1982

CSIRO Marine Laboratories
Report 202

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1989

National Library of Australia Cataloguing-in-Publication Entry

Forbes, A. M. G. (Andrew M. G.).
Meteorological data from the Leeuwin Current Interdisciplinary Experiment: a data report.
ISSN 0725-4598
ISBN 0 643 04830 8.

1. Meteorology - Western Australia - Observations.
I. Morrow, Rosemary A. (Rosemary Anne). II. Commonwealth Scientific and Industrial Research Organisation (Australia). Marine Laboratories. III. Title. (Series : Report (Commonwealth Scientific and Industrial Research Organisation (Australia). Marine Laboratories); no. 202).

551. 5'09941

Printed by Rank Xerox Australia Pty Ltd Melbourne ESS/PAS 4/89 600

Meteorological data from the Leeuwin Current Interdisciplinary Experiment: a data report

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CSIRO Marine Laboratories Report No. 202

Abstract

This report presents meteorological data acquired along the west coast of Australia between 18° and 35°S during an interdisciplinary study of the Leeuwin Current from September 1986 to August 1987. The data were gathered by CSIRO from offshore buoys and by the Bureau of Meteorology from coastal stations. This report presents tables of simple statistics and time series plots of wind velocity vectors; alongshore, onshore, northward and eastward velocity components; atmospheric pressure and air temperature for each station and buoy.

Introduction

Between September 1986 and August 1987, as part of the Leeuwin Current Interdisciplinary Experiment (LUCIE) off the west coast of Australia, wind, pressure and temperature data were gathered from 14 coastal stations operated by the Australian Bureau of Meteorology (ABM) and from two meteorological buoys operated by the CSIRO Division of Oceanography. Additional wind data were obtained from the Fremantle Port Authority. A general description of this experiment has been given by Church et al. (1989).

The ABM stations stretch from Broome in the north to Esperance in the south, spanning the central coastal region (which was also covered by current meter moorings), plus several hundred kilometres on each end. Two meteorological buoys – one off Dongara and the other off Cape Naturaliste – were part of the cross-shelf current meter mooring arrays; both were sited near the shelf-break. Results from the meteorological observations are presented here, while the current-meter observations are summarised in a companion CSIRO Marine Laboratories Report, No. 198.

Instrument Deployment

The fourteen Bureau of Meteorology coastal stations are part of a permanent network. At eight of them, observations were made twice daily at 0900 and 1500 h, and at six of them, observations were made every three hours. The bureau provided records of standard surface observations of ten parameters, but here we present only wind speed and direction, air pressure and air temperature. Hourly winds were also obtained from measurements at the Fremantle Port Authority. Table 1 lists the location, sampling scheme and record length of each meteorological station. Figure 1 shows the locations of all these stations.

The two CSIRO buoys recorded hourly samples of vector-averaged wind speed and direction, air pressure, air and sea temperature and solar radiation. Anemometers on both buoys were mounted 3.5 m above sea level, and the other sensors were grouped at 3 m height. The ARGOS system was used to transmit meteorological and position data ashore, while on-board recording was achieved with EMS-16 data loggers manufactured by Steedman Ltd of Perth. Table 2 gives details of the sensors used on the buoys.

