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Tropical Cyclones in the Southwest Pacific: November 1979 to May 1989

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Summary

This report describes tropical cyclone occurrences in the Southwest Pacific during the ten year period from November 1979 to May 1989. In this survey we describe some of the characteristics of cyclones with respect to frequency, origin, spatial distribution and movement.

In the 10 seasons, there were 107 cyclones; this being the highest number for a decade ever observed in the Southwest Pacific. Of these, 48 cyclones became hurricanes. There was a maximum of 16 tropical cyclones in the 1982/83 El Nino year, and 14 in the 1988/89 La Nina year. About 20 percent of the hurricanes in the decade occurred during the 1982/83 season.

The maximum frequency of tropical cyclones occurred in the Vanuatu-New Caledonia region, and there were more cyclones to the west of the dateline than elsewhere. East of the dateline there were two notable features in the occurrence of tropical cyclones during the decade. The first was a high proportion of cyclones that became hurricanes. The second was that cyclonic activity was greater in the second half of the season.

Hurricanes were more likely to occur if the point of origin was at a relatively low latitude. During the intensification phase they were also associated with a small poleward component of motion as well as a westward movement.

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Craig Thompson, Stephen Ready and Xiaogu Zheng

1. Introduction

Tropical cyclones, capable of causing massive destruction, are a distinctive feature of the Southwest Pacific region of the Earth. They occur as a result of a particular combination of meteorological and oceanic conditions (Gray, 1988; Basher et al., 1992). Most tropical cyclones develop in the area between 5S and 20S within the climatological shear zones of the region (Gabites, 1960; Atkinson, 1971; Revell, 1981). These features are the oceanic portion of the North Australian Monsoon Trough on the western fringes of the Southwest Pacific region and the extensive South Pacific Convergence Zone.

This publication documents and summarises the basic characteristics of tropical cyclones in the Southwest Pacific occurring in the ten cyclone seasons 1979/80 to 1988/89. It is noted here that the tropical cyclone season has been taken as November to April inclusive. Tropical cyclones do occur in other months, such as October, May and June, but only very rarely.

The publication follows the format of earlier surveys on Southwest Pacific tropical cyclones by Kerr (1976) and Revell (1981). Kerr (1976), in a comprehensive historical survey, consolidated and extended earlier work by several researchers into a single publication. The principal survey period was 1939 to 1969; being the period before the advent of regular satellite surveillance of weather in New Zealand and the South Pacific. Kerr noted that owing to large gaps in the Southwest Pacific observing network, it was likely that several tropical cyclones passed through the region completely undetected. During the 1950s and 1960s there were 136 observed cyclones, but he surmises there may have been another 22 possible storms.

The survey by Revell (1981), covering the period 1969 to 1979, made extensive use of satellite information. Not only could the tracks of tropical cyclones be more precisely determined than previously, but estimates of cyclone intensity could be made with a higher degree of confidence.

In the following sections, we describe the method of constructing the "best tracks" of the tropical cyclones that occurred in the Southwest Pacific in the ten cyclone seasons 1979/80 to 1988/89. We also describe some of the basic characteristics of cyclones occurring in this decade with respect to their frequency, origin, spatial distribution and movement.

2. Classification of Tropical Cyclones

Tropical cyclones may be classified in terms of the intensity of the storm (Revell, 1981), where intensity is defined by the maximum sustained wind speed, or by the central pressure if no wind data are available (Holland, 1984). The classification scheme we use is given in Table 1. This is the same as proposed by Revell (1981) and adopted by Holland (1984) for a survey of tropical cyclones in the Australian region. Class 5 in the table is the same as class 4b in Revell (1981), and corresponds to the North Atlantic terminology for major hurricanes. In addition to the equivalent speed range for a given cyclonic description, Table 1 also provides estimates of the central pressures. This is similar to the maximum wind/central pressure relationship given by Dvorak (1975, 1984) and is used in current tropical cyclone forecasting procedures in New Zealand.

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Table 1. Classification of tropical cyclones

Class	Description	Speed range kt	km/h	Central pressure hPa
1	Tropical depression	<34	<62	>995
2	Gale	34-47	62-88	995-986
3	Storm	48-63	89-117	985-975
4	Hurricane	>63	>117	<975
5	Major Hurricane	>90	>167	<945

3. Tropical cyclone track analysis

Best tracks of tropical cyclones were derived from a post-cyclone re-analysis using the conventions outlined by Revell (1981). This involved

- Assembling tropical cyclone warnings and forecasts issued by Tropical Cyclone Warning Centres in Brisbane, Nadi and Noumea together with working charts from the New Zealand Meteorological Service's National Weather Forecasting Centre in Wellington. These centres use surface observations and satellite imagery as the basis on which forecasts are made and warnings issued.

- Extensive use of satellite imagery from polar orbiting and geo-stationary satellites. The method involved studying sequences of satellite pictures throughout the lifetime of the tropical cyclone to determine a complete history of each.

Following cross checking of sources of information, best tracks were determined. For each tropical cyclone the following details were tabulated and archived in electronic medium for computer access:

- Latitude and longitude of the centre at every 6 or 12 hours. The times given in Coordinated Universal Time (UTC).

- The corresponding intensity class based on the scheme shown in Table 1.

- Point of origin and final position (if still in Southwest Pacific region).

- Principal direction of movement during the life of the tropical cyclone.

- Information, if available, about points of recurvature and maximum speed.

Error estimates of the underlying cyclonic position and intensity are still difficult to assess, despite improvements in satellite-interpretation techniques. Errors in the location of cyclones is 20-100km at best, and occasionally up to 150km (WMO, 1977; Revell, 1981; Holland, 1984). Maximum wind and central pressures have tended to be poorly estimated. Average errors of 8-15kt (15-28km/h) are cited by WMO (1977), and are probably acceptable for the Southwest Pacific (Revell, 1981). In the vast data sparse areas of this region, cyclonic central pressures may be biased and not low enough. Holland (1984), for example, estimates Coral Sea tropical cyclones to be weaker by about 10hPa.

Archived track information has been used to computer-generate the best estimates of cyclone tracks in the 10 seasons 1979/80 to 1988/89. The tracks are presented in a series of charts. They have been grouped by months during the tropical cyclone season (Charts 1.1 to 1.5), except that October, November and December tracks were placed on one chart (Chart 1.1), as were tracks during May and April (Chart 1.5). Individual tracks are shown entirely on one chart. If a cyclone spans two months, then the track is assigned to the month in which it originated. In the second series of charts, cyclone tracks are grouped according to season (Charts 2.1 to 2.10).

Track positions are given at 6 hour intervals, at 0000 UTC, 0600 UTC, 1200 UTC and 1800 UTC whenever data were available.

The intensity at each stage of the tropical cyclone is indicated on the charts. No distinction was made between hurricane and major hurricane, because of the inherent uncertainties in intensity estimates. A thick bold line on the charts represents the length of time at the hurricane phase; a thin bold line, storm intensity; a hatched line, gale intensity, and a dotted line below gale intensity.

4. Frequency of tropical cyclones

The monthly and seasonal frequencies of tropical cyclones are given in Table 2. The statistics include all cyclones in classes 2, 3, 4 and 5. The seasonal total is the number of individual tropical cyclones occurring in the season. Monthly frequencies were calculated on the basis that, if a cyclone tracked through the end of one month into the next, it was counted as being an occurrence in both months.

Table 2. Monthly and seasonal numbers of tropical cyclones south of the Equator from 145E to 125W in the decade October 1979 to May 1989

Season	Oct-Nov	Dec	Jan	Feb	Mar	Apr-May	Total
1979/80		1	2	3	4	1	10
1980/81	1		2	7	6		13
1981/82		1	2	3	1	3	7
1982/83	2	1	3	4	6	4	16
1983/84		2	1	4	2	1	10
1984/85		2	6		2		9
1985/86			2	4	2	3	10
1986/87	1	3	3	4	3	2	12
1987/88			2	3	3	1	6
1988/89		2	3	5	2	5	14
Total	4	12	26	37	31	20	107

Tropical cyclone seasons normally extend from November to April, but occasionally there are early and late season storms. Monthly variation in Table 2 shows a peak occurring mostly in February with peaks also in some years during January or March. In the decade there was just one early-season cyclone; this being Joti in October 1982. Five late-season cyclones occurred in May; Claudia (1982), Namu (1986), Blanche (1987) and Meena and

Ernie (1989). It is interesting to note that Cyclone Namu was the only one to become a hurricane, and was paired with Typhoon Lola at the same longitudes in the Northwest Pacific.

The pattern of monthly variation shown in Table 2 showed a 50 percent increase in February and a 80 percent increase in March from the survey done by Revell (1981). The trend of a greater frequency of cyclones near the end of the season continued with more in April/May compared to the previous decade.

A total of 107 tropical cyclones affected the Southwest Pacific region during the decade 1979/89. This is an 18 percent increase in cyclones over the previous decade when 91 storms were reported by Revell (1981). To test whether the increase in cyclone activity over the previous decade was significant, we performed a Students t-test on the differences in the mean frequencies in each decade. A test statistic of 1.25 was computed. This is clearly not significant at the 0.05 percent probability level.

The increase in frequency of cyclones is most likely to be an indication of the interannual variation in the large scale tropical circulation anomalies associated with the Southern Oscillation (SO). Tropical cyclone/SO associations in the Southwest Pacific/Australian region have been found to be most significant during extreme phases of the SO (Ralph, 1983; Streten, 1983; Krishna, 1989; Basher and Zheng, 1992). However, Ramage and Hori (1981) using Kerr's data (Kerr, 1976) could not detect any inter-seasonal variation in tropical cyclone frequency with the SO. Hastings (1990) suggests that tropical cyclone/extreme phase SO correlations may be masked to some extent by relatively weaker tropical cyclone/SO relationships at times when the SO was in a transition mode from one phase to another.

There is another possible influence on the frequency of tropical cyclones in the Southwest Pacific. Geostationary satellite imagery became available at the beginning of the decade and allowed tropical meteorologists to closely monitor any developments every three hours (and one hour by end of decade). The decade total includes 7 cyclones that were unnamed. All of them were minor with their classification of tropical cyclone status open to debate.

During the decade of this survey, there were three major Southern Oscillation episodes; two El Nino's (1982/83 and 1986/87) when the Southern Oscillation Index (SOI) was negative and one La Nina (1988/89) when the SOI was positive. 16, 12 and 14 tropical cyclones were reported during these extreme seasons. Ten of the 16 tropical cyclones in 1982/83 were hurricanes, including 6 major ones. In the same season 5 hurricanes occurred in the French Polynesia region which represented one more than was experienced in the same area over the previous 13 seasons. In the previous decade there was a dominant La Nina episode spanning three cyclone seasons from mid 1973 to mid 1976 with a temporary weakening late 1974 and early 1975. During the La Nina episode 11 (1973/74), 5 (1974/75) and 10 (1975/76) tropical cyclones were observed.

5. Intensity of tropical cyclones

The maximum intensity reached by all 107 tropical cyclones is given in diagrams of cumulative frequency (Figure 1 and 2). Figure 1 gives the intra-seasonal distribution of intensity classes. When a cyclone occurred in two adjacent months, the intensity given in the figure is the maximum attained in each month separately. In Figure 2 the inter-seasonal variation is shown.

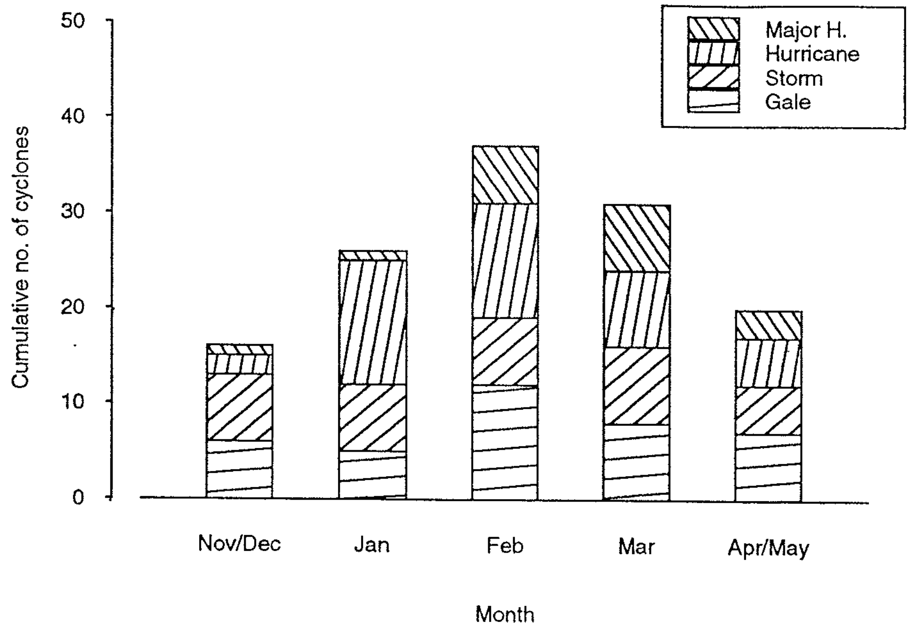


Figure 1. Intra-seasonal distribution of intensity classes of tropical cyclones during the period November 1979 to May 1989 for all tropical cyclones south of the Equator from 145E to 125W.

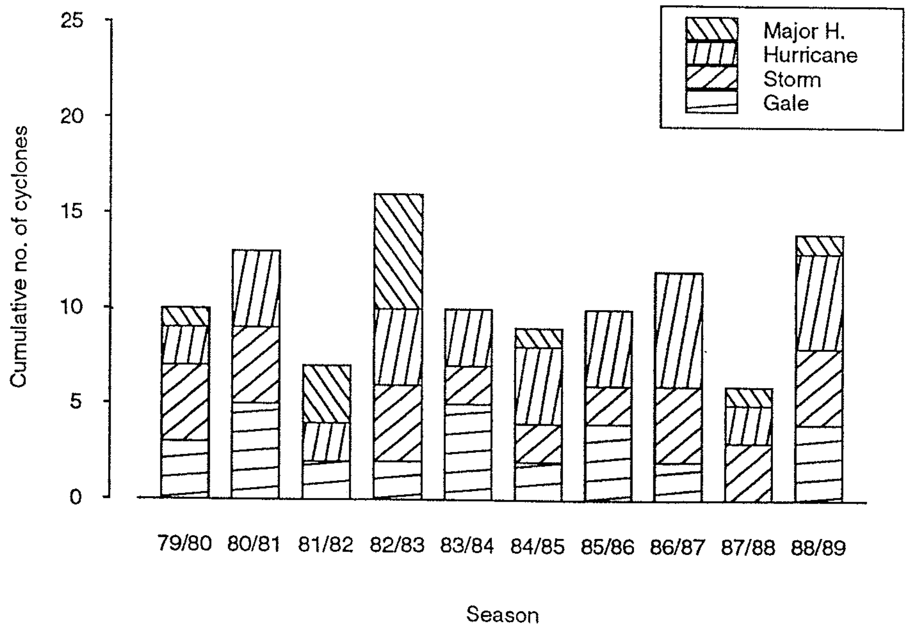


Figure 2. Inter-seasonal distribution of intensity classes of tropical cyclones during the period November 1979 to May 1989 for all tropical cyclones south of the Equator from 145E to 125W.

