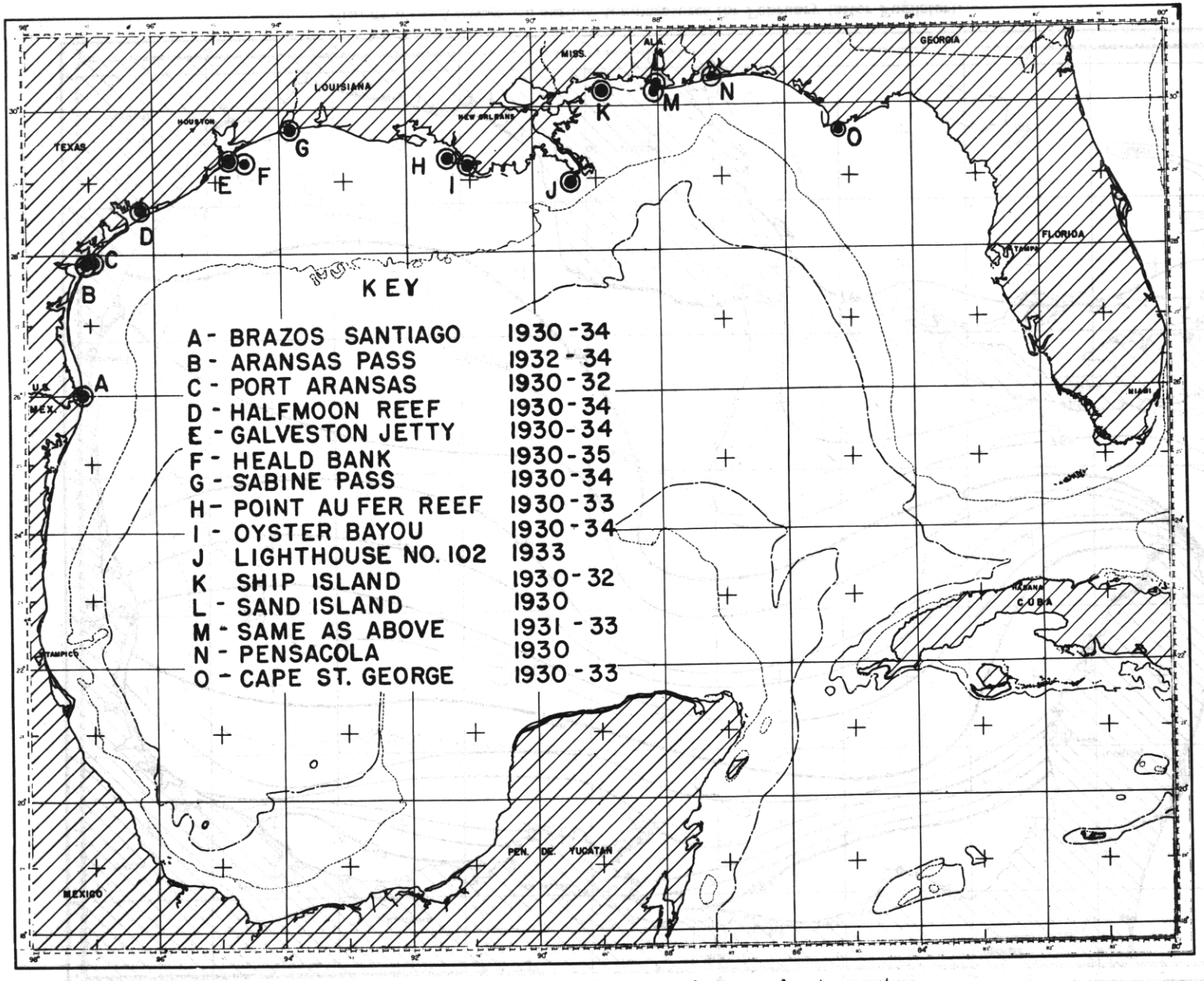

FIGURE 38.—Shore stations measuring sea surface temperature.

