

THE STATE OF THE CALIFORNIA CURRENT IN 1993-1994

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ABSTRACT

This report is a summary and preliminary interpretation of recent shore-station and shipboard observations made of the coastal waters of California. The emphasis is upon data currently being collected by the CalCOFI (California Cooperative Oceanic Fisheries Investigations) program. The California Current was affected by El Niño conditions in 1992 and 1993, which were evident as elevated coastal sea level; widespread positive sea-surface temperature anomalies; a thicker mixed layer and deeper nutricline; and relatively low values of chlorophyll, primary production, and macrozooplankton biomass. A strong and broad inshore countercurrent was evident in January and February of 1992 and 1993. During 1992 and 1993, anomalies in coastal sea level and the circulation pattern were most pronounced during late winter to early spring, and structure during the remainder of the year was less extreme. A different pattern is developing in 1994. The inshore countercurrent was absent in January 1994, and coastal sea level was anomalously low. Mesoscale physical structure of the California Current was strong during the entire period described here. A particularly striking feature is the sharp coastal meander, which was first sampled during October 1993 and which remained evident through March 1994.

RESUMEN

Este reporte ofrece un resumen e interpretación preliminar de observaciones obtenidas en estaciones litorales y buques en aguas costeras de California. El enfoque es en los datos que están siendo colectados por el programa CalCOFI ("California Cooperative Oceanic Fisheries Investigations"). Las condiciones El Niño en 1992 y 1993 influenciaron a la Corriente de California; estas condiciones se revelaron como un nivel del mar elevado, condiciones extendidas de anomalías positivas de temperatura del agua superficial, capa de mezcla más gruesa y nutriclina más profunda, y valores relativamente bajos de clorofila, producción primaria y macro-zooplankton. En Enero y Febrero de 1992 y 1993 hubo evidencia de una contra-corriente fuerte cercana a la costa. Durante 1992 y 1993 las anomalías en el nivel del mar y el patrón de circulación costero fueron más pronunciados de finales de invierno a principios de verano, mientras que el resto del año la estructura fué menos marcada. En 1994 se está desarrollando un esquema distinto; en Enero no hubo

contra-corriente cercana a la costa y el nivel del mar se mantuvo anormalmente bajo. Durante todo el intervalo aquí descrito, la estructura física de la Corriente de California en la meso-escala fué marcada. Una característica que llama la atención es un meandro costero bien definido que en un principio fué muestreado en Octubre de 1993 y que persistía hasta Marzo de 1994.

INTRODUCTION

This report summarizes recent coastal and shipboard observations of the physical, chemical, and biological state of the California Current system. Data collected from July 1992 through April 1994 on CalCOFI (California Cooperative Oceanic Fisheries Investigations) time-series survey cruises are emphasized. This is an introduction to the data being collected, and an attempt to make these timely observations more accessible to researchers and other users of the coastal ocean. This report follows a summary of the structure of the California Current region in 1991 and early 1992 (Hayward 1993). A brief interpretation of these data is presented in light of the impact of the 1992-93 El Niño event.

DATA SETS AND ANALYTICAL TECHNIQUES

Coastal sea level is measured continuously at several tide gauge stations. Data from La Jolla and San Francisco are used in this report as examples of southern and northern coastal sites. These stations have long time series which can be used for comparison with the recent data. The data shown in this report are corrected for the secular rise in sea level (Roemmich 1992). Anomalies from the monthly mean sea level were calculated by subtracting the long-term mean (1925-91 for La Jolla and 1900-90 for San Francisco).

Sea-surface temperature (SST) and salinity are also measured daily at several coastal stations (Walker et al. 1992). SST data from La Jolla (SIO Pier) and Pacific Grove are given in this report to complement the coastal sea-level data. SST and daily anomalies are calculated from the long-term harmonic mean temperature (1916-93 for La Jolla and 1919-93 for Pacific Grove).

The CalCOFI monitoring program started in 1949; a brief history and description of the program is given by Hewitt (1988). The present form of the sample grid (figure 1) and the program of quarterly sampling, (typically in January, April, July, and October) was

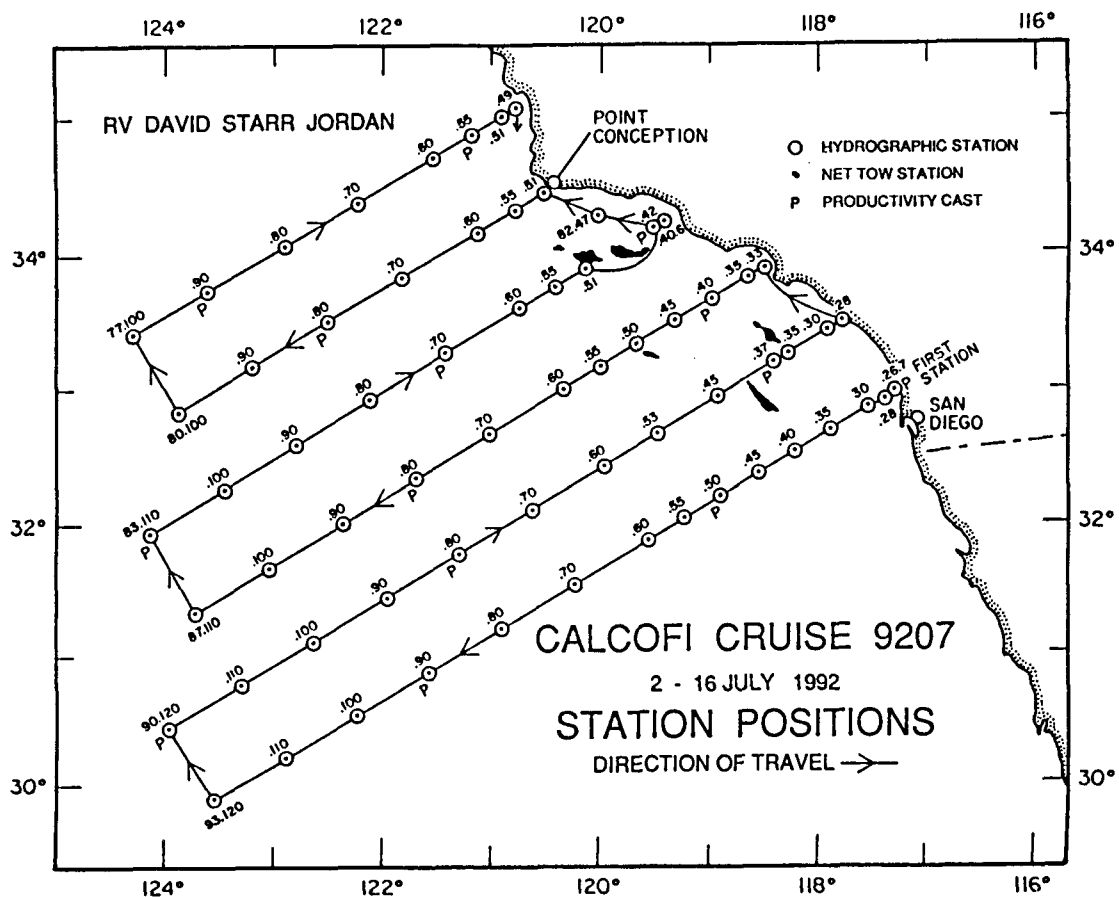


Figure 1. Cruise track for CalCOFI cruise 9207, July 1992, as an example of the present CalCOFI station plan. Core measurements at each station consist of a CTD/Rosette cast, an oblique bongo net tow, and a surface net tow. Continuous measurements of light, ADCP currents and backscatter intensity, as well as nearsurface temperature, salinity, chlorophyll fluorescence, and dissolved oxygen are made along the cruise track.

established in 1985. Lines are spaced at 40-nautical-mile (74 km) intervals, with stations spaced at 40 n. mi. intervals in the offshore region and at 8–20 n. mi. (15–37 km) intervals near the coast. This pattern has been occupied for the last ten years, and a set of “core” data has been collected with comparable techniques. Cruises are designated by year and month; e.g., cruise 9401 sampled in January 1994. Station locations are designated by a line and station number; e.g., 90.60 is station 60 on line 90, which is located due west of San Diego (figure 1). Descriptions of CalCOFI data given in this report discuss sections along a line (e.g., along line 90) as well as stations (e.g., inshore of station 60).

The core time-series data now collected at each CalCOFI station include a CTD/Rosette cast with sensors for pressure, temperature, salinity, dissolved oxygen, PAR (photosynthetically active radiation), fluorescence, and transmissivity. Water samples are collected with 10 l sample bottles on the rosette at 20 depths in the upper 500 m for determinations of salinity, dissolved oxygen, nutrients (NO_3 , NO_2 , PO_4 , SiO_3), phytoplankton pigments (chlorophyll a and phaeophytin), and primary

production (^{14}C uptake at one station per day). Oblique and surface (neuston) net tows (505 μm mesh) are taken at each station. Continuous near-surface measurements of temperature, salinity, dissolved oxygen, and chlorophyll fluorescence are made from water pumped through the ship, and the data are logged at one-minute intervals. Surface PAR and acoustic Doppler current profiler (ADCP) data are also recorded continuously. The ADCP data provide a measure of zooplankton biomass based upon acoustic backscatter, as well as a measure of upper-ocean currents. The most recent data presented here are preliminary, and some changes may be made after the final processing and quality control checks. The methods are described in more detail in the CalCOFI cruise data reports (e.g., Scripps Institution of Oceanography 1993a). Several cooperative research programs on recent CalCOFI cruises collected additional data, including bird observations, phytoplankton species composition, copepod egg production, full-depth CTD casts (FastFish), spectral light, physiological properties of the phytoplankton, and observations with an in situ optical particle counter.

