Australian Government

Bureau of Meteorology

DARWIN REGIONAL SPECIALISED METEOROLOGICAL CENTRE

February 1988, VOL 7 No 02

ISSN 1321 - 4233

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DARWIN TROPICAL DIAGNOSTIC STATEMENT

FEBRUARY 1988

ISSUED BY DARWIN RMC

The Hadley circulation was particularly weak during February with the mean position of the summer hemisphere monsoon trough remaining well north of the north Australian coast. The southern oscillation index (SOI) fell to -6, still less than one standard deviation below the mean. Three cyclones formed in the southern hemisphere during the month with a fourth persisting from January.

INDICES

1. Darwin mean MSL pressure February 1988 : 1006.7 hPa
   pressure anomaly (1882-1985 mean): +0.2 hPa
2. Tahiti mean MSL pressure February 1988 : 1010.2 hPa
   pressure anomaly: -1.1 hPa
3. Troup's southern oscillation index : -6
   5-month mean (centred upon December): -4

4. Troup's SOI for the last 26 months:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	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										

Graphs of the monthly SOI and five month running mean SOI for the past ten years are given in figure 1. The ENSO event of 86/87 is clearly evident, and represents the second major negative excursion of the SOI in the past decade.

RAINFALL

Monthly rainfall quintiles for selected stations in February are given in figure 2.

Rainfall deficiencies were reported over northern China, Korea and Japan as well as parts of southern India. Lower than normal totals over much of Indonesia and northern Australia is indicative of a weaker than normal summer monsoon in this region during February. Extreme low falls were experienced in parts of southwestern Australia. In contrast, greater than normal rainfall was reported in Borneo, Malaysia, central China and northern India.

TROPICAL CYCLONES

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

Tropical Cyclone Frederic, which formed late in January, continued into the early part of the month. Three other southern hemisphere cyclones formed in the Darwin RMC chart area, and all 3 reached severe tropical cyclone strength. One of the cyclones (T.C. Charlie) crossed the Queensland coast.

Tropical Cyclone Frederic continued its southward movement having crossed the Cocos Island group on the 30th of January during its formative stage. It dissipated on the 3rd while moving over cooler water.

Tropical Cyclone Gwenda formed in the Indian Ocean monsoon trough on the 8th, and followed an oscillating track to the west-southwest. It reached severe tropical cyclone status on the 11th before it crossed into the Mauritian area of responsibility and was renamed Ezenina; the cyclone decayed over water on the 16th.

T.C. Charlie was first evident as a depression over the southwest Gulf of Carpentaria on the 10th, having formed during a brief but intense period of monsoonal activity over this region (see Fig. 10). After initially moving westward and passing to the south of Groote Eylandt it then reversed course and tracked steadily east toward Cape York Peninsula. At this stage cyclone development was inhibited by vertical shear. As a monsoon depression it continued to track eastward, moved over the Coral Sea on the 15th and developed cold cored characteristics causing strong winds and heavy rain. Subsequently it tracked east-northeastward until the 21st, when it changed course to the south. At this point the depression was well sheared, with the low level circulation east of the main area of convection. Over the next two days its structure became more organized, the depression deepened and tropical cyclone status was reached early on the 23rd. Charlie then followed a meandering and erratic course to the west-southwest, alternating between a tropical cyclone and a tropical depression several times during the next few days. Rapid intensification occurred overnight on the 29th and the storm reached severe tropical cyclone status as it neared the coast. Severe T.C. Charlie crossed the coast south of Townsville on the 1st of March and caused widespread flooding with the loss of one life.

The pre-Bola depression was first observed in the western Pacific monsoon trough on the 26th. The depression intensified rapidly as it moved initially westward toward Vanuatu, before turning to follow a slow and meandering southerly course as it further deepened. Bola reached severe tropical cyclone strength on the 29th over the southern islands of Vanuatu. Further details of Bola's history will be reported next month.

SEA SURFACE TEMPERATURE

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

Most notable is the warm water anomaly dominating the entire southern hemisphere chart area as well as the northern Indian Ocean. As a consequence, the negative anomaly noted last month in the southern Tasman Sea was replaced by positive anomalies with a maximum near New Zealand. Similarly, the positive anomaly of the southern Indian Ocean intensified, while the area of warmest anomaly near southern India increased.

In the northwest Pacific, the cold anomaly along 20^{o}N intensified slightly from last month while the very warm anomaly off the coast of Japan weakened. Figure 2 indicates the continued southward march of the axis of warmest water to near 10^{o}S, with seasonally expected cooling of the water in the Northern Hemisphere.

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 fields in figures 8 and 9.

The surface charts indicate there was a stronger than normal subtropical ridge over China and Japan in February with anomalously strong northeast trades through the East China and South China Seas. Little of this flow, however, penetrated into the southern hemisphere monsoon trough as indicated by the strong westerly anomalies in the Pacific between the Philippines and the dateline. In combination, there were significant southerly and easterly anomalies through Indonesia and parts of northern Australia implying a persistence from last month of the weaker than normal monsoonal activity in this region. This was substantiated by the rainfall distribution of figure 2. 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 February. These charts indicate that the month was dominated by relatively dry east to northeast flow with only a brief northwesterly monsoon event which started on the ninth and lasted about four days. This was responsible for much of the monthly rainfall.

In the southern Indian Ocean, a strong cyclonic anomaly developed, with a broad belt of anomalous westerlies centred near 20^{o}S, presumably due to the prolonged presence of the extratropical remnants of Cyclone Gwenda. The anomalous anticyclonic flow near the West Australian coast noted in January moved slightly eastward as did the associated region of higher than normal pressures; it is difficult to reconcile these anomalies with the broad and long-lived warm sea surface temperature anomalies. Moreover, examination of Japanese GMS imagery indicates that tropical convection was generally very suppressed this wet season.

The Tasman Sea blocking pattern observed last month was replaced by a broad cyclonic anomaly and below average pressures. Negative pressure anomalies were observed over India with the vector wind anomaly field in rough geostrophic balance.

UPPER LEVEL FLOW

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

Anomalous equatorial northwesterlies west of 150^{o}E indicate that cross-equatorial flow into the Northern Hemisphere as part of the Hadley circulation was weaker than normal in February. The subtropical ridges of the winter and summer hemispheres were located near their mean positions as were the respective subtropical jets (STJ's). The STJ in the southern hemisphere however was weaker than normal.

The absence of any anticyclonic or cyclonic anomly pair persisted near the dateline, confirming the decline of a well-defined ENSO event. Of particular note was the formation of a well-developed anomalous trough over Western Australia with weaker than normal westerlies south of the continent. In association with stronger than normal downstream flow, this is consistent with the positive pressure anomalies and lower than normal rainfall recordings noted earlier.

VELOCITY POTENTIAL

Charts of the velocity potential fields at 950 hPa and 200 hPa for February are given in Figs. 13, and 14.

The major area of low level convergence was centred near the southeast tip of Papua New Guinea with an axis extending northwest to another centre east of the Philippines. At high levels the axis of maximum divergence was located close to the equator, suggesting that the unseasonal northward migration of the upper branch of the Hadley cell continued from last month. The strongest subsidence region associated with the downward branch of the cell was located over Korea with an axis extending southeast over Japan. This correlates well with the below average rainfall and positive pressure anomalies in this region mentioned earlier.

WIND CROSS SECTIONS

Cross sections of zonal wind along 100^{O}E, 130^{O}E and 160^{O}E are shown in Figs 15, 16 and 17 respectively; the equatorial cross section of meridional wind is given in Fig. 18.

The longitudinal cross sections illustrate the weak monsoon westerlies of the summer hemisphere were confined to the north of 08^{O}S, maintaining the trend observed in January. Of note at high levels in the southern hemisphere was the development of a STJ core maximum near 160^{O}E, perhaps in association with the anomalous upstream trough noted earlier. In the Northern Hemisphere, the STJ maintained its intensity from January whilst migrating slightly equatorward.

The equatorial cross section of meridional wind shows a marked weakening of the high level southerly return flow since January. Indeed, near 95^{O}E, there was a low level southerly component to the flow which, in association with high level northerlies, indicate a complete reversal of the normal circulation. This is supported by the relative lack of convection in this region noted earlier.

