NOAA Technical Report NWS 31

A Monthly Averaged Climatology of Sea Surface Temperature

Silver Spring, Md.
June 1982

U.S. DEPARTMENT OF COMMERCE
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National Weather Service

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NOAA Technical Report NWS 31

A Monthly Averaged Climatology of Sea Surface Temperature

Richard W. Reynolds
Climate Analysis Center
National Meteorological Center

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June 1982

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

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A Monthly Averaged Climatology of Sea Surface Temperatures

Richard W. Reynolds

Climate Analysis Center, National Meteorological Center, NWS
Washington, DC 20233

ABSTRACT. A monthly one-degree global sea surface temperature climatology was processed from a National Climatic Center summary of surface marine reports. The summary's grid-scale noise has been eliminated from the climatology; however it still preserves much of the smaller-scale upwelling features and the strong gradients of the western boundary currents.

1. INTRODUCTION

In an analysis of sea surface temperature (SST) fields, a SST climatology is useful as a means to check the observations used in the analysis. Furthermore, a climatology is essential to produce anomaly fields and is needed as an input field to many atmospheric models. However, the SST climatologies currently available have different spatial resolutions, are measured by different instruments, are based on different analysis periods, and were analyzed by a variety of techniques, both objective and subjective. To help understand the differences among climatologies, a new global climatology is needed which is based on the largest amount of SST observations currently available, minimizes the subjective and objective processing of the observations, and maximizes the spatial resolution. This paper presents a monthly climatology that attempts to satisfy these requirements. In another study now being prepared for publication (Reynolds, 1982), this climatology is compared with other SST climatologies.

2. CLIMATOLOGICAL SST SUMMARIES

To avoid reprocessing large amounts of data, two climatological data summaries were examined in which the SST mean, standard deviation, and number of observations had been computed on a one-degree latitude and longitude grid (centered on the half degree) for each month. Both summaries were produced after editing procedures had eliminated some of the extreme observations.

The first data summary was produced by S. Levitus (Levitus and Oort, 1977) from all data in the National Oceanography Data Center's (NODC) files through 1976. These data, henceforth called casts, had oceanographic station data--including Nansen casts plus some salinity-temperature-depth (STD) casts--as well as expendable and mechanical bathythermograph (BT) casts. The BT's, although not as accurate as the station data, have typical accuracies of several tenths of a degree C (Tabata, 1978a).

The second data summary was produced by the National Climatic Center (NCC) from surface marine weather reports (the major data source) and from the surface part of the NODC casts. The NCC summary was completed at different times for different geographical regions. Thus, although the summary includes all data before 1970, the ending period of the data varies between 1970 and 1976, depending on the location. NCC has analyzed this climatological summary on a five-degree latitude and longitude grid and produced twelve hand-contoured analyses of monthly SST fields, as well as other marine fields, in the U.S. Navy Marine Climate Atlas of the World (1981). However, this resolution is too coarse to properly resolve many small-scale features, such as coastal upwelling or western boundary currents.

The surface marine reports consist of bucket and engine-intake temperatures. The intake temperatures, which have dominated the reports after the Second World War, are roughly accurate to only the nearest degree C. This is less accurate than the bucket measurements or any of the NODC cast data. Furthermore, Tabata (1978b) and others found intake temperature biases of up to several tenths of a degree C, depending on season and ship position.

However, although the surface marine observations are less accurate, the NODC casts amount to only 4% of the total data in the NCC files. The spatial coverage of the casts for all Julys on a two-degree grid can be seen in figure 1. Here most of the 155 thousand observations are in the Northern Hemisphere and thus there is very little coverage south of the Equator. Figure 2 shows the spatial coverage for all Julys from surface marine observations. Now three million surface marine observations yield better Northern Hemisphere coverage and also adequate coverage in the Southern Hemisphere to below 40°S.

For this paper the surface marine summary has been selected, since the data sampling is so superior to the cast summary. Because of the large regions with data voids in the cast summary, only the surface marine summary could be processed by simple objective techniques into a monthly climatology that retains SST detail on a one-degree resolution. Since there are more than 25 times as many surface marine observations as cast observations, the more frequent sampling of the surface marine data should smooth out many of the effects of the larger measurement errors when the mean field is computed.

3. DATA PROCESSING

The data distribution is now re-examined to determine conservative latitudinal limits for which the NCC summary has enough data for all months on a one-degree grid. The southern limit (see Fig. 2) was obtained from the July data distribution. Here most ocean two-degree quadrangles had at least ten observations north of 41°S. A similar distribution for January, not shown, leads to a northern limit of 61°N. (The latitudinal limits were chosen as odd values to facilitate possible later averaging into a two-degree grid that easily preserves 40°S and 60°N limits.)

Before any data were processed, the July SST summary, as it was obtained from NCC, was plotted (Fig. 3). Only data with four or more observations

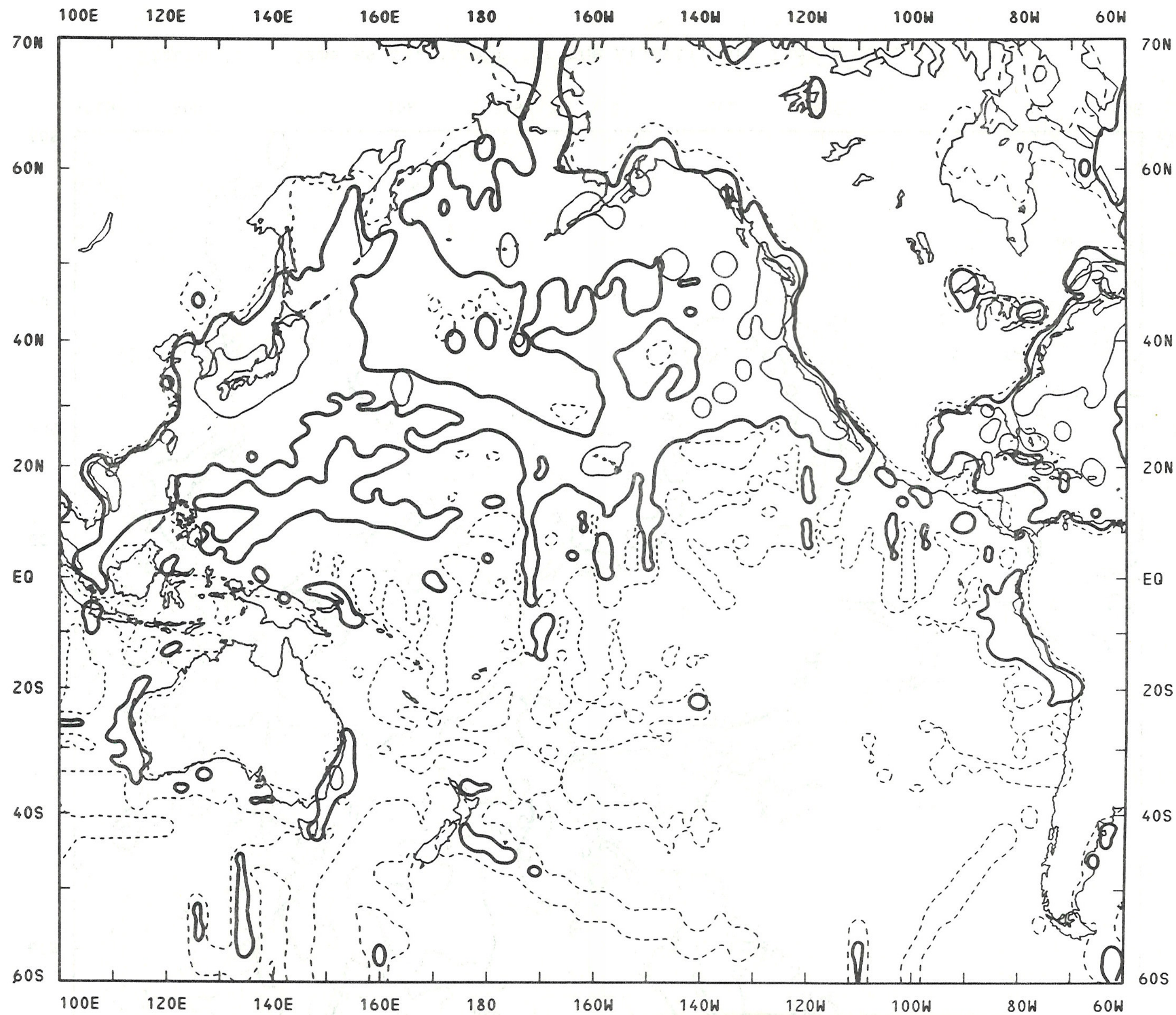


Figure 1a Data density of cast SST measurements on a two-degree grid for the Pacific Ocean for July. The dashed line indicates a contour interval of one observation per grid quadrangle; the heavy solid line indicates ten observations; and the light solid line indicates 100 observations.

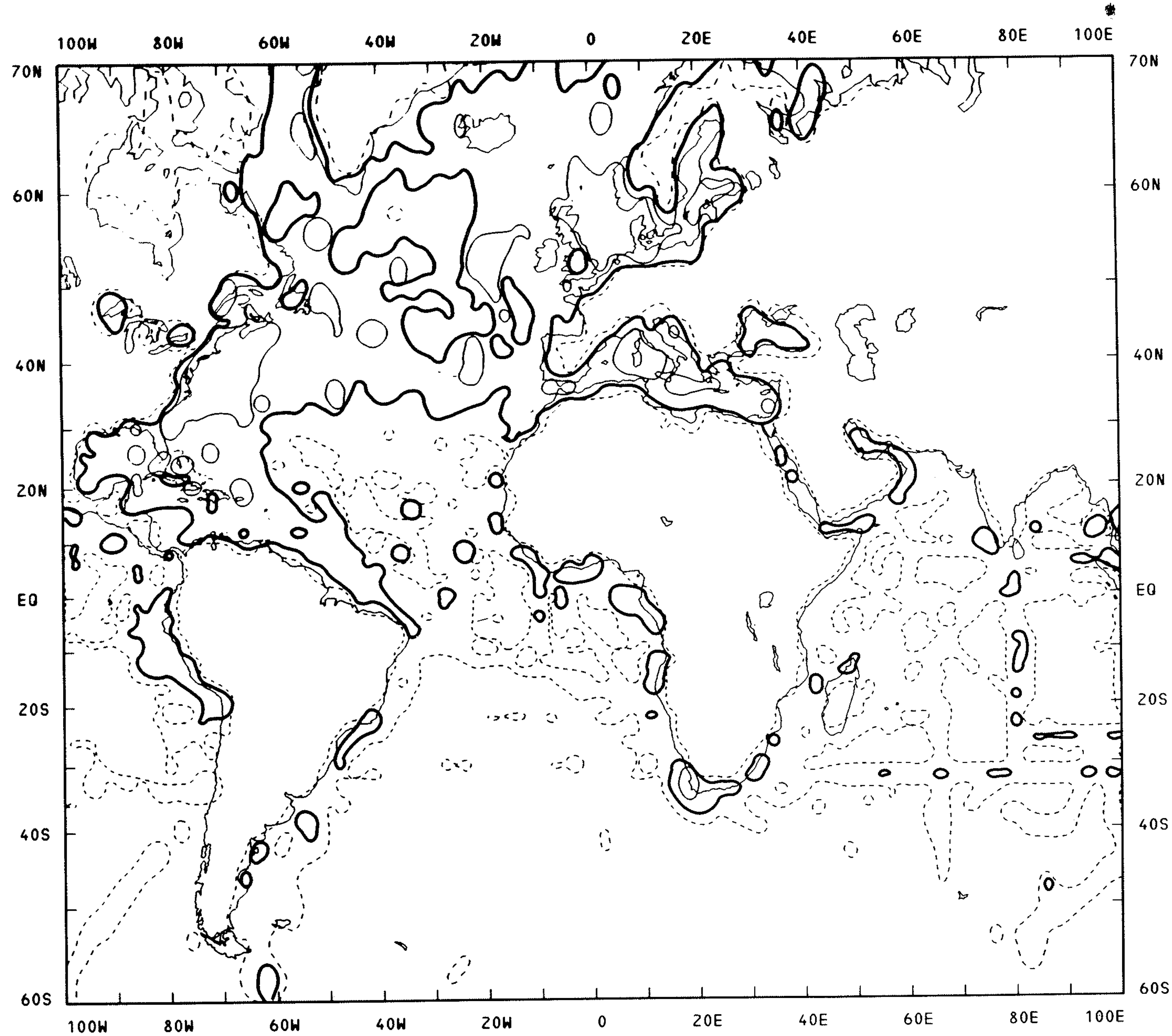


Figure 1b Same as 1a, except for the Atlantic and Indian Oceans.

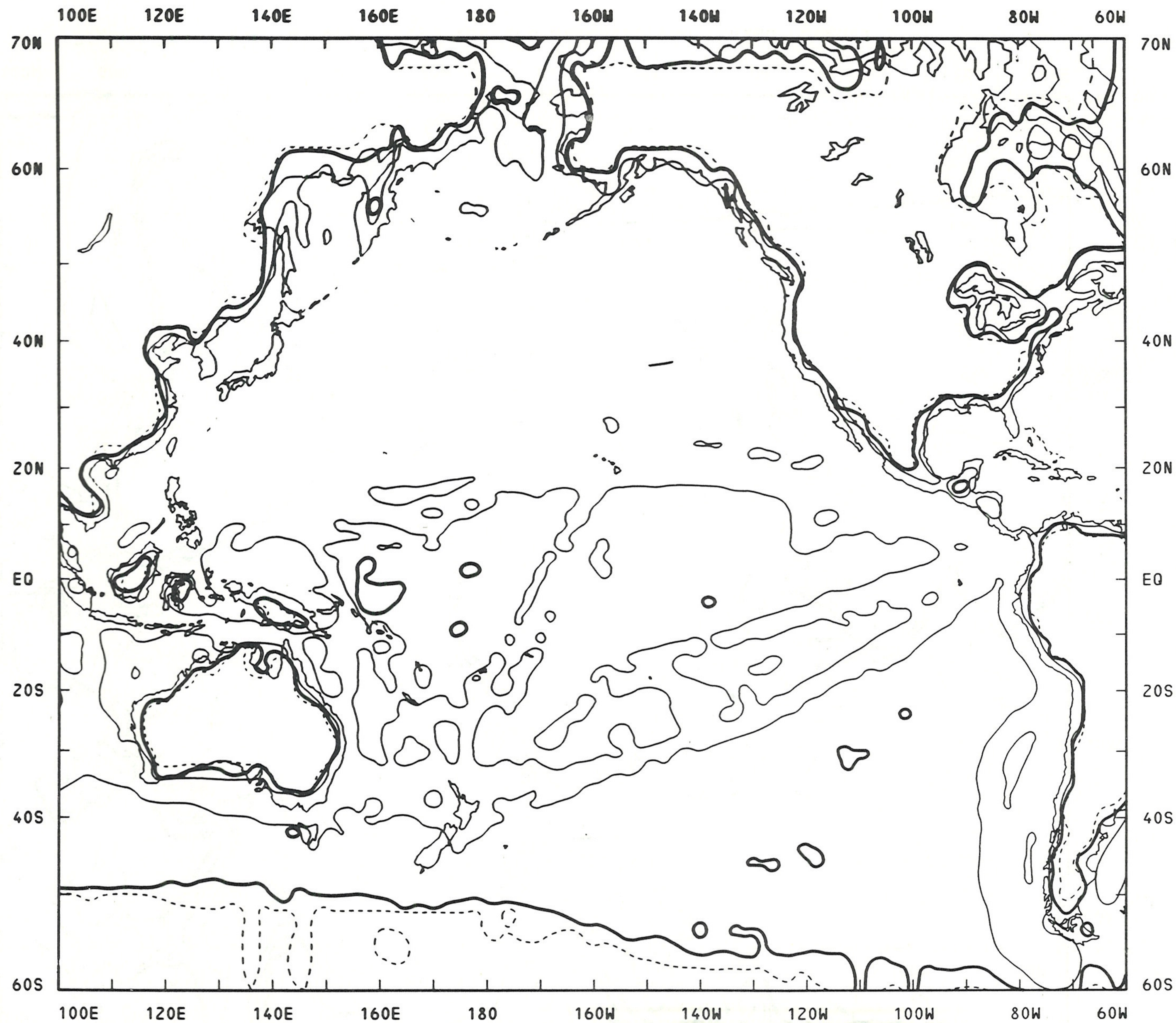


Figure 2a Number of surface marine SST measurements on a two-degree grid for the Pacific Ocean for July (see also Figure 1a).