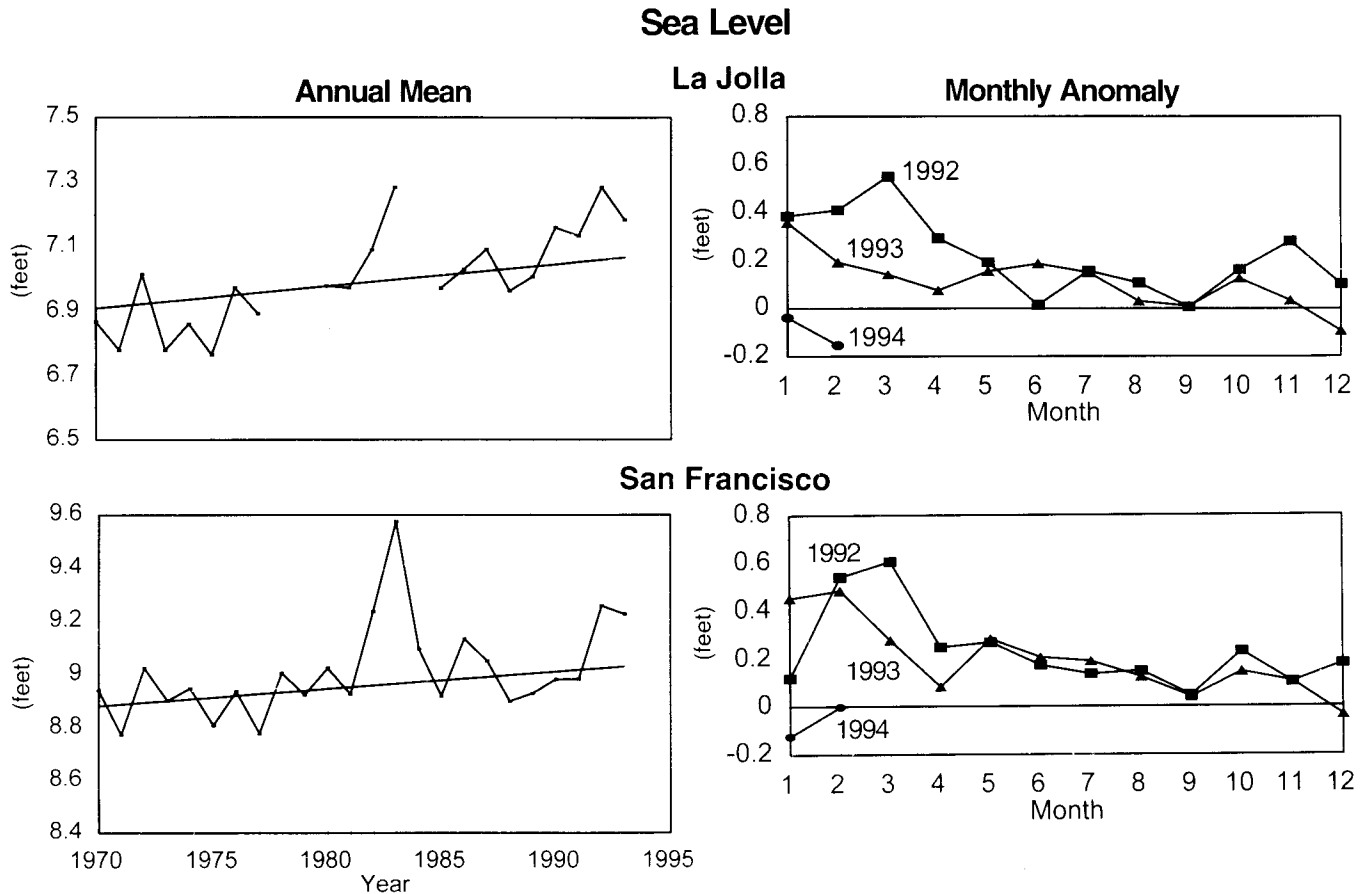


Figure 2. Coastal sea level at La Jolla and San Francisco. *Panels on the left* show the annual mean sea level; the *solid line* shows the linear regression for the secular rise in sea level for 1925–91 at La Jolla and 1900–90 at San Francisco. *Panels on the right* show the monthly anomalies in sea level for San Francisco and La Jolla for 1992–94. Monthly anomalies are the deviations from the long-term monthly mean, corrected for the secular rise.

Shipboard ADCP velocity data were collected and analyzed on CalCOFI cruises 9310 and 9401 as part of the pilot study for the WOCE time series station, PRS3. Velocities have been corrected for calibration (scale factor) and transducer misalignment (Kosro 1985; Pollard and Read 1989), and navigated from ship relative to absolute currents using GPS position measurements (Bahr and Firing 1989). Potential bias errors from noise and filter skew were minimized through selection of profiler parameters affecting filter tracking—bin and pulse length, signal-to-noise screening, low-pass filter bandwidth, and tracking parameters (Chereskin and Harding 1993). These data are preliminary in that no corrections or filtering for tides and inertial oscillations have been applied. For this report, velocities were vector averaged and gridded every 0.1 degree in latitude/longitude along the ship track.

Vertical profiles of temperature and salinity from hydrographic (CTD bottle trip) data are compared to the long-term mean distributions by comparing the observed values with the long-term (1950–92) harmonic means calculated at standard depths for the midpoint of the cruise (Lynn and Simpson 1987). These anomalies show

how the structure during a cruise differed from the long-term mean pattern for that month. Monthly mean values (1951–84) for the station grid have also been calculated for macrozooplankton biomass. Chlorophyll and primary production were not measured in the early years of CalCOFI, so their time series is insufficient to properly estimate the monthly mean. Cruise mean values of chlorophyll and primary production are compared with the data taken since 1984.

The data, station plan, and methods for CalCOFI survey cruises are published in cruise data reports (Scripps Institution of Oceanography 1993a, b). CalCOFI hydrographic data are also available on the Internet via the Nemo hydrographic data server at Scripps Institution of Oceanography. These data can be accessed via telnet to **nemo.ucsd.edu**; using username: **info**. The cruise data reports can be cited as a source of data and methods.

EVOLUTION OF STRUCTURE

Coastal Shore Stations

The annual mean coastal sea level was anomalously high in 1992 and 1993 at La Jolla and San Francisco (figure 2). The high sea level in the annual means was mostly

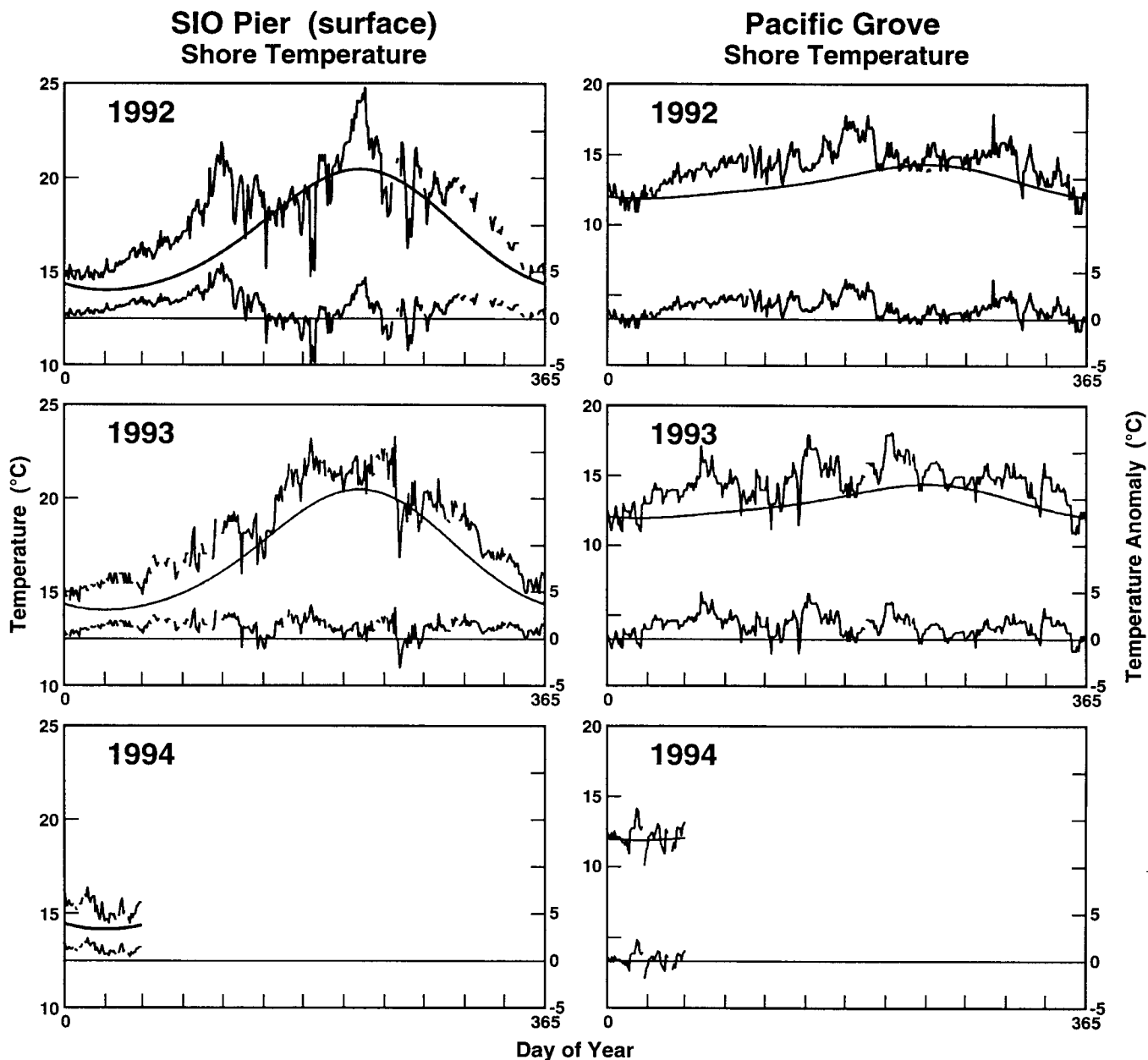


Figure 3. Sea-surface temperature at La Jolla (SIO pier) and Pacific Grove. The *upper curves* in each panel show the daily temperature and the long-term harmonic mean daily temperature for 1916–93 for La Jolla and 1919–93 for Pacific Grove. The *lower curve* shows the daily temperature anomaly from the harmonic mean.

due to large positive anomalies in the first few months of each year, with smaller positive values during the remainder of the year. The annual pattern was similar at both sites. Sea level in early 1994 was anomalously low at both sites.