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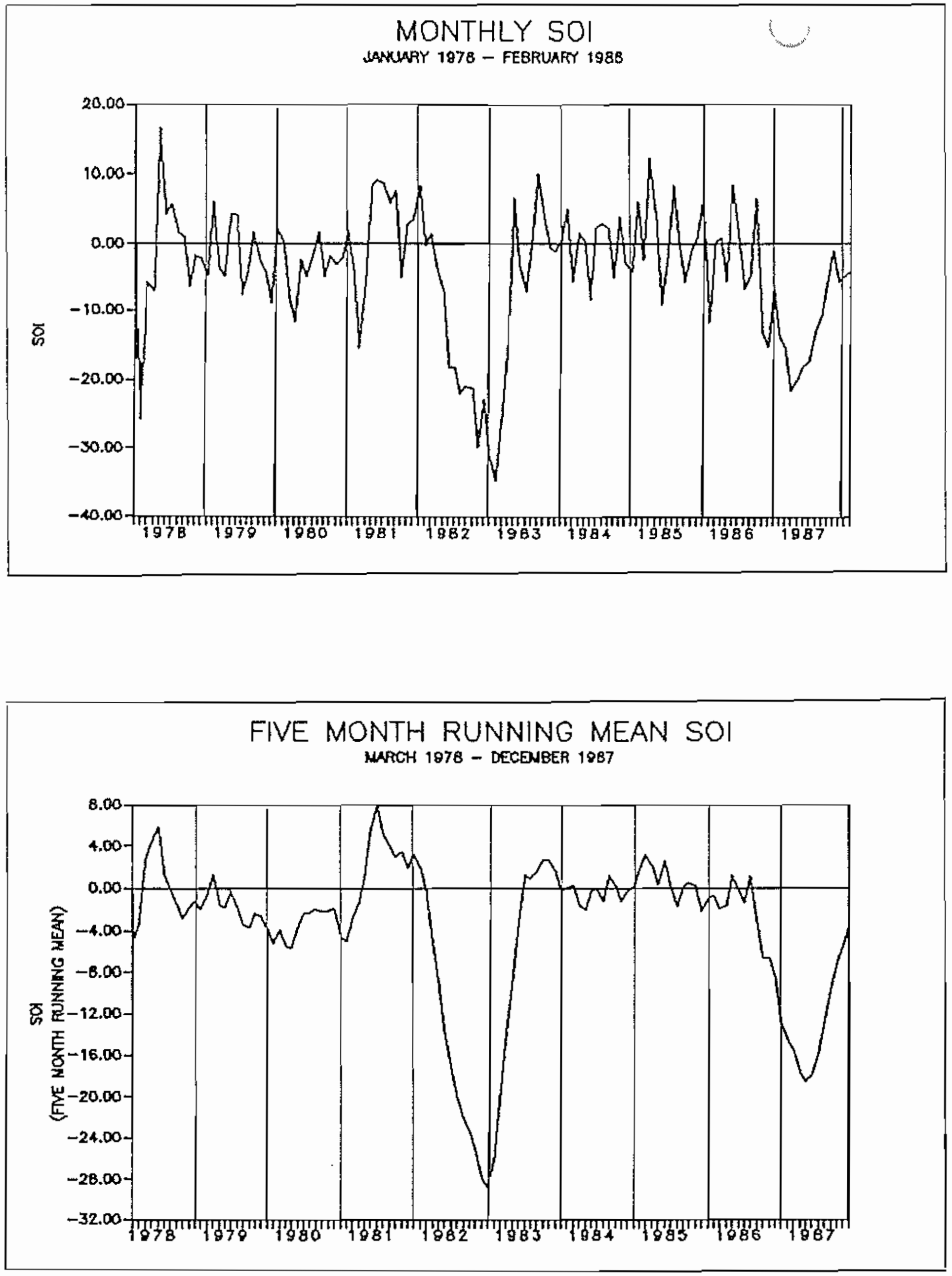


Fig.1 SOUTHERN OSCILLATION INDEX (1978-1988)
Monthly SOI and 5-month running mean SOI

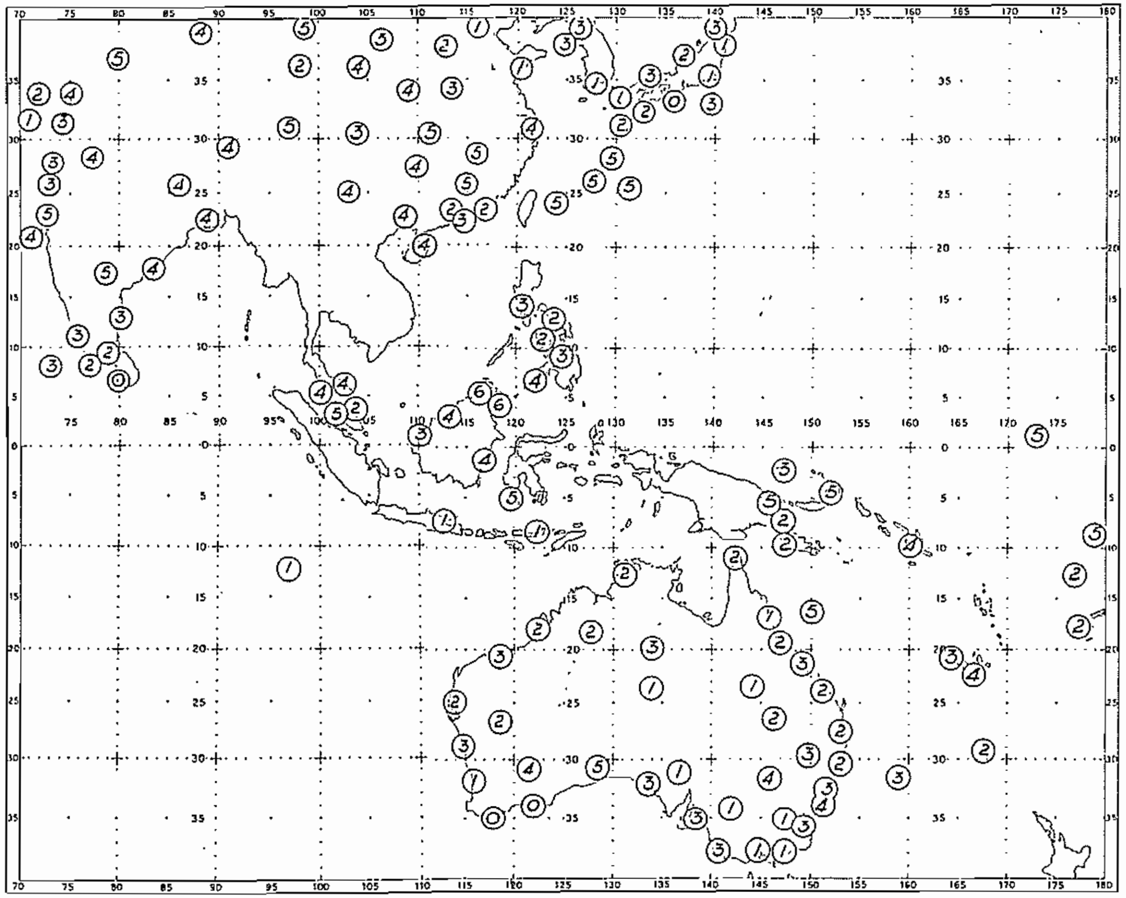


Fig.2 MONTHLY MEAN RAINFALL QUINTILES from selected climat stations
FEBRUARY 1988