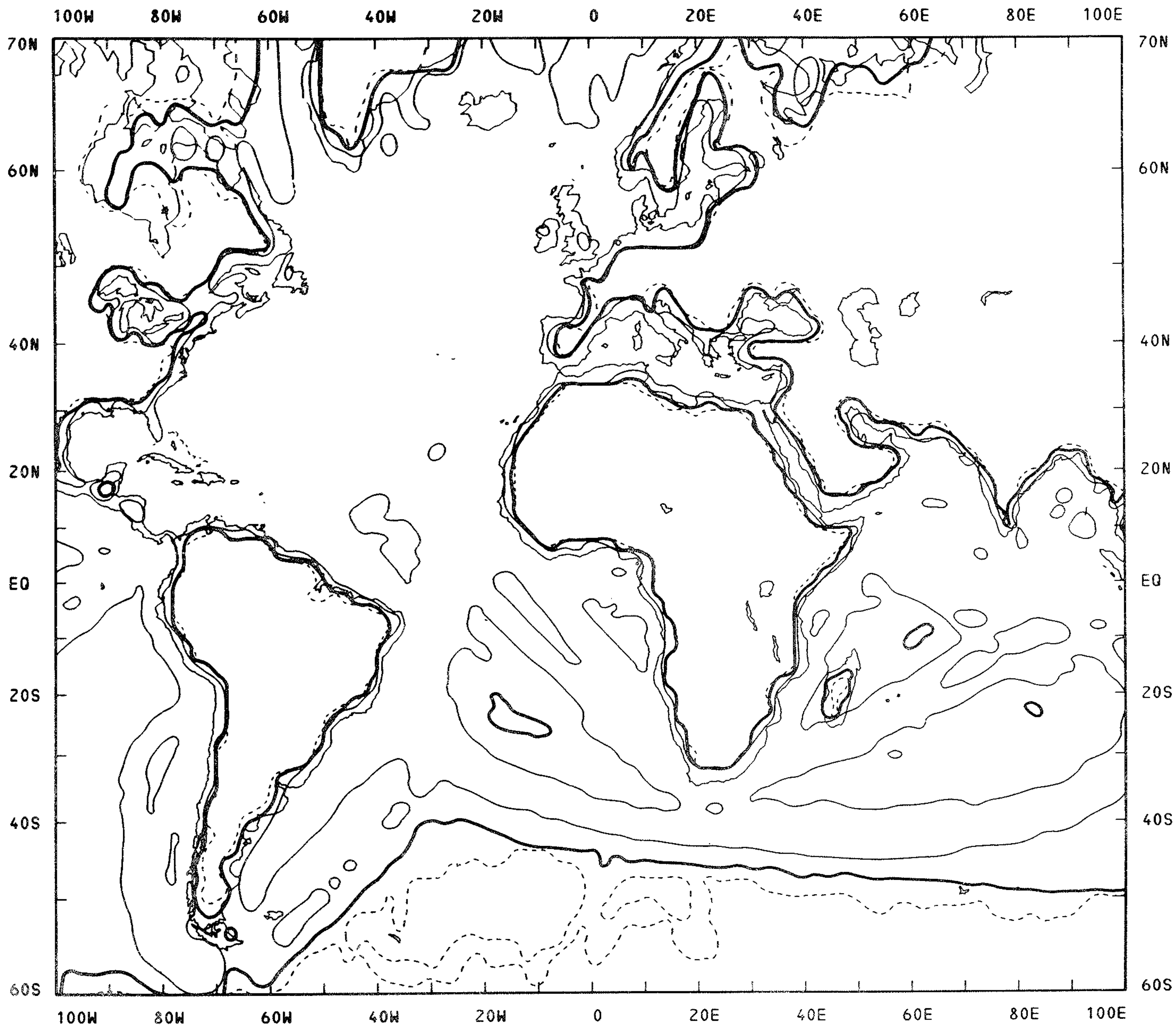


Figure 2b Same as 2a, except for the Atlantic and Indian Oceans.

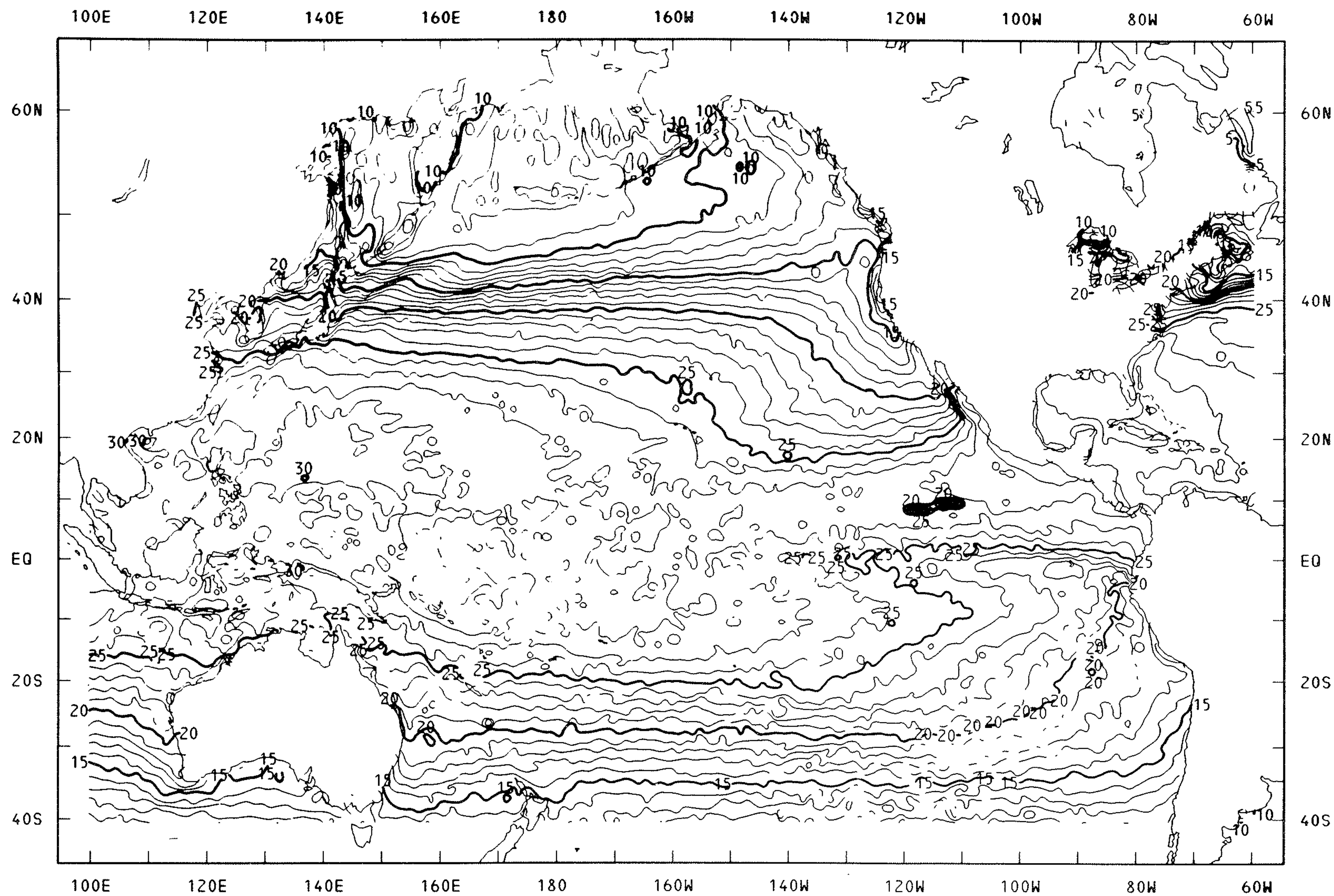


Figure 3a Original NCC mean SST summary (in °C) on a one-degree grid for the Pacific Ocean for July.

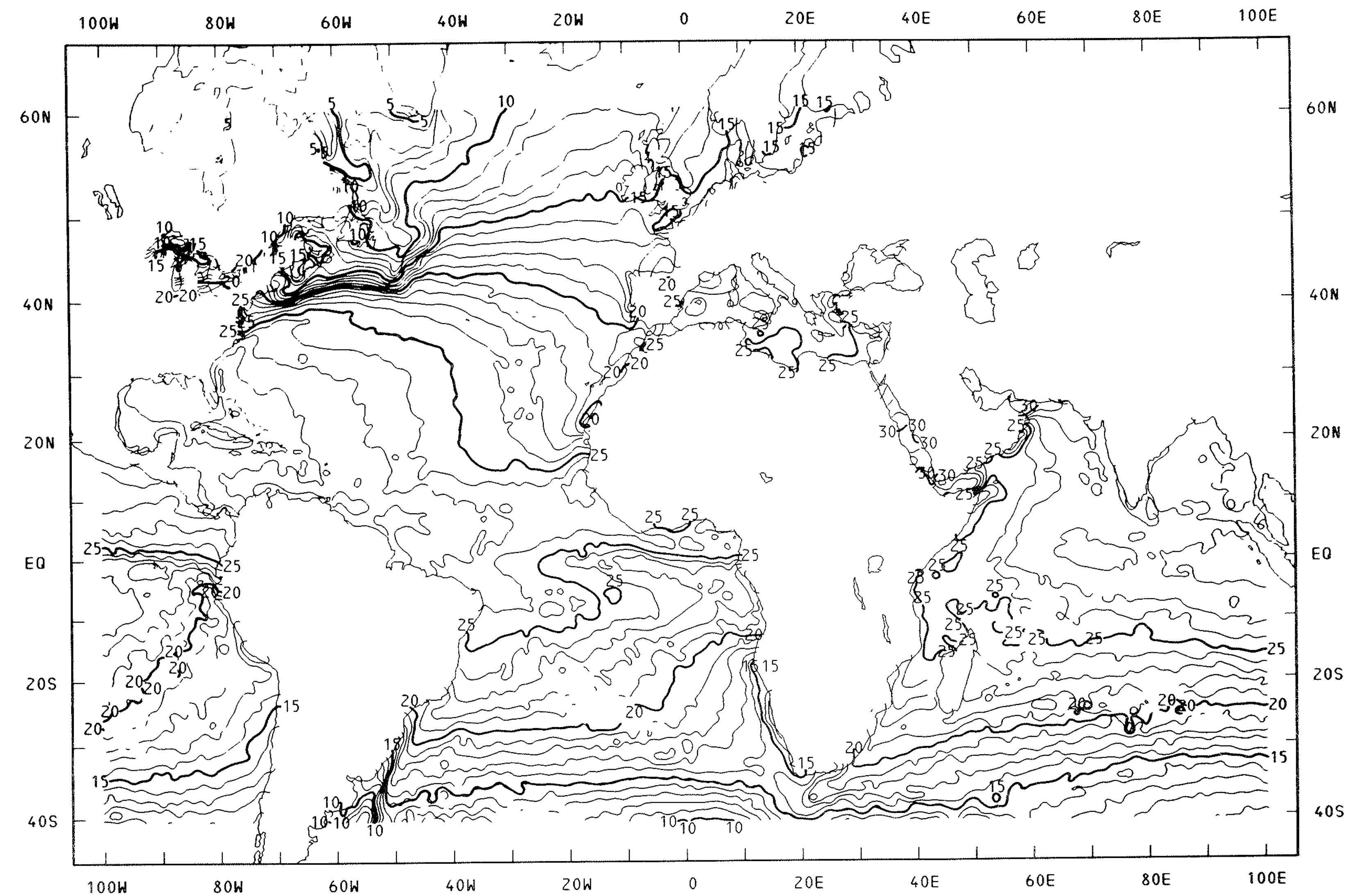


Figure 3b Same as 3a except for the Atlantic and Indian Oceans.

per one-degree grid quadrangle were used; missing data are indicated by broken contours. Although further data filtering is clearly necessary, the basic SST field is correct. In the Pacific the strong Kuroshio gradients are evident, as is the general zonal gradient of the North Pacific. In addition, the upwelling areas off Peru and California are strongly evident. The Atlantic clearly shows the Gulf Stream, including its topographically linked bend near 50°W, and shows strong upwelling regions off the west coast of Africa near 30°S.

The July summary (Fig. 3) was used because only this month showed strong evidence of questionable data. Here ten one-degree quadrangles near 10°N and between 110°W and 120°W had temperature data that were over 10°C cooler than the surrounding values. This difference was caused by a large set of observations with position errors (Carpenter, personal comunication). Since only the data summary was available, the ten bad July values were replaced by linearly interpolated values.

To filter the data, a nonlinear filter based on computation of medians (Rabiner, 1975) was used. Since medians were used rather than weighted means, extreme points could be systematically eliminated from the final product. The median was computed over a maximum of four grid prints so some smoothing could occur across land boundaries. To eliminate this nonphysical processing of oceanic temperatures, the world oceans were divided into two regions: the Pacific, bounded by the 99°E meridian and the west coast of the Americas; and the Atlantic and Indian, bounded by the 101°E meridian and the east coast of the Americas. Furthermore, data from inland sea areas such as the Mediterranean, the Sea of Japan, and the Gulf of California were eliminated. Finally, regions of poor data coverage, such as parts of the Sea of Okhotsk and the Gulf of Carpentania, were also eliminated so that data points at the grid edge were not based on only a few observations. (All discarded data could later be treated as individual regions and then added to the finished product.)

Since the filtering technique cannot process missing data or the initial and final four points of a spatial series, the missing interior data were interpolated, and the grid was extended four grid points by extrapolation. The filter was then applied, first horizontally and then vertically, for each monthly field. However, after filtering, all the extrapolated points were discarded, and only the open-ocean interpolated points were retained. Final SST values near the edge of the the grid may be slightly affected by the filtering of extrapolated points; however, as will be seen, this effect is very minor.

At this stage each field was re-examined, and some minor grid-scale noise was evident. A light linear smoothing by a five-point binomial filter (Holloway, 1958) was then carried out both horizontally and vertically. This eliminated most of the noise and completed the data processing.

