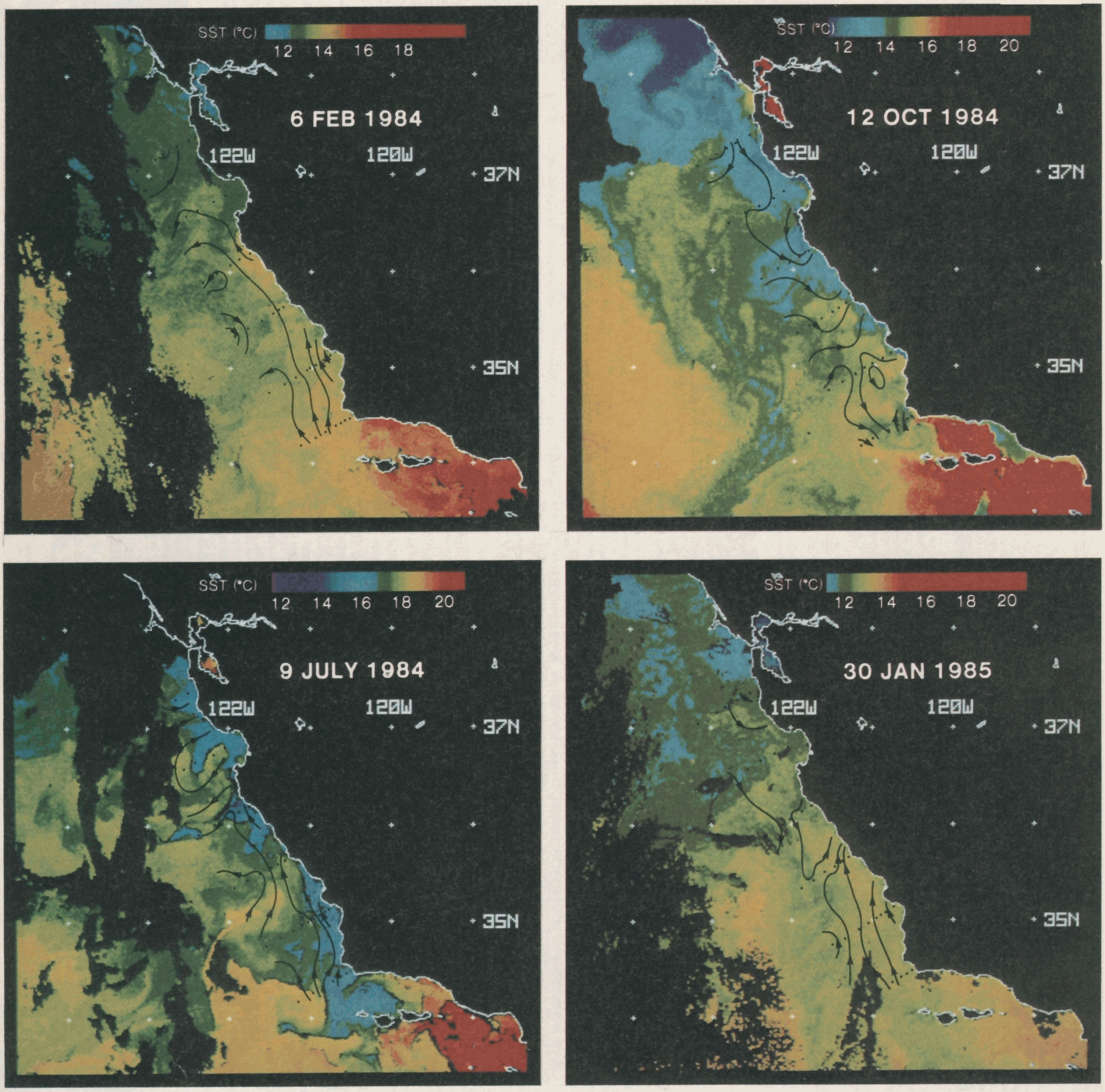
EOS

Transactions, American Geophysical Union
Vol. 68 No. 1 January 6, 1987



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Cover. Color-coded advanced very high resolution radiometer (AVHRR) images of sea surface temperatures for February 6, July 9, and October 12, 1984, and January 30, 1985. Contours correspond to dynamic topography relative to 500 m (2 dyn cm contour interval), determined from nearly coincident conductivity-temperature-depth (CTD) measurements at locations indicated by the dots. In the February image, northward flow of warm water is evident along the entire central California coast. Similar structure is present over the southern half of the central California coast in July, with offshore movement of cooler water near Point Sur at 36.4°N. In October an onshore movement of warm water can be seen near 35.5°N. January 1985 marked a return of northward flowing warm water over the southern half of the central California coast. These satellite and CTD data were acquired as part of an 18-month observational program called the Central California Coastal Circulation Study (CCCCS). Winds, currents, water temperature, and bottom pressure were also measured during this study, with the goal of describing and understanding the spatial and temporal variability of the circulation on the continental shelf and upper continental slope along the central California coast. For more information, see "The Central California Coastal Circulation Study" by D. B. Chelton et al., p. 1.

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The Central California Coastal Circulation Study

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Introduction

The Central California Coastal Circulation Study (CCCCS) was an 18-month field program designed to study the variability of water mass characteristics and the velocity field on the continental shelf and upper continental slope of California from Point Conception to San Francisco. This study was funded by the U.S. Department of Interior, Minerals Management Service (MMS), as part of an overall assessment of the impact of development of oil and gas resources on the ecosystem of coastal California. The Santa Maria Basin area, which extends from Point Conception to Point Buchon (100 km to the north) and about 50 km offshore, is of particular interest, as this area will be the focus of oil and gas exploration and production over the next decade. However, MMS is also interested in how the ocean variability in this region relates to the large-scale flow of the California Current System. The field work for CCCCS was conducted from February 1984 through July 1985 by Raytheon Service Company (Lexington, Mass.). This paper summarizes some of the preliminary results from analysis of the CCCCS data.