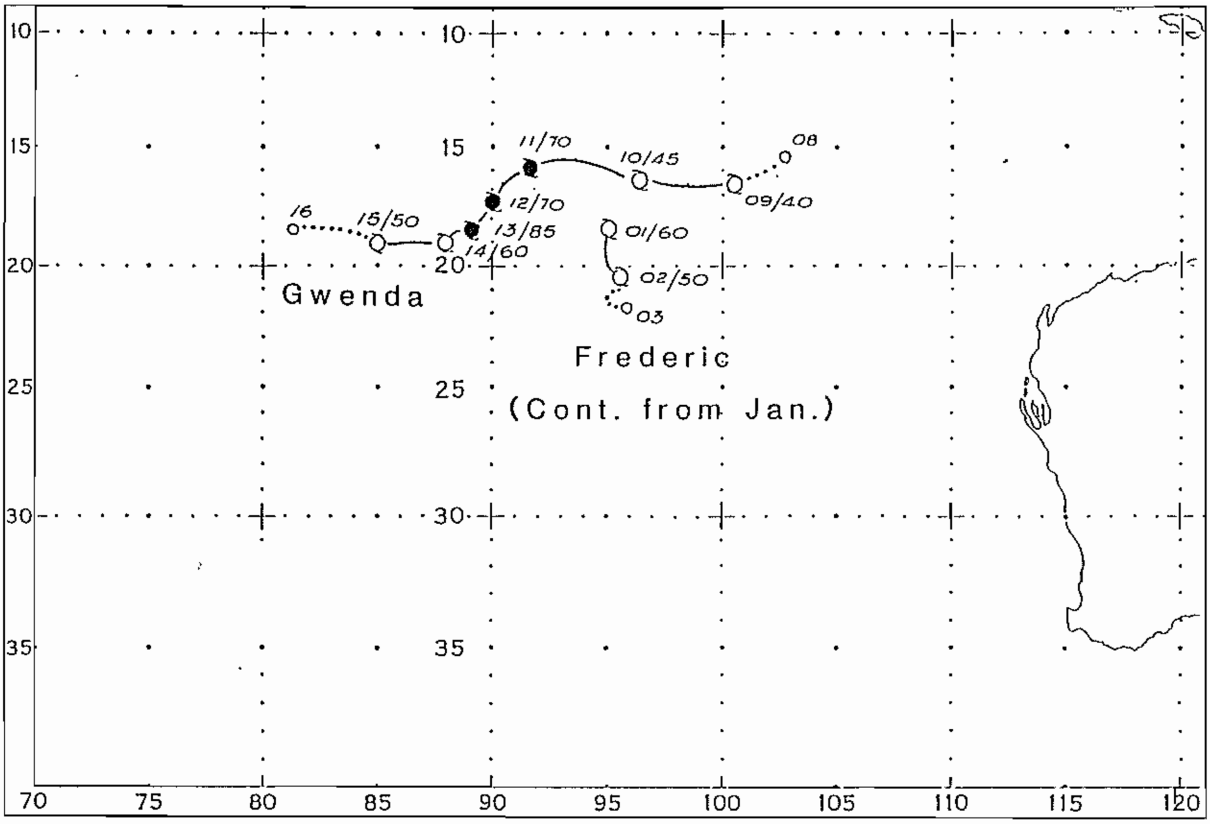


Fig.3(a) UNOFFICIAL TRACKS OF CYCLONES FREDERIC AND GWENDA (FEBRUARY 1988)
Date (DD) and maximum sustained wind (ff) in knots denoted by DD/ff.

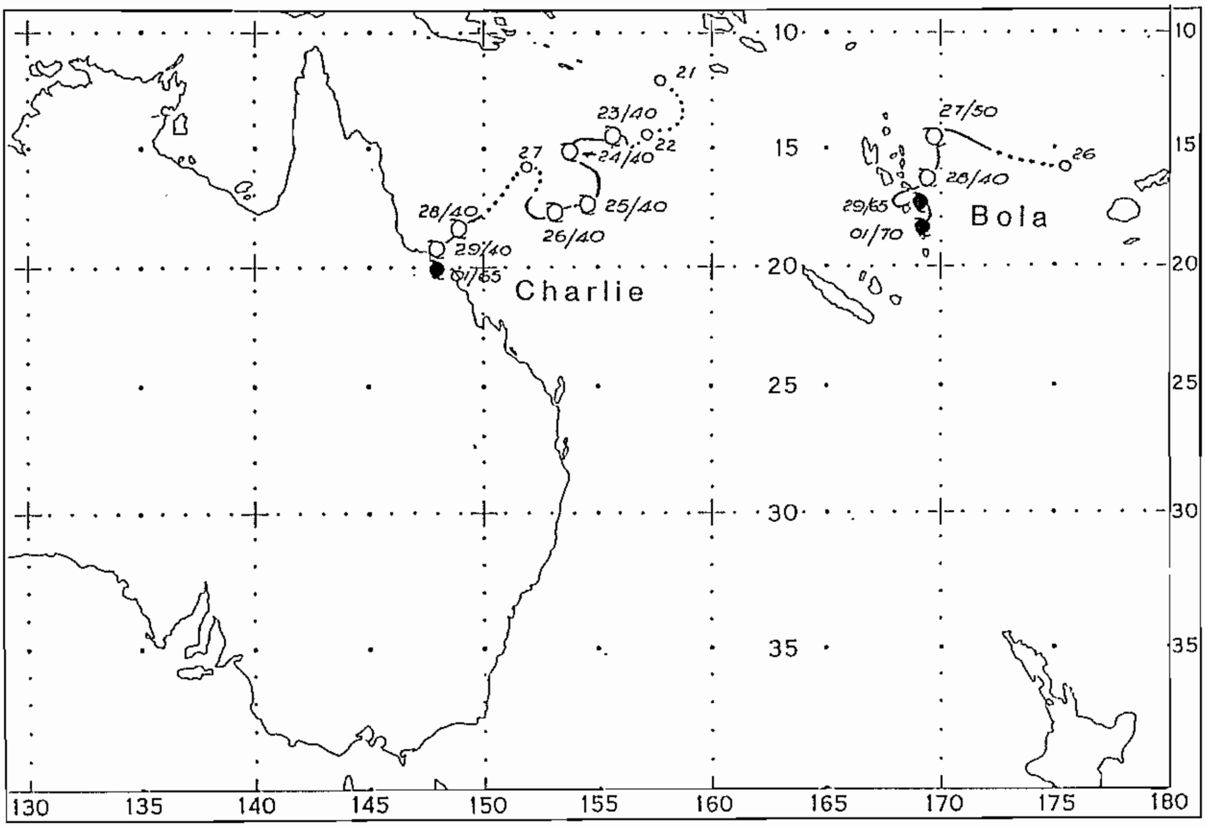


Fig.3(b) UNOFFICIAL TRACKS OF CYCLONES BOLA AND CHARLIE (FEBRUARY 1988)
Date (DD) and maximum sustained wind (ff) in knots denoted by DD/ff.

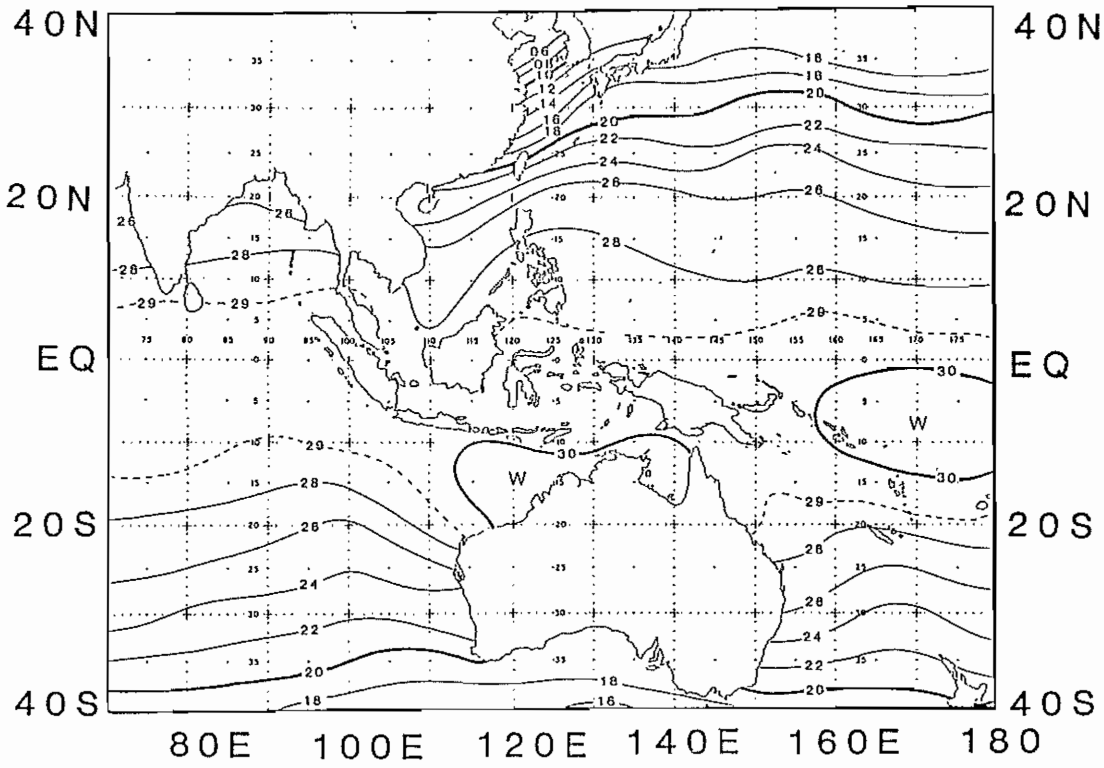


Fig. 4 MEAN SEA SURFACE TEMPERATURES, BASED ON WEEKLY DARWIN RMC ANALYSES AVERAGED OVER THE MONTH, FEBRUARY 1988. Isotherm interval 2° C.