Coastal surface temperatures at both La Jolla and Pacific Grove were anomalously high during most of 1992 and 1993 (figure 3). The exceptions were periods during summer 1992 when temperatures fluctuated about their seasonal norms. These coastal temperature records reflected large-scale and persistent anomaly patterns in the

eastern North Pacific (Climate Diagnostic Bulletins, monthly). By March of 1992 positive SST anomalies developed along the western seaboard from central Mexico to the Alaskan border. The anomalies continued to increase in magnitude and to expand to the north to include Alaska and to the south to include the separately developing equatorial warming. The positive anomalies occupied the eastern third of the temperate North Pacific. By summer, magnitudes decreased but the overall pattern continued. Some coastal areas had below-normal SSTs only in September. Larger anomalies occurred again

in the early months of 1993, and widespread positive anomalies continued through to the latest observations in April 1994.

Cruise Data

Cruise means of vertically integrated chlorophyll, vertically integrated primary production, and macrozooplankton biomass generally fell within the scatter of the preceding years, but values during 1992-94 were on the low side of the range (figure 4). The main seasonal pattern in each property was a spring-summer maximum (which may be either absent or unsampled in some years). Fall and winter values were generally low. The quarterly CalCOFI cruises are too widely spaced to properly sample the annual cycle, and short-term seasonal blooms could easily be missed with this sampling scheme. Comparison with the 1951-84 monthly means shows that macrozooplankton biomass was anomalously low during the entire 1984-94 period (Roemmich and McGowan 1994).

Chronological Summary

The following is a chronological summary of the structure on each CalCOFI cruise, with emphasis upon the circulation pattern and its relation to biological patterns. These observations followed the early part of 1992—a period of El Niño conditions in the California Current characterized by anomalously warm water and elevated sea level (Hayward 1993). Chlorophyll and primary production were low. There was an anomalously strong inshore countercurrent. Conditions changed abruptly in April 1992, when the more typical pattern of strong southward flow of low-salinity water of the California Current returned, and chlorophyll and primary production increased. The positive anomalies of both coastal sea level and SST dropped markedly in April 1992.

9207. In July 1992, southward flow of the low-salinity core water of the California Current was split into two jets and altered by three cyclonic eddies (figure 5). Comparison with the harmonic mean dynamic height field shows that dynamic height was higher than normal, with the largest anomalies in the middle of the pattern. This suggests that there was weaker-than-normal southward flow in the outer part of the pattern, and stronger-than-normal flow around stations 50 and 60. Ten-meter temperature was lower than normal inshore of the main flow of the California Current along the coast from Santa Barbara to Del Mar. The mixed layer was warmer than normal over the remainder of the pattern. Ten-meter chlorophyll was also relatively high (values greater than $1 \mu\text{g l}^{-1}$) in the entire coastal region.

9210. In October, there was a southeastward-flowing jet of low-salinity water in the middle of the pattern. The three cyclonic eddies observed during July appeared

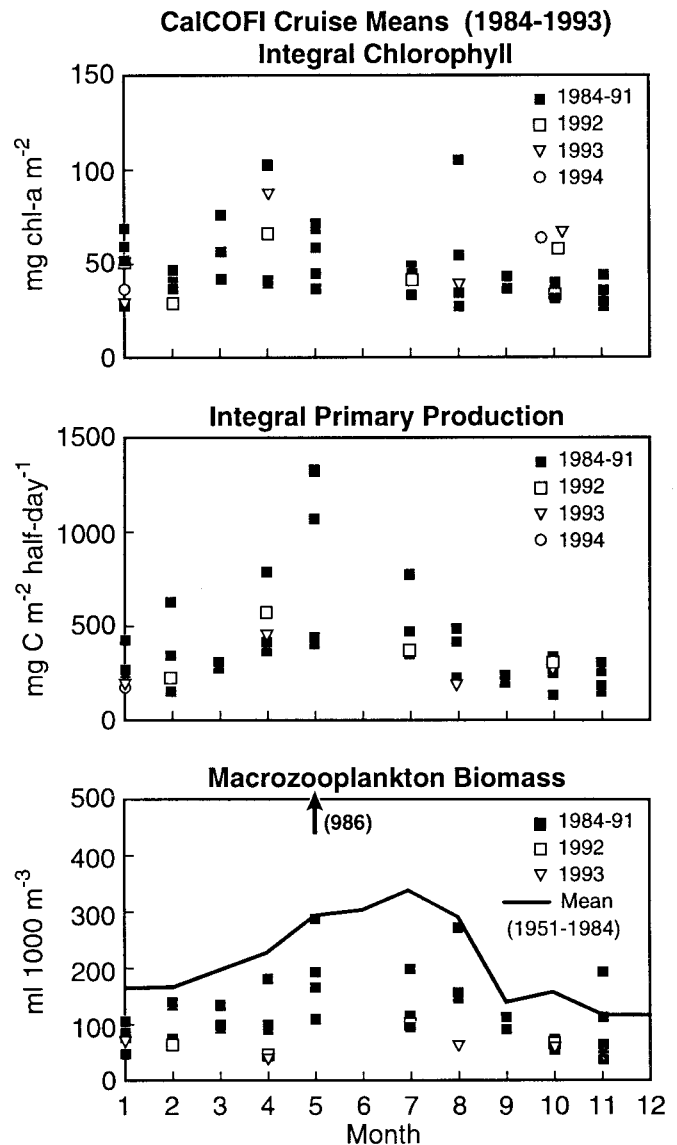


Figure 4. Cruise means of vertically integrated chlorophyll, vertically integrated primary production, and macrozooplankton biomass plotted versus the month of the cruise. Each point represents the mean of all of the measurements made on a single cruise. The solid squares show cruises that took place from 1984 to 1991; open symbols show values from 1992 to 1994. The monthly mean macrozooplankton biomass for the study area from 1951 to 1984 is shown as the solid line.

to still be present, but weaker than before (figure 6). Dynamic heights remained above normal, with maximum anomalies in the offshore region. The anomaly pattern is consistent with stronger-than-normal southward flow around stations 70 to 90, and stronger-than-normal northward flow in the inshore parts of lines 87 to 93. Ten-meter temperature was greater than normal over most of the grid, except for a band along the coast, where patches with large negative anomalies were observed. Ten-meter chlorophyll was generally low throughout the sample grid, with values greater than $1 \mu\text{g l}^{-1}$ evident only in the coastal area near Point Conception.