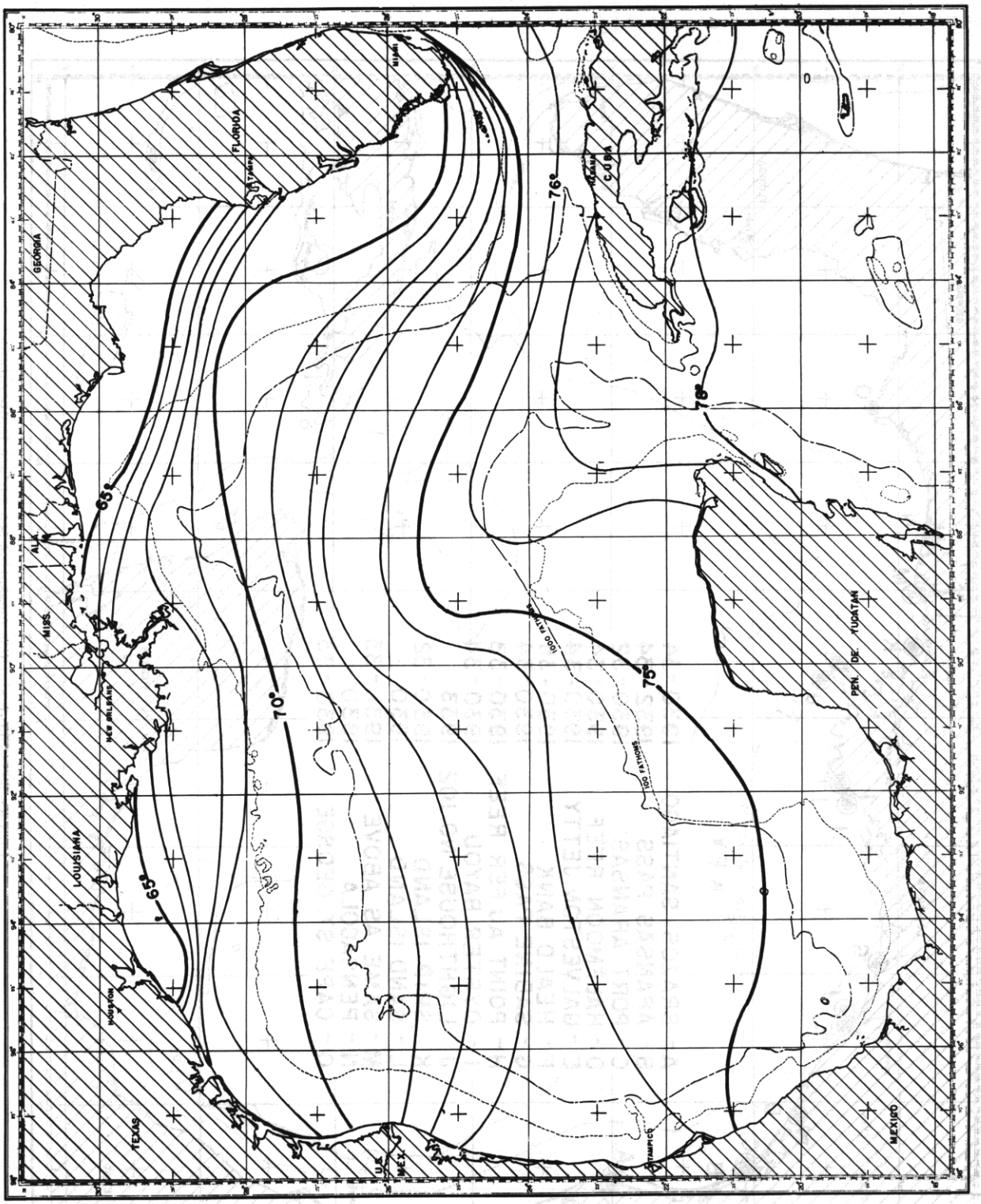

FIGURE 39.—Average sea surface temperatures for February (after Fuglister).

