United States
Naval Postgraduate School

THESIS

A STUDY OF MEAN MONTHLY THERMAL
CONDITIONS AND INFERRED CURRENTS
IN MONTEREY BAY

by

Lennis Larry Lammers

Thesis Advisor: D. F. Leipper

June 1971

A Study of Mean Monthly Thermal Conditions and Inferred Currents in Monterey Bay

by

Lennis Larry Lammers
Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1960

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
June 1971

ABSTRACT

Temperature data, collected over the past 40 years, was compiled and averaged in the first known study of mean thermal conditions throughout the waters of Monterey Bay. The following results were obtained:

(1) The distribution of mean sea surface temperature in the Bay was obtained by calculating mean monthly values at selected grid points and drawing isotherms,

(2) Progressive warming of the upper 100m was observed to occur in a nearly linear fashion with time, resulting in a maximum temperature increase of 1.8°C over the 29 year interval from 1931 to 1960. This implies that the intensity of upwelling is also decreasing with time,

(3) Geographic variations in the rates of upwelling and downwelling, causing a relatively "warm tongue" along the Canyon axis, appeared to be a major element influencing the dynamics of the Bay, and

(4) Mean currents were inferred from the topographies of mean monthly isothermal surfaces. Limited comparisons of the inferred flow to past measured currents were very encouraging and tended to support the feasibility of such an inference in the shallow waters and irregular topography of Monterey Bay.

TABLE OF CONTENTS

I. INTRODUCTION -------------------------------------- 10

A. THERMAL CONDITIONS IN MONTEREY BAY ---------- 10

B. CURRENTS IN MONTEREY BAY -------------------- 11

1. Importance ------------------------------ 11

2. Why Little is Known Concerning Distribution of Bay Currents -------------------- 11

3. The Feasibility of Approximating Mean Currents by the Geostrophic Approach ---- 12

a. The Classical Geostrophic Method ---- 12

b. Approximations Derived from the Classical Method ------------------- 13

C. OBJECTIVES --------------------------------- 14

D. ORGANIZING AND USING THE DATA -------------- 15

II. VALIDITY OF THE COMPUTED MEAN MONTHLY TEMPERATURES (AND DENSITIES) -------------------------- 17

A. TIME RANGE OF DATA ------------------------- 17

B. POSITIONING OF STATIONS -------------------- 19

C. USE OF THREE DIFFERENT DATA COLLECTION SYSTEMS ------------------------------------ 20

D. GEOGRAPHIC DISTRIBUTION OF DATA ------------ 21

III. THERMAL CONDITIONS ------------------------------ 23

A. THE ANNUAL THERMAL CYCLE IN MONTEREY BAY ---- 23

1. The Canyon Region ---------------------- 23

a. The "Upwelling Period" ------------- 23

b. The "Oceanic Period" --------------- 24

c. The "Davidson Current Period" ------- 24

2. The Regions of the Shallows ------------ 24

B. THE VARIATIONS IN INTENSITY OF UPWELLING ---- 25

C. COMPARISON OF THE ANNUAL THERMAL CYCLE IN THE BAY TO THAT OF AN OFFSHORE LOCATION ----- 28

1. Mixing in the Upper Layers ------------- 28

2. Upwelling ------------------------------ 28

D. PROGRESSIVE WARMING ------------------------ 29

E. THE DISTRIBUTION OF MEAN MONTHLY SEA SURFACE TEMPERATURE IN MONTEREY BAY ---------------- 29

1. Description of Figures ----------------- 29

2. Discussion ----------------------------- 32

a. The Annual Cycle of Mean Sea Surface Temperature ----------------------- 32

(1) Upwelling -------------------- 32

(2) The Variation in Mean Air Temperature ---------------------- 32

b. Horizontal Sea Surface Temperature Gradients ------------------------- 33

3. Summary -------------------------------- 35

IV. USE OF ISOTHERMAL SURFACES AS INDICATORS OF MEAN CURRENT ------------------------------------ 36

A. POSSIBLE GENERATING FORCES ----------------- 36

1. Offshore Currents ---------------------- 36

a. The California Current ------------- 36

b. The Davidson Current --------------- 36

2. Winds ---------------------------------- 37

3. Tides ---------------------------------- 37

4. Upwelling ------------------------------ 37

B. VERIFYING THE CORRELATION BETWEEN ISOTHERMAL AND ISOPYCNAL SURFACES --------------------- 37

C. PORTRAYAL OF THE ISOTHERMAL SURFACES -------- 38

1. Selecting the Isothermal Surface for Portrayal ------------------------------ 39

2. Description of Figures ------------------ 39

D. MEAN CURRENTS INDICATED BY THE ISOTHERMAL SURFACES -- 40

1. Intensities of Mean Flow in the Bay and Offshore ---------------------------------- 41

2. Annual Variations of Mean Flow in the Bay -- 42

a. November to February ---------------- 42

b. February to April ------------------- 43

c. August to October ------------------- 44

d. October ----------------------------- 46

e. April·to August --------------------- 46

E. COMPARISONS OF INFERRED MEAN CURRENT TO PREVIOUSLY MEASURED CURRENTS ---------------- 48

1. March ------------------------------------ 49

2. July ------------------------------------- 49

3. August ----------------------------------- 49

a. McKay's G.E.K. Measurements --------- 49

b. Stoddard's Drogue Study ------------- 51

4. September -------------------------------- 51

5. October ---------------------------------- 52

6. November --------------------------------- 53

F. SUMMARY ------------------------------------- 55

V. CONCLUSIONS AND RECOMMENDATIONS ----------------- 56

A. CONCLUSIONS --------------------------------- 56

B. RECOMMENDATIONS ----------------------------- 56

APPENDIX A: Data Sources --------------------------- 58

APPENDIX B: Computer Processing of Data ------------- 64

APPENDIX C: List of Figures ------------------------ 75

COMPUTER PROGRAMS -- 127

LIST OF REFERENCES -------------------------------------- 159

INITIAL DISTRIBUTION LIST ------------------------------- 161

FORM DD 1473 -- 164

LIST OF TABLES

I. The Range in the Total Number of Temperatures Averaged to Compute the Means for Blocks in the Bay -- 30

II. Listing of Specific Data Contained on Computer Master Tape, NPS 306 ------------------------------ 66

III. The Station Title Record ------------------------ 67

IV. The Station Data Record ------------------------- 69

V. Definition of Computer Variables in the Final Output of Program Number 11 -------------------- 74

LIST OF FIGURES

1. Computer Grid System Used in Monterey Bay ------- 75

2. The Initial Computer Grid System ---------------- 76

3. Location of Major Data Sources ------------------ 77

4. Annual Mean Temperature Cycle by Skogsberg ------ 78

5. Annual Mean Temperature Cycle by Bolin ---------- 79

6. Annual Mean Temperature Cycle Based on CalCOFI Surveys -- 80

6A. The Progressive Warming of Bay Waters ---------- 81

7. Standard Deviation of Temperature for Selected Blocks as a Function of Time ------------------- 82

8. Standard Deviation of Temperature for Selected Blocks as a Function of Depth ------------------ 83

9. The Annual Mean Temperature Cycle at Block 19 --- 84

10. The Annual Mean Temperature Cycle at Block 3 ---- 85

11. Vertical Mean Temperature Sections S-1 and S-2 for the Month of November --------------------- 86

12. The Geographic Regions of the Bay (as Defined by Author) -- 87

13. The Annual Cycles of Mean Sea Surface Temperature in Very Shallow Regions of the Bay ------------- 88

14. The Annual Mean Temperature Cycles at Blocks 1 and 5 -- 89

15. The Annual Cycles of Mean Sea-Surface Temperature in Relatively Deeper Regions of the Shallows -------------------------------------- 90

16. The Annual Mean Temperature Cycles at Blocks 2 and 4 -- 91

17. Typical Annual Mean Temperature Cycles of a Canyon versus an Offshore Station -------------- 92

18. Dipping of the Isotherms Across the Canyon in March -- 93

19-30. Distribution of the Mean Monthly Sea Surface Temperature for January Through December ------- 94-105

31. Intensities of Mean Flow in the Bay and Offshore -- 106

32. The Annual Mean Density Cycles at Selected Blocks -- 107

33. The Annual Mean Temperature Versus Density Cycles at Block 13 ---------------------------- 108

34-48. Topographies of Selected Mean Isothermal Surfaces for January Through December ------------- 109-123

49. Comparisons of Inferred Currents to Past Measured Currents in August -------------------- 124

50. Comparison of Inferred Currents to Past Measured Currents in November Using the Plotted Position of the 12°C Isothermal Surface -------- 125

51. Comparison of Inferred Currents to Past Measured Currents in November Using a Translated Position of the 12°C Isothermal Surface -- 126

I. INTRODUCTION

Monterey Bay is a large, semi-elliptical indentation in the California coastline separated into nearly equal halves by a deep submarine canyon (Figure 1).[1] The outer extremity of the Bay may be defined by a line joining Point Santa Cruz to the north and Point Pinos to the south.

A. THERMAL CONDITIONS IN MONTEREY BAY

Several studies have been conducted of thermal conditions at specific locations in Monterey Bay. The most extensive were those by Skogsberg [1936] and Bolin [1964], both spanning five year periods. Skogsberg studied the southern portion of the Bay from 1929-1933 and Bolin researched conditions at a station in the Monterey Submarine Canyon (see Appendix A). Although these studies well defined the thermal conditions for a portion of the Bay, apparently no one had investigated the Bay as a whole.

As discussed in Appendix A, the author compiled a considerable amount of temperature (and some salinity) data covering the period of time from Skogsberg's study until the present. As outlined by the author's objectives (Paragraph C), this data was utilized to study mean monthly thermal conditions throughout the Bay and to investigate the possible relationship between the thermal conditions and indicated mean currents.

---

[1] All figures will be found in Appendix C.

B. CURRENTS IN MONTEREY BAY

1. Importance

The distribution of current in Monterey Bay is virtually unknown but there is little doubt of its great importance in determining the ecological future of the area. Pollutants, transported by the currents, are scattered freely along the beaches in the form of sewage and general rubbish. Less evident is the adverse effect on marine life created by the discharge of industrial pollutants into the Bay. Currents not only distribute "harmful" pollutants but also serve to maintain the chemical and thermal balance necessary to support marine life.

2. Why Little is Known Concerning Distribution of Bay Currents

The well established currents of the open oceans are relatively strong and unchanging with time (e.g., the Gulf Stream and the offshore California Current) and hence, their general movements are fairly well understood. Monterey Bay, being enclosed on three sides, presents a different situation. The Bay currents are weak and variable and their mean flow is almost completely disguised by the effects of local winds, tides, topography, and seasonal changes in the offshore currents.

Past current studies in the Bay have been of a limited nature, both in time and in geographical coverage. They have contributed towards an understanding of "short term" currents (such as those resulting from the tides) but too few observations have been made to be of much use in

describing the mean flow. In time, and with many additional current observations, a study of the combined effects could prove to be of great value.

3. The Feasibility of Approximating Mean Currents by the Geostrophic Approach

Indirect approximations of current using the geostrophic theory may be divided into two categories: (1) the classical use of the geostrophic method, and (2) approximations derived from the classical method.

a. The Classical Geostrophic Method

Basically, flow obtained by classical application of the geostrophic method is that which results from the balancing of the Coriolis force and the pressure force between two points on a surface of variable elevation. (Neumann and Pierson [1966] discuss the theory in their book entitled, Principles of Physical Oceanography). Computed elevation of the sea surface at a given location in the ocean is represented by a term called the "dynamic height," a relative parameter based on the density of sea water at the location and referred to an assumed level-of-no-motion. A high value of density (usually colder water) yields a lower dynamic height and conversely. By geostrophic theory, the circulation in the Northern Hemisphere is counterclockwise about locations of lower dynamic height (depressed surfaces) and clockwise about locations of higher dynamic heights (elevated surfaces). The level-of-no-motion is the depth of water (as best can be ascertained) where

absolute current velocity equals zero and this rarely occurs at depths less than 150m.

Accurate representation of the mean current based on the classical geostrophic method thus requires two prerequisites; (1) a knowledge of mean temperature and salinity (to obtain mean density) of the water column at several well spaced locations in the area of interest, and (2) a level-of-no-motion everywhere shallower than the depth of the bottom (otherwise, there is no reference except the bottom itself from which to compute true velocity). Finally, of course, wind driven and tidal currents are neglected in computing means.

b. Approximations Derived from the Classical Method

Several approximations to the classical approach have been used in relatively deep waters with considerable success. Barker and Denham [1970] used the classical method to plot geopotential topographies (surfaces of equal dynamic height) for various levels-of-no-motion off the northeast coast of New Zealand. The close correlation between the shapes of the topographies suggested that broad current patterns could be approximated without using an accurate level-of-no-motion. Duncan and Nell [1969] demonstrated that isopycnal (equal density) surfaces were closely related to current patterns in their study off the Cape Coast. Drift cards were employed to measure general current trends and were found to follow the isopycnal contours as predicted by geostrophic theory for

the Southern Hemisphere. Leipper [1970] demonstrated that temperature data alone could be used to approximate current in the Gulf of Mexico. Monthly topographies of the 22°C isothermal surface were constructed by him from data collected on various cruises during the period 1965-1966. The current was found to closely follow the contours, moving in a direction placing colder waters to the left of the flow. These results were verified by geostrophic flows computed at various locations in the Gulf. This approach is based on the assumption that temperature changes are directly proportional to density changes throughout the water column, and thus isothermal surfaces may be considered in place of isopycnal surfaces.

Application of any of the above approximations to the shallow waters and irregular topography of Monterey Bay would be a considerable extension of usual practice. However, the theory of geostrophic flow does not depend on the depth of water, therefore, geostrophic methods might be useful in indicating broad current patterns in the shallow waters of the Bay. Considerable temperature data was compiled for Monterey Bay in this study (see Appendix A). The author used this data to investigate the feasibility of relating mean currents to mean isothermal surfaces in a manner similar to that of Leipper.

C. OBJECTIVES

The objectives of this study are to:

1. Compile temperature and salinity data from previous oceanographic studies conducted in Monterey Bay,

2. Conduct a study of the distribution of mean monthly temperature in Monterey Bay and construct charts of the mean monthly distribution of sea surface temperature,

3. Investigate the feasibility of inferring mean currents from the topographies of mean isothermal surfaces, and

4. Prepare a computer program for the continuing storage and retrieval of oceanographic data collected in Monterey Bay.

D. ORGANIZING AND USING THE DATA

The IBM 360 computer at the Postgraduate School was used to compile the temperature data and to compute monthly averages (as discussed in Appendix B). A grid system, dividing the Bay into 19 blocks, 4mi by 4mi in dimensions, was used to segregate the temperature data (Figure 1). The author's initial grid system covered a larger area (Figure 2) containing 39 blocks, but only the numbered blocks held significant data. The mean temperature of a given block, based on the averaging of all temperatures compiled for that block, was assumed to be effectively located at its center.

The temperature data was compiled over the 40 year interval from 1929 through 1968. Temperatures collected by all reliable methods were combined in the averaging process (although the computer program did allow for data to be retrieved by type, i.e., Nansen, XBT, BT).

The risks inherent in the "lumping" together of all types of temperature data spanning a 40 year interval and further reducing data from 4mi by 4mi blocks to represent points in their centers were fully realized. This lumping was essential due to the erratic distribution of data within the Bay and also because no reasonably short time span held enough data to support this study. The errors introduced by the above procedures are discussed in Chapter II.

II. VALIDITY OF THE COMPUTED MEAN MONTHLY TEMPERATURES (AND DENSITIES)

A discussion of the questions raised in the Introduction involving the method of computing mean monthly temperatures is considered necessary before an appraisal of the results (Chapters III and IV) can be made.

A. TIME RANGE OF DATA

Data from three separate time intervals within the previously mentioned 40 year time span was averaged and compared to determine the degree of consistency of thermal conditions relative to the progression of time. Three Bay studies (as referenced in Appendix A) were used: (1) Skogsberg (1929-1933), (2) Bolin (1951-1955), and (3) CalCOFI surveys (1954-1967).[2] The time intervals between midpoints (mean years) of the studies were 22 years from Skogsberg to Bolin and 7 years from Bolin to CalCOFI, with a total time interval of 29 years (1931 to 1960).

The annual thermal cycles of the three periods (Figures 4-6) were generally similar in shape with upwelling noticeable from the surface to 500m (as characterized by the humps in the isotherms during the months of April through June). A consistent feature over the 29 year interval was the apparent weakening in intensity of upwelling

---

[2] The oceanographic stations used in these studies are shown in Figure 3. Skogsberg's station is denoted by "C", Bolin's by "B" and CalCOFI by a square numbered "3". It is noted that the three stations are contained within a radius of two mi.

with time. The 9°C isotherms from all three studies are plotted in Figure 4 to demonstrate the effect. It was observed that the depths of the 9°C isotherms were relatively close together during the winter months. During the remainder of the year (especially noticeable in May) the 9°C isotherms were observed to deviate from one another. The deviation followed a consistent pattern with the 9°C isotherm of the earliest study (Skogsberg in 1931) at the shallowest depth and the 9°C isotherms of the later two studies at greater depths as time progressed. This "flattening out" of the 9°C isotherm with time could indicate a weakening in intensity of upwelling.

A general warming with time was also observed to occur throughout the waters of the Bay. Figure 6A depicts the temperature increase (ΔT) observed to occur over the period from 1931 (Skogsberg's mean) to 1960 (CalCOFI's mean) at selected depths throughout the year. The curves represent the variation of ΔT for each month and for depths from the surface to 500m. Figure 6A shows that the maximum temperature increase occurred at depths from the surface to 100m and during the period from October to December. At depths from 200-500m, ΔT cycled between positive and negative values throughout the year; however, ΔT was always positive (temperature increase) in the months of May, June, September, and October.

The consistently positive values of ΔT in May and June for depths from the surface to 500m might be another indication that upwelling was decreasing in intensity (with time)

throughout this region, since the warming in May and June would also indicate a flattening out of the isotherms. The reasons for the maximum temperature increase during the months of October to December are unknown. It could be related to changes in the "Oceanic Period," or possibly, to changes in the transition period between the influence of the California and Davidson current systems.

In summary, the general warming of the water column with time was observed to be consistent in the upper 100m (by the similarity in the shape of the ΔT curves in Figure 6A at these depths). At depths below 200m, the consistency was not as good (as observed by the ΔT curves cycling between positive and negative values); however, the total range of ΔT was only 0.5°C in the deeper waters.

The maximum temperature increase over the 29 year interval was 1.8°C (the 50m curve in November from Figure 6A) resulting in about 1/15th of a degree C increase per year. This small annual temperature change, along with the general similarity of the curves (as observed in Figures 4-6) was considered to represent consistent behaviour with time. It was concluded that the author's method of averaging temperature values was justified. This provided averages that were representative of the overall period.

B. POSITIONING OF STATIONS

The computer grid system was based on the assumption that all temperature values found in a given block were located at its center. The grid system was initially positioned

so as to minimize the distance of known oceanographic stations from grid centers. The maximum deviation from such centers was 1.6 mi. Data was assumed to be scattered randomly around the centers of the blocks in the grid system.

C. USE OF THREE DIFFERENT DATA COLLECTION SYSTEMS

The data was collected by Nansen, BT, and XBT devices. Several papers have been written concerning system errors peculiar to each. The magnitude of the errors in the BT's and XBT's are apparently undeterminable.

To investigate the significance of possible system errors, the standard deviations (σ) of temperature (and density) values were included in the computer output. ($\bar{X} \pm \sigma$) represented the interval containing 67% of all values averaged for a given mean ($\bar{X}$).

Standard deviations of mean monthly sea surface temperature versus time (by months) were plotted for selected blocks. Figure 7 (Block 13) represented the worst condition found. The larger standard deviation in July was not representative; the consistent features of all graphs were: (1) minimum values of standard deviation for the month of January, and (2) the relatively small variation of the values throughout the year.

Plots of standard deviation versus depth (Figure 8) were also consistent. Values of standard deviation halved within 30-40m of the surface, reached values of 0.5°C anywhere from 50-275m and then linearly decreased to minimum values of

0.1-0.2°C in deeper waters. The decrease of standard deviation with increasing depth of water and its practically invariable value (0.1-0.2°C) below 800m, where the data was exclusively from Nansen casts, indicated that seasonal changes were mainly responsible for variations in mean temperatures. System errors were thus neglected.

D. GEOGRAPHIC DISTRIBUTION OF DATA

The 3000 oceanographic stations used in this study (25,100 temperatures) were erratically distributed throughout the blocks in the computer grid system (Figure 2). Blocks 1-6, 13, 20, and 21S contained the major portion of the data (10-85 surface temperatures per block per month) and thus were given major consideration in the analysis. The remainder of the blocks contained random amounts of data, except for Blocks 17 and 19 which generally contained 3-6 values per month each.

Clearly, the blocks containing relatively few temperatures (less than 10 per month) would yield less reliable averages than blocks with many values. Choosing a minimum number of temperature values to achieve relatively accurate mean monthly temperatures was based on a study of continuity between weak blocks (with less than 10 temperatures per month at a given depth) and strong blocks (more than 10 temperatures).

Graphs of annual mean temperature cycles, mean monthly temperature sections, and standard deviation versus time and depth were drawn for weak Blocks 8, 17, and 19 and for strong Blocks 1-6 and 13. The annual mean temperature cycles of the

weak blocks compared closely to those of the strong blocks. This comparison was well represented by Block 19 (Figure 9) and Block 3 (Figure 10).

Further continuity in data between weak and strong blocks was demonstrated by Figure 11, showing the thermal structures of two vertical sections (see Figure 12 for location of sections), one oriented north to south connecting Blocks 1, 2, 17, and 5 (S-1) and the other oriented along the Monterey Submarine Canyon axis (S-2) connecting Blocks 13, 3, 17, and 19. The isotherms were smooth and continuous in the upper and lower waters for both sections throughout the year. In depths from 50-100m, the isotherms were smooth and continuous along section S-2. Along section S-1 the isotherms were occasionally depressed at Block 17. The depression of isotherms at Block 17 in section S-1 and lack of depression for the same block in section S-2 will be shown to be consistent in Chapter III, paragraph B.

Finally, the standard deviations of mean monthly temperatures versus time and depth were comparable for all blocks, weak or strong (Figure 7 and 8 were representative).

The continuity exhibited in the vertical sections between adjacent weak and strong blocks (and within the blocks as time progressed) supported the limited use made of the weak blocks for constructing mean monthly isothermal surfaces in Chapters III and IV. As the isothermal surfaces were prepared, the weak blocks demonstrated further consistency of data, especially Blocks 8, 17, and 19. Examples of this are noted in Chapter IV.

III. THERMAL CONDITIONS

A. THE ANNUAL THERMAL CYCLE IN MONTEREY BAY

The "3-phase" annual thermal cycle occurring at specific locations in Monterey Bay has been described by Skogsberg [1936], Bolin [1964] and others. The following discussion considers the variation in mean thermal conditions relative to various geographic locations throughout the Bay, a subject apparently not previously dealt with.

Figure 12 depicts three geographic regions in the Bay that the author will refer to in this Chapter. The choice of the 50 fathom curve as a dividing line was arbitrary, but gave the desired sectioning.

1. The Canyon Region

Since Bolin described the thermal conditions for the Canyon region a detailed account will not be repeated here; however, a brief description of the "phases" will be necessary for later comparisons.

a. The "Upwelling Period"

Commonly considered to span from mid-January to September, the Upwelling Period is characterized by the rising of the deep, colder waters. As found in this study (Figure 10), the cold waters began their upward movement in mid-January from depths as great as 700m (however, the movements were minimal below 300m). The maximum rate of rise occurred between February and March and the peak was found in April or May when the 11°C water nearly reached the

surface. Although upwelling reached its peak later at greater depths, none was observed after July.

The descent (downwelling) of the cold waters generally commenced in June and was apparent until late November at greater depths.

b. The "Oceanic Period"

This period is commonly considered to occur during September and October and is well defined by the sharp vertical temperature gradients at depths from the surface to about 100m.

c. The "Davidson Current Period"

In November the south-moving California Current is displaced by the north-moving Davidson Current along the coast. The influx of warmer waters into the Bay results in a weakening of the vertical temperature gradients and a resulting well-mixed layer of water from the surface to about 50m. The northerly flow continues until mid-January when the California Current again predominates and the "3-phase" annual cycle commences again.

2. <u>The Regions of the Shallows (see Figure 12)</u>

The annual thermal cycle in the Shallows was similar to that in the Canyon Region with two noteworthy exceptions:

First, the very shallow regions at the extreme northern and southern ends of the Bay possessed unique annual thermal cycles at depths from the surface to 10m. Referring to Figure 13, the annual cycle of the surface temperature in the Canyon (Block 3) showed a clear decrease

in temperature from January until early May and then a steady increase until late September (this was typical for all the deep water areas). The annual cycles of surface temperature for the very shallow waters (Blocks 1 and 5) showed no similar decrease in late winter but rather a steady increase from mid-January until late September (Figures 13 and 14). This steady temperature increase, unique for the shallow water regions (less than 75m), was probably due to greater heating of the water column from bottom reflection and the insolation of nearby land masses. This greater heating of the shallow areas is clearly shown in the distribution of mean monthly sea surface temperatures as will be discussed in paragraph E (Figures 19-30). The relatively deep regions of the Shallows areas (Blocks 2 and 4) exhibited a very slight amount of cooling from January until May, but not nearly as much as did the canyon Region (see Figures 15 and 16). The second exception is discussed below.

B. THE VARIATIONS IN INTENSITY OF UPWELLING

In studying the various graphs constructed for the analysis of thermal conditions, the author came upon a feature which could be an important element in the dynamics of the Bay in general. Figure 17 is introduced to show the months of the maximum rates of upwelling and downwelling during the year. Inspection of the annual cycle in Block 3 shows maximum rates of upwelling from February to March, and

maximum rates of downwelling (or heating) from July to August (note the slopes of the 10°C and 11°C isotherms).

Vertical temperature section S-1 (see Figure 12) shows a strange dipping of the isotherms at Block 17 for all of the above mentioned months (Figure 18 is representative). Block 17 was a weak block (less than 10 temperatures per month) and thus the dipping was suspected. To attempt to verify the dipping of isotherms in the Canyon, two additional sections were constructed (see Figure 12 for locations), both running across the Canyon axis (as did section S-1). Section S-3 connected Blocks 2, 3, and 4, and section S-4 connected Blocks 2, 3, and 6 (emphasis is placed on the fact that sections S-3 and S-4 contained only strong blocks with greater than 20 temperatures per month each).[3] The results are clearly illustrated in Figure 18 which shows marked dipping of the isotherms across the Canyon axis in all sections. This results in a relatively warm tongue along the Canyon axis for the months of maximum rates of upwelling and downwelling.

The dipping of the isotherms across the Canyon axis could have been caused by the up-slope entry of the cold upwelling waters into the regions of the Shallows. During February and March, when upwelling rates are highest, the cold waters are ascending from depths down to 300m. As the

---

[3] Table V lists the number of temperatures compiled for the various blocks of the computer grid system.

cold, dense water spreads to the Canyon walls, its horizontal movement is interrupted, and thus it is accelerated up the walls and into the shallower adjacent regions. Conversely, in July and August, when downwelling rates are highest, the cold waters are descending from the near-surface regions. Their rates of descent are accelerated into the Canyon since the deepening topography offers no resistance to their sinking. The transition period (from April to June) between upwelling and downwelling showed no dipping of isotherms across the Canyon.

No dipping of isotherms was observed along the Canyon axis. This would be as expected since the depth of water along the axis (section S-2) was everywhere deeper than 300m thus affording no bottom influence upon the cold upwelling waters.

The annual mean temperature cycles of the relatively deep regions (Figure 16) and the very shallow regions (Figure 14) of the Shallows further demonstrated the up-slope surge idea. During the months of highest up/downwelling rates, Blocks 2 and 4 (adjacent to the Canyon) exhibited somewhat stronger upwelling (greater slopes of the 10°C and 11°C isotherms) than did Blocks 1 and 5 which were at the extreme northern and southern ends of the Bay. It thus appeared that the cold up-surging waters might have lost some of their momentum by the time they reached the very shallow regions of Blocks 1 and 5.

C. COMPARISON OF THE ANNUAL THERMAL CYCLE IN THE BAY TO THAT OF AN OFFSHORE LOCATION

Block 20, located 22 mi west-southwest of the Bay (Figure 2) was compared to Block 3 in the Canyon. Figure 17 demonstrated two broad differences between the thermal conditions of the two locations.

1. Mixing in the Upper Layers

The offshore station exhibited generally warmer surface waters throughout the year and better mixing of the upper waters (0-50m) from January to April. At onset of the "Oceanic Period" in September, the offshore and Bay stations both exhibited maximum vertical temperature gradients.

At the close of the "Oceanic Period" in November, the Bay station exhibited somewhat better mixing than did the offshore station, maintaining its more uniform surface waters until January. The weakening of the vertical temperature gradients in the Bay (as described by Bolin) was assumed to be the result of the influx of warm waters brought into the Bay by the north-flowing Davidson Current (during the period of November through January). The more uniform mixing of the Bay waters might have been due to a greater influence by the Davidson Current nearshore.

2. Upwelling

Upwelling is considered to result from the northerly winds deflecting the surface waters to the right and away from the coast, allowing the deeper cold waters to rise. The intensity of upwelling should then decrease as the distance

to the coast increases. Figure 17 demonstrated that this was indeed the case, Block 20 showing less intense upwelling than Block 3.

D. PROGRESSIVE WARMING

Chapter II, paragraph A, contains a discussion of the progressive warming found for the entire water column in the Bay over the 29 year interval from 1931 to 1960. It should be noted that Bolin [1964] found an opposite indication of progressive cooling from 1951-1955. He investigated the "previous and subsequent" sea surface temperatures taken at selected locations along the west coast of North America and found that the years of his study were all relatively cool and that 1955 had the minimum temperature in a "long-term trend." In Chapter II, evidence was presented indicating continual progressive warming over the 29 year interval noted above. It thus appears that the cooling observed by Bolin was a short-term cycle.

E. THE DISTRIBUTION OF MEAN MONTHLY SEA SURFACE TEMPERATURE IN MONTEREY BAY

Figures 19-30 depict the distribution of mean monthly sea surface temperature in Monterey Bay.

1. <u>Description of Figures</u>

The dots on each figure (representing the centers of their respective blocks) served as the points from which isotherms were drawn. The values of mean monthly temperature are directly below the points. Table I lists the total number of temperature measurements per block per month (at

TABLE I. The Range in the Total Number of Temperatures Averaged to Compute the Means for Blocks in the Bay

BLOCK NO.	DEPTH (m)	J	F	M	A	M	J	J	A	S	O	N	D
		RANGE OF TOTAL TEMPERATURES PER MONTH AT 0 & 50m											
1	0	65	62	62	65	64	61	67	65	60	70	72	70
	50	0	0	0	0	0	1	0	0	0	0	1	0
2	0	62	64	64	67	64	61	68	65	61	68	70	67
	50	6	9	6	9	8	10	10	9	8	11	9	9
3	0	79	79	79	84	77	69	84	81	77	83	94	85
	50	23	25	20	24	21	18	23	21	24	22	32	26
4	0	76	80	68	76	72	72	86	78	72	83	87	80
	50	20	25	10	13	15	20	23	16	18	23	28	21
5	0	65	66	67	67	63	60	68	64	63	70	69	68
	50	--------- DEPTH OF WATER LESS THAN 50m ---------											
6	0	69	60	64	70	66	62	69	65	60	67	70	68
	50	9	6	6	8	6	7	11	7	6	9	8	7
7	0	0	0	0	0	0	1	0	0	3	2	1	0
	50	0	0	0	0	0	0	0	0	2	1	1	0
8	0	11	5	0	10	8	9	6	5	2	7	8	5
	50	11	5	0	9	8	7	5	5	2	7	8	5
13	0	22	24	20	23	27	23	22	21	18	25	21	21
	50	22	24	20	23	27	23	22	21	18	25	21	21
16	0	2	0	0	2	0	4	1	0	1	0	1	1
	50	--------- DEPTH OF WATER LESS THAN 50m ---------											
17	0	4	18	4	4	3	3	5	3	6	5	6	4
	50	4	18	4	4	3	3	5	3	6	5	6	4
19	0	4	4	4	3	4	5	4	3	4	5	6	4
	50	4	4	4	3	4	3	4	3	4	5	6	4
20	0	10	3	2	12	8	13	9	5	5	6	5	3
	50	10	3	2	12	8	13	9	5	5	6	5	3
		J	F	M	A	M	J	J	A	S	O	N	D

Note 1: Blocks 9-11, 14, and 18 seldom contained data.

Note 2: Block 20 (see Figure 3) is located 22 mi offshore.

the surface and 50m) that were used to compute the mean temperatures. Mean temperatures are not listed (or used) in the figures if less than four values were available for averaging. Dashed lines represent probable extensions of the isotherms.

The circle in the upper right hand corner of each figure displays the local mean wind condition (taken from the U. S. Naval Oceanographic Office "Pilot Charts," series H.O. 1401) and the mean offshore currents (taken from the U. S. Naval Oceanographic Office Publication H.O. 570). The local mean winds are shown as a series of arrows (fine lines) that fly with the winds. The lengths of the arrows represent the percentages of the month that winds were from the directions shown (the percentage shown for the longest arrow serves as a reference). The number of tails on a given arrow defines the wind force by the Beaufort Scale, as shown below:

Number of Tails	Mean Wind Force (kt)
0	0
1	1-3
2	4-6
3	7-10
4	11-16
5	17-21
6	22-27
7	28-33

The mean offshore current is displayed by an arrow (bold line) extending the diameter of the circle. Mean current

direction is with the arrow and its speed (miles per day) is displayed inside the inner circle.

The upper left hand corner of each figure shows the mean sea surface temperature at a location 15 mi offshore. This data was taken from Naval Oceanographic Office Special Publication, SP-123, and represented mean monthly values based on ship's injection temperatures collected over the past 100 years.

2. Discussion

a. The Annual Cycle of Mean Sea Surface Temperature

The following two factors appear to influence the distribution of mean sea surface temperature.

(1) Upwelling

The coldest waters in the Bay occur during the period from February to May (with April being the coldest month of the year) coinciding with the upwelling period. Figures 20-22 show the intrusion of the colder waters from seaward. It appears that the main intrusion broadly occurs along the axis of the Submarine Canyon (note the 11°C and 12°C isotherms in Figure 22).

(2) The Variation in Mean Air Temperature

According to data contained in the U. S. Naval Oceanographic Office Pilot Chart series, the mean air temperature is at a minimum in January, rises to an annual maximum in September to October, and then falls to a minimum again in January.

The relation of mean sea surface to mean air temperatures is demonstrated by following the monthly position of the 13°C isotherm. In January and February its

absence implies generally colder waters. In March it was seen to intrude into the Bay near the Moss Landing area. In April, the 13°C isotherm appears to be pushed aside by the intrusion of the colder waters (Figure 22). During the period from May to October, the 13°C isotherm was observed to move steadily seaward as the waters in the Bay continued to warm. Although the positions of the 13°C isotherms are nearly identical in September and October, the overall thermal distribution shows September to be the warmest month of the year (Figure 27). From October until January, the 13°C isotherm was observed to move steadily towards shore indicating the broad cooling of the surface waters.

b. Horizontal Sea Surface Temperature Gradients

Horizontal temperature gradients are weakest during the period from November through January with nearly uniform temperature throughout the Bay (less than 0.5°C change) occurring in January. The uniform temperatures characterizing this period are probably due to the influx into the Bay of warmer waters from the north-flowing Davidson Current (prevailing during the above period). In February, the temperature gradients are stronger and continue to increase in strength until reaching their annual maximum in July. The mean offshore sea surface temperature of 13.9°C in July indicates that strong gradients are also set up offshore as well as in the Bay. Steady weakening of temperature gradients occur from August until January, completing the annual cycle.

It will be recalled that maximum vertical temperature gradients occur in the surface layers during the Oceanic Period from September to October (see Figure 10). Bolin related the occurrence of maximum vertical gradients to the relatively windless (and also the minimum velocity of the California Current) conditions prevalent during this period. The occurrence of the maximum horizontal sea surface temperature gradients in July (2-3 months earlier than the maximum vertical gradients) might be related to the greater velocity of the south-flowing California Current. The cooler waters carried into the Bay by this current move at twice the velocity in July as compared with September to October (3.6 versus 1.7 mi/day). Hence, the outer Bay regions are colder while the inner or nearshore regions continue to warm from atmospheric heating.

The mean sea surface temperatures in the northern and southern areas of the Bay are consistently warmer than those in the center area for all months except November through January (when generally uniform temperatures prevail). The northern area exhibited consistently higher temperatures than did the southern area throughout this period. The warm spot in the northern region is probably due to the shallower depths of water there (see Figure 12) thus permitting greater insolation and reflective heating of the waters as earlier mentioned. Also, the shallower northern region is somewhat isolated from the effects of upwelling and thus does not undergo mixing with the deeper and colder waters.

3. Summary

Inspection of the mean isothermal surfaces portrayed in Figures 19-30 reveal several blank spots in the data field, especially in the northeastern section of the Bay. It would be of considerable benefit to conduct a further search for data within these blank spots (Blocks 16, 18, and the non-numbered block shown crossed out in Figure 1) thus providing a more complete picture of the sea surface temperature distribution.

IV. USE OF ISOTHERMAL SURFACES AS INDICATORS OF MEAN CURRENT

If mean flow can be approximated in Monterey Bay using mean isothermal surfaces, then the topographies of these surfaces must be associated with all dynamic forces acting to establish mean flow. Some of the factors involved are as follows:

A. POSSIBLE GENERATING FORCES

1. Offshore Currents

The offshore currents are considered by some to be the major driving forces behind the generation of Bay currents. Some theorists believe that a northerly flow adjacent to the Bay will establish a clockwise gyre within it, and conversely for a southerly flow. This theory was presented recently by Garcia [1971] using a mathematical model of the Bay.

a. The California Current

Transgressing a large clockwise circle in the Northern Hemisphere, the California Current makes its way south along the coast year-round. The southern flow of its outer boundaries is felt at the seaward edge of the Bay from mid-February until early November, with mean velocities ranging from 1.0 to 6.7 mi/day (see Chapter III, paragraph E.1).

b. The Davidson Current

Prevailing from November to early February, the Davidson Current flows north adjacent to the coast, bringing relatively warmer waters into the Bay (see Figure 31).

2. Winds

Long acting and relatively steady winds will generate related current patterns wherever and whenever such wind systems exist.

3. Tides

Tidal currents are active in Monterey Bay but are not considered in this study since they are very nearly (if not entirely) averaged out in taking monthly means.

4. Upwelling

Upwelling has been studied as thoroughly as any oceanographic feature, but almost all studies considered only its vertical aspects. As discussed in Chapter III, paragraph B, the author found that the horizontal differences in upwelling in the vicinity of the Submarine Canyon were apparently a contributing factor in the resulting shapes of the mean isothermal surfaces (possibly a major factor during the months of maximum rates of up/downwelling). The possible influence of up/downwelling upon mean indicated currents is discussed in paragraph D of this chapter.

B. VERIFYING THE CORRELATION BETWEEN ISOTHERMAL AND ISOPYCNAL SURFACES

To employ an approach similar to that used by Leipper [1970] in the Gulf of Mexico (discussed in the Introduction), it was first necessary to show that changes in mean density were directly proportional to changes in mean temperature throughout the water column in the Bay. There was not enough data available on mean density to allow the construction of vertical density sections, therefore, annual

cycles of mean density and temperature (for several blocks) were compared. The results showed that mean density and temperature were closely related throughout the Bay and at all depths considered except in the region above 10m where the correlation was not quite as good. The below listed comparisons demonstrated the results:

(1) Figure 32 (mean density structure, Blocks 1 and 5) to Figure 14 (mean temperature structure, Blocks 1 and 5),

(2) Figure 32 (mean density structure, Block 20) to Figure 17 (mean temperature structure, Block 20),

(3) Figure 33 (mean temperature structure with mean density structure (dashed lines) superimposed, Block 13).

The relatively small total change in mean density throughout the water column was not unexpected. Previously measured currents in the Bay were generally on the order of 0.25 to 0.5 kt, and rarely (if ever) exceeded 1 kt. Therefore, the small changes in density (assuming isopycnal surfaces are related to indicated mean current) would imply small values of mean current. This appears to be the case.

C. PORTRAYAL OF THE ISOTHERMAL SURFACES

The foregoing results provide evidence demonstrating the close correlation between mean isothermal and isopycnal surfaces. Assuming that Leipper's approximate geostrophic approach could be extended from deep waters to the waters of Monterey Bay, the mean isothermal surfaces would then effectively replace the mean isopycnal surfaces and indicated mean currents could be deduced from them. On this basis,

topographies of the mean monthly isothermal surfaces were assumed to represent mean flow and were portrayed in Figures 34-48.

1. <u>Selecting the Isothermal Surface for Portrayal</u>

The annual variation in upwelling, causing the isotherms to rise and fall through a considerable depth interval, prevents the use of any one isothermal surface for the whole year. Instead, isotherms were chosen for a given month by inspection of selected vertical temperature sections. The isotherm that best described the temperature characteristics of the mid-waters (40-100m) was chosen from the corresponding vertical section. When a shift was made from one isothermal surface to another, both surfaces were drawn to assist in observing continuity. The mid-waters were chosen for two reasons: (1) rapidly changing thermal conditions in the surface waters could be misleading since they did not correlate as well to mean density conditions as did the deeper waters, and (2) the 40-100m region should respond to offshore currents, upwelling, and wind (to a lesser extent) and thus provide mean isothermal surfaces most likely to be related to changes in mean current.

2. <u>Description of Figures 34-48</u>

The comments in paragraph III. E.1 concerning location of data points, mean winds, and mean offshore currents are applicable to these figures as well. The number of temperature values used to compute the mean temperatures for each block are listed in Table I (the values at 50m are representative of those throughout the mid-waters).

Topographies of the mean isothermal surfaces were contoured at 10m intervals. Dashed lines indicate probable extensions of contours where data was not available. Depth contours of isothermal surfaces are portrayed only in regions of the Bay where depths of water are greater than or equal to the values of the contours. The termination of a given contour is shown by a short segment of the equal valued bottom contour drawn across it.

The letter H (high) indicates the greatest depths of the isothermal surface and the letter L (low) indicates the shallowest depths.

D. MEAN CURRENTS INDICATED BY THE ISOTHERMAL SURFACES

In considering the indicated mean currents it should be emphasized that the results are based on the combination of data compiled from 1929 through 1968. The various regions of "highs" and "lows" appearing on the mean monthly isothermal surfaces (Figures 34-48) cannot be considered as fixed. Skogsberg [1936] showed that internal waves and advection, acting in the southern portion of the Bay, caused daily (and even hourly) changes in the thermal structures. For any given month the contours vary from day to day and also from year to year, and therefore, the figures are useful as indicators of the average thermal conditions and not the conditions for any given time.

Since it was assumed that the topographies of the mean isothermal surfaces represented mean flow (see paragraph C), the following rules apply: (1) mean circulation is counterclockwise about regions marked with an L (cold water, high

mean density regions), and clockwise about regions marked with an H (warm water, low mean density regions), (2) mean flow follows the contours with the colder water always to the left, and (3) stronger currents are indicated by closer spacing of the contours, and conversely.

The indicated mean currents (inferred from Figures 34-48) are discussed below. To prevent repetition, the term "mean flow" will be used to imply indicated or inferred mean flow and the term "intensity" (or "strength") will imply the relative intensity based on the spacing of contours.

1. Intensities of Mean Flow in the Bay and Offshore

The intensity of mean flow (I) in the Bay is represented by a formula relating it to contour spacing as follows:

$$I = \Delta D/5L$$

where,

I = Intensity of mean flow in mi/day,

ΔD = The difference in depth (m) between contours,

L = The measured length (in) between contours.

The factor of 5 (in the denominator) was applied to make the annual range of I agree with the annual range of mean offshore current (mi/day) as found in H.O. 507 (see Figure 31). The values of I plotted in Figure 31 represent the maximum intensities (minimum spacing of contours) for a given month. Thus, the assumption is made that the strongest monthly average currents in the Bay are equal to the average currents offshore. Months where two isothermal surfaces are portrayed are represented by an average value of I.

The annual cycle of the mean offshore current (dashed line in Figure 31) was divided into two periods. The California Current prevailed from February (mid-points of the months are plotted on the abscissa) until early November, the Davidson Current prevailing the remainder of the year. The annual cycle of mean current intensity in the Bay shows peaks in December, March, and August. The peak in December and the general shape of the curve from November to February is similar to that of the offshore Davidson Current. The peaks in March and August do not appear to be related to peaks of the offshore current; in fact, the shapes of the Bay and offshore curves approach that of a mirror image during the period from March until August. These peaks appear to be related to upwelling and are discussed in subparagraph 2 below.

2. Annual Variations of Mean Flow in the Bay

Inferred mean flow is depicted by arrows with the intensity of flow (I) indicated to the nearest whole number (mi/day) in Figures 34-48).[4]

a. November to February (Figures 47, 48, and 34)

The variations in intensity of flow (as noted above) are similar for the Bay and the offshore Davidson Current prevailing during this period. As described in paragraph A.1, a north-flowing offshore current is considered by some to generate a clockwise driven current within the Bay.