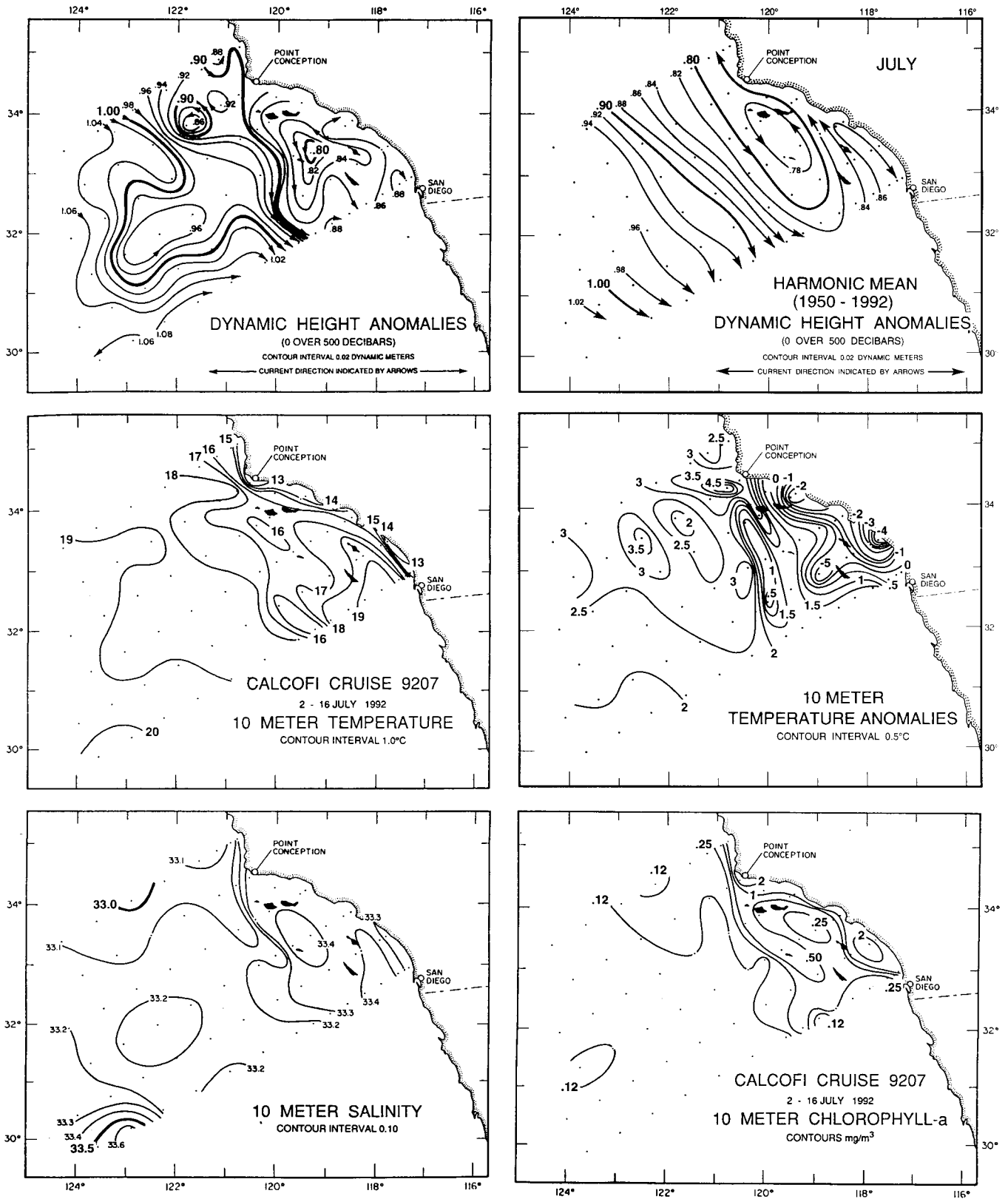


Figure 5. Spatial patterns for CalCOFI cruise 9207, 2-16 July 1992, including upper-ocean flow field derived from 0 over 500 m dynamic height anomalies, long-term (1950-92) harmonic mean 0 over 500 m dynamic height field calculated for 9 July, 10 m temperature, 10 m temperature anomalies, 10 m salinity, and 10 m chlorophyll.

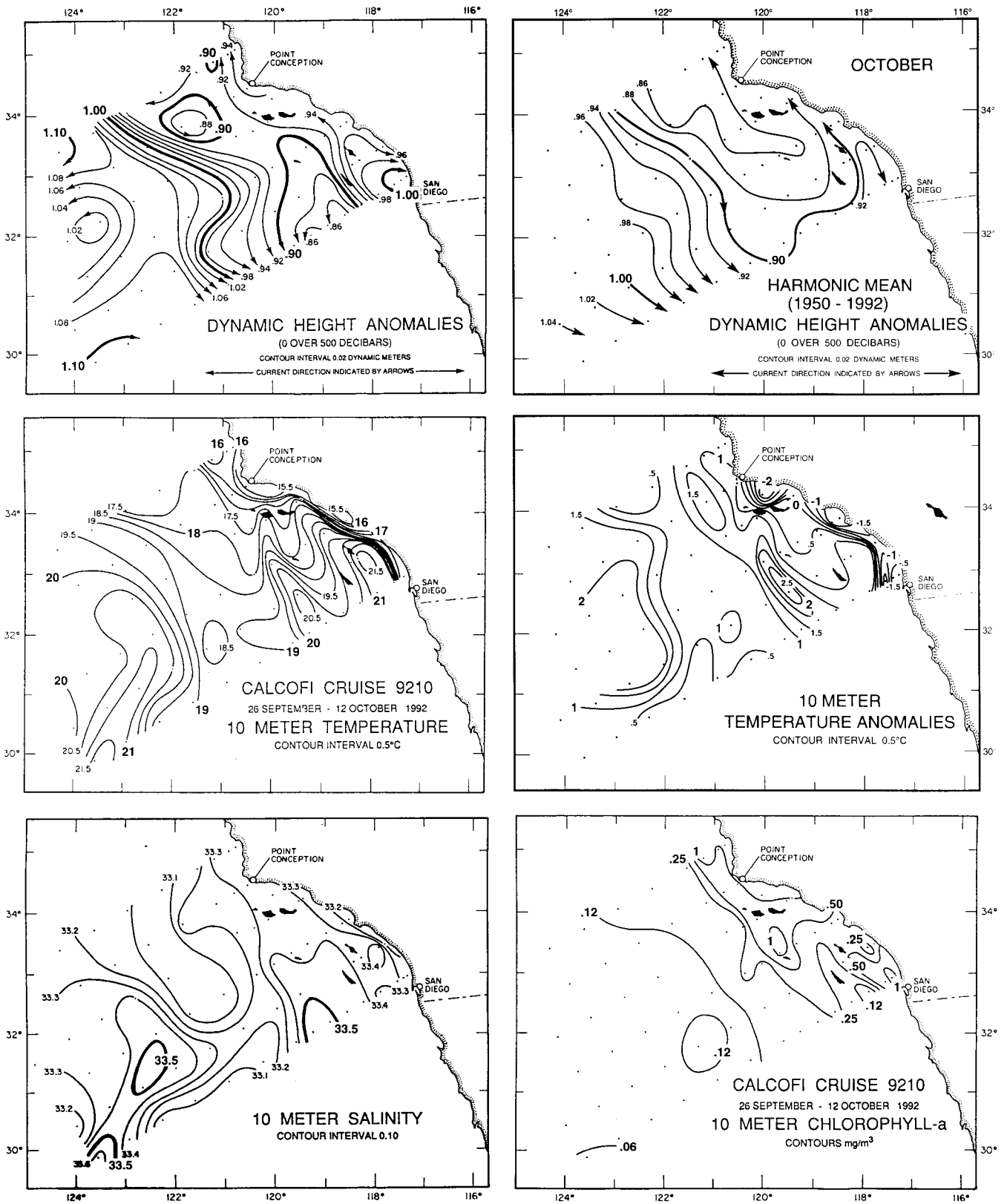


Figure 6. Spatial patterns (as described for figure 5) for CalCOFI cruise 9210, 26 September-12 October 1992. Harmonic mean dynamic heights and temperature were calculated for October 3.

9301. The January 1993 dynamic height field shows that there was a well-developed northward-flowing inshore countercurrent, and southward flow of the low-salinity water of the core of the California Current in the center of the grid (figure 7). The Southern California Eddy was broad, with a broad band of northward flow from the coast to offshore of the Channel Islands. This pattern was quite similar to the long-term mean field, although both the inshore countercurrent and the offshore flow of the California Current were stronger than normal. In contrast to other seasons, there is no southward flow on the Southern California Shelf. The pattern of a strong and broad inshore countercurrent was similar to that of January 1992 (Hayward 1993). Enhanced poleward flow in the coastal region in both years coincided with anomalously high sea level at La Jolla and San Francisco. The ten-meter temperatures were slightly above normal for most of the pattern. Mixed-layer chlorophyll was low throughout the grid, with values greater than $1 \mu\text{g l}^{-1}$ evident at only a few coastal stations.

Sections of several properties along CalCOFI line 90 are given in the SIO cruise data report series. We calculated vertical sections of temperature and salinity anomalies from the long-term harmonic mean to complement a selection of these sections given in figure 8. The boundary between the coastal countercurrent and the southward flow of the California Current at station 90.70 is evident in these sections as a sharper slope in the thermocline and nutricline. Temperature was anomalously low in the upper thermocline at station 90.70 because of the shoaling of the thermocline. Temperature was anomalously high over most of the section, with the largest anomalies at the top of the thermocline (as is expected in conditions where the mixed layer is warmer and deeper than normal). Salinity was slightly lower than normal over most of the section.

9304. In April 1993 the inshore countercurrent was absent, as it is in the long-term mean for April, at which time the Southern California Eddy is weakly developed or absent (figure 9). The southward flow of the California Current was stronger than normal. Southward flow throughout the sample grid was perturbed by two mesoscale eddies in the offshore region. The strong southward flow near Point Conception was consistent with local upwelling in the region. Ten-meter temperature was anomalously high over most of the grid, except in the northern area along the coast. Chlorophyll levels were quite high on this cruise, with values greater than $8 \mu\text{g l}^{-1}$ evident in the coastal region near Point Conception. Elevated chlorophyll was consistent with the return to a more normal circulation pattern because shoaling of the pycnocline and nutricline associated with southward flow brings nutrients closer to the euphotic zone.

The vertical sections along line 90 were strongly influenced by the mesoscale flow field. The strong eddy at station 70, and coastward flow inshore of this perturbed the normal onshore-offshore gradients in vertical structure (figure 10). East-west gradients in temperature, salinity, and nutrients were weak along the section. Temperature was anomalously high in the inshore region of the section, but there were anomalously cool pools in the upper thermocline in the offshore region where the thermocline had shoaled in association with the circulation pattern. Salinity was again anomalously low throughout the section.

9308. Values of dynamic height were approximately 9 dynamic cm higher in 9308 (figure 11) than in the long-term mean for July (figure 5), reflecting the generally thicker and/or warmer surface layer. Although roughly similar in pattern to the long-term mean, the inshore countercurrent was broader, and the Southern California Eddy was enlarged. A strong cyclonic eddy dominated the offshore edge of the California Current jet (along line 90), a pattern very similar to that found during the 9304 survey (figure 9). Ten-meter temperatures were above mean values along the southern California coast and in two offshore-tending E-W bands. Ten-meter temperature was well below normal in the Santa Barbara Channel and in the middle part of the pattern. Ten-meter chlorophyll was relatively high near Point Conception, and low over the remainder of the grid. The 100 m temperature field is sometimes used as a proxy to indicate pycnocline topography and the pattern of surface flow. Temperature data are usually available at an early stage of data processing. As in this example, the 100 m temperature pattern is usually a good indicator of the surface circulation pattern.