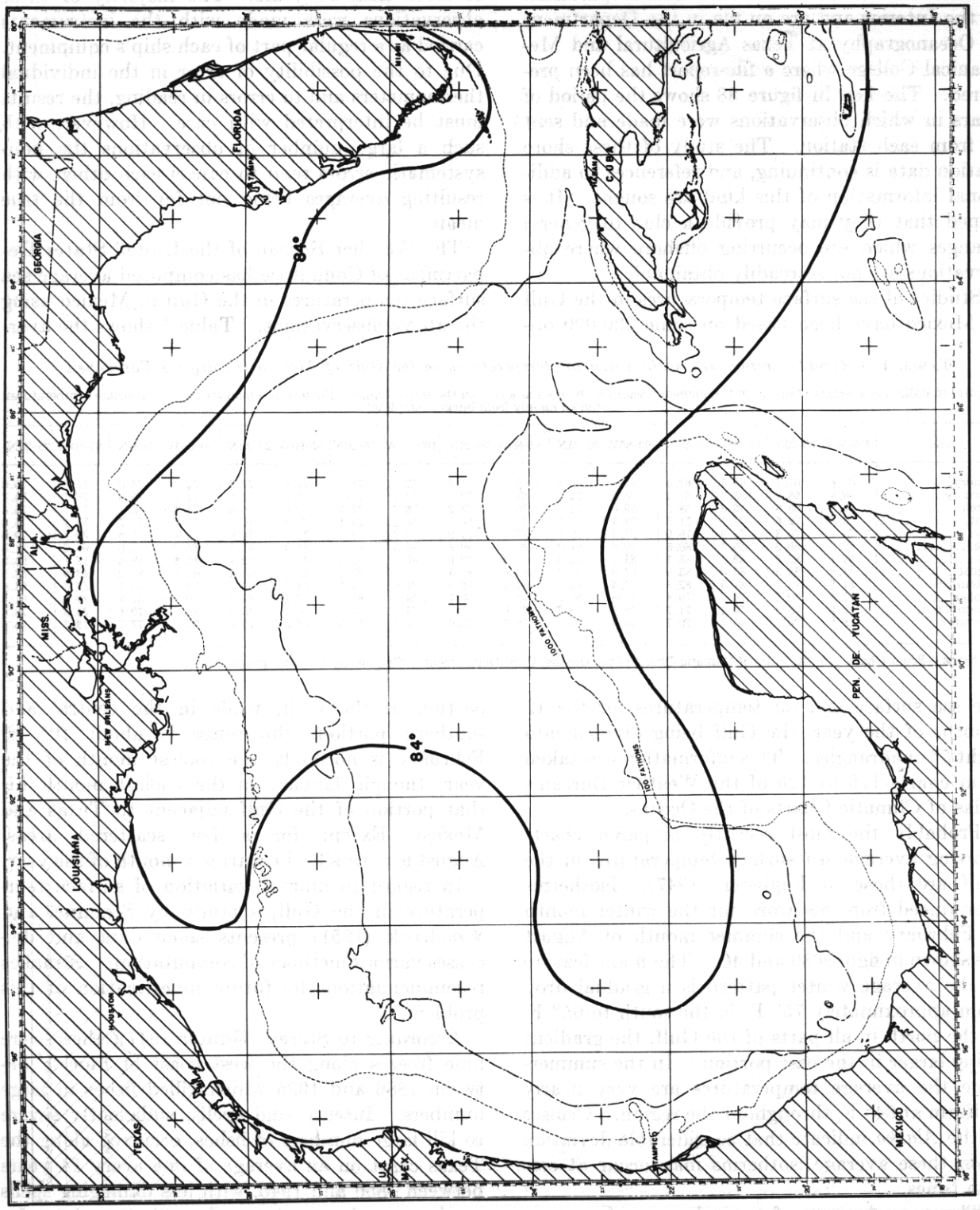

FIGURE 40.—Average sea surface temperatures for August (after Fuglister).

38 have been made available through the Fish and Wildlife Service of the United States Department of the Interior and are on file in the Department of Oceanography at Texas Agricultural and Mechanical College where a file-report has been prepared. The key in figure 38 shows the period of years in which observations were made and sent in from each station. The study of these shore station data is continuing, and references to additional information of this kind are sought. It is hoped that they may provide a clue to general changes which are occurring offshore where observations are not so readily obtainable.

Studies of sea surface temperatures in the Gulf of Mexico have been based on some 200,000 observations taken on ships in this area over a period of more than 50 years. The majority of these observations were made with the instruments carried as a regular part of each ship's equipment. Due to the possibility of error in the individual thermometers and to errors in reading, the results must be interpreted with care. However, with such a large number of observations the nonsystematic errors tend to cancel each other, with resulting averages being not far from the true mean.

The Weather Bureau of the United States Department of Commerce has computed average sea surface temperatures in the Gulf of Mexico using the above observations. Table 1 shows the average sea surface and air temperatures for the 12 months of the year, the Gulf being divided into eight 5° quadrangles. This information was taken from charts 115 to 126 of the Weather Bureau's Atlas of Climatic Charts of the Oceans.

TABLE 1.—*Monthly average sea surface and air temperatures in the Gulf of Mexico (in degrees Fahrenheit)*

[Figures in italics are averages of dry bulb thermometer readings observed as a rule on the ship's bridge. Figures in roman are mean sea surface temperatures, obtained mainly from bucket sampling]

Area	100–95W 30–25N		95–90W 30–25N		90–85W 30–25N		85–80W 30–25N		100–95W 25–20N		95–90W 25–20N		90–85W 25–20N		85–80W 25–20N	
January	*66.8*	67.7	*63.5*	67.9	*68.1*	72.5	*69.3*	73.2	*70.7*	73.0	*72.5*	74.3	*74.1*	76.3	*71.9*	75.0
February	*66.9*	68.3	*63.7*	67.3	*68.3*	72.1	*69.2*	72.7	*70.4*	72.6	*72.7*	73.9	*74.1*	76.0	*72.1*	74.7
March	*67.5*	68.8	*66.3*	68.5	*69.8*	72.6	*70.9*	73.2	*72.7*	73.3	*73.9*	74.6	*75.3*	76.4	*73.3*	75.3
April	*73.3*	72.6	*71.1*	71.6	*73.3*	74.6	*74.0*	75.2	*75.4*	75.4	*76.2*	76.1	*77.1*	77.7	*75.9*	76.8
May	*75.6*	76.3	*75.9*	76.0	*77.3*	77.7	*77.5*	77.9	*78.6*	78.5	*78.8*	78.6	*79.4*	79.5	*78.7*	79.0
June	*80.3*	80.5	*80.3*	80.6	*80.8*	81.0	*80.6*	80.8	*80.8*	81.1	*81.0*	81.2	*81.2*	81.6	*81.3*	81.5
July	*83.1*	82.6	*82.5*	83.1	*82.4*	82.9	*82.3*	82.6	*81.7*	82.5	*82.1*	82.4	*82.2*	82.6	*82.7*	83.0
August	*82.9*	83.3	*83.0*	83.9	*82.9*	83.7	*82.6*	83.4	*82.5*	83.3	*82.4*	83.2	*82.5*	83.2	*83.0*	83.8
September	*81.8*	83.3	*81.5*	82.8	*81.8*	82.9	*81.9*	82.9	*81.6*	83.1	*82.1*	83.2	*82.2*	83.1	*82.3*	83.4
October	*77.2*	80.2	*76.4*	79.4	*77.8*	80.3	*78.5*	80.7	*79.1*	81.3	*80.2*	81.6	*80.1*	81.8	*79.6*	81.5
November	*77.2*	76.3	*70.4*	74.7	*72.8*	76.7	*74.0*	77.5	*75.1*	77.9	*76.5*	78.5	*76.9*	79.5	*75.8*	78.8
December	*69.3*	70.7	*65.4*	70.7	*69.8*	74.2	*70.9*	75.0	*71.7*	74.5	*73.8*	75.9	*75.2*	77.7	*73.3*	76.5

NOTE.—From Charts 115–126, Atlas of Climatic Charts of the Oceans, U. S. Department of Commerce, Weather Bureau.

Probably the most recently prepared charts showing average sea surface temperatures in the Gulf are those of Fuglister (1947). Isotherms reproduced from his work for the winter month of February and the summer month of August are shown in figures 39 and 40. The main feature of the average winter pattern is a gradual drop from approximately 75° F. in the south to 65° F. in the north in all parts of the Gulf, the gradient being larger in the east portion. In the summertime the average temperatures are very nearly uniform at 84° F. throughout the region. Cruises of the *Alaska* indicate that considerable deviation from these average isotherms may occur at certain times.

