FLUCTUATIONS OF SEA SURFACE TEMPERATURE AND DENSITY AT COASTAL STATIONS DURING 1976

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Sea surface temperature (SST) and density measurements have been made routinely at many U.S. National Ocean Survey (NOS) tide gages and other coastal stations for many years. Although the data suffer from various problems such as gaps in coverage or inadequate exposure to open ocean conditions, careful selection of stations allows the data to be used as an inexpensive monitor of climatic fluctuations in nearshore waters. This report summarizes monthly mean SST and density fluctuations for 1976 and long-term means for three coasts of North America. The data are contoured in a common manner for each coast to flag unusual climatic events and to allow comparison of fluctuations between coasts.

This report is a refinement for 1976 of a similar report by Goulet (1978). His plots were for 1974 and 1975 only, as earlier data were not available in a computer compatible format. Subsequently, a computer tape of all available historical monthly mean temperature, density, and sea level data taken at NOS tide gage control stations was developed.[2] The Tides Branch of NOS provided update punch cards of monthly mean data. These data and certain Canadian data[3] were merged with the historical tape for preparation of this report. The data are now archived by the National Oceanographic Data Center and are available through their Data Services Division.

McLain (1978) presented time series of monthly mean anomalies of SST's at coastal stations along the west coast of North America. Presented here are distance vs. time contours of long-term means and anomalies from the means for 1976 SST and density at selected

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stations along the coasts of North America (Appendix 10.1).

The 1976 data are presented as anomalies from a long-term mean for the period 1948-75. This reference period differs from the 1948-67 period used for other data sets such as maps of SST anomaly (McLain, Paper 9). The change was necessary to develop means for certain stations which were established in the last decade.

The stations used in this report are shown in Figure 10.1. The stations chosen were those which had the best combination of desirable characteristics: exposure to open ocean conditions, long data records, minimum gaps in data records, and equidistance between stations. The ideal combination seldom existed and consequently many of the sations used were in estuaries, had gaps in coverage, or were at varying intervals along the coast. For example, data coverage is poor in Oregon and Washington as all stations are in estuaries or are subject to river runoff (as at Neah Bay near the mouth of the Strait of Juan de Fuca). Good coverage was available from British Columbia lighthouses which have long complete data records from open, exposed locations.

The data are plotted as contoured isopleths of the long-term mean and anomaly by month and station position along the coast. Temperature data are in degrees Celsius while density data are in sigma-t units [(density-1) x 1000]. Density values are computed for a standard water temperature of 15.0C. All monthly means represent at least 12 daily observations.

WEST COAST SEA SURFACE TEMPERATURES

The long-term monthly mean (1948-75) SST's at stations along the west coast of North America (Fig. 10.2) had minimum values in January and February and maximum values in July or August. Minimum winter temperature occurred at Kodiak, AK, while maximum summer temperature occurred at Los Angeles, CA. The winter minima occurred earlier (in January) at the southern stations (California to southern British Columbia) than at the northern stations, where minimum values occurred in February. Summer maxima occurred in August at all stations along the coast except at Neah Bay, WA, where the maximum occurred in July.

Bakun et al. (1974) described the long-term mean distribution of SST from ships in 1-deg squares of longitude and latitude adjacent to the west coast of the United States. Their data show that offshore SST minima and maxima occur about one month later than at the shore stations. This may result from more rapid warming in spring and cooling in fall in shallower coastal waters. The summer maximum temperatures reported by Bakun et al. (1974) are similar to those at the coastal stations but winter minimum temperatures are about 1C lower at the coastal stations. This depression of coastal coastal temperatures may result from the lower heat capacity of the shallower water column at the coastal stations as compared to the offshore areas.

Both Figure 10.2 and the figure of Bakun et al. (1974) show a horizontal trend to the isotherms near Point Conception, CA, between Port San Luis and Los Angeles. This "flattening" of the isotherms is an indication of change of ocean water masses at Point Conception between the cold California Current water to the north and the warmer water of the Los Angeles Bight to the south.

During 1976 the anomalies of SST's at coastal stations were rather noisy and the only major trend was the presence of cooler than normal water along the coast during spring and summer from Sitka, AK, south to California. During summer, first in southeastern Alaska and later farther south, the anomalously cool water was replaced by warmer than normal water which reached maximum anomalies of +2.5C at Yakutat, AK, and off southern California in November and December.

The SST charts presented monthly in _Fishing Information_ showed general negative anomalies of SST along the coast during 1976 until July when positive anomalies first impinged against the Oregon and southern California coasts. Positive anomalies spread during summer and fall and occurred along the entire coast in November and December, in agreement with the coastal station data.

WEST COAST DENSITIES

The long-term mean distribution of density along the west coast of North America (Fig. 10.3) showed that minimum densities occurred off California in February, probably in response to winter rains. In Alaska, however, minimum densities occurred in June or July due to snow and glacial melt.

During 1976, observations of density were spotty but showed positive anomalies off most of the coast most of the year. Large positive anomalies of density off San Francisco and Crescent City were associated with drought conditions existing over California most of the year. The low densities at Kodiak, AK, in August and September were apparently in response to local precipitation.