In Figure 1 highest frequencies of all intensities occured mostly in Februrary, in the middle of the cyclone season. In other months there is a trend to fewer, less intense cyclones, with least at the start and end of the season. Hurricanes are most common from January to March. In the 1979/89 decade, there were 48 hurricanes; an average of 4.8 per season. Major hurricanes were more prevalent in February and March than at other times of the season.

The distribution of intensity classes by cyclone season (Figure 2) shows that the number of tropical cyclones per season fluctuated from a minimum of 6 in 1987/88 to a maximum of 16 in 1982/83, with an average of nearly 11 per season. There was also a lot of variation in the proportion of each class (2, 3, 4, or 5) within the seasonal total. For example in the 1982/83 El Nino episode, 10 of the 16 cyclones were hurricanes, but in the 1979/80 season only 3 out of 10 became hurricanes.

6. Origins of tropical cyclones

Most tropical cyclones originate within or near the South Pacific Convergence Zone (SPCZ) or its western neighbouring northern Australian monsoon trough. These form an extensive area of cloudiness and are dominant climatological features of the Southwest Pacific and Australian cyclone season. In general the monsoon trough extends along 10-20S and eastwards to about 170E where it merges with the SPCZ. The SPCZ usually extends east to south-east from between Fiji and Samoa and to the north of the Southern Cook Islands towards Easter Island in the eastern Pacific Ocean.

The origin of a tropical cyclone refers to the point at which a cyclonic circulation is first detected, either from surface observations or from the appearance of a disturbance in satellite images.

Figure 3 shows the origins and ultimate maximum intensity of all tropical cyclones in the 1979/89 decade. It is well known that there is considerable inter-seasonal, and intra-seasonal variation in the origins of tropical cyclones. This is related to the migrations of the monsoon trough and South Pacific Convergence Zone (Kiladis and van Loon, 1988), which Trenberth (1976) noted to be associated with the Southern Oscillation. In El Nino years the distribution of origins are spread out over a broad area of the Southwest Pacific (Revell and Goulter, 1986; Hastings, 1990) as the monsoon trough and SPCZ moves north and east of its mean position. During La Nina years, points of origin are mostly concentrated west of the dateline (Hastings, 1990) in the Coral Sea.

We note that the very small, high latitude tropical cyclone, Hinano which developed south-east of Pitcairn Island at 27S 127W in February 1989, lies outside the boundaries on Figure 3. Little is known about the life history of this cyclone, apart from occurring simultaneously with cyclone Judy whose origin was 1600km north-west at 14.4S 150.5W.

From Figure 3, the following points may be noted

- To the west of the dateline, the points of origin are clustered between 10-18S (see also Figure 4 which displays the frequency of points of origin by latitude).

- Of those cyclones which ultimately became hurricanes, there was a tendancy for origins to be further north by a few degrees than in the Coral Sea, and to be near 10S at

140W. This is due to the inter-relationship between the Southern Oscillation and the seasonal location of the SPCZ and monsoon trough (Trenberth, 1976; Hastings, 1990).

- East of the dateline, a higher proportion of cyclones became hurricanes.

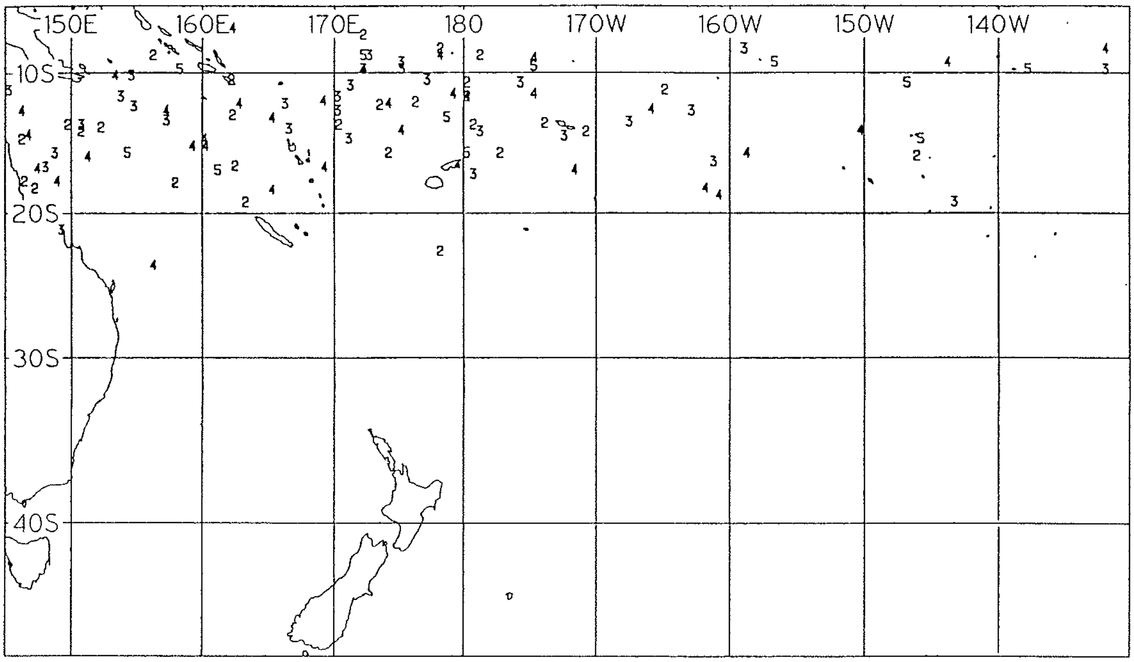


Figure 3. Location of points of origin of tropical cyclones during the period November 1979 to May 1989.

Table 3. Intra-seasonal variation in latitude of origin of tropical cyclones in 2 degree zones

Latitude	Oct-Dec	Jan	Feb	Mar	Apr-May
0-2			1		
2-4					
4-6	1	1			1
6-8					2
8-10	6	2	2	1	2
10-12	2	3	2	6	5
12-14	2	4	8	4	4
14-16	3	4	6	3	3
16-18	2	3	8	3	
18-20		3	4	2	
20-22			1		
22-24		1			
24-26		1			
26-28			1		

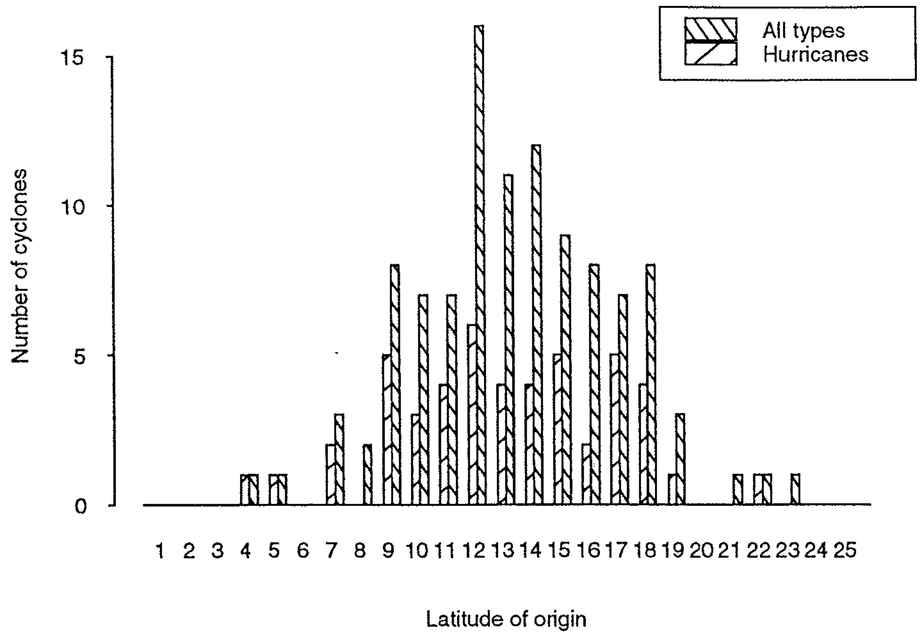


Figure 4. Latitudinal distribution of frequency of points of origin of tropical cyclones south of the Equator from 145E to 125W.

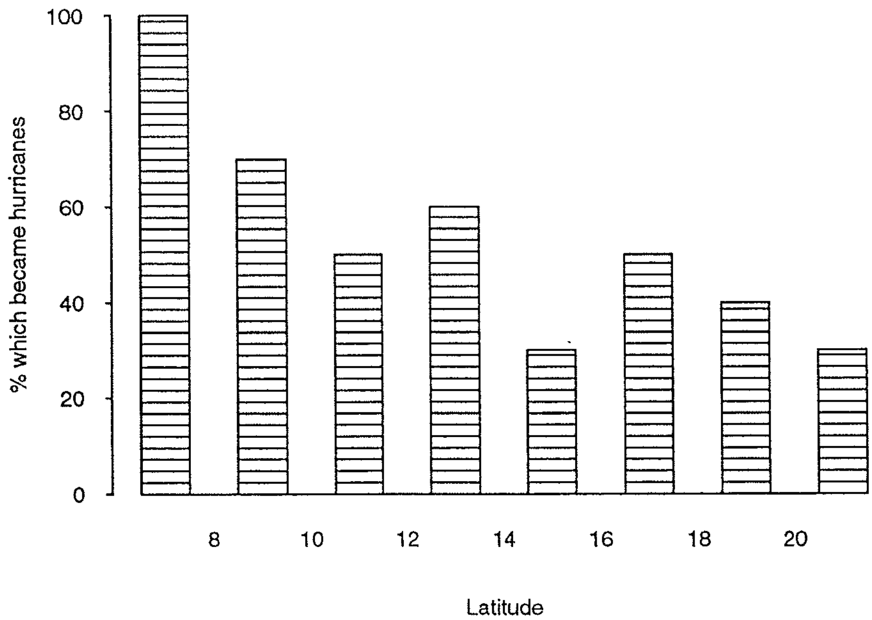


Figure 5. Percentage of tropical cyclones that became hurricanes in relation to the latitude in which gale intensity was observed.

The percentage of tropical cyclones that became hurricanes in relation to the latitude in which gale intensity (Class 2) was first observed is shown in Figure 5. North of 14S, 7 out of 10 cyclones reaching gale intensified further into hurricanes, while at higher latitudes the frequency was about 1 in 3.

An analysis of the intra-seasonal variation of the latitude of origin of tropical cyclones is given in Table 3. The monthly variation for this decade was similar to that given by the data for the 1969/79 period (Revell, 1981).

7. Spatial distribution of cyclone occurrences

The frequencies with which tropical cyclones passed through 5-degree latitude-longitude squares in the decade are given in Charts 3.1 - 3.3. Note that because of the small sample (number of cyclone seasons), the mapped data do give some indication of the risk of a cyclone passing through a 5-degree square.

In Chart 3.1, which covers the entire tropical cyclone season, there was a greater concentration of tracks in the Fiji - Vanuatu - New Caledonia region than in other regions of the chart. There are also more track occurrences in the squares west of the dateline than to the east, with greatest numbers between 10S and 25S. In the survey by Revell (1981) for the previous decade, his data showed a higher proportion of tracks between 15S and 25S from 170E to the Australian coast than is seen in this most recent decade. South of 25S, the distribution became more uniform, although highest frequencies tend to be east of the dateline.

Cyclonic activity is greater in the second half of the season from February to April (Chart 3.3) than in the early part of the season (Chart 3.2). Relative frequencies remain high in the squares along 20S from the Australian coast to the dateline, but in Chart 3.3 there is a marked increase in the numbers of tracks to the east. As a composite of ten cyclone seasons, these charts show the influence of Southern Oscillation, and in particular the two major El Nino seasons of 1982/83 and 1986/87. As has been pointed out in a previous section, the origin of tropical cyclones in these years tend to be spread out across the Southwest Pacific with the northward and eastward migration of the South Pacific Convergence Zone and Australian monsoon trough.

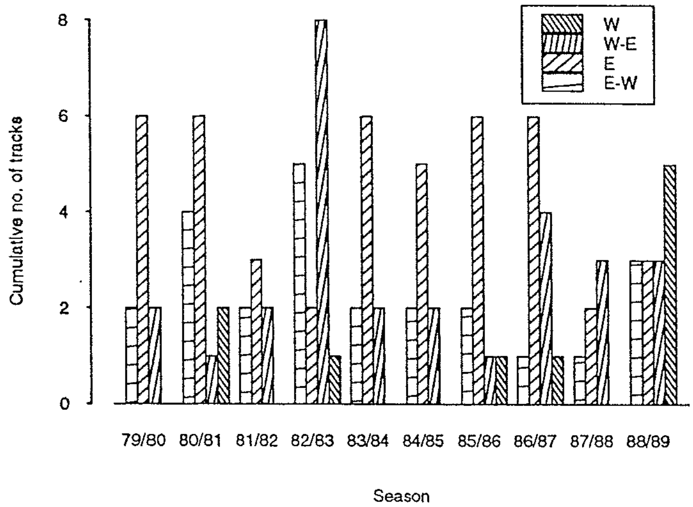
Following the approach of Basher and Zheng (1992), Chart 4 provides maps of the frequency of storms and hurricanes passing through two degree latitude-longitude squares for the Southwest Pacific. An occurrence within a square was counted only if a cyclone had attained an intensity of at least Class 3 while passing through that square. In Chart 4 there was a frequency maximum from near the dateline to the Queensland coast between 16S and 22S. In the eastern Southwest Pacific, a maxima is also apparent from Samoa, south-eastwards to the area of the Southern Cook Islands. South of about 22S, occurrences of tropical storms and hurricanes are generally uniform and small.