4. RESULTS

The final SST climatology is shown in figures 4-15 for each month, beginning with January. The grid-scale noise of the original summary is gone, and the large-scale features, especially near the Equator, are now

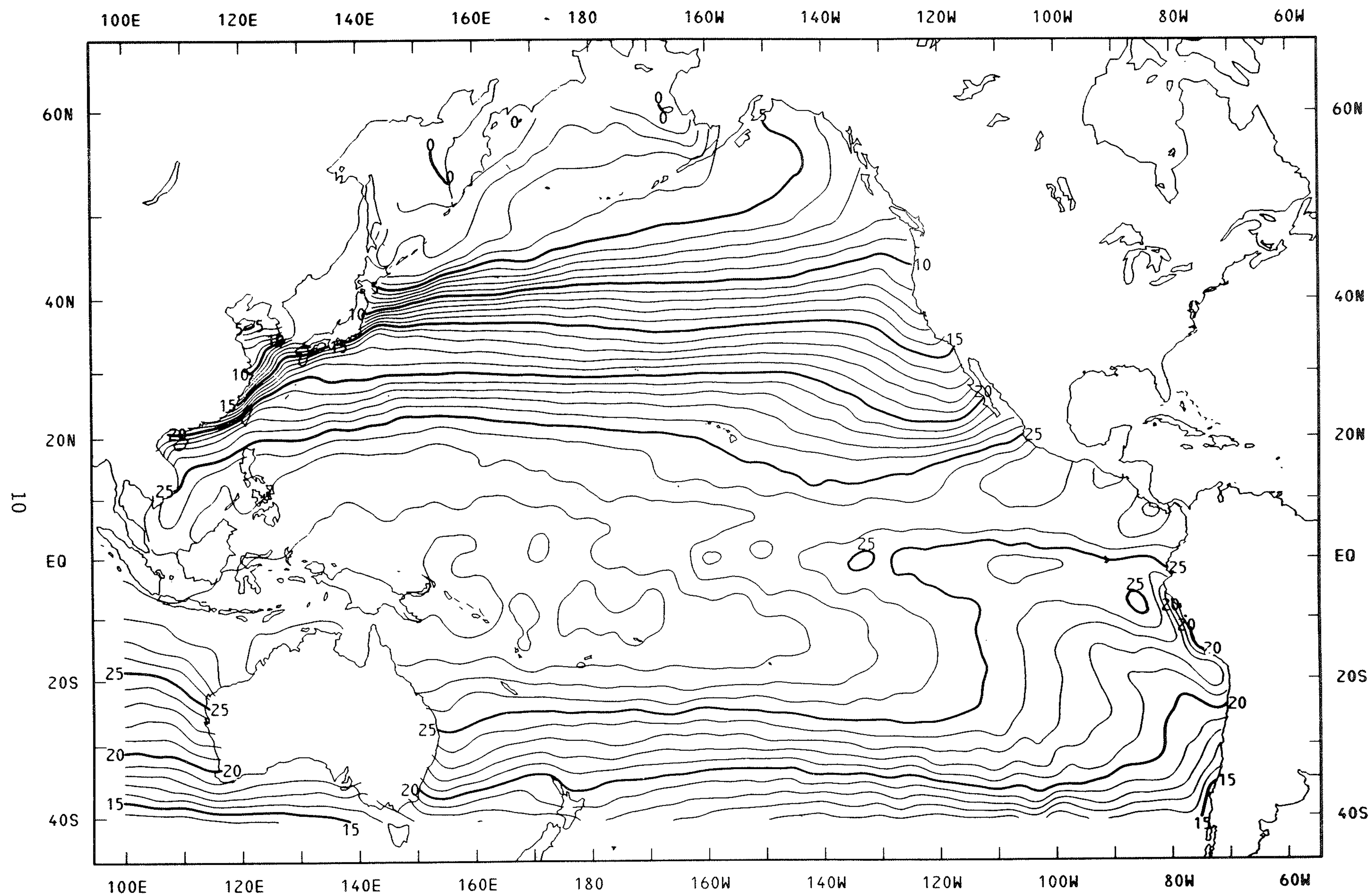


Figure 4a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for January.

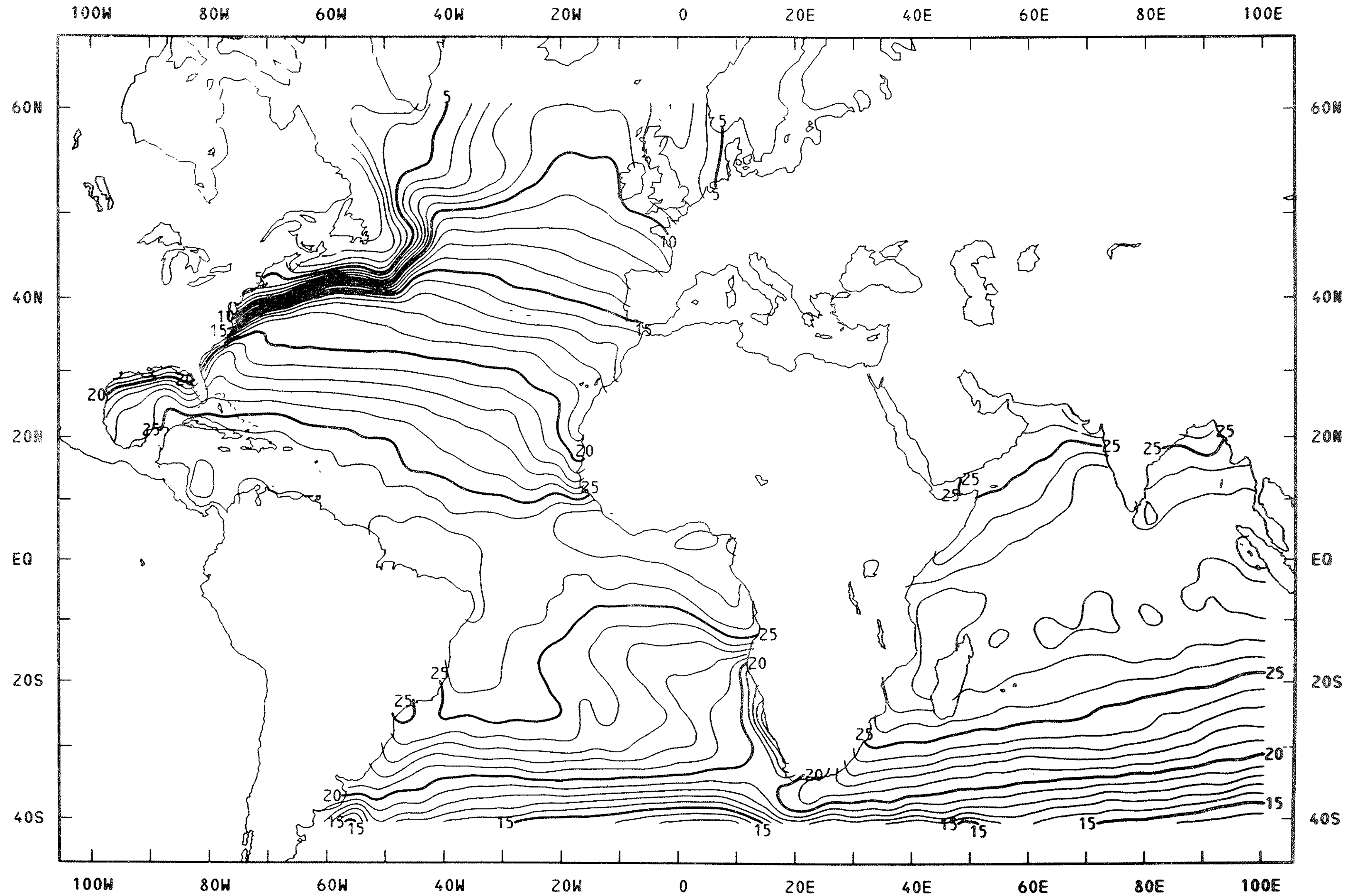


Figure 4b Same as 4a except for the Atlantic and Indian Oceans.

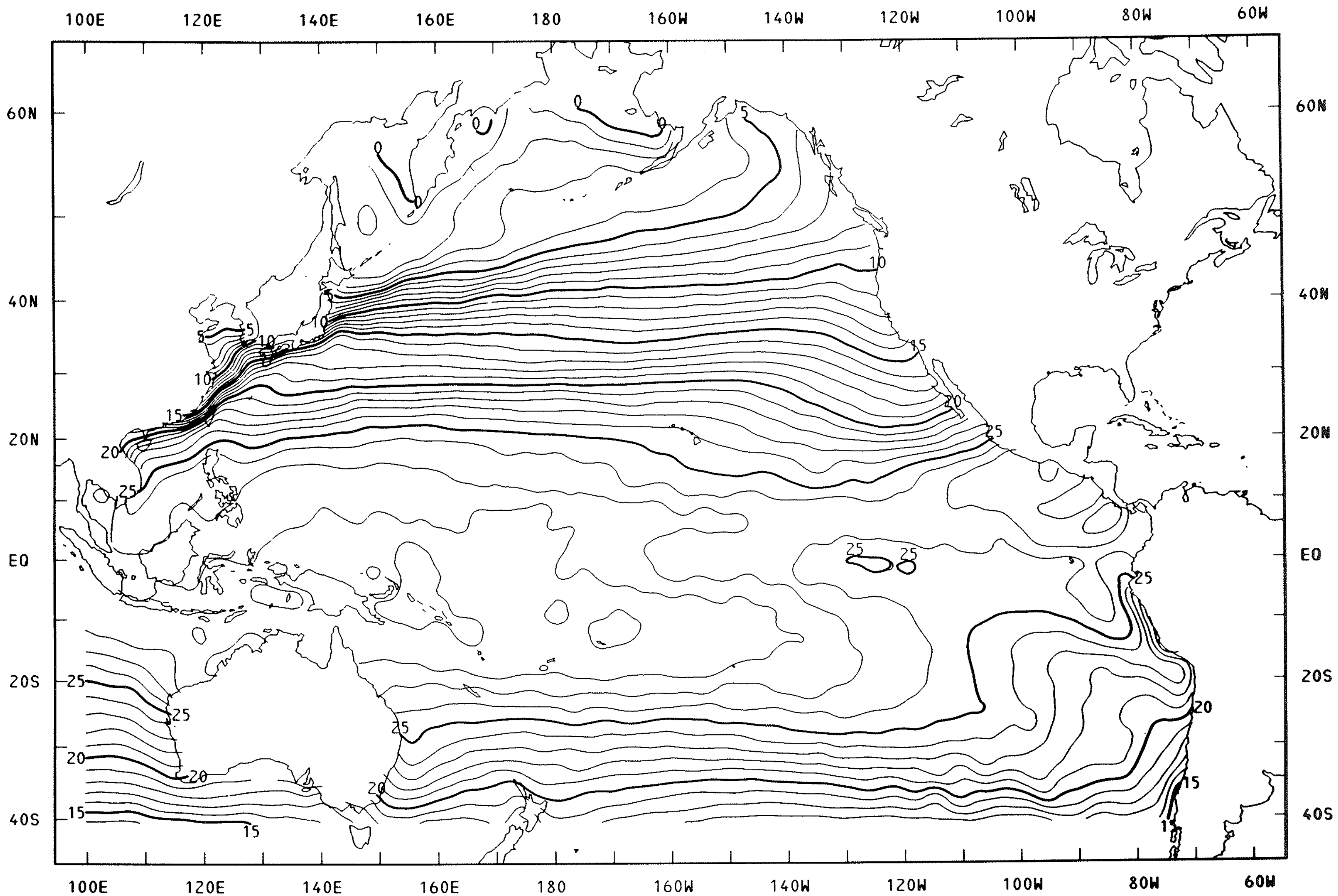


Figure 5a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for February.

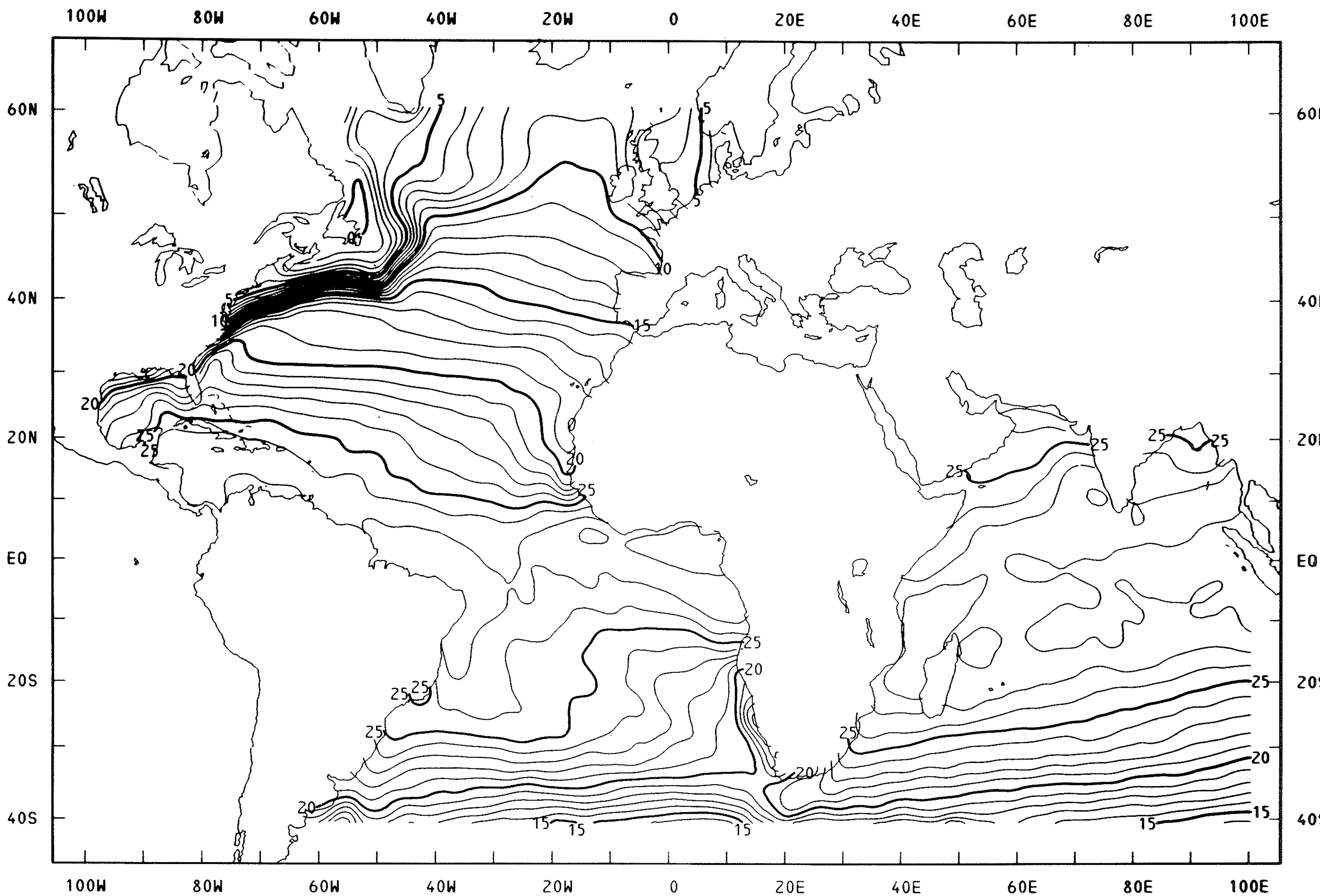


Figure 5b   Same as 5a except for the Atlantic and Indian Oceans.

