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DARWIN TROPICAL DIAGNOSTIC STATEMENT

MARCH 1988

ISSUED BY DARWIN RMC

The Southern Oscillation Index (SOI) has continued its gradual rising trend of the past 11 months. It was +1 for this month, the first positive value for SOI since October 1986. The Darwin MSL pressure anomaly was -0.8 hPa, the first negative value since August 1986. Only one cyclone formed in the Southern Hemisphere during the month with two others persisting from February. Two monsoon depressions significantly affected the Australian continent late in the month.

INDICES

1. Darwin mean MSL pressure March 1988: 1006.8 hPa
   pressure anomaly (1882-1985 mean): -0.8 hPa
2. Tahiti mean MSL pressure March 1988: 1011.2 hPa
   pressure anomaly: -0.5 hPa
3. Troup's Southern Oscillation index: +1
   5-month mean (centred upon January): -3

4. Troup's SOI for the last 27 months:

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
1986	7	-12	0	1	-6	8	2	-7	-5	6	-13	-16
1987	-7	-14	-15	-22	-20	-18	-18	-13	-11	-6	-1	-6
1988	-2	-6	+1									

Graphs of the monthly SOI and the five month running mean SOI for the past ten years are given in figure 1. The gradual rise out of the ENSO event of 1986/87 is clearly evident.

TROPICAL CYCLONES

Unofficial tropical cyclone tracks are shown in figures 3 (a) and 3 (b).

Both tropical cyclones "Charlie" and "Bola" formed over the Southwest Pacific region late in February and continued into the early part of this month.

Tropical Cyclone "Charlie" intensified to severe status close to the Queensland coast on the 1st March. However, it was downgraded to a tropical depression by the 2nd as it moved slowly inland.

Severe Tropical Cyclone "Bola" reached maximum intensity near the southern islands of Vanuatu on the 2nd as it progressed in a general east to southeast direction. The system gradually decreased to below severe strength during the next two days and then on the 4th made the transition to a cold cored circulation. The resulting deep depression moved on a meandering track to the south and southwest, passing just to the north of New Zealand, causing widespread flooding and the loss of several lives.

Tropical Cyclone "Gasitao" formed over the Southern Indian Ocean on the 16th and moved steadily west-southwest. The system intensified to severe status as it recurved to the southeast over the following few days. Maximum intensity was reached on the 21st after which the system moved in a general southerly direction. Subsequently tropical cyclone "Gasitao" gradually weakened and was downgraded to an extra-tropical depression during the 23rd.

MONSOON DEPRESSIONS

Figure 3 (c) shows the unofficial tracks of two monsoon depressions which significantly affected a large area of the Australian continent late in the month.

The first monsoon depression formed over the Arafura Sea northeast of Darwin and moved in a southwest direction, passing Darwin during the 27th. As shown in Fig. 10(a) this was associated with a monsoonal burst at Darwin. This system then recurved over the Joseph Bonaparte Gulf and moved generally south and then southeastward across central Australia, passing very close to Alice Springs on the 30th.

The second monsoon depression formed over the southern Indian Ocean (Figure 3(c) commences the track from the 27th). This system was rather deep and moved generally east to southeastward before weakening well inland. It caused gales about the northwest coast and flood rains over northwest Australia as it moved slowly inland. The cloudband associated with this system sheared to the southeast and combined with the first monsoon depression causing flood rains over central and (in early April) eastern Australia, and the loss of several lives.

SEA SURFACE TEMPERATURE

The mean sea surface temperature and anomaly fields for March are shown in figures 4 and 5.

The entire region was dominated by warm anomalies with maxima over the southeastern Indian Ocean, the eastern Bay of Bengal and between Japan and the Philippines. Changes from February were only slight, the most notable being the weakening of cold anomalies over the Northwest Pacific along 20^{o}N and over the Yellow Sea. Weak negative anomalies developed over the equatorial Pacific.

MSL PRESSURE AND GRADIENT LEVEL FLOW

Mean MSL pressure and anomaly charts are shown in Figures 6 and 7, and the gradient level (950 hPa) streamline and vector wind anomaly charts in Figures 8 and 9.

Southeasterly anomalies dominated the southern hemisphere north of 10^{o}S, reflecting a much weaker than normal northwest monsoon. The high pressure system in the southern Indian Ocean was displaced some 20^{o} longitude further east than its normal position resulting in weaker east to southeast trades and hence westerly anomalies over the central Indian Ocean. Anomalous troughing persisted near the West Australian coast which together with the negative pressure anomalies, reflect a displacement of the trough offshore.

Strong positive pressure anomalies over southeastern Australia and the anomalous southwest to southeast flow at 950 hPa indicate stronger than normal ridging over the region. This correlates well with the mostly below average rainfall over south and east Australia (except for the slightly above average falls along the central east coast).

Southwesterly anomalies persisted over the SW Pacific due to the stronger than normal ridge over southeast Australia and the anomalous troughing over New Zealand.

The anomalous flow over the NW Pacific was due to the replacement of the normal sub-tropical high northeast of Taiwan by a marked trough. The displacement southeastward and weakening of the normal anticyclonic flow, usually located over northern India and the northern Bay of Bengal, caused well below average presssures through this region and west to southwest anomalies to the south of the ridge axis. This explains the above average rainfall about the west coast of India.

850 hPa DAILY MEAN ZONAL AND MERIDIONAL WINDS

Figures 10 (a), (b) and (c) are plots of the 3 day running means of zonal and meridional 850 hPa winds at Darwin along with 24 hour rainfall totals for March.

These figures reflect the retreat of the monsoon trough to the north of Darwin early in the month, followed by a prolonged period of southeasterlies. However the movement of the monsoon trough southward late in the month resulted in a more typical northwest monsoonal flow. Heavy rain on the 28th and 29th was associated with the passage of a monsoon depression (see Fig.3 (c)).

UPPER LEVEL FLOW

The mean 200 hPa streamline and vector wind anomaly charts for March are given in Figures 11 and 12.

The southern hemisphere sub-tropical ridge (STR) was displaced some 5° north of the mean resulting in a generally weaker than normal southeast return flow. The axis of the sub-tropical jetstream (STJ) was located over Queensland and the SW Pacific, north of its mean position and much stronger than normal. Consequently west to northwest anomalies were reflected through this region. The anomalous trough persisted over southwest of West Australia, though it was displaced up to 5° further west.

The strong southwesterly anomalies over most of the northern hemisphere north of 25°N is a reflection of the much larger and stronger than normal STJ.

VELOCITY POTENTIAL

Charts of the velocity potential fields at 950 hPa and 200 hPa for March are given in Figures 13 and 14.

The main area of low level convergence was centred just north of West Irian with axes extending northward to just west of the Philippines and westwards along the equator towards Sumatra.

The axis of the major upper divergent region which was displaced 5° south of the low level convergence maxima,lay over Indonesia just south of the equator (in a similar position to that of February).

WIND CROSS SECTIONS

Cross sections of zonal wind along 100°E, 130°E and 160°E are shown in Figures 15, 16 and 17 respectively; the equatorial cross section of meridional wind in given in Figure 18.

At 100°E stronger low level easterlies were evident along about 8°N, whilst the monsoonal westerlies, in the Southern Hemisphere, weakened.

At 130^{O}E the cross section shows the axis of low-middle level monsoonal westerlies near 5^{O}S. The upper and middle level easterlies near the equator have weakened considerably since February.

The latitudinal cross section shows the weak and variable cross equatorial flow at low levels. However a good southerly component of the flow was evident at upper levels particularly near 100^{O}E and east of 160^{O}E.

RAINFALL

Monthly rainfall quintiles for selected stations in March are given in Fig.2.

The Australian continent received well above average falls over northwest and central parts due mainly to the passage of monsoon depressions mentioned previously. Well below average falls continued over southwest parts of West Australia and southeast Queensland.

The data in equatorial latitudes, though sparse, suggest above average rainfall at east occurred over parts of Malaysia and Indonesia. This could be due to its close proximity to the low level convergent and upper level divergent maxima. Below average rainfall over much of the Southwest Pacific is related to the northward displacement of the upper outflow and the consequently stronger than normal upper westerlies through the region. The only exceptions being the Vanuatu islands and New Zealand, where above average rainfall was caused by Tropical Cyclone "Bola" or its resulting ex-tropical system.

Above average rainfall occurred over Japan and southeast China in association with the anomalous 950 hPa trough located in the vicinity. The significant deficiences which occurred over parts of inland eastern China and Korea are presumably related to the stronger than normal low level ridging which persisted over the area during the month.

ERRATUM

There was an error in the comments on the 850 hPa Daily Mean Zonal and Meridional winds in the previous issue (February). The comments should have said that "These charts indicate that the month was dominated by a southeasterly flow with two brief periods of southwesterlies one from the 9th to the 13th and the other from the 25th to the end of the month".