---

[4] In this case, the value of I (shown in the Figures) represent relative intensities at given locations and not the maximum monthly values.

Referring to the mean isothermal surfaces, the current patterns exhibit this clockwise tendency throughout the period, suggesting that the Davidson Current might be the primary generating force.

In November, the mean flow enters the Bay from the south and spreads into the northeast region with a broad clockwise movement indicated in the center region. Flow then exits from the northern region of the Bay (note the 40m contour).

In December and January, the same general clockwise tendency of flow is indicated. However, the flow appears to enter from the northern region and exit from the southern region of the Bay. The difference in entry points could be due to the offshore current intensity which increases from 1 mi/day in November to 3.4 mi/day in December and January.

b. February to April (Figures 35-37)

In February, the "high" (located near the center of the Bay) intensifies and the resulting intensity of flow doubles over that in January. Flow appears to enter and exit from the northern region following a well defined clockwise path throughout the Bay. The clockwise tendency of flow could not have resulted from offshore current generation since the direction of the offshore current is away from and nearly perpendicular to the coast (and also at its annual minimum speed of 1 mi/day). The maximum rates of upwelling occurring in February and March (as discussed in Chapter III, paragraph B) may explain the inferred clockwise

tendency of the currents. As previously postulated, the spreading or up-surge of the cold waters from the Canyon into the Shallows regions cause a relatively warm tongue (high) in the Canyon region. The high established by this up-surge might tend to overshadow the influence of the weak flowing California Current during February.

The 10°C and 11°C isothermal surfaces were constructed for March. Both have similar patterns but the gradients are stronger at the greater depths (10°C surface, Figure 37). This further indicates the influence of upwelling since upwelling rates are maximum from 60-100m. The currents indicated by the 11°C surface (Figure 36) enter the Bay from the south and follow a snake-like pattern before exiting from the northern region. The 10°C surface (Figure 37) exhibits the same general isothermal structure except there is another well formed low observed in the northern region and the overall intensity of flow is greater. The development of the "lows" in March could be caused by an influence of the California Current which had increased to 5 mi/day (near its annual maximum intensity). The influence, by the theory of offshore generation, would be to cause a counterclockwise gyre within the Bay which would agree with formation of a "low." This was not indicated to be a major feature by the isothermal topographies.

c. August to October (Figures 42-44)

This period is discussed next because the mean flow in the Bay is believed to be a result of conditions similar to those described above. August and September (the

months of maximum rates of downwelling) showed the same dipping of isotherms across the Canyon and the same relative warm spots in the Canyon region as were observed during February and March. The possible relationship was discussed in Chapter III, paragraph B. The well established highs in August and, for the 10°C surface, in September (the deeper surface where downwelling rates are also greater) demonstrate the possible influence of downwelling. Current trends are clockwise (as in February and March) and thus opposite to the currents theoretically predicted due to influence by the California Current. On the other hand, the 11°C surface (shallower waters) in September exhibits more complex trends that could have been partly influenced by the California Current. Current patterns are counterclockwise in the middle and northern regions and a clockwise trend is observed in the southern region. Downwelling is weaker above 50m (in September) and apparently does not exert as great an influence on the indicated currents. It was also observed that flow indicated by the shallow waters (11°C surface) is nearly opposite in direction to that indicated by the deeper waters (10°C surface). Since the whole region of the midwaters (40-100m) is assumed to represent the indicated currents, it is concluded that the shallow and the deep surfaces (in September) combined in some fashion to represent mean flow. The best approximation of the mean flow is thus a combination of flows inferred from both surfaces.

d. October (Figures 45 and 46)

The current trends indicated by the 11°C isothermal surface are similar to those of the 11°C surface in September (Figure 44). Flow enters the southern region of the Bay, follows an "S-shaped" path, and exits from the northern region. The high observed in the southern region appears to be a holdover from the high observed during July and August.

The 12°C surface (Figure 46) is generally similar to the 11°C surface except the high is absent. The general counterclockwise trends (expecially for the 12°C surface)conform to the theory of generation by an offshore current.

In general, it appeared that weaker offshore currents came into the Bay, while stronger currents caused a reverse eddy within the Bay.

e. April to August (Figures 38-41)

The intensity of indicated mean flow is low throughout this period. Figure 31 shows the weak mean currents which decrease to an annual minimum in June.

Current trends in April are similar to those in March (Figures 36-37) but the intensity of flow is only half as great. The weakening of the high in the center region corresponds to the decrease in the rate of upwelling which ends altogether in May to June. The low in the southern region remained the same strength as it was in March but intruded further into the Bay (as noted by the 40m contour in Figure 38).

The indicated mean flow during May is almost due south, dipping into the Bay and broadly following the shoreline. The direction of flow corresponds closely to the direction of mean offshore current in the central and northern regions and tends seaward in the southern region.

A high develops in June which extends throughout the Bay. Mean flow enters the Bay from the north and follows a broad clockwise path, exiting also from the northern region. Intensity of mean flow is at its annual minimum in June.

The high persists in July and a low is seen to develop in the northern region. Flow enters the Bay from the north and is observed to exit from the southern region.

The development of the high in June and its subsequent strengthening from June through August (Figure 42) could have been partly due to downwelling which commences in June and ends in early November (see Chapter III).

In summary, the inferred mean flow in the Bay is based solely on the topographies of mean monthly isothermal surfaces. Inferred current trends could be related to generation by offshore currents only during the Davidson Current Period and possibly in the month of May. Trends of inferred current during the remainder of the year appear to be influenced more by up/downwelling than by offshore currents. The possibility of up/downwelling exerting a greater influence than offshore currents on mean flow is difficult to test and verify. However, the maximum intensity of mean offshore current during any month of upwelling or downwelling

is only 5 mi/day (about 1/5th of a kt), and the annual maximum reaches only 6.7 mi/day. Thus, it would appear that the relatively small horizontal density changes (assumed to be mainly a result of the surging of the cold waters during up/downwelling) between the waters of the Canyon and those of neighboring shallow areas could be equally (if not more) responsible for influencing mean Bay currents. The above phenomena are of course, related in some complex manner.

There is insufficient data concerning previously measured currents in the Bay to verify the influence of up/downwelling on Bay currents. However, the author found several limited current studies which could be compared to the inferred Bay currents of this report.

E. COMPARISONS OF INFERRED MEAN CURRENTS TO PREVIOUSLY MEASURED CURRENTS

Comparisons between the inferred mean monthly flow (based on many years of data) and several short term (6-48 hours) current measurements during a given month cannot be expected to show more than broad agreement for specific times. The positions of the highs and lows (and hence the distribution of indicated current) on the mean isothermal surfaces for a given month represent the most likely conditions over a long time period and not those for a given day of the month, or even for a given year for that month. Finally, the short term currents must be considered only as general trends since their directions and speeds are heavily influenced by tidal forces and local winds. The following comparisons are more encouraging than the above limitations suggest.

1. <u>March</u>

Stevenson [1964] deployed three surface drogues in early March from a location 1/2 mi offshore in the southernmost area of the Bay. All drogues moved shoreward (until beaching) as shown by the dotted arrows in Figure 36. The shoreward movements of the drogues would appear to agree with the inferred currents which tend shoreward in the region where the drogues were deployed.

2. <u>July</u>

McKay [1970] conducted current measurements in late July using a Geomagnetic Electrokinetograph (G.E.K.). The measured currents (indicated by dotted arrows in Figure 41) did not fully agree with the plotted indicated current patterns; however, the position of the "low" in the northern region would support such current movement. The shape of the "low" could not be determined since there was no data for adjacent blocks to the north and east.

3. <u>August</u>

McKay conducted current measurements with the G.E.K. in early and mid-August, 1969 (solid short arrows in Figure 49) and Stoddard [1971] employed surface drogues in mid-August, 1970 (dotted arrows).

a. McKay's G.E.K. Measurements

The shorter solid arrows represent individual G.E.K. measurements. Considering the region bounded by the 60m and 80m contours, the correlation of the measured currents to the inferred mean currents is very close, with

about 3/4ths of the G.E.K. measurements observed to follow the contours. In the region bounded by the 80m contour, the measured currents broadly exhibit a clockwise motion with a general confusion in direction noted (which agrees with the plotted position of the high).

The G.E.K. measurements to the south of the 60m contour appear somewhat confused in direction when considered as a whole. The arrows with tails represent measurements taken on 5 August while all other solid arrows represent measurements taken from 11-12 August. During 11-12 August the measured currents in the extreme southern region are seen to move northward and then to turn towards the west. This trend would appear to agree with the mean flow which exits the Bay (between the 50m and 60m contours) from the southern region and could force the northerly current to turn westward. The currents measured on 5 August tend towards the southwest which could be due to the conditions such as displayed by the isothermal surfaces in July (note the 30m contour in Figure 41). Since all surfaces are assumed to represent the mid-month conditions, the mean flow in July might influence that in early August. The above discussion is conjectural since insufficient data is available to construct contours in the region of interest. The intention is to show that the current trends by McKay in this (southeastern) region show plausible agreement with those inferred from the isothermal surfaces. The measured current velocities were all significantly higher than inferred

values (I). This is as expected since they were virtually instantaneous measurements.

b. Stoddard's Drogue Study

The longer dotted arrows in Figure 49 represented surface drogue tracks. Six drogues were tracked for about 17 hours and one (the southernmost shorter track) was tracked for 7 hours.

The two tracks in the region bounded by the 70m contour follow definite clockwise gyres, not too far removed from the location of the high (generally agreeing with its plotted position). The remaining tracks do not correlate with mean flow; in fact the three tracks to the south are nearly 180 degrees out. Data was not available during August in Blocks 10, 11, 14, and 21S (see Figure 1) and therefore, the isothermal surfaces (as shown for this region) could be in error.

4. September

Stoddard tracked six surface drogues in late September, 1970. The tracks show good correlation to the shallower 11°C isothermal surface (Figure 44) but generally are not well related to the 10°C surface (Figure 43). The following discussion is based on comparison to the 11°C surface (although the best approximation of indicated mean flow would lie somewhere in between the two surfaces).

The duration of the drogue tracks varied from 12 to 25 hours. The author computed the speed of each drogue based on the distance made good from deployment until the end of tracking. The average value of the six speeds was 2.75 mi/day

which compared favorably to the arbitrary value of I for September of 3.6 mi/day (Figure 31). The value of I represents the maximum mean intensity (minimum contour spacing) for a given month, and was made to agree (in total range of values) with the intensity of mean flow for the offshore current (see paragraph D.1).

Drogues 1-3 (see circled numbers adjacent to dotted arrows in Figure 44) all exhibit clockwise trends which broadly agree with the location of the high in the southeastern region of the Bay. Closer correlation is not possible since no data exists in the block to the right of the high (shown crossed out in Figure 1).

Tracks of drogues 4 and 5 cut directly across the 40m contour; however, their tendencies to move to the right when seaward of Point Pinos agree with the general mean current patterns (note the north-flowing mean current which would force the currents indicated by tracks 4 and 5 to the right).

The track of drogue 6 agrees with indicated mean flow, following the 40m contour and tending in a slight clockwise path. The speed of drogue 6 (computed as above) was computed to be 4.1 mi/day versus an arbitrary value of I equal to 4 mi/day in the same region.

5. <u>October</u>

Stoddard tracked four surface drogues in early October, 1970. The tracks show excellent correlation to the shallower 12°C surface (dotted arrows in Figure 46) and fair correlation to the 11°C surface (Figure 45). Drogue 3 was

tracked for 10 hours and all other drogues were tracked for only six hours. The average computed speed for drogues 1, 2, and 4 was eight mi/day, while drogue 3 made good a speed of 6 mi/day. The speeds inferred from contour spacing are only 2 to 3 mi/day. Since the duration of tracking was short, the effects of the tidal currents (and local winds) could have introduced considerable influence on the speeds and directions of the drogue tracks.

All drogue tracks broadly followed the 30m contour (Figure 46) and all except drogue 3 moved in a direction related to the indicated mean current. The path of drogue 4 almost exactly agrees with the indicated flow.

6. November

Stoddard tracked eight surface drogues in mid-November, 1970 (shown by solid, dashed, and dotted arrows, numbered 1-8 in Figure 50). The duration of tracking varied from 6-42 hours. The computed speeds (again based on distance made good per total tracking time) are listed below:

Drogue No.	Duration of Tracking (hr)	Computed Speed (mi/day)
1	.42	5.7
2	22	3.9
3	21	1.2
4	23	3.4
5	7.5	11.2
6	6.5	14.1
7	6.5	10.7
8	6	10.8

The consistently greater speeds for drogues 5-8 were probably due to tidal currents prevalent in the short

duration of tracking time and were thus disregarded. Drogues 1-4 exhibited speeds closely related to the arbitrary value of I for November. The combined average speed of drogues 1-4 was 3.6 mi/day while the arbitrary maximum value of I was 4.2 (Figure 31). The average value of I for November would be somewhat lower (but nearly impossible to estimate from contour spacing alone).

The tracks of all drogues exhibited clockwise tendencies which correlated with indicated mean current about the extensive high in the center of the Bay. The individual tracks of drogues 1 and 8 closely approximate the indicated mean current while the remaining drogues showed fair correlation (Figure 50).

It is noted that the speed of drogue 3 (1.2 mi/day) is significantly lower than the speeds of drogues 1, 2, and 4. Also, the track of drogue 3 describes a tight clockwise path which is not the case for the other tracks. This led the author to believe that drogue 3 might have been nearer the center of a high than is shown in Figure 50. It is assumed that the high (and the entire mean isothermal surface as well) could probably vary in location from day to day (and year to year) for a given month. On this basis, the mean isothermal surface for November was translated to a position where the high overlayed the track of drogue 3. The distance of translation was 3 mi in a west-southwest direction. Figure 51 shows the results of the translation. All drogue tracks are now observed to closely follow the

translated contours and the correlation to indicated mean current is excellent.

F. SUMMARY

The general agreement between measured currents from past studies and indicated mean currents for this study is encouraging. The total number of comparisons made is far from that required to fully substantiate the inferred mean currents of this study; however, the comparisons do lend considerable support to the feasibility of using mean isothermal surfaces as indicators of mean flow, which was a primary objective of this study.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Progressive warming with time is indicated throughout Monterey Bay, mainly occurring at depths from the surface to 300m. The temperature was noted to increase as much as 1.8°C over the 29 year interval from 1931 to 1960.

2. The intensity of upwelling varies in different geographic regions of the Bay. This variation in the maximum rates of upwelling (and downwelling) is believed to be a major factor controlling the shapes of mean isothermal surfaces (and indicated mean currents as well) during the months of maximum up/downwelling.

3. The method of using mean isothermal surfaces as indicators of mean current shows promise. The comparisons of inferred mean flow to direct current measurements (as shown in Figures 34-48) demonstrates general agreement between the two.

B. RECOMMENDATIONS

1. The data collected throughout Monterey Bay is insufficient for several of the blocks in the author's grid system (Figure 1). To obtain a more complete picture, both in the mean monthly sea surface temperature distribution and in the topographies of mean monthly isothermal surfaces, a continued search of data for the following blocks would be beneficial: 7, 8, 9, 10, 11, 14, 16, 18, 21S as well as the block shown crossed out in Figure 1.

2. Future studies should be made of the mean monthly current distribution in the Bay (the author was unable to locate any previous work in this area). Whatever methods are used in the future might be compared to the mean flow inferred in this study for purposes of attempted verification.

3. To aid in the future study of oceanographic parameters (in general) of Monterey Bay, a computer storage and retrieval system should be instituted and maintained on a continuing basis. An example of a computer system designed for this purpose is presented in Appendix B (the "final computer program, number 11").

Closer coordination with NODC is required of all oceanographic facilities so that the oceanographic data collected in Monterey Bay over the years can be made available to any investigator desiring its use.

APPENDIX A: DATA SOURCES

A. PROBLEMS ENCOUNTERED

The only previous research found that categorized oceanographic data collected in Monterey Bay was that presented in an NPS research paper by P. M. Magruder, Jr., [1969]. Magruder's paper was most beneficial in delineating the major sources of data. Many reports were located covering related subjects such as biology, sound velocity variation, and light attenuation studies. Many of these reports used temperature and salinity data. However, the data was generally not contained therein, nor is there any reference to its location in some reports. There is a general lack of continuity in reports which contained temperature and salinity data. Methods of collection were sometimes omitted and very seldom was there any information describing environmental conditions, etc.

B. MAJOR DATA SOURCES (FIGURE 3)

1. Bolin Data

Rolf L. Bolin and collaborators [1964] collected Nansen samples over a five year period from 1951-1955 at the position 36-42N, 122-02W. Casts of 24-bottles were generally employed to depths of 1000m at weekly intervals. A total of 233 casts were made and analyzed for temperature, salinity, and other chemical parameters. A copy of this report is on file at the Naval Postgraduate School Library.

2. Fleet Numerical Weather Center (FNWC) XBT Data

Nansen cast, bathythermograph (BT), experimental BT (XBT), and message BT data are on file at FNWC. The Nansen cast and BT data are also filed at the National Oceanographic Data Center (NODC) and are kept more completely there.

FNWC is presently digitizing the XBT data for inclusion in computer tape files at NODC. Two 9-track computer tapes (NPS 264 and NPS 265), held by Dr. Denner at the Naval Postgraduate School Oceanography Department, contain the world oceans XBT data which consists of about 40,000 individual stations. A computer program (see article B.2, Appendix B) written by the author reveals only 43 XBT stations scattered randomly throughout the Bay. There have been considerably more than 43 XBT drops in the Bay over the last three years but the data is not as yet available.

3. Hopkins-CalCOFI Data

Hopkins Marine Station has conducted a continuous hydrobiological survey of Monterey Bay for the California Cooperative Oceanic Fisheries Investigations (CalCOFI) since 1951. Commencing in March of 1954 the data (unpublished) was tabulated and distributed in annual reports containing monthly averages of Bucket, Nansen, and BT temperatures, salinities, and densities (sigma-T) for six oceanographic stations in the Bay. The averages were based on approximately weekly visits to each station; [Hopkins 1954-1967].

a. Ocean Temperatures

Surface temperatures were read from a bucket thermometer and BT data was listed at 10m intervals from the surface to 50m for stations 2, 3, 4, and 6, and to 30 and 20m for stations 1 and 5, respectively. This data was not computerized since the majority of it was included as NODC-BT data in paragraph 4 below.

b. Salinity and Sigma-T Data

Nansen samples taken at the surface and 15m were titrated for chlorinity and thence salinity and sigma-T were determined. Temperature, salinity, and sigma-T were tabulated along with their monthly averages for each station.

4. <u>National Oceanographic Data Center (NODC) Data</u>

Magruder obtained complete printed listings of Nansen cast and BT data from NODC in January of 1969. The area of coverage included Marsden Squares 121 (61 and 62). The listings are available in the NPGS Oceanography files.

For purposes of, (1) rapid computer processing, and (2) updating of data through 1970; magnetic tapes were requested from NODC. Two 7-track tapes were received in December 1970, one listing Nansen cast data in Marsden Square 121(R1019) and the other listing BT data (R1030). The formats of these tapes were different and had to be processed separately (see articles B.4, 5 of Appendix B). The tapes are the property of the NPGS Oceanography Department (see Dr. Leipper).

The total number of Nansen and BT stations within Monterey Bay (retrieved from above tapes) were 107 and 1377 respectively.

a. Nansen Cast Data

The data included temperature, salinity, oxygen, phosphates, silicates, nitrates, and pH as observed parameters. All values were interpolated to standard depths by a three point Lagrange method. Each station is identified by a Master Card, which lists such information as ship name, position, date, etc.

b. BT Data

BT temperatures were listed at 5m intervals from the surface to maximum depth. Each station was again identified by a Master Card.

5. Naval Postgraduate School (NPGS) Data

Four stations were established by NPGS in October 1966. Nansen casts and BT drops were made regularly and all chemical parameters were filed quarterly.

A continuing program of computer processing and filing of data cards for these stations is in progress.

6. Skogsberg Data

Tage Skogsberg [1936] conducted an exhaustive study of thermal conditions in the southern portion of Monterey Bay, collecting over 15,000 samples from 1929-1933. Data included temperature, chlorinity, phosphate, and silicate from 23 separate stations. The original data is on file at Hopkins Marine Station. Skogsberg tabulated monthly temperature

averages for two of his stations, both of which were used in the author's analysis (Chapters III and IV).

7. Sea Surface Temperatures

a. Hopkins Marine Station

Sea surface temperature and salinity has been measured daily at the station since 1919. All records are filed by Hopkins and monthly averages are published by Scripps Institution of Oceanography under the title: "Data Report, Surface Water Temperatures at Shore Stations, United States West Coast and Baja California."

b. Santa Cruz

Sea surface temperature has been measured daily since 1956 and data is also published by Scripps under the same title as above.

C. MINOR DATA SOURCES

The below listed sources comprise data covering either small areas or that limited to only several observations. A complete listing was impossible.

1. "Monterey Bay Bibliography" [Baron, 1971]

This comprehensive study was recently completed by the Moss Landing Marine Laboratories' of the California State Colleges. It includes all known scientific literature concerning Monterey Bay. Limited copies are now being published.

2. Yeske and Waer Data

Yeske and Waer [1968] studied light attenuation at two stations in the Bay during the period 26 July to 31 August, 1968. A total of 39 Nansen casts were made and BT

drops accompanied each cast. Data was filed with NODC and is contained on the computer tapes referenced in paragraph C.4 above.

3. Message BT Data

Very little data was found at FNWC (only 21 stations for all of Marsden Square 121) and none more recent than 1968.

4. OC-3520 Data

The Chemical Oceanography Course (OC- 3520) at NPGS sponsors limited duration Bay cruises for students. Various oceanographic parameters are collected and final reports are required. The data is not currently being filed but some of it is available.

D. DISCUSSION

It was clear that a complete source listing of the chemical parameters in the Bay would be a monumental task. NODC maintains a computer listing of oceanographic data throughout the world's oceans but little of the data collected in Monterey Bay has ever reached there. Only 107 Nansen casts were recorded by NODC for the last 40 odd years, representing a trifle of the data actually collected.

APPENDIX B: COMPUTER PROCESSING OF DATA

Two major goals were sought in designing the "final computer program": (1) to store temperature, salinity, and density data in a form suitable for the computation of mean monthly averages at given geographic locations, and (2) to design a flexible system for storage and retrieval of various oceanographic parameters on a continuing bases.

The second goal was achieved by designing the "station title card" in such a manner that a simple extension could be made to the "station data card" to include additional selected oceanographic parameters without modification of existing formats (see paragraphs A.2.a & b). The institution of such a card system could make the retrieval and usage of oceanographic data from Monterey Bay a very simple task.

A. STORAGE OF TEMPERATURE, SALINITY AND DENSITY (SIGMA-T) DATA

1. Problems Encountered

About 60% of available data was already in computer format, either on magnetic tape or on data cards. Regrettably, no two formats were consistent. Thus, a separate computer program had to be written to reduce each data source to the author's format. This often included calculation of densities (when they were not included as part of the original format) and always required interpolation of one form or another to place the data at the author's selected "standard depths" (standard depths are listed in Table IV).

The reduction of data already in computer format was actually more time consuming than processing the tabulated data.

The remainder of the available data was tabulated in the various reports cited in Appendix A. First it was keypunched onto computer cards in various formats, depending on the format of the data source. The next step was the printing out of data on computer paper to compare it for accuracy against the original source. After proofreading, computer programs were written to convert the data on punched cards to the desired format. Again, this included calculations and interpolations for the desired results.

The last step in the process was to check the various outputs for correctness and then write the data onto a computer "master tape." Paragraph B describes the various computer programs to the extent of including information not apparent from inspection of the programs themselves.

2. Format of the Master Tape

The master tape (NPS serial number 306) served as the storage location for all data processed. The general format of data includes a station title record (identifying the oceanographic station) and a station data record (listing the oceanographic parameters). Table II lists all data contained on the master tape.

a. The Station Title Record

The station title record allows the flexibility required in general retrieval of data. Referring to Table III, the "80-column record numbers" refer to the inclusive positions on the station title record where the information

TABLE II. Listing of Specific Data Contained on Computer Master Tape, NPS 306

Data Source	Data	Year(incl.)	Remarks
Bolin	T,S,σ_t	1951-1955	229 Nansen stations
FNWC	T	Various	40 XBT stations
Hopkins-CalCOFI	T,S,σ_t	1954-1967	972 Nansen stations, each station representing the monthly average of 4 stations at 0 and 15m.
NODC	See Chap II	Various	107 Nansen stations
NODC	T	Various	1377 BT stations
NPGS	See Chap II	Sept 1966-Sept 1967	175 Nansen stations

Note 1: See Appendix A for detailed discussion of data sources.

Note 2: In cases where only portions of a data source were computerized, the year and type of data defines such portions.

Note 3: The "Data Source" is listed by author or collecting activity.

TABLE III. The Station Title Record

80-Column Record No.	Variable	Definition
1-2	NCARDS	The total number of station data records following the title record.
4-7	NANS, XBT, BT, STD	A left-adjusted variable defining the type of data collected.
9-10	NDAY	The day data collected.
12-13	NMO	The month data collected.
15-16	NYEAR	The last two digits of the year data collected.
18-21	NTIME	The time (GMT) data collected. If unknown, NTIME appears as 0000.
24-25	LATDEG	The degrees of station latitude.
27-30	RLATMI	The minutes and tenths of minutes of station latitude.
33-35	LONDEG	The degrees of station longitude.
37-40	RLONMI	The minutes and tenths of minutes of station longitude.
43-45	NWF	NWF=999 specifies Hopkins-CalCOFI monthly average values (4 stations per average).
48-63		Ship name.
---------- or, ----------		
48-49		NODC country code.
50-51		NODC ship code.
52-55		NODC station I.D. number.
56-59		NODC Stano number.

65-80	REF	Reference data by author or facility controlling data collection.

was entered. "Variable" was the computer name (applied by author) used in programming. Desired data may be retrieved from the master tape by any one, or any combination of the listed variables. For example, assume an investigator is interested in conducting a study of experimental (XBT) versus mechanical (BT) bathythermograph data in the Submarine Canyon, collected over the last five years. By a series of "computer logical IF statements" [see Blatt, 1968] all station title records are eliminated except those that are either XBT or BT, have geographic positions in the Canyon, and fall within the time frame (NYEAR) of 1966 or later.

b. The Station Data Record

Each station data record contains the standard depth of observation (m) plus one or more of the parameters listed in Table IV above the dashed line. The oceanographic parameters below the dashed line were not included on the master tape but are listed as the recommended additions referred to in the second paragraph of this Appendix.

B. COMPUTER PROGRAMS USED IN DATA STORAGE

Ten computer programs were required to compile the master tape and are briefly described below. The programs will be found in the section entitled, "Computer Programs."

1. Bolin Data

a. Program Number One

Cards were punched from the tabulated data of depth, temperature, and salinity. Program number one calculated densities and linearly interpolated all data to the

TABLE IV. The Station Data Record

80-Column Record No.	Variable	Definition
1-5	STDEP	The author's selected standard depths (m), as: 0000. Standard depths used were: 0, 10, 15, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, ... , 1400, 1500, 1750, 2000, 2500, 3000, 4000, .. , 6000.
7-11	TEM	The temperature to hundredths of degrees C, as: 10.25.
13-17	SAL	The salinity to hundredths of parts per thousand, as: 33.65.
19-23	SGT	Sigma-T (density) to hundredths of units, as: 26.77.
------	------	------
25-27	XOXG	Oxygen to tenths of ml per l.
29-31	XPO4	PO4-P to tenths of g-at per l.
33-35	XNO2	NO2-N to tenths of g-at per l.
37-39	XNO3	NO3-N to tenths of g-at per l.
41-43	SIO4	SiO4-Si to tenths of g-at per l.
45-47	XPH	pH of seawater to tenths of units.
49-80	---	Can be used for additional storage as required; e.g., computed sound velocity, dynamic parameters, etc.

Note 1: Data above dashed line is included on master tape. Data below dashed line is the recommended additions for a future storage and retrieval system.

selected standard depths. Linear interpolation was considered accurate since the maximum difference between tabulated and standard depths was only 25m. The final output consisted of computer cards in the format for the master tape.

2. Fleet Numerical Weather Center (FNWC) Data

a. Program Number Two

The existing 9-track tapes (NPS 264 and 265) containing world ocean's XBT data through 1968 were processed. Data in Monterey Bay was retrieved, linearly interpolated, and punched out on computer cards in the format for the master tape. Linear interpolation was exact because XBT data occurred at every depth where temperatures deviated from a linear path.

3. Hopkins-CalCOFI Data

a. Program Number Three

Computer cards were punched from the tabulated annual reports [Hopkins 1954-1967]. Program number three processed the computer cards, linearly interpolated for the 10m values (a selected standard depth), and punched new computer cards in the format for the master tape.

Since each station represented a monthly average value (generally the average of four stations) the data had to be processed differently in the final program. A weighting factor (NWF=999) was added to each station title record and served as a branch instruction to weight this data "four to one" over other data on the tape.

4. <u>National Oceanographic Data Center (NODC) Nansen Cast Data</u>

a. Program Number Four

This program read data from a 7-track tape (R 1019), computed the number of station data records following each station title record (NCARDS), and wrote the data (in modified format) onto a 9-track tape (NPS 297).

b. Program Number Five

Data within Monterey Bay was retrieved from the 9-track tape (NPS 297) and written directly onto the master tape in the author's format. One linear interpolation for 15m was required per station, all other data being at the author's standard depths.

5. <u>National Oceanographic Data Center (NODC) Bathythermograph Data</u>

a. Program Number Six

Data was read from a 7-track tape (R 1030) and written directly onto a 9-track tape (NPS 296). Each station title record contained the number of following station data records, hence, no further programming was necessary.

b. Program Number Seven

Data within Monterey Bay was retrieved from the 9-track tape (NPS 296) and written directly onto the master tape in the author's format. No interpolation was required as data was entered on the tape (R 1030) at 5m intervals.

6. Naval Postgraduate School Data

a. Program Number Eight

This program was written by Robert Middelberg for the Oceanography Department. He was kind enough to allow the author to copy and then modify the program for usage herein. Data cards prepared by Mr. Middleberg were read by the modified program and densities were computed. All data was interpolated to the author's standard depths using Middleberg's "three point Lagrange" method. The Lagrange interpolation method more closely approximates the normal shape of a temperature profile when data is widespread (50-150m between observations) as was the case here. Finally, data was written directly onto the master tape in the author's format.

7. Transferring Punched Card Data

a. Program Number Nine

Program number nine read the punched output from programs 1, 2, and 3 above and wrote it onto the master tape.

8. Master Tape Record Count

a. Program Number Ten

When working with computer tape it is essential to keep an accurate record count of data as it is stored; otherwise, errors that may be made would be nearly impossible to locate. Program number ten was used to keep a running account of data stored and a double check for correct format.

C. THE FINAL COMPUTER PROGRAM

Program number 11 computes the mean monthly temperatures and densities (at author's standard depths) throughout the Bay, using data from the master tape as its input. Table V defines the output as it appeared on the master printout. Figure 2 shows the initial field of blocks used for the segregation of data. The numbered blocks on the Figure were the only ones containing significant data (at least one month with three or more temperatures in the block). This program will also be found in the section entitled, "Computer Programs."

TABLE V: Definition of Computer Variables in the Final Output of Program Number 11

Variable	Definition
TEMP(AV)	The average of all temperatures (weighted and unweighted) for a given block, month, and depth.
SIGMA-T(AVG)	As above for density (sigma-T).
NR WTD VALUES	The number of weighted stations processed.
SUM WTD TEMPS	The sum of all weighted temperature values.
STDEV WTD TEMPS	The computed standard deviation of all weighted temperature values.
SUM WTD SIGMA-T	As above for density.
STDEV WTD SIGMA-T	As above for density.
NR UNWTD TEMPS	The number of non-weighted temperature values.
SUM UNWTD TEMPS	The sum of all non-weighted temperature values.
STDEV UNWTD TEMPS	The computed standard deviation of all non-weighted temperature values.
NR UNWTD SIGMA-T	As above for density.
SUM UNWTD SIGMA-T	As above for density.
STDEV UW SIGMA-T	As above for density.
WTD TEMPS	A listing of all weighted temperature values.
WTD SIGMA-T	A listing of all weighted sigma-T values.
UNWTD TEMPS	A listing of all non-weighted temperature values.
UNWTD SIGMA-T	A listing of all non-weighted sigma-T values.

Note 1: All variables above are for a given block, month, and standard depth.

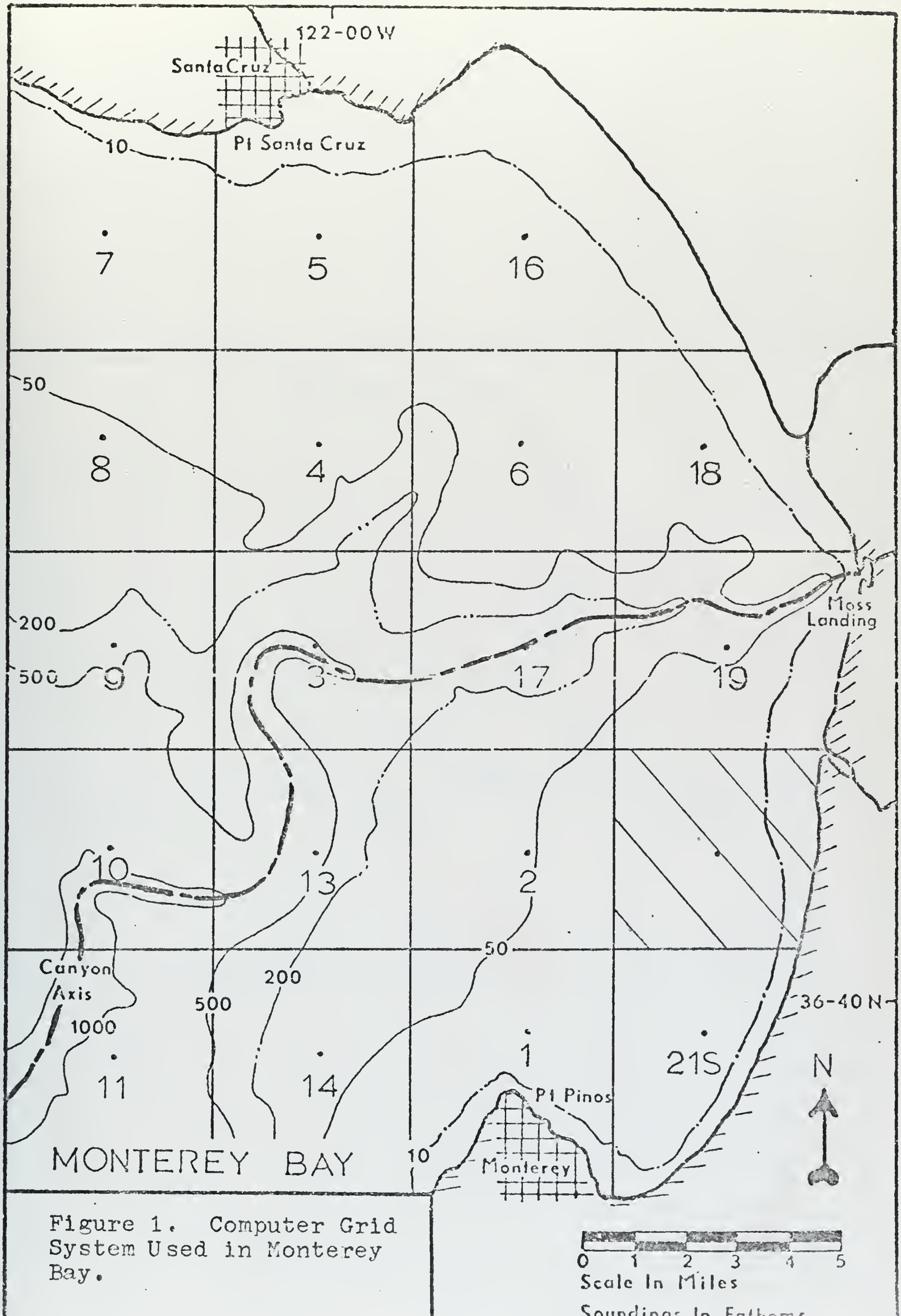
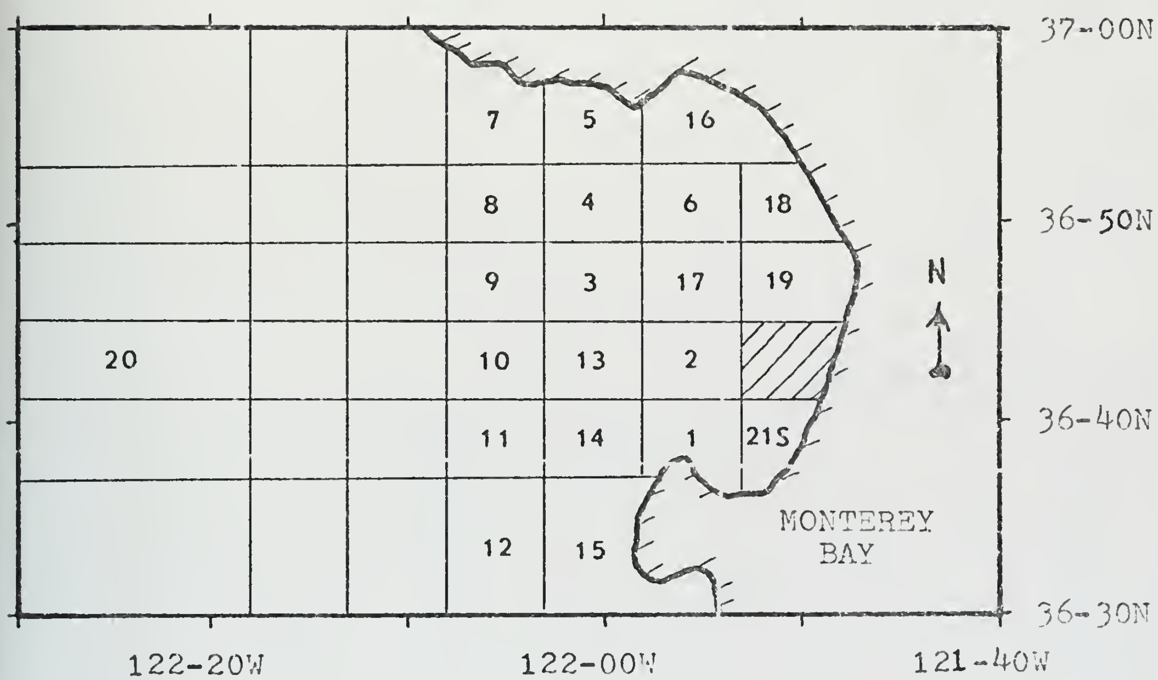


Figure 1. Computer Grid System Used in Monterey Bay.



NOTE: Only the numbered blocks contained significant data.

Figure 2. The Initial Computer Grid System.

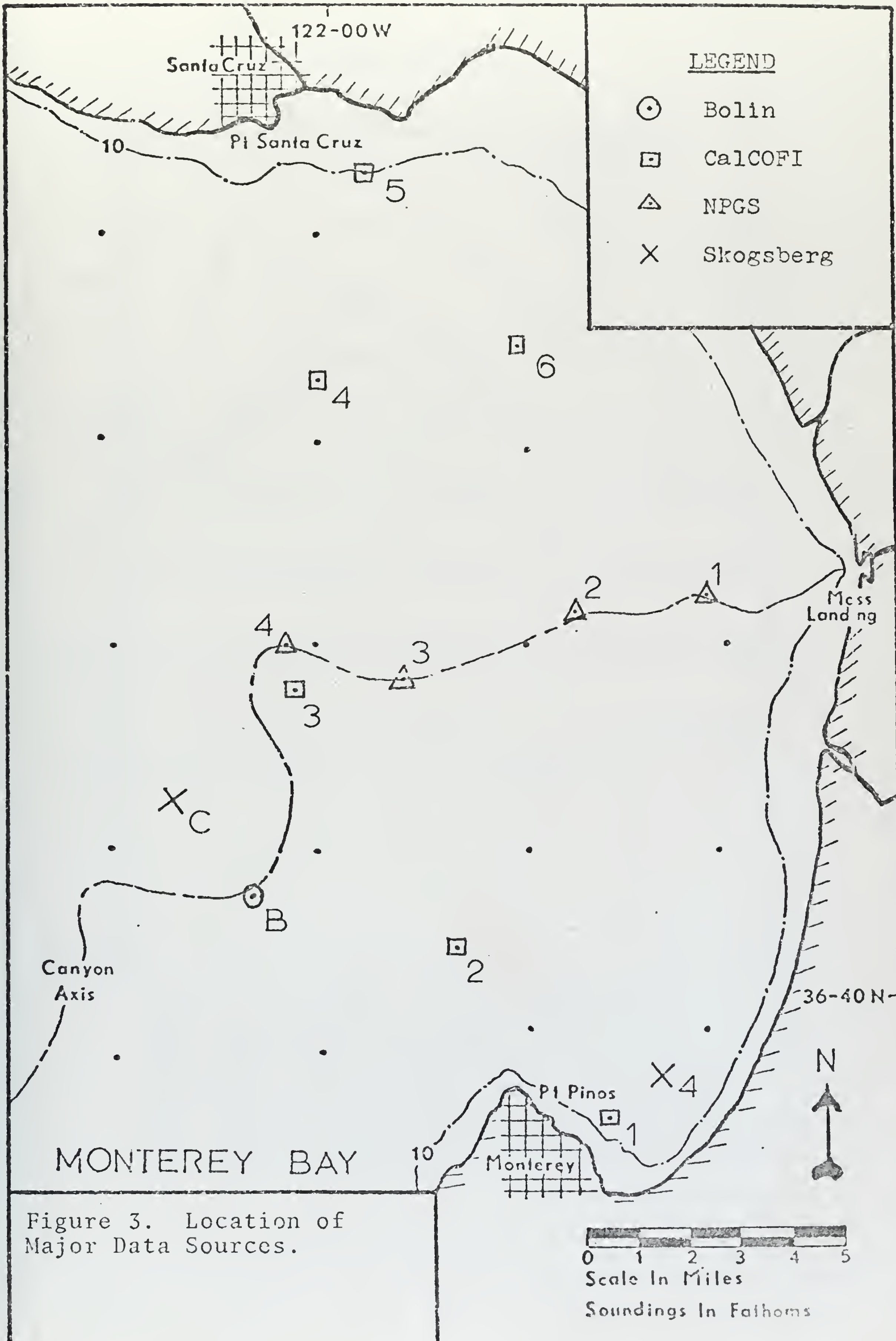


Figure 3. Location of Major Data Sources.

