WIND STRESS AND WIND STRESS CURL OVER THE CALIFORNIA CURRENT

Craig Scott Nelson

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WIND STRESS AND WIND STRESS CURL
OVER THE CALIFORNIA CURRENT

by

Craig Scott Nelson

June 1976

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The wind stress curl is positive near the coast and negative in the region offshore. A line of zero wind stress curl parallels the coast 200 km to 300 km offshore, except off central Baja California. The patterns of wind stress curl are consistent with the existence of a southward Sverdrup transport offshore and a poleward transport near the coast.

Wind Stress and Wind Stress Curl over the California Current

by

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Lieutenant, National Oceanic and Atmospheric Administration
B.S., Yale University, 1971

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Historical surface marine observations are summarized by 1-degree square area and long term month to describe the seasonal distribution of wind stress over the California Current. Off the coasts of southern California and Baja California, an alongshore equatorward component is present throughout the year. The distributions north of Cape Mendocino are characterized by marked changes in direction and magnitude between summer and winter. The predominant wind stress maximum shifts northward coherently from off Point Conception in March to south of Cape Blanco in September, and extends approximately 500 km in the offshore direction and 1000 km in the alongshore direction. Maximum values of surface wind stress occur during July near Cape Mendocino.

The wind stress curl is positive near the coast and negative in the region offshore. A line of zero wind stress curl parallels the coast 200 km to 300 km offshore, except off central Baja California. The patterns of wind stress curl are consistent with the existence of a southward Sverdrup transport offshore and a poleward transport near the coast.

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I. INTRODUCTION

Spatial variation in the distributions of surface wind stress has long been recognized as a fundamental quantity in discussions of the wind-driven ocean circulation. Sverdrup's (1947) transport balance relates the vertically integrated meridional mass transport in the interior ocean to the open ocean wind stress curl. Munk (1950) extended the theory to a closed basin and estimated the mass transports for several oceanic circulations from a knowledge of the wind stress alone. Recent theoretical developments have attempted to explain the well-known westward intensification, but have largely ignored the wind-driven circulation in eastern boundary currents, such as the California Current.

The California Current flows southeastward along the west coast of the United States as one branch of the large anticyclonic gyre in the North Pacific Ocean. The predominant surface flow occurs between a cell of high atmospheric pressure to the west and a continental thermal low situated over California. Seasonal variations in the direction and strength of the surface wind are related to shifts in location of the high pressure system and intensification of the semi-permanent thermal low.

The basic features of the California Current system may be described in terms of the local wind stress (Reid et al. 1958). The equatorward surface current and poleward undercurrent are typical of eastern boundary currents (Wooster and Reid 1963). Munk (1950) has suggested that the average wind distribution off California is consistent with the existence of an equatorward surface flow offshore and

a poleward flow inshore. However, lack of an adequate data base has precluded a detailed analysis of the relationships among the distributions of surface wind stress, the southward flowing California Current, and the northward flowing countercurrent which appears seasonally off the coasts of California, Oregon, and Washington.

A related phenomenon in eastern boundary currents is the process of coastal upwelling. The role of upwelling in bringing nutrients into the surface layers where they are available for organic production is widely recognized. According to the simplified model (Sverdrup 1938), equatorward wind stress parallel to the coast induces flow in the surface Ekman layer of the ocean which is deflected offshore by the earth's rotation (Ekman 1905). When this occurs over an expanse of coast where horizontal surface flow cannot compensate for that driven offshore, the balance is maintained by upwelling of subsurface water. Smith (1968) suggests that wind stress, being the driving force in this mechanism, may be the most important single parameter in coastal upwelling.

Previous estimates of the surface wind stress over the oceans have been based primarily on wind data taken from the U.S. Hydrographic Office Pilot Chart wind roses (Hidaka 1958, Hellerman 1967). The large scale features evident in these distributions are consistent with the occurrence of the major cyclonic and anticyclonic circulations in the oceans. However, the coarse spatial and temporal resolution of these data (5-degree quadrilateral space average and 3 month time average) are not adequate to describe the locally driven processes evident in the California Current system.

Wooster and Reid (1963) used Hidaka's estimates of surface wind stress to calculate the offshore Ekman transport and described the locations and seasonal timing of the major coastal upwelling regimes in terms of these "upwelling indices." Bakun (1973) extended the concept of the upwelling index by computing estimates of Ekman transport from routinely available analyzed surface atmospheric pressure fields. Temporal fluctuations are well described by these data. However, both the derived quantities based on Hidaka's wind stress data, and Bakun's upwelling indices suffer from an inability to characterize small scale features of the Ekman transport field, particularly near the coast. For example, where these data may indicate surface divergence on the large scale, smaller scale surface convergence might exist, with associated effects on the distributions of organisms within the coastal upwelling zone.

This report is an attempt to provide more detailed descriptions of the surface wind stress distributions over the California Current. The study differs from previous work by calculating the monthly mean values on a 1-degree square area basis. Surface marine wind observations have been utilized in the computations. Roden (1974) evaluated the surface wind stress on a 1-degree latitude-longitude grid. However, Roden's distributions have been derived from monthly mean surface atmospheric pressure analyses based on a 5-degree latitude-longitude grid. Thus, any information concerning space scales smaller than 5 degrees is due to the particular interpolation scheme used to refine the data to a 1-degree grid, rather than due to observed data.

The monthly mean data described in this report adequately resolve the seasonal cycle, which is the dominant time scale for coastal

upwelling (Mooers et al. 1976). The high resolution in space and time may provide the observational background for more detailed investigations of the relationships among the local wind stress distributions, the equatorward surface current offshore, the poleward surface and subsurface flow inshore, and the distributions of certain species of fish, such as the northern anchovy (Engraulis mordax), and the Pacific mackerel (Scomber japonicus).

II. DATA REDUCTION

The monthly mean distributions of surface wind stress presented in Appendix A are based on summaries of data contained in the National Climatic Center's file of surface marine observations (Tape Data Family - 11). The total file contains approximately 40 million individual ship reports dating from the mid-nineteenth century. Over 1 million of the reports are within the area of the California Current system.

Long term composite monthly fields of surface wind stress have been compiled on a 1-degree square area basis within the geographical area outlined in Figure 1. The data grid extends from 20° N latitude to 50° N latitude and parallels the coastline configuration, extending 10° of longitude in the offshore direction. Each 1-degree quadrilateral is centered on a whole degree of latitude and longitude. Approximately 25% of the total available reports contain positions recorded to the nearest whole degree of latitude and longitude. The grid orientation used in this study thus minimizes spatial bias which might be introduced by summarizing the data according to the Marsden square numbering system.

The historical data contain errors in position, measurement, and processing. A single pass editor was used to remove gross errors in the data, including duplicate reports (0.5%), position errors (0.1%), and measurement errors (0.5%). Erroneous wind directions and wind speeds greater than 100 m sec^{-1} were removed. Reports of variable winds were treated as calms.

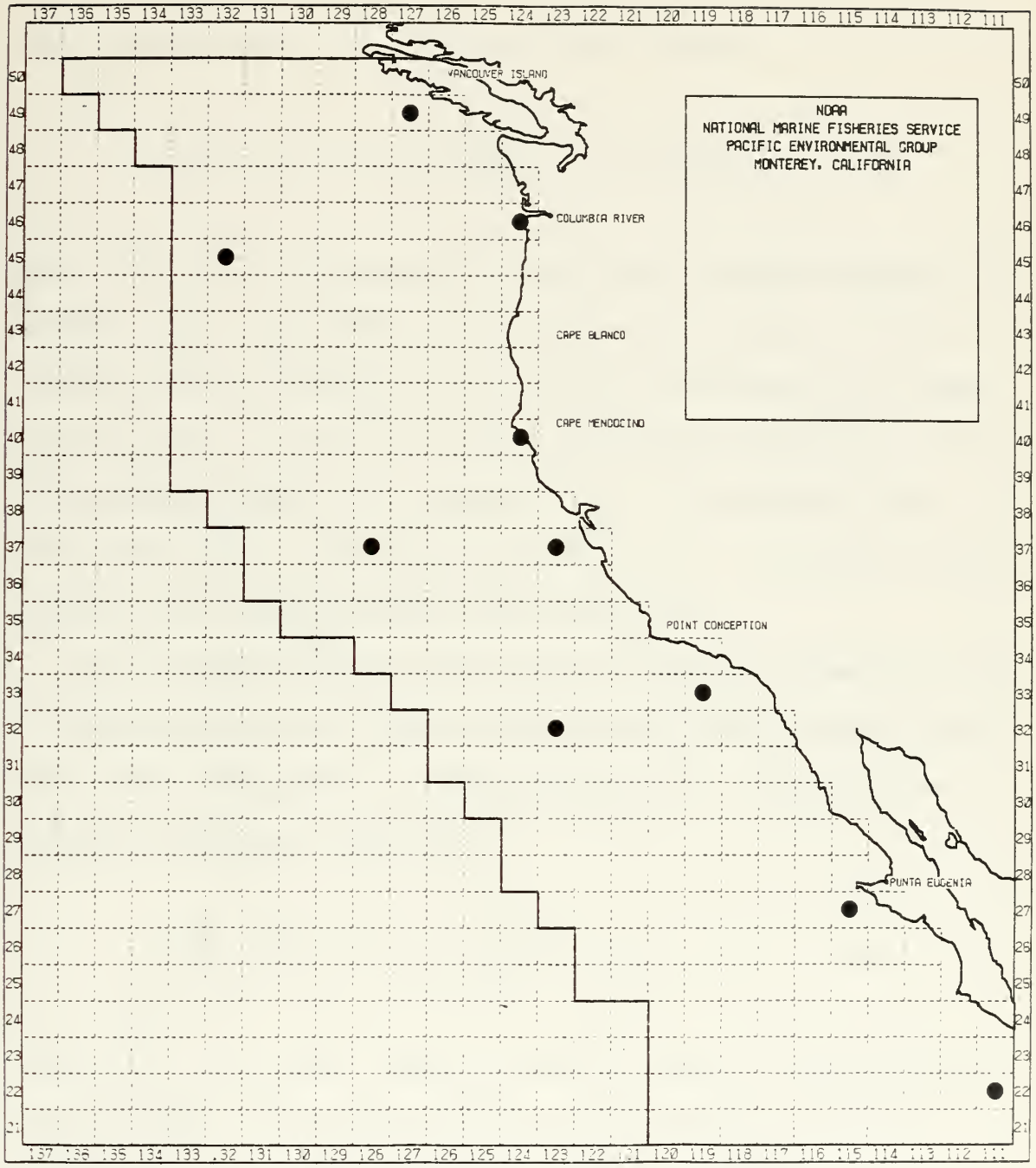

FIGURE 1. Chart of the west coast of the United States showing the grid of 1-degree squares used for summaries of wind observations. Large dots indicate squares for which frequency diagrams are displayed in Figures 9-12.

An estimate of the surface wind stress was calculated for each wind velocity report according to the bulk formula:

$$(\tau_x, \tau_y) = \rho_a C_D (|\vec{W}_{10}| U_{10}, |\vec{W}_{10}| V_{10}) \qquad (1)$$

where τ_x and τ_y denote the eastward and northward components of stress, ρ_a is the density of air which was considered to have a constant value of 0.00122 g cm^{-3}, $|\vec{W}_{10}|$ is the observed wind speed, and U_{10} and V_{10} are the eastward and northward components of the wind velocity measured at a height of 10 m. The empirical drag coefficient C_D is referred to the 10 m level. A constant value of 0.0013 (Kraus 1972) was used in the calculations.

The resultant long term monthly mean vectors were computed as the arithmetic means by east and north components of all available reports from 1850 to 1972 within a 1-degree square area. The appropriate average is defined in Equation 2:

$$(\overline{\tau}_x, \overline{\tau}_y) = \frac{1}{N} \sum_{i=1}^{N} (\tau_x, \tau_y)_i \qquad (2)$$

where N is the total number of reports within a 1-degree square area and month. The values $(\tau_x, \tau_y)_i$ were evaluated according to Equation 1. A mean value for each long term month and square is therefore formed from a data set which is independent of all other months and squares. The monthly fields of surface wind stress are displayed in Appendix A as vector quantities and as east and north components. No attempt has been made to smooth the fields, either by removing data which do not appear to fit the distributions or by

applying objective smoothing procedures. The mean values were contoured by machine and "bull's-eyes" in the contours, even where they possibly reflect erroneous data, were left in the figures as indications of the general degree of consistency in the composite distributions. The "bull's-eyes" may reflect either a paucity of ship observations, or extreme variability associated with inadequate sampling of strong winds.

The spatial distribution of observations is biased in that "ship of opportunity" reports are generally confined to the coastwise shipping lanes. The total numbers of observations per 1-degree square area are shown in Figure 2. The highest density of reports is found within 300 km of the coast, exceeding 40,000 observations per 1-degree square in the area south of Point Conception. The number of reports per 1-degree square per month varies from less than 20 (in January off Vancouver Island) to more than 3800 (in May off Los Angeles). A significant increase in the number of observations is evident along the shipping route between San Francisco and Hawaii. Less than 20% of the vector means are based on fewer than 50 observations per 1-degree square per month. Some temporal bias may also exist, since approximately 50% of the total reports have been taken since 1945. However, the general coherence of the resulting vector fields indicates that the composite wind stress distributions can be used to describe the dominant seasonal cycle in the California Current system.

A. QUALITY OF INPUT DATA

The historical surface marine observations used in this study have been obtained primarily from ship logs, ship weather reporting forms,

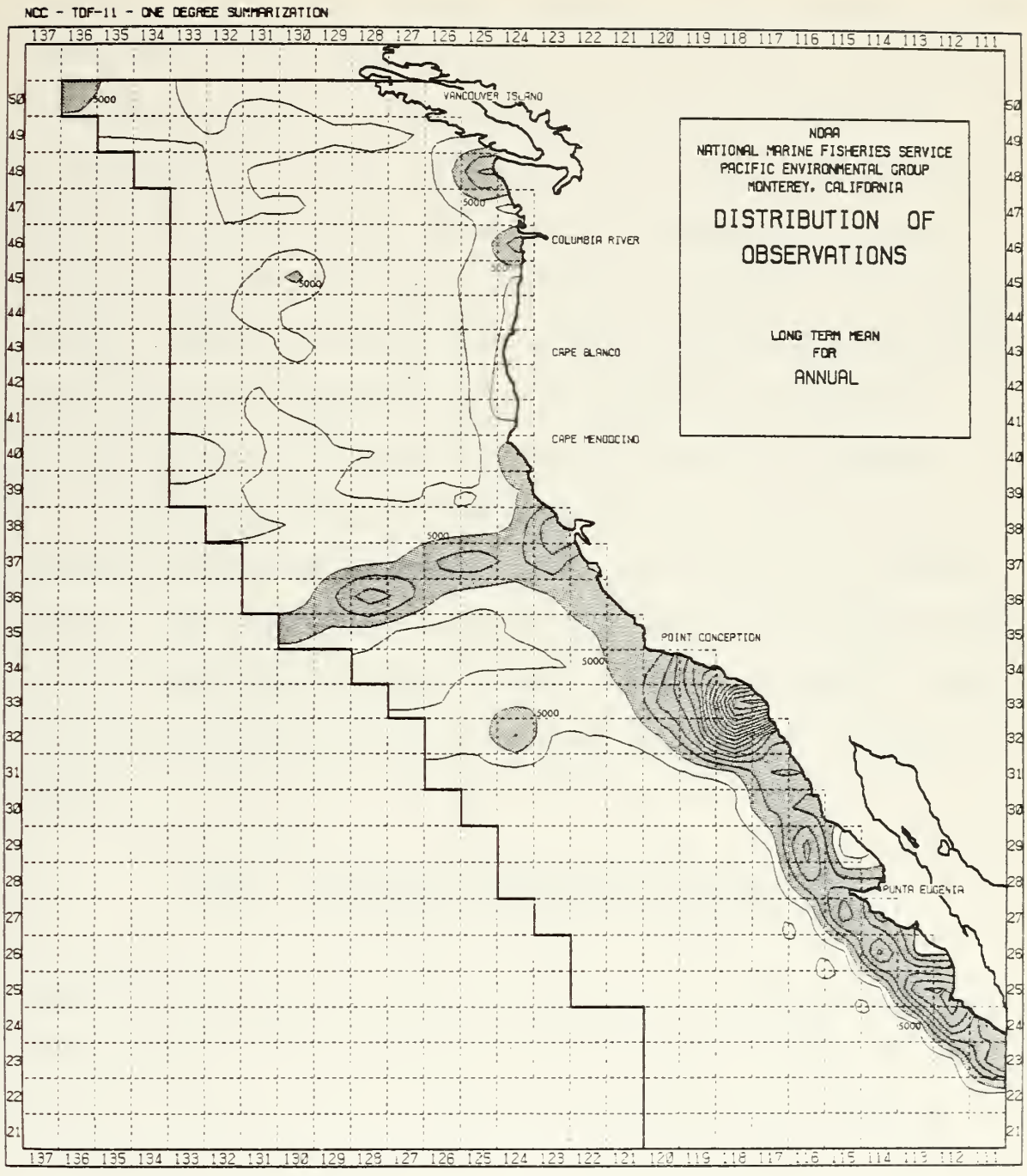

FIGURE 2. Distribution of observations per 1-degree square. The contour interval is 2500 observations. Values greater than 5000 are shaded.

and published ship observations. The reports differ markedly in method and precision of measurement, ranging from observations made aboard 19th century vessels, to those taken aboard modern oceanographic research ships. Possible errors in wind measurement have been summarized by Hantel (1970). These include influences of anemometer height, atmospheric stability, wind gusts, and duration of the observation. Sources of error in wind estimates include the wind effects observed, error in determining the true wind from the observed apparent wind, and the unavoidable subjectivity of the observer.

A substantial portion of the historical data consists of wind reports based on the antiquated Beaufort wind force scale (Kinsman 1968). Table 1 lists the conversion scale between the Beaufort number and the equivalent wind speed in knots and meters per second. These estimates are equivalent to a wind speed measurement at a height of 10 m.[1]

TABLE 1. Wind speed equivalents of Beaufort force estimates in knots and meters per second

Beaufort	0	1	2	3	4	5	6	7	8	9	10	11	12
Knots	0	2	5	9	13	18	24	30	37	44	52	60	68
M sec^{-1}	0.0	0.9	2.4	4.4	6.7	9.3	12.3	15.5	18.9	22.6	26.4	30.5	34.8

Based on the documentation for the National Climatic Center's data file (TDF-11)[2] , a determination was made of the number of wind

[1]Resolution 9, International Meteorological Committee, Paris, 1946.

[2]National Climatic Center, Tape Data Family 11, NOAA/EDS/NCC, Asheville, N.C.

observations estimated and those actually measured by an anemometer. Approximately 35% of the reports in this study consisted of Beaufort wind force estimates. An additional 53% of the reports were estimated wind speeds which did not correspond to the Beaufort wind force scale. Less than 12% of the total reports consisted of measured quantities.

In addition to the errors introduced by the necessary calculation of true wind from the measured apparent wind, the reported directions vary in precision. Resolution varies from $\pm$ 11.25° to $\pm$ 5° corresponding to observations based on 16 points of a 32 point compass and a 36 point compass respectively.

The above considerations lead to the conclusion that random observational errors may be as large as real non-seasonal fluctuations in the distributions of surface wind stress. The problem may be formalized by expressing the individual stress estimates τ_x , τ_y as the sums of monthly mean values $\overline{\tau}_x$, $\overline{\tau}_y$, deviations from the monthly means τ_x' , τ_y' , and error terms τ_x^ϵ , τ_y^ϵ . The second and higher moment statistics would consist of the non-zero correlations between the deviations from the monthly means and the error terms. If the observational errors are greater than the real fluctuations, then the standard deviations of the monthly means would reflect observational noise rather than actual non-seasonal variability. However, provided that these errors are not systematic, the resultant first moment statistics will be the appropriate estimates of the monthly mean wind stress.

The standard error of the mean provides a more appropriate quantitative measure of the relation between the standard deviation of a set of measurements and the precision of the mean value of the data

set (Young 1962). The standard errors of the means are defined by:

$$(S_{\bar{\tau}_x}, S_{\bar{\tau}_y}) = (S_{\tau_x}/\sqrt{N}, S_{\tau_y}/\sqrt{N}) \qquad (3)$$

where $S_{\bar{\tau}_x}$, $S_{\bar{\tau}_y}$ are the standard errors of the means of the eastward and northward components respectively, S_{τ_x}, S_{τ_y} are the standard deviations, and N is the number of observations. Large values of N and small values of S_{τ_x}, S_{τ_y} correspond to mean values $\bar{\tau}_x$, $\bar{\tau}_y$ which closely approximate the population means.

The computed standard errors of the means and numbers of observations for each 1-degree square area and long term month are tabulated in Appendix B. Values less than 0.1 dyne cm^{-2} occur throughout a large portion of the summary area, although spatial and seasonal dependence is evident. Standard errors greater than 0.1 dyne cm^{-2} occur over large areas north of Cape Mendocino and between 500 km and 1000 km off the coast of Baja California. High values are generally associated with regions of sparse data, although inadequate sampling of intense storms may also lead to large values. Typical ratios of the standard error to the mean stress $(S_{\bar{\tau}_x}/\bar{\tau}_x)$ range from 0.01 off southern California to 1.0 offshore from Cape Blanco. Near Cape Mendocino, this ratio varies between 0.02 and 0.10. Minimum values adjacent to the coast south of 40° N latitude and along the shipping lane between San Francisco and Hawaii are well correlated with the distribution of observations shown in Figure 2.

III. DEPENDENCE OF STRESS ESTIMATES ON C_D

A constant drag coefficient was used to compute the surface wind stress data displayed in Appendix A. Stress calculations were made for each wind report and then averaged to form the resultant monthly mean vectors. Different results might have been obtained if the stress were calculated from monthly mean wind data, or if effects of atmospheric stability were considered. These aspects are discussed below.

The errors associated with the observational data used in this study place certain limitations on the form of the bulk exchange formula expressed in Equation 1. If measurement errors are large, there may be little value in refining the parameterization by replacing C_D by a variable drag coefficient which is a function of stability or wind speed. Even with a constant C_D, the bulk formula contains non-linearities. Therefore, the drag coefficient must be appropriate for the particular time averaged winds used in the calculations.

A. EFFECT OF AVERAGING

The empirically derived transfer coefficient C_D, determined by eddy correlation and profile methods, is based on wind measurements averaged over periods of 30 to 60 minutes. Pond (1975) indicates that the appropriate values of $|\vec{W}_{10}|$, U_{10}, and V_{10} should be obtained over a period of a few minutes to a few hours at most. If the surface stress were calculated using winds averaged over much longer periods, a higher drag coefficient would be required. The surface stress calculated from a monthly mean surface wind field would

be significantly less than the surface stress field calculated as the mean of the individual stress estimates, if the same drag coefficient is used and all other parameters are held constant.

The difference described above has been determined for the data used in this study. For each 1-degree square area and long term month the following ratio has been calculated:

$$(C_D)_{equ} = \frac{|\overline{\vec{\tau}}|}{\rho_a \left(|\overline{\vec{W}_{10}}|\right)^2} \qquad (4)$$

where $|\overline{\vec{\tau}}|$ is the magnitude of the monthly mean surface stress, $|\overline{\vec{W}_{10}}|$ is the magnitude of the monthly mean surface wind, and $(C_D)_{equ}$ is an equivalent drag coefficient. This is the value which would be necessary to make the stress values calculated from the monthly mean wind data agree with the values calculated as the means of individual stress estimates.

The values of $(C_D)_{equ}$ for the months of June and December are shown in Figures 3 and 4. The values are significantly different from the constant value of $C_D = 0.0013$ employed in this study. In all cases, $(C_D)_{equ}$ is greater than C_D. Spatial and seasonal variability is marked. There is a tendency for much higher values in the northern section of the grid than in the southern area. Large values of $(C_D)_{equ}$ are more evident in December than in June. The geographical and seasonal variations in the quantity $(C_D)_{equ}$ agree with the general geographical and seasonal fluctuations in meteorological conditions over the Northeast Pacific Ocean. This would indicate that a large part of the monthly variance of the wind stress data is due to actual intra-month fluctuations and not due to observational errors.

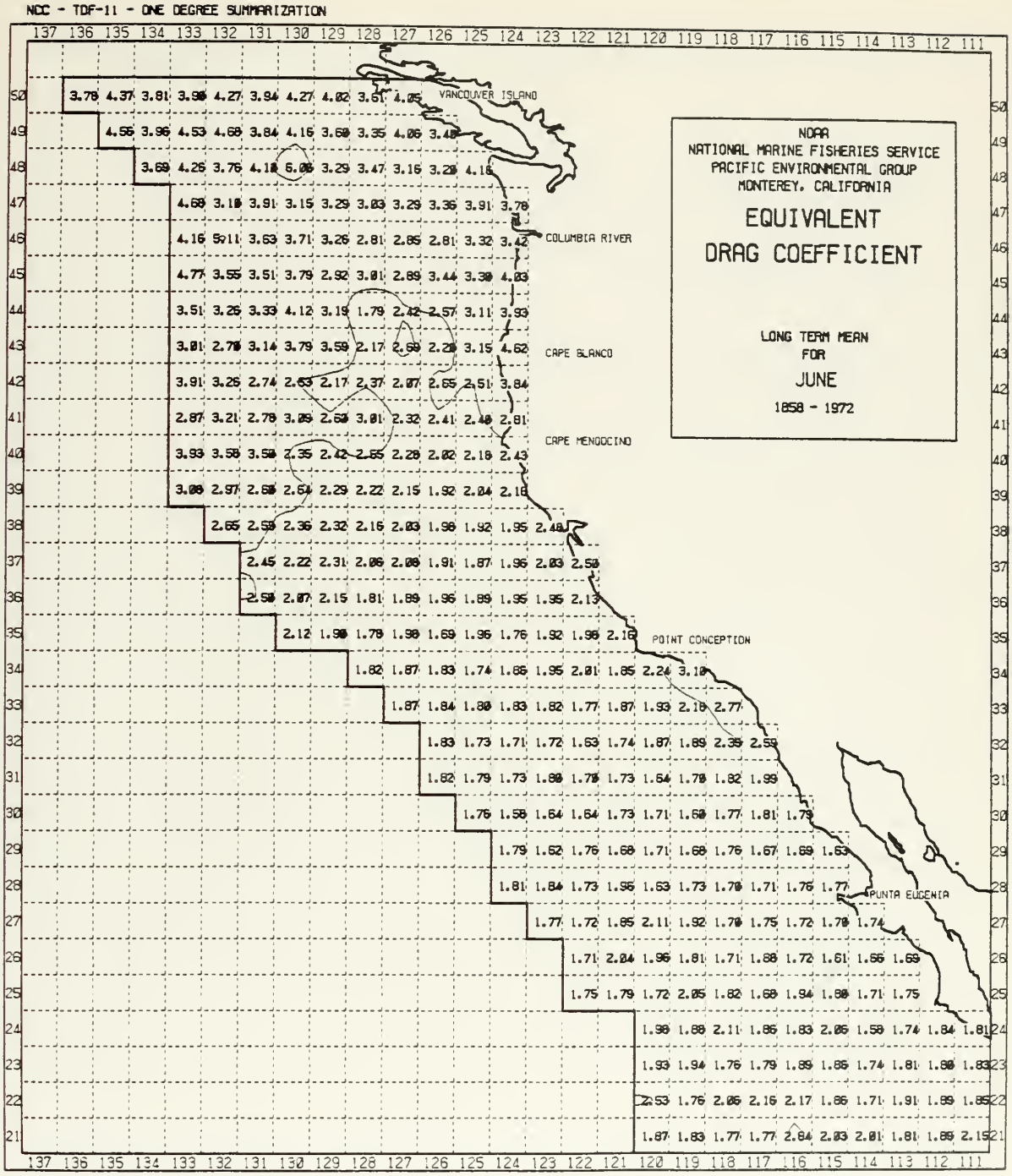

FIGURE 3. Equivalent neutral drag coefficient for JUNE. The plotted value is the drag coefficient appropriate for wind observations averaged over a month. The contour interval is 2.5.

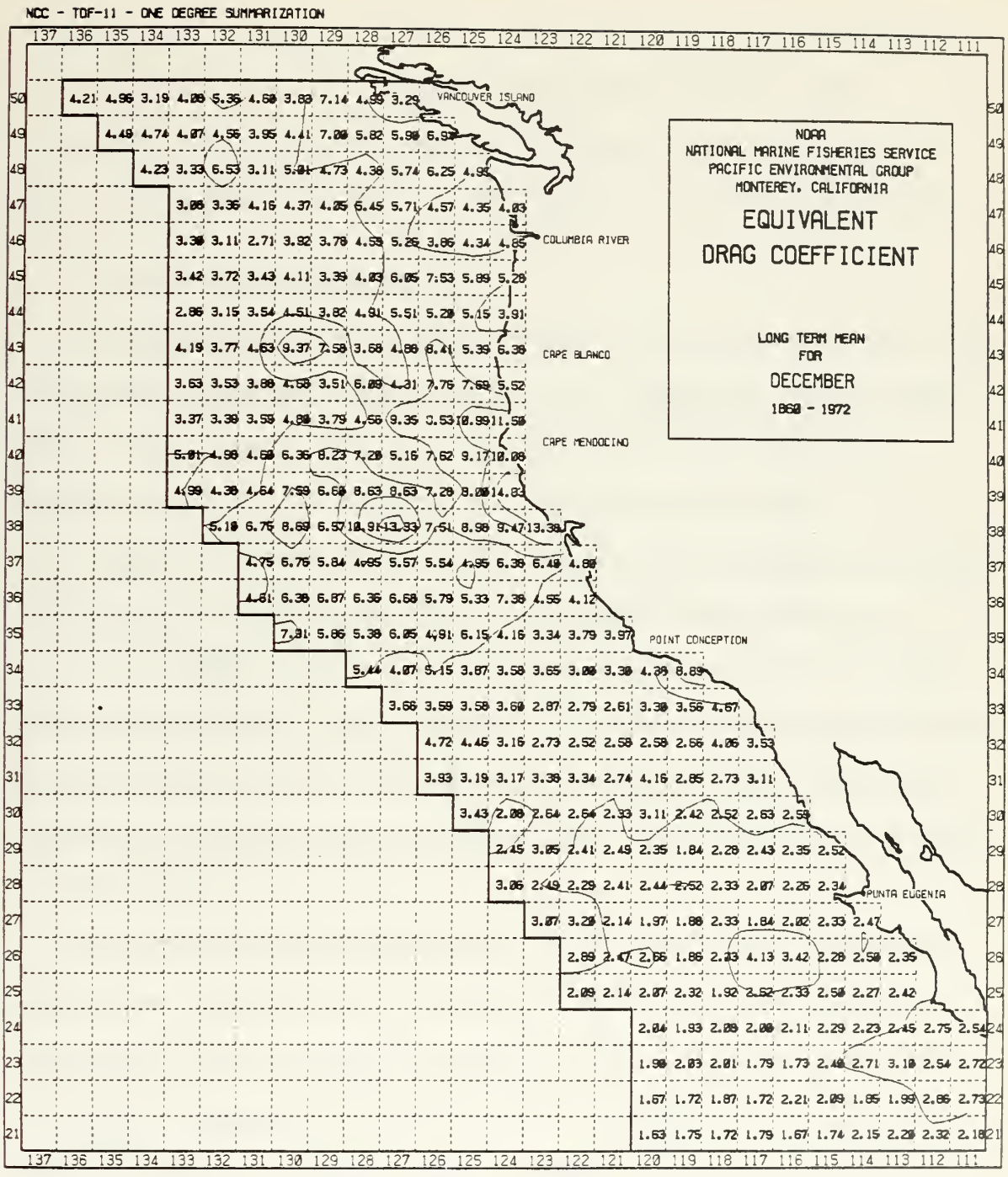

FIGURE 4. Equivalent neutral drag coefficient for DECEMBER. The plotted value is the drag coefficient appropriate for wind observations averaged over a month. The contour interval is 2.5.

If a resultant surface wind stress were calculated from the monthly mean wind field, these calculations imply that the wind stress estimates would be underestimated, on average, by as much as 50% to 100%. The departures would be even larger off Oregon and Washington.

B. EFFECT OF ATMOSPHERIC STABILITY

Investigations on the functional form of the drag coefficient have alternately suggested constant values, or a dependence on wind speed. Wilson (1960) gave a detailed review of the available data and adopted values of $C_D = 0.0024 \pm .005$ for strong winds and $C_D = 0.0015 \pm .0008$ for light winds. Smith (1970) proposed a constant value of $C_D = (1.35 \pm 0.34) \times 10^{-3}$. Wu (1969) adopted the form $C_D = (0.5 \times U_{10}^{1/2}) \times 10^{-3}$. Considering the large scatter in the open ocean determinations of C_D, the lack of conclusive data at wind speeds greater than 15 m sec^{-1}, and the lack of agreement among individual observers, a constant value for the neutral drag coefficient was used in this study.

Recent investigations by Davidson (1974) and Denman and Miyake (1973) have demonstrated the dependence of the drag coefficient on atmospheric stability and the spectral shape of the ocean wave field. A generally accepted formulation of the dependence of C_D on wave properties does not seem well enough established to be incorporated in the calculations of surface wind stress based on historical ship observations. However, effects of atmospheric stability on the momentum exchange may be significant in the regions where seasonal upwelling typically produces a stable boundary layer.

The specific effects of atmospheric stability on the exchange of

momentum have not been completely determined and are still under investigation. However, for a given wind speed, the effect of stable (unstable) stratification is to decrease (increase) the magnitude of the momentum exchange (surface wind stress) across the atmosphere-ocean interface.

Deardorff (1968) defined the bulk Richardson number as an appropriate dimensionless measure of atmospheric stability. The monthly mean fields of surface wind stress were recomputed, replacing the constant value C_D in Equation 1 by a coefficient varying with atmospheric stability. The method of Deardorff was adopted to parameterize the dependence of the drag coefficient on stability, while neutral stability was assumed when the absolute value of the air-sea temperature difference was less than 1° C. Details of the calculations will be reported elsewhere.

The effect of atmospheric stability was computed as a percentage increase (decrease) in the magnitude of the monthly mean surface wind stress above (below) the appropriate neutral values. The following ratio was calculated:

$$R = \left(\frac{|\overrightarrow{\tau}|_{var}}{|\overrightarrow{\tau}|_{neu}} - 1 \right) \times 100 \qquad (5)$$

where $|\overrightarrow{\tau}|_{var}$ is the magnitude of the surface wind stress calculated using a drag coefficient which varies with stability, and $|\overrightarrow{\tau}|_{neu}$ is the magnitude of the surface wind stress computed with a constant (neutral) coefficient. A value of $R = 0.0$ corresponds to neutrally stable conditions.

The ratio defined by Equation 5 is displayed in Figures 5 and 6 for the months of June and December respectively. The average percentage difference is between 2% and 5%. Values greater than 10% are rare. In December, the values are positive, indicating unstable conditions. Negative values occur in June. These are related to the stable stratification induced by positive air-sea temperature differences within the coastal upwelling zone. The effects of atmospheric stability determined in this study are less than the values of 6% to 15% reported by Husby and Seckel (1975) for Ocean Weather Station "Victor", but consistent with the values of less than 5% reported by Dorman et al. (1974) for Ocean Weather Station "November."

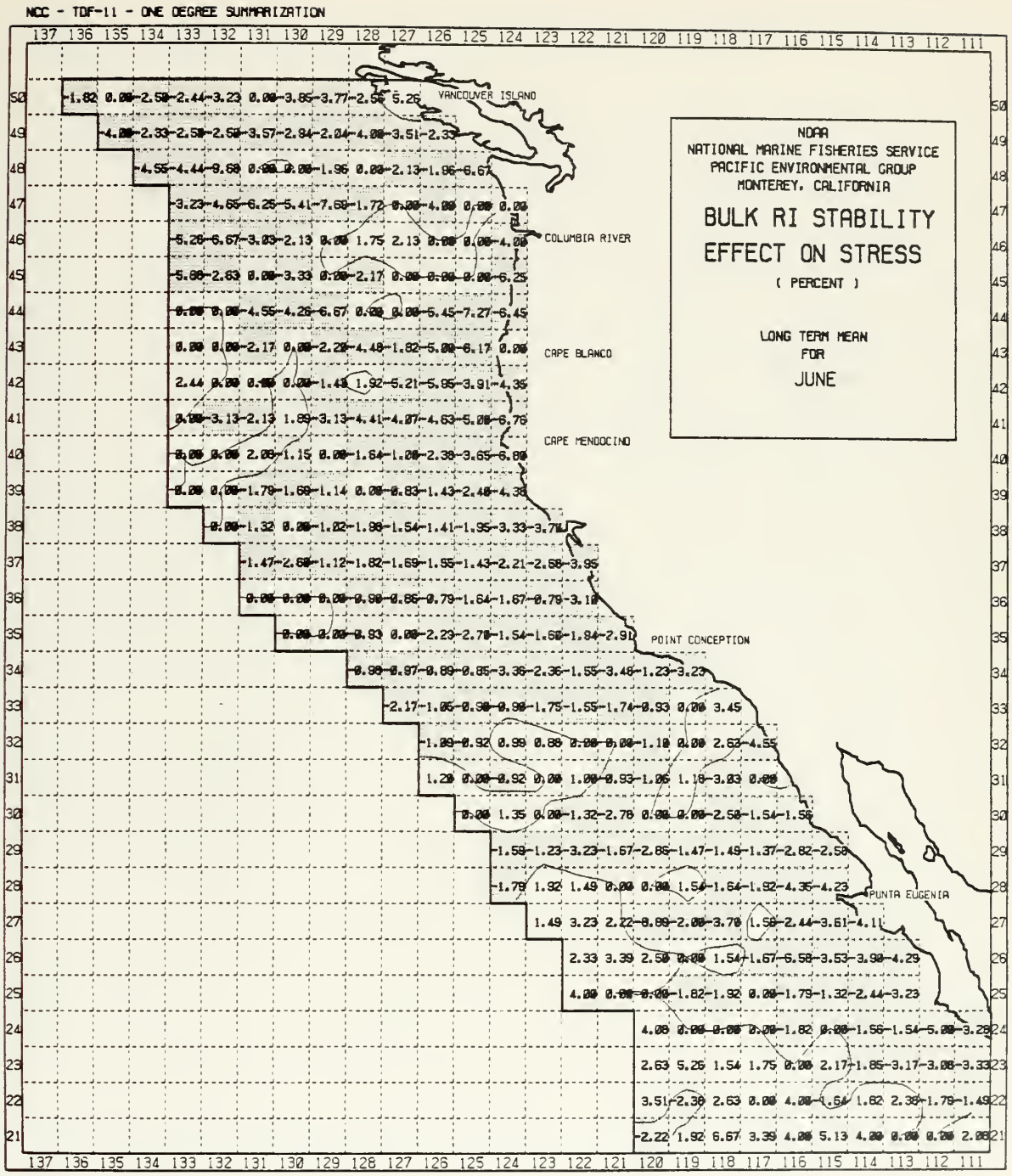

FIGURE 5. The effect of atmospheric stability on surface wind stress for JUNE. Plotted values are the percentage increase (decrease) in the surface wind stress above (below) neutrally stable conditions. The contour interval is 10.0. Positive values correspond to unstable conditions. Negative values are shaded.

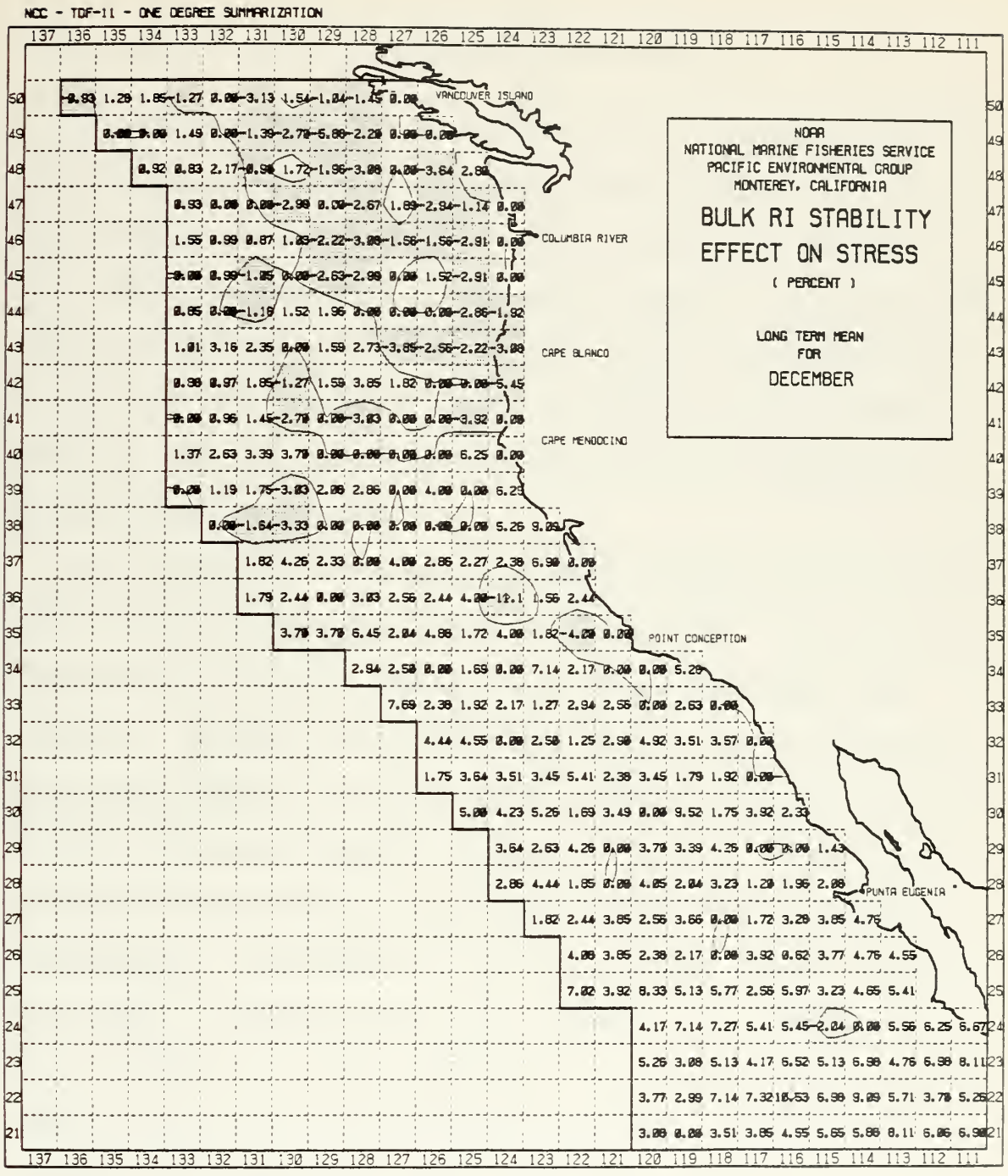

FIGURE 6. The effect of atmospheric stability on surface wind stress for DECEMBER. Plotted values are the percentage increase (decrease) in the surface wind stress above (below) neutrally stable conditions. The contour interval is 10.0. Positive values correspond to unstable conditions. Negative values are shaded.

IV. THE WIND STRESS DISTRIBUTIONS

The long term composite monthly mean fields of surface wind stress are displayed in Appendix A as resultant vectors (Charts 1 to 12), east components (Charts 13 to 24), and north components (Charts 25 to 36). These data indicate two characteristic features. The mean stress tends to be directed equatorward along the coast from Cape Mendocino to Baja California throughout the year. Off the coasts of Oregon and Washington, the wind stress exhibits marked seasonal variability in both magnitude and direction.

The distributions of surface wind stress off Baja California have been previously discussed by Bakun and Nelson (1975). They concluded that most of the seasonal variability is in magnitude rather than direction. The mean surface wind stress tends to have an alongshore, equatorward component during all months, implying conditions generally favorable for coastal upwelling throughout the year. This is contrasted with the situation to the north. Off the coasts of Oregon and Washington, the patterns of surface wind stress change seasonally. From December to February, the stress impinges on the coast at Cape Blanco, forming the southern boundary of the low pressure system which develops in the Gulf of Alaska during the winter. From May through September, the surface wind stress veers toward the south. The components are directed onshore and equatorward. The months of March and April, and October and November appear as transition periods. The surface wind stress is directed primarily onshore during these months.

The most evident feature in these distributions is the position

and extent of the predominant wind stress maximum. For purposes of discussion, this maximum is defined by the 1.0 dyne cm^{-2} contour and is highlighted by light shading in Charts 1 to 12. Large values of stress occurring between 45°N and 50°N latitude during winter are probably associated with either high winds or sparse data, and will be ignored in this discussion.

The maximum is first evident in March, south of Point Conception. During succeeding months, the maximum strengthens, increases in size, and shifts northward. In April, values exceeding 1.0 dyne cm^{-2} cover an area from Point Conception to San Francisco. Winds off Oregon have veered, suggesting an alongshore component and implying conditions generally favorable for coastal upwelling. The pattern of surface wind stress is repeated in May. The northern boundary of the central maximum reaches the coast south of Cape Blanco.

The mean wind stress reaches maximum intensity during June and July off Cape Mendocino, where characteristic values exceed 1.5 dynes cm^{-2}. The large scale maximum extends approximately 500 km in the offshore direction and 1000 km in the longshore direction. A more intense coastal maximum ($|\bar{\tau}|>1.5$ dynes cm^{-2}) is coherent over an area approximately one-fifth this size. Maximum values of mean surface wind stress typically occur 200 km to 300 km off the coast, rather than adjacent to the coast. This feature was previously observed by Munk (1950) and Reid et al. (1958). The mean distributions for August and September suggest relaxing conditions. The maximum is reduced in extent and intensity. These months still exhibit a degree of equatorward stress along the coasts of Oregon and Washington, but in October, the direction backs to the north. The poleward components correspond to

onshore Ekman transport and subsequent downwelling at the coast. The distributions for November, December, January, and February indicate characteristic winter conditions. Mean values are typically less than 0.5 dyne cm^{-2}. High winds associated with intense storm activity in the North Pacific Ocean result in regions of mean surface wind stress exceeding 1.0 dyne cm^{-2} off the coasts of Oregon and Washington.

The seasonality of the surface wind stress and its association with coastal upwelling is easily observed along the northern section of the grid. Large changes in mean direction are apparent. Maximum magnitudes occur during the winter. Winds favorable for coastal upwelling occur from April to September. During the remaining months, the direction of the mean surface wind stress corresponds to downwelling at the coast.

The coast along southern California and Baja California is characterized by winds favorable for upwelling throughout the year. Peak values of surface wind stress occur in April and May. Values exceeding 0.5 dyne cm^{-2} are evident from February to July. A local maximum immediately north of Punta Eugenia is easily observed in May. This feature is consistent throughout the year. A region of local wind stress minima is indicated along the coast south of Point Conception. This feature corresponds in location to the semi-permanent cyclonic eddy which dominates the ocean surface circulation in the Southern California Bight (Reid et al. 1958).

