TECHNICAL MEMORANDUM

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Surface temperatures May 1982 June 1983

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1. INTRODUCTION

The period May, 1982 - June, 1983 is of considerable interest to the meteorological and oceanographical communities. It covers much of the history of one of the strongest ever recorded El Nino events. Monthly mean sea surface temperature anomalies as large as 7°C were observed in the eastern Pacific at times during this period.

There is no doubt that sea surface temperature plays a major role in determining the climate of the atmosphere (and of atmospheric models). There is also reason to believe that the atmosphere is sensitive to large changes in sea surface temperature on shorter time scales.

The Climate Analysis Center at NOAA in Washington has re-analysed the sea surface temperature for the period May, 1982 through to June, 1983 using much data that was not available for the operational analyses. The purpose of the report is firstly, to document the sea surface temperatures during this period, and secondly, to discuss the sea surface temperatures used at ECMWF.

Section 2 discusses how sea surface temperatures are obtained and used at ECMWF. This is followed in Section 3 with a comparison between the climatology used at ECMWF and that used at the Climate Analysis Center (hereafter refered to as CAC). The ECMWF analyses during the period May, 1982 through to June, 1983 are discussed in Section 4, and Section 5 compares these with the operational NMC analyses. Section 6 describes the CAC re-analysis of the period, and Section 7 compares these with the operational analyses.

2. SEA SURFACE TEMPERATURE ANALYSIS AT ECMWF

Prior to the 21st July, 1982 there was no analysis of sea surface temperature carried out at ECMWF. The RAND climatology, interpolated to our 1.875° grid, was used directly in the forecast model; the climatology being changed abruptly at the beginning of each month. From the 21st July, 1982 an analysed sea surface temperature from NMC was used, with a delay of one day.

The operational NMC sea surface temperature analysis is carried out on a 129*129 polar stereographic grid which has a mesh length of 202.6km at 80°(N/S) and 102.1 km at the equator. This data is disseminated on the GTS, in whole degrees, on a regular 5° grid. The hemispheric SST received on the GTS changes, in part, every day; the northern hemisphere changes one day and the southern hemisphere the next. The NMC SST data as received over the GTS is the only data, other than the background climatology, which is used in our SST analysis.

At ECMWF the sea surface temperature analysis is (broadly) performed as follows. The 5° regular lat/long analyses from NMC are decoded from the GTS. The ECMWF sea surface temperature climatology (RAND) is interpolated from the ECMWF grid to a regular 5° lat/long grid. The NMC analysis and ECMWF climatology are subtracted to obtain an increment field on the 5° grid. The increment field is then interpolated onto the ECMWF grid. Finally, the increment field is added to the ECMWF climatology to give the ECMWF analysis. The reason for the calculation of increments with respect to climate, rather than simply interpolating the NMC analysis from its 5° grid to the ECMWF grid, is that the former process is intended to retain some of the small scale structure present in the climate field that is not present in the coarser resolution analysis. One difference between the ECMWF and NMC analyses is in the specification of ice surface temperature. The NMC SST analyses never fall below -2°C, whereas the ECMWF climate, in regions of ice, falls below -50°C. Thus when the NMC SST analysis is -2°C (again, broadly speaking) the SST is set to the ECMWF climatology. Except in regions of ice and also on the smallest scales (<5° lat/long), the ECMWF analysis should be identical to the NMC analysis as disseminated over the GTS.

Dave Shaw has gone through an original bulletin on the GTS and could find no discrepancy between it and the corresponding ECMWF chart. He concluded that we correctly analyse what is sent to us.

The forecast model is not allowed to change the sea surface temperature, it remains constant through the forecast.

3. THE CLIMATOLOGIES COMPARED

The sea surface temperature climatology used at ECMWF is the RAND climatology (RAND Report R-1310-ARPA) which is available (at ECMWF) on a 1° regular lat/long grid. This climatology for January is shown in Fig.1. The data is shown on a regular 1.875° lat/long grid.

The climatology used at the CAC is more recent and is regarded by them as being the best currently available (NOAA Tech. Report NWS 31, 1982). The climatology is available (at ECMWF) on a 1° regular lat/long grid. It is shown, for January, in Fig.2 on a 1.875° regular lat/long grid. As a point of interest, the CAC climatology is identical to the NCC (National Climatic Centre) climatology which is also available at ECMWF.

In comparing the RAND and CAC climatologies for January the most immediate impression is for the richness of structure that is present in the CAC climatology compared to that of the RAND climatology. This is also true for the other months of the year (not shown). The second obvious feature is that the CAC climatology never falls below -2°C whilst the RAND climatology falls below -50°C. These, of course, are differences in ice surface rather than sea surface temperatures.

Figs.3-14 show the RAND minus the CAC climatologies for January through to December. The large differences in the polar regions are due to differences in ice surface rather than sea surface temperature, as discussed above. The largest differences in sea surface temperature occur over the southern oceans, south of around 50°S, where differences as large as ±3°C are common in all months. Other areas of significant difference are coastal regions in the vicinity of relatively strong ocean curents e.g. Gulf Stream, Kuroshio and the Brazil Current. In these regions differences of typically ±2°C are apparent over very short distances, presumably due to sampling problems. In the tropics and low latitude extratropics the climatologies rarely differ by more than about ±1°C. The RAND climatology tends to be slightly warmer than the CAC climatology in the Pacific close to the equator and also slightly warmer in the eastern Pacific at around 45°S; it also tends to be slightly cooler in low latitudes to the north and south of the equator. These differences are very rarely more than about 1°C and typically reach 0.5°C.

4. THE ECMWF SST ANALYSES AUGUST, 1982 TO JUNE, 1983

As pointed out in Section 2, prior to 21st July, 1982 no sea surface temperature analysis was carried out at ECMWF. The discussion will therefore begin with August, 1982. For economy of presentation the anomalies rather than the actual sea surface temperatures are shown. Figs.15-25 show the monthly means of the anomalies of the ECMWF SST analyses with respect to the **CAC climatology.** The CAC climatology has been used to display the anomalies rather than the RAND climatology as this simplifies comparison with the CAC analyses which are considered later. What follows is a brief account of the main features of the anomalies as revealed by the operational analyses.

The largest anomalies occur over the southern oceans and are typically ±3°C. These anomalies vary in magnitude and location from month to month, which suggests either a large natural variability or uncertainty in the analysis.

In August, 1982, away from the southern oceans, the largest positive anomalies (about +1°C) occurred in the eastern equatorial Pacific close to the equator and in the Arabian Sea region; the north and south Pacific was characterised by anomalously cold water (-1° or -2°C). During September the positive anomalies in the equatorial Pacific spread westward and increased slightly in magnitude, a region of +2°C was evident at about 95°W,2°S. This warming continued during October particularly in the central Pacific. During the same period the north Pacific anomalies reduced slightly from -2°C to about -1°C; the anomalies in the Arabian Sea remained at about +1°C. A region of large negative anomalies (-2°C) in the northern Atlantic, south of Greenland, appeared during September and remained through October.

The warm equatorial anomalies continued to spread westward during November and the cold anomalies in the north Pacific continued to be reduced. Away from the Pacific, the positive anomaly in the Arabian Sea began to decrease and negative anomalies of -1°C became apparent in the south Indian Ocean. The negative anomaly in the north Atlantic increased in magnitude to -3°C. During December the positive anomalies in the equatorial Pacific became a little larger, with more areas of +2°C being apparent. The trend towards lower negative anomalies in the north Pacific reversed with anomalies of -2°C once more observed. In January the positive anomalies in the equatorial Pacific spread further to the west reaching as far as 160°E. The positive anomalies in the Arabian sea reduced to between 0.5 and 1°C. Whilst the negative anomalies in the south Indian Ocean increased to -2°C and those in the north Atlantic increased to -4°C. By February positive anomalies covered almost the entire equatorial Pacific and their magnitude increased locally to +3°C in the region of 130°W,5°S. The negative anomalies inceased to -3°C in the north Pacific, those in the north Atlantic decreased to -3°C, and in the southern Indian Ocean to -0.5°C. Positive anomalies of +1°C appeared in the central Indian Ocean, and the anomalies over the Arabian Sea began to disappear.

During March the anomalies in the western equatorial Pacific began to become negative, but near to the coast of Peru the positive anomalies increased to +2°C. The positive anomalies in the central equatorial Pacific continued to be reduced through April and those off the coast of Peru continued to increase and reached +4°C. The latter trend continued with anomalies off the coast of Peru reaching 7°C in May and June.

5. A COMPARISON BETWEEN THE ECMWF AND NMC OPERATIONAL ANALYSES

As discussed in Section 2, except in regions of ice and also on the smallest scales (<5° lat/long), the ECMWF analysis should be identical to the NMC analysis as received over the GTS; provided that we correctly interpret the data we receive. However, the NMC analysis that we receive over the GTS will not be identical to the original NMC analysis, as it is disseminated in whole degrees on a coarser grid. Thus we should not expect the ECMWF analysis to be identical to the original NMC analysis, but there should be no significant differences except on the very smallest scales and over ice.

Rather than comparing the actual SST's it is sufficient to compare the ECMWF anomalies with the NMC anomalies. NMC uses the CAC climatology to compute its anomalies. In Figs.15-24 the CAC climatology has been used to compute the anomalies of the ECMWF analyses. If the SST's are identical so should the anomalies be. We receive from NMC, on a fairly regular basis, their monthly climatic summary. This summary often includes maps of SST anomalies as computed from their operational SST analyses. One such map for February, 1983 is reproduced in Fig.26. This should be compared with the corresponding ECMWF anomalies shown in Fig.21 (note that Fig.26 is a mercator projection). It is immediately obvious that these two anomaly maps are not identical, and not just on the smallest scales. Closer inspection however, reveals that the ECMWF analyses are cooler almost everywhere by about 0.5°C. In fact if one adds 0.5°C to the ECMWF anomalies (which has been done to produce Fig.27) one obtains an anomaly field which is almost identical in magnitude and pattern to the NMC anomalies. This 0.5°C bias is evident in all the months, August, 1982, through to May, 1983. The corresponding NMC anomalies for June, 1983 are not yet available to us, so we can not say that the bias is still present.

This bias led to the deduction that the NMC data was being truncated, rather than rounded, to whole degrees prior to dissemination over the GTS. This would introduce, over a period of a month, a systematic bias of -0.5°C. This was subsequently confirmed by NMC, and we have reason to believe that they corrected this error at the end of May, 1983, although we are unable to confirm this as yet.

6. THE CAC RE-ANALYSIS MAY, 1982 THROUGH JUNE, 1983

The re-analysis of the SST's by the CAC, as available at ECMWF, is on a regular 2 degree lat/long grid, and covers the area 40°S to 60°N. As in Section 4, for economy of presentation, the anomalies rather than the actual sea surface temperature are shown. These anomalies, with respect to the CAC climatology, interpolated to a 1.875° regular lat/long grid, are shown in Figs.28-41. The following discussion concentrates on the anomalies in the region of the equatorial Pacific.

The anomaly map for May, 1982 shows, except for a small region at 150°W, positive anomalies of about 1°C extending across the entire equatorial Pacific and Indian Ocean; much of the equatorial Atlantic is also anomalously warm. Parts of the north and south Pacific are anomalously cool; -0.5°C over much of the north Pacific and -1°C locally in both the north and south Pacific. These anomalies increased during June, with several regions of +2°C apparent in the equatorial Pacific and -2°C in the north Pacific. During July the Pacific anomalies reduced slightly, becoming negative in the western equatorial Pacific. August saw an increase in area covered by the +2°C anomaly, particularly in the eastern equatorial Pacific. The positive anomalies in the equatorial Pacific increased in magnitude again during September and extended westwards - many regions of +3°C extended westwards from Peru to about 135°W. There was a small region of +4°C anomaly at about 125°W,2°N. The anomalies also deepened in the north atlantic, becoming locally -2°C again. The positive anomalies continued to extend westwards along the equatorial Pacific during July, reaching about 150°E. There was a region +3°C along the equator between 90°W and 138°W, a region of +4°C between 100°W and 133°W and a small region of +5°C at about 117°W. By November the positive anomalies stretched across the entire equatorial Pacific and Indian Oceans with regions of +4°C extending from the coast of Peru westwards as far as 145°W and a small region of +5°C off the coast of Peru at 85°W. The anomalies increased again during December with regions of +2°C extending as far west as 167°E. Along the equator, there was a region of +5°C between 115°W and 133°W. During January the anomaly in the central Pacific decreased to +4°C but there was an indication of a +5°C anomaly just off the coast of Peru. The anomaly in the central Pacific continued to decrease during February, with the area covered by the +4°C anomaly becoming much smaller; the +5°C anomaly was still apparent off the Peruvian coast. During March the equatorial anomalies became slightly negative at 155°E and the central Pacific anomalies decreased to +3°C; +5°C anomalies were still observed off the Peruvian coast. During April small negative anomalies covered the Pacific west of about 160°E, the central Pacific anomalies decreased to +2°C but the anomalies off the coast of Peru increased to +6°C. These anomalies increased in May to +7°C and remained at +7°C during July.

7. THE CAC RE-ANALYSES AND THE OPERATIONAL ANALYSES COMPARED

In comparing the re-analyses with the ECMWF operational analyses we should first remind ourselves of the conclusions drawn in Section 5; that is the ECMWF analyses have, in the mean, a systematic bias of -0.5°C relative to the original NMC analyses (probably due to incorrect dissemination by NMC). This bias was present at least up to and including May, 1983. Thus if we subtract the ECMWF analyses from the CAC analyses we should expect to see a difference of about +0.5°C. Figs.42-52 show the CAC minus the ECMWF analyses for August, 1982 through to June, 1983. In order to gain a more accurate impression of the true differences we should mentally subtract 0.5°C from these pictures. If this is done, August, 1982 shows maximum differences of about ±1.5°C, with the most significant differences being in the Pacific.

September shows differences ranging from about -1°C to +1.5°C, but the area of +1.5°C covers a large area of the central equatorial Pacific. By October the differences in this region are about +3.5°C; they remain at that level in November, increase to +4.5°C in December, decrease to about 2.5°C in January, further decrease to about 1.5°C in February and remain at that level through to June. Differences off the Peruvian coast of about 1.5°C occur in October, increase to 2.5°C in November and December, further increase to about 3.5°C in January then decrease to about 2.5°C in February. They remained at that level during March and April. During May and June the differences were confined to a narrow region very close to the coast.

It is clear from these figures that over very large areas of the Pacific ocean the operational analyses consistently underestimated the sea surface temperature anomalies by as much as 4.5°C, which is almost as large as the anomaly itself. The conclusions of Section 5 suggest that this problem was compounded at ECMWF by errors introduced by NMC truncating their analyses to whole decrease prior to dissemination over the GTS. In the presence of these very large anomalies the NMC analysis system retains the climatological background, which is cool water typical of equatorial upwelling.

The poor quality of the operational SST analyses is largely due to problems with satellite SST estimates. As discussed in the recent Special Climate Diagnostics Bulletins issued by CAC, the El Chichon eruptions last Spring have resulted in inaccuracies in the satellite SST estimates. The aerosols injected into the atmosphere by those eruptions introduced a significant negative bias in the satellite SST estimates. Immediately following the eruption the errors were limited to a relatively narrow latitude band, centred at 18°N, the latitude of the volcano. However, with the continued spread of the aerosols, there is now a negative bias in the SST estimate over much of the tropics and sub-tropics. This leaves only a sparse set of merchant ship observations from which to construct the NMC operational SST analysis over the equatorial Pacific. The NMC operational analysis scheme uses climatology to help generate a conservative estimate of the anomaly in regions where there is little ship data.

8. DISCUSSION

As mentioned in the introduction, the purpose of this report is partly to document the sea surface temperatures for the period May, 1982 through to June, 1983 and partly to discuss the quality of the operational analyses. Clearly, with anomalies rising as high as 7°C, it is not a very good idea to use a climatological sea surface temperature in the model, but with errors of 4°C the operational analysis is not very satisfactory either. A possible alternative is to use the climatological field modified with the previous month's anomalies. Using the previous month's anomalies allows time to gather all the available data and make the best possible analysis. The error in this method (for the monthly mean) is simply the difference in the anomalies between the current and previous months. On a daily basis the error will be affected by the daily variability of the SST, but one suspects that the variance of the SST field is significantly less than the errors in the operational analysis. December, 1982 was one of the worst months for the operational analysis with errors, in the mean, of about 4.5°C. If the climatology for December is adjusted with the anomalies for November the resulting field can be used as an estimate of the December SST. The error in this method, as mentioned above, is the difference in the December and November anomalies which is shown in Fig.53. The maximum error is about ±1°C, a big improvement over the operational analysis. The differences in anomalies for consecutive months have been calculated throughout the period May, 1982 to June, 1983; the differences can be as large as ±3°C (although these large changes may reflect some uncertainty in the analysis) but are usually in the ±1°C range. Therefore probably the most satisfactory solution would be to use the current climatology modified by the previous month's anomalies as the background to a proper SST analysis. This would help to prevent too rapid a return to climatology in data sparse regions.

Fig.1

JANUARY RAND CLIMATOLOGY

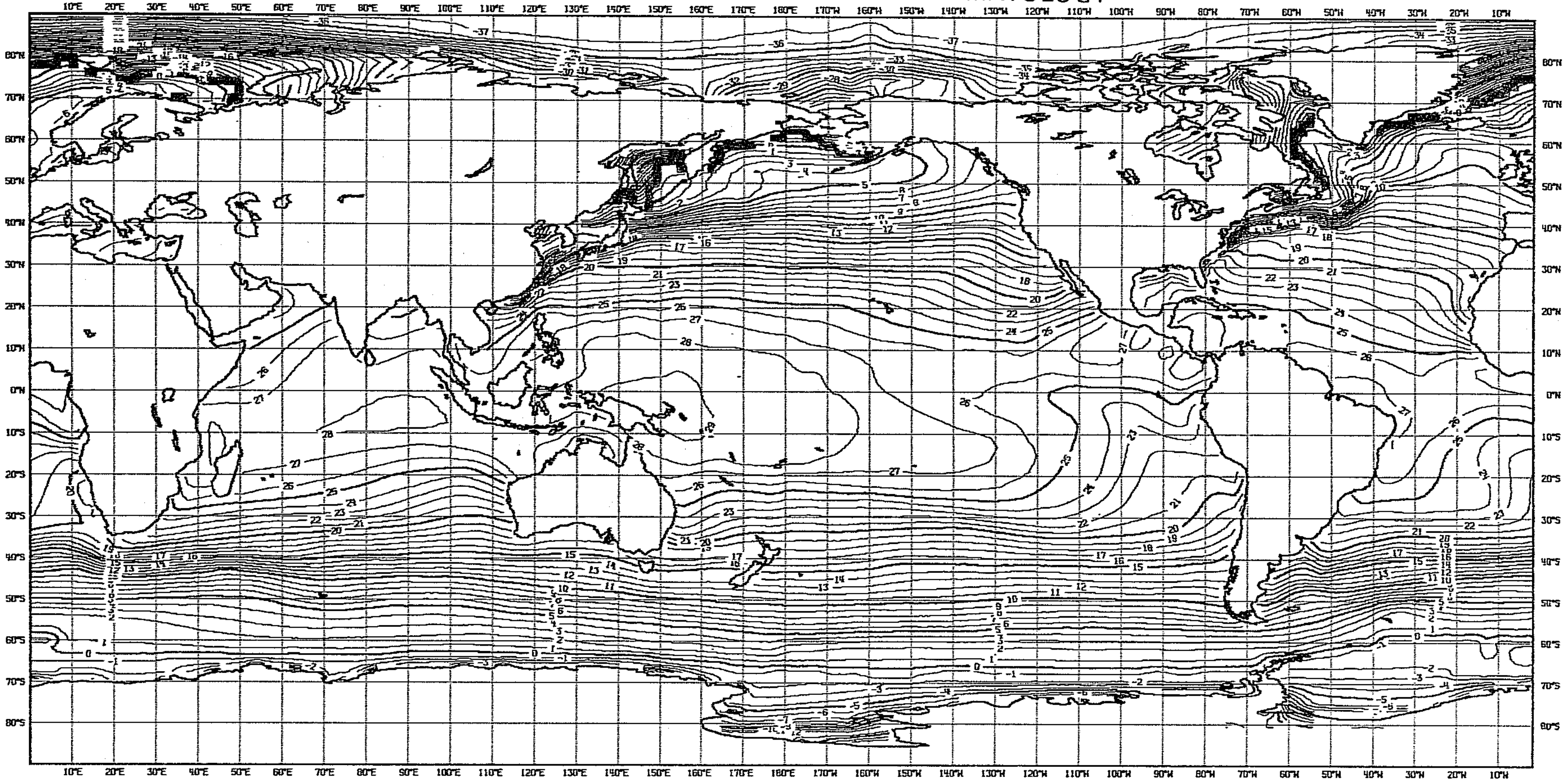


Fig. 2

JANUARY CAC CLIMATOLOGY (EC GRID)

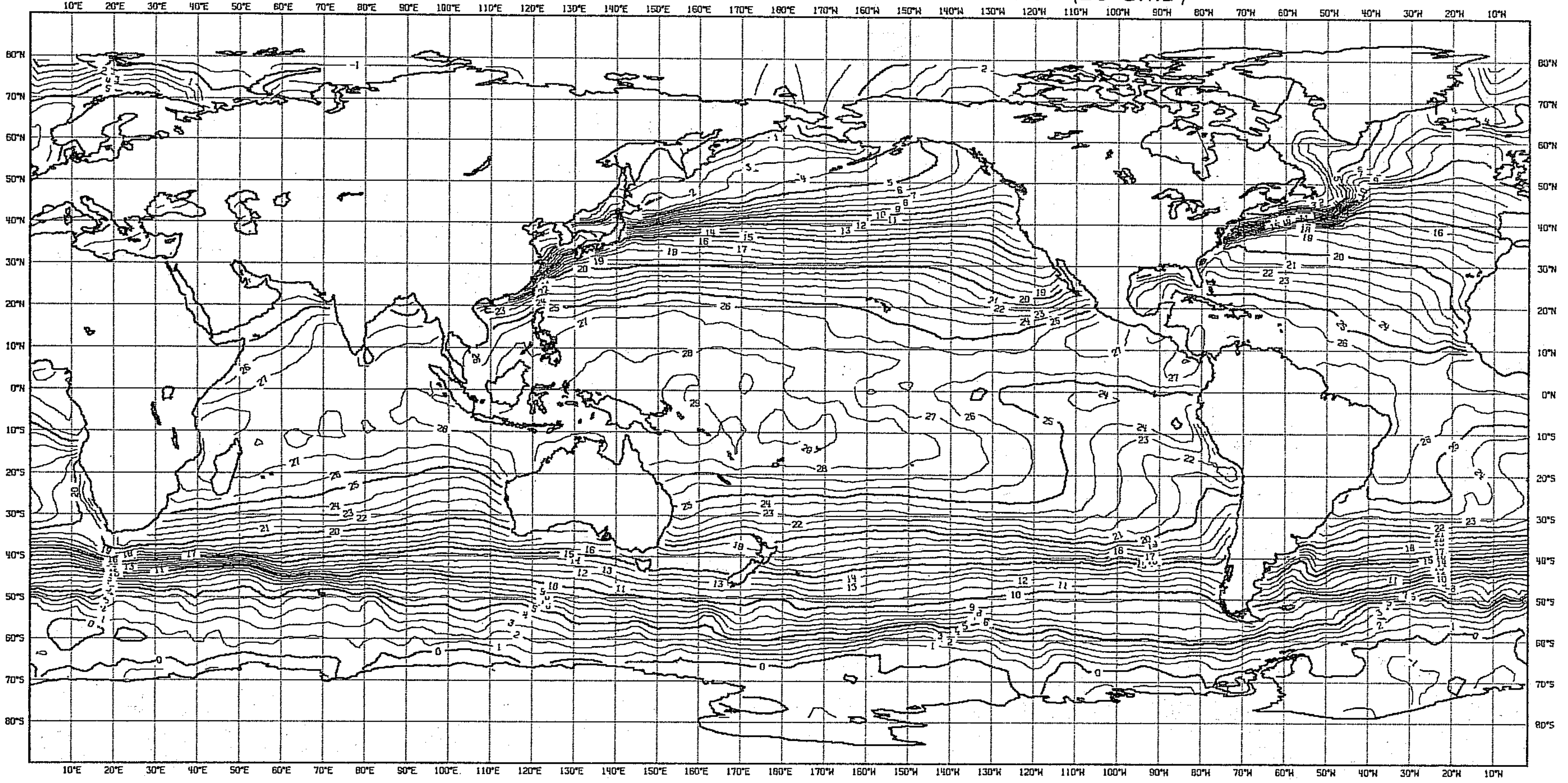


Fig. 3

JANUARY (RAND–CAC) CLIMATOLOGIES (EC GRID)

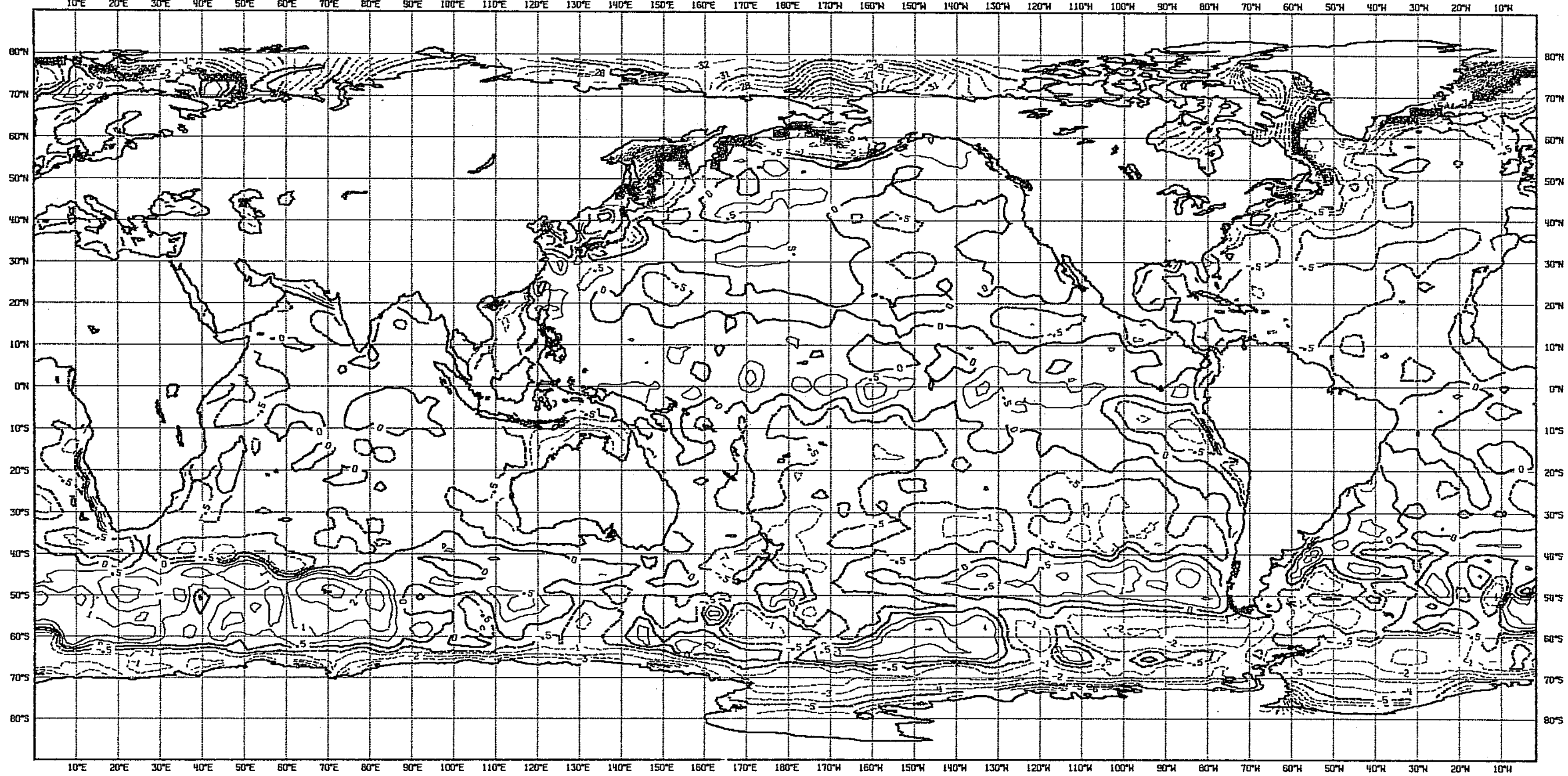


Fig. 4

FEBRUARY (RAND–CAC) CLIMATOLOGIES (EC GRID)