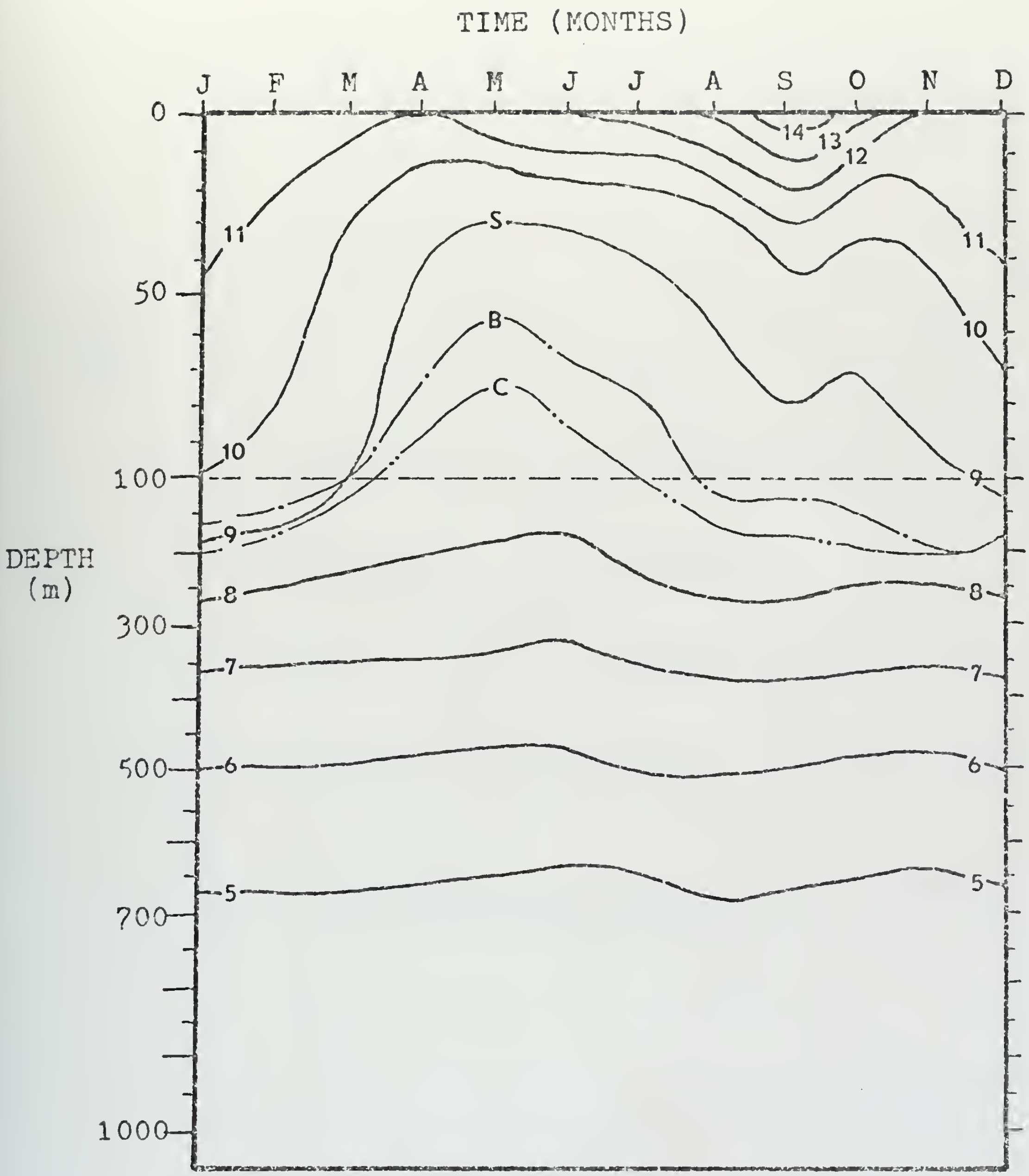
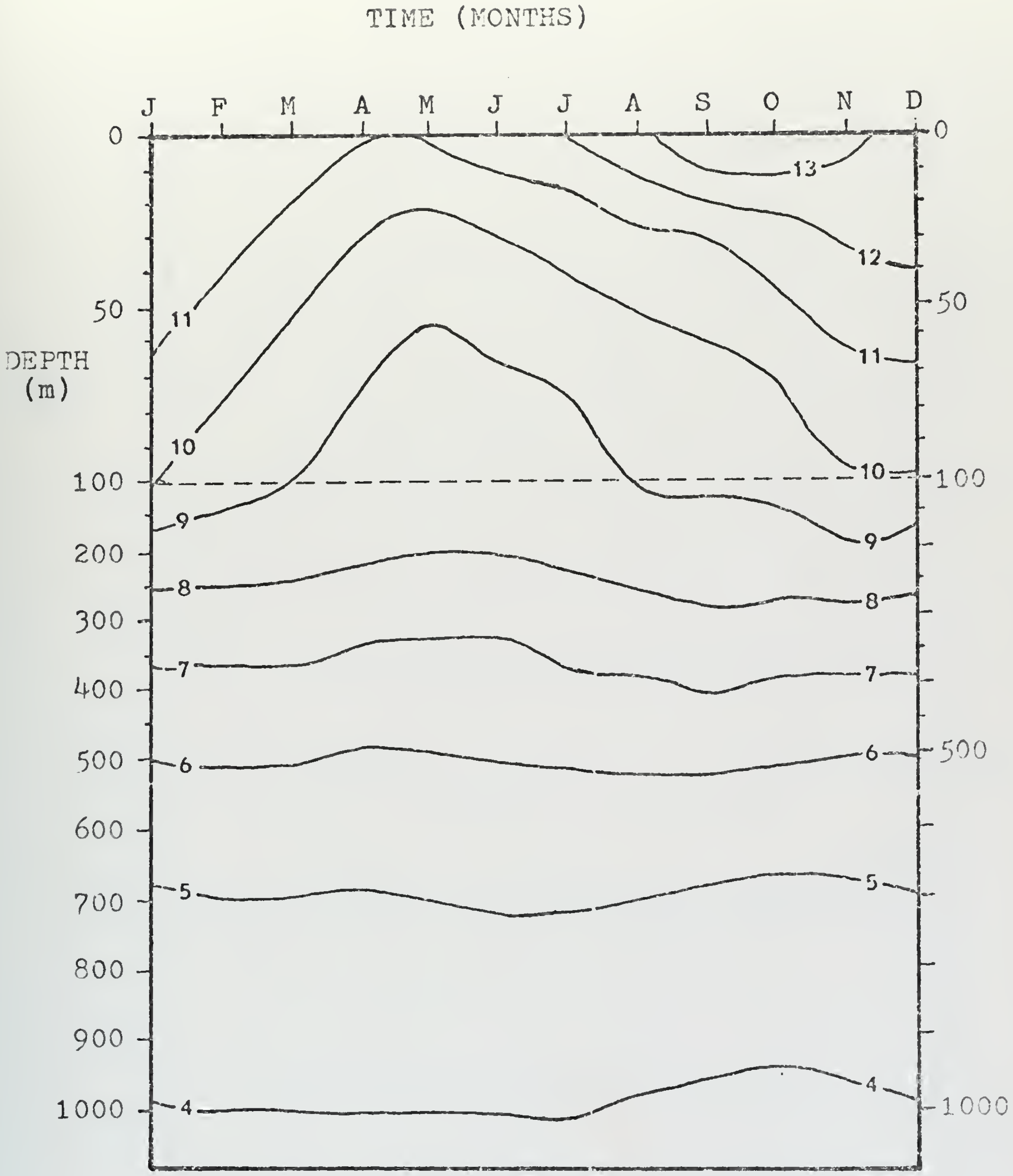
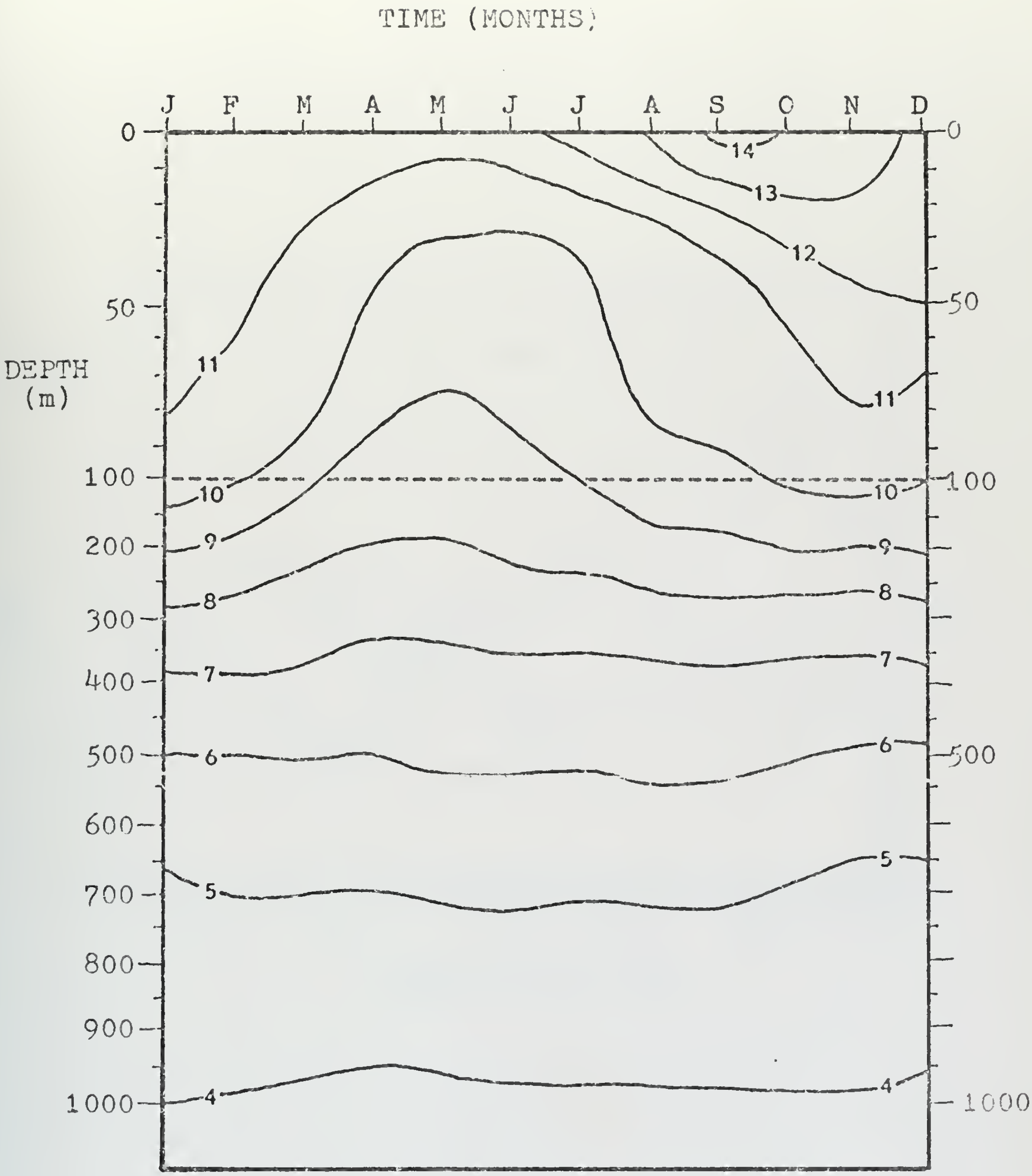


Figure 4. Average annual temperature (°C) cycle based on five years of data (upper 100m from 1929-1933, below 100m from 1932-1933) by Skogsberg. Dashed lines note scale change. Note: The 9°C isotherms by Skogsberg (S), Bolin (B) and CalCOFI surveys (C) demonstrate the downward migration of isotherms.



NOTE: Dashed line denotes scale change.

Figure 5. Annual Mean Temperature Cycle by Bolin.



NOTE: Dashed line denotes scale change.

Figure 6. Annual Mean Temperature Cycle Based on CalCOFI Surveys.

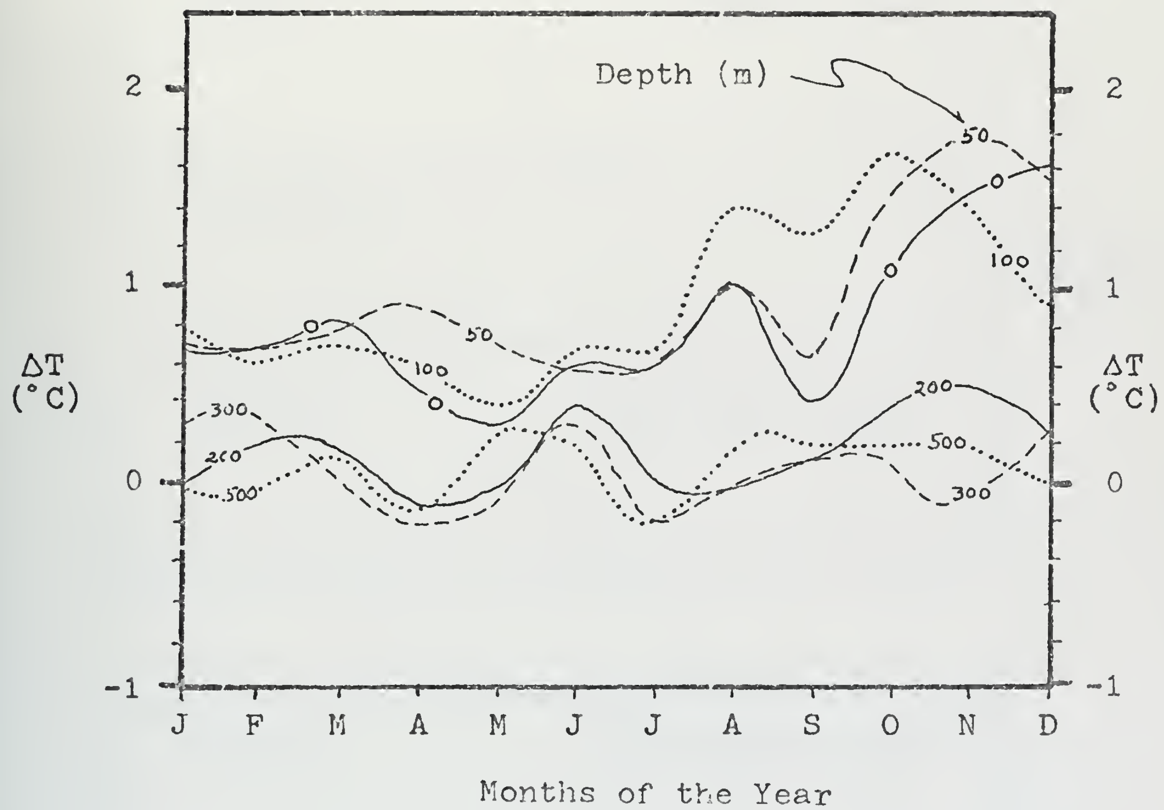


Figure 6A. The Progressive Warming of Bay Waters.

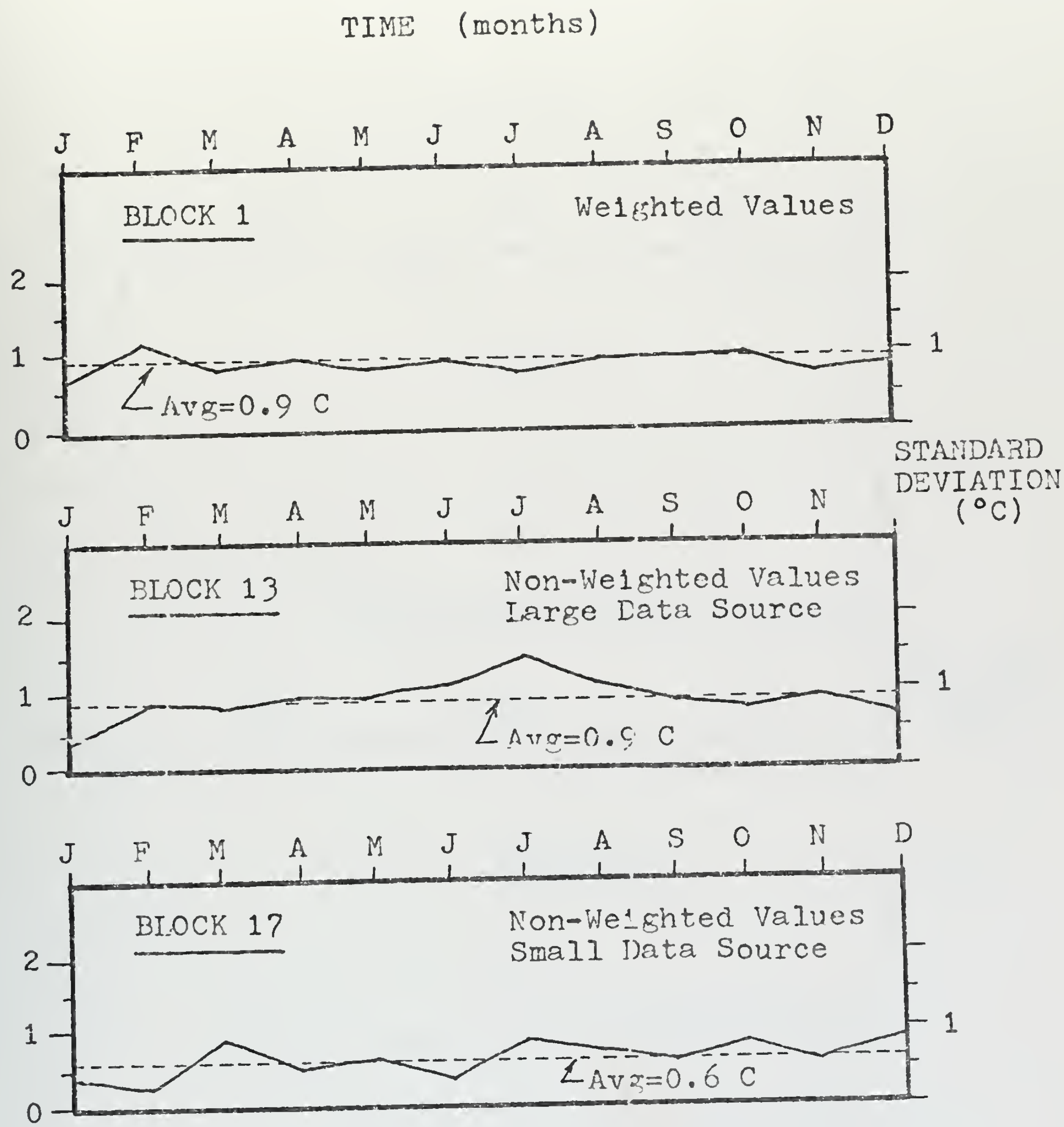


Figure 7. Standard Deviation of Temperature for Selected Blocks as a Function of Time. Sea Surface Temperature.

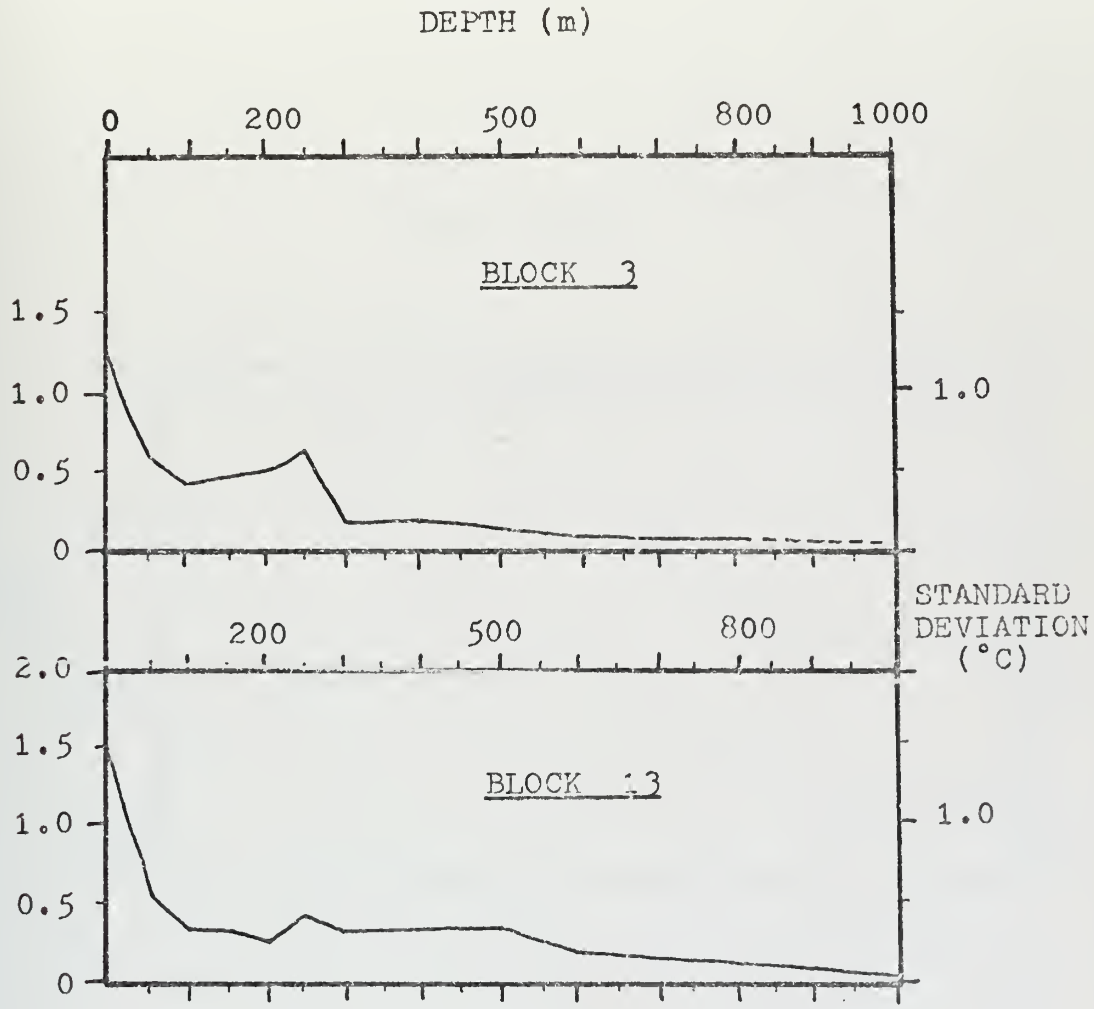


Figure 8. Standard Deviation of Temperature, Averaged in Typical Blocks, as a Function of Depth.

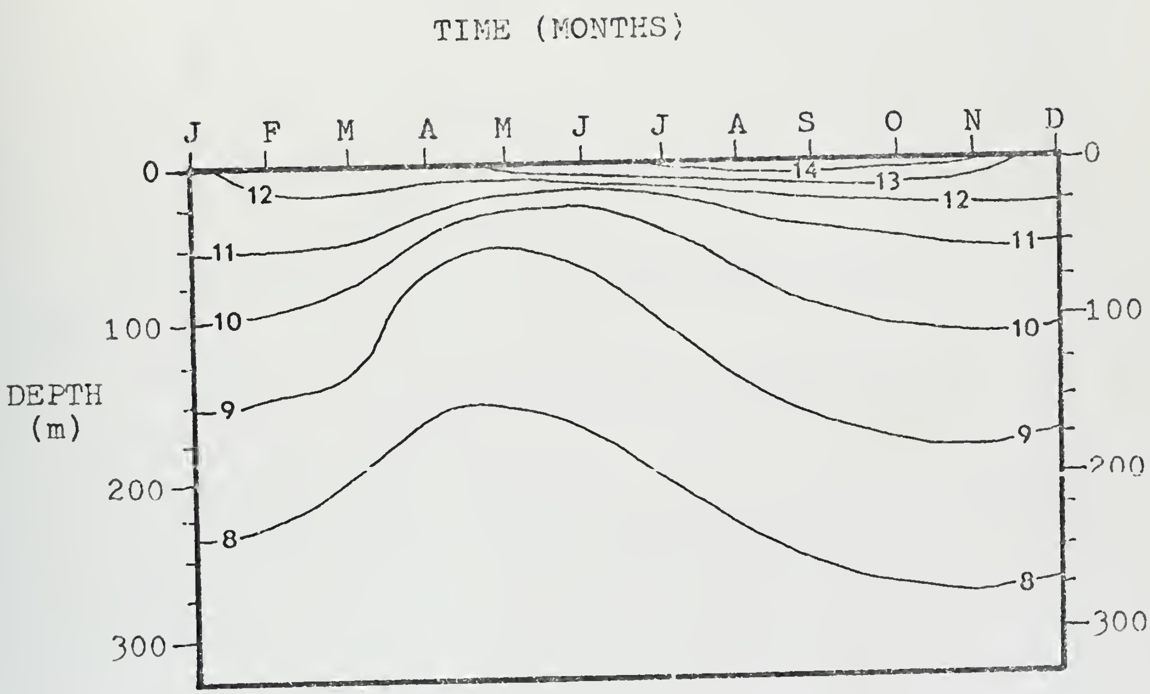


Figure 9. The Annual Mean Temperature Cycle at Block 19.

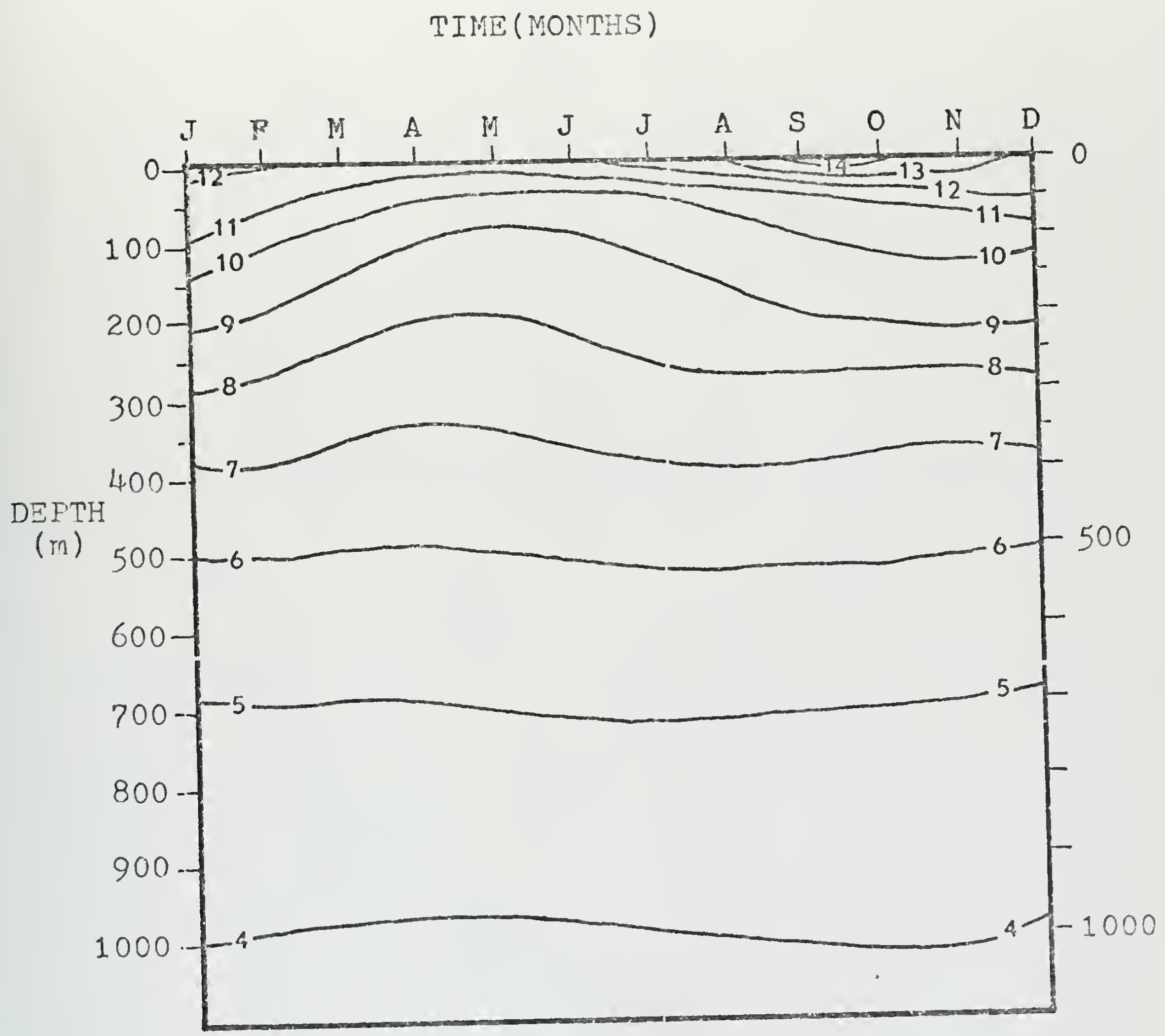
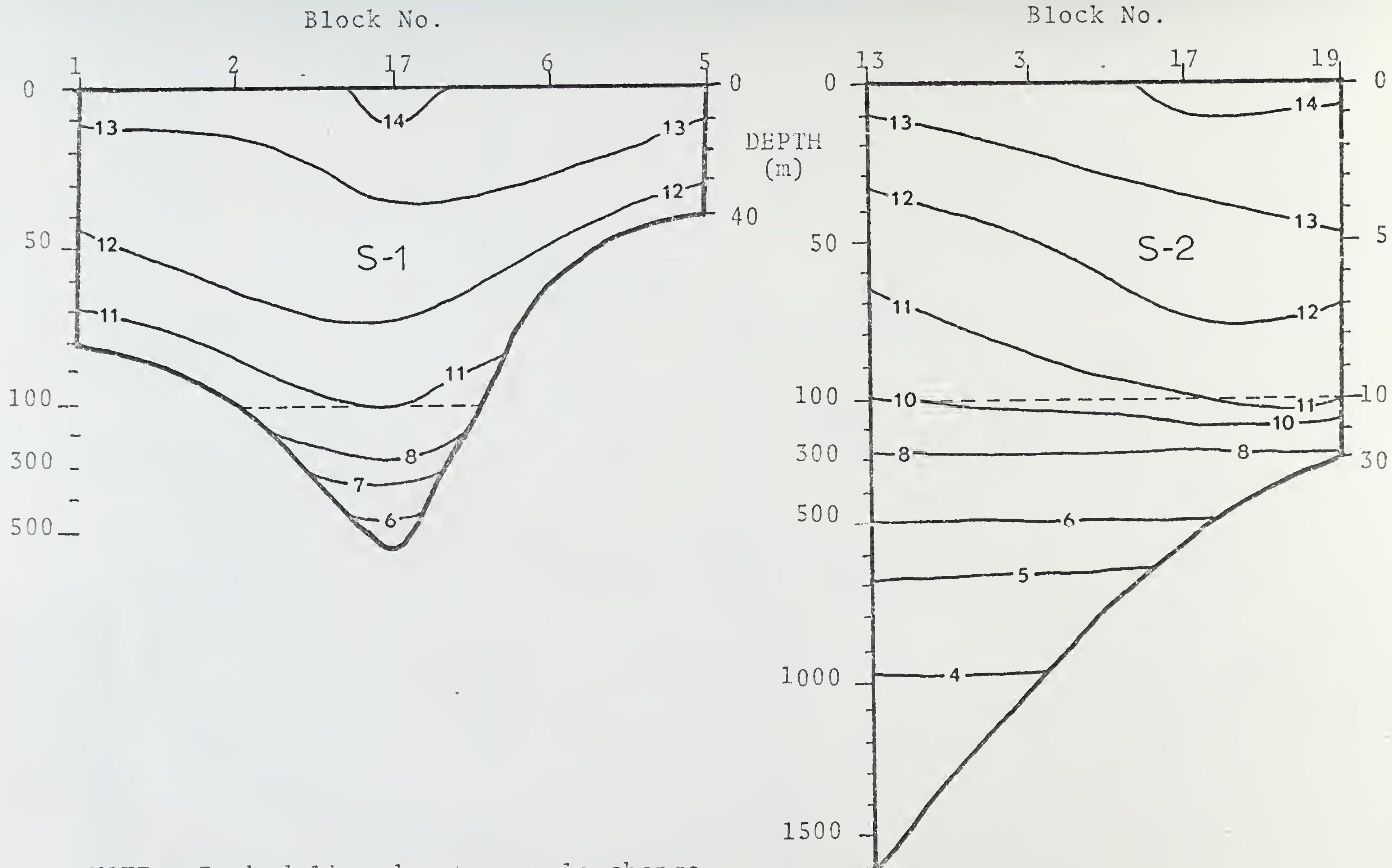
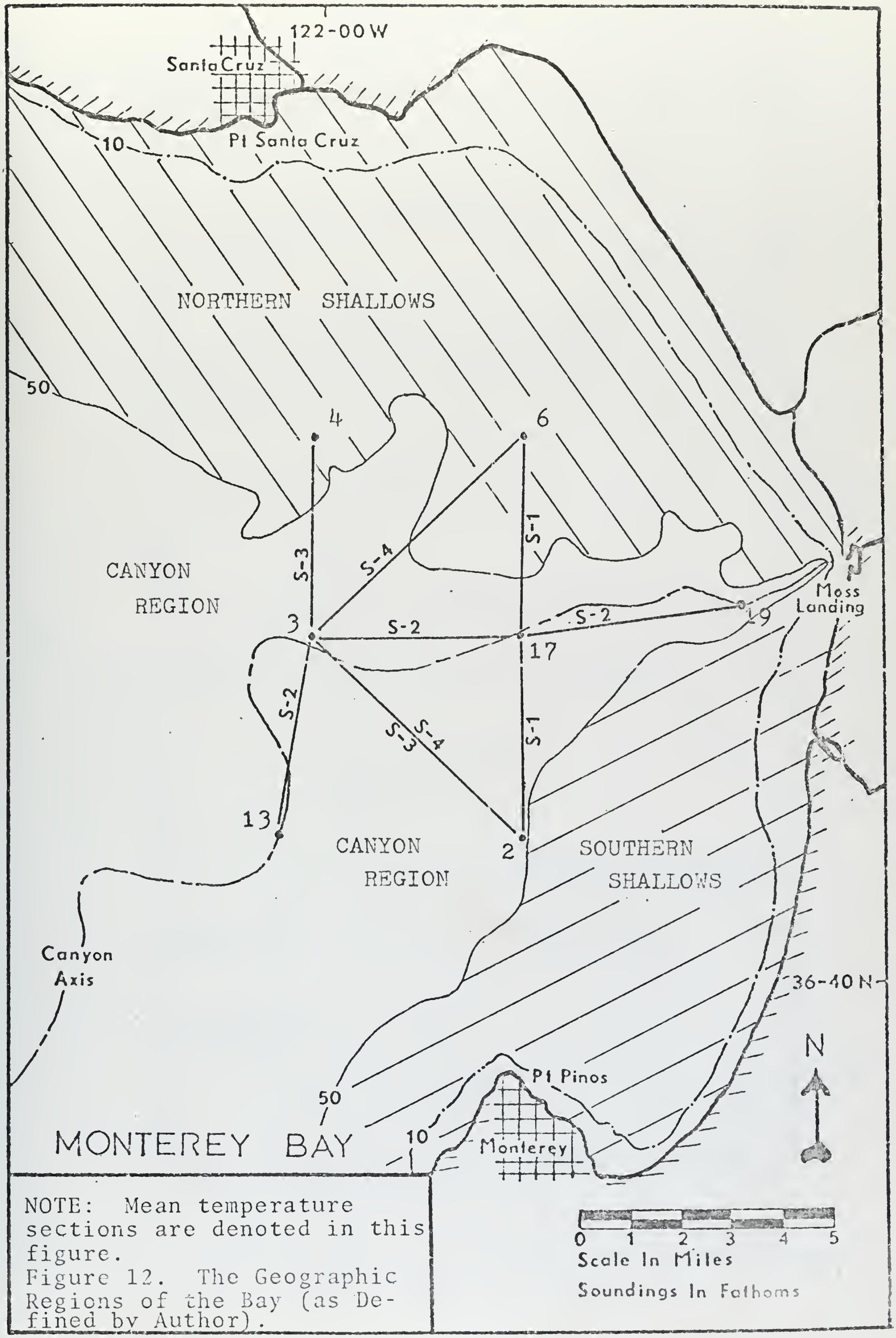


Figure 10. The Annual Mean Temperature Cycle at Block 3.



NOTE: Dashed line denotes scale change.

Figure 11. Vertical Mean Temperature Sections S-1 and S-2 for the Month of November.



NOTE: Mean temperature sections are denoted in this figure.

Figure 12. The Geographic Regions of the Bay (as Defined by Author).

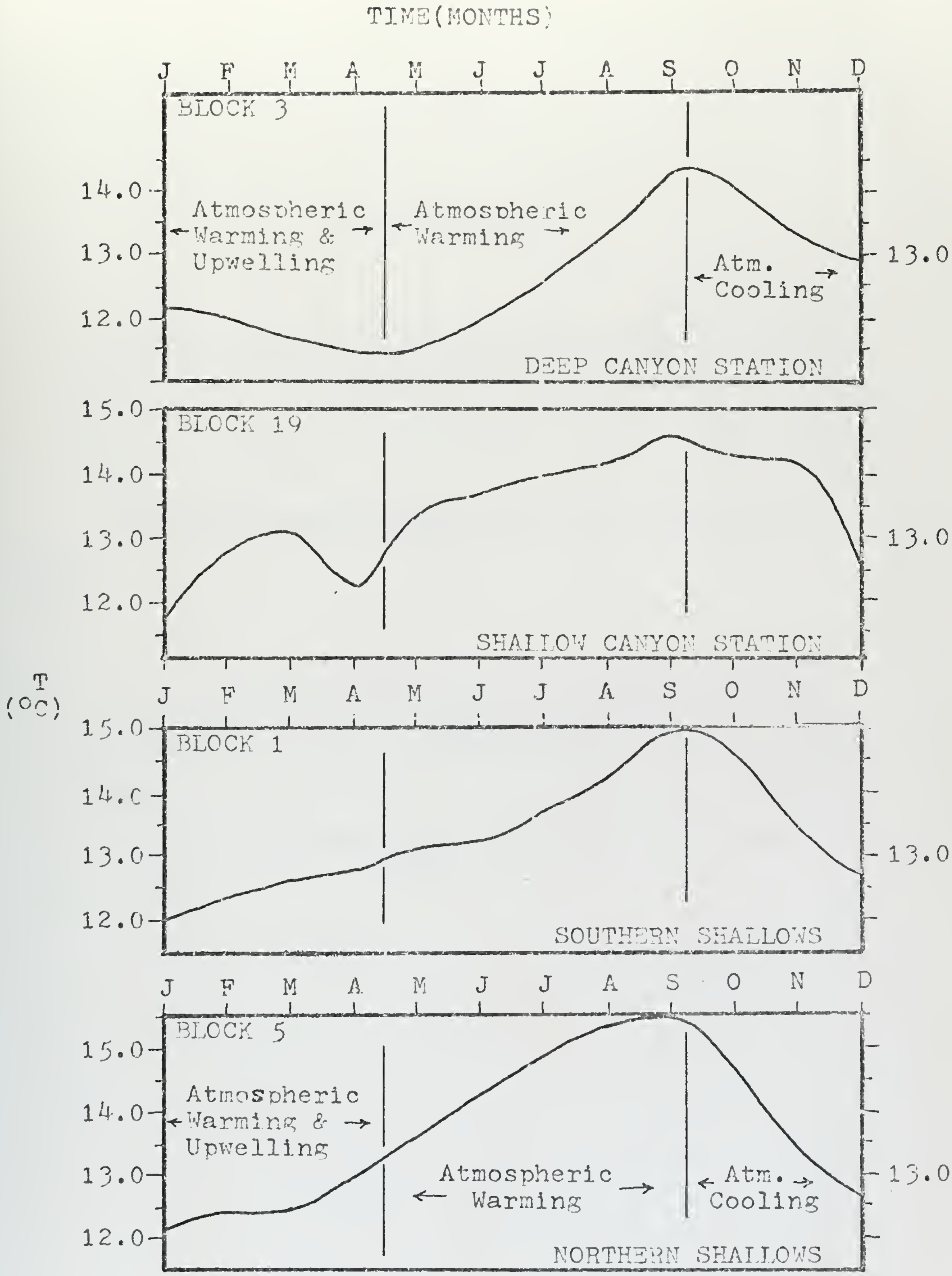


Figure 13. The Annual Cycles of Mean Sea Surface Temperature in Very Shallow Regions of the Bay.

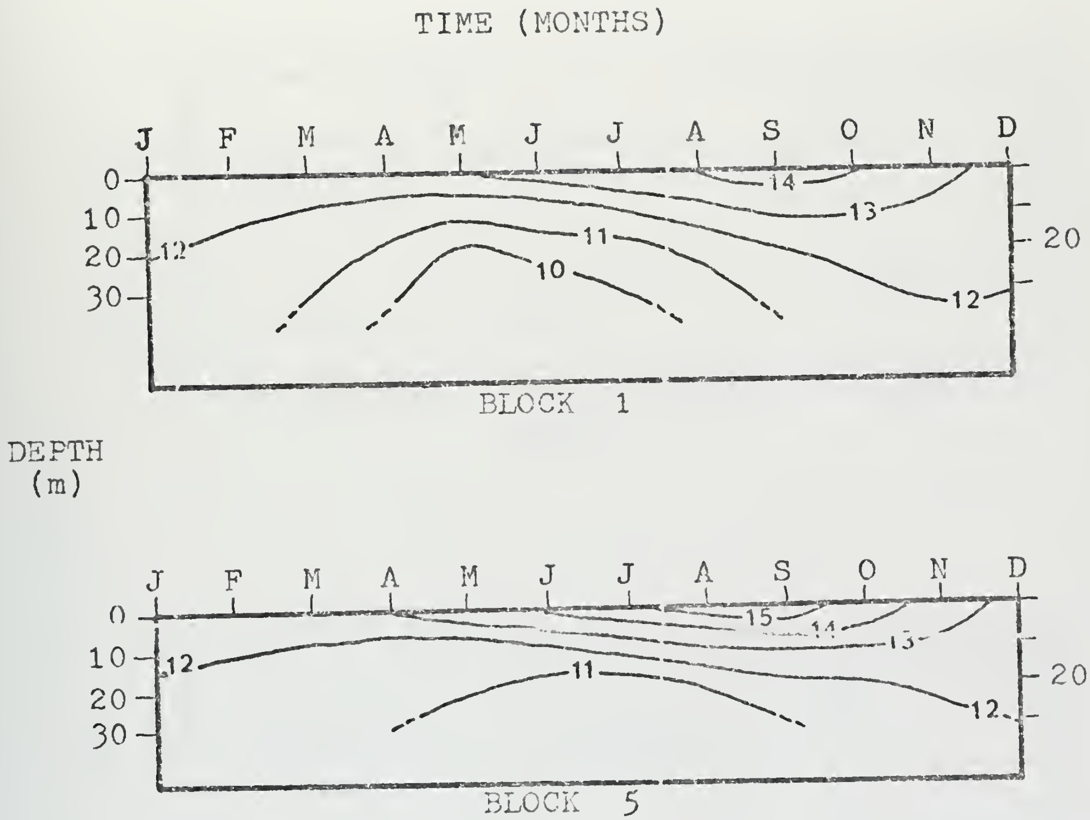


Figure 14. The Annual Mean Temperature Cycles at Blocks 1 and 5.