Historically, the California Current has been studied extensively since 1949 by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Seasonal variability of the flow has been summarized by *Hickey* [1979] and *Chelton* [1984]. During any particular month, the flow pattern may differ significantly from the seasonal mean [for example, *Wyllie,* 1966]. Much of the year-to-year variability may be attributed to eddies and meanders with relatively short time scales [e.g., *Mooers* and Robinson, 1984]. In addition, a large fraction of the variability is due to interannual variations with very large spatial scales and time scales of several years [*Chelton et al.,* 19821.

The objectives of the CCCCS observational program were to acquire a comprehensive set of measurements of the physical oceanography over the continental shelf and slope off central California. The sampling array was designed to resolve variability over space and time scales unaddressable from historical observations in this area. The extensive CCCCS data set included densely sampled conductivity-temperaturedepth (CTD) measurements, drifters, a nearly continuous 18-month time series of satellite images, current meter measurements, and buoy measurements of vector winds and sea surface temperature.

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Elements of the Observational Program

Hydrographic Data

The CCCCS CTD sampling grid was designed to have approximately 20 km cross-shore station spacing along the six standard CalCOFI lines 63, 67, 70, 73, 77, and 80. These parallel lines (Figure 1) are oriented approximately perpendicular to the central California coastline and are separated by approximately 65 km. The CCCCS sampling grid extended offshore from the coast to the standard CalCOFI stations 60 along each line (a distance of approximately 80 km). This coupling to the CalCOFI grid was motivated by the desire to relate the CCCCS measurements to historical data at the same locations and to place the field study period in the context of the "normal" conditions inferred from CalCOFI data. CCCCS CTD surveys were conducted four times over the 18 month field program (February, July, and October 1984 and January 1985). For all four hydrographic surveys, the CTD data were augmented with temperature profiles from expendable bathythermographs (XBTs) between each of the CTD stations.

The southern portion of the CCCCS sampling region was sampled more densely in the alongshore direction. The line spacing was approximately 10 km from Point Conception to Point Buchon (Figure 1), resulting in a total of about 75 station locations over the full CCCCS region. For the first three surveys, this southern "snapshot region" was sampled twice during an 8-day period to investigate how rapidly the water mass and flow field characteristics change. Each of the 50 CTD station locations in snapshot 1 was resampled approximately 4 days later in snapshot 2. For the January 1985 survey, the snapshot region was sampled only once.

Drifters

Approximately 20 surface drifters [see *Cook et al.,* 1980] were deployed from aircraft in the snapshot region during each of the four hydrographic surveys. These drifters were tracked by aircraft twice daily for about 15 days by using a radio direction finder and Loran C aircraft position determination. One of the objectives of these drifter studies was to evaluate surface transport characteristics between prime areas of resource development and environmentally sensitive areas of the California coastal region.

Satellite Imagery

Infrared images of the central California coast from the Advanced Very High Resolution Radiometers (AVHRR) on board the NOAA 6, NOAA 7, and NOAA 9 satellites were collected and archived by the National Weather Service in Redwood City, Calif. The average collection rate was about four images per day. All images judged to be sufficiently cloud-free were then further processed at SeaSpace (San Diego, Calif.) to obtain sea surface temperature estimates on a fixed geographical grid. Approximately 500 useful images were obtained over the full 18-month study. In general, cloud-free images were less frequent in summer (when much of the California coastal region is covered with stratus clouds) and in winter (because of the passage of storms over the central California coast).

Current Meter Moorings

Long-term current meter moorings were deployed at 11 locations along five lines across the continental shelf and upper continental slope (Figure 1). At each location, near-surface and subsurface instruments were deployed on separate moorings to isolate the deeper instruments from surface wave motion transmitted down the mooring wire. On the surface moorings, Ocean Data Equipment Corporation (ODEC, now located in Fall River, Mass.) electromagnetic current meters were installed at nominal depths of 10 and 30 m. Aanderaa current meters (Aanderaa Instruments, Woburn, Mass.) were installed on the subsurface moorings at nominal depths of 70,220, and 470 m. Thermistors were included at all sample depths, and bottom pressure gages were installed at moorings A, C, F, H, and K. The moored instruments were initially deployed in mid-February 1984 and were serviced at approximately 90-day intervals throughout the 18-month field study. Final recovery of the moorings was in mid-July 1985.

Virtually all of the near-surface measurements of current velocity were lost for the entire 18-month period because of a wide range of problems. The primary source of data loss was an improper implementation of the vector-averaging algorithm in the microprocessor-based electronics package of the ODEC current meters. Secondary sources were vandalism, fishing gear entanglement, and rundown by large ships. By the end of the second deployment period, the vector-averaging algorithm problem was discovered as a result of ocean intercalibration tests. However, after correcting the vector-averaging algorithm, difficulties were encountered with other aspects of the ODEC current meter design. Subsequently, no ODEC current meters were deployed through the remainder of the field program. Several EG&G Sea-Link vector measuring current meters (EG&G Ocean Products, Cataumet, Mass.) were deployed for near-surface measurements during the last three (of six) deployment periods.