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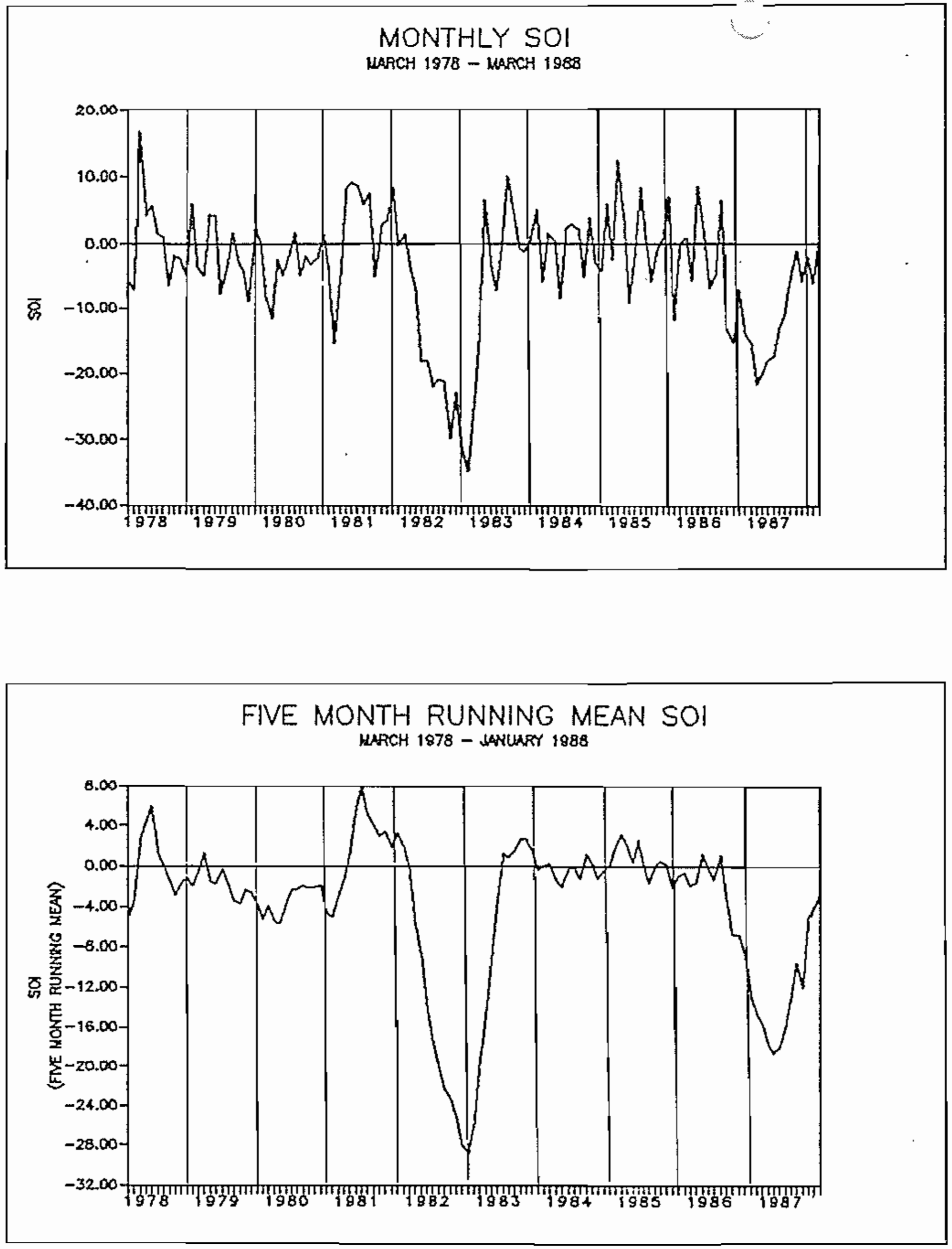


Fig.1 SOUTHERN OSCILLATION INDEX (1978-1988)
Monthly SOI and 5-month running mean SOI

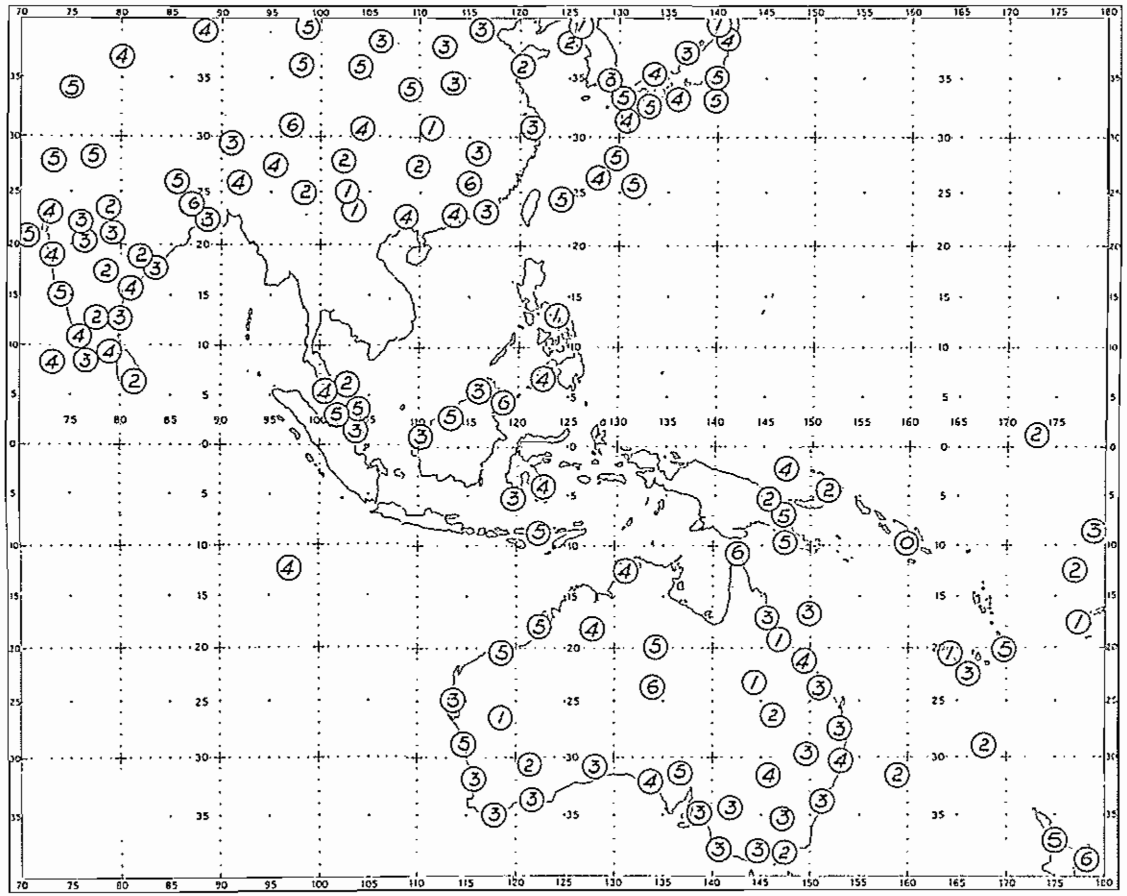


Fig.2 MONTHLY MEAN RAINFALL QUINTILES from selected climat stations (MARCH 1978)

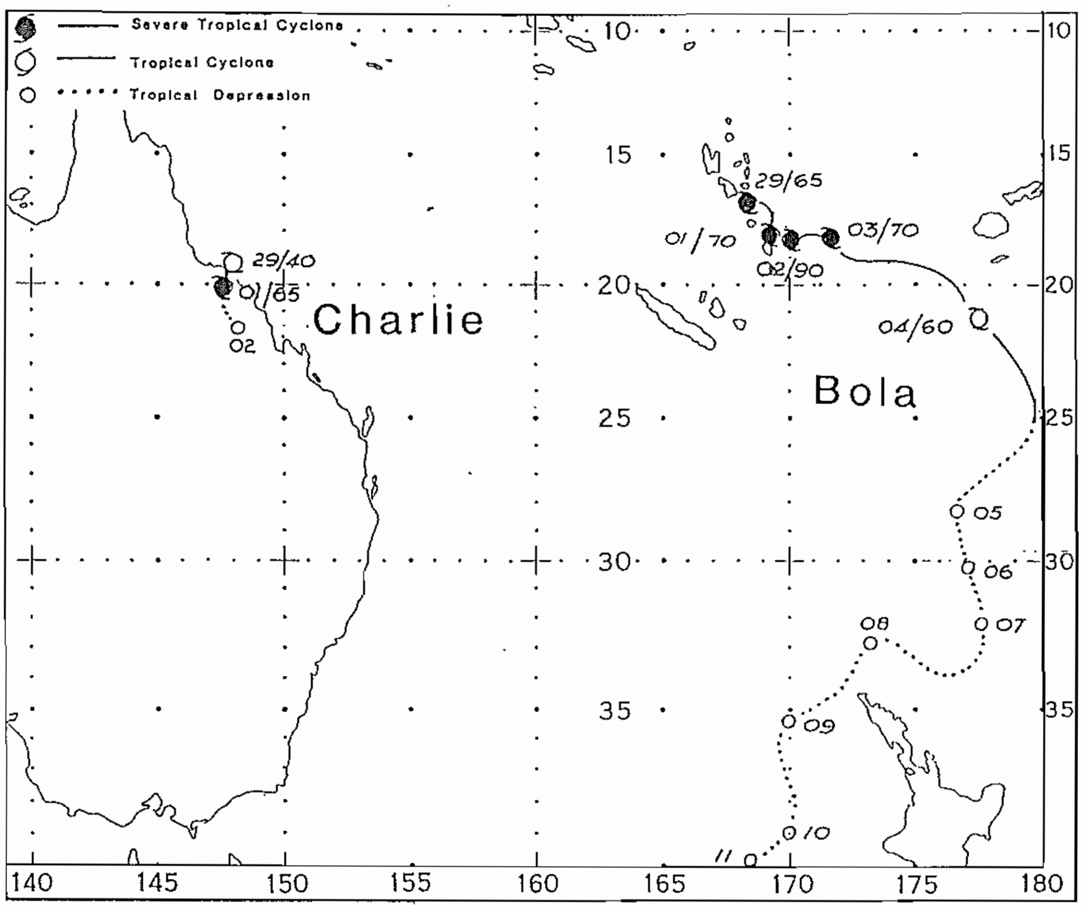


Fig.3(a) UNOFFICIAL TRACKS OF CYCLONES CHARLIE AND BOLA (MARCH 1988)
Date (DD) and maximum sustained wind (ff) in knots denoted by DD/ff.

