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WIND VARIATION IN THE LOWER
STRATOSPHERE AT GAN, 1964-1975

by

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1. Introduction.

The last upper air balloon sounding from Gan (00.68°S , 73.15°E) took place at the end of 1975. The Gan radiosonde station was almost unique in being situated within one degree of latitude of the equator and having a relatively long record (c. 11 yr) of upper air wind and temperature data at lower stratospheric levels. The data has been particularly useful for monitoring low frequency equatorial stratospheric wind oscillations. Some rocketsonde firings have also taken place from Gan but are too few in number to provide useful information about long period fluctuations. With the closure of the station it would seem appropriate to provide a summary of the lower stratospheric wind data obtained at Gan between 1964 and 1975.

The dominant wind oscillation in the lower equatorial stratosphere is the quasi-biennial oscillation (QBO) of the zonal component. Its presence in this region of the atmosphere was first detected in 1961^{1,2}. In more recent years studies of the QBO in zonal wind have been extended to include extra-tropical latitudes, the higher stratosphere and mesosphere, the troposphere and stratospheric-tropospheric coupling. Similar oscillations have been detected in the temperature, ozone concentration and meridional wind fields of the stratosphere. This note will be confined to the QBO, annual and semi-annual oscillations of wind components at standard pressure levels between 70 mb and 10 mb and the Gan data will be compared with similar data from Ascension Island (7.98°S , 14.4°W) and Canton Island (2.77°S , 171.71°W).

2. Data and Method.

Many of the studies of wind in the stratosphere have been carried out using rocket sounding data, but only balloon soundings have been considered in the analysis to be presented here. The data for Gan and Ascension Island cover the period from September 1964 to August 1975 and that for Canton Island is for the period January 1955 to August 1967. Monthly mean values of wind components have been calculated

from daily values at 70, 50, 30, 20 and 10 mb using a pentad method. At 10 mb it is probable that not all the high frequency 'noise' will have been eliminated by the averaging process as only small amounts of data were available during some months. It should be remembered, when comparing the observations at the three stations with each other or with results from other investigators, that the QBO is not a pure sinusoidal feature. The amplitude and phase are continually changing with time and some differences, other than latitudinal ones, are to be expected between the data at Canton Island (1955-67) and the other two stations (1964-75). Data for Canton Island is presented only at the 50 mb and 30 mb levels.

The main analysis of the wind components makes use of a band pass filter technique designed by Craddock³ and is similar to that previously used by Ebdon⁴ and Edmond⁵ to analyse zonal wind components for Canton Island. The filters used here differ slightly in that they have been constructed by combining Craddock's unitary filters to minimise the effects of undesirable sidebands. The three filters used in the analysis are shown in Fig 1. The first filter peaks at about 27 months, the approximate mean period of oscillation of the zonal component at Gan for the years analysed. It can be seen that each filter has almost zero response at the peak frequency of each other filter, and at its own peak frequency the response is approximately unity.

3. Zonal Wind.

Zonal wind components at Gan have been presented previously by Ebdon⁶ as a continuing sequence to the data for Canton Island but here they will be analysed independently. Figure 2(a), (b) depicts cross-sections of the zonal component between 70 mb and 10 mb at Gan and Ascension Island. The greater magnitude and frequency of the easterlies at Ascension Island is clearly illustrated at all levels and the monthly mean zonal wind at 50 mb at Gan is easterly on approximately 40% of occasions whereas at Ascension Island the figure is 60%. At 20 mb the values rise to 50% and 80% respectively. Long term means are given in Table I. These values are not indicative of the real wind, because of the presence of the QBO, but are representative of the net flow at each station. The means also further emphasise the

dominance of the easterlies in the tropical stratosphere.

TABLE I. Mean values of zonal wind components (ms^{-1}) at Gan, Ascension Island (1964-1975) and Canton Island (1955-1967)

	70 mb	50 mb	30 mb	20 mb	10 mb
Gan	2.5	0.5	-6.8	-7.8	-8.2
Ascension	-2.0	-5.7	-12.9	-14.7	-14.3
Canton	-	0.6	-4.4	-	-

The period of data analysed for Gan (Fig 3) and Ascension Island is approximately five complete oscillations of the QBO, and for Canton Island about five and a half oscillations. For the purpose of filtering the QBO, a series of different filters were initially applied to the data. These filters represented average periods in the range 24-30 months but it was found that the variability of the zonal component at Gan was best accounted for by an average period of approximately 27 months.

The results of the filter analysis are presented in Table II; the variance of the filtered series is expressed as a percentage of the variance of the original series. Amplitudes of the most significant waves are shown in brackets and have been calculated as a mean of the peaks of the oscillation at each level. The percentage variances for the 27 month wave are similar for all three stations at all levels of comparison although amplitudes at Gan and Canton Island are generally larger than those at

TABLE II. Results of the application of a set of unitary filters to monthly mean zonal wind data (Amplitudes are in ms^{-1})

(a) Average period = 27 months

	Percentage variance (amplitude)				
	70 mb	50 mb	30 mb	20 mb	10 mb
Gan	47(6.7)	79(16.3)	73(22.1)	71(24.3)	61(22.3)
Ascension	45(5.6)	73(13.2)	71(16.1)	71(17.2)	53(16.7)
Canton	-	63(14.7)	67(21.1)	-	-

(b) Average period = 12 months

Gan	14(3.5)	5(-)	5(-)	3(-)	5(-)
Ascension	40(5.2)	14(5.8)	7(-)	4(-)	18(9.8)
Canton	-	3(-)	1(-)	-	-

Ascension Island, which is in agreement with the work of previous authors. Maximum amplitudes occur at about 20 mb (27 km), but the amplitude changes little between 30 mb and 10 mb.

There is little evidence of the existence of the annual wave in the 70-10 mb region at the two stations closest to the equator. At Ascension Island the percentage variance accounted for by the filtered values at 50 mb and 10 mb is similar to that at 70 mb for Gan but at 70 mb the annual wave accounts for approximately the same variation as the QBO at the same level and has a similar amplitude. Results for the semi-annual wave have not been tabulated since the percentage values at all levels for all three locations never exceeded 5%. The statistical significance of the filtered series has been determined by applying the F-test to the data, as suggested by Craddock. This showed that all the filtered series for the QBO were significant at the 1% level, as was the annual wave for Ascension at 70 mb and 10 mb. The annual wave at 70 mb for Gan and 50 mb for Ascension Island were significant at the 5% level.

4. Meridional Wind.

Until recently^{7,8} little analysis has taken place of the meridional wind components in the equatorial stratosphere. When Veryard and Ebdon (1961) originally examined stratospheric wind data from various equatorial stations they found no marked fluctuations in the meridional component. Similarly a recent analysis (Nastrom, et al, 1975) found little evidence of any periodic variation near the equator with a periodicity comparable with that of the QBO in zonal wind. Meridional components are of course very small in the vicinity of the equator and periodic fluctuations may be difficult to detect. Near 70 mb synoptic disturbances are likely to mask long period variations whilst at 10 mb a lack of daily observations can cause the monthly means to be less reliable.