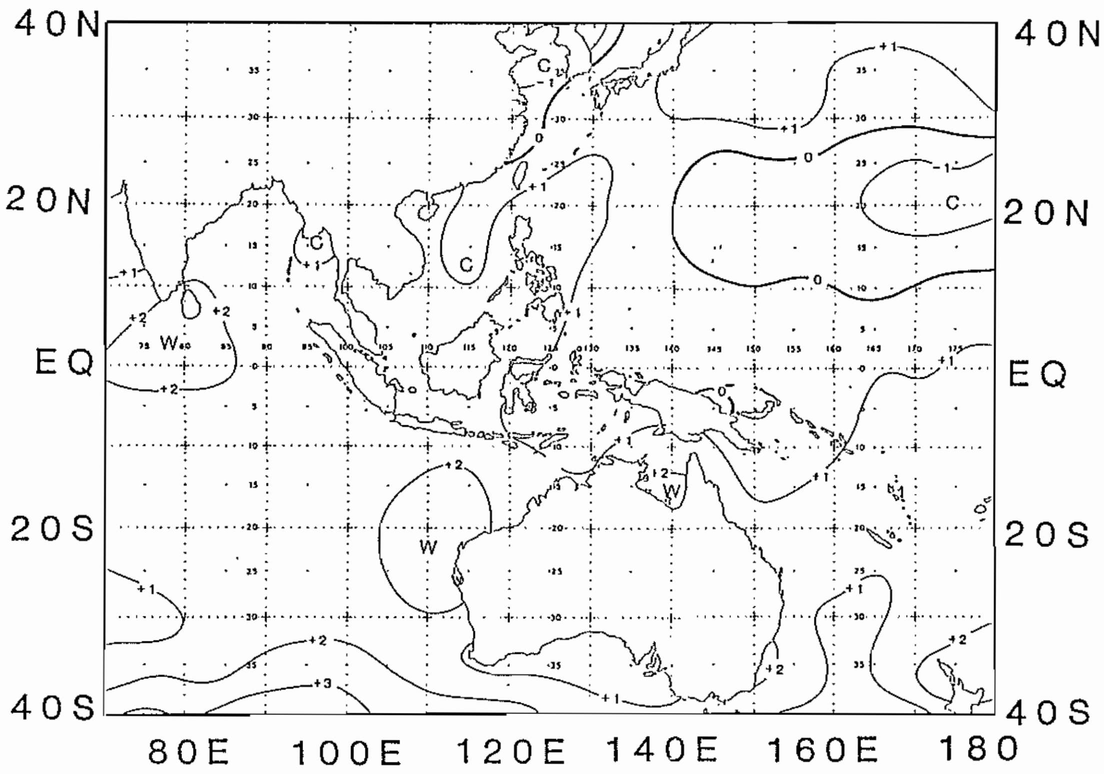


Fig. 5 SST ANOMALY CHART, BASED ON FIG. 4 AND THE CLIMATOLOGY OF REYNOLDS, NOAA REPORT NWS 31, 1983 Isotherm interval 1° C.

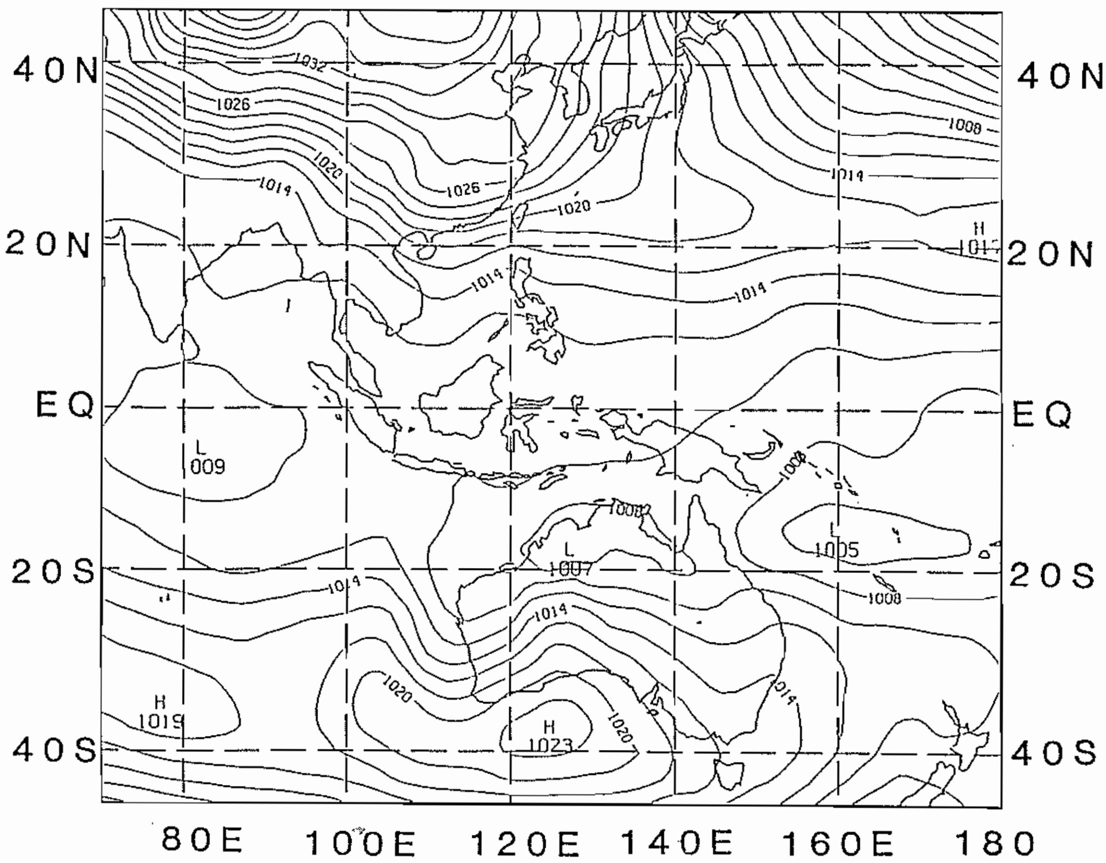


Fig. 6 MONTHLY MEAN MSL PRESSURE, FEBRUARY 1988
Isobar interval 2 hPa

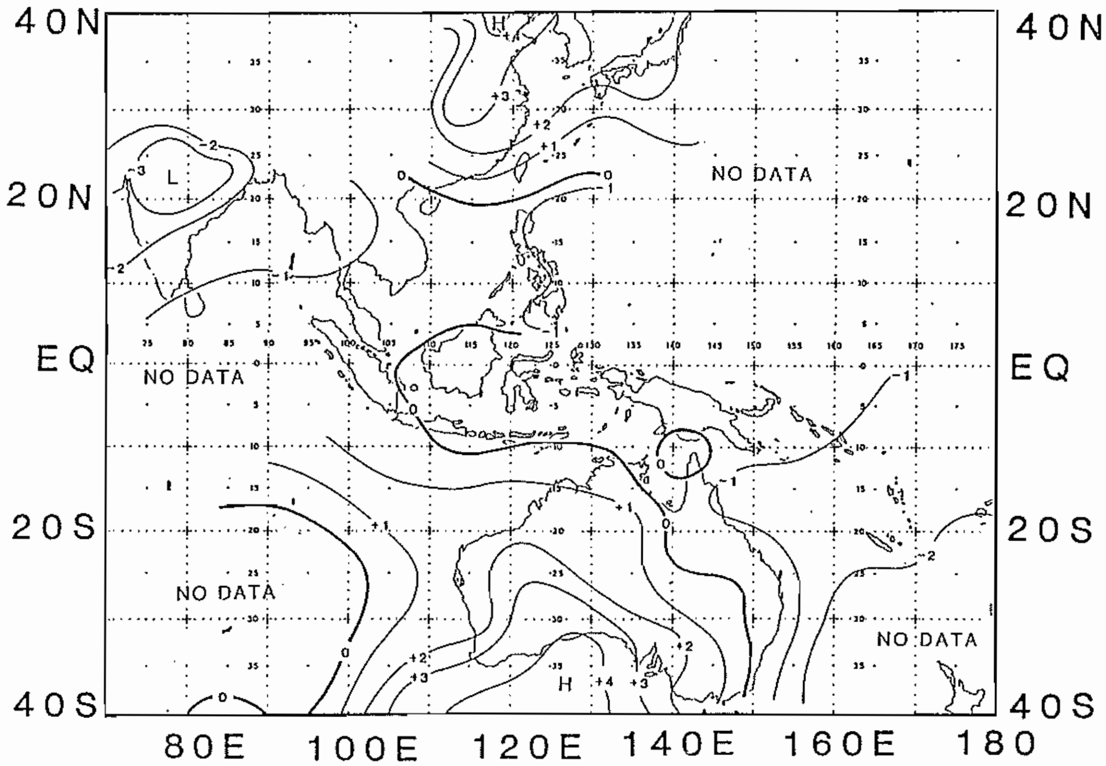


Fig. 7 MSL PRESSURE ANOMALY BASED ON CLIMAT MESSAGES
(AND MELBOURNE WMC DATA SOUTH OF 10^{o}S)
Contour interval 1 hPa.