8. Movement of tropical cyclones

The predominant directions of movement of cyclones have been analysed from the plots of their tracks (Charts 1 and 2). They were divided into four basic types, corresponding to those defined by Kerr (1976) and Revell (1981), as follows

- W (mainly westward movement throughout lifetime north of 30S)
- W-E (initial westward movement, but later recurving to the east)
- E (mainly eastward movement throughout lifetime north of 30S)
- E-W (initial eastward movement but later recurving to the west)

(a)



(b)

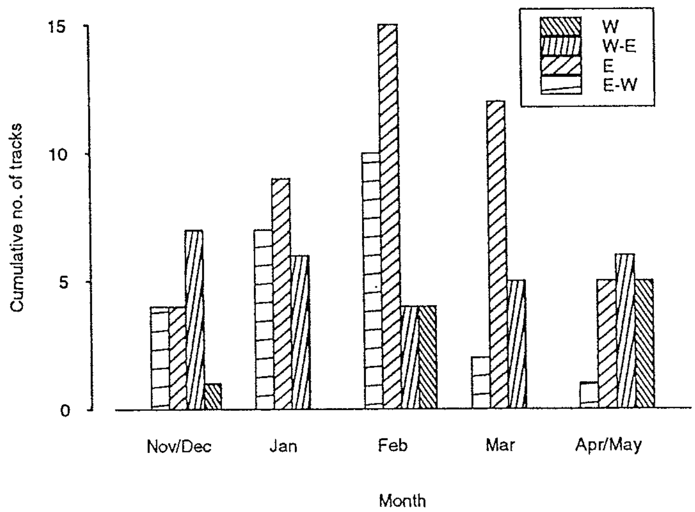


Figure 6. Frequency of four track categories in relation to (a) cyclone season, (b) month of origin.

In Figure 6 nearly 70 percent of this decade's Southwest Pacific tropical cyclones track eastwards (E) or recurve to the east after initially moving west (W-E). The biggest proportion of these two track categories occurred from January to March. These two track types predominated most seasons with the exception of 1988/89 when there was a predominant westerly component in the cyclone movement. Also in 1980/81 and 1982/83 there was a relatively high frequency of cyclones that turned to the west after initially having tracked east (E-W). In the earlier decade, cyclones with E and E-W tracks were the dominant track types (Revell, 1981).

The frequency of track types in relation to the cyclone intensity is shown in Figure 7. For each class of cyclones, the frequency of type E-W tracks was nearly a constant fraction at about 20 percent. For cyclones up to and including hurricane intensity, the frequency of E type tracks were by far the largest. There were relatively smaller proportions of cyclones with westward components of motion (W) or westward moving components before recurvature (W-E).

Major hurricanes were largely associated with initially westward moving cyclones before recurving to the east at higher latitudes. Many major hurricanes in the Southwest Pacific develop from small westward moving troughs and disturbances within the SPCZ (Revell, 1981).

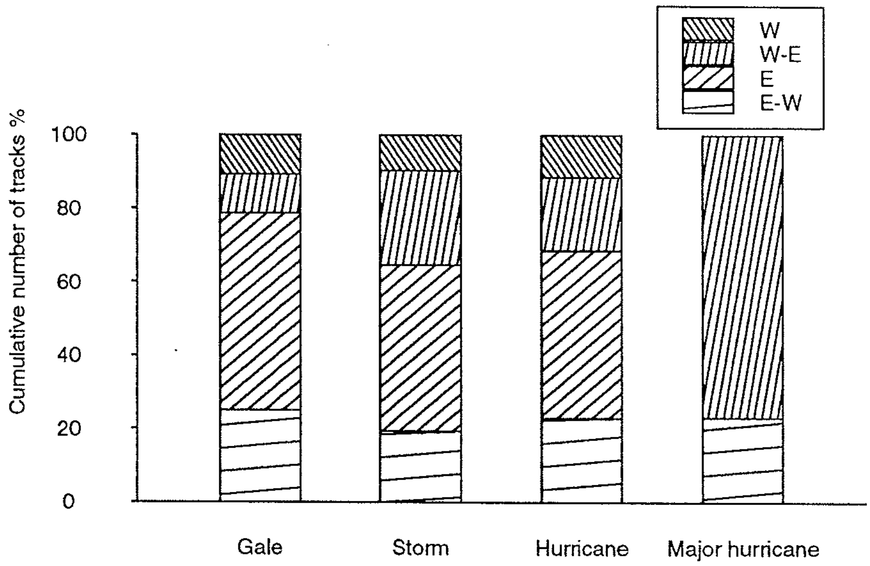


Figure 7. Frequency of tracks in relation to cyclone intensity.

The percentage of cyclones moving eastwards in the early development stage in relation to the month of origin is presented in Figure 8. About 70 percent of the cyclones from January to March moved with an initial eastward movement, with significantly lower frequencies at the start and end of the cyclone season. This pattern is similar in some respects to the pattern presented by Revell (1981) in which there was a distinct February maximum. However, an analysis of initial cyclone movement by Hutchings (1953) showed an opposite pattern with a significant westward component of movement during February. Some of the difference can be ascribed to the non-detection of tropical cyclones during Hutchings' 1940-1951 survey period.

In the Southwest Pacific the net movement of cyclones in the intensification phase from gale to storm has been calculated for the three classes; storm, hurricane and major hurricane. Figures showing the net rate of movement of cyclones during intensification are given in terms of the net poleward displacement (Figure 9) and net eastward displacement (Figure 10). From the data contained within these two figures, intensifying cyclones had a median speed of about 8km/h.

The results in Figure 9 show that the development of hurricanes was associated with polewards movements of less than 4 degrees per day during the intensification phase. Cyclones which displayed a net equatorwards movement accounted for less than six percent of all cases, but every one developed into a hurricane.

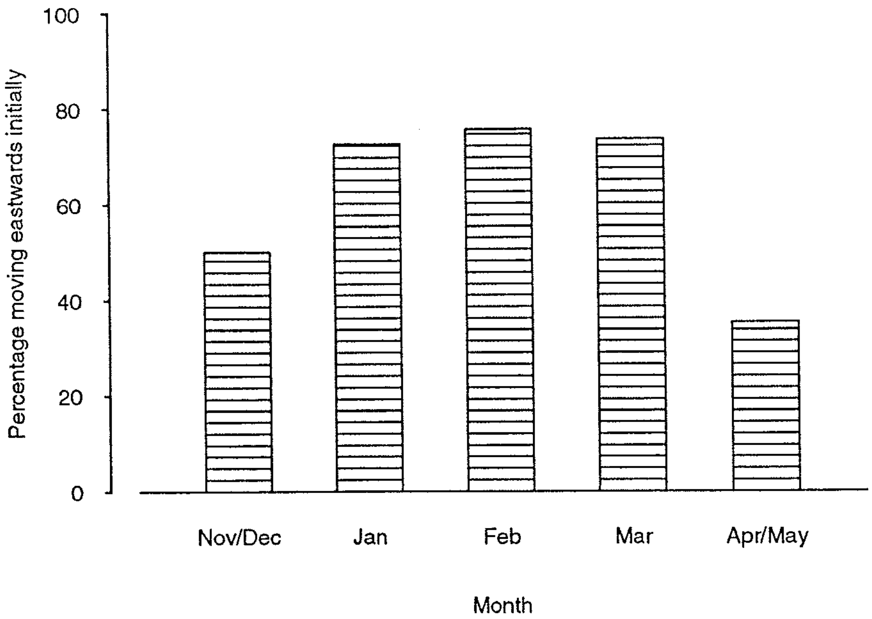


Figure 8. Percentage of tropical cyclones moving initially eastwards in relation to month of origin.

In Figure 10, there was a good degree of correlation between the maximum intensity of the cyclone and net zonal movement during the intensification from gale to storm. Over 70 percent of tropical cyclones with a net westerly movement became hurricanes, compared to nearly 40 percent of those having a net eastwards movement. During the previous decade, while the frequency of cyclones having a net eastwards displacement is similar to this survey period, 86 percent of intensifying cyclones moving westwards in the earlier survey ultimately became hurricanes.

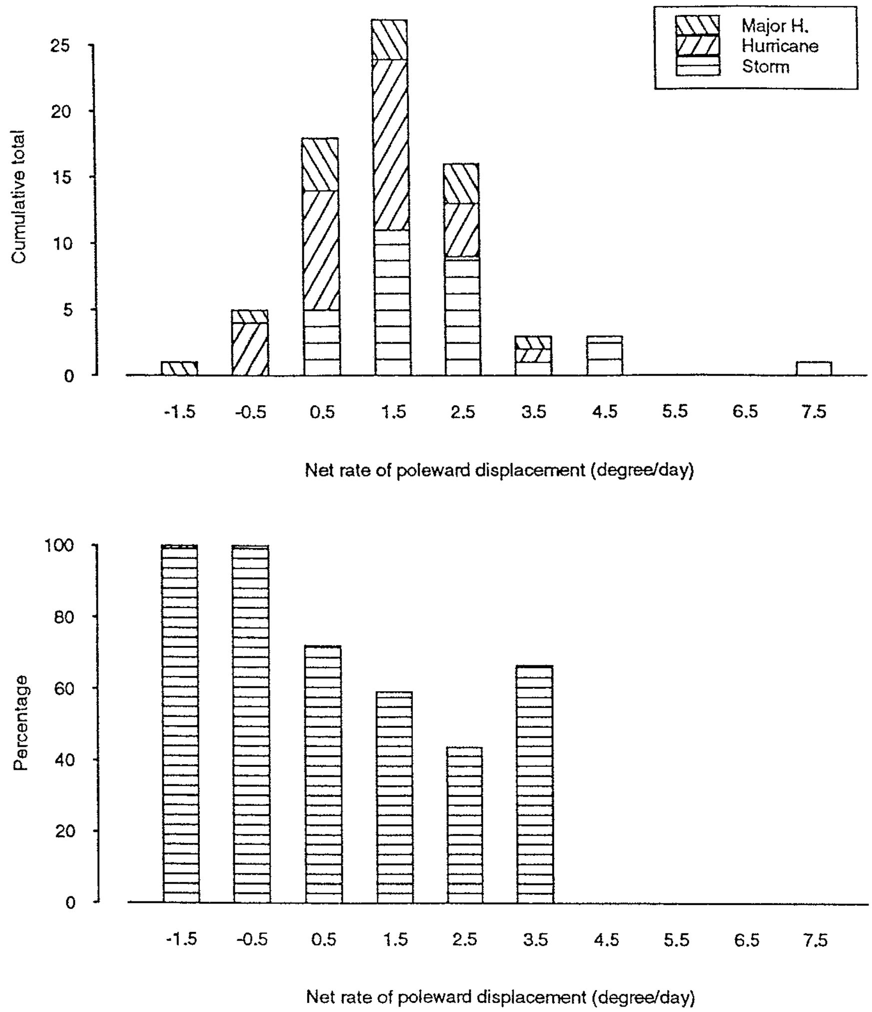


Figure 9. Net rate of poleward displacement of tropical cyclones during intensification from gale to storm, and the percentage which became hurricanes corresponding to each displacement rate.

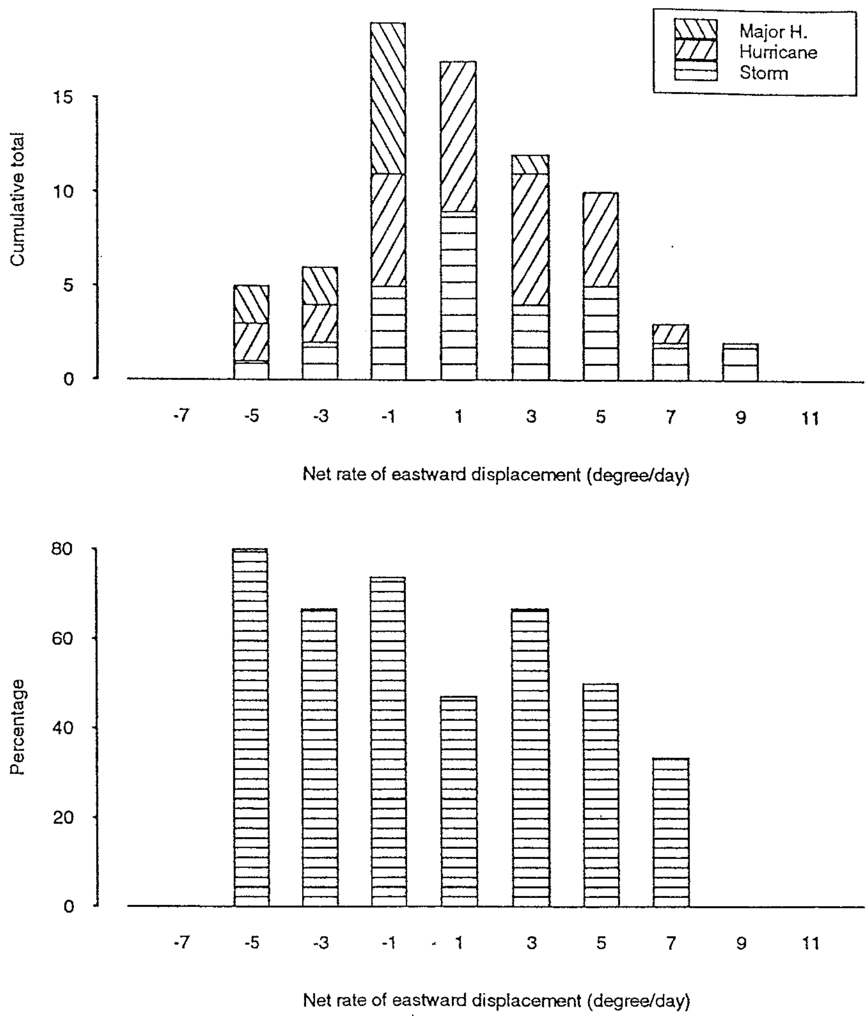


Figure 10. Net rate of eastward displacement of tropical cyclones during intensification from gale to storm, and the percentage which became hurricanes corresponding to each displacement rate.