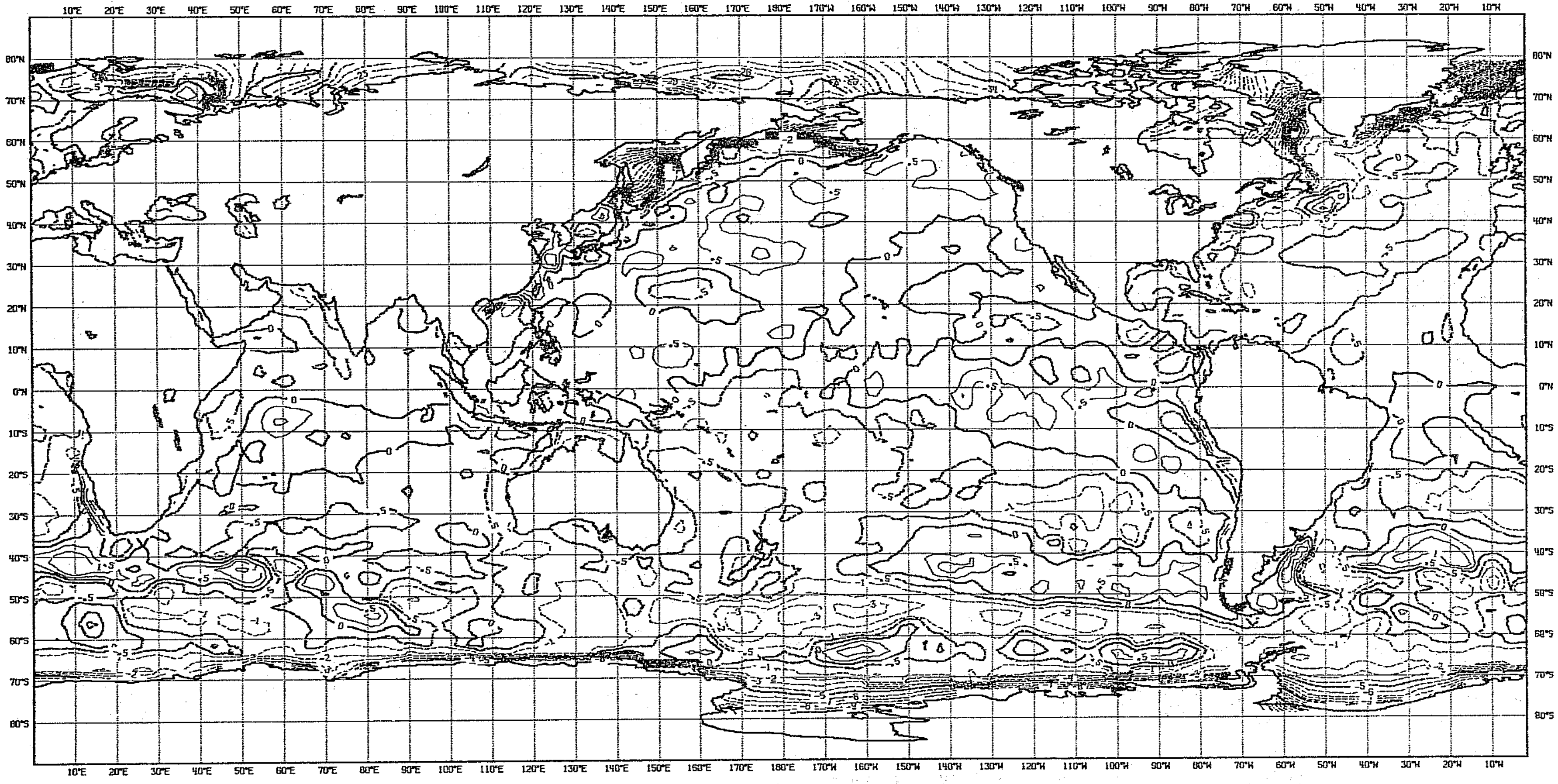


Fig. 5

MARCH (RAND-CAC) CLIMATOLOGIES (EC GRID)

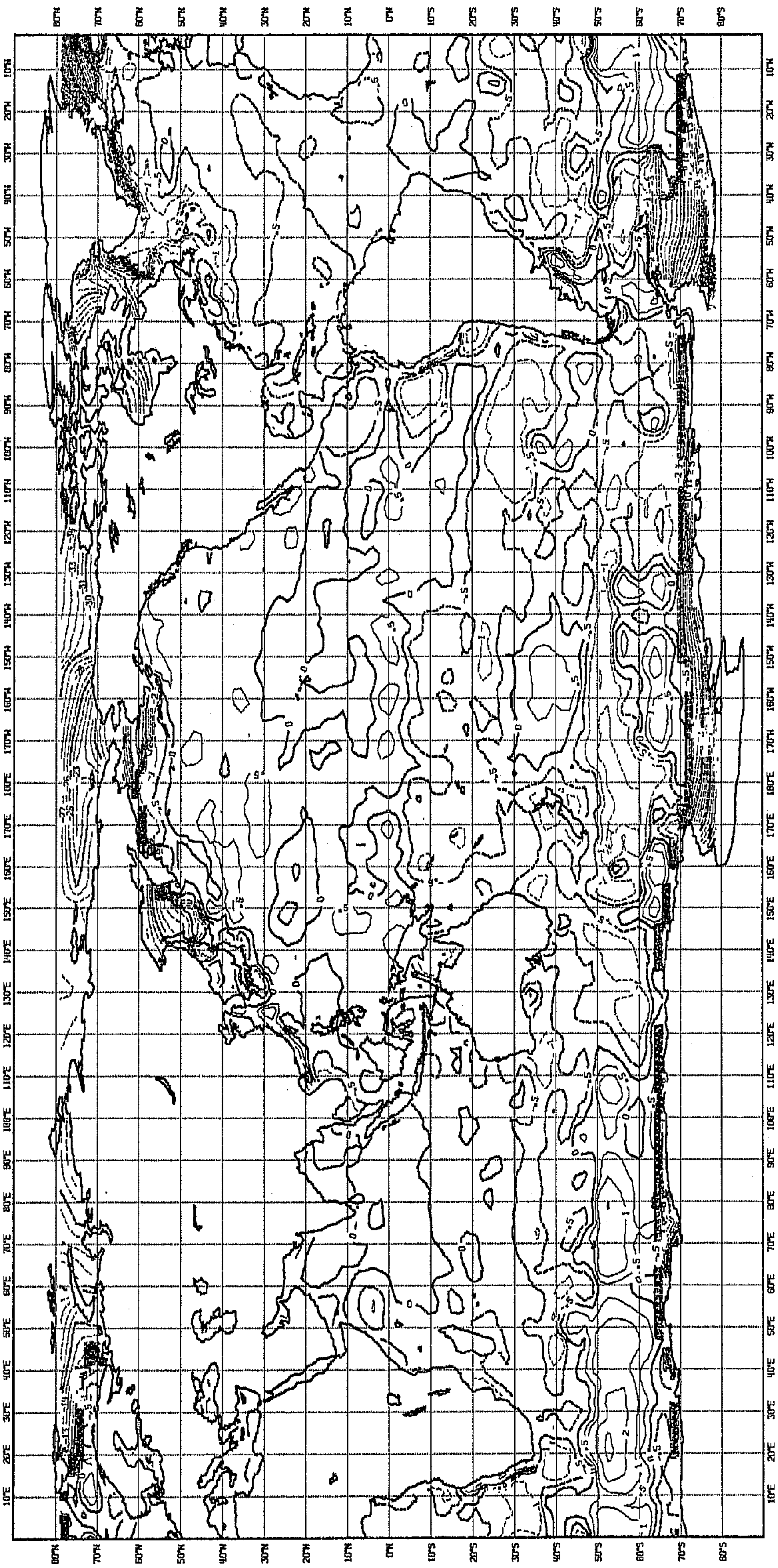


Fig. 6

APRIL (RAND—CAC) CLIMATOLOGIES (EC GRID)

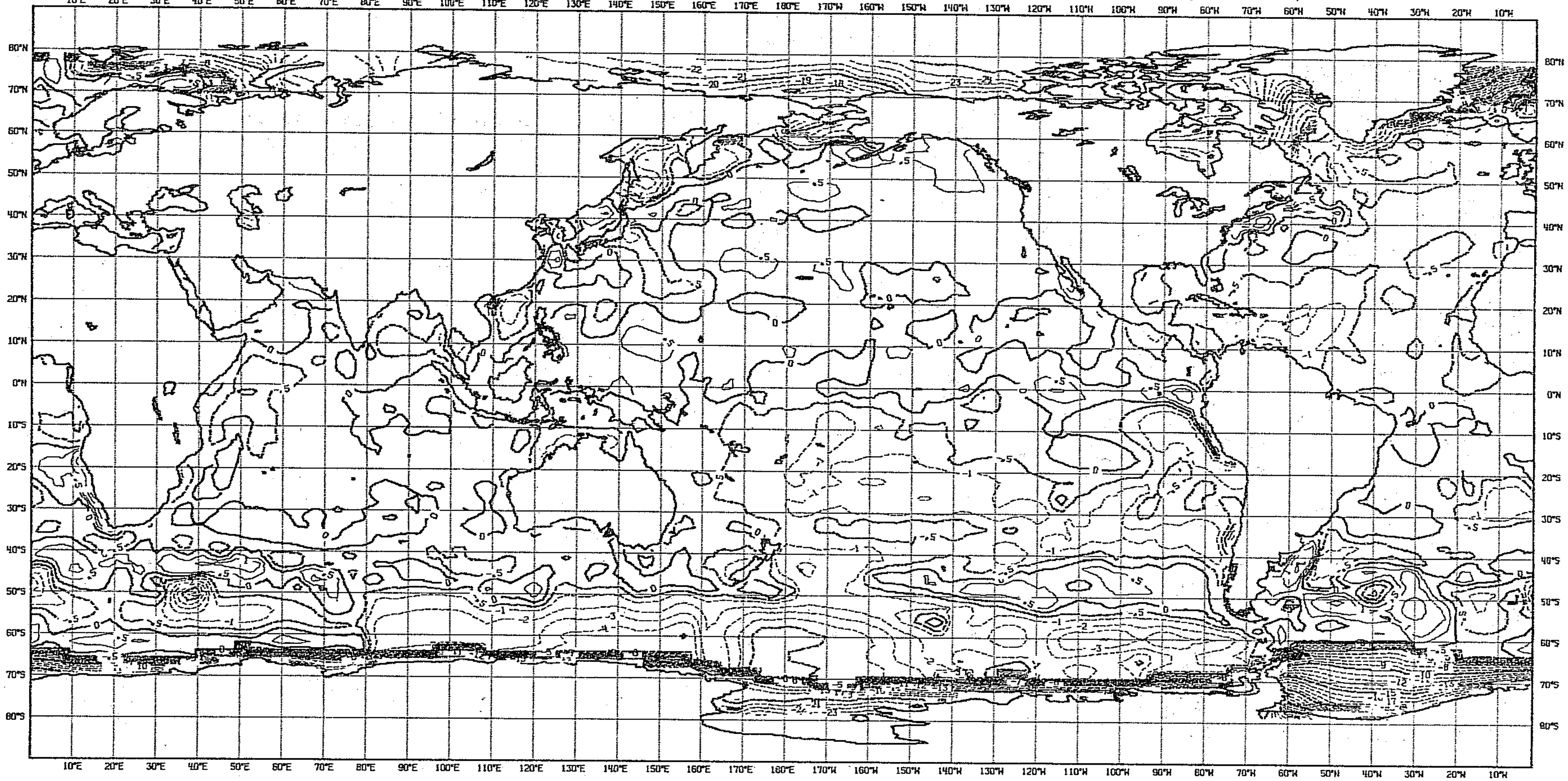


Fig. 7

MAY (RAND—CAC) CLIMATOLOGIES (EC GRID)

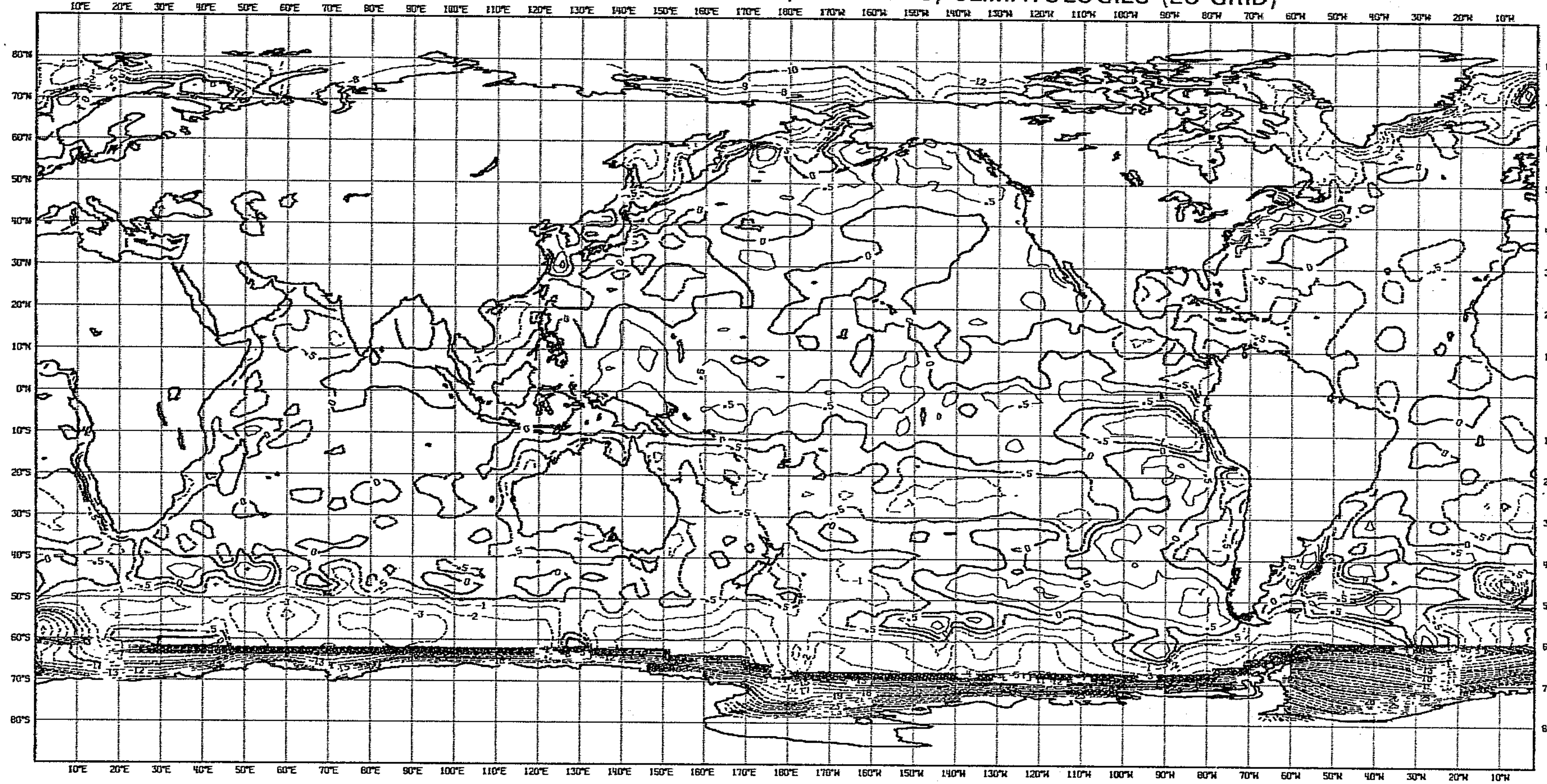


Fig. 8

JUNE (RAND–CAC) CLIMATOLOGIES (EC GRID)

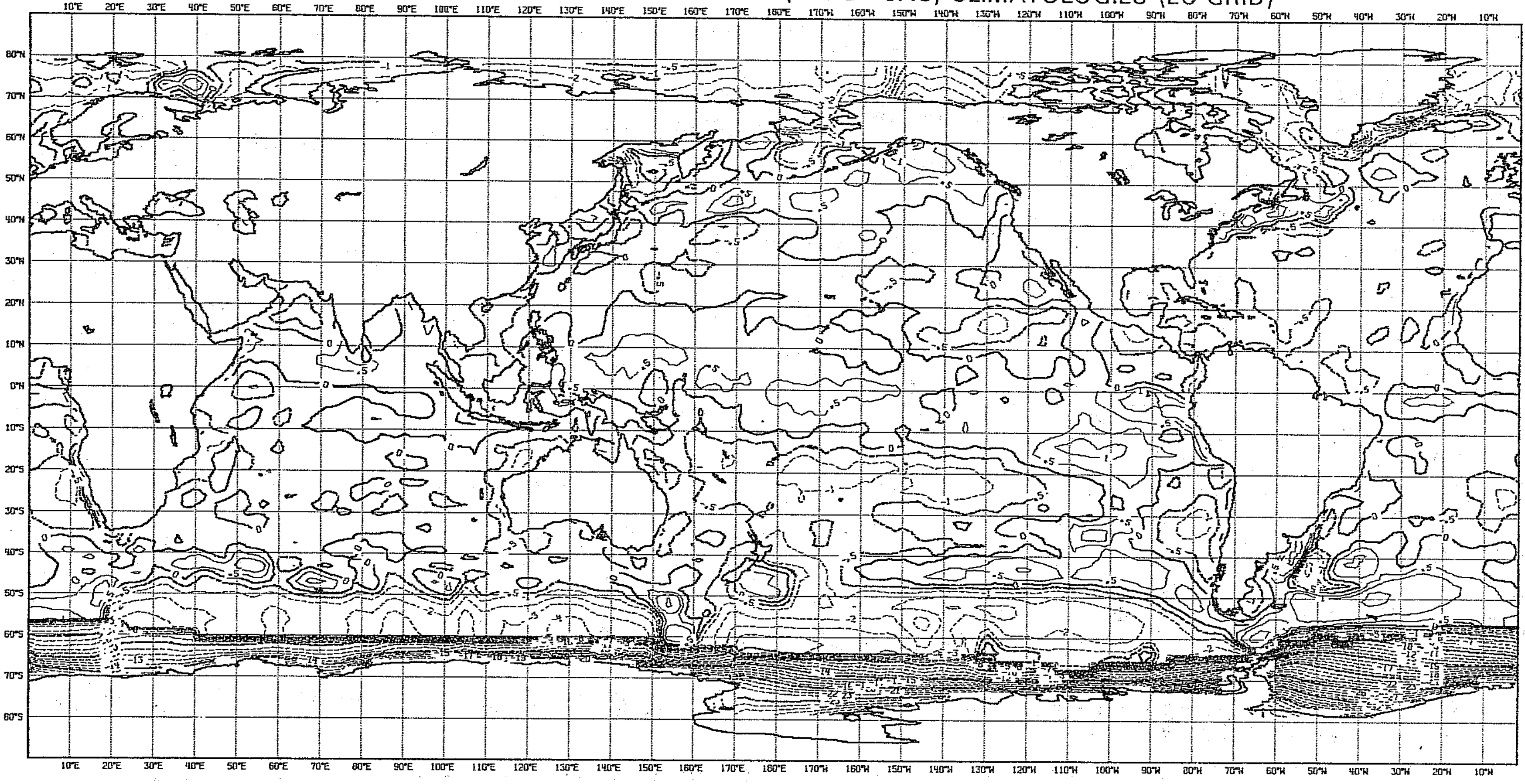


Fig. 9

JULY (RAND–CAC) CLIMATOLOGIES (EC GRID)

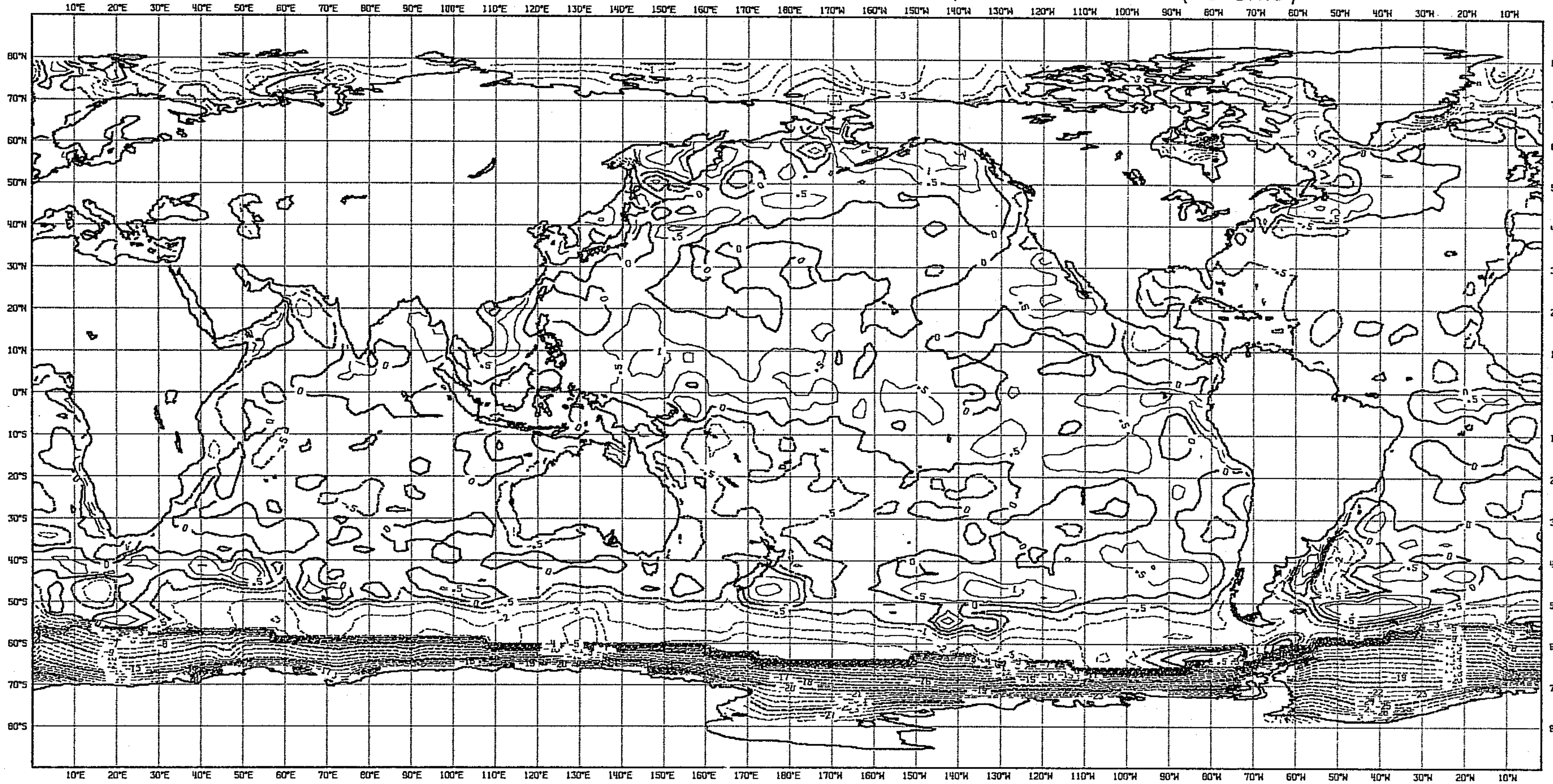


Fig.10

AUGUST (RAND–CAC) CLIMATOLOGIES (EC GRID)

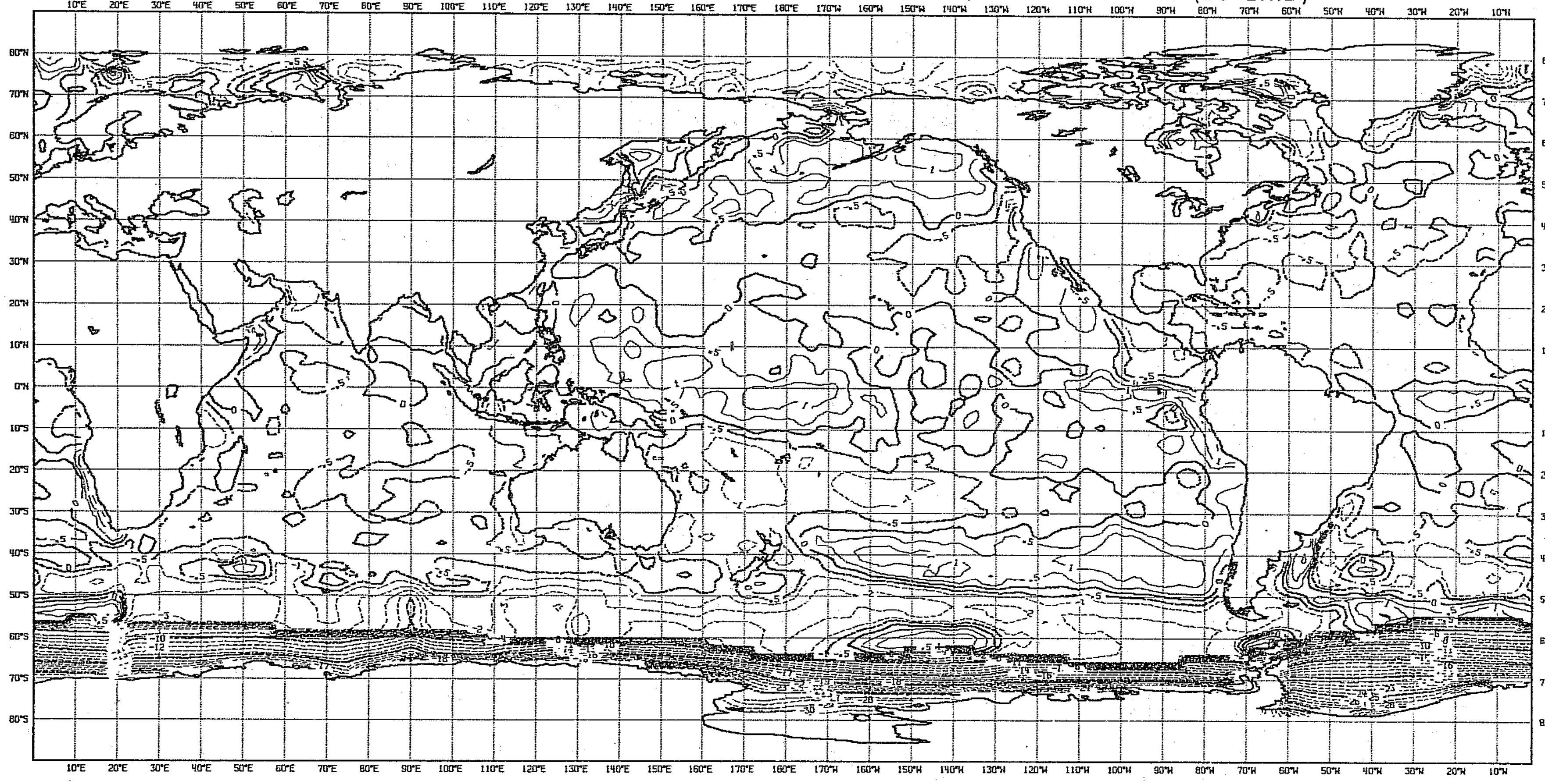


Fig. 11

SEPTEMBER (RAND-CAC) CLIMATOLOGIES (EC GRID)