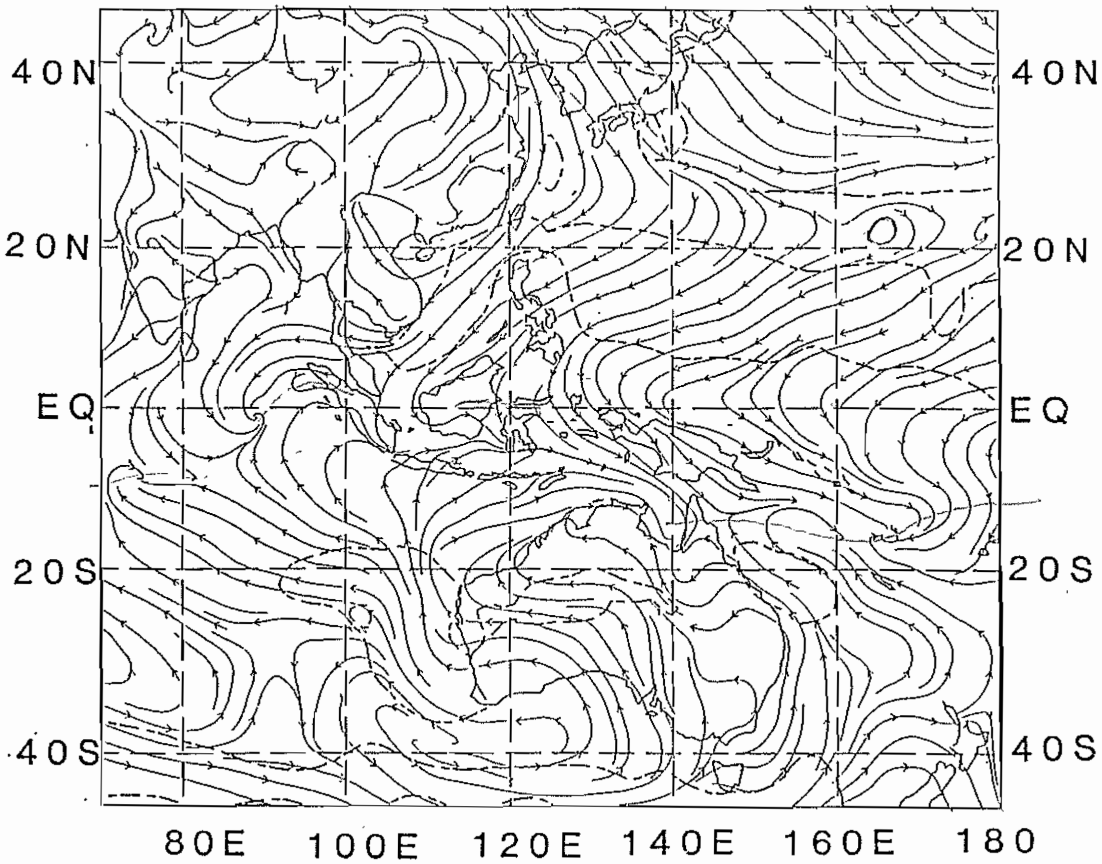


Fig. 8 950 hPa STREAMLINE ANALYSIS, FEBRUARY 1988
Isotachs (dashed line) at 10 knot intervals

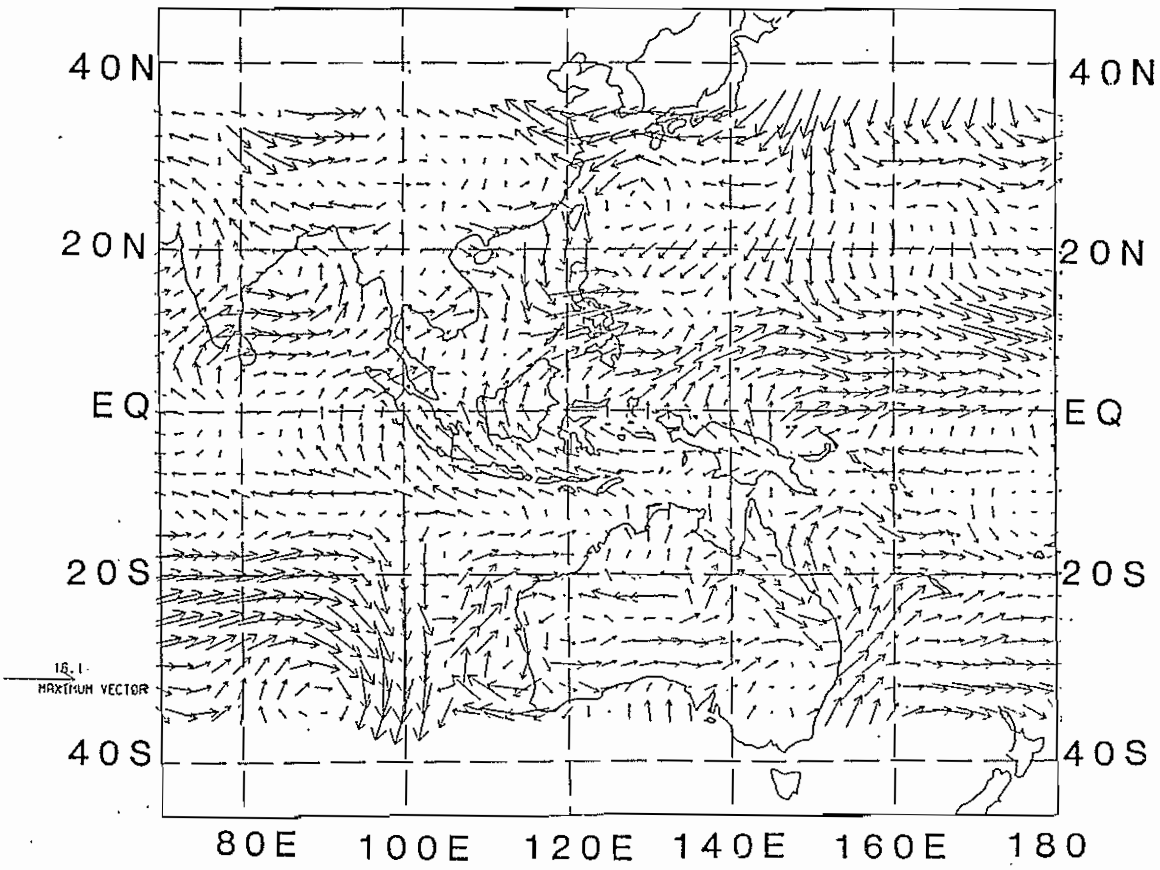


Fig. 9 950 hPa VECTOR WIND ANOMALY BASED ON FIG. 8
(Arrow length indicates magnitude)