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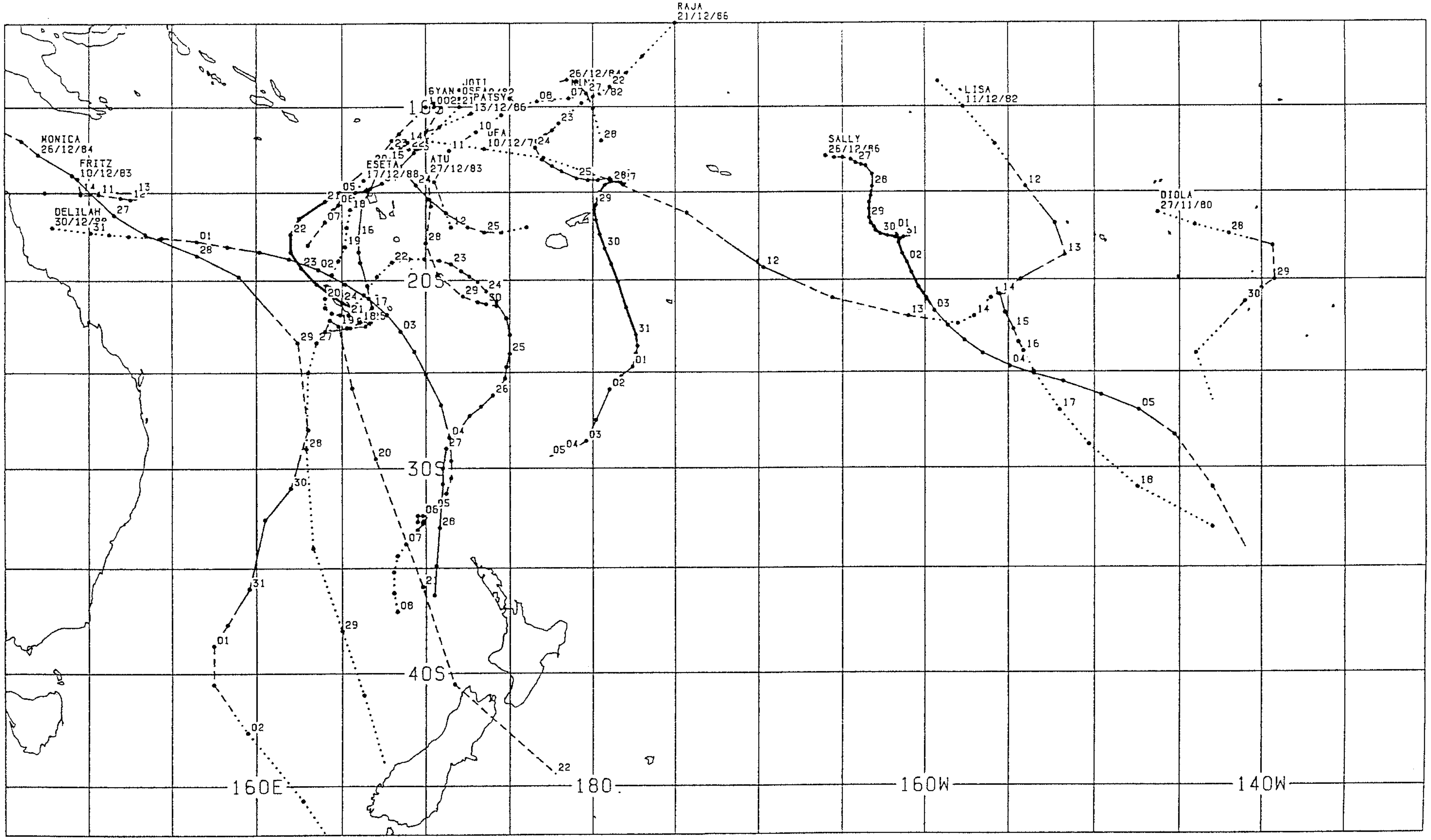

Chart 1.1. Tracks of tropical cyclones October, November and December 1979 to 1988 inclusive.

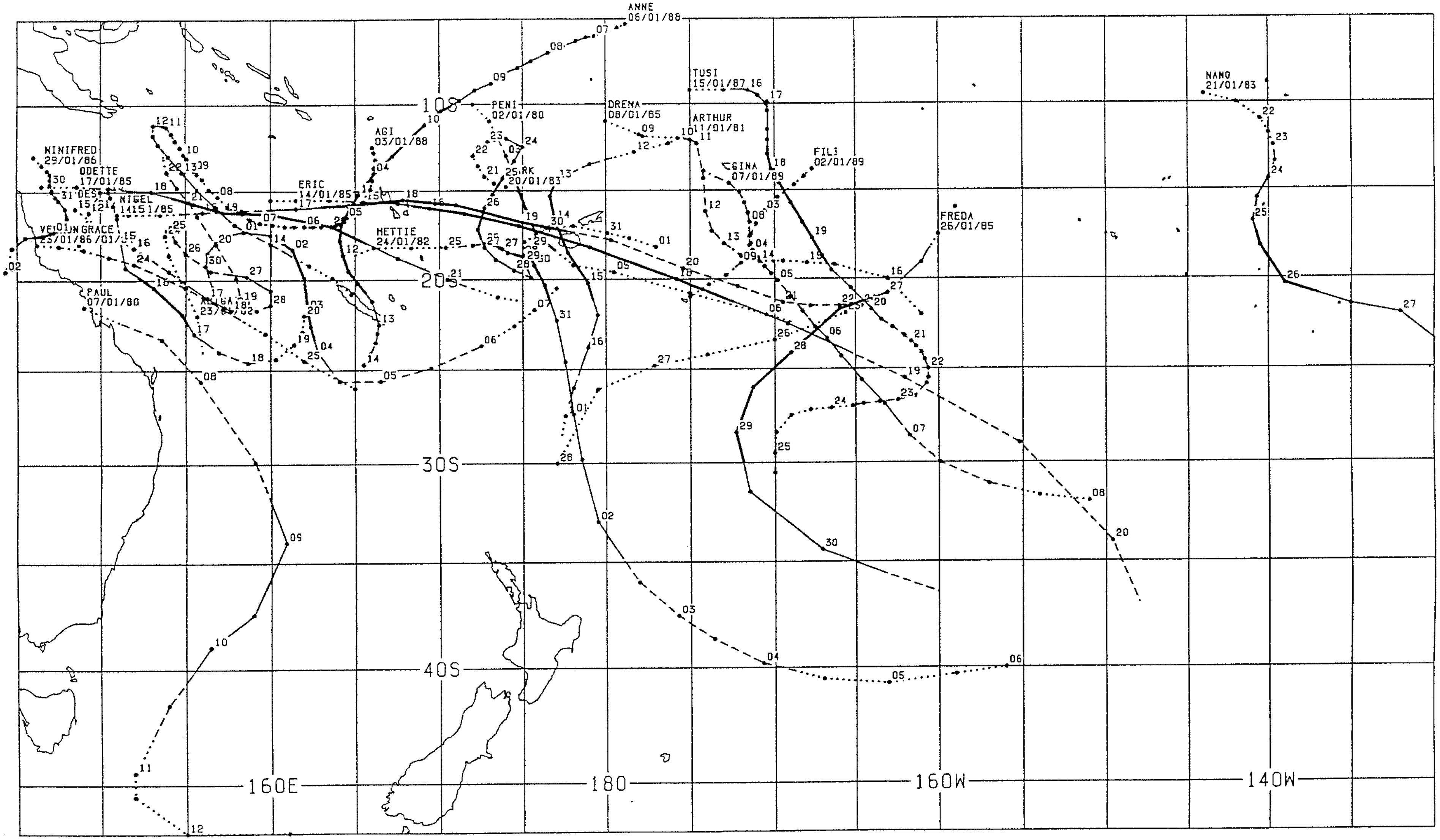

Chart 1.2. Tracks of tropical cyclones January 1980 to 1989 inclusive.

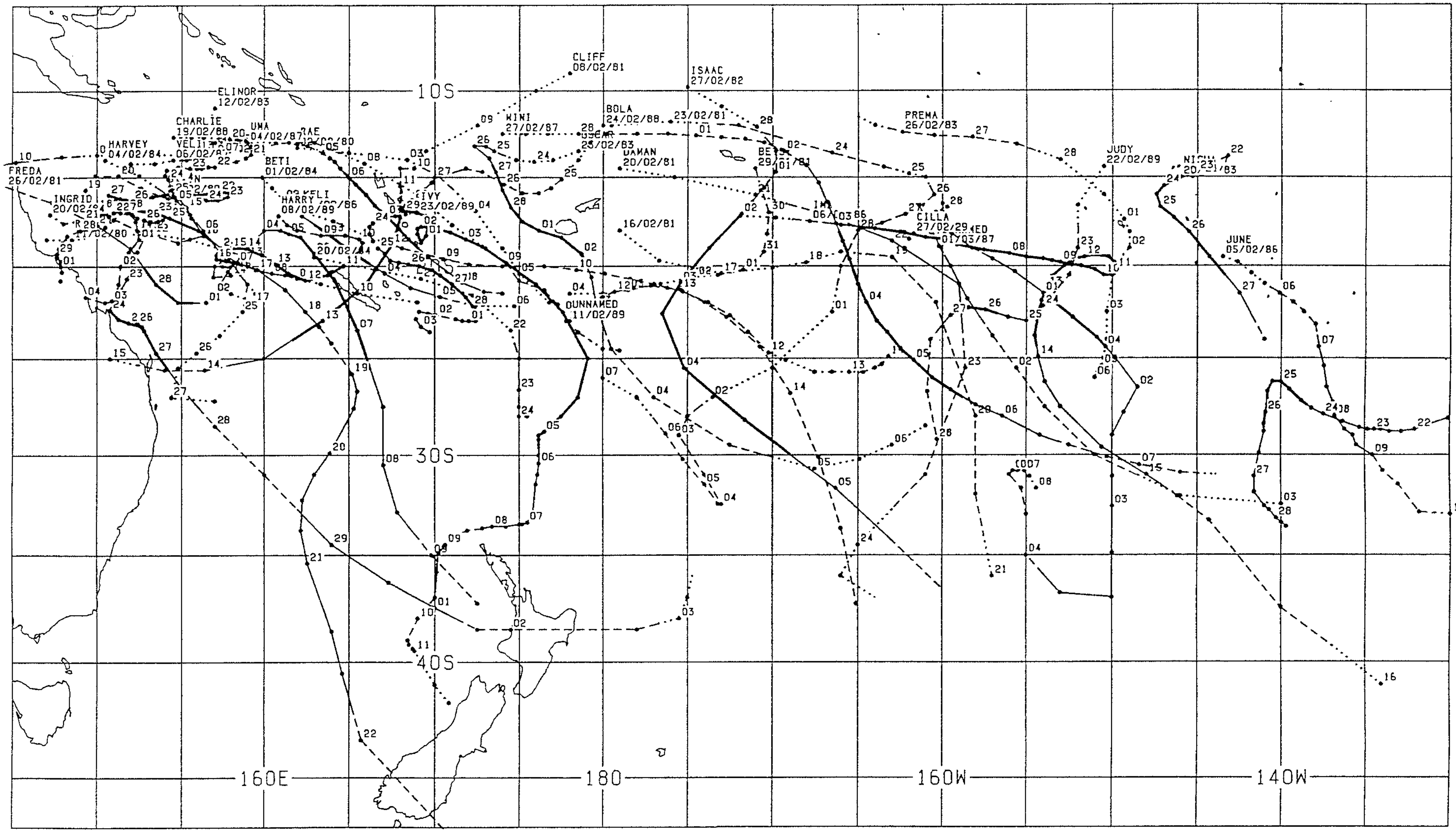

Chart 1.3. Tracks of tropical cyclones February 1980 to 1989 inclusive.

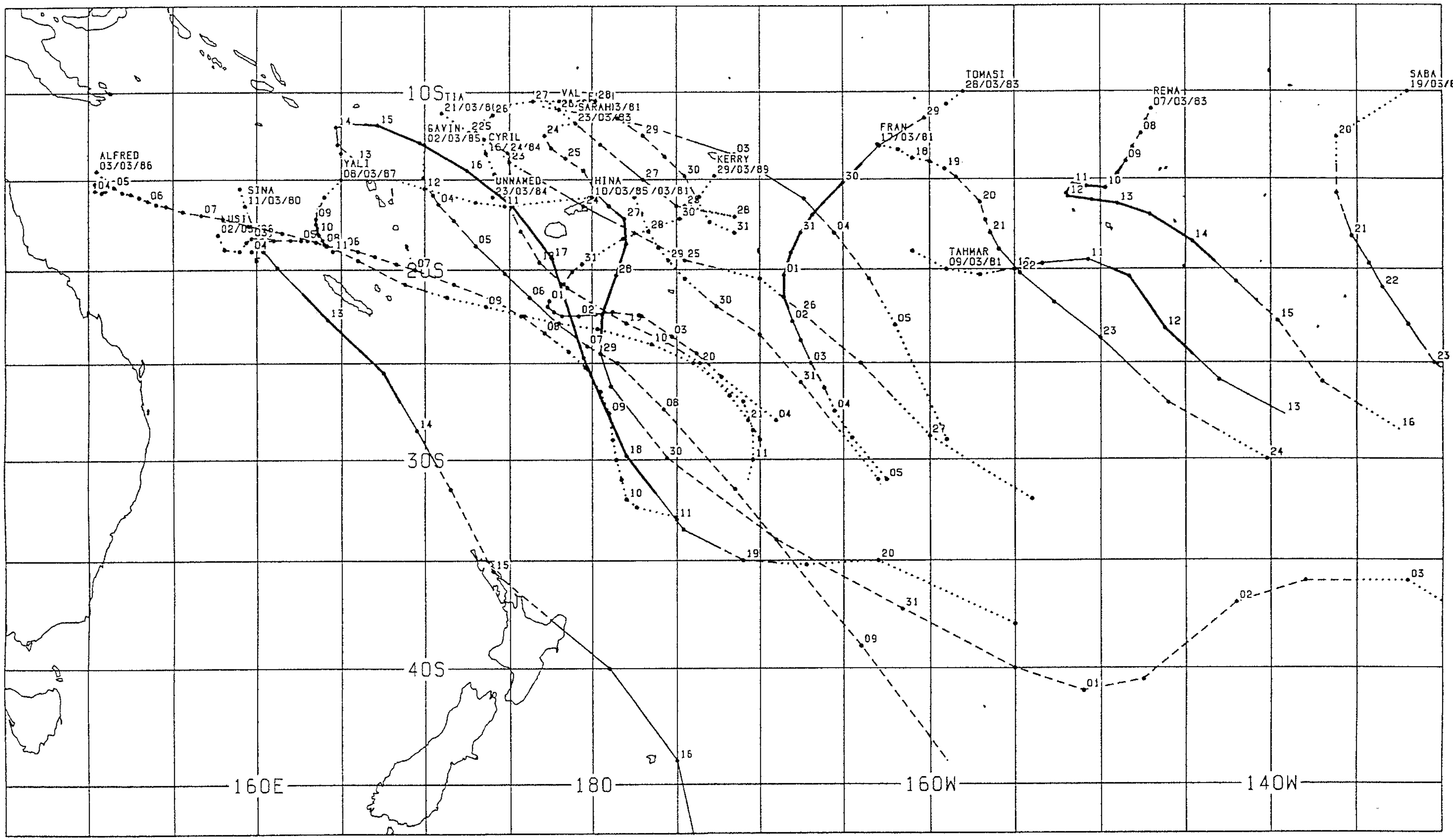

Chart 1.4. Tracks of tropical cyclones March 1980 to 1989 inclusive.