A. SPATIAL AND TEMPORAL VARIABILITY

Spatial and seasonal variability of the monthly distributions will be described in terms of standard errors of the means (Equation 3),

constancy of the wind stress, and frequency diagrams for selected 1-degree square areas and months. In general, these data indicate greater variability in magnitude and direction within the region north of Cape Mendocino than in the area to the south. Summer distributions are characterized by well defined mean directions and magnitudes. Broad-banded frequency histograms are typical of the winter months.

Within the regions outside of the primary shipping lanes (see Figure 2), the monthly mean distributions are based on fewer than 2500 observations per 1-degree square area. Intercomparisons of the magnitudes of the computed standard errors of the means should be a function of the measured wind stress variability. Accordingly, standard errors to the north of Cape Mendocino are larger by a factor of 2 to 3 than those to the south. Thus, the data imply a greater degree of variation in the direction and magnitude of the surface wind stress off Oregon and Washington than off California.

A contrast between winter and summer conditions is also evident. South of Cape Mendocino, the magnitudes of the standard errors of the means remain nearly constant throughout the year. Off Oregon and Washington, the computed values decrease to a minimum during the summer. Typical values range from 0.10 dyne cm^{-2} in June to 0.30 dyne cm^{-2} in December.

Similar features of the large scale temporal and spatial variations are evident in the monthly distributions of constancy of the wind stress as defined by the ratio of the magnitude of the average stress to the average magnitude of the stress. Figures 7 and 8 show the patterns for June and December. During December, values greater than 0.5 occur south of Point Conception. To the north, the wind stress

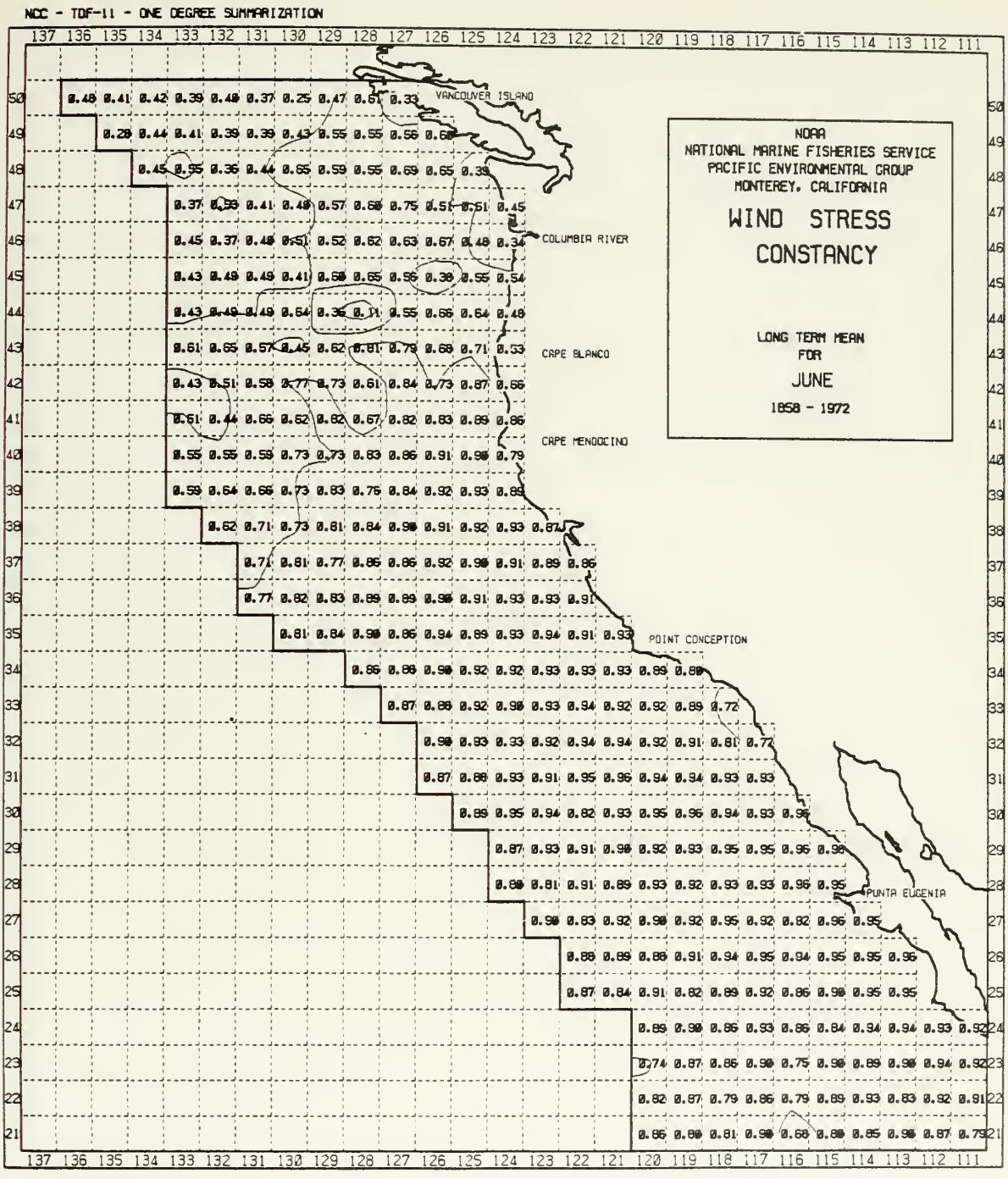

FIGURE 7. Wind stress constancy for JUNE. The plotted values are defined as the ratios of the vector means to the scalar means. The contour interval is 0.25.

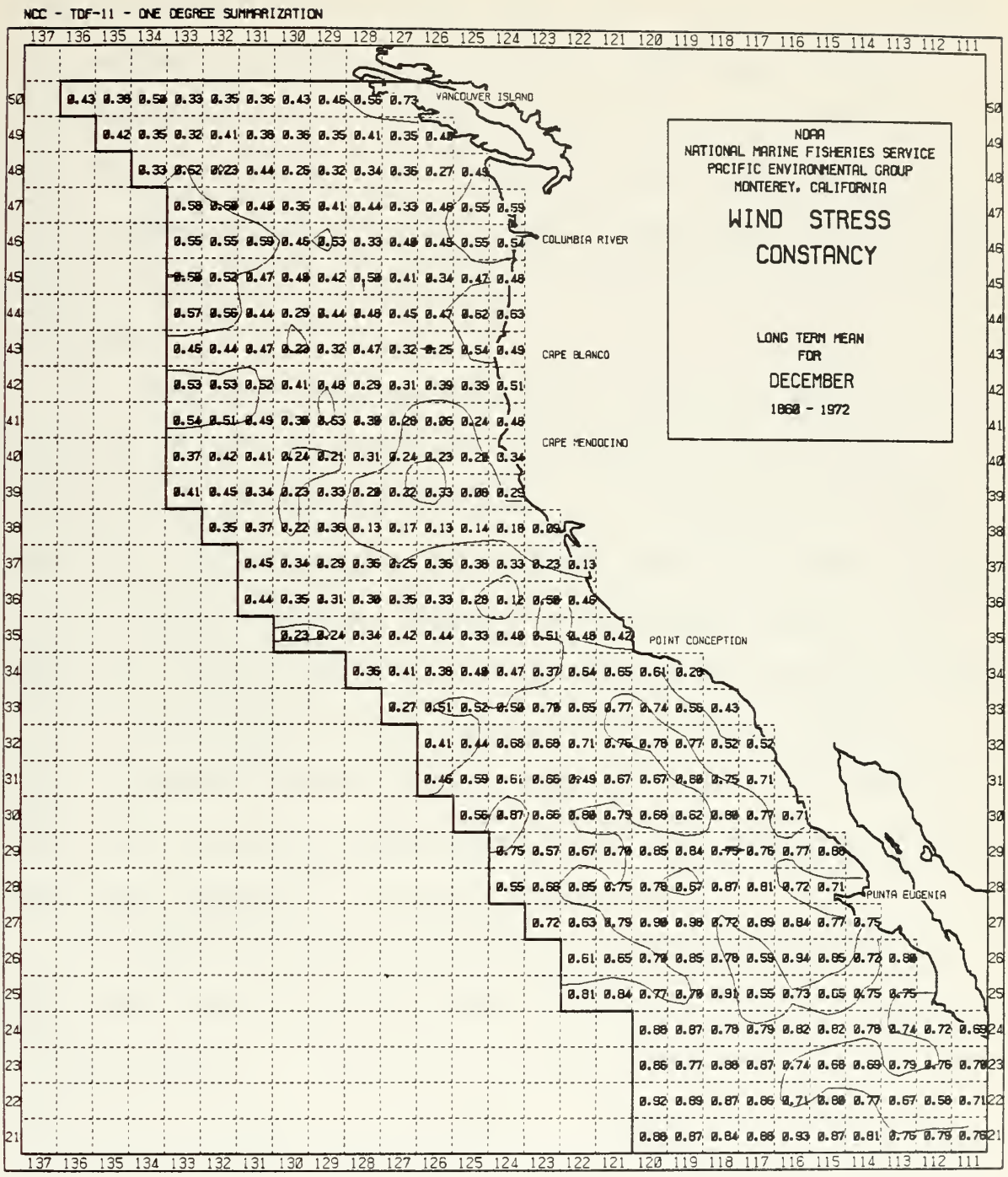

FIGURE 8. Wind stress constancy for DECEMBER. The plotted values are defined as the ratios of the vector means to the scalar means. The contour interval is 0.25.

constancy decreases to relatively small values, implying a high degree of directional variability. An increase in directional stability is indicated during June. Values greater than 0.50 extend from Baja California to Vancouver Island. Values less than 0.50 occur only in the northwest section of the grid. South of Cape Mendocino, the ratios approach a value of 1.0, implying very little variation in wind stress direction.

The patterns of wind stress constancy indicate possible error in estimates of the total mechanical energy transfer at the air-sea interface. In the region off California, the magnitude of the mean vector wind stress appears to be a good estimator of the total stress acting on the sea surface. However, in the northern regions of the data grid, these data show that the magnitude of the mean vector wind stress underestimates the total stress acting on the sea surface. This has important implications for mixed-layer modelling, in which the input of turbulent energy depends on the total stress acting on the sea surface regardless of direction (Denman 1973).

The large scale spatial and temporal variations in the surface wind stress distributions are finally described in terms of selected frequency diagrams. Data for the 10 squares indicated in Figure 1 are displayed in Figures 9, 10, 11, and 12. Figures 9 and 10 show data for June and December taken from the 5 squares indicated in the inset. Similar data at 5 different locations are presented for July and January in Figures 11 and 12.[3]

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[3]Wind roses for all 1-degree squares within the area north of 34° N latitude may be found in, Climatic study of the near coastal zone; West Coast of the United States, published by the Director, Naval Oceanography and Meteorology, June, 1976, 133 p.

The available wind stress data have been classed by direction and magnitude for each 1-degree square area and month. Relative frequencies have been determined for 16 direction bands and for 11 magnitude bands. A category for calm winds also includes variable winds. The direction bands are 22.5° wide and the magnitude bands correspond to equivalent wind speed intervals of 2.0 m sec^{-1}.

The relative frequency surfaces shown in these figures display contours of percentage of total reports falling within a given direction and magnitude band. The contours were drawn by hand. A contour interval of 2.5% was used. The 2.5% contour is labelled and is indicated by a solid line. Alternating dashed and solid contours indicate larger relative frequencies. The mean vector magnitude and direction is indicated by an arrow. Note that directions are defined with the oceanographic convention (i.e. the direction toward which the wind blows).

The histograms shown to the right of each frequency surface display relative frequencies for magnitude at the top, and direction at the bottom. Relative percent is labelled along the ordinate. Midpoints of the magnitude and direction class intervals are labelled on the abscissa.

If Figures 9 and 10 are compared, the contrast between winter and summer distributions appears as a change in the character of the frequency surfaces. In general, the number of contours indicated for June is greater than the number of contours appearing in December. Evidently, the wind stress is relatively constant in magnitude and direction during the summer months. A slight shift in the direction and magnitude of the wind stress is indicated between summer and

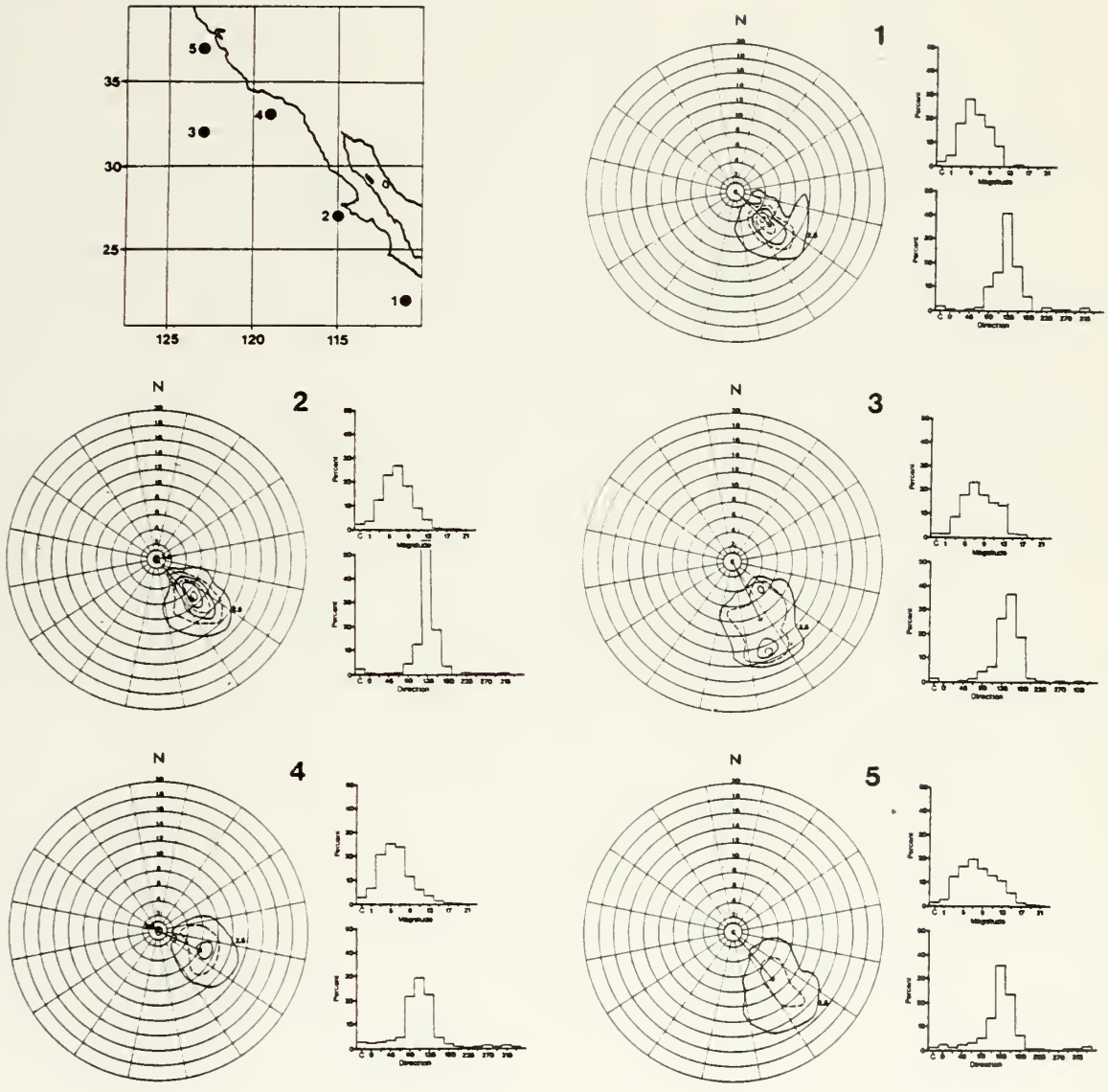


FIGURE 9. Relative frequency surfaces and frequency histograms for JUNE. Data are shown for the 1-degree squares labelled 1 through 5 in the upper left inset. Contours of relative frequency are drawn at intervals of 2.5%. Mean vector wind stress is indicated by an arrow.

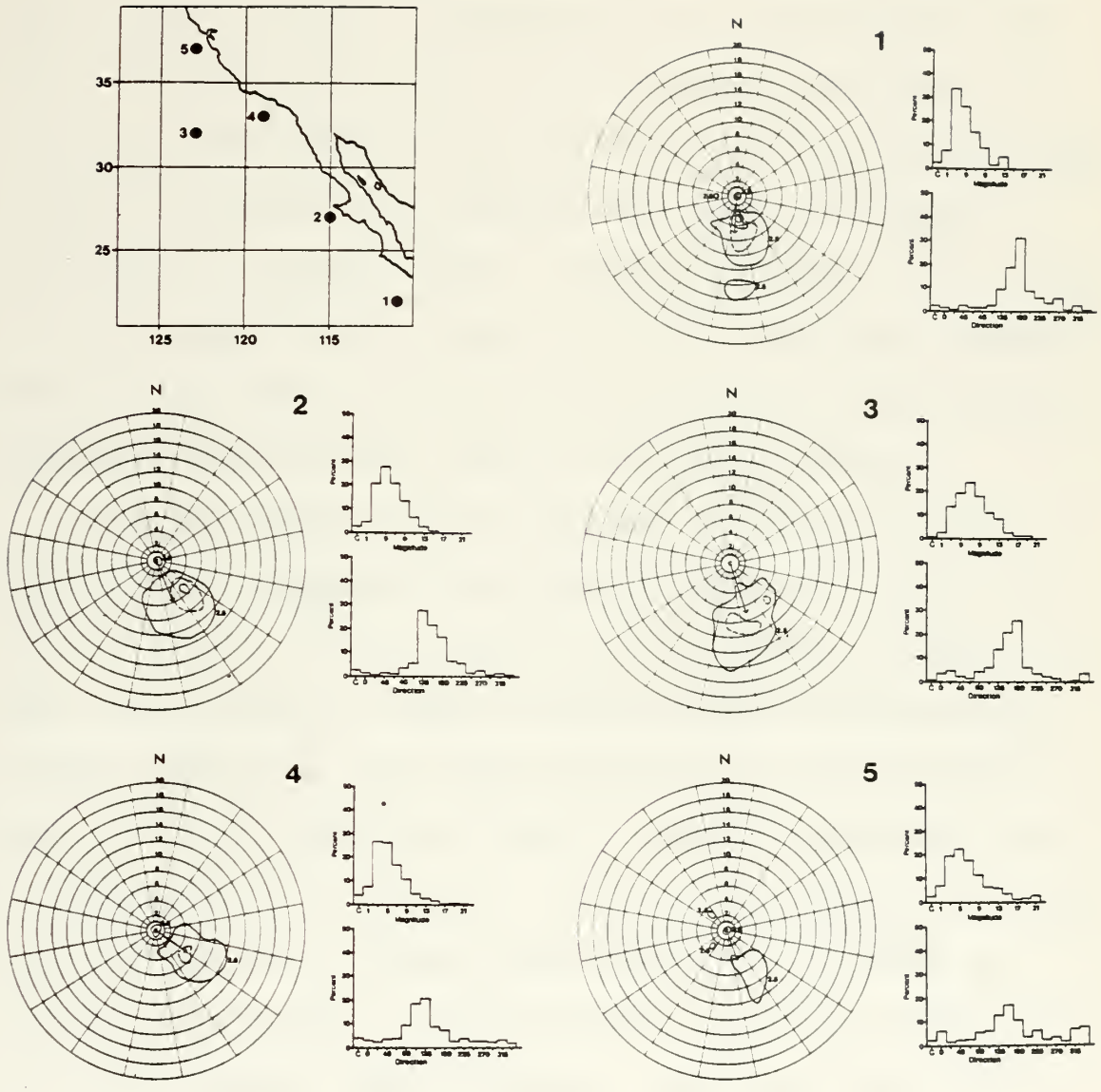


FIGURE 10. Relative frequency surfaces and frequency histograms for DECEMBER. Data are shown for the 1-degree squares labelled 1 through 5 in the upper left inset. Contours of relative frequency are drawn at intervals of 2.5%. Mean vector wind stress is indicated by an arrow.

winter. The mean stress in December is directed more toward the south, and the magnitude has decreased.

The frequency histograms also show these features. During June, the direction histogram is characteristically narrow-banded. Over 70% of the observations may be concentrated within 3 direction intervals. In December, the observations tend to be spread over a wider range of directions. The histograms are broader and the peaks in direction are less well defined. The peak magnitudes in June are generally one class interval larger than the peak magnitudes in December. However, the winter distributions are characterized by an increase in relative frequency at high values of wind stress magnitude.

A similar pattern of contrasts between the summer and winter distributions is apparent in the northern section of the grid. As shown in Figures 11 and 12, the direction histograms are generally well defined during the summer, although bimodal distributions are evident. During the winter, the observations are nearly uniformly spread among all directions. There is a lack of consistency in the frequency surfaces in Figure 12. The direction histograms for January are broad and flat. The peaks which characterize the summer distributions are missing. The mean directions shift from equatorward to poleward between summer and winter. A complete reversal in the mean direction occurs at point 7 (Figures 11 and 12). A shift in magnitude is equally pronounced. Peak magnitudes are higher in January than in July. There is a greater contribution of high wind speeds in January.

The above discussion adds a new dimension to the seasonal descriptions of the surface wind stress distributions over the California

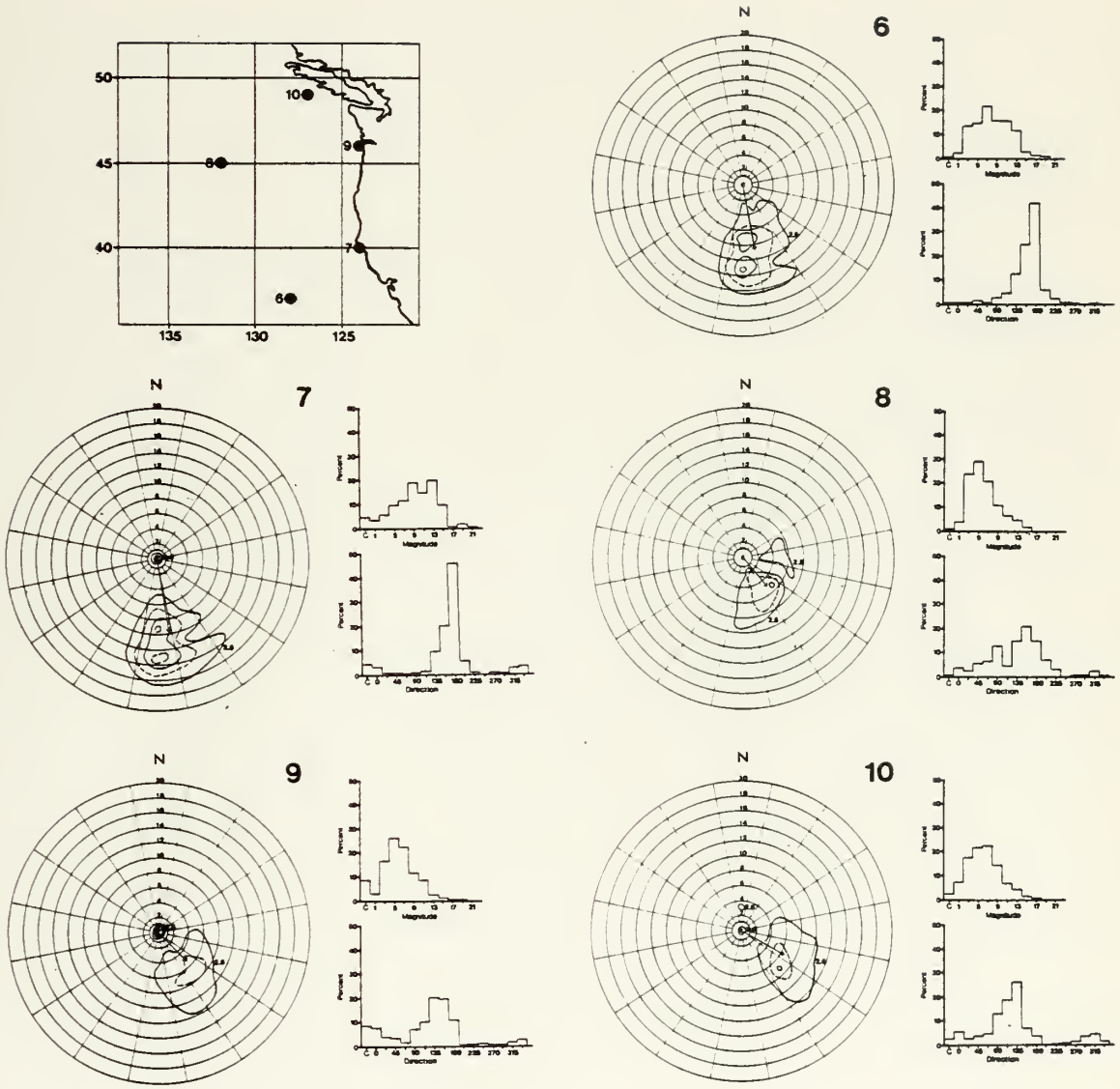


FIGURE 11. Relative frequency surfaces and frequency histograms for JULY. Data are shown for the 1-degree squares labelled 6 through 10 in the upper left inset. Contours of relative frequency are drawn at intervals of 2.5%. Mean vector wind stress is indicated by an arrow.

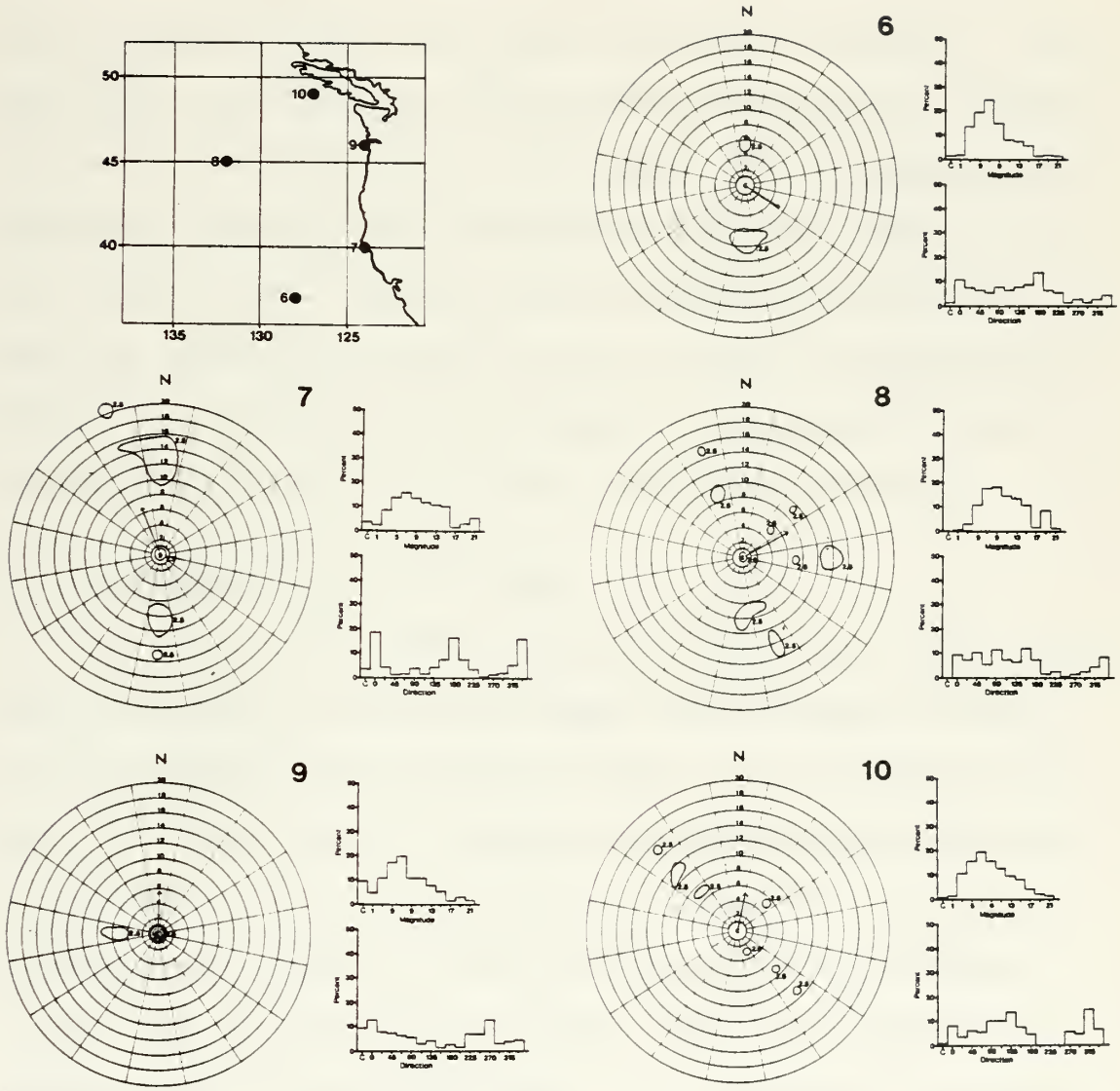


FIGURE 12. Relative frequency surfaces and frequency histograms for JANUARY. Data are shown for the 1-degree squares labelled 6 through 10 in the upper left inset. Contours of relative frequency are drawn at intervals of 2.5%. Mean vector wind stress is indicated by an arrow.

Current. Pronounced seasonal variations in the magnitude and direction of the monthly mean wind stress are indicated along the entire west coast of the United States. These changes are most evident off the coasts of Oregon and Washington. In addition, these data suggest month to month changes in the large scale spatial variability. The magnitudes and directions are broad-banded during the winter months, and along the northern coast. Well defined peaks in magnitude and direction characterize the distributions during the summer and along the southern coast. One may conclude that marine biological communities inhabiting the coastal zones off Oregon and Washington must respond to a wider range of environmental fluctuations than those organisms which exist in the waters off southern California.

B. THE SEASONAL CYCLE AT THE COAST

Time series of the surface wind stress within the 1-degree square areas immediately adjacent to the coast are displayed in Figure 13 as the alongshore component, and in Figure 14 as the onshore component. For these displays, the vector means have been resolved into components parallel and perpendicular to the coast. The coastline angles were determined by visually fitting a line to the dominant trend of the coast within each 1-degree square. The months are indicated along the top of the figures. The latitudes of the 1-degree squares are indicated on the right and left sides of the figures. Negative values are shaded and indicate equatorward stress in Figure 13 and offshore stress in Figure 14.

Several characteristic features are apparent in these figures. South of 40° N latitude, there is an equatorward component throughout

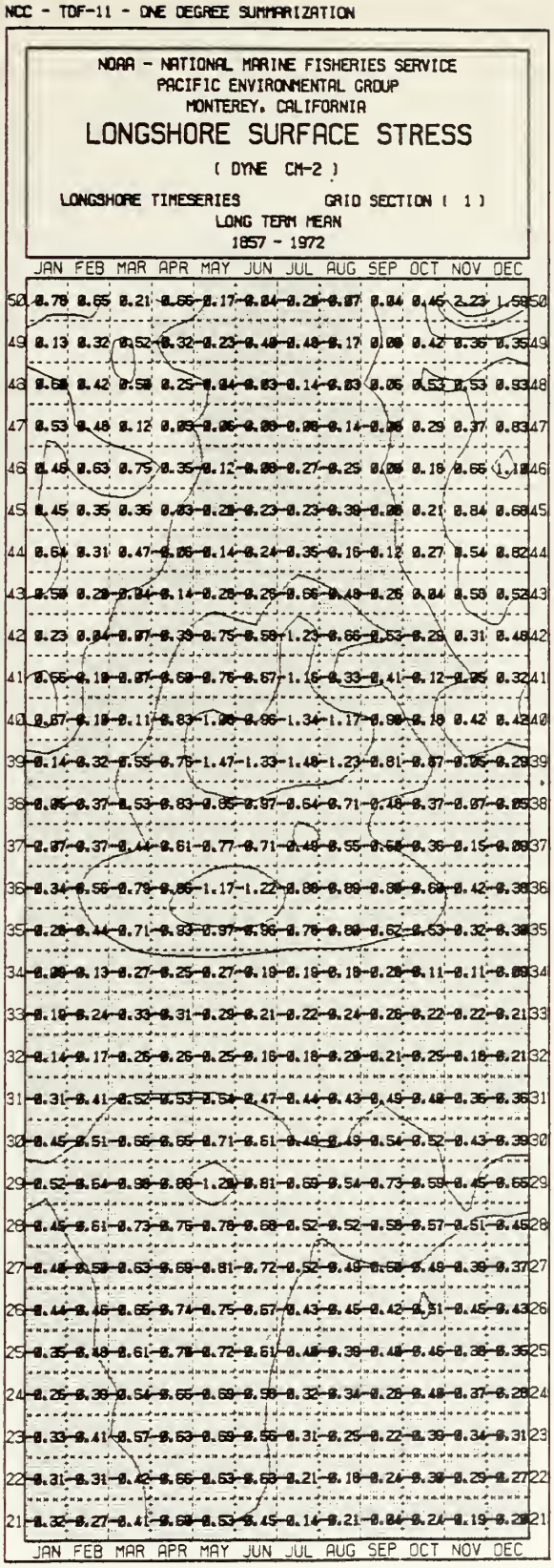


FIGURE 13. Seasonal cycle of alongshore surface wind stress near the coast. Means of alongshore components of wind stress were computed by month for the 1-degree squares immediately adjacent to the coast. Units are dyne cm^{-2}. Equatorward alongshore stress is shaded.

the year, implying conditions favorable for coastal upwelling in all months. Off the coasts of Oregon and Washington, the data suggest that upwelling occurs seasonally between the months of April and September.

Two relative maxima occur in the time/space domain. Off the coast of Baja California, maximum values of wind stress are evident near Punta Eugenia in May. A large maximum occurs just south of Cape Mendocino between May and August. A smaller, local maximum occurs in May and June at 36° N latitude.

The timing of the central maximum off the coast from Cape Mendocino agrees with the description of the mean yearly cycle of indicated upwelling given by Bakun (1973). However, Bakun's data are spatially distorted, and indicate maximum values at 33° N latitude, 119° W longitude in the middle of the Southern California Bight. The gross spatial distortion is primarily caused by the development of an intense thermal low over southern California during the summer. The influence of this low pressure system, and the effects of coastal mountain ranges distort the analyzed pressure fields used in Bakun's computations.

Figure 13 is similar in appearance to a time series of offshore Ekman transport shown by Bakun et al. (1974). They showed a good correlation between the occurrence of maximum offshore transport at 39° N latitude and a suppression of seasonal warming in the adjacent coastal waters during early summer.

The time series of alongshore surface wind stress (Figure 13) suggests a slight tilt, with time and space, to the region of maximum values. This corresponds to a northward shift in the intensity of

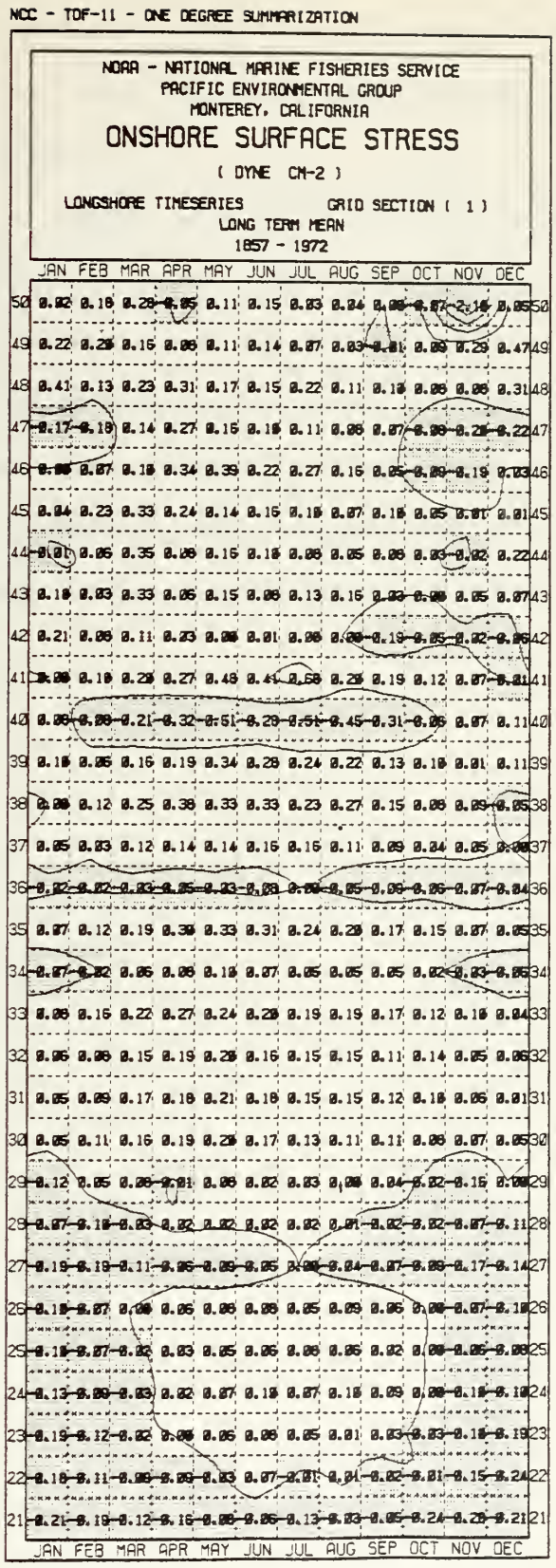


FIGURE 14. Seasonal cycle of onshore surface wind stress near the coast. Means of the onshore components of wind stress were computed by month for the 1-degree squares immediately adjacent to the coast. Units are dyne cm^{-2}. Offshore stress is shaded.

the surface wind stress from April and May off the coast of Baja California, to June, July, and August off Cape Mendocino and Cape Blanco.

Figure 14 indicates a tendency for the surface wind stress to be directed onshore throughout the year. Off the coast of Baja California, the surface stress is characterized by offshore components, except between the months of April and October. Offshore components are also apparent in the vicinity of Cape Mendocino and Point Conception. Near these points, abrupt changes in coastline orientation may influence the direction and magnitude of the surface wind stress.

V. WIND STRESS CURL

The surface wind stress curl is the forcing function for the vertically integrated mass transport of the wind-driven ocean circulation. Under linear, steady-state conditions on the " β -plane", in the absence of friction, the meridional component of mass transport (M_y) is directly proportional to the vertical component of the curl of the wind stress as expressed in Equation 6:

$$M_y = \frac{\vec{k} \cdot (\nabla \times \vec{\tau})}{\beta} \qquad (6)$$

where M_y is the meridional component of the vertically integrated mass transport, β is the meridional derivative of the Coriolis parameter f , and $\vec{k} \cdot (\nabla \times \vec{\tau})$ is the vertical component of the wind stress curl. According to the simplified model, positive (negative) wind stress curl is associated with northward (southward) meridional transport. Surface Ekman divergence (convergence) corresponding to positive (negative) wind stress curl is balanced by geostrophic convergence (divergence) in the northward (southward) meridional flow.

Coastal upwelling occurs only at the ocean boundary. However, wind induced upwelling will occur whenever divergence in the surface wind drift is not balanced by other modes of horizontal surface flow. Figure 15 shows a mechanism by which the wind stress curl determines the divergent or convergent nature of the surface wind drift offshore of the primary coastal upwelling zone. An increase in the equatorward

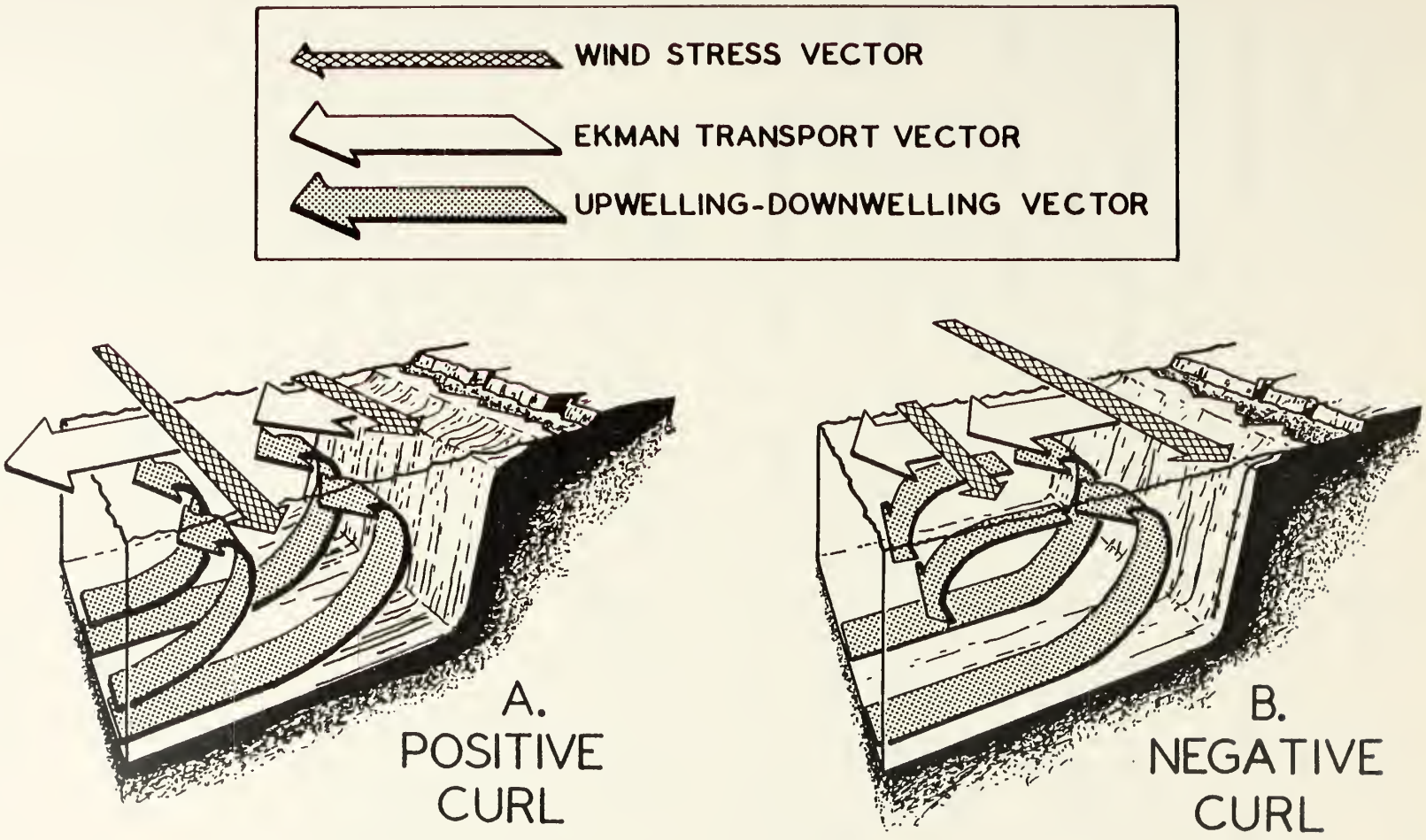


FIGURE 15. A conceptual diagram of the relationship of wind stress curl to divergence and convergence of surface Ekman transport offshore of the primary coastal upwelling zone (after Bakun and Nelson 1975).

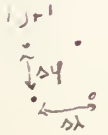
wind stress parallel to the coast (Figure 15A) is characterized by positive wind stress curl. In this situation, the offshore component of Ekman transport increases in the offshore direction, resulting in continued surface divergence. Upwelling is required to maintain the mass balance. If the equatorward longshore surface wind stress decreases in the offshore direction (Figure 15B), the wind stress curl is negative. Convergence in the surface wind drift will result. Frontal formation and downwelling may occur just offshore of the primary coastal upwelling zone.

Direct measurements of wind stress curl are not available. Since the curl is a linear operator, the curl of the monthly mean surface wind stress fields has been computed. The vertical component of the curl of the wind stress in spherical coordinates is defined by:

$$\vec{k}\cdot(\nabla\times\vec{\overline{\tau}}) = \frac{1}{R\cos\varphi}\left[\frac{\partial\overline{\tau}_y}{\partial\lambda} - \frac{\partial}{\partial\varphi}(\overline{\tau}_x\cos\varphi)\right] \qquad (7)$$

where R is the radius of the earth, φ and λ denote geographic latitude and longitude respectively, and $\overline{\tau}_x$ and $\overline{\tau}_y$ denote the eastward and northward components of the mean surface wind stress. A finite difference equation approximating the curl at the grid point (i,j) in Figure 16 is given by:

$$\vec{k}\cdot(\nabla\times\vec{\overline{\tau}}_{i,j}) = \frac{1}{R\cos\varphi_{i,j}}\left[\frac{\overline{\tau}_{y_{i+1,j}} - \overline{\tau}_{y_{i-1,j}}}{2\Delta\lambda} - \left(\frac{(\overline{\tau}_x\cos\varphi)_{i,j+1} - (\overline{\tau}_x\cos\varphi)_{i,j-1}}{2\Delta\varphi}\right)\right] \qquad (8)$$



$\Delta\lambda = \Delta\varphi = 1^\circ$

F 16 discretation grid used in calc. wind stress curl

centered differenced except @ boundaries

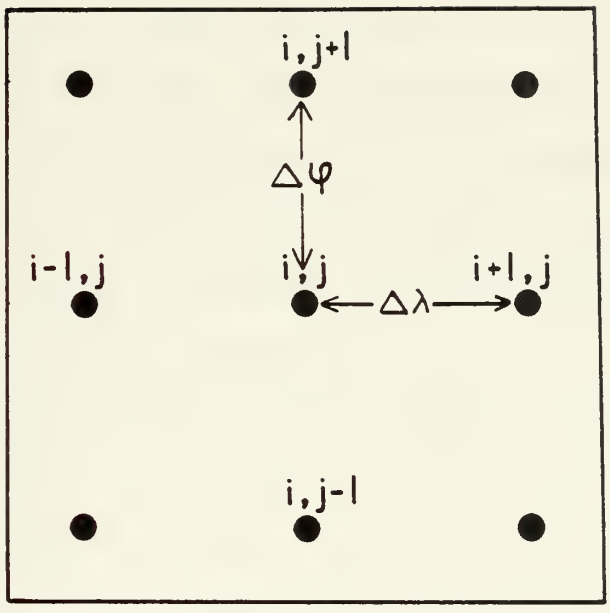


FIGURE 16. Discretization grid used in calculating the wind stress curl.

where $\Delta \varphi = \Delta \lambda = 1°$. The method is similar to calculations described by Hantel (1970). Centered differences were utilized throughout the interior of the data grid. Forward and backward differences were required along the boundaries. As a result, certain artificial features may have been introduced at these boundaries.

A. THE MONTHLY CURL DISTRIBUTIONS

Monthly fields of surface wind stress curl are displayed in Appendix C (Charts 37 to 48). These distributions correspond to the monthly mean wind stress distributions shown in Appendix A. The values are plotted in units of dyne cm^{-2} per 100 km. A value of 1 dyne cm^{-2} per 100 km is equivalent to 1×10^{-7} dyne cm^{-3}. Negative values of wind stress curl are shaded.