Monthly mean meridional winds were analysed using the three unitary filters described previously and the results are presented in Table III. Amplitudes of the significant periodicities are shown as before.

TABLE III. Results of the application of a set of unitary filters to monthly mean meridional wind data. (Amplitudes are in ms^{-1})

(a) Average period = 27 months

	Percentage variance (amplitude)				
	70 mb	50 mb	30 mb	20 mb	10 mb
Gan	12(0.5)	36(1.0)	41(1.3)	10(1.0)	14(1.3)
Ascension	8(-)	4(-)	5(-)	3(-)	5(-)
Canton	-	6(-)	6(-)	-	-

(b) Average period = 12 months

Gan	36(0.9)	21(0.7)	6(-)	51(2.1)	17(1.6)
Ascension	12(0.4)	5(-)	25(0.7)	17(0.7)	14(1.1)
Canton	-	14(0.5)	8(-)	-	-

(c) Average period = 6 months

Gan	4(-)	1(-)	5(-)	1(-)	4(-)
Ascension	8(-)	6(-)	6(-)	17(0.6)	21(1.1)
Canton	-	4(-)	1(-)	-	-

At Gan a QBO is particularly evident at the 50 mb and 30 mb levels, with amplitudes of 1.0 ms^{-1} and 1.3 ms^{-1} respectively. The F-test indicates significance at the 1% level for the 50 mb, 30 mb and 10 mb levels and at the 5% level for 70 mb and 20 mb. No similar periodicity was found at any level in the data for Ascension and Canton. Although the amplitudes for the meridional QBO at Gan are small Figs 4a, b do indicate an oscillation with a period similar to that of the QBO in zonal wind, whilst Fig 5 does suggest a downward phase progression.

For the annual wave all pressure levels were significant at the 1% level except 30 mb at Gan and Canton and 70 mb and 50 mb at Ascension. Amplitudes at Gan are generally larger than those calculated for Ascension but only reach 2 ms^{-1} at 20 mb. A semi-annual wave was only apparent at 20 mb and 10 mb at Ascension.

5. Discussion

Gan is situated within 80 km of the equator and thus the results presented here provide information about stratospheric winds in the immediate vicinity of the equator. It has been found that:-

- (i) amplitudes of the zonal wind QBO near the equator are in close agreement with those of previous authors^{9,10} and that the largest amplitudes occur at the two stations nearest the equator, particularly above 50 mb.
- (ii) the westerly phase of the zonal wind QBO is more persistent and strongest at Gan and Canton Island.
- (iii) the annual wave of the zonal component only provided a significant contribution to the total variance at the 70 mb level at Ascension Island.
- (iv) a semi-annual wave in the zonal component was not apparent at any level at any of the stations investigated.
- (v) there appears to be a significant QBO in the meridional component at Gan at the 50 mb and 30 mb levels although amplitudes are small ($\sim 1 \text{ ms}^{-1}$).

Fig.6 shows the phase correspondence of the filtered zonal and meridional components at 30 mb at Gan. A comparable oscillation was not found at the other two stations although Groves⁷ has previously shown a similar phase correspondence up to 40 km using combined Fort Sherman and Ascension Island data. Fig.6 further illustrates agreement with Groves in that it suggests flow towards the poles during the westerly phase and towards the equator during the easterly phase of the zonal QBO.

The existence of a QBO in meridional wind is not generally consistent with the results of other authors and neither is the phenomenon explained by current theory. However, it is unlikely that instrumental error would cause such results particularly

as they are not repeated at levels other than 50 mb and 30 mb. Further investigation into stratospheric wind data from stations very close to the equator (e.g. Singapore) may be worthwhile.

Acknowledgements

I would like to thank Mr R A Ebdon for providing the daily observation data from Canton Island.

References

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APPENDIX

Wind speed and direction data used in this memorandum was extracted from a variety of sources and is now held on magnetic tape as daily values. A separate tape exists for each of the three stations and contains data at the 70, 50, 30, 20 and 10 mb levels. Monthly mean values of wind components are held on cards whilst the daily values of wind speed and direction, wind components and monthly means at the five levels are held in computer print-out form.

Data Summary

1. Canton Island (1954-1967)

Most of the data was originally extracted by Met O 13 staff from New Zealand Daily Weather Bulletins and U.S. Daily Series Synoptic Weather Maps Pt.II; it covers the period January 1954-September 1967. Until the end of 1958 observations were made at 0300Z and 1500Z but thereafter were at 0001Z and 1200Z. Two datasets have been produced, one for data at or near 00Z and the other for data at or near 12Z. Data at 00Z is primarily for the 50 mb and 30 mb levels but observations at 70, 20 and 10 mb are included from July 1965-September 1967. Data for 12Z is at 50 mb only.

2. Ascension Island (1962-1976)

The majority of the data was extracted from microfilm held in the Meteorological Office Library although the most recent data was taken from COSMOS upper air data listings supplied to the Stratospheric Analysis Group. The period of data is from January 1963 onwards.

3. Gan (1964-1975)

All data was extracted from the British DAR series and is for the period from May 1964-December 1975.

Dataset Information

Each dataset contains the daily values of wind speed and direction, written unformatted, one year at a time. The datasets are held on three, 9-track 1600 BPI tapes with standard labels as follows:-

Canton Island:-

1. DSN = M19.ACANT.UW.Y54
LABEL = (1,SL)
DCB = (RECFM=VSB,BLKSIZE = 14972)
2. DSN = M19.ACANT.T12Z
LABEL = (2,SL)
DCB = (RECFM=VSB,BLKSIZE=3068)

Ascension Island:-

DSN = M19.AI.UW.Y63
LABEL = (1,SL)
DCB = (RECFM=VSB,BLKSIZE=14972)

Gan:-

DSN = M19.AI.UW.Y6405
LABEL =)
DCB =) as for Ascension Island

Each years data is written as follows:-

- (i) a four byte integer containing the year
- (ii) an alphanumeric array of heading data written as 20, four-byte variables.
- (iii) a three-dimensional array (REAL*4) of dimensions (12, 5, 31) containing wind direction data. (NB Canton Island data at 12Z is a two-dimensional array (12, 31)).
- (iv) a three-dimensional wind speed array with dimensions as for wind direction.

All four items listed above were written to tape with a single write statement.