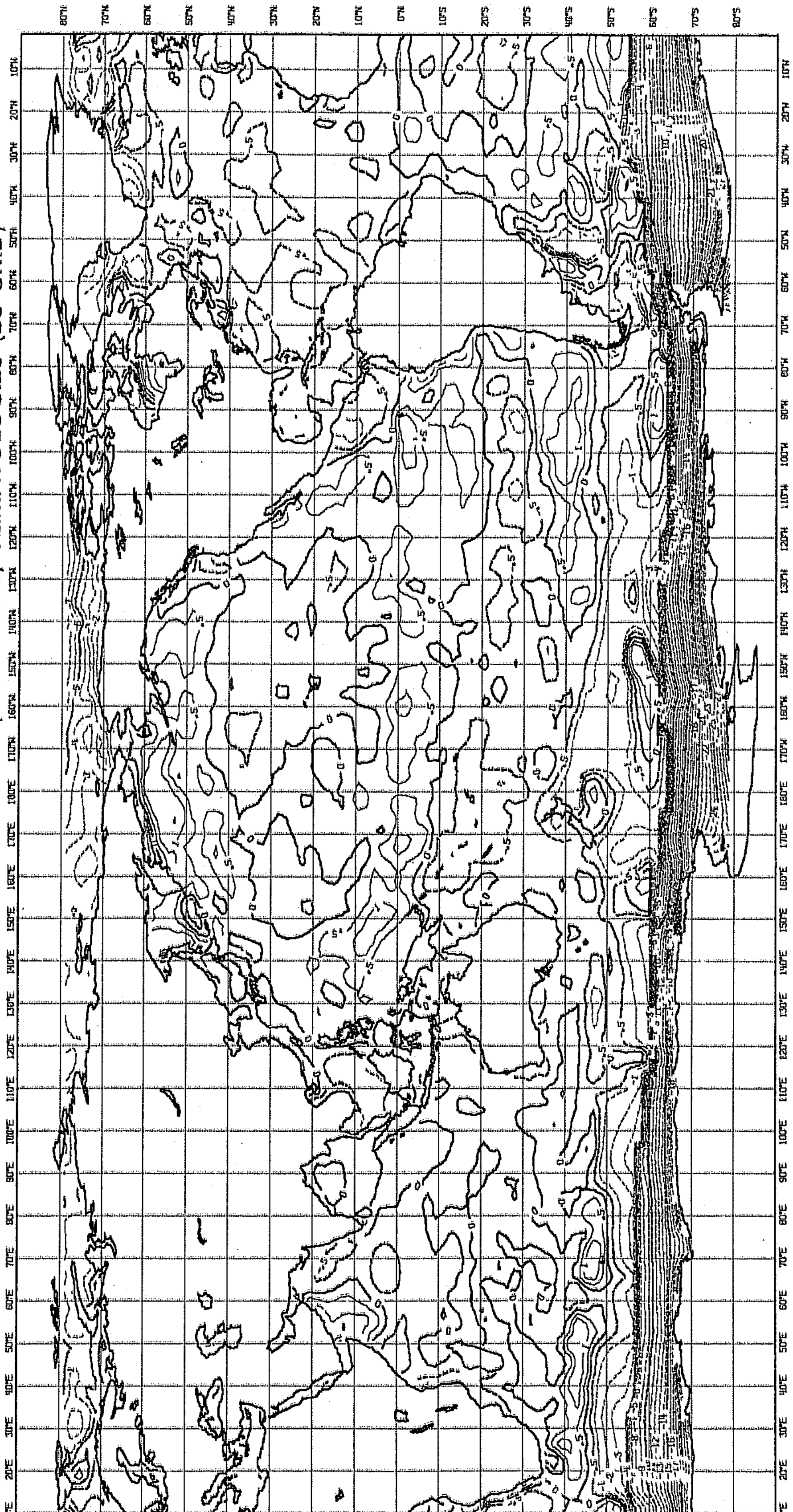


Fig. 12

OCTOBER (RAND–CAC) CLIMATOLOGIES (EC GRID)

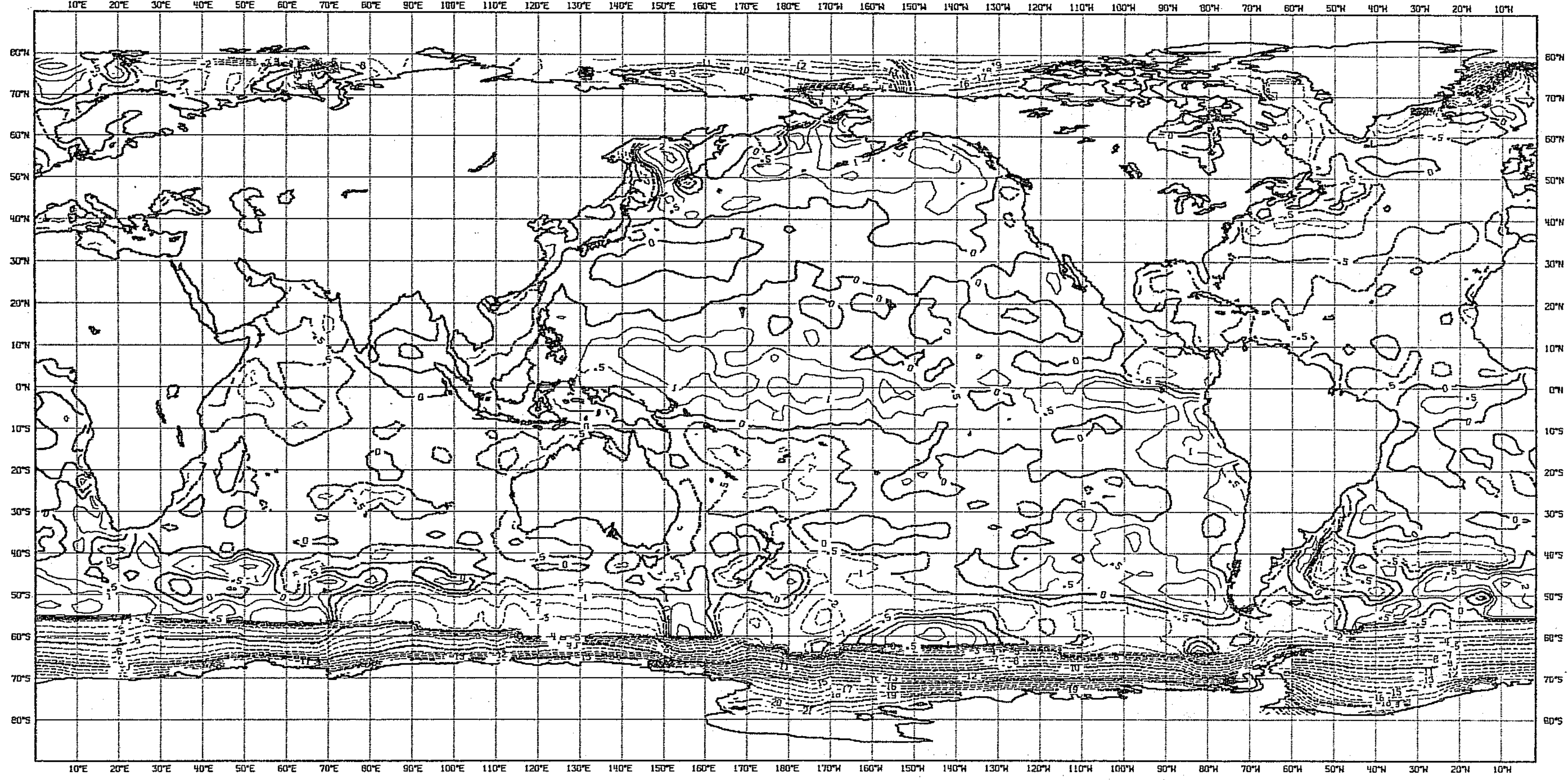


Fig. 13

NOVEMBER (RAND—CAC) CLIMATOLOGIES (EC GRID)

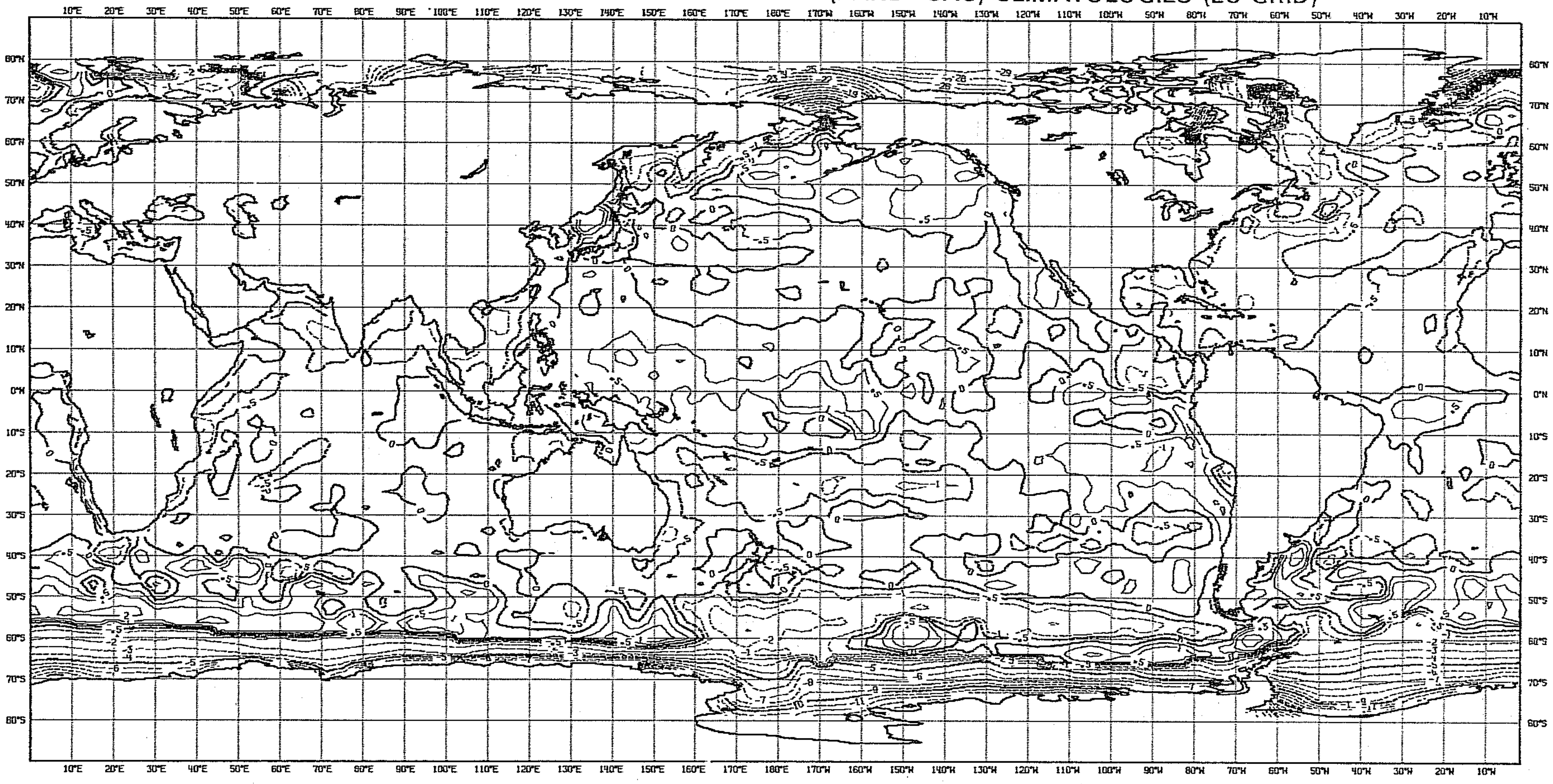


Fig. 14

DECEMBER (RAND–CAC) CLIMATOLOGIES (EC GRID)

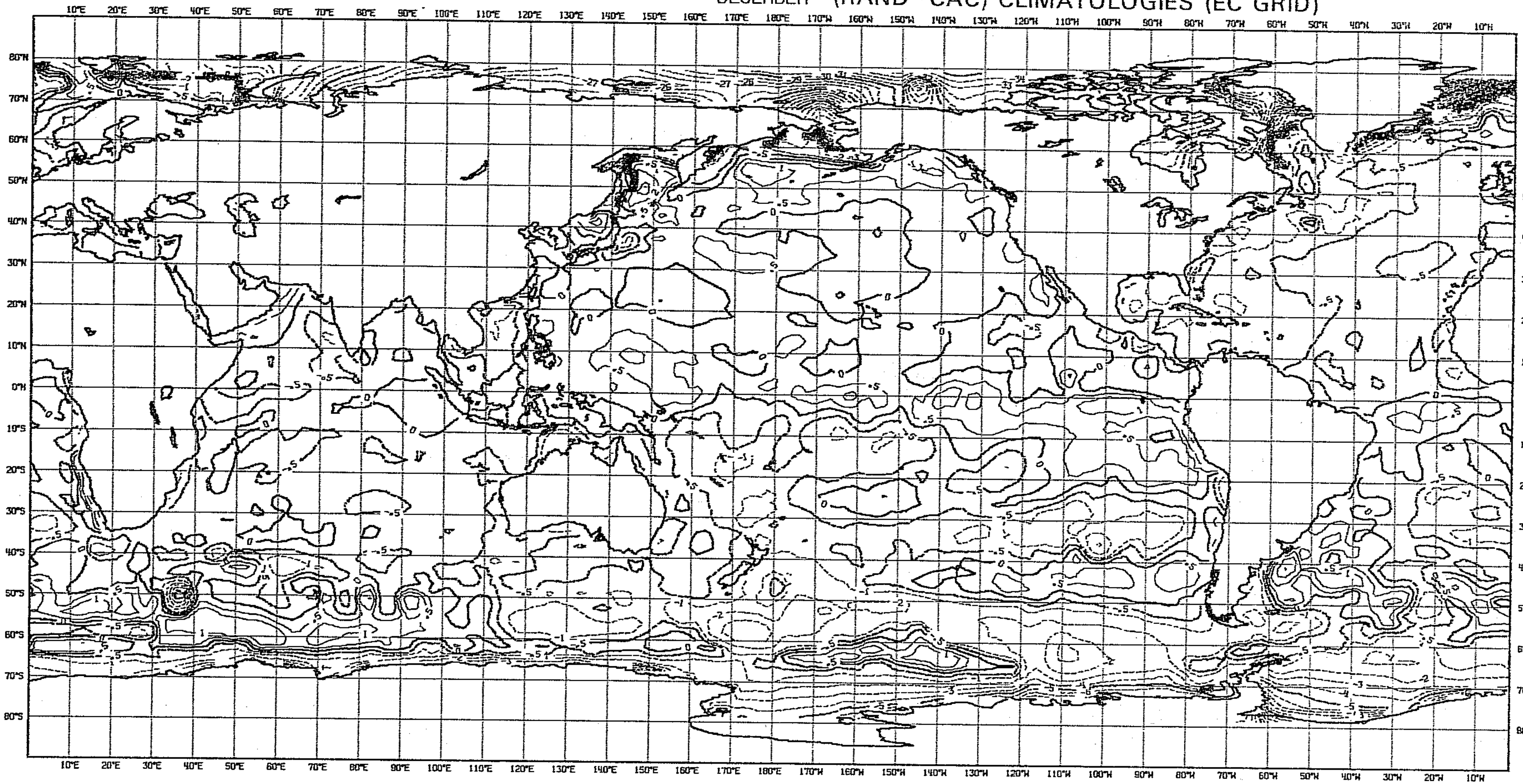
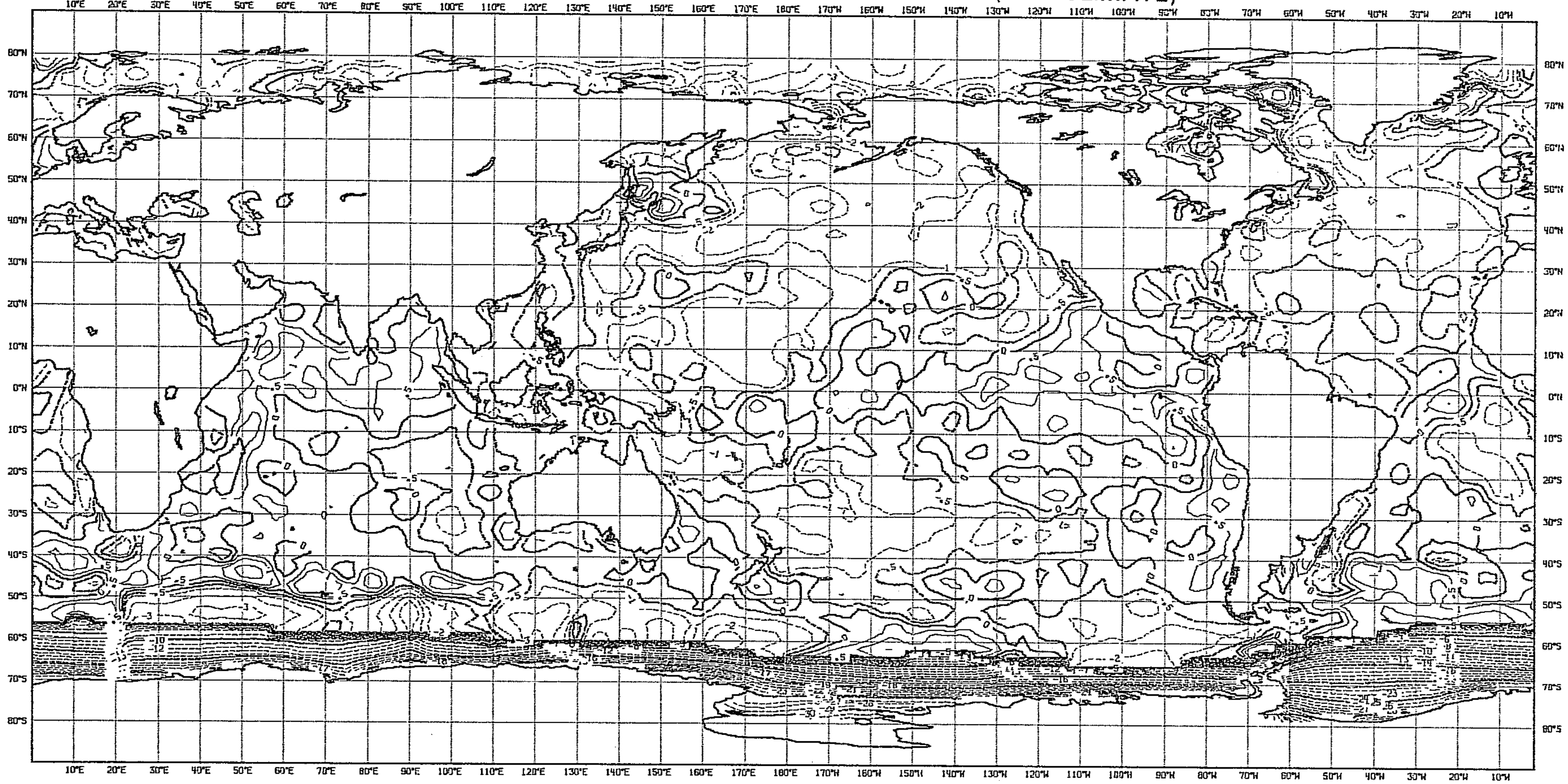


Fig. 15



AUGUST 1982 EC ANOMALY (CAC CLIMATE)

Fig. 16

SEPTEMBER 1982 EC ANOMALY (CAC CLIMATE)

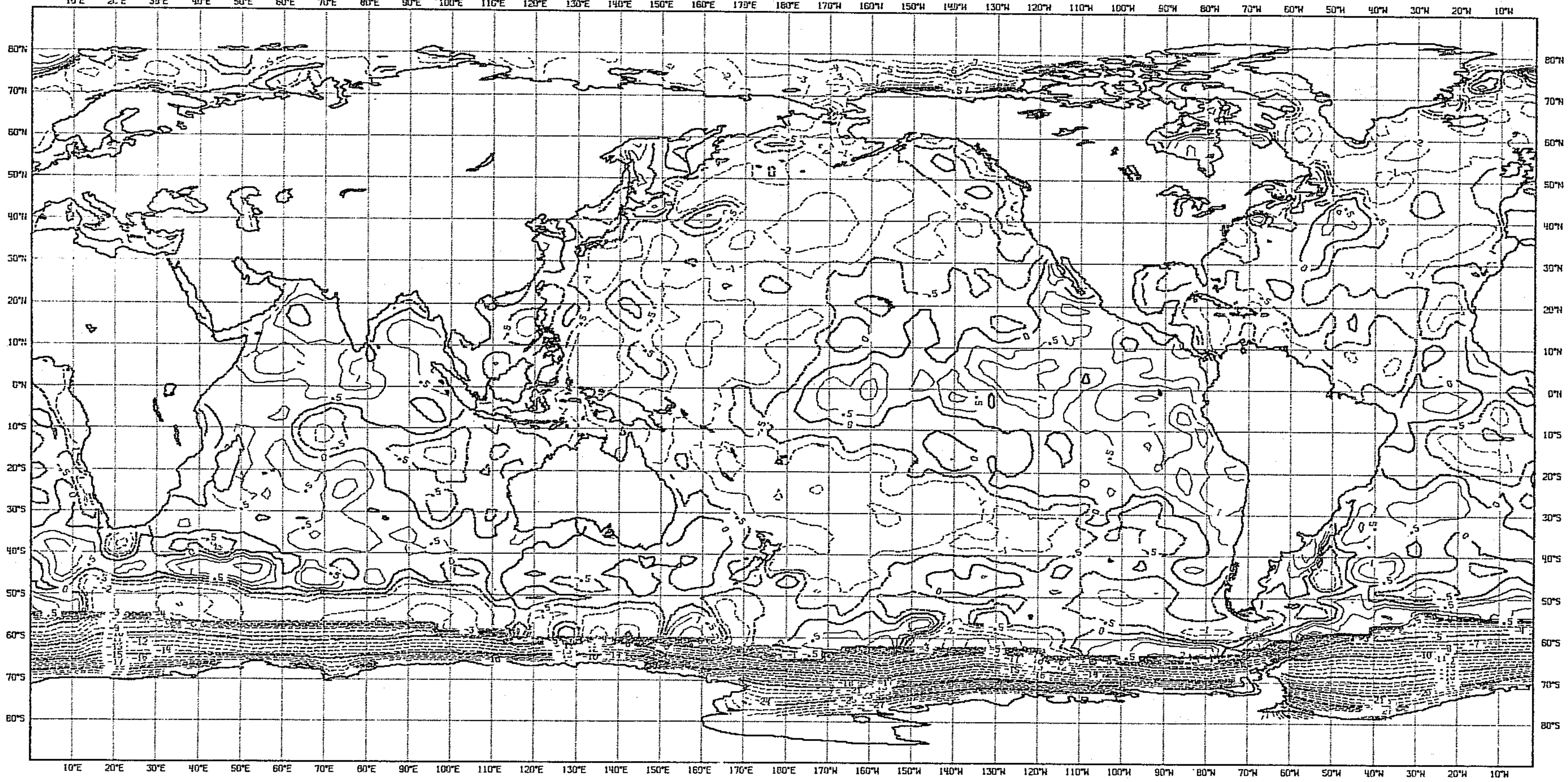


Fig. 17

OCTOBER 1982 EC ANOMALY (CAC CLIMATE)

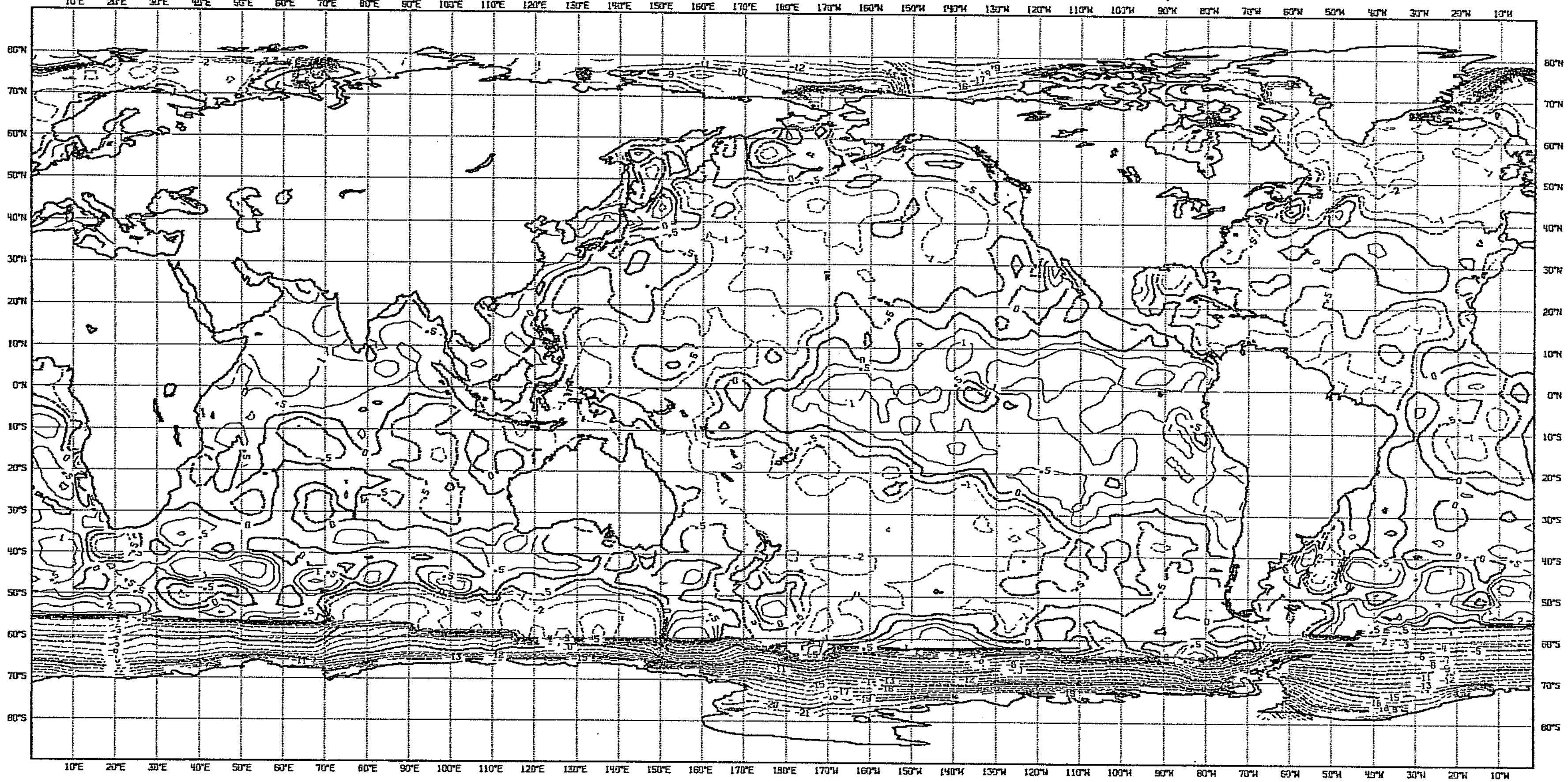


Fig. 18

NOVEMBER 1982 EC ANOMALY (CAC CLIMATE)