The small scale features evident in these distributions should be viewed with caution. Detail within a single 1-degree square area which is not supported by similar values in surrounding squares probably reflects "noise" in the monthly means of surface wind stress. Objective smoothing procedures applied to the monthly mean wind stress fields would result in more homogeneous distributions of wind stress curl. A particular method has been described by Evenson and Veronis (1975).

Characteristic absolute magnitudes of the spatially averaged wind stress curl are 1×10^{-8} dyne cm^{-3}. This value is approximately an order of magnitude less than the summertime mean reported by Halpern (1976) for an upwelling region near the Oregon coast. Considering the time and space averages used in the present study, this difference appears to be reasonable. The probable errors associated with these

estimates of wind stress curl may be calculated from a knowledge of the spatial distributions of standard errors of the (wind stress) component means (see Appendix B). On average , the expected error is 1×10^{-8} dyne cm^{-3}, with maximum and minimum errors of 4×10^{-8} dyne cm^{-3} and 1×10^{-10} dyne cm^{-3} respectively. Of course, these values apply to particular individual 1-degree squares. Large values generally correspond to "holes" in the distributions, which are easily seen in the monthly charts. For larger space scales, the errors associated with the gradients of the mean wind stress components would tend to cancel. Thus, greater confidence may be expected for the patterns of wind stress curl which are consistent over several degrees of latitude and longitude.

The large scale features of positive and negative curl along the coast are significant. The important details to note are the sign of the wind stress curl at the coast, and the position of the line of zero wind stress curl. A general feature common to all months, is the occurrence, on average, of positive wind stress curl near the coast, and negative curl at some distance offshore. This feature is well developed from May to September. Greater spatial variability is evident in the winter distributions.

The existence of an offshore wind stress maximum results in a line of zero wind stress curl approximately parallel to the coast. Positive curl occurs inshore of the maximum wind stress. Negative curl in the offshore region is associated with the anticyclonic atmospheric circulation over the interior ocean. The positive curl near the coast is related to topography and to local features in the surface wind stress distributions.

The distributions from December to March are characterized by positive wind stress curl near the coast from San Francisco to northern Baja California, and south of Punta Eugenia. Large areas of associated Ekman divergence extend several hundred kilometers off the coast. The patterns of wind stress curl are less well behaved near the coasts of Oregon and Washington. However, negative wind stress curl near this coastal region appears to be typical of the distributions during the winter.

During the spring and summer upwelling, the dominant patterns of surface wind stress curl are easily recognized. The line of zero wind stress curl parallels the coast approximately 200 km to 300 km offshore, along the entire boundary from northern Baja California to Vancouver Island. This is a consistent feature from June through September. Yoshida and Mao (1957) placed this boundary at approximately 500 km from the coast. Considering the coarse resolution (5-degree squares of latitude and longitude) of their data, the disparity is not surprising.

The months of April and May, and October and November appear as transitional periods. During the transition from spring to summer, the negative curl along the coasts of Oregon and Washington shifts to positive curl. The offshore distribution takes on a more uniform character. Scattered regions of positive and negative curl are replaced by a large area of negative curl. The late fall transition is marked by a total breakdown in the curl distributions within the northern sector of the grid.

Several local (positive) curl maxima are associated with major topographic changes in the coastline configuration. Large values

of positive wind stress curl are found near Cape Blanco, Cape Mendocino, San Francisco, and Point Conception. These features may be real, or they may be artifacts of the finite difference calculations or the data distributions. However, one does note that near Point Conception, the values of positive wind stress curl are consistent with a decrease in the magnitude of the surface wind stress in the lee of the point. Where areas of positive wind stress curl extend offshore of capes, there would tend to be a continued, although much reduced level of upwelling outside of the primary coastal upwelling regime.

A region of negative wind stress curl (Ekman convergence) reaches the coast of Baja California between Punta Eugenia and Punta Baja to the north. This feature appears consistently throughout the year. A partial breakdown in this system occurs in August, October, and November. However, considering the probable uncertainties in these derived data, one might reasonably conclude that the coastal region near Punta Eugenia can be characterized in the mean by convergence in the surface wind drift. The distributions of wind stress curl in this area imply favorable conditions for formation of fronts and convergent patches of recently upwelled water.

B. COASTAL TIME SERIES

The mean annual cycle of wind stress curl near the coast is shown in Figure 17. Positive wind stress curl occurs along most of the coast throughout the year. Exceptions to this generalization are found in the region south of 30°N latitude and between 40°N and 47°N latitude. The temporal persistence of the negative wind stress curl

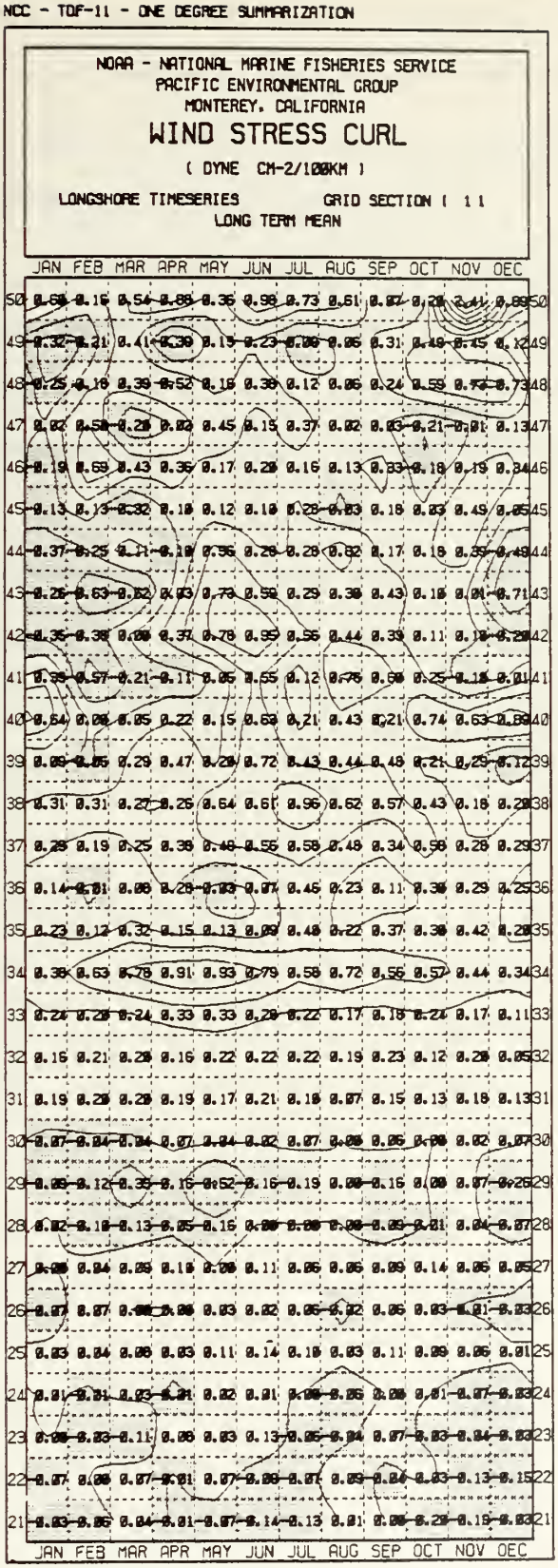


FIGURE 17. Seasonal cycle of wind stress curl near the coast. The wind stress curl is shown by month for the 1-degree squares immediately adjacent to the coast. The calculations were based on the monthly mean surface wind stress distributions. Units are dyne cm^{-2} per 100 km. The contour interval is 0.25 dyne cm^{-2} per 100 km. Negative values are shaded.

near Punta Eugenia (29°N latitude) is clearly seen in this time series. A similar feature occurs near the tip of Baja California. A seasonal variation between positive and negative curl is apparent from Cape Mendocino to the Columbia River.

Yoshida and Mao (1957) presented evidence indicating that open-ocean upwelling is related to the wind stress curl. This process is distinct from coastal upwelling which is primarily a boundary phenomenon. However, the two mechanisms are not totally independent. In regions where positive wind stress curl occurs, such as between 30°N and 40°N latitude throughout the year, and near the coasts of Oregon and Washington during the summer, the ascending motion related to the wind-induced divergence offshore, enhances the upwelling associated with the more dominant coastal divergence.

VI. DISCUSSION

The monthly distributions of surface wind stress show an offshore maximum which progressively develops over a large extent of the California Current and shifts northward and intensifies on the seasonal time scale. This process is a primary forcing function for coastal upwelling. Off Baja California, wind-induced surface divergence occurs on average throughout the year. Downwelling occurs near the coast of Vancouver Island, except during the restricted period between May and August when a small equatorward component is observed.

The major seasonal variations in the magnitude and direction of the surface wind stress can be described simply in terms of the general atmospheric circulation over the Northeast Pacific Ocean. Monthly mean surface pressure charts typically show two well developed pressure cells. A high pressure system over the ocean shifts northward and increases in strength from spring to summer. The center of the cell moves in a northwestward direction. The seasonal variation of the high pressure system is small. This shift in the large scale anticyclonic circulation results in the observed winter to summer reversal in the alongshore wind component off the coasts of Oregon and Washington. A low pressure system is situated over the southwestern United States throughout the year. This semi-permanent thermal low is fully developed over the Central Valley in California during the summer. Cyclonic circulation associated with the low leads to equatorward surface wind stress parallel to the coast. The amplitude of the annual cycle is large. During the winter, both of these pressure cells weaken. The high

pressure system moves southward and the coasts of Oregon and Washington come under the influence of the intense low pressure system in the Gulf of Alaska.

The primary mechanism controlling the location and strength of the wind stress maximum and the associated coastal upwelling is described by seasonal variations in the gradient between the two pressure cells. During the winter, this gradient is weak. Strong heating over the continent during the summer deepens the low and increases the amplitude of the onshore-offshore pressure gradient. As a result of the northward shift and slight strengthening of the high, and deepening of the low, the region of maximum wind stress moves from the area south of Point Conception to the vicinity of Cape Mendocino. These variations are, of course, a function of differential ocean-continent heating related to the annual cycle of solar radiation.

A. PHYSICAL IMPLICATIONS

The climate of the adjacent coastal regions is influenced by upwelling. During the summer, the dome of high pressure which develops over the North Pacific Ocean, favors large scale subsidence and a strong temperature inversion over the west coast of the United States. This suppresses deep cloud formation and greatly inhibits precipitation. Unpublished distributions of cloud cover, summarized from ship observations, show a large onshore-offshore gradient in the total cloud amount. Minima occur at the coast. The effect of the large scale subsidence is noted in the true desert climate of Baja California, and in the almost complete lack of rainfall along the coasts of California, Oregon, and Washington during the summer. Coastal upwelling primarily

influences the local climate of the nearshore zone within 10 km to 20 km of the coast and contributes to the formation of low stratus clouds and fog typical of much of the coast along California and Oregon.

A secondary mechanism may account for local intensification of the surface wind stress and persistence of coastal upwelling over periods ranging from several weeks to a few months (Bakun 1974). In a simplified positive feedback model, wind stress parallel to the coast brings cold water to the surface and cools the adjacent air. The resulting temperature contrast between the continent and the ocean increases the local pressure gradient. The alongshore surface winds are increased and upwelling is enhanced (Ramage 1971). This mechanism may be slightly modified by the effect of atmospheric stability. Within the summertime coastal upwelling zone, the air-sea temperature difference is usually positive. This stable stratification decreases the magnitude of the surface wind stress. The resulting negative feedback may partially offset the increase in surface winds associated with the described changes in the local pressure gradient.

The existence of maximum wind stress some 200 km to 300 km from the coast is an interesting feature. Of course, a maximum in the onshore-offshore pressure gradient offshore may explain this phenomenon. The positive feedback associated with wind-induced upwelling extending hundreds of kilometers off the coast may act to intensify the alongshore winds. However, this feature also suggests a coastal boundary layer which acts to frictionally retard the winds near the coast, leading to a positive wind stress curl in the nearshore region.

A characteristic feature of the wind stress curl distributions is the occurrence of a line of zero curl at some distance from the coast. Observations show positive curl inshore of this line and negative curl in the offshore region. A theoretical analysis suggests that a poleward undercurrent along an eastern boundary is favored by positive wind stress curl along the coast and a poleward decrease in surface heating (Pedlosky 1974). The monthly distributions of wind stress curl presented in this study are generally consistent with an equatorward Sverdrup flow offshore and a poleward Sverdrup flow near the coast, except in the region from Punta Eugenia to Punta Baja, where the wind stress curl is negative. The general pattern of positive wind stress curl along the coast and observations of the California Countercurrent (Wooster and Jones 1970, Wickham 1975), are consistent with Pedlosky's theory.

The Sverdrup transport balance expressed in Equation 6 may provide a simple and reasonable explanation for the existence of the current-countercurrent system observed along the west coast of the United States. Transport calculations based on the July wind stress curl data for the line of 1-degree squares extending offshore of Cape Blanco (43° N latitude), show a net southward transport of 3.53×10^{12} g sec^{-1}. Within 300 km of the coast, an integrated northward transport of 2.20×10^{12} g sec^{-1} is required. Negative wind stress curl between 127° W and 133° W longitude is associated with a southward vertically integrated mass transport of 5.73×10^{12} g sec^{-1}. These values somewhat underestimate the total volume transport of the California Current (10 sv) suggested by Sverdrup et al. (1942, p. 724).

B. BIOLOGICAL IMPLICATIONS

Relationships among patterns of coastal and equatorial upwelling and the distributions of primary production have been discussed by Cushing (1969). Favorable conditions for phytoplankton growth are maintained within the surface photic layers by upwelling of nutrient rich subsurface water. Offshore divergence related to the vorticity of the wind stress effectively extends the width of the biological upwelling zone. Fronts may form in areas of negative wind stress curl just offshore of the primary coastal convergence, such as near Punta Eugenia. These fronts would tend to concentrate both the available food and the grazers within the same areas. This process may be important to the survival of fish stocks which spawn in this coastal region.

Seasonal changes in the surface circulation may also provide mechanisms for survival and possible separation of stocks along the coast. The current-countercurrent system characteristic of southern California suggests a mechanism whereby fish stocks could migrate seasonally from primary feeding grounds within the coastal upwelling regime off northern California to spawning grounds off Baja California.

A relationship between wind stress curl and the California Current system has been suggested. The data indicate that the poleward undercurrent observed along the west coast of North America may be driven locally by positive wind stress curl. However, a possibility does exist that the boundary current is not entirely the result of local forcing. Coastal areas may respond to wave-like disturbances propagating from other regions of the ocean, as in the case of El Niño (Wyrtki 1975).

A general requirement for vertically integrated northward Sverdrup transport along the coast apparently breaks down near Punta Eugenia where negative wind stress curl is observed (Figure 18A). Within this region, there must be southward vertically integrated Sverdrup transport.

With this consideration in mind, it is interesting to note the winter distribution of surface currents depicted in Figure 18B. The large scale pattern suggests two separate cyclonic gyres associated with positive wind stress curl within the Southern California Bight, and south of Punta Eugenia. In the region of negative wind stress curl, the indicated surface flow is toward the south.

Correspondences of features in the patterns of wind stress curl, surface currents, and winter distributions of the northern anchovy (Engraulis mordax) (Vrooman and Smith 1971) are highly suggestive (Figure 18C). A mechanism which could lead to formation of subpopulations of pelagic fishes in the California Current is described by Parrish (MS)[4]. Distributions of Pacific mackerel (Scomber japonicus) are similar to those for the Central and Southern subpopulations of northern anchovy shown in Figure 18C.

This study has demonstrated the utility of historical marine observations in describing details of surface properties over an area of the North Pacific Ocean. Resolution by 1-degree square and long term month is feasible when the seasonal cycle is large. This method

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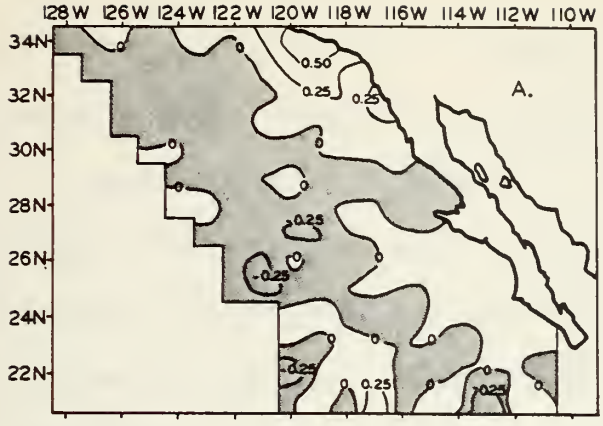
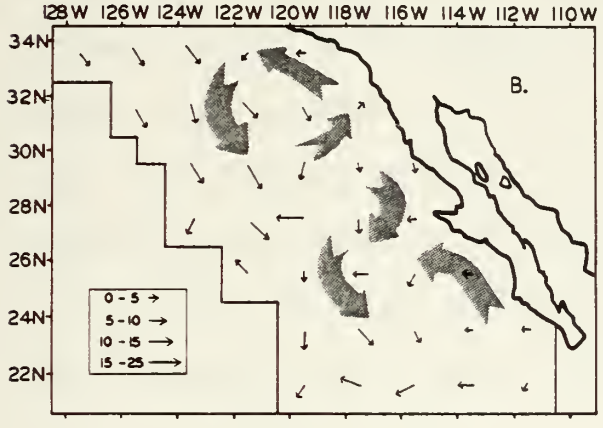
[4] PARRISH, R.H. (MS) Environmental-dependent recruitment models and exploitation simulations of the California Current stock of Pacific mackerel (Scomber japonicus) Ph.D. Thesis, Oregon State University (in preparation).





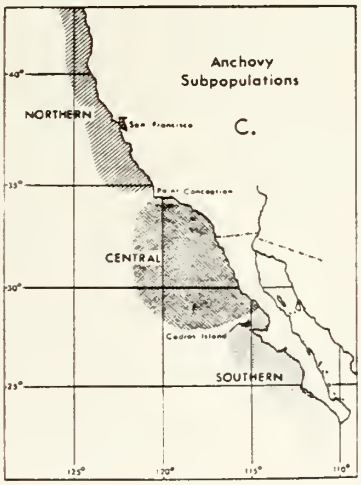


FIGURE 18. Distributions of A. Wind stress curl, B. Surface currents, and C. Anchovy subpopulations. Wind stress curl is shown for September. Units are dyne cm^{-2} per 100 km. The contour interval is 0.25 dyne cm^{-2} per 100 km. Negative values are shaded. The winter distribution of surface currents is depicted in terms of 2-degree summarizations of ship drift data. Vector symbols are scaled according to the key on the chart. Units are cm sec^{-1}. Large arrows suggest the split cyclonic circulations which develops off southern California and Baja California. The winter distribution of the three subpopulations of northern anchovy are shown in the bottom figure. Figures A and B are after Bakun and Nelson (1975). Figure C is after Vrooman and Smith (1971).

of summarization may fail in regions of sparse data, or in the tropics where long term fluctuations frequently obscure the seasonal cycle.

Summarization of these data by 1-degree square, month, and year often fails to produce consistent time series. The resulting fields may not be statistically significant if the mean values are based on too few observations. Objective analysis provides a method to obtain consistency in time and space. However, with these methods, continuity in time is gained at the expense of spatial resolution. An engineering approach might be used to calibrate the large scale analyzed fields in terms of the features evident in higher resolution distributions as presented in this report. The resulting time series could be related to fluctuations of marine biological communities which must respond to wide variations in environmental conditions on time scales ranging from a few days to several years.

APPENDIX A

MONTHLY SURFACE WIND STRESS DISTRIBUTIONS

The long term composite monthly mean surface wind stress distributions are displayed in Charts 1 to 12 as resultant vectors, in Charts 13 to 24 as the eastward components, and in Charts 25 to 36 as the northward components. The values are plotted in units of dyne cm^{-2}. The month is indicated in the figure legend in the upper right corner of the charts. The two years displayed below the month, for example 1858-1972, correspond to the year of the earliest report and the year of the most recent report respectively. The coastline configuration is superimposed on the grid as a visual aid and does not represent a conformal mapping.

In Charts 1 to 12, the vectors are plotted according to the scale shown below the figure legend. The mean vector magnitudes are contoured at intervals of 0.5 dyne cm^{-2}. Contour labels have been omitted for clarity. Magnitudes greater than 1.0 dyne cm^{-2} are shaded.

Charts 13 to 24 display contoured values of the eastward component of the resultant surface wind stress. The contour interval is 0.5 dyne cm^{-2}. Positive values correspond to eastward components. Negative values are shaded.

The northward component of the resultant stress is plotted in Charts 25 to 36. The contour interval is 0.5 dyne cm^{-2}. Positive values correspond to northward components. Negative values are shaded.

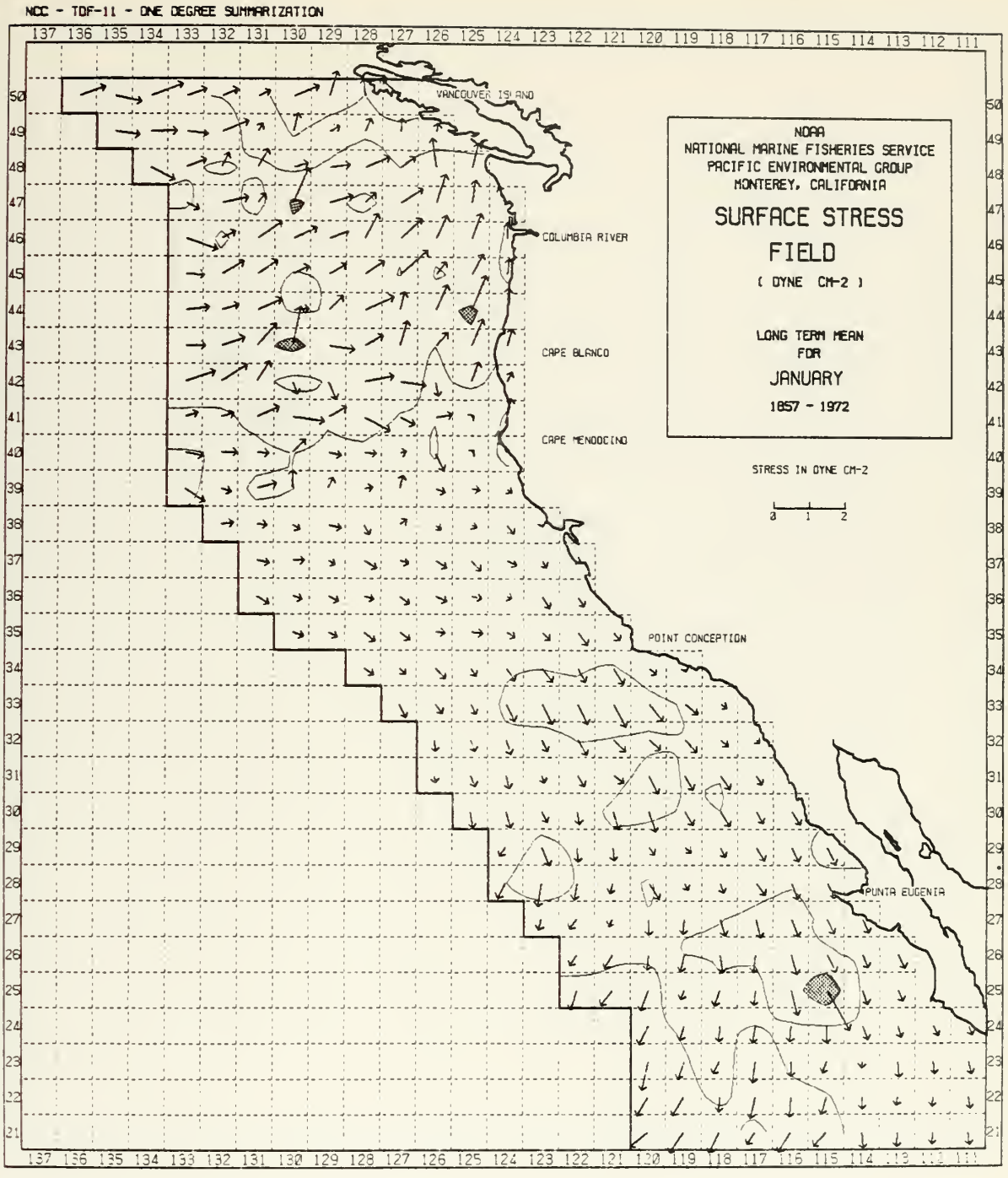


CHART 1. Resultant surface wind stress vectors for JANUARY.

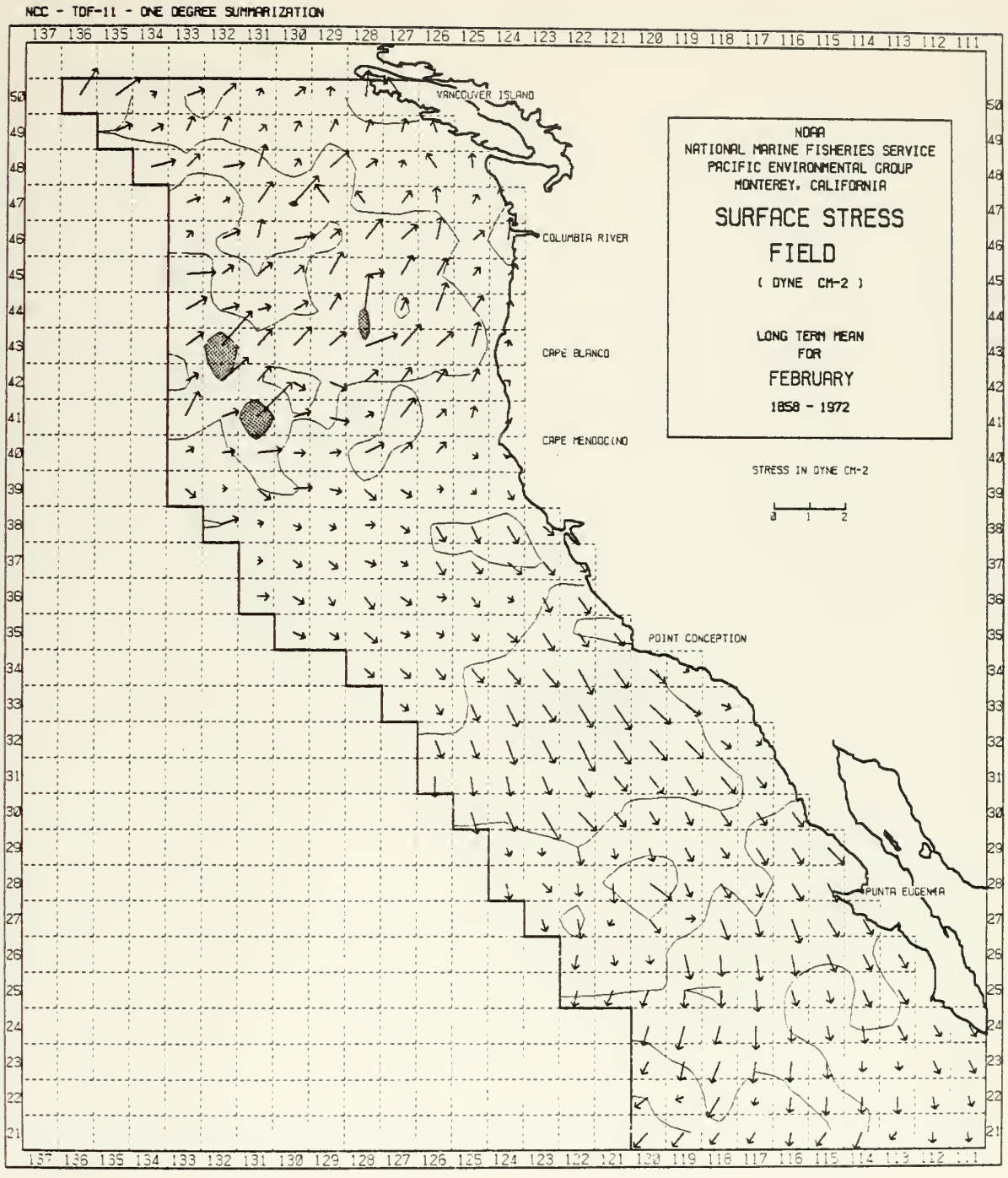


CHART 2. Resultant surface wind stress vectors for FEBRUARY.

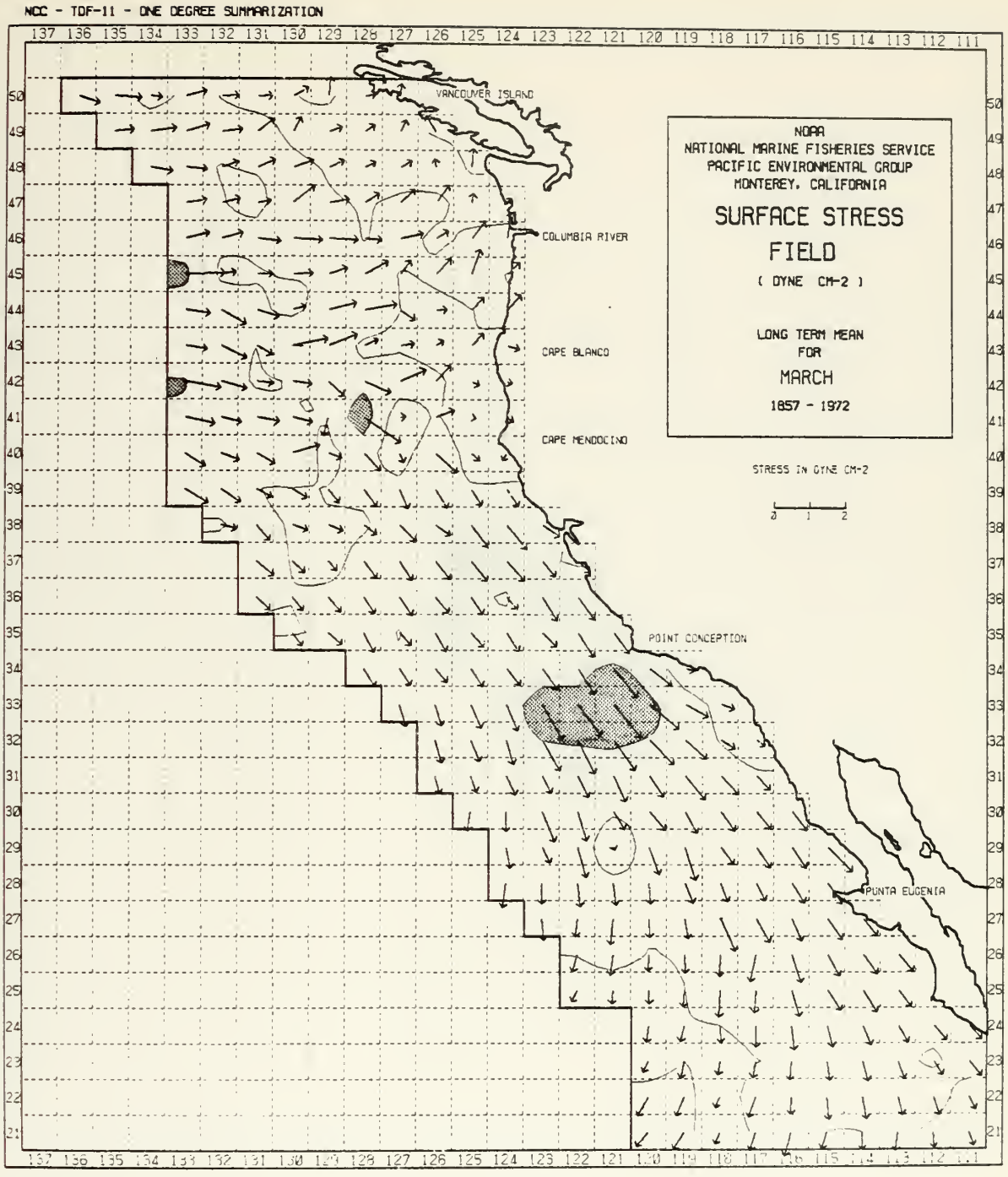


CHART 3. Resultant surface wind stress vectors for MARCH.

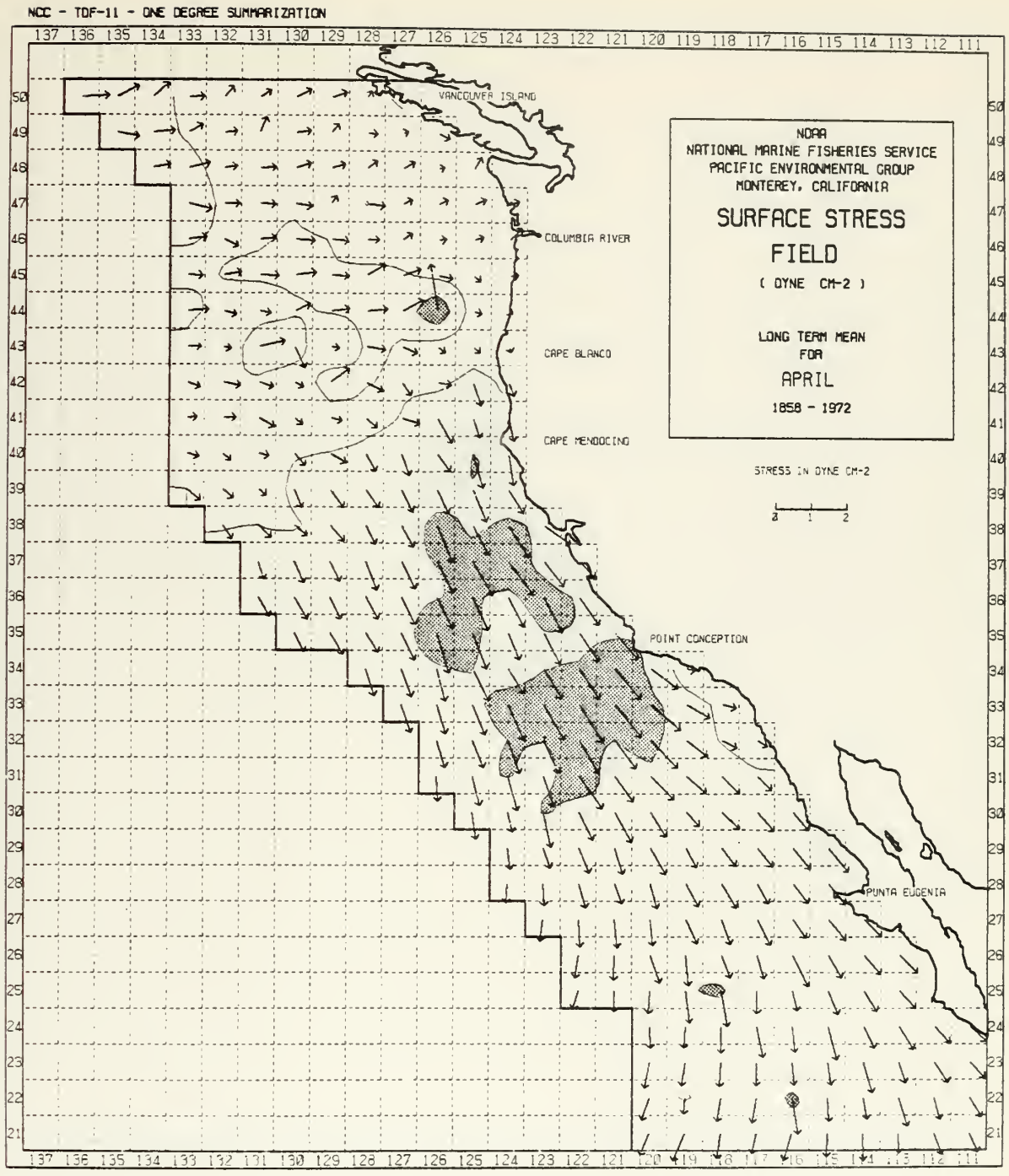


CHART 4. Resultant surface wind stress vectors for APRIL.

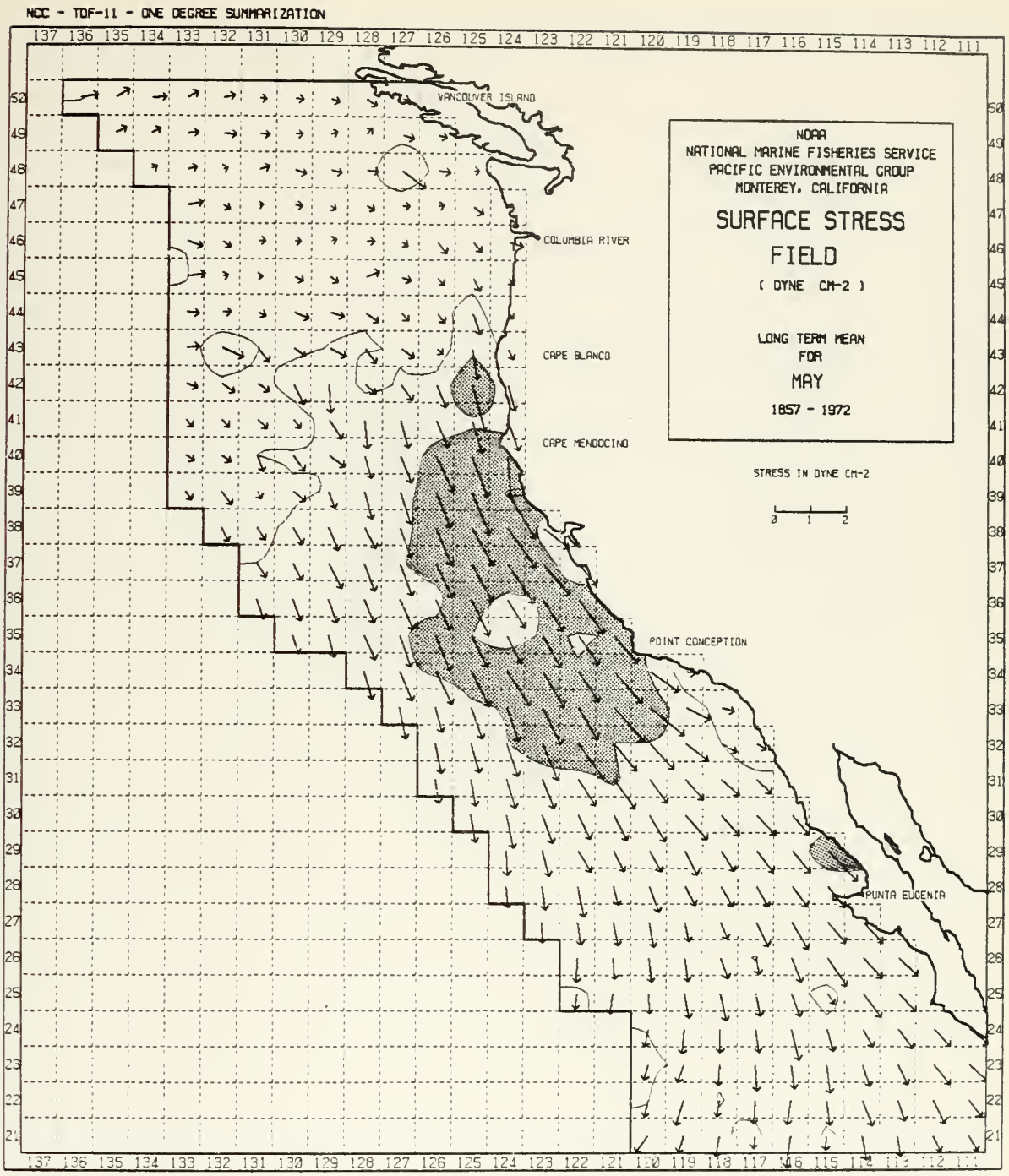


CHART 5. Resultant surface wind stress vectors for MAY.

Shaded areas > 1.0 dyne/cm^{-2}

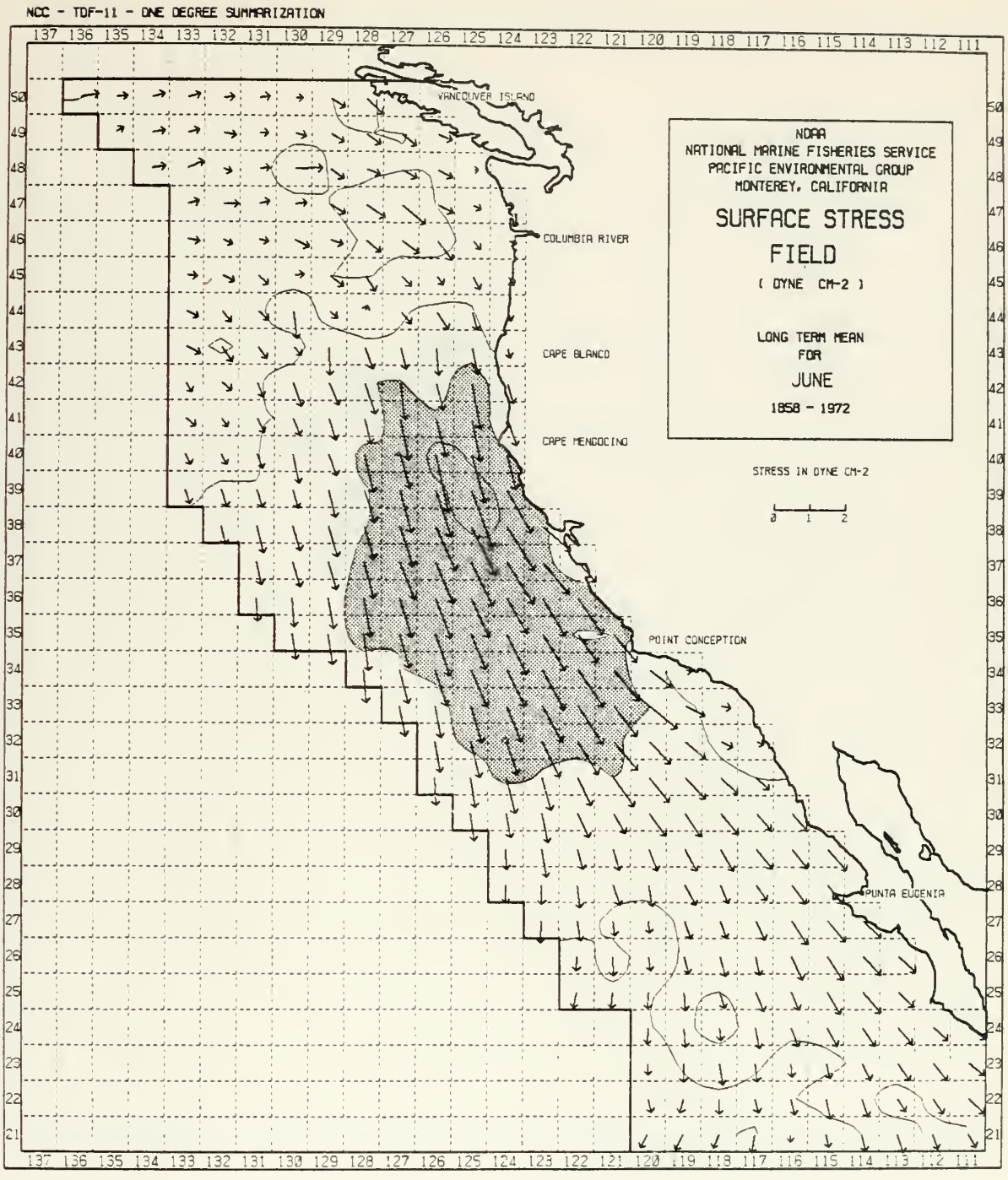


CHART 6. Resultant surface wind stress vectors for JUNE.

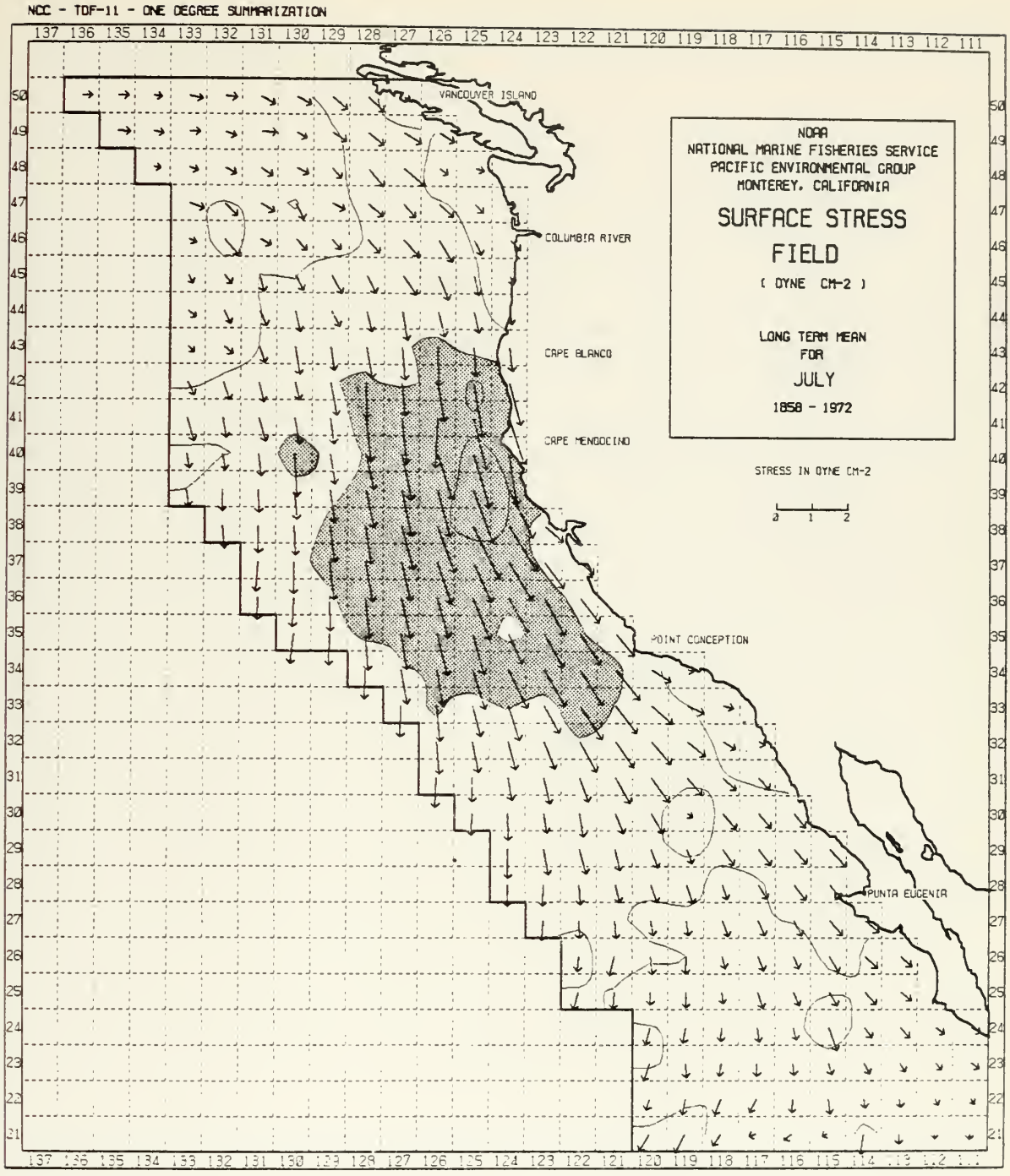


CHART 7. Resultant surface wind stress vectors for JULY.