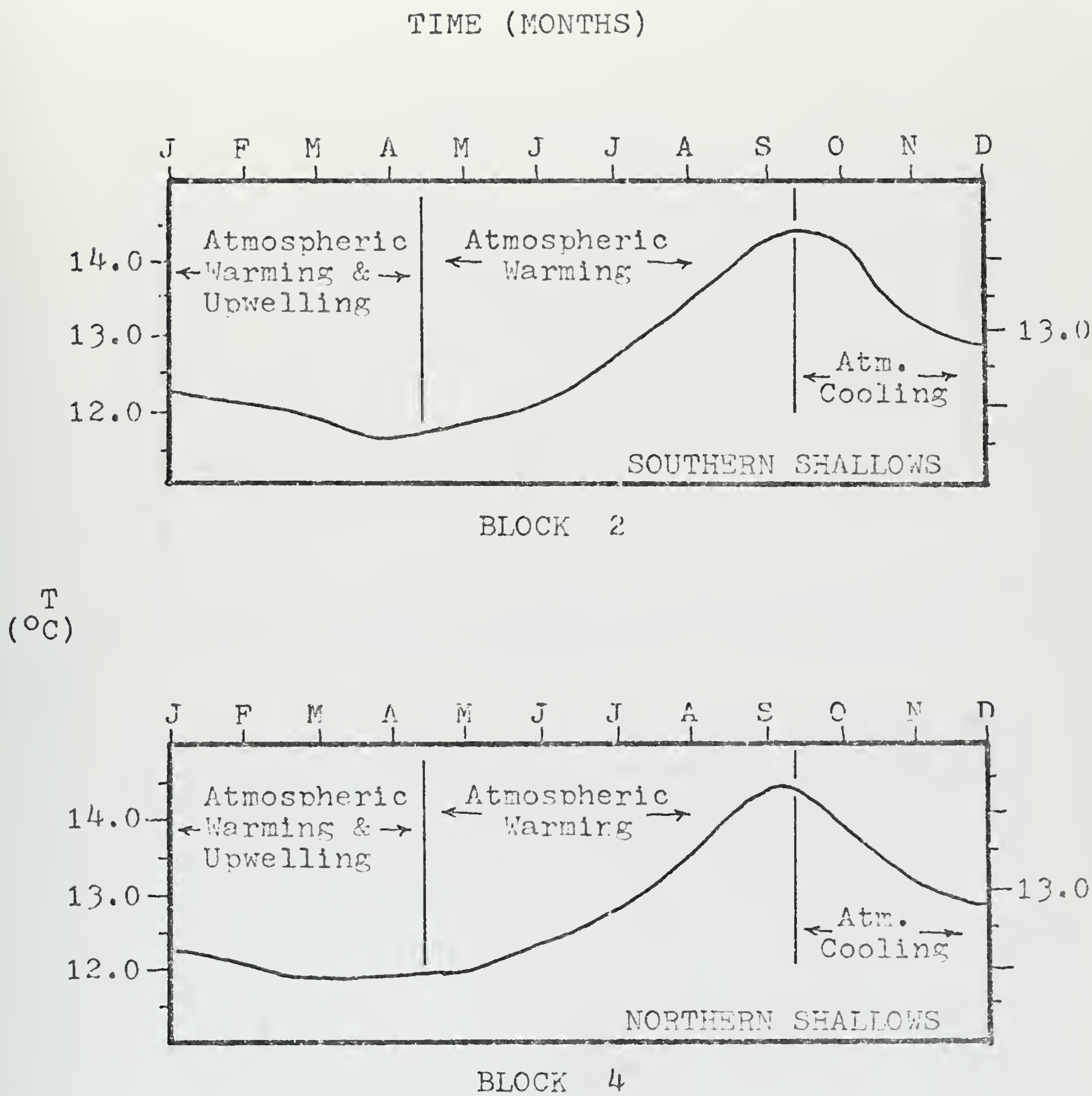
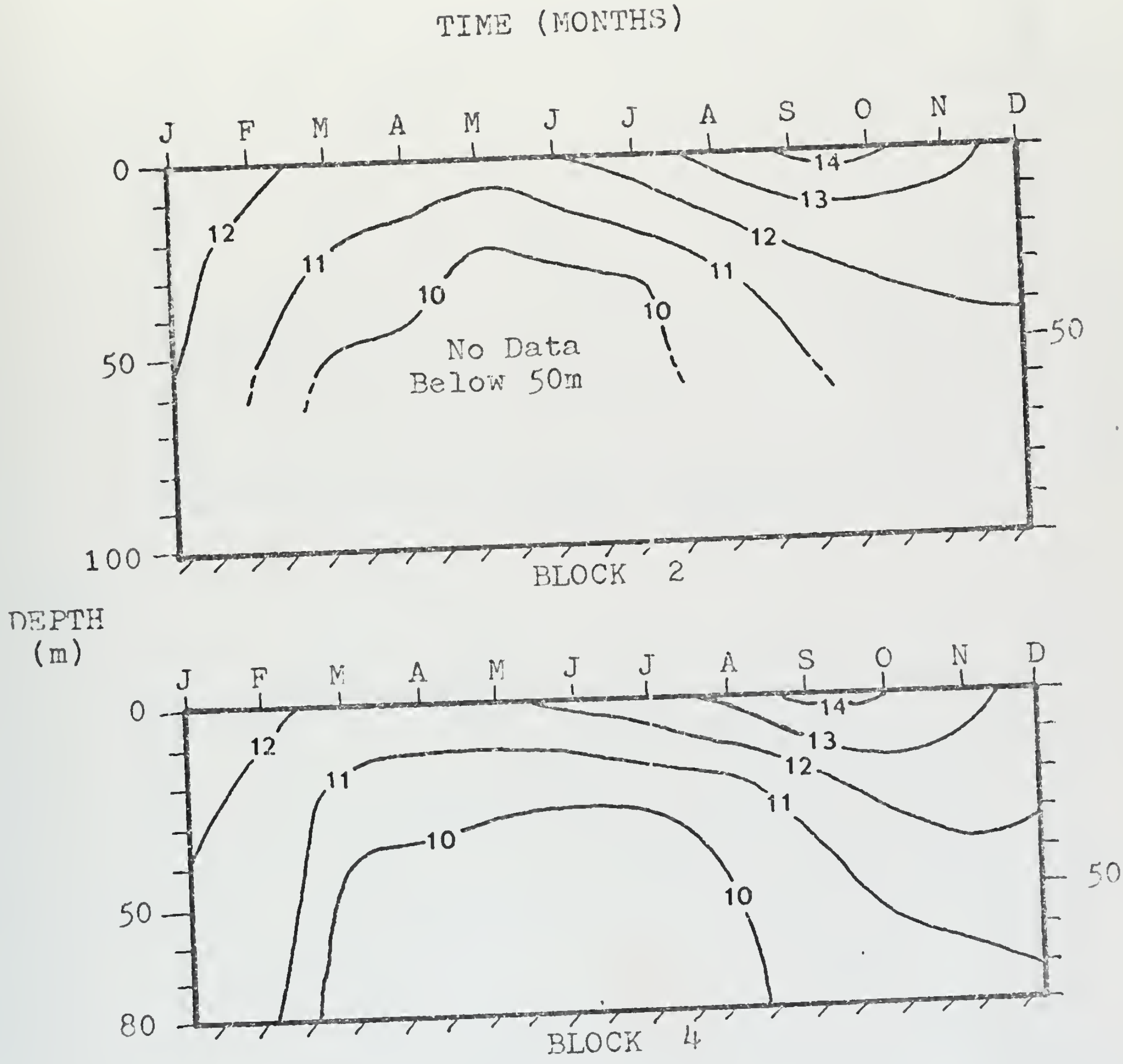
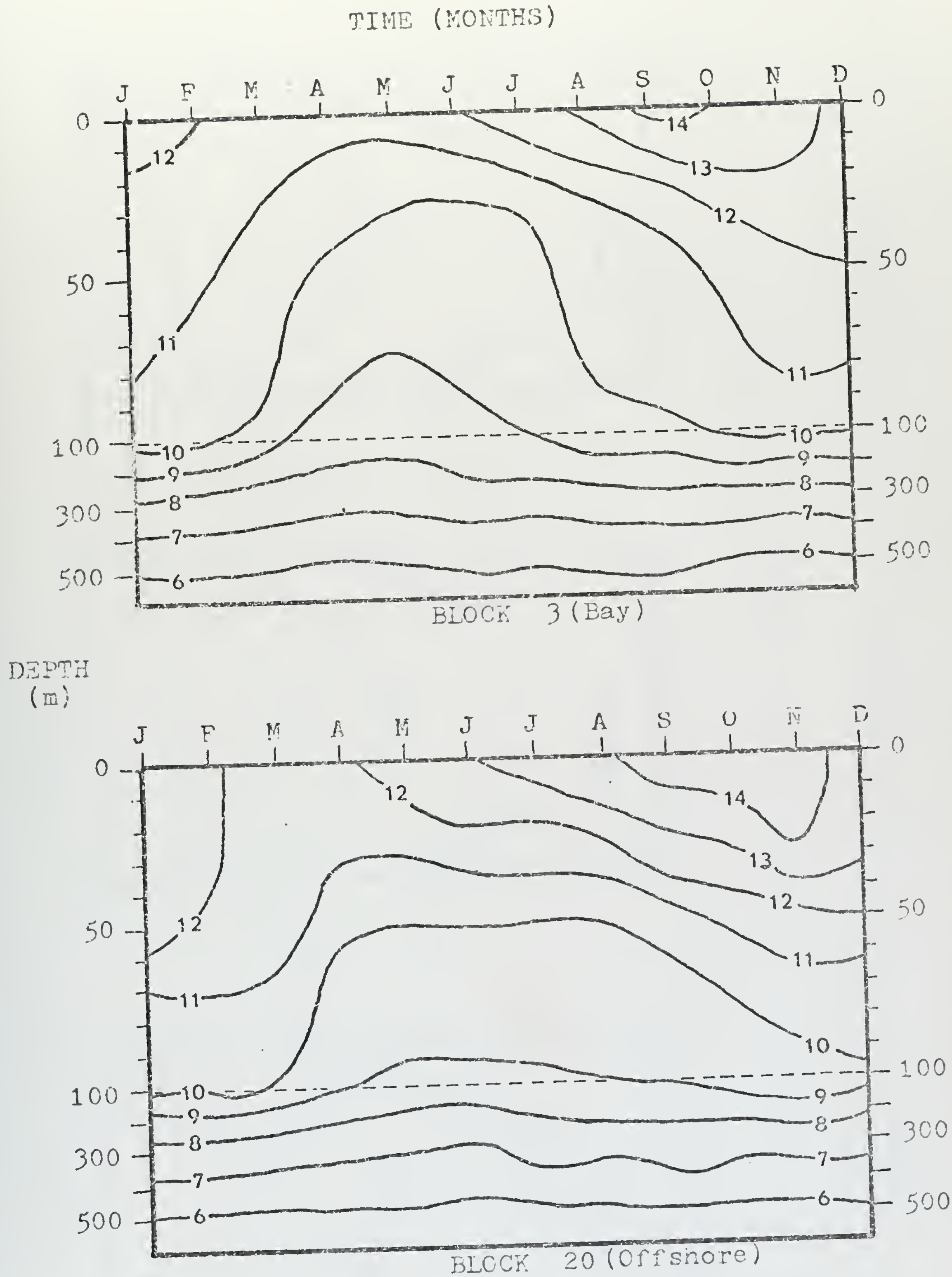


Figure 15. The Annual Cycles of Mean Sea Surface Temperature in Relatively Deeper Regions of the Shallows.



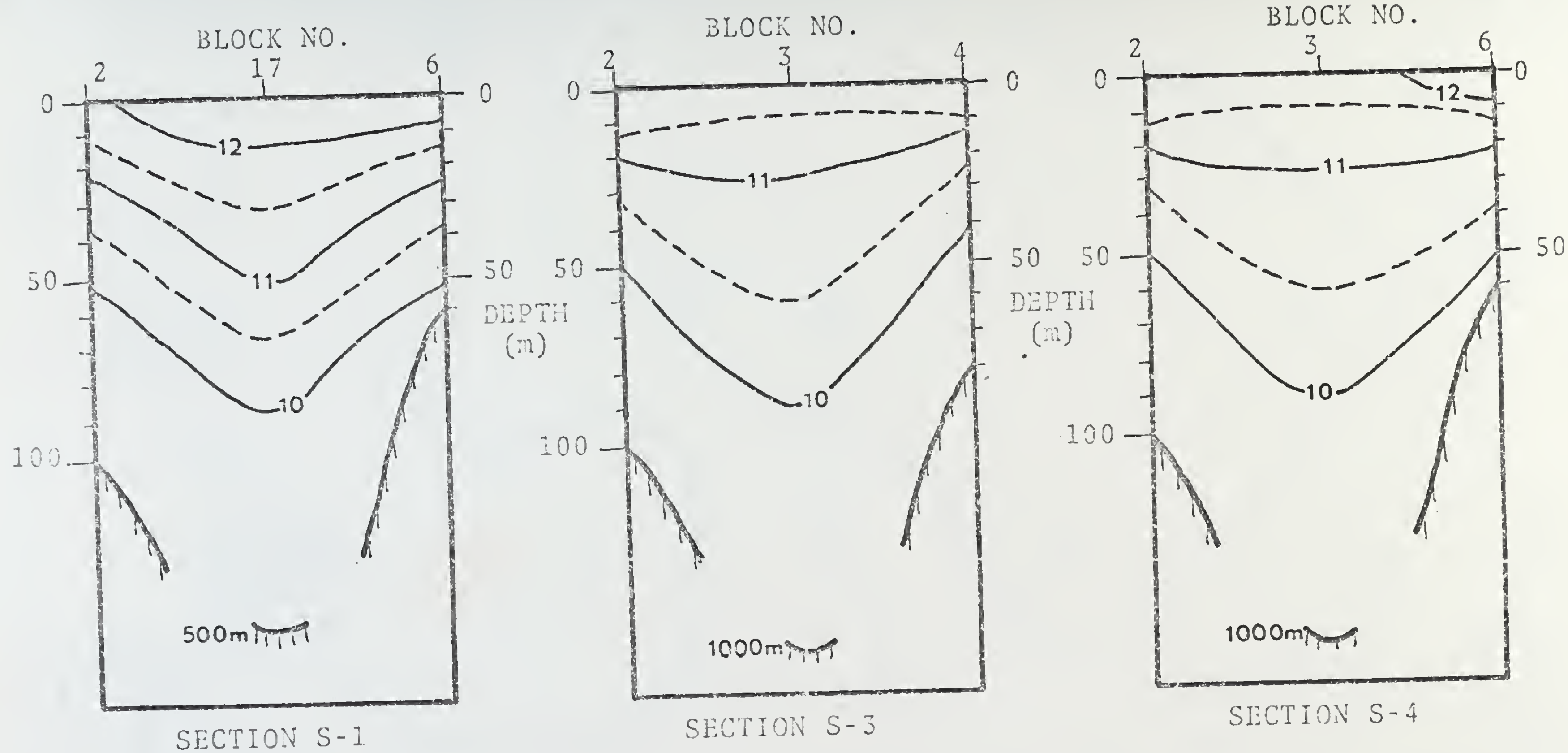
NOTE: The steep slopes of the 10°C and 11°C isotherms at Block 4 illustrate the up-slope entry of cold waters into the region.

Figure 16. The Annual Mean Temperature Cycles at Blocks 2 and 4.



NOTE: Dashed lines denote scale change.

Figure 17. Typical Annual Mean Temperature Cycles of a Canyon versus an Offshore Station.



NOTE: See Figure 12 for locations of mean temperature sections.

Figure 18. Dipping of the Isotherms Across the Canyon in March.