EAST COAST SEA SURFACE TEMPERATURES

The long-term mean SST's at stations along the east coast (Fig. 10.4) showed minimum temperatures at all stations January-March, and maximum temperatures July-September. As for the west coast, the peaks were earlier (January and July-August) at the southern stations and later (February-March and August-September) at the northern stations. Minimum winter temperatures of 0.6C occurred in February at Portland, ME, and maximum summer temperatures of 30.7C occurred in August at Key West, FL.

Two regions of rapid change of SST with distance can be seen (Fig. 10.4). These regions are between Kiptopeke Beach, VA, and Myrtle Beach, SC, and between Mayport and Miami Beach, FL. As at Point Conception on the west coast, these regions are associated with changes in ocean circulation and occur at Cape Hatteras and Cape Canaveral, respectively. Unlike Point Conception, however, where the greatest SST change between adjacent stations occurred in summer (4.0C change in August), the greatest changes in SST between stations on the east coast occurred in winter or spring (8.2C change in January at Cape Canaveral and 5.7C in April at Cape Hatteras).

During 1976, sampling at the stations was incomplete and many values were missing. In January anomalies of SST were negative along the entire coast as were air temperatures over most of the eastern United States (Wagner 1976). Anomalous warming occurred in February, and by March SST's were above normal along the coast (up to 2.6C above normal at Charleston, SC). This warming also was mentioned by Taubensee (1976a). During the summer months anomalies were positive at Montauk Point, NY, and to the north but were negative to the south. SST's were generally below normal during the fall, and became extremely cold in November as the unusually cold winter of 1976-77 began. An extreme negative anomaly of -5.5C was observed at Sandy Hook, NJ, in November.

Chamberlin and Armstrong (Paper 5) summarized air temperature data along the east coast to show the development of the winter of 1976-77 when strong northerly winds occurred over much of the eastern United States. Their data, from National Weather Service weather stations for the period July 1976-January 1977, indicated that anomalies of air temperatures in fall 1976 were most negative during November over most of the coast. This is in agreement with the SST data. In neither the air temperature nor the SST data did large negative anomalies occur as far south as Miami or Key West, FL. Dickson (1977) also showed that southern Florida air temperatures were not unusually cold in November. The strong negative anomalies of SST in November were a response to the extremely southern location of the jet stream and the consequent cold, dry winds from the north and northwest. These atmospheric conditions enhanced heat loss from the water, strengthened southward-flowing coastal currents, and increased vertical mixing. Evidently these processes were not fully effective at Miami and Key West where SST's are more closely associated with Gulf Stream advective processes.

EAST COAST DENSITIES

The long-term mean density data on the east coast (Fig. 10.5) show that many of the stations are affected by land runoff. Such runoff is particularly evident in the figure at Boston, MA, Sandy Hook, NJ, Kiptopeake Beach, VA, and Charleston, SC, where closed contours enclose regions of minimum water density. Minimum density water occurred at the northern stations March-May, while at the southern stations it occurred January-April. This delay in the time of minimum density at the northern stations resulted from retarded snowmelt and river discharge in spring in the north relative to winter precipitation in the south. The timing of maximum water density similarly is delayed to the north as maximum density generally occurred May-September at the southern stations and during September or October at the northern stations.

During 1976 density observations were frequently missing, and the available observations did not have much coherence from station to station or month to month. A region of coherent positive anomalies occurred from Montauk Point, NY, and north over most of the year, with the obvious exception of Boston, MA, and Portland, ME, during January-March. Positive density anomalies at Woods Hole, MA, and Montauk Point increased rather steadily during the year.

Large and variable anomalies occurred at Charleston, SC, and Mayport, FL, and resulted from fluctuations of river discharge near these stations. For example, the positive anomalies of density at these stations February-May were associated with drought during February and March (Dickson 1976a; Taubensee 1976a). Similarly the negative density anomalies at these stations in June were associated with higher than normal precipitation in the area (Dickson 1976b; Taubensee 1976b).

GULF OF MEXICO COAST SEA SURFACE TEMPERATURES

The long-term means of SST's at all stations along the U.S. coast of the Gulf of Mexico (Fig. 10.6) showed minimum values in January and maximum values in July or August. Minimum winter temperatures occurred at the most northern, estuarine station, Dauphin Island, AL, and maximum summer temperatures occurred at the most southern, open ocean station, Key West, FL.

During 1976, observations of SST's at Gulf coast stations were fairly complete and showed good coherence in space and time. A pattern of SST anomalies similar to that observed at east coast stations from New Jersey to Florida occurred. SST's were anomalously cold at all Gulf coast stations during December 1975 and January 1976 with the greatest anomalies in Florida. Anomalous warming began in February in Texas, and SST anomalies peaked in March at Cedar Key, FL. Anomalous cooling then occurred over most of the area for the remainder of the year, peaking in the large negative anomalies of November over most of the coast. The negative anomalies in November were <1C in magnitude only at Key West, FL. The greatest negative anomaly (-5.1C) was at Galveston, TX, in November. Chamberlin and Armstrong (Paper 11) in their summary of Gulf coast air temperatures during late 1976 also found greatest negative anomalies at Galveston during November. The anomalies of air temperature were caused by strong northerly winds, whereas the SST anomalies were caused by heat losses to the cold, dry air.