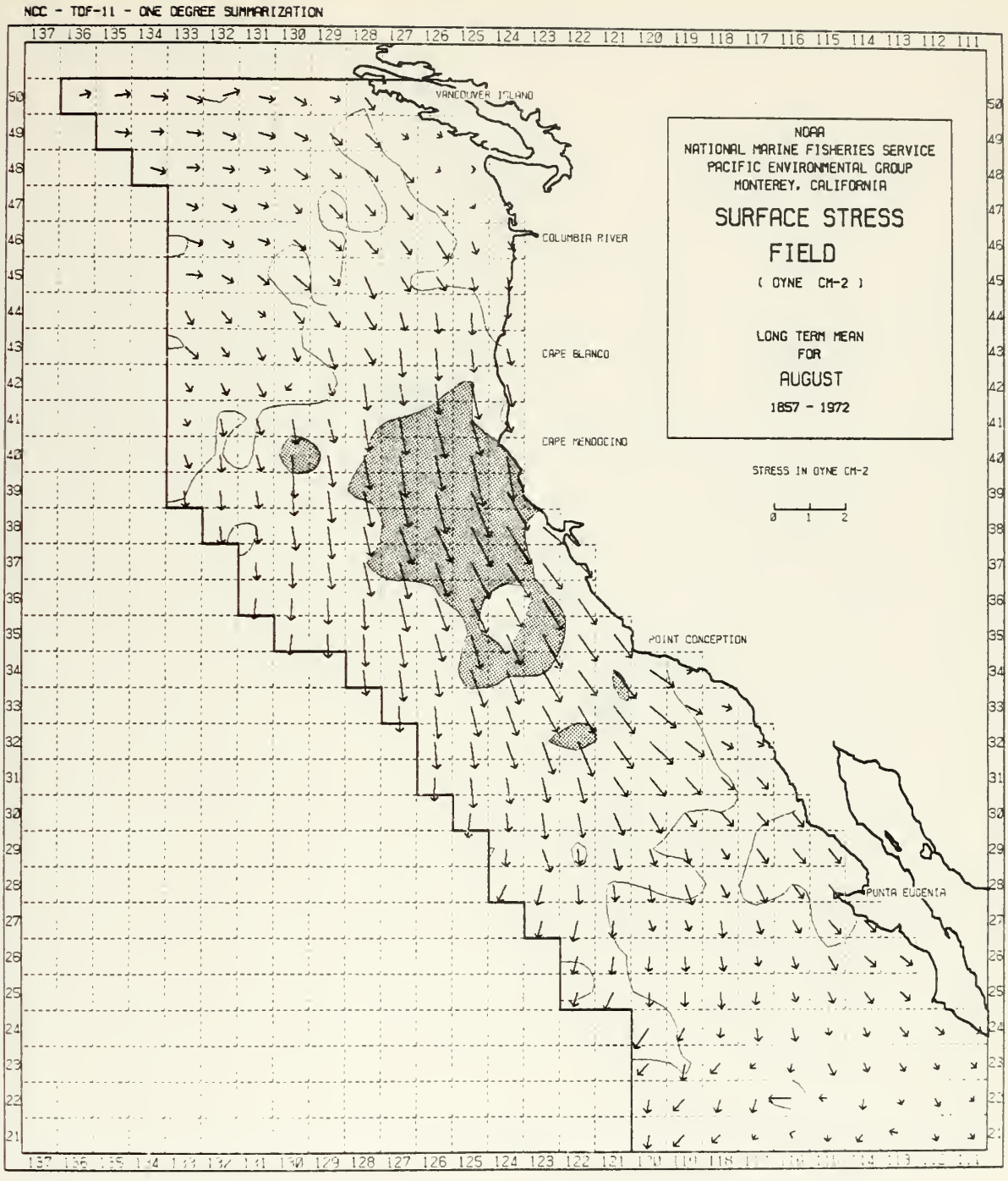


CHART 8. Resultant surface wind stress vectors for AUGUST.

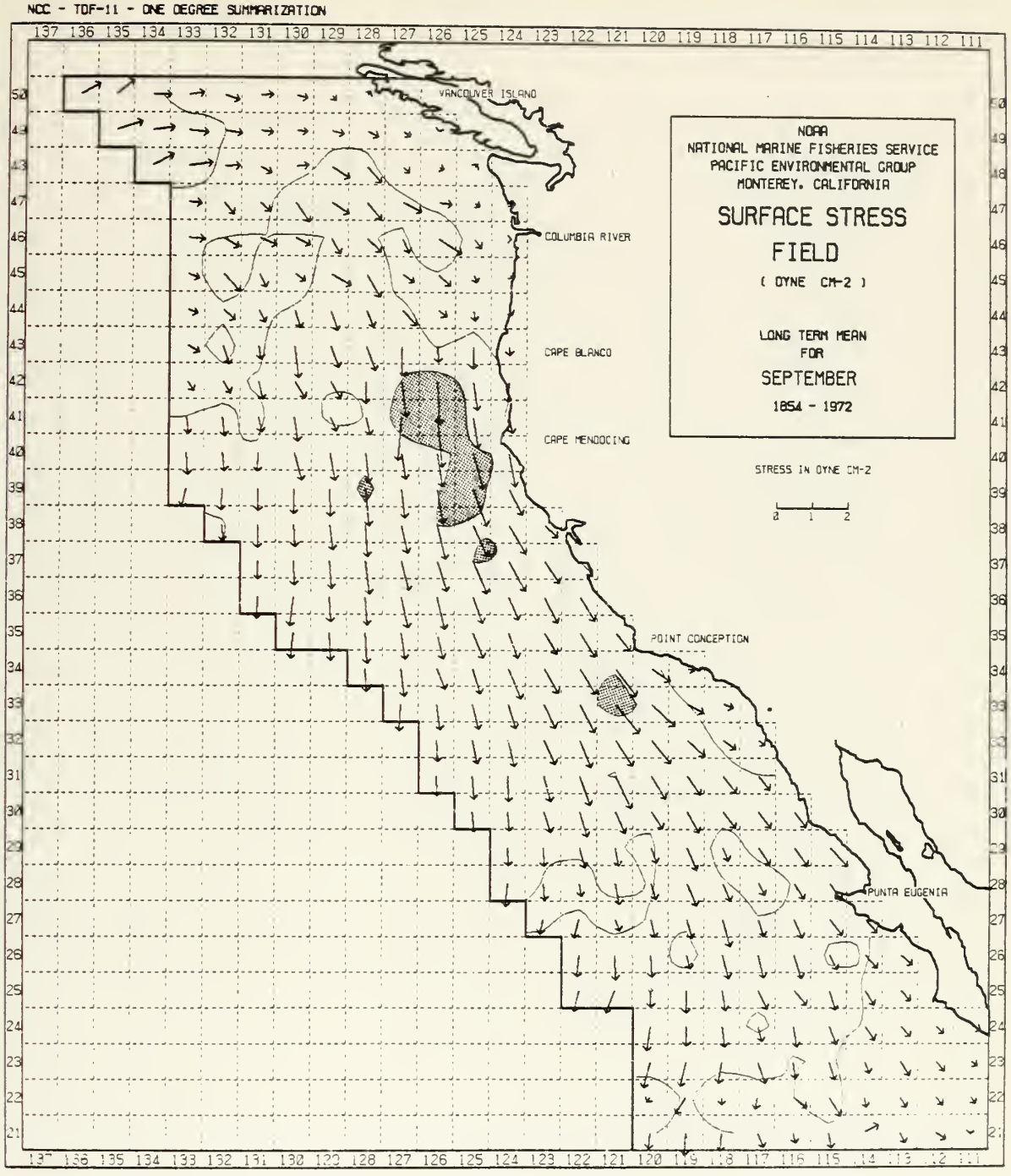


CHART 9. Resultant surface wind stress vectors for SEPTEMBER.

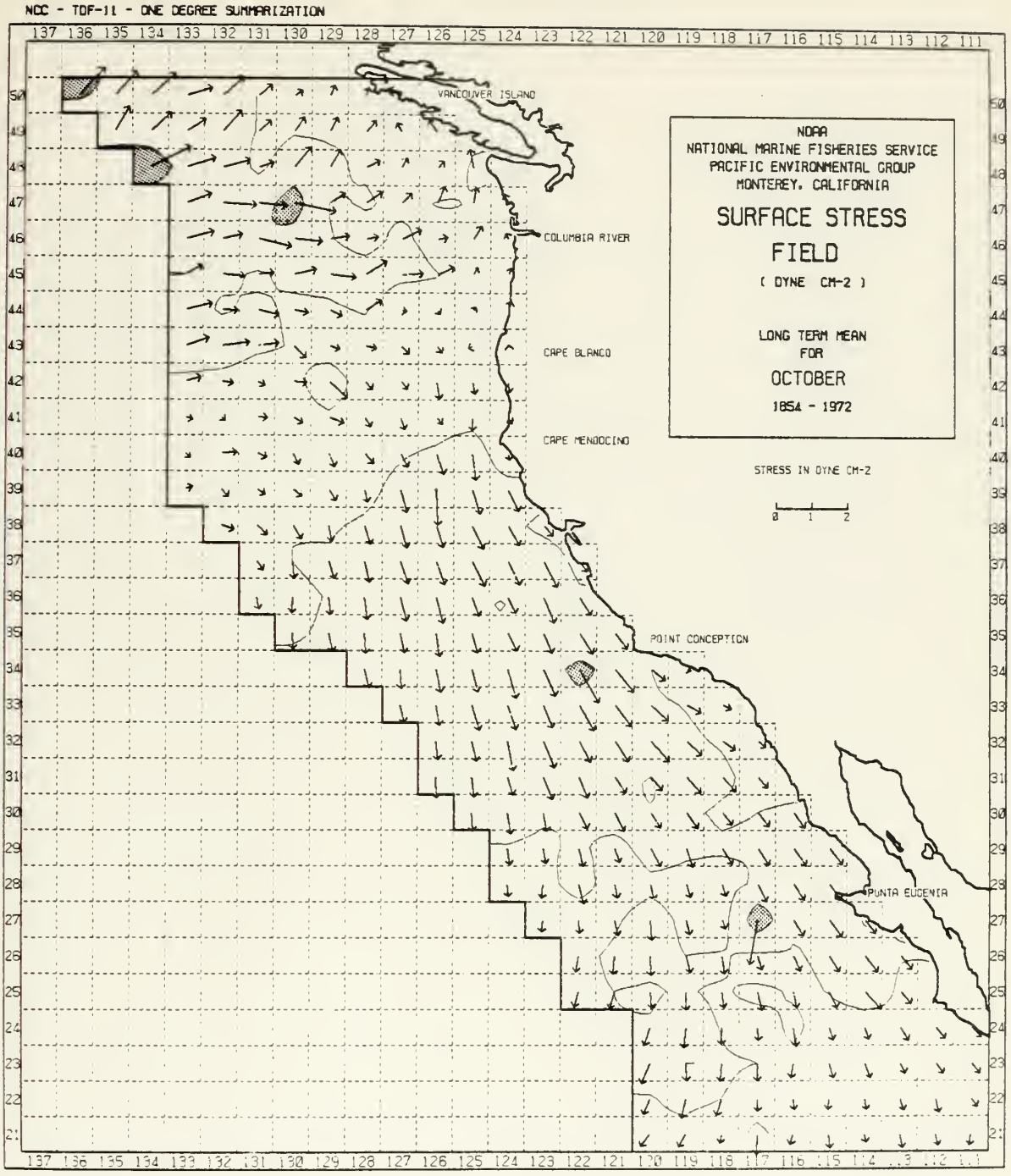


CHART 10. Resultant surface wind stress vectors for OCTOBER.

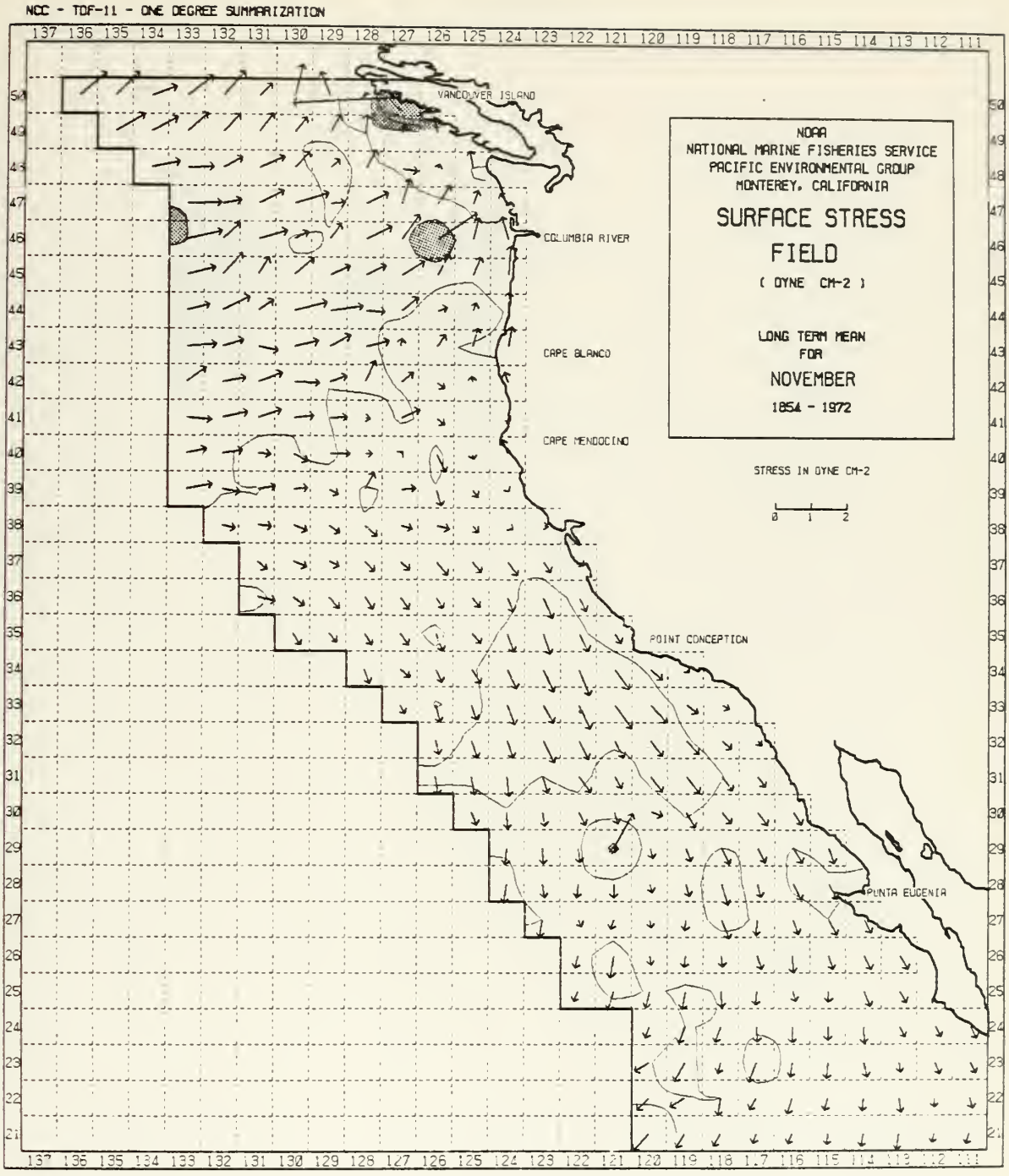


CHART 11. Resultant surface wind stress vectors for NOVEMBER.

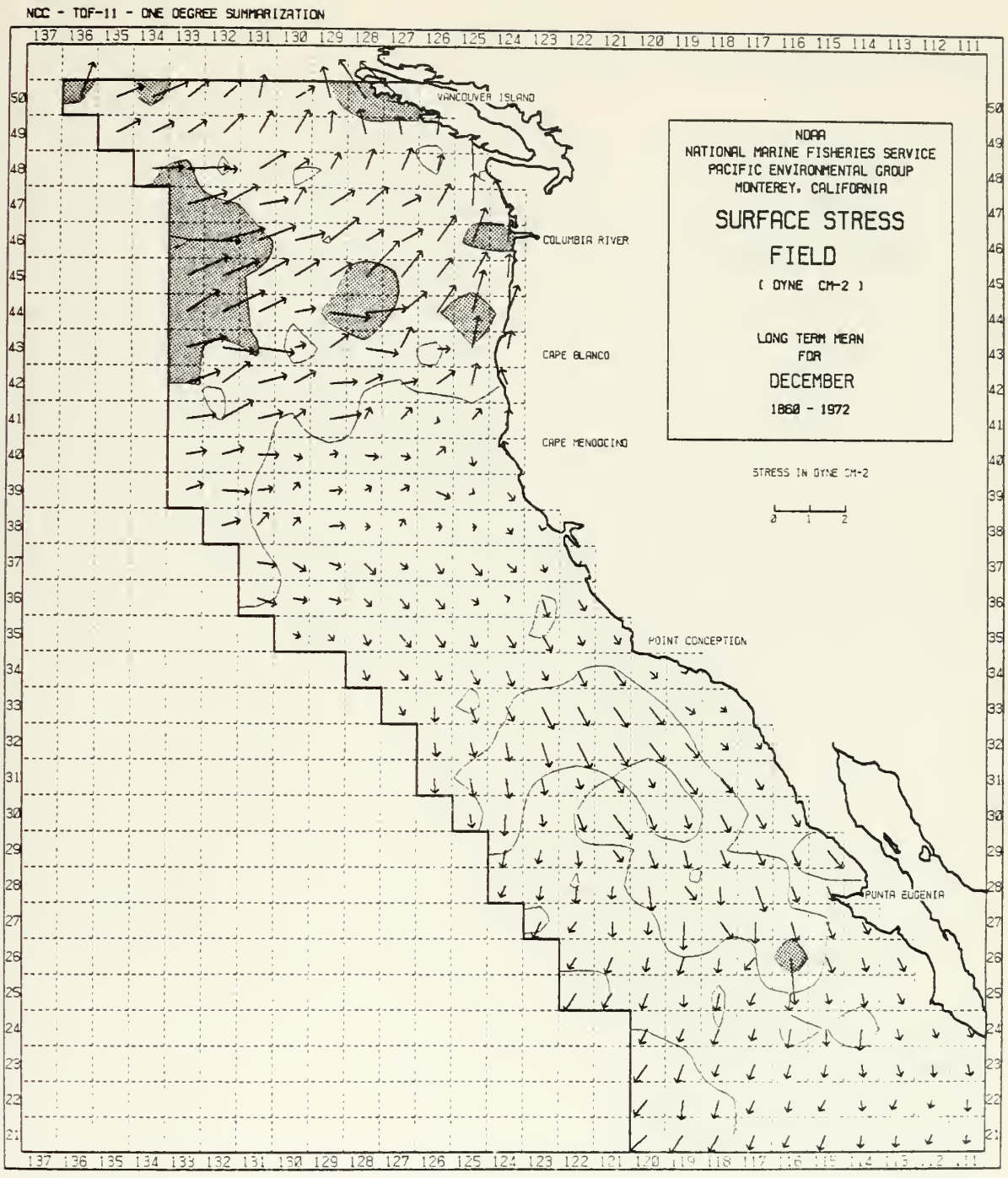


CHART 12. Resultant surface wind stress vectors for DECEMBER.

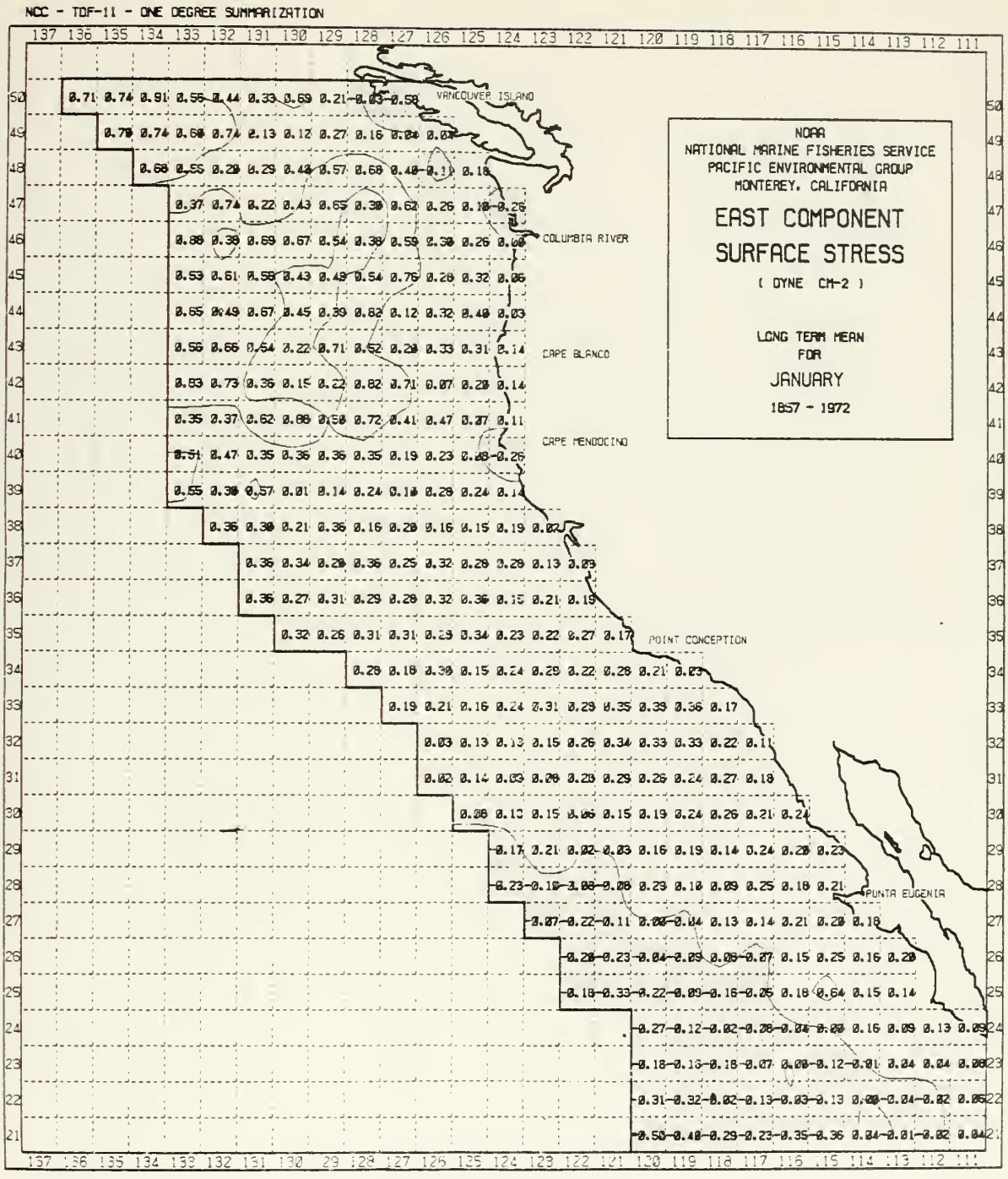


CHART 13. East component surface wind stress for JANUARY.

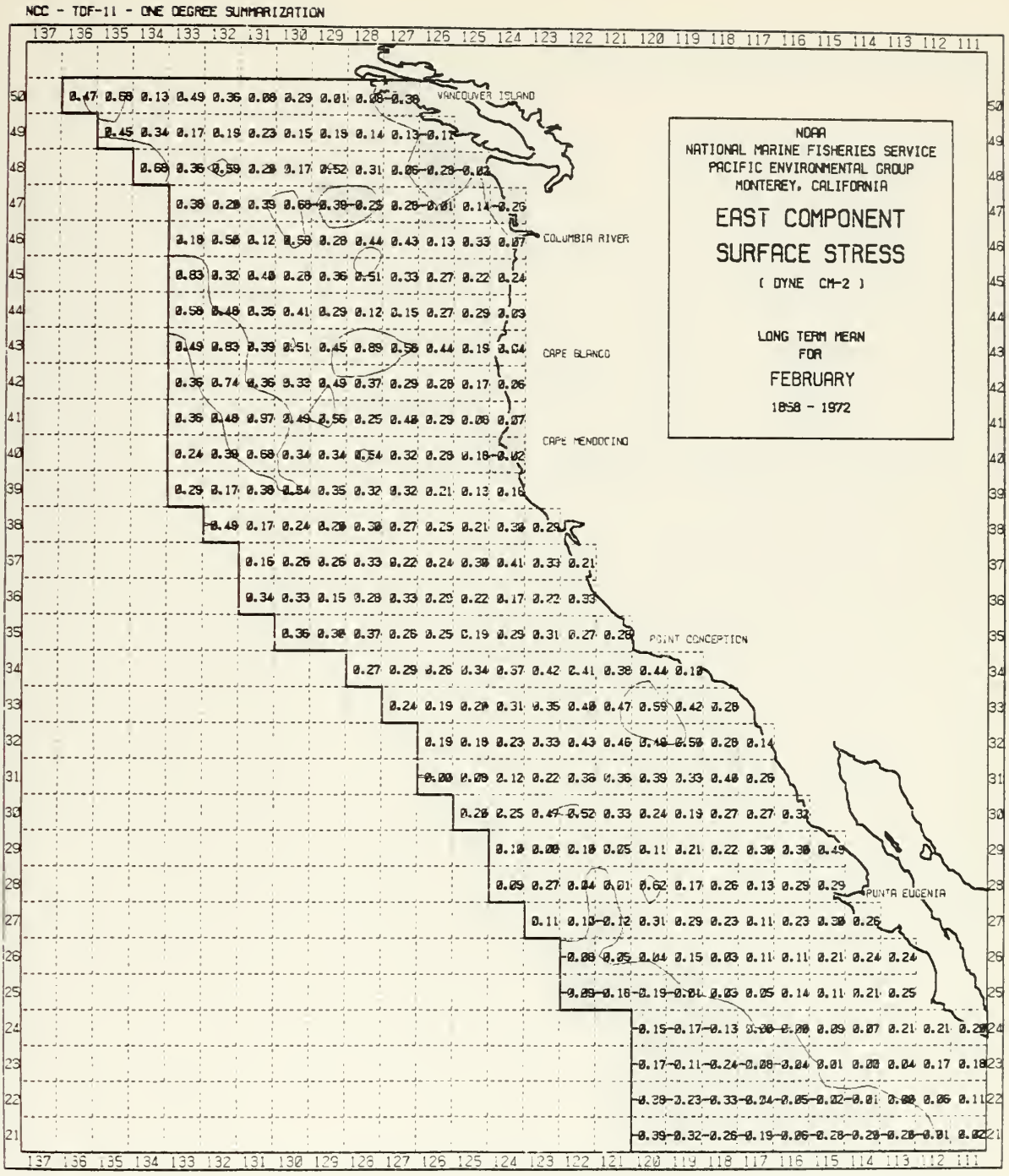


CHART 14. East component surface wind stress for FEBRUARY.

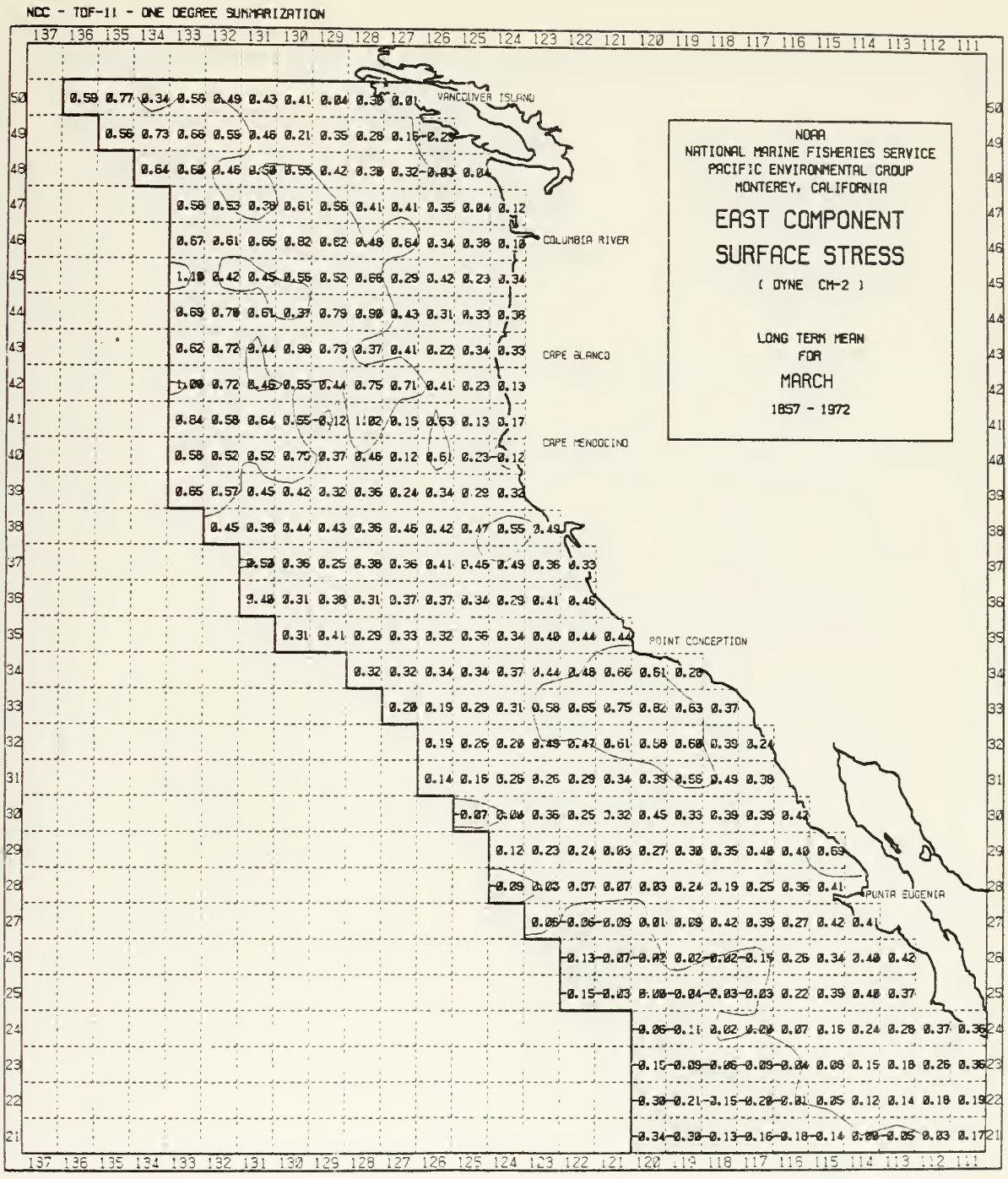


CHART 15. East component surface wind stress for MARCH.

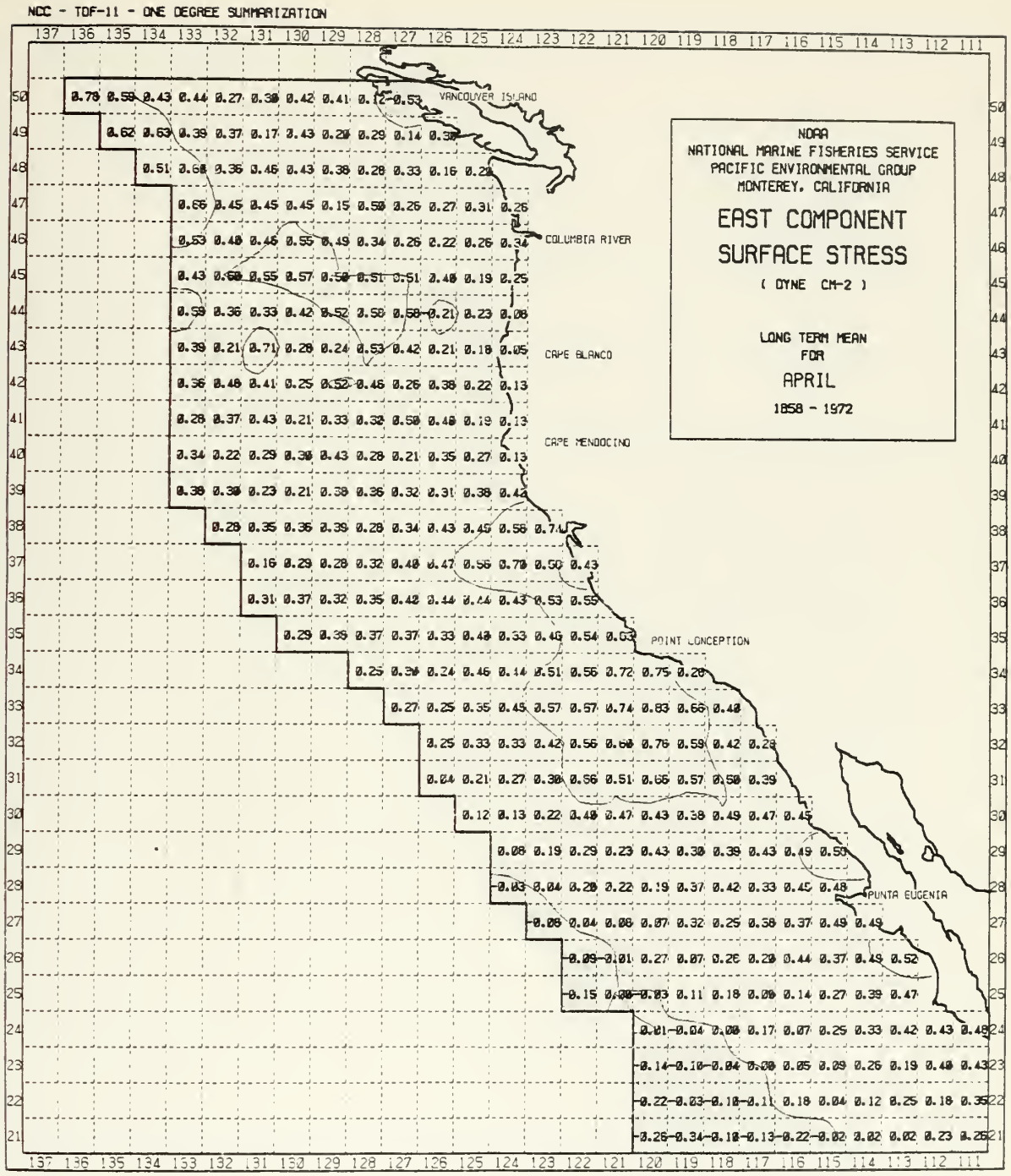


CHART 16. East component surface wind stress for APRIL.

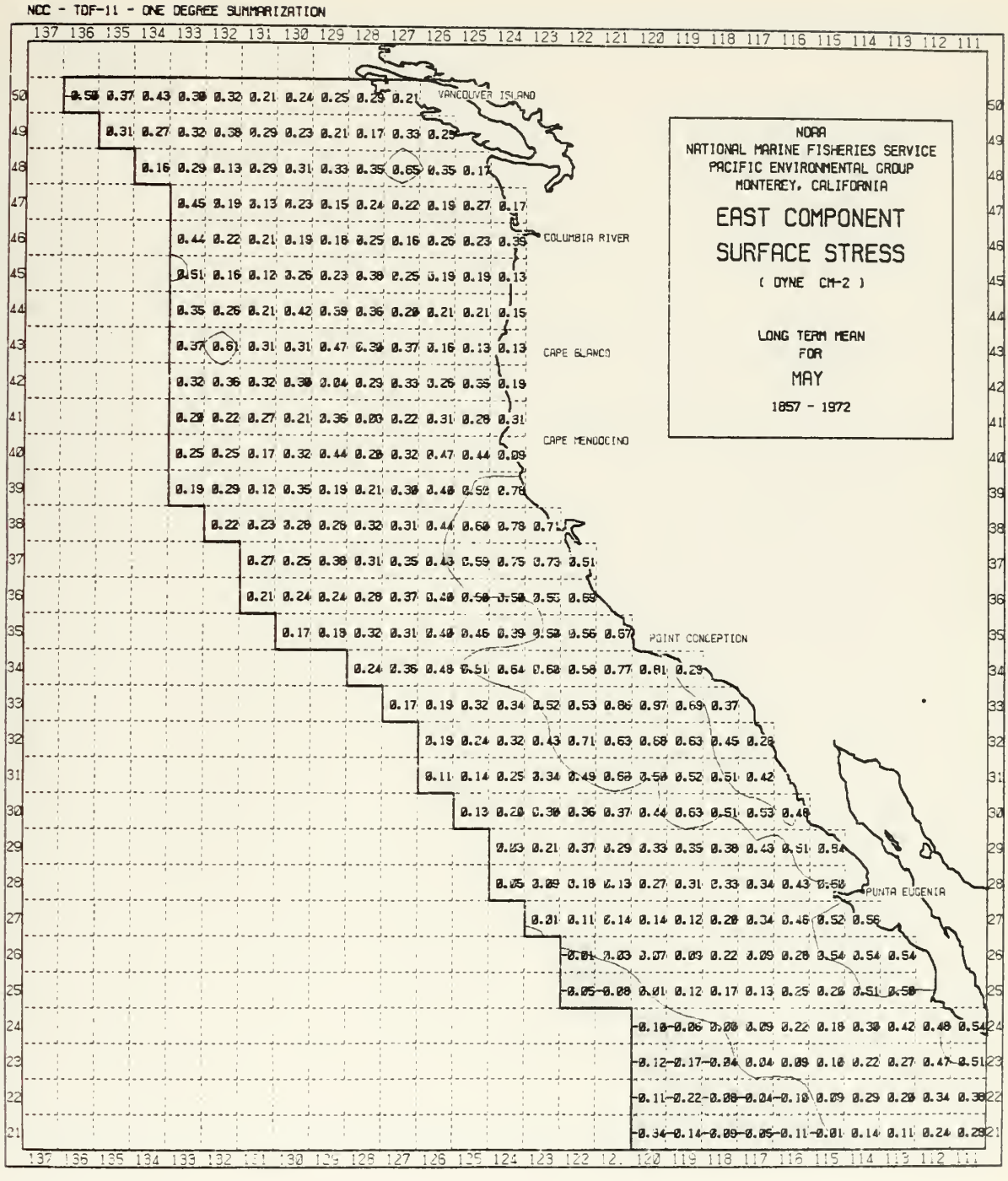


CHART 17. East component surface wind stress for MAY.

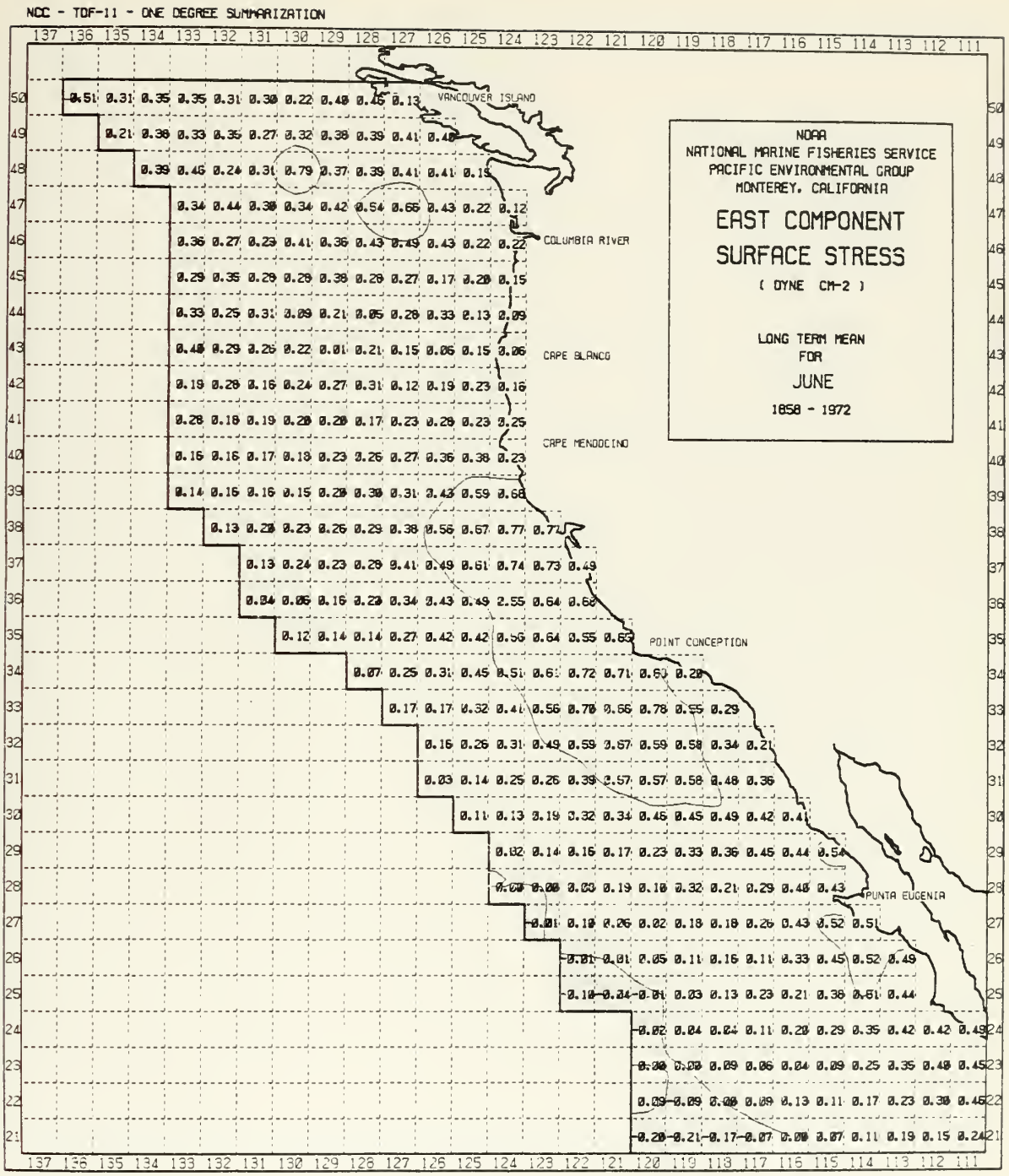


CHART 18. East component surface wind stress for JUNE.

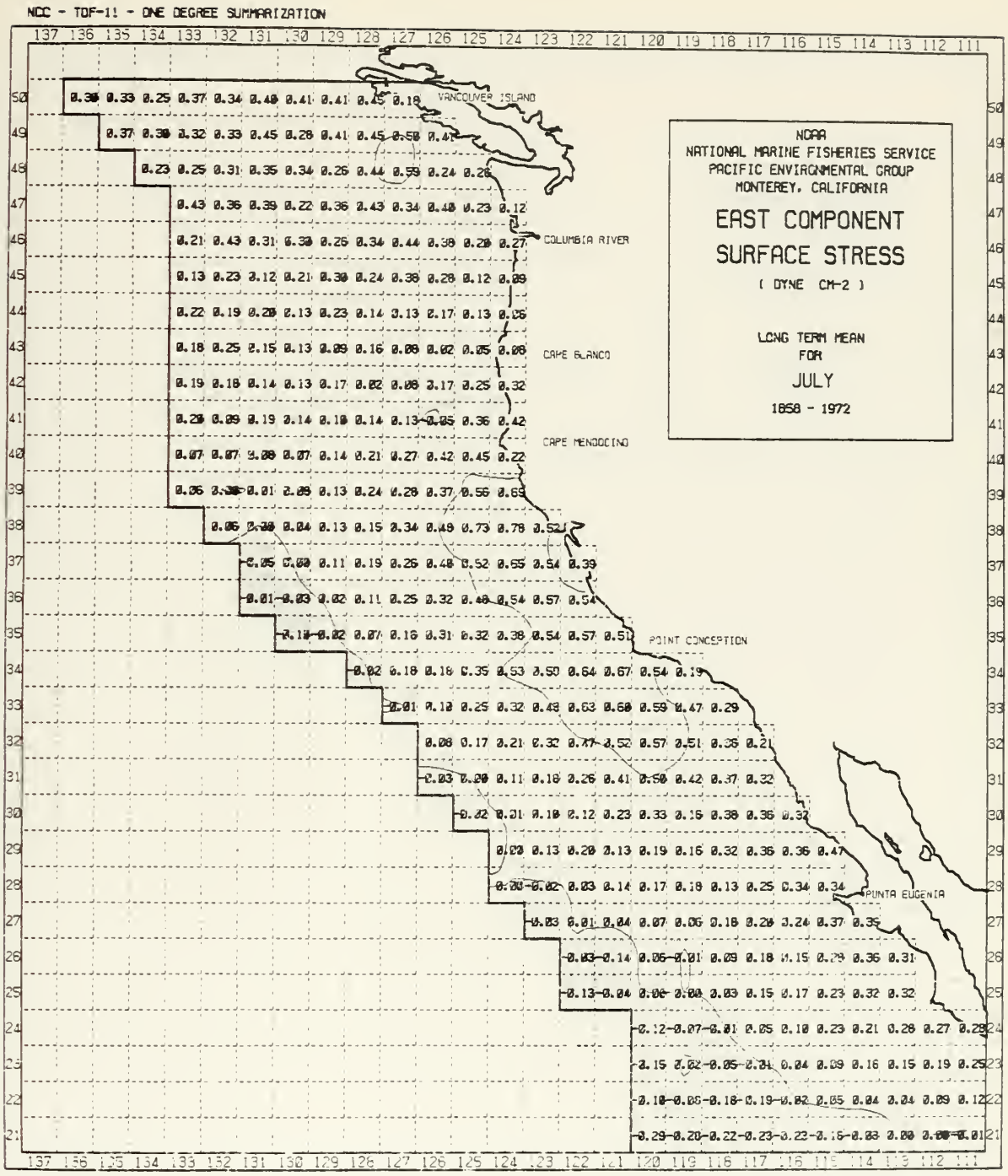


CHART 19. East component surface wind stress for JULY.