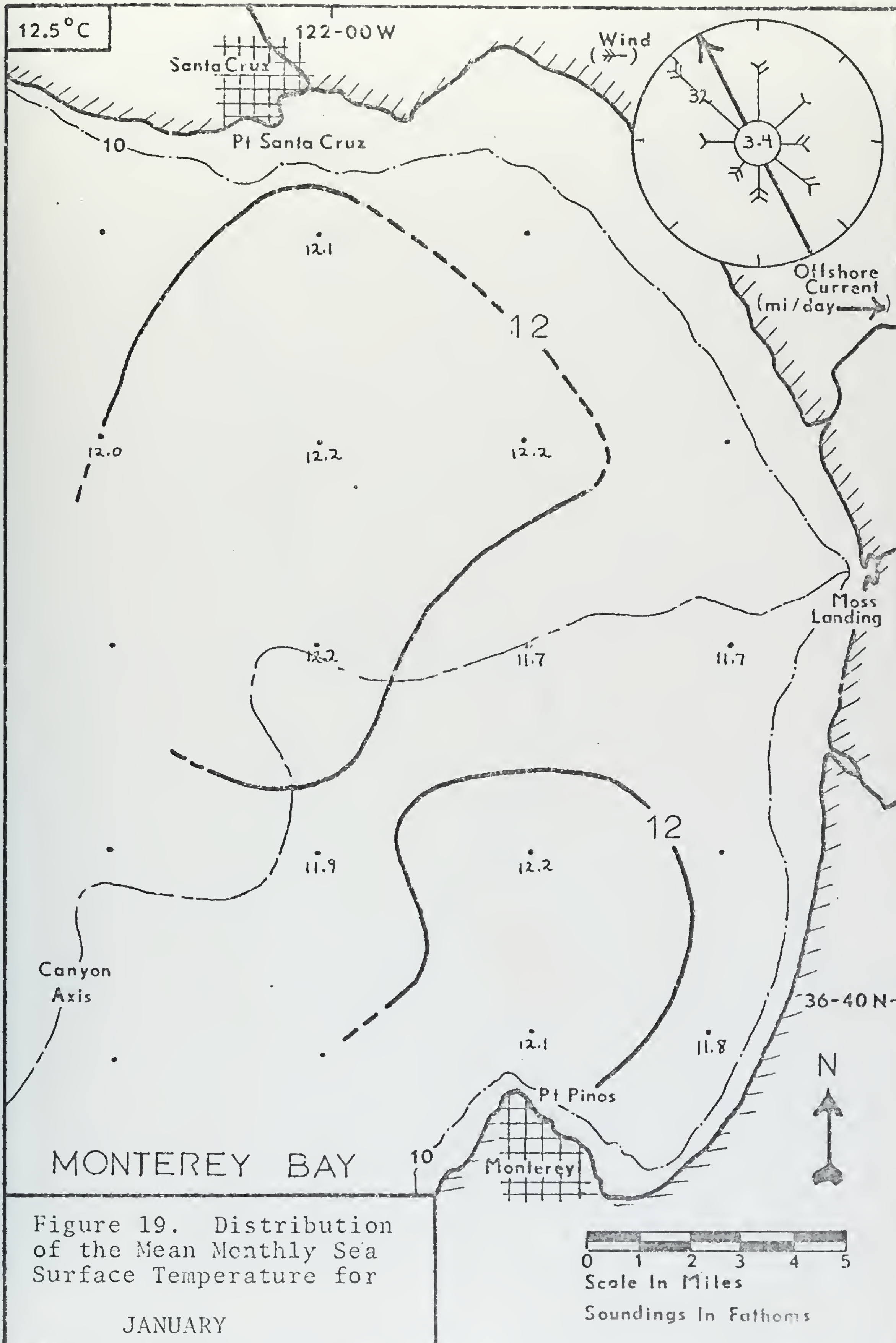


Figure 19. Distribution of the Mean Monthly Sea Surface Temperature for

JANUARY

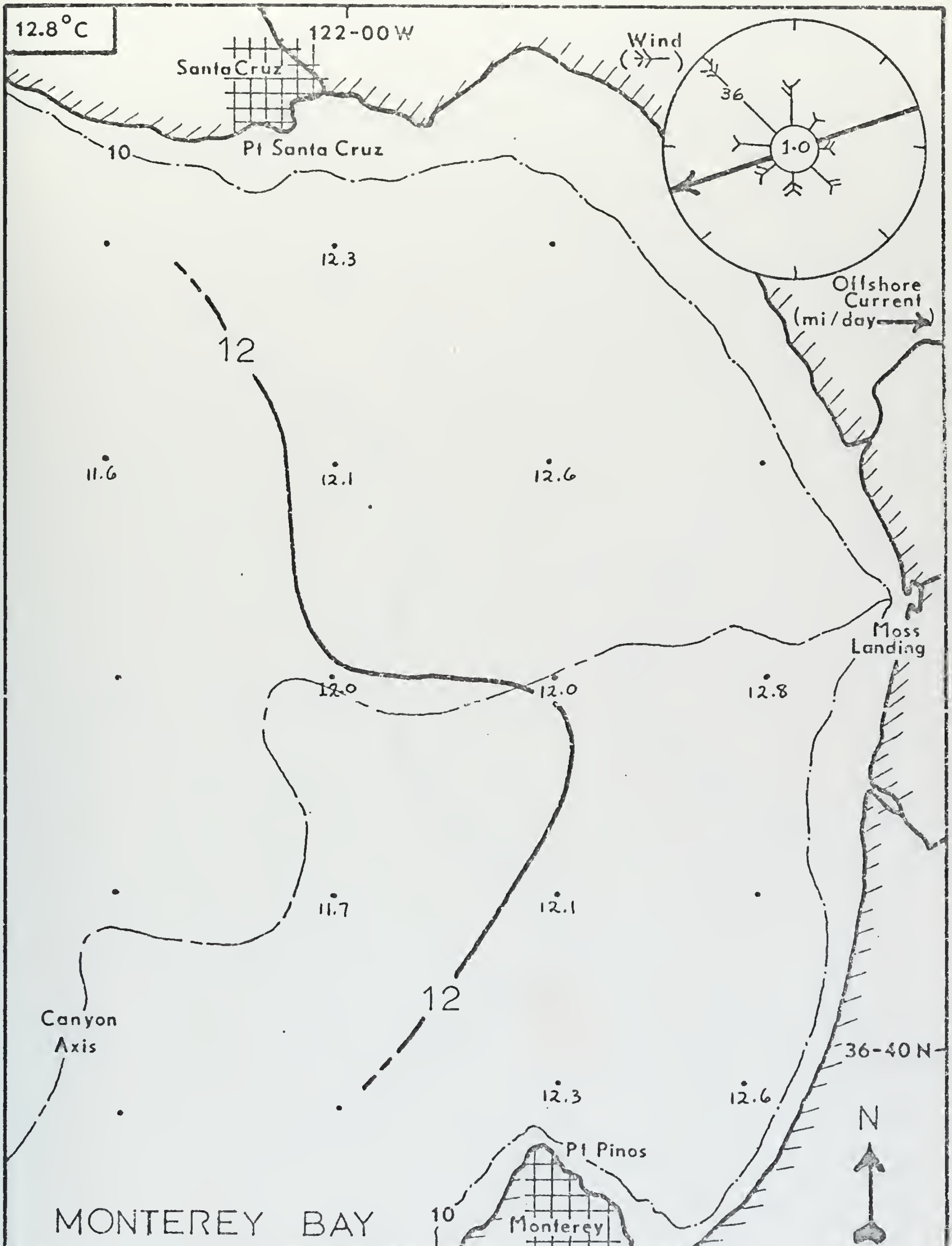


Figure 20. Distribution of the Mean Monthly Sea Surface Temperature for

FEBRUARY

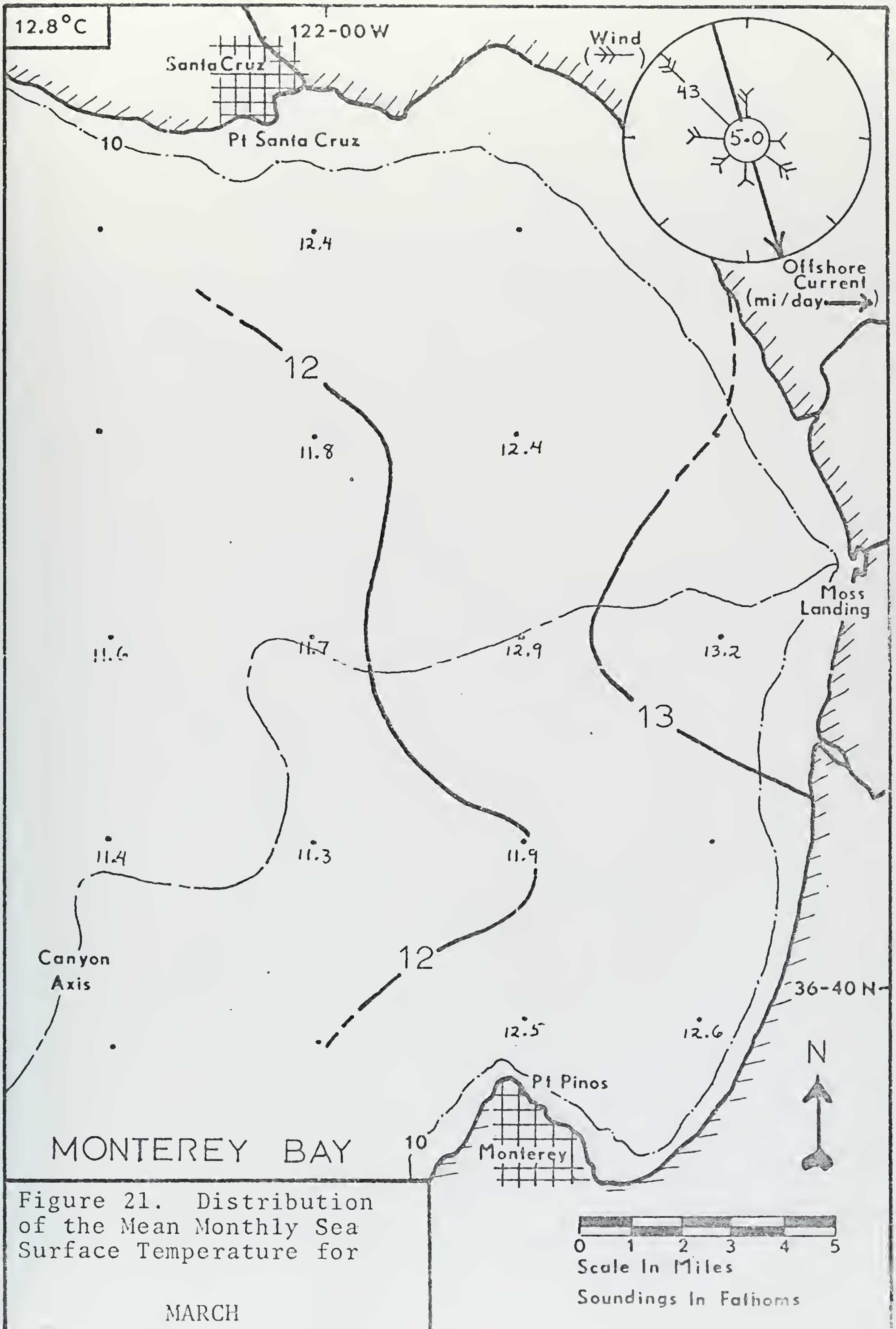


Figure 21. Distribution of the Mean Monthly Sea Surface Temperature for

MARCH

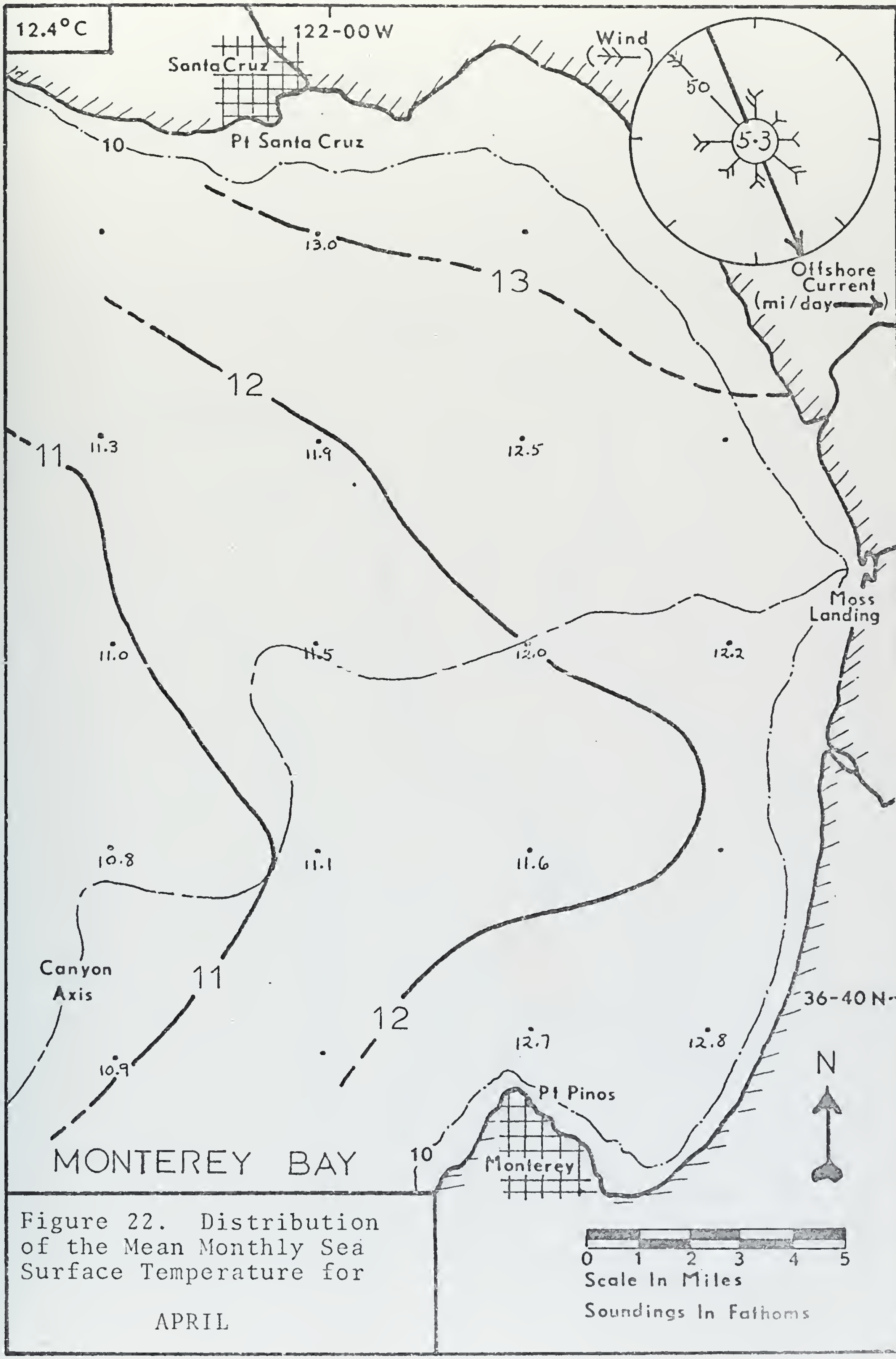


Figure 22. Distribution of the Mean Monthly Sea Surface Temperature for

APRIL

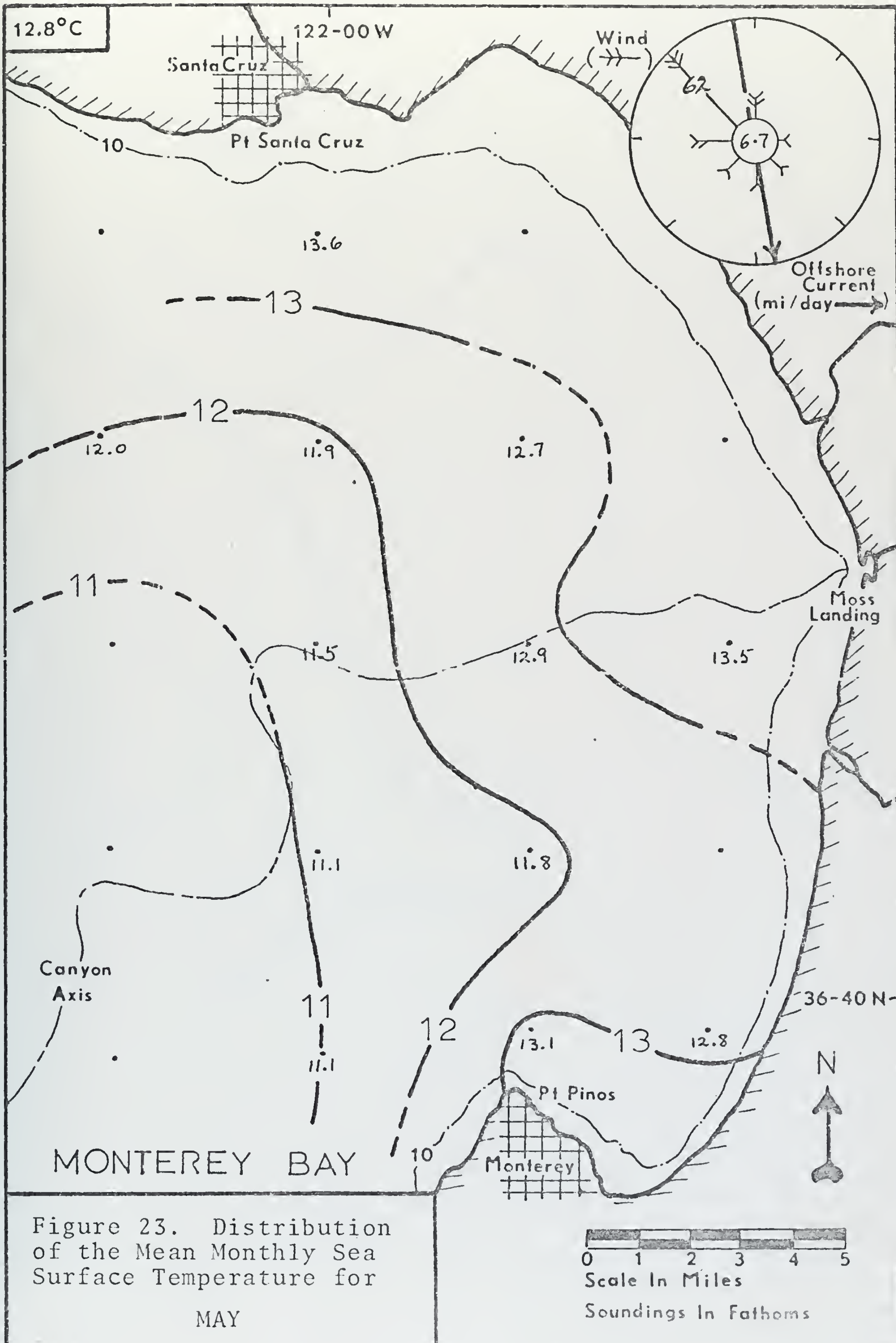


Figure 23. Distribution of the Mean Monthly Sea Surface Temperature for

MAY

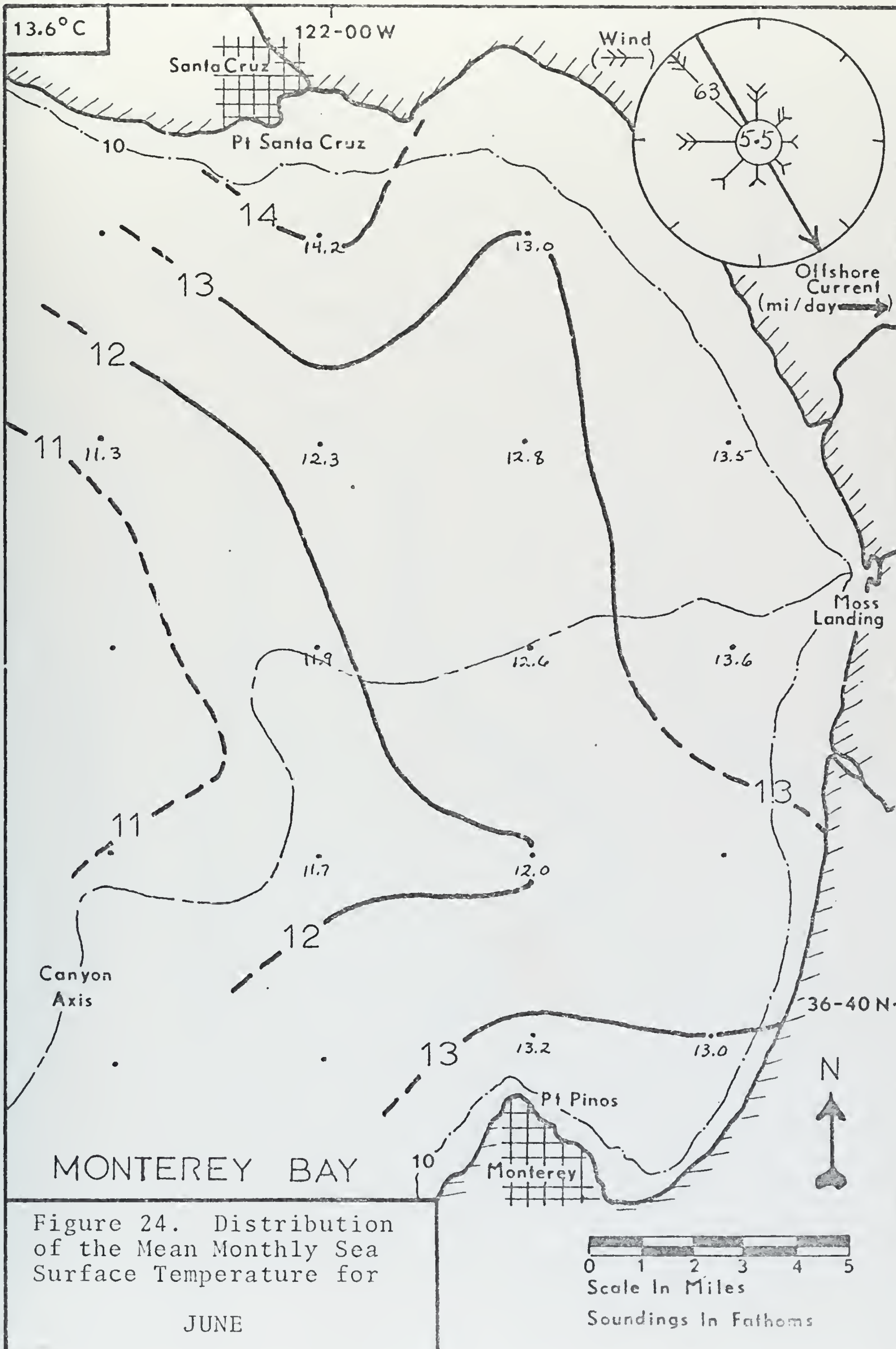


Figure 24. Distribution of the Mean Monthly Sea Surface Temperature for

JUNE

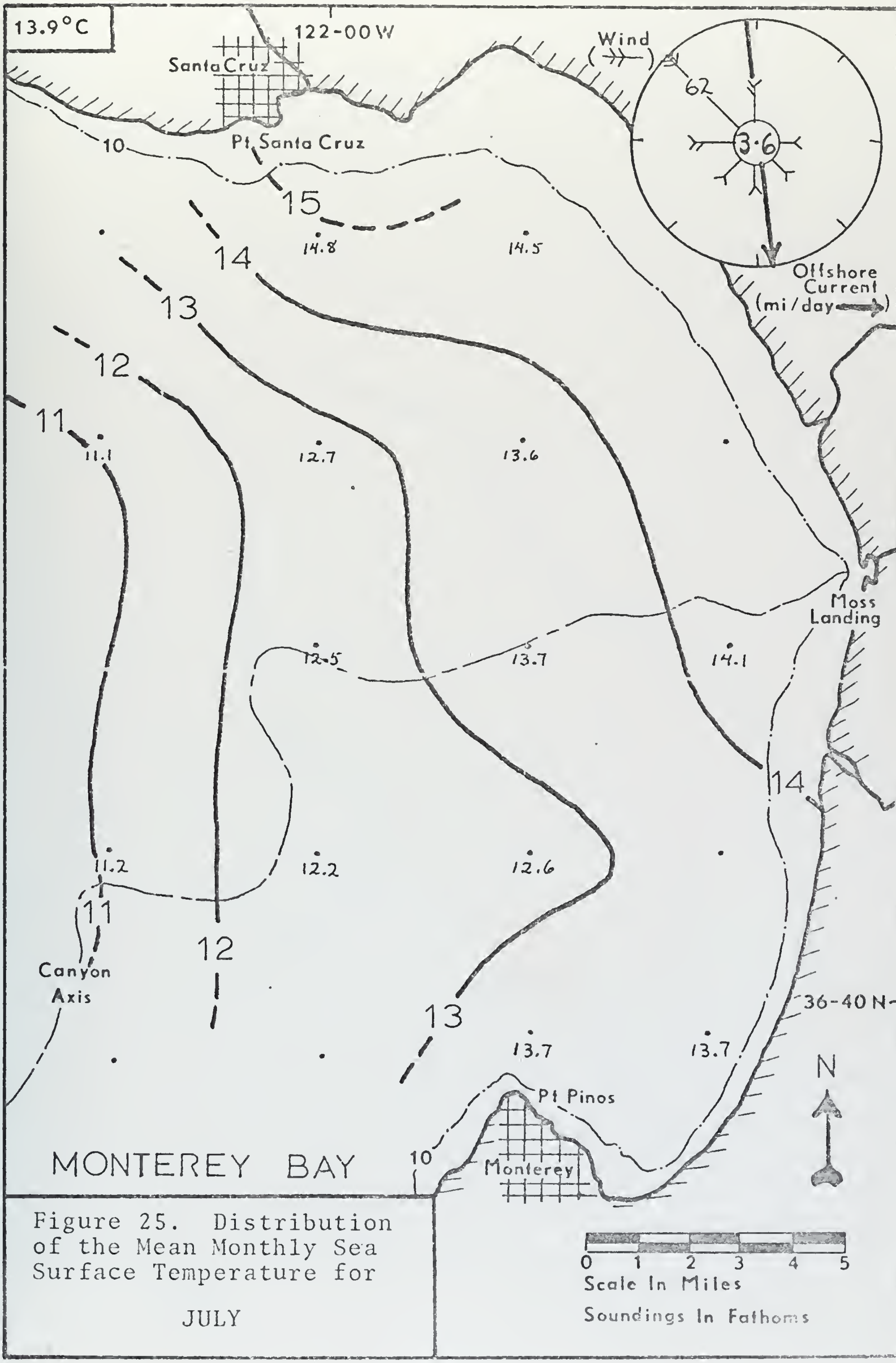


Figure 25. Distribution of the Mean Monthly Sea Surface Temperature for

JULY

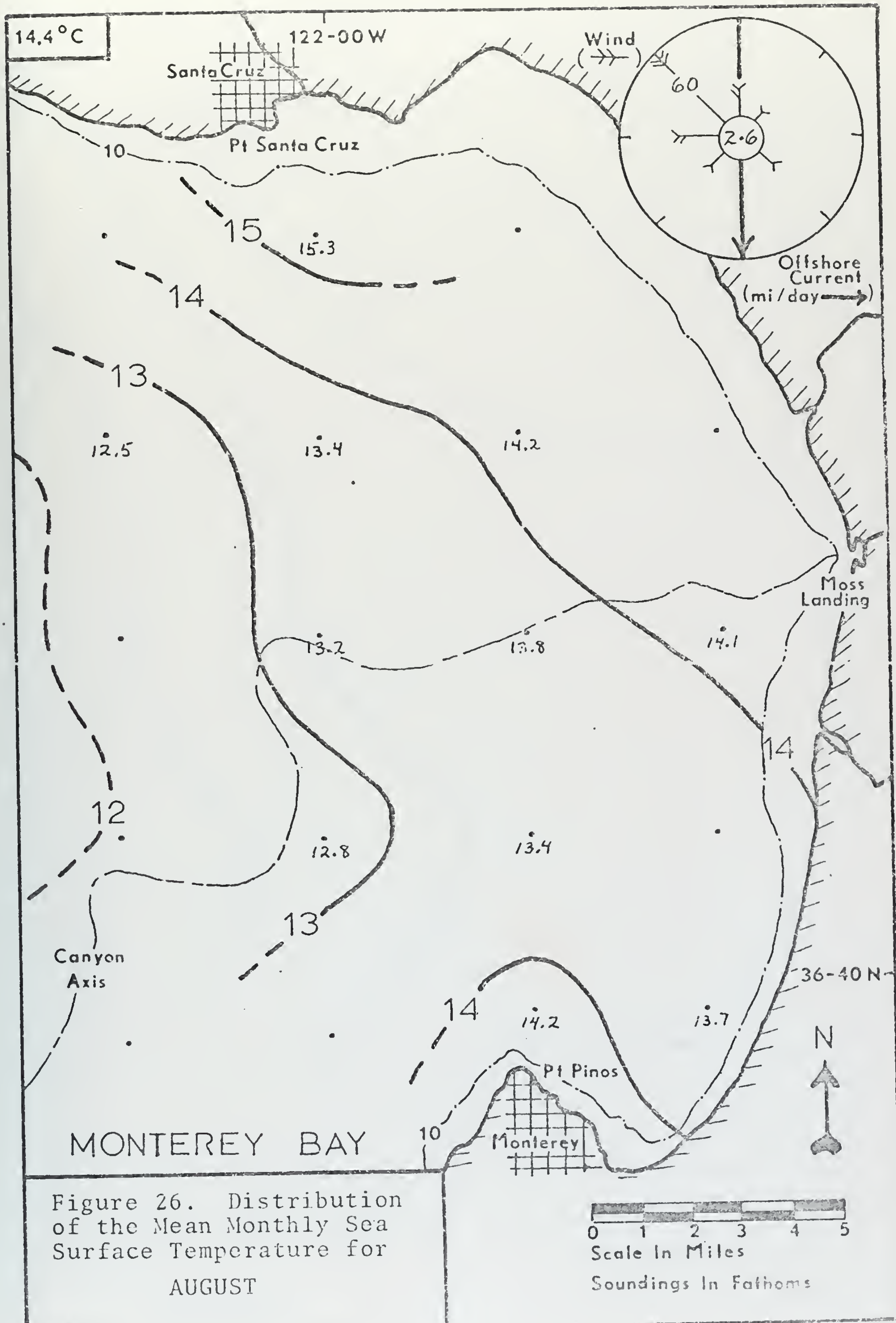


Figure 26. Distribution of the Mean Monthly Sea Surface Temperature for AUGUST

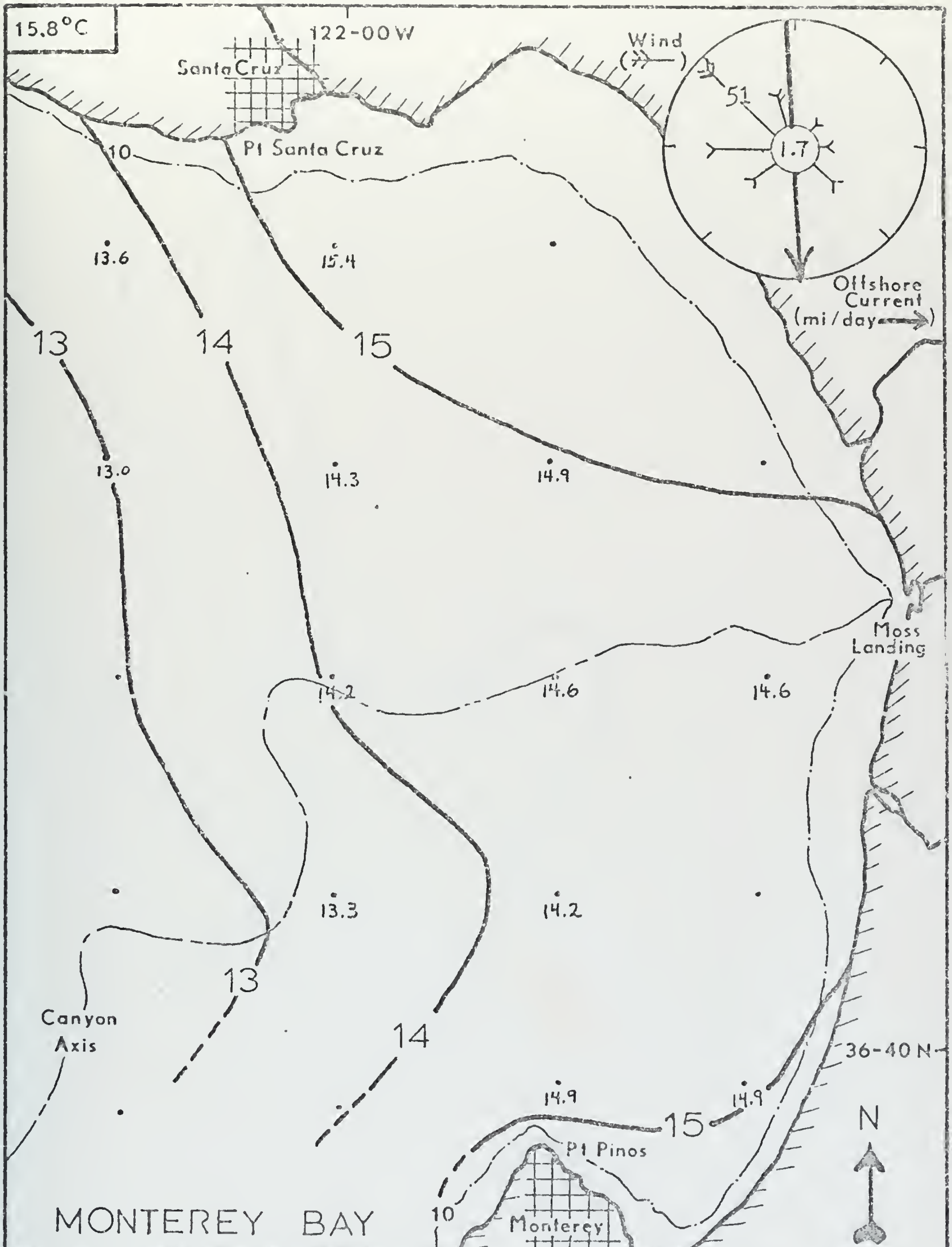


Figure 27. Distribution of the Mean Monthly Sea Surface Temperature for

SEPTEMBER

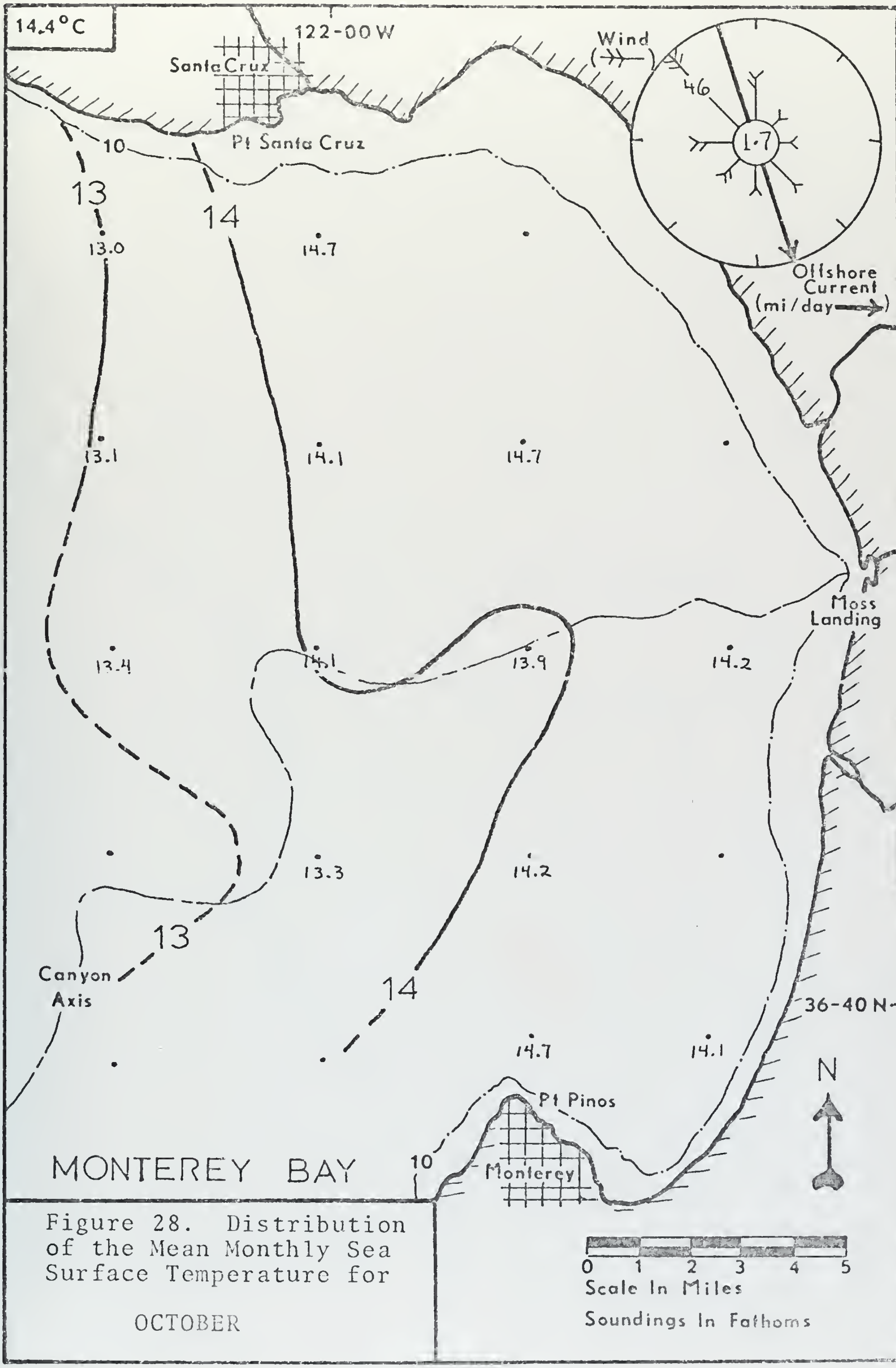


Figure 28. Distribution of the Mean Monthly Sea Surface Temperature for

OCTOBER

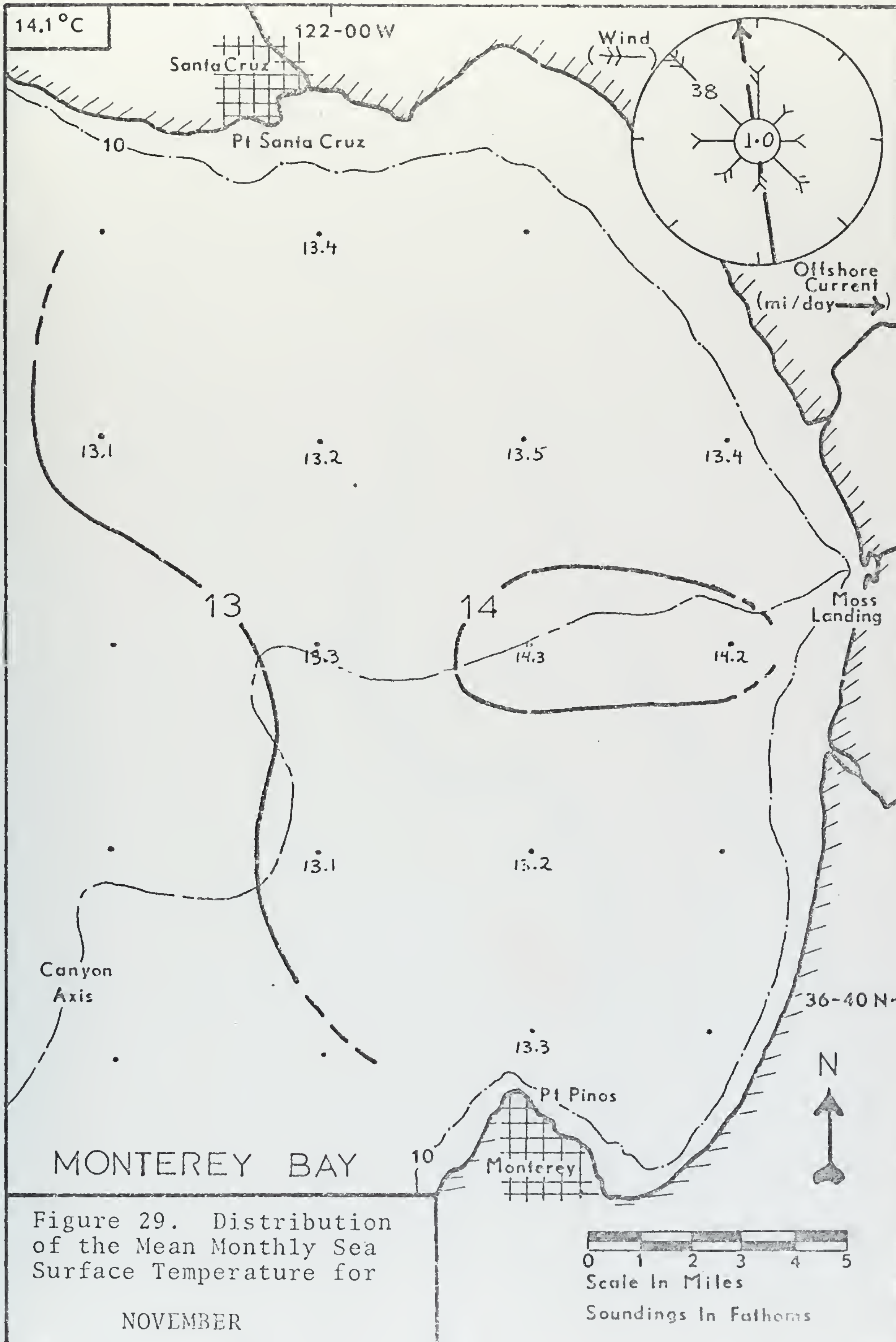


Figure 29. Distribution of the Mean Monthly Sea Surface Temperature for

NOVEMBER

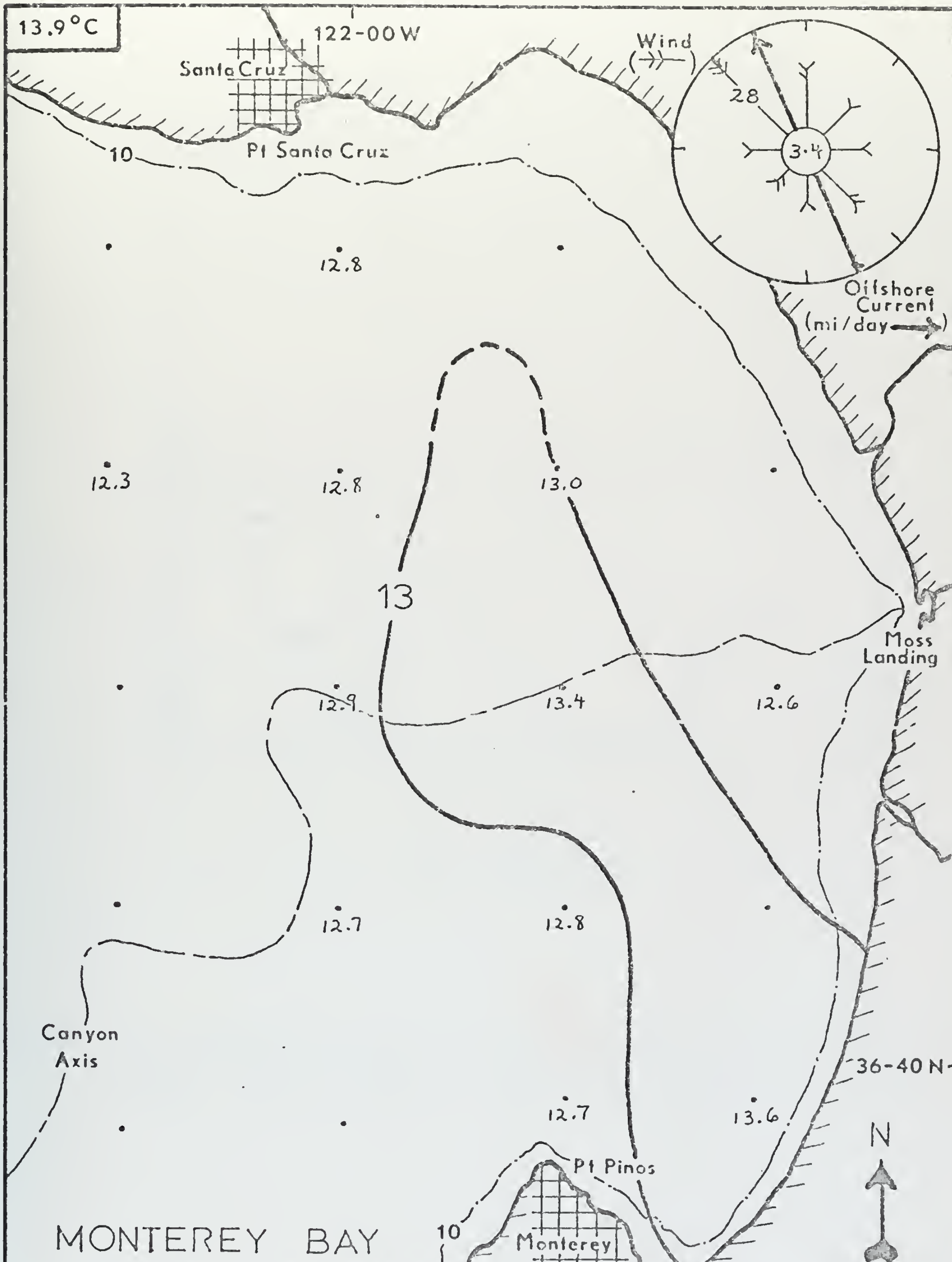
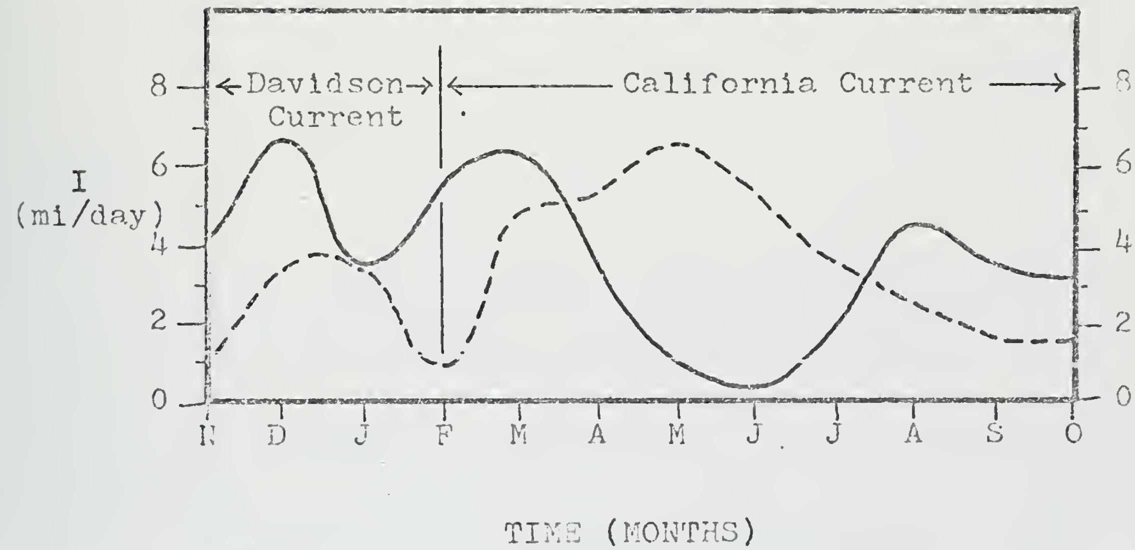


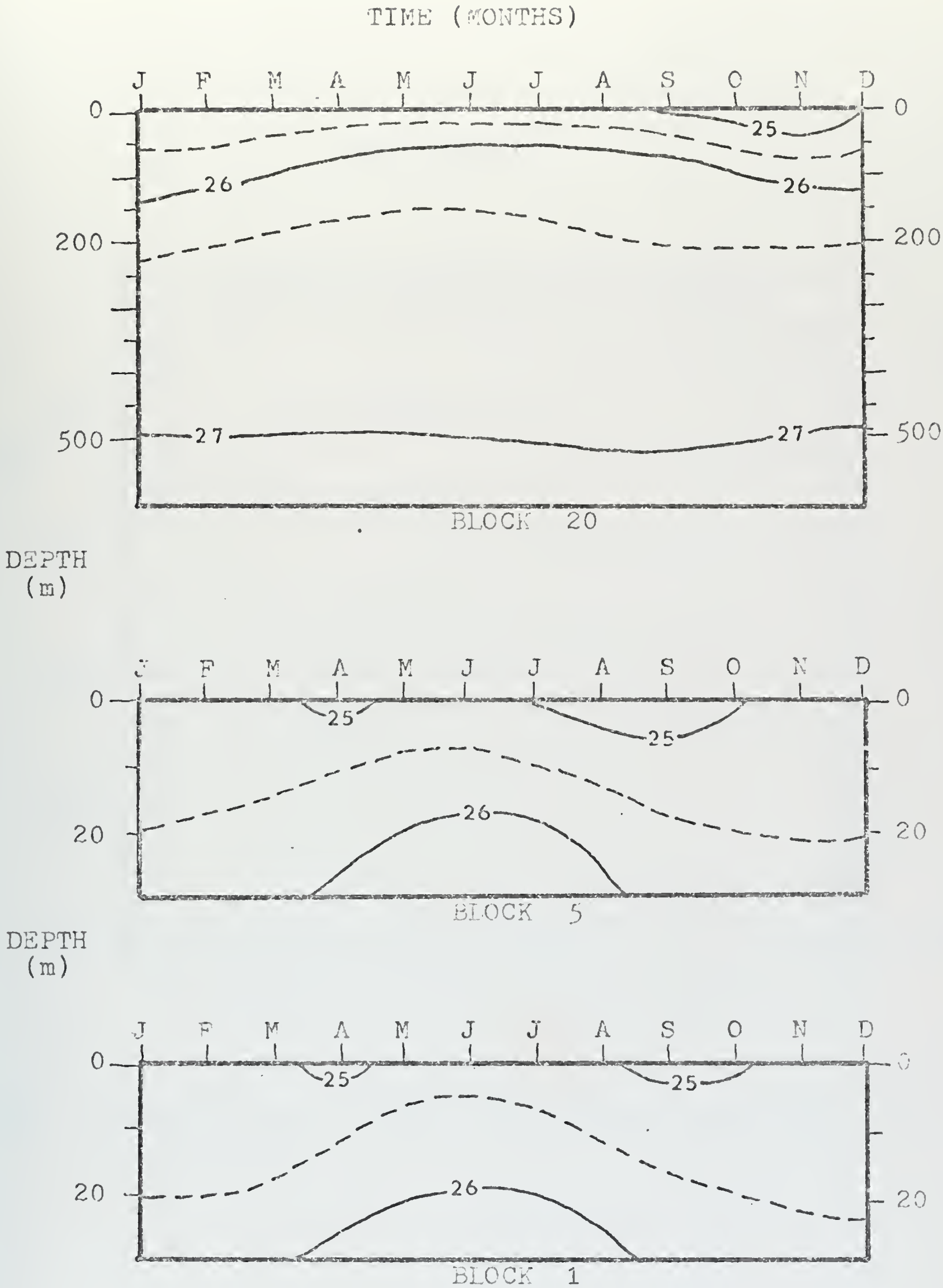
Figure 30. Distribution of the Mean Monthly Sea Surface Temperature for

DECEMBER



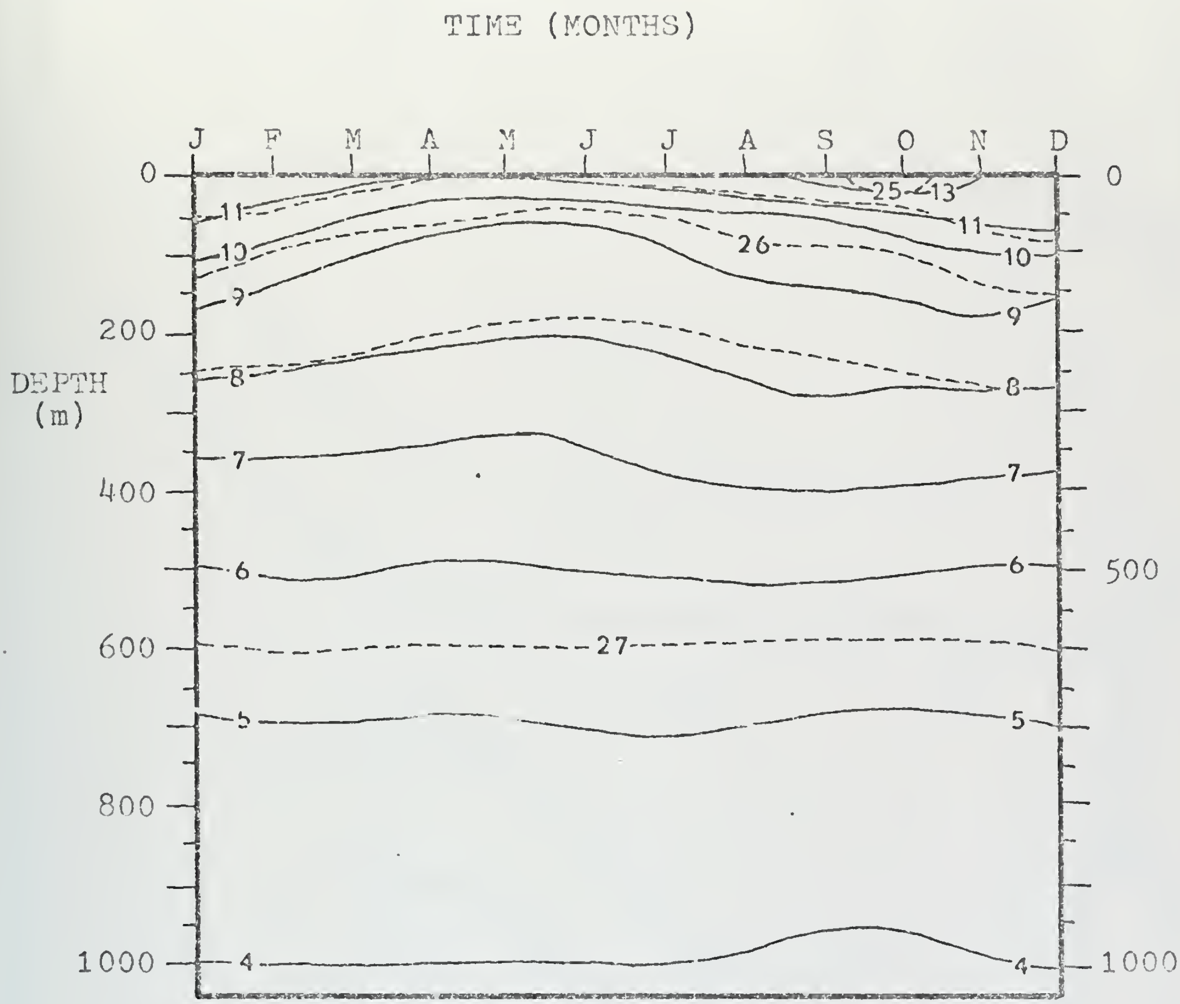
NOTE: The intensity of flow in the Bay (I) is based on contour spacing and is shown by a solid line. The dashed line denotes the mean offshore flow.

Figure 31. Intensities of Mean Flow in the Bay and Offshore.



NOTE: The dashed lines denote mid-values of mean density.

Figure 32. The Annual Mean Density Cycles at Selected Blocks.



NOTE: The non-labeled dashed lines denote mid-values of mean density.

Figure 33. The Annual Mean Temperature versus Density Cycles at Block 1[illegible].

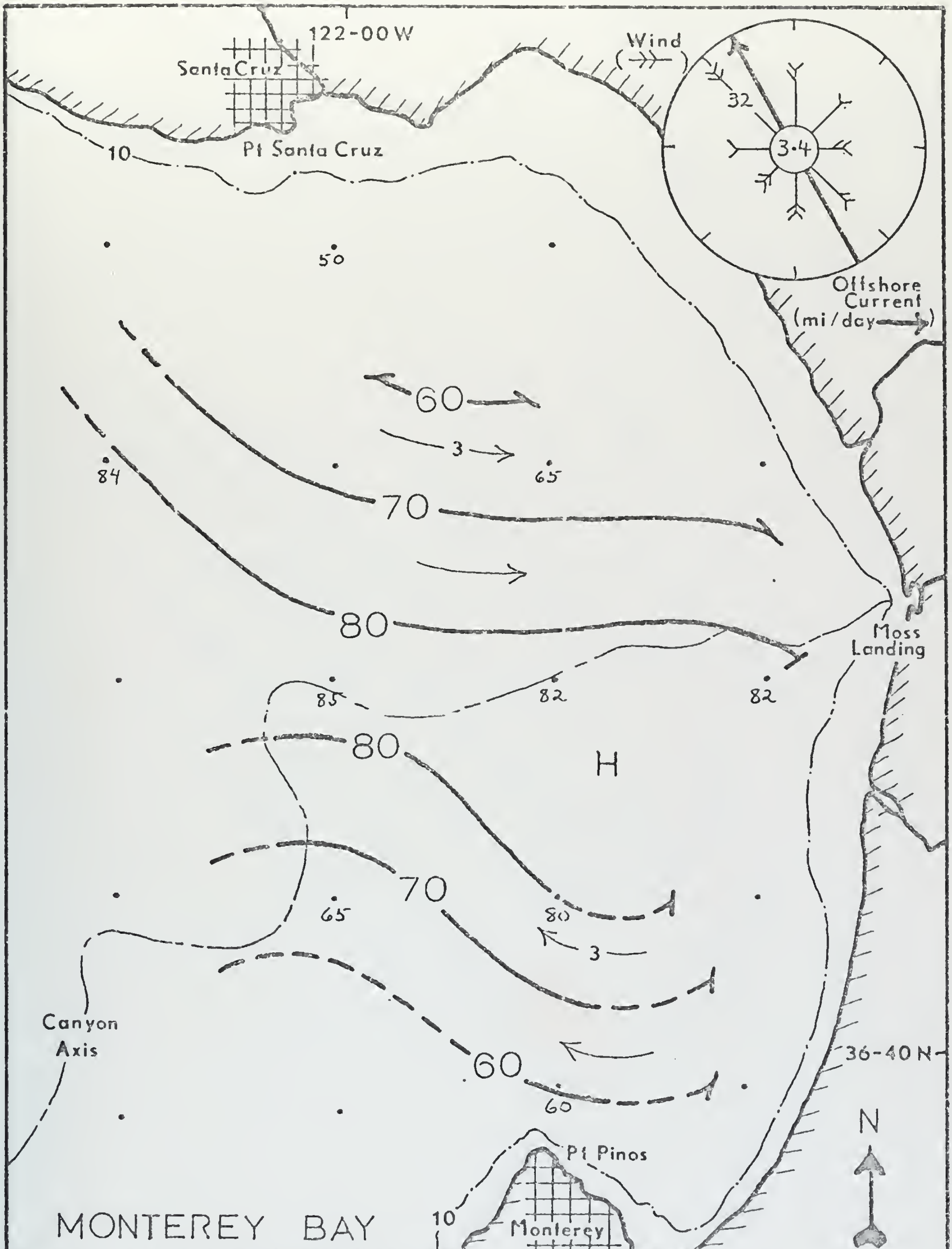


Figure 34. The Topography of the 11°C Mean Isothermal Surface for January.

0 1 2 3 4 5
Scale In Miles
Soundings In Fathoms

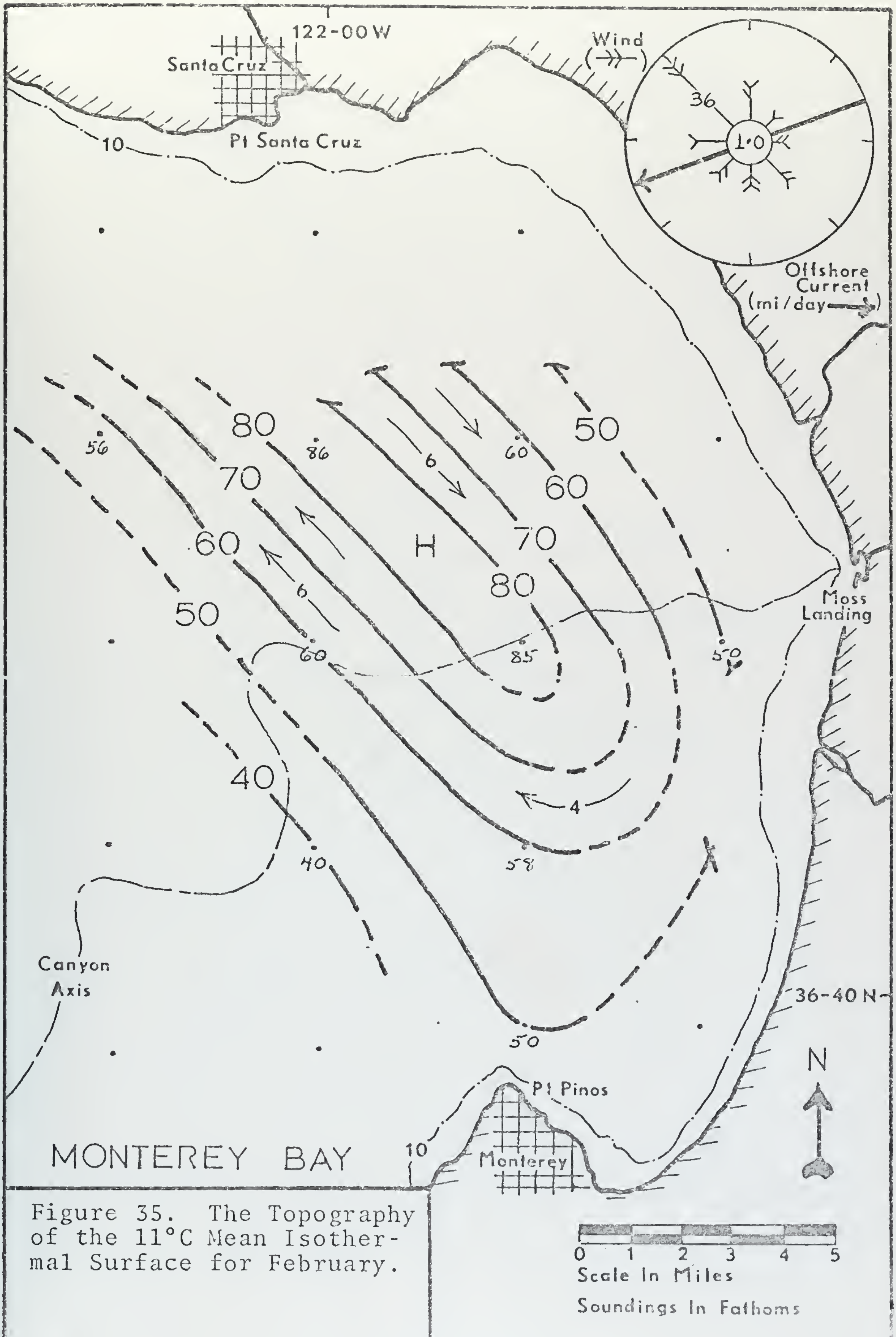


Figure 35. The Topography of the 11°C Mean Isothermal Surface for February.

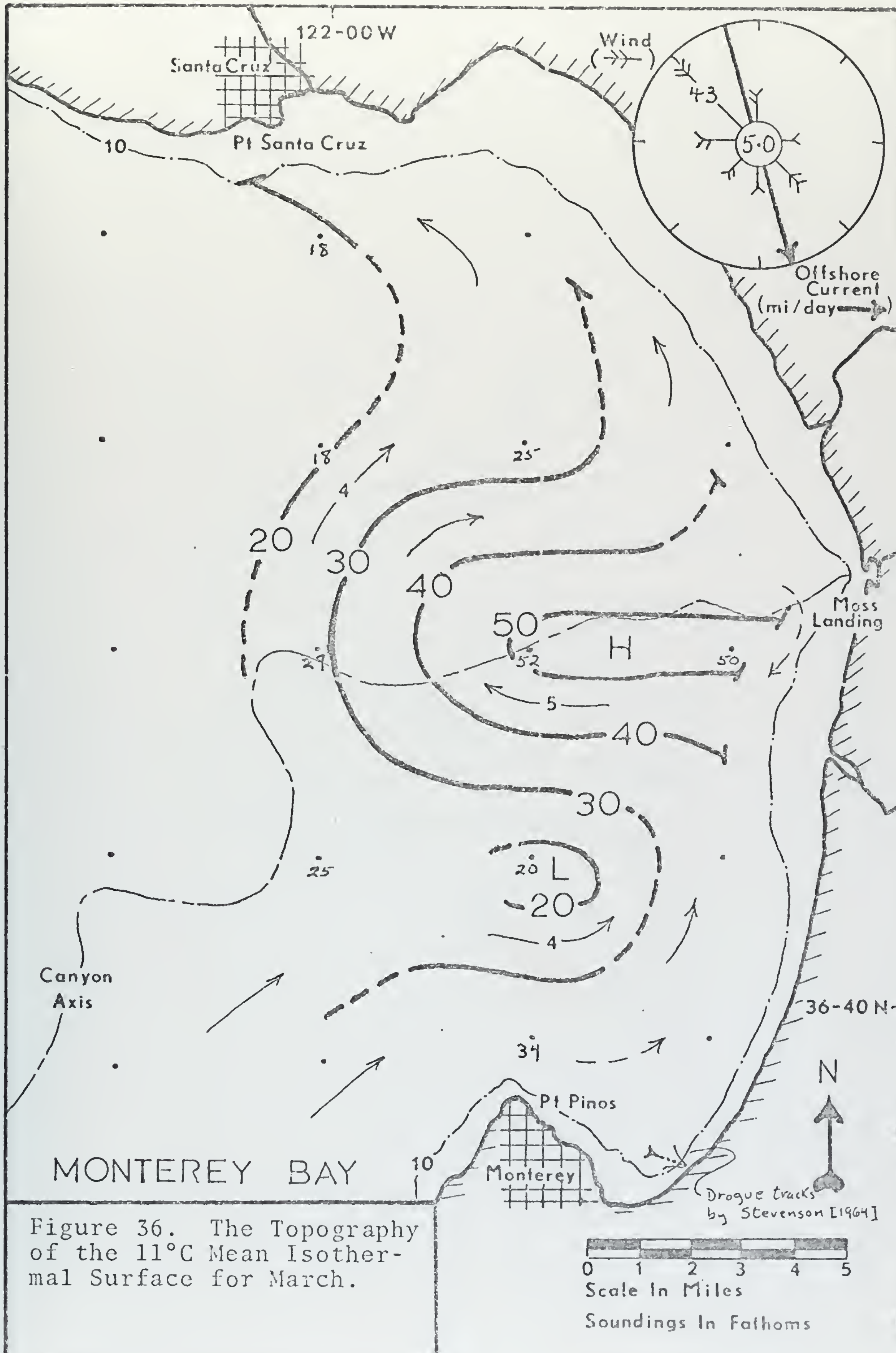


Figure 36. The Topography of the 11°C Mean Isothermal Surface for March.

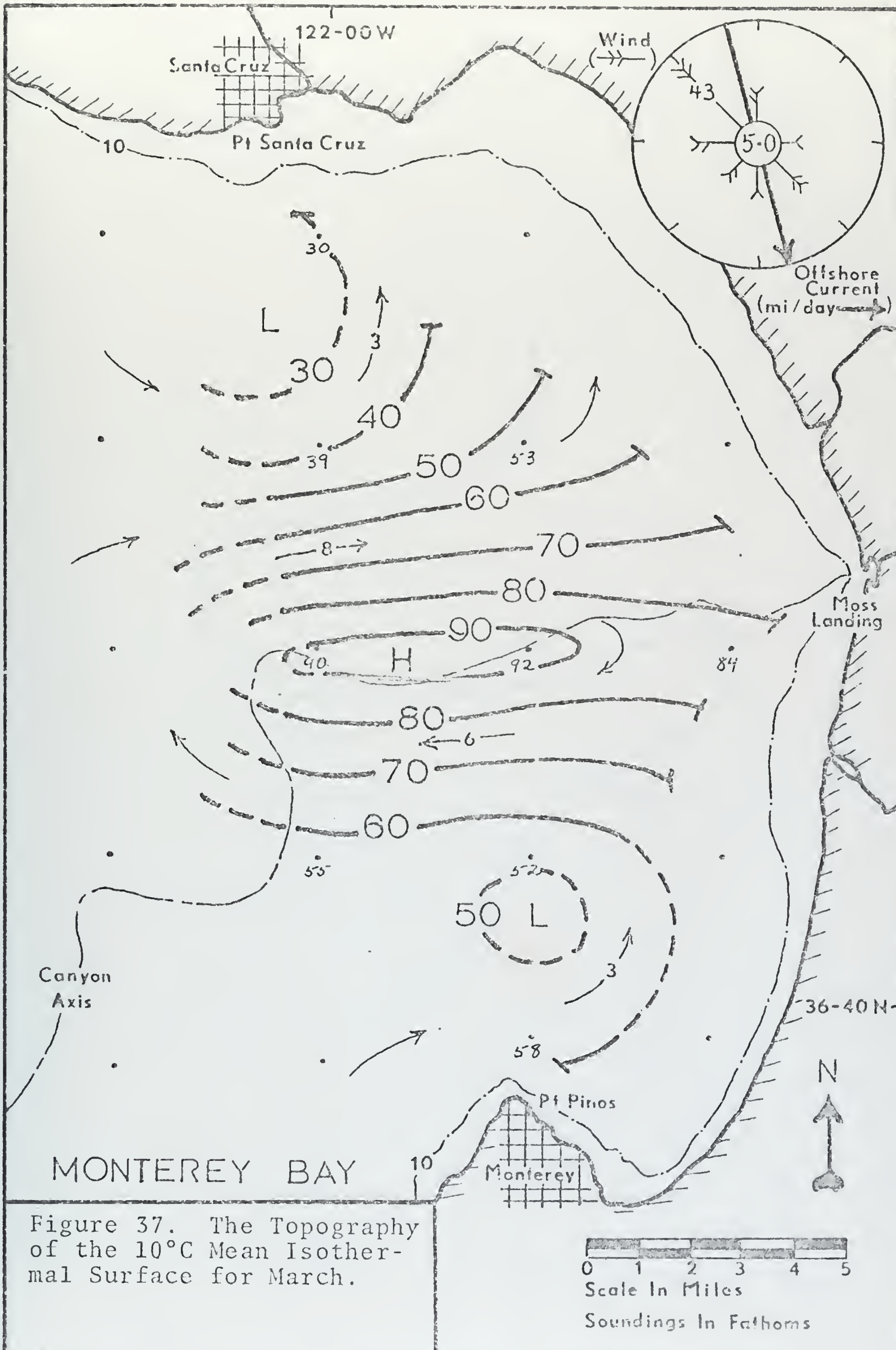


Figure 37. The Topography of the 10°C Mean Isothermal Surface for March.

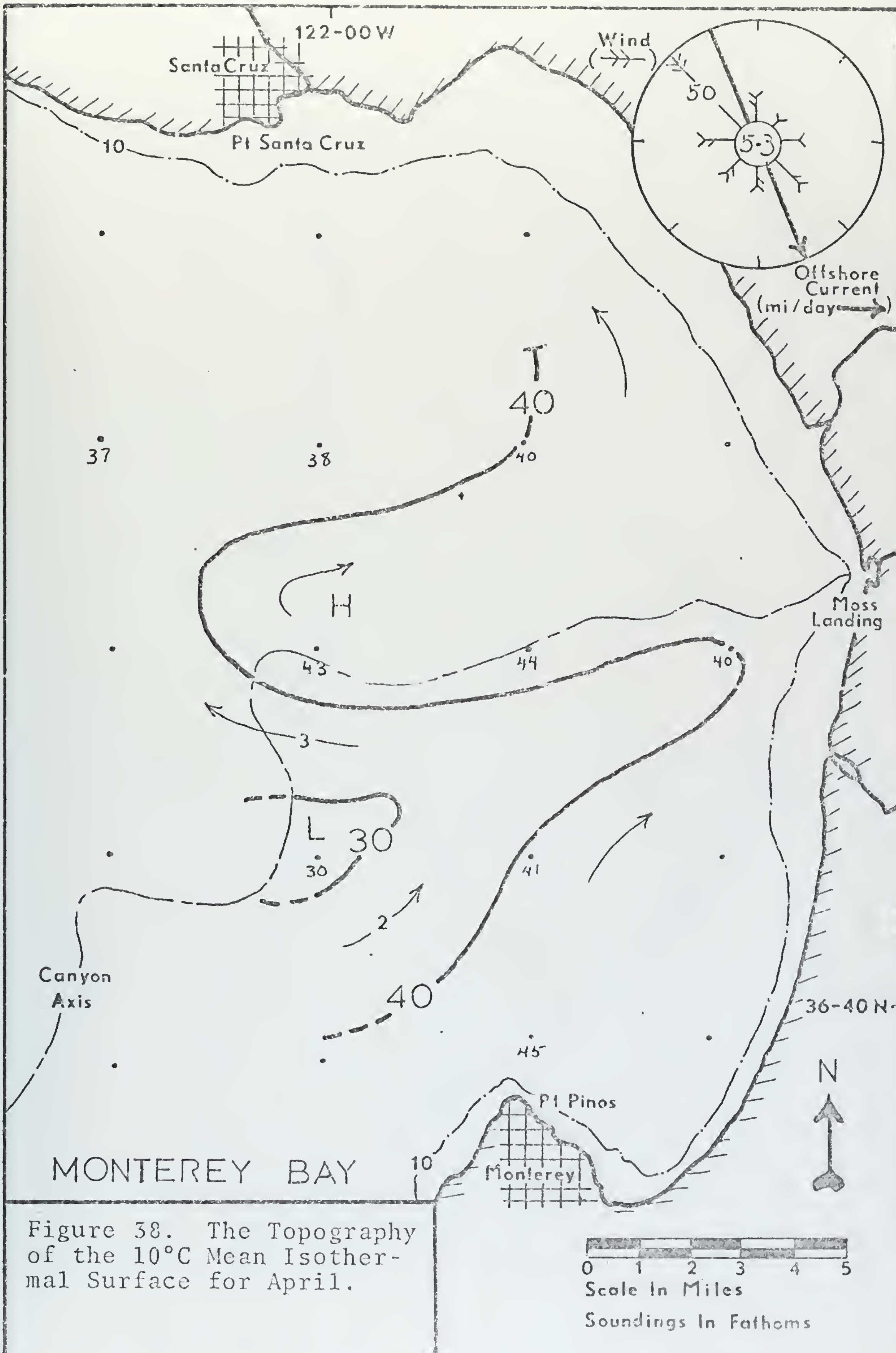


Figure 38. The Topography of the 10°C Mean Isothermal Surface for April.

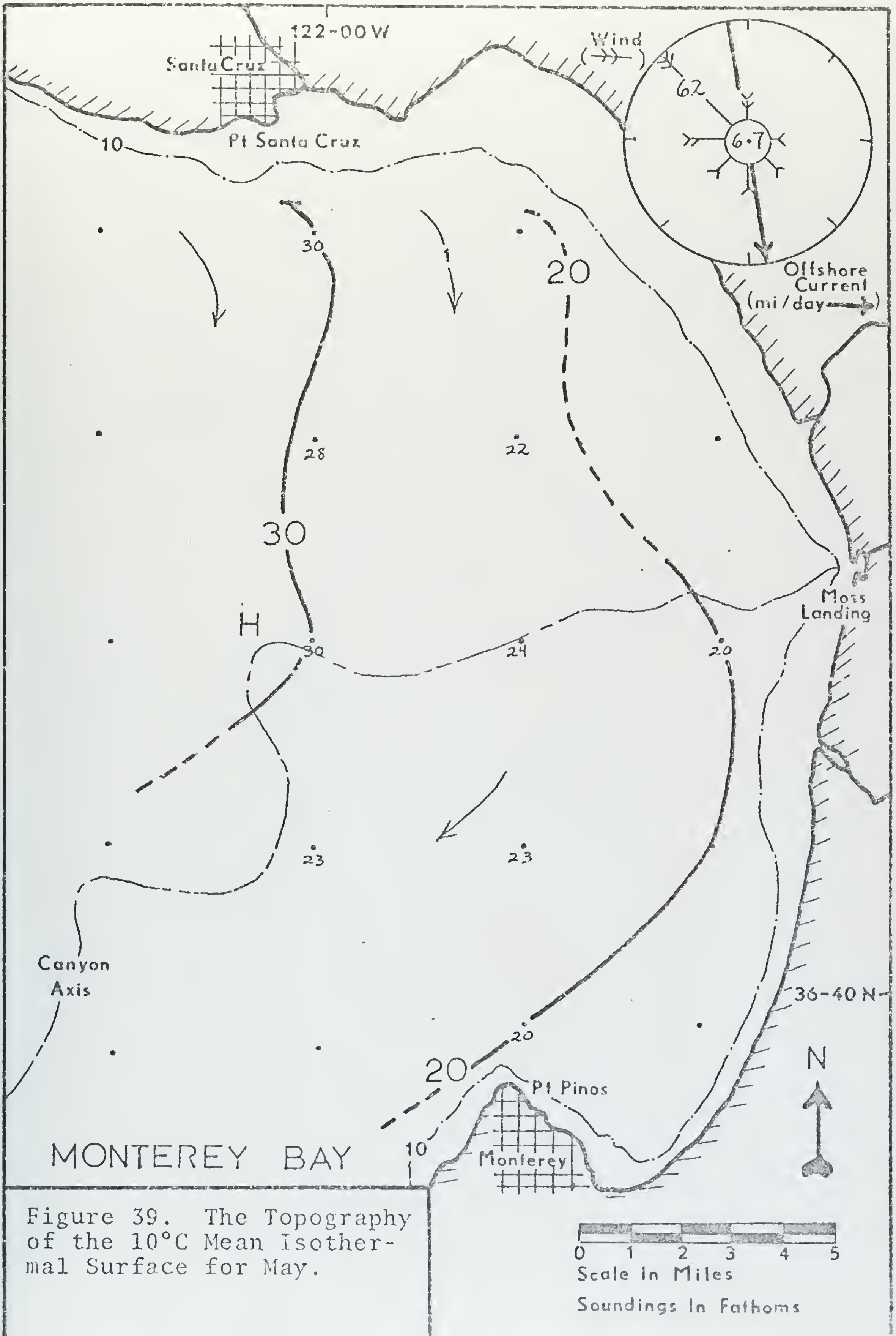


Figure 39. The Topography of the 10°C Mean Isothermal Surface for May.

