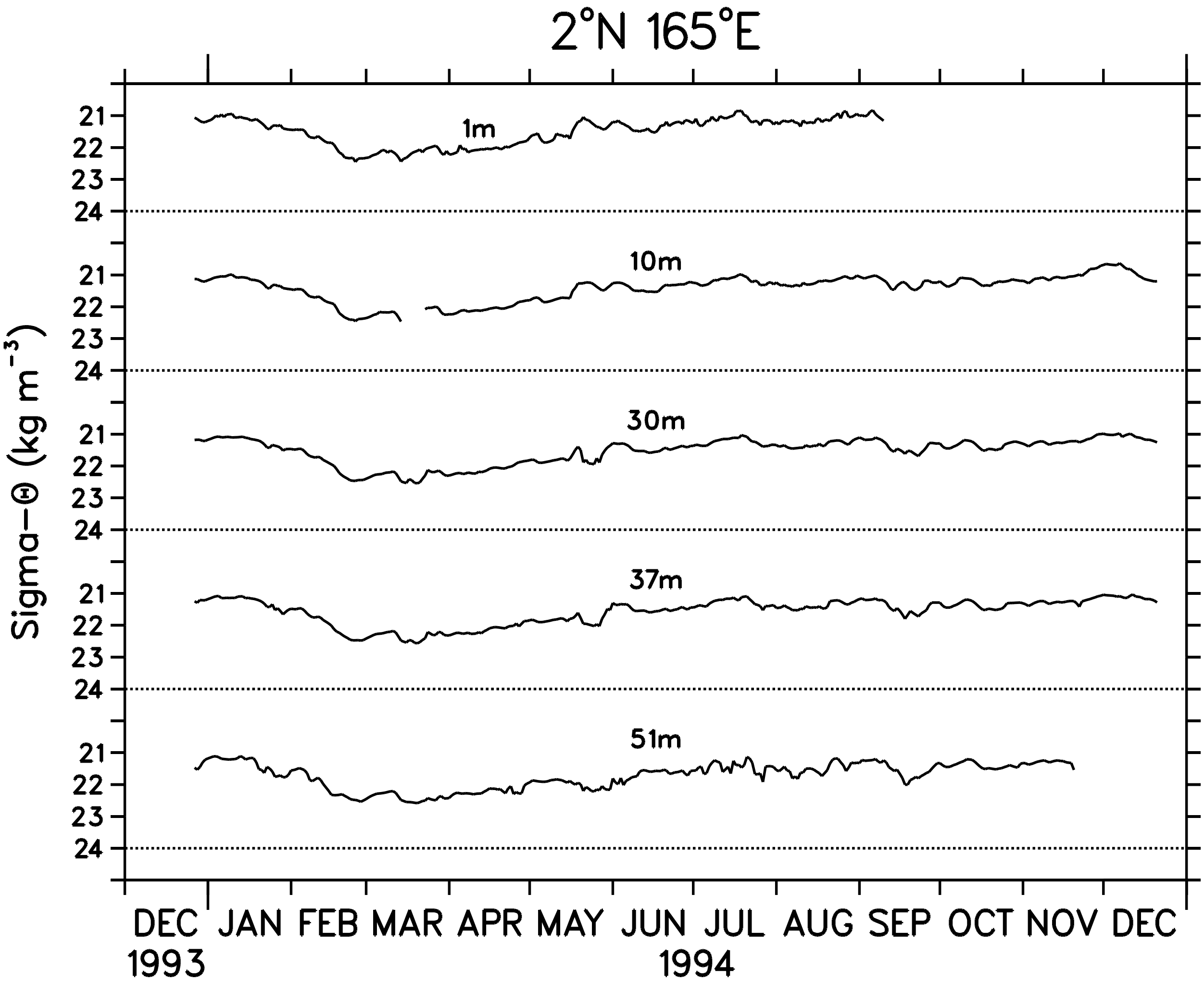

5°S 156°E
Salinity (psu)
35.0
34.5
34.0
33.5
1m
3m
Sigma-Θ (kg m^{-3})
21
22
23
24
A O D F A J A O D F A J A O D F A J A O D
1991
1992
1993
1994