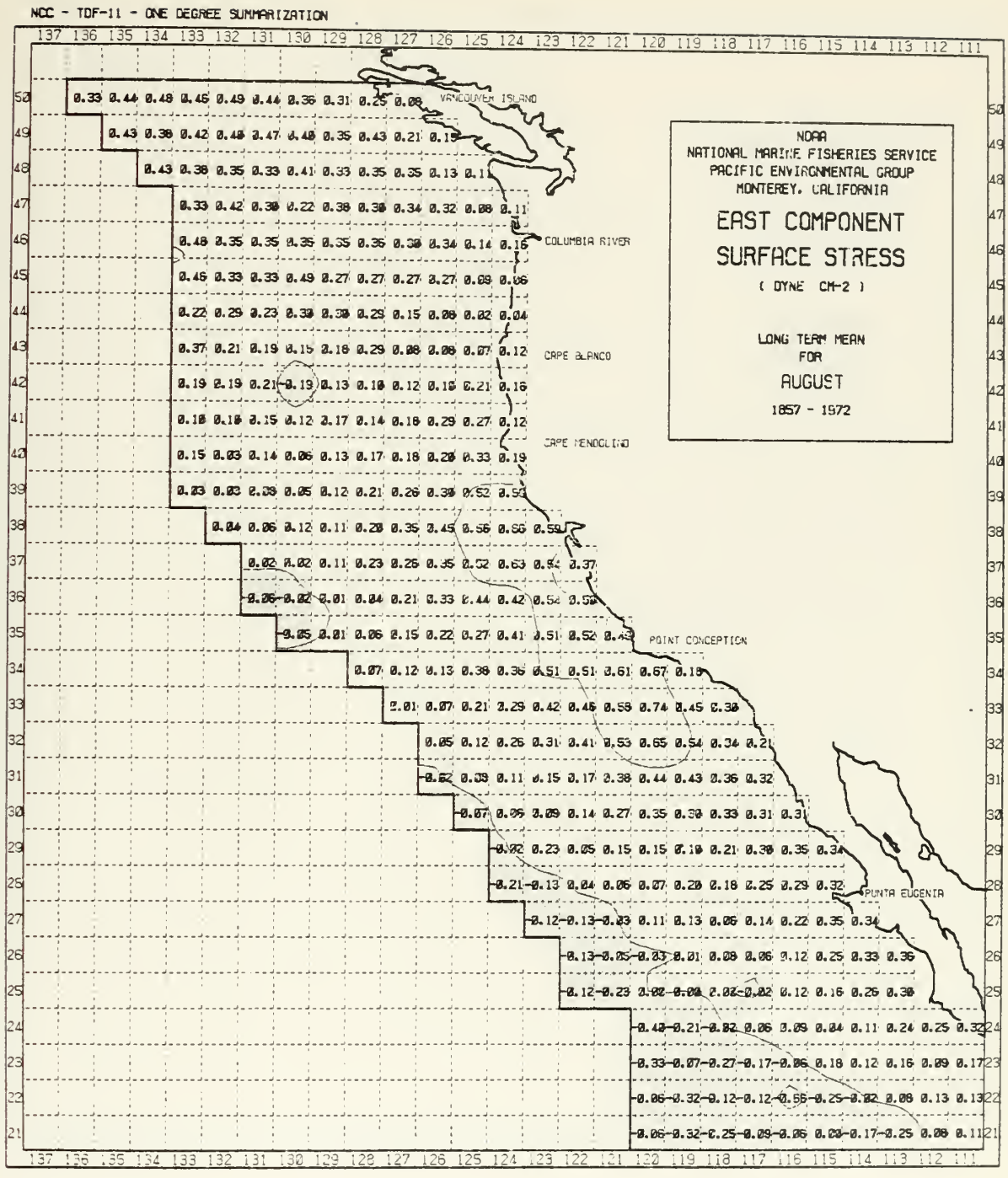


CHART 20. East component surface wind stress for AUGUST.

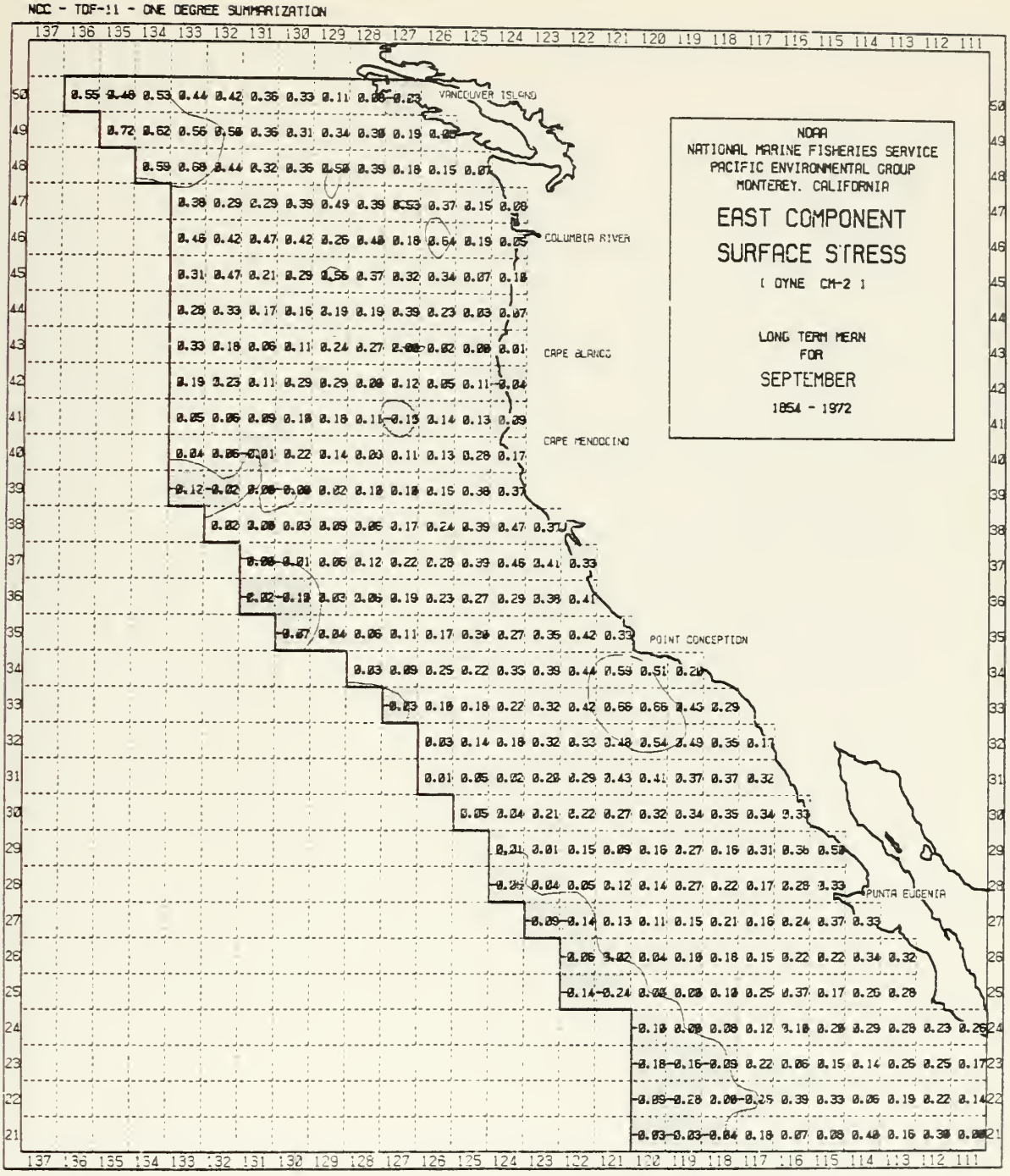


CHART 21. East component surface wind stress for SEPTEMBER.

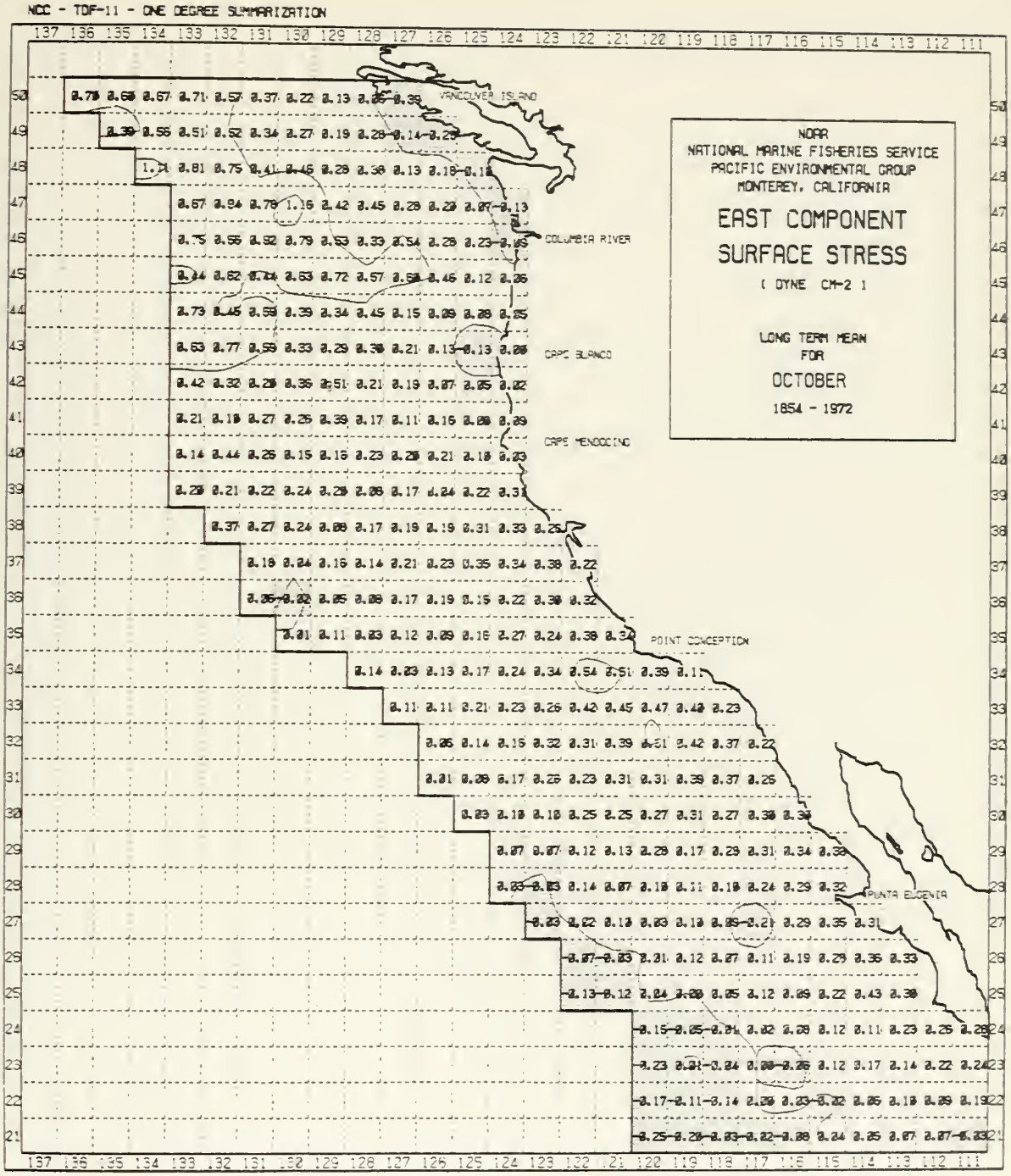


CHART 22. East component surface wind stress for OCTOBER.

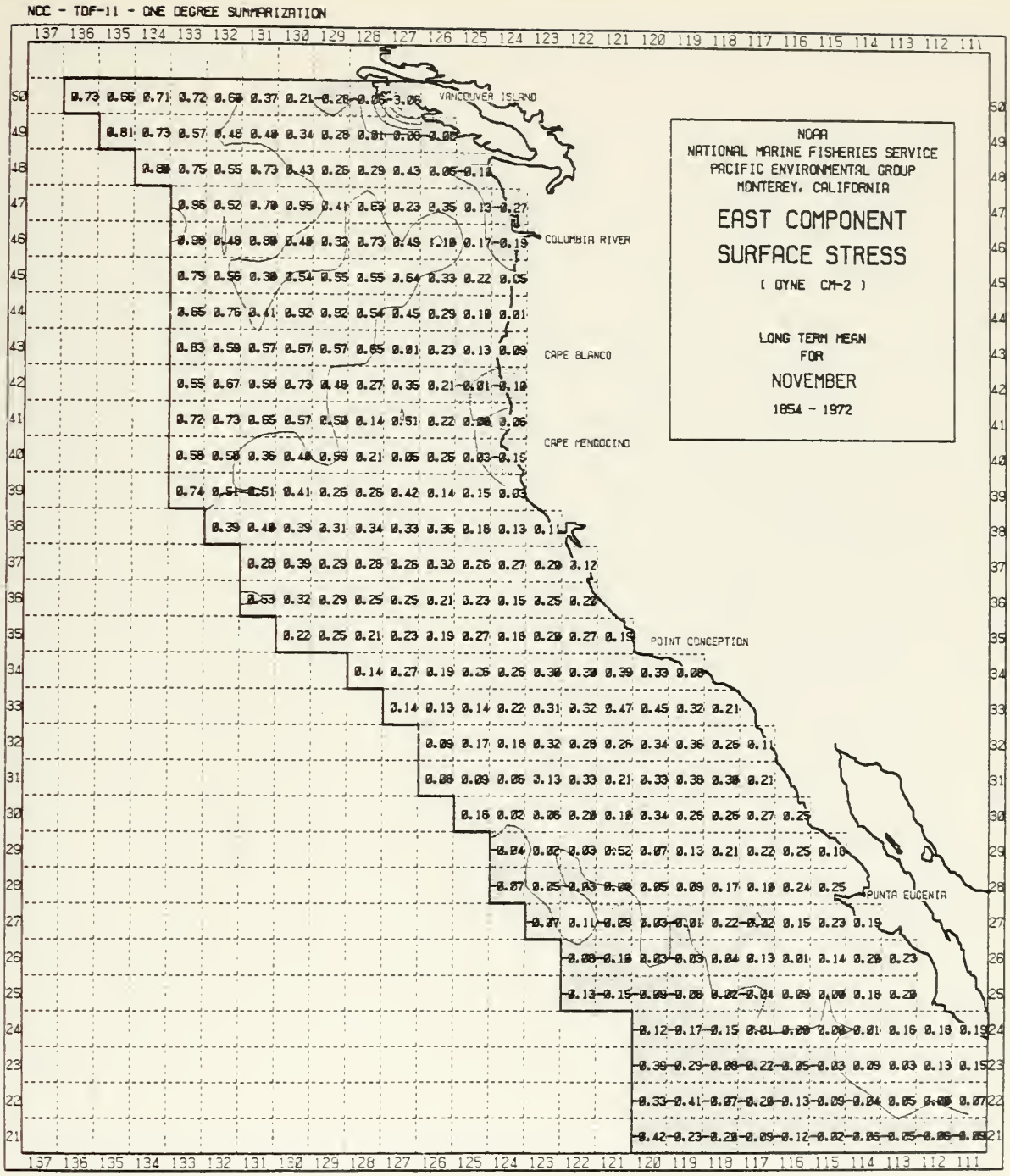


CHART 23. East component surface wind stress for NOVEMBER.

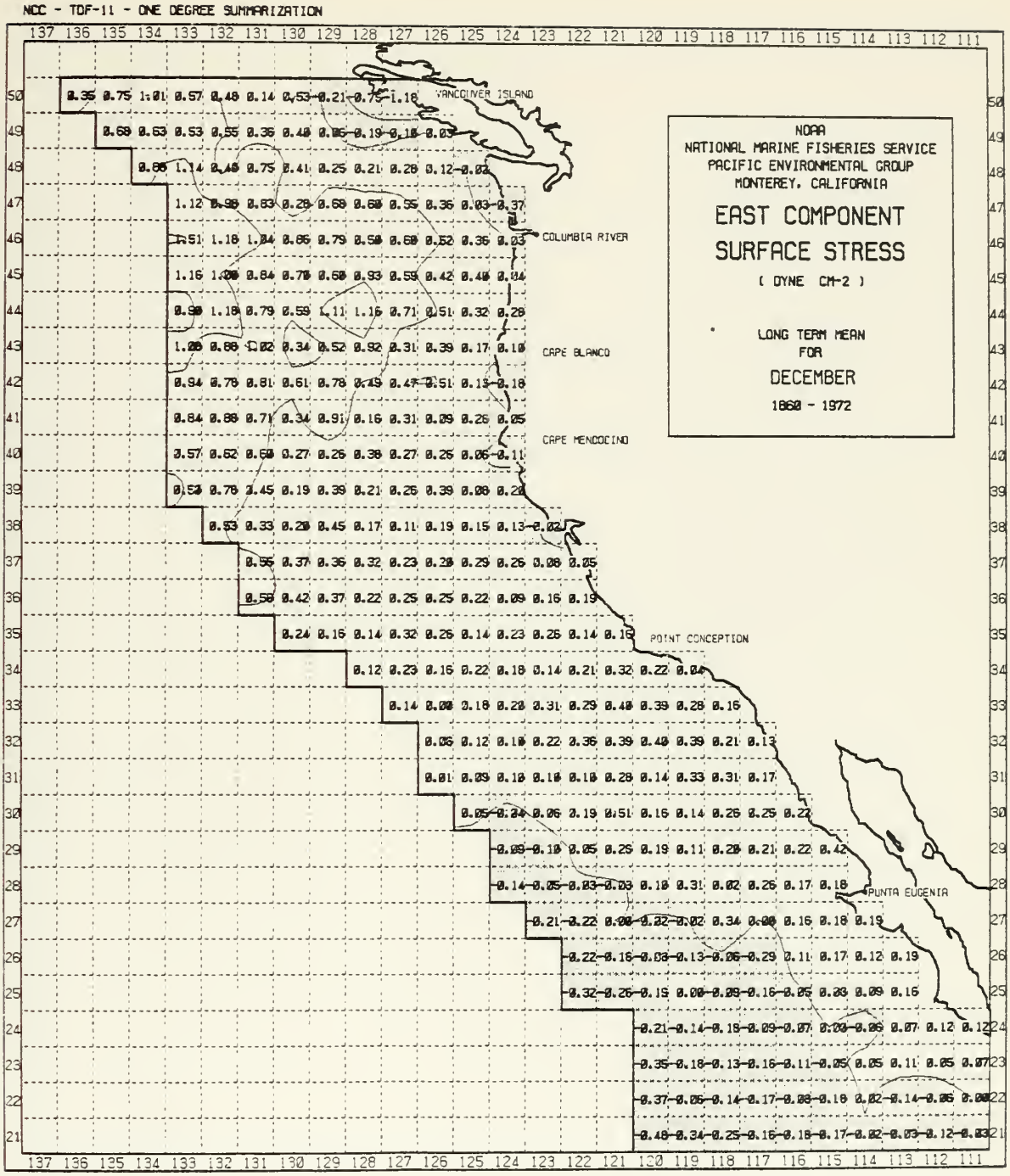


CHART 24. East component surface wind stress for DECEMBER.

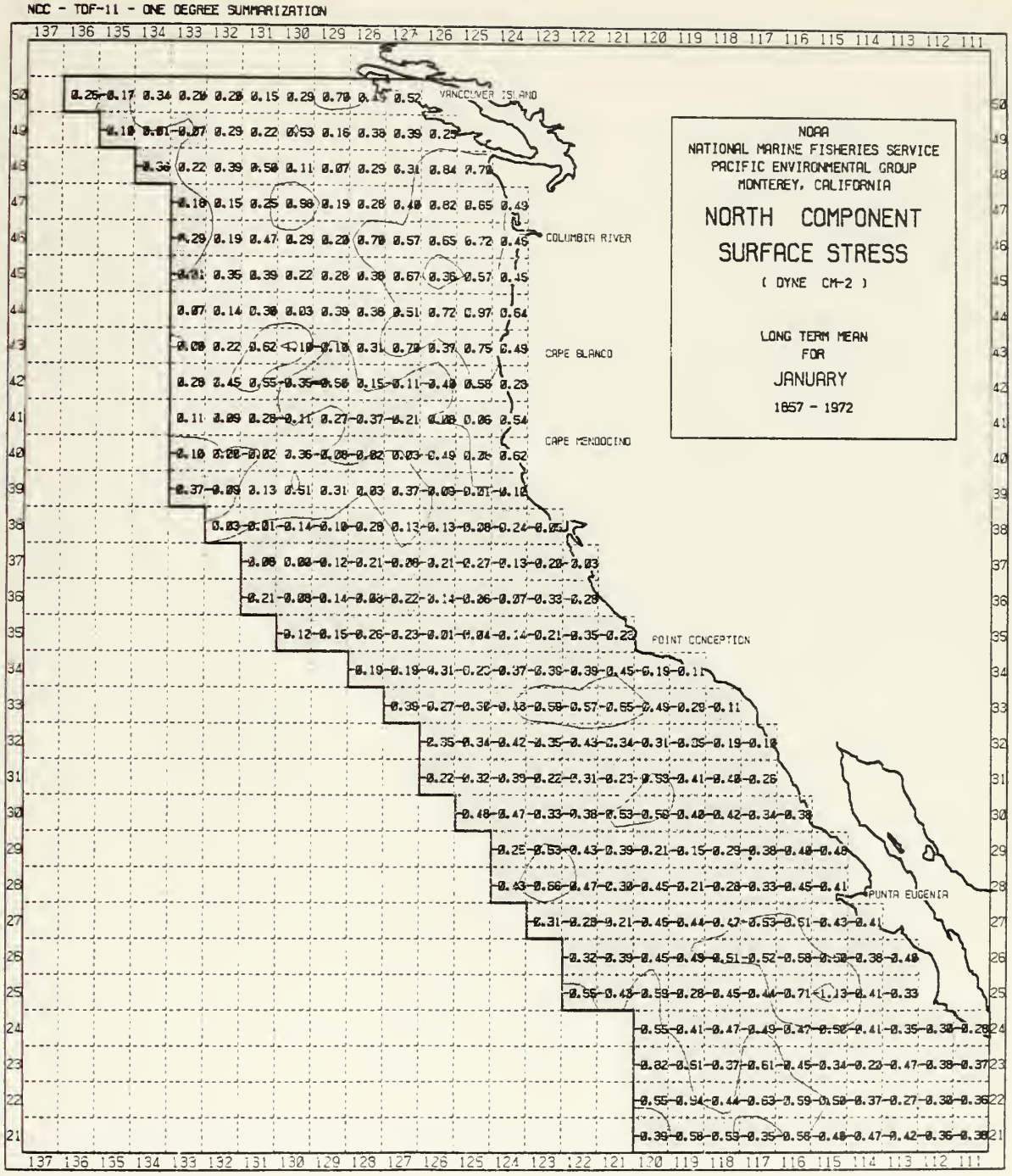


CHART 25. North component surface wind stress for JANUARY.

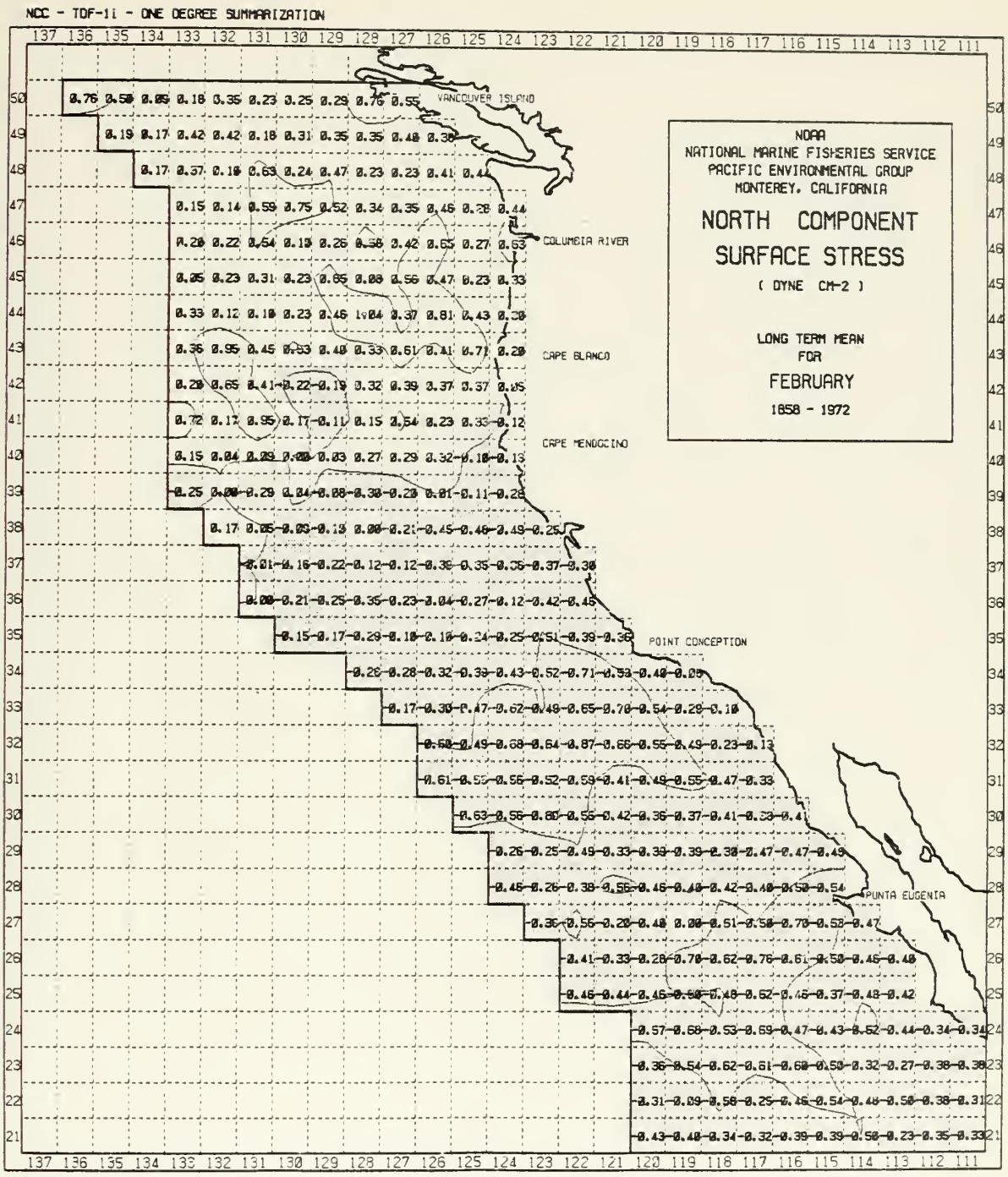


CHART 26. North component surface wind stress for FEBRUARY.

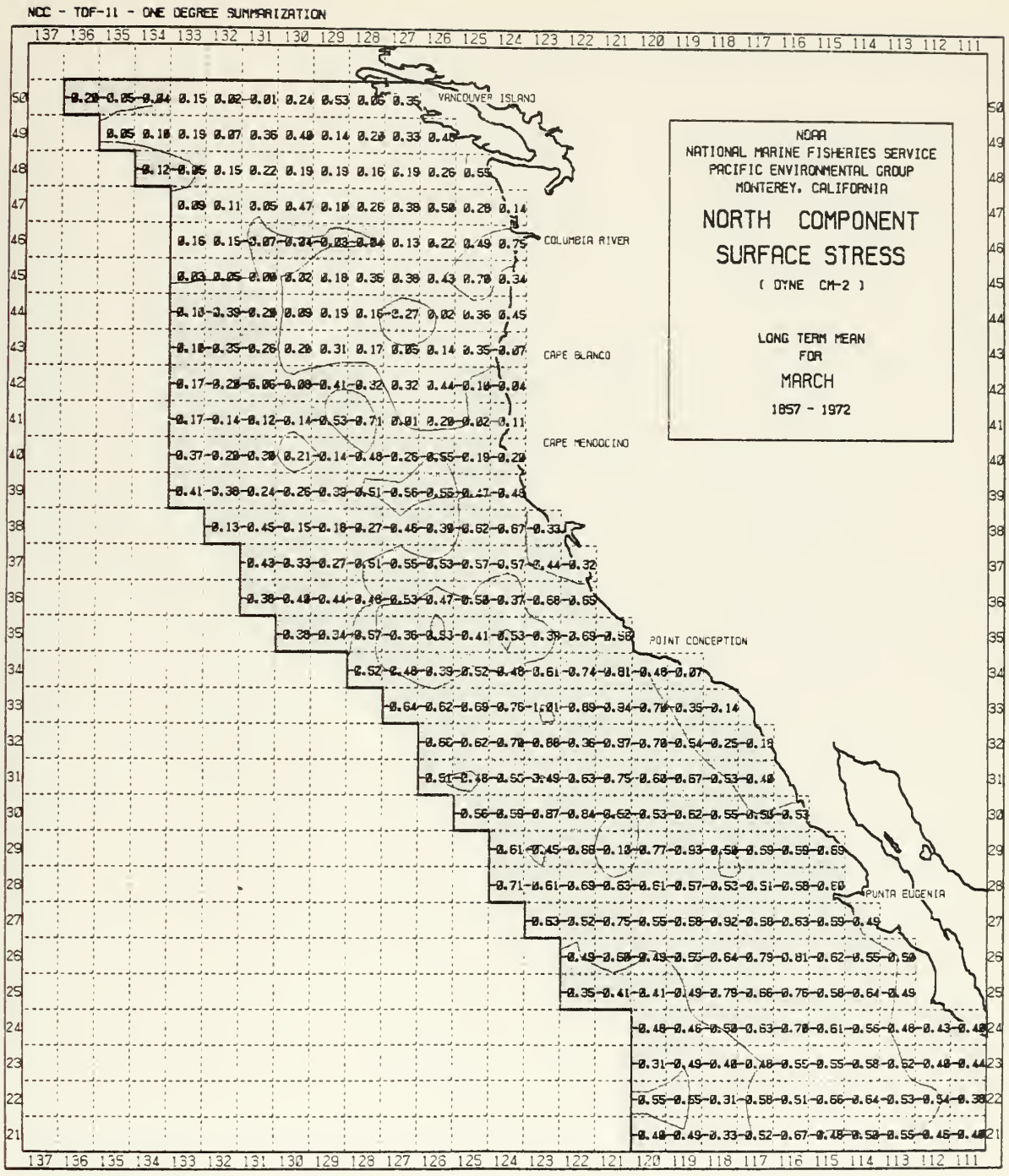


CHART 27. North component surface wind stress for MARCH.

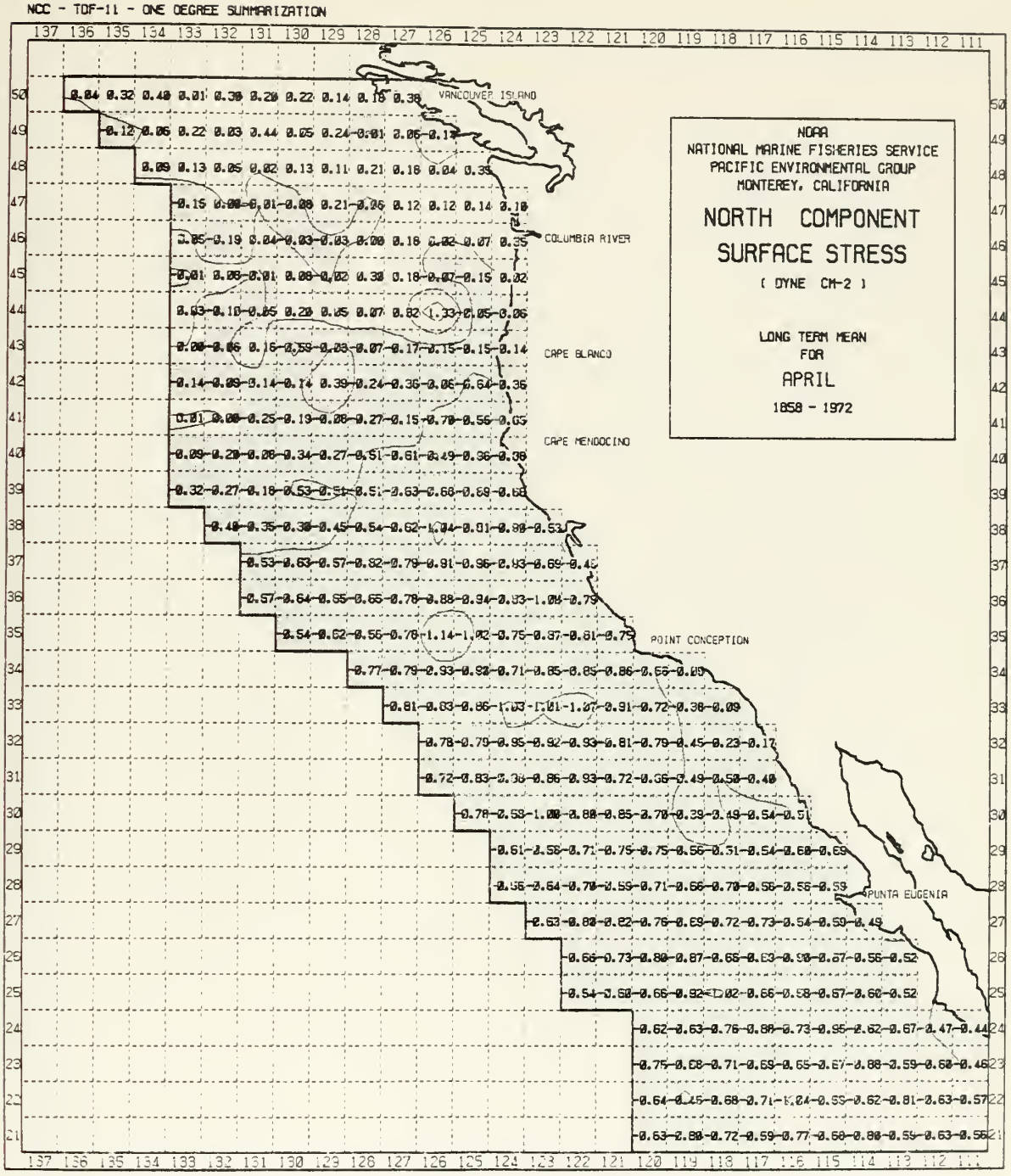


CHART 28. North component surface wind stress for APRIL.

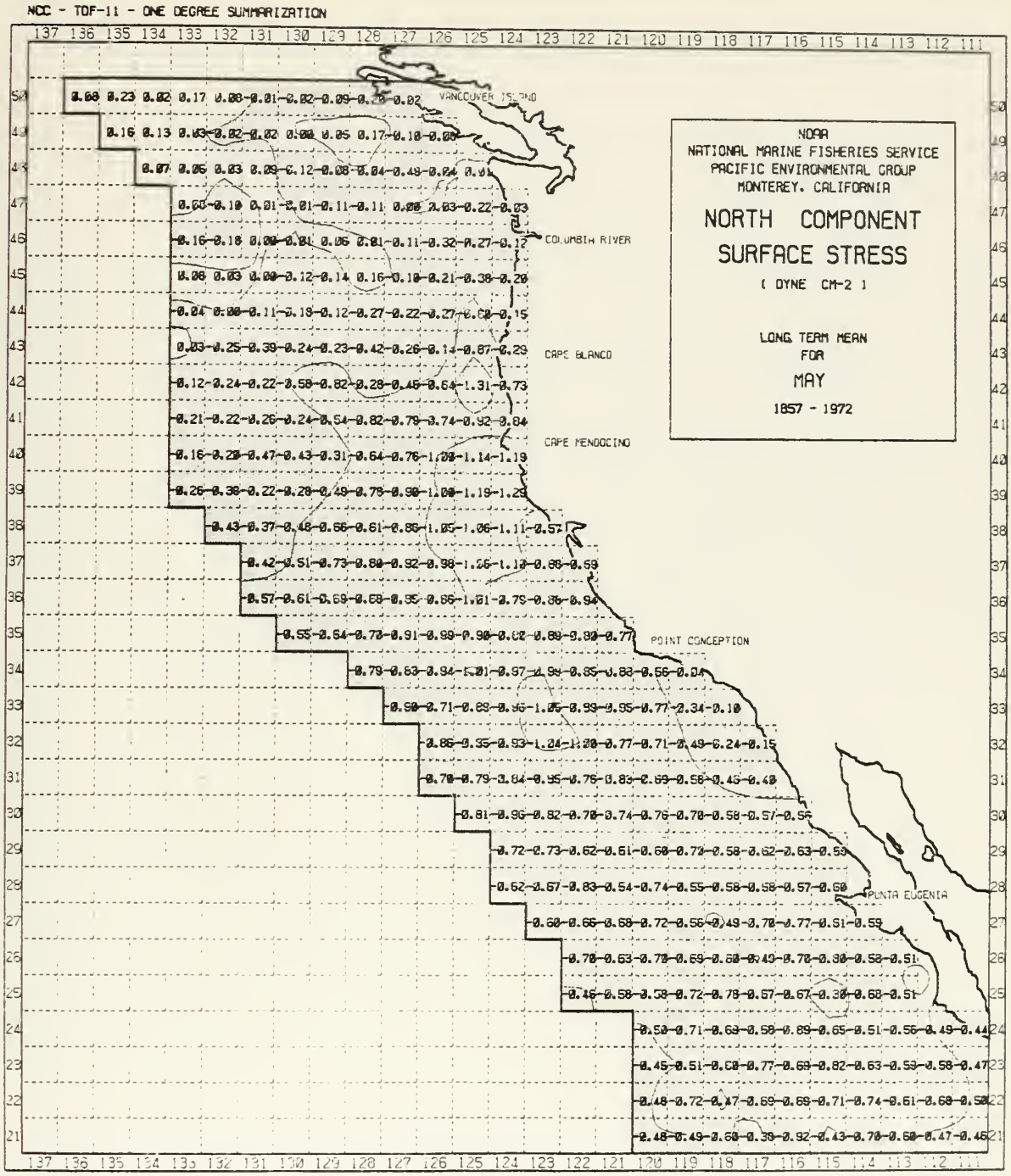


CHART 29. North component surface wind stress for MAY.

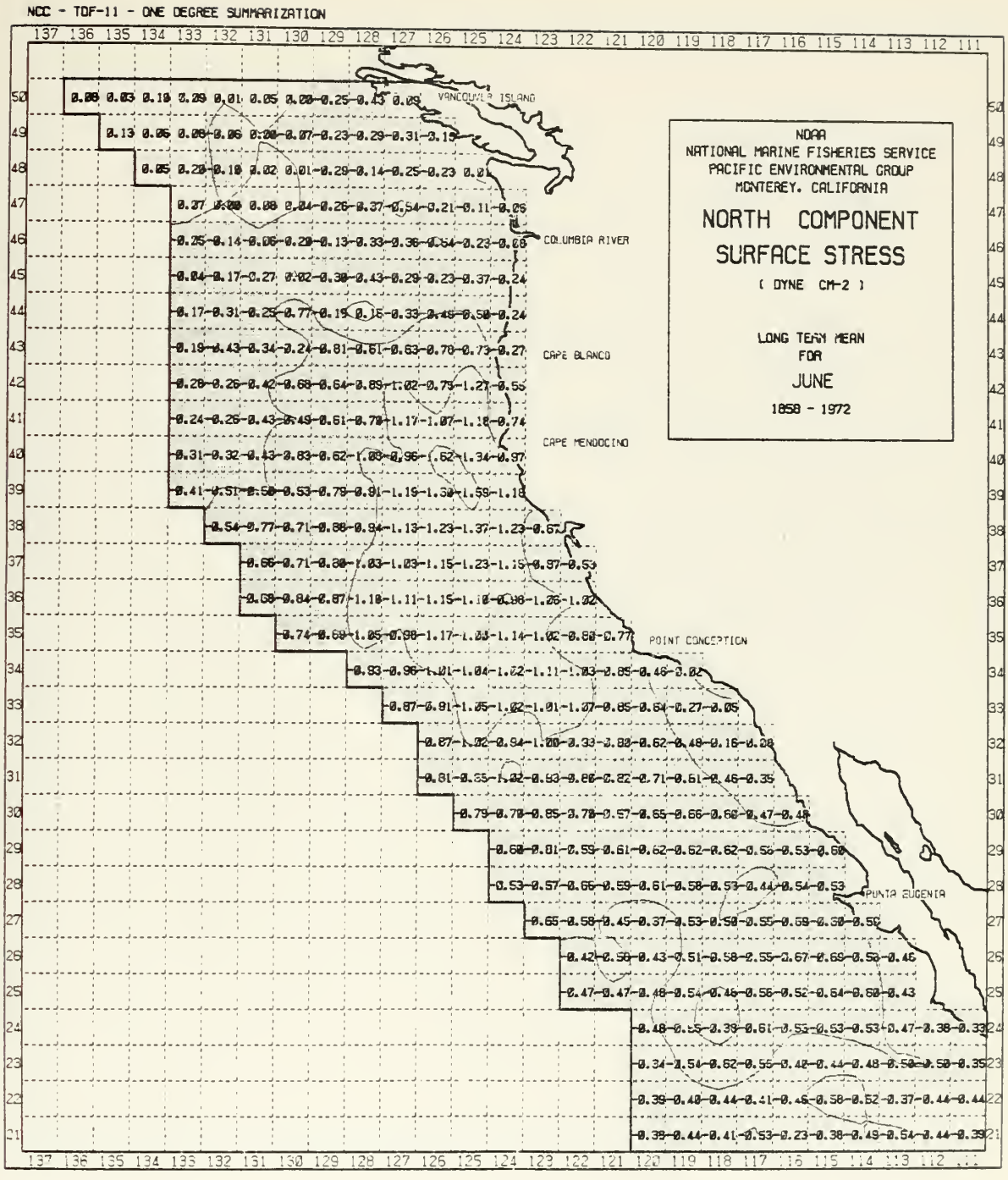


CHART 30. North component surface wind stress for JUNE.

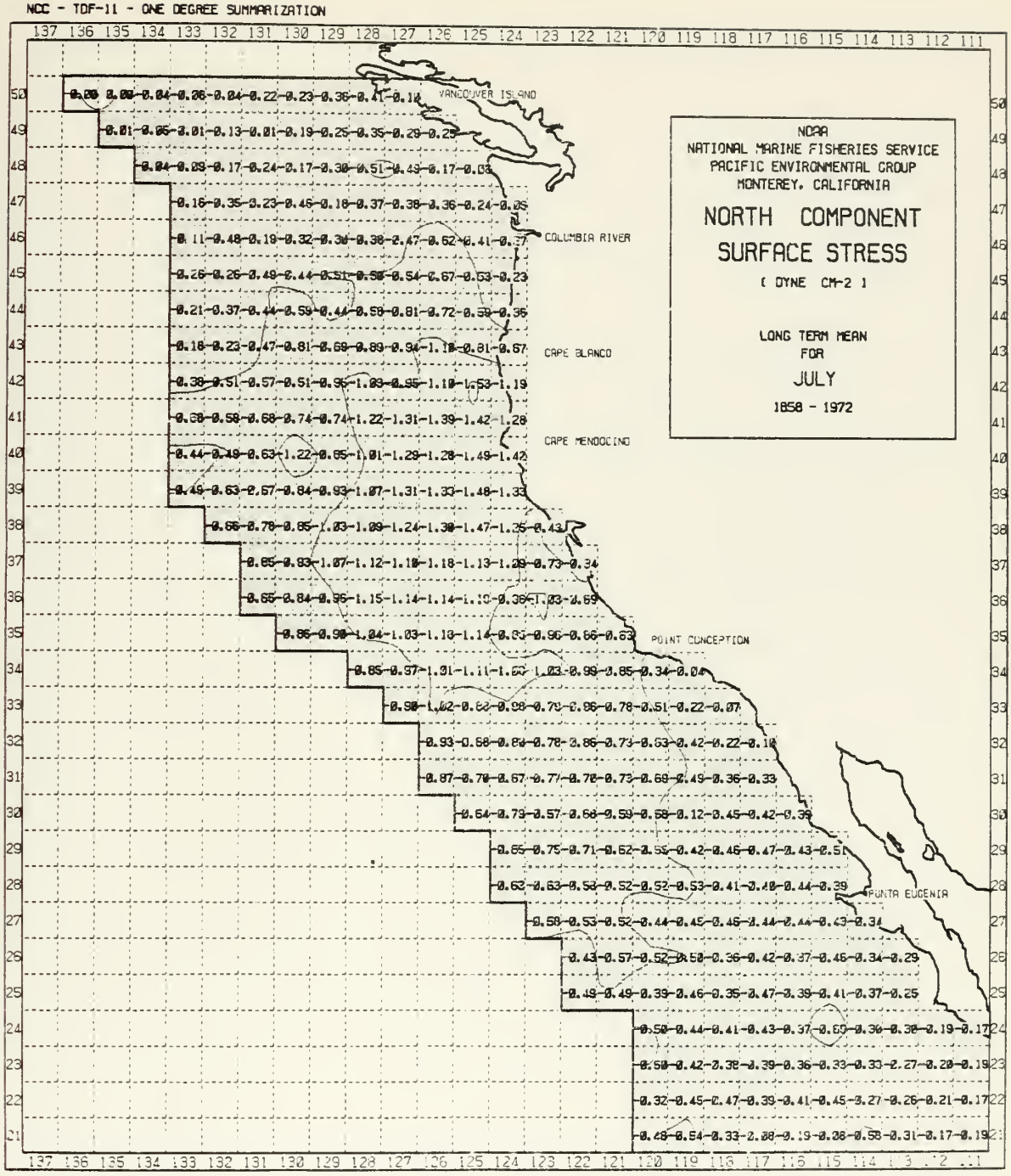


CHART 31. North component surface wind stress for JULY.

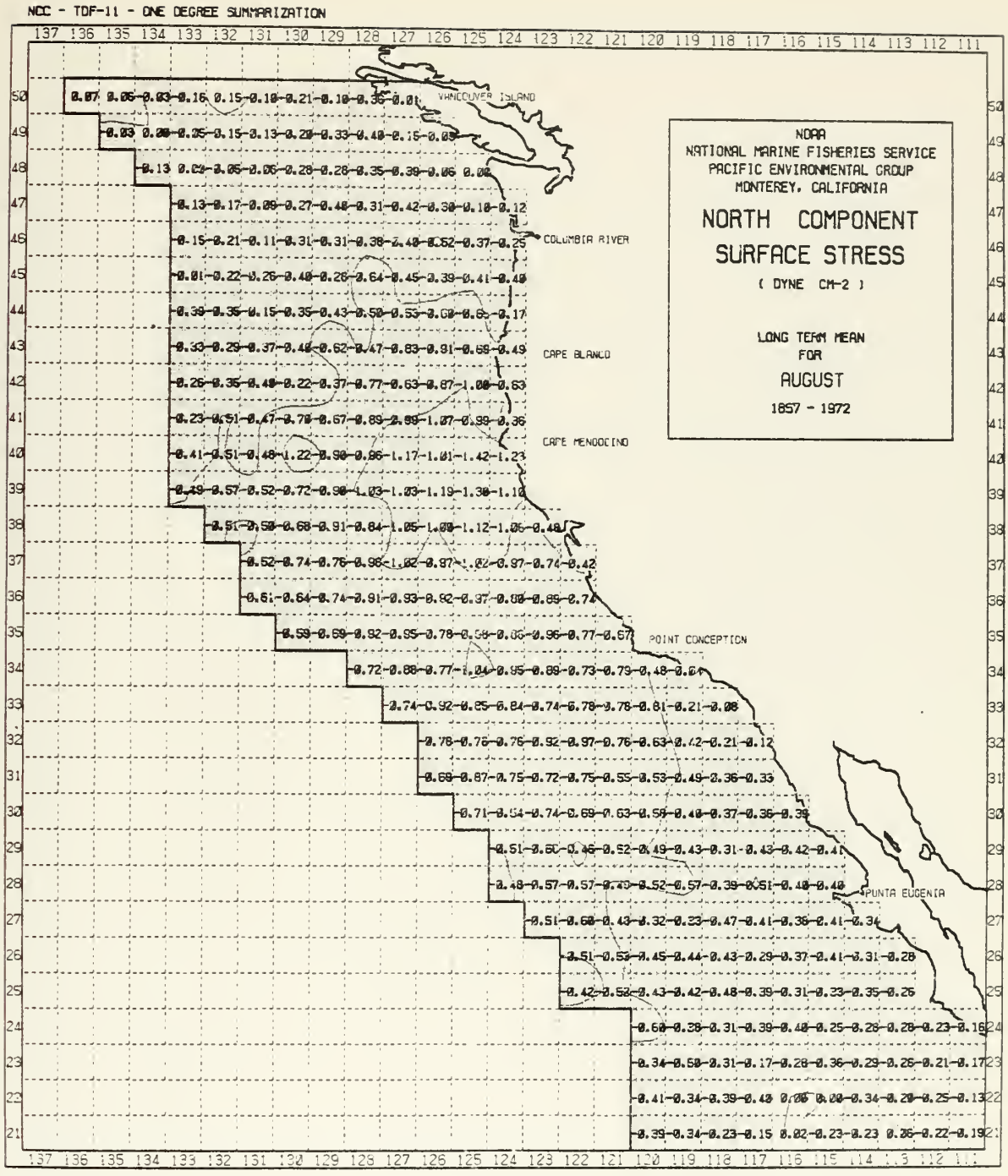


CHART 32. North component surface wind stress for AUGUST.