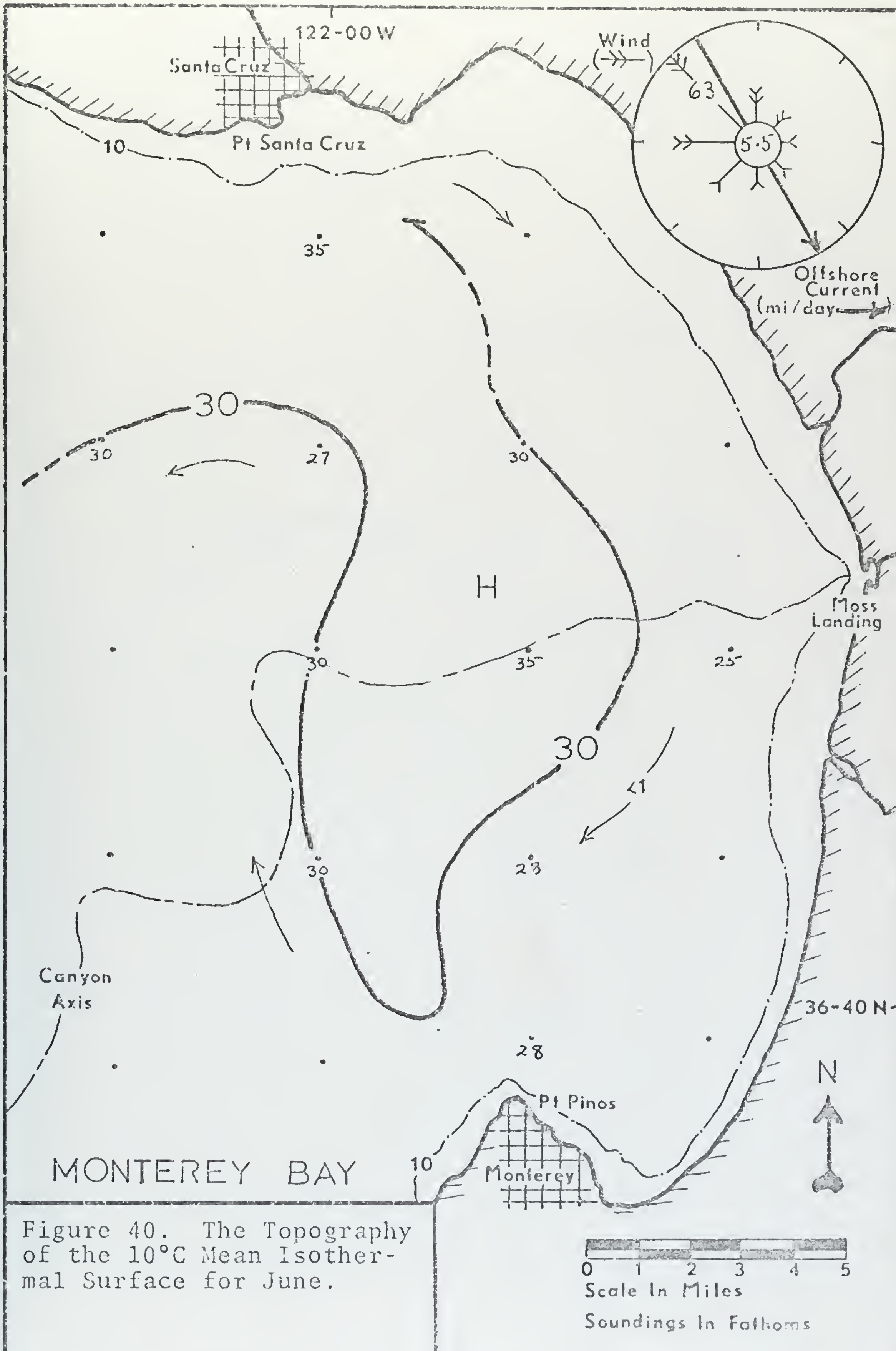


Figure 40. The Topography of the 10°C Mean Isothermal Surface for June.

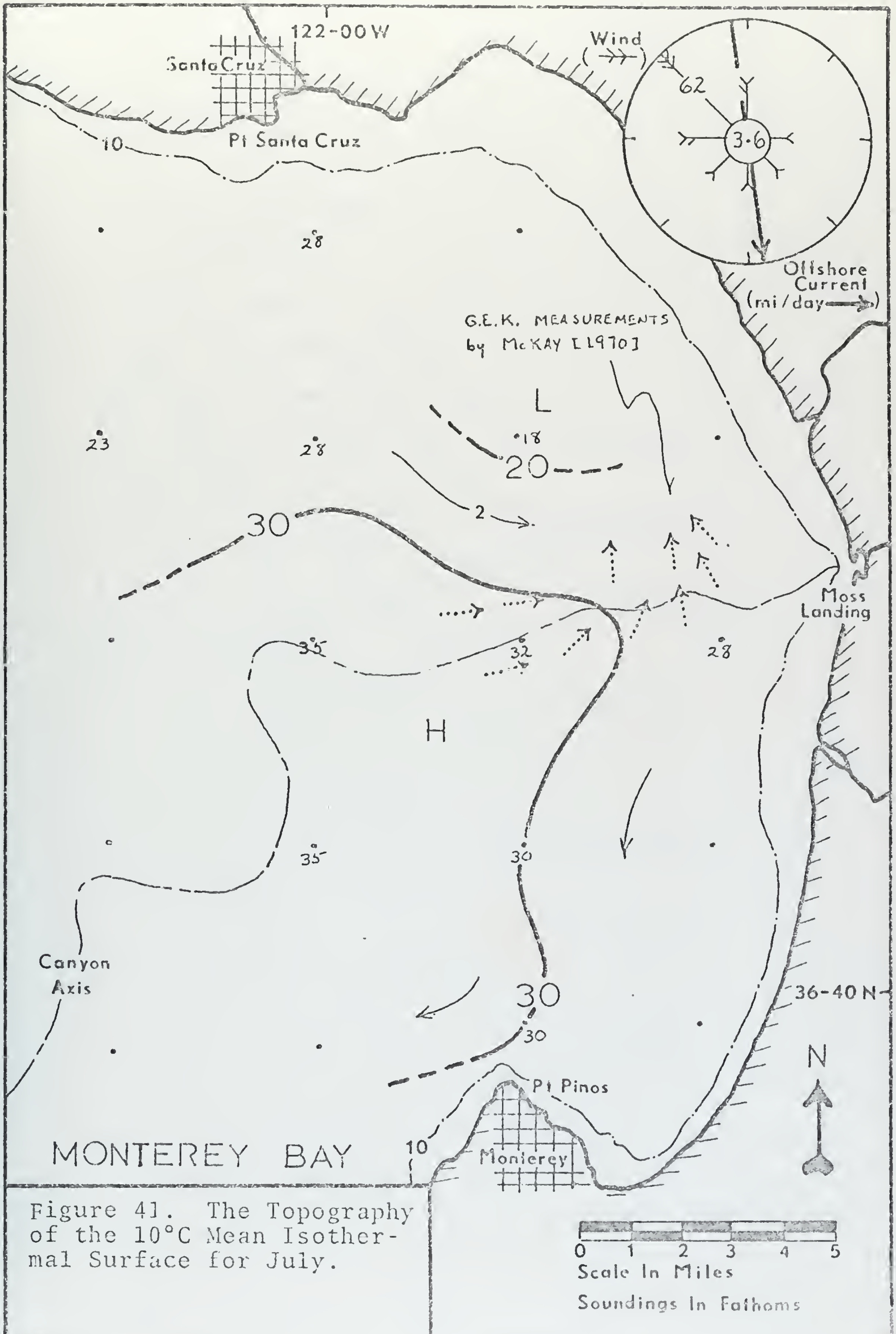


Figure 41. The Topography of the 10°C Mean Isothermal Surface for July.

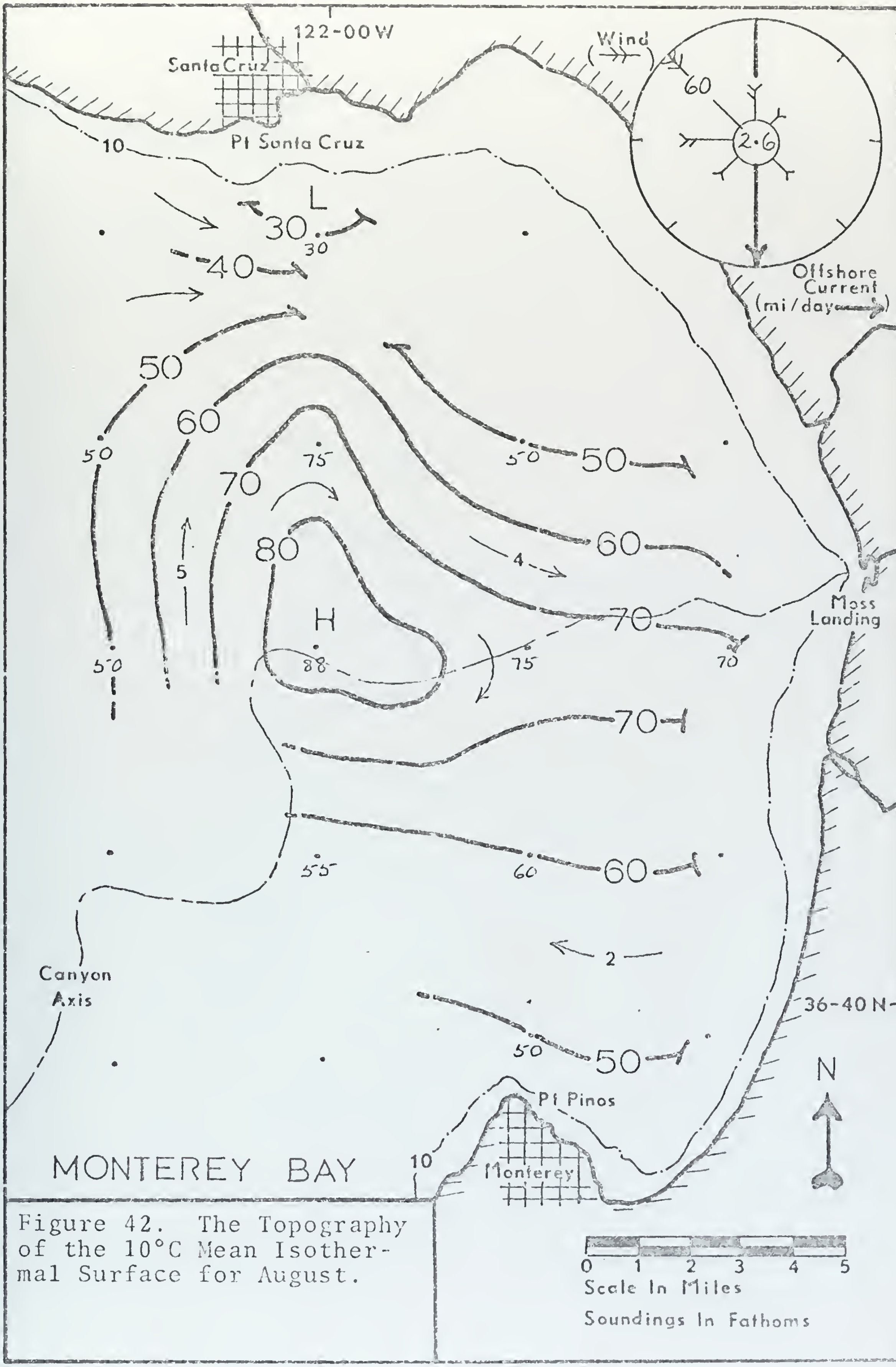


Figure 42. The Topography of the 10°C Mean Isothermal Surface for August.

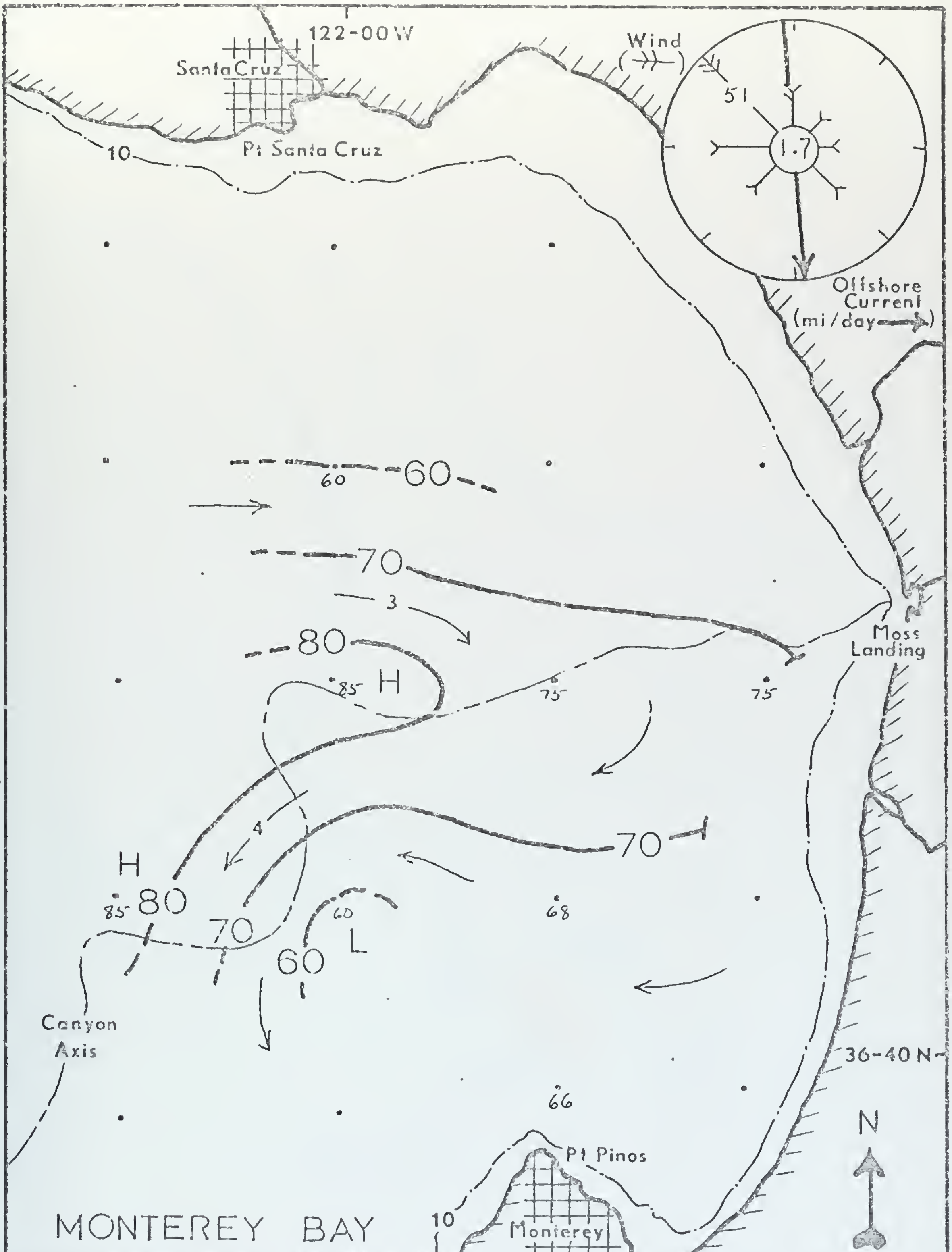


Figure 43. The Topography of the 10°C Mean Isothermal Surface for September.

0 1 2 3 4 5
Scale In Miles
Soundings In Fathoms

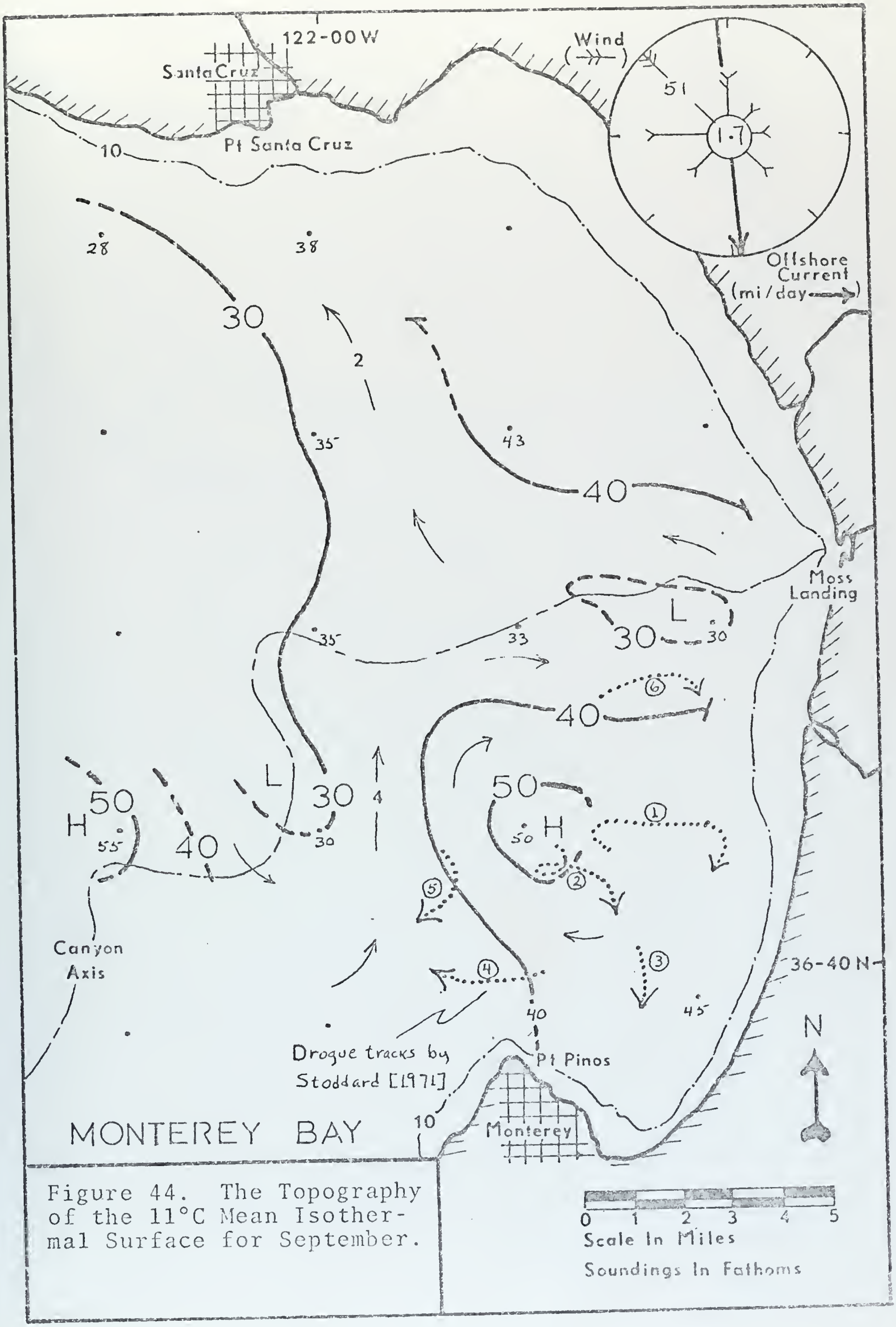


Figure 44. The Topography of the 11°C Mean Isothermal Surface for September.

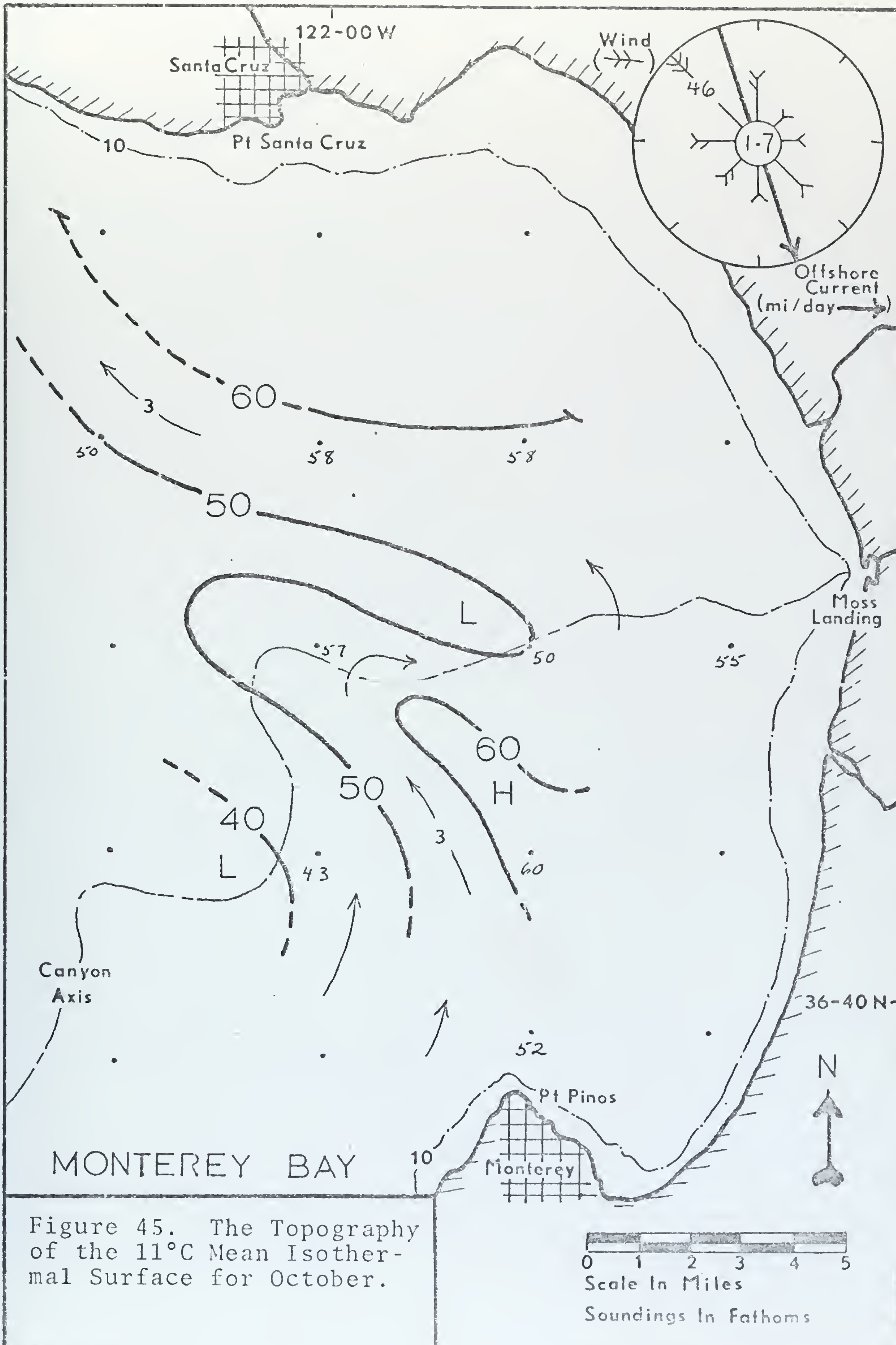


Figure 45. The Topography of the 11°C Mean Isothermal Surface for October.

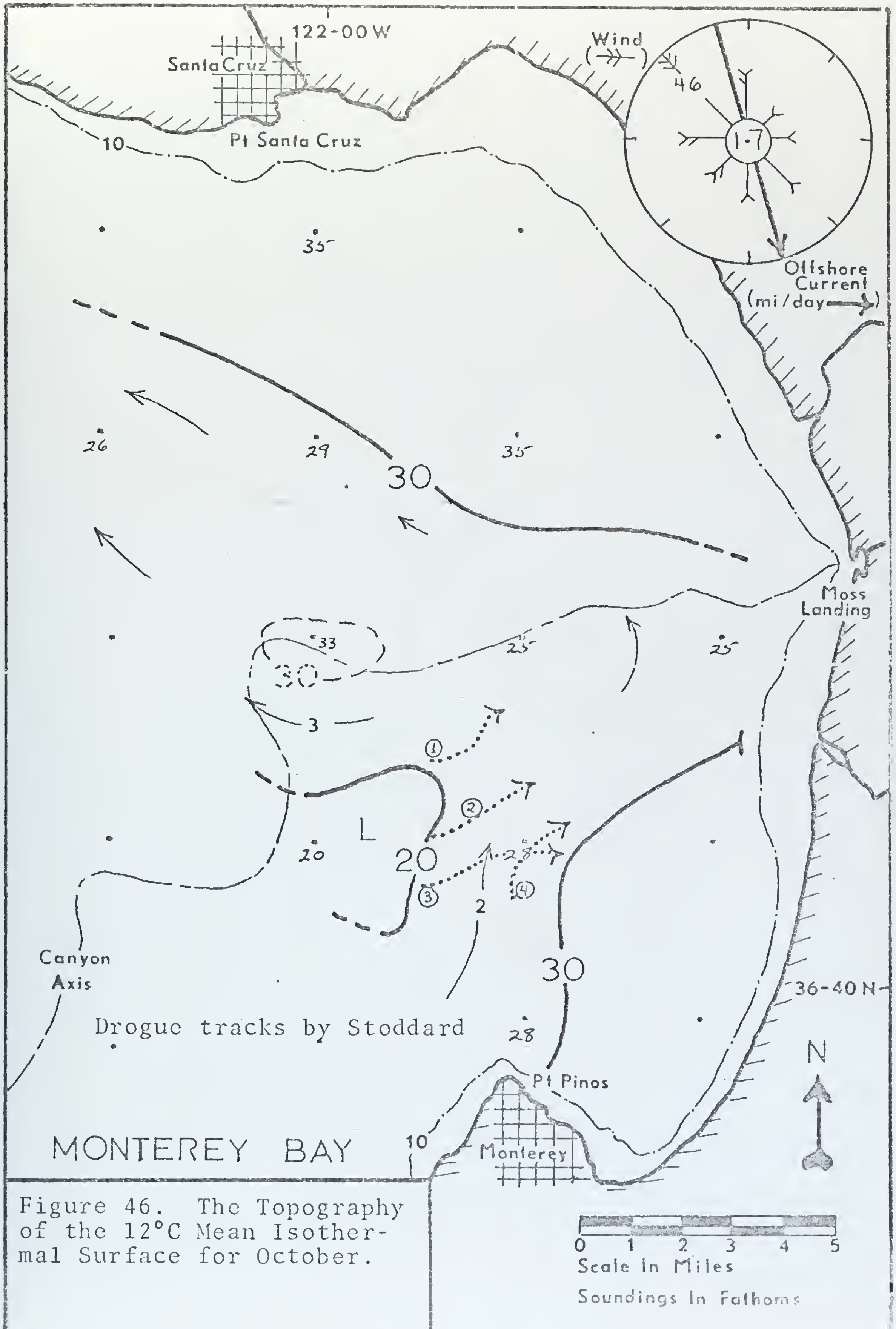


Figure 46. The Topography of the 12°C Mean Isothermal Surface for October.

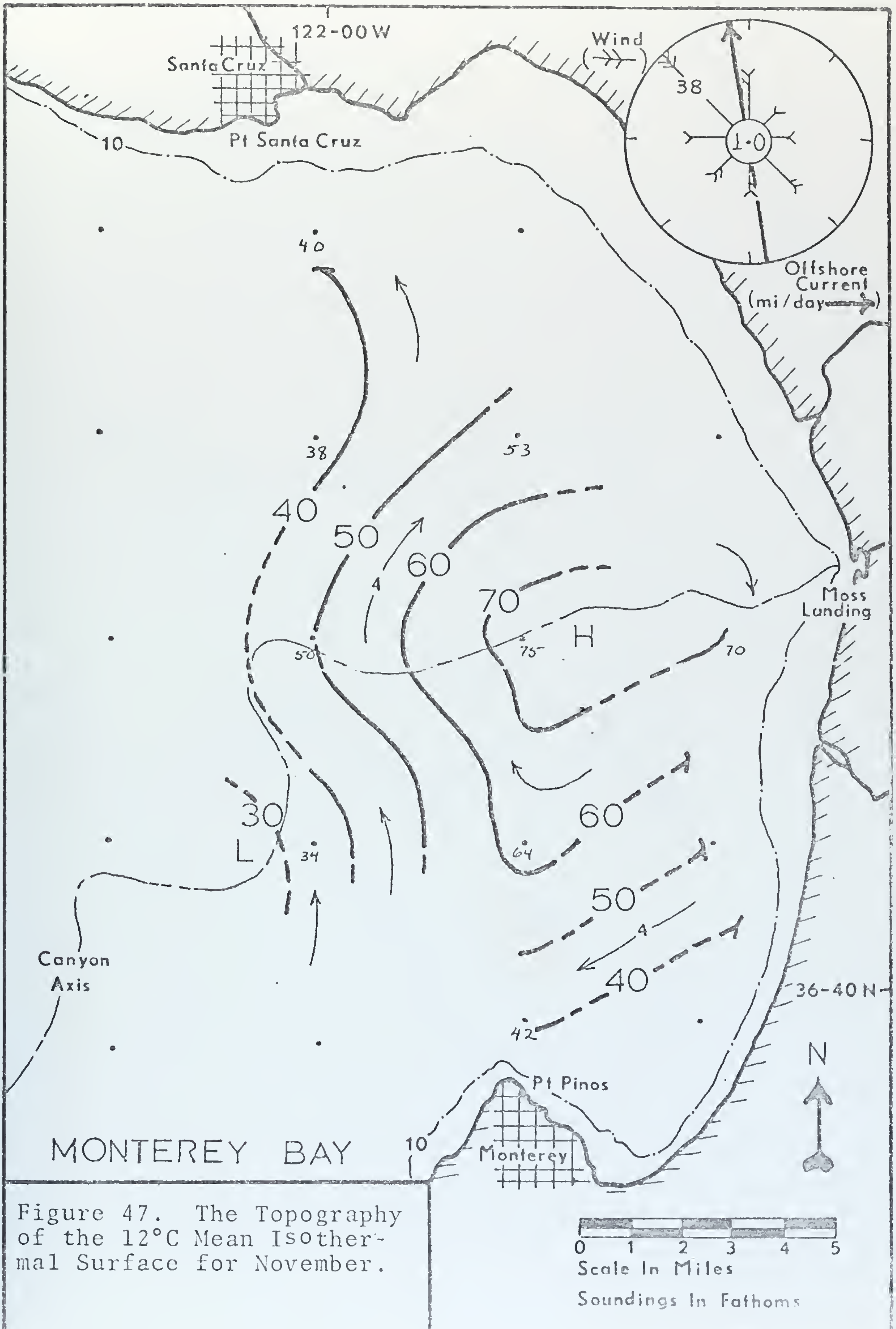


Figure 47. The Topography of the 12°C Mean Isothermal Surface for November.

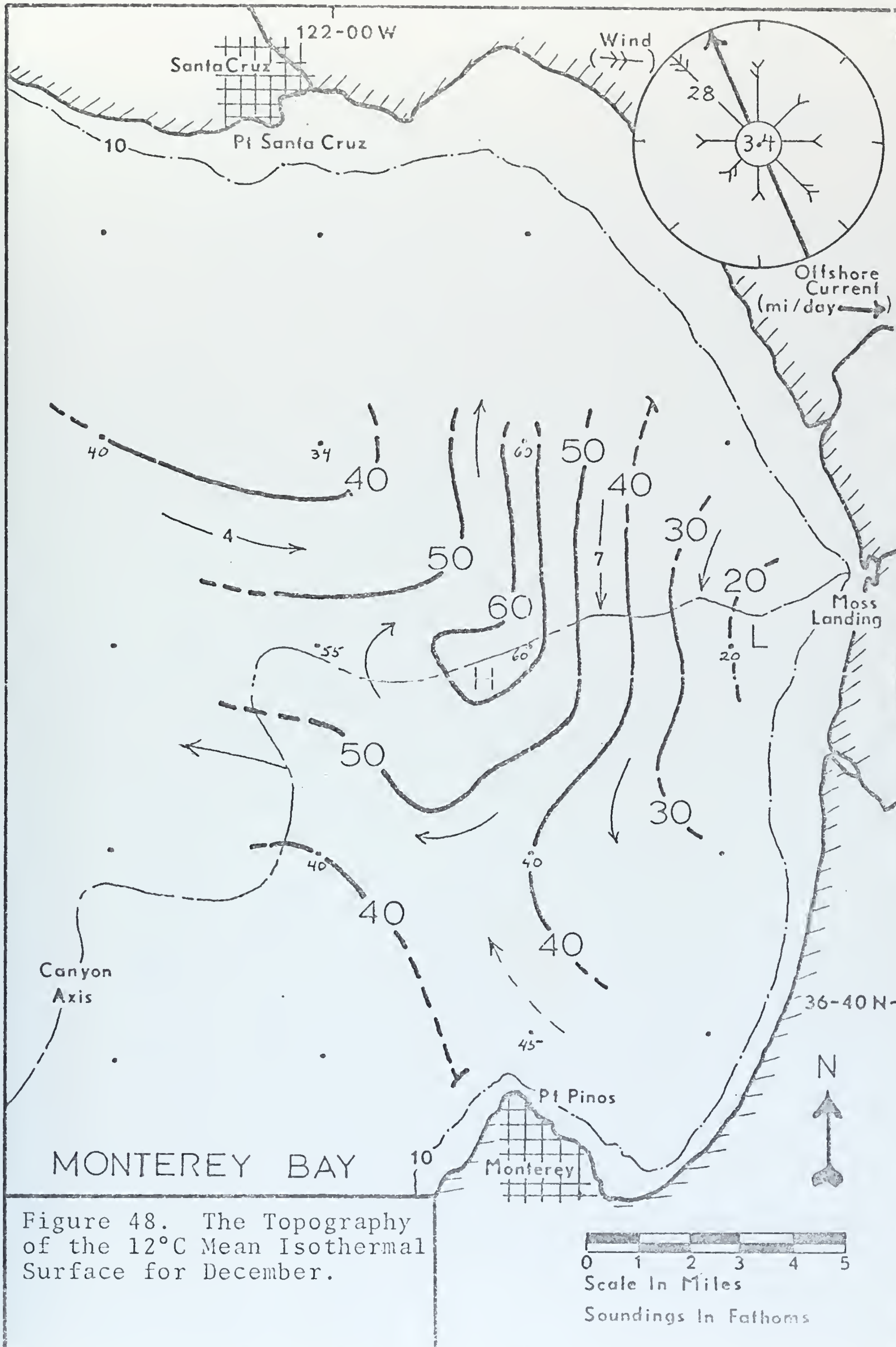
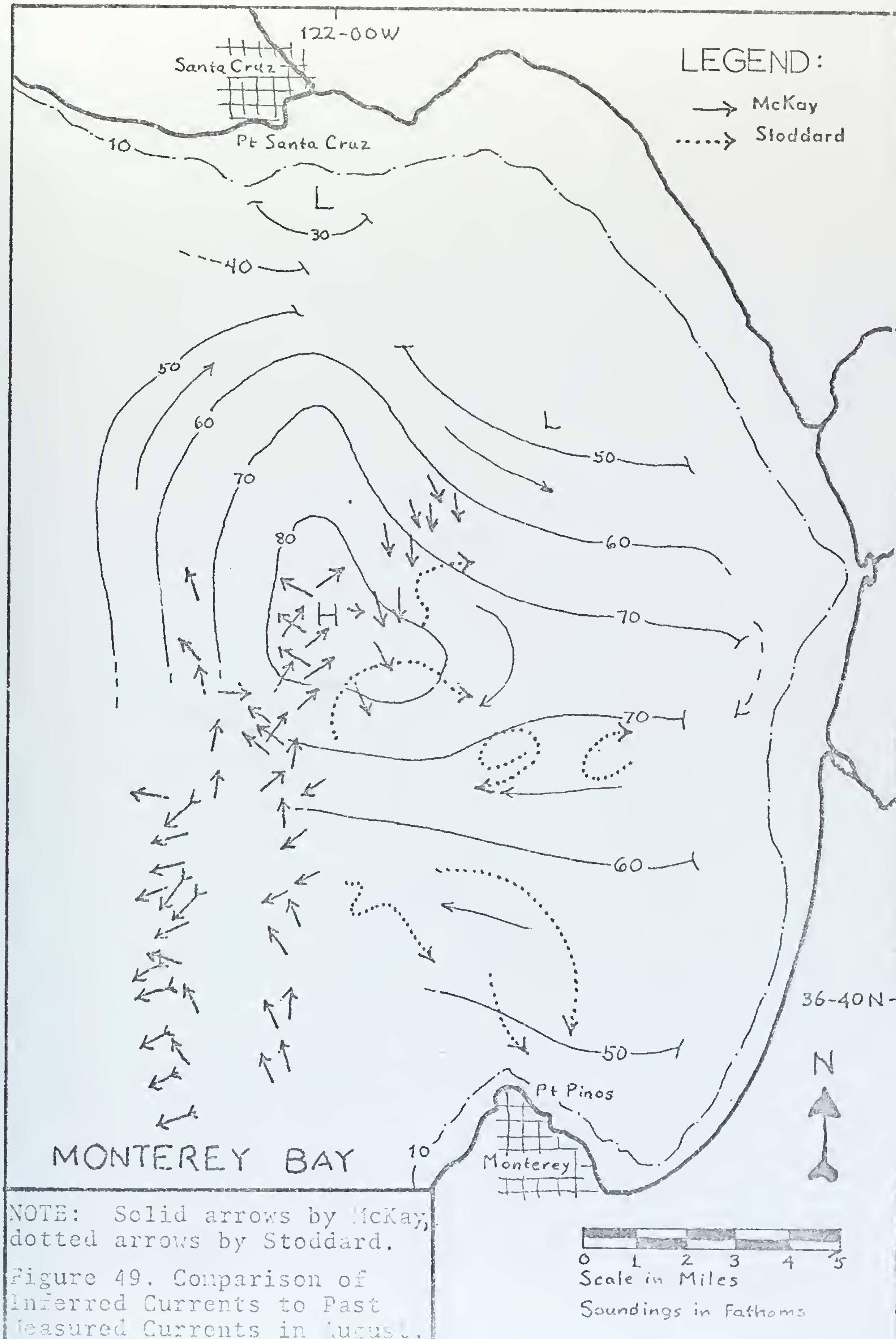


Figure 48. The Topography of the 12°C Mean Isothermal Surface for December.



NOTE: Solid arrows by McKay, dotted arrows by Stoddard.

Figure 49. Comparison of Inferred Currents to Past Measured Currents in August.