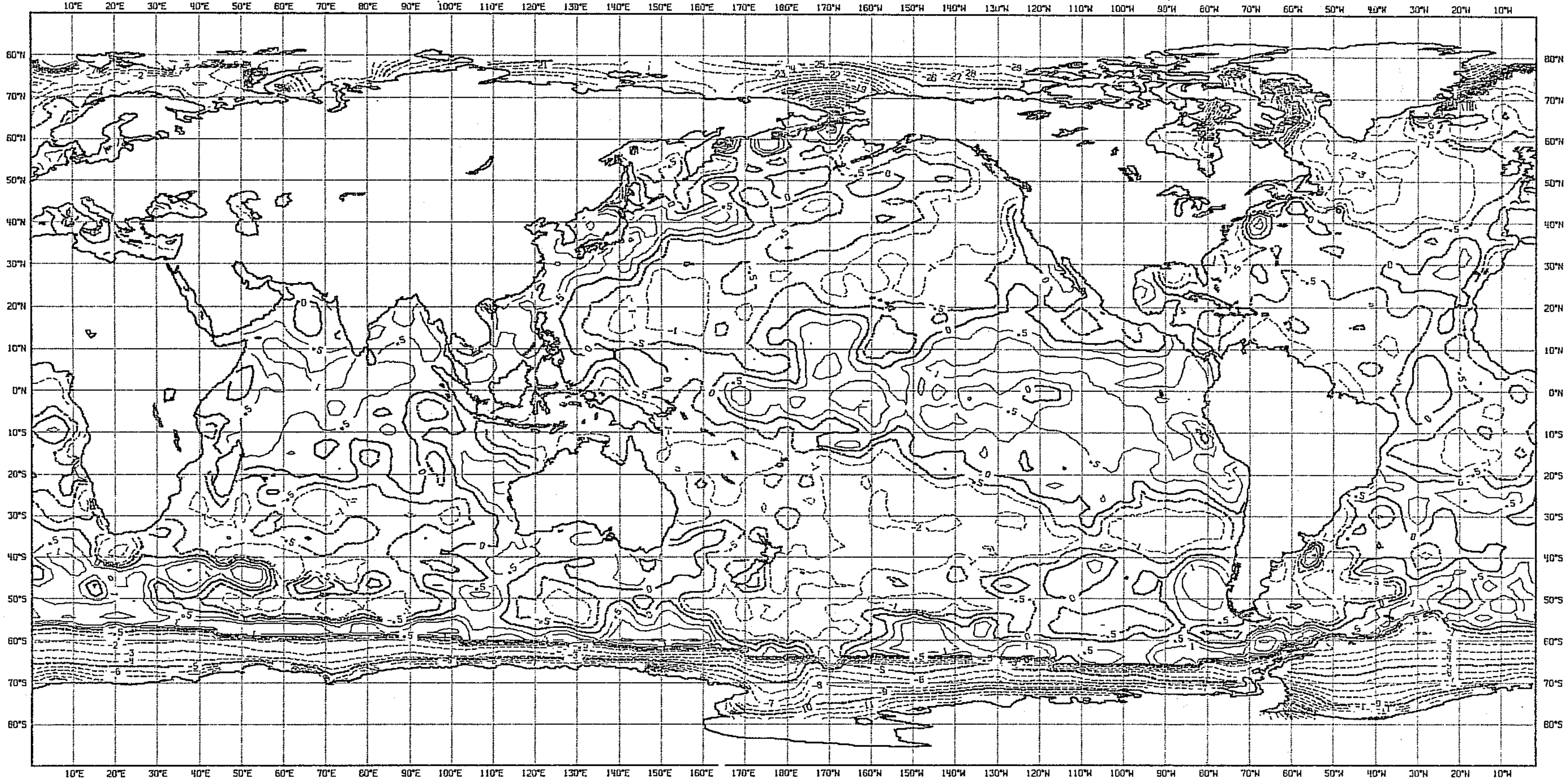


Fig.19

DECEMBER 1982 EC ANOMALY (CAC CLIMATE)

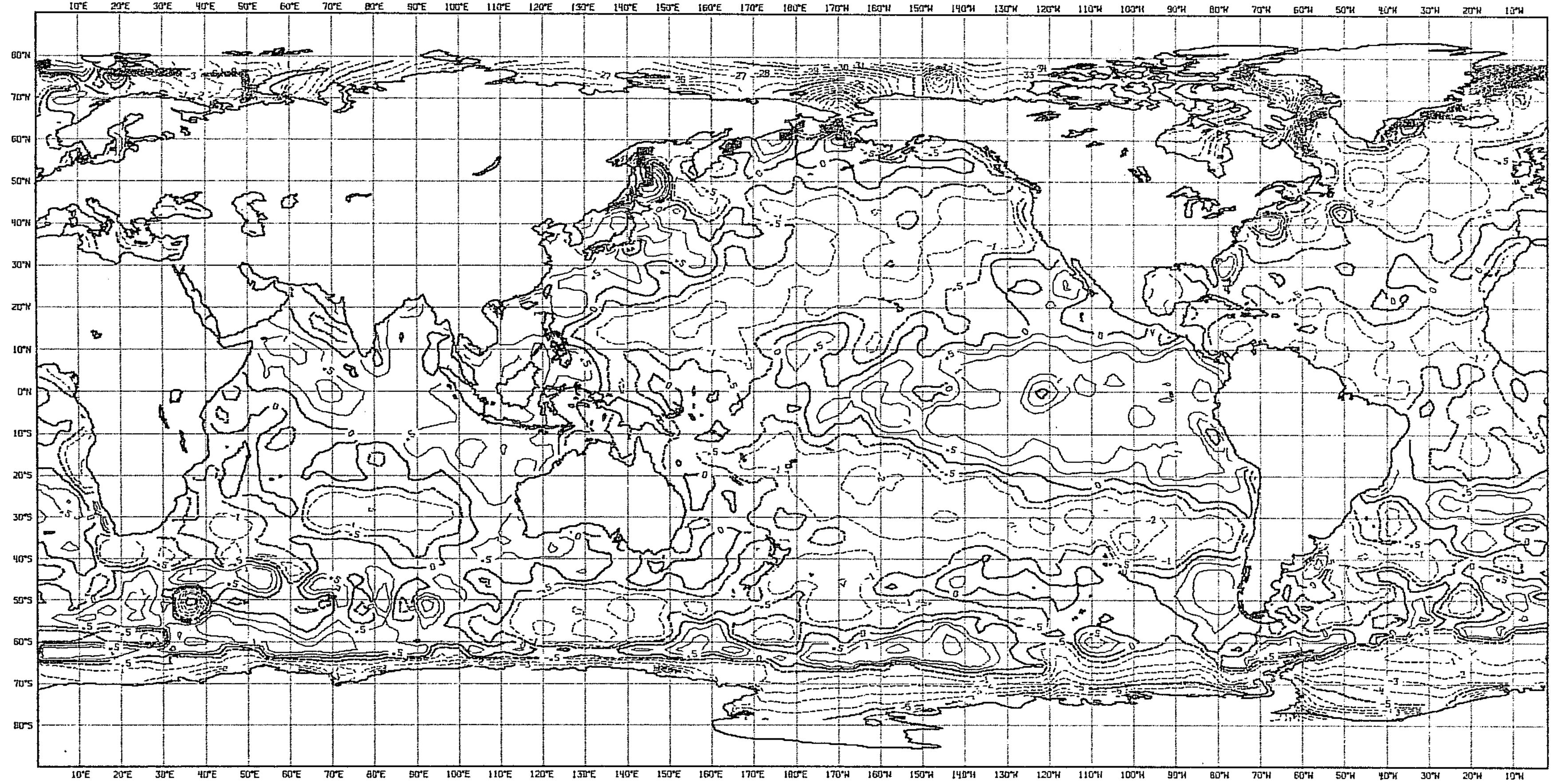


Fig. 20

JANUARY 1983 EC ANOMALY (CAC CLIMATE)

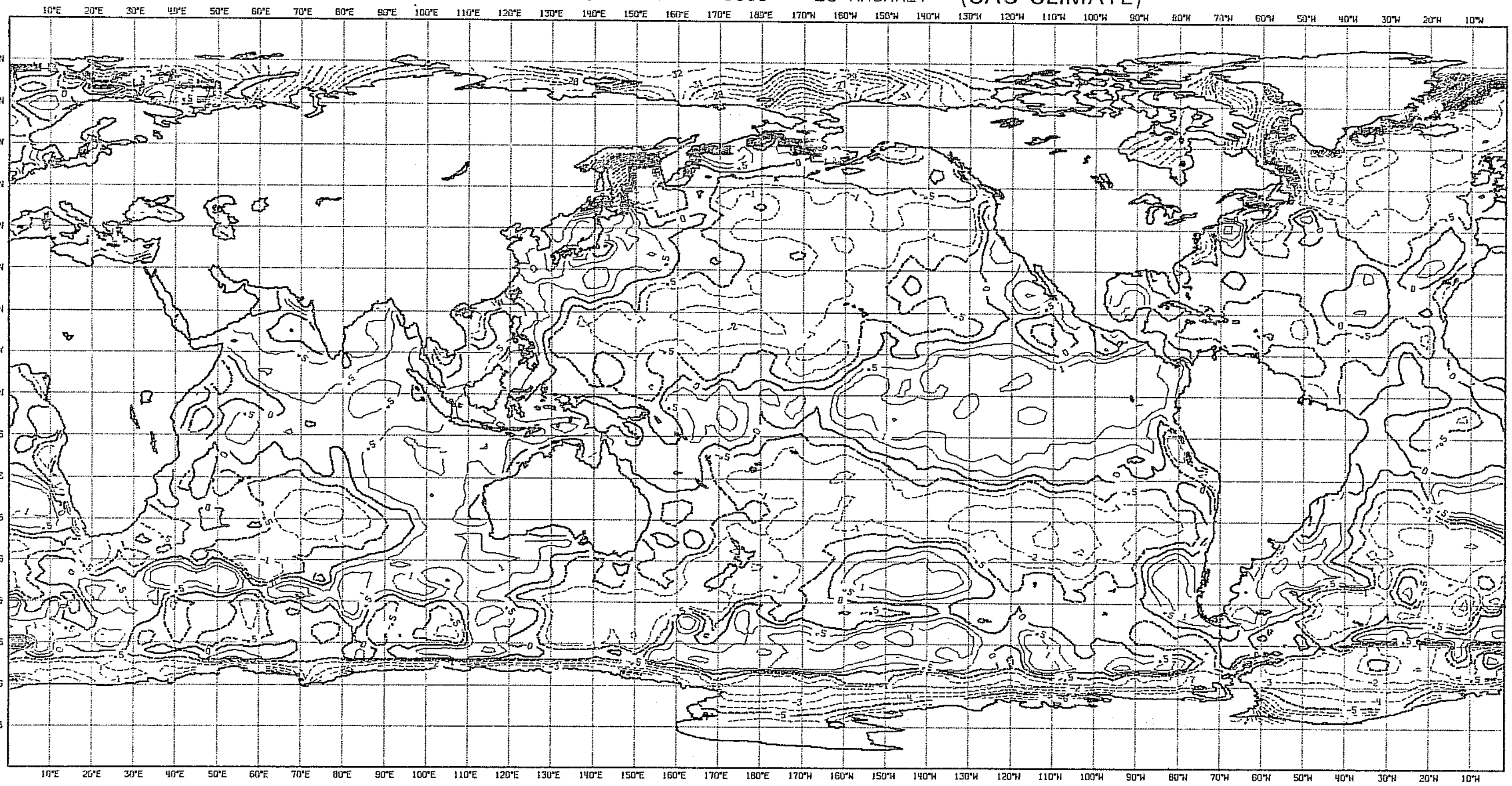
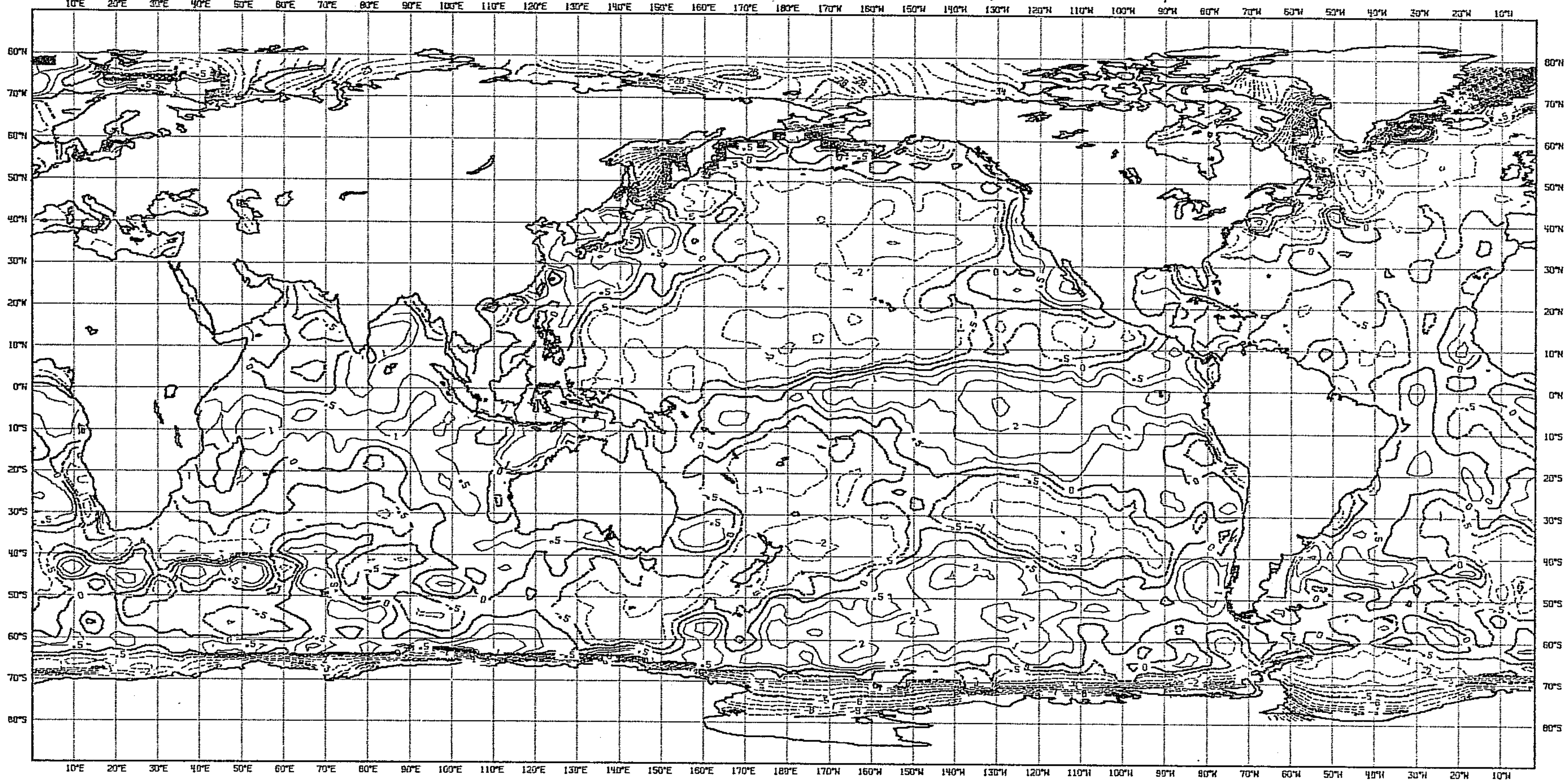


Fig. 21



FEBRUARY 1983 EC ANOMALY (CAC CLIMATE)

Fig. 22

MARCH 1983 EC ANOMALY (CAC CLIMATE)

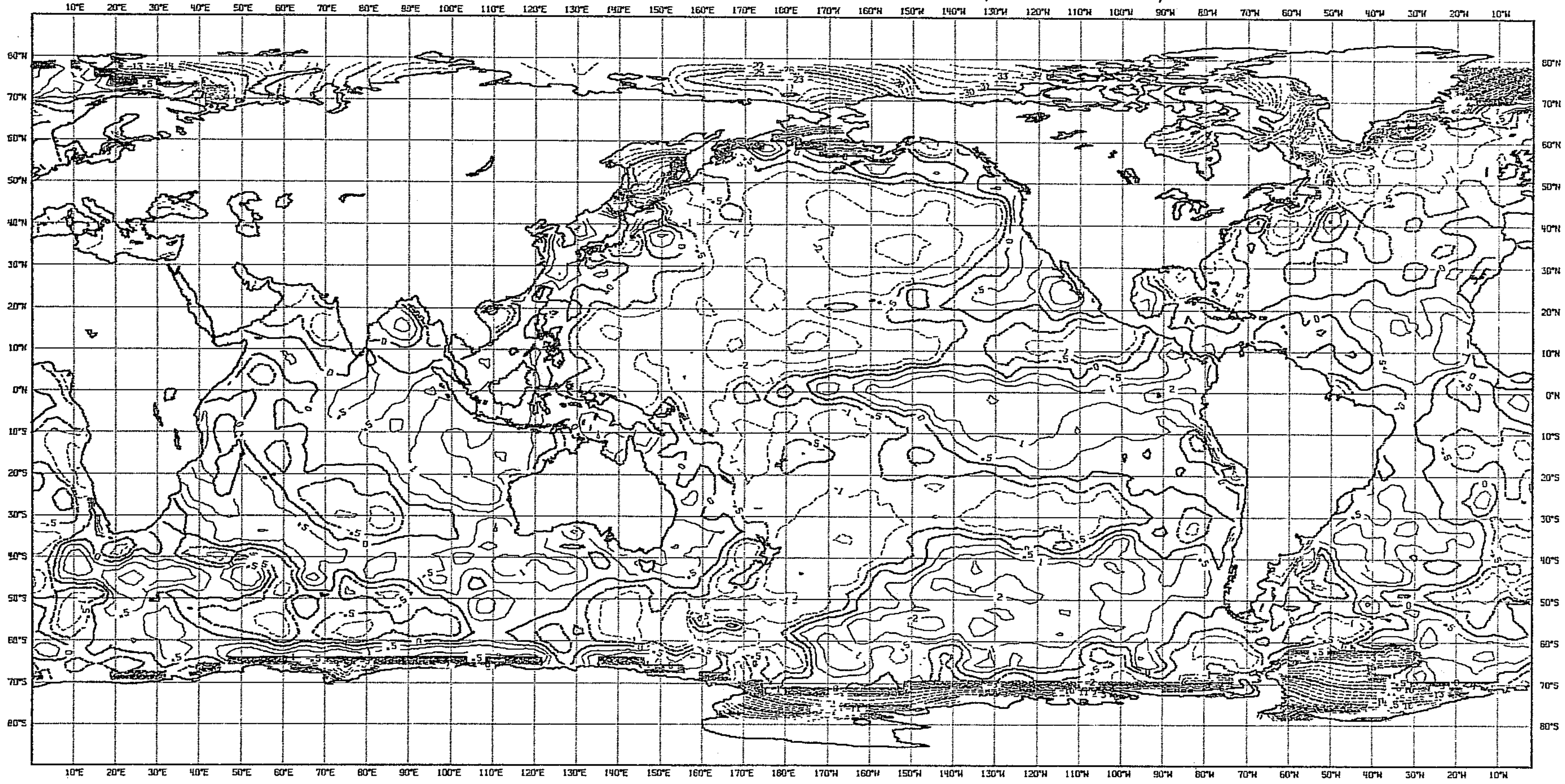


Fig. 23

APRIL 1983 EC ANOMALY (CAC CLIMATE)

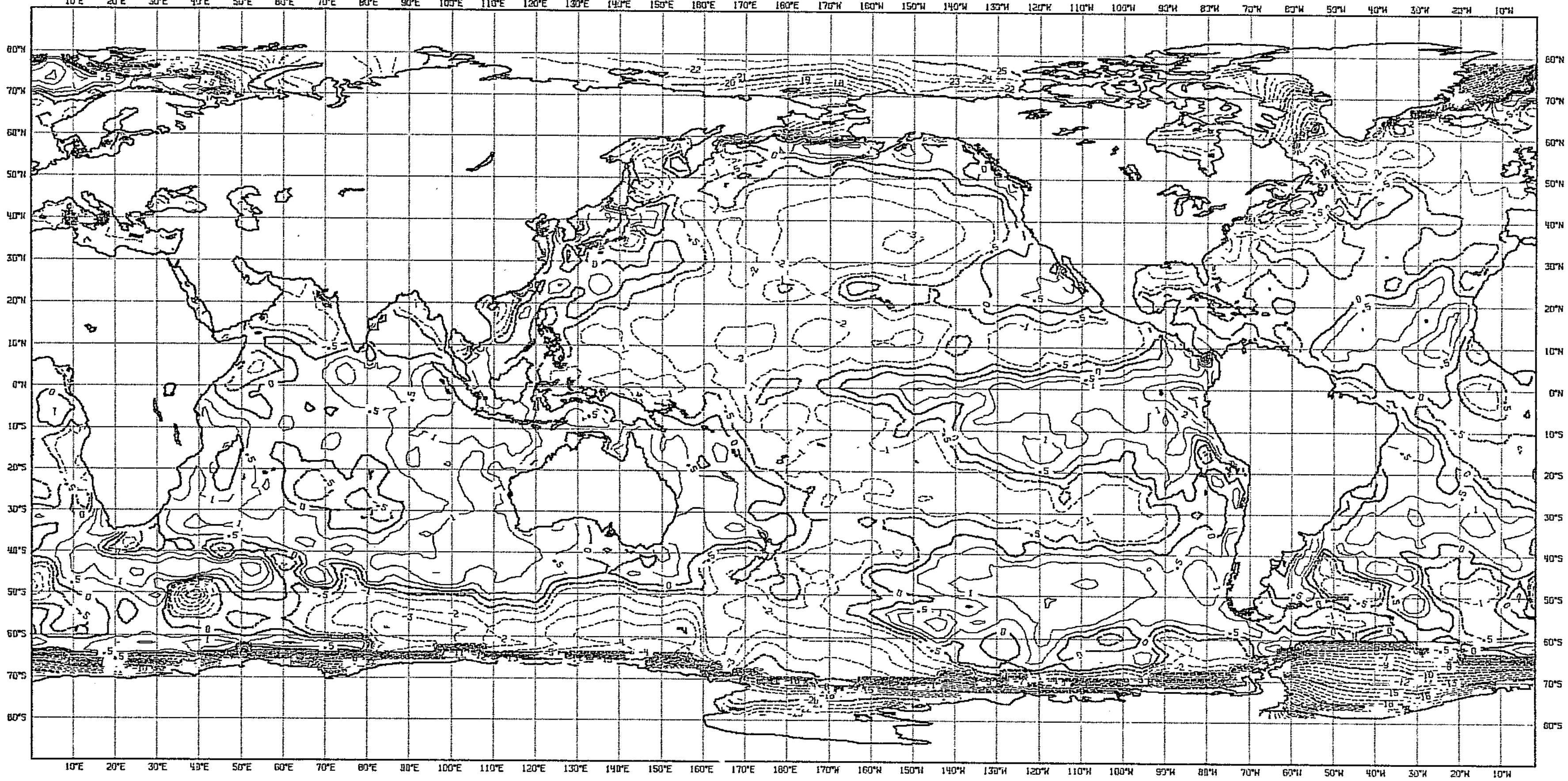


Fig. 24

MAY 1983 EC ANOMALY (CAC CLIMATE)