The annual range of normal sea surface temperature varies from 15° to 20° F. in the northern portion of the Gulf, while in the central and southern portions the range is about 10° F. February is normally the coolest month of the year, though January is the coolest month for that portion of the Gulf adjacent to Texas and Mexico. Except for a few scattered areas, August is normally the warmest month of the year.

In regard to diurnal variation of surface temperature in the Gulf, a study by Stommel and Woodcock (1951) presents some data and discusses various methods of computation. It makes recommendations for future investigation of this problem.

According to Storey (Gunter 1947), there were nine freezes along the west coast of Florida between 1886 and 1936 which killed fishes in large numbers. Intense cold spells, sufficiently severe to kill large numbers of fishes, occurred along the Texas coast on an average of one every 14 years between 1856 and 1940, with less damaging spells coming at shorter intervals. Similar data for other parts of the Gulf coast are not available.

Slocum (1934–36) has made a comparative study of sea surface temperatures for various regions of the Gulf in different years. This study is based on temperature observations taken from 1912 to 1933. The year-to-year changes are summarized in table 2 for the regions shown by

TABLE 2.—*Some variations of mean annual sea surface temperatures for 1912–33* [1] *in various regions of the Gulf* (° F.)

[After Slocum]

Variation	(1) 25–26° N. 84–86° W.		(2) 27–29° N. 90–93° W.		(3) 26–28° N. 86–89° W.		(4) 21–25° N. 90–94° W.		(5) 23–24° N. 82–84° W.		(6) 21–22° N., 85–87° W. 22–23° N., 84–87° W.	
High	79.5		77.0		78.7		79.7		80.9		81.1	
Dif.		1.1		1.5		0.9		1.2		1.0		0.8
Mean	78.4		75.5		77.8		78.5		79.9		80.3	
Dif.		1.6		1.6		1.2		0.9		2.1		1.0
Low	76.8		73.9		76.6		77.6		77.8		79.3	
High-Low Dif.		2.7		3.1		2.1		2.1		3.1		1.8

[1] The number of observations varies from year to year. Few observations were made in 1917–19. In other years, the number ranged from 100 to over a thousand in each region. Locations are shown in figure 41.

encircled numbers in figure 41. The mean temperature for each year has been computed. It is of interest to note that in one case the minimum mean yearly temperature for a given region for this period of years differed from the overall mean temperature for the region by 2.1° F. Moreover, the maximum and minimum mean yearly temperatures differ by 3.1° F. in two localities. For one of these extreme examples, in the region 27–29° N., 90–93° W., the lowest mean yearly temperature recorded was for the year 1915 which showed a mean temperature of 73.9° F. In 1922 and 1927, the highest mean temperatures were recorded here, being 77.0° F. For the other example, the low was 77.8° F., the high 80.9° F. Slocum's study also included consideration of the means for the different months of the year.

SEA TEMPERATURE VARIATIONS WITH DEPTH

The sea temperatures obtained by the *Mabel Taylor* below the surface have been published by Parr (1935). Although the depths of these observations are not known accurately, they do give considerable information about vertical temperature distribution. An average temperature-salinity correlation in the Gulf of Mexico proper as worked out by Parr for the months February–April is given as table 3.

In the early 1940's the United States Navy developed the bathythermograph for making observations of sea temperature continuously from the surface to depths as great as 900 feet. To date, some 10,000 observations or bathythermograms have been made in the Gulf. Copies of these are now filed at the Woods Hole Oceanographic Institution where they are processed and in the Department of Oceanography at Texas Agricultural and Mechanical College. Their distribution by 1° quadrangles is shown in figure 42.

TABLE 3.—*An average temperature-salinity correlation for the Gulf of Mexico proper*

[After Parr]

Average temperature	Average salinity	Weighted average depth
° C.	°/∞	m.
24.74	36.19	5
23.06	36.06	15
21.03	36.14	58
19.25	36.28	94
17.09	36.22	125
14.85	35.95	192
13.00	35.68	237
10.89	35.35	321
9.60	35.16	380
8.57	35.04	432
7.42	34.93	562
6.39	34.88	647

Two bathythermograms, one for summer and the other for winter, were chosen from each of four parts of the Gulf within the 1,000-fathom line. These locations are indicated by encircled crosses in figure 41. The bathythermograms were chosen as being typical after considering range of temperature variation, general shape of temperature-depth curve, depth of thermocline, and other features. Unfortunately, due to the paucity of observations it was not possible at any one of the four positions to obtain "typical" summer and winter bathythermograms from the same year. However, by plotting a typical summer and a typical winter bathythermogram for each position on the same coordinates it was possible to show in a general