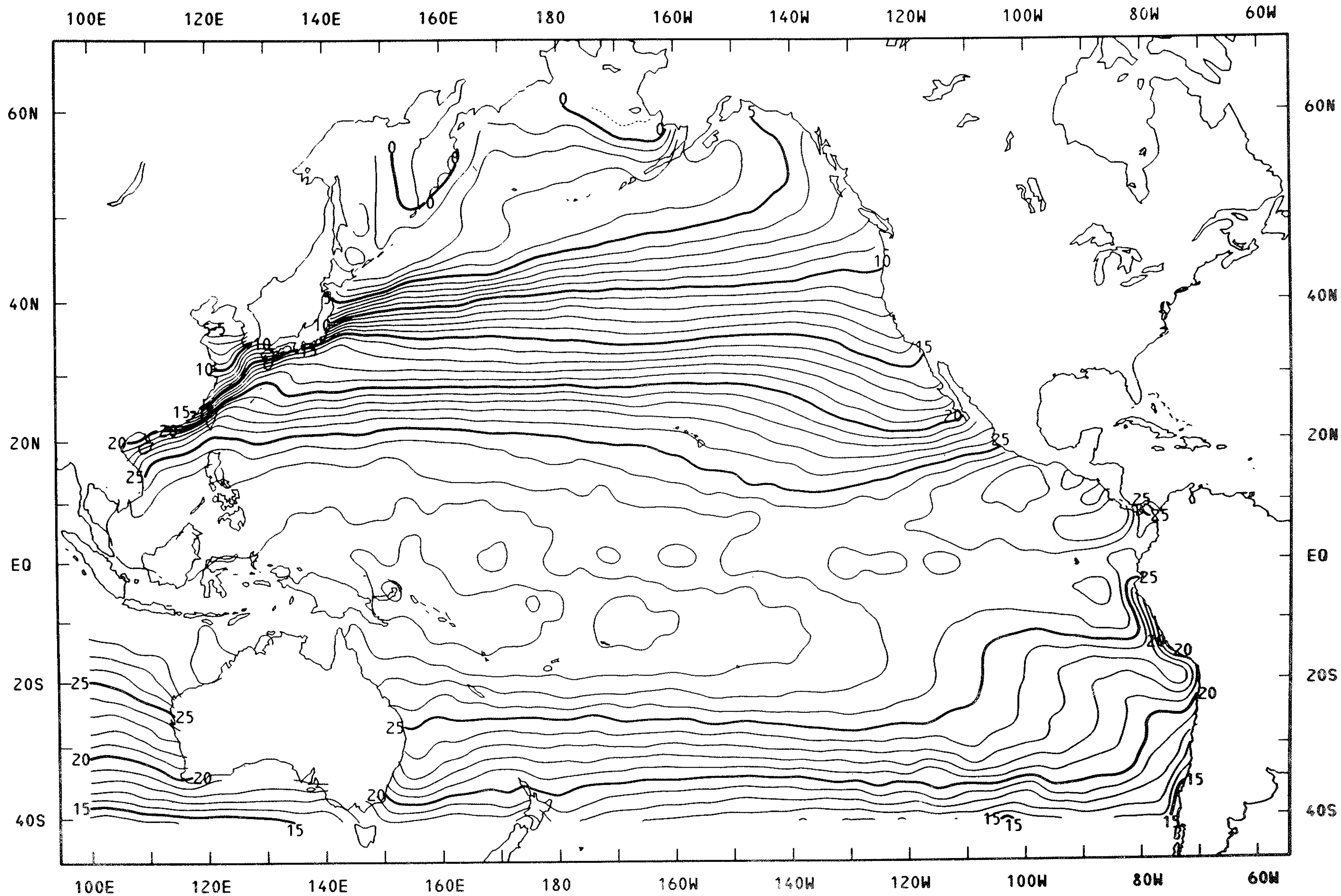


Figure 6a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for March.

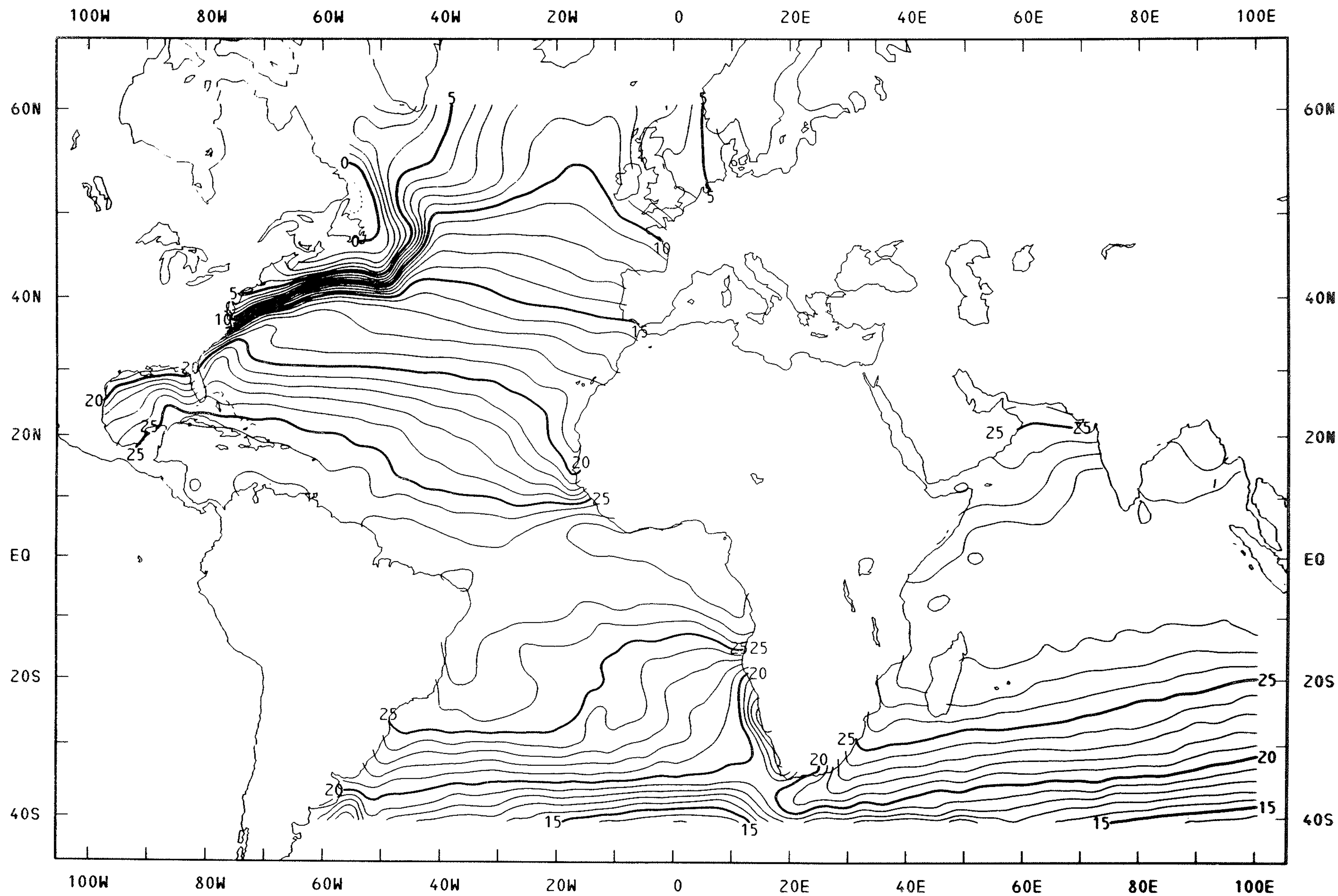


Figure 6b   Same as 6a except for the Atlantic and Indian Oceans.

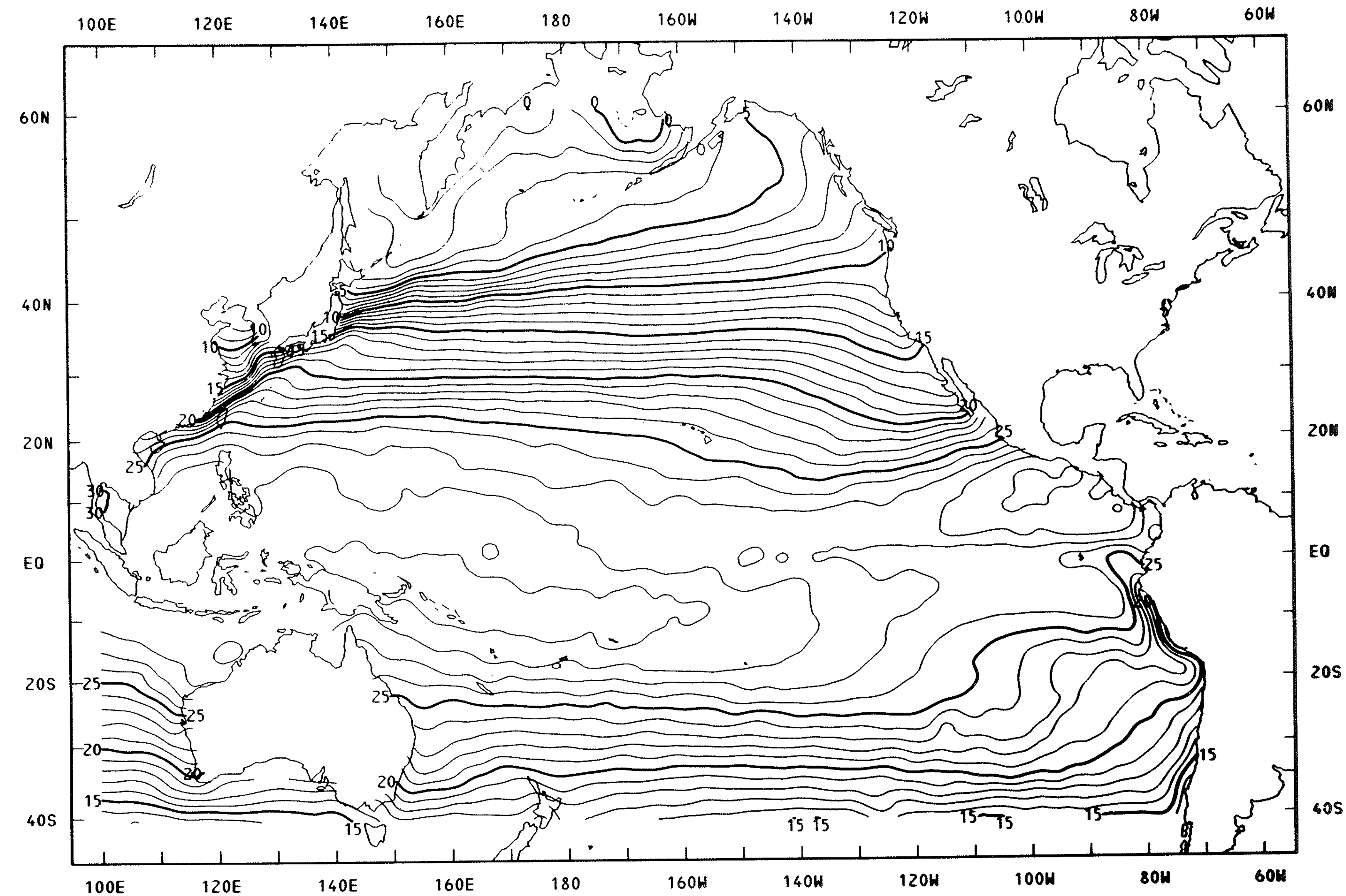


Figure 7a   Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for April.

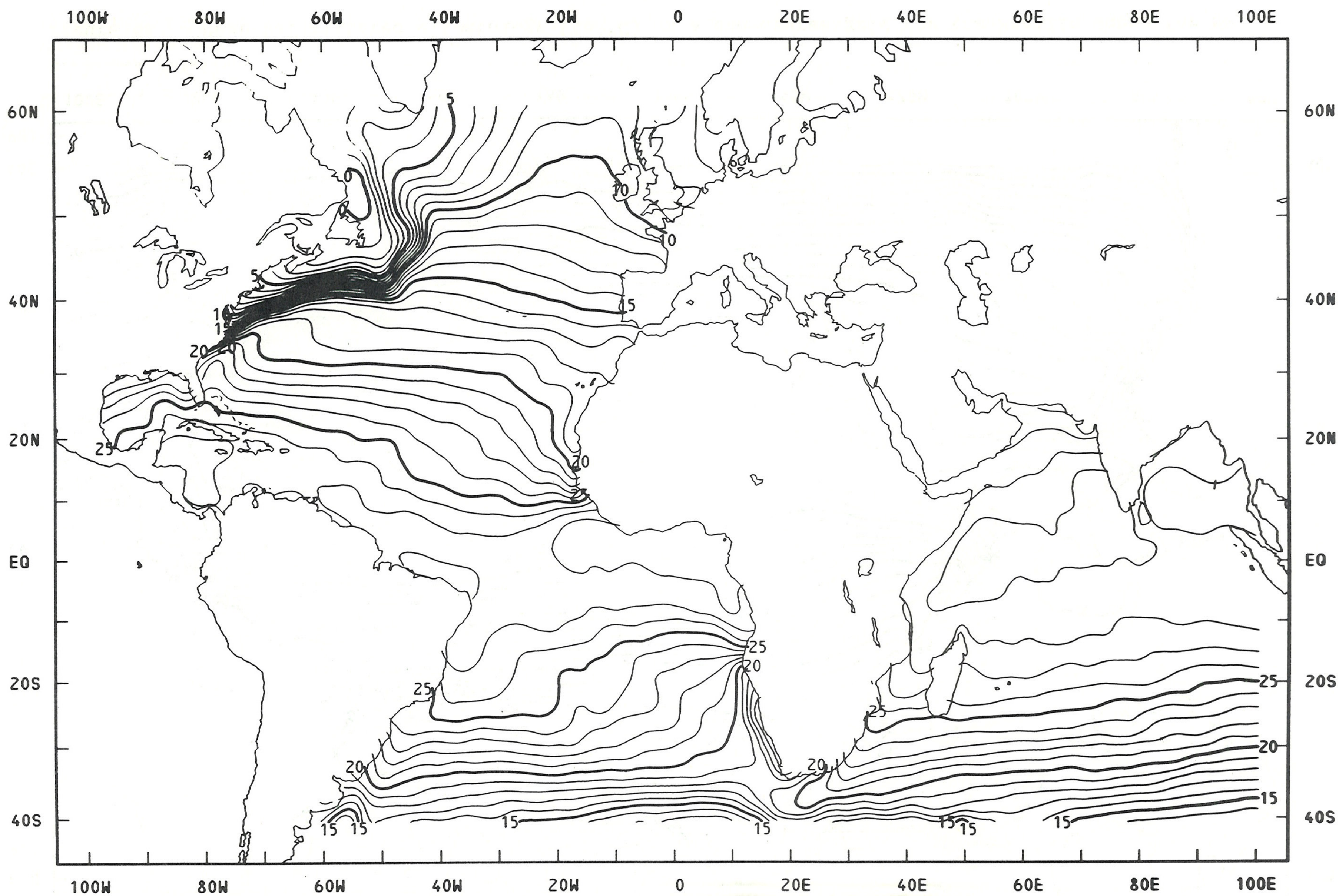


Figure 7b   Same as 7a except for the Atlantic and Indian Oceans.