GULF OF MEXICO COAST DENSITIES

Long-term mean water density (Fig. 10.7) ranged from almost fresh in January at Dauphin Island, AL (in Mobile Bay), to open ocean conditions at Key West, FL. The months of minimum and maximum densities varied and reflected variations in timing of local river discharge. Minimum densities occurred January-June and maximum densities occurred June-November.

Anomalies of density in 1976 were variable, and apparently were related to local fluctuations of precipitation and runoff. Negative anomalies of density were observed almost all year at south Texas stations. Positive anomalies occurred during August-October from Dauphin Island to Key West, and into December at stations in southern Florida.

SUMMARY

Although coastal station data are noisy and have frequent gaps in coverage, they do show large-scale coherences among stations. These coherences are in general caused by climatic fluctuations that affect long stretches of coastline. An extreme example of such a climatic change is the strong northerly winds over much of the eastern United States during November 1976. These winds created negative anomalies of SST at coastal stations of at least

-1C in magnitude from Portland ME, to Mayport, FL, and from St. Petersburg, FL, to Padre Island, TX. Extreme anomalies of -5.5C were observed at Sandy Hook, NJ, and -5.1C at Galveston, TX, in November.

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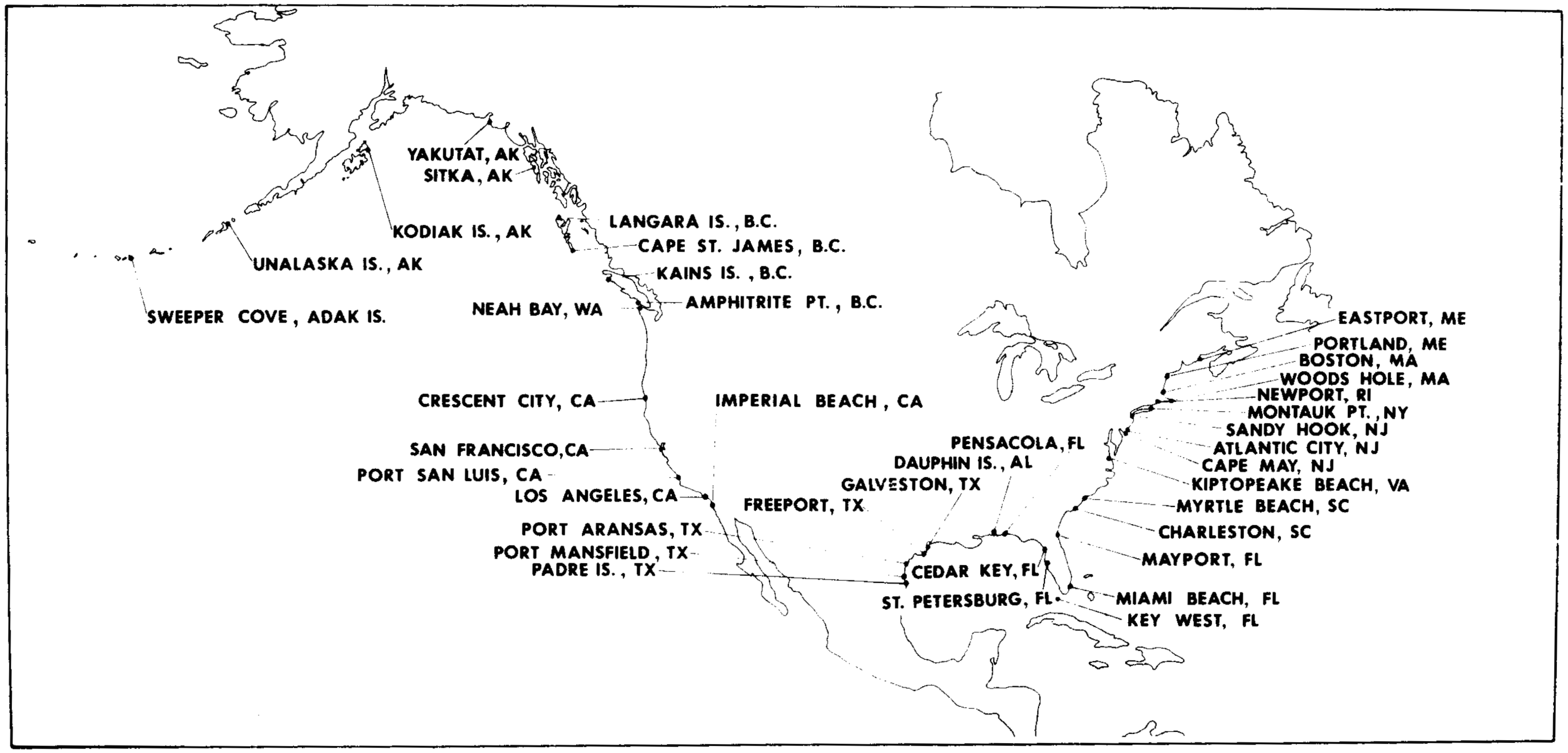

Figure 10.1.—Location of coastal stations (see Appendix 10.1).