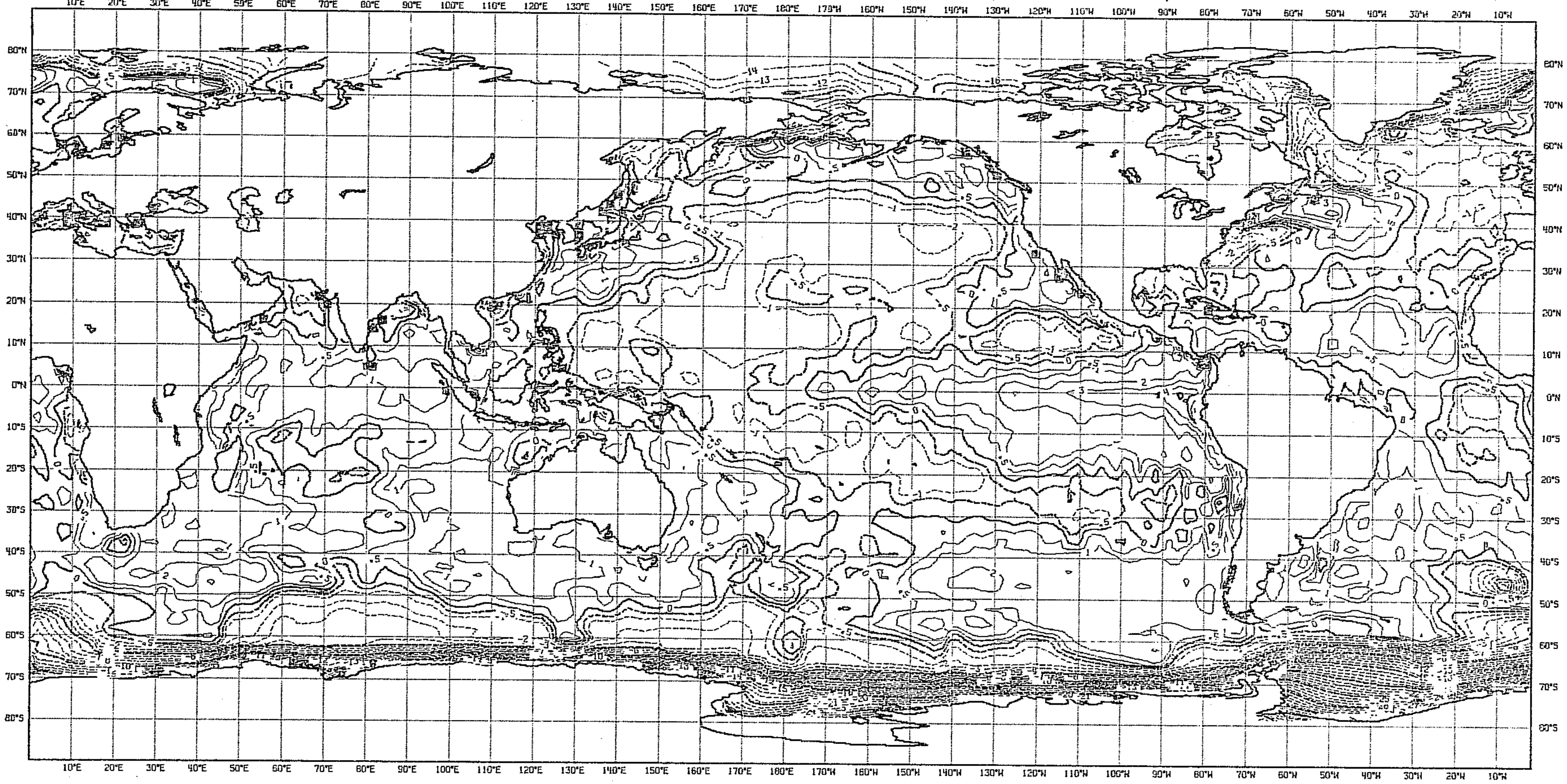
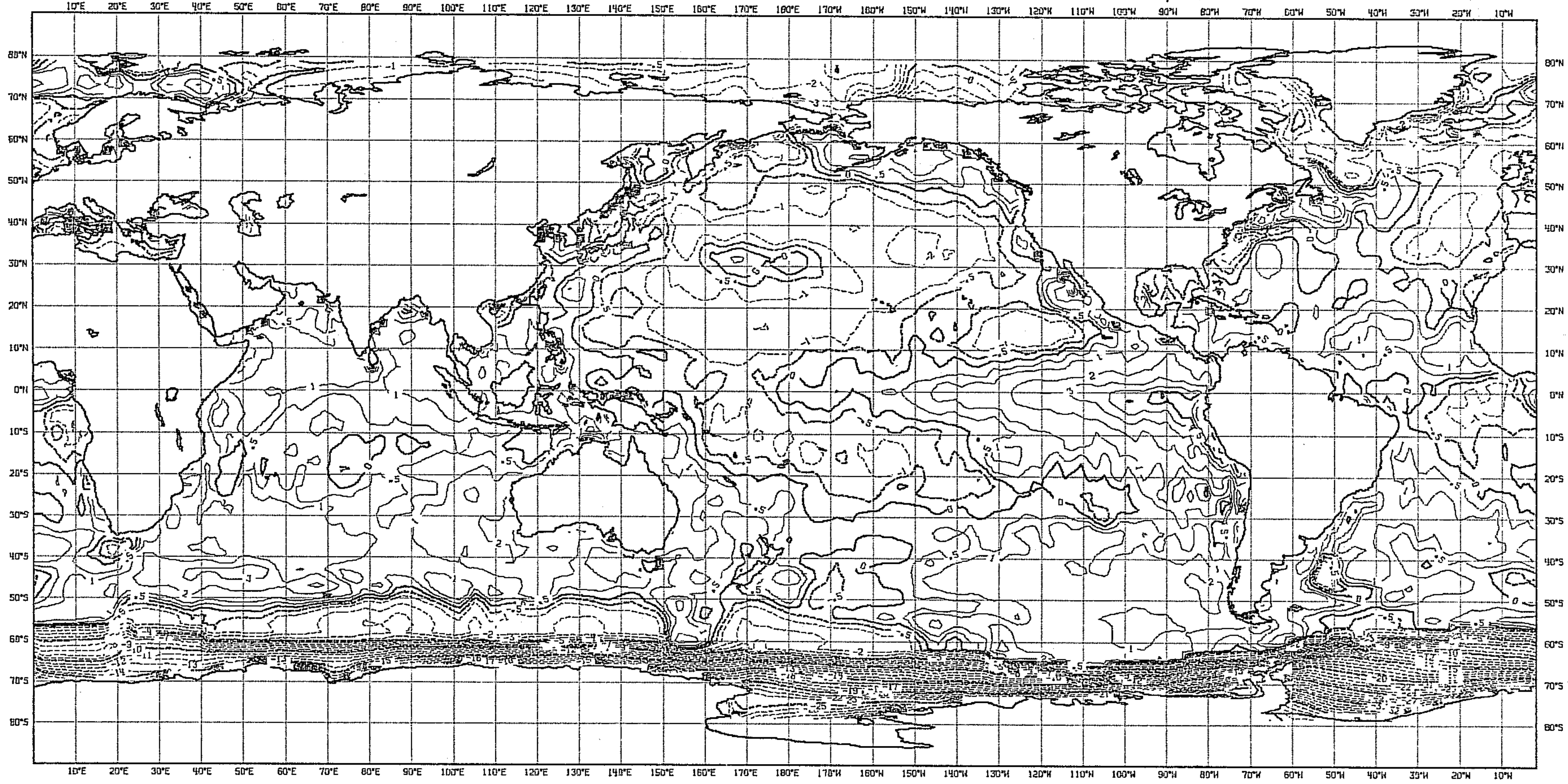
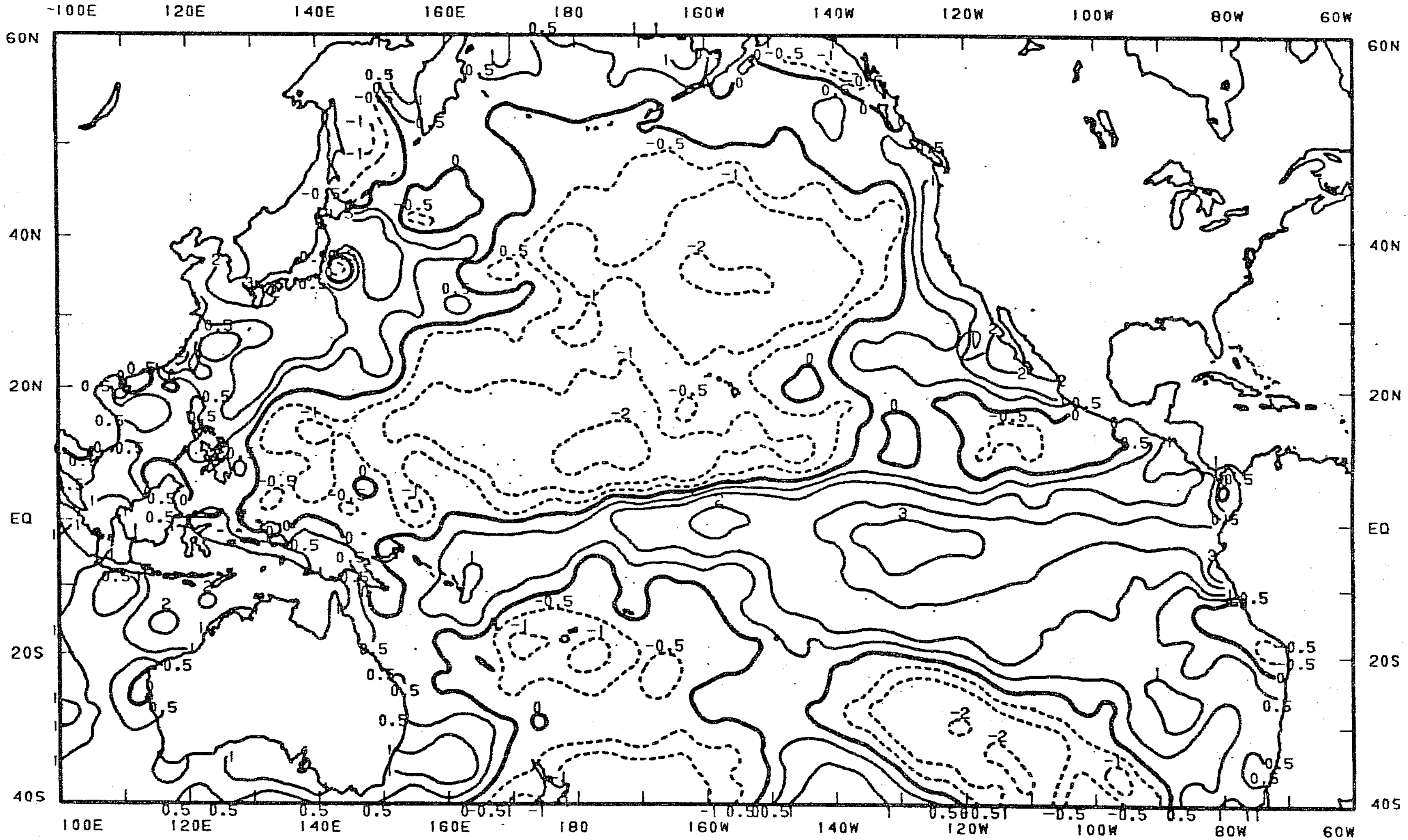


Fig. 25



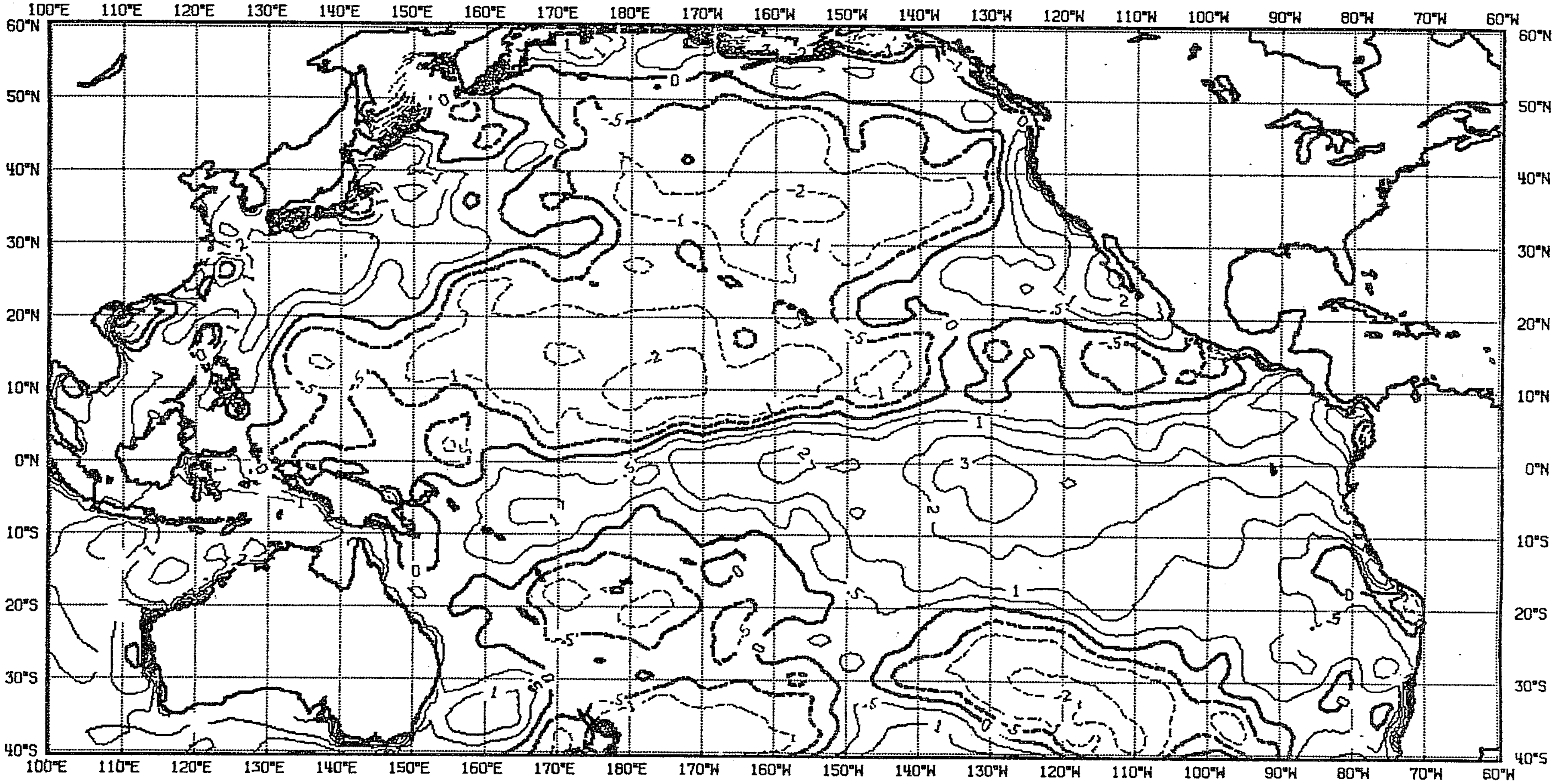
JUNE 1983 EC ANOMALY (CAC CLIMATE)