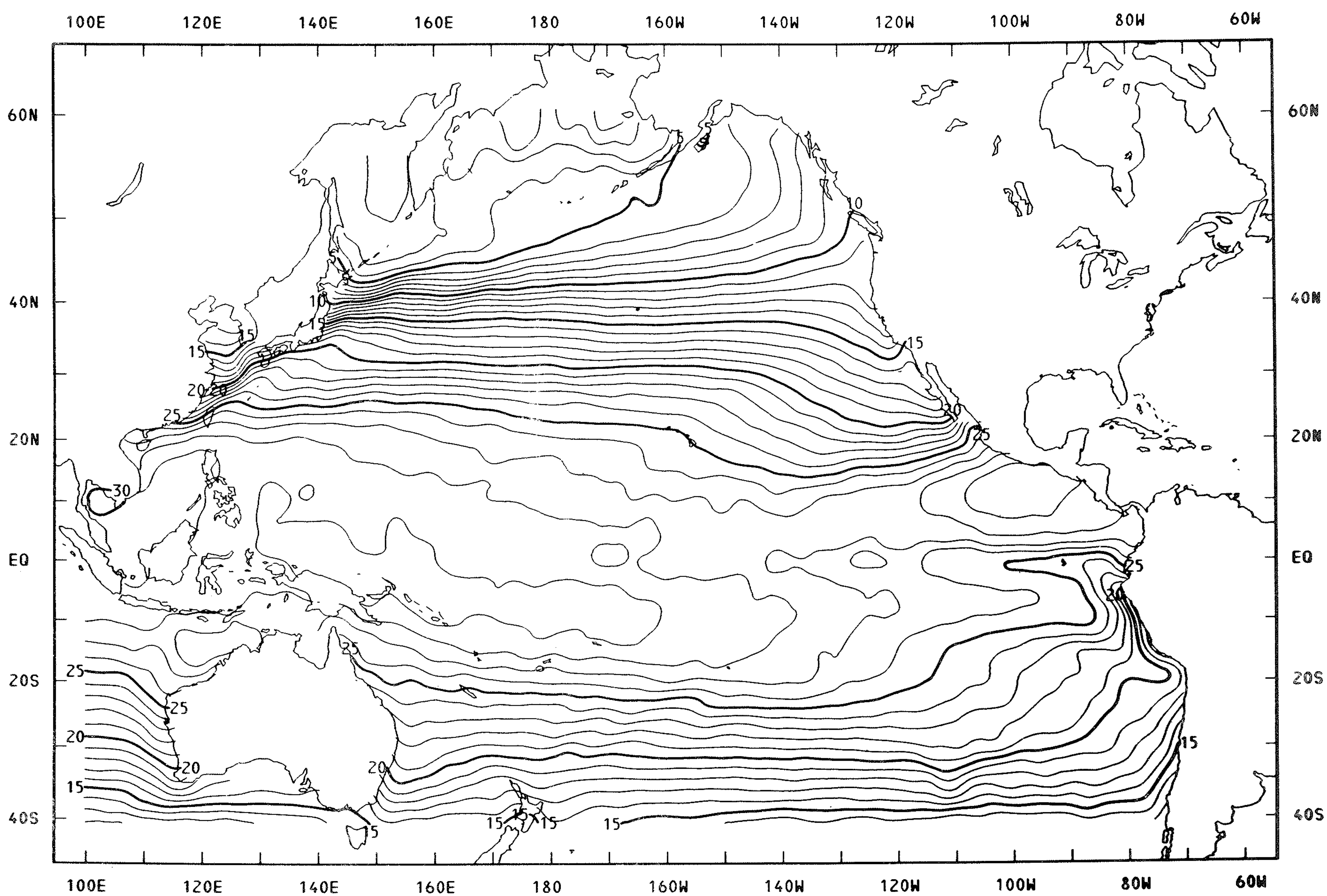


Figure 8a   Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for May.

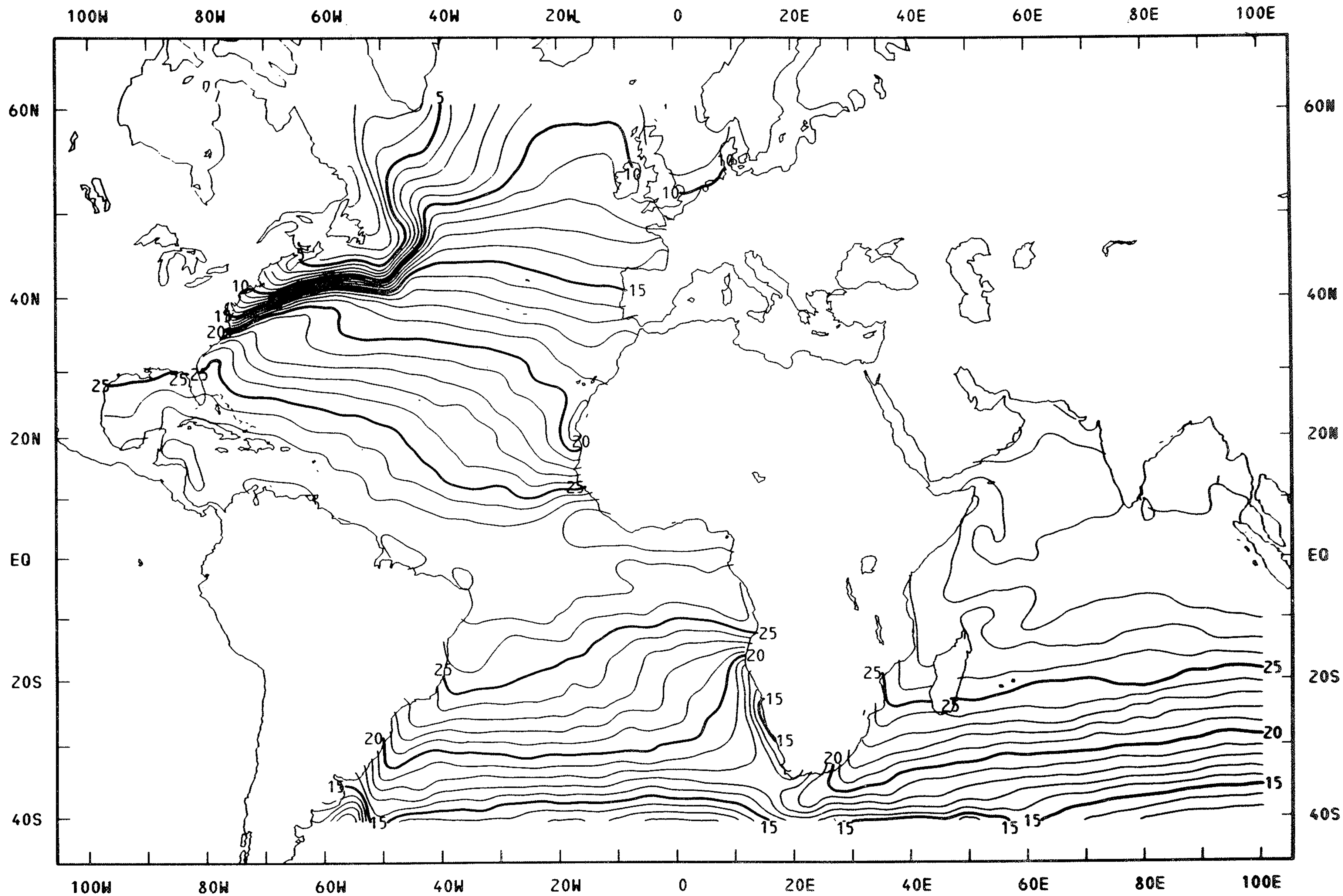
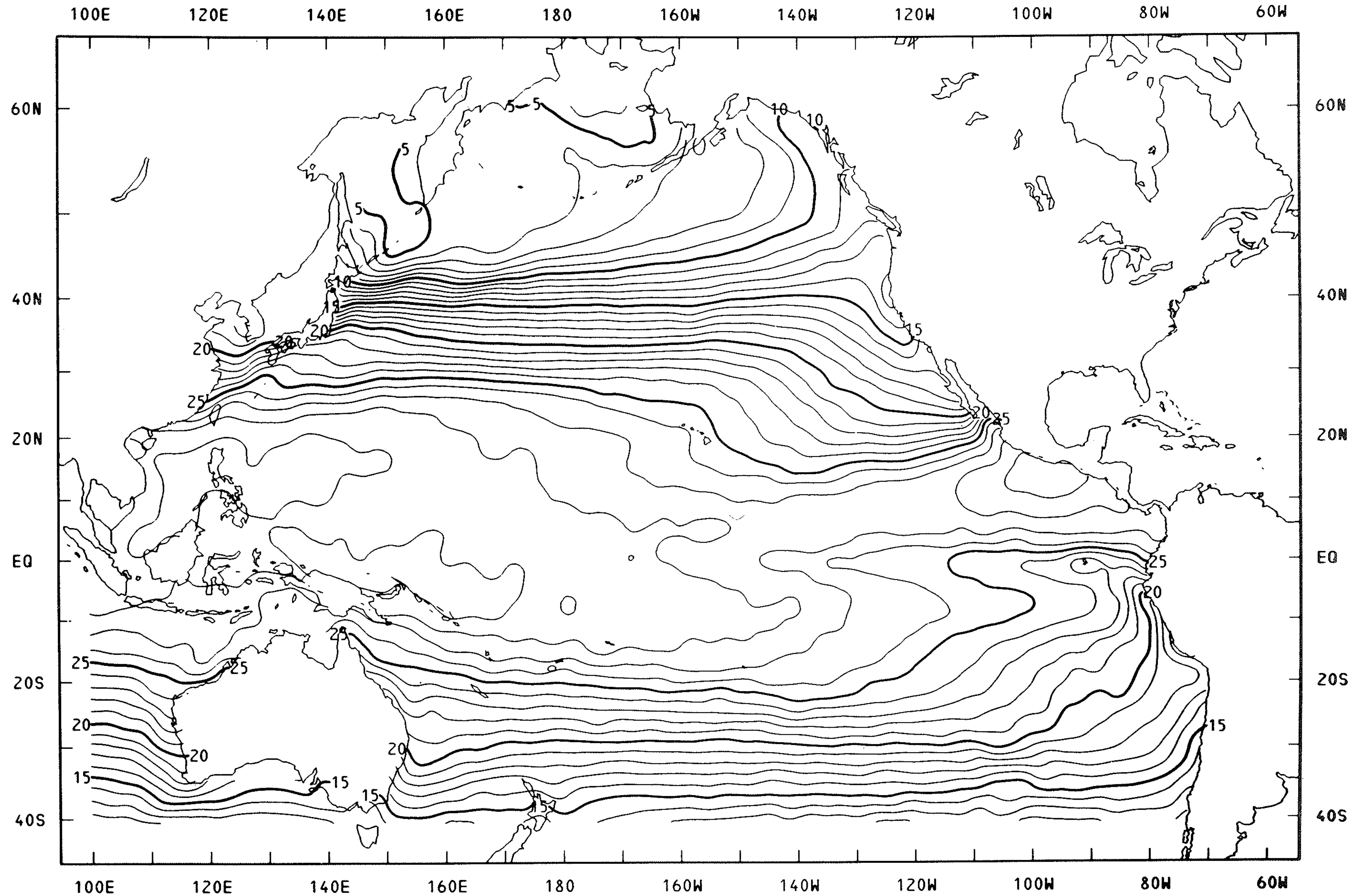


Figure 8b   Same as 8a except for the Atlantic and Indian Oceans.



Figure, 9a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for June.

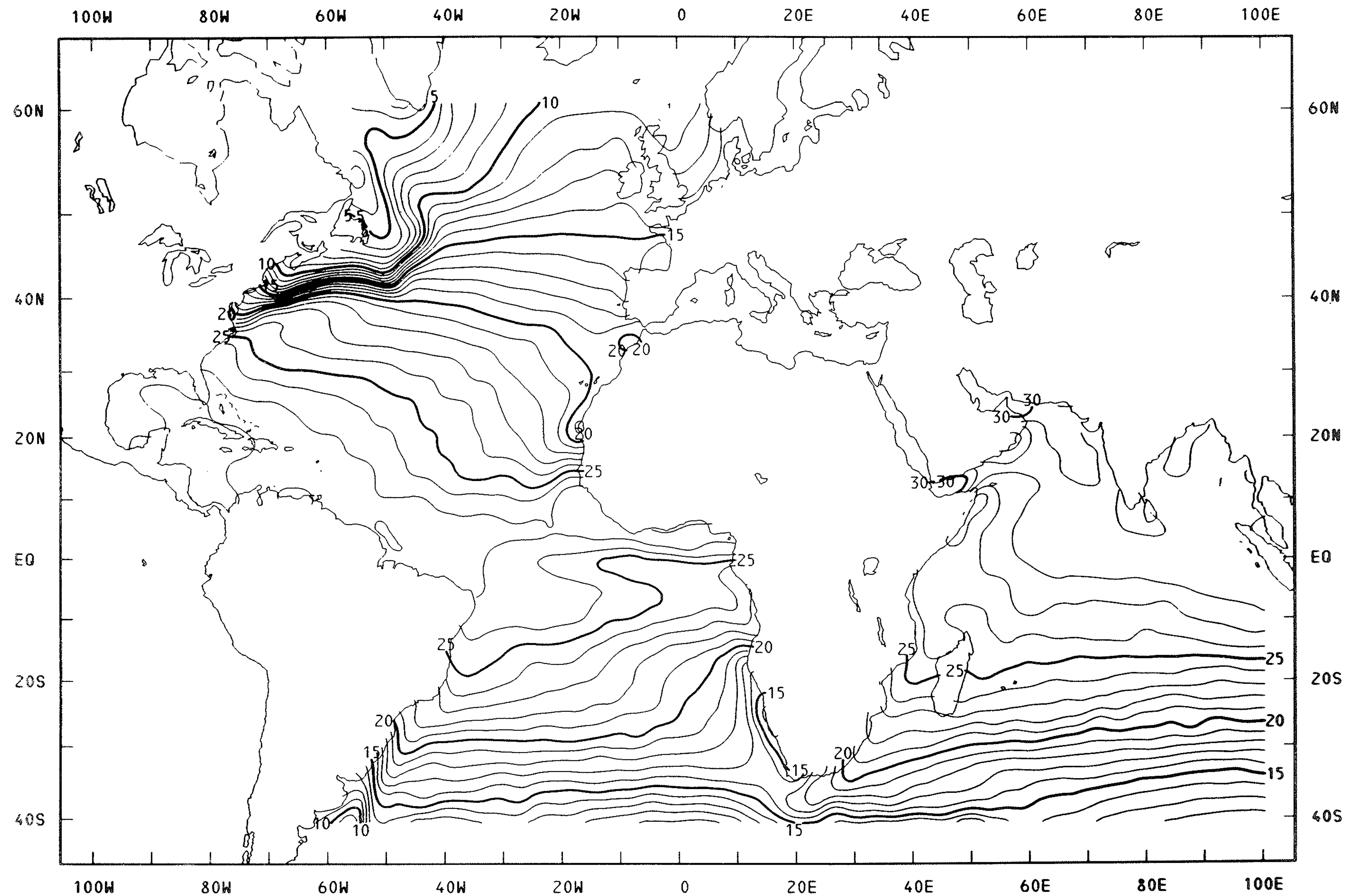


Figure 9b Same as 9a except for the Atlantic and Indian Oceans.