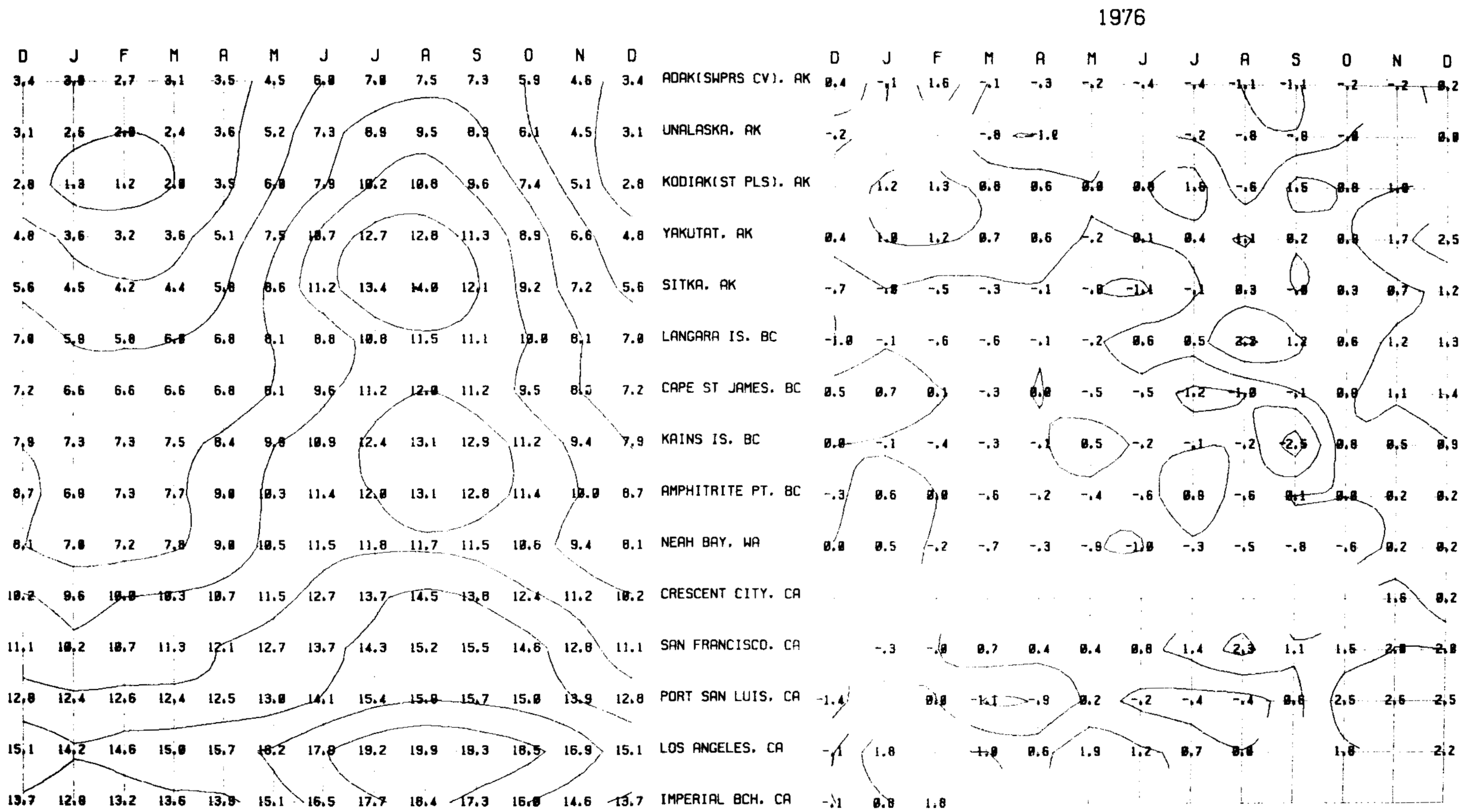

Figure 10.2.—Long-term mean for 1948-75 (left) and anomalies for 1976 (right) of sea surface temperature (degrees C) along the U.S. west coast. Contour intervals are 2.0C for mean and 1.0C for anomalies.