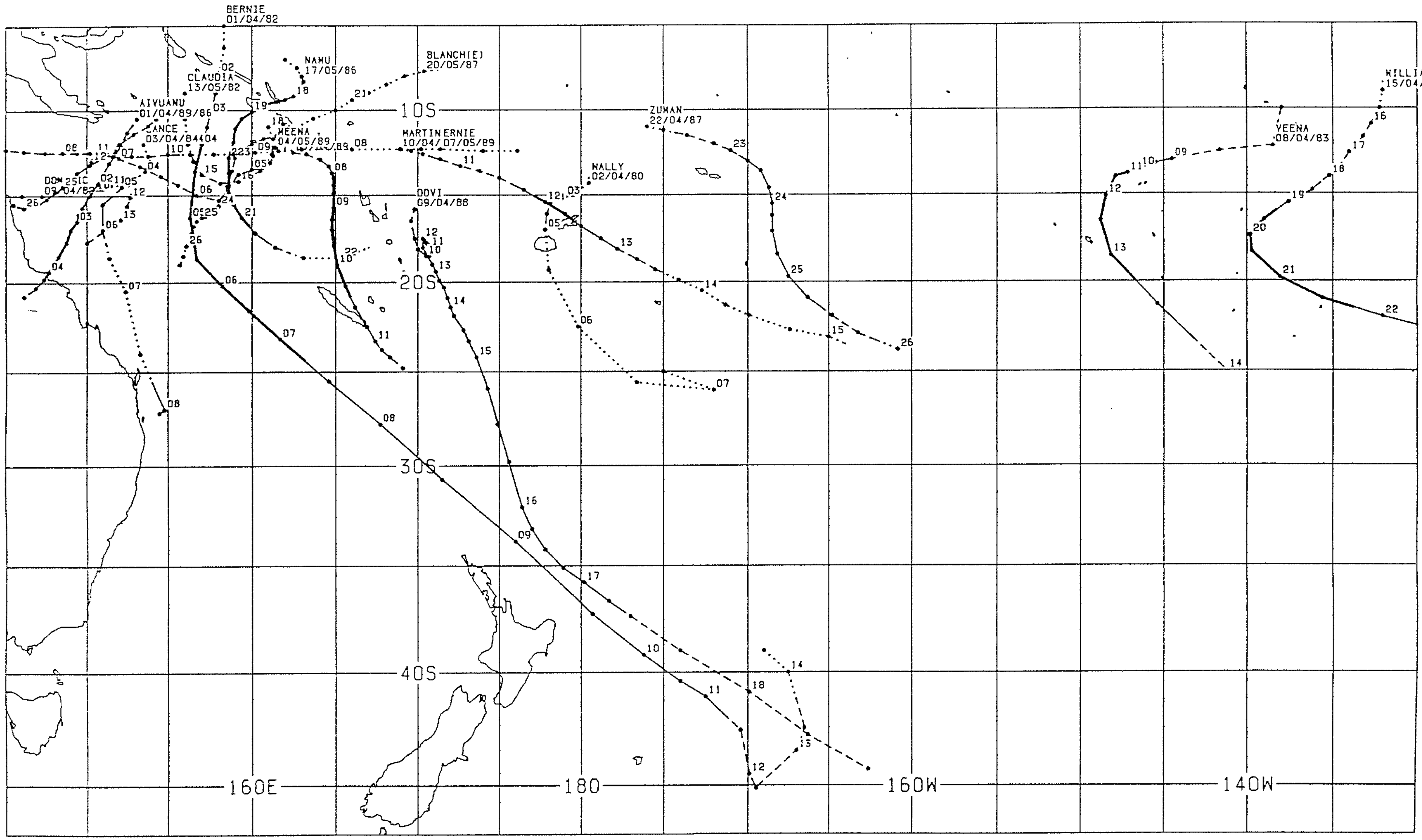

Chart 1.5. Tracks of tropical cyclones April and May 1980 to 1989 inclusive.

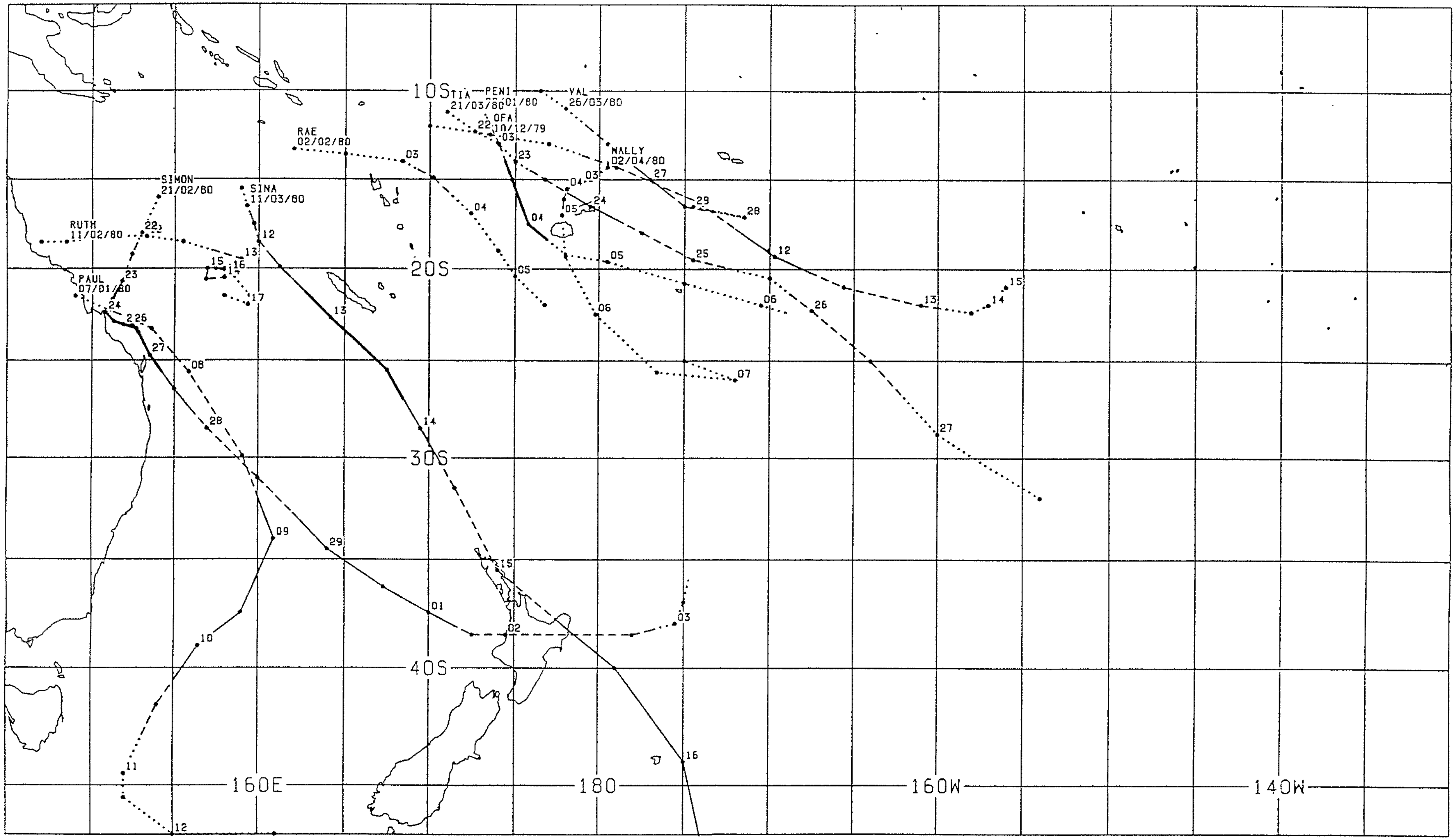

Chart 2.1 Tracks of tropical cyclones 1979/1980 season, showing intensities.

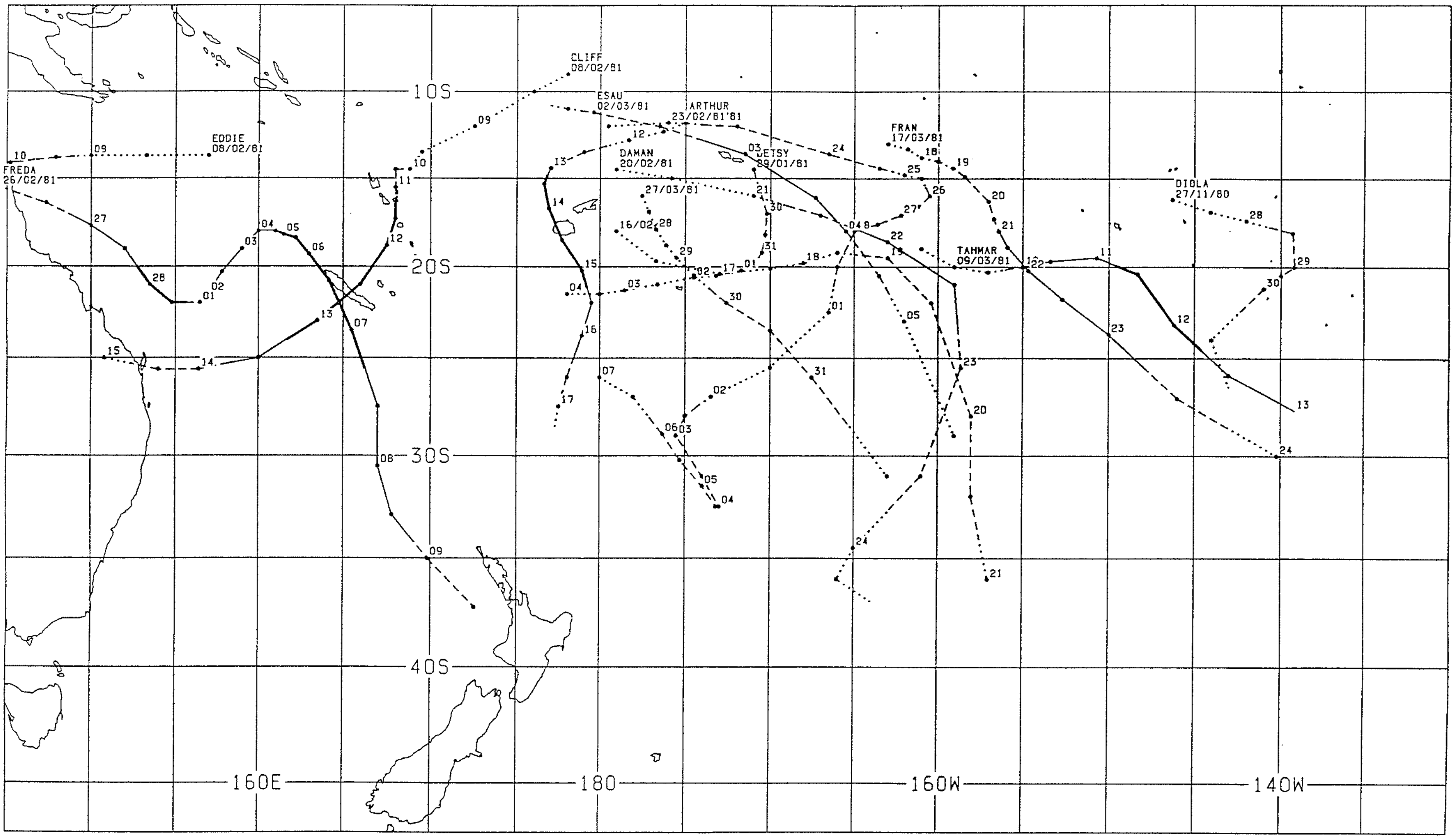

Chart 2.2 Tracks of tropical cyclones 1980/1981 season, showing intensities.

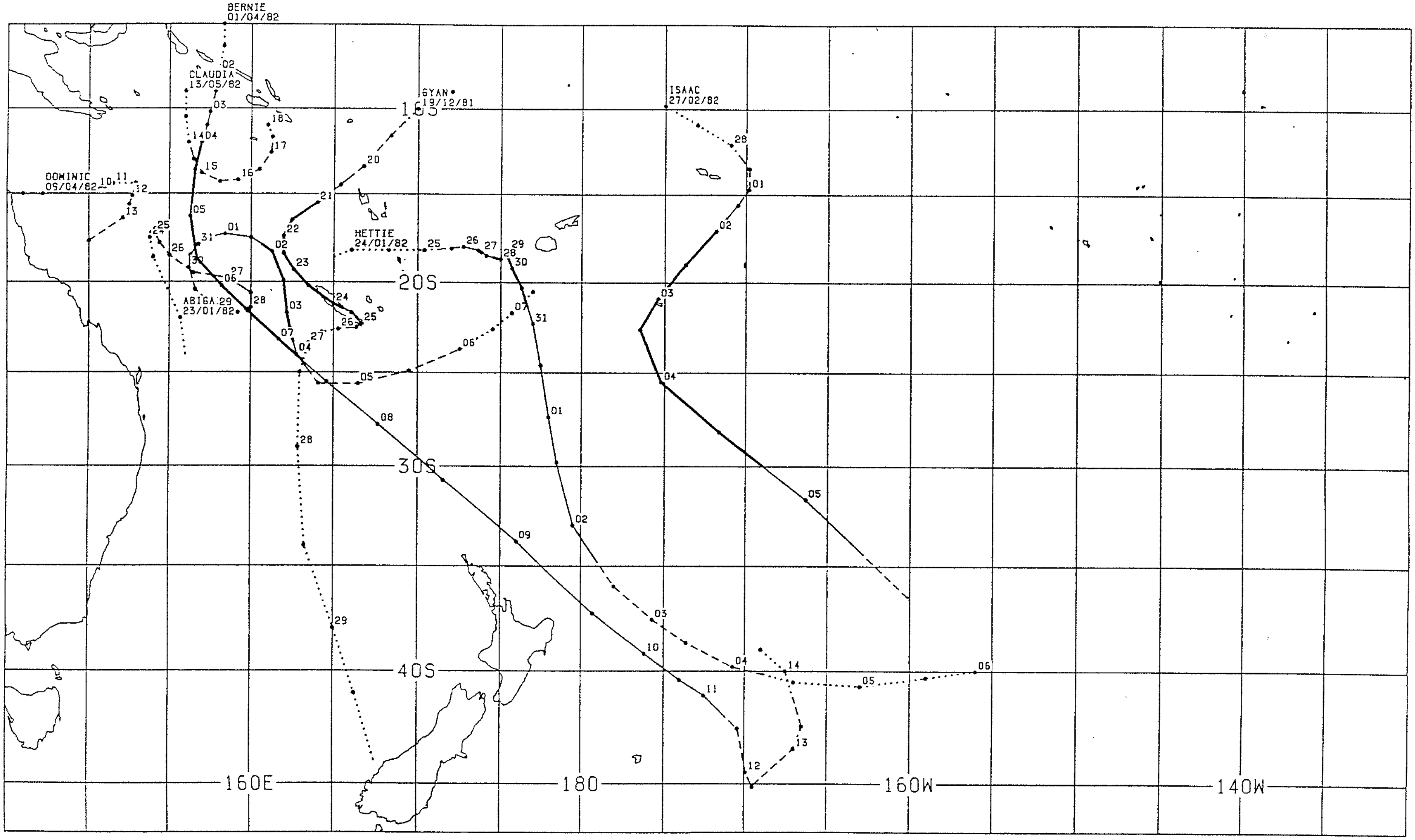

Chart 2.3 Tracks of tropical cyclones 1981/1982 season, showing intensities.