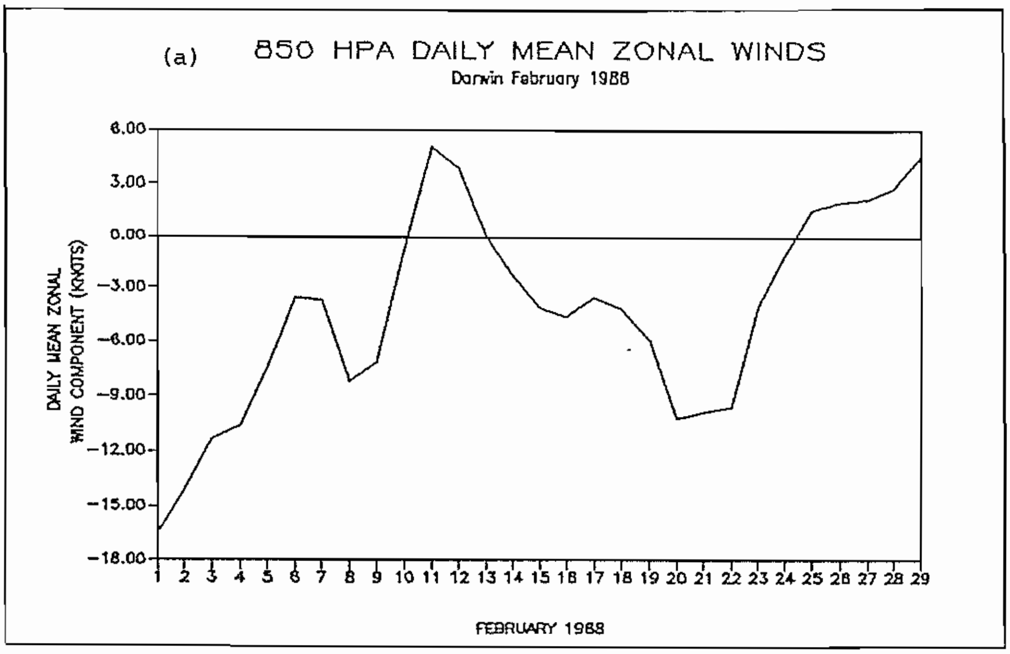
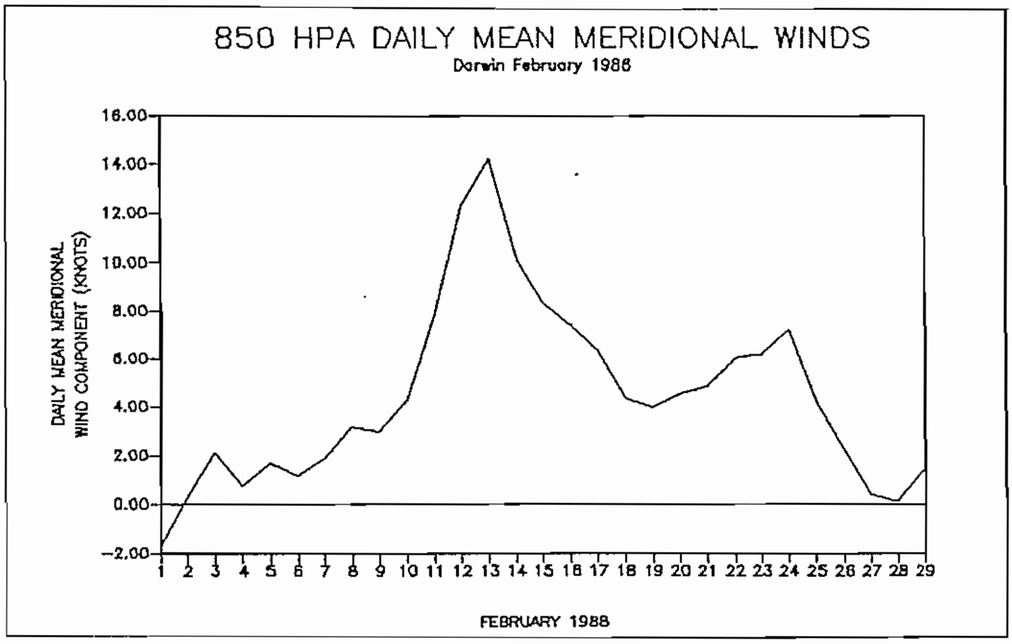
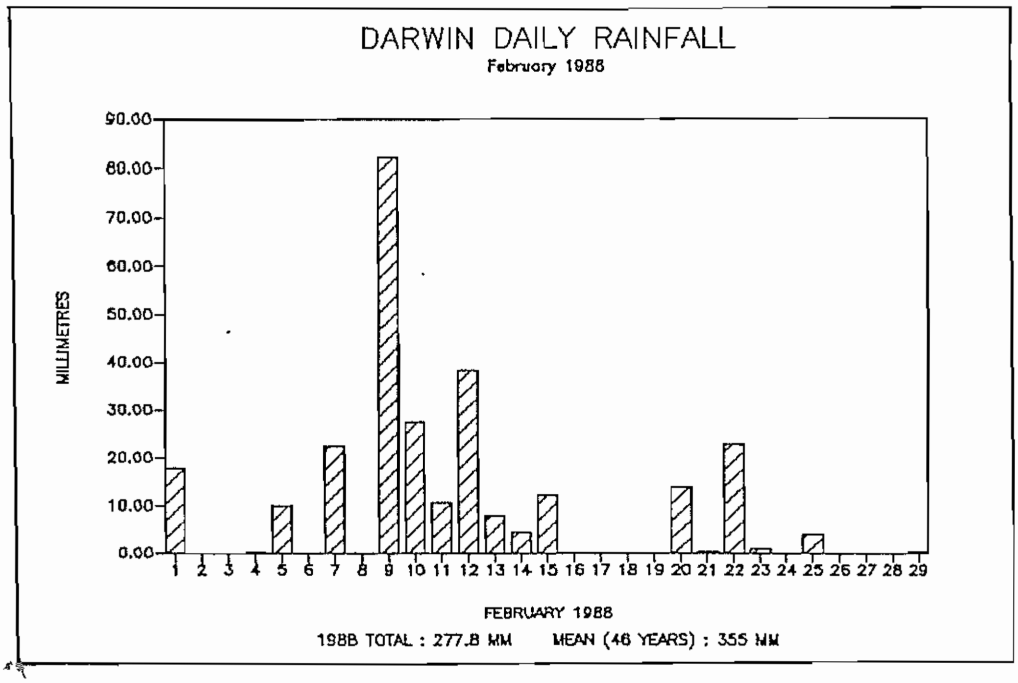


Fig.10 (a) DARWIN 850 hPa 3-DAY MEAN ZONAL WIND, FEBRUARY 1988



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



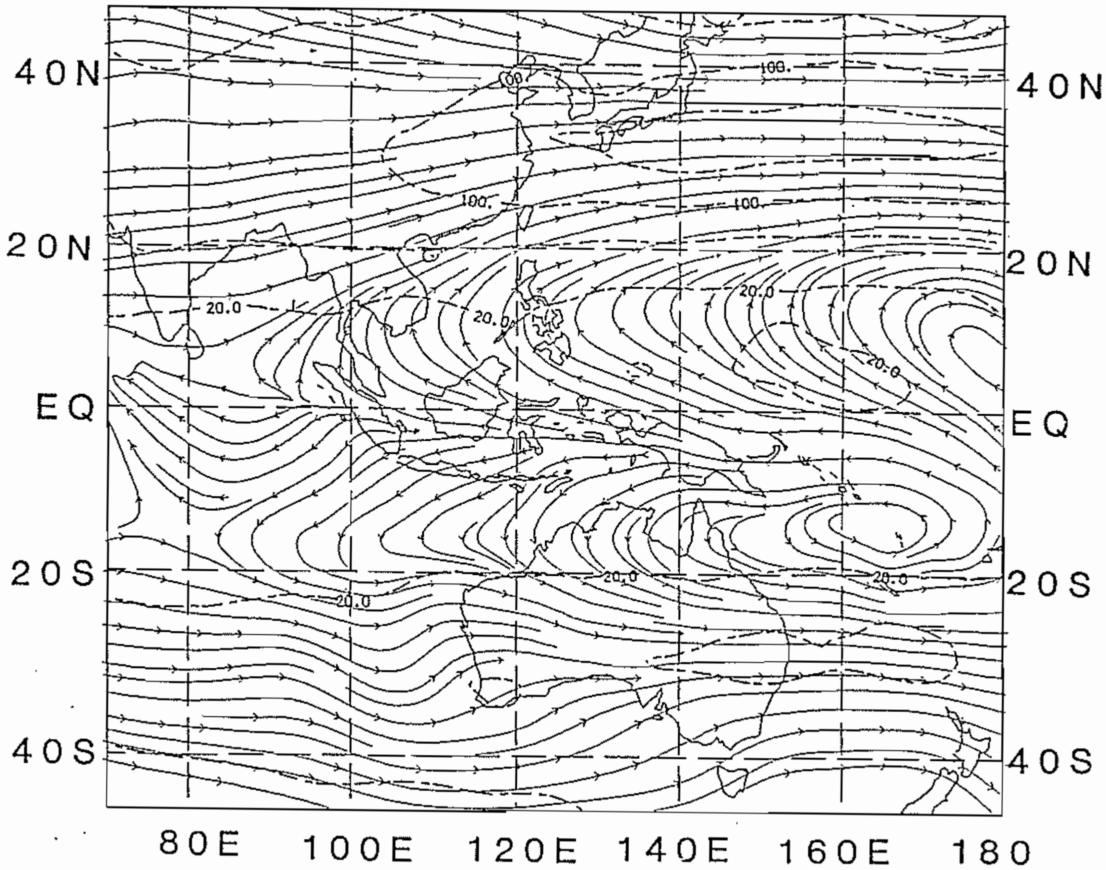


Fig.11 200 hPa STREAMLINE ANALYSIS, FEBRUARY 1988
Isotachs (dashed line) at 40 knot intervals.

