LARGE-SCALE SEA-SURFACE TEMPERATURE ANOMALIES IN THE NORTHEAST PACIFIC OCEAN

L. E. EBER
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center
La Jolla, CA 92038

ABSTRACT

Slow-developing, long-lasting perturbations of sea-surface temperature in the eastern North Pacific are revealed by anomaly patterns representing monthly deviations from the mean seasonal cycle. These patterns are typically defined by a central core of anomalously warm (or cold) water located approximately between latitudes 30°–45°N, and west of longitude 140°W, which is partially surrounded by anomalously cold (or warm) water to the north, east, and south. They can persist up to several years and then, in a relatively short time, undergo a pattern reversal in which warm anomalies are replaced by cold anomalies and vice versa. Some examples are presented that represent selected periods in the 1960s and 1970s. A comparison of mean wind fields for January 1976 and January 1980, which were periods of sharply contrasting sea-temperature anomaly patterns, suggest that air-sea interaction processes have an active role in forming and maintaining these patterns.

RESUMEN

Perturbaciones de lento desarrollo y larga duración de temperaturas de la superficie del mar en el Pacífico nordeste son reveladas por patrones de anomalías que representan desviaciones mensuales del ciclo estacional medio. Estos patrones se identifican típicamente por un núcleo central de agua anómalamente templada (o fría), que se encuentra aproximadamente entre las latitudes 30° y 45°N, y al oeste de la longitud 140°O, y que está parcialmente rodeado por agua anómalamente fría (o templada) al norte, este y sur. Los patrones pueden persistir durante unos cuantos años y de repente, en un período relativamente corto, se puede reversar el patrón, donde se reemplazan las anomalías templadas con anomalías frías y viceversa. Se presentan algunos ejemplos que representan períodos selectos durante los 1960s y los 1970s. Una comparación del promedio de los campos del viento para enero de 1976 y enero de 1980, períodos en que se exhibían patrones anómalos contrastantes de temperatura marina, sugiere que los procesos de interacción aire-mar juegan un papel activo en la formación y el mantenimiento de estos patrones.

[Manuscript received 20 April 1981.]

INTRODUCTION

Large-scale departures of sea-surface temperature from mean conditions in the North Pacific Ocean can persist over extensive periods of time. Surface temperatures reflect thermal conditions in the entire upper mixed layer, which may reach to depths of 100m or more. Consequently, a variation of 1° or 2°C from normal may reflect a significant gain or loss of heat in this layer.

Monthly charts of sea-surface temperature for the northeast Pacific, along with charts showing deviations from long-term monthly means, have been prepared since 1960 for Fishing Information (Southwest Fisheries Center). These charts are based on data contained in radio reports of ship's synoptic weather observations, collected through the National Weather Service. The sea-surface temperature fields were analyzed from values averaged for areas 1° latitude by 1° longitude. Anomaly charts were constructed by subtracting the corresponding long-term monthly mean field from the analyzed termperature field for a particular month. Prior to 1974, the long-term monthly means were based on charts in H.O. 225 (U.S. Hydrographic Office). After that, a new set of monthly means were prepared from data representing the period 1948–67, obtained through the U.S. Navy's Fleet Numerical Weather Facility. All of the figures presented here were taken directly from, or are based on, charts published in Fishing Information. Temperature units used for these charts were converted from Fahrenheit to Celsius between 1977 and 1978. Consequently, both kinds of units appear in the figures.

The charts are all based on observations from January so that interyear comparison will be unaffected by seasonal variation and because sea-surface temperatures in winter months are less affected by transient fluctuations in thin surface layers.

SEA-TEMPERATURE ANOMALY PATTERNS

The examples selected for presentation here depict anomaly patterns that are typically defined by a central core of anomalously warm (or cold) water located approximately between latitudes 30 °–45 °N, and west of longitude 140 °W, which may be partially surrounded by anomalously cold (or warm) water to the

north, east, and south. Similar patterns have been found for periods in the 1950s (Eber 1971).

Figure 1 shows the sea-temperature anomalies for January 1965 and represents a regime characterized by positive values in the central core with scattered areas of negative anomalies in the peripheral region. This was a very stable pattern which persisted more than three years, into 1968. Figures 2–4 show the evolution of this regime in successive Januarys. The warm central core remained the dominant feature throughout the period, in terms of both spatial distribution and magnitude of deviations from normal conditions. In January 1967 the negative anomalies had nearly vanished, but by January 1968 the pattern had returned to a state remarkably like that of January 1965.

This general type of regime characterized by a warm central core and cool periphery reappeared again in January 1974 (Figure 5). However, in this case the negative anomalies were the dominant feature, extending well offshore along the entire west coast of North America. At this time, the central core of the positive anomalies was poorly defined. During the ensuing year, however, the evolution of the warm core continued between latitudes 25°–35°N while the negative anomalies spread further into the surrounding areas, as shown in Figure 6. By January 1976 (Figure 7) the warm central core had consolidated in the vicinity of latitude 30°N, longitude 160°W and was almost completely encircled by the peripheral cold region.

In 1976, a transition began to take place which led to a nearly complete pattern reversal in the anomaly field. Figure 8 depicts the new regime as it existed in January 1977, with a central cold core between latitudes 35°–40°N and relatively warm conditions everywhere east of longitude 145°W. During 1977, the negative anomalies spread eastward to about longitude 135°W while positive anomalies spread out along the southern periphery (Figure 9). Midway through 1978, a disruption of the pattern occurred, which led to the occurrence of negative anomalies along the coastal zone and in most of the area between latitudes 25°–35°N (Figure 10). This was relatively short-lived, and by January 1980 the typical pattern characteristics were again evident (Figure 11).

Although it is beyond the scope of this paper to try to explain why these patterns of anomalous sea-temperature distributions develop, it is reasonable to assume that air-sea interaction processes are involved. In particular, one would expect to find contrasting atmospheric conditions corresponding to contrasting sea-temperature anomaly patterns. The anomaly fields for January 1976 and January 1980 are examples of opposite temperature regimes (Figures 7 and 11). Figure 12 shows the difference in the temperature fields for these two months. These differences portray an enhanced image of the typical anomaly pattern described in this study. Negative differences in the central core area represent lower temperatures in 1980 than in 1976, and positive differences along the North American coast and in the peripheral region represent higher temperatures in 1980 relative to 1976.

For comparison, Figure 13 shows the difference in the surface wind field for January 1976 and January 1980. The arrows represent the vector difference of wind observations averaged by areas 5° latitude by 5° longitude for the respective months. In terms of air circulation, Figure 13 shows that the flow in 1980 was from the south (relative to that in 1976), east of longitude 135°W and south of latitude 40°N, where the maximum positive temperature differences occurred. Conversely, the flow in 1980 was from the north (relative to that in 1976) in the area between latitudes 25°–35°N and longitudes 145°–160°W, where the maximum negative temperature differences occurred.

The magnitude of differences in wind speed between the two years is substantial, and the described relationships between differences in winds and sea temperatures are consistant with the effects that would be expected from wind-induced advection, evaporation, and sensible heat transfer. It appears likely, therefore, that air-sea interaction processes have a tangible role in forming and maintaining persistant patterns of sea-surface temperature anomalies.

LITERATURE CITED

Eber, L. E. 1971. Characteristics of sea-surface temperature anomalies. Fish. Bull., U.S. 69:345-355.

Southwest Fisheries Center. 1960-1980. Environmental charts, Pacific Ocean. Fishing Information, J.A. Renner (ed.), Nat. Mar. Fish. Ser., NOAA.