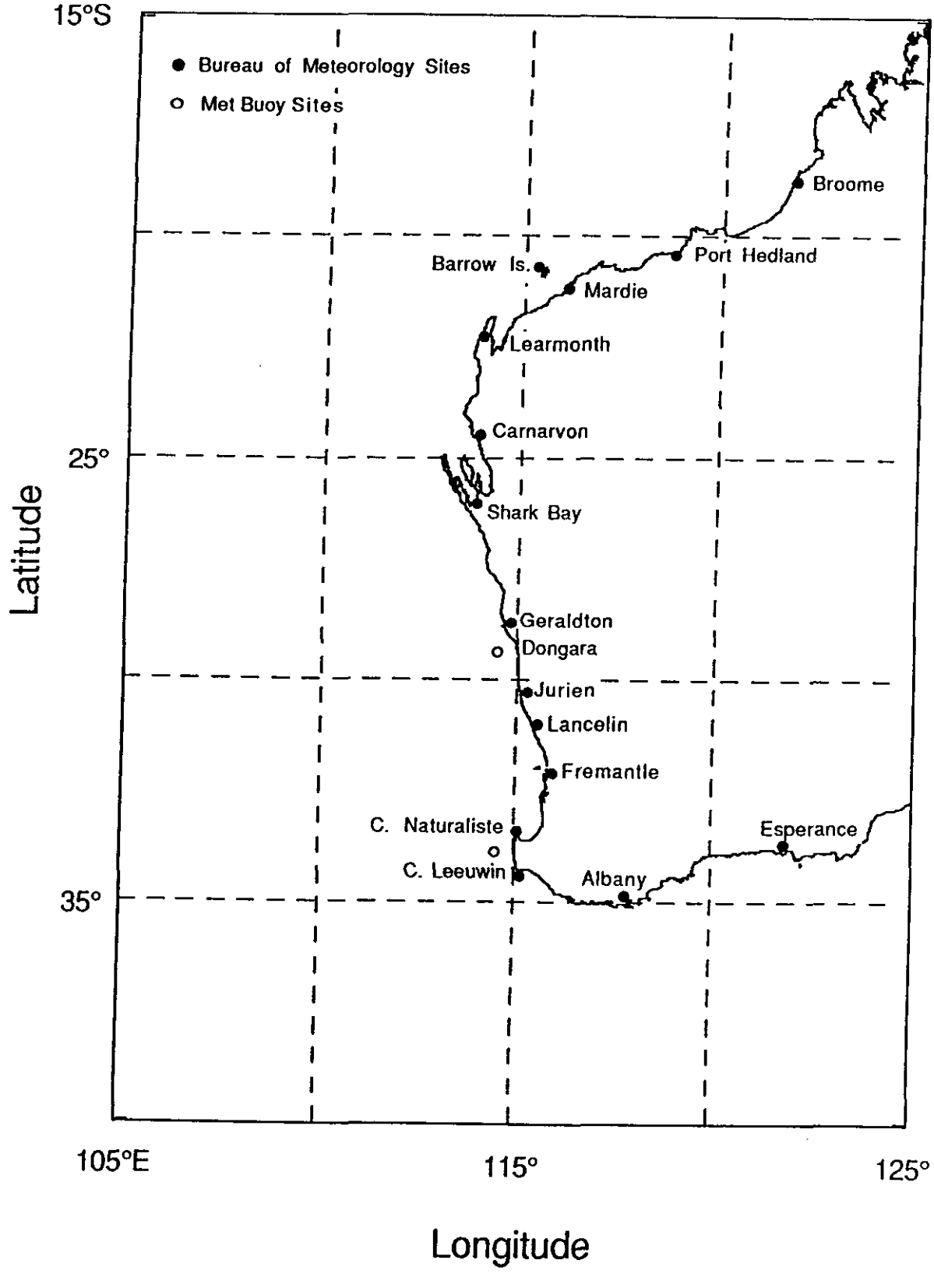

Figure 1. Map showing locations for all meteorological stations

Table 1. Coastal meteorological stations and offshore met buoys in Western Australia analysed for the Leeuwin Current Interdisciplinary Experiment (LUCIE).