9310. As found in the long-term mean pattern for October (figure 6) there is a fully developed inshore countercurrent during October 1993 as well as the equatorward-flowing California Current jet (figure 12). The gradients are larger, however, indicating stronger flow both poleward and equatorward. A cyclonic eddy is partly resolved at the outer edge of the pattern (lines 87 and 90); perhaps this is the same feature found in the previous two surveys. The California Current jet is greatly distorted by a large shoreward meander. In the long-term mean there is a shoreward turn to the current immediately south of the present grid (Lynn et al. 1982). The position and strength of the feature found in 9310 is highly anomalous. Ten-meter temperature anomalies were mostly positive throughout the sample grid, with Santa Monica Bay having the greatest values of 2.3°C . Ten-meter chlorophyll was low over most of the grid, with values greater than $1 \mu\text{g l}^{-1}$ evident only in the coastal area near Point Conception. Pattern in the flow field derived from dynamic height is compared with the

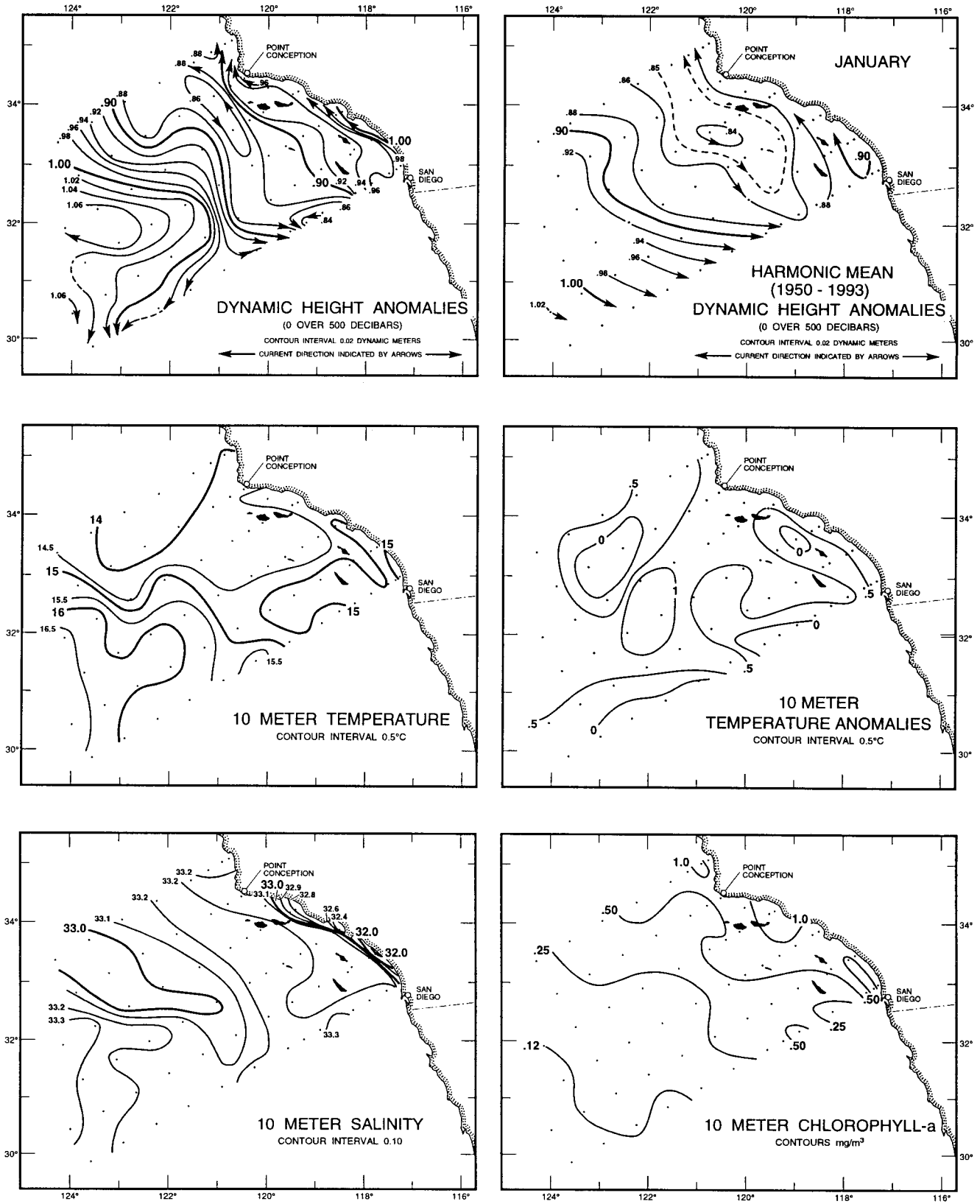


Figure 7. Spatial patterns (as described for figure 5) for CalCOFI cruise 9301, 12-27 January 1993. Harmonic mean dynamic heights and temperature were calculated for January 14.

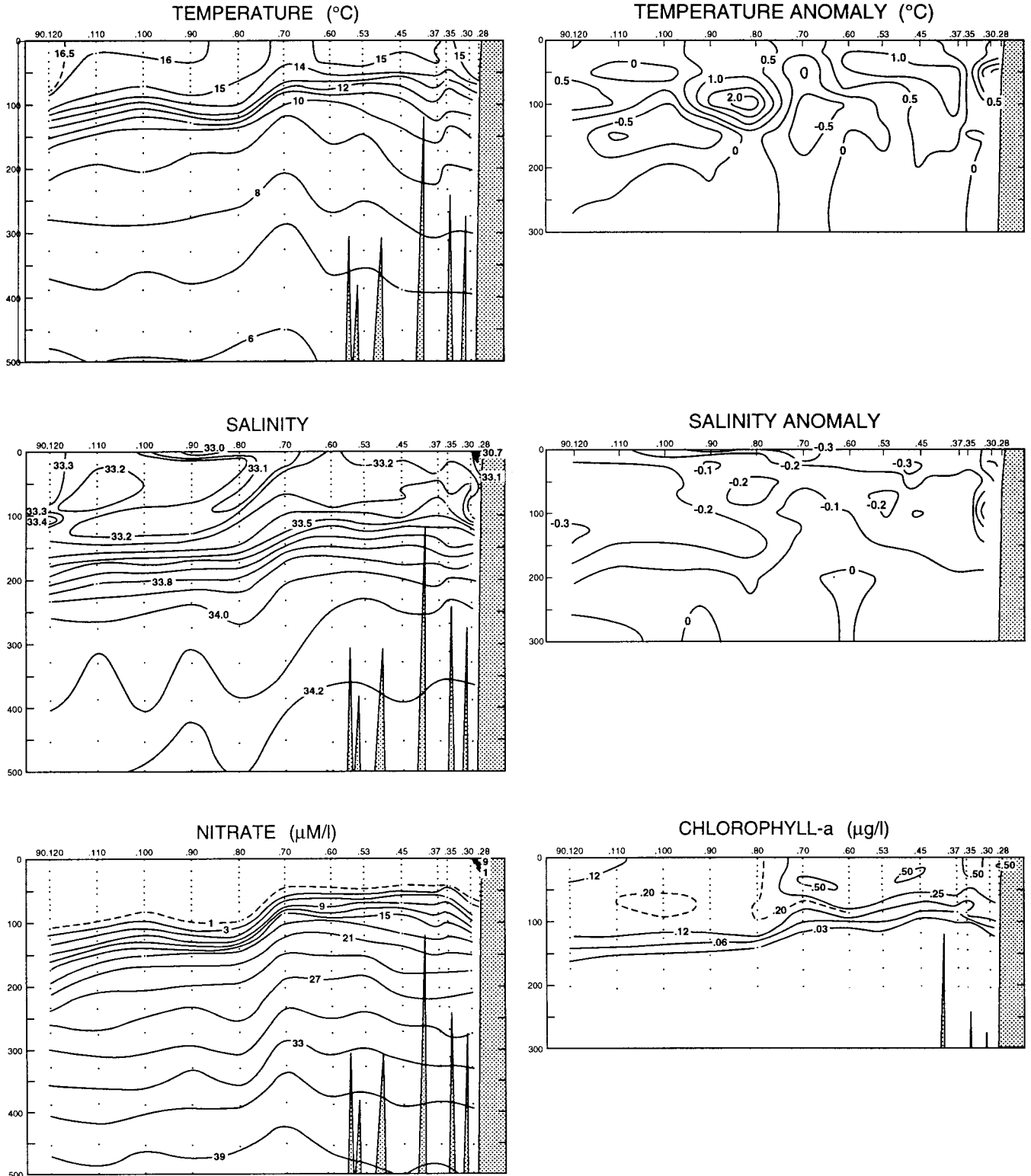


Figure 8. Vertical sections of temperature, temperature anomaly, salinity, salinity anomaly, nitrate, and chlorophyll along CalCOFI line 90 for cruise 9301.