U. S. Hydrographic Office. 1944. World atlas of surface temperatures. H.O. No. 225. U.S. Navy.

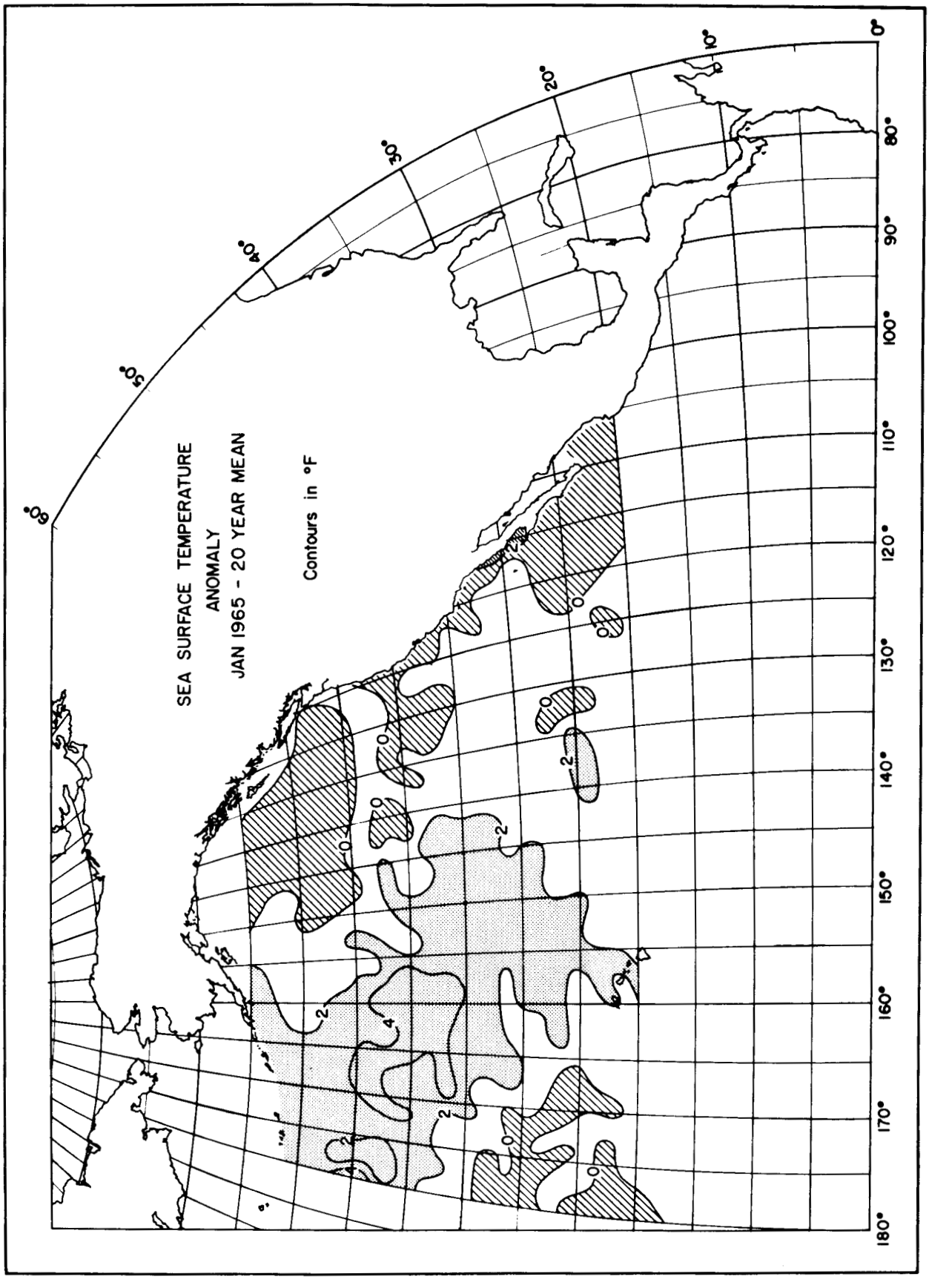

Figure 1. Deviation of sea-surface temperature for January 1-31, 1965, from the long-term mean. Hatched areas colder in 1965, clear and stippled areas warmer in 1965.

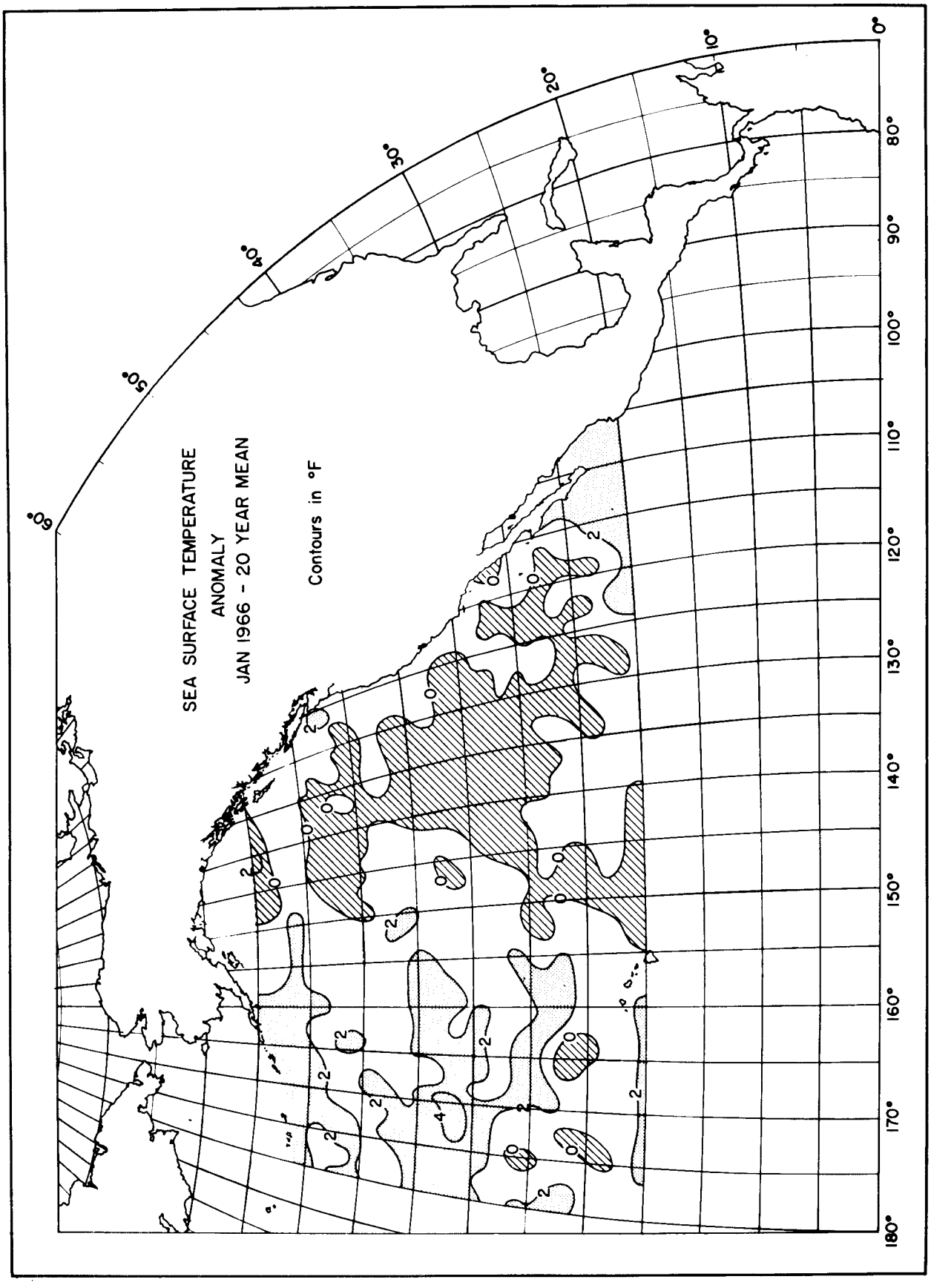

Figure 2. Deviation of sea-surface temperature for January 1-31, 1966, from the long-term mean. Hatched areas colder in 1966, clear and stippled areas warmer in 1966.