0° 160°30'E
Salinity (psu)
35.0
34.5
34.0
33.5
3m
5m
10m
15m
20m
30m
M J J A S O N D J F M A M J J A S O N D J F M A
1992
1993
1994

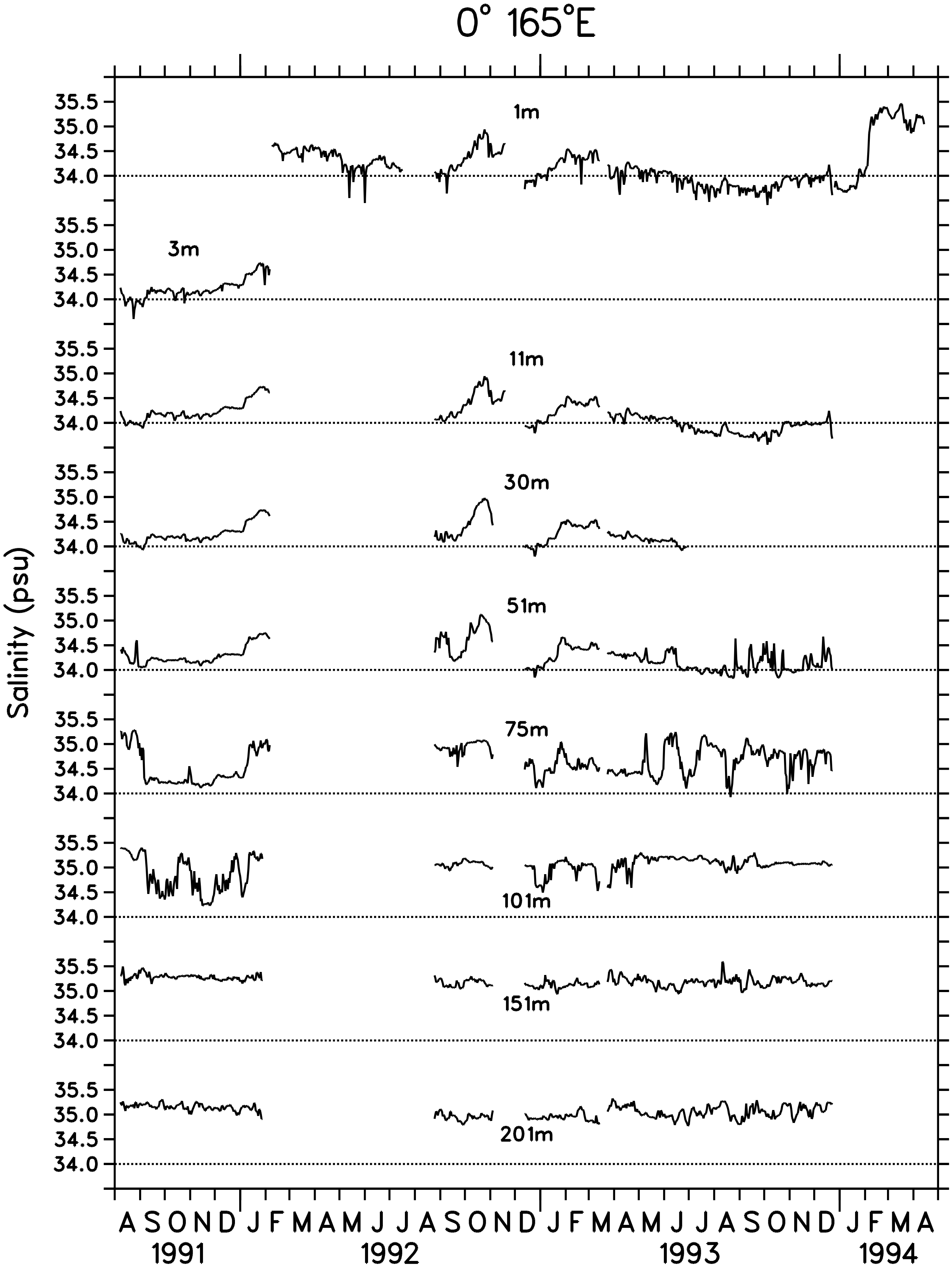

0° 160°30'E
3m
5m
10m
15m
20m
30m
21
22
23
24
Sigma−Θ (kg m^{-3})
M J J A S O N D J F M A M J J A S O N D J F M A
1992
1993
1994