Fig. 26



NMC SST ANOMALIES FOR FEB 1983 USING NCC CLIMATOLOGY

Fig. 27



ECMWF SST ANOMALIES +0.5°C FOR FEB 1983 USING NCC CLIMATOLOGY

Fig. 28 MAY 1982 CAC ANOMALY

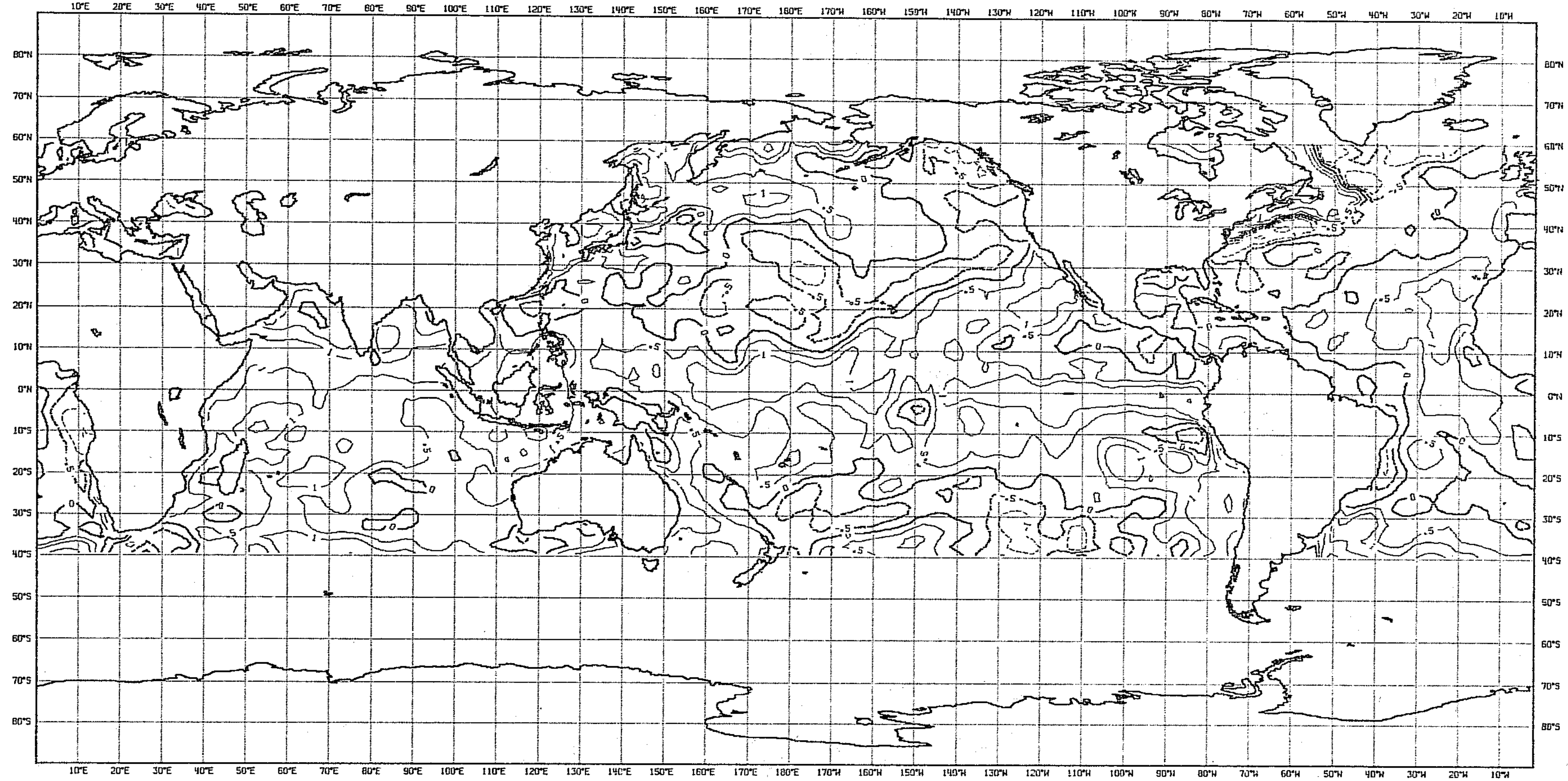


Fig. 29

JUNE 1982 CAC ANOMALY

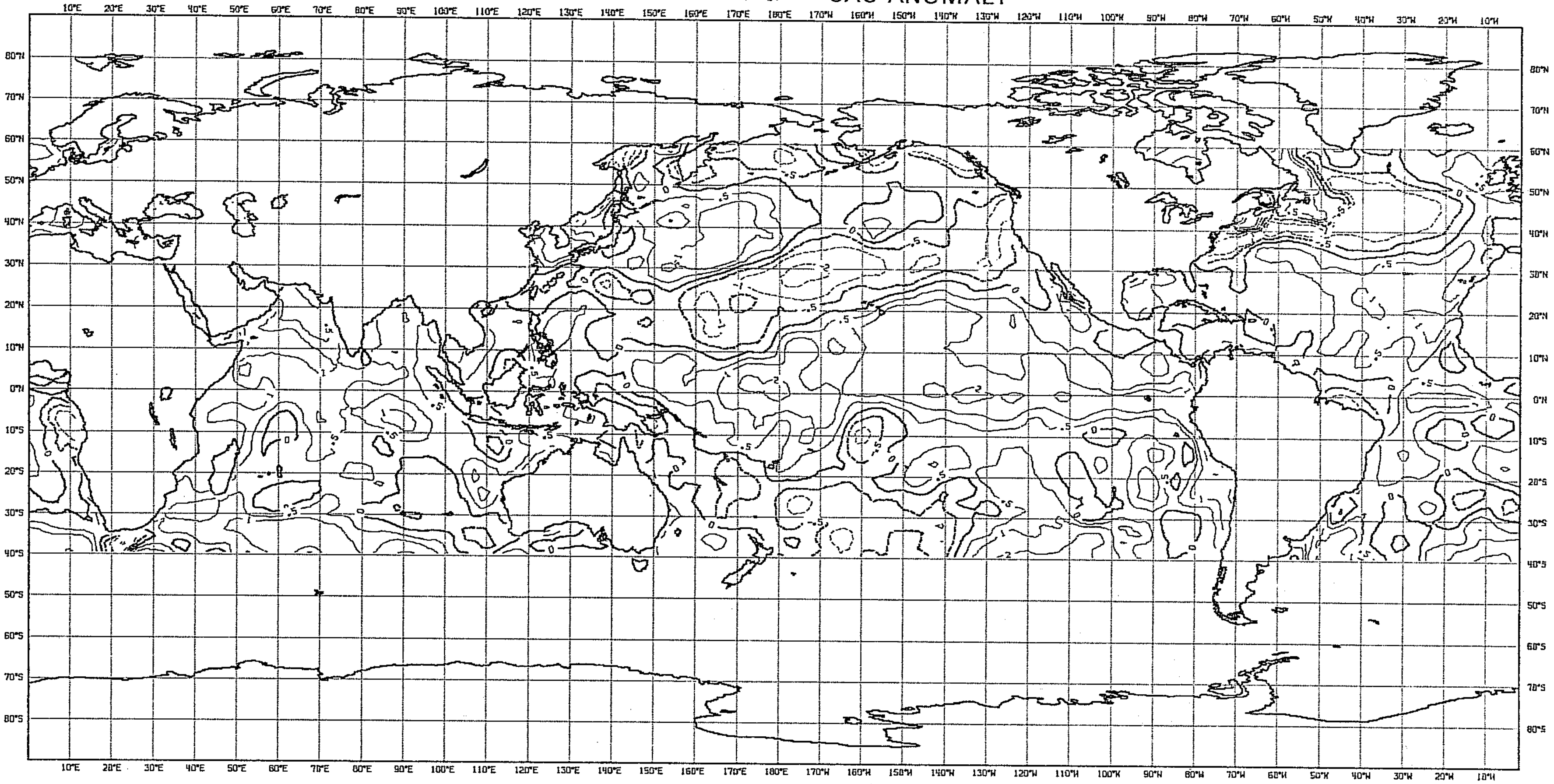


Fig. 30 JULY 1982 CAC ANOMALY

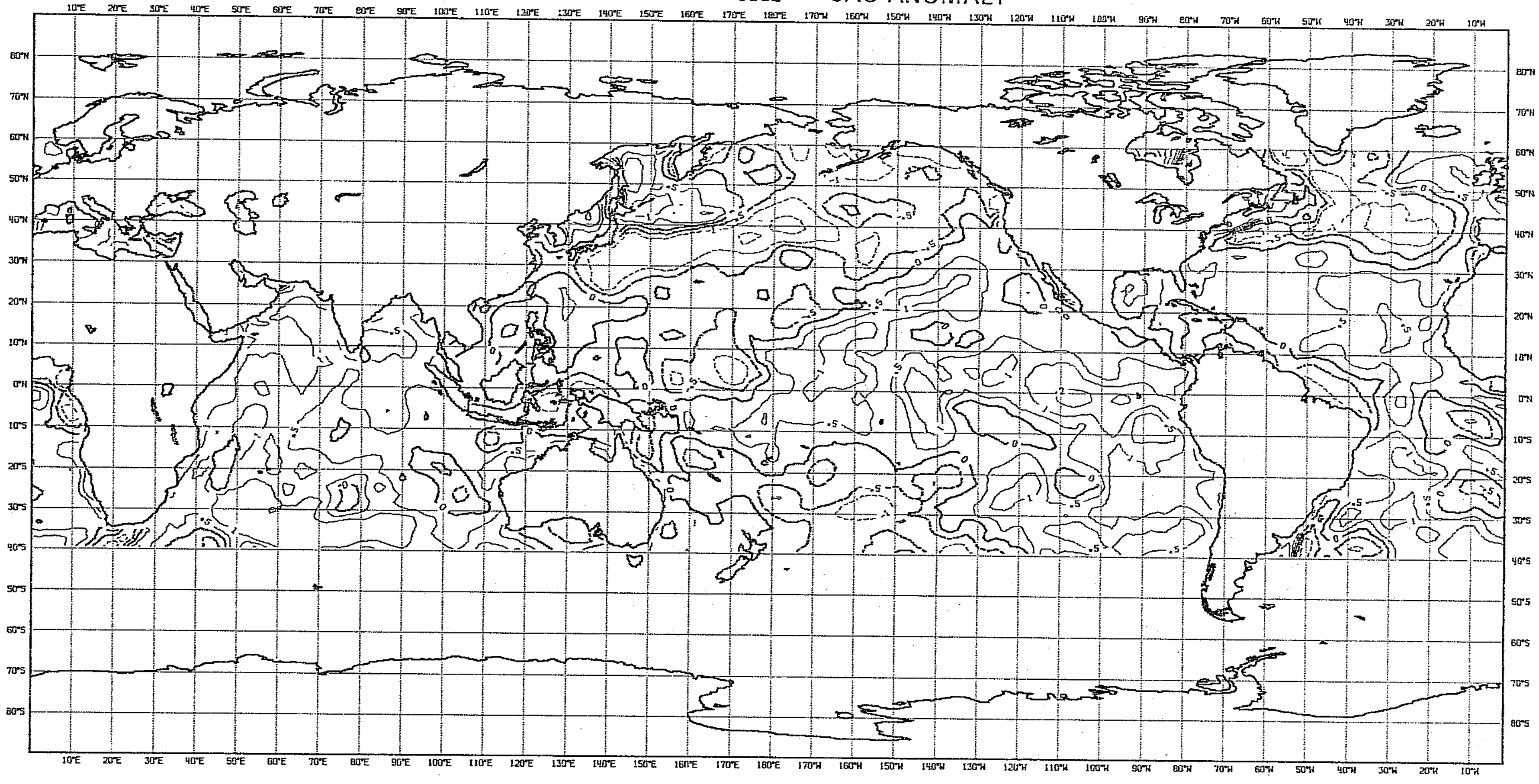


Fig. 31

AUGUST 1982 CAC ANOMALY

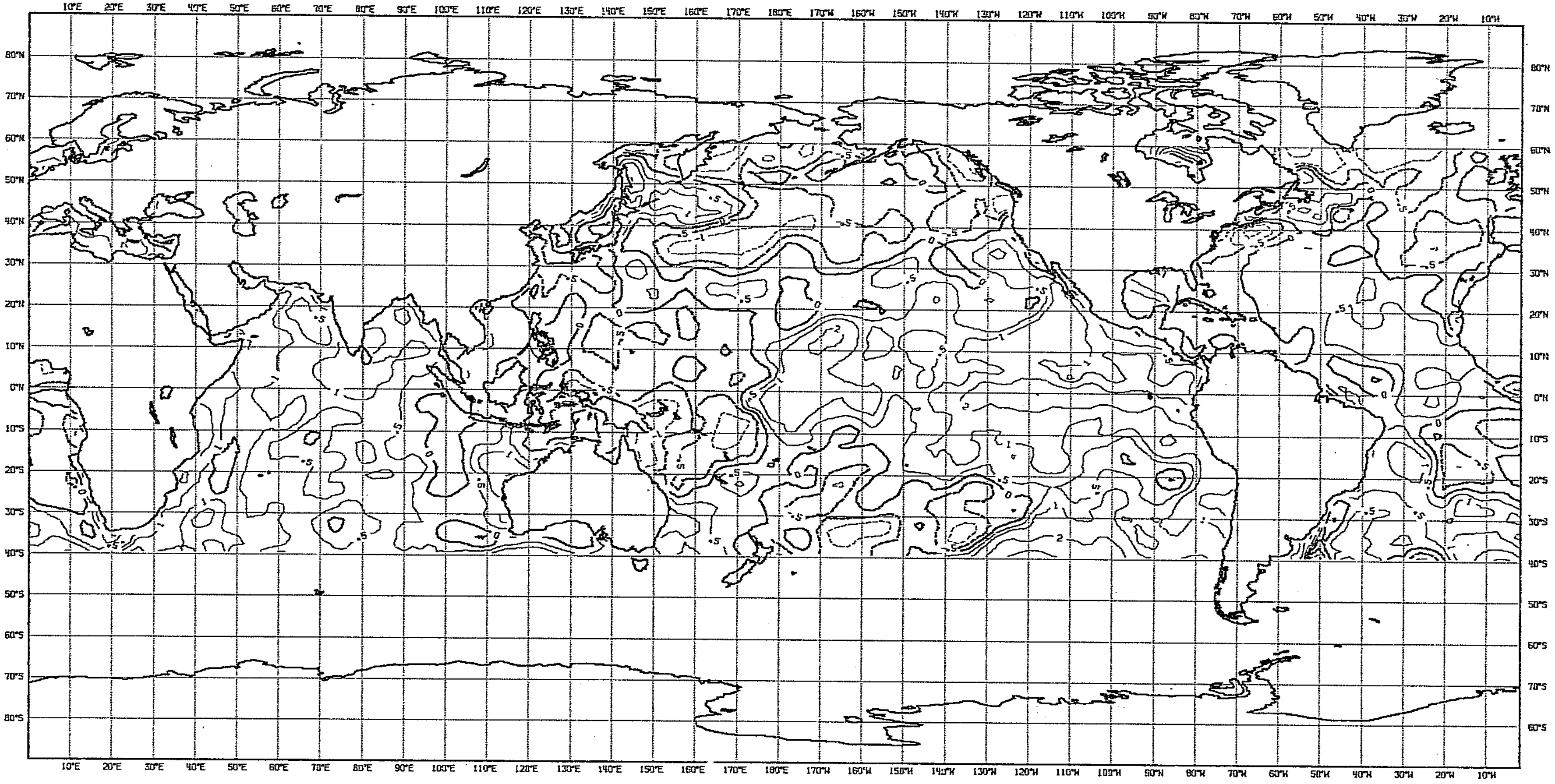


Fig. 32

SEPTEMBER 1982 CAC ANOMALY

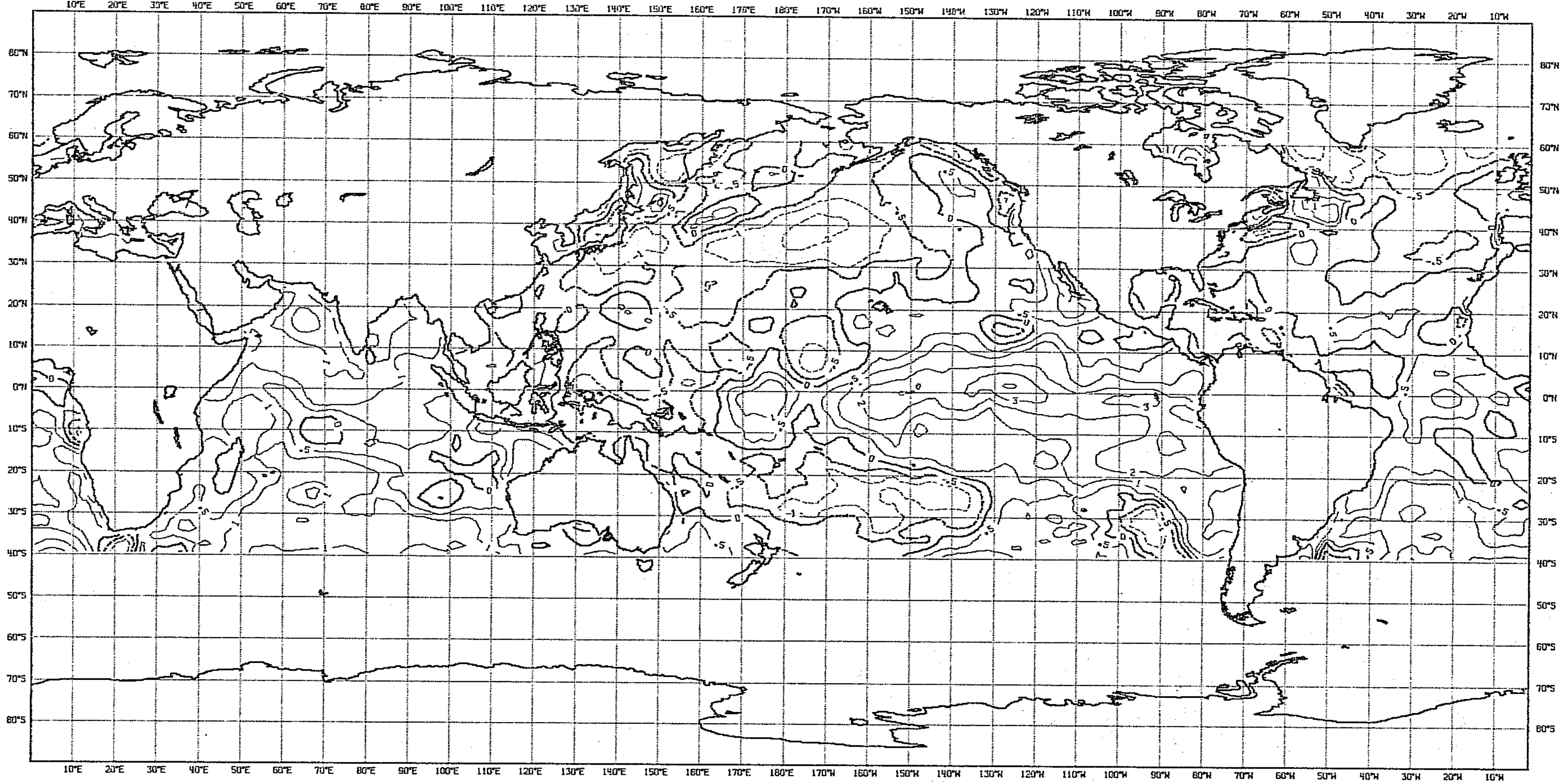


Fig. 33

OCTOBER 1982 CAC ANOMALY

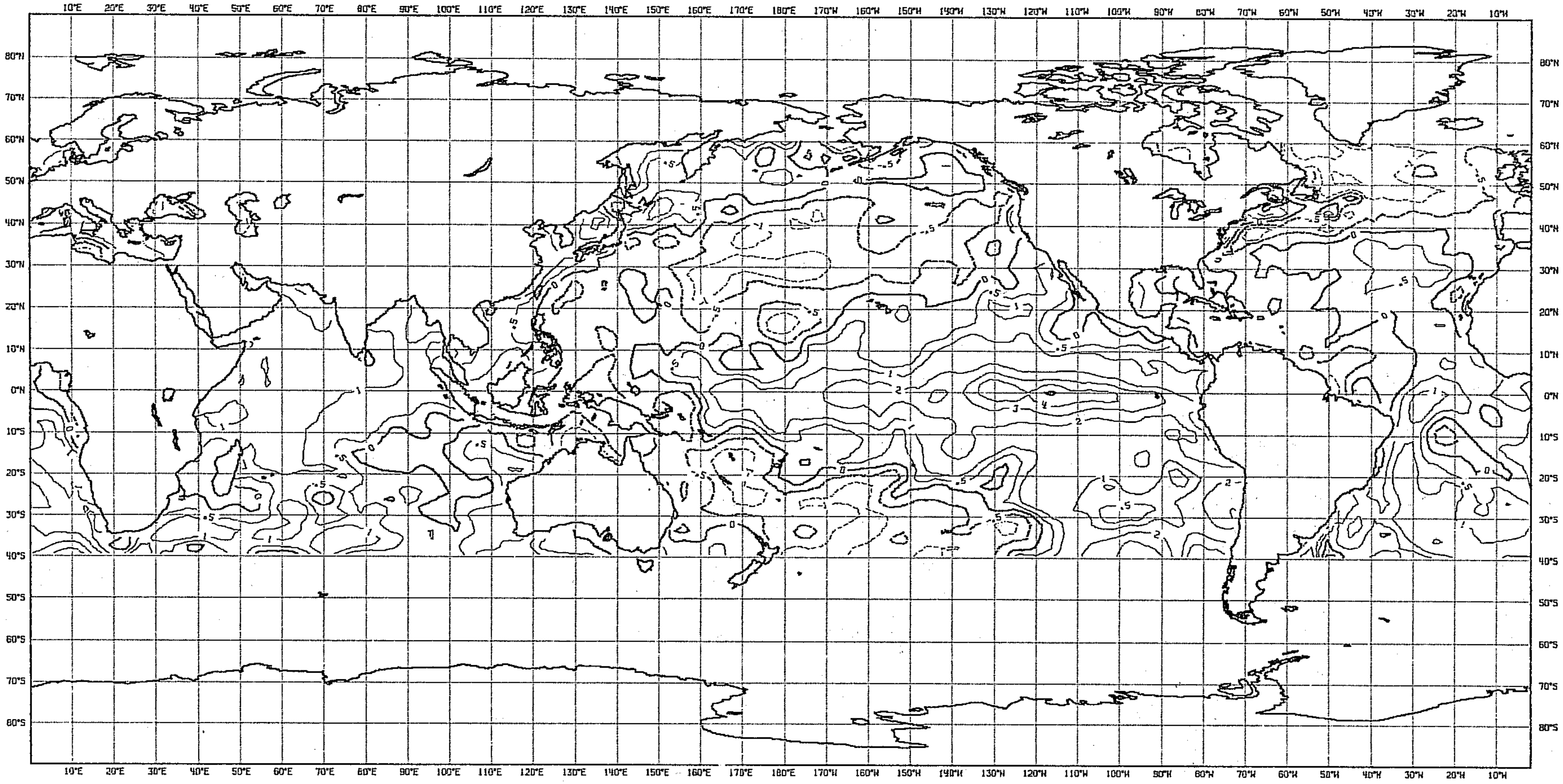


Fig. 34

NOVEMBER 1982 CAC ANOMALY

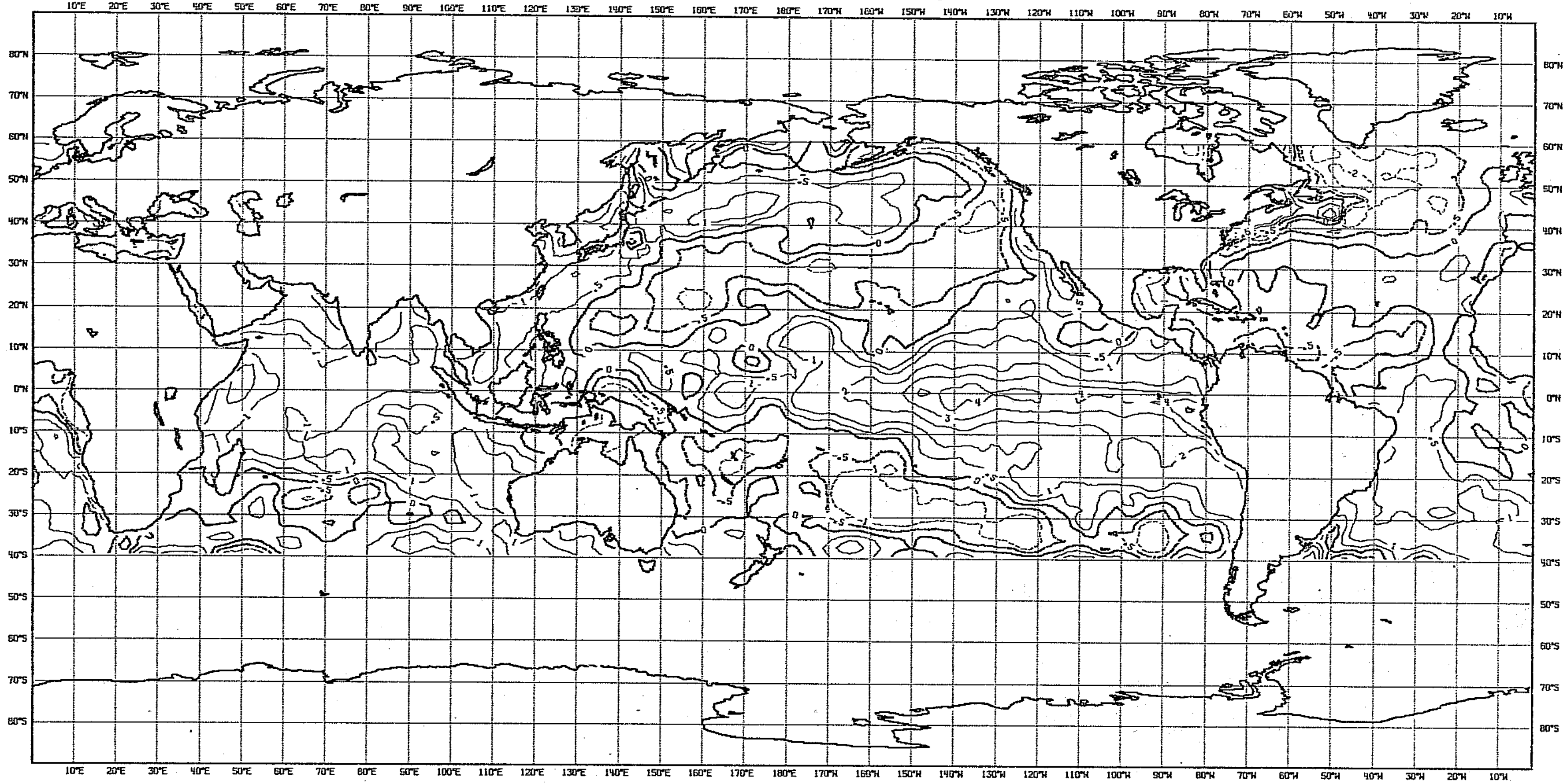


Fig. 35