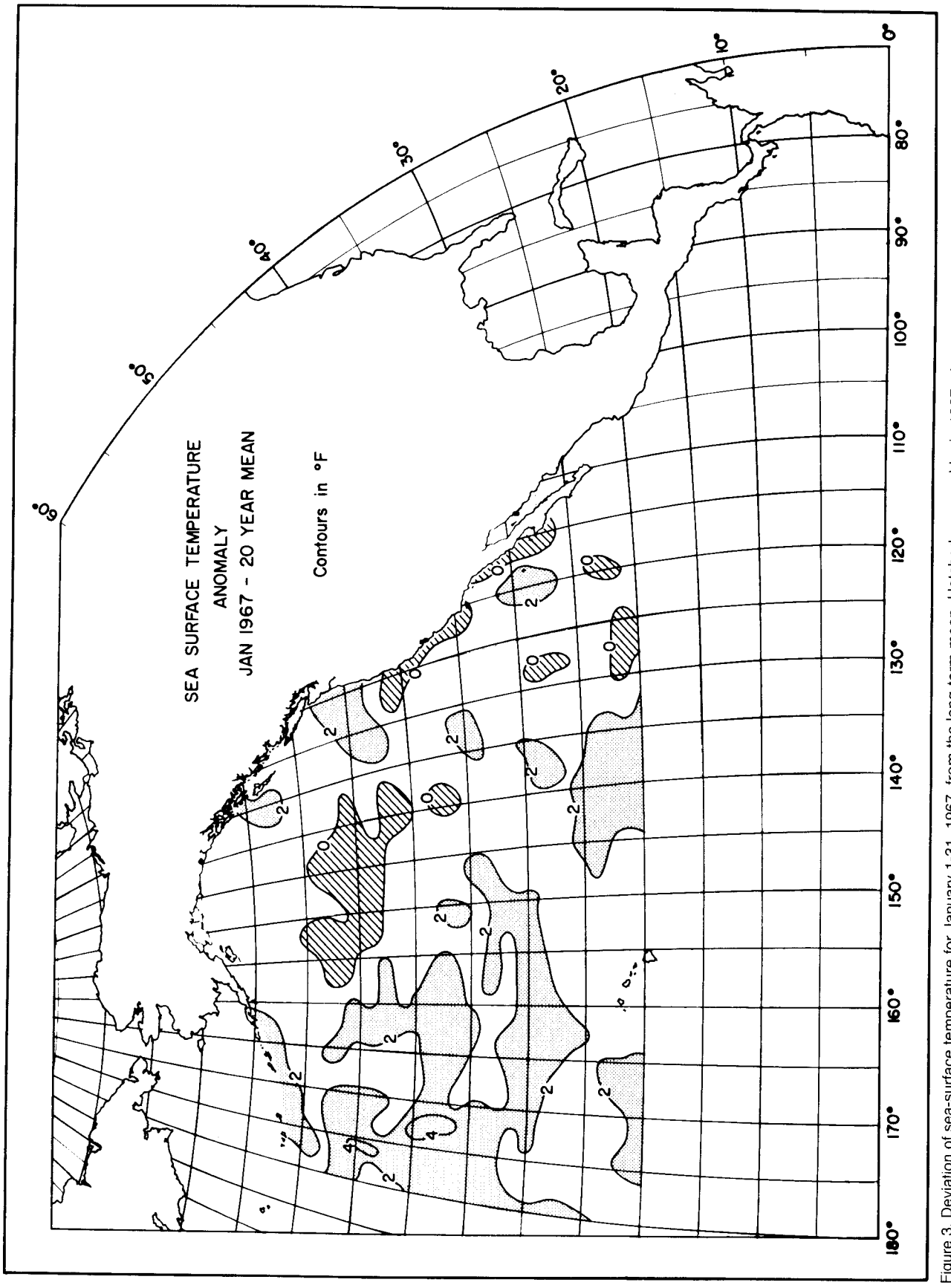

Figure 3. Deviation of sea-surface temperature for January 1-31, 1967, from the long-term mean. Hatched areas colder in 1967, clear and stippled areas warmer in 1967.