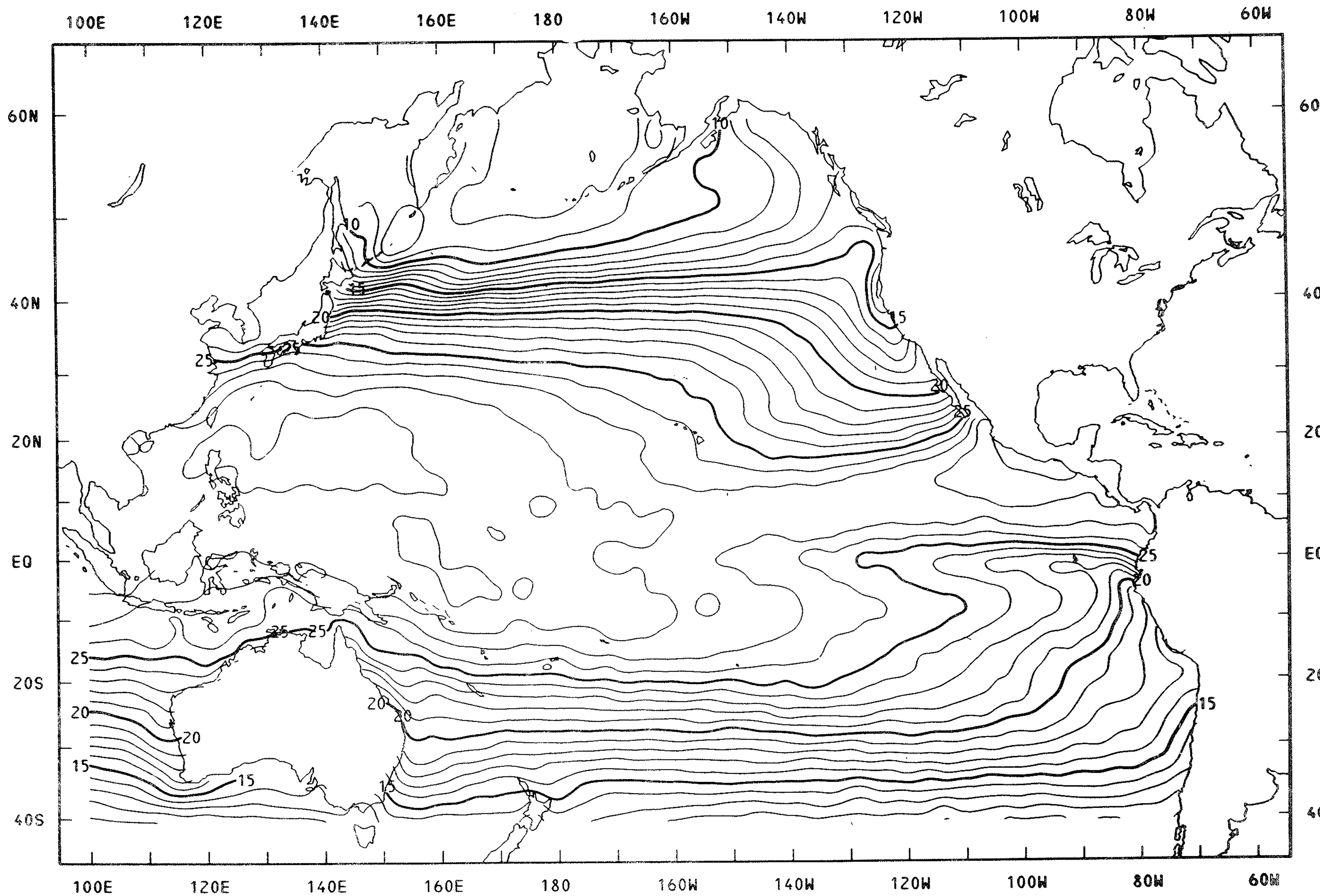


Figure 10a   Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for July.

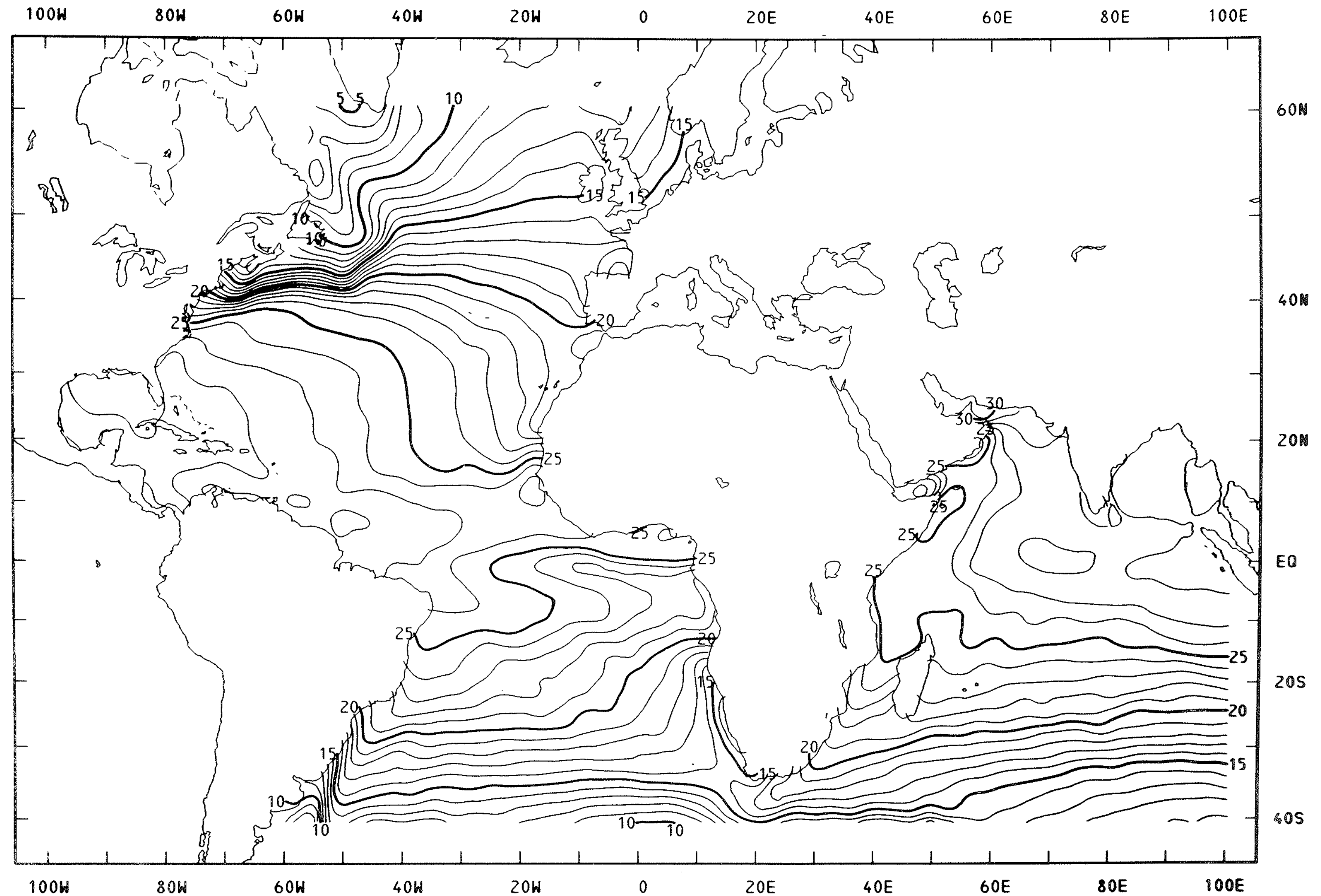


Figure 10b Same as 10a except for the Atlantic and Indian Oceans.

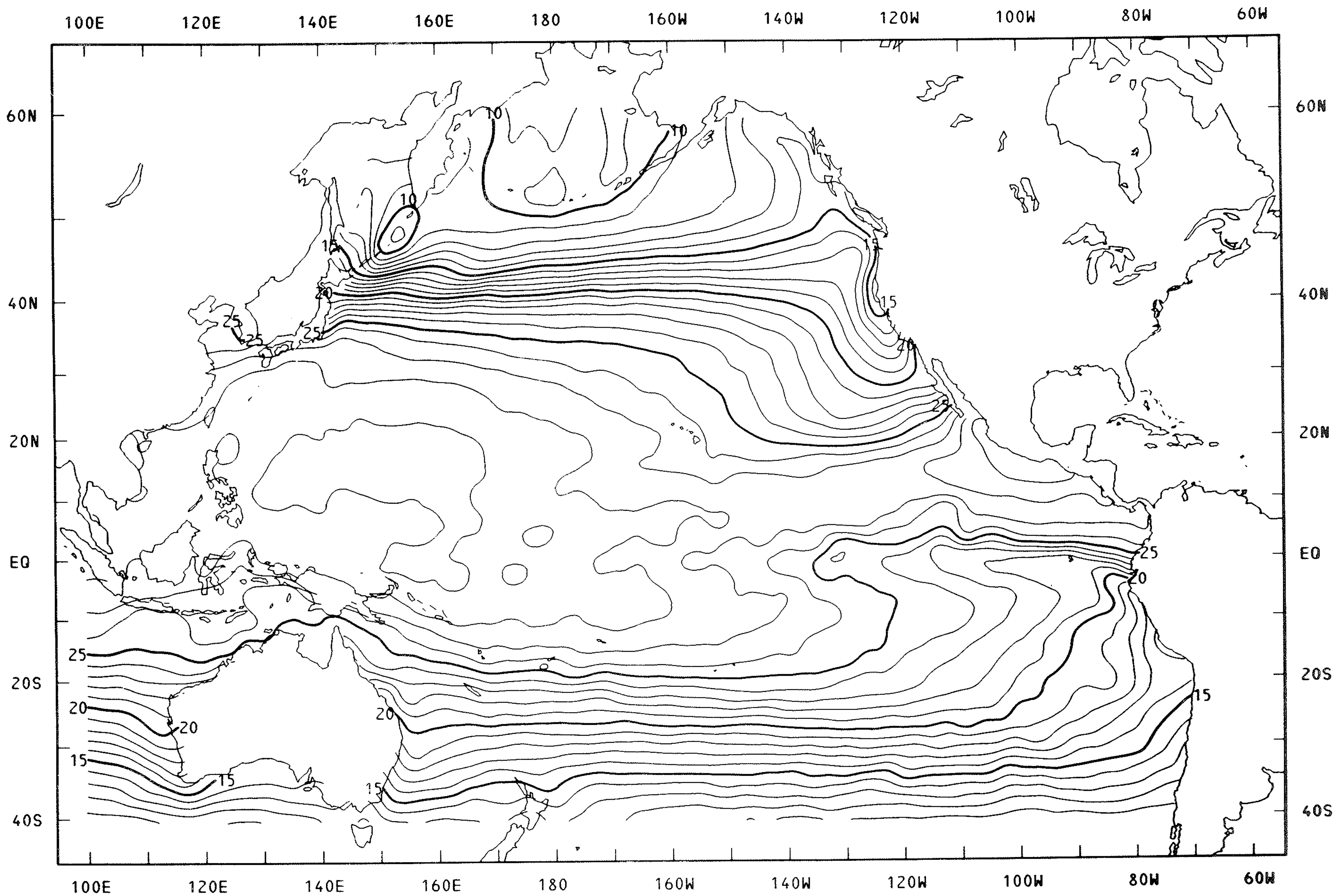


Figure 11a   Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for August.

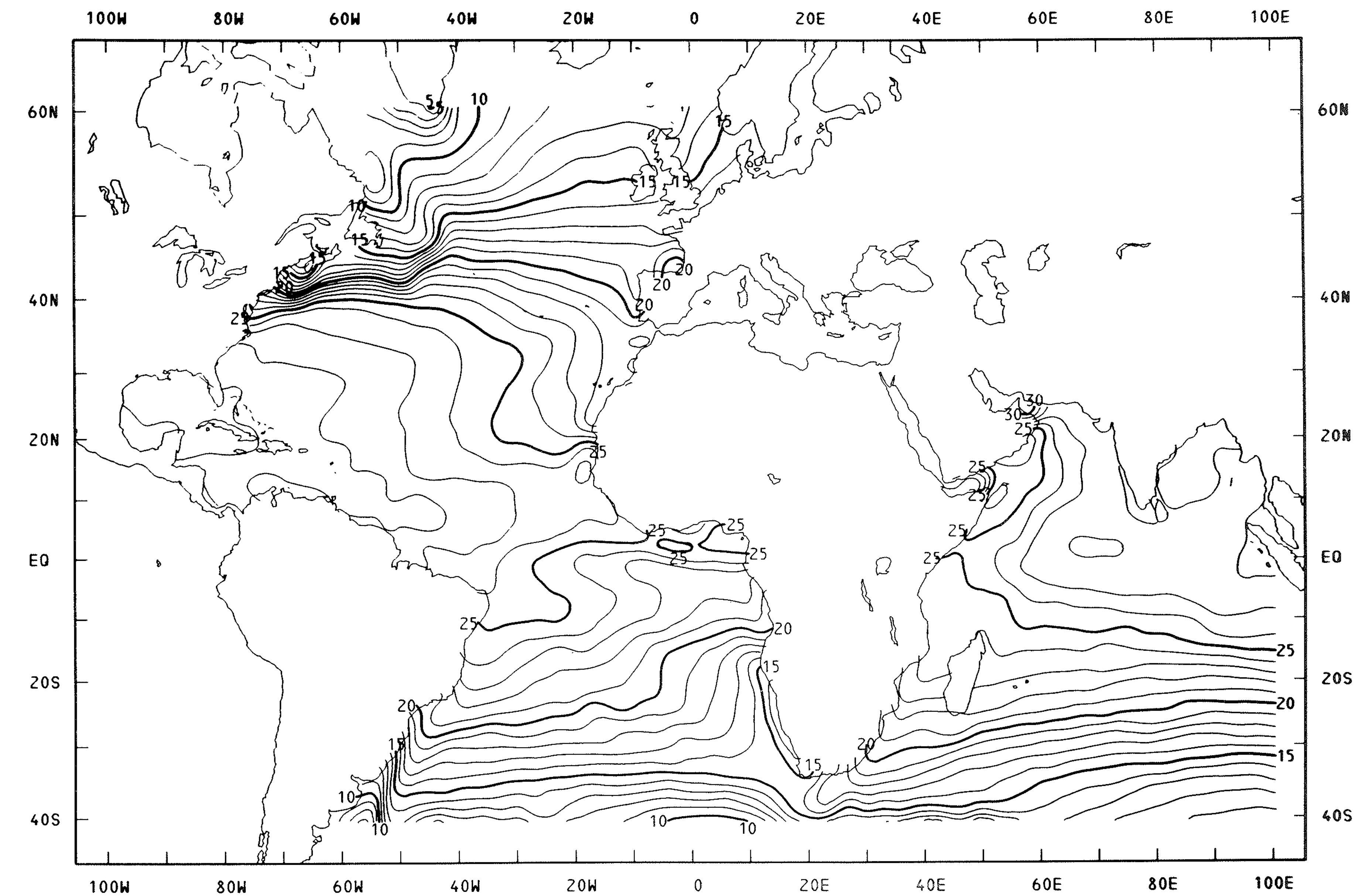


Figure 11b Same as 11a except for the Atlantic and Indian Oceans.