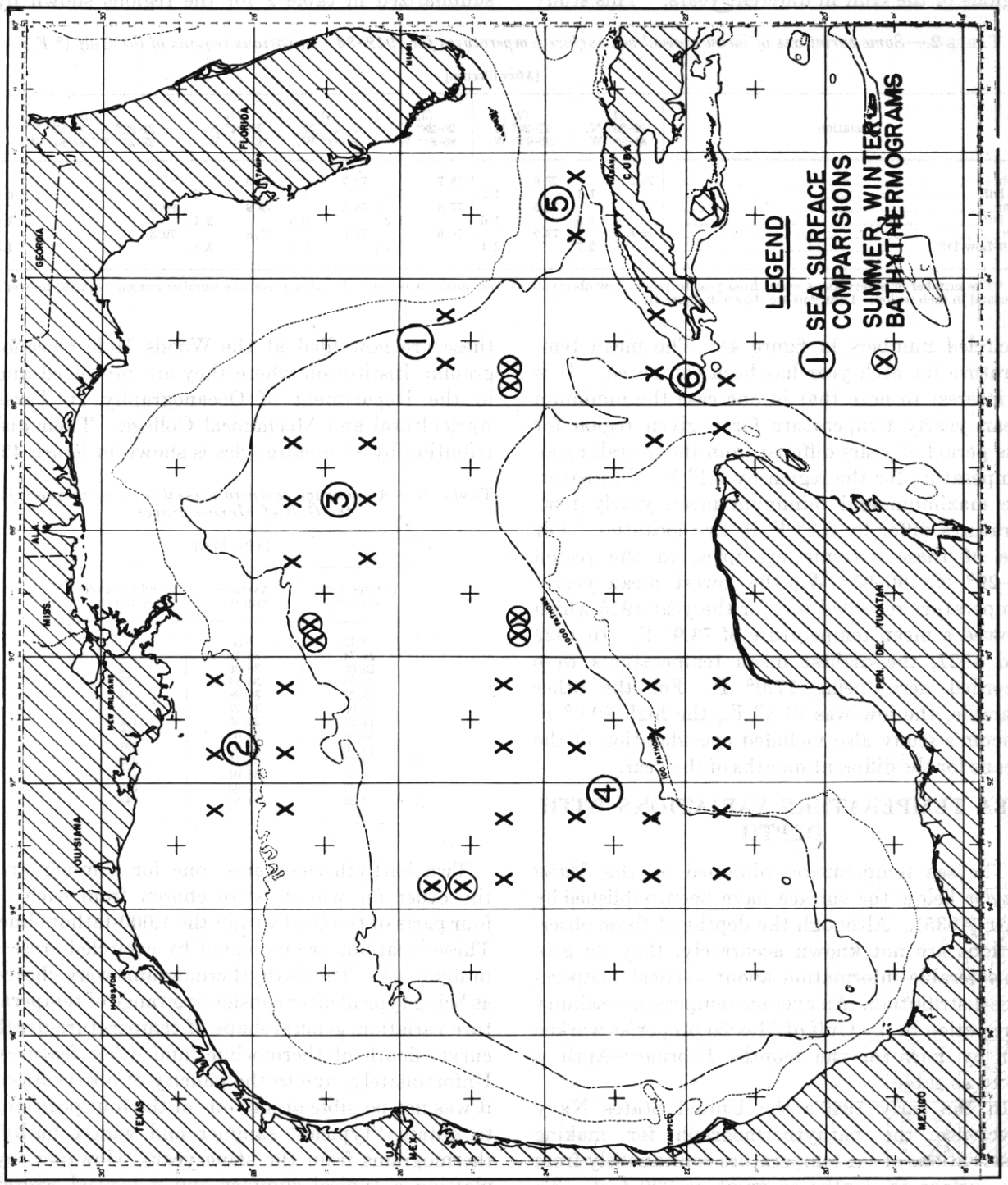

FIGURE 41.—Regions where comparative studies of sea temperatures were made.