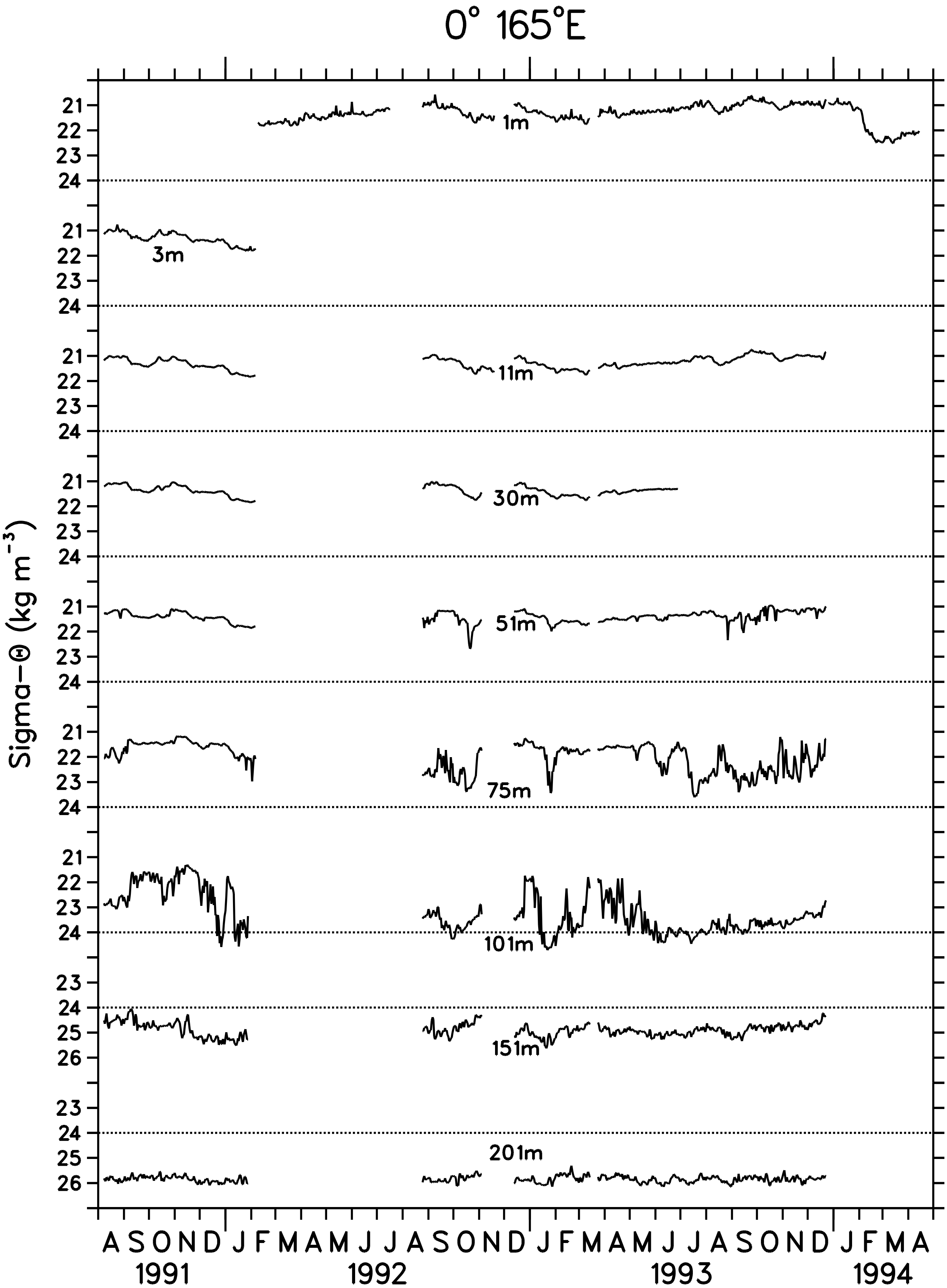

5°N 165°E
Salinity (psu)
35.5
35.0
34.5
34.0
33.5
33.0
1m
Sigma-Θ (kg m⁻³)
20
21
22
23
24
25
1m
D J F M A M J J A S O N D J F M A
1994
1995