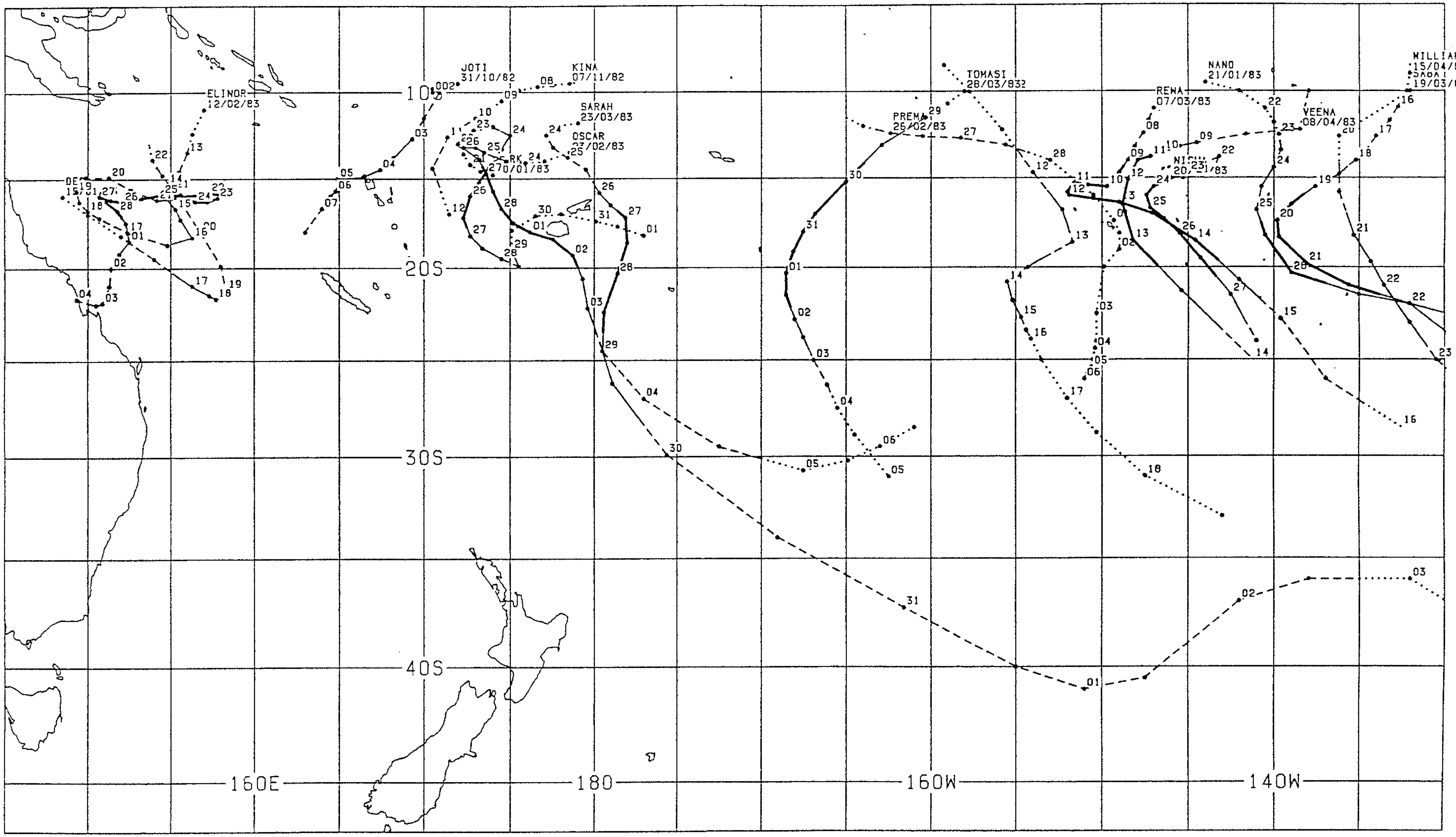

Chart 2.4 Tracks of tropical cyclones 1982/1983 season, showing intensities.

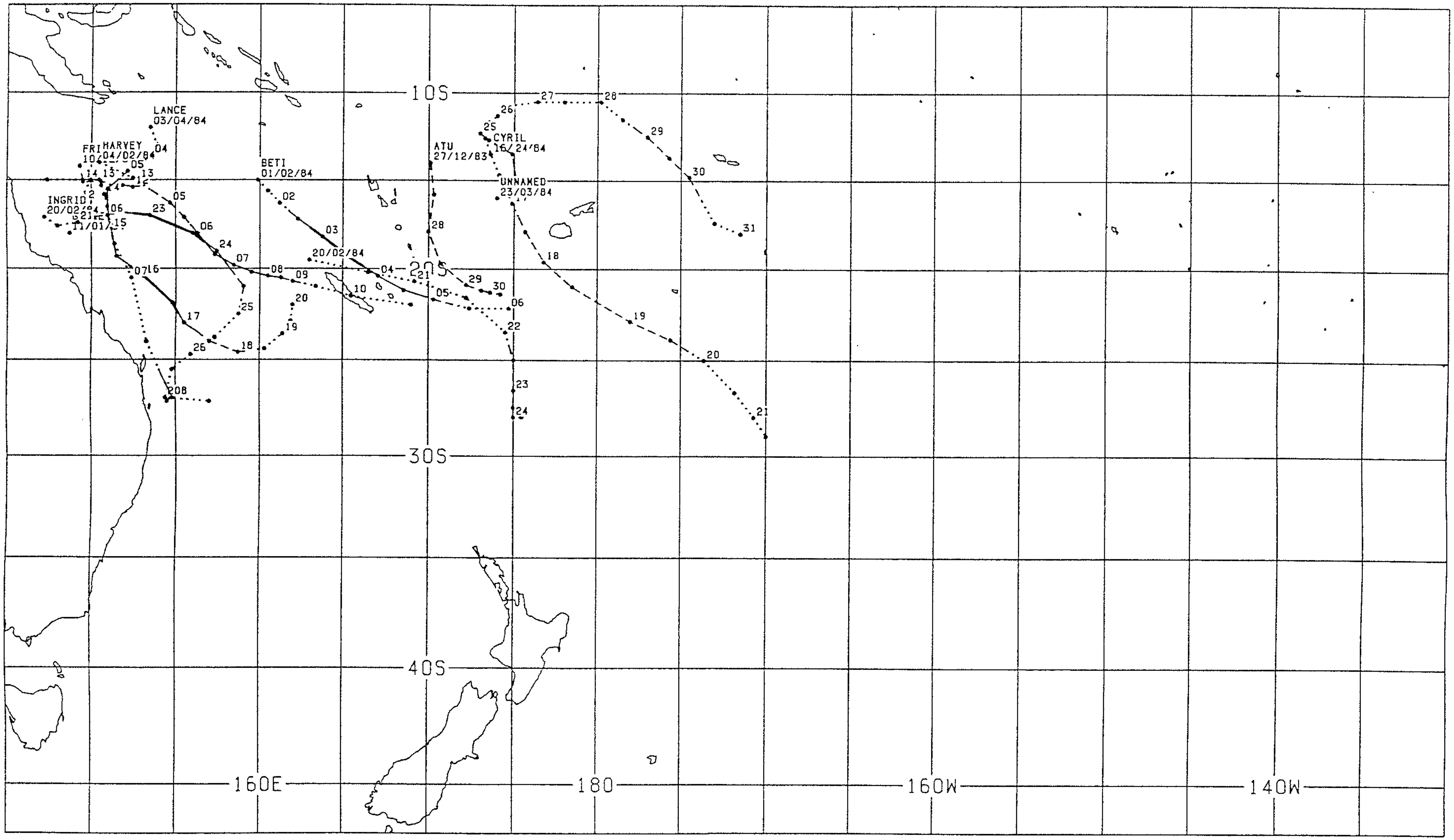

Chart 2.5 Tracks of tropical cyclones 1983/1984 season, showing intensities.

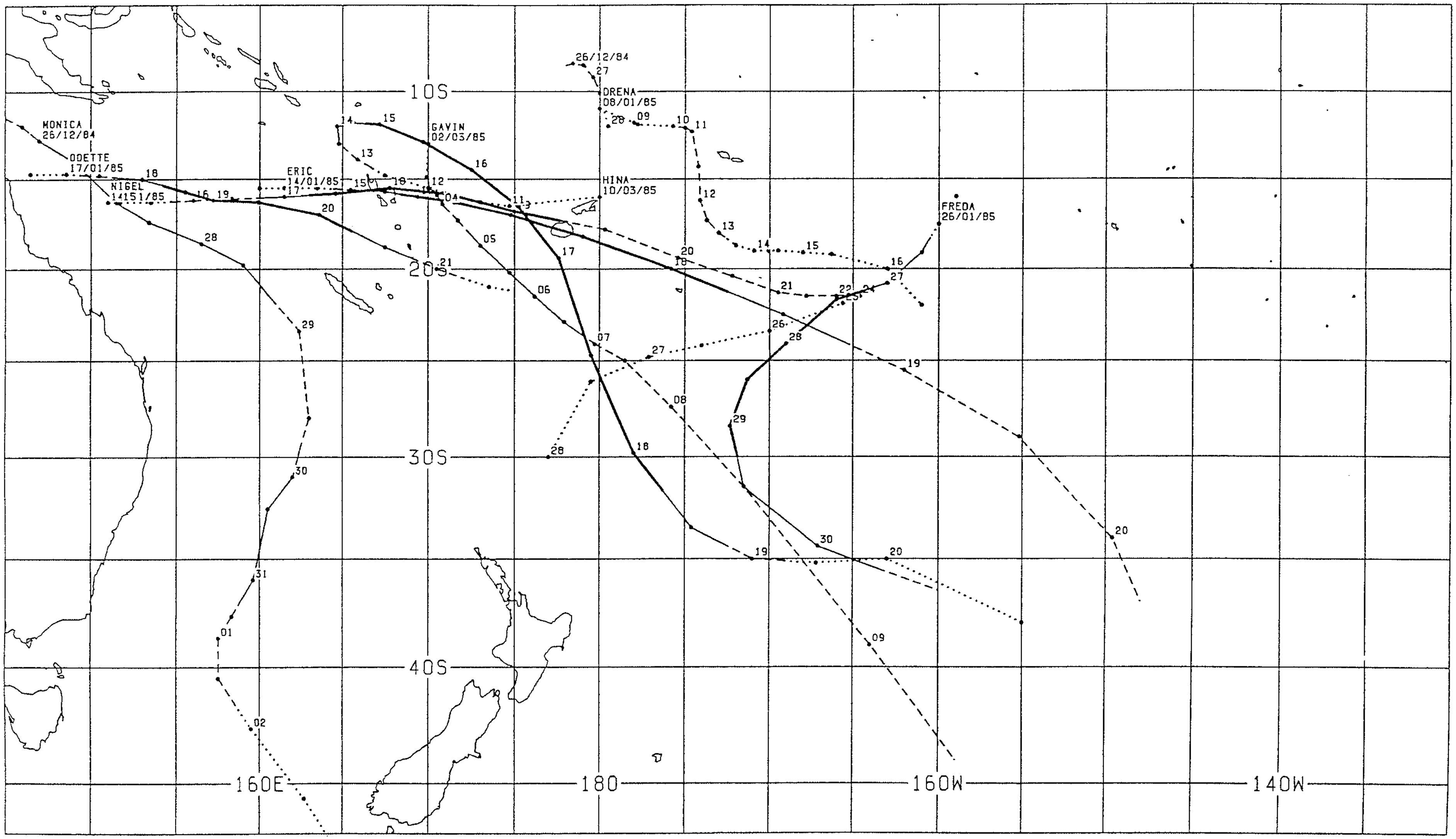

Chart 2.6 Tracks of tropical cyclones 1984/1985 season, showing intensities.

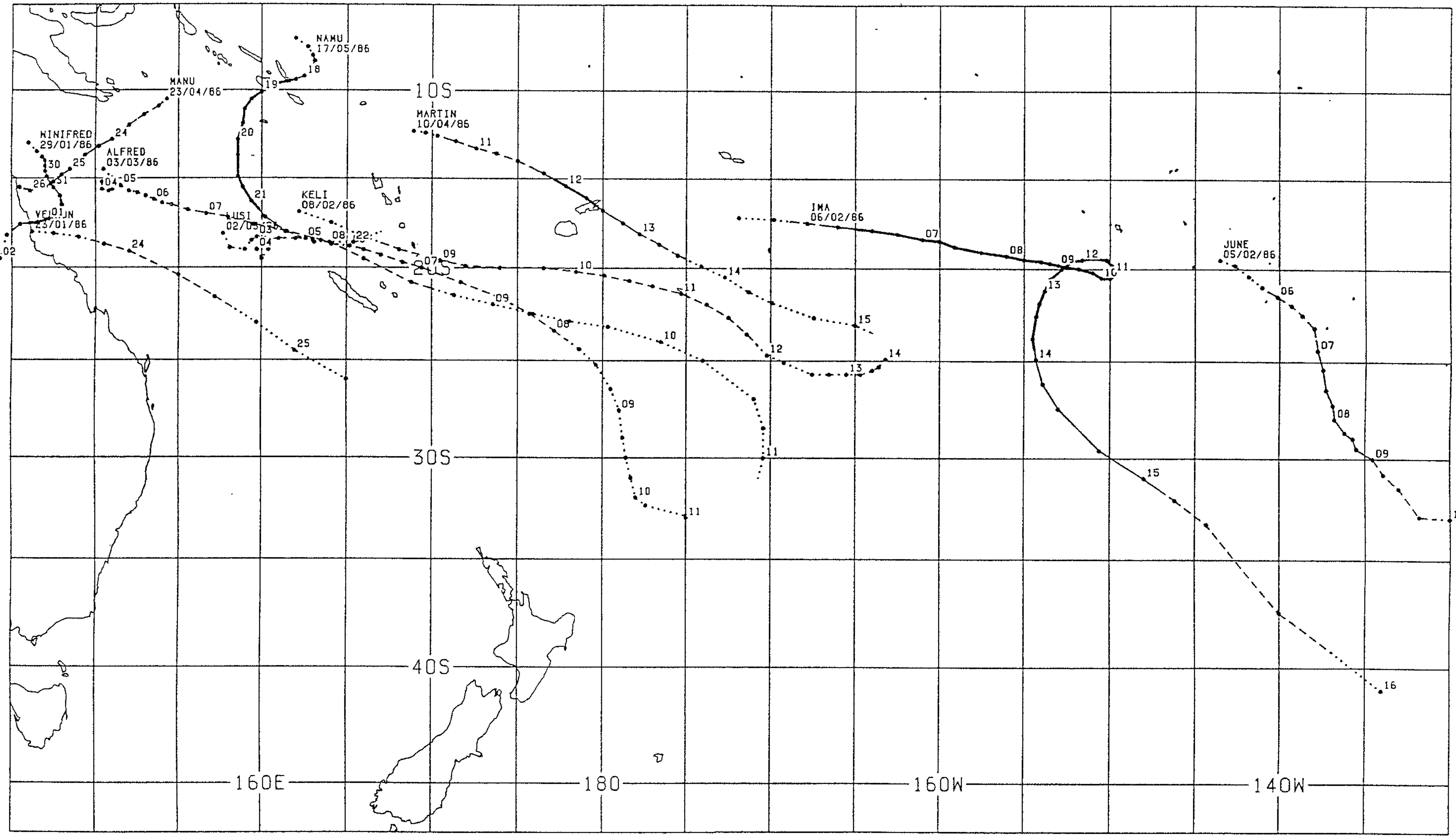

Chart 2.7 Tracks of tropical cyclones 1985/1986 season, showing intensities.