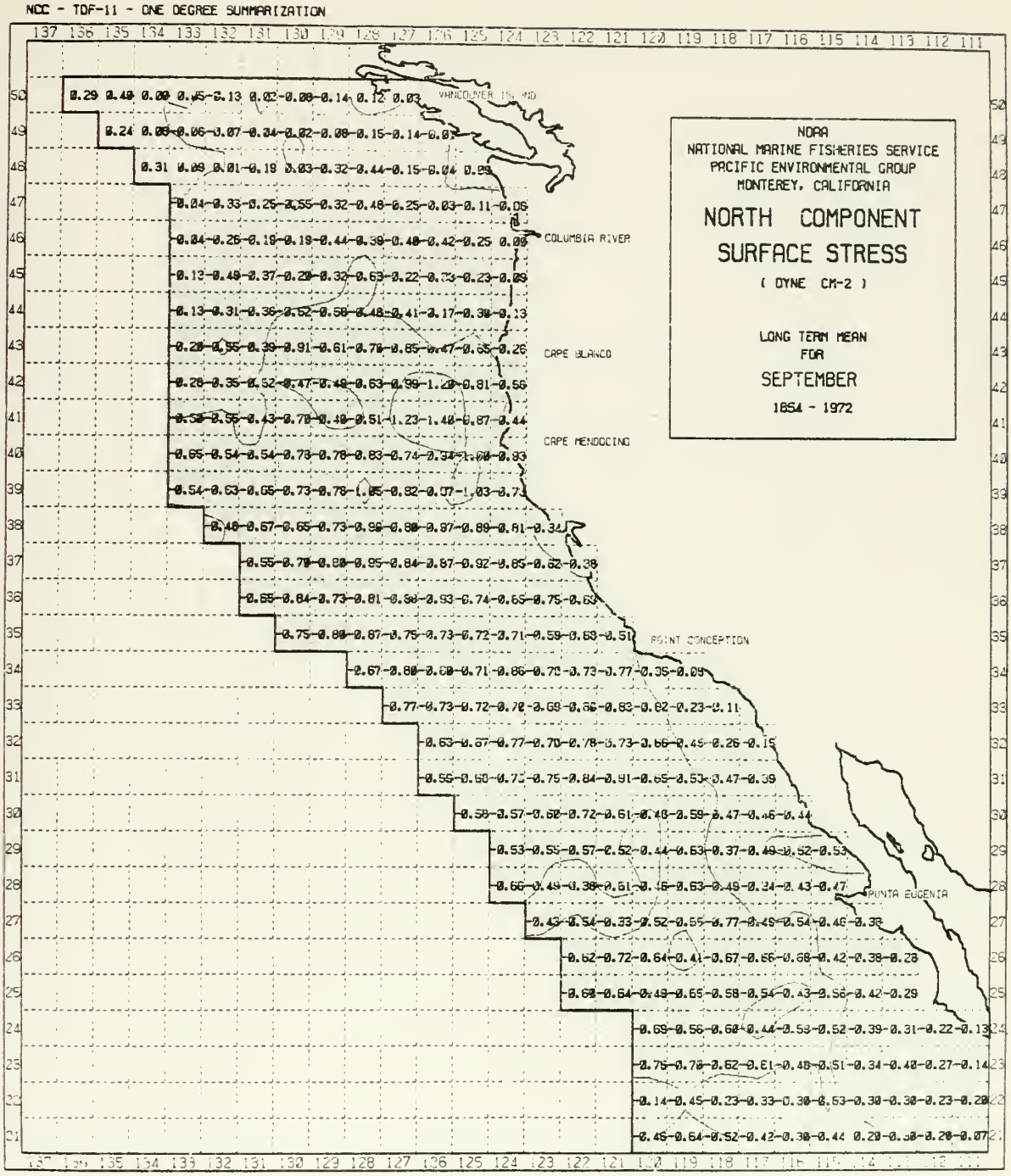


CHART 33. North component surface wind stress for SEPTEMBER.

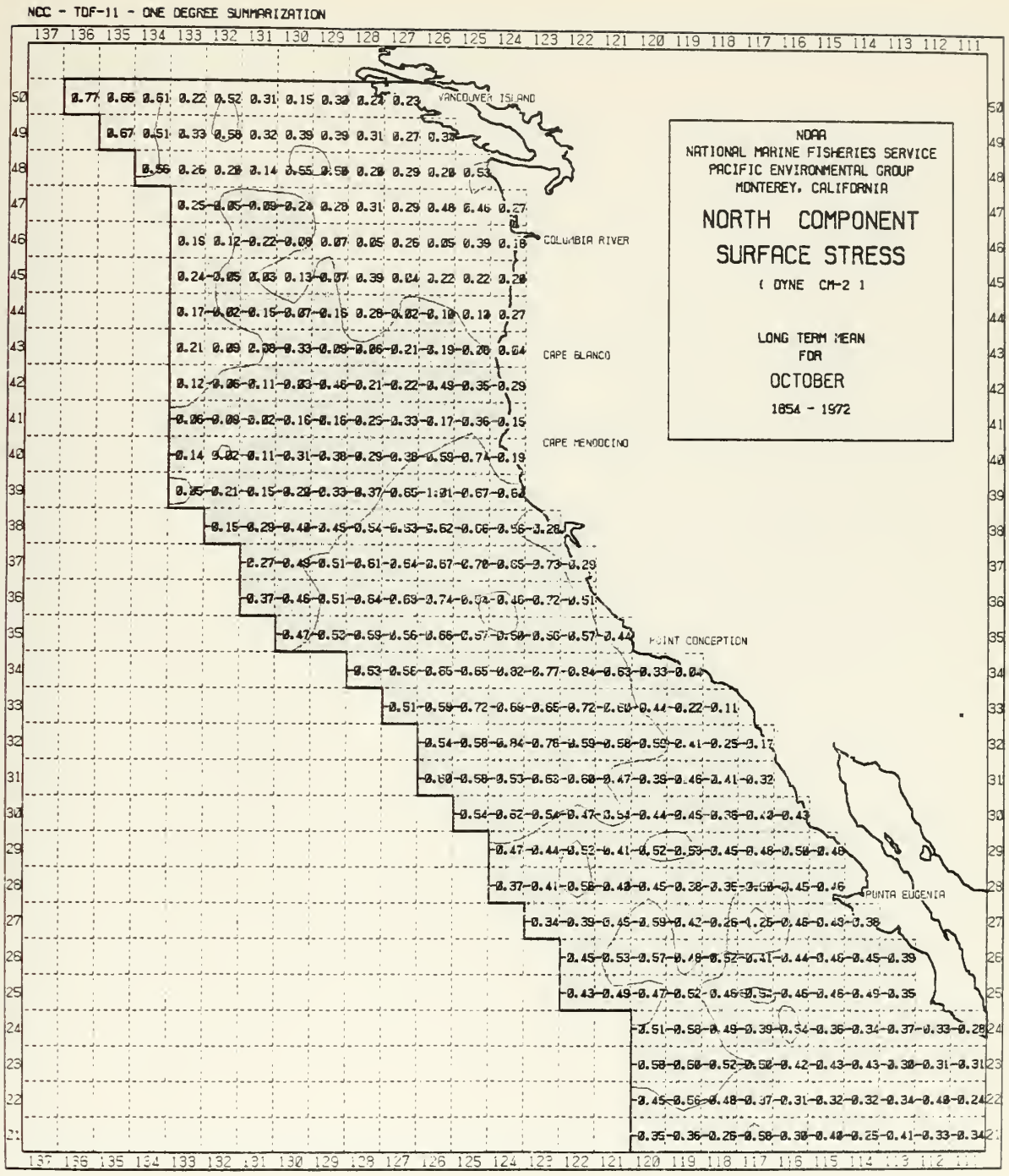


CHART 34. North component surface wind stress for OCTOBER.

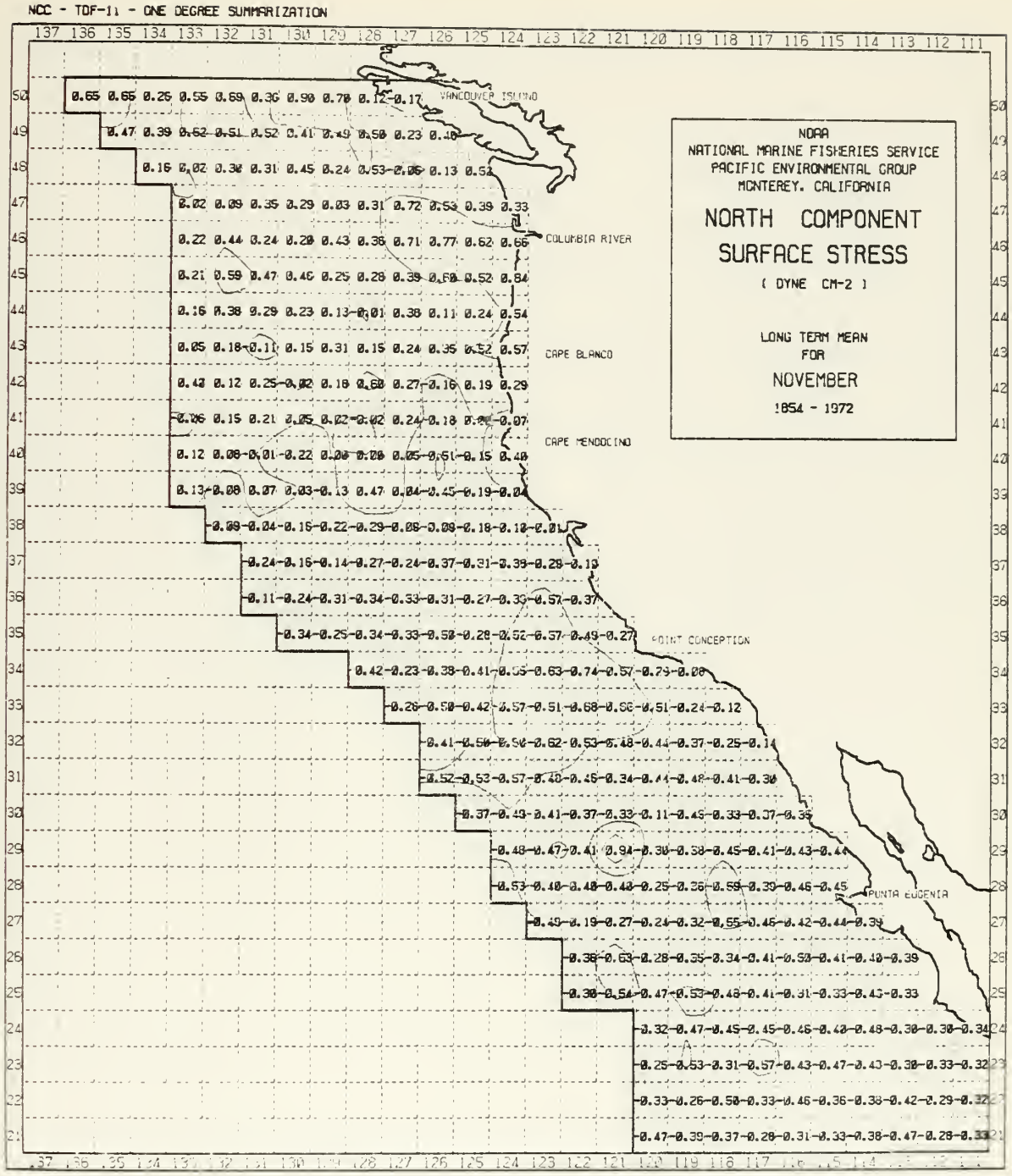


CHART 35. North component surface wind stress for NOVEMBER.

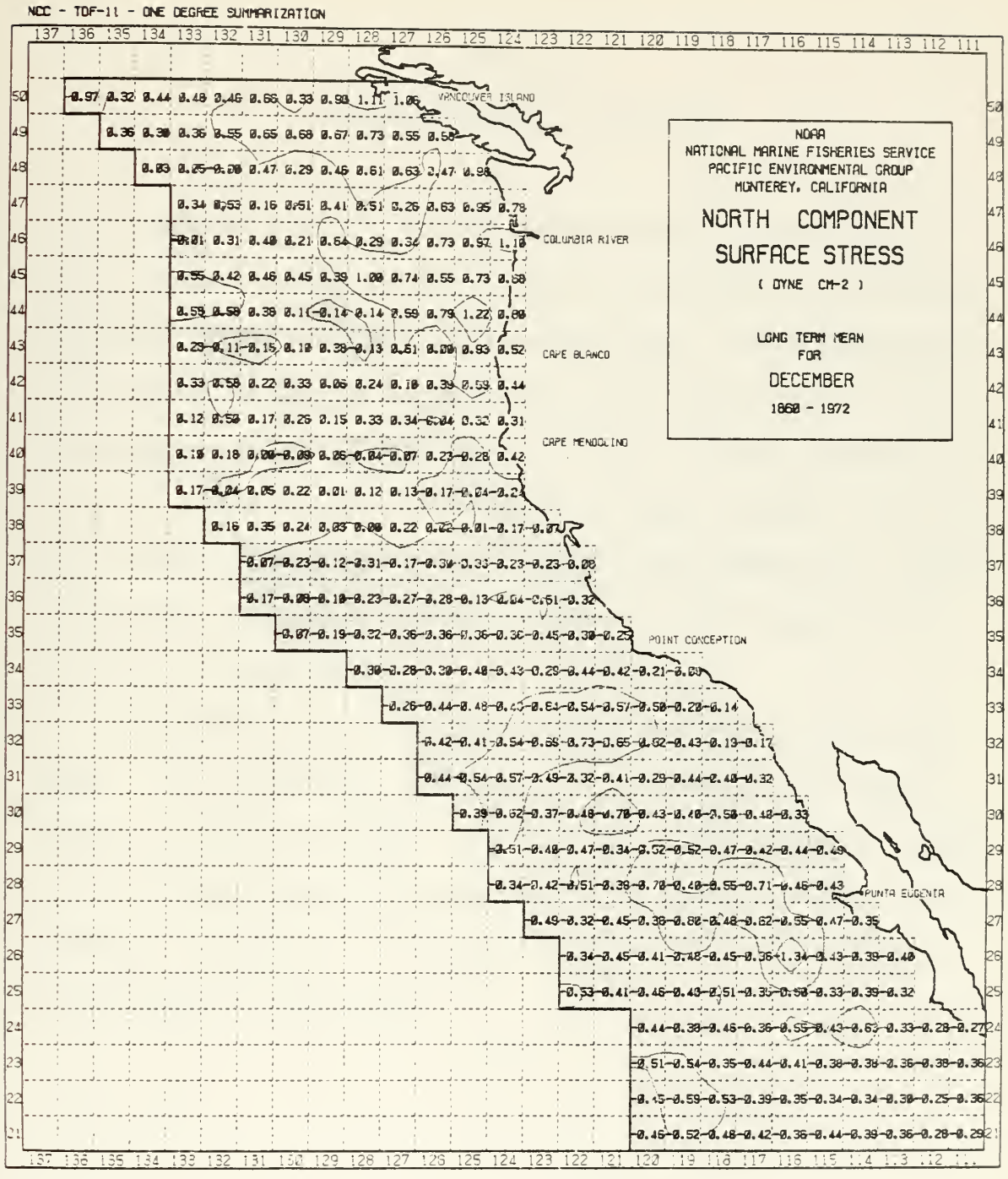


CHART 36. North component surface wind stress for DECEMBER.

APPENDIX B

STANDARD ERRORS OF THE MEANS

The following tables list the computed standard errors of the monthly means by 1-degree square area for the eastward and northward components of the resultant surface wind stress. The standard errors of the means are defined by Equation 3. Each page contains values for 30 one-degree squares blocked in groups of 10. Within each group of 10, all 1-degree squares are defined by a common latitude. The first set of values corresponds to the 1-degree square immediately adjacent to the coast. The final tabulations refer to the 1-degree square farthest from the coast.

The standard error of the mean is tabulated for each month and square. The latitude and longitude of the center of the 1-degree square is listed at the left. The first two numbers below each month are the standard errors of the means for the eastward and northward components respectively. The units are dyne cm^{-2}. The last value is the number of observations.

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
21 N 111 W	.04 .05 74	.03 .03 71	.03 .04 95	.03 .05 75	.03 .04 88	.04 .04 87	.06 .04 101	.04 .04 85	.03 .06 107	.06 .04 95	.08 .05 81	.02 .03 94
21 N 112 W	.03 .05 51	.02 .03 68	.02 .07 52	.03 .07 48	.04 .06 61	.03 .05 66	.08 .06 57	.11 .07 35	.04 .08 57	.04 .06 45	.04 .04 46	.04 .04 57
21 N 113 W	.04 .06 35	.11 .08 50	.04 .10 38	.04 .09 39	.05 .08 39	.04 .07 39	.05 .06 40	.15 .16 25	.08 .16 33	.04 .10 38	.08 .1[illegible] 37	.05 .05 58
21 N 114 W	.04 .[illegible]8 41	.10 .[illegible]7 39	.04 .[illegible]8 33	.07 .17 22	.05 .11 24	.08 .1[illegible] 21	.08 .24 32	.15 .16 18	.35 .28 23	.07 .04 28	.03 .07 32	.05 .08 42
21 N 115 W	.16 .09 29	.09 .10 26	.08 .07 35	.08 .13 18	.[illegible]5 .[illegible]6 23	.06 .08 23	.03 .02 31	.[illegible]5 .[illegible]8 17	.08 .11 19	.[illegible]7 .11 20	.03 .08 27	.04 .06 40
21 N 116 W	.15 .12 26	.[illegible]4 .06 28	.07 .09 32	.09 .14 15	.10 .14 13	.07 .07 14	.08 .12 26	.14 .16 15	.20 .15 18	.08 .06 18	.04 .09 18	.03 .06 25
21 N 117 W	.06 .09 38	.[illegible]3 .06 26	.[illegible]7 .09 25	.11 .09 19	.05 .10 12	.05 .09 22	.16 .08 15	.13 .19 21	.14 .10 23	.09 .09 22	.02 .06 24	.04 .07 26
21 N 118 W	.09 .08 34	.10 .05 21	.06 .07 24	.14 .14 18	.08 .12 19	.08 .06 19	.12 .09 22	.19 .24 18	.11 .15 21	.03 .03 38	.05 .08 23	.05 .08 34
21 N 119 W	.09 .08 24	.07 .08 26	.06 .09 30	.11 .11 27	.04 .10 19	.09 .06 27	.16 .13 21	.11 .06 22	.08 .18 30	.[illegible]4 .05 33	.04 .06 43	.07 .07 37
21 N 120 W	.[illegible]9 .10 24	.[illegible]5 .[illegible]6 34	.[illegible]6 .[illegible]5 30	.05 .[illegible]9 28	.[illegible]6 .07 38	.[illegible]6 .05 31	.12 .07 39	.05 .09 34	.07 .07 37	.09 .13 40	.05 .05 40	.08 .06 27
22 N 111 W	.02 .04 128	.03 .03 101	.02 .03 164	.04 .05 122	.02 .03 169	.03 .03 150	.03 .02 143	.[illegible]3 .03 150	.07 .07 161	.[illegible]3 .03 160	.02 .02 150	.03 .05 120
22 N 112 W	.02 .04 73	.[illegible]2 .04 60	.[illegible]3 .05 78	.06 .06 80	.03 .05 99	.03 .04 117	.02 .03 105	.15 .08 116	.04 .04 110	.04 .04 100	.02 .03 90	.03 .05 69
22 N 113 W	.03 .04 51	.04 .11 47	.03 .06 67	.05 .12 57	.03 .07 67	.03 .05 75	.03 .03 84	.04 .05 68	.09 .11 7[illegible]	.03 .04 73	.03 .05 77	.06 .04 57
22 N 114 W	.03 .06 34	.04 .09 42	.04 .09 45	.02 .07 52	.05 .08 53	.03 .07 50	.04 .04 61	.09 .[illegible]7 35	.11 .[illegible]2 59	.03 .[illegible]4 45	.04 .05 38	.03 .04 66
22 N 115 W	.07 .[illegible]9 37	.10 .14 36	.06 .[illegible]9 54	.04 .11 38	.05 .09 36	.03 .09 37	.05 .07 32	.19 .18 34	.09 .07 31	.07 .07 34	.04 .07 22	.07 .06 30
22 N 116 W	.06 .10 24	.[illegible]5 .10 30	.[illegible]4 .12 32	.11 .19 15	.[illegible]5 .[illegible]1 32	.03 .09 30	.03 .07 26	.32 .29 17	.26 .29 24	.[illegible]8 .06 21	.04 .07 32	.07 .06 33
22 N 117 W	.05 .11 33	.05 .09 29	.08 .10 34	.06 .11 23	.07 .14 19	.08 .12 15	.07 .10 21	.13 .27 17	.12 .10 17	.05 .06 25	.06 .07 26	.05 .05 27
22 N 118 W	.06 .09 28	.1[illegible] .11 27	.04 .06 33	.10 .13 21	.08 .11 17	.05 .12 18	.15 .14 15	.05 .12 17	.21 .17 17	.05 .07 19	.06 .09 23	.05 .07 34
22 N 119 W	.07 .[illegible]8 31	.07 .27 24	.08 .[illegible]8 24	.07 .[illegible]5 25	.10 .1[illegible] 19	.04 .[illegible]6 24	.06 .12 19	.12 .10 26	.13 .18 21	.10 .07 21	.12 .07 26	.05 .09 32
22 N 120 W	.07 .08 33	.08 .10 26	.07 .06 31	.09 .08 23	.04 .07 38	.17 .14 17	.08 .1[illegible] 20	.14 .13 19	.11 .14 22	.07 .07 23	.06 .06 34	.07 .08 20
23 N 111 W	.01 .1[illegible] 1059	.01 .1[illegible] 1030	.01 .1[illegible] 1125	.01 .1[illegible] 1159	.01 .1[illegible] 1241	.01 .0[illegible] 1126	.01 0.06 1178	.02 .03 1152	.01 .01 1132	.01 .01 1199	.01 .01 1083	.03 .01 986
23 N 112 W	.02 .02 155	.02 .03 124	.02 .03 146	.03 .04 135	.03 .03 192	.02 .03 245	.02 .01 203	.04 .03 181	.03 .03 206	.02 .02 187	.02 .03 154	.03 .05 140
23 N 113 W	.03 .09 47	.03 .04 48	.06 .06 47	.03 .06 54	.03 .05 78	.05 .05 73	.02 .03 76	.04 .05 72	.04 .10 79	.03 .04 75	.02 .04 70	.06 .11 47
23 N 114 W	.04 .04 45	.02 .05 44	.04 .08 49	.05 .13 59	.03 .06 79	.03 .05 71	.02 .03 84	.04 .04 96	.05 .06 74	.04 .06 73	.03 .05 59	.06 .09 47
23 N 115 W	.11 .04 42	.03 .07 45	.04 .06 55	.03 .06 67	.03 .[illegible]9 65	.02 .05 71	.03 .04 62	.05 .[illegible]5 52	.04 .06 71	.04 .[illegible]4 68	.05 .05 55	.05 .07 57
23 N 116 W	.04 .07 42	.07 .09 37	.04 .06 48	.05 .07 46	.03 .07 63	.05 .06 46	.03 .05 62	.07 .04 50	.05 .08 51	.[illegible]4 .06 47	.05 .06 45	.06 .05 54
23 N 117 W	.[illegible]9 .10 30	.[illegible]4 .11 34	.[illegible]6 .[illegible]7 50	.05 .12 38	.[illegible]6 .[illegible]6 48	.04 .07 46	.04 .05 43	.16 .19 28	.09 .09 40	.06 .[illegible]8 38	.09 .10 33	.05 .04 52
23 N 118 W	.05 .08 34	.10 .10 29	.03 .[illegible]8 37	.05 .11 33	.06 .[illegible]4 36	.06 .11 27	.05 .06 32	.16 .16 22	.11 .11 29	.06 .[illegible]0 32	.06 .06 26	.04 .05 38
23 N 119 W	.06 .08 35	.05 .09 38	.03 .09 38	.05 .09 33	.05 .07 38	.06 .04 39	.06 .08 30	.07 .12 16	.10 .11 24	.07 .09 26	.17 .10 24	.10 .[illegible]8 37
23 N 120 W	.10 .1[illegible] 37	.05 .[illegible]6 30	.06 .1[illegible] 21	.11 .14 17	.04 .[illegible]6 22	.05 .09 23	.08 .17 17	.08 .[illegible]9 22	.07 .1[illegible] 24	.[illegible]8 .1[illegible] 18	.14 .[illegible]8 32	.06 .08 42

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
24 N 111 W	.01 .01 572	.01 .01 494	.01 .01 590	.01 .01 587	.02 .01 591	.01 .01 603	.01 .01 596	.01 .01 602	.03 .06 566	.01 .01 535	.01 .01 594	.01 .01 604
24 N 112 W	0.00 .01 1226	.01 .01 1279	.02 .01 1375	.01 .01 1380	.01 .01 1458	.01 .01 1398	.01 0.00 1453	.01 .01 1324	.01 .01 1382	0.00 .01 1379	0.00 .01 1336	.01 .01 1208
24 N 113 W	.02 .04 143	.03 .04 142	.03 .03 195	.03 .05 151	.02 .03 176	.02 .03 211	.02 .02 193	.02 .02 223	.03 .03 214	.03 .03 177	.02 .02 172	.02 .03 141
24 N 114 W	.07 .06 42	.06 .09 39	.05 .08 45	.05 .07 38	.04 .05 58	.04 .05 54	.03 .05 54	.04 .06 70	.05 .06 78	.04 .05 62	.05 .08 44	.14 .18 25
24 N 115 W	.07 .09 29	.05 .08 31	.05 .08 39	.07 .16 45	.04 .07 59	.07 .14 45	.03 .06 87	.04 .05 51	.05 .06 68	.05 .05 56	.03 .07 44	.07 .10 22
24 N 116 W	.05 .07 35	.03 .06 43	.08 .09 37	.04 .08 55	.04 .08 67	.03 .06 63	.02 .04 75	.06 .05 73	.04 .08 56	.03 .05 59	.02 .06 56	.04 .10 39
24 N 117 W	.05 .07 43	.06 .15 29	.04 .09 33	.05 .18 44	.04 .08 62	.03 .07 71	.03 .06 71	.04 .05 62	.04 .06 61	.03 .05 56	.04 .05 51	.04 .05 57
24 N 118 W	.05 .06 35	.06 .08 47	.04 .06 49	.03 .09 46	.05 .08 52	.03 .06 52	.02 .06 47	.09 .06 44	.03 .08 51	.04 .05 57	.04 .06 48	.07 .06 39
24 N 119 W	.03 .05 40	.11 .13 41	.08 .07 56	.05 .10 44	.04 .07 57	.04 .09 39	.06 .08 53	.13 .08 38	.05 .09 36	.04 .07 40	.08 .08 36	.04 .04 50
24 N 120 W	.07 .08 47	.04 .07 55	.03 .08 57	.03 .08 45	.05 .06 41	.03 .03 35	.08 .05 38	.15 .10 29	.08 .11 35	.07 .05 38	.05 .06 46	.05 .06 48
25 N 113 W	0.00 .01 1297	.01 .01 1257	.01 .01 1441	.01 .01 1403	.01 .01 1509	.01 .01 1467	0.00 0.00 1508	0.00 .01 1431	.01 .01 1431	0.00 .01 1426	0.00 .01 1408	.01 .01 1269
25 N 114 W	.02 .04 147	.02 .04 128	.04 .05 139	.03 .07 150	.03 .04 176	.03 .03 206	.04 .04 177	.02 .02 225	.03 .04 20	.13 .09 185	.03 .04 149	.03 .03 125
25 N 115 W	.56 .65 31	.04 .09 32	.05 .08 42	.03 .08 59	.03 .07 86	.05 .03 66	.03 .04 81	.04 .04 73	.03 .05 67	.02 .04 66	.05 .05 46	.08 .09 30
25 N 116 W	.10 .17 15	.08 .16 22	.12 .14 27	.05 .12 23	.08 .18 35	.06 .09 31	.03 .05 46	.02 .03 53	.14 .08 44	.04 .11 25	.05 .06 37	.10 .16 14
25 N 117 W	.04 .07 23	.11 .10 27	.10 .12 30	.04 .09 39	.04 .05 52	.05 .05 40	.03 .05 51	.06 .06 59	.06 .08 38	.05 .07 45	.05 .08 34	.11 .16 22
25 N 118 W	.06 .06 33	.04 .10 29	.06 .10 34	.05 .20 41	.04 .08 61	.04 .06 58	.02 .05 67	.05 .07 57	.06 .10 48	.02 .05 61	.05 .08 42	.03 .08 50
25 N 119 W	.06 .08 52	.06 .10 34	.05 .07 50	.05 .14 42	.05 .03 54	.04 .07 70	.03 .07 58	.03 .05 59	.04 .09 56	.03 .05 58	.05 .11 49	.05 .06 48
25 N 120 W	.07 .09 37	.07 .12 36	.04 .06 49	.04 .08 52	.04 .07 61	.03 .05 44	.02 .04 55	.04 .06 51	.04 .07 41	.04 .06 45	.04 .09 54	.07 .08 36
25 N 121 W	.07 .06 46	.05 .10 42	.03 .06 53	.03 .07 38	.04 .06 49	.04 .06 41	.03 .06 55	.08 .08 46	.08 .08 41	.05 .05 60	.09 .15 33	.07 .07 37
25 N 122 W	.05 .08 50	.07 .08 52	.04 .06 56	.05 .08 59	.02 .05 63	.04 .05 36	.04 .06 44	.06 .06 45	.05 .09 48	.05 .06 54	.10 .06 49	.09 .06 56
26 N 113 W	.01 .02 372	.01 .02 399	.02 .02 424	.02 .02 397	.02 .02 444	.01 .02 452	.01 .06 398	.01 .01 408	.02 .02 428	.01 .02 427	.01 .02 439	.02 .02 389
26 N 114 W	.01 .01 1199	.01 .01 1201	.01 .01 1438	.01 .01 1327	.01 .01 1367	.01 .01 1334	.01 .01 1360	.01 .01 1346	.01 .01 1331	.01 .01 1333	.01 .01 1253	.01 .01 1165
26 N 115 W	.04 .04 120	.03 .04 115	.04 .05 126	.03 .05 117	.04 .04 135	.02 .04 158	.02 .03 149	.02 .03 154	.03 .05 147	.03 .04 149	.02 .04 129	.03 .05 96
26 N 116 W	.08 .09 32	.07 .14 24	.08 .11 34	.05 .10 46	.04 .07 65	.04 .07 68	.03 .04 68	.03 .05 59	.04 .07 60	.03 .05 55	.05 .08 60	.15 .80 30
26 N 117 W	.07 .16 16	.12 .18 15	.24 .28 16	.04 .09 33	.03 .07 37	.03 .03 37	.04 .05 59	.05 .08 48	.04 .09 42	.03 .06 35	.04 .05 30	.20 .19 16
26 N 118 W	.04 .09 32	.06 .09 24	.12 .12 32	.04 .15 26	.04 .08 35	.04 .07 34	.04 .05 35	.04 .06 43	.04 .07 52	.04 .07 39	.05 .10 25	.10 .14 13
26 N 119 W	.05 .09 33	.10 .11 29	.09 .09 26	.05 .14 33	.04 .08 41	.04 .04 36	.03 .06 43	.02 .08 38	.06 .10 24	.05 .07 31	.04 .07 37	.04 .09 27
26 N 120 W	.10 .07 30	.10 .15 24	.13 .15 44	.11 .09 38	.03 .04 57	.02 .05 59	.05 .08 50	.03 .06 45	.06 .09 48	.03 .08 57	.06 .06 43	.05 .09 38
26 N 121 W	.05 .07 59	.10 .12 26	.04 .10 40	.04 .09 54	.04 .09 55	.03 .06 64	.08 .08 43	.03 .05 66	.04 .09 47	.04 .05 51	.05 .14 42	.07 .08 46
26 N 122 W	.05 .06 37	.04 .06 52	.06 .06 61	.03 .03 54	.03 .07 55	.02 .04 57	.03 .05 60	.03 .05 57	.03 .06 60	.03 .04 63	.03 .05 70	.08 .07 50

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
27 N	.02	.02	.02	.02	.02	.02	.01	.01	.02	.01	.02	.02
114 W	.02	.02	.02	.02	.02	.02	.01	.01	.02	.01	.02	.02
	468	458	542	517	548	483	527	452	549	524	511	521
27 N	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
115 W	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.02
	1113	1085	1245	1204	1250	1194	1209	1188	1169	1183	1122	973
27 N	.06	.04	.02	.03	.04	.04	.02	.02	.03	.03	.03	.04
116 W	.07	.06	.13	.04	.05	.05	.04	.03	.06	.06	.05	.07
	76	102	88	103	101	110	99	120	131	84	86	52
27 N	.08	.05	.08	.05	.05	.03	.03	.03	.03	.03	.06	.06
117 W	.12	.07	.10	.11	.05	.06	.06	.06	.05	.03	.07	.10
	29	34	43	48	51	64	71	71	76	55	51	25
27 N	.06	.07	.10	.05	.04	.03	.02	.03	.04	.03	.05	.24
118 W	.10	.16	.14	.11	.08	.05	.05	.04	.08	.04	.09	.10
	28	20	23	32	36	48	75	53	49	31	37	19
27 N	.03	.10	.11	.06	.04	.05	.03	.04	.04	.03	.04	.04
119 W	.09	.32	.08	.09	.10	.10	.10	.05	.07	.06	.05	.22
	19	12	16	34	32	32	29	32	37	37	26	20
27 N	.07	.11	.08	.06	.03	.03	.04	.04	.08	.04	.09	.06
120 W	.11	.27	.11	.11	.14	.08	.07	.07	.09	.09	.14	.08
	34	19	23	20	30	33	29	38	36	26	17	15
27 N	.13	.06	.11	.06	.04	.05	.04	.03	.06	.04	.07	.08
121 W	.09	.05	.12	.12	.08	.11	.12	.05	.13	.07	.07	.14
	40	25	29	42	46	16	31	49	24	49	33	17
27 N	.07	.09	.06	.03	.05	.05	.05	.04	.06	.02	.07	.07
122 W	.06	.12	.11	.10	.09	.06	.09	.08	.09	.05	.08	.05
	36	33	51	53	58	64	54	62	48	75	53	62
27 N	.04	.08	.06	.03	.02	.03	.05	.03	.03	.02	.06	.06
123 W	.07	.09	.09	.07	.05	.05	.08	.05	.04	.04	.08	.09
	69	52	63	75	93	9	60	80	91	105	77	61
28 N	.03	.02	.01	.02	.01	.01	.01	.01	.01	.01	.01	.02
115 W	.06	.02	.02	.03	.02	.01	.01	.01	.02	.01	.02	.02
	688	617	742	720	723	568	632	685	709	695	676	524
28 N	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.02
116 W	.02	.02	.02	.02	.01	.01	.01	.01	.01	.01	.01	.02
	812	747	866	843	874	903	831	840	835	875	821	735
28 N	.06	.05	.05	.03	.04	.03	.04	.03	.04	.04	.04	.09
117 W	.05	.07	.06	.05	.06	.04	.05	.07	.05	.05	.08	.12
	75	72	65	69	59	69	53	66	75	71	55	56
28 N	.05	.07	.05	.07	.05	.03	.02	.04	.04	.02	.05	.05
118 W	.06	.11	.09	.15	.06	.07	.06	.04	.07	.06	.10	.14
	34	24	25	30	41	47	56	63	54	43	33	22
28 N	.06	.04	.05	.05	.04	.04	.03	.03	.04	.03	.06	.13
119 W	.06	.11	.08	.09	.05	.07	.07	.07	.11	.06	.10	.14
	38	30	33	43	53	72	67	55	39	39	33	19
28 N	.20	.29	.08	.06	.06	.03	.06	.04	.03	.05	.05	.10
120 W	.16	.36	.09	.11	.08	.06	.06	.07	.06	.08	.12	.20
	17	18	36	43	33	39	36	41	45	22	31	20
28 N	.06	.08	.08	.05	.04	.05	.05	.02	.04	.04	.03	.06
121 W	.09	.25	.11	.10	.09	.10	.09	.05	.09	.07	.08	.13
	35	14	28	41	31	41	29	48	32	39	31	23
28 N	.06	.04	.07	.05	.05	.05	.03	.05	.03	.03	.08	.05
122 W	.11	.10	.12	.10	.13	.08	.08	.08	.05	.08	.16	.11
	56	34	45	32	44	44	55	58	43	54	27	35
28 N	.10	.08	.06	.03	.05	.05	.03	.07	.04	.03	.07	.06
123 W	.12	.10	.12	.12	.06	.11	.10	.07	.05	.04	.09	.06
	47	50	44	68	70	37	41	65	65	80	75	58
28 N	.06	.05	.05	.05	.03	.05	.06	.08	.09	.02	.06	.06
124 W	.08	.07	.12	.09	.07	.05	.09	.07	.08	.04	.07	.09
	48	46	43	44	65	54	46	47	38	88	67	51
29 N	.07	.07	.11	.07	.09	.05	.07	.07	.05	.05	.12	.08
115 W	.09	.09	.09	.09	.11	.09	.07	.04	.07	.05	.07	.09
	62	38	90	80	71	66	61	63	59	98	77	57
29 N	.02	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
116 W	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	1030	1049	1209	1155	1246	1138	1081	1115	1139	1112	1051	983
29 N	.03	.02	.02	.02	.02	.02	.02	.01	.02	.02	.02	.03
117 W	.03	.03	.03	.03	.03	.02	.02	.02	.02	.02	.03	.03
	252	249	336	308	250	294	267	280	273	269	261	229
29 N	.03	.08	.07	.07	.05	.04	.05	.03	.08	.04	.05	.06
118 W	.06	.10	.08	.07	.07	.07	.06	.05	.06	.05	.05	.09
	108	58	71	65	59	64	49	56	54	55	56	37
29 N	.07	.07	.10	.05	.05	.04	.03	.05	.04	.02	.10	.05
119 W	.09	.09	.22	.08	.10	.09	.07	.10	.09	.05	.09	.07
	27	21	34	36	43	45	43	33	42	54	33	35
29 N	.06	.07	.12	.05	.04	.04	.05	.03	.04	.06	.06	.06
120 W	.11	.09	.12	.09	.07	.08	.07	.05	.08	.09	.09	.11
	29	28	25	56	48	44	52	68	55	36	27	36
29 N	.05	.11	.09	.05	.05	.03	.04	.03	.07	.04	.46	.08
121 W	.08	.12	.12	.08	.08	.07	.08	.07	.07	.08	1.27	.09
	59	29	42	51	51	69	59	54	45	44	42	34
29 N	.05	.09	.07	.04	.05	.03	.04	.03	.05	.03	.07	.08
122 W	.10	.13	.13	.10	.06	.05	.09	.06	.06	.06	.07	.08
	73	48	51	55	81	84	52	86	44	82	62	39
29 N	.08	.05	.09	.05	.04	.03	.03	.16	.02	.03	.07	.06
123 W	.12	.13	.11	.12	.07	.08	.06	.07	.05	.06	.09	.09
	63	39	39	46	65	61	65	61	73	68	54	58
29 N	.06	.07	.07	.05	.03	.04	.04	.02	.05	.04	.07	.08
124 W	.11	.07	.14	.08	.07	.07	.10	.05	.05	.06	.08	.11
	51	50	36	50	75	54	54	57	53	80	89	31

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
30 N 116 W	.02 .02 571	.02 .02 576	.02 .03 637	.01 .02 581	.01 .02 624	.01 .02 593	.01 .01 547	.01 .01 537	.01 .02 553	.01 .02 557	.01 .02 545	.01 .02 481
30 N 117 W	.01 .02 604	.01 .02 630	.01 .02 698	.01 .02 658	.05 .04 658	.01 .01 554	.01 .01 666	.01 .01 693	.01 .02 651	.01 .01 672	.03 .04 645	.02 .02 591
30 N 118 W	.04 .05 194	.02 .05 209	.03 .04 197	.04 .04 201	.03 .04 193	.03 .04 190	.02 .03 195	.02 .02 188	.02 .03 189	.02 .02 203	.03 .03 182	.04 .05 165
30 N 119 W	.07 .08 76	.06 .09 65	.07 .08 60	.04 .05 65	.11 .10 38	.04 .06 73	.02 .03 139	.03 .06 52	.05 .08 60	.09 .09 91	.06 .10 48	.08 .10 42
30 N 120 W	.05 .09 63	.05 .08 113	.08 .10 58	.03 .07 99	.03 .05 86	.05 .05 91	.04 .06 67	.05 .06 70	.04 .05 56	.04 .04 95	.07 .07 37	.06 .10 52
30 N 121 W	.07 .08 71	.06 .07 81	.07 .11 58	.04 .08 107	.03 .07 91	.04 .05 86	.03 .05 84	.03 .05 102	.04 .05 73	.03 .06 89	.04 .08 35	.10 .11 53
30 N 122 W	.05 .07 92	.12 .06 60	.09 .12 47	.08 .11 51	.04 .08 104	.03 .03 77	.03 .06 88	.04 .06 73	.04 .07 74	.05 .06 74	.05 .08 51	.05 .09 49
30 N 123 W	.05 .08 78	.13 .13 50	.12 .15 48	.07 .14 54	.04 .06 87	.03 .07 80	.03 .06 72	.03 .12 73	.05 .09 69	.03 .09 82	.04 .10 69	.03 .05 96
30 N 124 W	.11 .11 66	.09 .11 80	.04 .07 55	.03 .07 76	.04 .07 110	.02 .05 108	.04 .08 60	.05 .07 83	.03 .07 66	.03 .07 113	.04 .09 87	.05 .09 63
30 N 125 W	.08 .12 78	.16 .15 66	.16 .10 57	.05 .10 65	.07 .08 95	.04 .03 74	.04 .03 64	.04 .08 78	.04 .05 73	.03 .07 86	.06 .09 72	.06 .08 65
31 N 117 W	.01 .01 776	.01 .02 793	.01 .01 922	.01 .01 880	.01 .01 916	.01 .01 865	.01 .01 926	.01 .01 837	.01 .01 861	.01 .01 821	.01 .02 793	.01 .02 706
31 N 118 W	.02 .03 394	.03 .03 402	.02 .03 446	.02 .02 442	.02 .03 441	.02 .02 384	.01 .02 360	.01 .01 443	.02 .02 499	.02 .02 441	.02 .02 459	.03 .03 372
31 N 119 W	.02 .03 294	.02 .04 294	.04 .06 236	.04 .04 286	.03 .03 253	.02 .03 296	.02 .03 255	.02 .03 214	.02 .03 267	.02 .02 345	.04 .04 222	.04 .05 154
31 N 120 W	.05 .07 169	.04 .06 143	.05 .07 131	.03 .05 149	.04 .06 144	.03 .05 124	.03 .05 158	.03 .04 126	.04 .06 98	.03 .03 212	.04 .07 122	.03 .06 84
31 N 121 W	.05 .08 103	.04 .08 145	.05 .10 101	.03 .05 131	.06 .06 119	.05 .07 105	.03 .04 132	.04 .05 95	.04 .08 78	.04 .05 131	.04 .06 101	.06 .08 78
31 N 122 W	.04 .06 115	.05 .10 98	.05 .10 87	.03 .11 70	.06 .07 104	.03 .07 104	.03 .05 106	.04 .06 87	.04 .09 79	.03 .08 127	.05 .10 107	.05 .08 87
31 N 123 W	.03 .06 171	.06 .10 110	.06 .08 84	.04 .10 91	.04 .06 109	.03 .07 123	.02 .05 170	.03 .05 142	.03 .06 133	.03 .07 153	.04 .06 111	.05 .10 79
31 N 124 W	.07 .09 112	.07 .12 86	.06 .11 105	.04 .07 173	.02 .04 207	.03 .06 169	.02 .05 166	.02 .06 102	.03 .06 133	.03 .05 146	.05 .08 119	.06 .10 107
31 N 125 W	.06 .08 134	.05 .09 121	.04 .07 139	.05 .08 144	.03 .06 126	.03 .04 150	.02 .04 160	.03 .05 125	.03 .06 124	.03 .08 166	.05 .09 122	.05 .11 92
31 N 126 W	.05 .08 157	.06 .10 137	.06 .07 152	.04 .07 145	.03 .05 149	.03 .05 155	.03 .06 158	.02 .05 145	.02 .04 144	.03 .06 184	.05 .06 148	.05 .09 131
32 N 117 W	.01 .01 1046	.01 .01 912	.01 .01 1065	.01 .01 967	.01 .01 1095	0.00 0.00 1054	0.00 0.00 931	0.00 0.00 1097	.01 .01 1041	.01 .01 1062	.01 .01 887	.01 .01 714
32 N 118 W	.01 .01 2163	.01 .01 1933	.01 .01 2268	.01 .01 2283	.01 0.00 2375	0.00 0.00 2221	.01 0.00 1934	0.00 0.00 2512	.01 0.00 2363	.01 .01 2284	.01 .01 1882	.01 .01 1133
32 N 119 W	.01 .02 1178	.02 .02 981	.02 .02 1244	.01 .02 1106	.01 .01 1143	.01 .01 1100	.01 .01 1054	.02 .01 1128	.01 .01 1220	.01 .01 1399	.02 .02 1017	.02 .02 768
32 N 120 W	.02 .03 451	.03 .05 356	.03 .03 491	.03 .04 479	.03 .03 465	.03 .04 354	.02 .04 500	.02 .02 433	.02 .02 573	.02 .03 492	.02 .03 419	.04 .05 262
32 N 121 W	.03 .06 241	.04 .06 262	.04 .07 235	.04 .05 249	.03 .05 254	.04 .05 196	.02 .04 272	.03 .04 225	.03 .04 245	.05 .05 293	.05 .06 233	.05 .07 189
32 N 122 W	.04 .07 198	.05 .08 214	.04 .08 212	.03 .08 214	.04 .06 188	.03 .06 19	.03 .05 229	.04 .06 171	.03 .05 191	.03 .04 302	.03 .05 208	.05 .08 176
32 N 123 W	.03 .06 287	.05 .08 197	.04 .07 218	.05 .08 198	.04 .07 190	.03 .07 172	.02 .04 203	.03 .05 188	.03 .05 181	.03 .06 253	.03 .06 232	.04 .08 184
32 N 124 W	.01 .04 771	.02 .04 531	.02 .03 630	.03 .05 432	.01 .04 569	.01 .03 551	.01 .02 662	.01 .02 711	.01 .02 662	.01 .04 824	.02 .03 623	.01 .03 637
32 N 125 W	.03 .05 302	.03 .06 273	.05 .06 289	.04 .05 267	.04 .05 273	.02 .05 263	.02 .05 268	.02 .04 284	.02 .04 237	.02 .05 353	.02 .04 323	.03 .06 363
32 N 126 W	.03 .05 289	.05 .07 252	.07 .05 307	.03 .05 300	.03 .05 273	.02 .04 257	.02 .05 267	.02 .04 280	.01 .04 247	.02 .05 320	.03 .04 352	.03 .06 311