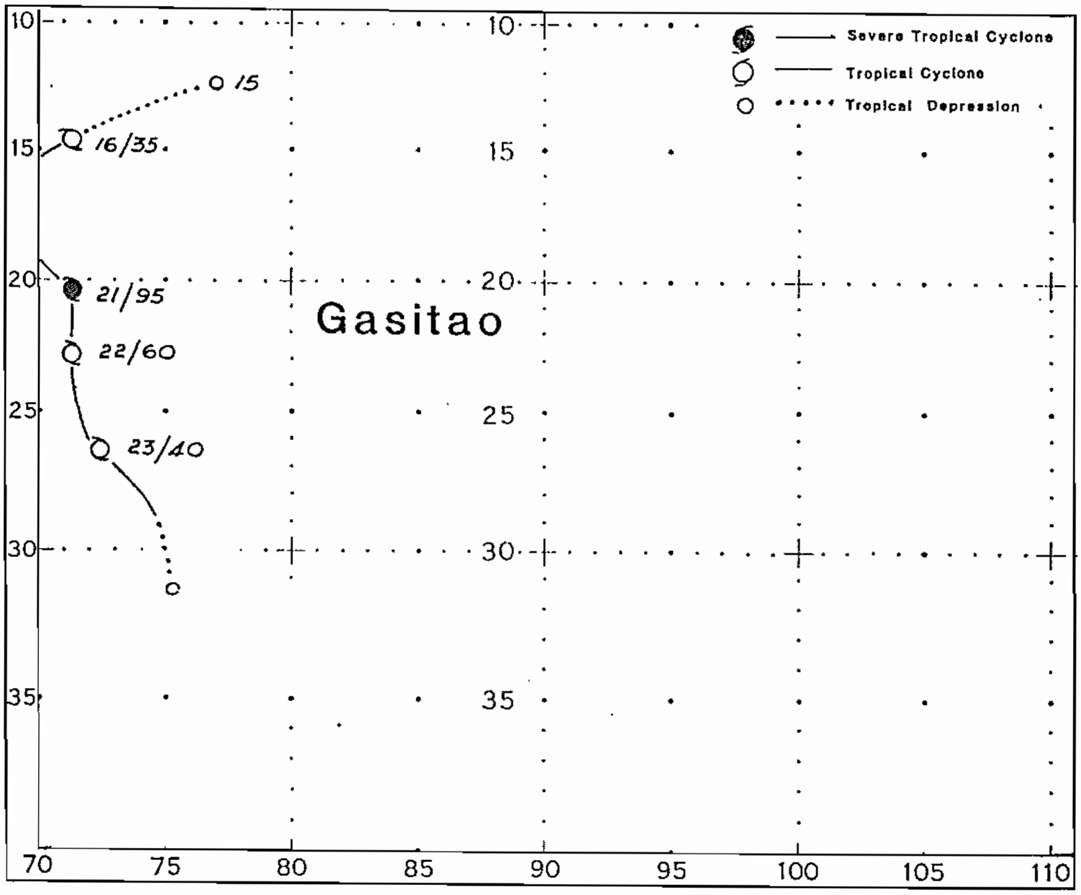


Fig.3(b) UNOFFICIAL TRACK OF CYCLONE GASITAO (MARCH 1988)
Date (DD) and maximum sustained wind (ff) in knots denoted by DD/ff.

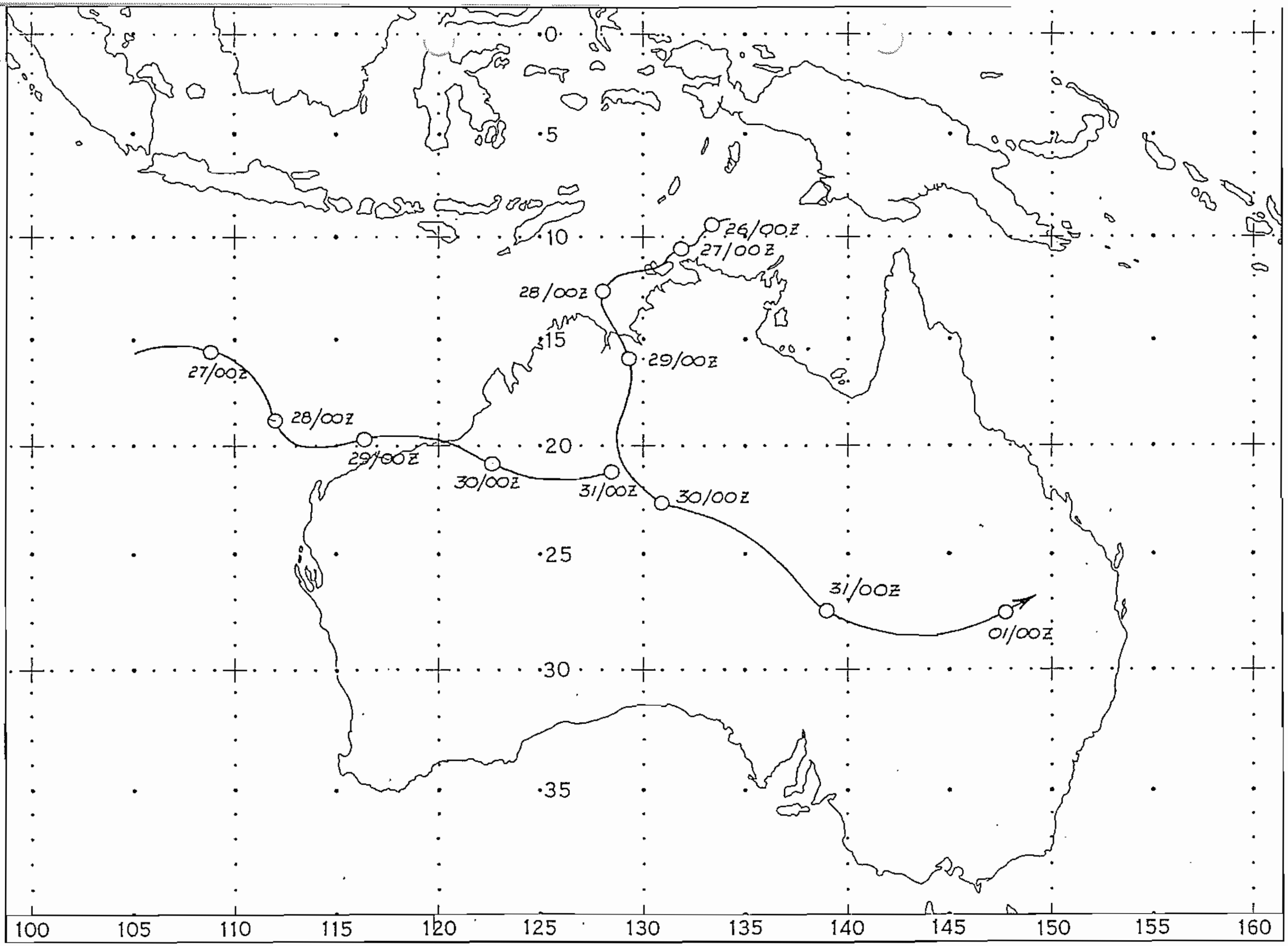


Fig.3(c) UNOFFICIAL TRACKS OF TWO MONSOON DEPRESSIONS WHICH SIGNIFICANTLY AFFECTED THE AUSTRALIAN CONTINENT

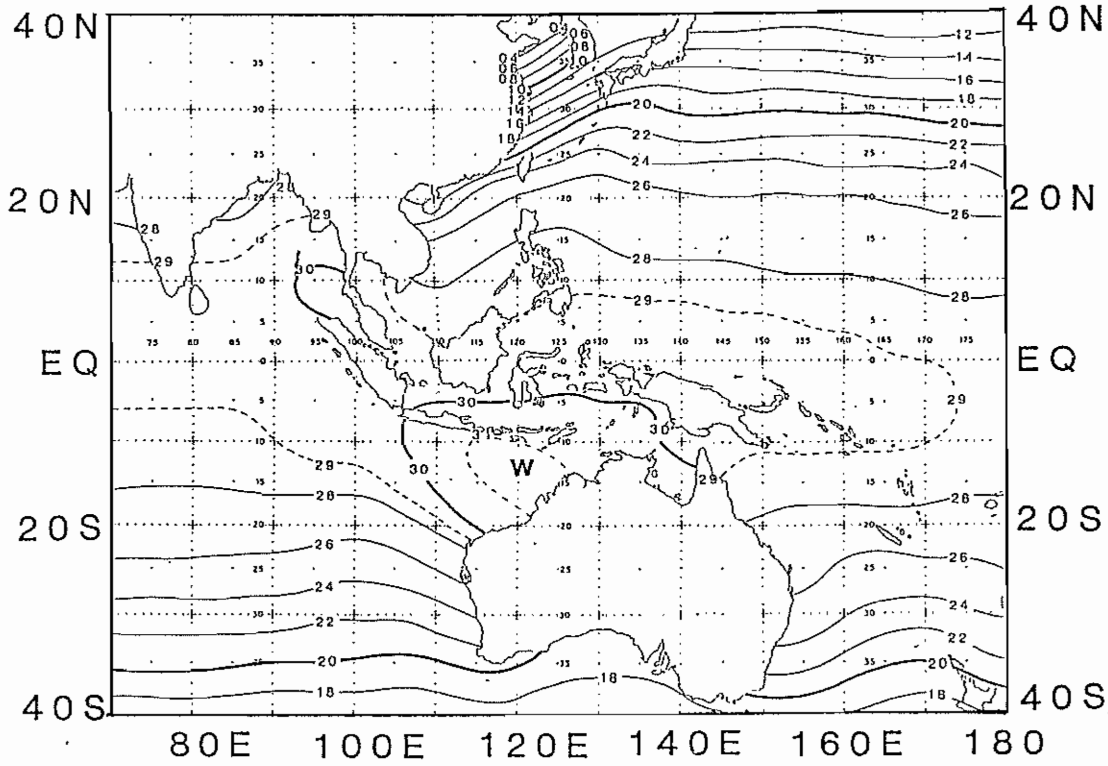


Fig. 4 MEAN SEA SURFACE TEMPERATURES, BASED ON WEEKLY DARWIN RMC ANALYSES AVERAGED OVER THE MONTH, MARCH 1988. Isotherm interval 2° C.