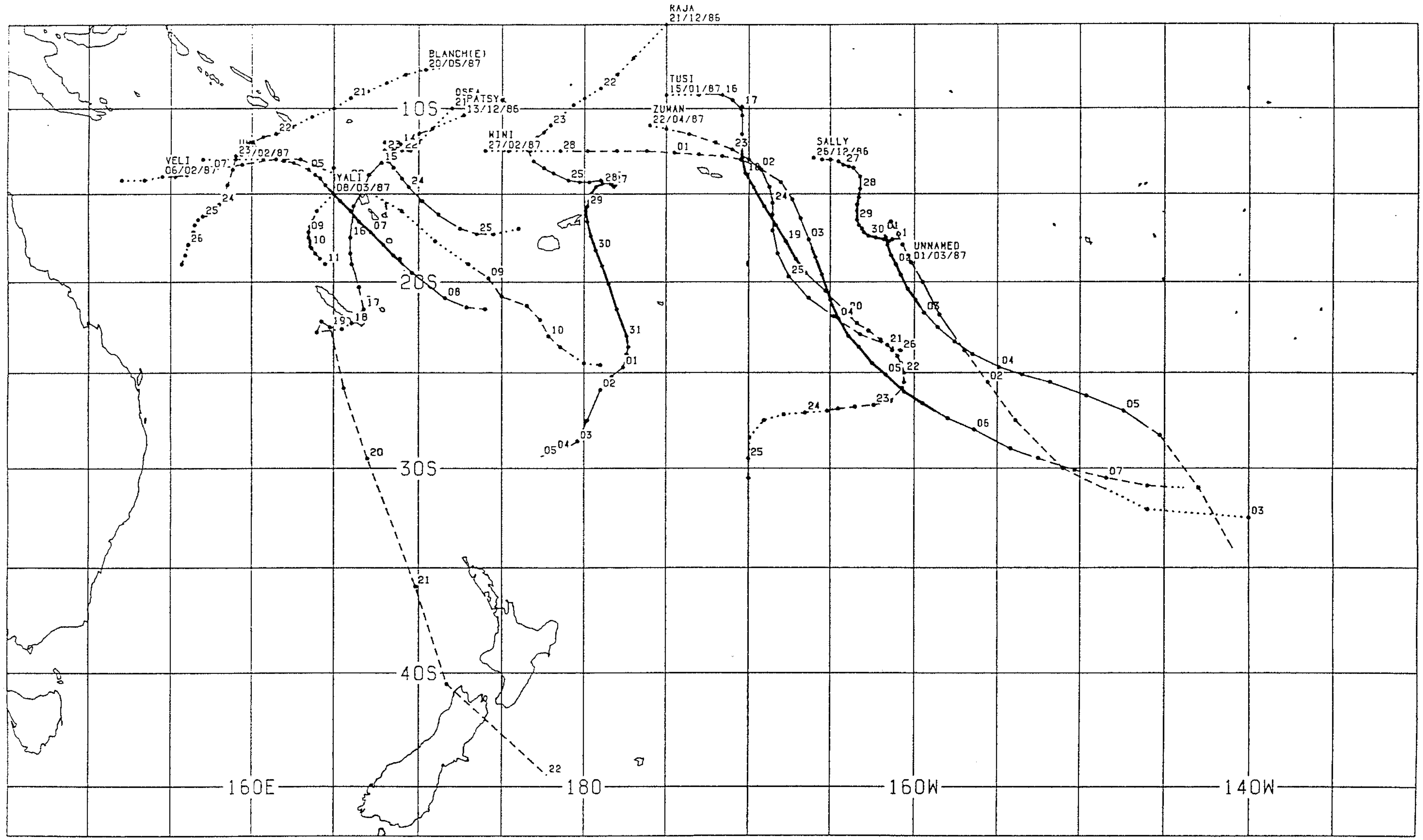

Chart 2.8 Tracks of tropical cyclones 1986/1987 season, showing intensities.

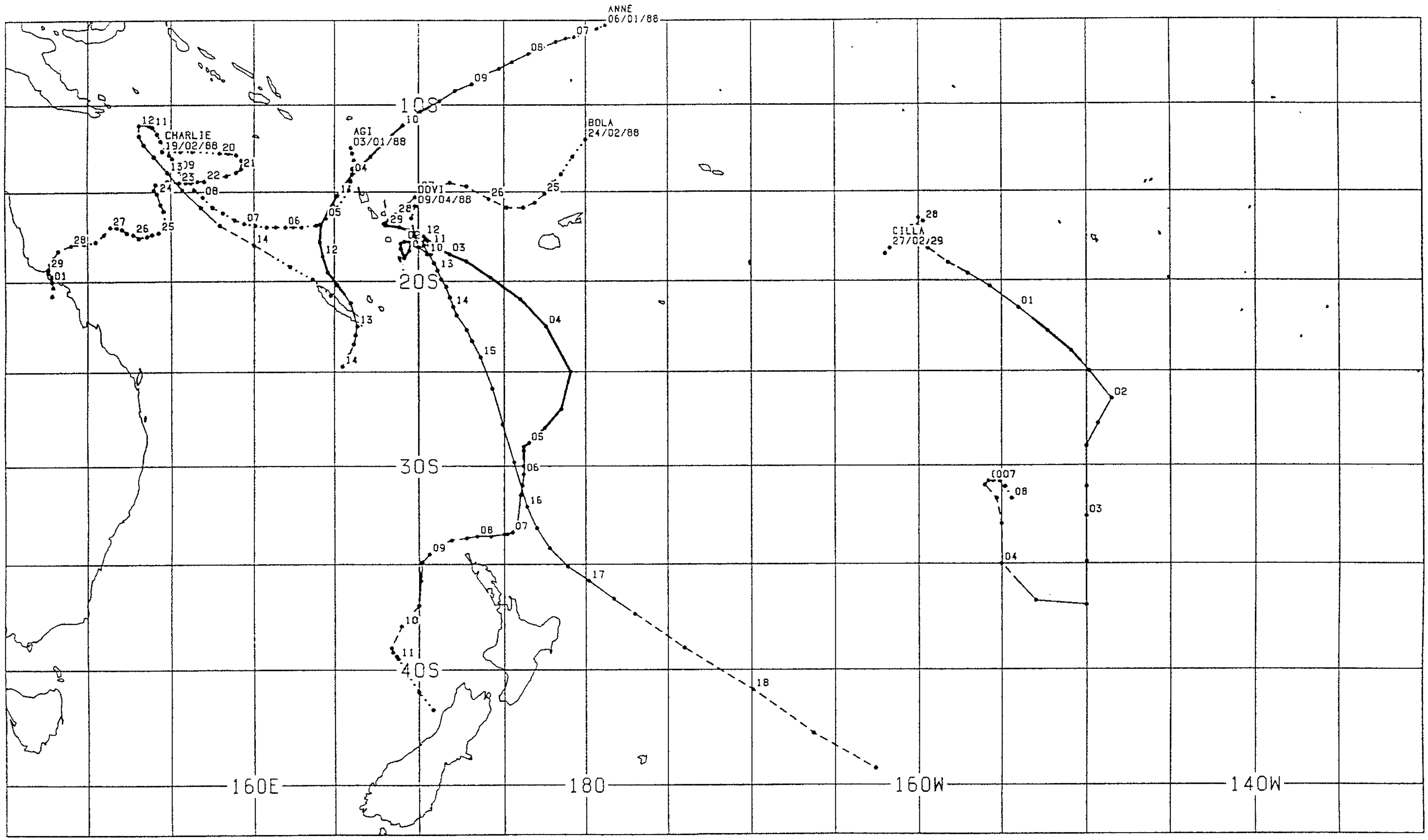

Chart 2.9 Tracks of tropical cyclones 1987/1988 season, showing intensities.

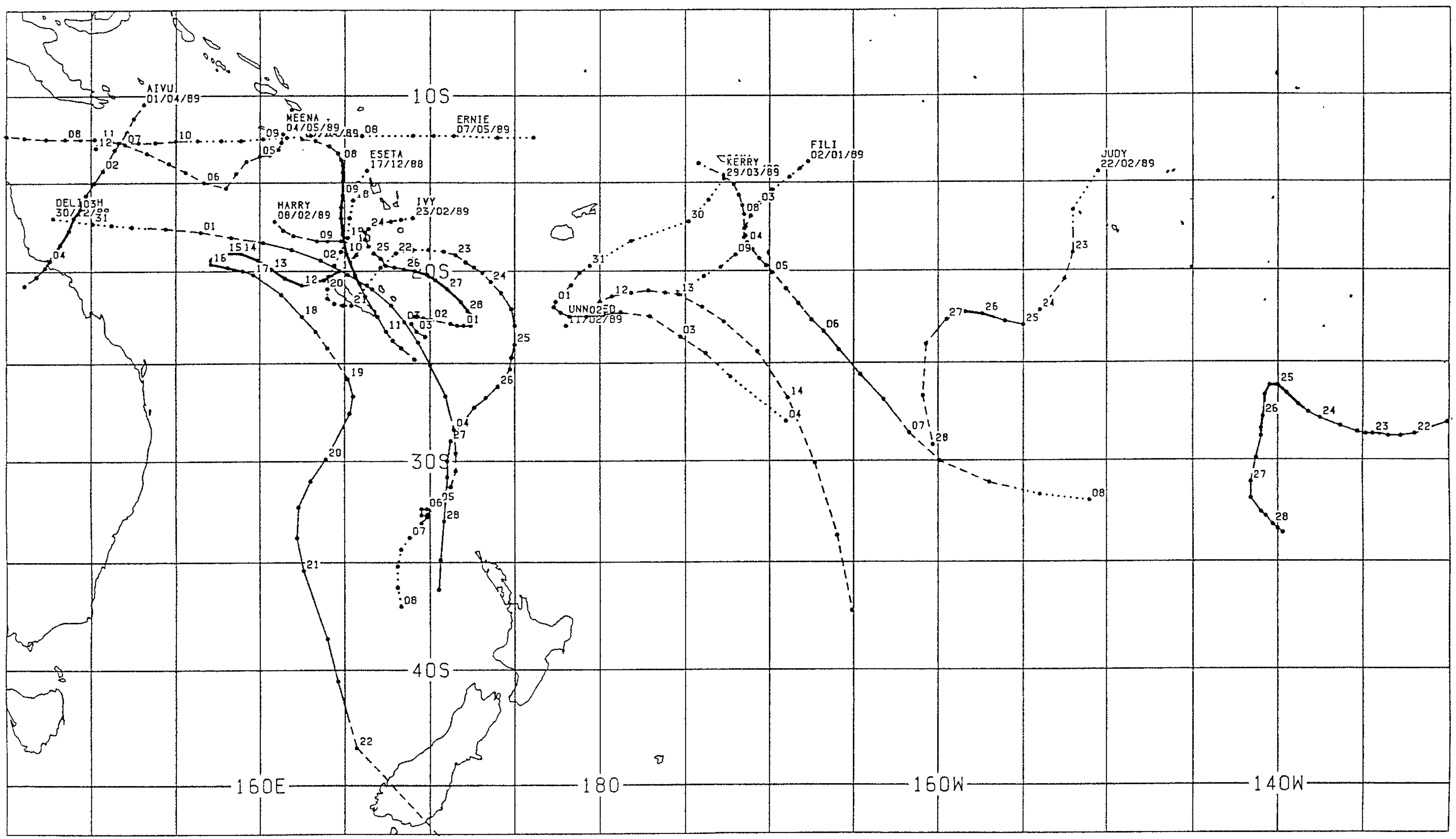

Chart 2.10 Tracks of tropical cyclones 1988/1989 season, showing intensities.