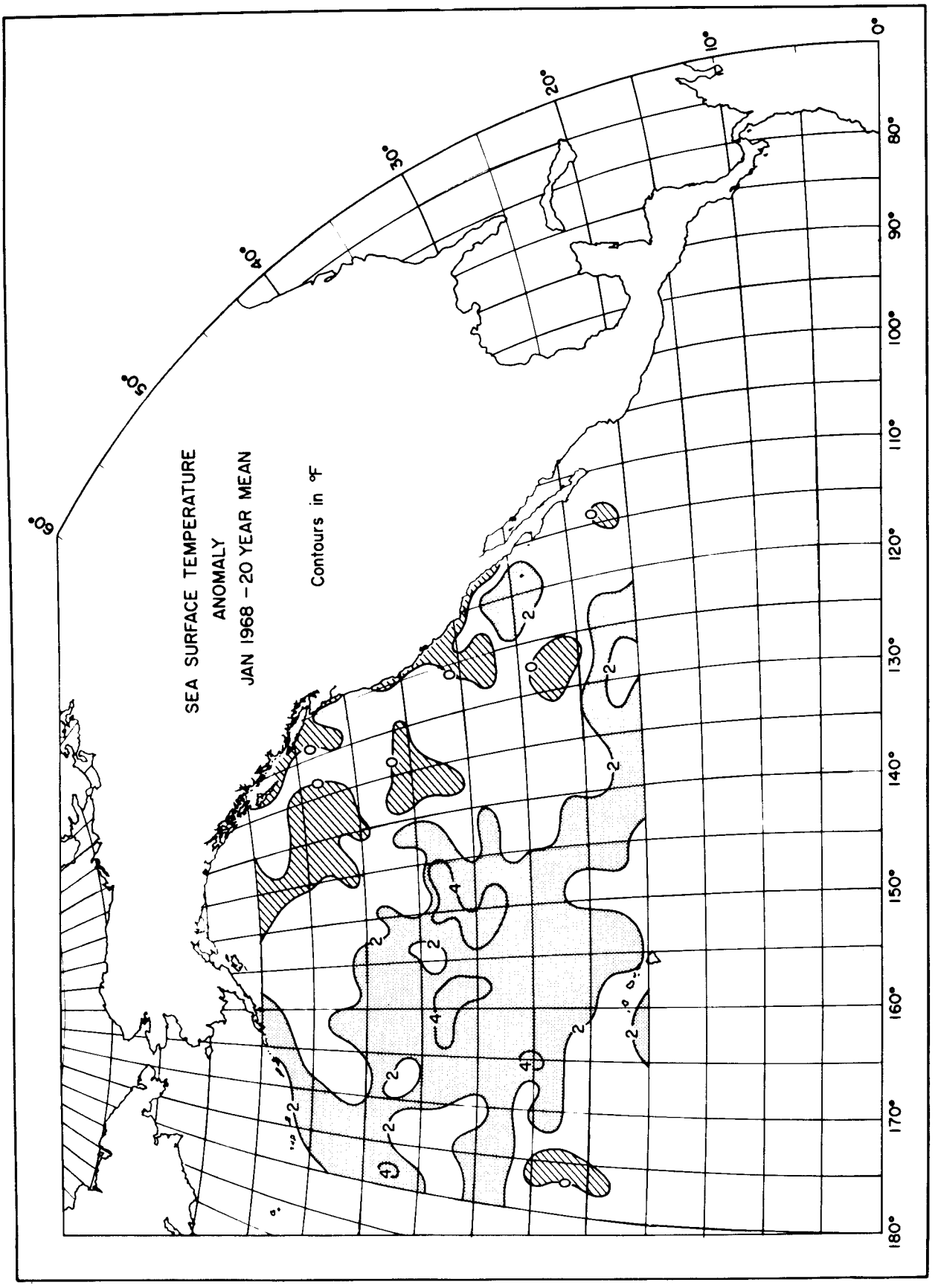

Figure 4. Deviation of sea-surface temperature for January 1-31, 1968, from the long-term mean. Hatched areas colder in 1968, clear and stippled areas warmer in 1968.

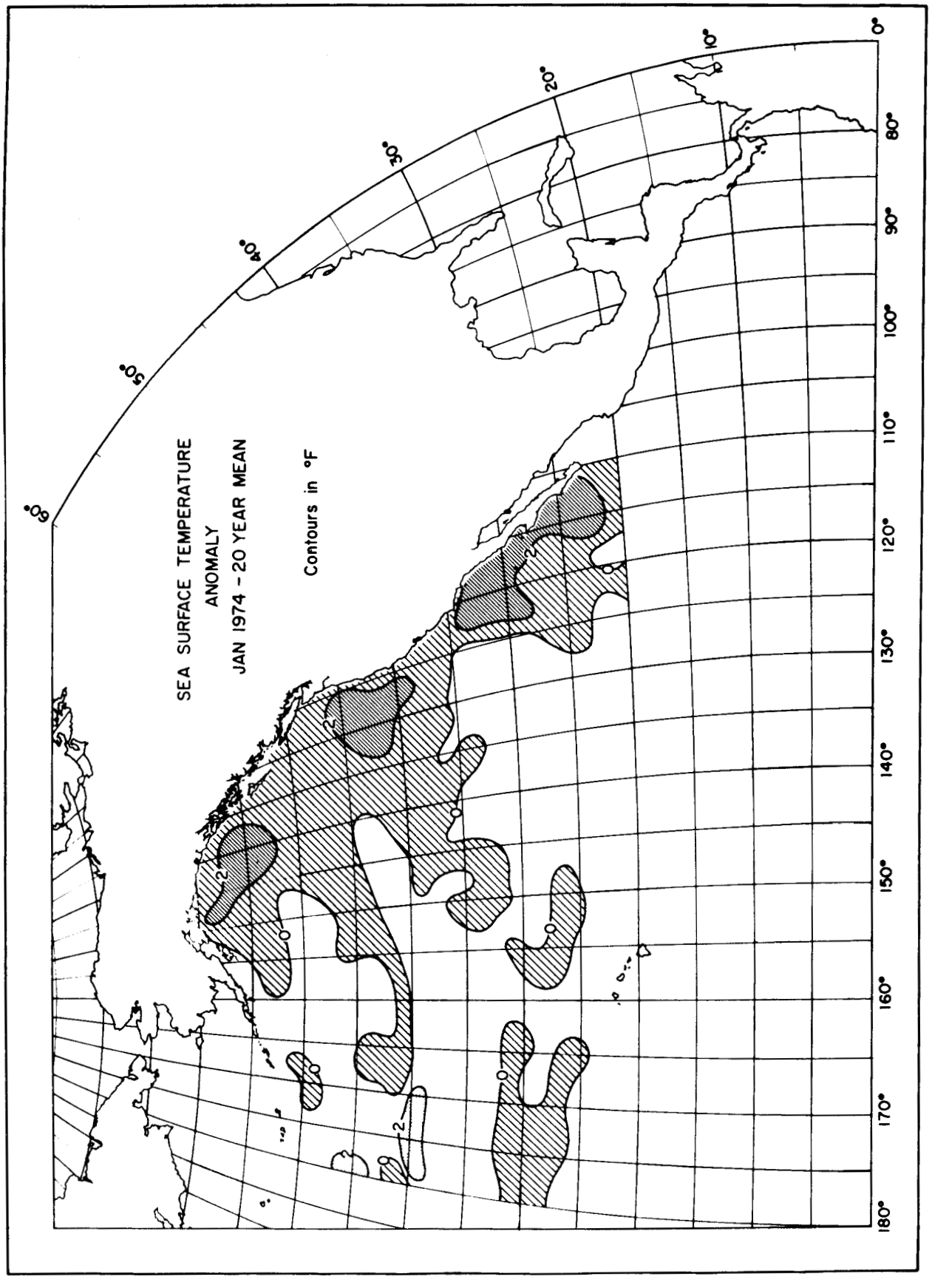

Figure 5. Deviation of sea-surface temperature for January 1-31, 1974, from the long-term mean. Hatched areas colder in 1974, clear and stippled areas warmer in 1974.