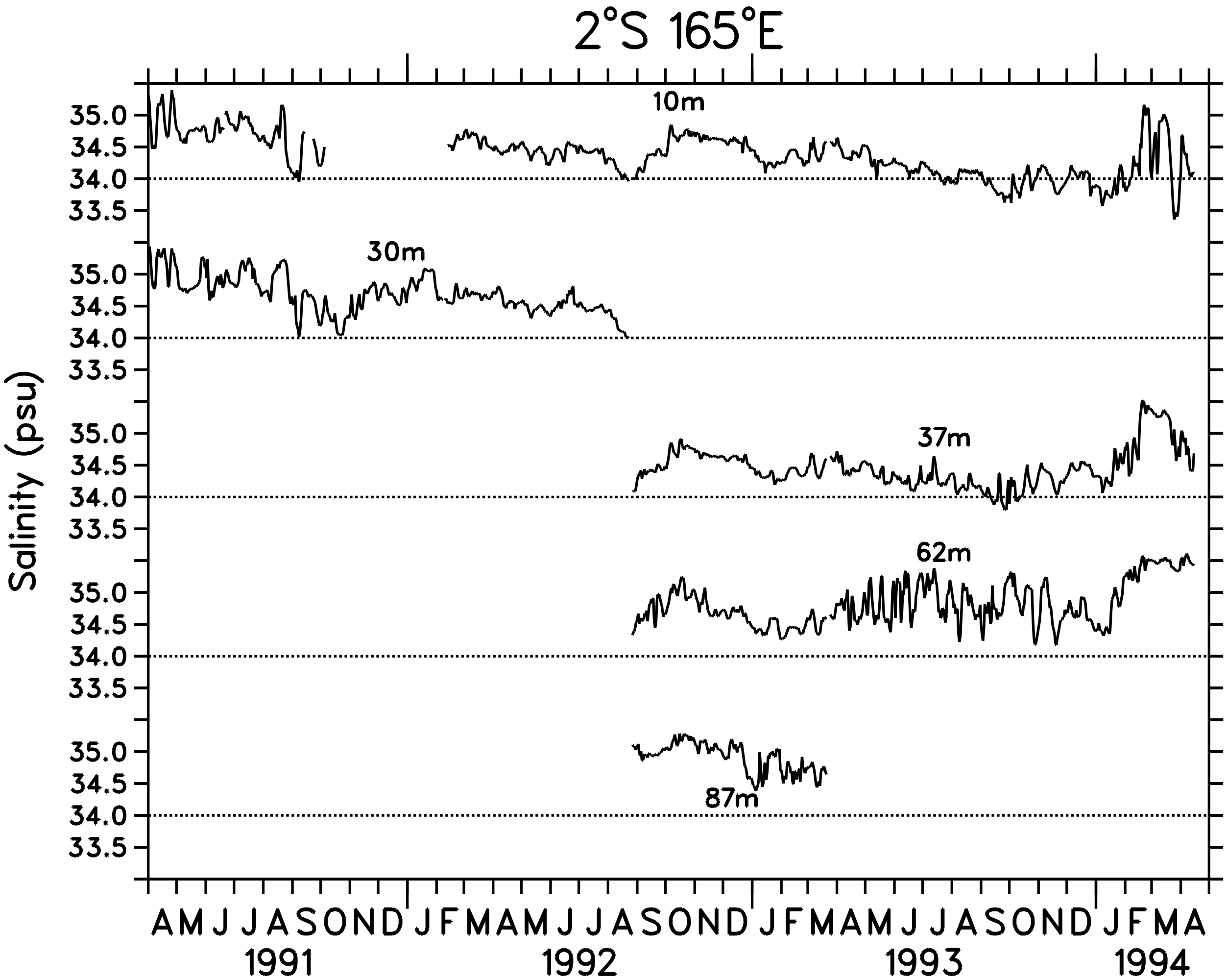

2°N 165°E
Salinity (psu)
35.0
34.5
34.0
33.5
3m
10m
30m
37m
51m
DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1993
1994