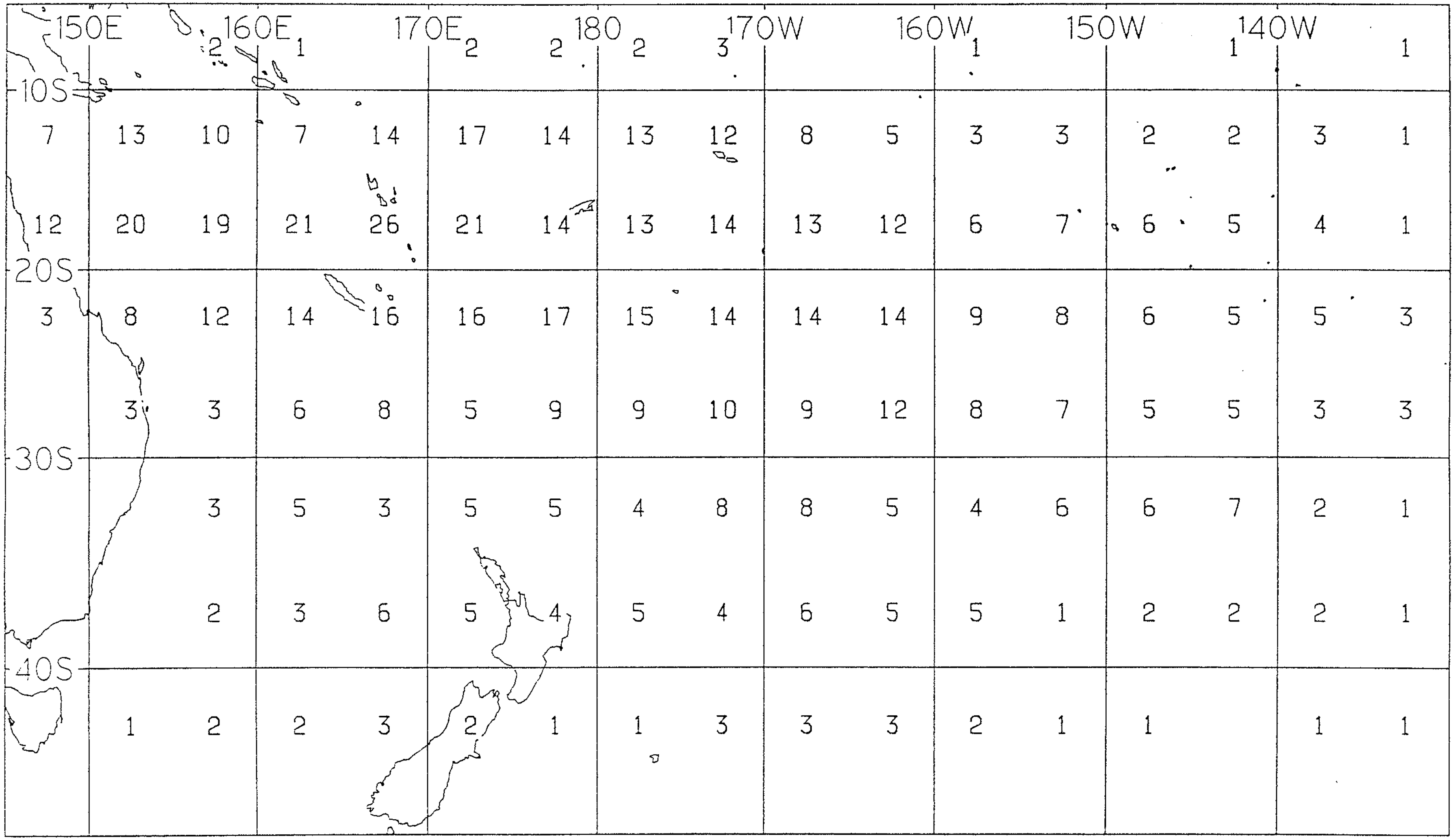

Chart 3.1. Number of cyclones that crossed each 5 degree latitude-longitude square in the 10 seasons November 1979 to May 1989.

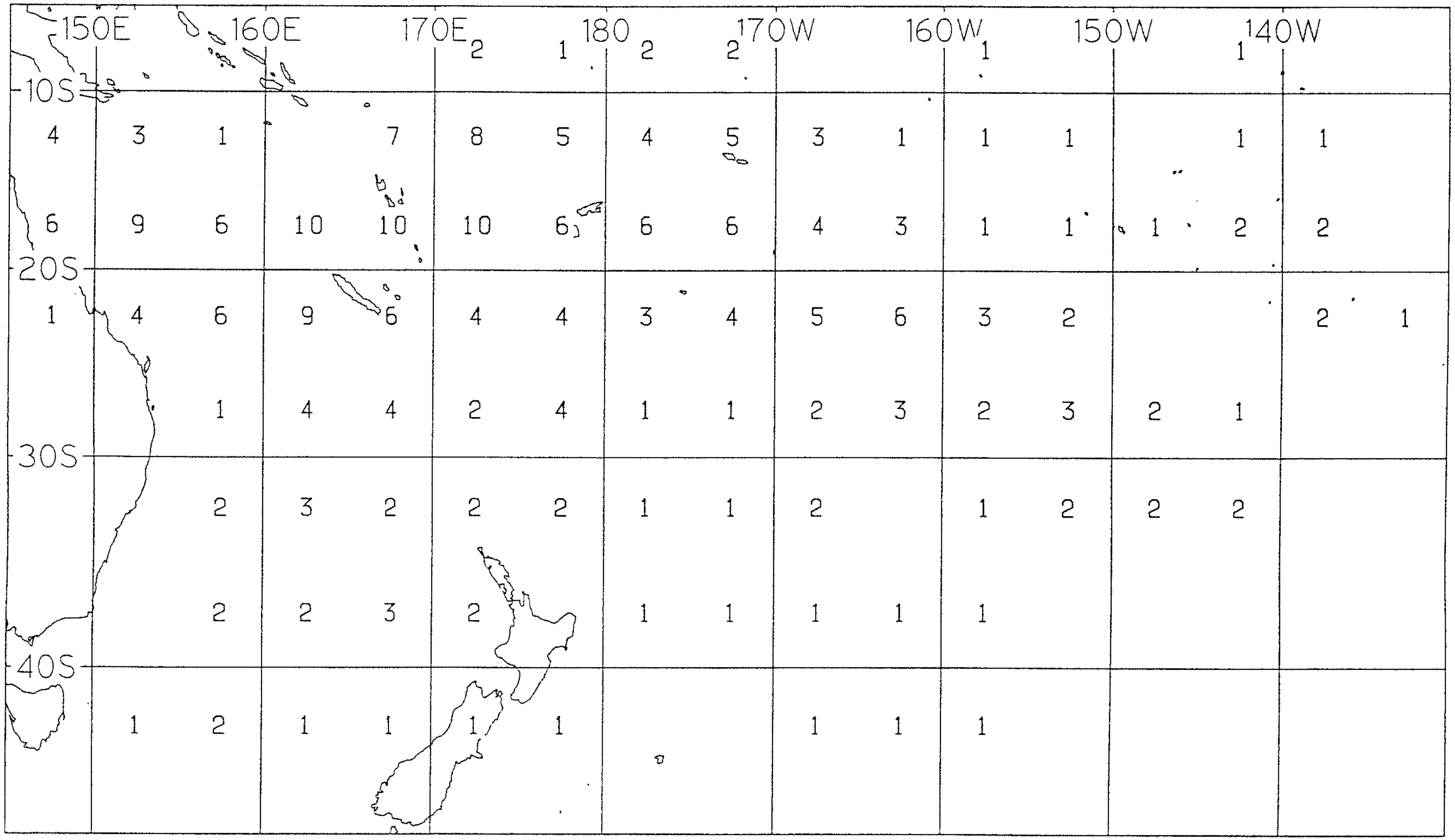

Chart 3.2. Number of cyclones that crossed each 5 degree latitude-longitude square in the months October, November, December and January in the 10 seasons.

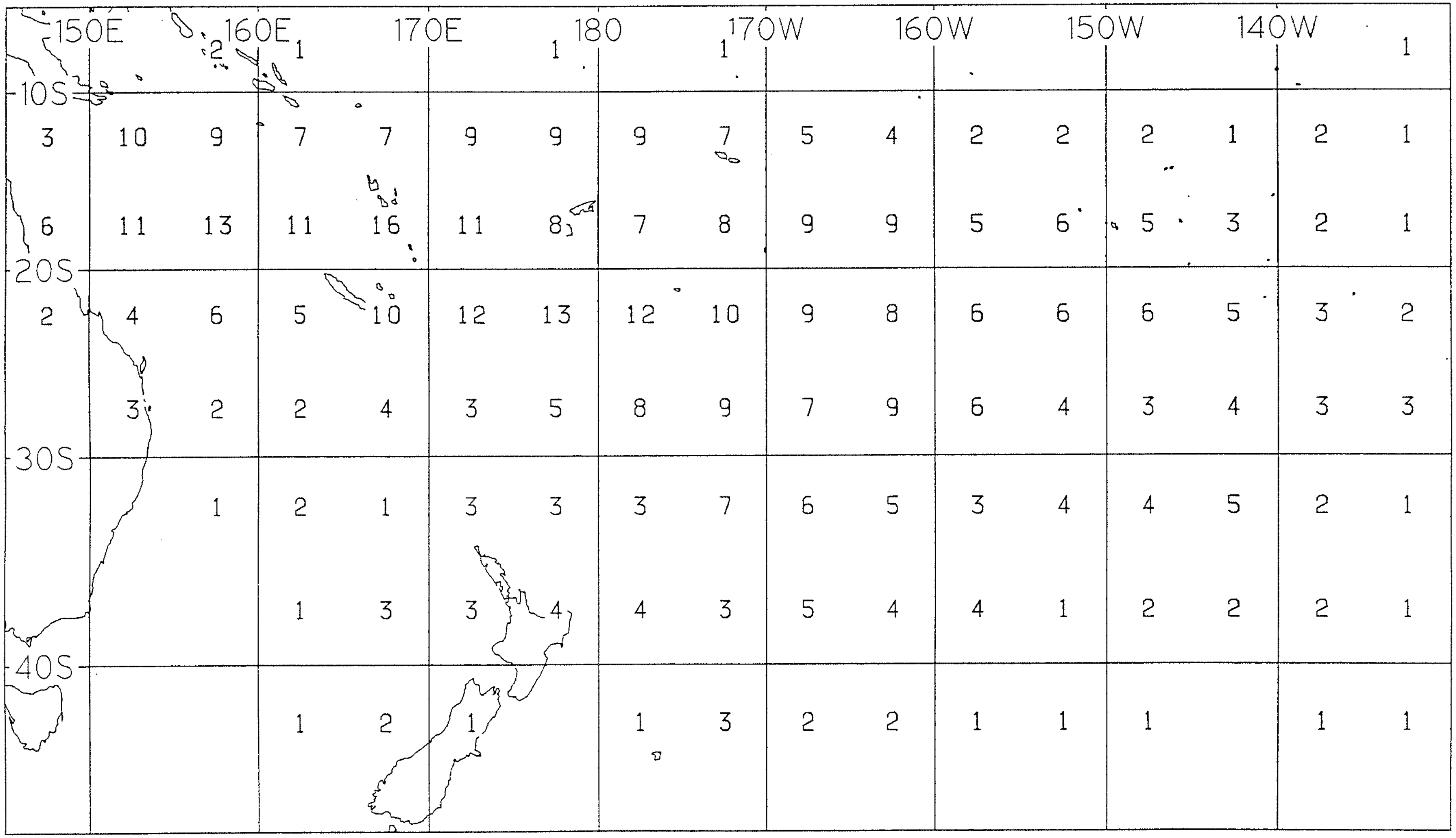

Chart 3.3. Number of cyclones that crossed each 5 degree latitude-longitude square in the months February, March April and May in the 10 seasons.

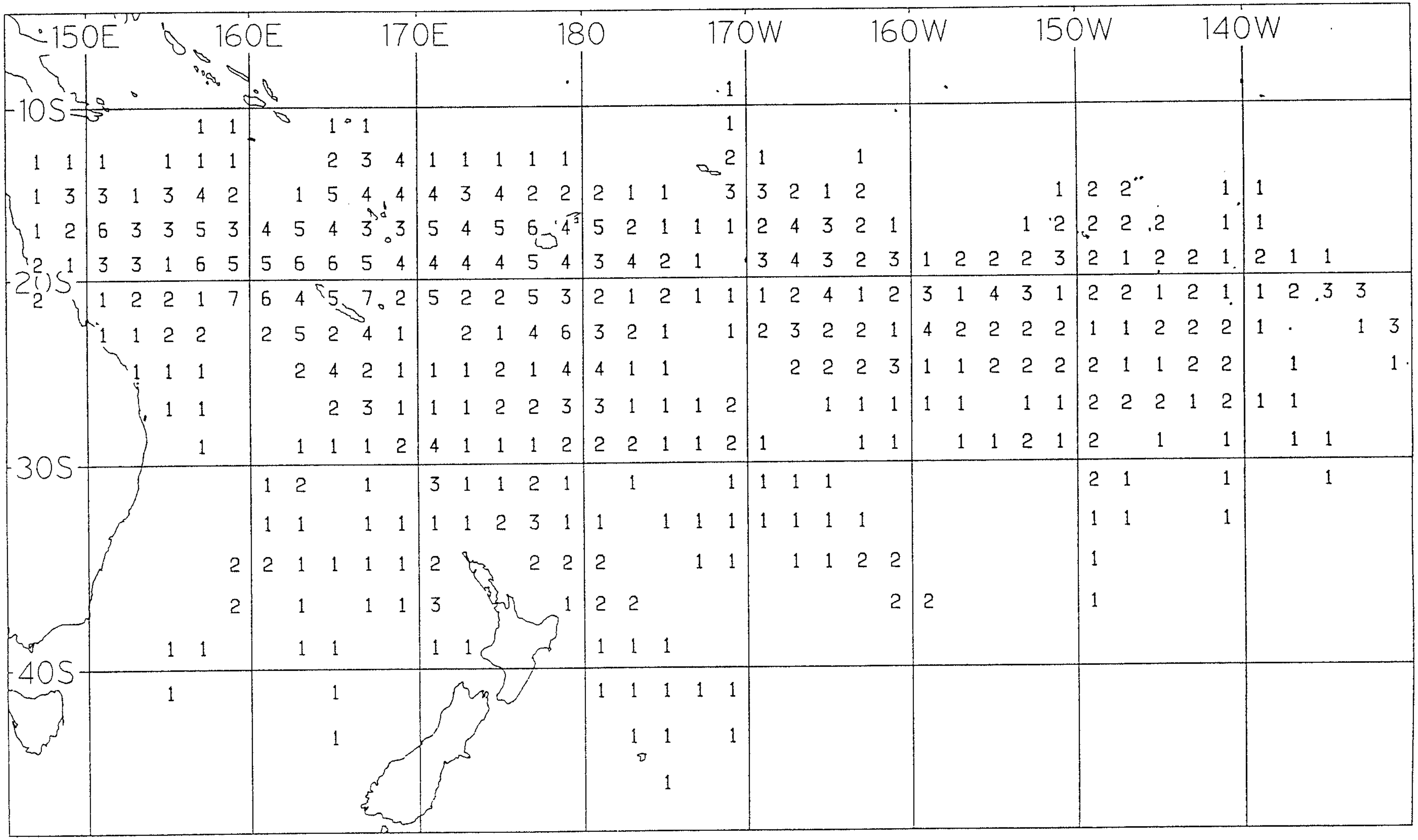

Chart 4. Number of storms and hurricanes that crossed each 2 degree latitude-longitude square in the 10 seasons November 1979 to May 1989.