A typical program to retrieve data would be:-

```
DIMENSION NB(20) D(12,5,31),S(12,5,31)
```

```
READ(8)IYR,NB,D,S
```

```
.
```

```
.
```

```
.
```

```
Process data
```

```
.
```

```
.
```

```
.
```

```
STOP
```

```
END
```

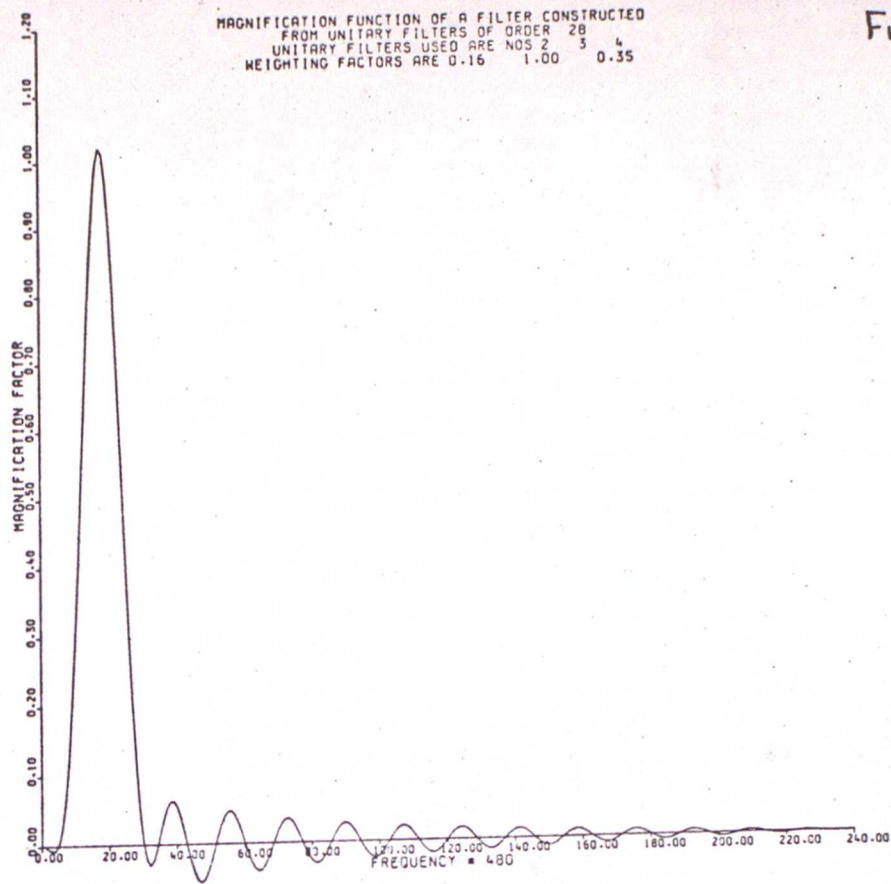



Fig 1(a)

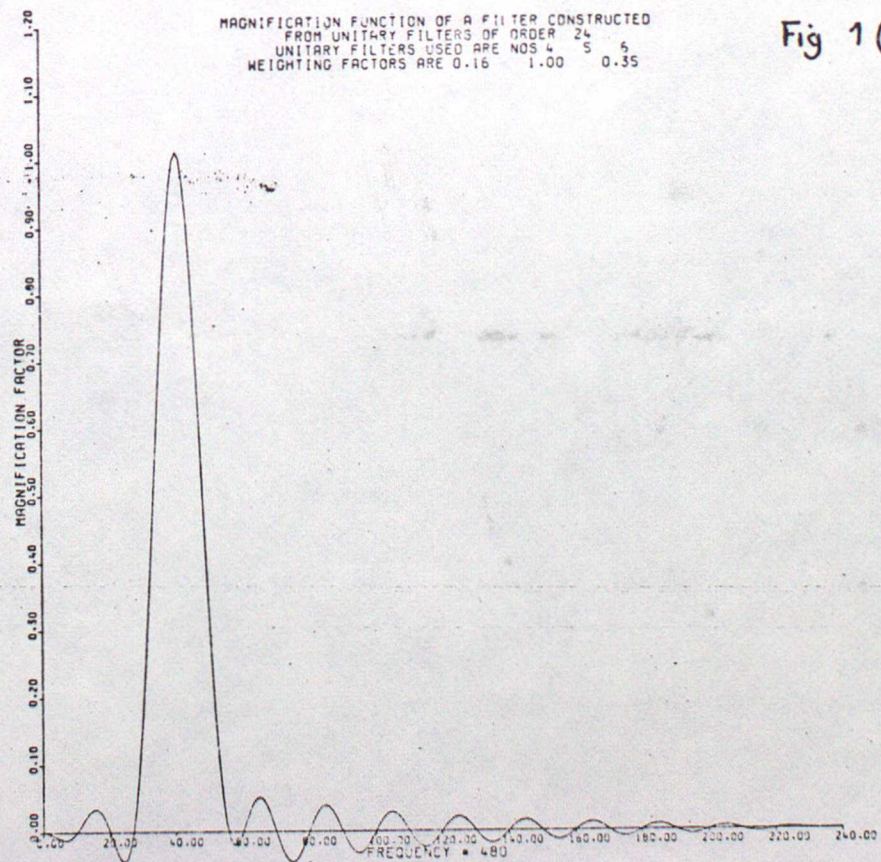
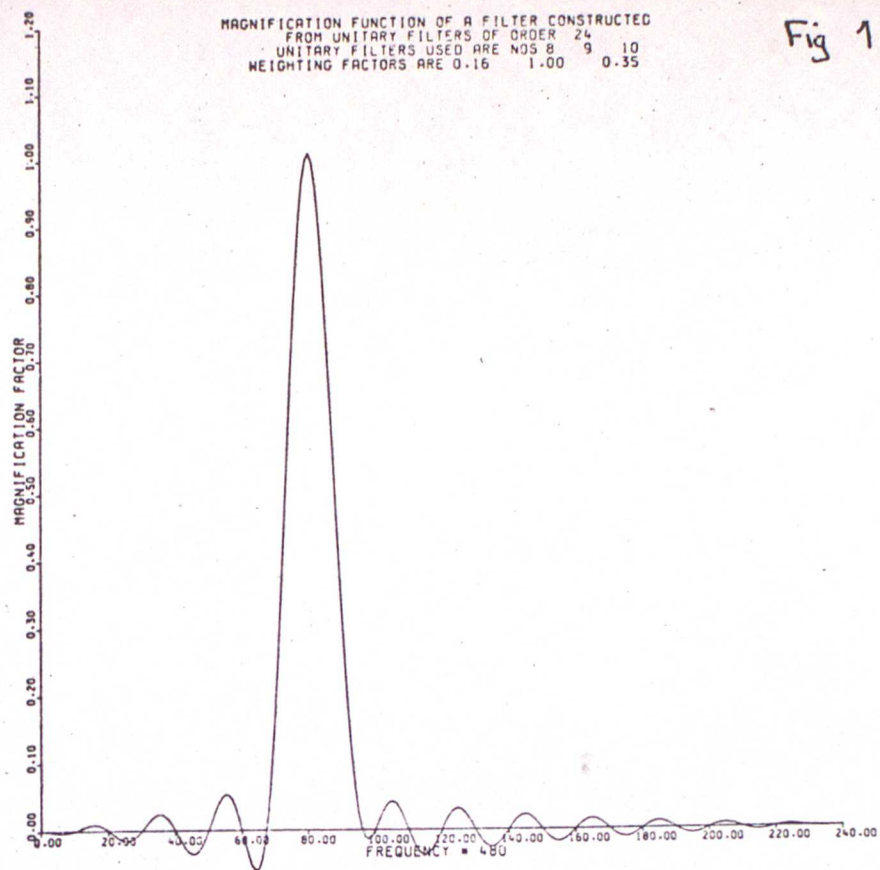