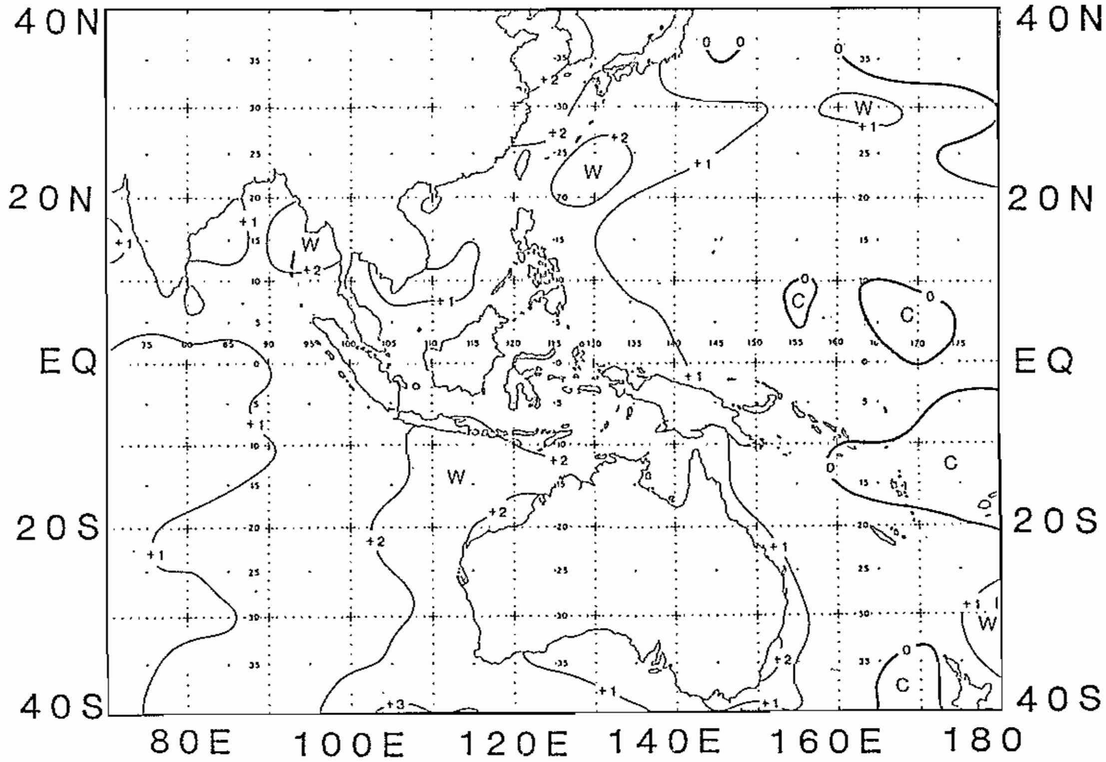


Fig. 5 SST ANOMALY CHART, BASED ON FIG. 4 AND THE CLIMATOLOGY OF REYNOLDS, NOAA REPORT NWS 31, 1983 Isotherm interval 1° C.

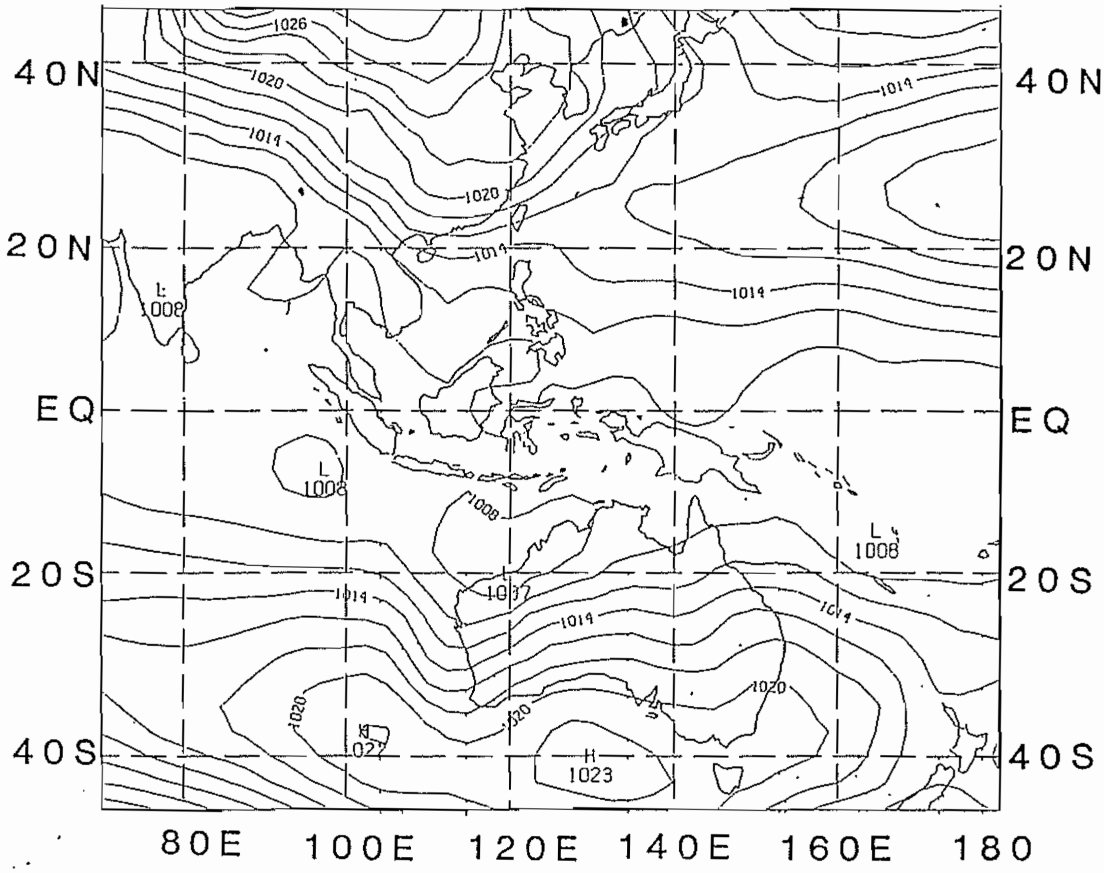


Fig. 6 MONTHLY MEAN MSL PRESSURE, MARCH 1988
Isobar interval 2 hPa

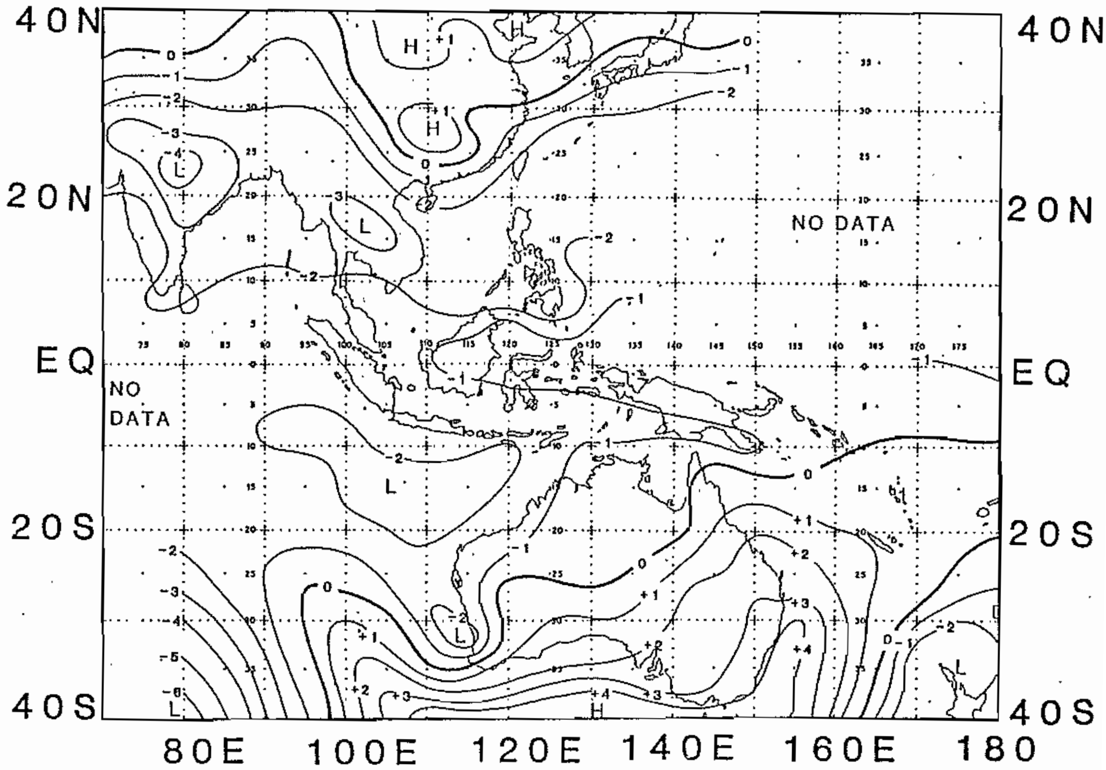


Fig. 7 MSL PRESSURE ANOMALY BASED ON CLIMAT MESSAGES
(AND MELBOURNE WMC DATA SOUTH OF 10^{o}S)
Contour interval 1 hPa.