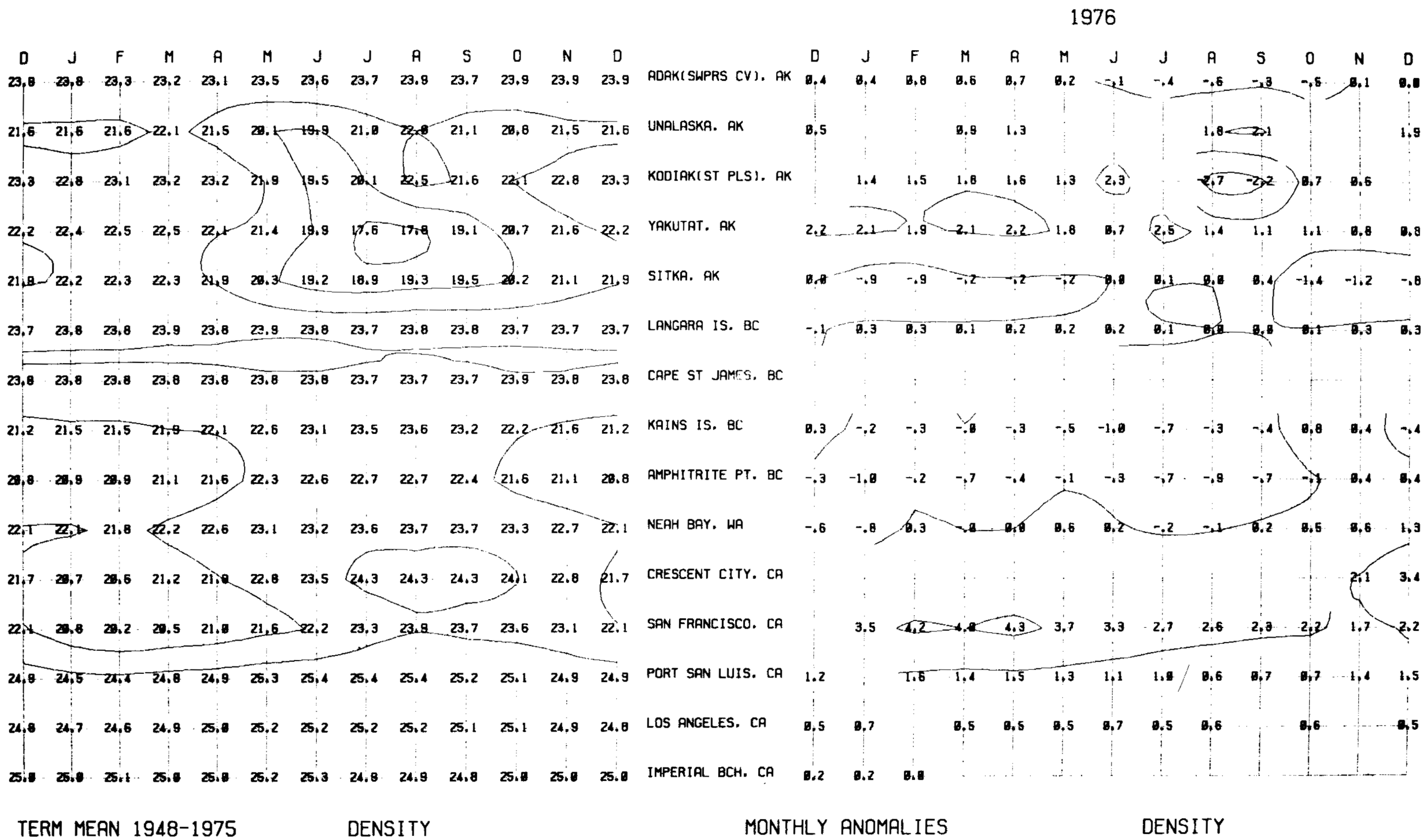

Figure 10.3.—Long-term mean for 1948-75 (left) and anomalies for 1976 (right) of density (sigma-t) along the U.S. west coast. Contour interval is 2 units.