DECEMBER 1982 CAC ANOMALY

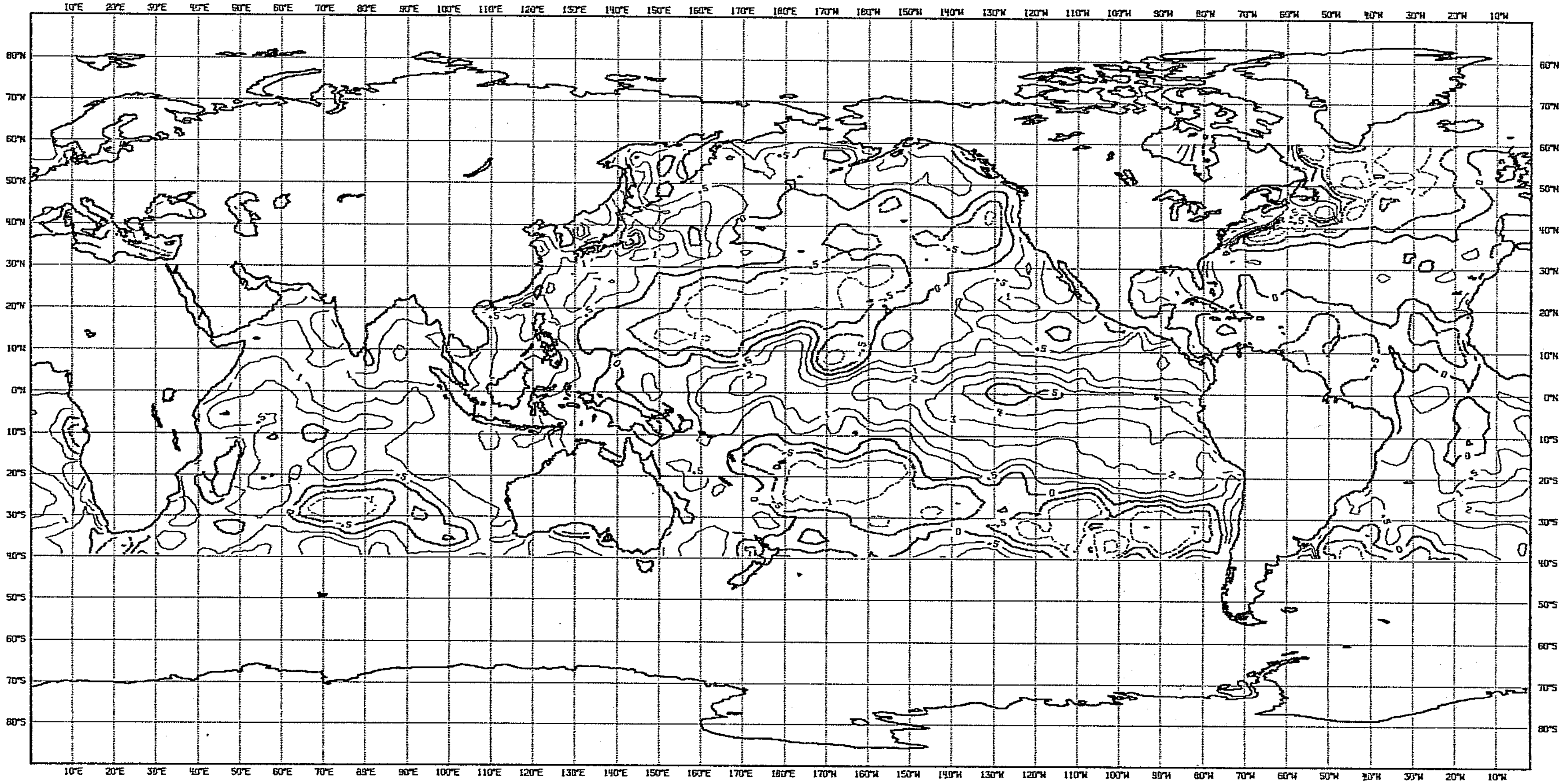


Fig. 36

JANUARY 1983 CAC ANOMALY

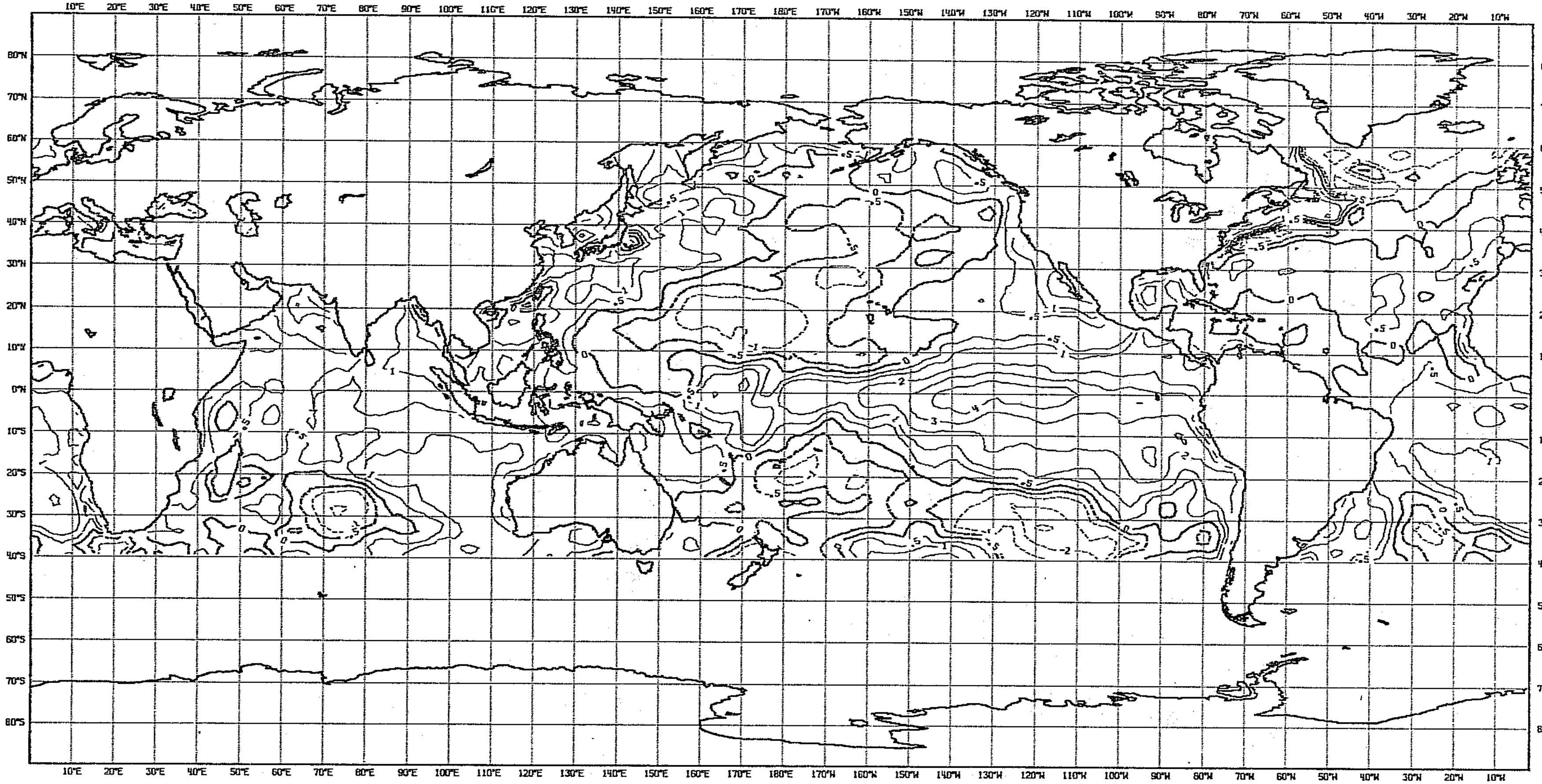


Fig. 37 FEBRUARY 1983 CAC ANOMALY

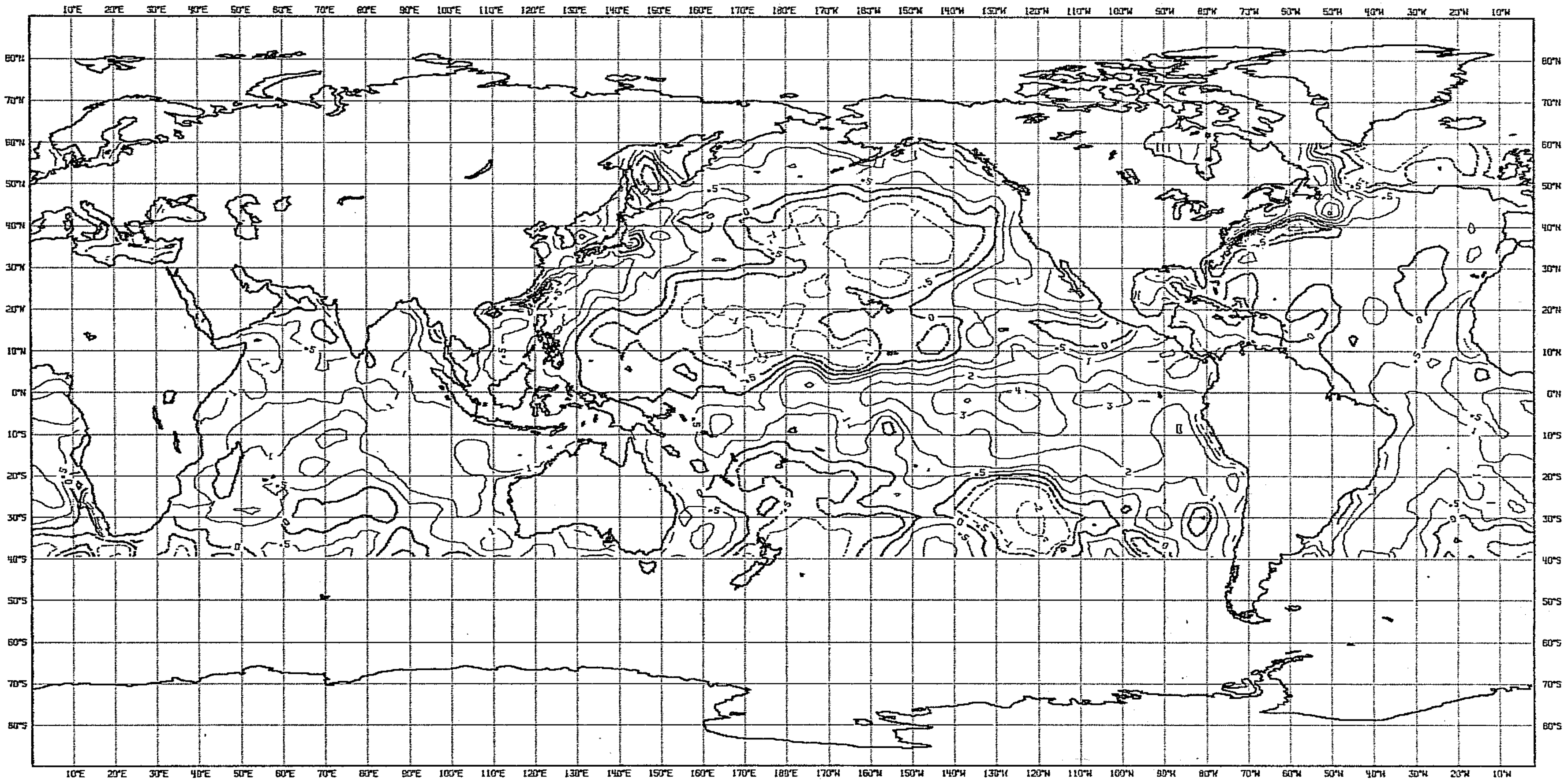


Fig. 38 MARCH 1983 CAC ANOMALY

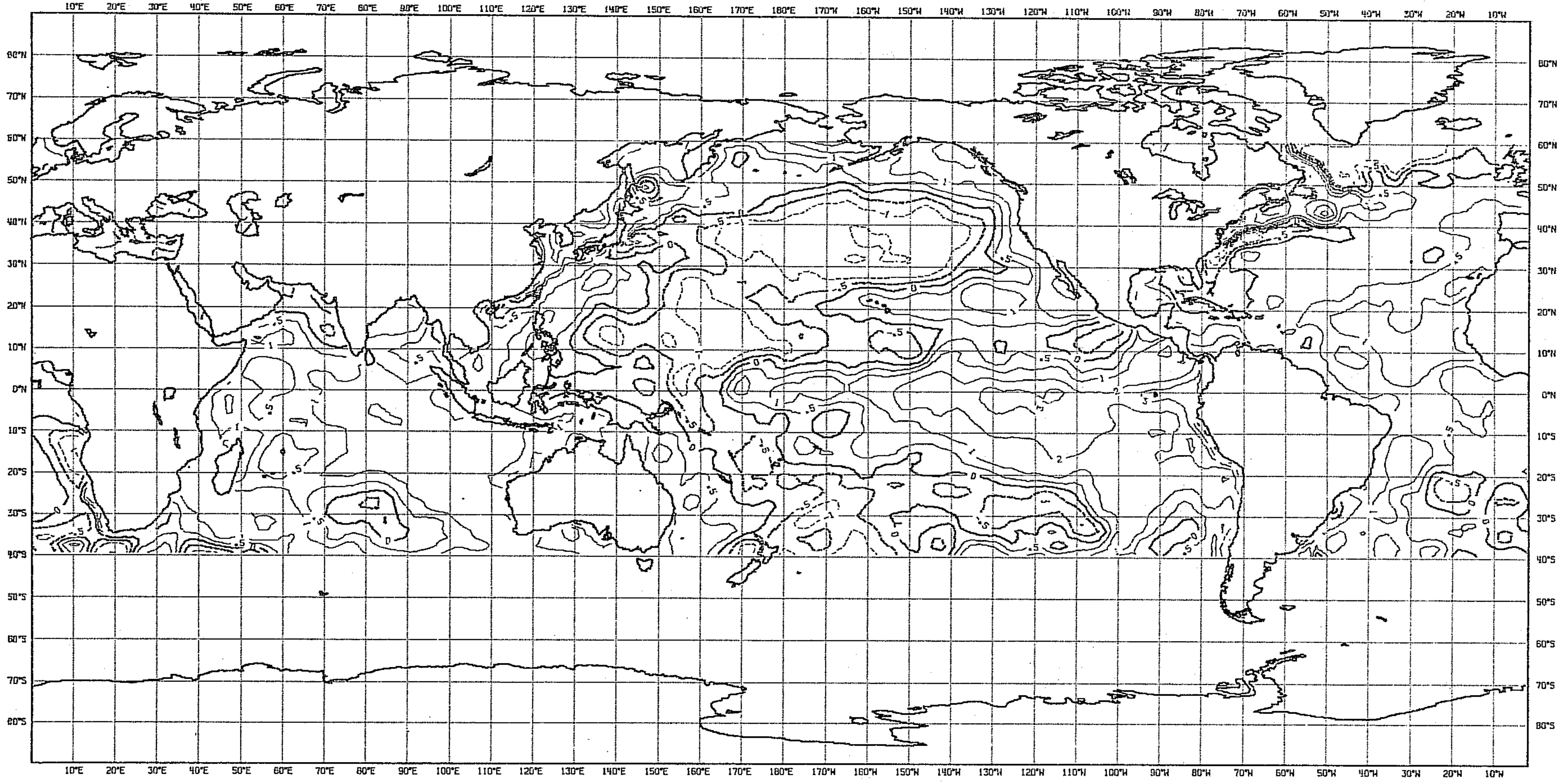


Fig. 39 APRIL 1983 CAC ANOMALY

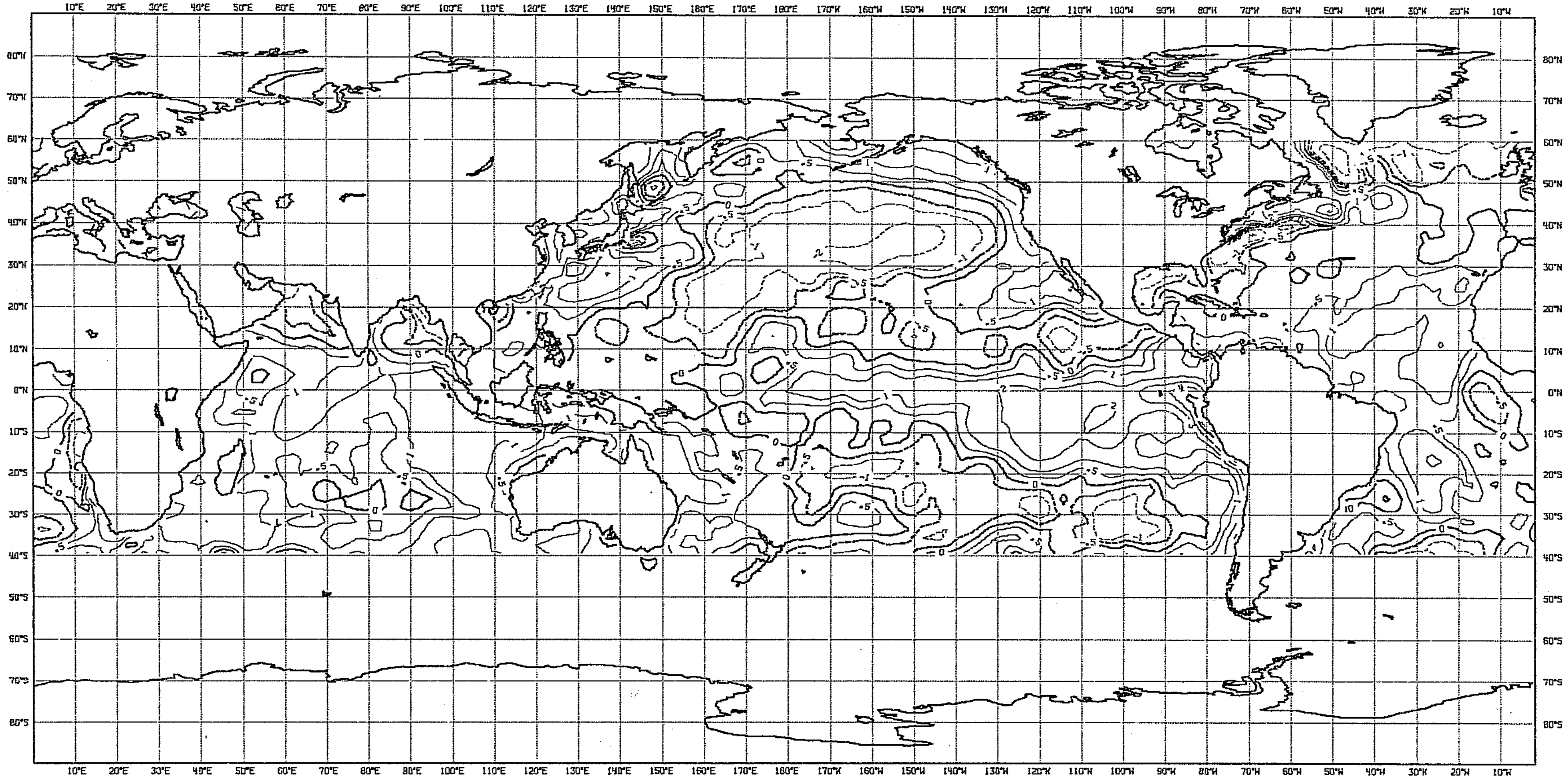


Fig. 40 MAY 1983 CAC ANOMALY

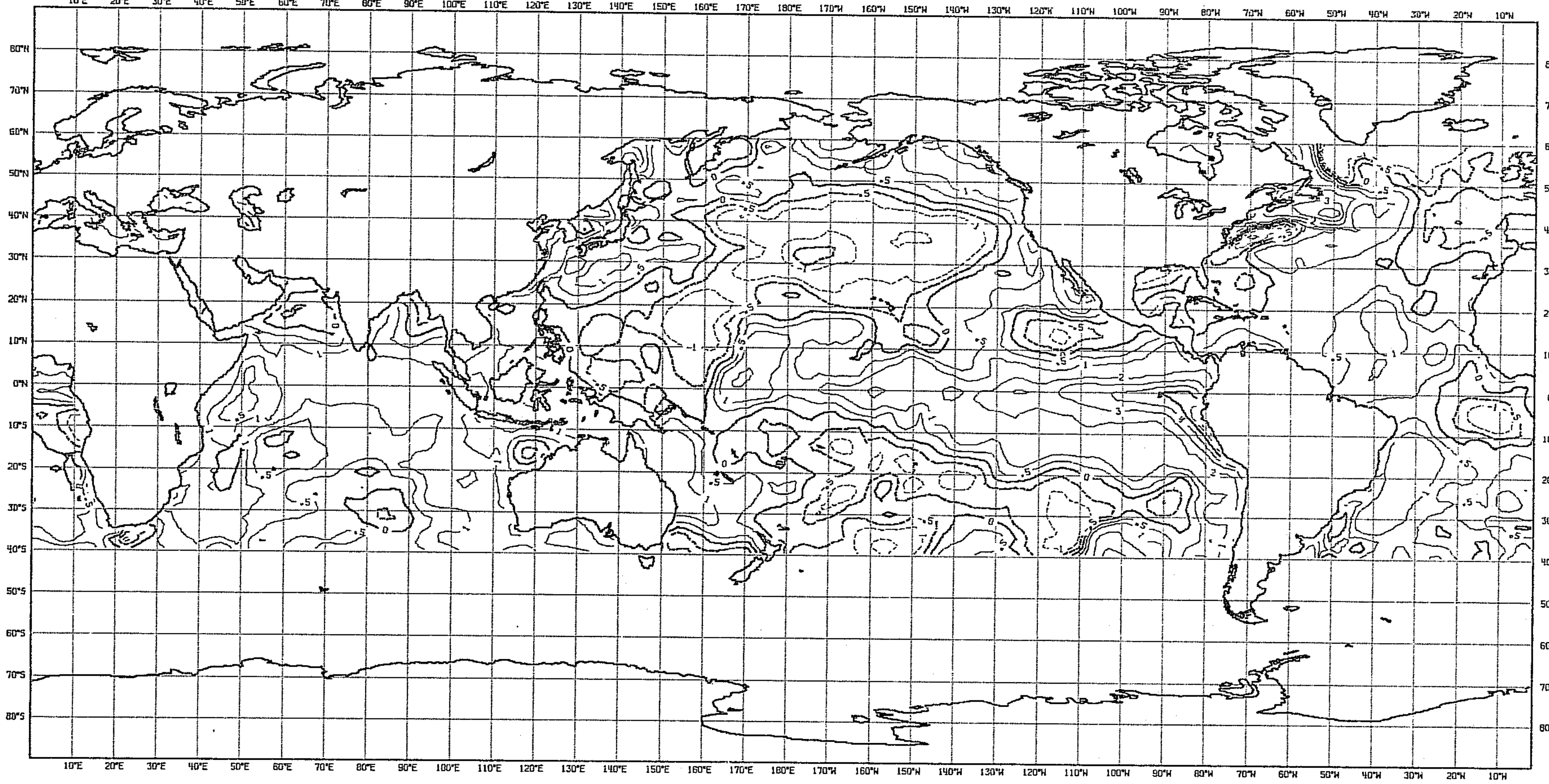


Fig. 41 JUNE 1983 CAC ANOMALY

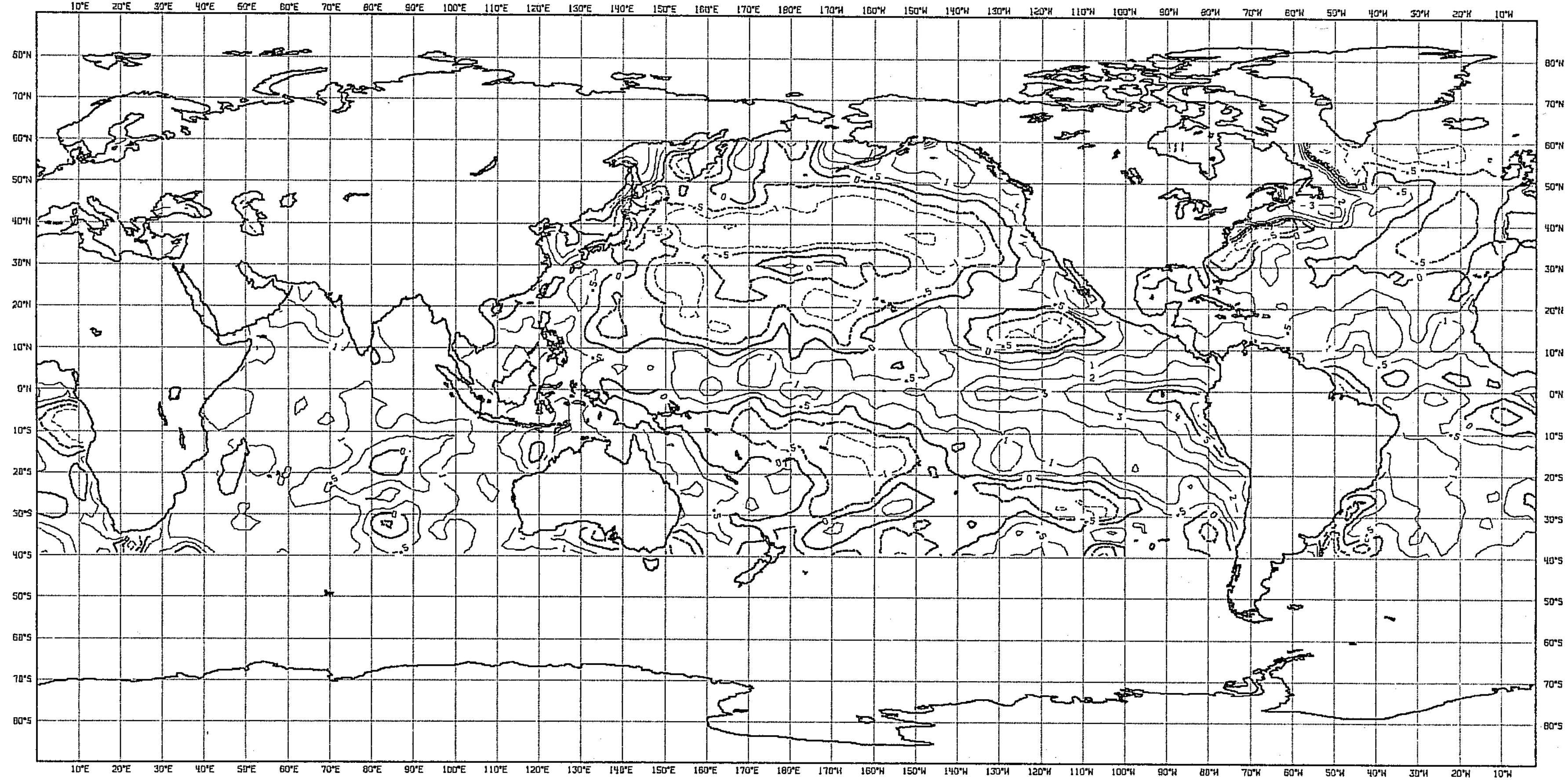


Fig. 42

AUGUST 1982 CAC-ECMWF

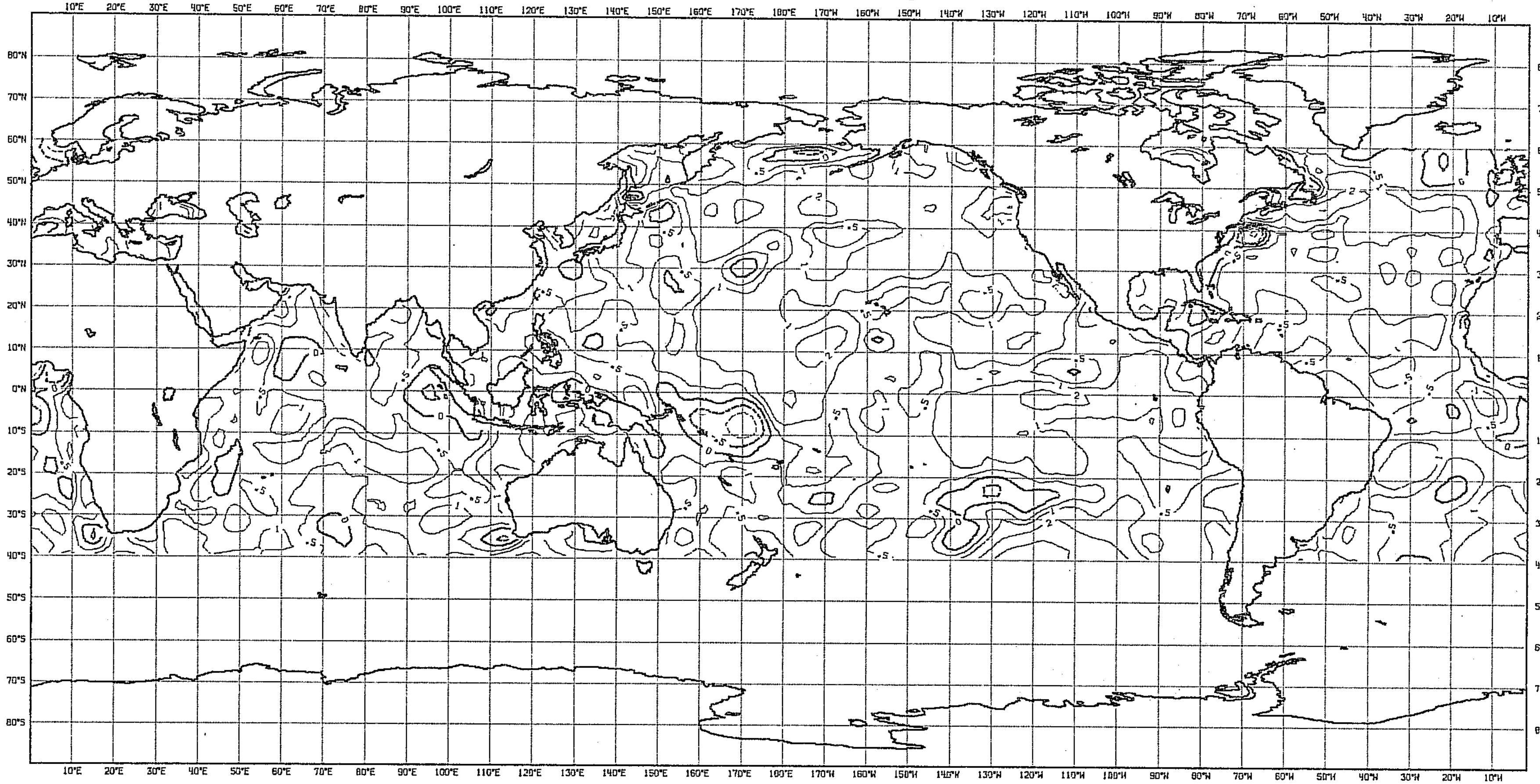


Fig. 43 SEPTEMBER 1982 CAC-ECMWF

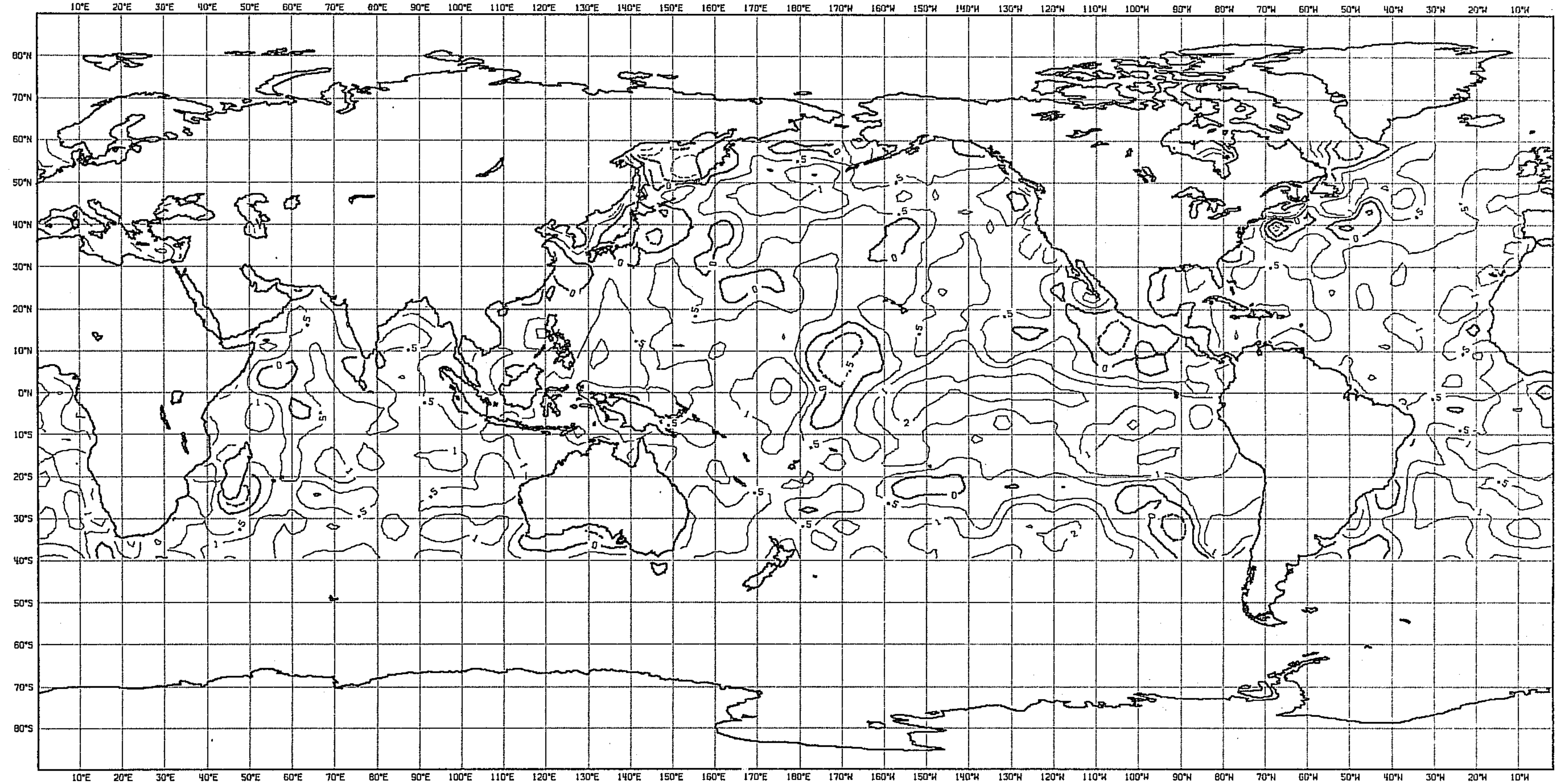


Fig. 44

OCTOBER 1982 CAC-ECMWF