Data recovery from the subsurface moorings was much more successful. Ten of the 11 moorings were recovered with good data return for most of the Aanderaa current meters. Current measurements are thus available at 10 locations at nominal depths of 70, 220, and 470 m. Overall, the data return for the current meter measurements was approximately 40% over the 18-month field pro-

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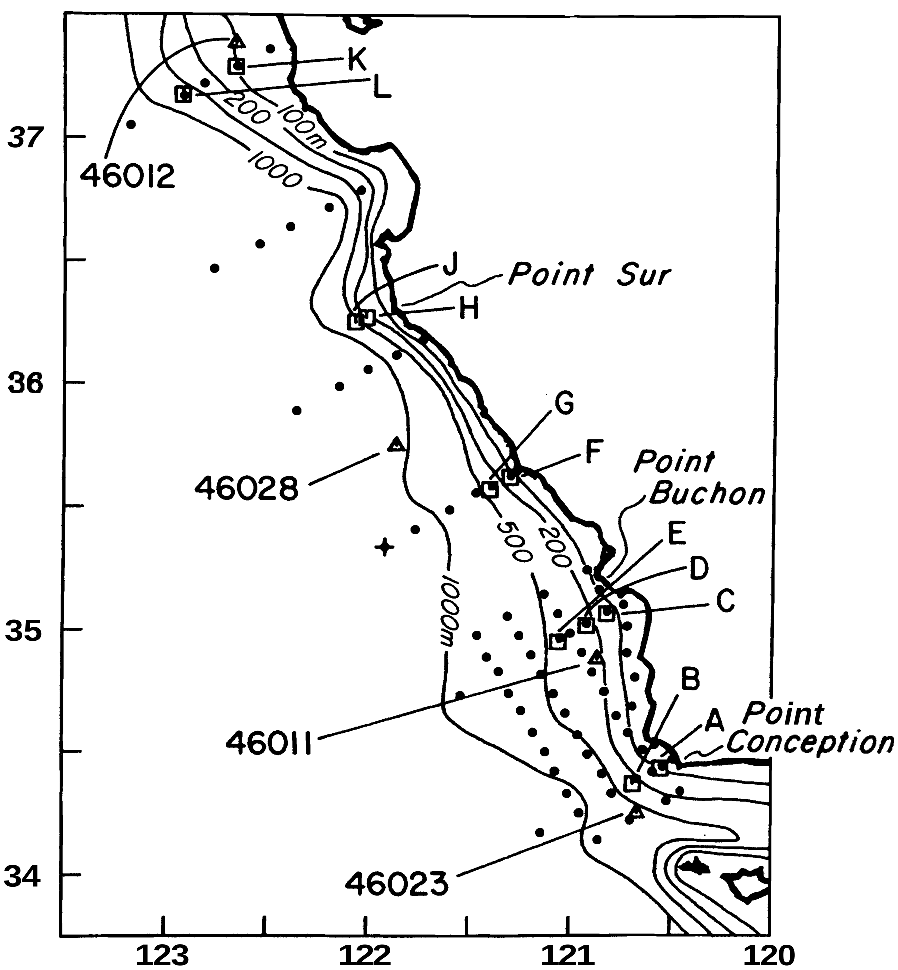

Fig. *1*. Map of the CCCCS study region overlayed on depth contours in meters. NDBC wind buoys are shown by the triangles, and current meter moorings are shown by the squares. The dots indicate the locations of CTD stations, and the CTD station marked by a plus symbol corresponds to the location of the temperature, salinity, and density profiles in Figure **3** and the outer station of the cross shore vertical sections in Figure **5**.

gram, based upon the original array design and instrument deployment scheme. Allowing for the highly modified near-surface measurement plan 6 months into the 18-month measurement period, the effective data return was about 70%.

Atmospheric Data

Atmospheric pressure and vector wind measurements were obtained from 21 **land**-based meteorological stations in California and four National Data Buoy Center (NDBC) buoys (Figure 1). The NDBC buoys also measured water temperature at 2 m depth. The time period spanned by the atmospheric data was January 27, 1984, through July 31, **1985**.

Preliminary Results

The Wind Field

The cross-shelf component of winds was weak at all locations (generally less than 3 m/s). From the alongshore component of winds at NDBC buoys 46011 and 46012 (Figure 2), which were separated by about 300 km, it is apparent that the winds over the CCCCS study region were highly coherent spatially. The seasonal cycle is evident at all buoys, with the strongest equatorward winds occurring in April and May and a number of poleward events in November and December. Events associated with **2–10-day** weather variability exhibit a high degree of spatial coherence among all of the NDBC buoys in this region. This short time scale variability was least energetic in August and September 1984.

The contrast between 1984 and 1985 is noteworthy. During February–May 1984, the winds fluctuated between calm and 10–12 **m/s** equatorward. For the same period in 1985 the winds also fluctuated, but the **equatorward** events were typically only half as strong. This approximately corresponds to a four-fold decrease in wind stress.

The Temperature Field

The annual signal in temperature variability was 2–4 times greater at 2 m than at 60 m with a phase lead of about 3 months (Figure 2). The temperature difference between 2 m and 60 m was greatest in summer, when the winds were weakest and solar insolation levels the highest. This vertical gradient of upper ocean temperature was very small in winter and spring, when wind events associated with 2–10-day weather patterns were most energetic, presumably because of a greater mixing from the combined effects of wind forcing and surface cooling.