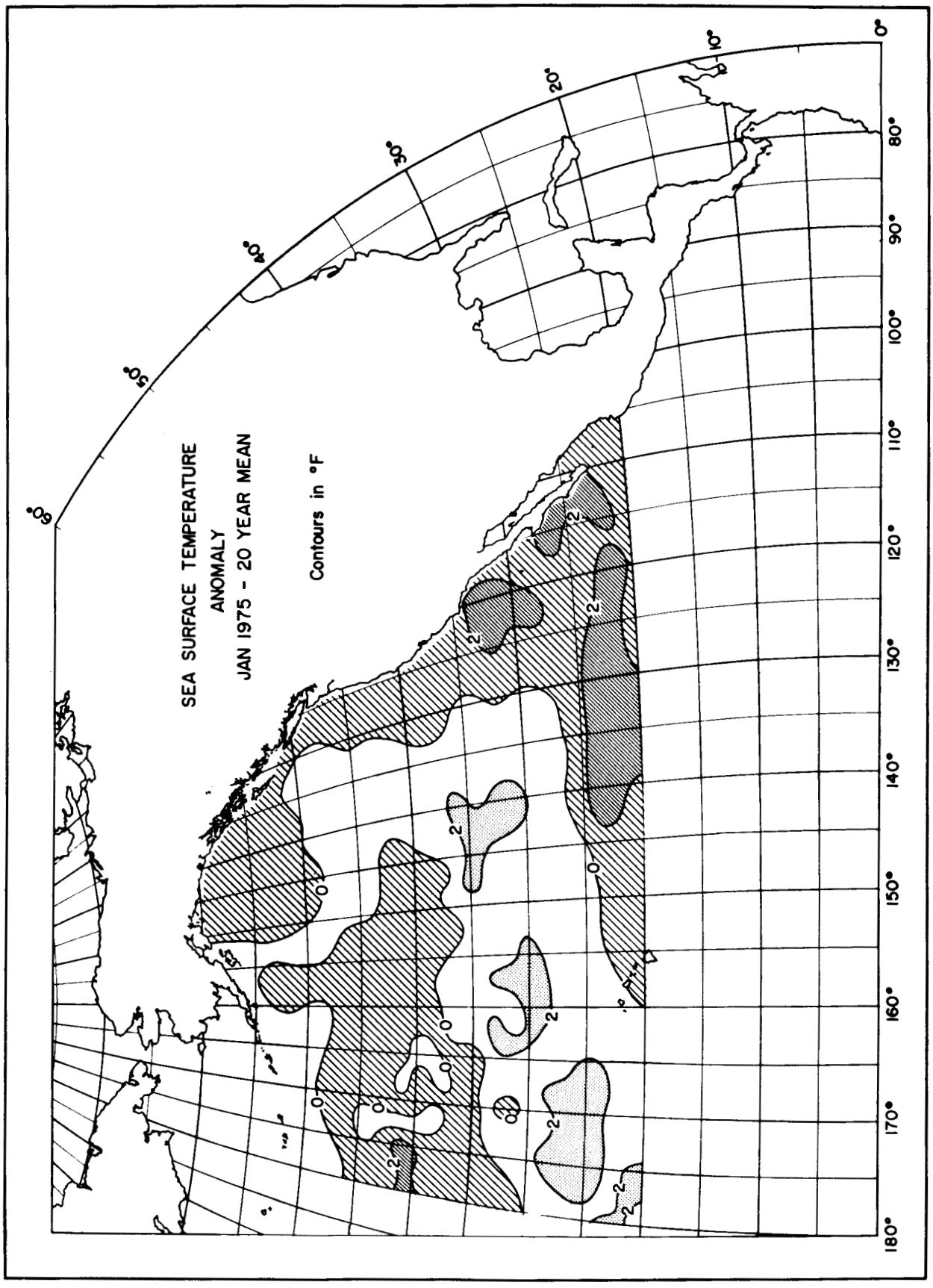

Figure 6. Deviation of sea-surface temperature for January 1-31, 1975, from the long-term mean. Hatched areas colder in 1975, clear and stippled areas warmer in 1975.

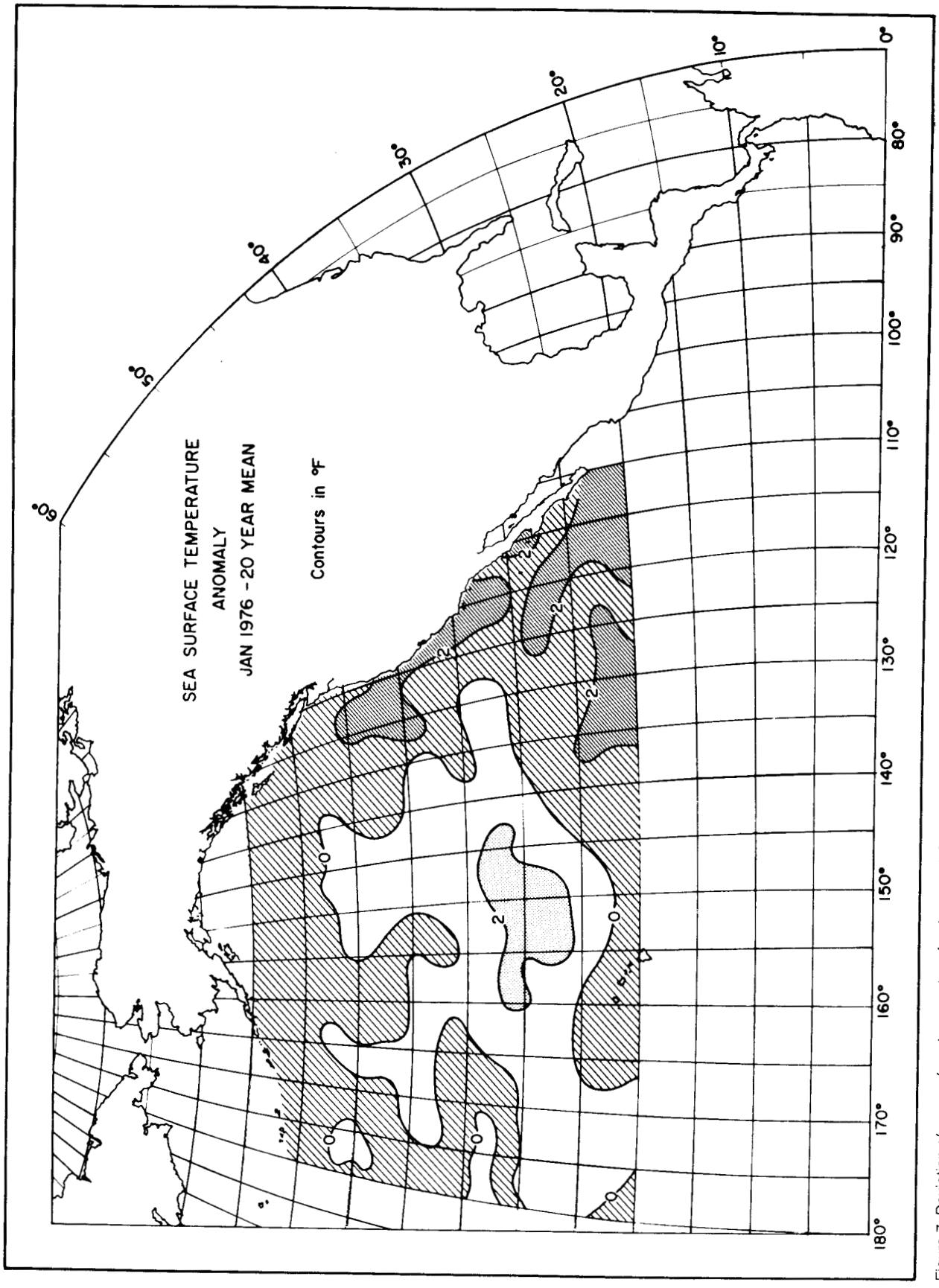

Figure 7. Deviation of sea-surface temperature for January 1-31, 1976, from the long-term mean. Hatched areas colder in 1976, clear and stippled areas warmer in 1976.