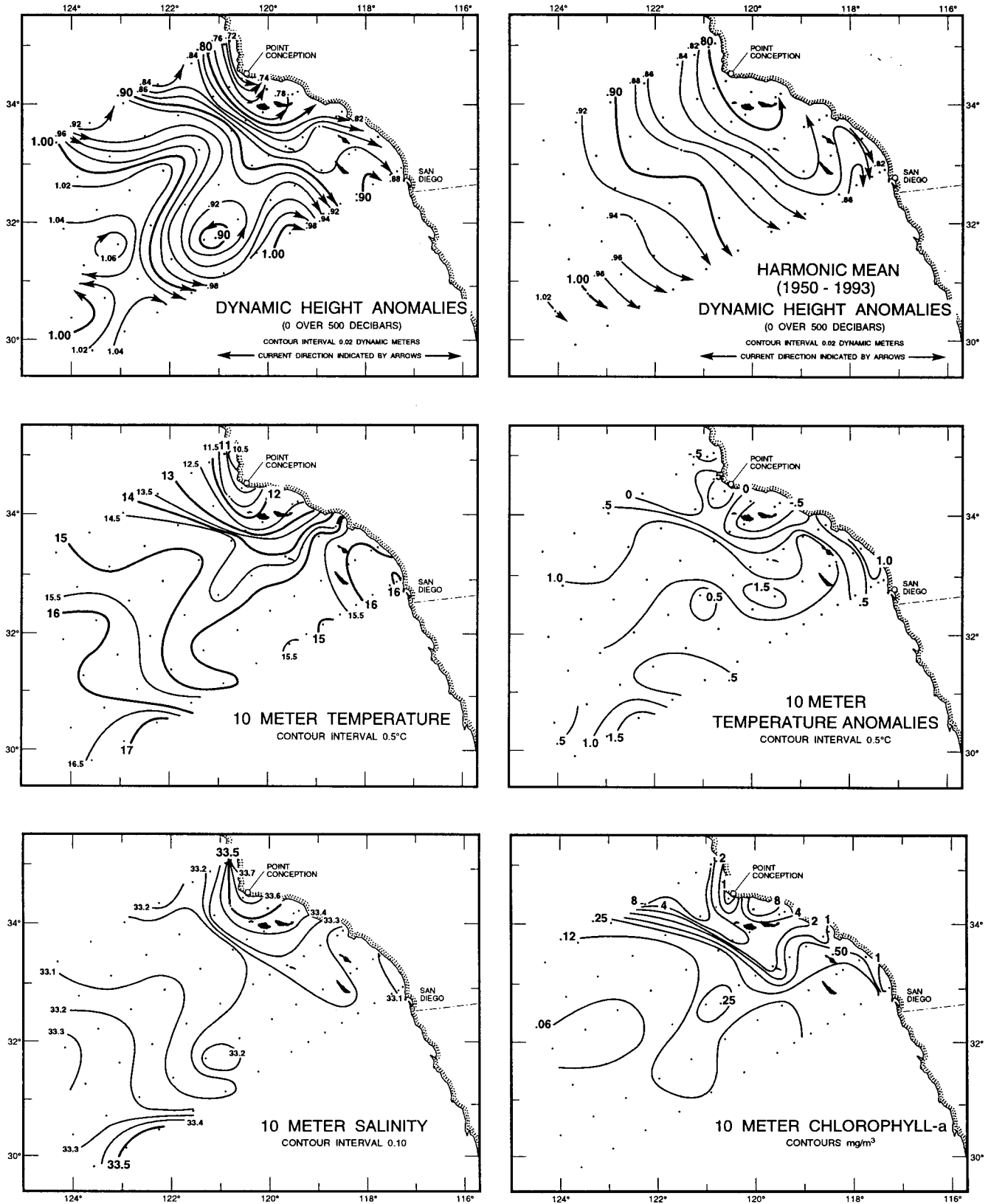


Figure 9. Spatial patterns (as described for figure 5) for CalCOFI cruise 9304, 30 March-15 April 1993. Harmonic mean dynamic heights and temperature were calculated for April 6.

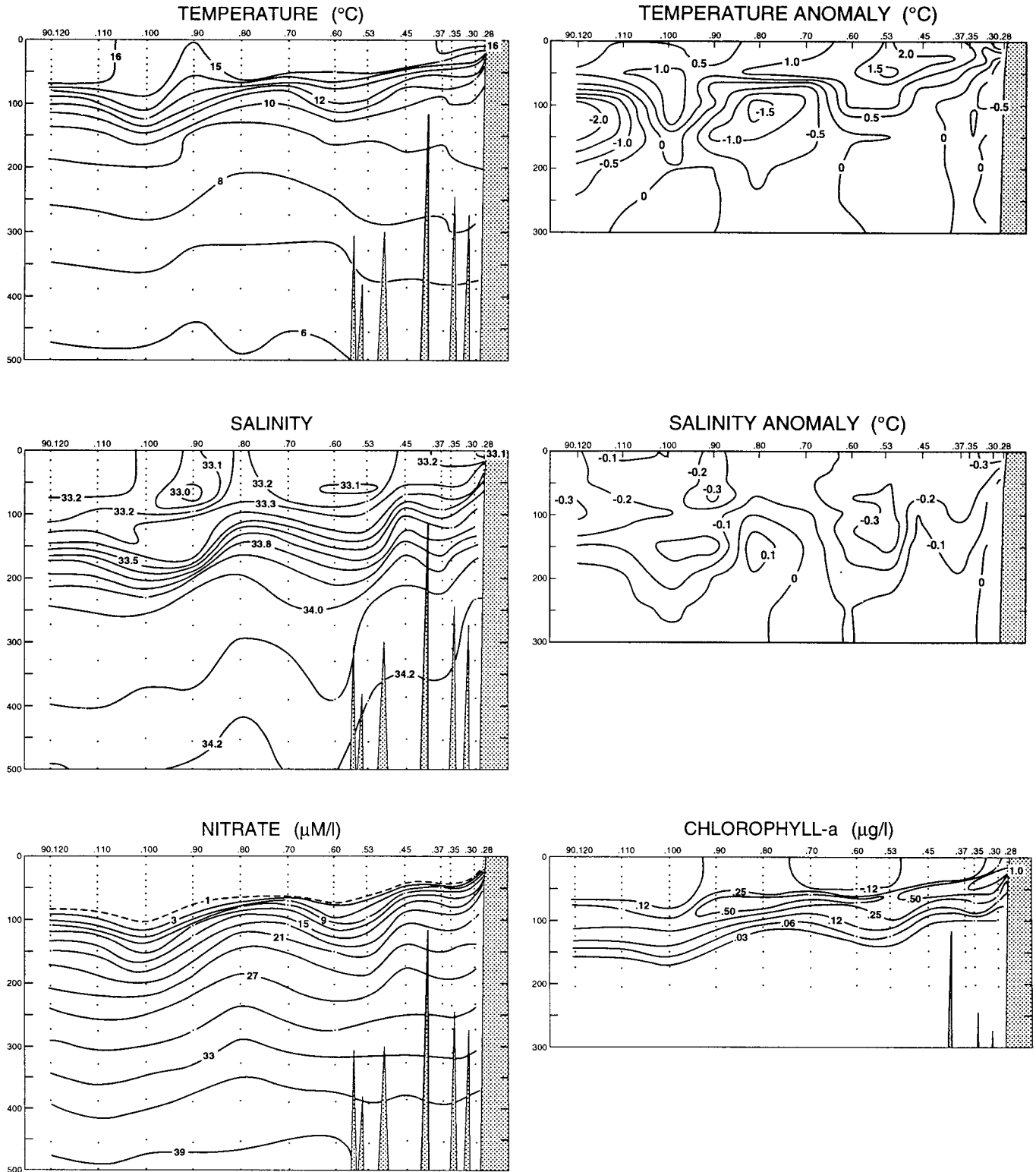


Figure 10. Vertical sections of temperature, temperature anomaly, salinity, salinity anomaly, nitrate, and chlorophyll along CalCOFI line 90 for cruise 9304.