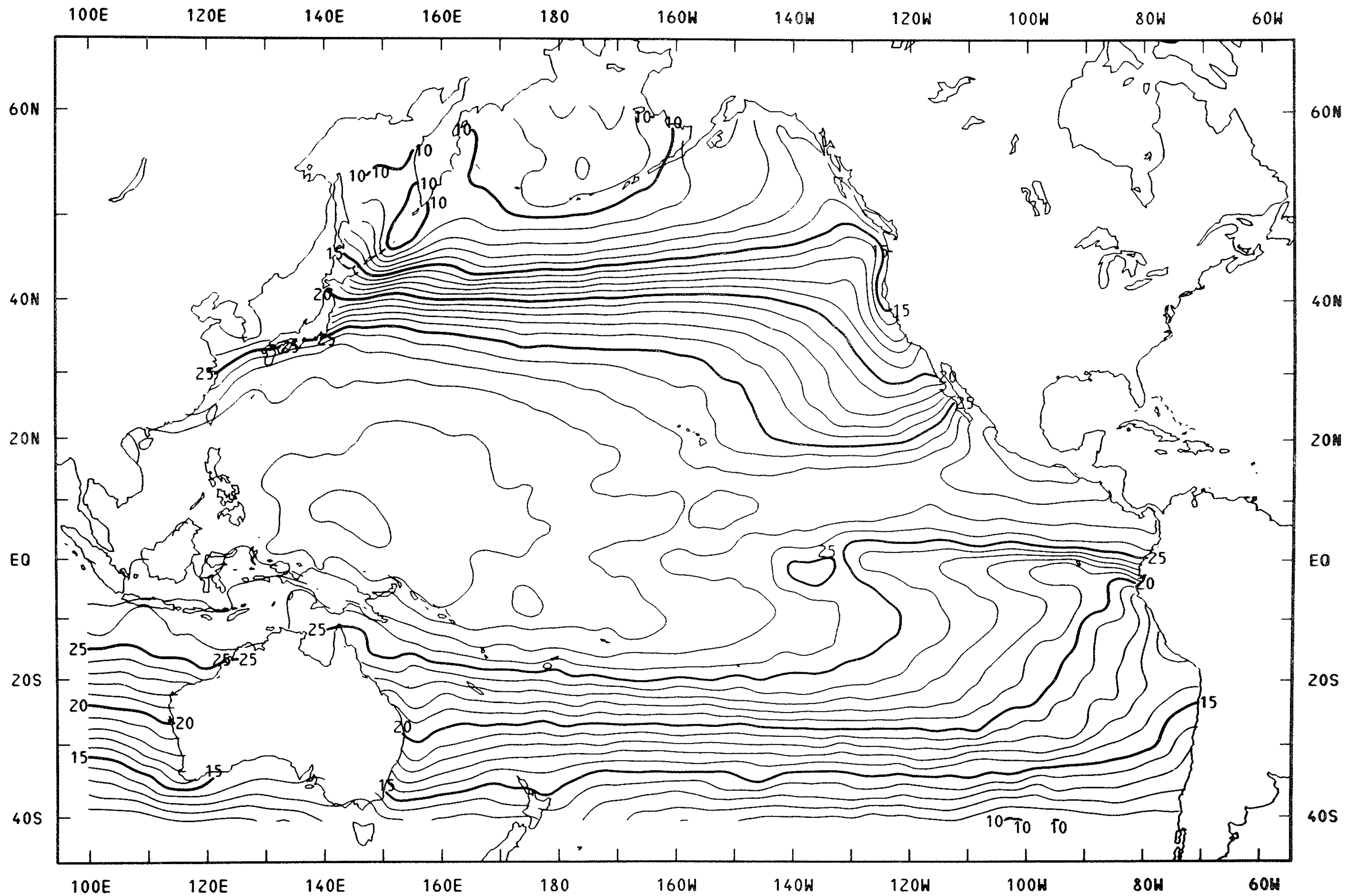


Figure 12a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for September.

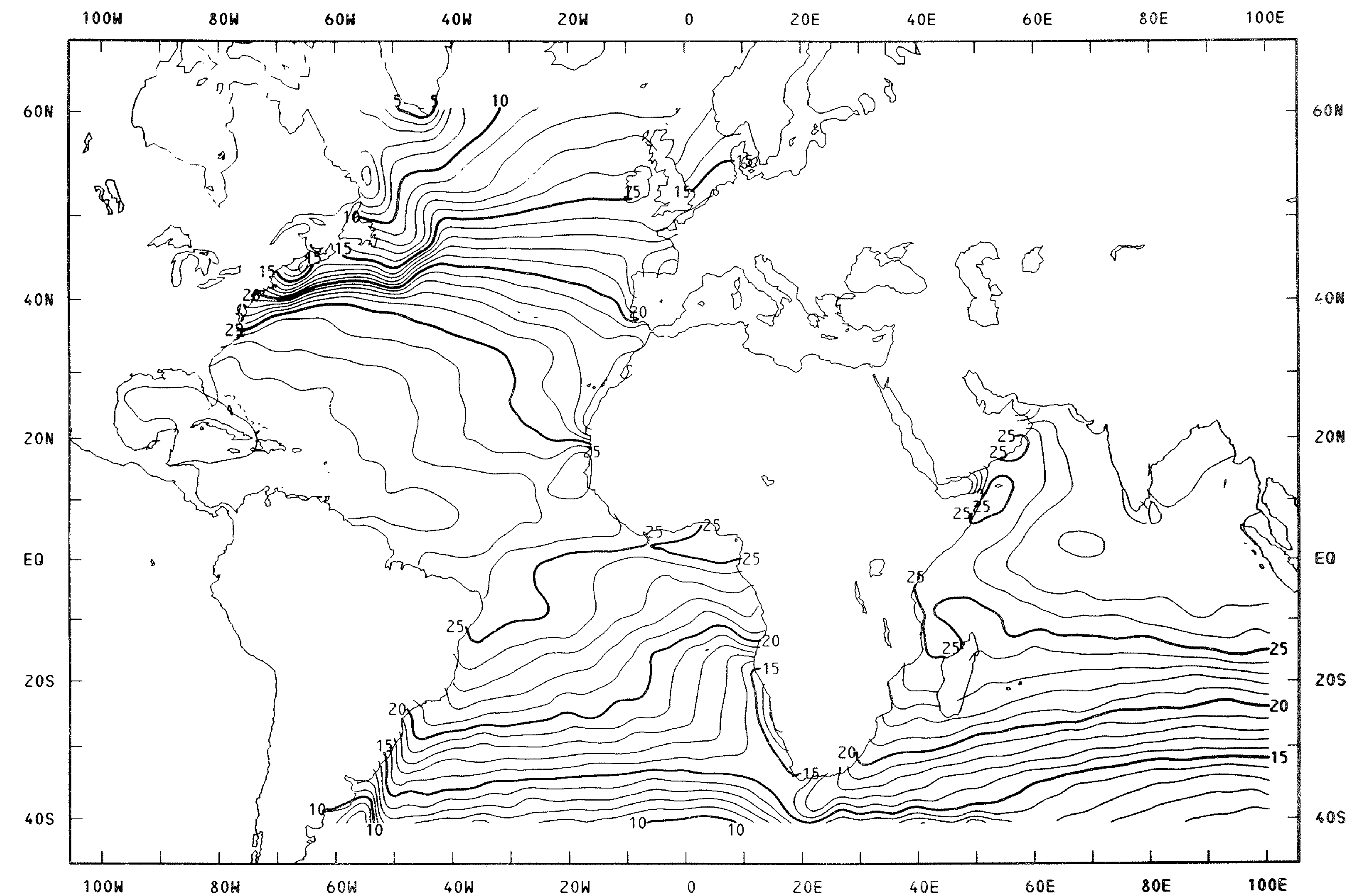


Figure 12b   Same as 12a except for the Atlantic and Indian Oceans.

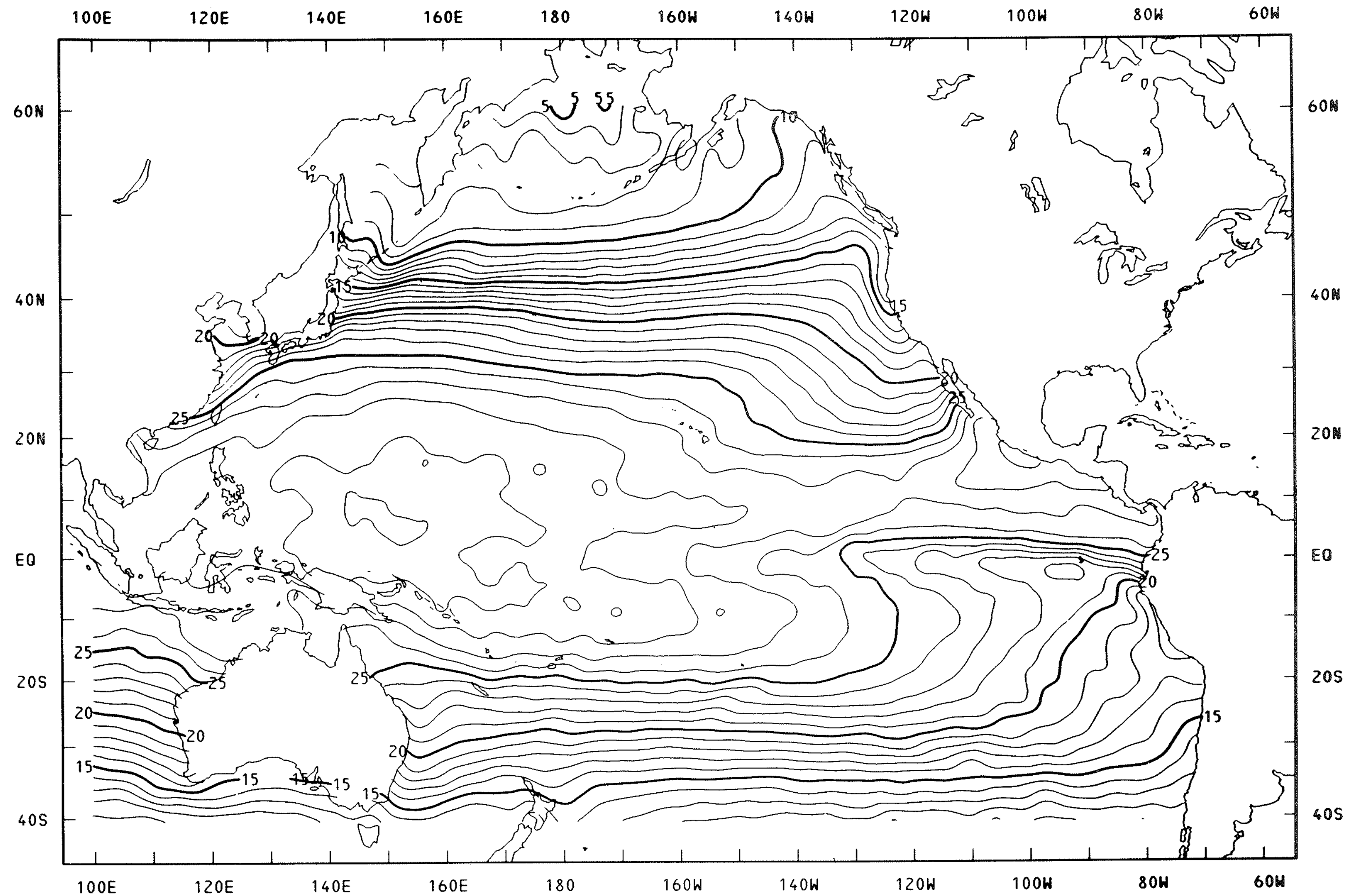


Figure 13a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for October.

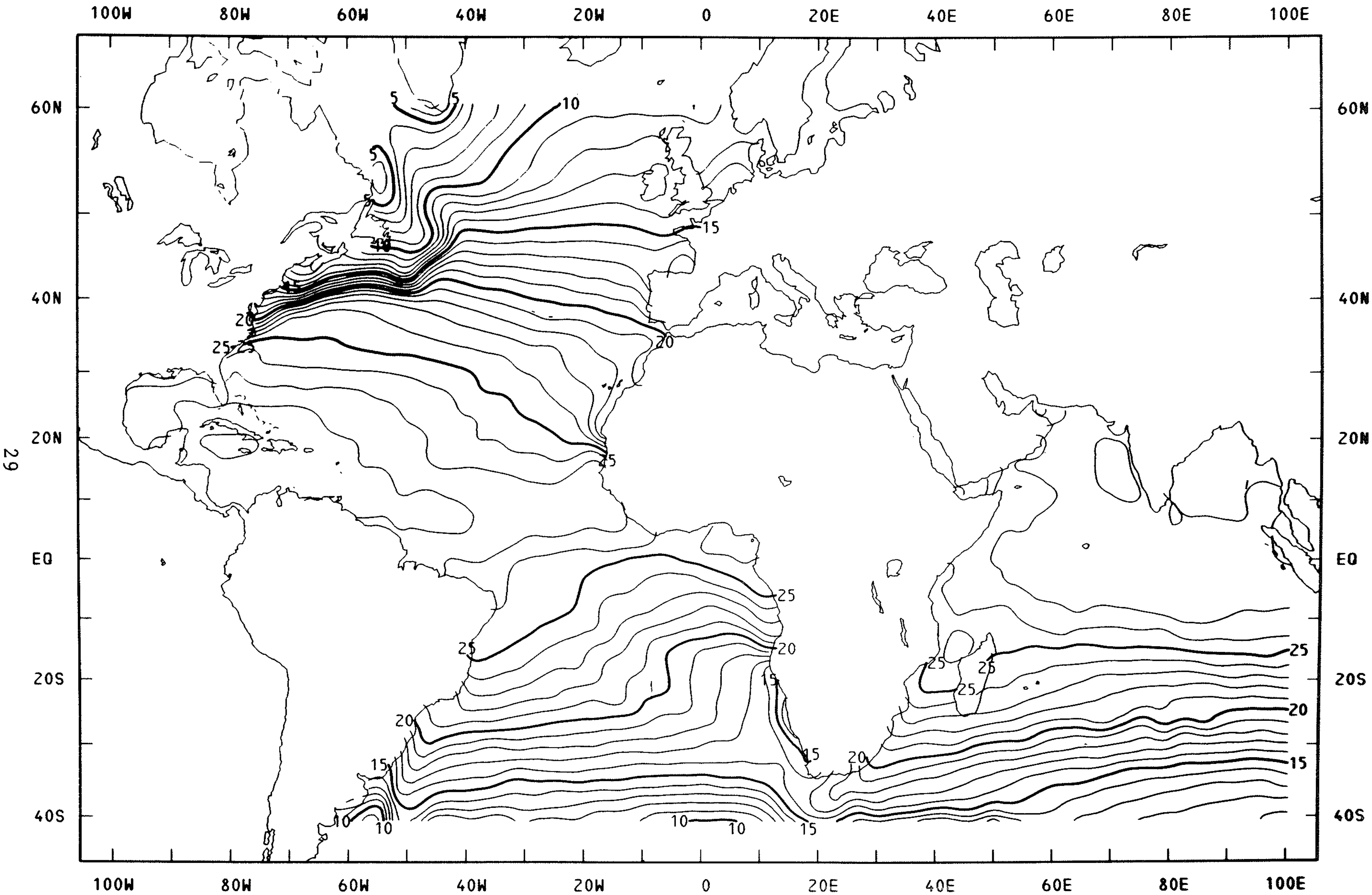


Figure 13b   Same as 13a except for the Atlantic and Indian Oceans.