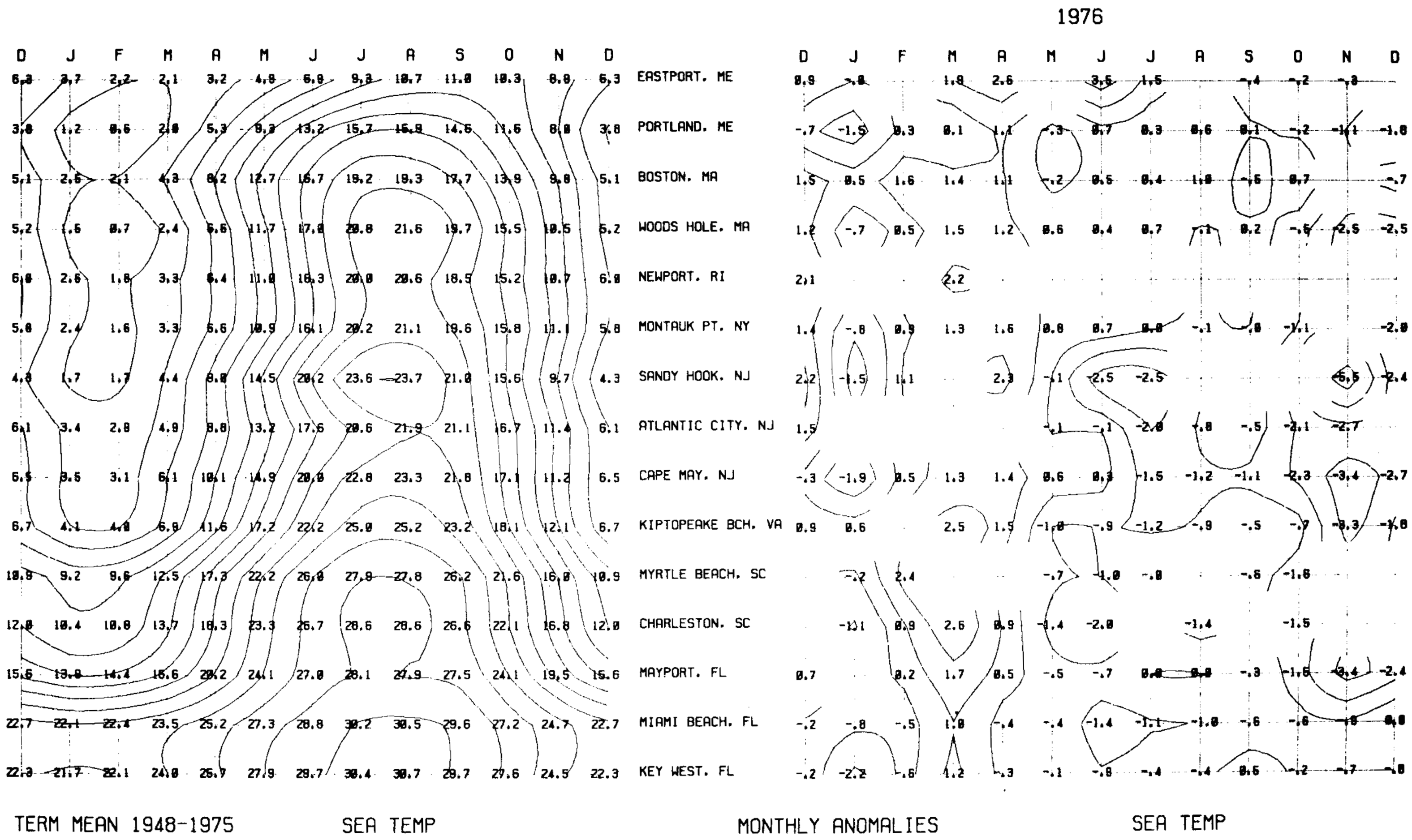

Figure 10.4—Long-term mean for 1948-75 (left) and anomalies for 1976 (right) of sea surface temperature (degrees C) along the U.S. east coast. Contour intervals are 2.0C for mean and 1.0C for anomalies.