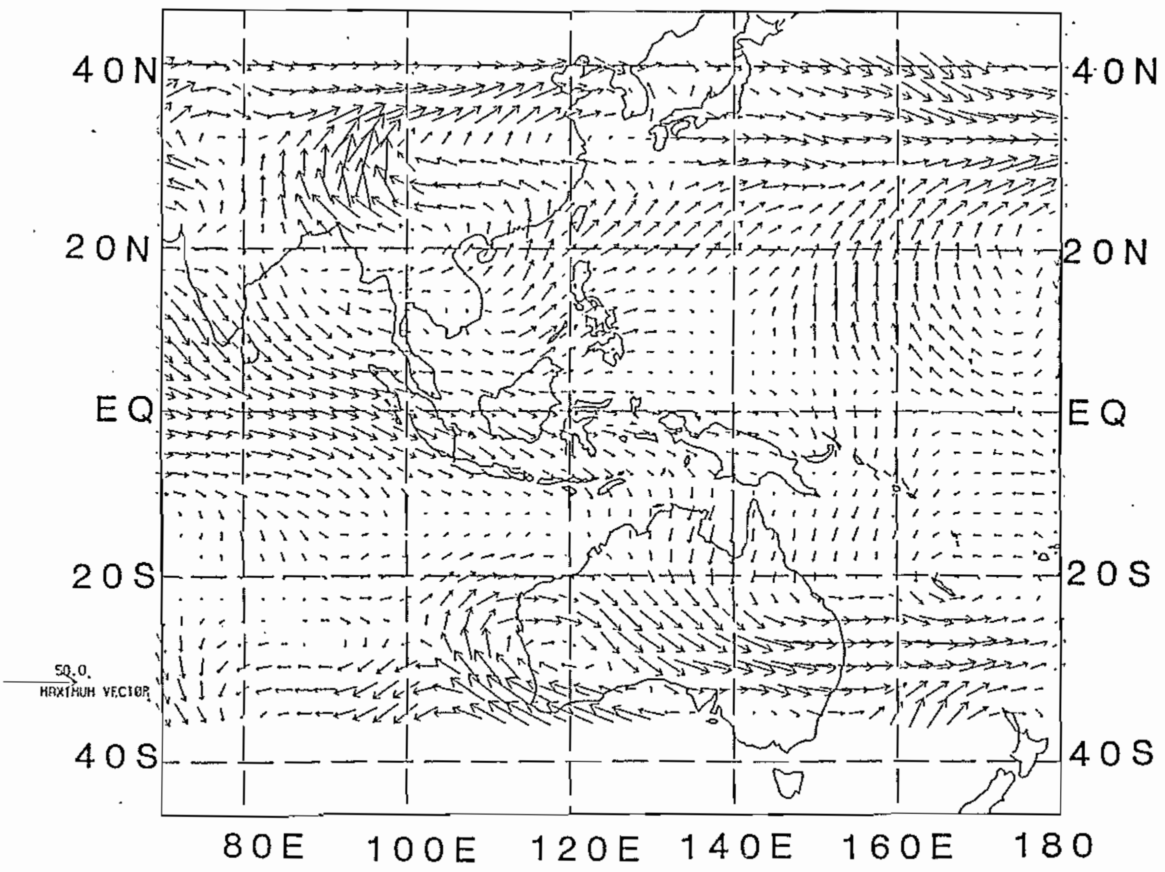


Fig.12 200 hPa VECTOR WIND ANOMALY BASED ON FIG. 11
(Arrow length indicates magnitude).

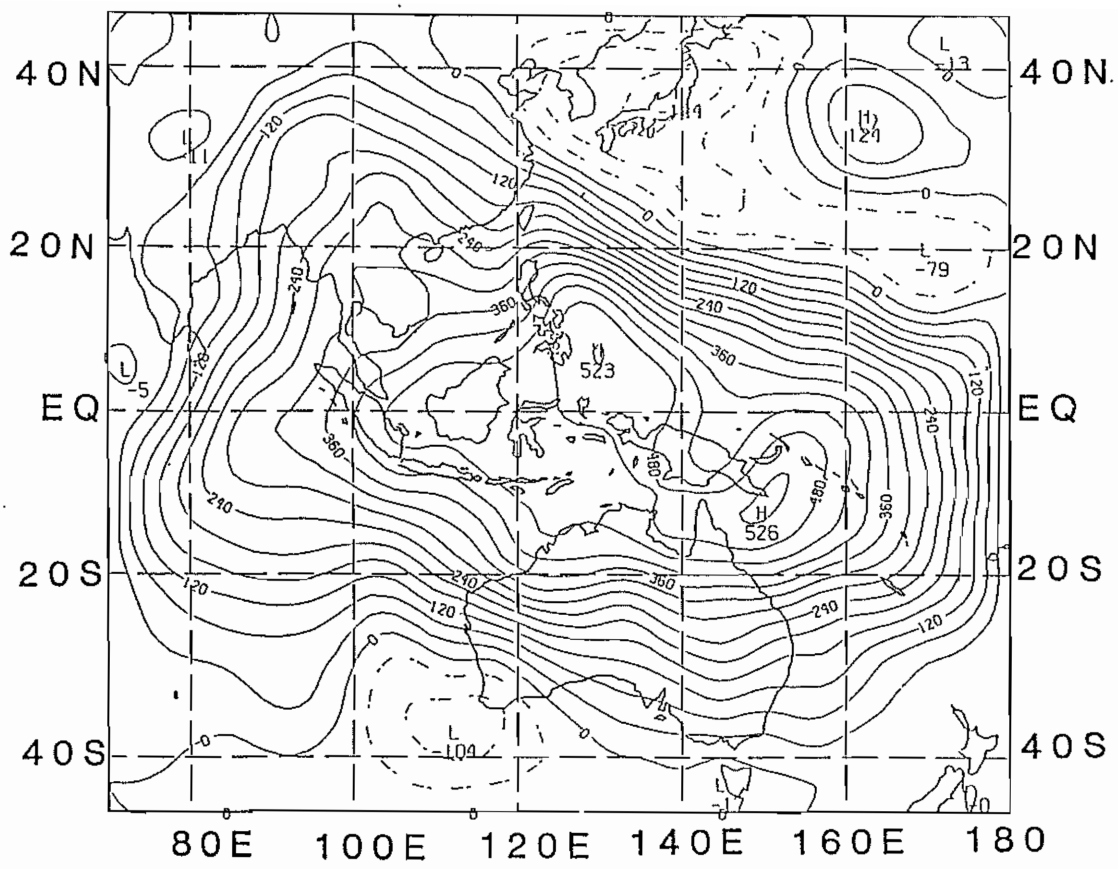


Fig.13 950 hPa VELOCITY POTENTIAL, FEBRUARY 1988
Contour interval 40 x 10^5 m^2 s^{-1}