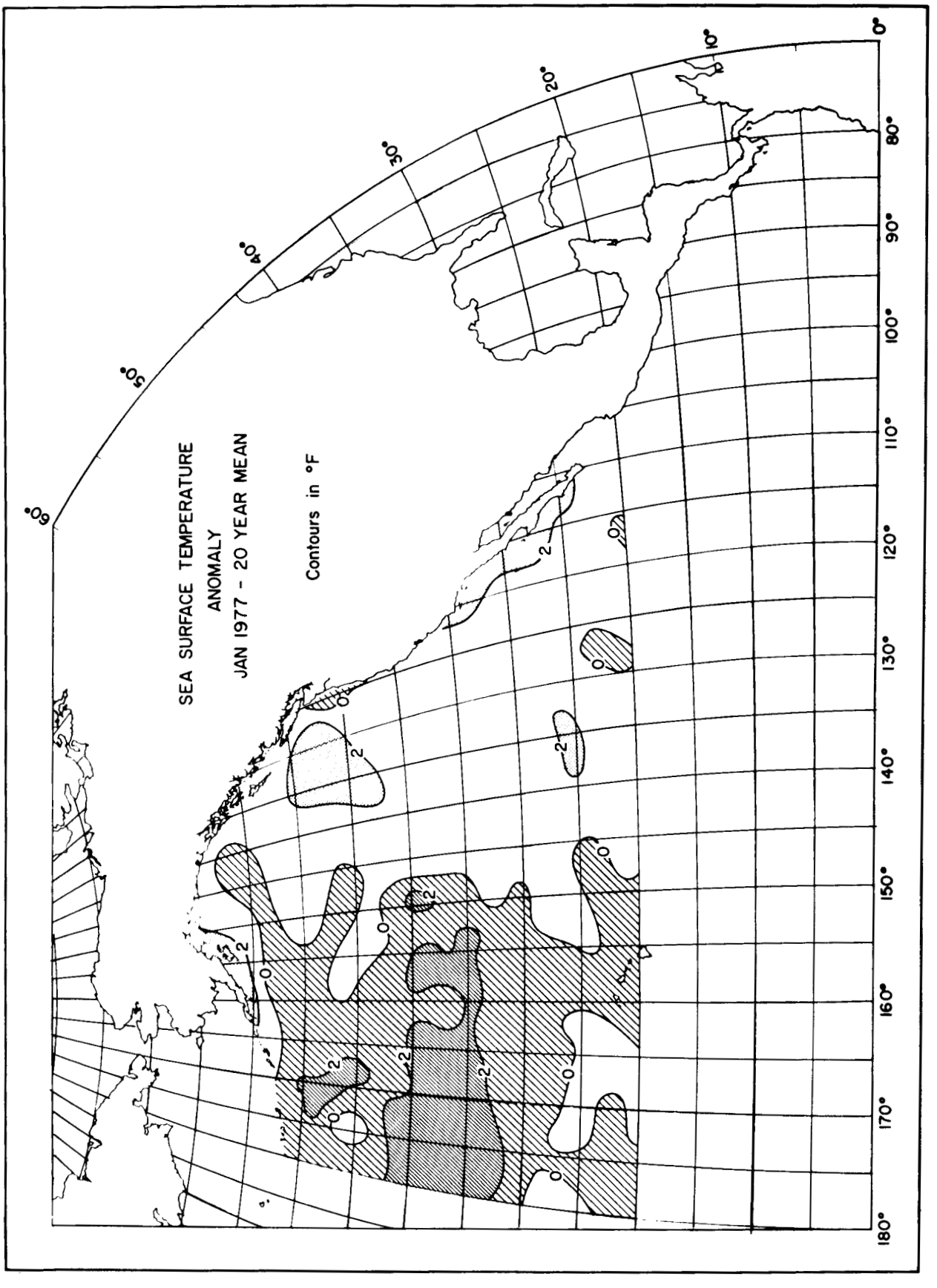

Figure 8. Deviation of sea-surface temperature for January 1-31, 1977, from the long-term mean. Hatched areas colder in 1977, clear and stippled areas warmer in 1977.

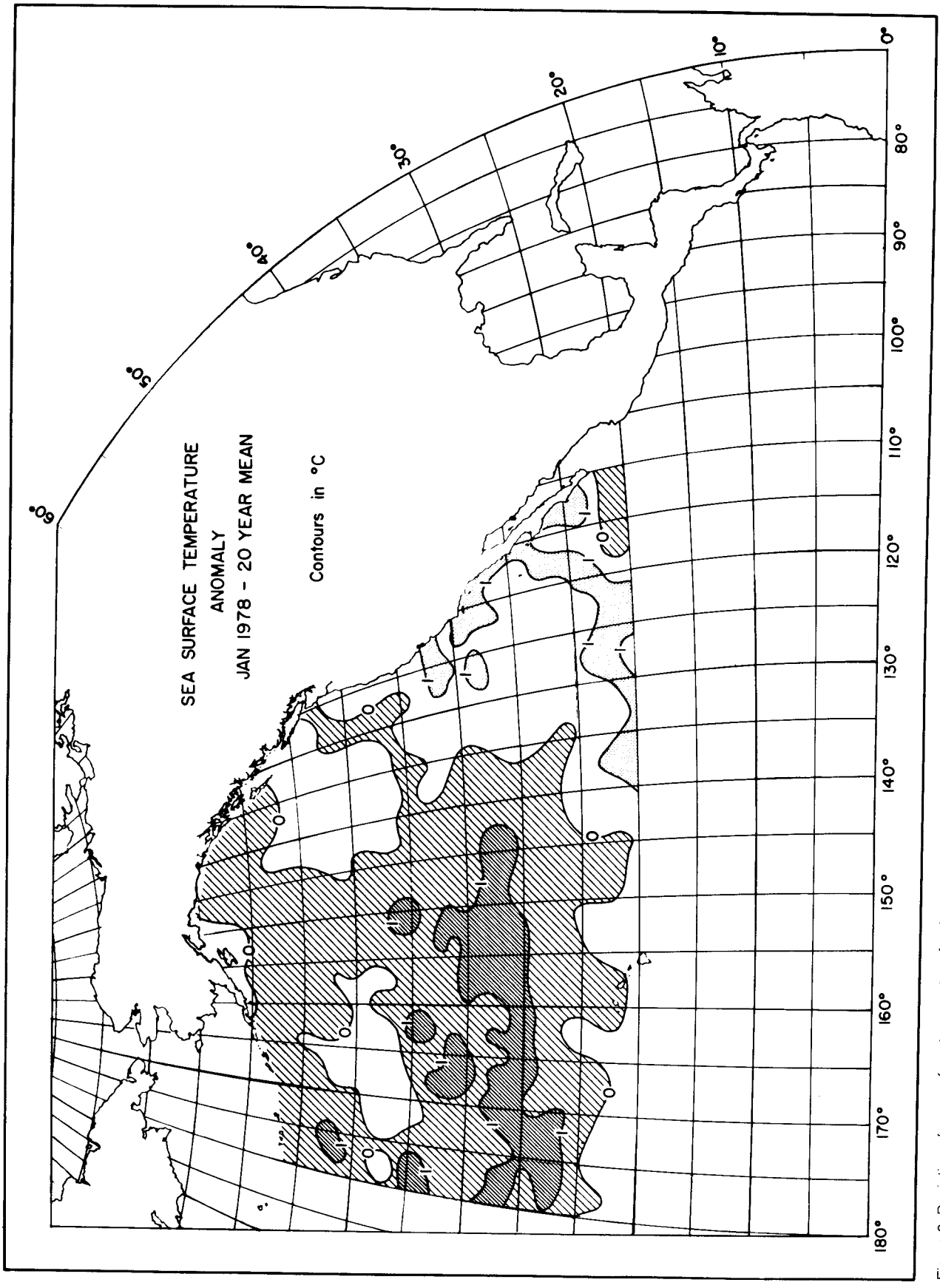

Figure 9. Deviation of sea-surface temperature for January 1-31, 1978, from the long-term mean. Hatched areas colder in 1978, clear and stippled areas warmer in 1978.