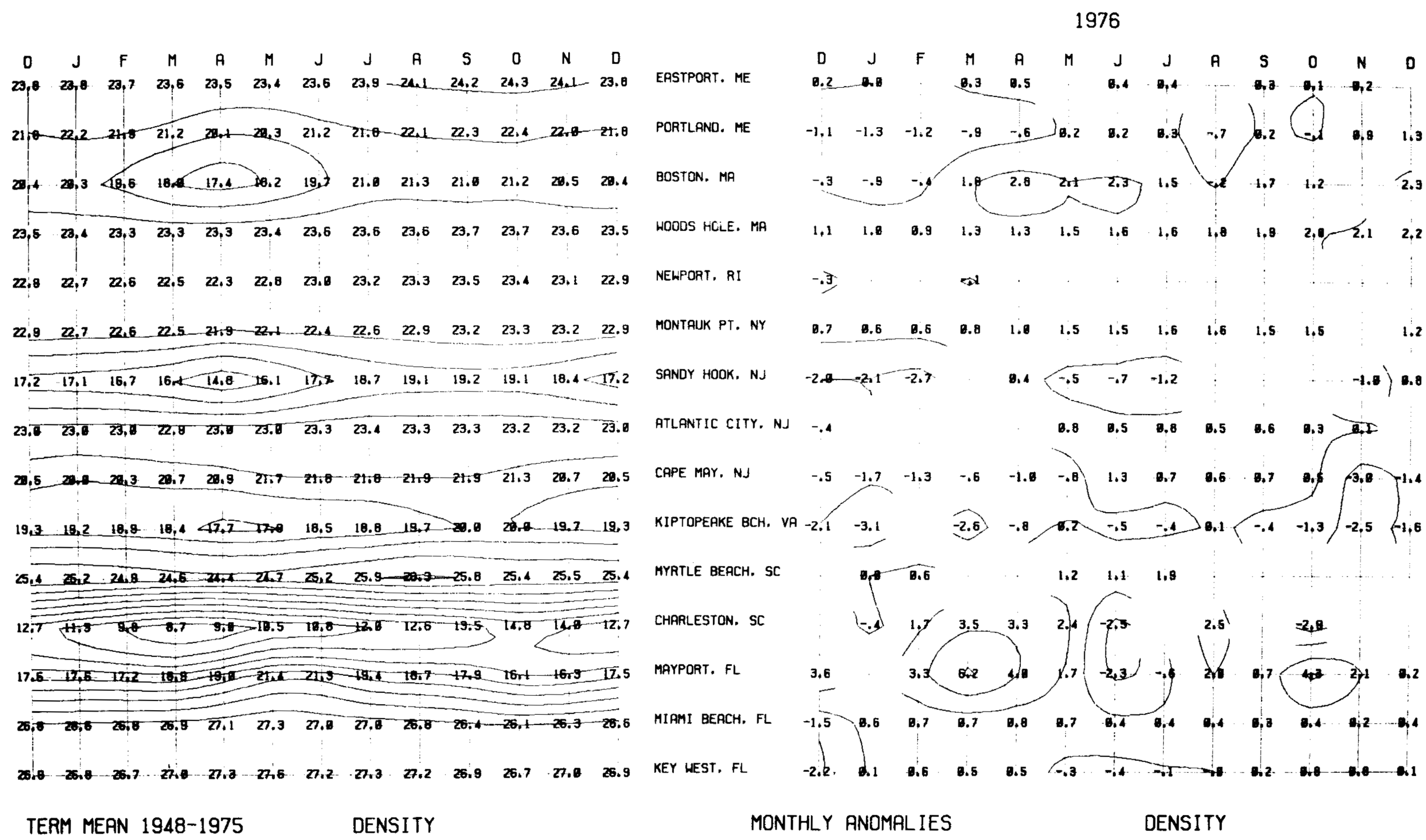

Figure 10.5.—Long-term mean for 1948-75 (left) and anomalies for 1976 (right) of density (sigma-t) along the U.S. east coast. Contour interval is 2 units.

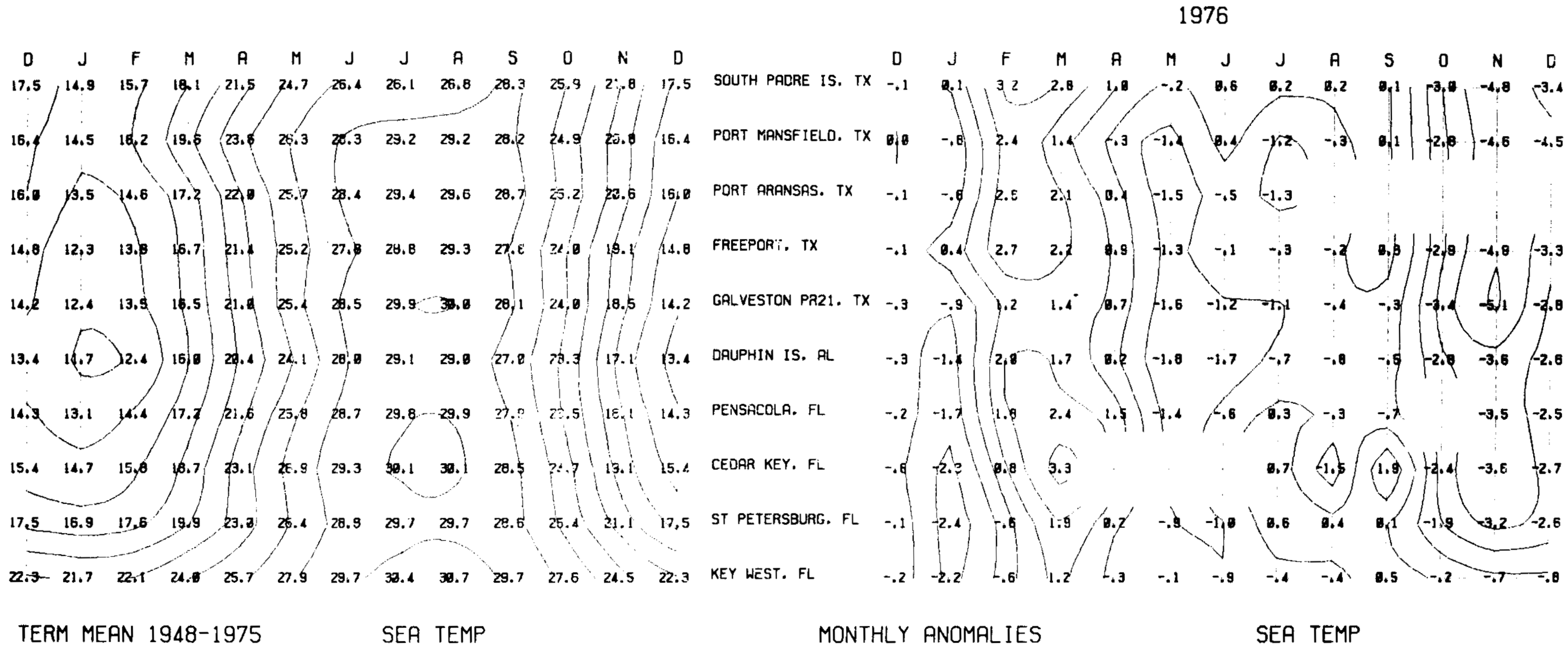

Figure 10.6.—Long-term mean for 1948-75 (left) and anomalies for 1976 (right) of sea surface temperature (degrees C) along the U.S. Gulf coast. Contour intervals are 2.0C for mean and 1.0C for anomalies.