The amplitude of the seasonal cycles in near-surface temperature was greater at buoys 46011 and 46023 than at NDBC buoys farther north. This is consistent with the results of *List* a d Koh **[1976]**, who found large annual variation in coastal sea surface temperature (SST) south of Point Conception and relatively small annual variation along the central California coast. This difference in amplitude of seasonal variation is probably related to the strong annual variation in **cur**rents off central California [*Chelton,* **1984]**, where the nearshore surface flow is seasonally equatorward in summer and **poleward** in winter. The combined effects of alongshore advection and tilting of near-surface **iso**therms associated with geostrophic adjustment from seasonal variations in alongshore flow would both tend to moderate an otherwise strong annual cycle in SST caused by seasonal heating and cooling. Since the flow is much weaker inside the Channel Islands, the effects of solar heating on nearshore SST would be more dominant south of Point Conception. Buoy 46011 is close enough to the **Santa** Barbara Channel that it is probably influenced more by conditions to the south.

The variability associated with **10–15-day** "events" in temperature fluctuations is about twice as energetic at 2 m as at 60 m (Figure 2). Many of these events occur simultaneously at both depths; however, there are a large number of cases that exhibit little vertical coherence. Some of these features can be related to wind forcing, but most appear to be responses to **nonlocal** forcing.

Fluctuations in near-surface temperature over time scales of about a month were large **(4°–5°C)** at buoy 46011 between July and October. Similar **variability** occurred at buoy 46023, but the amplitude was much smaller than at the more northern buoys. These variations bear little resemblance to the wind forcing but are closely related to near-surface variations in alongshore current velocity measured at 70 and 220 m (Figure 2).

The most dramatic signal is a rapid drop in 2 m temperature, which occurred at all NDBC buoys over a period of less than 1 week in mid-October. The magnitude of this temperature decrease ranged from about 3°C in the north to **5°C** in the south. This "fall transition" to cooler temperature coincided with the initiation of a **period** of strong poleward flow at stations G and J. It also coincided with a strong southward pulse in alongshore winds at buoy **46012**. However, this was apparently a relatively localized wind event, as there was little evidence for such a wind signal at any of the other buoys. At the three northern lines of current meter moorings the sudden decrease in temperature was evident at 60 m depth, as well as at 2 m, but did not penetrate as deep as 220 m. This signal was not as apparent in any of the subsurface temperatures along the two southern lines of current meter moorings.

The Current Field

At all current meter locations, average velocities on the shelf and upper continental slope were poleward. In fact, there were relatively few events of equatorward flow in these