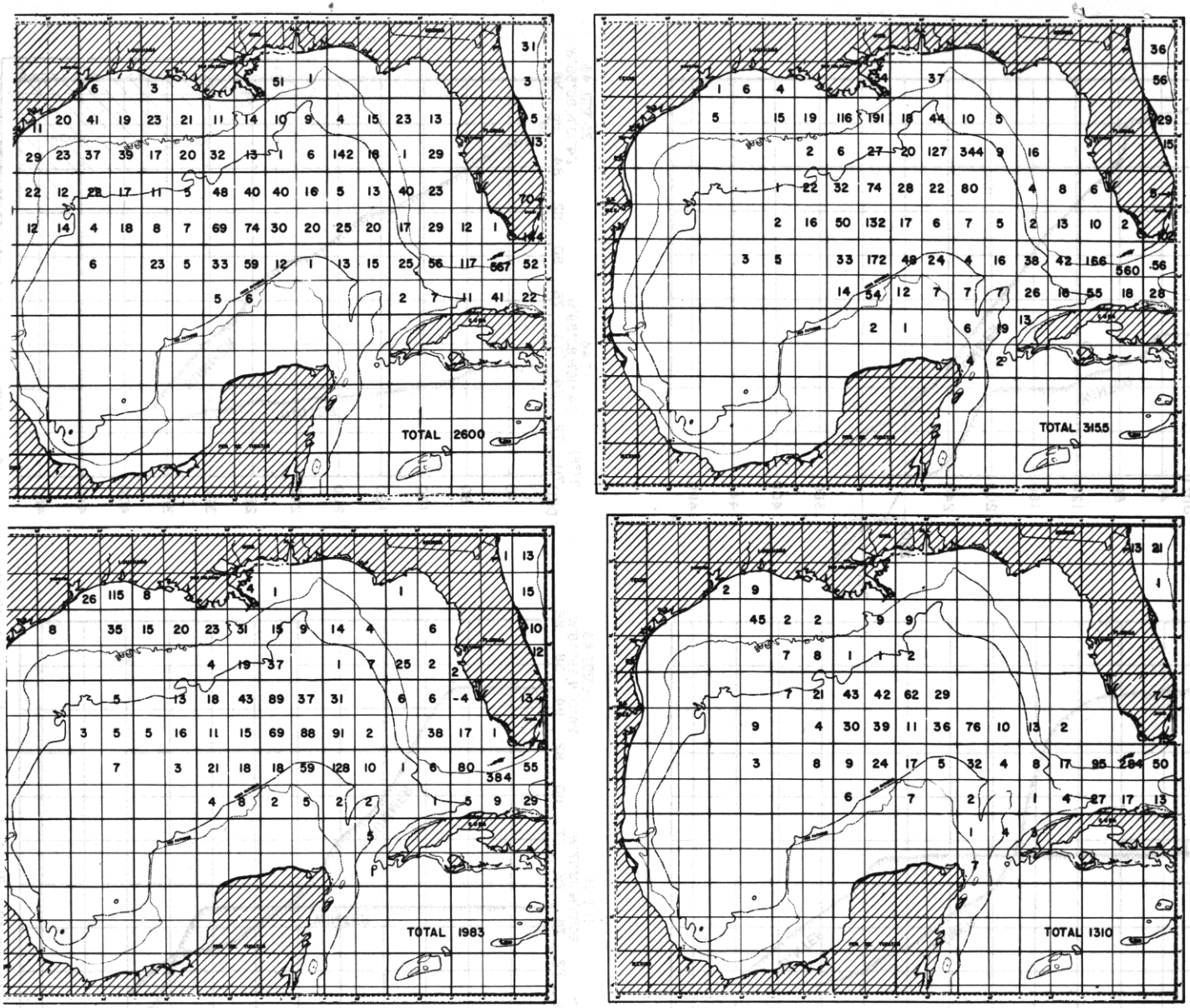

FIGURE 42.—(Upper left) Distribution of available bathythermograms January, February, March, 1941 through 1949. (Upper right) Distribution of available bathythermograms April, May, June, 1941 through 1949. (Lower left) Distribution of available bathythermograms July, August, September, 1941 through 1949. (Lower right) Distribution of available bathythermograms October, November, December, 1941 through 1949.

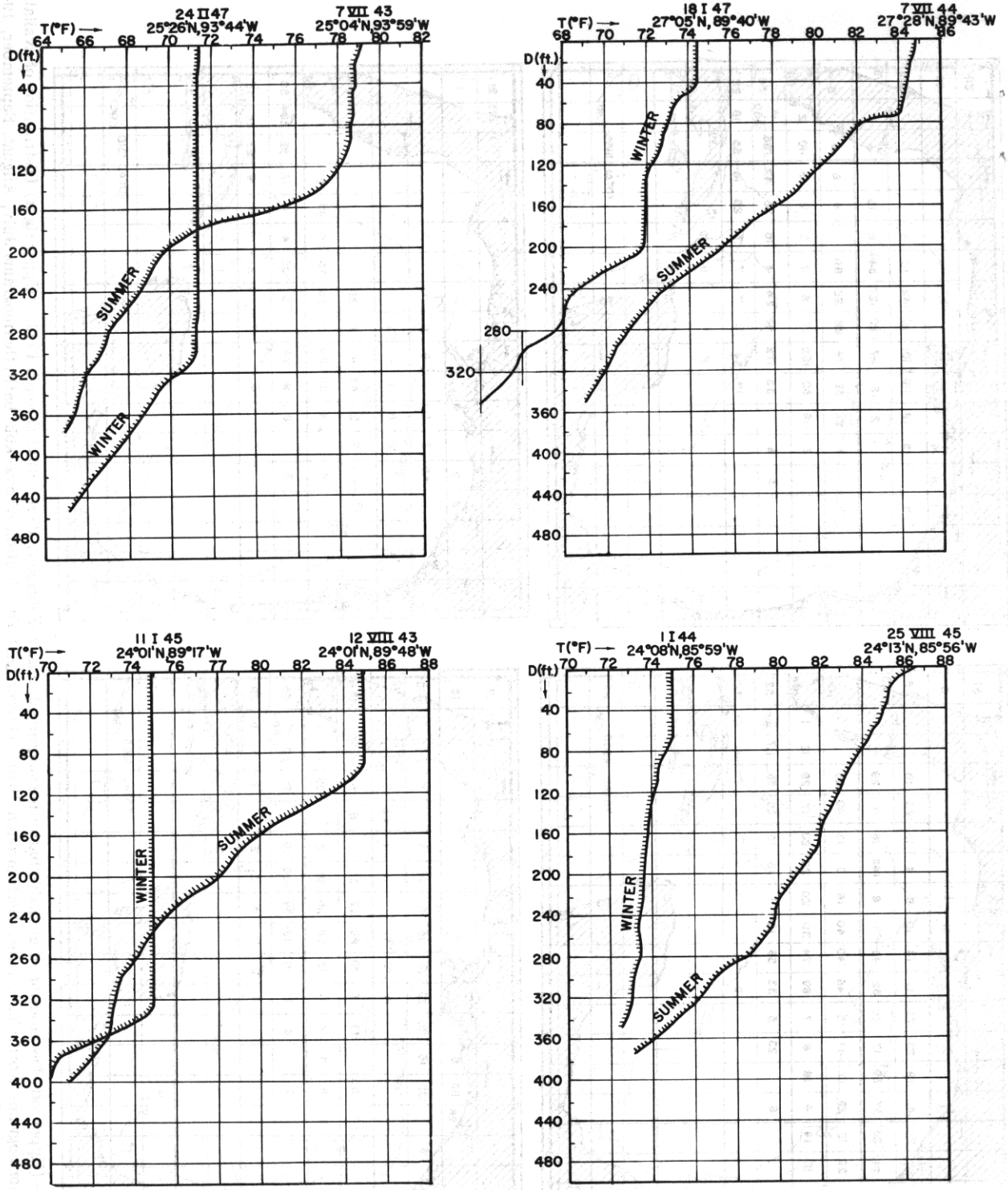

FIGURE 43.—Typical summer and winter bathythermograms from different areas in the Gulf of Mexico.