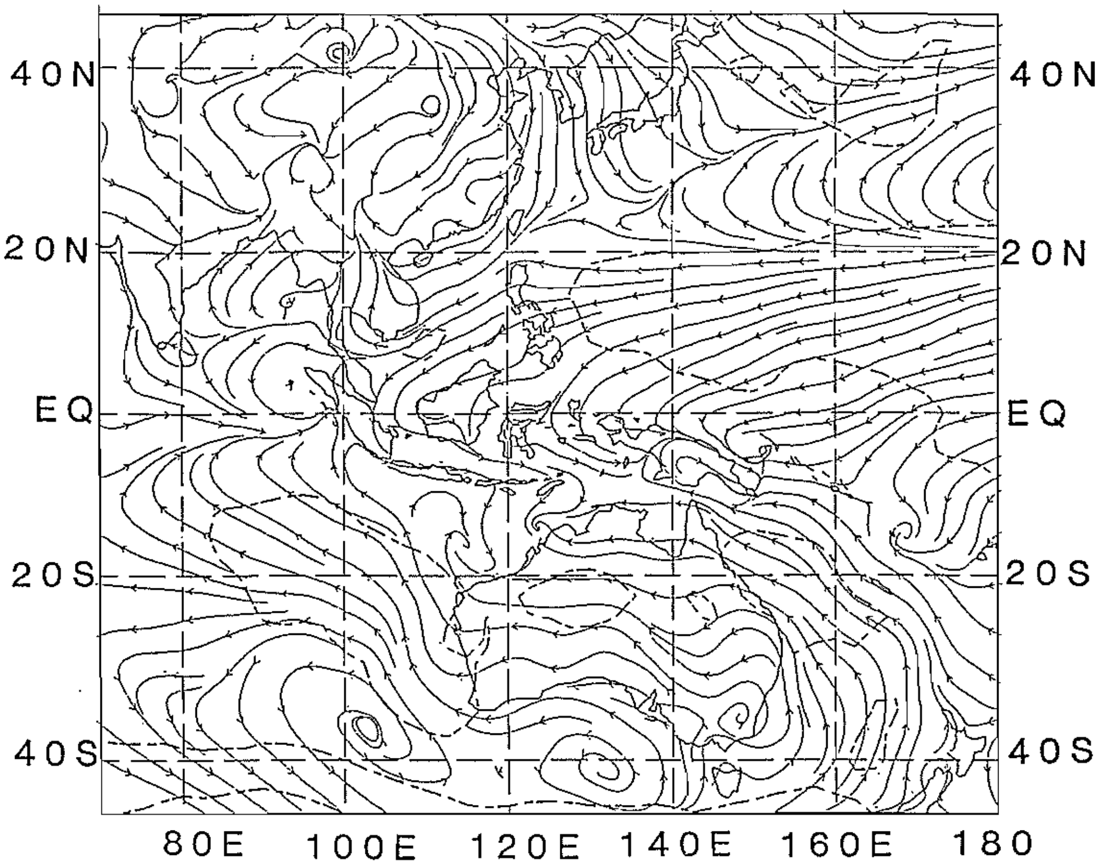


Fig. 8 950 hPa STREAMLINE ANALYSIS, MARCH 1988
Isotachs (dashed line) at 10 knot intervals

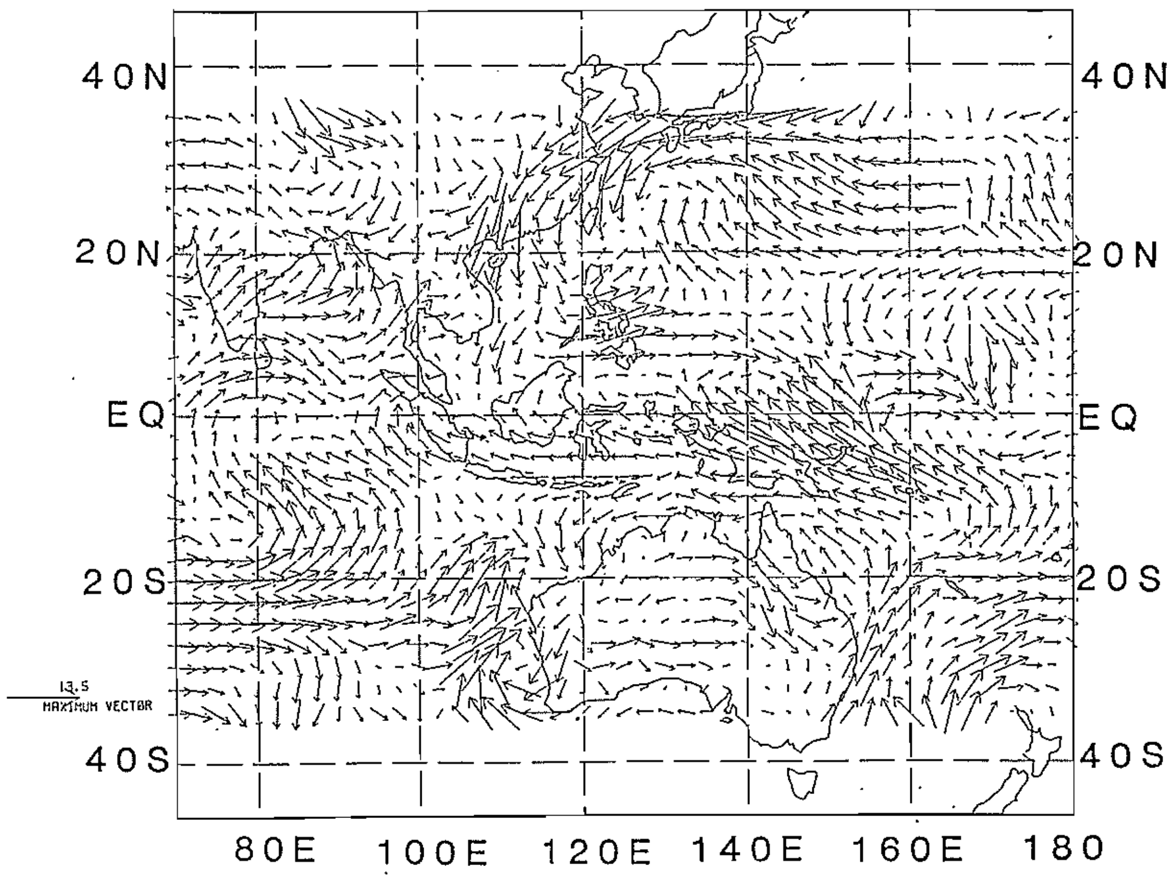


Fig. 9 950 hPa VECTOR WIND ANOMALY BASED ON FIG. 8
(Arrow length indicates magnitude)