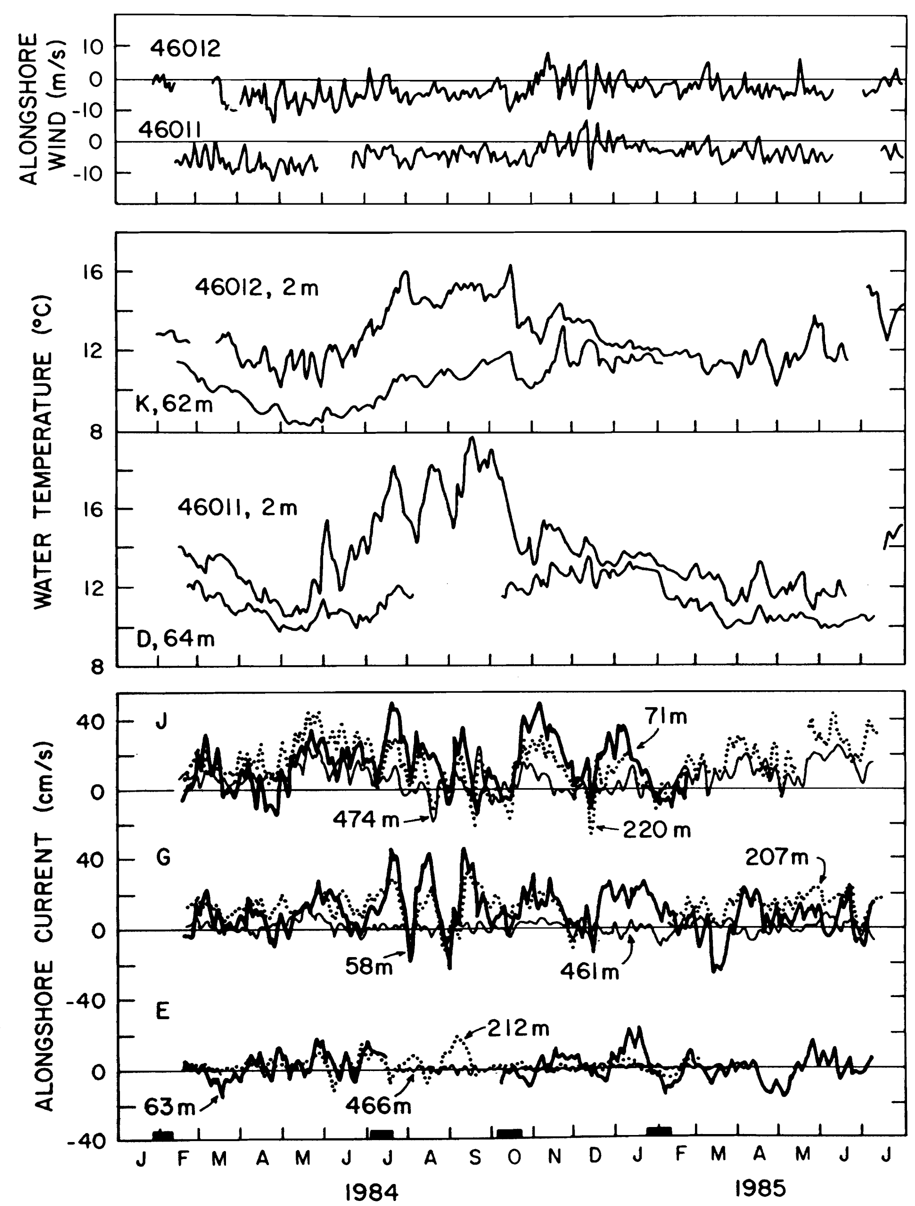

Fig. 2. 18-month time series of (top) alongshore winds at NDBC buoys 46012 and 46011, (middle) water temperatures at 2 m at the same buoys and 60 m temperatures at moorings K and D, and (bottom) alongshore currents at three depths at moorings J, G, and E. Bottom velocity is virtually indistinguishable at mooring E on this plot scale. All time series have been low-pass filtered to attentuate fluctuations with periods shorter than 2 days. For the purposes of this presentation, alongshelf is defined to be positive toward 325°T. The bars along the current meter axis indicate the times of the four CTD surveys.

shelf/slope currents over the survey period (Figure 2). This poleward flow was generally counter to the winds, which were equatorward throughout most of the survey period (except for the few poleward wind events in November and December 1984). Similar nearshore mean counterflows have been noted previously from current meter moorings on the shelf at 35.7°N during 1979 and 1980 [*Wickham et al.*, 1987] and at 34.7°N during 1981 and 1982 [*Strub et al.*, 1987]. This mean poleward flow may seem rather surprising in view of the seasonal pattern of geostrophic velocity inferred from CalCOFI hydrographic data. However, the CalCOFI surveys do not sample this nearshore region over the shelf and upper continental slope. This very narrow coastally trapped poleward flow may be a normal feature that is not resolved by the CalCOFI hydrographic data.

At all CCCCS mooring locations, the variability of alongshore currents was dominated by time scales of the order of 1–3 months (most energetic during the period June 1984–January 1985). There was little indication of any seasonal cycle in the flow. The mean velocities were higher and variability was greater at all depths at the moorings along the three northern lines. Peak 70-m velocities exceeded 50 cmls poleward along the three northern mooring lines and somewhat less than 20 cm/s along the two southern lines. The 70-m velocities at mooring G were highly coherent with those at mooring J, approximately 100 km to the north. However, there was relatively little coherence with 70 m velocities at mooring E, approximately 75 km to the south, suggesting that the flow field in the CTD snapshot region was fundamentally different from the flow field farther north. This speculation is further supported by hydrographic and drifter measurements (see discussion below).

Along the two northern mooring lines, there was relatively little vertical shear in velocity between the 70-m and 470-m current meters during winter and spring 1984, but there was strong vertical shear during summer and fall 1984. In contrast, there was strong vertical shear in velocity all year at the three southern mooring lines. At moorings J and G, the alongshore velocities at 220 m depth were highly coherent with the flow at 70 m but were generally stronger (except in summer). This is indicative of an undercurrent with core deeper than 70 m (see also Figure 5). The bottom velocity (470 m depth) was small along the three northern CCCCS mooring lines (generally less than 10 cm/s) and negligible (less than 3 cm/s with a mean of zero) along the two southern lines.

An important characteristic of the flow (see Figure 2) is that there is no obvious relation between the local wind field and alongshore current components at depths of 60 m or more. The major pulses of alongshore flow were not preceded by anomalous events in alongshore winds. Not only did the shelf and slope currents appear to be unrelated to local wind forcing, but the time scales of variability were also fundamentally different. While current variations do exist with the 2–10-day time scale characteristic of the winds, the most energetic pulses in alongshore currents persisted for periods of a month or longer and approached the seasonal time scale.

Hydrography

The seasonal progression of water mass characteristics is clearly evident in profiles of temperature, salinity, and σ_t (i.e., Knudsen's parameter of sea surface water relative density) (Figure 3). The thermocline was shallowest in July 1984. Below 75 m, the temperature profiles were virtually identical during February and October 1984 and January 1985. However. the water in the thermocline was 1°–3°C colder during July 1984.

The salinity profiles are perhaps the most interesting. There were large differences in salinity between the two winter surveys. In February 1984, the salinity at this particular location (shown as the plus symbol in Figure 2) was lower throughout the water column

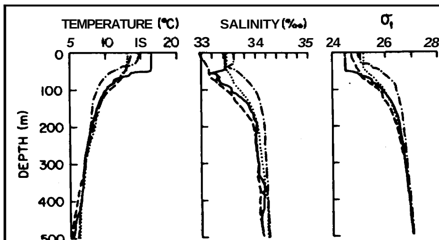

Fig. 3. Vertical profiles of temperature in degrees Celsius, salinity in per mil, and σ_t at the station denoted by the plus in Figure 1 for February 1984 (dashed line), July 1984 (dash-dotted line), October 1984 (solid line), and January 1985 (dotted line).