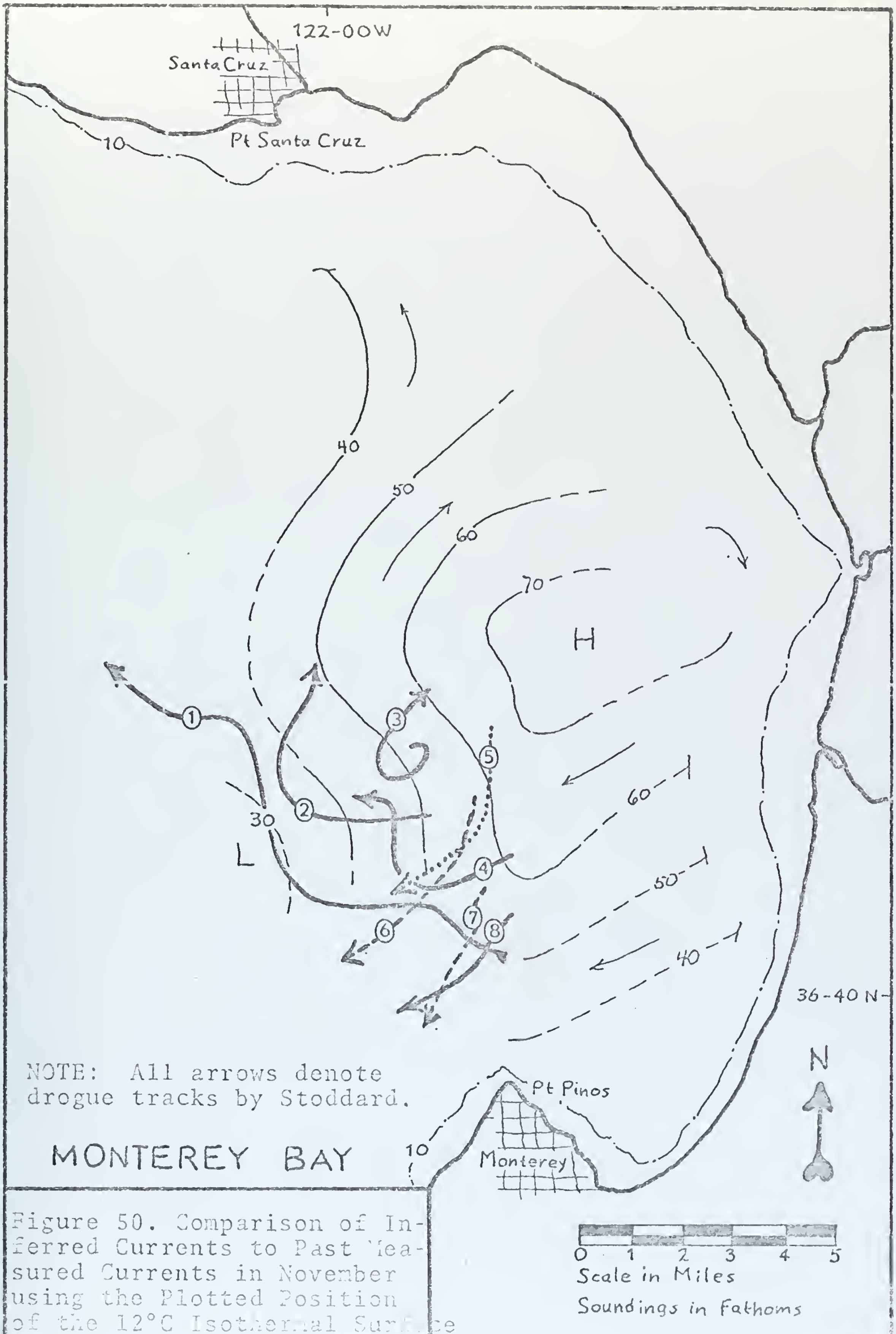


Figure 50. Comparison of Inferred Currents to Past Measured Currents in November using the Plotted Position of the 12°C Isothermal Surface

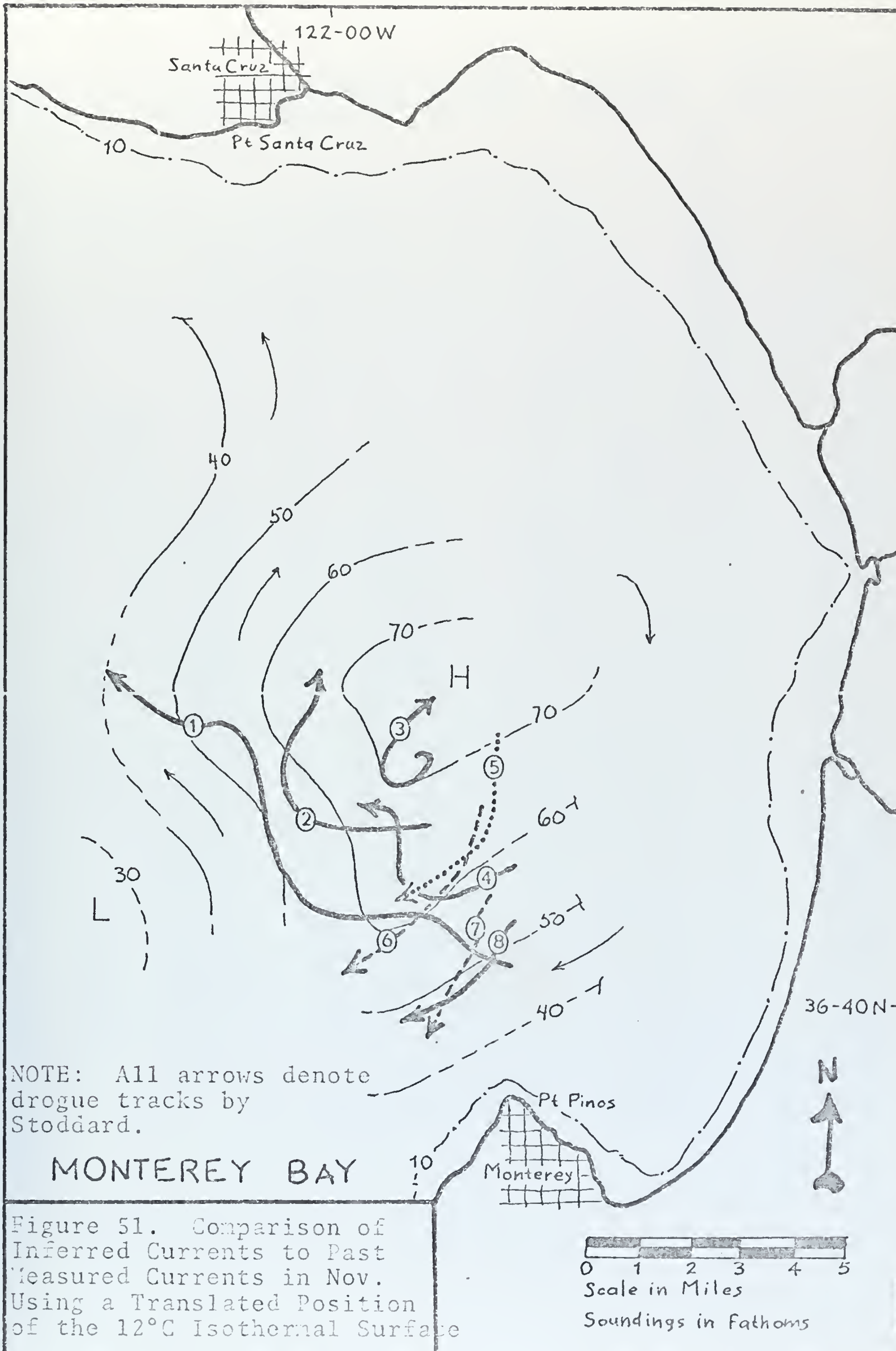


Figure 51. Comparison of Inferred Currents to Past Measured Currents in Nov. Using a Translated Position of the 12°C Isothermal Surface

```
//LAMM0001  JOB (0687,0446FT,DEG9),'L.L.LAMMERS'
//  EXEC  FORTCLGP,REGION.GO=100K
//FCRT.SYSIN DD *
C
C
C          PROGRAM  1       L.L.LAMMERS     11 JAN 1971
C
C
C      THIS PROG READS BOLIN DATA IN OBSERVED FORM AND:
C        (1) COMPUTES SIGMA-T
C        (2) INTERPOLATES TO STD VALUES(ALL DATA)
C        (3) PRINTS OUT DATA IN AUTHOR'S FORMAT
C        (4) PUNCHED CARDS OUT IN AUTHOR'S FORMAT
C      WHEN DEBUGGED, ALL DATA WILL BE WRITTEN ON THE MASTER TAPE
C
C
      DIMENSION DEP(20),TEM(20),SAL(20),SGT(20),STDEP(20),STEM(20),      01
     $STSAL(20),STSGT(20)                                                 02
      DATA IND/'NANS'/                                                    03
      DATA STDEP/0.,10.,15.,20.,30.,50.,75.,100.,125.,150.,200.,250.,     04
     $300.,400.,500.,600.,700.,800.,900.,1000./                           05
      DO 300 I=1,500                                                      06
      READ(5,500,END=1000,ERR=999) NDAY,NMO,NYEAR,NVAL                    07
C      NVAL=NR OF DATA CARDS FOR TITLE CARD
  500 FORMAT(3I2,1X,I2)                                                   08
C      NOW READ DATA CARDS
      DO 10 K=1,NVAL                                                      09
      READ(5,501) DEP(K),TEM(K),SAL(K)                                    010
  501 FORMAT(F9.0,F10.2,F10.2)                                            011
C      NOW CALCULATE SIGMA-T(SGT) FOR EACH OBSERVED DEPTH. ST,SO,CL,AT,
C      BT ARE VARIABLES USED IN THE CALCULATION
      ST=-(((TEM(K)-3.98)**2)/503.57)*((TEM(K)+283.)/(TEM(K)+67.26))      012
      CL=(SAL(K)-.030)/1.805                                              013
      SO=-.069+1.4708*CL-.00157*CL**2+3.98E-5*CL**3                       014
      AT=TEM(K)*(4.7867-.098185*TEM(K)+.0010843*TEM(K)**2)*1.E-3          015
      BT=TEM(K)*(18.030-.8164*TEM(K)+.01667*TEM(K)**2)*1.E-6              016
      SGT(K)=ST+(SO+.1324)*(1.-AT+BT*(SO-.1324))                          017
   10 CONTINUE                                                            018
C      NOW INTERPOLATE FOCR STD DEPTHS THE VALUES  STDEP,STEM,STSAL,STSGT
C       JJ COUNTS STD DEPTHS/TEMPS,KK COUNTS OBSERVED DEPTHS/TEMPS
      JJ=0                                                                019
      KK=0                                                                020
   50 JJ=JJ+1                                                             021
   60 KK=KK+1                                                             022
C      CHECK FOR LAST DATA CARD(ON THIS STATION)
      IF(KK.GT.NVAL) GO TO 200                                            023
C      1ST OBS  DEPTH MUST = 0 MET = 1ST STD DEPTH(JJ=1)
      IF(JJ.EQ.1) GO TO 90                                                024
```

```
C         WE ARRIVE AT 70 READY TO INTERPOLATE WITH FORMULA:
C           X=D-((B-R)(D-C)/(B-A)), WHERE:
C              X=STEM,STSAL,STSGT(JJ)        R=STDEP(JJ)
C              A=DEP(KK-1)                   C=TEM,SAL,SGT(KK-1)
C              B=DEP(KK)                     D=TEM,SAL,SGT(KK)
C         LET  C1=B-R  AND  C2=B-A
   70  C1=DEP(KK)-STDEP(JJ)
       C2=DEP(KK)-DEP(KK-1)
C       INTERPOLATE FOR TEMPERATURE
       STEM(JJ)=TEM(KK)-(C1*(TEM(KK)-TEM(KK-1)))/C2
C       INTERPCLATE FOR SALINITY
       STSAL(JJ)=SAL(KK)-(C1*(SAL(KK)-SAL(KK-1)))/C2
C       INTERPOLATE FSOR SIGMA-T
       STSGT(JJ)=SGT(KK)-(C1*(SGT(KK)-SGT(KK-1)))/C2
C       SET KK BACK TO KK-1  AND PROCESS FOR NEXT STD DPTH
       KK=KK-1
       GC TO 50
   90  IF(STDEP(JJ).EQ.DEP(KK)) GO TO 100
C       IF WE ARRIVE HERE, 1ST OBS DEPTH.NE.0.0,STOPPING
       WRITE(6,502) I
  502  FCRMAT(//1X,'FIRST OBS DEPTH.NE.0.0,STOPPING.NANS STA NR=',I6)
       STOP
  100  STEM(JJ)=TEM(KK)
       STSAL(JJ)=SAL(KK)
       STSGT(JJ)=SGT(KK)
       GC TO 50
C       WE GET TO 200 WITH INTR. COMPLETED. NOW WRITE NEW TITLE CARD
  200  JJ=JJ-1
C       JJ DEFINES NR OF STD VALUES INTERPOLATED
       WRITE(6,503) JJ,IND,NDAY,NMO,NYEAR
  503  FORMAT(//1X,I2,1X,A4,1X,3(I2,1X),6X,'36 42.2',2X,'122 02.0',24X,
      $'BOLIN,R.(51-55)')
       WRITE(7,510) JJ,IND,NDAY,NMO,NYEAR
  510  FORMAT(I2,1X,A4,1X,3(I2,1X),6X,'36 42.2',2X,'122 02.0',24X,
      $'BOLIN,R.(51-55)')
C       NOW WRITE JJ DATA CARDS
       DO 250 MM=1,JJ
       WRITE(6,504) STDEP(MM),STEM(MM),STSAL(MM),STSGT(MM)
  504  FCRMAT(1X,F5.0,1X,3(F5.2,1X))
       WRITE(7,511) STDEP(MM),STEM(MM),STSAL(MM),STSGT(MM)
  511  FORMAT(F5.0,1X,3(F5.2,1X))
  250  CCNTINUE
C       THIS COMPLETES ONE NANS STATION, NOW START AGAIN
  300  CONTINUE
C       SHOULD NOT ARRIVE HERE(MORE THAN 500 NANS STATIONS)
```

```
      WRITE(6,507)                                                      058
  507 FORMAT(//1X,'TOTAL NANS STA EXCEEDED 500,STOPPING')               059
      STOP                                                              060
  999 WRITE(6,508) I                                                    061
  508 FORMAT(//1X,'READ ERROR,STOPPING: NANS STA NR=',I6)               062
      STOP                                                              062A
 1000 I=I-1                                                             063
      WRITE(6,509) I                                                    064
  509 FORMAT(//1X,'END OF DATA:',10X,I4,3X,'NANS STA PROCESSED')        065
      STOP                                                              066
      END                                                               067
//GO.FT06F001 DD SPACE=(CYL,(3,1))
//GO.FT07F001 DD SPACE=(CYL,(3,1))
//GO.SYSIN DD *
C
C
C*****************************************************************************
C
C
//LAMM0002  JOB (C687,0446FT,0EG9),'L.L.LAMMERS'
//  EXEC  FORTCLGP,REGION.GO=100K,TIME.GO=30
//FORT.SYSIN  DD  *
C
C
C            PROGRAM  2     L.L.LAMMERS     15 NOV 1970
C
C
C        MODIFIES TO INCLUDE PUNCHING OUT OF DATA CARDS
C     THIS PROGRAM READS TAPE NPS264 TO DETERMINE:
C        1.  IF ANY XBT DATA EXISTS FOR MTRY BAY
C        2.  TO COUNT DATA CARDS THAT FOLLOW EACH TITLE CARD AND PRINT
C     NR OF DATA CARDS FOLLOWING EACH TITLE CARD.
C        3.  THEN PRINT ALL TITLE AND DATA CARDS FOUND FOR MTRY BAY IN
C     THE FORMAT:
C          A. IF MTRY BAY,WRITE NEW TITLE CARD(NR DATA CARDS INCL)
C          B. IF MTRY BAY,WRITE DATA CARDS
C
C
      DIMENSION KK(26),LL(26,50)                                        001
      DATA IBT/'XBT '/,KN/'N   '/,KW/'W   '/,LDS/'36  '/,LDL/'37  '/,   002
     $LMS/'30  '/,LML/'10  '/,LODS/'121 '/,LODL/'122 '/,LOML/'30  '/    002A
      REWIND 2                                                          002B
      IEND=0                                                            003
C     READ FIRST TITLE CARD
      READ(2,1) KK                                                      004
    1 FORMAT(10A4,2A2,A1,A2,A1,A4,A3,A1,A2,A1,4A4,I3,A2)                005
C     NOW START OUTER LOOP TO READ 25000 XBT STATIONS
      DO 20 M=1,25000                                                   006
```

```
C     AND 121-30 TC 122-20W).
      IF(KK(15).NE.KN) GO TO 70
      IF(KK(20).NE.KW) GO TO 70
      IF(KK(12).EQ.LDS) GO TO 9
      IF(KK(12).EQ.LDL) GO TO 40
      GC TO 70
    9 IF(KK(14).GE.LMS) GO TO 19
      GC TO 70
   19 IF(KK(17).EQ.LODS) GO TO 69
      IF(KK(17).EQ.LODL) GO TO 30
      GC TO 70
   30 IF(KK(19).LE.LOML) GO TO 69
      GO TO 70
   40 IF(KK(14).LE.LML) GO TO 50
      GC TO 70
   50 IF(KK(17).EQ.LODS) GO TO 69
      IF(KK(17).EQ.LODL) GO TO 60
      GC TO 70
   60 IF(KK(19).LE.LOML) GO TO 69
      GO TO 70
C     WE GET TO 69 IFF TITLE CARD IS FOR MTRY BAY. NOW TURN ON IWR.
   69 IWR=1
   70 CONTINUE
C     NOW READ AND COUNT DATA CARDS UNTIL WE FIND ANOTHER TITLE CARD.
C     J COUNTS DATA CARDS FOR US.
    3 DO 10 J=1,50
    5 READ(2,1,END=21,ERR=8) (LL(I,J),I=1,26)
C     TEST FOR A TITLE CARD
      IF(LL(1,J).NE.IBT) GO TO 10
C     IF WE GET HERE WE HAVE A TITLE CARD
      GC TO 11
    8 WRITE(6,200) M,J
  200 FORMAT('OREAD ERROR',10X,'M=',I6,10X,'J=',I5)
      GO TO 5
   10 CCNTINUE
C     WE SHOULD NEVER GET TO HERE. IF WE DO , J.GT.50 DATA CARDS
      GO TO 3
   21 IEND=1
   11 J=J-1
      IF(IWR.EQ.0) GO TO 44
      KK(25)=J
C     NOW WRITE NEW TITLE CARD WITH 'J' DATA CARDS WRITTEN ON IT
      WRITE(7,2) KK
C     NOW WRITE J DATA CARDS
```

```
      WRITE(7,43) ((LL(MM,NN),MM=1,24),NN=1,J)                          031
   43 FORMAT(10A4,2A2,A1,A2,A1,A4,A3,A1,A2,A1,4A4)                      031AA
C     WRITE(3,1) KK    "WHEN WE TRANSFER TO A TAPE"
C     WRITE(3,1) ((LL(MM,NN),MM=1,26),NN=1,J)   "WHEN TRANSF. TO TAPE"
C
C     WE GO TO 44 IF NOT MTRY BAY, TO PICK UP LAST TITLE CARD READ IN
C
C   CHECK IEND SWITCH.IF IT IS ON(IEND=1) WE HAVE RAN OUT OF CARDS,STOP
   44 IF(IEND.NE.0) GO TO 1000                                          031A
      J=J+1                                                             032
      DO 4 L=1,26                                                       033
    4 KK(L)=LL(L,J)                                                     034
   20 CONTINUE                                                          036
 1000 WRITE(6,500) M                                                    036A
  500 FORMAT('0LAST XBT STATION NR IS',3X,I6)                           036B
      STOP                                                              036C
      END                                                               037
//GO.FTC2F001  DD  UNIT=2400,VOL=SER=NPS264,LABEL=(,SL),DSNAME=MAGRUD,
//         DISP=OLD,DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
C
C
C***********************************************************************
C
C
//LAMM0003  JOB (0687,0446FT,OEG9),'L.L.LAMMERS'
//  EXEC  FORTCLGP,REGION.GO=100K
//FORT.SYSIN DD *
C
C
C            PROGRAM  3     L.L.LAMMERS     18 JAN 1971
C
C
C
C       *****  INCLUDES PUNCHED OUTPUT IN AUTHOR'S FORMAT  *****
C
C       1. READS CALCOFI(HOPKINS) DATA AT 0 AND 15 METERS,CONSISTING OF:
C          A. TEMP
C          B. SALINITY
C          C. SIGMA-T
C       ALL VALUES ARE COMPUTED MONTHLY AVERAGES AND WILL HAVE A WEIGHT
C       OF 4 TO 1 IN FINAL PROGRAM(DATA TAKEN 4 TIMES/MONTH)
C       *** NOTE THE USE OF THE WEIGHTING INDICATOR(999) TO EARMARK DATA
C       2. INTERPOLATES DATA TO STD DEPTHS OF 0,10, AND 15 METERS
C       3. WRITES OUT DATA IN AUTHOR'S FORMAT
C       4. WHEN DEBUGGED, PUNCHED CARD OUTPUT WILL FOLLOW
C
C
      DIMENSION DEP(2),TEM(2),SAL(2),SGT(2),STDEP(3),STEM(3),STSAL(3),    1
     $STSGT(3),LATMI(6),LON(6),LONMI(6)                                   2
```

```
      DATA LONMI/'53.5','57.0','01.0','00.0','59.0','55.0'/
C      "I"= A DATA SET(ONE MONTH'S AVGS; 6 STATIONS)
      DO 200 I=1,500
C      READ A TITLE CARD
      READ(5,101,END=500,ERR=400) NMO,NYEAR
  101 FORMAT(2I2)
C      NOW READ 6 STATIONS(STA NR=L) 2 CARDS PER STA(K=DATA AT 0 & 15M)
      DO 30 L=1,6
      DO 10 K=1,2
C      READ DATA CARDS FOR STA NR "_"
      READ(5,102) TEM(K),SAL(K),SGT(K)
  102 FORMAT(17X,3(F9.2,1X))
   10 CONTINUE
C      ONE NANS STA READ IN;NOW ASSIGN & INTERPOLATE VALUES TO 0,10,15M
      STEM(1)=TEM(1)
      STSAL(1)=SAL(1)
      STSGT(1)=SGT(1)
      STEM(3)=TEM(2)
      STSAL(3)=SAL(2)
      STSGT(3)=SGT(2)
C      NOW INTERPOLATE FOR STD DEPTH OF 10 METERS(STDEP(2));FORMULA IS:
C        X=D-((B-R)(D-C)/(B-A)), WHERE:
C           X=STEM,STSAL,STSGT(2)            R=STDEP(2)
C           A=DEP(1)                         C=TEM,SAL,SGT(1)
C           B=DEP(2)                         D=TEM,SAL,SGT(2)
C
C      LET C1=B-R AND C2=B-A
      C1=DEP(2)-STDEP(2)
      C2=DEP(2)-DEP(1)
C      INTERPOLATE FOR STD TEMP,SALINITY AND SIGMA-T, RESPECTIVELY
      STEM(2)=TEM(2)-(C1*(TEM(2)-TEM(1)))/C2
      STSAL(2)=SAL(2)-(C1*(SAL(2)-SAL(1)))/C2
      STSGT(2)=SGT(2)-(C1*(SGT(2)-SGT(1)))/C2
C      NOW WRITE THE TITLE CARD
      WRITE(6,103) NMO,NYEAR,LAT,LATMI(L),LON(L),LONMI(L),L
  103 FORMAT(1X,'03',1X,'NANS',4X,I2,1X,I2,7X,A2,1X,A4,2X,A4,A4,2X,
     $'999',19X,'CCFI S',I1,1X,'MO AVG')
      WRITE(7,104) NMO,NYEAR,LAT,LATMI(L),LON(L),LONMI(L),L
  104 FORMAT('03',1X,'NANS',4X,I2,1X,I2,7X,A2,1X,A4,2X,A4,A4,2X,
     $'999',19X,'CCFI S',I1,1X,'MO AVG')
C
C      NOW WRITE STATION DATA CARDS
      DO 20 JJ=1,3
      WRITE(6,105) STDEP(JJ),STEM(JJ),STSAL(JJ),STSGT(JJ)
  105 FORMAT(1X,F5.0,1X,3(F5.2,1X))
```

```
      WRITE(7,106) STDEP(JJ),STEM(JJ),STSAL(JJ),STSGT(JJ)
  106 FORMAT(F5.0,1X,3(F5.2,1X))
   20 CONTINUE
C       NOW GET NEXT STATICN NR (L)
   30 CONTINUE
C       GET NEXT DATA SET(ANOTHER MONTH'S DATA)
  200 CONTINUE
C       SHOULD NEVER ARRIVE HERE(TOTAL DATA SETS.GT.500)
      WRITE(6,107)
  107 FORMAT(//1X,'ERROR: MORE THAN 500 DATA SETS,STOPPING')
      STOP
  400 WRITE(6,108) I
  108 FORMAT(//1X,'READ ERROR,STOPPING: I=',I6)
      STOP
  500 I=I-1
      II=6*I
      III=24*I
      WRITE(6,109) II,III
  109 FORMAT(//1X,'END OF DATA: TOTAL OCEAN STA=',I6,5X,
     $'TOTAL 80 BYTE RECORDS=',I8)
      STOP
      END
//GO.FT06F001 DD SPACE=(CYL,(3,1))
//GO.FTC7F001 DD SPACE=(CYL,(3,1))
//GO.SYSIN DD *
C
C
C*****************************************************************************
C
C
//LAMMC004  JOB (0687,0446FT,OEG9),'L.L.LAMMERS'
//  EXEC  FORTCLG,TIME.GO=6
//FCRT.SYSIN DD *
C
C
C           PROGRAM  4     L.L.LAMMERS     22 JAN 1971
C
C
C       READS NODC NANSEN DATA FROM 7-TRACK TAPE(SER=R1019), AND:
C         1. COMPUTES NR OF DATA CARDS FOL EACH TITLE CARD(NR CARDS=J)
C         2. WRITES NEW TITLE CARD WITH J IN COLUMNS 79-80
C         3. WRITES J DATA CARDS
C       ***DATA WRITTEN ONTO NPGS 9-TRACK TAPE(SER=NPS297)
C       (A 9-TRACK TAPE) FOR LATER PROCESSING IN AUTHOR'S FORMAT
C
      DIMENSION INDATA(19),NSAVE(35,19)
      DATA NTOT/0/,M/0/,JTOT/0/,I/0/
C       NTOT=TOTAL NR OF 80 COLUMN RECOFDS WRITTEN(NTOT=M+JTOT)
```

```
C      READ FIRST TITLE CARD
C      NR1 AND NR2 DEFINE DATA FOUND IN COLUMNS 77, 78, AND 79 OF ALL CARDS
C
      READ(3,101,END=800,ERR=900) INDATA,NR1,IND
  101 FORMAT(19A4,A3,I1)
      IF(IND.NE.1) STOP
C      NOW READ DATA CARDS UNTIL ANOTHER TITLE CARD IS FOUND. NOTE:
C      TITLE CARDS(IND=1), DATA CARDS(IND=6)
C
    5 DO 10 J=1,35
      READ(3,102,END=800,ERR=900) (NSAVE(J,K),K=1,19),NR2,IND
  102 FORMAT(19A4,A3,I1)
      IF(IND.EQ.1) GO TO 30
   10 CONTINUE
C      SHOULD NEVER GET HERE(J.GT.35 STD VALUES)
      WRITE(6,103) M,NTOT
  103 FORMAT(//1X,'ERROR: MORE THAN 35 STD VALUES.',5X,I6,2X,'TITLE CARD
     $S AND ',2X,I6,2X,'80 COLUMN RECORDS WRITTEN')
      STOP
C      WE GET TO 30 WITH J-1 DATA CARDS. THE LAST VALUE OF J DEFINES THE
C      NEXT TITLE CARD.
   30 M=M+1
      J=J-1
      JTOT=JTOT+J
C      NOW WRITE THE PREVIOUS TITLE CARD(FORMAT MODIFIED TO INCLUDE J)
      WRITE(4,105) (INDATA(K),K=1,16),INDATA(18),INDATA(19),NR1,J
  105 FORMAT(18A4,A3,3X,I2)
C      NOW WRITE PREVIOUS SET OF DATA CARDS
      DO 40 L=1,J
      WRITE(4,107) (NSAVE(L,K),K=1,16)
  107 FORMAT(16A4)
   40 CONTINUE
C      RECALL THAT NEXT TITLE CARD(INCLUDING NR2) WAS READ AS THE
C      LAST DATA CARD. NOW LOAD IT INTO INDATA AND NR1 AND SAVE UNTIL
C      J COMPUTED FOR NEXT STATION
      J=J+1
      DO 45 K=1,19
      INDATA(K)=NSAVE(J,K)
   45 CONTINUE
      NR1=NR2
C      NOW GO BACK AND READ DATA CARDS UNTIL NEXT TITLE CARD IS FOUND
      GO TO 5
C      WE GET TO 800 AT END OF TAPE WITH 1 TITLE CARD AND J-1 DATA CARDS
C      LEFT TO BE WRITTEN
  800 J=J-1
```

```
      M=M+1
      JTOT=JTOT+J
C       WRITE LAST TITLE CARD
      WRITE(4,105) (INDATA(K),K=1,16),INDATA(18),INDATA(19),NR1,J
C
C       FINALLY, WRITE LAST SET OF DATA CARDS
      DO 850 L=1,J
      WRITE(4,107) (NSAVE(L,K),K=1,16)
  850 CONTINUE
      NTOT=M+JTOT
      WRITE(6,108) M,NTOT
  108 FORMAT(//1X,'END OF TAPE: TOT NANS STA=',I6,5X,'TOT 80-COLUMN REC=
     $',I6)
      GO TO 950
  900 NTOT=M+JTOT
      WRITE(6,109) M,NTOT
  109 FORMAT(//1X,'READ ERROR,STOPPING: TOT NANS STA=',I6,5X,'TOT 80-COL
     $UMN REC=',I6)
      STOP
  950 END FILE 4
      REWIND 4
      DO 960 JJ=1,50
      READ(4,110) INDATA,NDUM
  110 FORMAT(20A4)
      WRITE(6,111) INDATA,NDUM
  111 FORMAT(1X,20A4)
  960 CONTINUE
      REWIND 4
      STOP
      END
//GO.FT03F001  DD  UNIT=2400-1,VOL=SER=R1019,LABEL=(,NL),
//         DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=80,TRTCH=ET)
//GO.FT04F001  DD  UNIT=2400,VOL=SER=NPS297,LABEL=(,SL),DSNAME=LAMMERS,
//         DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.SYSIN DD *
C
C
C*****************************************************************************
C
C
//LAMM0005 JOB (0687,0446FT,OEG9),'L.L.LAMMERS'
//   EXEC  FORTCLG,TIME.GO=3
//FORT.SYSIN DD *
C
C
C
C          PROGRAM  5     L.L.LAMMERS     25 JAN 1971
C
```

```
C           121-30W TO 122-30W)
C        3. WRITES DATA ON UNIT NR 6 FOR PROOF-READING
C        4. DATA ALSO WRITTEN ONTO THE MASTER TAPE(SER=NPS306)
C
      DIMENSION DEP(35),TEM(35),SAL(35),SGT(35)                           1
      DATA DEP/35*0.0/,TEM/35*0.0/,SAL/35*0.0/,SGT/35*0.0/,M/0/,NTOT/0/,  2
     $JTOT/0/,DEP15/0015./                                                3
C       I COUNTER DEFINES TOTAL NANSEN STATIONS PROCESSED
      DO 1000 I=1,10000                                                   4
C       READ A TITLE CARD
      READ(4,101,END=900,ERR=800) NREF1,LATDEG,RLATMI,LONDEG,RLONMI,      5
     $NYEAR,NMO,NDAY,NHR,TNTHS,NREF2,NREF3,NCARDS                         6
  101 FORMAT(A4,I2,F3.1,I3,F3.1,3X,4I2,F1.1,40X,2A4,3X,I2)                7
C       CONVERT NHR AND TNTHS TO HOURS AND MINUTES(=NTIME)
      NTIME=NHR*100+TNTHS*60.0                                            7A
C       NOW READ DATA CARDS
      DO 5 J=1,NCARDS                                                     8
      READ(4,102,END=950,ERR=850) DEP(J),TEM(J),SAL(J),SGT(J)             9
  102 FORMAT(27X,F4.0,1X,3(F4.2,1X))                                      10
    5 CONTINUE                                                            11
C       NOW EXCLUDE STATIONS NOT IN MTRY BAY BEFORE PROCESSING
      RLAT=LATDEG*100+RLATMI                                              12
      RLON=LONDEG*100+RLONMI                                              13
      IF((RLAT.GE.3630.0).AND.(RLAT.LE.3710.0)) GO TO 10                  14
      GO TO 1000                                                          15
   10 IF((RLON.GE.12130.0).AND.(RLON.LE.12230.0)) GO TO 20                16
      GO TO 1000                                                          17
C       ARRIVE AT 20 IF STATION IN MTRY BAY. NOW EXCLUDE DATA IF THE
C       SURFACE VALUES ARE ZERO.
   20 IF(DEP(1).NE.0.0) GO TO 1000                                        18.
      IF(TEM(1).EQ.0.0) GO TO 1000                                        19
      IF(NCARDS.LT.3) GO TO 200                                           20
C       ARRIVE HERE READY TO INTERPOLATE FOR 15 METER VALUES OF TEMP(T15),
C       SALINITY(SL15) AND SIGMA-T(SGT15). THESE WILL THEN BE WRITTEN
C       BETWEEN J=2 VALUES(10M) AND J=3 VALUES(20M)
C       USE FORMULA    X=D-((B-R)(D-C)/(B-A)),  WHERE:
C         X=T15,SL15,SGT15                   R=DEP15(15 METERS)
C         A=DEP(2)                           C=TEM(2),SAL(2),SGT(2)
C         B=DEP(3)                           D=TEM(3),SAL(3),SGT(3)
C       LET:    C1=B-R  AND  C2=B-A
C
      C1=DEP(3)-DEP15                                                     21
      C2=DEP(3)-DEP(2)                                                    22
C       INTERPOLATE FOR TEMPERATURE. FIRST INSURE THAT TEM(2,3).NE.0.0
      IF((TEM(2).EQ.0.0).OR.(TEM(3).EQ.0.0)) GO TO 90                     23
```

```
      T15=TEM(3)-(C1*(TEM(3)-TEM(2)))/C2
C      NOW SALINITY AND SIGMA-T
      IF((SAL(2).EQ.0.0).OR.(SAL(3).EQ.0.0)) GO TO 95
      SL15=SAL(3)-(C1*(SAL(3)-SAL(2)))/C2
      SGT15=SGT(3)-(C1*(SGT(3)-SGT(2)))/C2
      GO TO 200
   90 T15=0.0
      SL15=0.0
      SGT15=0.0
      GO TO 200
   95 SL15=0.0
      SGT15=0.0
C      ARRIVE AT 200 WITH ONE STATION READY TO BE WRITTEN
C      M DEFINES TOTAL NANS STA WRITTEN(OR TITLE CARDS)
C      JTOT DEFINES TOTAL NR OF STATION DATA CARDS WRITTEN
C      NTOT=M+JTOT DEFINES TOTAL NR OF 80-BYTE RECORDS WRITTEN
  200 M=M+1
C      MUST INCREASE NCARDS BY ONE TO INCLUDE THE 15M VALUES
      NCARDS=NCARDS+1
      JTOT=JTOT+NCARDS
C      NOW WRITE A TITLE CARD IN AUTHOR'S FORMAT
      WRITE(6,103) NCARDS,NDAY,NMO,NYEAR,NTIME,LATDEG,RLATMI,LONDEG,
     $RLONMI,NREF1,NREF2,NREF3
  103 FORMAT(1X,I2,1X,'NANS',1X,3(I2,1X),I4,2X,I2,1X,F4.1,2X,I3,1X,F4.1,
     $7X,3A4,5X,'NODC TAPE=R1019')
      WRITE(10,104) NCARDS,NDAY,NMO,NYEAR,NTIME,LATDEG,RLATMI,LONDEG,
     $RLONMI,NREF1,NREF2,NREF3
  104 FORMAT(I2,1X,'NANS',1X,3(I2,1X),I4,2X,I2,1X,F4.1,2X,I3,1X,F4.1,
     $7X,3A4,5X,'NODC TAPE=R1019')
C
C      SET NCARDS BACK ONE TO ORIGINAL NUMBER
      NCARDS=NCARDS-1
C      NOW WRITE DATA CARDS. NOTE: THE 3RD DATA CARD IS FOR T15,SL15,...
      DO 250 JJ=1,NCARDS
      IF(JJ.EQ.3) GO TO 230
  210 WRITE(6,105) DEP(JJ),TEM(JJ),SAL(JJ),SGT(JJ)
  105 FORMAT(1X,F5.0,1X,3(F5.2,1X))
      WRITE(10,106) DEP(JJ),TEM(JJ),SAL(JJ),SGT(JJ)
  106 FORMAT(F5.0,1X,3(F5.2,1X))
      GO TO 250
  230 WRITE(6,105) DEP15,T15,SL15,SGT15
      WRITE(10,106) DEP15,T15,SL15,SGT15
C      NOW GO BACK TO 210 AND WRITE J=3,NCARDS  DATA
      GO TO 210
  250 CONTINUE
C      ONE STATION WRITTEN. GO BACK FOR NEXT ONE
 1000 CONTINUE
      WRITE(6,107) M
```

```
  800 WRITE(6,108) M
  108 FORMAT(//1X,'READ ERROR ON TITLE CARD,STOPPING: NR OF MTRY BAY STA
     $ WRITTEN=',5X,I6)
      STOP
  850 WRITE(6,109) M
  109 FORMAT(//1X,'READ ERROR ON DATA CARD,STOPPING: NR OF MTRY BAY STA
     $WRITTEN=',5X,I6)
      STOP
C      GET TO 900 IF PROG ENDS TRYING TO READ TITLE CARD(NORMAL END)
  900 I=I-1
      NTOT=M+JTOT
      WRITE(6,110) I,M,NTOT
  110 FORMAT(//1X,'END OF TAPE(NORMAL END): TOT NANS STA ON TAPE=',I8,5X
     $,'NANS STA WRITTEN=',I8,5X,'TOT 80-BYTE REC WRITTEN=',I8)
      STOP
  950 I=I-1
      NTOT=M+JTOT
      WRITE(6,111) I,M,NTOT
  111 FORMAT(//1X,'END OF TAPE(ABNORMAL END): TOT NANS STA ON TAPE=',I8,
     $5X,'NANS STA WRITTEN=',I8,5X,'TOT 80-BYTE REC WRITTEN=',I8)
      STOP
      END
//GO.FT06F001 DD SPACE=(CYL,(3,1))
//GO.FT04F001  DD  UNIT=2400,VOL=SER=NPS297,LABEL=(,SL),DSNAME=LAMMERS,
//        DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.FT10F001  DD  UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//        DISP=(MOD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.SYSIN DD *
C
C
C***********************************************************************
C
C
//LAMM0006 JOB (0637,0446FT,CEG9),'L.L.LAMMERS'
//CONVERT  EXEC FORTCLG
//FORT.SYSIN DD *
C
C
C            PROGRAM  6     L.L.LAMMERS     14 JAN 1971
C
C
C      WRITES NODC 7-TRACK BT DATA TAPE(REEL NR R1030) ONTO NPGS TAPE
C      SERIAL NPS 296 (A 9-TRACK TAPE) FOR LATER PROCESSING
C      DATA FROM NODC ARCHIVES LAST UPDATED 31 SEP 1969
C      TAPE NR 8= 7-TRACK AND TAPE NR 9= 9-TRACK
```

```
C
      DIMENSION INDATA(20)
      REWIND 8
      REWIND 9
      J=0
   20 J=J+1
      READ(8,101,END=50,ERR=40) INDATA
  101 FORMAT(20A4)
      WRITE(9,101) INDATA
      GC TO 20
   40 WRITE(6,102) J
  102 FCRMAT(//5X,'READ ERROR,RECORD NR=',I8)
      GO TO 20
   50 WRITE(6,103) J
  103 FORMAT(//5X,'END OF TAPE, RECORD NR=',I8)
      END FILE 9
      REWIND 9
C      NOW SEE IF CONVERSION WAS SUCCESSFUL. WRITE OUT 25 LOG RCDS FROM
C      TAPE NR 9
      DC 80 JJ=1,25
      READ(9,101,ERR=90) INDATA
      WRITE(6,104) INDATA
  104 FORMAT(1X,20A4)
   80 CCNTINUE
      STOP
   90 WRITE(6,105) JJ
  105 FORMAT(1X,'READ ERROR,TAPE NR 9,STCPPING: RCDNR=',I4)
      STOP
      END
//GC.FT08F001   DD  UNIT=2400-1,VOL=SER=R1030,LABEL=(,NL),
//         DISP=(OLD,KEEP),DCB=(DEN=1,RECFM=F,BLKSIZE=80,TRTCH=ET)
//GC.FT09F001   DD  UNIT=2400,VOL=SER=NPS296,LABEL=(,SL),DSNAME=LAMMERS,
//         DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
C
C
C*********************************************************************************
C
C
//LAMM0007 JOB (0687,0446FT,CEG9),'L.L.LAMMERS'
//  EXEC  FORTCLG,TIME.GO=6
//FCRT.SYSIN DD *
C
C
C           PROGRAM  7     L.L.LAMMERS     22 JAN 1971
C
C
C      READS 9-TRACK TAPE(NPS296), CONTAINING NODC-BT DATA, AND WRITES
C      DATA OUT ONTO MASTER TAPE(NPS306) IN AUTHOR'S FORMAT
```

```
     $300.,400.,500./
      CATA TEM/10C*0.0/,DEP/100*0.0/,STEM/15*0.C/
C       TO AVOID LENGTHY DATA STAEMENT, INITIALIZE DEP(K) TO VALUES AT
C       5 METER INTERVALS
      DC 3 K=1,100
      DEP(K)=(K-1)*5.0
    3 CONTINUE
      NTOT=0
      II=0
C       I COUNTS TOTAL BT STATIONS
C       II COUNTS BT STATICNS FOUND IN MTRY BAY(36-30N TO 37-10N &
C       121-30W TO 122-30W)
C       NTOT COUNTS TOTAL NR OF 80-BYTE RECORDS WRITTEN OUT
      DO 1000 I=1,10000
C       READ A TITLE CARD
      READ(9,101,END=900,ERR=800) NDAY,NMO,NYEAR,NTIME,LATDEG,RLATMI,
     $LONDEG,RLONMI,MXDEP,NCRDS
  101 FORMAT(14X,3I2,I4,3X,I2,F2.0,I3,F2.0,4X,I2,32X,I2)
C       READ A SUB-TITLE CARD
      READ(9,102) (NSHIP(N),N=1,4)
  102 FORMAT(52X,4A4)
C       NOW READ DATA CARDS. THERE SHOULD BE A MAX OF 5 (20 VALUES PER
C       CARD) FOR 100 VALUES MAXIMUM. NCRDS DEFINES NR CARDS PER STATION.
C       I.E.. 2 TITLE CARDS + DATA CARDS
      NCRDS=NCRDS-2
      IF(NCRDS.LT.6) GO TO 5
      WRITE(6,103) I,NCRDS
  103 FORMAT(//1X,'ERR: NCRDS TOO GREAT,STOPPING; BT STA NR=',I6,5X,
     $'NCRDS=',I4)
      STOP
C       WE GET TO 5 READY TO READ DATA CARDS. MXDEP DEFINES MAX TRACE
C       DEPTH IN TENS OF METERS. BELOW WE USE THIS TO DETERMINE HOW MANY
C       BT VALUES TO READ(NVAL). NOTE: VALUES ARE RECORDED ON TAPE AT
C       5 METER INTERVALS. MAX NR OF NVAL=100.
    5 NVAL=(MXDEP*10/5)+2
      READ(9,104,END=950,ERR=850) (TEM(K),K=1,NVAL)
  104 FORMAT(10X,20F3.1)
C       BEFORE PROCESSING IN AUTHOR'S FORMAT, EXCLUDE ANY STATIONS NOT IN
C       MTRY BAY
      RLAT=100*LATDEG+RLATMI
      RLON=100*LCNDEG+RLONMI
      IF((RLAT.GE.3630.0).AND.(RLAT.LE.3710.0)) GO TO 10
      GO TO 1000
   10 IF((RLON.GE.12130.0).AND.(RLCN.LE.12230.0)) GO TO 20
      GC TO 1000
```

```
C        ARRIVE AT 20 IF STATION IN MTRY BAY. NOW PROCESS & WRITE OUT
C        IN AUTHOR'S FORMAT. FIRST, COMPARE DEP(KK) TO STDEP(JJ) TO FIND
C        VALUES AT STD DEPTHS.
   20 JJ=0
      KK=0
   25 JJ=JJ+1
   30 KK=KK+1
      IF(KK.GT.NVAL) GO TO 200
      IF(TEM(KK).EQ.0.0) GO TO 200
      IF(DEP(KK).EQ.STDEP(JJ)) GO TO 50
      IF(DEP(KK).LT.STDEP(JJ)) GO TO 30
C        SHOULD NOT ARRIVE HERE. DEP(KK) CANNOT EXCEED STDEP(JJ) WITHOUT
C        STEPPING TO WHERE IT IS EQUAL THERETO
      WRITE(6,105) I
  105 FORMAT(//1X,'OBS & STD DEPTHS CUT OF SEQUENCE,STOPPING:BT NR=',I9)
      STOP
   50 STEM(JJ)=TEM(KK)
      GO TO 25
C        WE ARRIVE AT 200 WITH VALUES AT STD DEPTHS. NOW WRITE DATA
  200 JJ=JJ-1
C        JJ DEFINES NR OF STD VALUES FOUND
      II=II+1
      NTOT=NTOT+1+JJ
C        WRITE AUTHOR'S TITLE CARD
      WRITE(10,107) JJ,NDAY,NMO,NYEAR,NTIME,LATDEG,RLATMI,LONDEG,RLONMI,
     $(NSHIP(N),N=1,4)
  107 FORMAT(I2,1X,'BT',3X,3(I2,1X),I4,2X,I2,1X,F4.1,2X,I3,1X,F4.1,7X,
     $4A4,1X,'NODC TAPE=R1030')
C
C        NOW WRITE DATA CARDS
      DO 250 L=1,JJ
      WRITE(10,109) STDEP(L),STEM(L)
  109 FORMAT(F5.0,1X,F5.2)
  250 CONTINUE
C
C        NOW PROCESS NEXT BT STATION
      GO TO 1000
  800 WRITE(6,110) I
  110 FORMAT(//1X,'READ ERROR ON TITLE CARD,STOPPING: BT STA NR=',I10)
      STOP
  850 WRITE(6,111) I
  111 FORMAT(//1X,'READ ERROR ON DATA CARDS,STOPPING: BT STA NR=',I10)
      STOP
  900 I=I-1
      END FILE 10
      WRITE(6,112) I,II,NTOT
  112 FORMAT(//1X,'END OF DATA(NORMAL): BT STA NR=',I10,5X,'MTRY BAY STA
     $=',I10,5X,'TOT 80-BYTE REC=',I10)
```

```
      WRITE(6,113) I,II,NTOT
  113 FORMAT(//1X,'END OF DATA(ABNORMAL): BT STA NR=',I10,5X,
     $'MTRY BAY STA=',I10,5X,'TOT 80-BYTE REC=',I10)
      STOP
 1000 CONTINUE
      WRITE(6,114) II,NTOT
  114 FORMAT(//1X,'ERROR:MORE BT STATIONS ON TAPE THAN ALLWD BY I
     $COUNTER',5X,'MTRY BAY STA=',I10,5X,'TOT 80-BYTE REC=',I10)
      STOP
      END
//GO.FT09F001  DD  UNIT=2400,VOL=SER=NPS296,LABEL=(,SL),DSNAME=LAMMERS,
//        DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.FT10F001  DD  UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//        DISP=(NEW,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.SYSIN DD *
C
C
C*****************************************************************************
C
C
//LAMM0008  JOB (0687,0446FT,OEG9),'L.L.LAMMERS'
//  EXEC  FORTCLG,REGION.GO=100K,TIME.GO=6
//FORT.SYSIN DD *
C
C
C          PROGRAM  8      L.L.LAMMERS      26 JAN 1971
C
C
C       ***  DATA IS WRITTEN ONTO THE MASTER TAPE(SER=NPS306)  ***
C       THIS PROGRAM MODIFIES MIDDLEBERG PROGRAM TO OUTPUT I.A.W. AUTHOR'S
C       FORMAT.
      REAL *8 ITL(12),INFO(30,8)
      DIMENSION IT(50),IS(50),IO(50)
      DIMENSION MO(12)                                                  0002A
      DIMENSION D(50),T(50),S(50),O2(50),SNDV(50)
      DIMENSION SD(24),ST(24),SS(24),SGT(24),SV(24),SVA(24)
      DIMENSION SGP(24),DH(24),BDH(24),DD(24),SLEV(48),BSVA(24)
      DIMENSION NPA(49),NPB(48),NO(48),NSTA(48,3),ALT(48),ALM(48)
      DIMENSION ALN(48),ANM(48),IDATE(48,3),DHT(48,24),ADH(24)
    8 FORMAT (1H1,'STATION,',3A4,' LATITUDE ',I2,F5.1,'N LONGITUDE ',
     1I3,F5.1,'W  DATE ',3A4/5X,' TO,',3A4,' LATITUDE ',I2,F5.1,
     2'N LONGITUDE ',I3,F5.1,'W  DATE ',3A4//)
    9 FORMAT (8(1X,2I2,F5.0))
   10 FORMAT (1H1,'STATION ',3A4,' LATITUDE = ',I2,F5.1,'N LONGITUDE =',
     1I4,F5.1,'W  DATE ',3A4//)
```

```
   12 FORMAT (10X,'* INDICATES ADJUSTED VALUE')
   13 FORMAT (I4,3A4,F3.0,2F5.1,F4.1,3A4)
   14 FORMAT (8F10.3)
   15 FORMAT (F10.3,F9.2,A1,F10.3,A1,F8.2,A1,8X,4A8)
   16 FORMAT (10X,'DEPTH  TEMPERATURE  SALINITY  SIGMA-T  OXYGEN'//)
   17 FORMAT (20X,'OBSERVED VALUES'//)
   18 FORMAT (//20X,'INTERPOLATED VALUES'//)
   19 FORMAT (10X,'DEPTH  TEMPERATURE  SALINITY  SIGMA-T   SND VEL   SPE
     1C VOL   SPEC V ANOM  MEAN SVA   DELTA D  DYNAMIC HEIGHT'//)
   20 FORMAT(10X,F5.0,F10.2,F12.3,F9.3,F12.2,F10.4,F12.6,25X,F10.5/80X,
     12F12.6)
   21 FORMAT (10X,F5.0,F10.2,A1,F11.3,A1,F8.3,F9.2,A1,4X,4A8/)
      DATA IN/'NANS'/,IZ/'NPGS'/                                         0020A
      DATA MO/'JAN ','FEB ','MAR ','APR ','MAY ','JUN ','JUL ','AUG ',
     $'SEP ','OCT ','NOV ','DEC '/
      DATA SD/0.,10.,15.,20.,30.,50.,75.,100.,125.,150.,200.,250.,300.,
     $400.,500.,600.,700.,800.,900.,1000.,1100.,1200.,1300.,1400./
      JTOT=0
      NTOT=0
      NSD=24
      READ (5,13) NGC
      IF(NGC.EQ.0) GO TO 410
      READ (5,9) (NPA(I),NPB(I),SLEV(I),I=1,NGC)
  410 NPA(NGC+1)=0
      DO 41 L=1,48
C
C         READ HEADING CARD, CHECK FOR  END OF DATA, THEN
C         READ NOV DATA CARDS.
C
      READ(5,51,END=99,ERR=98) NOV,(NSTA(L,K),K=1,3),ALT(L),ALM(L),
     $ALN(L),ANM(L),NDAY,NMO
   51 FORMAT(I4,3A4,F3.0,2F5.1,F4.1,2X,A2,1X,A3)
C      NEXT LOOP CONVERTS NMO FROM A-4 TO NUMERIC(I.E..01,02,....,12)
      DO 22 LL=1,12                                                      0028C
      IF(NMO.EQ.MO(LL)) GO TO 23                                         0028D
   22 CONTINUE                                                           028E
      WRITE(6,600) L,NMO                                                 0028F
  600 FORMAT(1X,'MONTH CODED IMPROPERLY,STOPPING:  NANS STA NR=',I4,5X,  0028G
     $'MO=',3X,A3//)                                                     0028H
      STOP                                                               0028I
   23 CONTINUE                                                           0028J
      IF (NOV) 32,32,24
   24 DO 25 I=1,NOV
      READ (5,15) D(I),T(I),IT(I),S(I),IS(I),O2(I),IO(I),
     1(INFO(I,J),J=1,4)
C
C         SGTSVA IS SUBROUTINE TO COMPUTE SIGMA-T, SPECIFIC VOLUME
C         AND SPECIFIC VOLUME ANOMALY.
```

```
C          LGTP IS SUBROUTINE TO COMPUTE INTERPOLATED VALUES
C
      CALL LGTP(NOV,D,T,NSD,SD,ST,NA)
      CALL LGTP(NOV,D,S,NSD,SD,SS,NB)
      NO(L)=NA
      DO 27 I=1,NA
      CALL SNDVEL (ST(I),SS(I),SD(I),SNDV(I))
      CALL SGTSVA (ST(I),SS(I),SD(I),SGT(I),SV(I),SVA(I))
   27 CONTINUE
      NLT=ALT(L)
      NLN=ALN(L)
      WRITE(6,50) NA,IN,NDAY,LL,NLT,ALM(L),NLN,ANM(L),IZ,(NSTA(L,K),K=2,
     $3)
   50 FORMAT(1X,I2,1X,A4,1X,A2,1X,I2,1X,'67',7X,I2,1X,F4.1.2X,I3,1X,
     $F4.1,24X,3A4)
      WRITE(10,70) NA,IN,NDAY,LL,NLT,ALM(L),NLN,ANM(L),IZ,(NSTA(L,K),K=2
     $,3)
   70 FORMAT(I2,1X,A4,1X,A2,1X,I2,1X,'67',7X,I2,1X,F4.1,2X,I3,1X,F4.1,
     $24X,3A4)
      DO 31 I=1,NA                                                      0057A
      WRITE(6,52) SD(I),ST(I),SS(I),SGT(I)
   52 FORMAT(1X,F5.0,1X,3(F5.2,1X))                                     0058A
      WRITE(10,71) SD(I),ST(I),SS(I),SGT(I)
   71 FORMAT(F5.0,1X,3(F5.2,1X))                                        0058C
   31 CONTINUE
      JTOT=JTOT+NA
   41 CONTINUE
      IF(NGC.EQ.0) GO TO 33
   32 DO 42 L=1,48
      IF (NPA(L).EQ.0) GO TO 33
      BASE=SLEV(L)
      N1=NPA(L)
      N2=NPB(L)
      NU1=NC(N1)
      NU2=NC(N2)
      DO 43 I=1,NU1
   43 ADH(I)=DHT(N1,I)
      DO 44 I=1,NU2
   44 BDH(I)=DHT(N2,I)
      NLT=ALT(N1)
      NLN=ALN(N1)
      MLT=ALT(N2)
      MLN=ALN(N2)
      WRITE (6,8) (NSTA(N1,K),K=1,3),NLT,ALM(N1),NLN,ANM(N1),
     1(IDATE(N1,K),K=1,3),(NSTA(N2,K),K=1,3),MLT,ALM(N2),MLN,
```

```
    2ANM(N2),(IDATE(N2,K),K=1,3)
     ALAT=ALT(N1)+ALM(N1)/60.
     ALON=ALN(N1)+ANM(N1)/60.
     BLAT=ALT(N2)+ALM(N2)/60.
     BLON=ALN(N2)+ANM(N2)/60.
     CALL DSTSTA (ALAT,ALON,BLAT,BLON,X2)
  42 CALL GEOCUR (NU1,ADH,NU2,BDH,SD,BASE,X2)
  98 WRITE(6,601) L
 601 FORMAT(//' READ ERROR,STOPPING: NANS STA NR=',5X,I4)
     STOP
  99 L=L-1
     NTOT=JTOT+L
     WRITE(6,602) L,NTOT
 602 FORMAT(//1X,'END OF DATA: TOT NANS STA=',I6,5X,'TOT 80-BYTE REC=',
    $I6)
  33 STOP
     END


     SUBROUTINE GEOCUR (NA,ADH,NB,BDH,SD,BASE,X2)
     DIMENSION ADH(NA),BDH(NB),SD(24),RVEL(24),VEL(24),AMB(24)
  10 FORMAT (13X,'DEPTH     DYN HT     DYN HT     DIFF HT    REL VEL    ABS
    1VEL          '/14X,'M.        STA A      STA B      A-B          CM/SEC
    2   CM/SEC'/)
  11 FORMAT (13X,F5.0,2X,3(F9.5,1X),2(F8.2,2X)/)
  12 FORMAT ('***** LEVEL OF NO MOTION MUST BE EQUAL TO A STANDARD DEPT
    1H *****')
     IF(NA.LE.NB) GO TO 51
     N=NB
     GO TO 52
  51 N=NA
  52 DO 53 I=1,N
     AMB(I)=ADH(I)-BDH(I)
  53 RVEL(I)=AMB(I)*X2
     DO 54 I=1,24
     IF(BASE.EQ.SD(I))GO TO 55
  54 CONTINUE
     WRITE (6,12)
     GO TO 70
  55 NM=I
     IF(NM.GT.N) NM=N
     DO 56 I=1,N
  56 VEL(I)=RVEL(NM)-RVEL(I)
  58 WRITE (6,10)
     DO 60 I=1,N
  60 WRITE (6,11) SD(I),ADH(I),BDH(I),AMB(I),RVEL(I),VEL(I)
  70 RETURN
     END
```

```
      SUBROUTINE DSTSTA (SATI,ONGI,SATII,ONGII,X2)
      IMPLICIT REAL*4 (K)
      REAL*8 A,E
      DATA A/111132.09/,B/566.05/,C/1.20/,D/.002/
      DATA E/111415.13/,F/94.55/,G/,012/
   10 FORMAT (10X,'MEAN LATITUDE = ',F6.2/15X,'DISTANCE = ',F6.2,
     1' KILOMETERS'/)
      CCN=2*3.1416/360
      AATI=SATI*CCN
      AATII=SATII*CON
      $MERI=A-B*CCS(2*AATI)+C*COS(4*AATI)-D*COS(6*AATI)
      PARI=E*COS(AATI)-F*COS(3*AATI)+G*COS(5*AATI)
      $MERII=A-B*COS(2*AATII)+C*COS(4*AATII)-D*COS(6*AATII)
      PARII=E*COS(AATII)-F*COS(3*AATII)+G*COS(5*AATII)
      ALLAT=($MERI+$MERII)/2
      ALLON=(PARI+PARII)/2
      DLAT=SATI-SATII
      DLON=ONGI-CNGII
      KLAT=DLAT*ALLAT/1000
      KLONG=DLON*ALLON/1000
      KDIX=SQRT(KLAT**2+KLONG**2)
      W2=1.458E-4
      PSI=(SATI+SATII)*0.5
      PSJ=(2.*3.14159/360.)*PSI
      SPSI=SIN(PSJ)
      IF(SPSI.LT.0.1) SPSI=0.1
      X2=1./(W2*SPSI*KDIX)
      WRITE(6,10) PSI,KDIX
      RETURN
      END


      SUBROUTINE LGTP(N,D,V,M,SD,CV,NN)
      DIMENSION D(N),V(N),CV(M),SD(M)
  111 DO 183 J=1,M
  112 DO 186 I=1,N
      IF(SD(J)-D(N))113,115,190
  115 CV(J)=V(N)
      GO TO 191
  113 IF(SD(J)-D(I))114,114,116
  114 CV(J)=V(I)
      GC TO 188
  116 IF(SD(J)-D(I+1))120,118,186
  118 CV(J)=V(I+1)
      GO TO 188
  120 IF(I-1)132,132,126
```

```
126  XA=(SD(J)-D(I))*(SD(J)-D(I+1))*V(I-1)/
    1((D(I-1)-D(I))*(D(I-1)-D(I+1)))
     XB=(SD(J)-D(I-1))*(SD(J)-D(I+1))*V(I)/
    1((D(I)-D(I-1))*(D(I)-D(I+1)))
     XC=(SD(J)-D(I-1))*(SD(J)-D(I))*V(I+1)/
    1((D(I+1)-D(I-1))*(D(I+1)-D(I)))
     ANSU=XA+XB+XC
132  IF ((I+2)-N)133,133,134
133  YA=(SD(J)-D(I+1))*(SD(J)-D(I+2))*V(I)/
    1((D(I)-D(I+1))*(D(I)-D(I+2)))
     YB=(SD(J)-D(I))*(SD(J)-D(I+2))*V(I+1)/
    1((D(I+1)-D(I))*(D(I+1)-D(I+2)))
     YC=(SD(J)-D(I))*(SD(J)-D(I+1))*V(I+2)/
    1((D(I+2)-D(I))*(D(I+2)-D(I+1)))
     ANSD=YA+YB+YC
134  ZA=(SD(J)-D(I+1))*V(I)/(D(I)-D(I+1))
     ZB=(SD(J)-D(I))*V(I+1)/(D(I+1)-D(I))
     ANSL=ZA+ZB
     IF(I-1)136,136,138
136  CV(J)=(ANSD+ANSL)/2.
     DLL=(ANSD+ANSL+ANSL)/3.
     GO TO 188
138  IF((I+2)-N)140,140,142
140  CV(J)=(ANSU+ANSD+ANSL)/3.
     UD=(ANSU+ANSD)/2.
     GC TO 188
142  CV(J)=(ANSU+ANSL)/2.
     ULL=(ANSU+ANSL+ANSL)/3.
     GO TO 188
186  CONTINUE
188  CONTINUE
190  J=J-1
191  NN=J
     RETURN
     END


     SUBROUTINE SNDVEL (T,S,D,SVL)
     IF(D.LE.100.) GO TO 10
     IF(D.LE.200.) GO TC 20
     IF(D.LE.400.) GO TO 30
     IF(D.LE.700.) GO TO 40
     IF(D.LE.1500.)GO TO 50
     IF(D.LE.2000.)GO TO 60
     P=D*(.10318+(D-2000.)*2.6E-7)
     GO TO 5
 10  P=D*(.10245+D*3.0E-7)
     GC TO 5
```

```
40    P=D*(.10267+(D-400.)*4.33E-7)
      GO TO 5
50    P=D*(.10280+(D-700.)*3.0E-7)
      GO TO 5
60    P=D*(.10304+(D-1500.)*2.7E-7)
 5    CONTINUE
      VT=T*(4.5721-T*(.044532-T*(2.6045E-4+T*(7.9851E-6))))
      VP=P*(.160272+P*(1.0268E-5+P*(3.5216E-9-P*(3.3603E-12))))
      VS=(S-35.)*(1.39799+(S-35.)*1.69202E-3)
      A1=T*(-.011244+3.1580E-8*P+T*(7.7711E-7+1.5790E-9*P))
      A2=P*(7.7016E-5-1.2943E-7*P)
      A3=P*T*(-1.8607E-4+T*(7.4812E-6+T*(4.5283E-8)))
      A4=P*P*(T*(-2.5294E-7+T*1.8563E-9)+P*T*(-1.9646E-10))
      SVL=1449.14+VT+VP+VS+(S-35.)*(A1+A2)+A3+A4
      RETURN
      END


      SUBROUTINE SGTSVA (T,S,D,SGT,SV,SVA)
      ST=-(((T-3.98)**2)/503.57)*((T+283.)/(T+67.26))
      CL=(S-.030)/1.805
      SO=-.069+1.4708*CL-.00157*CL**2+3.98E-5*CL**3
      AT=T*(4.7867-.098185*T+.0010843*T**2)*1.E-3
      BT=T*(18.030-.8164*T+.01667*T**2)*1.E-6
      SGT=ST+(SO+.1324)*(1.-AT+BT*(SO-.1324))
      AFST=1./(1.+SGT*1.E-3)
      A=D*AFST*1.E-9
      B=4886./(1.+1.83E-5*D)
      C=227.+28.33*T-.551*T**2+.004*T**3
      E=D*1.E-4
      G=(SO-28.)/10.
      H=147.3-2.72*T+.04*T**2
      U=105.5+9.5*T-.158*T**2
      V=1.5*D**2*T*1.E-8
      W=32.4-.87*T+.02*T**2
      X=4.5-.1*T
      Y=1.8-.06*T
      SV=AFST-A*(B-C+E*U-V-G*(H-E*W)+G**2*(X-E*Y))
      AZ=.972643
      YA=-227.+.01055*D
      YB=.0126*(147.3-.00324*D)
      AP=AZ-D*AZ*(B+YA-YB)*1.E-9
      SVA=SV-AP
      RETURN
```

```
      END
//GO.FT10F001  DD  UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//        DISP=(MOD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.SYSIN DD *
C
C
C*************************************************************************
C
C
//LAMM0009  JOB (0687,0446FT,OEG9),'L.L.LAMMERS'
//  EXEC  FORTCLG,TIME.GO=2
//FORT.SYSIN DD *
C
C
C            PROGRAM  9     L.L.LAMMERS     29 JAN 1971
C
C
C       READS MASTER TAPE(SER=NPS306) AND POSITIONS TAPE TO OC. STATION
C       NR 1535. THENCE CALCOFI,BOLIN,AND FNWC-XBT DATA CARDS ARE WRITTEN
C       ONTO MASTER TAPE.
C
      DIMENSION ITITLE(20),NDATA(20)
      DATA KTOT/0/,LTOT/0/,JTOT/0/,NTOT/0/
C       READ DUMMY VALUES ON NPS306 TO POSITION TO OC STA=1535 FOR WRITE.
      DO 20 II=1,1534
      READ(10,301) NCARDS
  301 FORMAT(I2)
      IF(NCARDS.EQ.0) GO TO 250
      DO 10 JJ=1,NCARDS
      READ(10,302) DUMMY
  302 FORMAT(A4)
   10 CONTINUE
      KTOT=KTOT+NCARDS
   20 CONTINUE
C       GET HERE WITH 1534 OC STA READ. FIRST WRITE TOT 80-BYTE RECORDS
      LTOT=1534+KTOT
      WRITE(6,303) LTOT
  303 FORMAT(//1X,'TAPE SEQUENCED: OC STA=1534',5X,'TOT 80-BYTE REC=',
     $I8)
C       NOW READY TO READ FROM UNIT 5 AND WRITE ON NPS306
      DO 200 I=1,5000
C       READ A TITLE CARD
      READ(5,101,END=190) NCARDS,(ITITLE(L),L=1,20)
  101 FORMAT(I2,1X,A1,19A4)
      IF(NCARDS.EQ.0) GO TO 260
C       WRITE TITLE CARD
      WRITE(10,101) NCARDS,(ITITLE(L),L=1,20)
C       NOW READ AND WRITE DATA CARDS
```

```
C       NOW WRITE DATA CARDS
        WRITE(10,103) (NDATA(LL),LL=1,20)
  150 CONTINUE
C       JTOT COUNTS TOTAL NR OF DATA CARDS
        JTOT=JTOT+NCARDS
  200 CONTINUE
        WRITE(6,105) JTOT
  105 FORMAT(//1X,'MORE THAN(I=) 5000 OC. STA: TOT DATA CARDS WRITTEN=',
     $I8)
        STOP
  190 I=I-1
C       NTOT COUNTS TOTAL 80-BYTE RECORDS WRITTEN
        NTOT=I+JTOT
        WRITE(6,106) I,NTOT
  106 FORMAT(//1X,'END OF DATA(NORMAL): TOT OCEAN STA=',I6,5X,'TOT 80-BY
     $TE REC=',I8)
        STOP
  195 WRITE(6,107) I,J
  107 FORMAT(//1X,'ERROR***END OF DATA(ABNORMAL): I=',I6,5X,'J=',I8)
        STOP
  250 WRITE(6,108) II
  108 FORMAT(//1X,'NCARDS=0,STOPPING: II=',I8)
        STOP
  260 WRITE(6,109) I
  109 FORMAT(//1X,'NCARDS=0,STOPPING: I=',I8)
        STOP
        END
//GO.FT10F001   DD  UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//       DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.SYSIN DD *
C
C
C*******************************************************************************
C
C
//LAMM0010 JOB (0687,0446FT,CEG9),'L.L.LAMMERS'
//   EXEC   FORTCLG
//FORT.SYSIN DD *
C
C
C            PROGRAM  10      L.L.LAMMERS      26 JAN 1971
C
C
C       READS MASTER TAPE (NPS306) TO DETERMINE TOTAL 80-BYTE RECORDS
C       CONTAINED THEREON
```

```
C
      DATA JTOT/0/,NTOT/0/
      DO 20 I=1,15000
C      READ A TITLE CARD( I COUNTS TOTAL NR OF TITLE C&RDS)
      READ(10,101,END=30) NCARDS
  101 FORMAT(I2)
      IF(NCARDS.EQ.0) GO TO 40
C      READ DATA CARDS (JTOT COUNTS TOTAL NR OF DATA CARDS)
      DO 10 J=1,NCARDS
      READ(10,102,END=35) DUMMY
  102 FORMAT(A4)
   10 CONTINUE
      JTOT=JTOT+NCARDS
   20 CONTINUE
      WRITE(6,103)
  103 FORMAT(//1X,'MORE THAN 15000 TITLE CARDS,STOPPING')
      STOP
C      GET TO 30 AT END OF TAPE
   30 I=I-1
      NTOT=I+JTOT
      WRITE(6,104) I,NTOT
  104 FORMAT(//1X,'END OF TAPE(NORMAL): TOT OCEAN STA=',I6,5X,'TOT 80-BY
     $TE RECORDS WRITTEN=',I8)
      STOP
   35 WRITE(6,105) I,J
  105 FORMAT(//1X,'END OF TAPE(ABNORMAL): I=',I6,5X,'J=',I4)
      STOP
   40 WRITE(6,106) I
  106 FORMAT(//1X,'NCARDS=0,STOPPING: I=',I6)
      STOP
      END
//GO.FT10F001  DD  UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//        DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GO.SYSIN DD *
C
C
C*************************************************************************
C
C
C
C
C       THE "FINAL COMPUTER PROGRAM" (11) IS LISTED BELOW:
C
C
C
C
//LAMM011   JOB (0687,0446FT,OEG9),'L.L.LAMMERS'
//  EXEC  FORTCLG,REGION.GO=300K,TIME.GO=10
```

```
C           PROGRAM  11     L.L.LAMMERS      03 FEB 1971
C
C
C         READS MASTER TAPE(NPS306) AND OUTPUTS MONTHLY AVERAGE VALUES
C         OF TEMP AND SIGMA-T FOR THE GRID SYSTEM SHOWN ON THE BASE CHART
C
      DIMENSION VALT(40),VALSG(40),NR(24),NS(24),MR(24),TEM(20,24,60),
     $SGT(20,24,30),TEMW(20,6,20),SGTW(20,6,20),STDEP(20)
      DATA VALT/40*0./,VALSG/40*0./,NR/24*0/,NS/24*0/,MR/24*0/,
     $TEM/28800*0./,SGT/14400*0./,TEMW/2400*0./,SGTW/2400*0./
      DATA STDEP/0.,10.,15.,20.,30.,50.,75.,100.,125.,150.,200.,250.,
     $300.,400.,500.,600.,700.,800.,900.,1000./
      DATA MMW/0/,SUMTW/0./,SUMSTW/0./,TWSQ/0./,STWSQ/0./,TWAV/0./,
     $STWAV/0./,T1/0./,SDTW/0./,ST1/0./,SDSTW/0./,MT/0/,SUMT/0./,
     $TSQ/0./,TUWAV/0./,T2/0./,SDTUW/0./,MST/0/,SUMST/0./,STSQ/0./,
     $STUWAV/0./,ST2/0./,SDSTUW/0./,A1/0./,A2/0./,TSUMT/0./,TAVT/0./
      DATA TSUMST/0./,TAVST/0./
  101 FORMAT(I2,9X,I2,10X,I2,1X,F4.1,2X,I3,1X,F4.1,3X,I1)
  102 FORMAT(6X,F5.2,7X,F5.2)
  103 FORMAT('1','*****************************************************',5X,
     $'MONTH NR=',I3,5X,'*****************************************************')
  104 FORMAT(//1X,'END OF TAPE(NORMAL): OC STA PROCESSED=',I8)
  105 FORMAT(//T55,'BLOCK NR=',I3/)
  106 FORMAT(/1X,'DEPTH',2X,'TEMP',2X,'SIGMA-T',2X,'NR WTD',3X,'SUM WTD'
     $,3X,'STDEV WTD SUM WTD  STDEV WTD  NR UNWTD  SUM UNWTD STDEV',1X,
     $'UNWTD NR UNWTD SUM UNWTD STDEV UW')
  107 FORMAT(1X,'(MET)  (AV)   (AVG)  VALUES    TEMPS',6X,'TEMPS',3X,
     $'SIGMA-T   SIGMA-T     TEMPS',6X,'TEMPS     TEMPS      SIGMA-T',3X,
     $'SIGMA-T   SIGMA-T')
  108 FORMAT(1X,F5.0,2X,F5.2,2X,F5.2,4X,I3,5X,F7.2,5X,F5.2,3X,F7.2,4X,
     $F5.2,6X,I3,6X,F7.2,4X,F5.2,7X,I3,5X,F7.2,4X,F5.2)
  109 FORMAT(1X,'WTD TEMPS:',5X,(5(F4.1,1X),1X,5(F4.1,1X),1X,5(F4.1,1X),
     $1X,5(F4.1,1X)))
  110 FORMAT(1X,'WTD SIGMA-T:',3X,(5(F4.1,1X),1X,5(F4.1,1X),1X,5(F4.1,1X
     $),1X,5(F4.1,1X)))
  111 FORMAT(1X,'UNWTD TEMPS:',(3X,5(F4.1,1X),1X,5(F4.1,1X),1X,5(F4.1,1X
     $),1X,5(F4.1,1X)))
  112 FORMAT(1X,'UNWTD SIGMA-T:',(1X,5(F4.1,1X),1X,5(F4.1,1X),1X,5(F4.1,
     $1X),1X,5(F4.1,1X)))
  113 FORMAT(//1X,'READ ERROR ON TITLE CARD,STOPPING: I=',I6)
  114 FORMAT(//1X,'READ ERR-DATA CARD,STOPPING: I=',I6,'JV=',I4)
  115 FORMAT(//1X,'ABNORMAL END OF DATA,STOPPING: STA PROCESSED=',I6)
  116 FORMAT(//1X,'I.GT.5000 OC STA,STOPPING')
  117 FORMAT(///1X,'12 MONTHS PROCESSED AND WRITTEN: END OF PROGRAM')
C       JMO LOOP PROCESSES ENTIRE PROGRAM BY ONE MONTH AT A TIME
```

```
      DO 2000 JMO=1,12
      WRITE(6,103) JMO
      DO 1000 I=1,5000
C      READ TITLE CARD
      READ(10,101,END=175,ERR=980) NCARDS,NMO,LATDEG,RLATMI,LONDEG,
     $RLONMI,NWF
C      READ DATA CARDS
      DO 40 JV=1,NCARDS
      READ(10,102,ERR=985,END=990) VALT(JV);VALSG(JV)
   40 CONTINUE
C      IF.LT.20 VALUES READ IN,ZEROIZE REMAINDER OF ARRAYS
      IF(NCARDS.GE.20) GO TO 50
      NC=NCARDS+1
      DO 45 JV=NC,20
      VALT(JV)=0.0
      VALSG(JV)=0.0
   45 CONTINUE
C      GET TO 50 WITH ONE STATION READ IN. NOW CHECK FOR CORRECT MONTH
   50 IF(NMO.NE.JMO) GO TC 1000
C      NOW FIND BLOCK NR(BLOCKS NOT NUMBERED IN SEQUENCE:SEE BASE CHART)
      RLAT=100.*LATDEG+RLATMI
      RLON=100.*LONDEG+RLONMI
C      VERIFY THAT STATION IS IN BAY THEN FIND CORRECT ROW(ROW NRS=55,
C      60,65,70,75,80)
      IF((RLAT.LT.3633.0).OR.(RLAT.GT.3700.0)) GO TO 1000
      IF((RLAT.GE.3633.0).AND.(RLAT.LT.3637.0)) GO TO 55
      IF((RLAT.GE.3637.0).AND.(RLAT.LT.3641.0)) GO TO 60
      IF((RLAT.GE.3641.0).AND.(RLAT.LT.3645.0)) GC TO 65
      IF((RLAT.GE.3645.0).AND.(RLAT.LT.3649.0)) GO TO 70
      IF((RLAT.GE.3649.0).AND.(RLAT.LE.3653.0)) GC TO 75
      IF((RLAT.GT.3653.0).AND.(RLAT.LE.3700.0)) GO TO 80
      GC TO 1000
C      SELECT COLUMN WITHIN ROW. K DEFINES BLOCK NRE(SEE BASE CHART)
   55 IF(RLON.GT.12208.0) GO TO 1000
      IF(RLON.LT.12203.0) K=15
      IF(RLON.GE.12203.0) K=12
      GO TO 85
   60 IF(RLON.LT.12153.0) GO TO 1000
      IF(RLON.GT.12230.0) GO TO 1000
      IF((RLON.GT.12208.0).AND.(RLON.LT.12223.0)) GO TO 1000
      IF((RLON.GE.12153.0).AND.(RLON.LT.12158.0)) K=1
      IF((RLON.GE.12158.0).AND.(RLON.LT.12203.0)) K=14
      IF((RLON.GE.12203.0).AND.(RLON.LE.12208.0)) K=11
      IF((RLON.GE.12223.0).AND.(RLON.LE.12230.0)) K=20
      GO TO 85
   65 IF(RLON.LT.12153.0) GO TO 1000
      IF(RLON.GT.12223.0) GO TO 1000
      IF((RLON.GT.12208.0).AND.(RLON.LT.12213.0)) GO TO 1000
```

```
      IF((RLON.GE.12203.0).AND.(RLON.LE.12208.0)) K=10
      IF((RLON.GE.12213.0).AND.(RLON.LT.12218.0)) K=23
      IF((RLON.GE.12218.0).AND.(RLON.LE.12223.0)) K=21
      GO TO 85
   70 IF(RLON.GT.12208.0) GO TO 1000
      IF(RLON.LT.12153.0) K=19
      IF((RLON.GE.12153.0).AND.(RLON.LT.12158.0)) K=17
      IF((RLON.GE.12158.0).AND.(RLON.LT.12203.0)) K=3
      IF((RLON.GE.12203.0).AND.(RLON.LE.12208.0)) K=9
      GO TO 85
   75 IF(RLON.GT.12208.0) GO TO 1000
      IF(RLON.LT.12153.0) K=18
      IF((RLON.GE.12153.0).AND.(RLON.LT.12158.0)) K=6
      IF((RLON.GE.12158.0).AND.(RLON.LT.12203.0)) K=4
      IF((RLON.GE.12203.0).AND.(RLON.LE.12208.0)) K=8
      GC TO 85
   80 IF(RLON.GT.12218.0) GO TO 1000
      IF(RLON.LT.12158.0) K=16
      IF((RLON.GE.12158.0).AND.(RLON.LT.12203.0)) K=5
      IF((RLON.GE.12203.0).AND.(RLON.LT.12208.0)) K=7
      IF((RLON.GE.12208.0).AND.(RLON.LT.12213.0)) K=24
      IF((RLON.GE.12213.0).AND.(RLON.LE.12218.0)) K=22
C      GET TO 85 WITH ONE VALUE OF K(BLOCK NR). LOAD 3-D ARRAYS.
C      IF NWF=9 WE HAVE CALCOFI WEIGHTED DATA(4 TO 1)
   85 IF(NWF.EQ.9) GO TO 150
C      LOAD UNWEIGHTED TEMPS
      NR(K)=NR(K)+1
      NRK=NR(K)
C      NR(K) COUNTS TOTAL UNWEIGHTED TEMPS IN GIVEN BLOCK
      IF(VALSG(1).EQ.0.0) GO TO 90
C      GET HERE IF THERE IS UNWEIGHTED(U.W.) SIGMA-T DATA. NS(K) COUNTS
C      TOT U.W. SIGMA-T STATIONS IN BLOCK
      NS(K)=NS(K)+1
      NSK=NS(K)
   90 DO 95 J=1,20
      TEM(J,K,NRK)=VALT(J)
      IF(VALSG(1).EQ.0.0) GO TO 95
      SGT(J,K,NSK)=VALSG(J)
   95 CONTINUE
C      NOW GET ANOTHER STATION
      GO TO 1000
C      GET TO 150 TO LOAD WEIGHTED DATA INTO 3-D ARRAYS.
  150 MR(K)=MR(K)+1
      MRK=MR(K)
C      MR(K) COUNTS TOT WEIGHTED TEMPS & SIGMA-T'S FOR BLOCK
      DO 160 J=1,20
```

```
      TEMW(J,K,MRK)=VALT(J)
      SGTW(J,K,MRK)=VALSG(J)
  160 CONTINUE
C      GET ANOTHER STATION
      GO TO 1000
C      GET TO 175 AFTER ALL DATA READ IN. COMMENCE PROCESSING
  175 I=I-1
      REWIND 10
      WRITE(6,104) I
      DO 300 K=1,24
C      IF NO WEIGHTED DATA(MR(K)=0),CHECK U.W. DATA(NR(K)) AND IF NONE,
C      SKIP KTH BLOCK
      IF((MR(K).EQ.0).AND.(NR(K).EQ.0)) GO TO 300
C      WRITE HEADING INFO FOR BLOCK K
      WRITE(6,105) K
      DO 295 J=1,20
C      DETERMINE TYPE DATA. MR(K) COUNTS WEIGHTED TEMPS & SIGMA-T'S,
C      NR(K) COUNTS UNWTD TEMPS, NS(K) COUNTS UNWTD SIGMA/T'S
      IF(MR(K).EQ.0) GO TO 185
      MRT=MR(K)
C      CLEAR ZERO VALUED WTD TEMPS & SIGMA/T'S FROM ARRAY
      DO 180 L=1,MRT
      IF(TEMW(J,K,L).EQ.0.0) GO TO 180
      MMW=MMW+1
C      MMW COUNTS TOT NON-ZERO WEIGHTED TEMPS(OR SIGMA-T'S)
      TEMW(J,K,MMW)=TEMW(J,K,L)
      SGTW(J,K,MMW)=SGTW(J,K,L)
C      ACCUMULATE WEIGHTED SUMS
      SUMTW=SUMTW+TEMW(J,K,MMW)
      SUMSTW=SUMSTW+SGTW(J,K,MMW)
      TWSQ=TWSQ+TEMW(J,K,MMW)**2
      STWSQ=STWSQ+SGTW(J,K,MMW)**2
  180 CONTINUE
C      COMPUTE STANDARD DEVIATION FOR WEIGHTED TEMPS AND SIGMA-T'S,
C      USE GENERAL EQUATION:
C      S=SQRT((XSUBI**2-N*XBAR**2)/(N-1)),  WHERE:
C      S=STDEV(SDTW,SDSTW)     XSUBI**2=TWSQ,STWSQ
C      N=MMW                   XBAR**2=TWAV,STWAV
C      IF MMW.LE.1 , SKIP STANDARD DEVIATION ALTOGETHER
      IF(MMW.LE.1) GO TO 185
      TWAV=(SUMTW/FLOAT(MMW))**2
      STWAV=(SUMSTW/FLOAT(MMW))**2
      T1=(TWSQ-MMW*TWAV)/FLOAT(MMW-1)
      SDTW=SQRT(T1)
      ST1=(STWSQ-MMW*STWAV)/FLOAT(MMW-1)
      SDSTW=SQRT(ST1)
C      GET TO 185 TO PROCESS UNWEIGHTED DATA. FIRST SEE IF THERE IS ANY.
  185 IF(NR(K).EQ.0) GO TO 205
```

```
      DO 190 L=1,NRT
      IF(TEM(J,K,L).EQ.0.0) GO TO 190
      MT=MT+1
C      MT COUNTS NON-ZERO U.W. TEMPS
      TEM(J,K,MT)=TEM(J,K,L)
C      ACCUMULATE SUMS
      SUMT=SUMT+TEM(J,K,MT)
      TSQ=TSQ+TEM(J,K,MT)**2
  190 CONTINUE
C      COMPUTE STDEV FOR U.W. TEMPS AS BEFORE
      IF(MT.LE.1) GO TO 205
      TUWAV=(SUMT/FLOAT(MT))**2
      T2=(TSQ-MT*TUWAV)/FLOAT(MT-1)
      SDTUW=SQRT(T2)
C      NOW PROCESS U.W. SIGMA-T'S
      IF(NS(K).EQ.0) GO TO 205
      NST=NS(K)
C      CLEAR ZERO U.W. SIGMA-T VALUES FROM ARRAY
      DO 200 L=1,NST
      IF(SGT(J,K,L).EQ.0.0) GO TO 200
      MST=MST+1
C      MST COUNTS NON-ZERO U.W. SIGMA-T'S
      SGT(J,K,MST)=SGT(J,K,L)
C      ACCUMULATE SUMS
      SUMST=SUMST+SGT(J,K,MST)
      STSQ=STSQ+SGT(J,K,MST)**2
  200 CONTINUE
C      COMPUE STDEV OF U.W. SIGMA-T'S AS BEFORE
      IF(MST.LE.1) GO TO 205
      STUWAV=(SUMST/FLOAT(MST))**2
      ST2=(STSQ-MST*STUWAV)/FLOAT(MST-1)
      SDSTUW=SQRT(ST2)
C      GET TO 205 TO PROCESS COMBINED(WTD & U.W.) AVGS AND SUMS
  205 IF((MMW.EQ.0).AND.(MT.EQ.0)) GO TO 290
C      GET HERE IF EITHER, OR BOTH WTD AND UNWTD DATA
      A1=MT+4.0*MMW
      TSUMT=SUMT+4.0*SUMTW
      TAVT=TSUMT/A1
      IF((MST.EQ.0).AND.(MMW.EQ.0)) GO TO 220
      A2=MST+4.0*MMW
      TSUMST=SUMST+4.0*SUMSTW
      TAVST=TSUMST/A2
C      NOW WRITE RESULTS,HEADING FIRST
  220 WRITE(6,106)
      WRITE(6,107)
```

```
      WRITE(6,108) STDEP(J),TAVT,TAVST,MMW,SUMTW,SDTW,SUMSTW,SDSTW,MT,
     $SUMT,SDTUW,MST,SUMST,SDSTUW
C      LIST ALL NCN-ZERO VALUES
      IF(MMW.EQ.0) GO TO 225
      WRITE(6,109) (TEMW(J,K,L),L=1,MMW)
      WRITE(6,110) (SGTW(J,K,L),L=1,MMW)
  225 IF(MT.EQ.0) GO TO 290
      WRITE(6,111) (TEM(J,K,L),L=1,MT)
      IF(MST.EQ.0) GO TO 290
      WRITE(6,112) (SGT(J,K,L),L=1,MST)
C      NOW SET ALL COUNTERS TO ZERO AND PROCESS FOR NEXT STD DEPTH
  290 MMW=0
      SUMTW=0.0
      SUMSTW=0.0
      TWSQ=0.0
      STWSQ=0.0
      TWAV=0.0
      STWAV=0.0
      T1=0.0
      SDTW=0.0
      ST1=0.0
      SDSTW=0.0
      MT=0
      SUMT=0.0
      TSQ=0.0
      TUWAV=0.0
      T2=0.0
      SDTUW=0.0
      MST=0
      SUMST=0.0
      STSQ=0.0
      STUWAV=0.0
      ST2=0.0
      SDSTUW=0.0
      A1=0.0
      TSUMT=0.0
      TAVT=0.0
      A2=0.0
      TSUMST=0.0
      TAVST=0.0
  295 CONTINUE
  300 CONTINUE
      GO TO 1500
  980 WRITE(6,113) I
      STOP
  985 WRITE(6,114) I,JV
      STOP
  990 I=I-1
```

```
      WRITE(6,116)
      STOP
C       ZEROIZE ALL ARRAYS AND START OVER AGAIN WITH NEXT MONTH
 1500 DO 1550 J=1,24
      NR(J)=0
      NS(J)=0
      MR(J)=0
 1550 CONTINUE
      DO 1600 JJ=1,20
      DO 1590 KK=1,24
      DO 1560 LL=1,60
      TEM(JJ,KK,LL)=0.0
 1560 CONTINUE
      DO 1570 LM=1,30
      SGT(JJ,KK,LM)=0.0
 1570 CONTINUE
 1590 CONTINUE
 1600 CONTINUE
      DO 1700 JW=1,20
      DO 1690 KW=1,6
      DO 1680 LW=1,20
      TEMW(JW,KW,LW)=0.0
      SGTW(JW,KW,LW)=0.0
 1680 CONTINUE
 1690 CONTINUE
 1700 CONTINUE
 2000 CONTINUE
      WRITE(6,117)
      STOP
      END
//GC.FT06F001   DD  SPACE=(CYL,(3,1))
//GC.FT10F001   DD  UNIT=2400,VOL=SER=NPS306,LABEL=(,SL),DSNAME=LAMMERS,
//       DISP=(OLD,KEEP),DCB=(DEN=2,RECFM=FB,LRECL=80,BLKSIZE=4000)
//GC.SYSIN DD *
C
C
C*************************   END OF PROGRAMS   ********************************
```