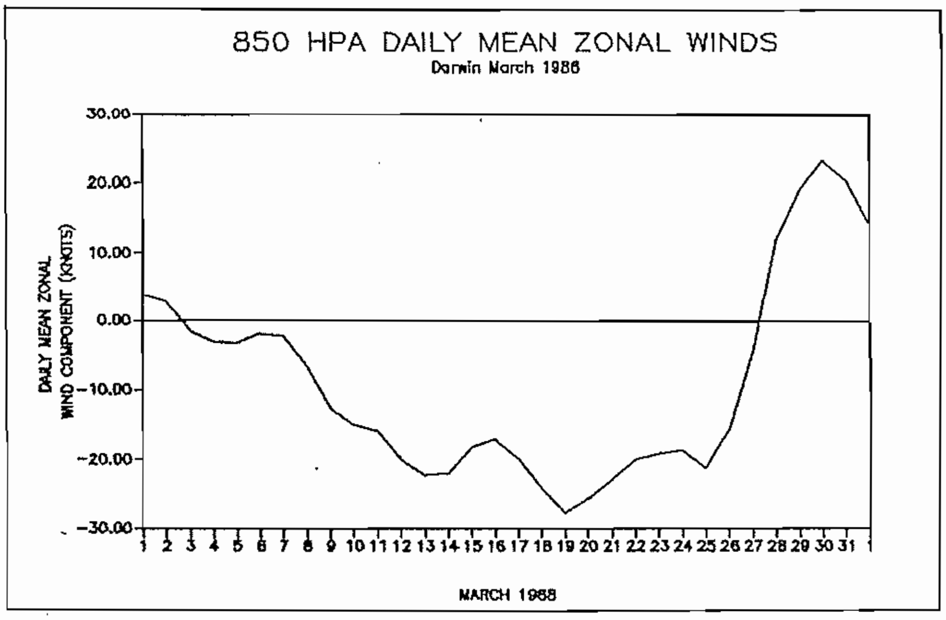
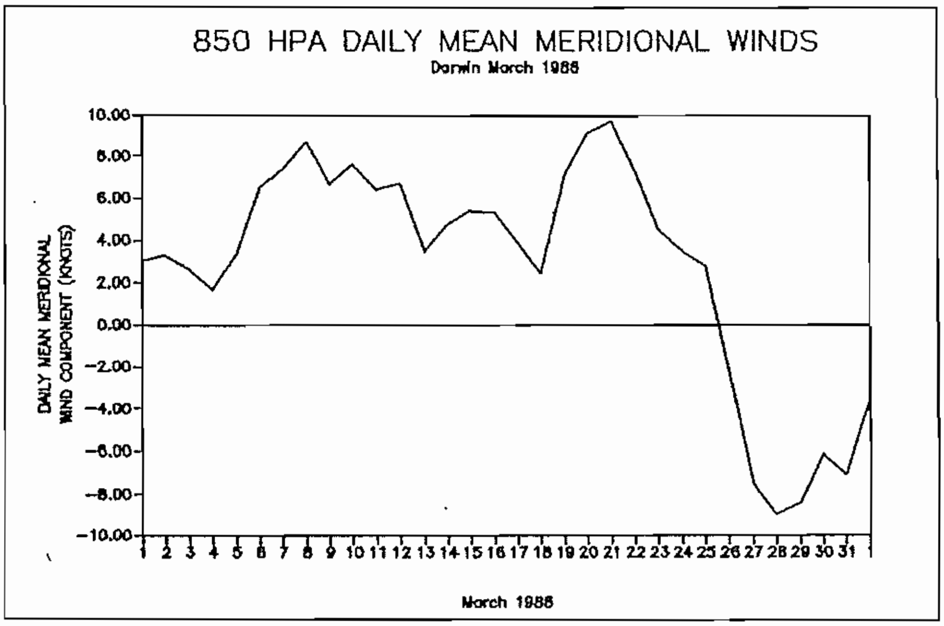
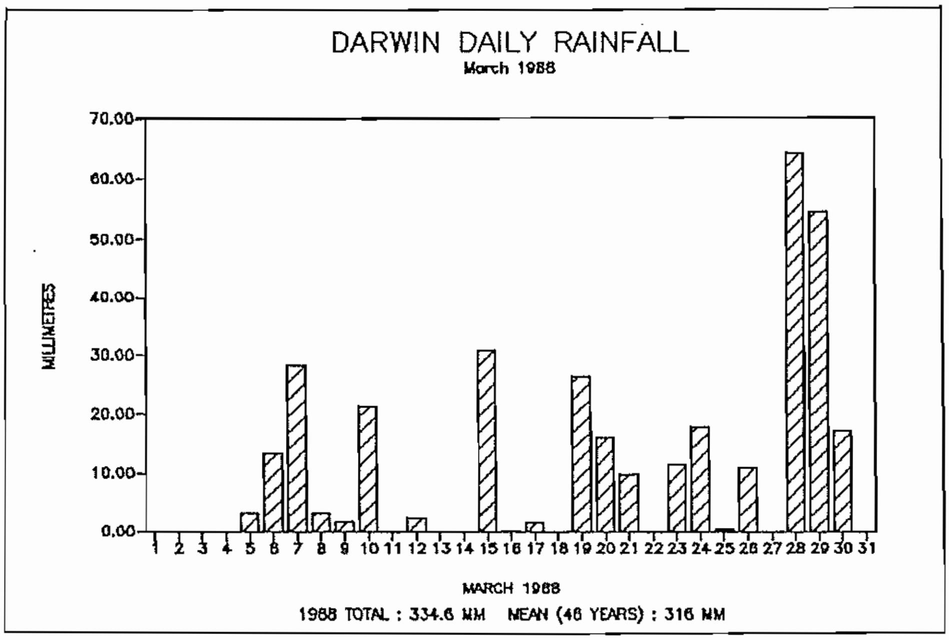


Fig.10 (a) DARWIN 850 hPa 3-DAY MEAN ZONAL WIND, MARCH 1988



(b) DARWIN 850 hPa 3-DAY MEAN MERIDIONAL WIND, MARCH 1988



(c) DARWIN DAILY RAINFALL, MARCH 1988

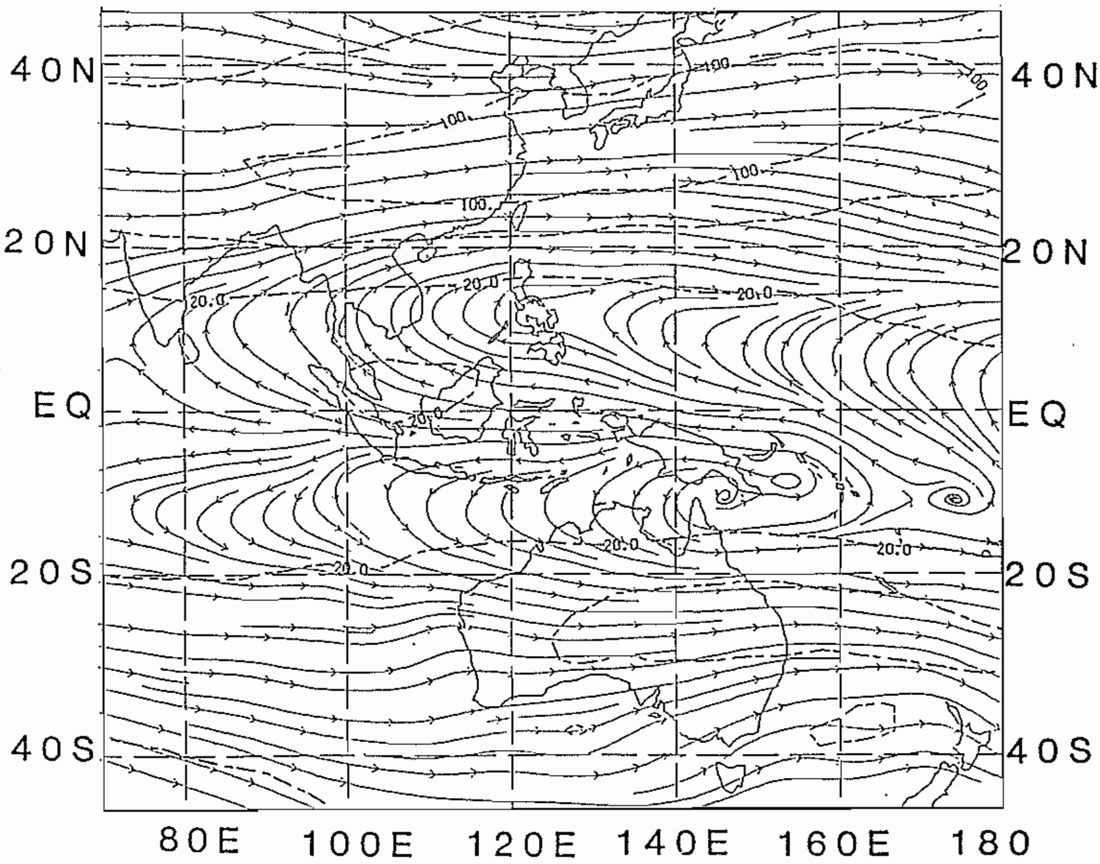


Fig.11 200 hPa STREAMLINE ANALYSIS, MARCH 1988
Isotachs (dashed line) at 40 knot intervals.

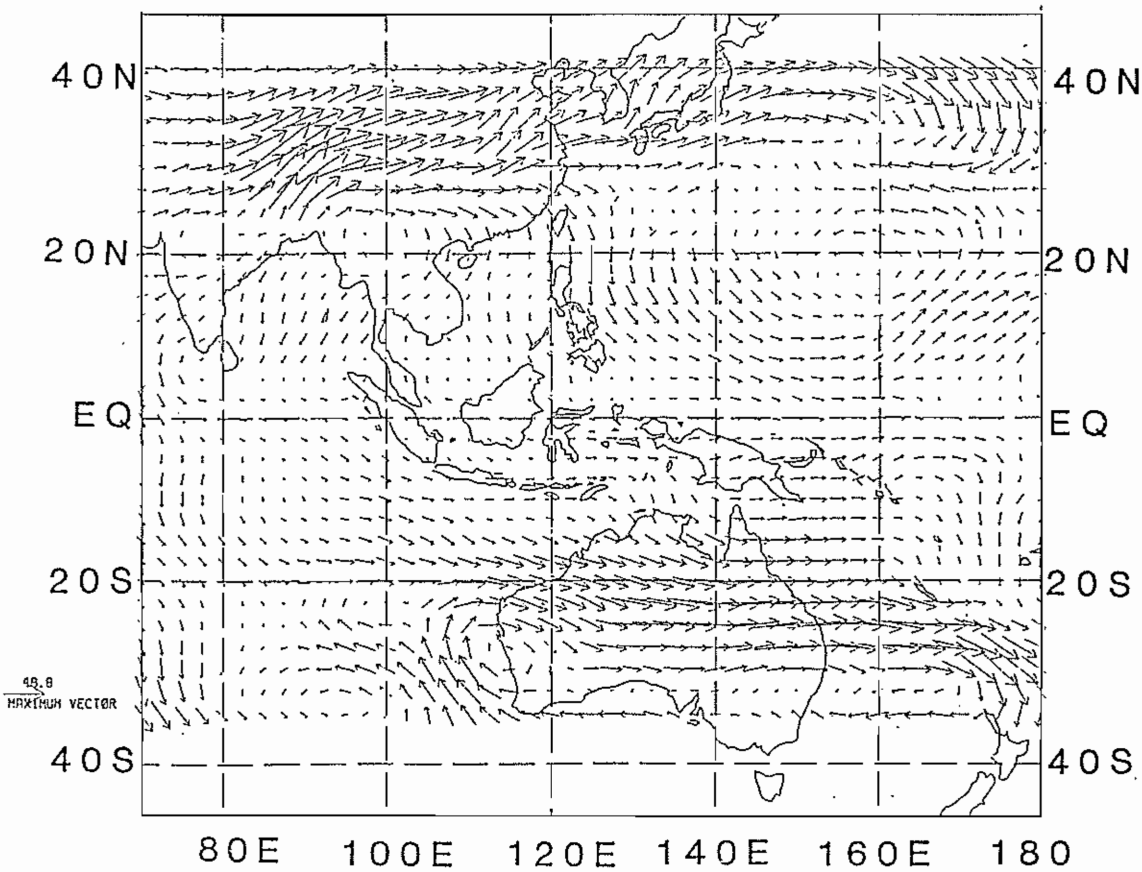


Fig.12 200 hPa VECTOR WIND ANOMALY BASED ON FIG. 11
(Arrow length indicates magnitude).