Fig 1(b)

MAGNIFICATION FUNCTION OF A FILTER CONSTRUCTED
FROM UNITARY FILTERS OF ORDER 24
UNITARY FILTERS USED ARE NOS 8 9 10
WEIGHTING FACTORS ARE 0.16 1.00 0.35

Fig 1(c)



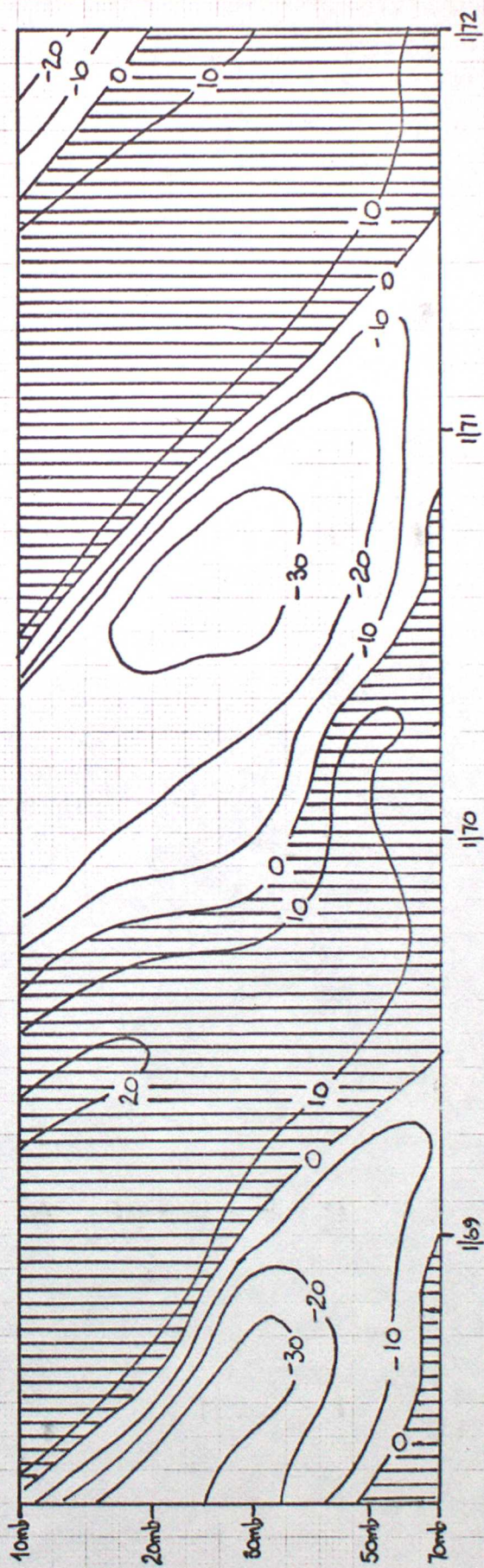
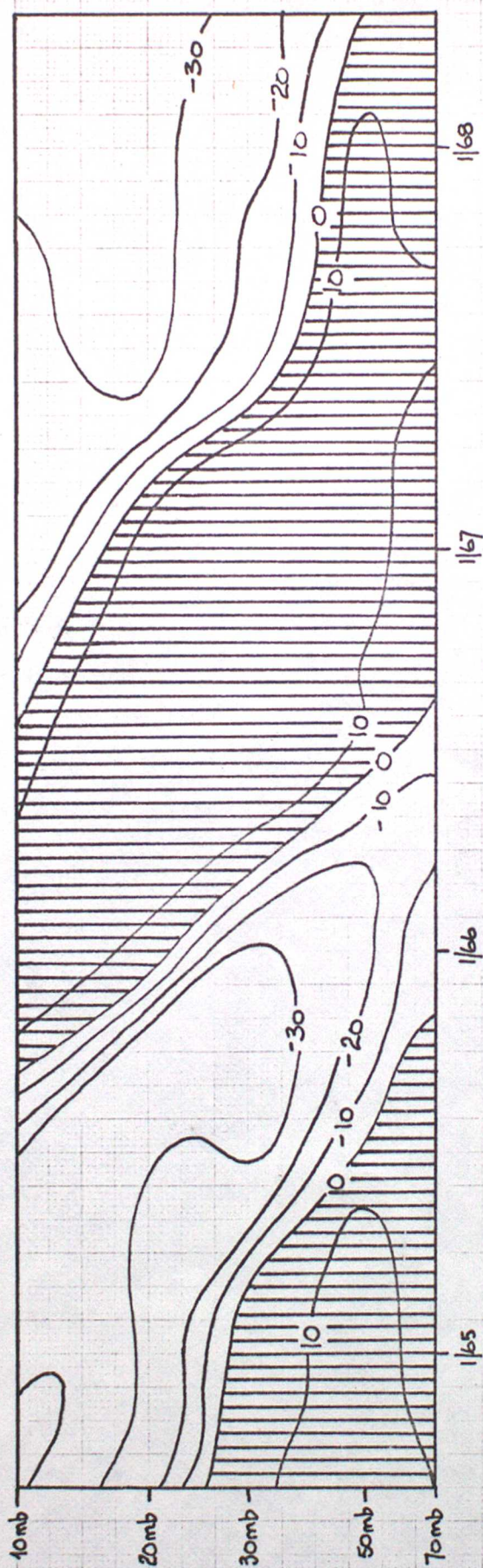


FIG 2(a). Cross-section of the zonal wind component at Gan, 70mb-10mb, September 1964 - September 1975, in m s^{-1} (Hatched areas represent winds from the west)