LIST OF REFERENCES

1. Defense Scientific Establishment Report 73, R.N.Z.F.A. TUI Oceanographic Cruise - T60, North Eastern New Zealand Waters, July to October, 1964, by F. H. Barker and R. N. Denham, p. 15-17, October 1970.

2. Moss Landing Marine Laboratories' of the California State Colleges Publication 71-1, Monterey Bay Bibliography, ed. by Doris Baron, p. 1-259, March 1971.

3. Office of Naval Research Contract N6 onr-25127, Hydrographic Data From the Area of the Monterey Submarine Canyon, 1951-1955, by R. L. Bolin and Collaborators, p. 1-101, 30 July 1964.

4. Blatt, J. M., Introduction to Fortran IV Programming: Using the Watfor Compiler, p18-22, Goodyear Publishing Company, 1968.

5. Division of Sea Fisheries Investigational Report 76, Surface Currents Off the Cape Coast, by C. P. Duncan and J. H. Nell, p. 14-15, 1969.

6. Garcia, R. A., Numerical Simulation of Currents in Monterey Bay, Master's Thesis, Naval Postgraduate School, Monterey, California, 1971.

7. Hopkins Marine Station of Stanford University Unpublished Annual Reports, CalCOFI Hydrographic Data, Collected on Approximately Weekly Cruises on Monterey Bay, California, January-December, Sponsored by the Marine Research Committee, 1954-1967.

8. Leipper, D. F., "A Sequence of Current Patterns in the Gulf of Mexico," Journal of Geophysical Research, v. 75, p. 637-657, 20 January 1970.

9. Margruder, P. M., Jr., Physico-Chemical Data Available for Monterey Bay, California, a research paper for the Naval Postgraduate School, Monterey, California, April 1969.

10. McKay, D. A., A Determination of Surface Currents in the Vicinity of the Monterey Submarine Canyon by the Electromagnetic Method, Master's Thesis, Naval Postgraduate School, Monterey, California, 1970.

11. Neumann, Gerhard, and Pierson, W. J., Jr., Principles of Physical Oceanography, 1st ed., v. XII, Prentice Hall, 1966.

12. Skogsberg, T., "Hydrography of Monterey Bay, California. Thermal Conditions, 1929-1933," Transactions of the American Philosophical Society, v. 29, December 1936.

13. Stevenson, C. D., A Study of Currents in Southern Monterey Bay, Master's Thesis, Naval Postgraduate School, Monterey, California, 1964.

14. Stoddard, H. S., Feasibility Study on the Utilization of Parachute Drogues and Shore-Based Radar to Investigate Surface Circulation in Monterey Bay, Master's Thesis, Naval Postgraduate School, Monterey, California, 1971.

15. Yeske, L. A. and Waer, R. D., The Correlation of Oceanic Parameters With Light Attenuation in Monterey Bay, California, Master's Thesis, Naval Postgraduate School, Monterey, California, 1971.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Department of Oceanography, Code 58 Naval Postgraduate School Monterey, California 93940	3
4.	Professor R. S. Andrews, Code 58Ad Department of Oceanography Naval Postgraduate School Monterey, California 93940	1
5.	Professor N. E. J. Boston, Code 58Bb Department of Oceanography Naval Postgraduate School Monterey, California 93940	1
6.	Professor W. W. Denner, Code 58Dw Department of Oceanography Naval Postgraduate School Monterey, California 93940	1
7.	Professor J. A. Galt, Code 58Gl Department of Oceanography Naval Postgraduate School Monterey, California 93940	1
8.	Professor E. C. Haderlie, Code 58Hc Department of Oceanography Naval Postgraduate School Monterey, California 93940	1
9.	Professor G. H. Jung, Code 58Jg Department of Oceanography Naval Postgraduate School Monterey, California 93940	1
10.	LCDR W. C. Knodle, Code 58Kn Department of Oceanography Naval Postgraduate School Monterey, California 93940	1

11. Professor D. F. Leipper, Code 58Lr 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

12. Professor R. J. Smith, Code 58Sj 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

13. Professor W. C. Thompson, Code 58Th 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

14. Professor E. B. Thornton, Code 58Tm 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

15. Professor E. D. Traganza, Code 58Tg 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

16. Professor S. P. Tucker, Code 58Tc 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

17. Professor J. J. von Schwind, Code 58Vs 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

18. Assoc Professor J. B. Wickham, Code 58Wk 1
Department of Oceanography
Naval Postgraduate School
Monterey, California 93940

19. President 1
Marine Technology Society, Code 58
Monterey Chapter
Naval Postgraduate School
Monterey, California 93940

20. Chairman 1
Association of the Monterey Bay Area
Governments (AMBAG)
Monterey, California 93940

21. National Oceanographic Data Center (NODC) 1
Washington, D. C. 20202

22. Director 1
Hopkins Marine Station of Stanford University
Pacific Grove, California 93950

23. Director 1
Moss Landing Marine Laboratories of the
California State Colleges
Moss Landing, California 95039

24. LCDR Lennis L. Lammers (USN) 1
Q.H. 201 5th Street
Mare Island Naval Shipyard
Vallejo, California 94592

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California 93940	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

A Study of Mean Monthly Thermal Conditions and Inferred Currents in Monterey Bay

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Master's Thesis, June 1971

5. AUTHOR(S) (First name, middle initial, last name)

Lennis L. Lammers

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1971	165	15

8a. CONTRACT OR GRANT NO. b. PROJECT NO c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Postgraduate School Monterey, California 93940

13. ABSTRACT

Temperature data, collected over the past 40 years, was compiled and averaged in the first known study of mean thermal conditions throughout the waters of Monterey Bay. The following results were obtained.

(1) The distribution of mean sea surface temperature in the Bay was obtained by calculating mean monthly values at selected grid points and drawing isotherms.

(2) Progressive warming of the upper 100m was observed to occur in a nearly linear fashion with time, resulting in a maximum temperature increase of 1.8°C over the 29 year interval from 1931 to 1960. This implies that the intensity of upwelling is also decreasing with time.

(3) Geographic variations in the rates of upwelling and downwelling, causing a relatively "warm tongue" along the Canyon axis, appeared to be a major element influencing the dynamics of the Bay, and

(4) Mean currents were inferred from the topographies of mean monthly isothermal surfaces. Limited comparisons of the inferred flow to past measured currents were very encouraging and tended to support the feasibility of such an inference in the shallow waters and irregular topography of Monterey Bay.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Monterey Bay						
Mean Monthly Circulation						
Mean Monthly Thermal Conditions						