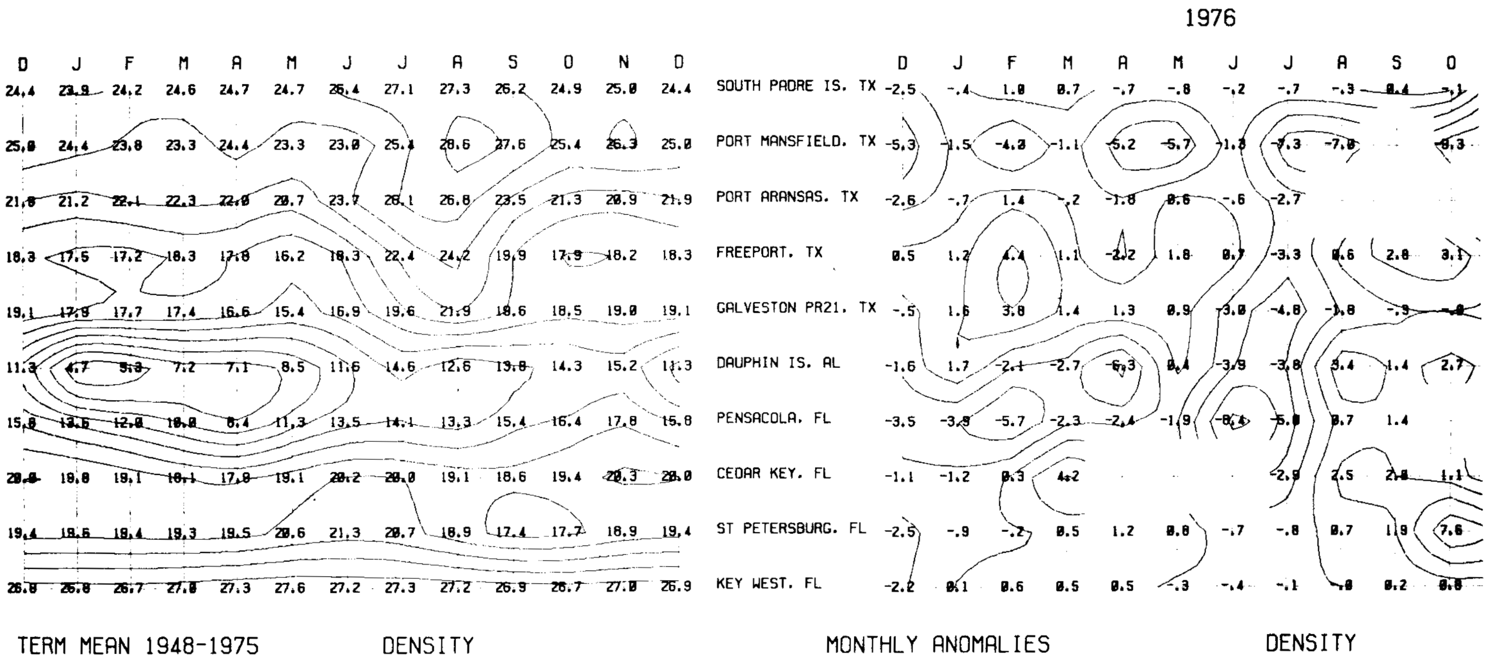

Figure 10.7.—Long-term mean for 1948-75 (left) and anomalies for 1976 (right) of density (sigma-t) along the U.S. Gulf coast. Contour interval is 2 units.

APPENDIX 10.1

Locations of stations shown in Figure 10.1.

West coast		
Adak, AK	51N52'	176W39'
UnaLaska, AK	53N53'	166W33'
Kodiak, AK	57N45'	152W29'
Yakutat, AK	59N33'	139W44'
Sitka, AK	57N03'	135W21'
Langara Island, B.C.	54N15'	133W04'
Cape St. James, B.C.	51N56'	131W01'
Kains Island, B.C.	50N27'	128W02'
Amphitrite Point, B.C.	48N55'	125W32'
Neah Bay, WA	48N22'	124W37'
Crescent City, CA	41N45'	124W12'
San Francisco, CA	37N48'	122W28'
Port San Luis, CA	35N10'	120W45'
Los Angeles, CA	33N43'	118W16'
Imperial Beach, CA	32N35'	117W08'
East Coast		
Eastport, ME	44N54'	66W59'
Portland, ME	43N40'	70W15'
Boston, MA	42N21'	71W03'
Woods Hole, MA	41N32'	70N40'
Newport, RI	41N30'	71W20'
Montauk, NY	41N03'	71W58'
Sandy Hook, NJ	40N28'	74W01'
Atlantic City, NJ	39N21'	74W25'
Cape May, NJ	38N58'	74W58'
Kiptopeke Beach, VA	37N10'	75W59'
Myrtle Beach, SC	33N41'	78W53'
Charleston, SC	32N47'	79W56'
Mayport, FL	30N24'	81W26'
Miami Beach, FL	25N46'	80W08'
Key West, FL	34N33'	81W49'
Gulf of Mexico Coast		
Padre Island, TX	26N04'	97W09'
Port Mansfield, TX	26N33'	97W26'
Port Aransas, TX	27N49'	97W04'
Freeport, TX	28N57'	95W19'
Galveston, TX	29N18'	94W47'
Dauphin Island, AL	30N15'	88W05'
Pensacola, FL	30N24'	87W13'
Cedar Key, FL	29N08'	83W02'
St. Petersburg, FL	27N46'	82W37'
Key West, FL	24N33'	81W49'