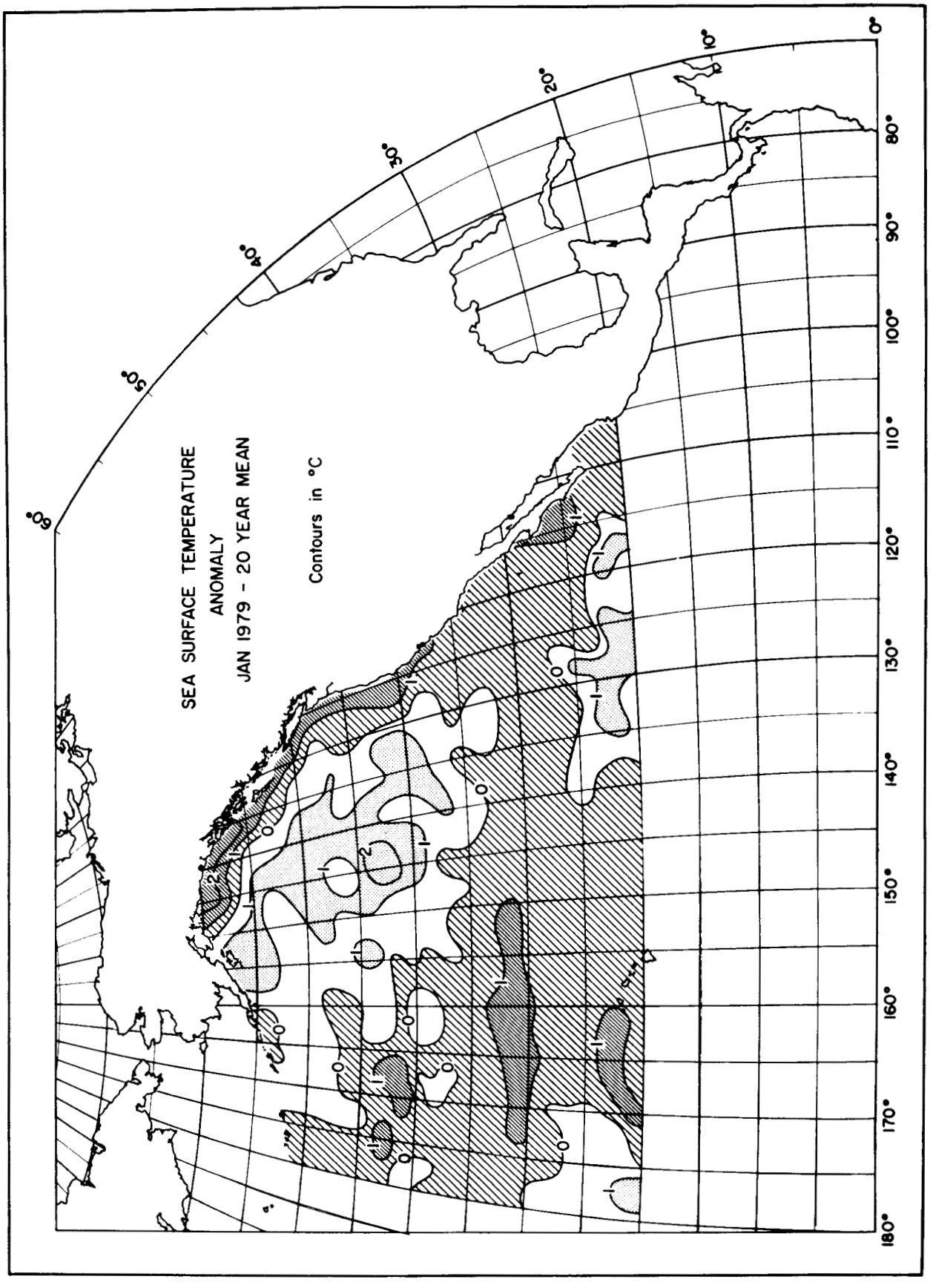

Figure 10. Deviation of sea-surface temperature for January 1-31, 1979, from the long-term mean. Hatched areas colder in 1979, clear and stippled areas warmer in 1979.

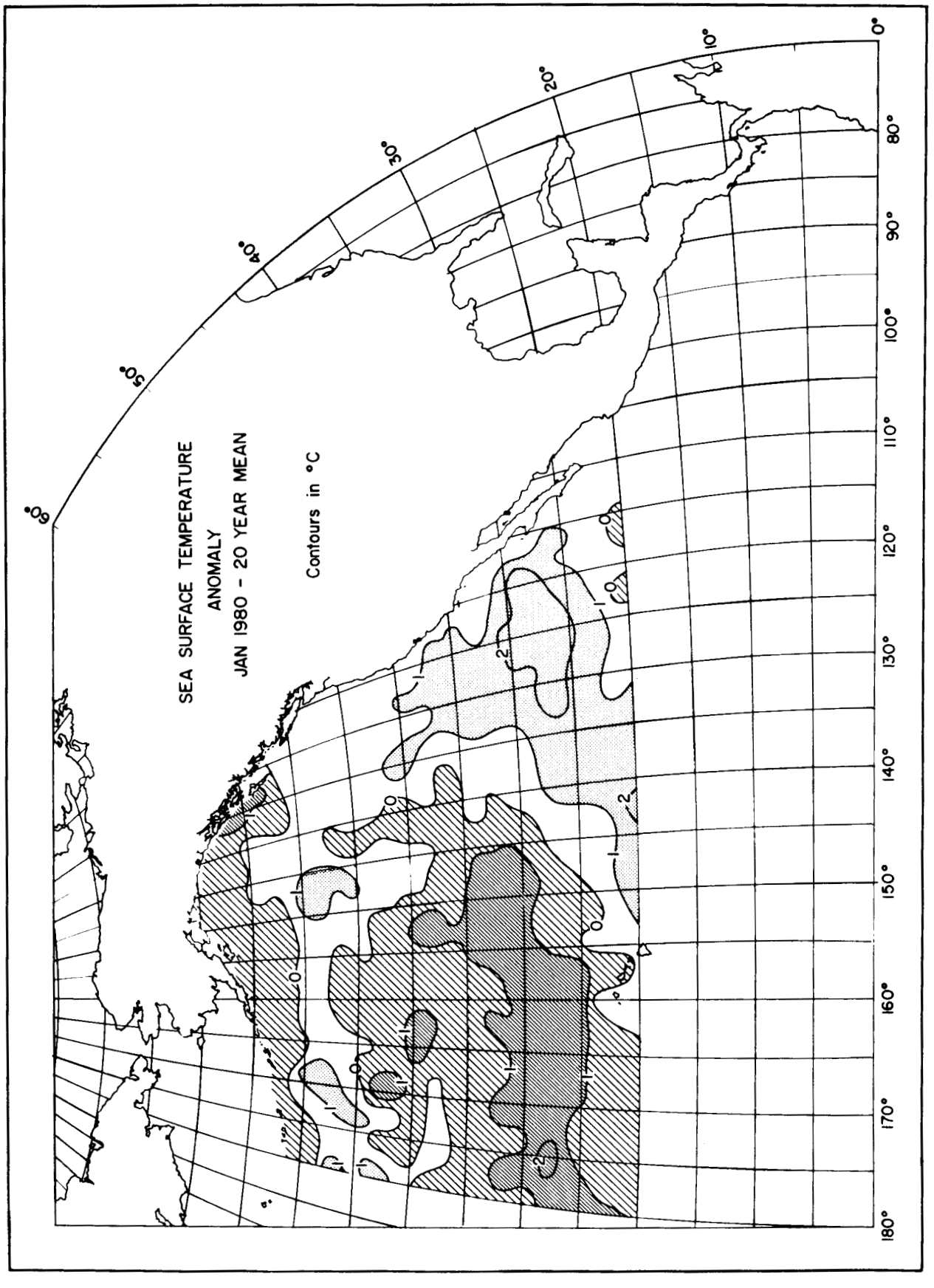

Figure 11. Deviation of sea-surface temperature for January 1-31, 1980, from the long-term mean. Hatched areas colder in 1980, clear and stippled areas warmer in 1980.