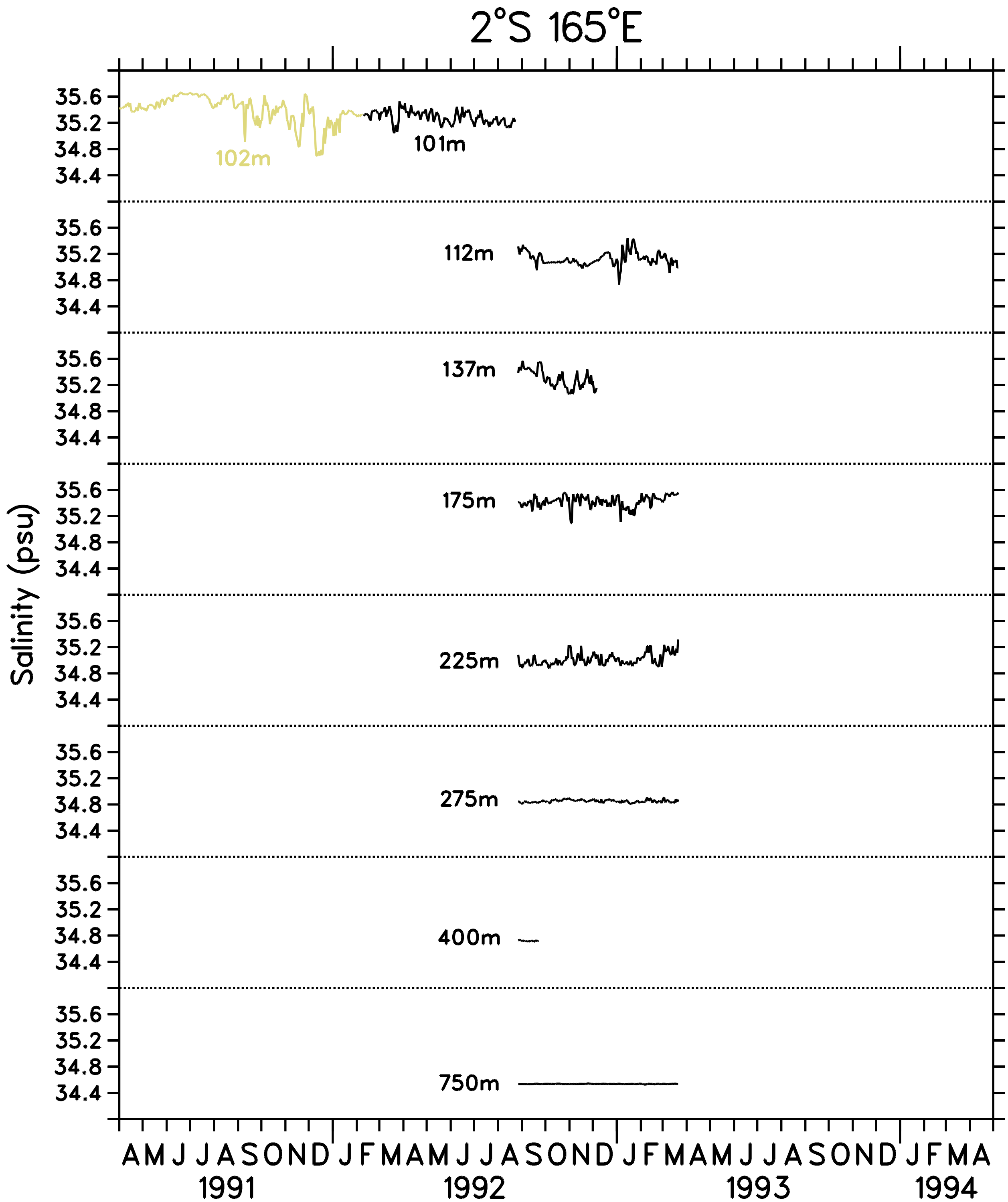


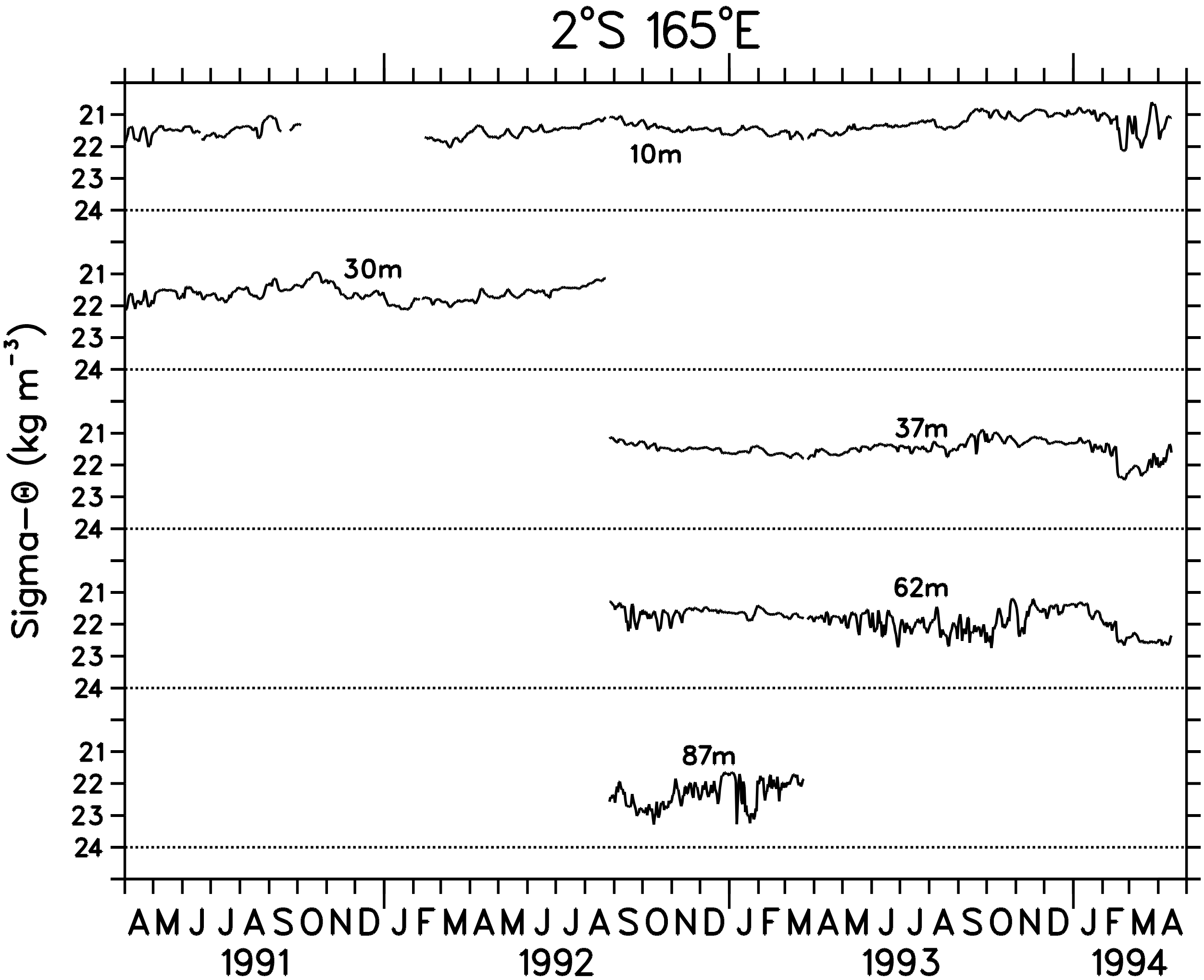
2°N 165°E
Sigma-Θ (kg m⁻³)
21
22
23
24
1m
10m
30m
37m
51m
DEC 1993
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1994