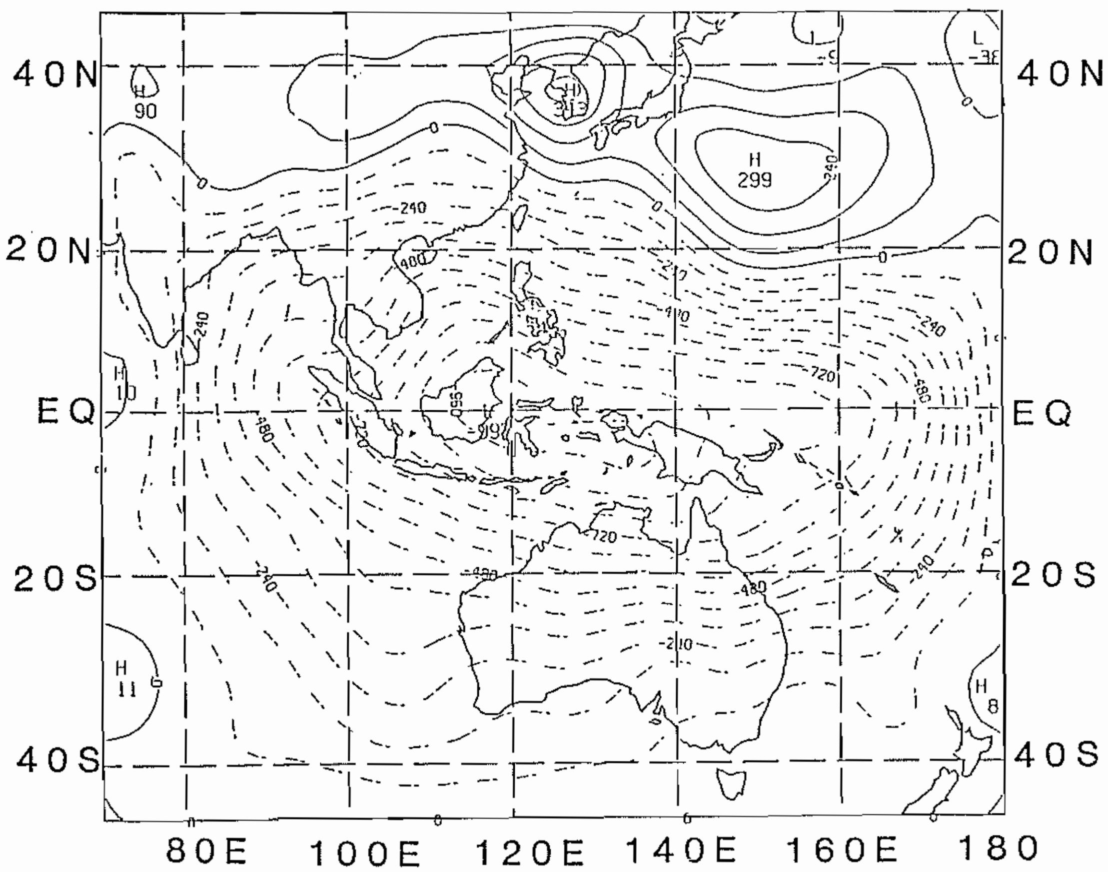


Fig.14 200 hPa VELOCITY POTENTIAL, FEBRUARY 1988
Contour interval 6 x 10^5 m^2 s^{-1}

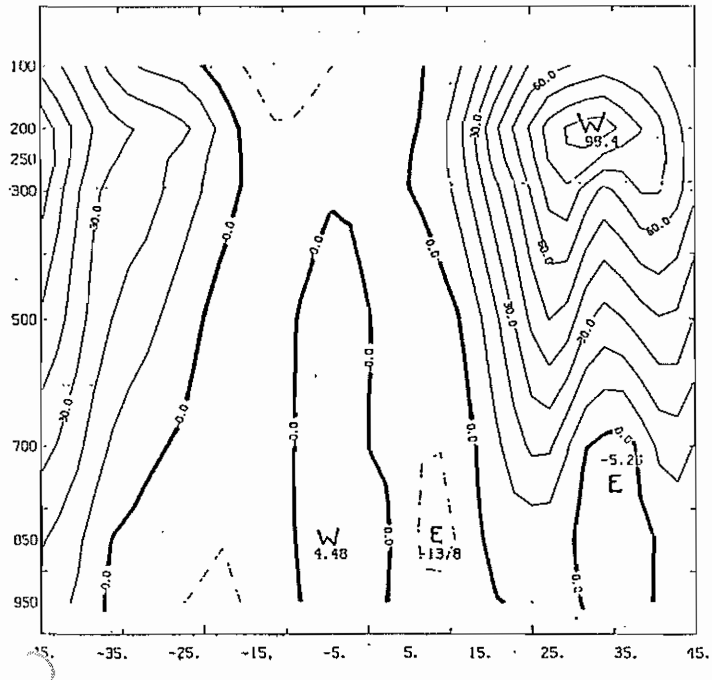


Fig.15 CROSS-SECTION OF ZONAL WIND ALONG 100°E, FEBRUARY 1988
Isotach interval 10 knots.

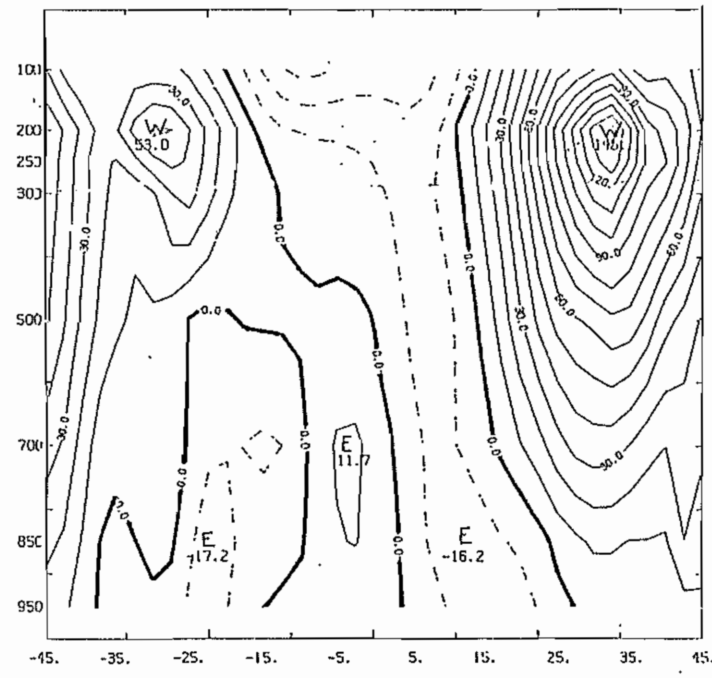


Fig.16 CROSS-SECTION OF ZONAL WIND ALONG 130°E, FEBRUARY 1988
Isotach interval 10 knots.

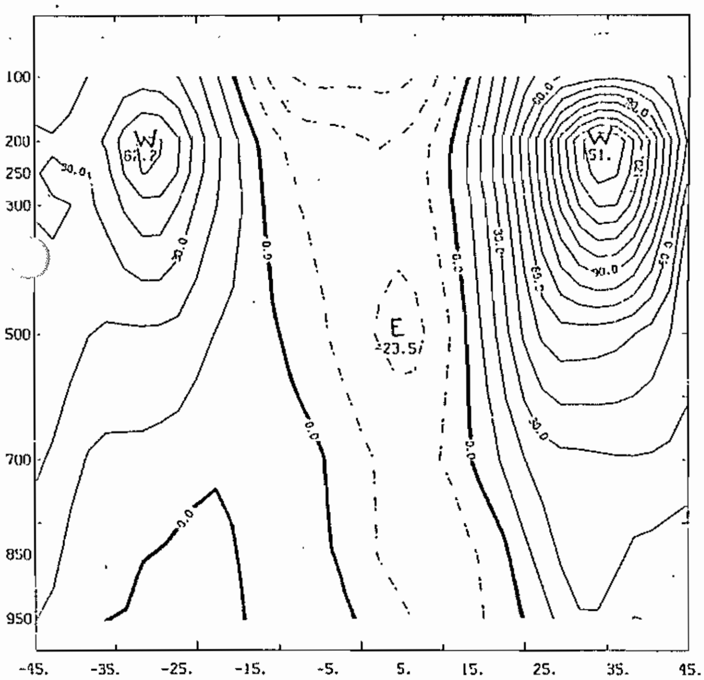


Fig.17 CROSS-SECTION OF ZONAL WIND ALONG 160° E, FEBRUARY 1988
Isotach interval 10 knots.

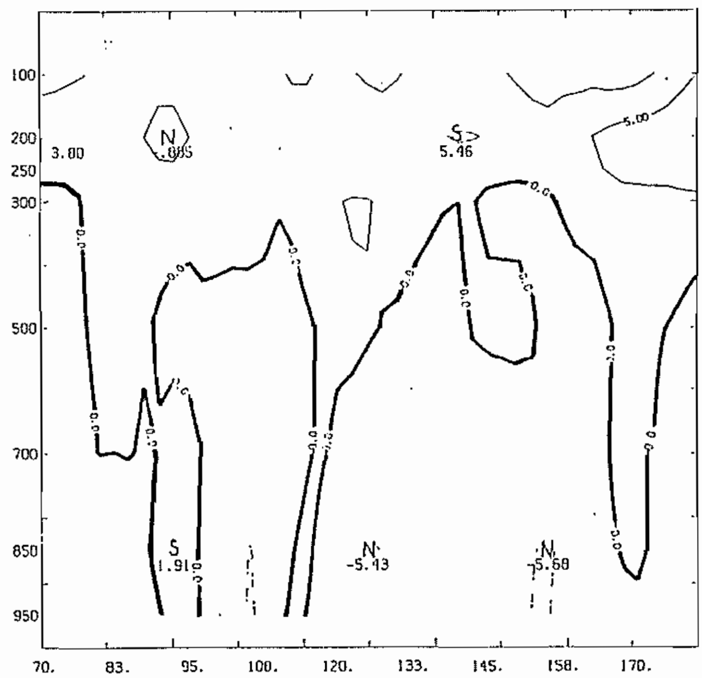


Fig.18 EQUATORIAL CROSS-SECTION OF MERIDIONAL WIND
BETWEEN 70°E AND 180°E, FEBRUARY 1988. 5 knot isotachs.

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

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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