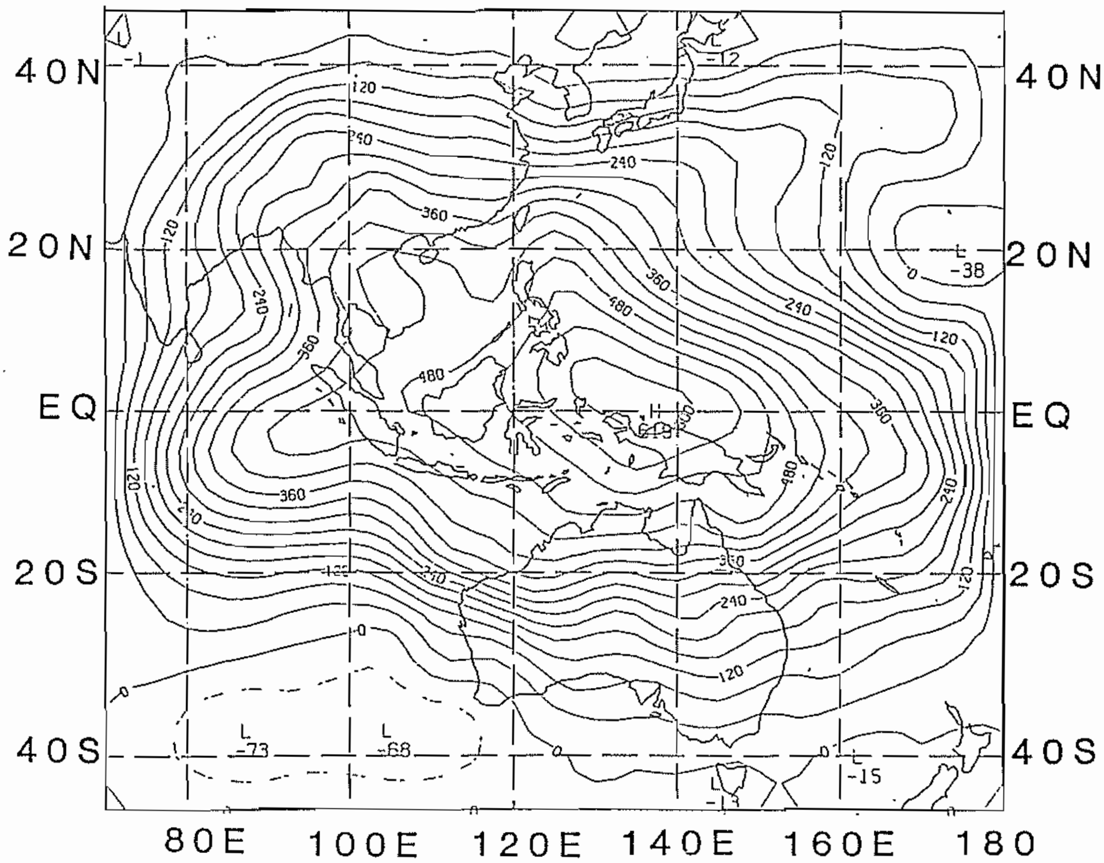


Fig.13 950 hPa VELOCITY POTENTIAL, MARCH 1988
Contour interval 40 x 10^{5} m^{2} s^{-1}

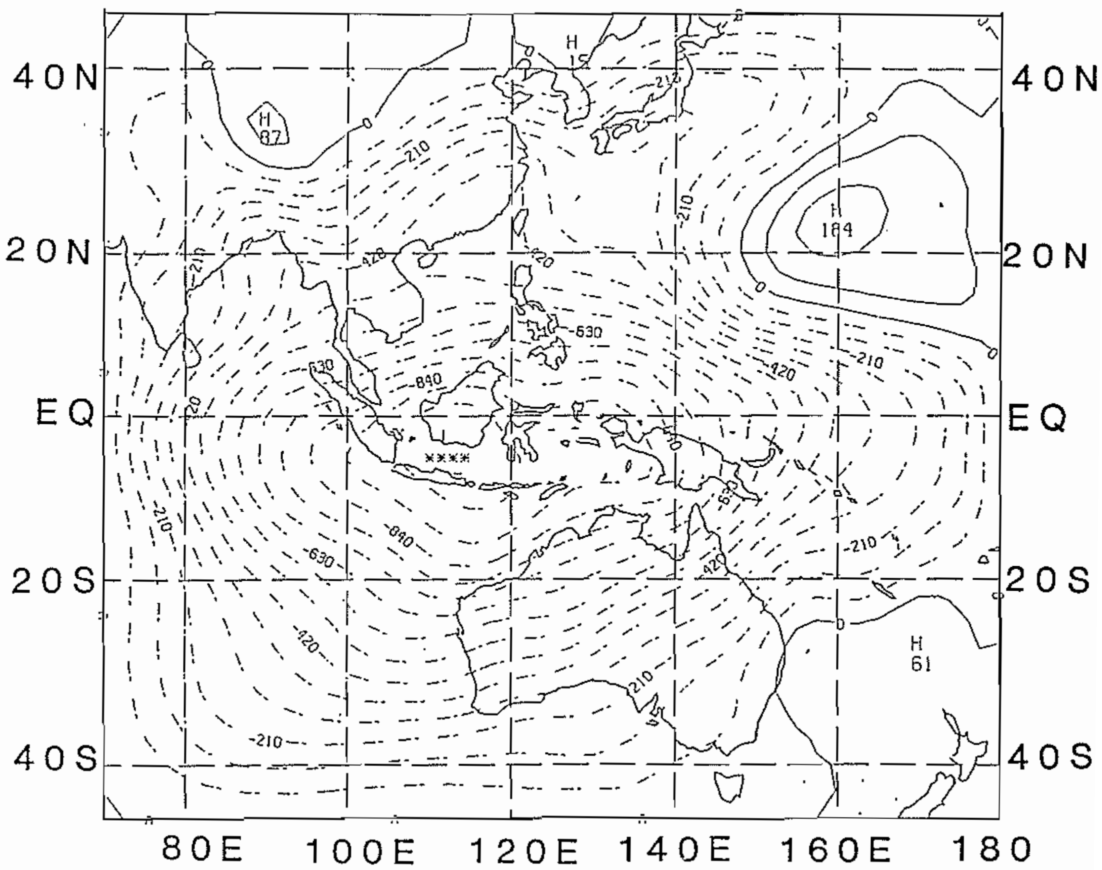


Fig.14 200 hPa VELOCITY POTENTIAL, MARCH 1988
Contour interval 7 x 10^{5} m^{2} s^{-1}

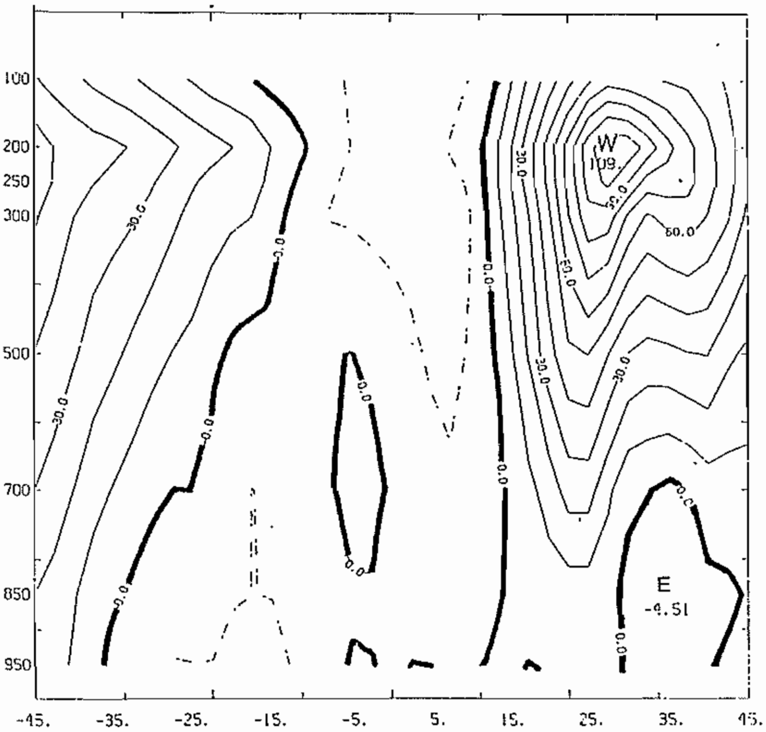


Fig.15 CROSS-SECTION OF ZONAL WIND ALONG 100^{O}E, MARCH 1988
Isotach interval 10 knots.

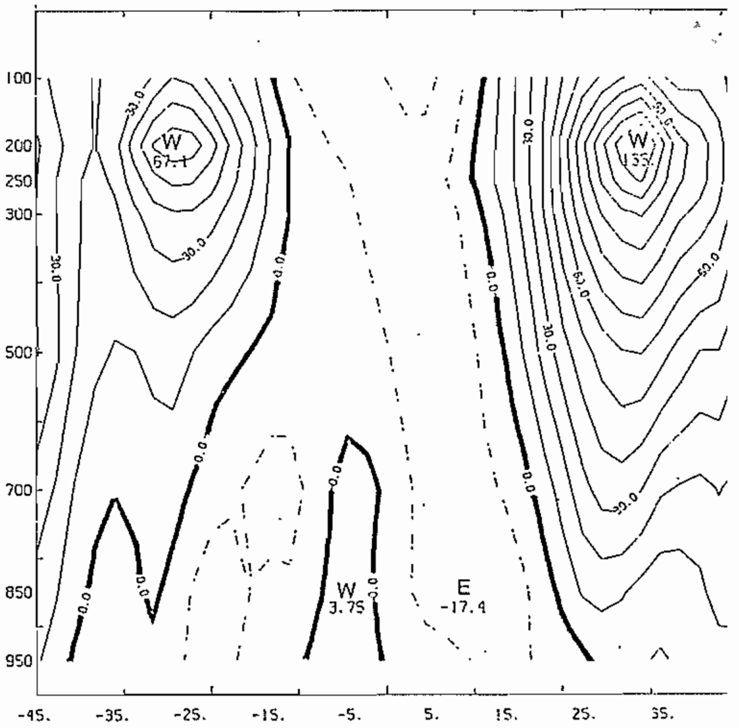


Fig.16 CROSS-SECTION OF ZONAL WIND ALONG 130^{O}E, MARCH 198
Isotach interval 10 knots.