way the seasonal differences. These curves are presented in figure 43 which gives the date and position of each observation. Typical curves properly selected are believed more representative of conditions than average ones, since certain characteristic features of temperature structure may be lost in the process of averaging. A report by Adams and Sorgnit (1951) gives similar information for each 1° quadrangle of the Gulf where data were available. It also shows the contours of the bottom of the mixed or isothermal layer in summer and winter insofar as can be determined.

SALINITY

Parr (1935) presents a chart of the distribution of average salinities in the upper 50 meters of the Gulf of Mexico. It shows the values to be typically 36.00 parts per thousand over the entire central region. Water from the Mississippi River reaches to depths of 50 meters and extends beyond *Mabel Taylor* station 1106 (fig. 36), a distance of 150 miles, keeping salinities below 36.00 parts per thousand. Near stations 1201 and 1202 the river extends its influence on salinity only about 85 miles seaward.

From the Yucatán Channel a subsurface intrusion of water having salinity over 36.50 parts per thousand extends north and bends westward to the central part of the Gulf. From February to April this tongue underwent a marked shift westward in position of some 120 miles according to the *Mabel Taylor* data.

Above 50 meters waters of salinity greater than 36.25 parts per thousand are found over both the wide Campeche and Florida Banks indicating possible upwelling of the subsurface intrusion.

Average variation of salinity with depth is shown in table 3.

TEMPERATURE-SALINITY RELATIONSHIPS

An average temperature-salinity relationship for the Gulf proper was shown in table 3. A single station typical of what Parr defined as the Gulf Complex is *Mabel Taylor* station 705 (fig. 36). Another which he calls typical of the Caribbean Complex, divided from the Gulf Complex by a line extending from the northeast corner of Yucatán Bank to the southwest corner of the Florida Bank, is station 701 (fig. 36). Data for these stations are listed in table 4. The primary difference between these two distributions is that at temperatures above 18° C. the Gulf Complex station has markedly lower salinities, being below 36.32 parts per thousand, while the Caribbean station has values as high as 36.73 parts per thousand.

The T–S curves in the Yucatán Channel do not seem to vary significantly from year to year, but those in the Straits of Florida are not so stable, particularly at temperatures above 20° C. Cruises in different years in the Straits have shown wide variations in the extent of Gulf water found in the upper 200 meters.

TABLE 4.—*Typical temperature and salinity data*

[After Parr]

Gulf Complex Station 705, Feb. 18, 27°42′ N., 86°00′ W.			Caribbean Complex Station 701, Feb. 16, 23°28′ N., 85°37′ W.		
Depth	Salinity	Temperature	Depth	Salinity	Temperature
m.	‰	° C.	m.	‰	° C.
0	35.52	23.75	0	36.18	25.34
30	36.15	23.15	100	36.32	25.28
100	36.32	18.59	200	36.73	21.88
150	36.21	16.58	300	36.44	18.21
200	35.96	14.94	400	35.94	14.96
300	35.52	12.30	600	35.08	9.12
500	35.08	7.88	800	34.86	6.86
700	34.87	5.91	1,000	----------	5.15
900	34.92	4.94			
1,200	34.95	4.21			
1,500	34.97	4.21			
2,000	34.97	4.16			
2,500	34.97	4.22			
3,000	34.97	4.24			

Parr (1935) believes that since—

> The presence of Gulf waters in the Straits of Florida is . . . identified with the location in which a countercurrent running in the opposite direction of the Caribbean-Florida Current flow is usually indicated on the hydrographic charts. . . . it seems reasonable to draw the tentative conclusion "the water masses of the Gulf of Mexico proper should be considered part of the coastal water system of the North and Central American Atlantic seaboard and not as part of the oceanic circulation system of the Caribbean and Florida Currents."

Considerable further evidence is required to fully support this tentative conclusion.

Below 800–1,200 meters depth observations of the *Mabel Taylor* showed hydrographic conditions in the Gulf so extremely uniform that it was not considered advisable to attempt to prepare vertical profiles for the deep layers. More accurate depth determinations on subsequent investigations may bring out significant variations at these depths.

OCEAN WIND WAVES AND SWELL

A basic and easily obtainable reference for climatic data on waves in the Gulf is the Atlas of Sea and Swell Charts of the United States Navy Hydrographic Office (1943–50), Miscellaneous Publication No. 10,712, A through D. Certain uses of these data are discussed by Fleming and Bates (1951).

Information concerning wave heights in some regions on certain specific days may be obtained by referring to wind data available through the United States Weather Bureau and applying a method of calculation described in United States Navy Hydrographic Office Publication No. 604, Techniques for Forecasting Wind Waves and Swell.

The problem of wave action on structures is discussed by Munk (1947). Considerable additional research will be required before knowledge of wave forces in the Gulf is complete. Such work has been underway at the University of California (La Jolla and Berkeley) and is being initiated at Texas Agricultural and Mechanical College.