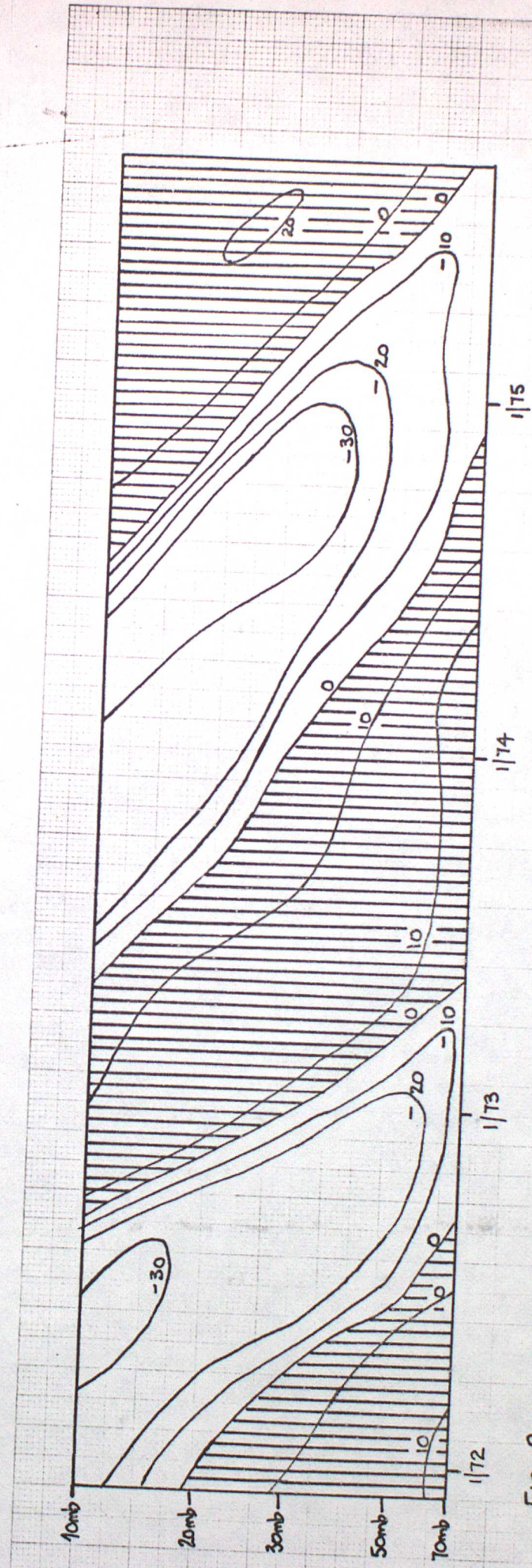


Fig. 2(a) Continued.

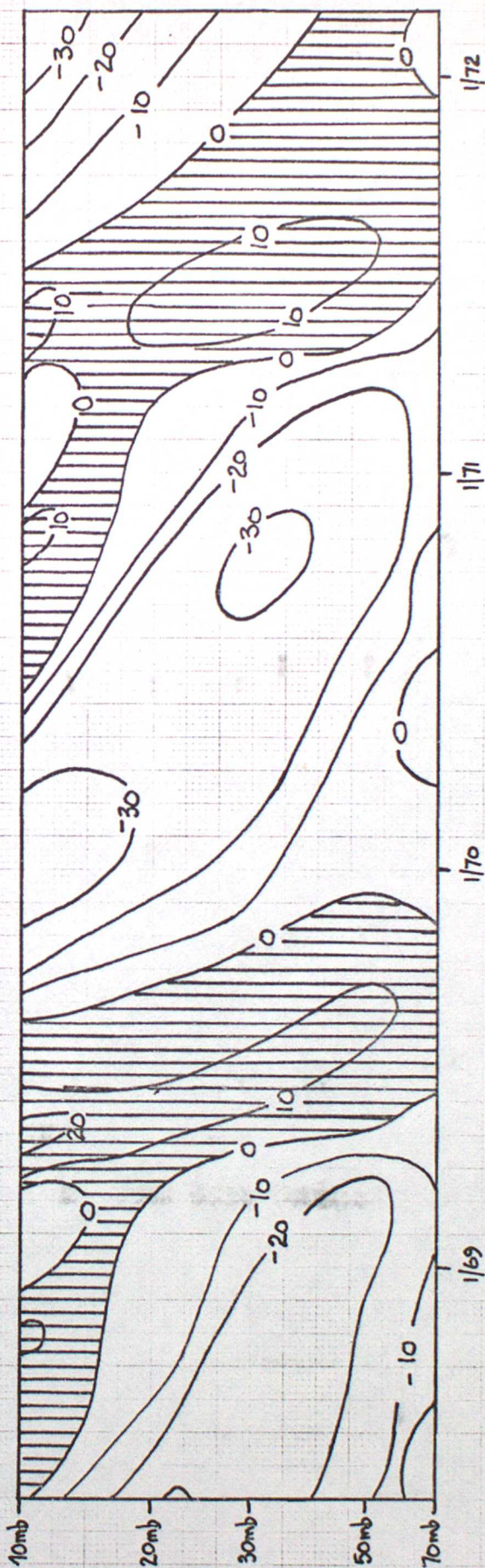
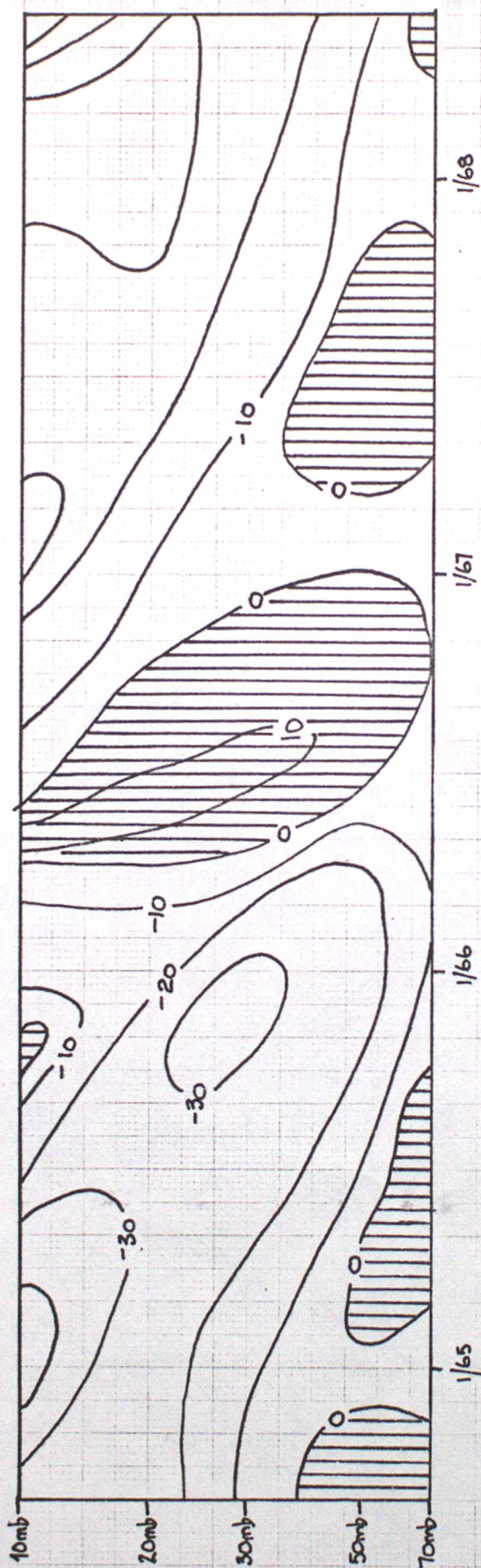