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
33 N	0.00	.01	.01	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01
118 W	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01
	3638	3329	3831	3776	3805	3305	3107	3712	3483	3796	3536	2251
33 N	.01	.02	.02	.02	.02	.01	.01	.01	.01	.01	.01	.02
119 W	.01	.02	.01	.01	.01	.01	0.00	.01	.01	.01	.01	.01
	1351	1121	1557	1412	1492	1320	1079	1595	1476	1686	1461	1023
33 N	.02	.03	.02	.03	.02	.02	.02	.01	.01	.01	.02	.03
120 W	.02	.04	.02	.02	.02	.02	.02	.02	.02	.02	.02	.03
	966	610	930	935	1064	1124	823	967	1000	975	934	699
33 N	.02	.03	.04	.04	.05	.03	.03	.02	.03	.03	.03	.03
121 W	.04	.06	.06	.05	.06	.04	.05	.03	.04	.04	.05	.05
	473	289	392	333	410	419	303	341	384	31	341	293
33 N	.03	.04	.04	.04	.03	.04	.04	.02	.02	.03	.03	.03
122 W	.06	.07	.06	.06	.04	.06	.05	.04	.04	.06	.05	.05
	345	305	372	350	332	276	306	269	298	297	347	332
33 N	.03	.03	.04	.02	.02	.03	.02	.02	.02	.02	.03	.03
123 W	.06	.06	.06	.04	.05	.05	.03	.04	.04	.04	.05	.05
	363	313	336	575	462	329	411	286	308	310	345	362
33 N	.02	.03	.03	.04	.02	.03	.02	.02	.02	.02	.03	.03
124 W	.05	.06	.05	.06	.05	.05	.05	.03	.04	.05	.05	.05
	400	286	395	313	389	313	314	378	287	406	377	377
33 N	.03	.03	.03	.03	.02	.04	.02	.01	.02	.02	.03	.03
125 W	.05	.06	.06	.06	.05	.05	.04	.04	.05	.05	.04	.06
	356	318	330	272	324	285	273	306	238	329	339	356
33 N	.06	.04	.04	.04	.02	.03	.02	.03	.02	.02	.03	.03
126 W	.07	.08	.08	.08	.05	.06	.06	.06	.06	.06	.06	.06
	244	187	217	186	217	164	204	187	182	216	221	256
33 N	.05	.05	.04	.07	.03	.04	.03	.03	.03	.03	.05	.06
127 W	.08	.09	.07	.08	.07	.06	.06	.06	.07	.06	.06	.11
	196	178	199	154	164	152	178	137	143	182	183	199
34 N	.01	.01	0.01	.01	.01	0.00	0.00	0.00	.01	.01	.01	.02
119 W	.01	.01	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	.01	.01
	1575	1637	1774	1990	1924	1615	1623	1420	1448	1472	1261	995
34 N	.02	.03	.03	.03	.04	.02	.02	.03	.02	.02	.02	.02
120 W	.02	.03	.02	.03	.03	.02	.02	.02	.02	.02	.02	.02
	599	588	743	705	643	721	775	650	656	640	652	769
34 N	.02	.03	.03	.03	.03	.02	.02	.02	.02	.02	.02	.03
121 W	.03	.04	.04	.04	.04	.03	.03	.02	.03	.03	.03	.04
	576	506	594	535	543	576	603	650	577	567	558	495
34 N	.03	.04	.04	.04	.04	.07	.03	.03	.03	.04	.04	.03
122 W	.05	.07	.07	.07	.06	.09	.04	.04	.05	.07	.08	.05
	276	261	274	239	253	265	284	232	246	228	272	256
34 N	.04	.05	.03	.04	.05	.05	.04	.04	.04	.03	.04	.03
123 W	.07	.08	.08	.07	.08	.08	.06	.06	.05	.07	.06	.07
	230	228	258	185	189	19	197	156	172	263	207	212
34 N	.03	.05	.04	.05	.06	.04	.04	.04	.03	.03	.04	.04
124 W	.05	.07	.07	.07	.08	.07	.08	.06	.13	.06	.07	.07
	265	204	229	218	147	166	152	146	188	273	206	241
34 N	.04	.05	.04	.05	.05	.04	.04	.07	.03	.02	.03	.06
125 W	.06	.08	.07	.07	.08	.07	.07	.07	.06	.07	.05	.09
	229	199	240	204	152	143	149	137	175	234	217	234
34 N	.07	.05	.05	.05	.05	.04	.03	.04	.04	.03	.05	.04
126 W	.08	.09	.07	.09	.09	.08	.07	.07	.05	.06	.08	.07
	206	200	204	196	149	132	141	101	142	189	184	232
34 N	.05	.06	.06	.05	.05	.04	.04	.03	.03	.03	.05	.05
127 W	.08	.07	.07	.08	.08	.07	.08	.08	.08	.06	.08	.06
	208	192	212	185	138	134	122	96	145	164	187	218
34 N	.05	.06	.06	.06	.04	.04	.03	.04	.03	.05	.05	.05
128 W	.08	.08	.07	.09	.07	.07	.06	.06	.07	.06	.08	.07
	230	184	224	182	179	144	127	129	130	169	186	215
35 N	.02	.03	.03	.03	.03	.03	.02	.02	.02	.02	.02	.03
121 W	.03	.04	.04	.04	.03	.04	.02	.03	.02	.03	.03	.04
	525	477	613	572	586	551	631	564	536	658	559	447
35 N	.03	.03	.04	.03	.03	.03	.03	.02	.02	.03	.02	.02
122 W	.05	.05	.05	.05	.04	.04	.04	.03	.03	.04	.04	.05
	296	310	376	388	432	48	441	445	418	422	423	274
35 N	.04	.04	.04	.03	.03	.04	.03	.02	.02	.02	.03	.04
123 W	.07	.08	.07	.06	.06	.05	.04	.06	.04	.04	.06	.08
	243	218	224	284	276	298	293	325	306	262	283	211
35 N	.04	.05	.04	.05	.03	.04	.03	.03	.02	.02	.03	.05
124 W	.08	.09	.08	.08	.06	.06	.06	.05	.04	.05	.06	.09
	222	202	186	189	243	229	225	243	204	279	237	202
35 N	.07	.04	.05	.05	.05	.04	.03	.03	.04	.03	.03	.06
125 W	.12	.07	.08	.09	.09	.07	.06	.06	.07	.07	.06	.10
	207	178	171	165	161	200	177	174	174	187	207	169
35 N	.06	.07	.05	.04	.06	.04	.04	.04	.04	.04	.04	.06
126 W	.12	.10	.12	.10	.08	.08	.08	.06	.07	.08	.08	.08
	189	147	157	183	141	134	139	147	139	174	179	184
35 N	.05	.05	.06	.05	.04	.05	.04	.03	.03	.05	.05	.05
127 W	.09	.08	.08	.08	.09	.07	.08	.06	.07	.08	.09	.09
	193	181	198	171	153	154	129	150	111	206	191	201
35 N	.04	.05	.04	.06	.03	.02	.02	.02	.03	.02	.03	.05
128 W	.06	.07	.06	.05	.05	.05	.05	.04	.06	.05	.05	.06
	366	317	373	253	271	243	313	316	273	356	370	368
35 N	.04	.05	.03	.04	.02	.02	.02	.02	.02	.03	.03	.04
129 W	.06	.06	.05	.05	.04	.04	.04	.03	.05	.05	.05	.05
	400	334	479	379	352	337	312	326	324	404	373	411
35 N	.04	.04	.03	.04	.02	.02	.02	.01	.02	.02	.03	.03
130 W	.05	.05	.05	.04	.04	.03	.04	.03	.04	.04	.04	.05
	568	523	577	487	492	442	464	446	476	592	554	562

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
36 N 122 W	.02 .04 552	.03 .05 465	.03 .04 592	.02 .04 621	.03 .04 631	.02 .03 759	.02 .03 767	.02 .03 561	.02 .03 604	.02 .04 553	.02 .03 561	.03 .04 411
36 N 123 W	.03 .06 286	.04 .06 342	.03 .05 298	.03 .07 364	.02 .04 468	.02 .04 391	.02 .04 377	.02 .03 525	.02 .03 478	.02 .05 418	.03 .05 380	.04 .09 247
36 N 124 W	.05 .08 240	.03 .08 228	.04 .06 215	.03 .07 279	.03 .05 360	.03 .05 351	.03 .05 339	.02 .04 360	.02 .05 286	.02 .06 269	.03 .06 257	.04 .06 246
36 N 125 W	.05 .08 296	.04 .09 206	.04 .07 225	.04 .08 271	.04 .06 281	.03 .06 298	.03 .06 297	.03 .05 291	.03 .07 258	.03 .07 25.	.03 .06 270	.04 .07 255
36 N 126 W	.04 .08 446	.03 .06 414	.03 .06 449	.03 .06 368	.03 .05 371	.03 .05 357	.02 .05 358	.02 .04 382	.02 .05 352	.03 .06 398	.02 .05 530	.04 .07 397
36 N 127 W	.02 .04 899	.03 .05 748	.03 .04 694	.02 .04 624	.02 .04 651	.02 .04 555	.02 .04 584	.01 .03 714	.02 .04 645	.02 .04 699	.02 .04 660	.02 .05 734
36 N 128 W	.02 .04 1060	.03 .04 875	.02 .03 963	.02 .03 859	.01 .03 769	.01 .03 969	.01 .03 861	.1 .02 952	.01 .04 929	.02 .03 913	.02 .03 1168	.02 .03 997
36 N 129 W	.04 .05 519	.04 .05 511	.03 .04 682	.03 .04 615	.02 .04 566	.02 .04 581	.01 .03 552	.01 .03 585	.01 .03 637	.03 .04 612	.03 .04 598	.04 .06 520
36 N 130 W	.06 .08 3[illegible]	.06 .06 315	.04 .06 382	.05 .06 331	.03 .05 274	.02 .05 298	.02 .05 249	.02 .04 259	.04 .05 299	.03 .04 373	.04 .05 404	.06 .07 322
36 N 131 W	.08 .09 235	.08 .08 266	.06 .08 272	.05 .07 238	.04 .05 212	.04 .05 209	.03 .05 138	.03 .5 185	.04 .06 191	.04 .6 25.	.06 .08 251	.07 .08 234
37 N 122 W	.03 .05 412	.03 .05 337	.03 .04 343	.03 .04 378	.03 .04 432	.03 .04 391	.01 .02 581	.02 .03 354	.02 .03 40.	.02 .03 433	.02 .04 376	.03 .05 325
37 N 123 W	.03 .5 688	.03 .6 591	.04 .5 688	.03 .05 672	.03 .04 738	.02 .03 998	.02 .02 381	.01 .03 836	.01 .02 882	.02 .04 797	.03 .04 687	.04 .06 637
37 N 124 W	.04 .07 578	.4 .06 572	.3 .05 605	.03 .06 514	.4 .05 504	.03 .05 57[illegible]	.03 .04 523	.2 .04 537	.02 .04 533	.03 .05 602	.02 .04 645	.03 .05 534
37 N 125 W	.02 .05 731	.03 .05 686	.02 .04 789	.02 .05 719	.02 .04 748	.02 .04 595	.02 .03 706	.02 .03 681	.02 .04 664	.02 .04 755	.02 .04 883	.02 .05 588
37 N 126 W	.03 .05 633	.02 .05 545	.02 .05 696	.02 .03 703	.02 .05 685	.02 .04 72[illegible]	.02 .04 684	.01 .03 603	.02 .04 602	.01 .04 651	.02 .04 722	.02 .05 617
37 N 127 W	.04 .06 435	.04 .08 391	.03 .06 424	.03 .05 473	.02 .05 532	.02 .06 447	.02 .05 438	.02 .05 406	.02 .05 453	.02 .05 528	.04 .05 489	.03 .07 430
37 N 128 W	.06 .08 313	.06 .08 299	.04 .07 352	.03 .05 343	.02 .05 369	.02 .05 361	.03 .06 286	.02 .06 274	.02 .06 405	.02 .05 410	.04 .06 357	.06 .07 337
37 N 129 W	.06 .08 263	.6 .08 236	.6 .09 279	.04 .05 322	.04 .06 306	.03 .06 331	.02 .06 253	.02 .05 283	.02 .05 333	.03 .05 387	.04 .06 351	.06 .09 271
37 N 130 W	.06 .09 233	.06 .08 230	.05 .08 243	.04 .07 312	.04 .05 281	.02 .05 306	.02 .05 271	.03 .05 261	.03 .05 345	.05 .05 338	.05 .06 298	.06 .10 267
37 N 131 W	.07 .09 223	.07 .10 201	.08 .[illegible] 209	.06 .05 266	.04 .05 229	.04 .06 239	.02 .05 234	.02 .04 242	.03 .05 262	.04 .05 291	.05 .07 266	.07 .08 254
38 N 123 W	.02 .03 956	.02 .03 919	.03 .03 937	.03 .03 1139	.02 .03 1121	.03 .03 1034	.01 .02 1132	.02 .02 931	.01 .02 1025	.01 .03 986	.02 .03 827	.03 .03 791
38 N 124 W	.04 .[illegible] 319	.04 .[illegible] 332	.04 .[illegible] 351	.03 .05 464	.04 .[illegible] 459	.03 .05 568	.03 .05 560	.02 .04 563	.02 .04 533	.03 .04 423	.03 .05 530	.04 .07 453
38 N 125 W	.05 .09 208	.05 .10 222	.06 .12 216	.04 .08 295	.04 .09 274	.03 .07 315	.03 .06 338	.3 .05 370	.03 .07 327	.03 .07 287	.03 .06 289	.05 .09 222
38 N 126 W	.[illegible] .14 162	.[illegible] .11 229	.05 .09 191	.04 .10 215	.03 .[illegible] 259	.03 .08 248	.04 .06 292	.03 .05 340	.03 .06 300	.03 .09 272	.06 .08 239	.07 .12 211
38 N 127 W	.07 .17 175	.07 .11 176	.05 .08 233	.04 .08 243	.02 .07 318	.03 .06 333	.03 .06 384	.03 .06 349	.03 .06 318	.03 .08 285	.04 .06 266	.08 .11 214
38 N 128 W	.06 .13 206	.09 .12 193	.04 .07 261	.04 .07 277	.03 .05 383	.02 .06 381	.02 .05 449	.02 .04 435	.02 .05 416	.04 .07 366	.05 .07 282	.07 .09 239
38 N 129 W	.08 .13 177	.06 .10 206	.06 .09 214	.05 .06 247	.03 .05 307	.02 .09 330	.02 .05 355	.2 .05 337	.03 .05 320	.03 .07 249	.05 .06 253	.08 .09 217
38 N 130 W	.[illegible] .15 140	.12 .11 172	.[illegible] .10 170	.06 .08 180	.03 .06 247	.03 .05 258	.03 .05 273	.02 .04 281	.03 .05 272	.05 .03 192	.08 .09 206	.10 .10 196
38 N 131 W	.09 .13 160	.08 .12 146	.[illegible] .12 151	.07 .09 151	.03 .05 243	.04 .08 201	.03 .05 232	.02 .04 291	.04 .06 221	.06 .08 198	.07 .08 174	.08 .12 190
38 N 132 W	.11 .17 126	.13 .12 139	.08 .08 166	.07 .[illegible] 146	.05 .[illegible] 189	.04 .06 181	.03 .05 208	.06 .[illegible] 225	.04 .[illegible] 238	.08 .[illegible] 193	.07 .08 178	.11 .12 157

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
39 N	.04	.04	.03	.04	.05	.04	.03	.03	.03	.02	.03	.09
124 W	.08	.07	.06	.05	.08	.06	.07	.05	.05	.05	.05	.12
	337	393	392	437	423	496	465	415	420	406	422	344
39 N	.10	.06	.08	.05	.05	.05	.04	.04	.04	.04	.05	.05
125 W	.12	.10	.15	.10	.13	.11	.08	.08	.09	.08	.12	.12
	181	171	162	202	229	273	311	267	242	218	157	158
39 N	.07	.09	.07	.04	.04	.03	.03	.03	.03	.07	.06	.08
126 W	.17	.11	.11	.09	.09	.07	.06	.07	.07	.17	.09	.13
	172	166	165	231	232	301	331	318	269	220	206	155
39 N	.09	.06	.07	.05	.05	.05	.04	.03	.04	.05	.08	.08
127 W	.17	.09	.13	.10	.11	.12	.08	.07	.09	.12	.10	.13
	134	173	167	213	173	182	222	244	196	197	174	141
39 N	.07	.10	.07	.06	.04	.04	.03	.03	.03	.05	.07	.08
128 W	.14	.11	.13	.11	.10	.09	.07	.07	.07	.10	.20	.11
	138	135	169	164	161	167	233	219	227	171	163	136
39 N	.07	.10	.07	.05	.04	.03	.02	.03	.03	.06	.06	.07
129 W	.11	.14	.11	.09	.05	.06	.06	.06	.07	.09	.09	.09
	133	162	212	229	249	254	288	248	238	178	184	172
39 N	.07	.07	.05	.03	.03	.02	.02	.02	.03	.06	.07	.05
130 W	.08	.07	.07	.07	.04	.04	.05	.05	.06	.10	.09	.07
	304	337	248	349	451	337	356	324	251	239	187	335
39 N	.13	.11	.06	.04	.04	.03	.02	.02	.04	.06	.09	.08
131 W	.13	.13	.08	.06	.04	.05	.04	.03	.07	.08	.09	.10
	138	149	192	216	347	264	400	357	284	187	198	174
39 N	.10	.13	.10	.06	.05	.04	.02	.03	.04	.04	.09	.13
132 W	.12	.15	.12	.09	.07	.05	.04	.06	.06	.07	.10	.14
	135	131	157	163	185	251	269	219	235	159	172	148
39 N	.12	.10	.08	.05	.05	.04	.03	.03	.04	.05	.09	.08
133 W	.18	.21	.11	.11	.08	.05	.04	.05	.04	.06	.08	.11
	132	112	145	149	162	206	240	186	246	316	220	150
40 N	.03	.03	.03	.02	.02	.02	.03	.05	.02	.02	.02	.04
124 W	.09	.06	.07	.06	.05	.04	.05	.06	.04	.06	.07	.08
	727	710	747	736	853	695	658	517	478	49	525	454
40 N	.07	.07	.05	.04	.05	.04	.05	.04	.04	.03	.05	.07
125 W	.16	.14	.11	.11	.12	.09	.09	.09	.11	.12	.11	.15
	178	168	184	210	167	223	212	233	193	191	213	151
40 N	.09	.06	.11	.05	.10	.06	.05	.04	.05	.06	.07	.09
126 W	.18	.28	.19	.13	.14	.17	.12	.11	.13	.13	.17	.23
	111	75	80	102	124	105	127	127	95	114	128	101
40 N	.09	.09	.13	.05	.04	.03	.04	.03	.04	.05	.07	.08
127 W	.14	.13	.16	.11	.09	.08	.09	.06	.09	.12	.16	.13
	127	122	115	165	167	196	204	270	162	169	122	123
40 N	.06	.09	.10	.05	.03	.03	.02	.03	.04	.05	.08	.08
128 W	.12	.14	.11	.08	.08	.07	.07	.06	.08	.09	.12	.09
	287	162	153	212	211	248	301	247	205	191	136	225
40 N	.07	.06	.05	.05	.04	.03	.03	.04	.05	.04	.08	.07
129 W	.10	.11	.07	.07	.05	.06	.05	.06	.08	.08	.09	.11
	167	189	276	305	279	230	268	249	243	253	218	158
40 N	.07	.06	.05	.04	.03	.02	.02	.02	.04	.04	.05	.05
130 W	.08	.07	.05	.05	.04	.04	.05	.06	.06	.05	.06	.08
	209	295	568	479	519	519	499	393	359	472	396	197
40 N	.10	.11	.08	.07	.05	.03	.04	.02	.05	.07	.08	.11
131 W	.15	.12	.10	.08	.15	.08	.05	.04	.06	.07	.10	.12
	108	156	145	168	191	185	216	245	170	147	153	129
40 N	.11	.14	.08	.05	.05	.02	.02	.02	.04	.13	.08	.10
132 W	.14	.09	.15	.07	.06	.04	.04	.03	.05	.08	.09	.13
	165	162	182	183	232	261	304	271	233	213	177	173
40 N	.09	.17	.08	.04	.04	.02	.02	.02	.03	.11	.08	.09
133 W	.11	.09	.08	.06	.05	.03	.03	.04	.04	.06	.07	.11
	172	166	226	291	268	384	375	341	429	362	235	203
41 N	.08	.04	.05	.05	.05	.04	.08	.02	.02	.03	.04	.07
124 W	.17	.10	.12	.21	.12	.11	.14	.06	.06	.06	.08	.07
	102	112	101	114	125	120	114	180	208	212	209	178
41 N	.06	.05	.03	.03	.03	.03	.04	.03	.03	.04	.03	.11
125 W	.16	.14	.09	.11	.10	.09	.09	.08	.10	.11	.11	.17
	204	227	256	226	243	258	271	236	236	271	246	192
41 N	.17	.09	.12	.09	.04	.05	.12	.06	.04	.08	.05	.10
126 W	.16	.19	.09	.13	.10	.14	.29	.14	.18	.27	.15	.19
	77	77	82	93	102	87	84	87	91	118	101	98
41 N	.12	.16	.16	.12	.04	.08	.07	.06	.09	.07	.11	.14
127 W	.22	.17	.26	.17	.10	.18	.14	.12	.20	.15	.19	.21
	88	84	73	117	105	66	64	85	66	82	94	84
41 N	.29	.13	.23	.06	.08	.06	.04	.04	.05	.08	.16	.14
128 W	.25	.14	.36	.09	.16	.13	.13	.14	.12	.12	.24	.14
	77	60	66	101	69	76	83	77	65	89	83	86
41 N	.13	.12	.30	.06	.06	.03	.03	.05	.04	.09	.10	.20
129 W	.18	.18	.13	.08	.09	.05	.07	.07	.09	.11	.12	.14
	103	97	108	120	119	154	137	122	113	111	107	113
41 N	.18	.11	.11	.04	.04	.03	.02	.02	.05	.08	.08	.10
130 W	.14	.16	.09	.06	.06	.05	.05	.05	.06	.08	.10	.15
	113	156	164	215	218	274	253	295	199	206	154	122
41 N	.09	.12	.09	.03	.04	.02	.05	.03	.04	.05	.08	.09
131 W	.12	.16	.11	.05	.06	.04	.11	.03	.05	.08	.12	.11
	175	202	221	283	268	272	344	341	247	227	195	161
41 N	.10	.14	.10	.08	.08	.05	.03	.04	.06	.09	.12	.12
132 W	.12	.18	.12	.09	.09	.05	.05	.07	.07	.08	.11	.17
	116	113	115	155	161	161	171	152	148	162	139	131
41 N	.12	.12	.13	.07	.08	.04	.04	.03	.05	.08	.15	.10
133 W	.16	.18	.16	.09	.08	.05	.06	.05	.07	.11	.12	.13
	117	99	119	133	114	157	152	168	141	137	113	123

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
42 N	.08	.06	.06	.05	.05	.05	.05	.05	.03	.02	.07	.06
124 W	.15	.14	.12	.15	.13	.09	.13	.13	.1	.09	.17	.12
	103	107	74	92	96	112	128	90	112	112	88	76
42 N	.06	.06	.04	.03	.04	.03	.03	.03	.03	.03	.03	.06
125 W	.12	.11	.08	.11	.14	.11	.09	.09	.11	.08	.1	.15
	221	241	273	258	214	303	296	238	243	268	272	196
42 N	.17	.15	.15	.08	.08	.05	.07	.04	.08	.10	.09	.17
126 W	.28	.25	.21	.14	.15	.13	.17	.12	.21	.23	.15	.23
	73	80	77	80	75	61	63	76	50	73	77	58
42 N	.18	.09	.18	.10	.05	.07	.08	.06	.08	.11	.12	.14
127 W	.21	.17	.23	.21	.09	.11	.12	.11	.18	.15	.15	.16
	86	92	95	89	83	73	72	64	69	94	114	102
42 N	.24	.10	.23	.10	.07	.10	.06	.07	.09	.08	.14	.16
128 W	.20	.18	.24	.13	.14	.25	.15	.18	.11	.13	.25	.20
	94	64	87	68	70	67	67	61	53	82	86	110
42 N	.12	.10	.06	.05	.06	.04	.04	.02	.11	.14	.11	.10
129 W	.16	.13	.09	.07	.07	.07	.06	.05	.13	.13	.13	.11
	212	166	250	244	241	157	143	264	48	61	152	257
42 N	.10	.14	.12	.07	.05	.04	.04	.02	.21	.12	.12	.14
130 W	.14	.17	.12	.09	.09	.07	.09	.09	.09	.12	.15	.19
	146	142	124	93	100	139	128	100	52	75	137	114
42 N	.07	.14	.07	.07	.05	.04	.03	.02	.05	.11	.10	.13
131 W	.09	.13	.10	.06	.07	.05	.04	.04	.07	.09	.13	.12
	187	158	199	215	160	183	280	298	206	166	158	138
42 N	.13	.11	.15	.08	.05	.04	.03	.04	.04	.08	.12	.12
132 W	.17	.15	.13	.09	.05	.03	.05	.05	.05	.09	.19	.21
	121	120	123	185	194	228	249	234	190	159	116	126
42 N	.15	.16	.13	.07	.06	.05	.03	.03	.04	.08	.15	.12
133 W	.15	.18	.10	.09	.07	.08	.04	.03	.05	.07	.17	.15
	144	110	167	181	256	257	233	259	219	200	119	139
43 N	.11	.09	.06	.03	.06	.03	.03	.03	.02	.02	.08	.07
124 W	.14	.11	.12	.12	.10	.07	.10	.09	.06	.08	.21	.13
	95	110	90	84	87	104	92	76	123	103	72	104
43 N	.06	.04	.06	.03	.03	.02	.02	.02	.02	.10	.04	.06
125 W	.13	.13	.10	.09	.09	.07	.05	.06	.09	.07	.09	.15
	254	272	255	241	241	281	304	213	281	456	423	224
43 N	.13	.13	.15	.13	.06	.06	.07	.13	.17	.17	.13	.12
126 W	.19	.22	.14	.12	.14	.17	.16	.17	.21	.12	.15	.23
	71	58	61	59	59	41	42	52	47	87	77	68
43 N	.24	.13	.12	.14	.06	.06	.04	.11	.07	.09	.11	.20
127 W	.33	.22	.20	.15	.09	.13	.10	.17	.14	.13	.15	.25
	71	84	84	64	64	48	58	54	53	105	110	83
43 N	.18	.23	.30	.11	.06	.04	.09	.05	.07	.09	.14	.16
128 W	.21	.31	.22	.14	.11	.08	.11	.08	.12	.17	.15	.22
	85	78	75	68	69	64	64	54	71	88	104	105
43 N	.14	.16	.14	.09	.12	.09	.05	.05	.07	.12	.15	.13
129 W	.17	.21	.15	.13	.13	.23	.08	.10	.08	.17	.18	.23
	136	98	123	93	97	87	76	86	77	82	135	107
43 N	.08	.08	.09	.06	.03	.02	.02	.02	.03	.09	.12	.07
130 W	.11	.12	.11	.08	.05	.05	.05	.04	.05	.10	.12	.10
	330	156	306	317	346	369	320	330	288	173	118	332
43 N	.12	.10	.11	.11	.05	.04	.04	.02	.06	.1	.11	.19
131 W	.15	.14	.11	.14	.10	.05	.06	.05	.09	.09	.12	.22
	119	149	139	117	133	150	150	169	126	130	116	103
43 N	.15	.12	.13	.11	.10	.07	.05	.05	.08	.14	.19	.17
132 W	.19	.26	.15	.15	.09	.08	.07	.08	.12	.12	.26	.22
	99	101	114	95	85	83	94	84	75	81	78	79
43 N	.14	.12	.09	.09	.08	.04	.04	.06	.07	.09	.13	.20
133 W	.13	.17	.10	.09	.09	.06	.05	.05	.07	.12	.12	.47
	127	112	107	147	122	129	115	129	101	149	143	121
44 N	.09	.08	.09	.04	.03	.01	.02	.01	.03	.03	.04	.11
124 W	.17	.10	.16	.08	.06	.07	.05	.05	.05	.03	.09	.16
	126	133	113	136	162	133	161	95	138	156	174	94
44 N	.07	.05	.05	.03	.06	.02	.01	.01	.01	.02	.03	.08
125 W	.14	.10	.09	.08	.07	.06	.05	.05	.04	.07	.06	.18
	229	252	305	237	259	271	341	286	543	492	437	221
44 N	.17	.14	.09	.18	.06	.05	.05	.02	.10	.16	.09	.17
126 W	.23	.25	.16	.63	.14	.12	.17	.09	.24	.19	.17	.32
	84	45	68	52	73	63	61	76	39	80	76	65
44 N	.20	.20	.13	.14	.08	.08	.05	.04	.10	.13	.09	.17
127 W	.28	.23	.22	.17	.12	.11	.15	.09	.12	.16	.14	.30
	75	52	77	55	77	55	42	54	51	77	103	81
44 N	.19	.16	.15	.11	.06	.27	.05	.05	.05	.05	.07	.25
128 W	.22	.23	.17	.11	.11	.47	.11	.08	.11	.07	.12	.22
	99	124	103	98	109	83	79	74	124	288	270	103
44 N	.15	.14	.16	.10	.07	.05	.04	.04	.05	.07	.16	.18
129 W	.18	.17	.17	.13	.06	.11	.07	.08	.08	.11	.12	.22
	99	94	115	126	142	107	104	94	119	168	145	139
44 N	.10	.11	.16	.10	.09	.07	.04	.06	.05	.09	.13	.16
130 W	.14	.15	.16	.16	.14	.25	.09	.09	.09	.14	.20	.19
	134	116	126	102	110	111	110	91	113	125	117	117
44 N	.10	.09	.07	.05	.04	.02	.02	.05	.03	.04	.06	.13
131 W	.12	.10	.07	.06	.06	.04	.04	.03	.05	.07	.08	.14
	231	194	318	255	288	417	384	385	381	372	273	238
44 N	.12	.11	.11	.07	.06	.05	.03	.03	.05	.08	.13	.11
132 W	.14	.17	.11	.07	.08	.05	.05	.05	.08	.11	.12	.17
	170	150	167	181	177	169	175	149	143	173	151	177
44 N	.14	.15	.13	.12	.07	.08	.06	.04	.07	.11	.13	.11
133 W	.16	.16	.12	.11	.07	.07	.06	.07	.10	.10	.14	.15
	137	133	118	101	105	110	108	109	100	137	116	135

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
45 N	.11	.06	.06	.04	.04	.01	.01	.01	.02	.04	.10	.11
124 W	.12	.08	.09	.03	.06	.04	.05	.04	.07	.07	.12	.14
	175	188	164	150	219	230	204	182	161	211	175	141
45 N	.06	.04	.06	.04	.03	.01	.01	.01	.01	.03	.05	.10
125 W	.10	.08	.14	.05	.05	.05	.04	.04	.03	.06	.10	.14
	277	338	329	277	344	343	368	238	422	458	355	233
45 N	.13	.08	.14	.07	.05	.03	.05	.05	.09	.14	.11	.18
126 W	.24	.12	.18	.15	.08	.08	.13	.08	.12	.16	.16	.27
	109	116	83	87	103	123	87	96	99	115	113	101
45 N	.19	.14	.12	.09	.06	.05	.06	.04	.05	.12	.11	.20
127 W	.26	.17	.17	.18	.11	.08	.11	.07	.12	.12	.15	.29
	98	101	116	82	104	75	81	81	72	11.	132	86
45 N	.11	.13	.10	.09	.04	.05	.05	.03	.07	.17	.14	.29
128 W	.20	.14	.15	.21	.04	.07	.08	.07	.11	.15	.13	.27
	1.2	99	1.3	105	297	10	79	147	71	113	121	85
45 N	.14	.13	.11	.08	.06	.05	.05	.04	.08	.19	.12	.11
129 W	.19	.13	.16	.10	.09	.07	.08	.07	.08	.14	.18	.16
	119	97	144	109	100	115	97	95	123	117	131	109
45 N	.06	.06	.05	.04	.03	.03	.01	.03	.03	.06	.07	.08
130 W	.07	.08	.05	.05	.05	.04	.04	.03	.03	.06	.09	.10
	507	6.6	539	554	386	420	559	307	471	379	482	425
45 N	.08	.09	.07	.05	.04	.03	.09	.03	.05	.07	.10	.11
131 W	.10	.10	.07	.07	.05	.04	.04	.05	.07	.08	.12	.12
	257	273	234	223	260	251	274	222	209	216	199	255
45 N	.12	.12	.11	.08	.07	.04	.05	.05	.06	.1.	.09	.18
132 W	.17	.12	.10	.08	.07	.06	.06	.06	.08	.11	.13	.16
	166	143	163	192	170	167	129	141	145	16	132	127
45 N	.23	.29	.23	.15	.16	.07	.08	.09	.07	.13	.16	.25
133 W	.29	.25	.22	.16	.12	.09	.08	.12	.09	.15	.18	.34
	61	53	59	59	55	68	56	45	56	93	79	75
46 N	.04	.04	.03	.03	.03	.02	.01	.01	.02	.03	.04	.06
124 W	.04	.06	.07	.05	.04	.03	.02	.02	.03	.05	.06	.08
	907	660	692	694	7.9	712	771	696	724	818	719	675
46 N	.09	.07	.08	.05	.03	.02	.02	.01	.04	.07	.07	.13
125 W	.10	.10	.08	.09	.05	.04	.04	.04	.06	.09	.12	.14
	22.	222	269	204	246	291	314	255	269	285	258	154
46 N	.13	.13	.18	.09	.06	.07	.04	.04	.19	.11	.24	.27
126 W	.19	.19	.17	.13	.1.	.13	.08	.08	.16	.27	.27	.21
	100	93	84	74	82	78	95	87	88	89	115	76
46 N	.14	.11	.11	.08	.05	.07	.05	.03	.06	.15	.12	.18
127 W	.16	.13	.14	.11	.05	.1.	.03	.06	.11	.15	.14	.15
	126	120	140	108	100	96	102	98	95	105	181	114
46 N	.12	.16	.1.	.08	.07	.05	.04	.05	.06	.11	.14	.12
128 W	.17	.15	.11	.10	.08	.08	.08	.06	.07	.12	.17	.13
	139	148	164	118	109	105	113	110	118	139	145	145
46 N	.16	.13	.12	.15	.05	.05	.05	.04	.05	.1.	.10	.13
129 W	.17	.16	.11	.11	.09	.06	.06	.05	.09	.14	.12	.18
	145	136	154	129	116	115	107	120	113	133	136	145
46 N	.11	.14	.11	.15	.06	.06	.05	.05	.09	.14	.12	.13
130 W	.14	.16	.12	.12	.06	.08	.07	.08	.12	.11	.12	.16
	131	130	152	123	12.	140	114	98	102	123	137	130
46 N	.14	.12	.11	.07	.05	.04	.04	.05	.08	.13	.15	.12
131 W	.15	.16	.15	.1.	.04	.03	.07	.05	.08	.13	.17	.12
	141	137	112	159	157	142	123	144	141	125	154	148
46 N	.10	.09	.09	.08	.05	.05	.14	.06	.07	.09	.13	.16
132 W	.10	.09	.08	.09	.05	.06	.12	.08	.08	.12	.14	.17
	240	182	254	296	229	145	138	121	151	121	114	134
46 N	.15	.17	.15	.12	.14	.07	.06	.05	.10	.13	.17	.24
133 W	.14	.20	.15	.12	.14	.08	.09	.06	.13	.12	.18	.23
	106	92	83	95	92	77	74	86	90	105	91	108
47 N	.18	.10	.07	.08	.04	.02	.02	.02	.03	.1.	.07	.18
124 W	.15	.11	.10	.10	.09	.03	.03	.04	.04	.06	.09	.19
	80	96	91	83	84	117	119	80	101	102	173	74
47 N	.1.	.08	.06	.07	.04	.02	.01	.01	.03	.04	.07	.11
125 W	.12	.10	.08	.09	.05	.03	.02	.02	.03	.17	.09	.15
	228	198	252	195	197	356	450	436	274	357	304	155
47 N	.14	.12	.13	.09	.05	.05	.03	.03	.09	.09	.10	.12
126 W	.16	.13	.11	.10	.08	.08	.06	.06	.10	.11	.11	.14
	196	158	177	185	174	152	143	174	157	192	223	138
47 N	.15	.10	.11	.08	.05	.08	.03	.05	.08	.07	.11	.14
127 W	.13	.12	.09	.12	.08	.11	.06	.06	.1.	.1.	.13	.13
	171	177	215	171	177	175	149	151	181	17.	186	159
47 N	.15	.16	.09	.10	.06	.09	.08	.04	.06	.08	.10	.15
128 W	.12	.19	.12	.13	.06	.12	.06	.08	.10	.09	.19	.17
	151	127	156	131	128	113	108	116	183	293	154	125
47 N	.19	.21	.13	.09	.06	.05	.04	.05	.08	.09	.11	.16
129 W	.18	.20	.16	.13	.06	.03	.07	.08	.09	.1.	.16	.18
	88	100	83	94	99	95	94	86	107	198	115	98
47 N	.10	.10	.10	.05	.05	.03	.02	.02	.07	.13	.19	.09
130 W	.12	.12	.09	.05	.05	.05	.03	.05	.06	.14	.21	.08
	262	283	299	276	213	247	270	242	257	148	78	282
47 N	.08	.12	.08	.06	.04	.03	.03	.03	.04	.11	.10	.10
131 W	.13	.16	.09	.08	.07	.04	.04	.05	.06	.11	.14	.12
	237	120	18.	20.	193	267	237	316	326	202	185	262
47 N	.11	.08	.09	.13	.04	.03	.03	.04	.04	.08	.08	.11
132 W	.16	.11	.12	.09	.08	.05	.04	.05	.06	.1.	.10	.17
	159	206	171	157	265	374	292	259	232	257	248	196
47 N	.16	.18	.19	.11	.10	.08	.07	.06	.08	.1.	.20	.18
133 W	.17	.19	.15	.17	.14	.11	.08	.10	.15	.12	.22	.17
	77	84	79	88	76	75	61	85	96	114	90	91

LAT/LON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
48 N	.06	.06	.04	.03	.02	.01	.01	.01	.02	.03	.05	.07
125 W	.05	.06	.06	.04	.02	.01	.01	.02	.03	.05	.05	.08
	930	739	848	771	767	769	1213	1138	754	795	823	529
48 N	.12	.11	.10	.07	.06	.05	.02	.02	.03	.07	.09	.12
126 W	.12	.09	.08	.07	.09	.05	.03	.02	.04	.05	.09	.12
	304	209	252	193	185	197	324	327	298	400	331	201
48 N	.12	.12	.10	.09	.08	.06	.06	.04	.04	.09	.09	.17
127 W	.12	.13	.12	.14	.1	.07	.07	.06	.06	.11	.11	.15
	143	131	130	101	151	140	137	134	206	136	247	137
48 N	.12	.11	.09	.06	.06	.05	.05	.05	.08	.13	.14	.15
128 W	.14	.16	.09	.08	.08	.06	.08	.07	.14	.14	.16	.16
	114	131	139	147	148	133	118	115	130	134	142	136
48 N	.12	.14	.10	.07	.06	.05	.05	.04	.08	.11	.13	.13
129 W	.17	.12	.11	.10	.03	.04	.08	.08	.14	.15	.16	.15
	111	125	126	110	147	115	135	131	141	117	114	122
48 N	.14	.11	.09	.13	.07	.45	.06	.04	.08	.10	.14	.15
130 W	.15	.17	.10	.11	.09	.18	.09	.06	.09	.15	.16	.16
	132	108	136	123	132	139	120	148	179	131	134	141
48 N	.19	.11	.11	.06	.05	.04	.03	.04	.07	.10	.11	.10
131 W	.18	.13	.12	.07	.06	.05	.04	.06	.09	.14	.16	.15
	143	126	134	167	207	168	173	161	178	169	162	184
48 N	.08	.07	.06	.05	.03	.03	.04	.04	.07	.13	.11	.08
132 W	.08	.07	.06	.07	.04	.05	.06	.05	.08	.13	.12	.10
	322	302	335	321	380	205	192	192	209	161	197	295
48 N	.12	.14	.13	.08	.08	.07	.04	.06	.1	.13	.12	.15
133 W	.13	.16	.15	.12	.08	.07	.05	.09	.09	.12	.16	.15
	124	95	116	134	136	133	137	107	147	143	147	153
48 N	.16	.18	.15	.13	.08	.06	.05	.08	.1	.22	.13	.28
134 W	.17	.26	.14	.13	.07	.04	.05	.07	.13	.34	.14	.25
	82	107	97	104	118	119	94	91	96	114	132	114
49 N	.20	.09	.24	.28	.26	.26	.03	.02	.05	.07	.09	.15
126 W	.13	.09	.13	.08	.05	.03	.02	.02	.04	.06	.12	.16
	98	140	124	141	149	145	406	378	235	207	122	106
49 N	.12	.09	.10	.08	.06	.05	.04	.03	.06	.08	.26	.12
127 W	.12	.10	.12	.10	.05	.06	.03	.03	.06	.08	.16	.11
	152	159	170	193	213	209	331	283	268	223	212	169
49 N	.13	.08	.11	.06	.04	.04	.04	.04	.06	.10	.10	.14
128 W	.13	.12	.13	.09	.05	.05	.05	.04	.07	.11	.10	.13
	185	175	234	197	453	273	325	322	272	207	267	184
49 N	.11	.10	.09	.05	.05	.04	.04	.03	.05	.09	.09	.13
129 W	.14	.09	.09	.03	.08	.05	.05	.05	.08	.11	.11	.14
	184	190	212	245	289	241	272	251	249	233	246	194
49 N	.13	.09	.06	.06	.04	.03	.03	.03	.05	.07	.07	.11
130 W	.12	.11	.07	.07	.05	.04	.05	.05	.06	.09	.08	.12
	308	316	314	315	298	293	303	325	346	280	332	304
49 N	.09	.09	.06	.05	.04	.02	.04	.03	.05	.05	.07	.07
131 W	.09	.09	.08	.08	.05	.03	.05	.04	.06	.06	.08	.11
	430	388	411	452	330	520	458	330	420	362	368	406
49 N	.15	.10	.10	.09	.06	.05	.03	.04	.06	.09	.11	.12
132 W	.14	.11	.11	.09	.05	.05	.04	.05	.08	.10	.10	.11
	182	197	189	191	240	212	235	220	225	227	235	217
49 N	.11	.10	.11	.07	.06	.04	.03	.04	.06	.11	.13	.11
133 W	.14	.12	.08	.09	.06	.05	.04	.05	.07	.11	.13	.13
	196	185	225	250	235	244	220	272	251	233	238	190
49 N	.14	.12	.10	.03	.05	.05	.04	.04	.07	.11	.11	.11
134 W	.13	.11	.09	.12	.10	.09	.04	.05	.07	.11	.12	.12
	200	179	201	210	249	240	227	252	277	257	262	211
49 N	.12	.11	.10	.09	.08	.08	.05	.05	.06	.08	.09	.11
135 W	.11	.11	.11	.12	.07	.05	.05	.06	.07	.11	.11	.10
	183	165	139	217	213	200	184	211	263	243	306	241
50 N	.38	.17	.28	.55	.09	.09	.05	.04	.03	.10	2.75	.54
127 W	.26	.16	.33	.32	.13	.10	.05	.01	.02	.07	.51	.55
	19	30	20	35	59	27	86	88	160	112	53	17
50 N	.18	.33	.19	.11	.13	.04	.09	.06	.09	.1	.12	.32
128 W	.17	.35	.13	.17	.13	.1	.08	.09	.12	.10	.17	.27
	68	48	68	69	62	95	102	69	77	81	84	61
50 N	.17	.18	.13	.11	.06	.08	.05	.05	.07	.13	.20	.22
129 W	.20	.16	.17	.13	.07	.09	.06	.07	.11	.14	.18	.24
	93	78	89	110	136	115	171	148	129	98	106	82
50 N	.19	.13	.15	.07	.05	.06	.04	.05	.05	.11	.13	.11
130 W	.14	.13	.14	.10	.06	.06	.07	.07	.09	.11	.20	.13
	124	123	121	140	189	210	216	183	187	152	139	110
50 N	.13	.12	.10	.07	.05	.03	.04	.04	.07	.10	.11	.12
131 W	.17	.13	.11	.10	.06	.06	.05	.05	.09	.11	.12	.15
	163	149	160	217	253	202	273	240	248	180	187	154
50 N	.12	.12	.12	.08	.05	.04	.04	.09	.05	.12	.13	.14
132 W	.16	.13	.10	.08	.06	.06	.05	.23	.08	.16	.12	.23
	138	129	160	173	223	213	254	234	228	148	170	125
50 N	.14	.14	.15	.06	.06	.06	.04	.04	.07	.14	.16	.16
133 W	.16	.14	.13	.08	.06	.07	.05	.05	.08	.12	.15	.17
	125	129	137	193	212	185	214	230	203	166	147	144
50 N	.12	.08	.07	.06	.04	.03	.03	.04	.07	.11	.11	.10
134 W	.11	.10	.06	.08	.05	.04	.04	.04	.08	.11	.10	.12
	327	261	331	309	328	409	335	313	203	163	284	289
50 N	.14	.13	.11	.08	.05	.04	.03	.05	.05	.10	.11	.15
135 W	.15	.11	.11	.08	.05	.04	.04	.06	.06	.11	.13	.15
	161	162	197	212	255	263	237	237	484	228	222	188
50 N	.08	.09	.05	.04	.04	.04	.03	.04	.04	.07	.08	.09
136 W	.08	.08	.05	.03	.04	.04	.03	.04	.06	.08	.07	.09
	485	463	649	681	595	537	384	406	446	499	536	566

APPENDIX C

MONTHLY WIND STRESS CURL DISTRIBUTIONS

The monthly mean wind stress curl distributions are displayed in Charts 37 to 48. The plotted values are estimates of the vertical component of the wind stress curl, calculated by applying a finite difference, spherical coordinate curl operator to the fields of monthly mean surface wind stress. The contoured values are plotted in units of dyne cm^{-2} per 100 km. A value of 1 dyne cm^{-2} per 100 km is equivalent to 1×10^{-7} dyne cm^{-3}. The contour interval is 0.25 dyne cm^{-2} per 100 km. Positive wind stress curl is associated with surface Ekman divergence (upwelling). Negative values are shaded. These correspond to surface Ekman convergence (downwelling).