SHALLOW WATER OCEANOGRAPHY

Much of the marine interest on the Gulf coast tends to center on the shallow waters. There are many bays, lagoons, and inlets of great importance to fishing, navigation, recreation, oil recovery, and other activities. Each of these presents its own peculiar problems, and extensive investigations have been carried on in many of them. A recent publication indicating the nature of this work is that of Collier and Hedgpeth (1950). A good bibliography is included indicating the variety of studies which are important in determining the physical characteristics of such regions.

Many analyses of shallow water areas have been conducted for private sponsors, and the results are not yet available. However, they are gradually being released for publication.

BIBLIOGRAPHY

Adams, Richard M., and Sorgnit, Ernest F.
1951. Comparison of summer and winter sea temperatures, Gulf of Mexico. Dept. of Oceanog., Texas Agricultural and Mechanical College, July.

Agassiz, A.
1888. Three cruises of the United States Coast and Geodetic Survey Steamer *Blake* . . . Bull. Mus. Comp. Zool., Harvard College, vols. 14 and 15. Cambridge, Mass.

Bigelow, Henry B.
1917. Explorations of the United States Coast and Geodetic Survey Steamer *Bache* in the western Atlantic, January–March, 1914, under the direction of the United States Bureau of Fisheries. Oceanography. App. 5, Rept., U. S. Comm. Fish., 1915 (1917). Bur. Fish. Doc. 833, 62 pp., 53 text figs., 1 chart. Washington.

Cline, I. M.
1920. Relations in changes in storm tides on the coast of the Gulf of Mexico to the center and movement of hurricanes. Monthly Weather Review 48: 127–146.

Collier, Albert, and Hedgpeth, Joel.
1950. An introduction to the hydrography of tidal waters of Texas. Inst. Mar. Science, Univ. of Texas, 1(2): 121–194, 32 figs.

Dietrich, Gunter.
1939. Das Amerikanische Mittelmeer. Gesellsch. f. Erdkunde zu Berlin, Zeitschr., pp. 108–130.

Fleming, R. H., and Bates, C. C.
1951. The engineering application of sea and swell data. Coastal Engineering, Council on Wave Research, The Engineering Foundation.

Fuglister, Frederick C.
1947. Average monthly sea surface temperatures of the western North Atlantic Ocean. Pap. in Phys. Oceanog. and Meteor., Massachusetts Inst. Tech. and Woods Hole Oceanog. Inst. 10(2): 3–25.

Geyer, Richard A.
1950. A bibliography on the Gulf of Mexico. Texas Jour. Sci. 2(1): 44–93.

Gunter, Gordon.
1947. Catastrophism in the sea and its paleontological significance, with special reference to the Gulf of Mexico. Am. Jour. Sci. 245(11): 669–676.

Lindenkohl, A.
1896. Resultate der Temperatur—und Dichtigkeitsbeobachtungen in den Gewassern des Golfstroms und des Golfs von Mexico durch das Bureau des U. S. Coast and Geodetic Survey. Petermanns Geogr. Mitteilungen, Heft II, pp. 25–29. map.

Montgomery, R. B.
1938. Fluctuations in monthly sea level on eastern U. S. coast as related to dynamics of western North Atlantic Ocean. Jour. Mar. Res. 1 (2): 165–185.

Munk, Walter H.
1947. Wave action on structures. Am. Inst. Mining and Metallurgical Engrs., Tech. Pub. No. 2322 Class G Petroleum Technology.

Parr, Albert Eide.
1935. Report on hydrographic observations in the Gulf of Mexico and the adjacent straits made during the Yale Oceanographic Expedition on the *Mabel Taylor* in 1932. Bull. Bingham Oceanog. Coll. 5 (1): 1–93.
1937. A contribution to the hydrography of the Caribbean and the Cayman Seas. Bull. Bingham. Oceanog. Coll. 5 (4): 1–110.

Phleger, F. B. and Francis L. Parker.
1951. Ecology of Foraminifera, northwest Gulf of Mexico. Pt. I, by F. B. Phleger. Foraminifera distribution. Mem. Geol. Soc. America, 46: 1–88.

PILLSBURY, J. E.
1889. Gulf Stream explorations; observations of currents, 1887. Rept. Supt. U. S. Coast and Geod. Sur. for 1887, App. 8, pp. 173–184. Washington.

SLOCUM, GILES.
1934–36. Sea surface temperature summaries for various sections of the Gulf of Mexico. Monthly Weather Review 62, 1934; 63, 1935; 64, 1936.

SMITH, F. G. WALTON; MEDINA, A. FRANCO; and ABELLA, A. F. BROOKS.
1951. Distribution of vertical water movement calculated from surface drift vectors. Bull. Mar. Sci. of the Gulf and Caribbean 1 (3). November.

STOMMEL, HENRY, and WOODCOCK, ALFRED H.
1951. Diurnal heating of the surface of the Gulf of Mexico in the spring of 1942. Am. Geophys. Union Trans. 34 (4). August.

SWEITZER, N. B., Jr.
1898. Origin of the Gulf Stream and circulation of waters in the Gulf of Mexico, with special reference to the effect on jetty construction. Trans. Am. Soc. Civil Engrs. 40: 86–98.

SVERDRUP, H. U.; JOHNSON, MARTIN W.; and FLEMING, RICHARD H.
1942. The oceans. 1087 pp. Prentice-Hall, Inc., New York.

TANNEHILL, I. R.
1927. Some inundations attending tropical cyclones. Monthly Weather Review 55: 453–455.

UNITED STATES COAST PILOT.
1949. Gulf coast Key West to Rio Grande. 3rd ed. p. 46. United States Government Printing Office, Washington.