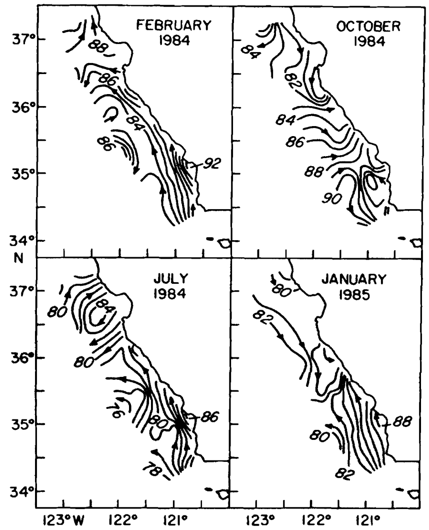

Fig. 4. Maps of surface dynamic topography relative to 500 m (1 dyn-cm contour interval) for each of the four CTD surveys. Periods of the CTD surveys are shown by the bars along the bottom axis of Figure 1.

han in January 1985 (differences ranging rom 0.5‰ near the surface to 0.15‰ at 00 m). The temperature profiles were virtu-lly identical for the two winter surveys. Maps f salinity constructed from all of the CTD ata for each of these months reveal that in ıe snapshot region south of 35°N, salinities ere nearly the same in both months. How-ver, salinities were generally lower to the orth during February 1984, particularly at ıe offshore stations.

Rienecker and Mooers [1986] found similar ›w salinities but near-normal temperatures uring the Ocean Prediction Through Obser-ation, Modeling, and Analysis (OPTOMA) ·uises off central and northern California uring the first half of 1984. They suggest ıat the different water mass characteristics ere related to the 1982–1983 El Niño occur-ence in the eastern tropical Pacific. On the asis of historical data in this region [*Lynn et* ., 1982], the lower-salinity water found in 384 is more representative of an open ocean ater mass, normally found approximately)0 km offshore.

Another noteworthy feature in the salinity rofiles in Figure 3 is the rich fine scale ructure during the October 1984 survey. hese salinity intrusions are compensated for similar temperature variations so that the ater column is stably stratified. The most ominent feature is a large intrusion of low-linity water just below a very well-defined ixed layer. The salinity decreased by 0.3‰ er vertical depth of less than 5 m, begin-ng at the base of the mixed layer. This fea-re was common over the entire CCCCS re-on during October 1984. Numerous other naller but significant salinity features were resent throughout the water column be-eath the mixed layer, even down to 500 m epth. CTD profiles off central California uring September 1982 [*Fleischbein et al.*, 983] reveal similar structures in salinity. hus these features possibly relate to a com-on phenomenon occurring during the fall this nearshore region. Such features are not well resolved by the historical CalCOFI hydrographic data, which consist of measurements from Nansen bottles at discrete depths (typically 20 bottles from the surface to 500 m).

To the extent that the flow is geostrophic, the dense spatial coverage of the CTD data complements the good temporal but poor spatial resolution of the current meter data. Maps of the surface dynamic topography relative to 500 m are shown in Figure 4 for the four surveys. Dynamic heights inshore of the 500-m isobath were extrapolated horizontally by the method of Montgomery [1941] and *Reid* and *Mantyla* [1976]. To avoid introducing biases from spatial inhomogeneities in sampling, the CTD data from the short lines in the snapshot region (see Figure 1) are not included in the contour plots in Figure 4.

The CTD data also permit an examination of the cross-shore and vertical structure of geostrophic current shear in the upper 500 m (Figure 5). Alongshore geostrophic velocities were computed from dynamic heights (extrapolated inshore of the 500-m isobath) relative to 500 m. Caution must be used in interpretation of the geostrophic flow relative to 500 m as absolute flow. However, the relative geostrophic velocities are generally consistent with the current meter data. This is particularly true in the southern half of the CCCCS region, where the current meter velocities at 470 m were negligible, thus justifying the use of 500 m as a reference level.

Generally, the poleward flow associated with the Davidson Current extends offshore at least 75–100 km from November through January and begins to decrease in offshore extent during February [*Chelton*, 1984]. During February 1984, the poleward flow inferred from the CCCCS data was trapped within about 50 km of the coast. A vertical section of February 1984 alongshore geostrophic velocity relative to 500 m (Figure 5) shows that this narrow coastally trapped poleward flow was also surface trapped. Alongshore geostrophic velocities at depths greater than 150 m were less than 5 cm/s. This very nearshore region is not well sampled by the coarse cross-shore spacing in the CalCOFI station pattern. Indeed, there was no evidence of any neashore poleward flow in either of two CalCOFI hydrographic surveys, one preceding the CCCCS survey by 1 week and other immediately following the CCCCS survey. Similar coastally trapped poleward geostrophic velocities have been previously noted from high-resolution CTD measurements within 25 km of the coast off Point Sur [*Wickham et al.*, 1986]. It thus appears that the historical CalCOFI data are inadequate for addressing some of the issues of interest to MMS over the continental shelf/slope region.

The July 1984 surface flow was very unusual, with poleward flow across the entire CCCCS sampling region, extending as far north as Point Sur. On the basis of the CalCOFI data, July normally marks the period of maximum equatonvard flow over the entire California Current. From a CalCOFI survey taken immediately after the CCCCS survey, it is evident that this nonseasonal poleward flow extended as far offshore as 150 km. This highly anomalous July pattern is more representative of the usual winter pattern of the Davidson Current. A detailed description of this nonseasonal summer poleward flow episode is given by R. L. Bernstein et al. in an unpublished manuscript. A July 1984 vertical section (Figure 5) shows poleward relative geostrophic velocity throughout the water column with 25 cm/s concentrated flow at depth between 100 and 250 m over the shelf and very small velocities deeper than 400 m.

The flow pattern for October 1984 was more typical of the seasonal norm inferred from CalCOFI data. Fall generally marks the period of transition near shore from strong summertime equatorward flow to wintertime poleward flow associated with the Davidson Current. In October 1984 the flow was weak and meandering, with poleward flow in some regions and equatorward flow in others.