FIG. 2(b). Cross-section of the zonal wind component at Ascension Island, 70mb-10mb, September 1964 - September 1975, ms^{-1} (Hatched areas represent winds from the west)

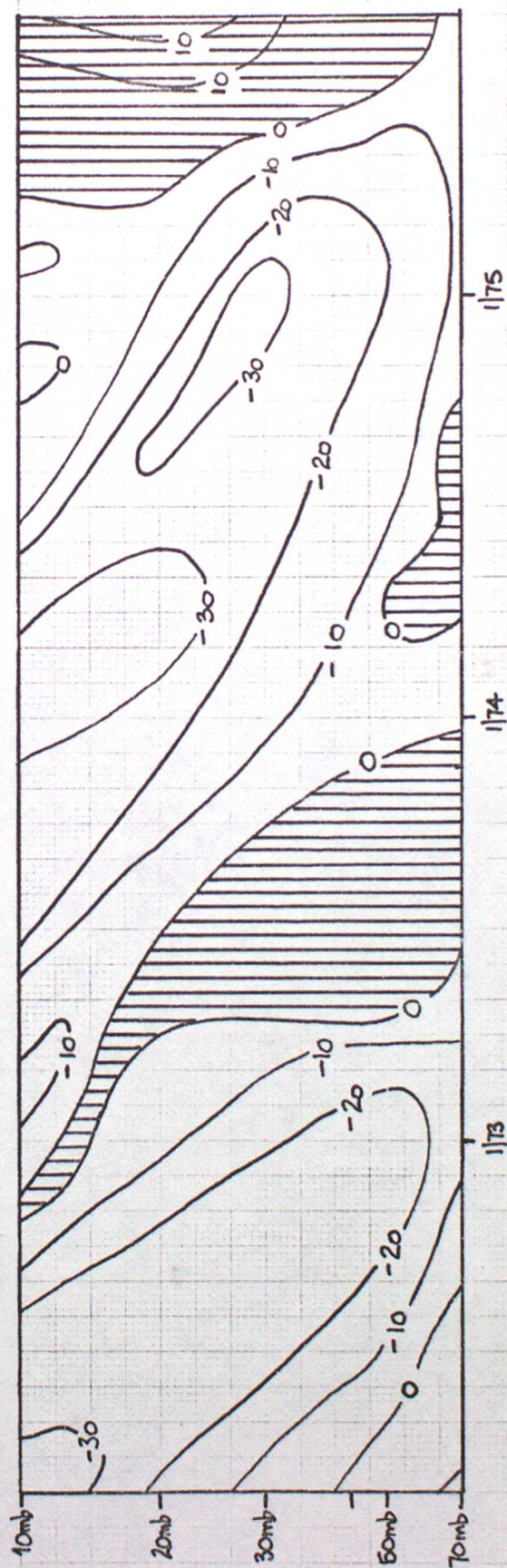


Fig. 2(b) Continued.

FIG. 3

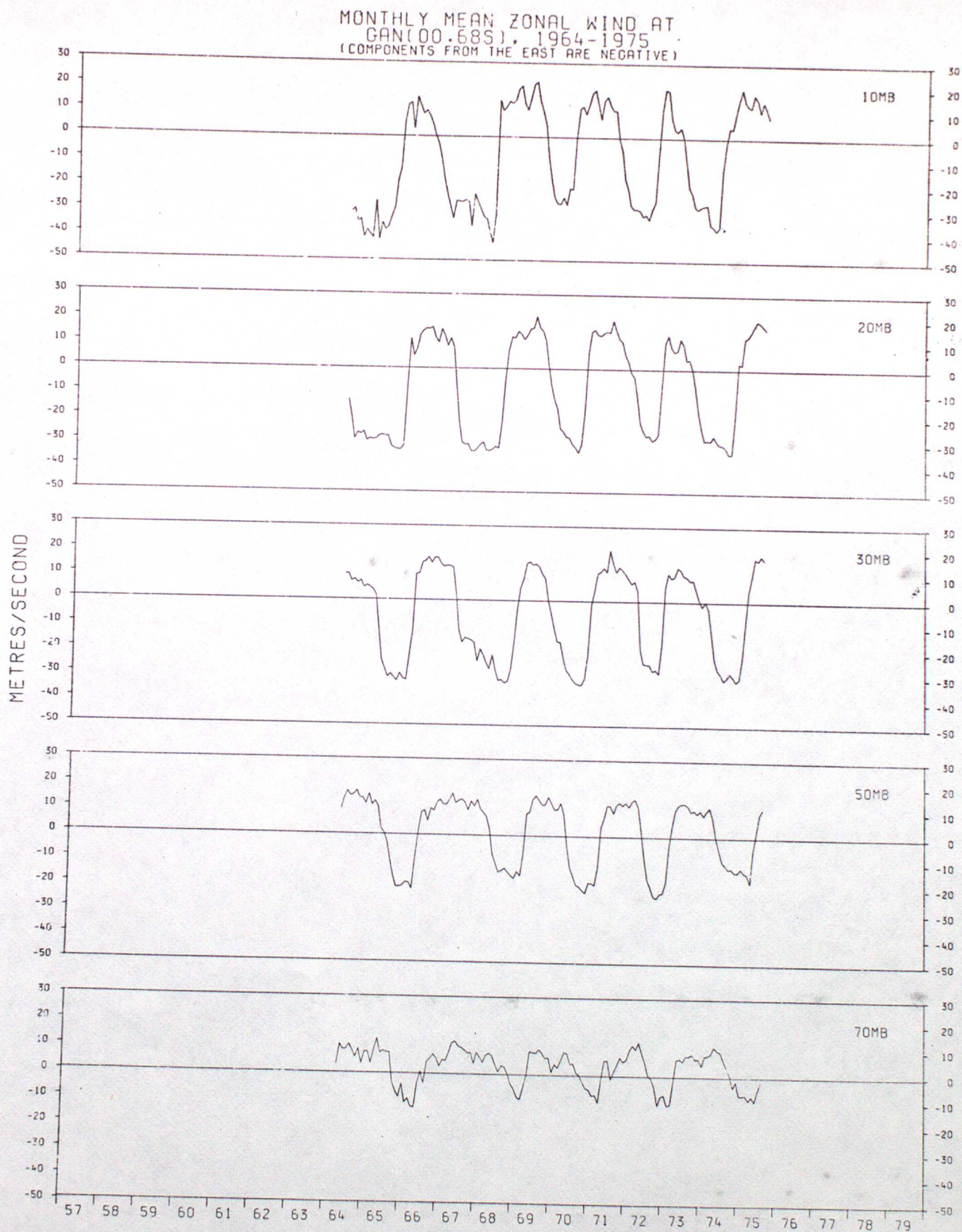


FIG 4(a) MONTHLY MEAN MERIDIONAL WIND AT SOMB FOR
CAN(00.68S). 1964-1975
(COMPONENTS FROM THE NORTH ARE NEGATIVE)