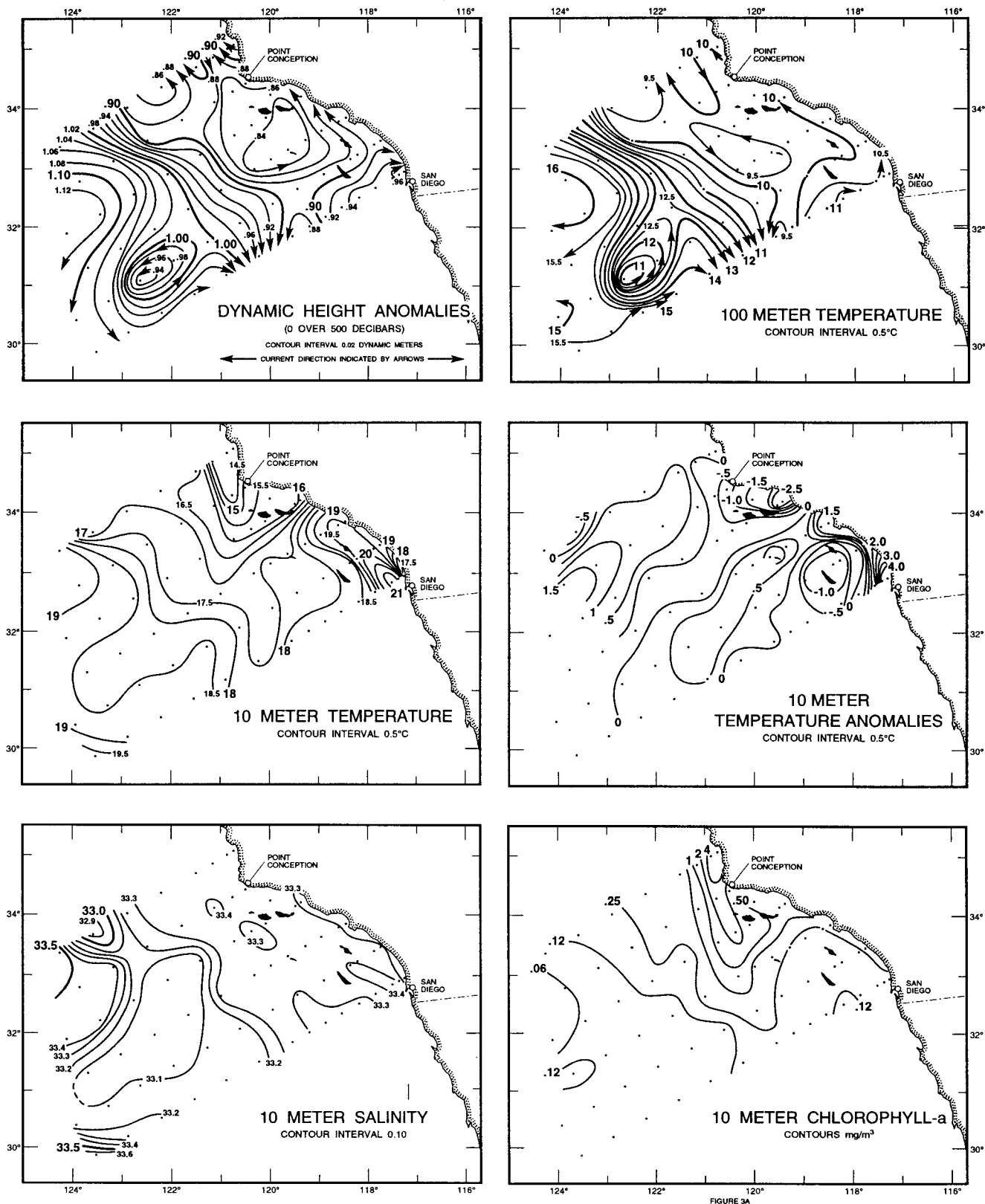


Figure 11. Spatial patterns for CalCOFI cruise 9308, 11-27 August 1993, including upper-ocean flow field derived from 0 over 500 m dynamic height anomalies, 100 m temperature field as a proxy for the upper-ocean flow field, 10 m temperature, 10 m temperature anomalies, 10 m salinity, and 10 m chlorophyll.

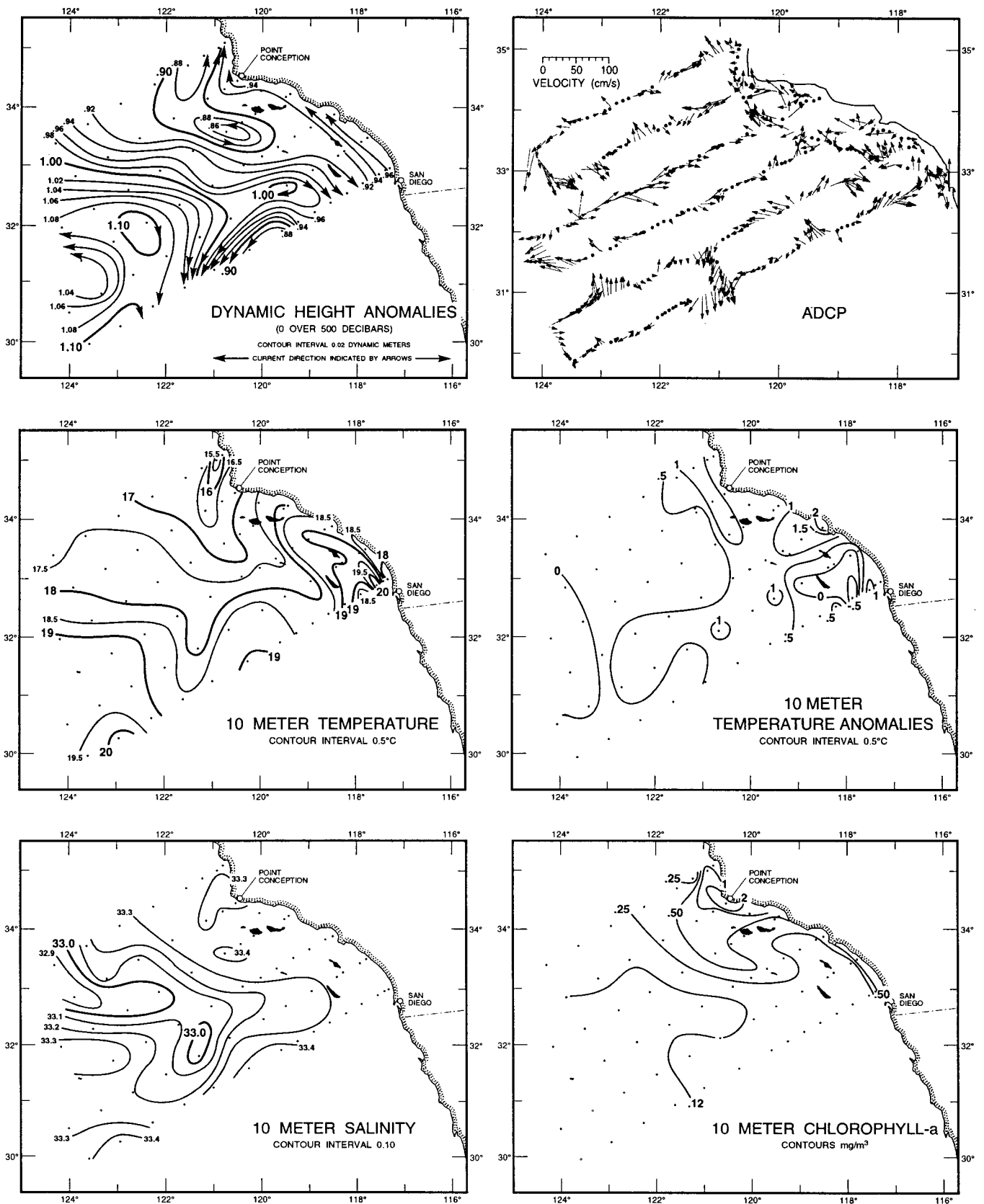


Figure 12. Spatial patterns for CalCOFI cruise 9310, 8-26 October 1993, including upper-ocean flow field derived from 0 over 500 m dynamic height anomalies, the 20-25 m flow field derived from ADCP, 10 m temperature, 10 m temperature anomalies, 10 m salinity, and 10 m chlorophyll.

upper-ocean flow field at 25 m derived from ADCP data. ADCP data provide point estimates of the actual flow in one depth zone in the upper ocean. The agreement throughout the grid is good.

9401. In January 1994, southward flow of the low-salinity core of the California Current was perturbed by a series of mesoscale eddies throughout the sample grid (figure 13). The flow field derived from dynamic heights was very much the same as given in the 20–25 m depth zone derived from ADCP data. The lack of a well-developed inshore countercurrent was anomalous when compared to the long-term mean pattern (shown in figure 7). Ten-meter temperature was generally between 1° and 2°C warmer than normal in the offshore region, and between 0.5° and 1°C warmer than normal near the coast. Ten-meter chlorophyll was generally low throughout the sample grid, with values less than $0.5 \mu\text{g l}^{-1}$, except at several of the most nearshore stations, where high values were seen. The sharp eastward bend of the California Current between lines 83 and 87 was again a prominent feature of the flow field. This appeared to bring offshore water near to the coast in the southern California coastal region.

9403. The dynamic height data from March 1994 were not available as this manuscript was being prepared, so the 100 m temperature was used as a proxy to infer the flow field. The inferred flow was primarily to the south, with some indication of a weak coastal countercurrent. There was a cyclonic eddy located on the outer stations of line 87. The coastal bend of the California Current was still present in the middle of the sample grid (figure 14). The upper layers were still anomalously warm over much of the grid. Chlorophyll values were relatively high in the coastal region in the northern part of the sample grid, where surface waters were relatively cool.

DISCUSSION

A strong tropical El Niño episode began in the fall of 1991 and, after a return to near normal conditions in the summer of 1992, developed a second punch in late 1992 (Climate Diagnostic Bulletin numbers 91-9 to 92-12). El Niño conditions continued until the end of 1993 (Climate Diagnostic Bulletin numbers 93-1 to 93-12). The large-scale impact of El Niño upon coastal sea level and SST off North America was evident in January 1992 (Hayward 1993). The regional effects off California, Oregon, and Washington include changes in the large-scale atmospheric pressure pattern (and hence gradient winds), reduced upwelling or increased downwelling, anomalously high sea level and SST, thickened surface mixed layer, depressed nutricline, and episodic enhancement of the inshore countercurrent. SST and sea level were above seasonal norms during 1992 and 1993 at both La Jolla and San Francisco. The largest anom-