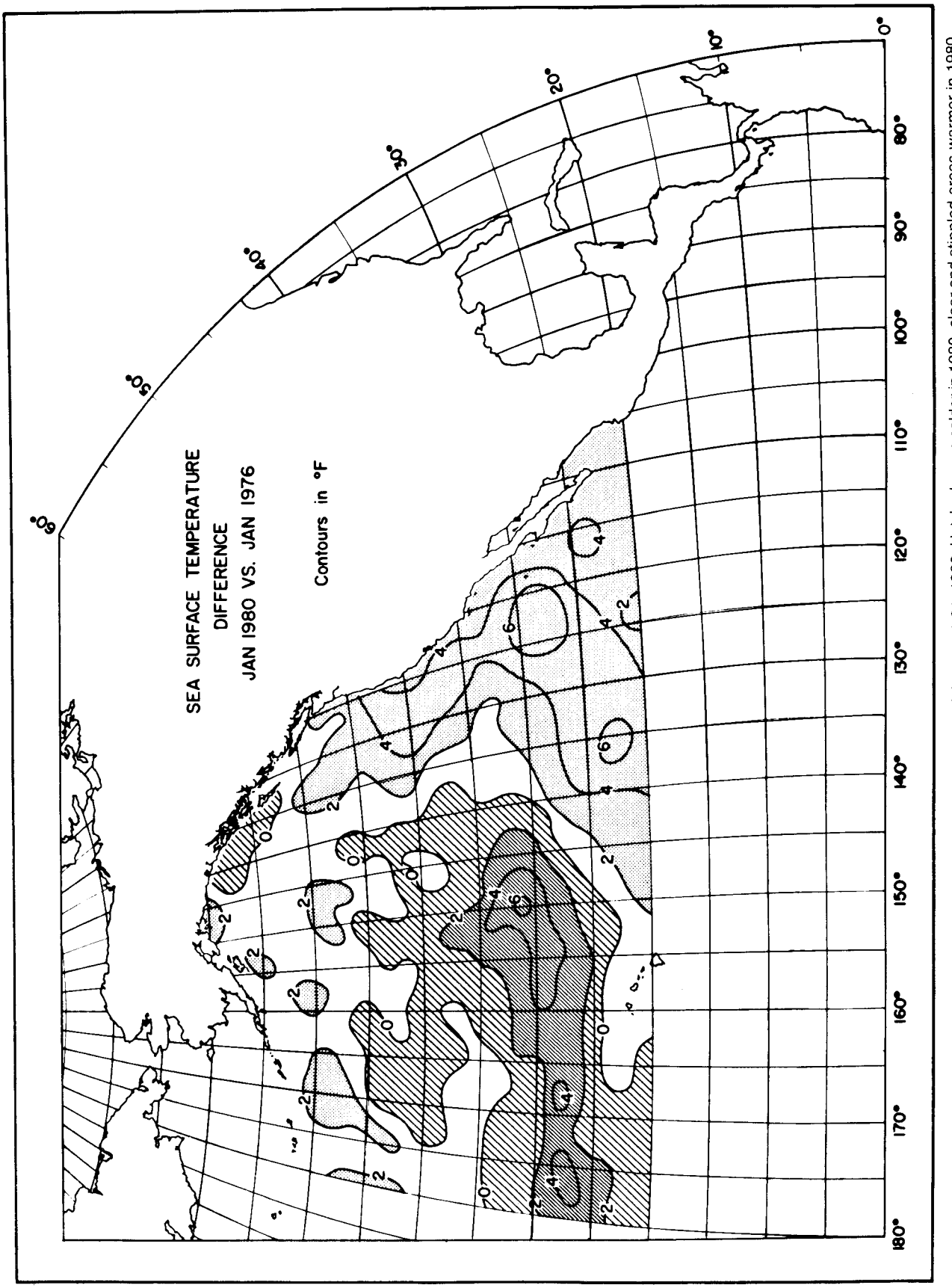

Figure 12. Difference of sea-surface temperature between January 1-31, 1976, and January 1-31, 1980. Hatched areas colder in 1980, clear and stippled areas warmer in 1980.

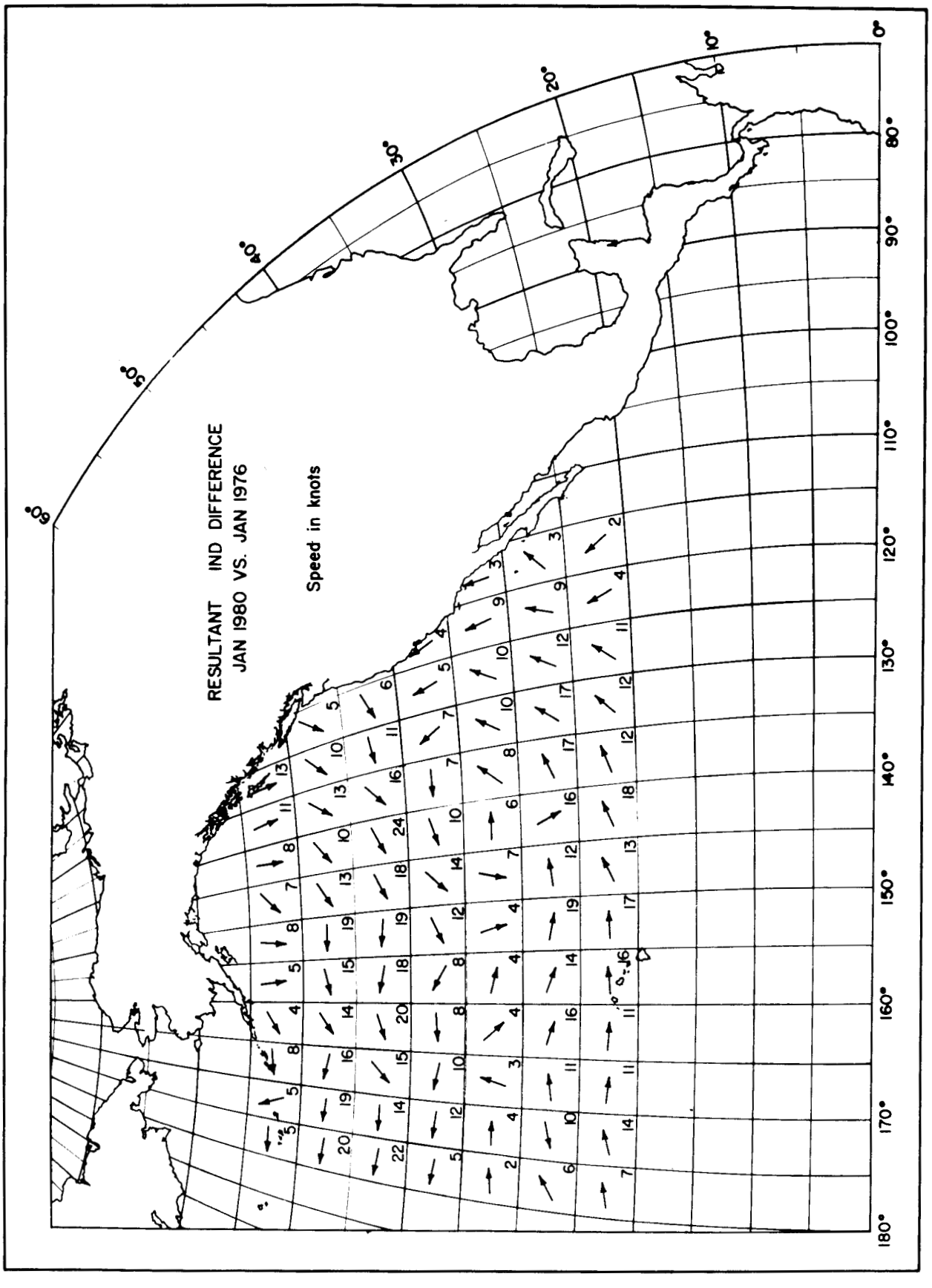

Figure 13. Arrows represent vector differences of winds averaged by areas 5° latitude by 5° longitude for January 1-31, 1976, and January 1-31, 1980. Numbers represent corresponding differences in wind speed. Differences were computed by subtracting 1976 from 1980 values.