By January 1985, generally poleward flow typical of the Davidson Current was well established over the southern half of the domain. In the northern half of the CCCCS region the flow in the offshore region was weakly equatonvard, with near-zero flow near the coast. The January 1985 alongshore geo-

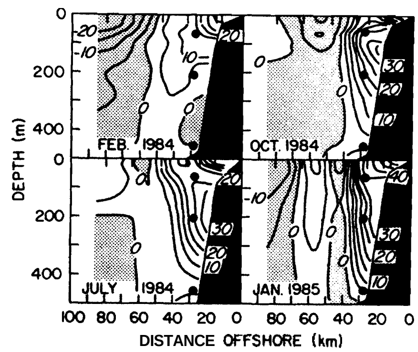

Fig. 5. Vertical sections of geostrophic velocity relative to 500 m (contour interval 5 cm/s) for each of the four CTD surveys. Sections correspond to the line marked at the outer station by the plus in Figure 1. Areas of equatorward flow are shaded. The three dots in each figure correspond to the current meter locations on mooring G, and tic marks along the upper axis indicate location of CTD stations used to compute relative geostrophic velocities.

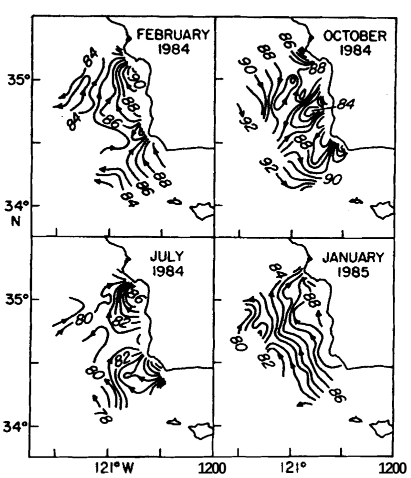

Fig. 6. As in Figure 4, except dynamic topography contoured for only the densely sampled snapshot region in the southern portion of the CCCCS sample area.

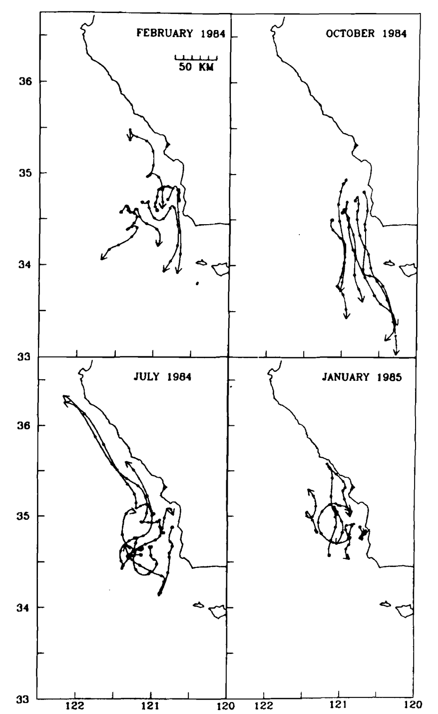

Fig. 7. **Drifter** trajectories for six **selected drifters fr**om each deployment. **Dots on drifter tr**acks are separated in **time by 1 day.**

strophic flow was distinctly different from the February 1984 pattern. Both winter surveys showed **poleward** flow out to about 50 km from the coast. However, the alongshore velocity was about a factor of two higher in January 1985 and extended much deeper in the water column (Figure 5). This is probably related to the previously noted fourfold decrease in equatorward wind stress between February **1984** and January 1985.

A unique aspect of the CCCCS hydrographic surveys was the spatially dense CTD sampling in the snapshot region. The **10-km** alongshore line spacing in this region resolves much shorter spatial scales than the 65-km line spacing used to construct the maps in Figure 4. **Geostrophic** flow patterns in the snapshot region (Figure 6) inferred from the full array of CTD stations are qualitatively consistent with the large-scale pictures in Figure 4: the flow was generally poleward, except for October 1984 when the flow in the snapshot region was equatorward. However, these maps based on the dense CTD coverage show considerable complexity in the flow, with numerous small-scale meanders and eddies. There was no comparable closely spaced CTD sampling grid north of **35°N** in the CCCCS surveys. Consequently, it is not known whether the small-scale structure in the flow field resolved by the dense station spacing is limited to the region just north of Point Conception or whether it is a general feature of the shelf and slope waters off central California.

Satellite Imagery

SST inferred from infrared satellite images is shown in the cover figure at times that approximately coincide with the four CTD surveys. The surface dynamic topography from Figure 4 is overlaid on each of the satellite images. There is remarkable agreement between the two fields. Generally, **poleward** flow is evident as warm water, while equatorward or offshore flow appears as colder water. There is remarkable agreement between many of the smaller-scale structures in the dynamic topography and similar features in SST. The limited offshore extent of the poleward flow is clearly evident in the two winter images as a narrow tongue of warm water trapped near the coast.

There is a well-defined filament of cold water extending offshore near Point Sur in the July 1984 image. Similar **jetlike** features off Point Sur have been previously observed in satellite imagery [***Traganza et al.***, 1980, 1981; ***Breaker and Mooers,* 1986]**, and it has been speculated that they are a common occurrence. Cold filaments emanating from Point **Sur** are present in many of the satellite images collected over the 18-month CCCCS field survey.