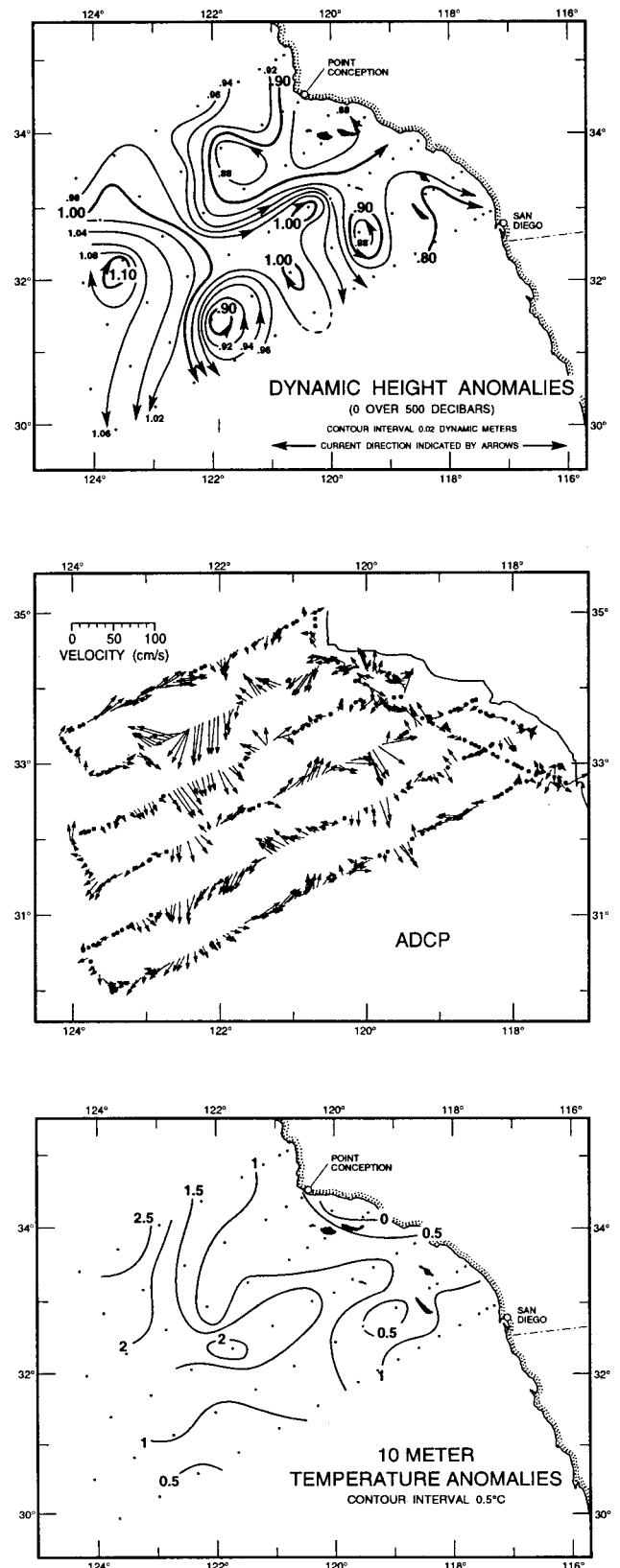


Figure 13. Spatial patterns for CalCOFI cruise 9401, 20 January–8 February 1994, including upper-ocean flow field derived from 0 over 500 m dynamic height anomalies, the 20–25 m flow field derived from ADCP, and 10 m temperature anomalies.

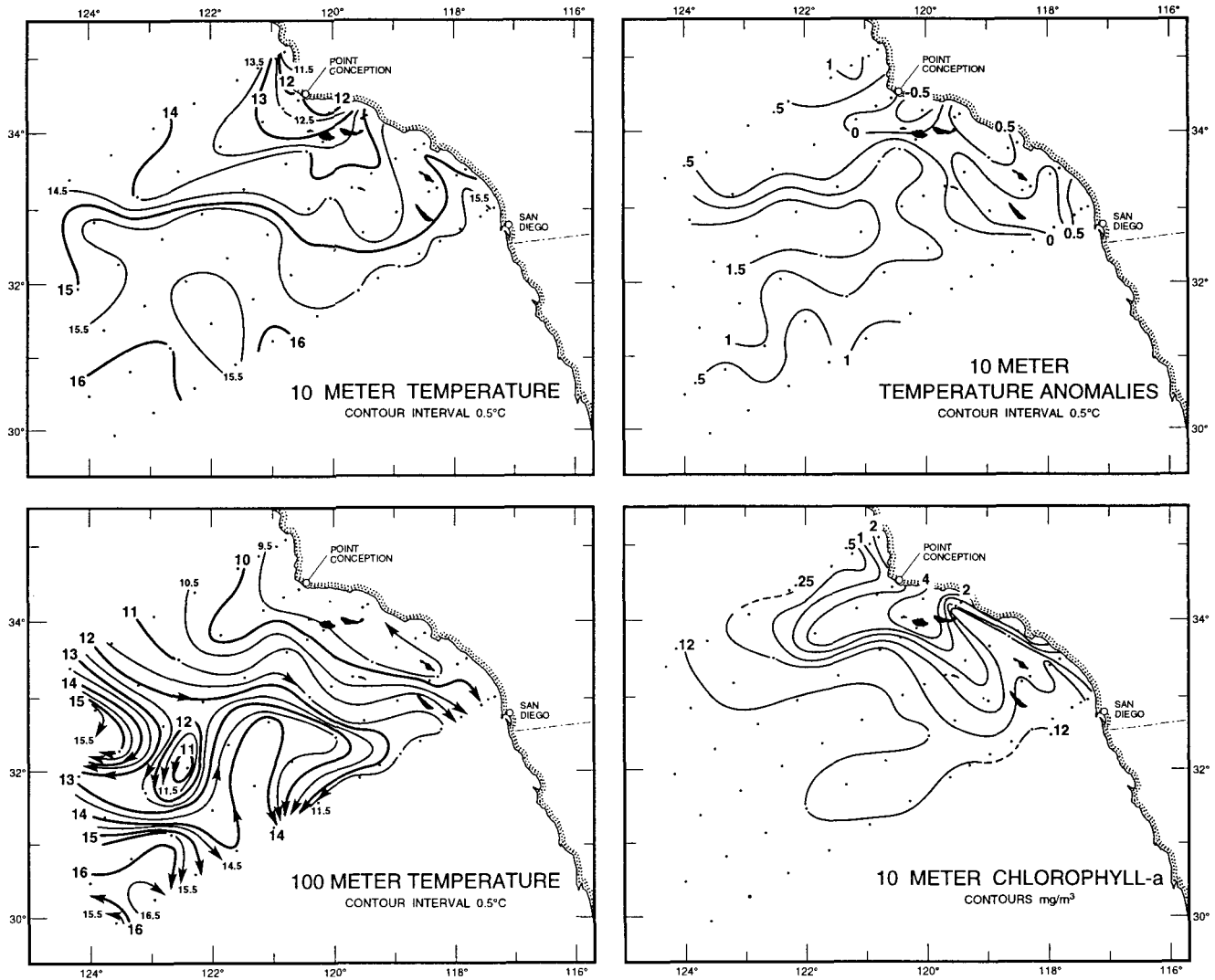


Figure 14. Spatial patterns for CalCOFI cruise 9403, 22 March–8 April 1994, including 10 m temperature, 10 m temperature anomalies, 100 m temperature as a proxy for the upper-ocean flow field, and 10 m chlorophyll.

alies in sea level and circulation occurred during late winter–early spring of both 1992 and 1993. Following a period of high coastal sea level and a broad inshore countercurrent in January of each year, sea level and the circulation pattern returned to much more typical patterns in March or April. The return to a typical circulation pattern was associated with a strong increase in primary production and plankton abundance. This spring increase could be called a spring bloom, but note that the cruise means in these properties were still below the higher values sampled in prior years, and macrozooplankton was well below the values of the prior decades throughout the period (Roemmich and McGowan 1994). Coastal sea-level anomalies are a useful indicator of anomalies in the large-scale circulation pattern of the California Current during the 1992–94 period (e.g., Reid and Mantyla 1976). SST remained anomalously high during

most of 1992 and 1993, and it thus gives a somewhat different impression of structure than does coastal sea level. It may be that the temperature anomalies are related to oceanographic conditions on a longer time scale. Roemmich and McGowan (1994) observed a decline in macrozooplankton over the last decade, along with an increase in coastal temperatures.

The oceanographic structure in 1994 is developing differently than in the two prior years. Sea level was anomalously low in the early part of 1994 at both La Jolla and San Francisco. The strong and broad inshore countercurrent observed during the preceding Januaries was weak or absent in January 1994. SST at the shore stations was above normal at La Jolla and near normal at Pacific Grove. SST patterns in the coastal waters began to show evidence of returning toward seasonal norms in April 1994 (NOAA/SWFSC CoastWatch El Niño Watch

94-4). It is expected that properties influenced by the northward advection along the coast will be less strongly affected in 1994.

Similarities in mesoscale current structure from survey to survey suggest that some features evolve slowly and persist over periods of months in the California Current system. Although the spatial scale of the CalCOFI grid is marginal in resolving mesoscale features, large and strong features are evident. The eddies observed during July and October 1992, and the cyclonic eddy seen in the offshore region in April, August, and October 1993 are examples of features that appeared to persist. There is no certainty, however, that the same feature was sampled from cruise to cruise. It is known that mesoscale eddies are more common in some regions of the California Current than in others (Lynn and Simpson 1987; Hayward and Mantyla 1990), and that they persist for months (Koblinsky et al. 1984). The sharp coastward bend of the California Current first observed in October 1993 was another unusual feature of the circulation that persisted for several months. The meander can also be seen in the January 1994 dynamic height, and the March 1994 100 m temperature field. This meander will have the effect of transporting plankton and other water properties characteristic of the offshore regime of the California Current to more coastal areas.

It will be helpful to know more about the persistence of mesoscale circulation features because they also strongly affect biological structure (Simpson et al. 1984; Hayward and Mantyla 1990). If it can be demonstrated that such features commonly persist for periods of several months, our ability to predict future pattern based upon the present structure will be improved. Examination of satellite images may help to determine the persistence of mesoscale circulation features, especially after SeaWiFS satellite color-sensor data become available.

The observations presented here are examples of the timely data that are available for the coastal ocean. The data that are rapidly available are generally those which are frequently collected, easy to process, and for which there is a good processing and management scheme in place. These timely data can be used to address questions that reflect the broad range of interests of the scientific community and users of the coastal ocean. In many cases, however, application of such data to the questions at hand is difficult because the relation between the available data (e.g., temperature and sea level)

and the questions at hand (e.g., understanding the causes and consequences of population fluctuations or detecting anthropogenic change) is highly complex or poorly known. Coastal data will be more widely applied to such questions as data collection, management, and distribution schemes improve, and as relations between the properties that can be measured and the questions of interest become more clear. Here we have described some of the data collected at coastal stations and on CalCOFI time series cruises, and we have attempted to show some of the relations between the properties that are measured and other aspects of coastal marine conditions.

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