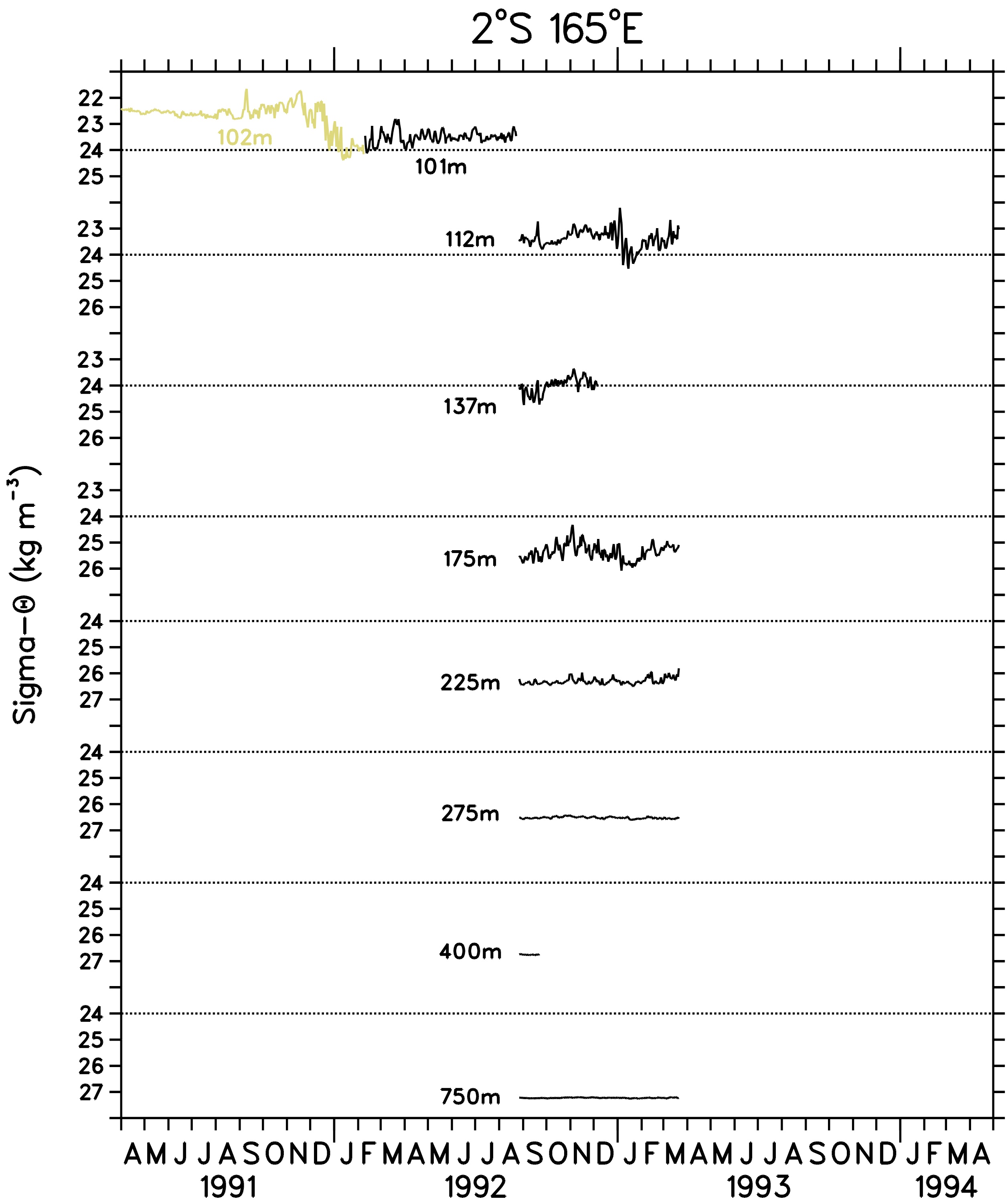

0° 165°E
Salinity (psu)
35.5
35.0
34.5
34.0
1m
3m
11m
30m
51m
75m
101m
151m
201m
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
1994