In the following charts, the month is indicated in the figure legend in the upper right corner of the charts. The coastline configuration is superimposed on the grid as a visual aid and does not represent a conformal mapping.

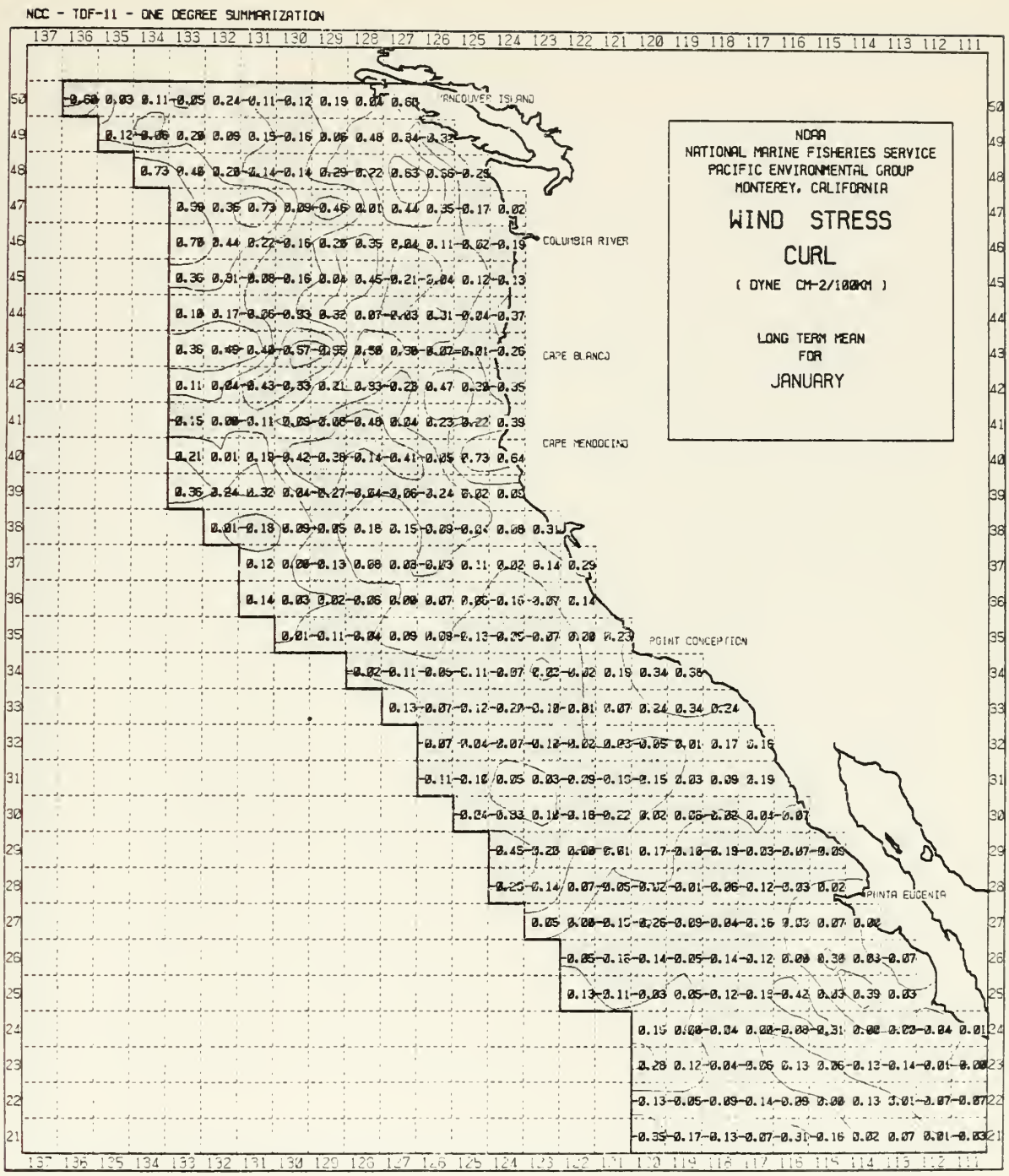


CHART 37. Wind stress curl for JANUARY.

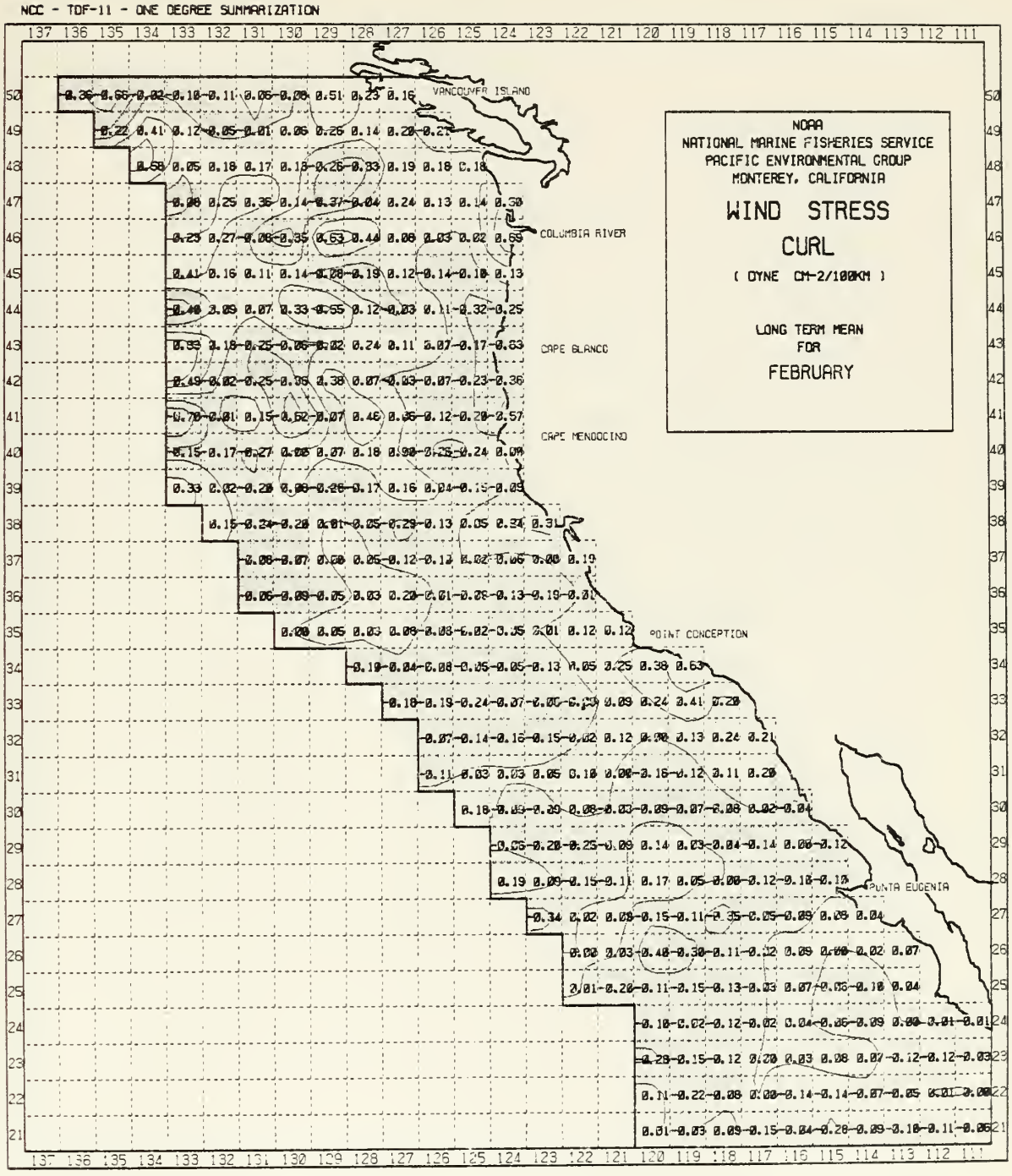


CHART 38. Wind stress curl for FEBRUARY.

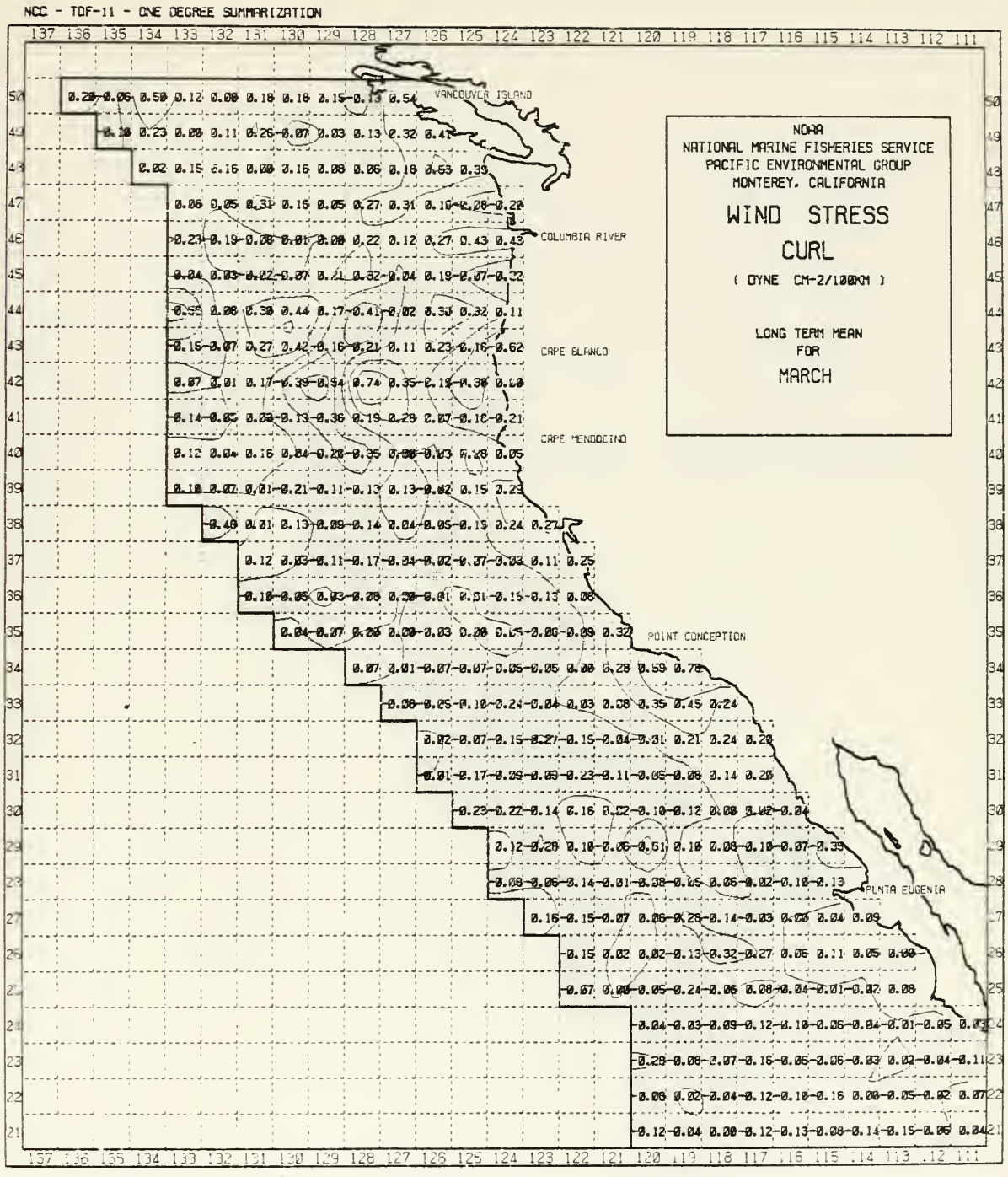


CHART 39. Wind stress curl for MARCH.

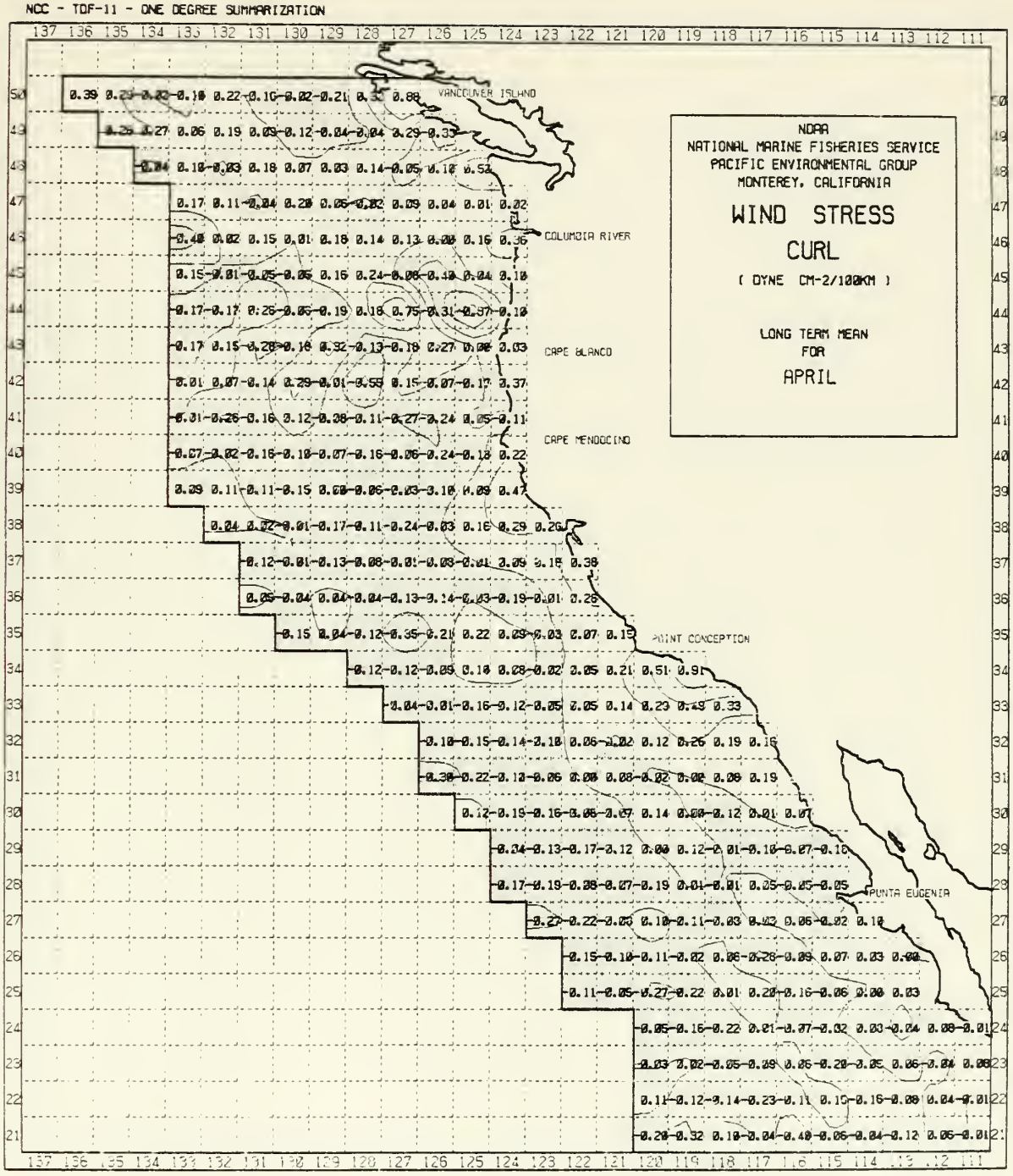


CHART 40. Wind stress curl for APRIL.

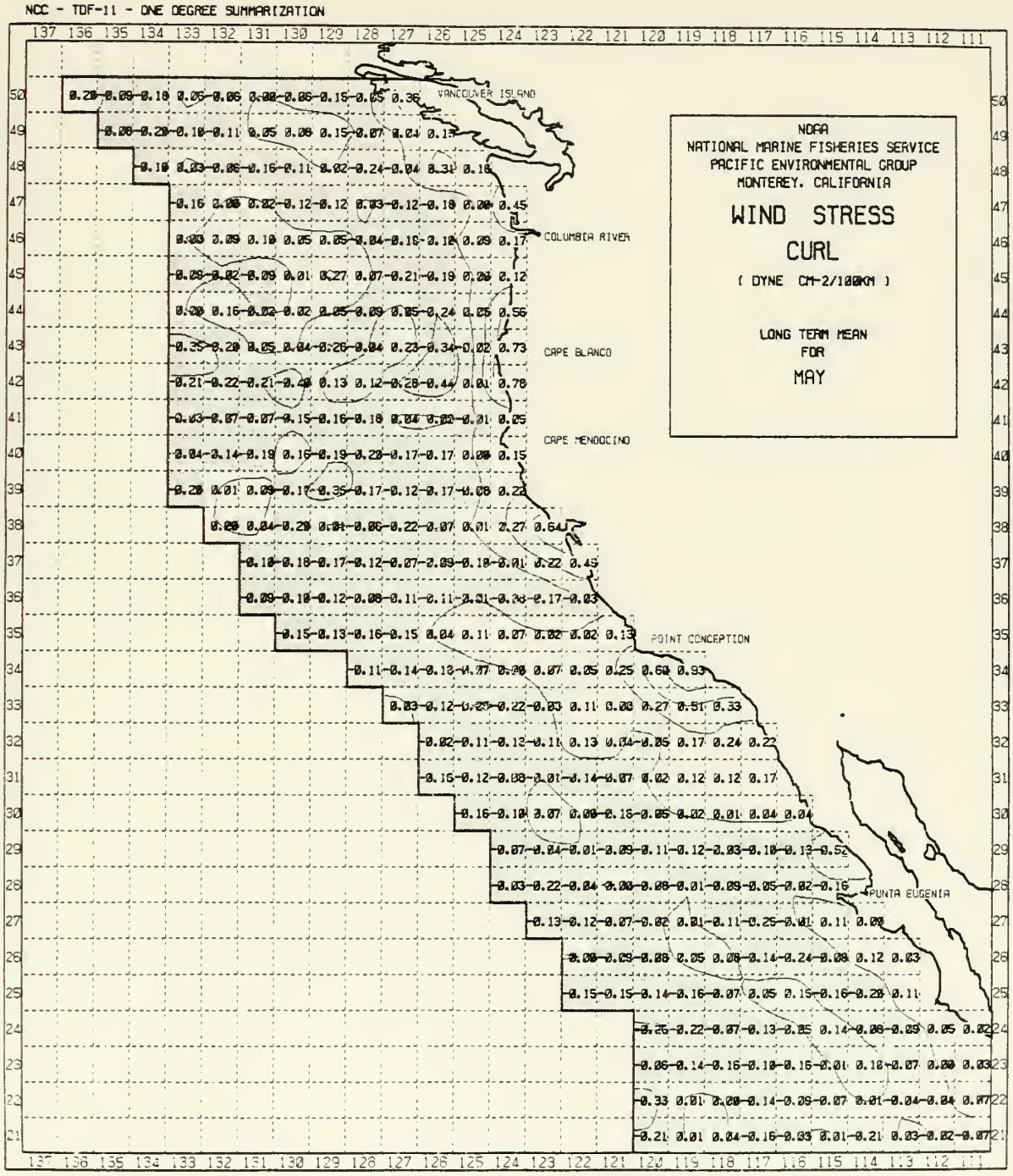


CHART 41. Wind stress curl for MAY.

+ values clear
Sfc Ekman
div upwelling

– values shaded
Sfc Ekman conv
dwn

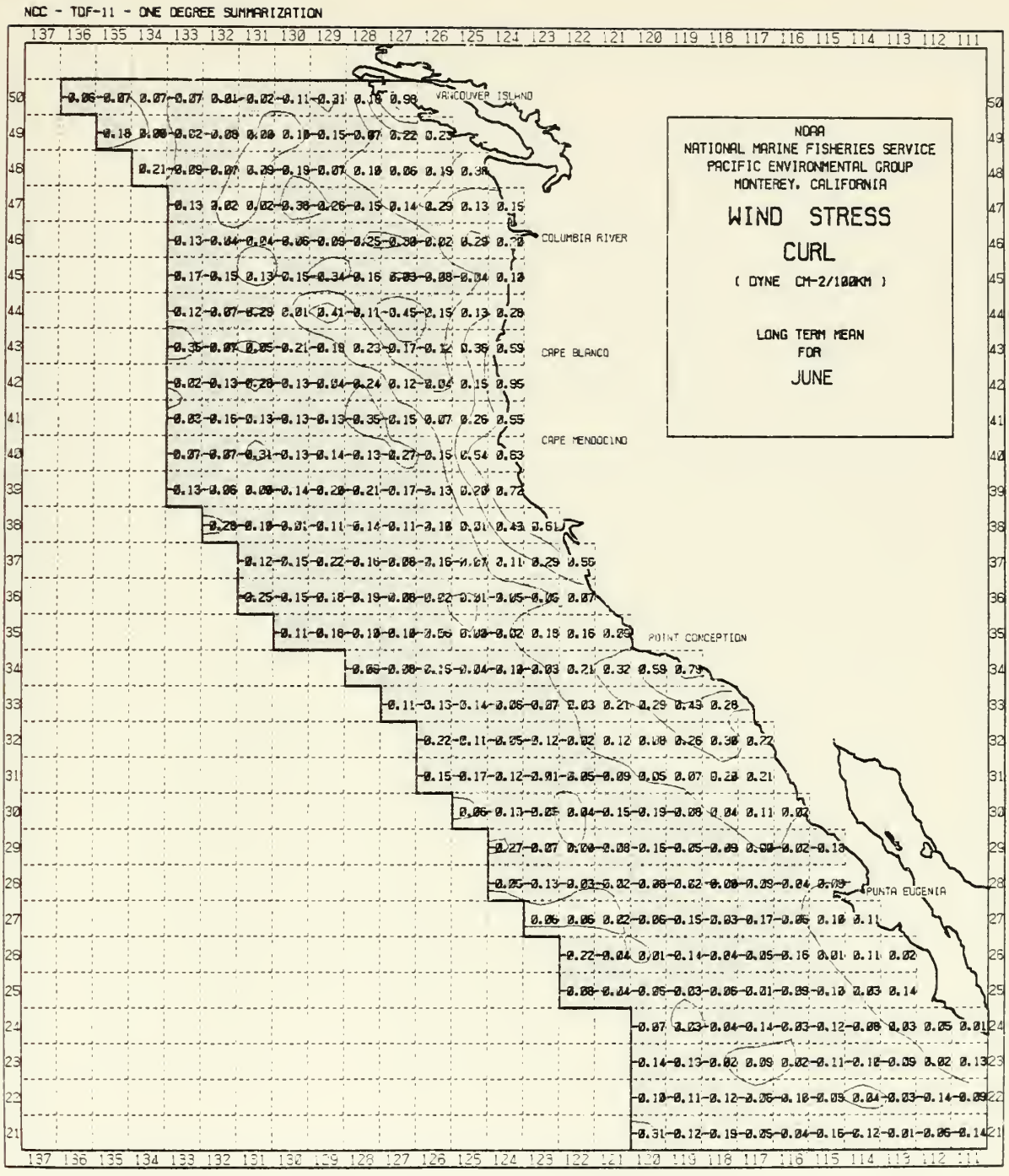


CHART 42. Wind stress curl for JUNE.

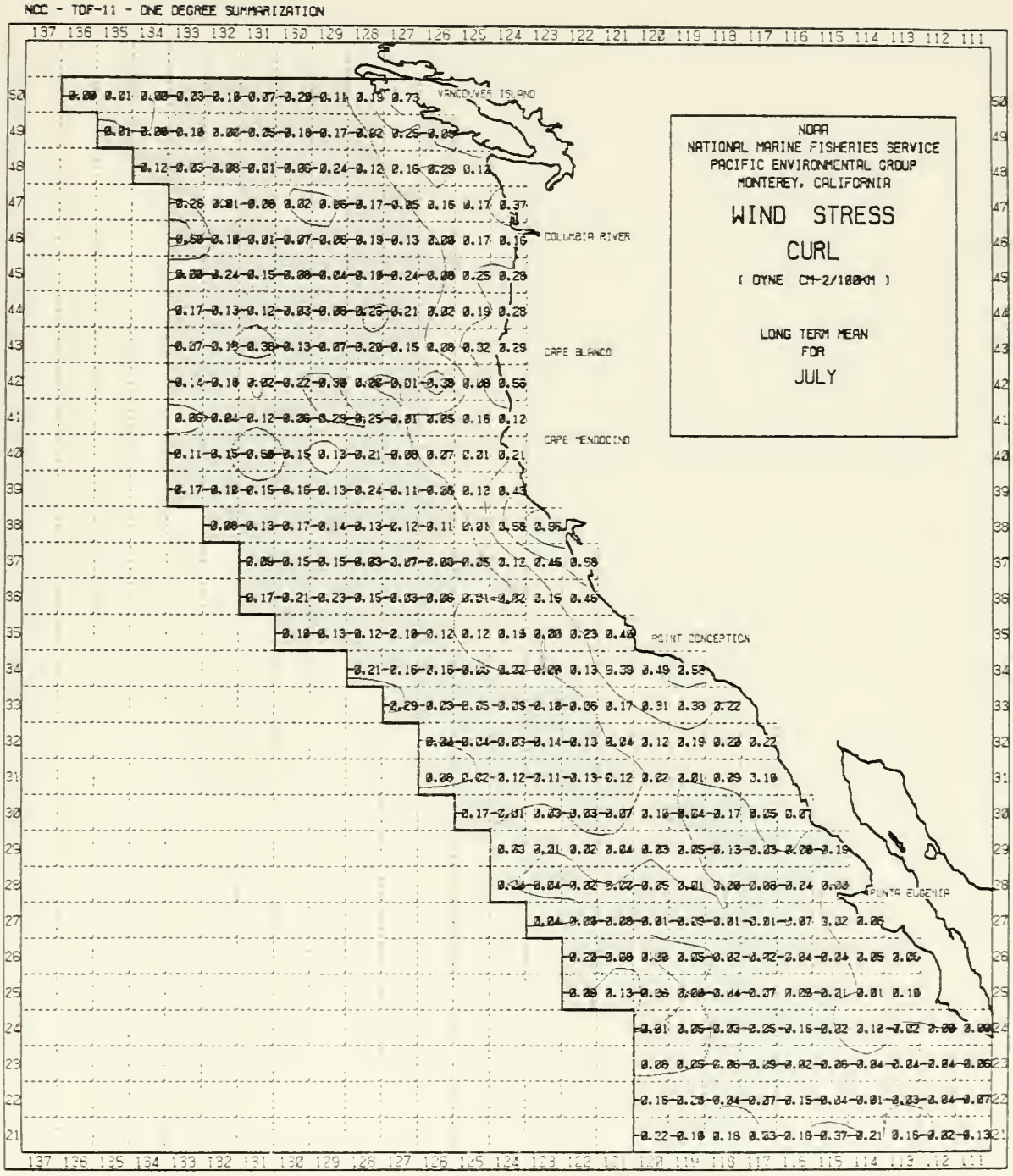


CHART 43. Wind stress curl for JULY.

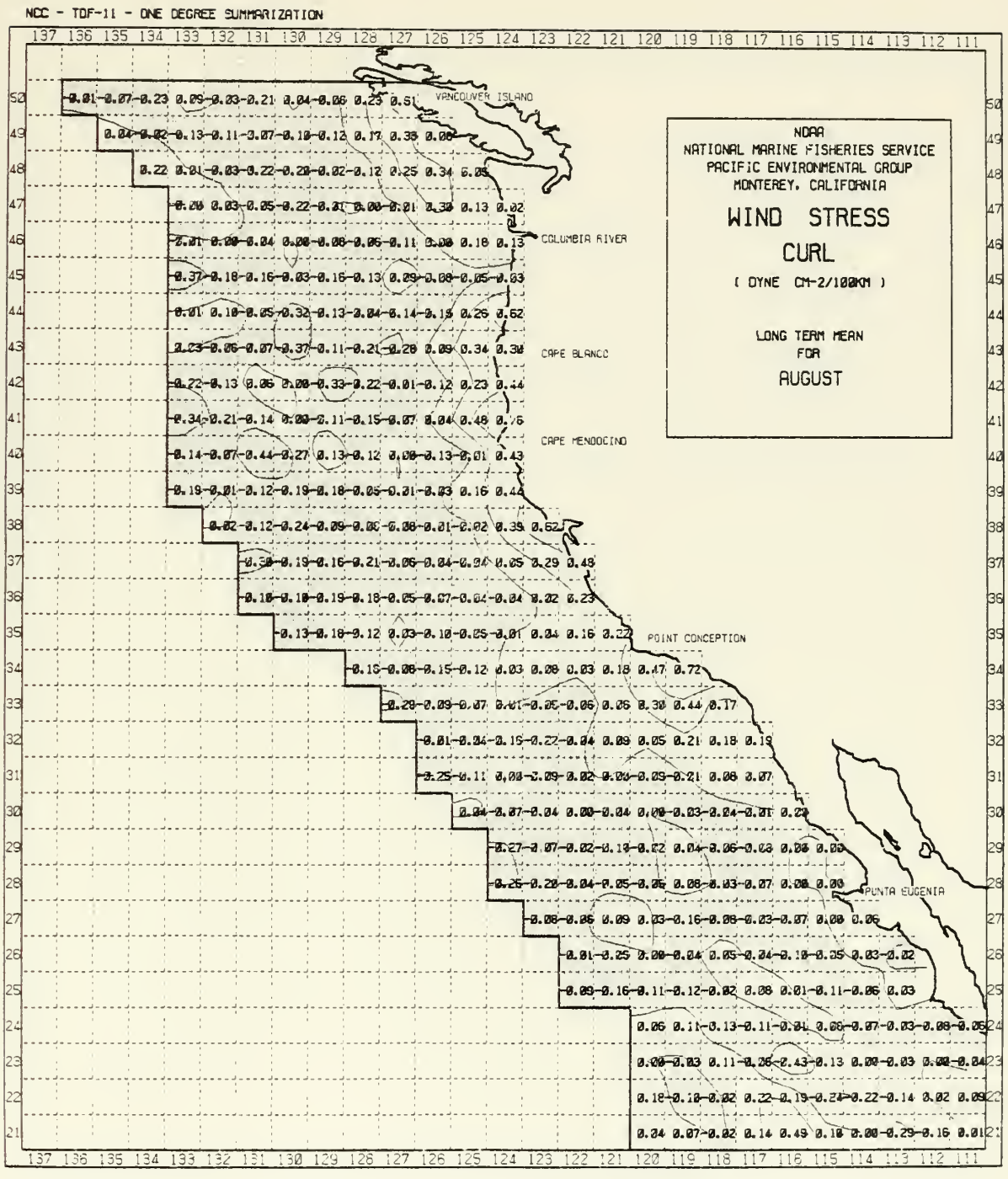


CHART 44. Wind stress curl for AUGUST.

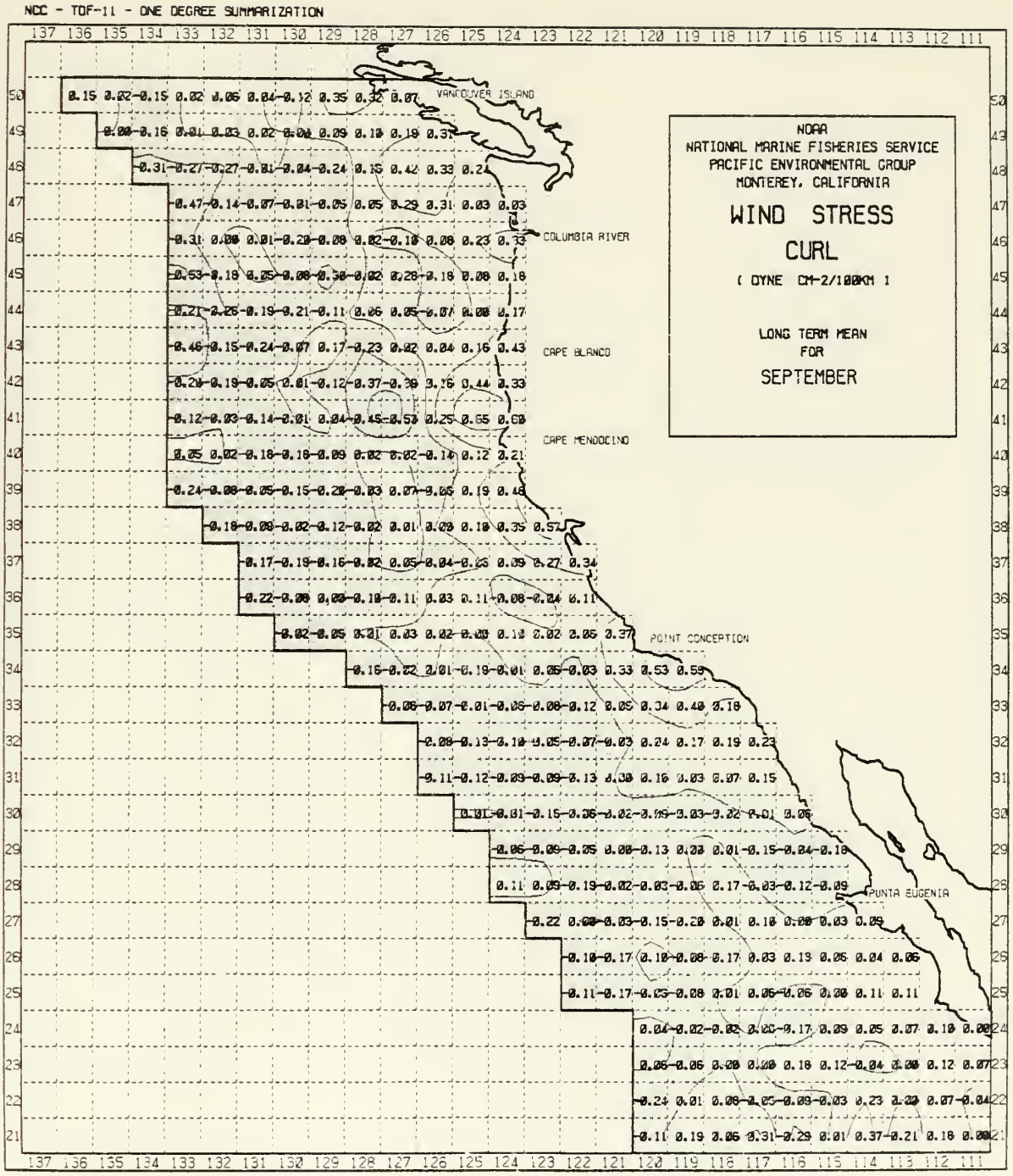


CHART 45. Wind stress curl for SEPTEMBER.

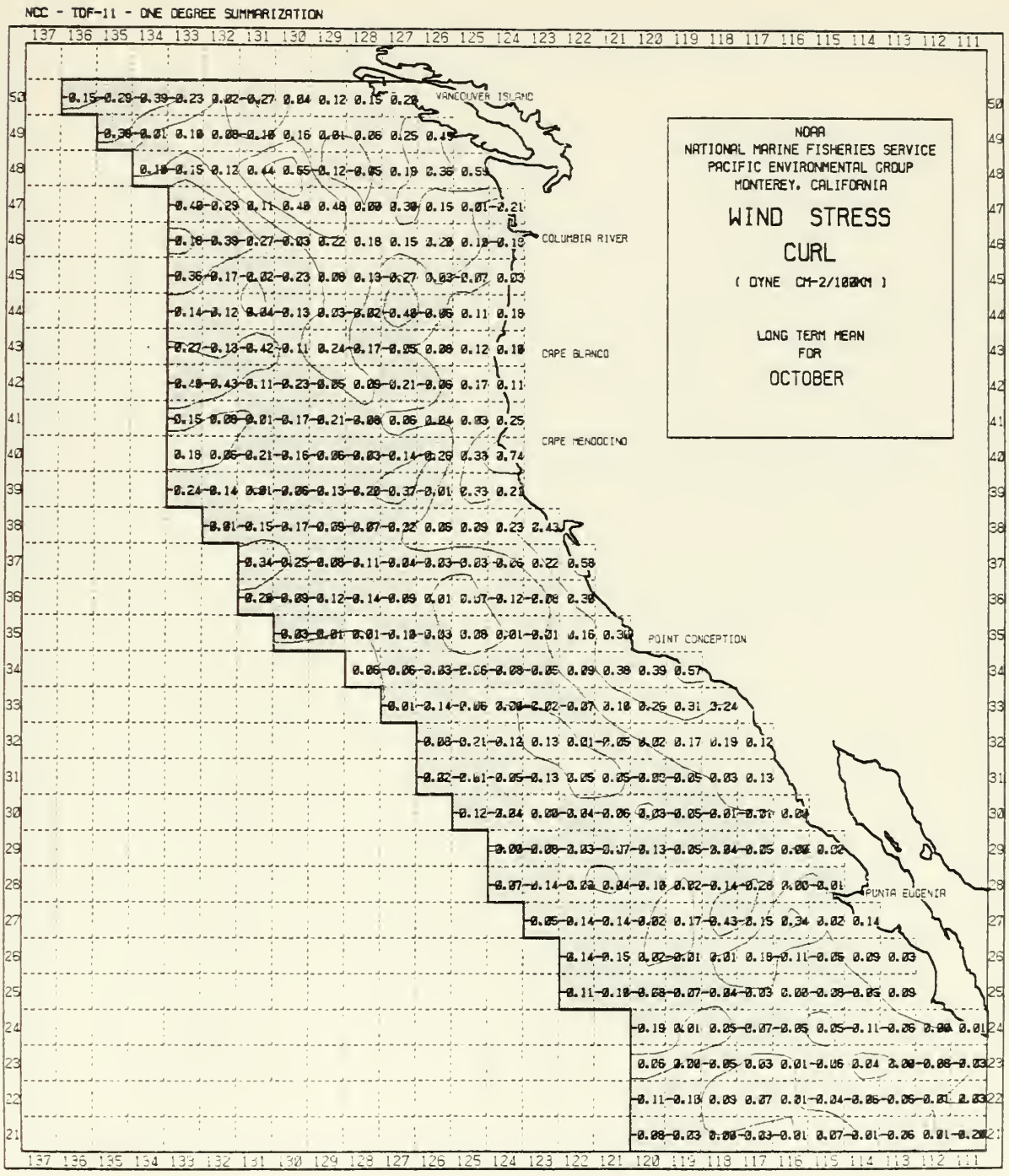


CHART 46. Wind stress curl for OCTOBER.

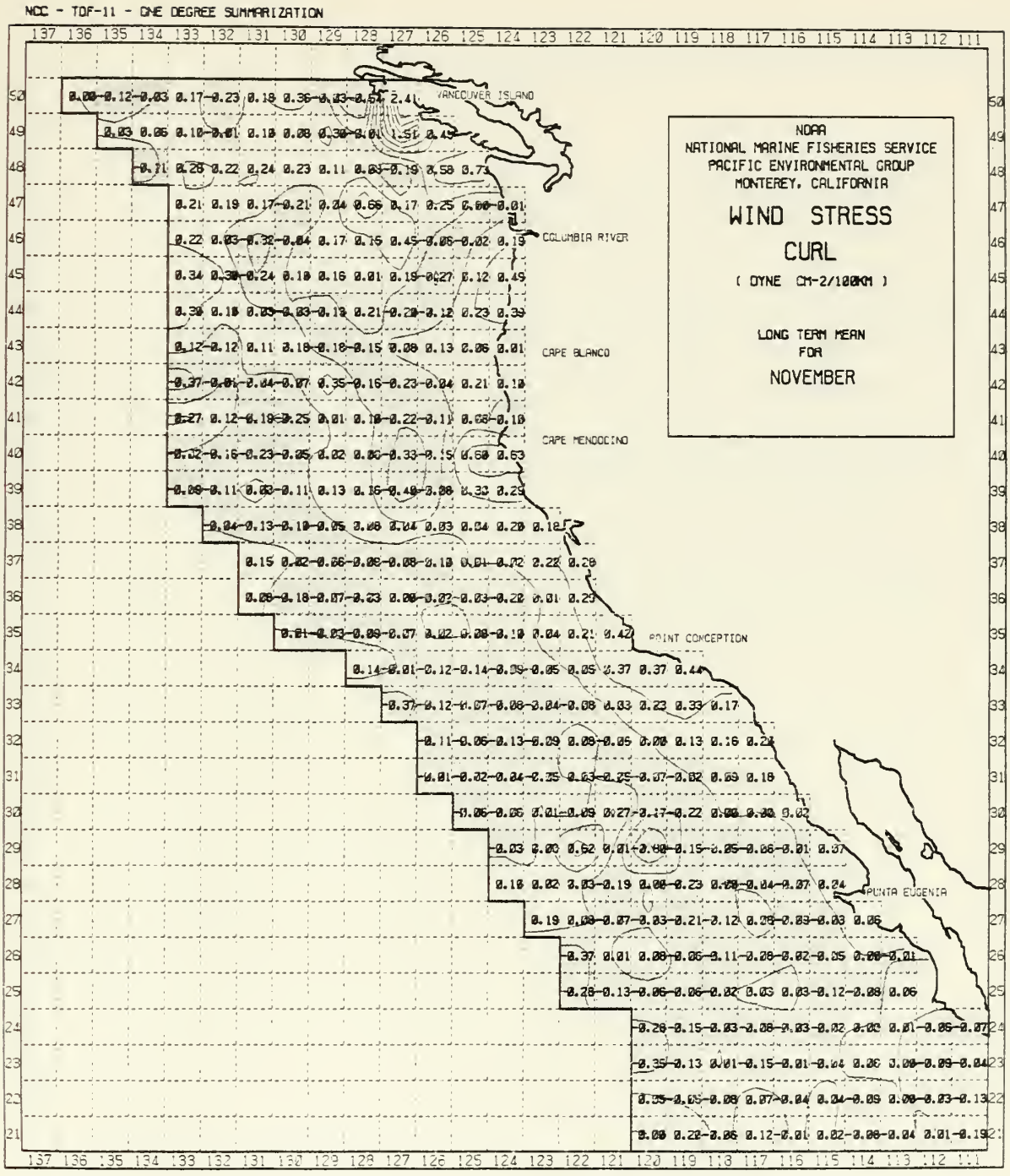


CHART 47. Wind stress curl for NOVEMBER.

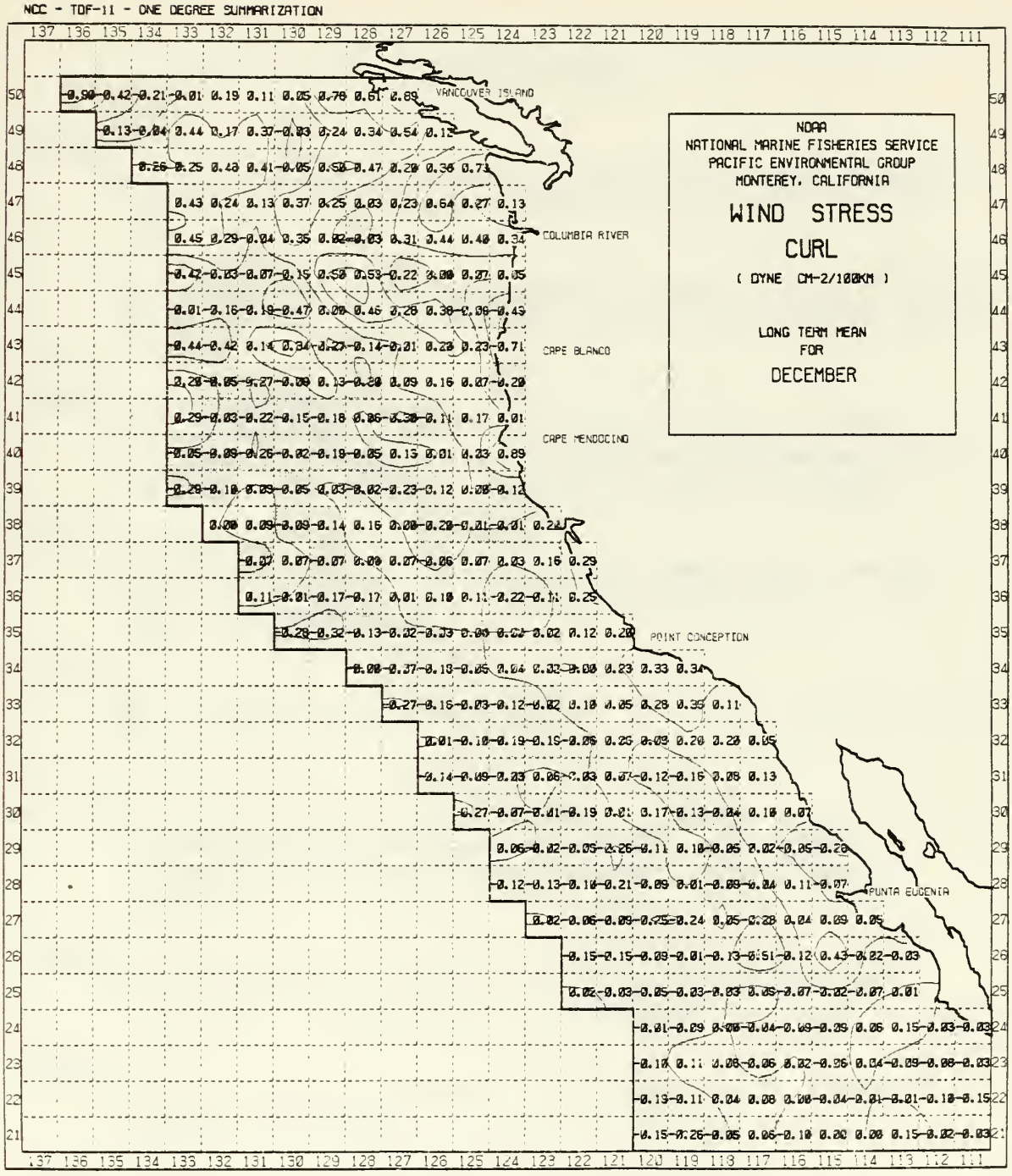


CHART 48. Wind stress curl for DECEMBER.

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