The satellite-inferred surface temperature signal associated with the July 1984 Point Sur filament is spatially limited to about 20 **km** width. Indeed, the feature cannot be detected in temperatures from coincident CTD measurements along two parallel lines on opposite sides of the filament. The 10-m temperatures were approximately the same (ranging from 14°C to **14.7°C)** along these two lines, which were separated by 65 km. However, the narrow cold water filament between the two CTD lines separates two very different water masses; the salinity at 10 **m** was very homogenous (about **33.6‰)** over the southern two thirds of the CCCCS region and dropped by more than **0.3‰** between the line just south of Point Sur and the neighboring line to the north. Examination of underway thermosalinograph data during the CTD survey indicates that this change in surface salinity occurred over a distance of less than 5 km in the alongshore direction. This salinity front extended to a depth of about 40 m.

As a consequence of the vertically integrated influence of the **large** change in salinity across the cold water filament, there was a large alongshore gradient of dynamic topography. This is indicative of strong offshore geostrophic velocity in this region **(*see*** Figure 4). As this feature is not well resolved spatially by the CTD data, it is not possible to estimate accurately the velocities in this offshore jet.

Drifters

The July 1984 drifter trajectories (Figure 7) were variable but generally **poleward** in the snapshot region, with very rapid poleward flow (speeds exceeding 75 **cm/s)** north of **35°N**. There is a suggestion of offshore turning of the drifters at the location of the Point Sur jet discussed previously. All of these features are consistent with both the current meter measurements and surface dynamic topography. The October 1984 drifter trajectories were also consistent with CTD data; all of the drifters (including those not show in Figure 7) moved steadily southward with typical speeds of 20–30 **cm/s.**

In contrast, the drifter trajectories for the two winter surveys are difficult to rationalize in terms of the flow patterns inferred from other data. For example, most of the February 1984 drifters moved in a generally southward or southwestward direction. Yet the geostrophic flow was consistently **poleward** in the drifter survey region (see Figures 4 and 5). Similarly, the January 1985 geostrophic flow was quite strong **poleward** in the drifter region, but the drifter trajectories are more indicative of variable flow.

The rather surprising discrepencies between the drifter and hydrographic data during the two winter surveys are presently under investigation. The drifters used in these surveys ***[Cook et al.,* 1980]** consist of a 130-cm tube that floats vertically like a spar buoy, with a cylinder 6 cm in diameter protruding about 20 cm above the water line. The drifters are coupled to the surface water motion by four orthogonal arms that radiate outward 60 cm from the tube, attached 15 cm below the water line. Field test **comparisions** with dye patches showed downwind motion of the dirfters at an average of 0.5% of the wind speed. For the winds observed during the CCCCS drifter surveys the corresponding wind drift velocities (less than 5 **cm/s)** are much smaller than the observed drifter velocities of 15–30 **cm/s.** Consequently, windage of the drifters is believed to be no problem. A more likely explanation for the discrepancies between drifter and hydrographic data is a **poor** representation by the hydrographic data of near-surface currents.

The flow appears to be considerably more complex in the snapshot region (Figure 7) than in regions both north of **35.2°N** and south of **34.4°N**. In all but the October 1984 survey, drifters tended to wander in the **snapshot** region but move steadily and rapidly either southward or northward outside of the snapshot region. The different character of the circulation in this region may be caused by the influence of flow in and out of the **Santa** Barbara Channel [*Brink* and ***Muench,* 1986]**, as well as by ocean conditions to the north and south. The wider continental shelf in this **region** (see Figure 1) may also be a contributing factor.

Summary and Future Efforts

Analysis of the extensive **CCCCS** observational data set is still in the very early stages and is expected to continue over the next year. One important conclusion that can be drawn from the preliminary analysis is that the historical **CalCOFI** hydrographic data do not adequately resolve spatial scales of variability in the shelf and slope waters. The horizontal spacing of the CalCOFI stations is too coarse to resolve the coastally trapped poleward flow, and the vertical spacing of **Cal**COFI Nansen bottles is too large to resolve the fine scale salinity structure that has been observed in the fall.

A number of very interesting and surprising features have been identified. Among the most notable is the relatively consistent **coast**ally trapped **poleward** flow over the shelf in the entire region from Point Conception to San Francisco. The cause of this mean poleward flow and the large fluctuations in the flow with time scales ranging from a few weeks to 3 months has not been identified. These features appear to be unrelated to local wind forcing, which is generally equatorward in this region and varies on a much shorter time scale. The large-scale **poleward** flow in July 1984 is particularly surprising, as it extended some 150 km offshore during a season when the flow is believed to normally be strongly equatorward.

The question of whether the circulation is truly more complex spatially (and perhaps temporally) in the region immediately north of Point Conception merits further investigation, as does the discrepancy between drifter trajectories and geostrophic velocities during the two winter surveys. Major differences in water mass characteristics between the two winter surveys and the greater presence of fine scale structure (intrusions) in the water column in the fall are other areas that need to be studied further.

Presently, data reports are in preparation for all of the CCCCS data. These include an atlas of satellite imagery; maps of drifter trajectories; maps, vertical sections, and profiles of hydrographic data; and time series of wind, temperature, currents, and bottom pressure. Completion of these data reports is expected by early 1987.

Acknowledgments

The collection and initial processing of CCCCS data were carried out by Raytheon Service Company (RSC) under Minerals Management Service Contract 14-12-0001-30020. Additional processing and analysis of the data were supported by subcontracts from RSC to Oregon State University, Sea-Space, and the University of Southern California. We would like to acknowledge R. Tait, N. Plutchak. G. Parker, and M. Falla for their help in coordinating and carrying out the field program and initial data processing. We would also like to thank T. Dickey, C. Mooers, and K. Brink for constructive comments on the manuscript.

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