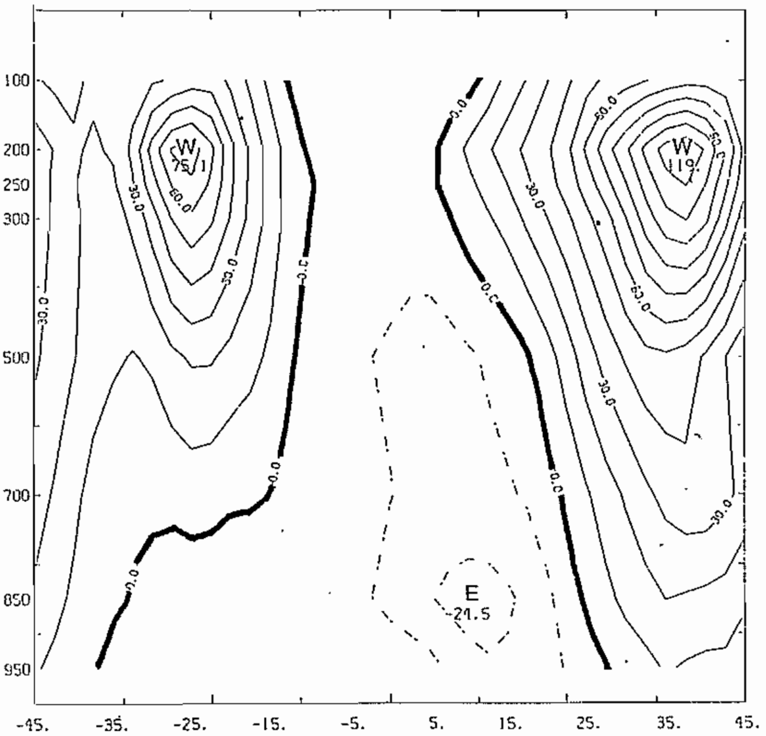


Fig.17 CROSS-SECTION OF ZONAL WIND ALONG 160^{O} E, MARCH 1988
Isotach interval 10 knots.

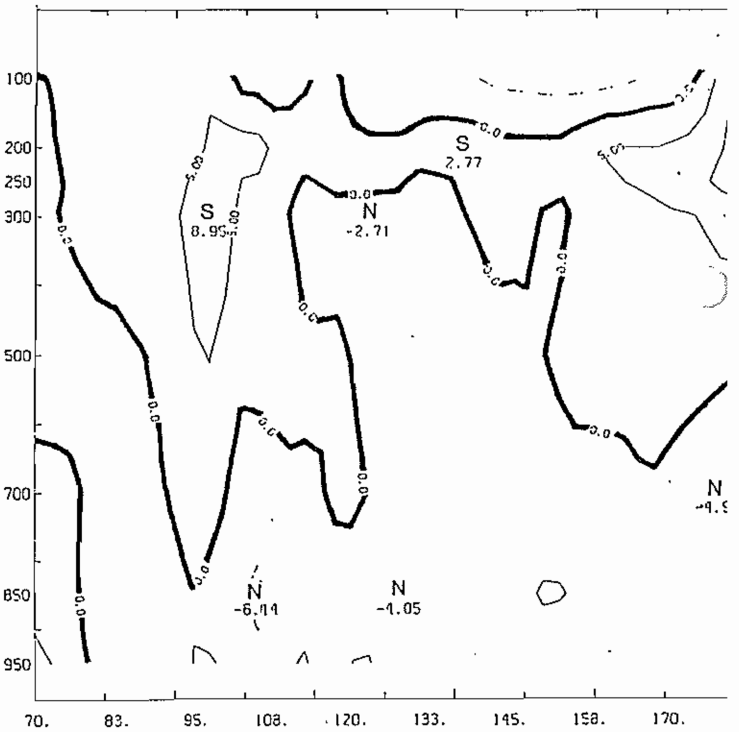


Fig.18 EQUATORIAL CROSS-SECTION OF MERIDIONAL WIND
BETWEEN 70^{O}E AND 180^{O}E, MARCH 1988. 5 knot isotachs

Explanatory Notes

1. **Darwin Tropical Diagnostic Statement** is a near real-time monthly diagnostic summary of the major tropical circulations within the Darwin Regional Specialised Meteorological Centre (RSMC) area of analysis responsibility, which covers 40°N-40°S, 70°E-180°. Caution does need to be exercised when quoting from this publication as not all information within it has been confirmed.

2. **Features** discussed generally include:

- El Niño - Southern Oscillation (ENSO) aspects
- Tropical cyclone (TC) occurrence
- Sea surface temperature (SST)
- Mean sea level pressure (MSLP).
- Lower and upper level wind
- Up-motion and convection
- Intra-seasonal variability

3. **Data sources:**

(i) $SOI = 10 x(\Delta P_{TAH} - \Delta P_{DAR}) / \sigma$

where ΔP_{TAH} =Tahiti (91938) monthly pressure anomaly (monthly mean minus 1933-1992 mean, averaging 3-hourly observations)

ΔP_{DAR} = Darwin (94120) monthly pressure anomaly (monthly mean minus 1933-1992 mean, averaging 0900, 1500LT observations)

σ = monthly deviation of the difference.

(ii) Operational tropical cyclone tracks based upon Darwin RSMC manual operational analyses. A tropical cyclone or cyclonic storm is defined as having mean wind > 17 ms^{-1} (34 kn) or a named system. Standard practice is to accept intensity and position as promulgated by the responsible warning agency, whenever possible. This may cause apparent discontinuities in intensity or track when cyclones cross warning area boundaries. Limited post analysis may sometimes be performed when warranted. A severe TC (equivalent to typhoon or hurricane) or very severe cyclonic storm is defined as having mean wind > 32 m s^{-1} (63 Kn).

(iii) Tropical cyclone climatology for the northwest Pacific and the south Indian and Pacific Oceans is based on *2004 Annual Tropical Cyclone Report*, by Atangan, J.F. and Preble, A., (2004), US Naval Pacific Meteorology and Oceanography Center/ Joint Typhoon Warning Center, Pearl Harbour, Hawaii, USA, (available at https://metoc.npmoc.navy.mil/jtwc/atcr/2004atcr/), which contains a climatology of 59 years. North Indian Ocean records are taken from WMO *Technical Document No. 430, Tropical Cyclone Report No.TCP-28* (Mandal, 1991), which contains a 99 year climatology.

(iv) SST analysis based on Darwin RSMC automated operational analyses (RSMC subset of the Australian National Meteorological and Oceanographic Centre (NMOC) global analysis: blended *in situ* and satellite data, 1°C resolution). The 1°x 1° global SST climatology from the US National Centers for Environmental Prediction (Reynolds and Smith 1995). A high resolution global sea surface temperature climatology, *J. Clim., 8,* 1571-1583 is used for the calculation of anomalies and as the default field for the analysis first guess.

(v) Mean MSLP, upper wind data, anomalies and velocity potential data from the Bureau of Meteorology's Global Assimilation and Prediction System (GASP - refer Bourke et al 1990. The BMRC global assimilation and prediction system. *ECMWF Seminar proceedings: Ten years of medium-range weather forecasting*, Sep 89) and NCEP2 22 year climatology, 1979-2000. MSLP anomaly analysis modified using CLIMAT messages.
Upper level equatorial cross section derived from Darwin RSMC real-time Tropical Limited Area Prediction Scheme (TLAPS - refer Puri et al, 1996, *BMRC Research Report No. 54, 41*).

(vi) The mean seasonal cycles for the Darwin 850 hPa wind components were constructed by averaging daily values over 39 years (1950 to 1988), each curve smoothed with 600 passes of a three day running mean weighted 1-2-1.

(vii) OLR time longitude plots and maps derived from the US National Oceanic and Atmospheric Administration.

4. **Some commonly-used acronyms:**

ISO	- Intra-seasonal oscillation
JMA	- Japan Meteorological Agency
JTWC	- Joint Typhoon Warning Center, Pearl Harbour
MT	- Monsoon trough
NET	- Near-equatorial trough
PAGASA	- Philippine Atmospheric, Geophysical and Astronomical Services
PNG	- Papua New Guinea
RSMC	- Darwin Regional Specialised Meteorological Centre (see note 1)
SCS	- South China Sea
SPCZ	- South Pacific convergence zone
STR	- Subtropical ridge
TD	- Tropical depression
TC	- Tropical cyclone (see note 3(ii))
STC	- Severe tropical cyclone
CS	- Cyclonic storm
VSCS	- Very severe cyclonic storm
TS	- Tropical storm (generally used for TC in northern Hemisphere sector)
TUTT	- tropical upper tropospheric trough

5. **Subscription rates** All costs in $AUSTRALIAN:

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	24.00 (Asia/Pacific)	110.80
	36.00 (Rest of the world)	122.80

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