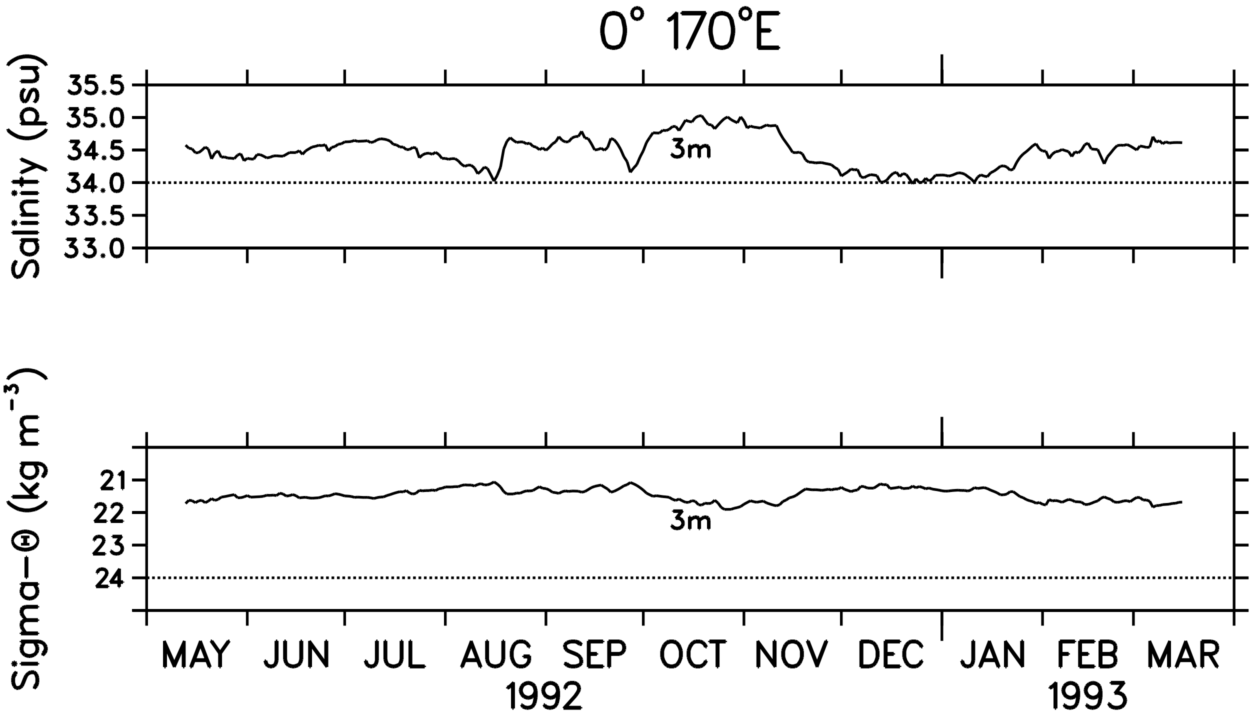

0° 165°E
Sigma−Θ (kg m⁻³)
1m
3m
11m
30m
51m
75m
101m
151m
201m
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
1994


2°S 165°E
10m
30m
37m
62m
87m
Salinity (psu)
35.0
34.5
34.0
33.5
A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
1994


2°S 165°E
Salinity (psu)
35.6
35.2
34.8
34.4
102m
101m
112m
137m
175m
225m
275m
400m
750m
A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
1994


2°S 165°E
Sigma−Θ (kg m⁻³)
21
22
23
24
10m
30m
37m
62m
87m
A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
1994


2°S 165°E
Sigma−Θ (kg m⁻³)
102m
101m
112m
137m
175m
225m
275m
400m
750m
A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1991
1992
1993
1994


0° 170°E
Salinity (psu)
35.5
35.0
34.5
34.0
33.5
33.0
3m
Sigma-Θ (kg m^-3)
21
22
23
24
3m
MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR
1992
1993