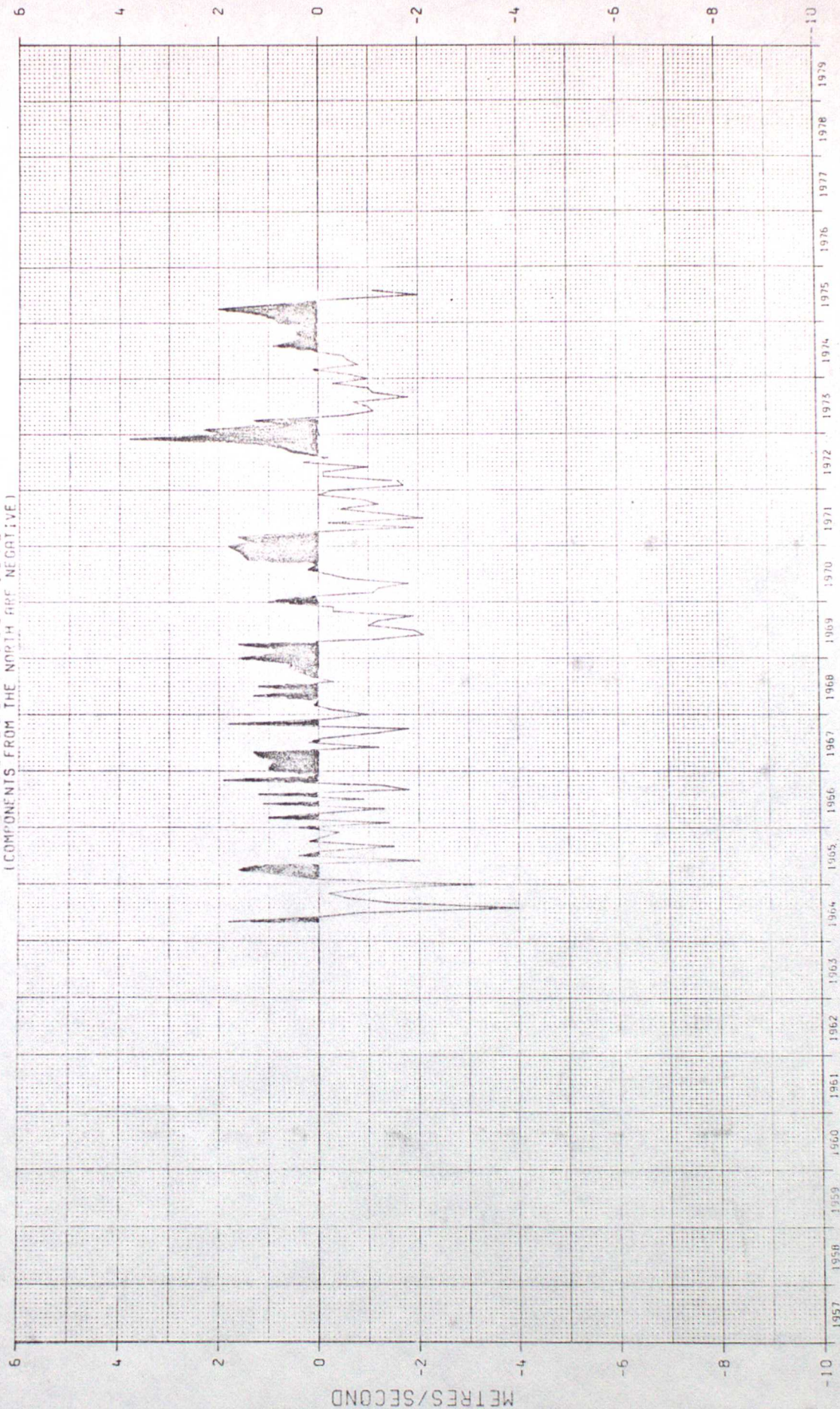
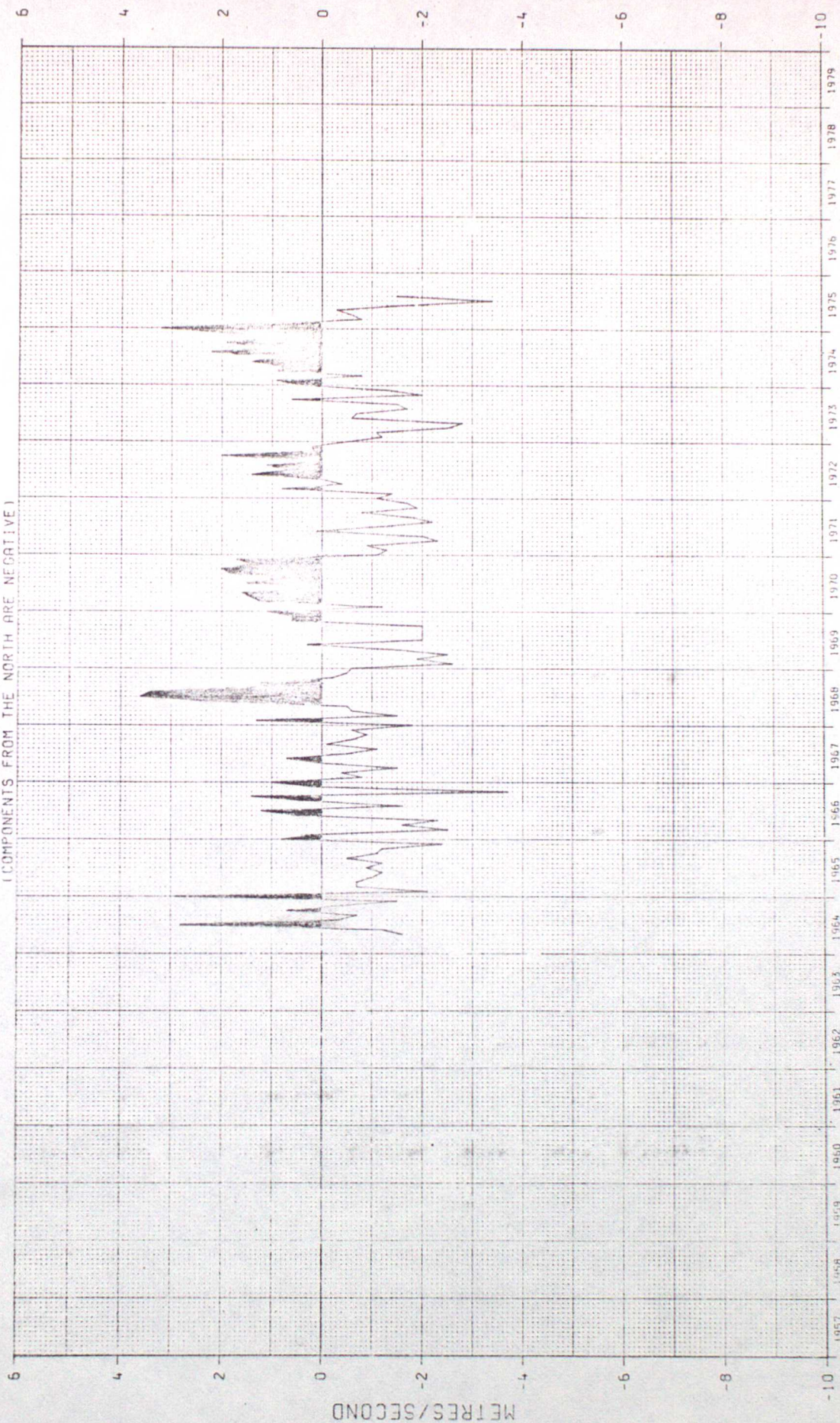