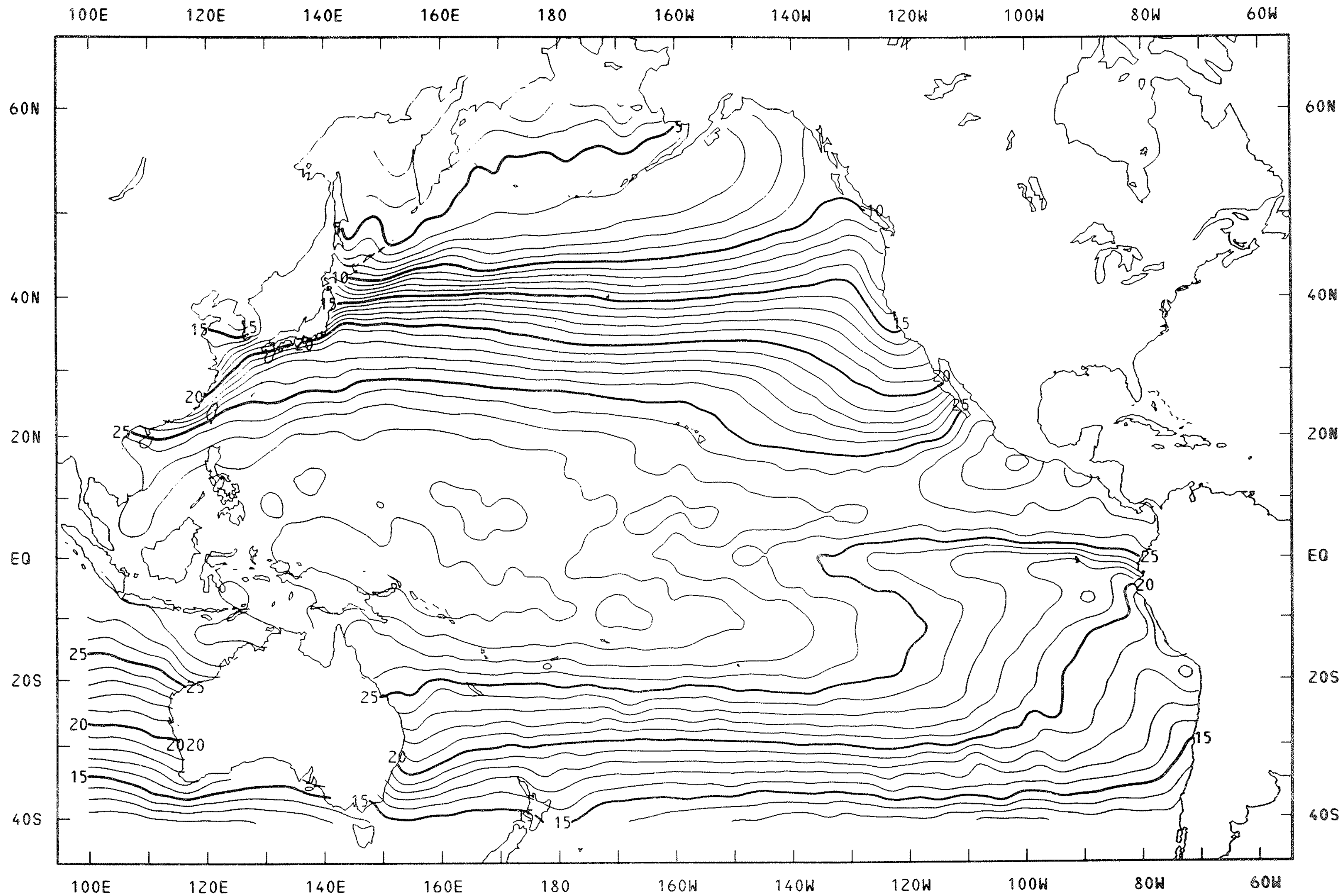


Figure 14a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for November.

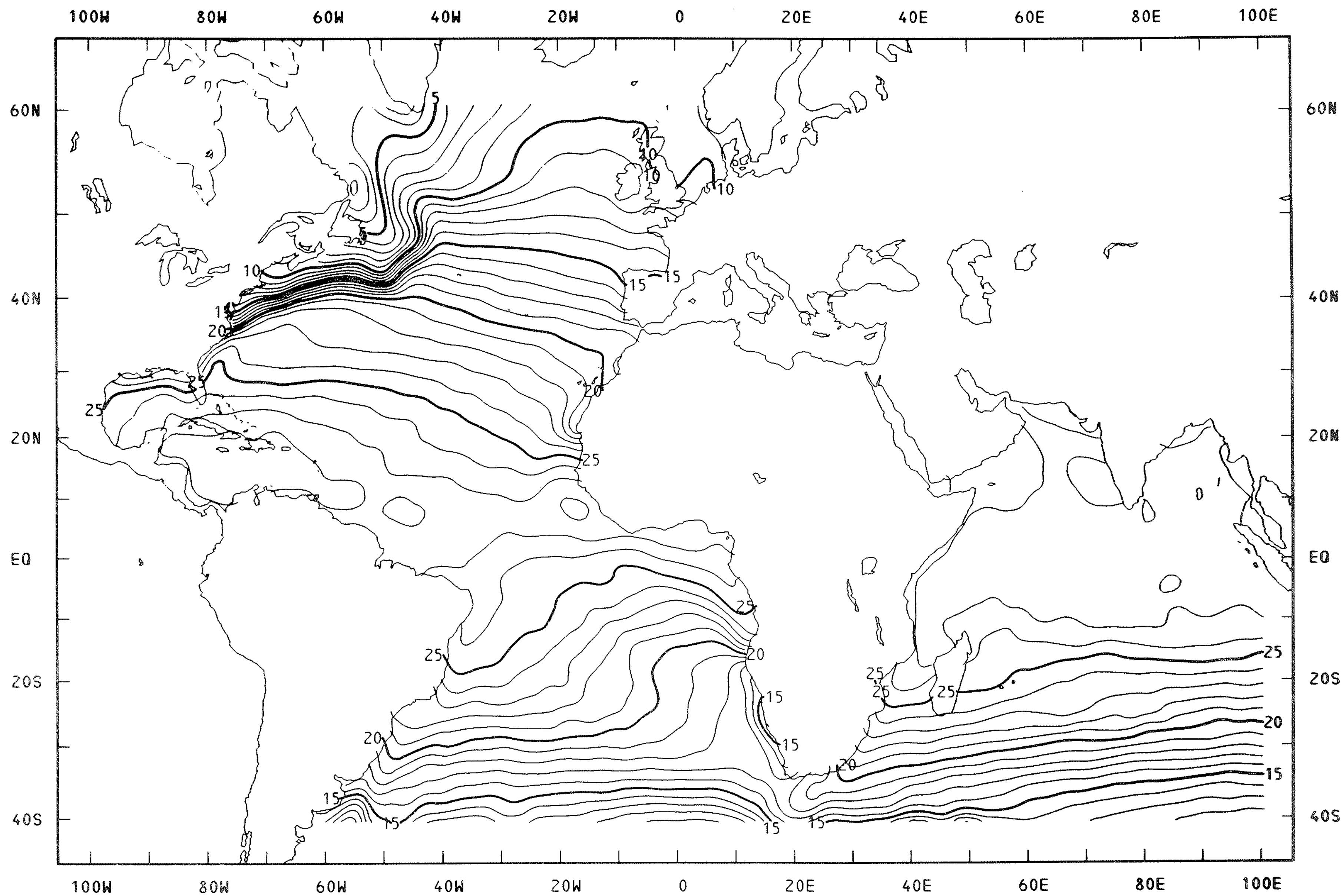


Figure 14b Same as 14a except for the Atlantic and Indian Oceans.

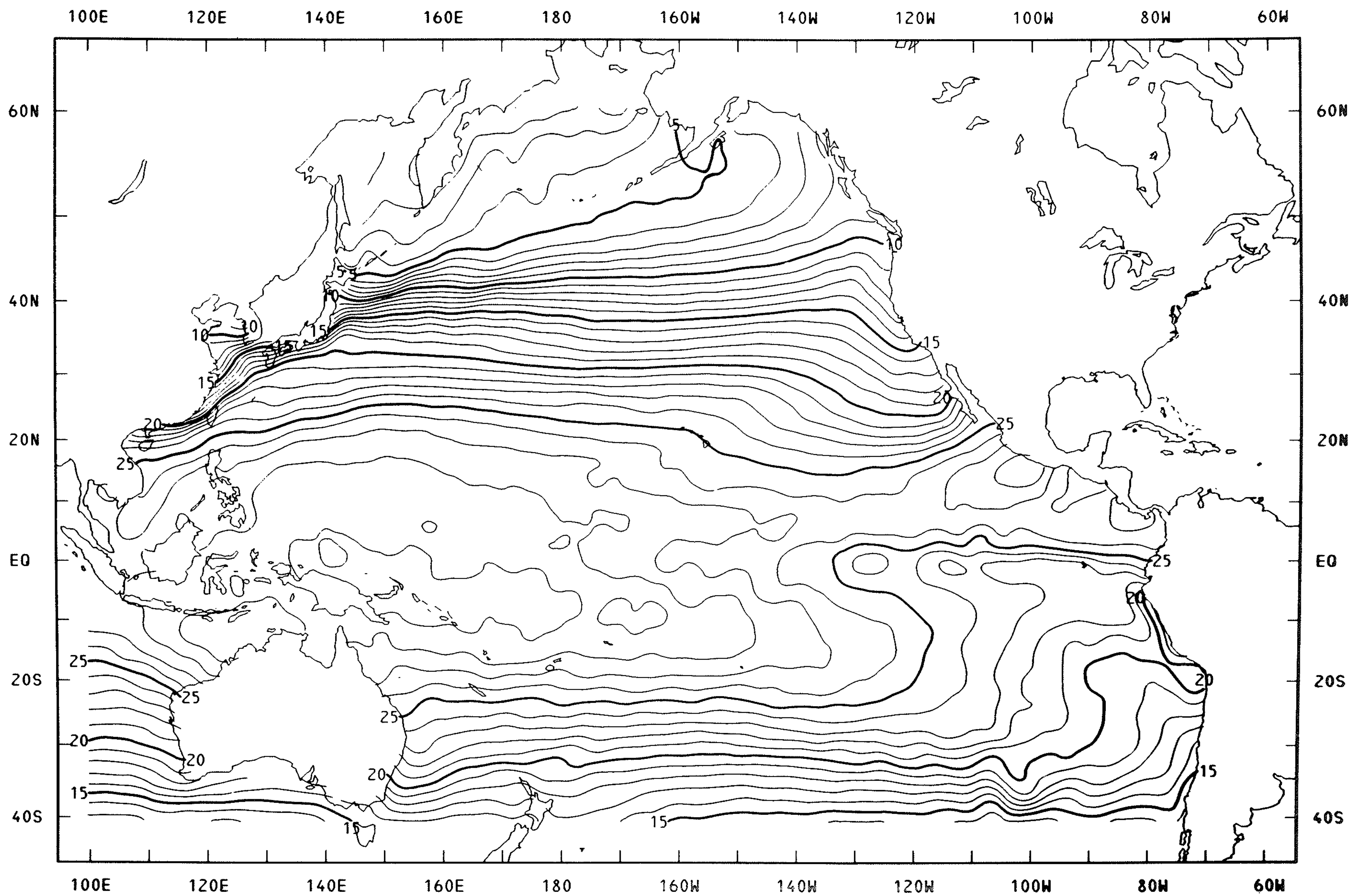


Figure. 15a Mean SST filtered climatology (in °C) on a one-degree grid for the Pacific Ocean for December.

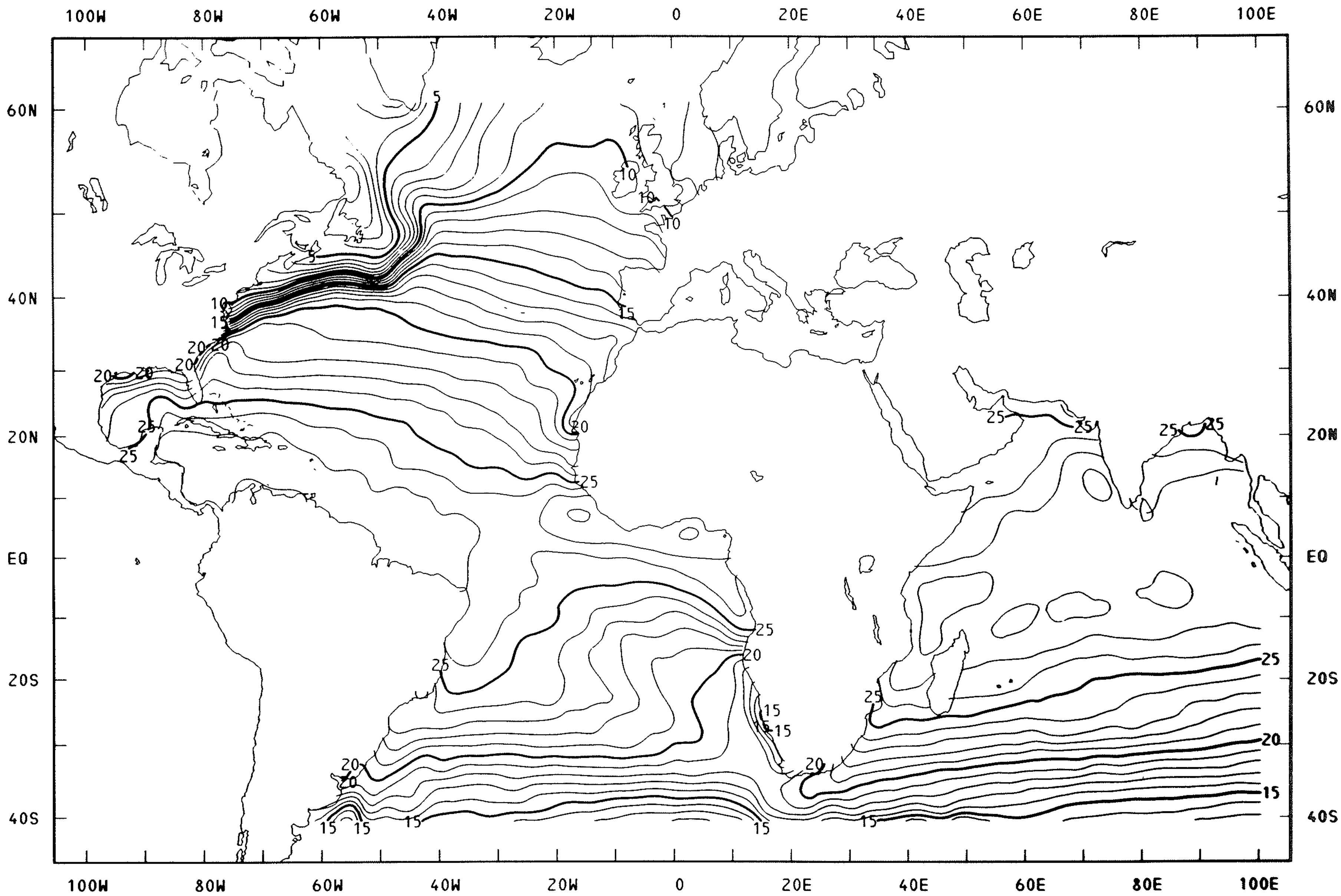


Figure 15b   Same as 15a except for the Atlantic and Indian Oceans.

clearly evident. Still preserved, however, are other smaller-scale phenomena such as the equatorial upwelling and the upwelling features off the west coast of the Americas and Africa, as well as the strong gradients of the Kuroshio and Gulf Stream. These smaller-scale features, especially the upwelling, tend to disappear in climatologies with coarser spatial resolution.

Careful comparisons of the original summary and finished climatologies for July (Figs. 3 and 10) show that in most cases the filtered contours are similar to what might have been done subjectively by hand. Furthermore, in the coastal region, no noticeable signal from the prefiltering extrapolation has been added to the temperatures. However, some real features have been obscured. An example of this is the small pool of 13°C water off the west coast of Africa near 30°S, in figure 3, which warmed to 14°C after filtering, in figure 10. However, the overall advantage of the filtering process is more important than these small losses.

There are some residual features, on scales of 500 to 1000 km, that cause some fluctuations of the contours south of 20°N, especially in the more isothermal equatorial regions. These fluctuations do not persist from month to month and thus may be considered to be noise. However, since heavier smoothing would seriously affect the upwelling and the western boundary current regions, discussed above, no further smoothing was carried out.

Some minor improvement of the climatology is planned. The boundary values will be reprocessed separately (as a spatial series that follows the coast line) to determine whether the filtering technique at the coast can be improved. The large inland sea regions, which have been excluded, will be reprocessed separately and added to the climatology. Finally, a three-point binomal filter will be applied in time to see if the 500-1000 km residual features, discussed above, can be smoothed without affecting the western boundary and upwelling areas.

In another study now in preparation (Reynolds, 1982), this climatology was compared with five other global SST climatologies. All climatologies were based on either surface marine or cast observations. It was shown that the surface marine climatologies were generally superior to the cast climatologies. The two cast climatologies differed not only from the surface marine climatologies but also from each other. Thus, although an individual cast observation is usually more accurate than a surface marine observation, the density of surface marine observations was high enough to give the surface marine climatologies a clear advantage over the cast climatologies. Furthermore, the surface marine climatology presented here defined both upwelling areas and western boundary currents better than the other surface marine climatologies, because its spatial resolution was the most detailed.

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