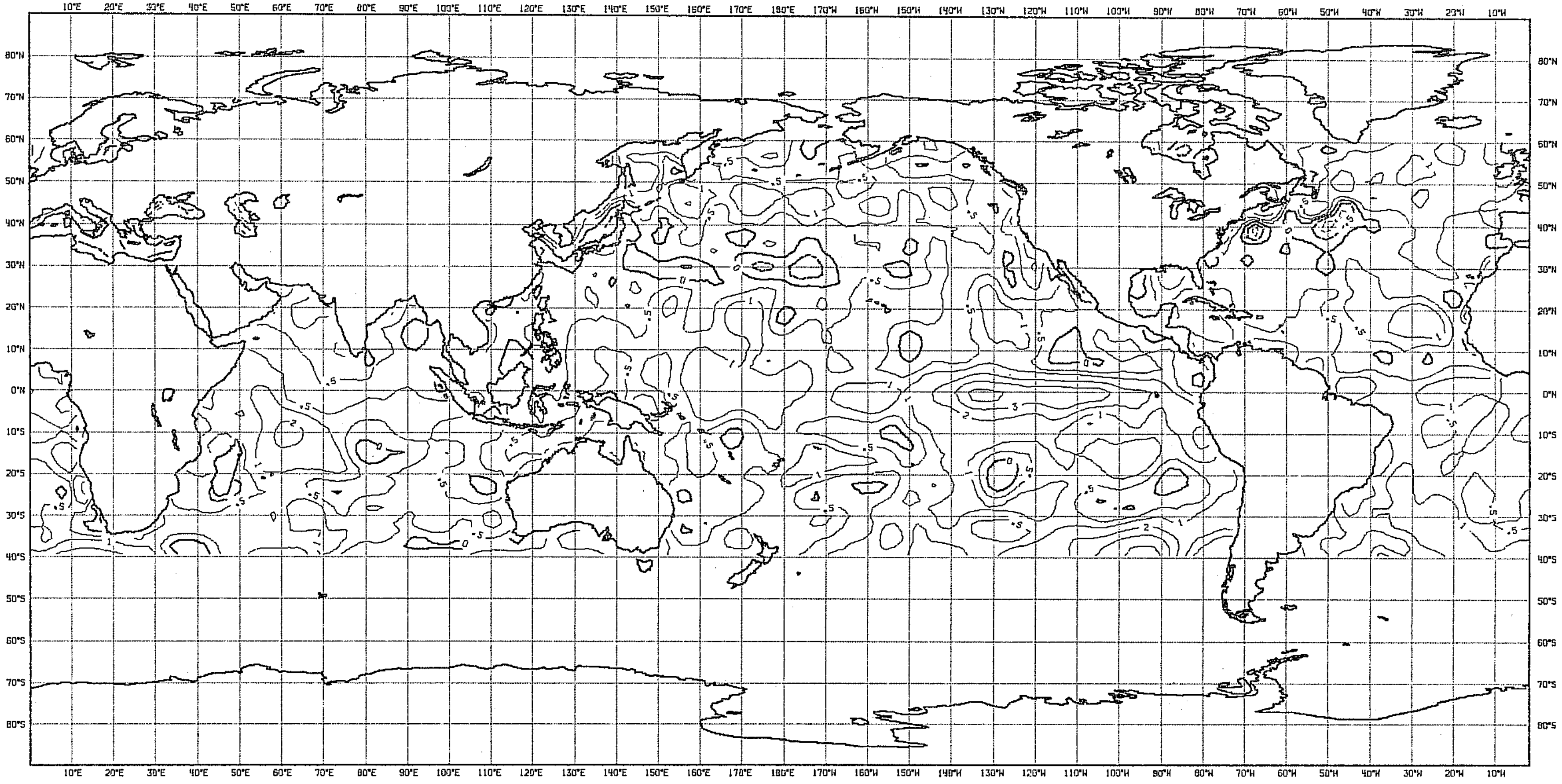


Fig. 45

NOVEMBER 1982 CAC-ECMWF

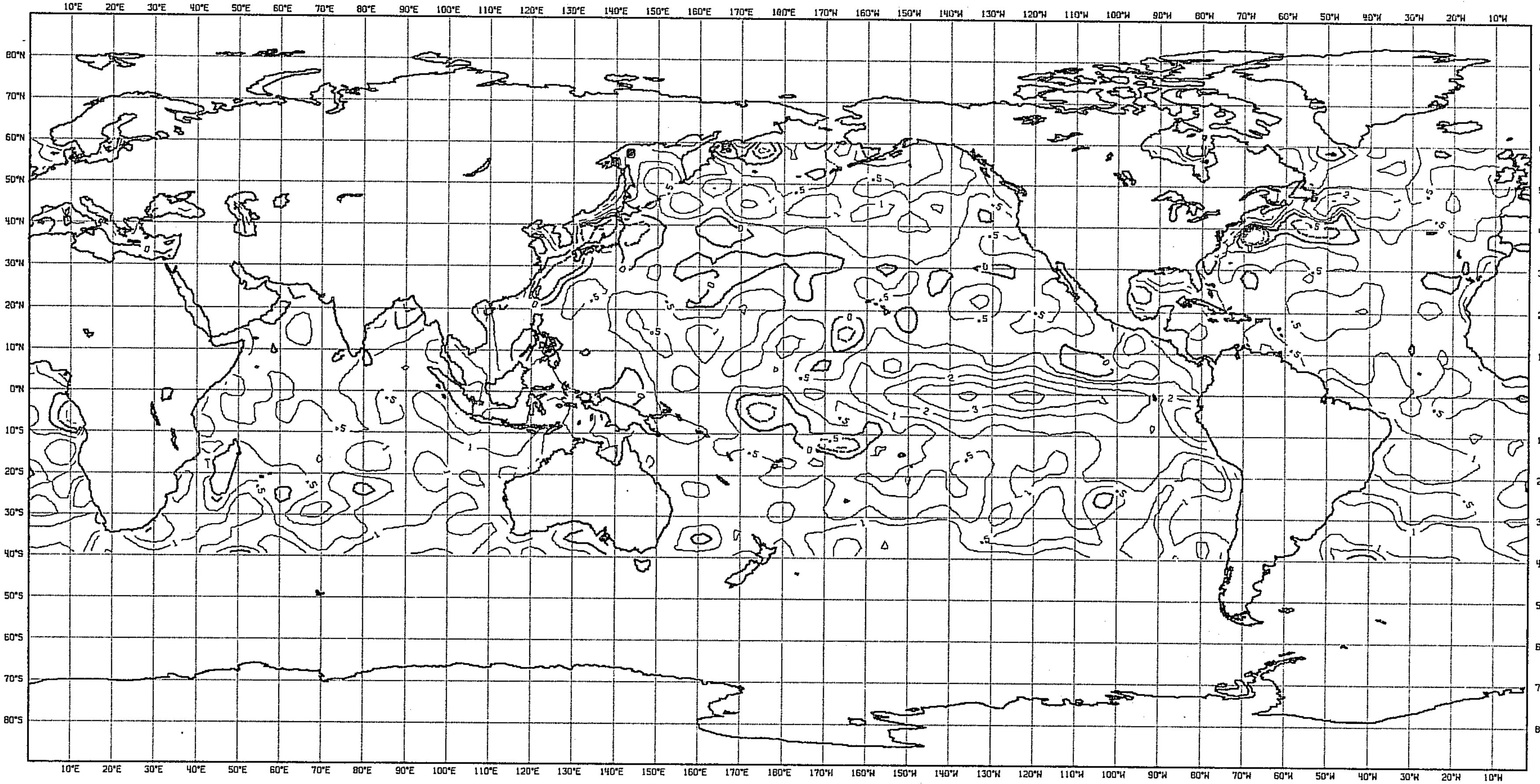


Fig. 46

DECEMBER 1982 CAC-ECMWF

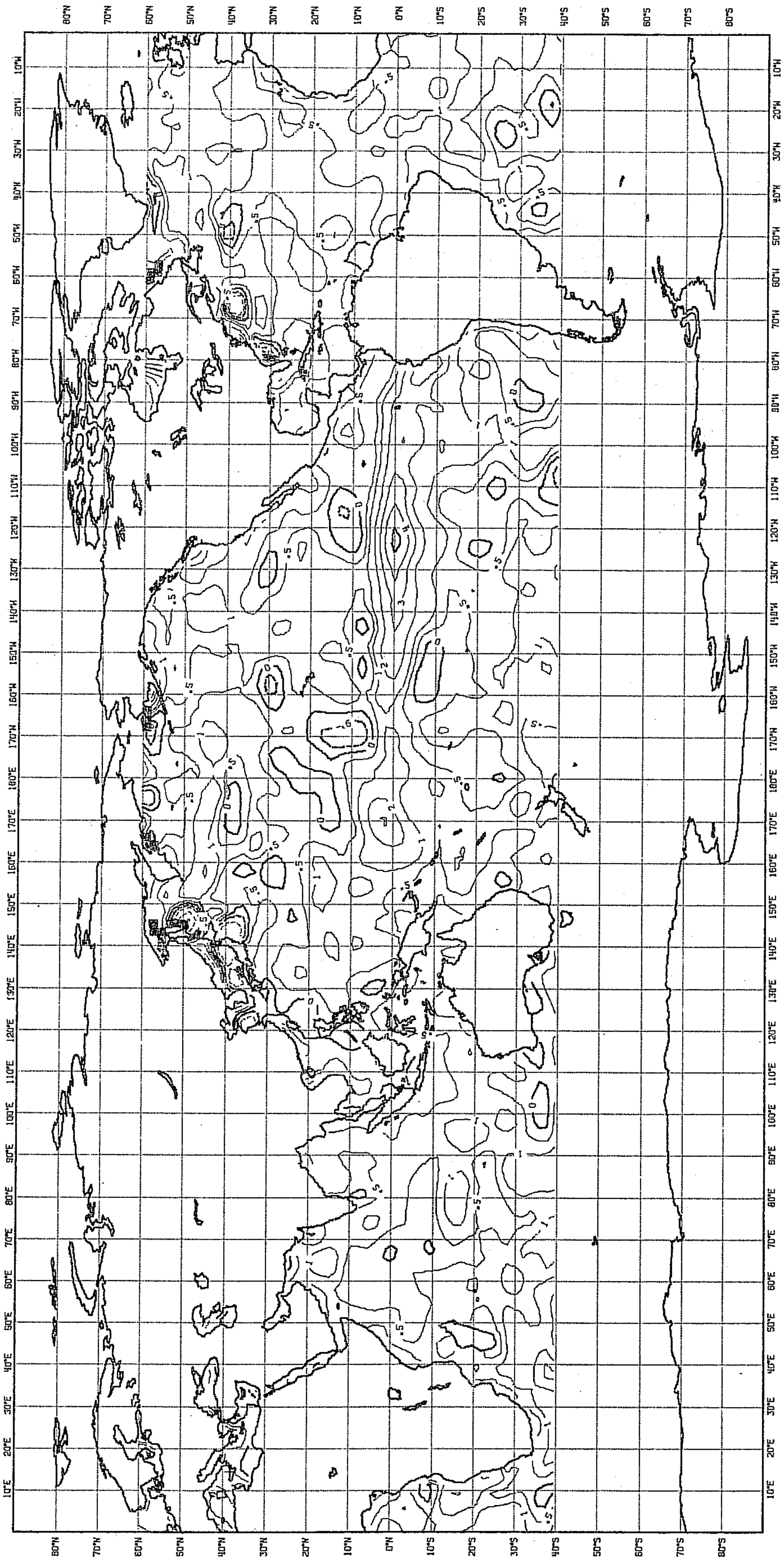


Fig. 47

JANUARY 1983 CAC-ECMWF

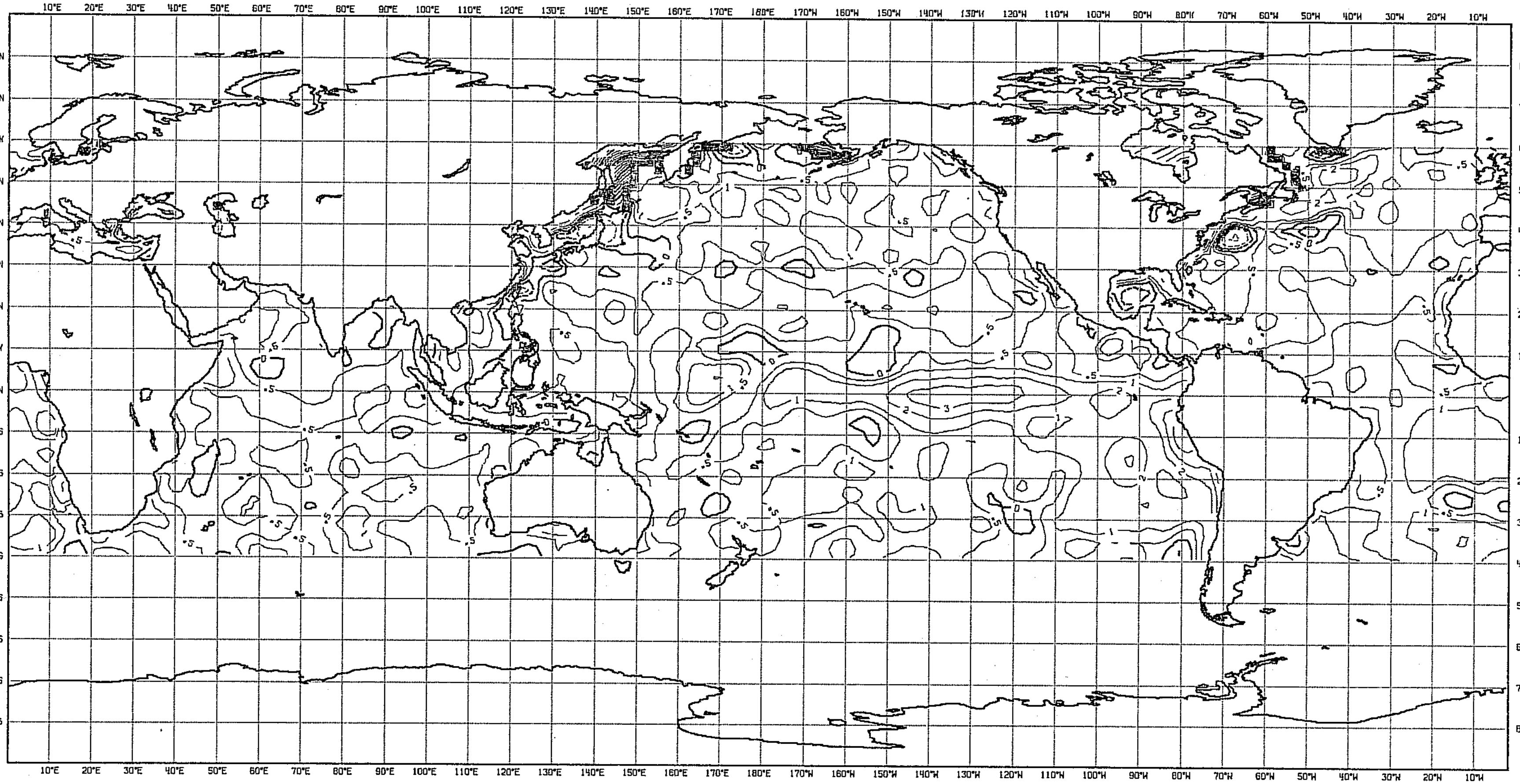


Fig. 48

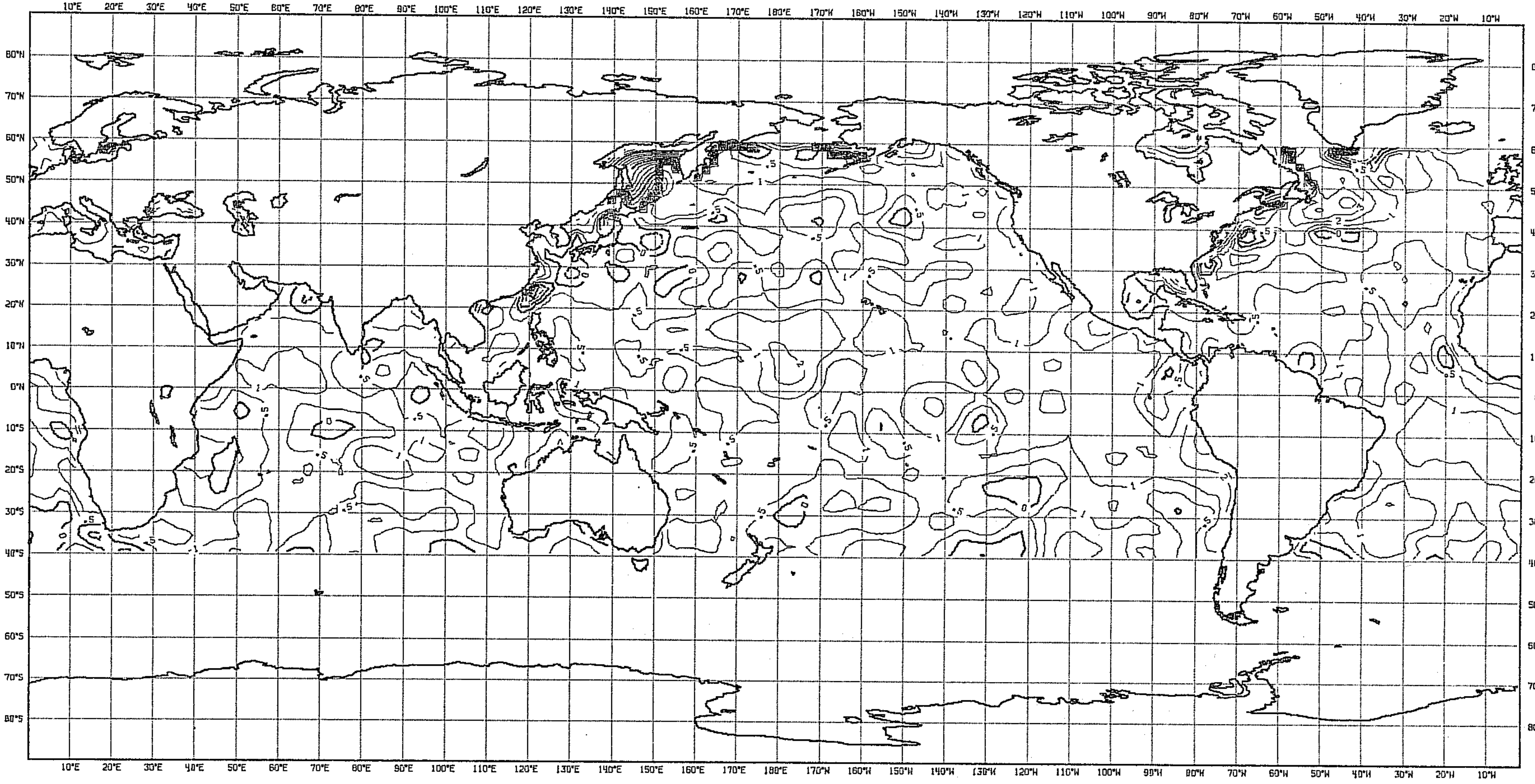

FEBRUARY 1983 CAC-ECMWF

Fig. 49

MARCH 1983 CAC-ECMWF

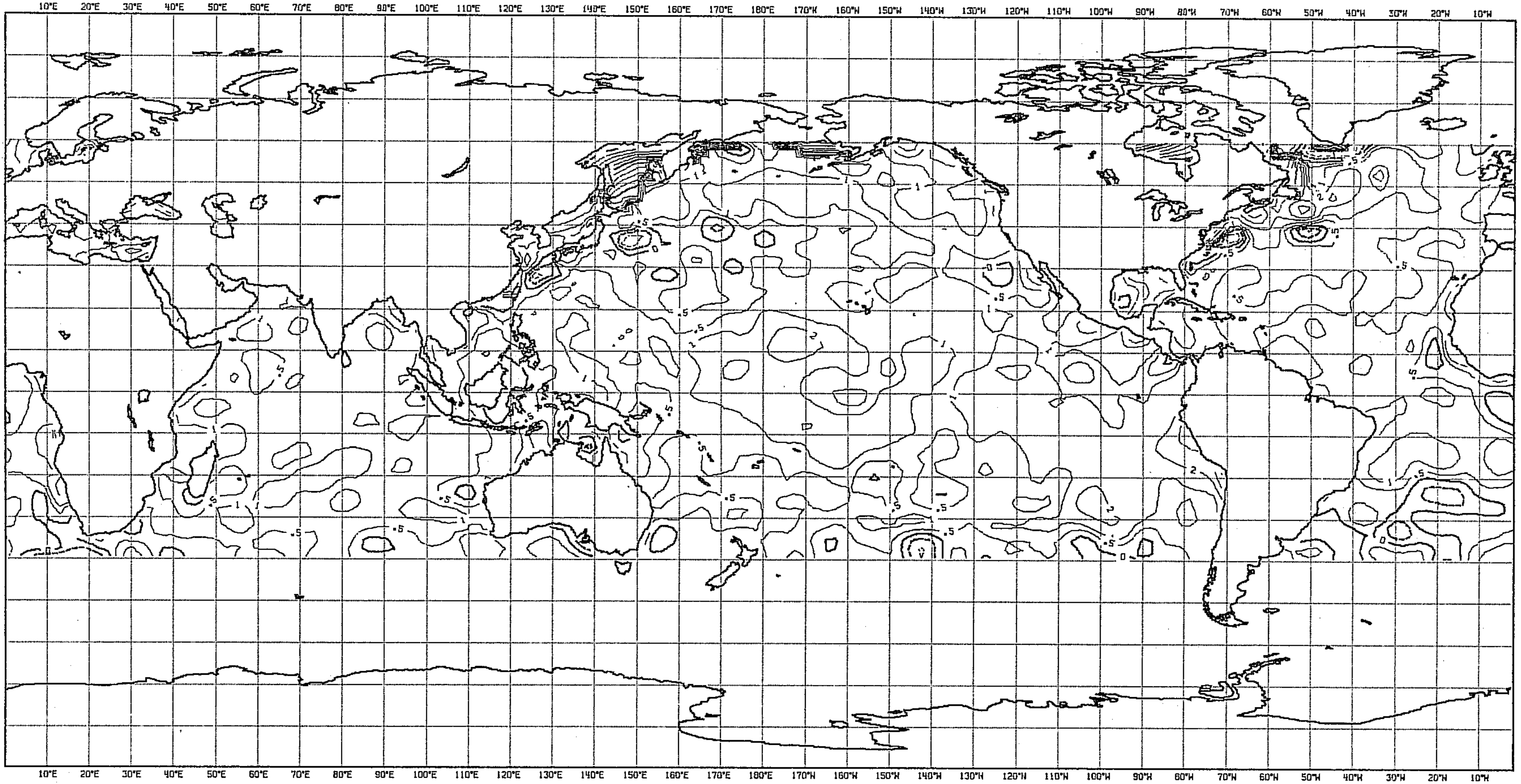


Fig. 50 APRIL 1983 CAC-ECMWF

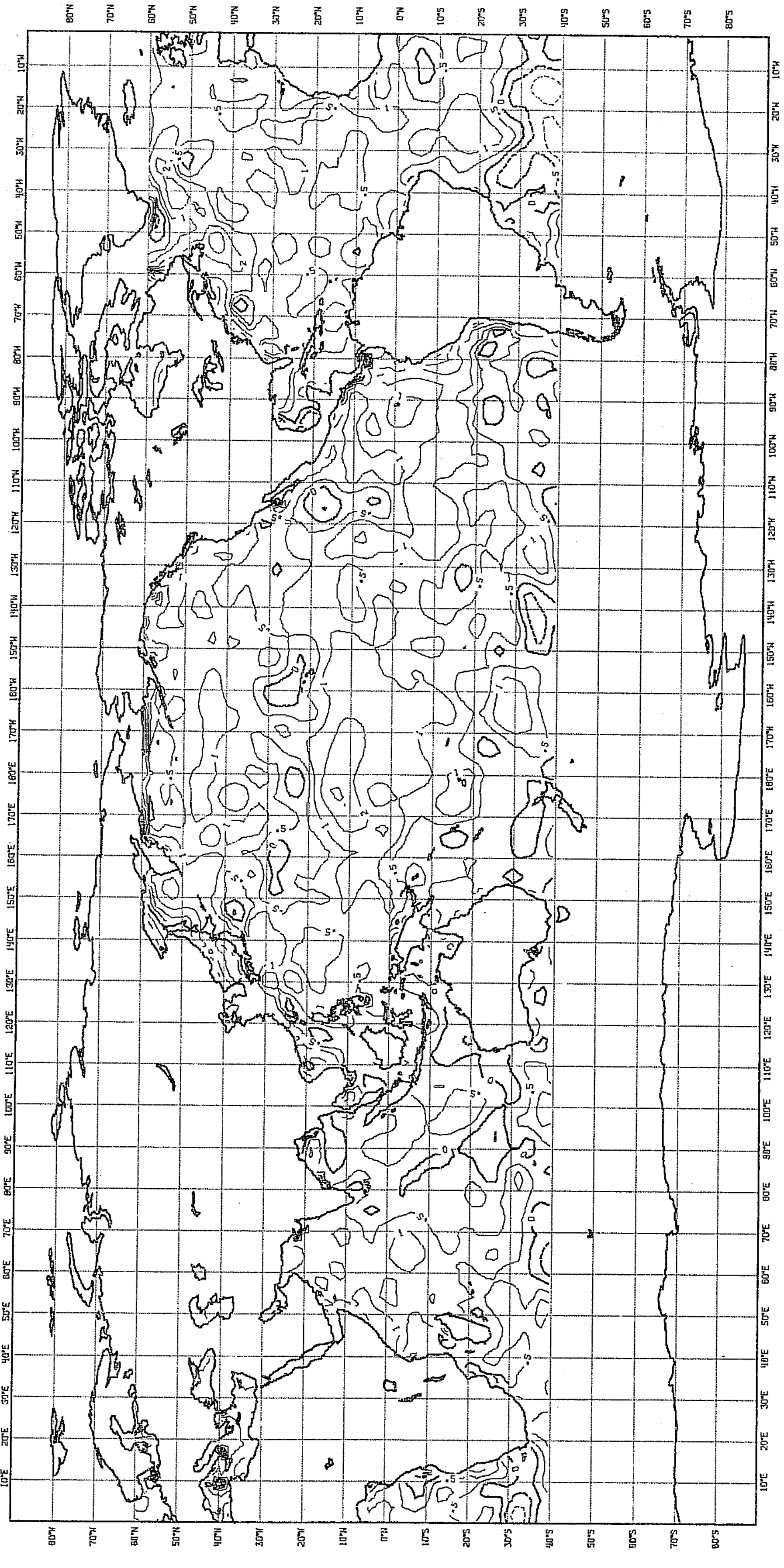


Fig. 51 MAY 1983 CAC-ECMWF

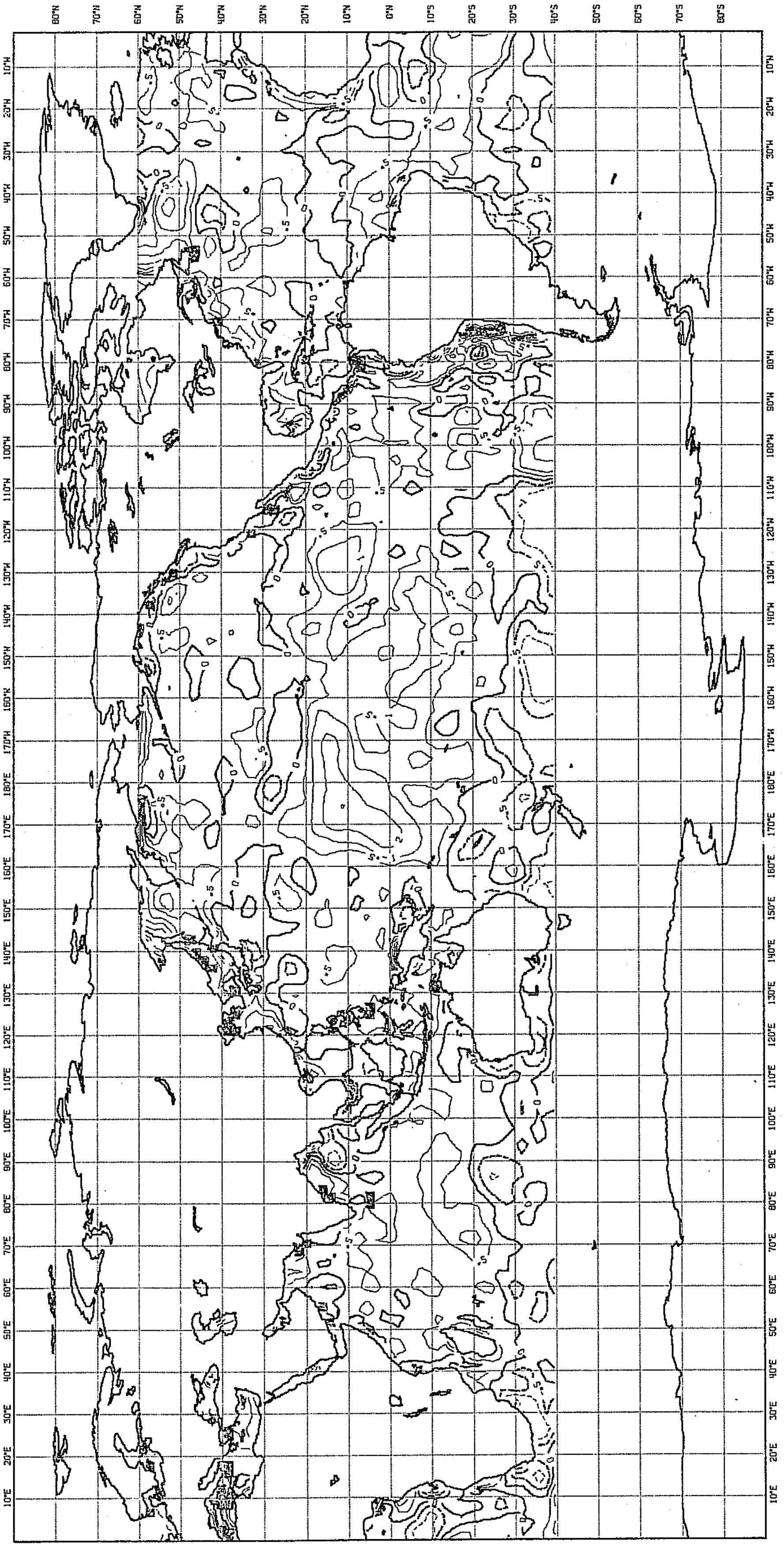


Fig. 52 JUNE 1983 CAC-ECMWF

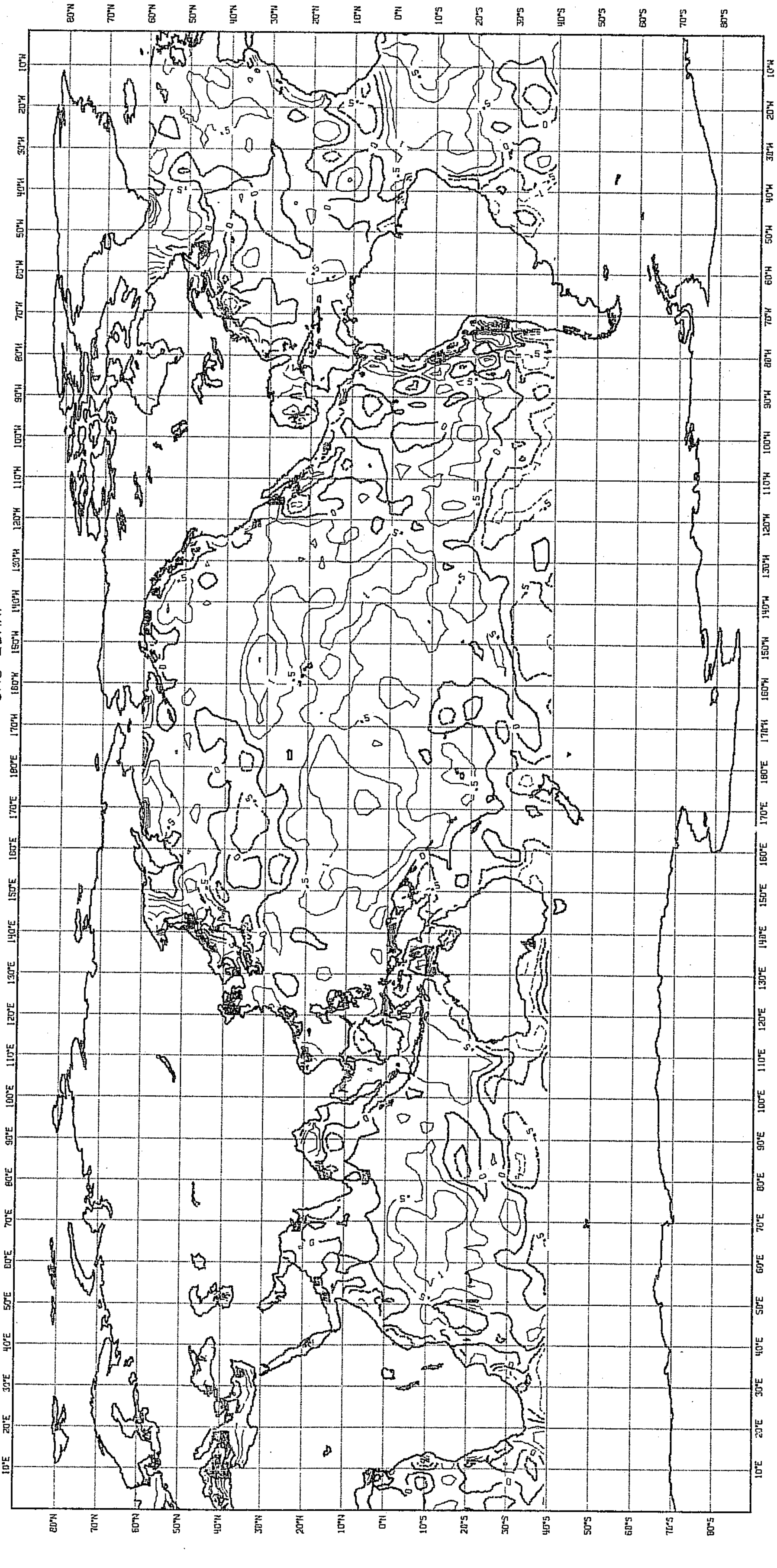


Fig. 53 DECEMBER 1982 MINUS NOVEMBER 1982 ANOMALY