FIG 4(b) MONTHLY MEAN MERIDIONAL WIND AT 30MB FOR
 GAN(00.68S), 1964-1975
 (COMPONENTS FROM THE NORTH ARE NEGATIVE)



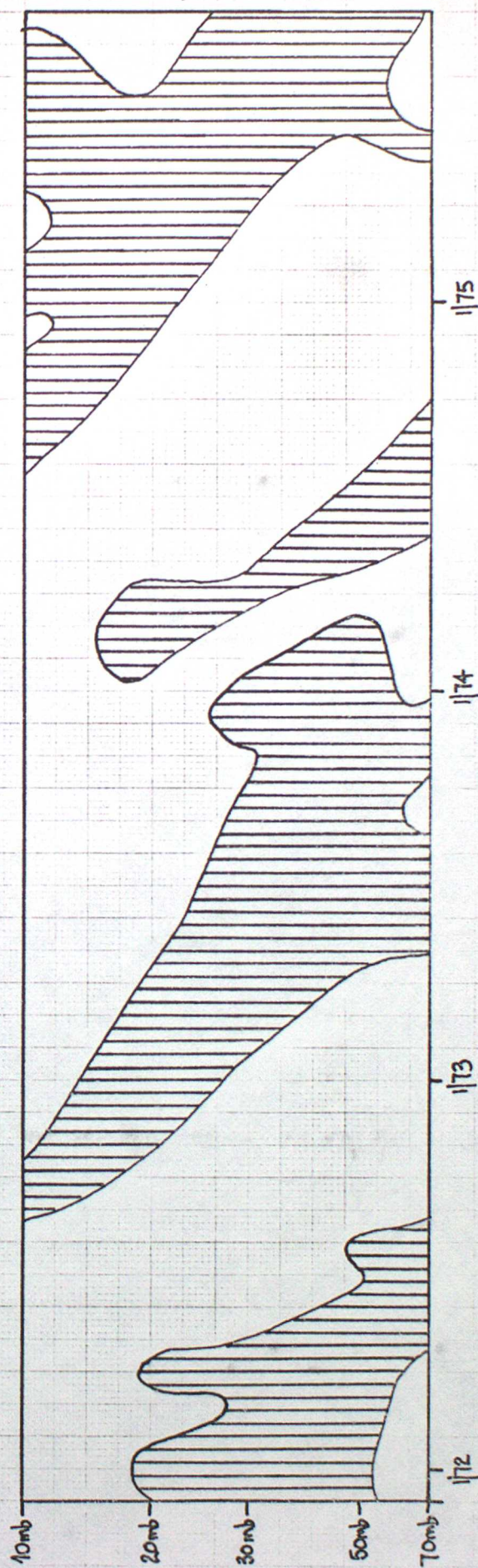
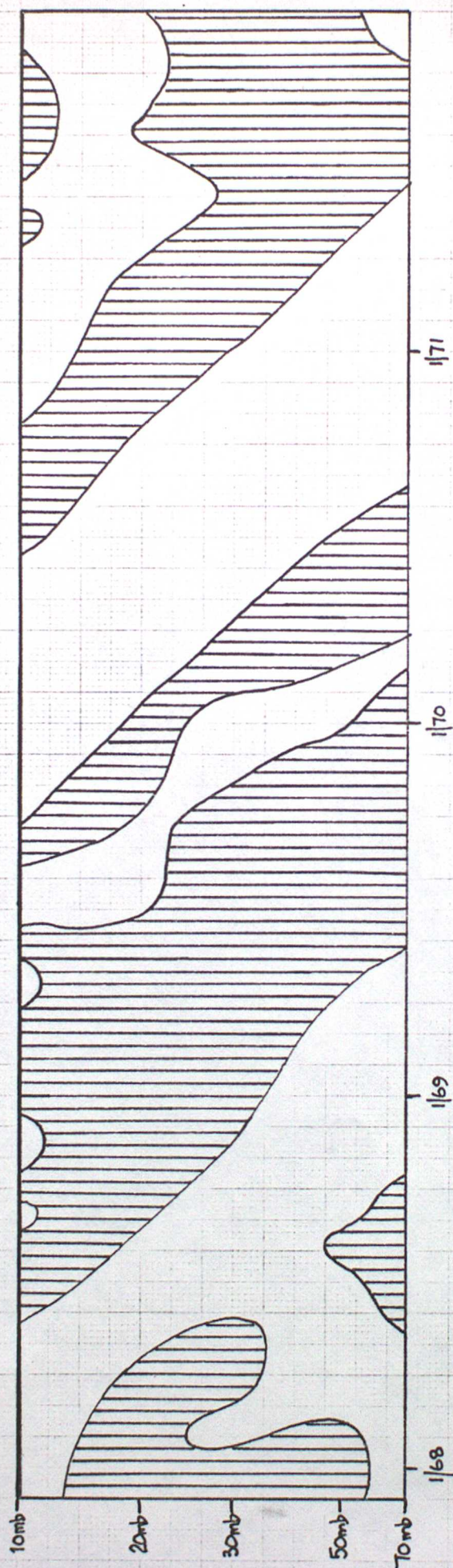


FIG. 5. Cross-section of meridional wind component at 60m, 70mb-10mb, November 1967-October 1975, in ms^{-1} (Hatched areas are winds from the north)

FIG. 6 FILTERED VALUES OF ZONAL AND MERIDIONAL WIND SPEED AT 30MB FOR GAN