Station name	Latitude	Longitude	Sampling interval type[+]	Alongshore direction	Record length (filtered)
Broome	18°41'S	121°46'E	2	045°	01Sep.86-30Aug.87
Port Hedland	20°23'S	118°38'E	3	045°	03Sep.86-28Aug.87
Mardie	21°11'S	115°58'E	2	045°	01Sep.86-30Aug.87
Barrow Is.	20°49'S	115°23'E	2	045°	01Sep.86-30Aug.87
Learmonth	22°14'S	114°05'E	3	020°	03Sep.86-28Aug.87
Carnarvon	24°53'S	113°40'E	3	000°	03Sep.86-28Aug.87
Shark Bay	26°15'S	113°48'E	2	000°	01Sep.86-30Aug.87
Geraldton	28°48'S	114°42'E	3	000°	03Sep.86-28Aug.87
Dongara*	29°32'S	114°16'E	1	000°	10Feb.87-27Apr.87
Jurien	30°18'S	115802'E	2	000°	01Sep.86-30Aug.87
Lancelin	31°01'S	115°20'E	2	000°	01Sep.86-29Mar.87
Fremantle	32°03'S	115°47'E	1	000°	06Sep.86-26Aug.87
C. Naturaliste	33°32'S	115°01'E	2	000°	01Sep.86-30Aug.87
C. Naturaliste*	34°01'S	114°28'E	1	000°	13Sep.86-31May.87[#]
C. Leeuwin	34°22'S	115°08'E	2	000°	01Sep.86-30Aug.87
Albany	34°57'S	117°48'E	3	270°	03Sep.86-28Aug.87
Esperance	33°49'S	121°53'E	3	270°	03Sep.86-28Aug.87

[+] type 1: hourly measurements; type 2: twice daily at 0900 and 1500 h; type 3: three hourly
* Offshore meteorological buoy
[#] Unfilled gap from 19Oct.86 to 10Feb.87

Table 2. Sensors used on CSIRO meteorological buoys during LUCIE.

Parameter	Manufacturer	Sensor type	Accuracy
Wind speed	R. M. Young	Aeroplane impeller	±0.5 ms^{-1}
Wind direction	R. M. Young	Aeroplane impeller	±5°
Atmospheric pressure	Yellow Springs Instr.	Aneroid	±0.5 mb
Air temperature	Rosemount	Platinum resistance	±0.3° C
Sea temperature	Rosemount	Platinum resistance	±0.3° C
Solar radiation	Haenni	Silicon pyranometer	±10 Wm^{-2}

The buoy off Dongara was a 3 m diameter discus; the southern buoy, off Cape Naturaliste, was a 2.5 m diameter toroid. They were located at the shelf-break so that they could gather offshore wind data to compare with the coastal stations and also serve as moorings for near-surface current meters in the zone where we expected the Leeuwin Current to be flowing strongly. All-chain slack moorings were used to ensure that the moorings did not "walk" their anchors in large swells and heavy seas.

Data were lost (see Table 3) when anemometers and moorings failed. In both moorings, components failed at the anchor attachment point after three months. The buoys were recovered after they had drifted a short distance, but only the Cape Naturaliste buoy had recorded data successfully. The Dongara buoy was struck by lightning shortly before deployment and its power supply failed intermittently after only a few hours in the water, rendering the record useless. The anemometer on the Cape Naturaliste buoy suffered from bearing corrosion, and produced only two months of good data. Both buoys were successfully re-deployed in February 1987, although the anemometer failed on the Dongara buoy after three months and the Cape Naturaliste deployment was shortened by one month due to fatigue of the mooring wire.

Table 3. Periods of meteorological records from CSIRO offshore bouys and reasons for short records. Each buoy was deployed twice: first in September 1986 and again in February 1987.

Station name	Deployment	Period of record	Recovery	Reason for short record
Dongara	1	11Sep.86-12Sep.86	15Nov.86	Struck by lightning and mooring failure
Dongara	2	04Feb.87-27Apr.87	15Jul.87	Anemometer rotor failure
C. Naturaliste	1	08Sep.86-16Oct.86	26Nov.86	Anemometer rotor and mooring failures
C. Naturaliste	2	06Feb.86-04Jun.87	04Jun.87	Mooring failure

Data Processing

Twice-daily ABM observations

The raw data consist of observations at 0900 and 1500 h (Western Standard Time zone). Small gaps were filled by linear interpolation, then filtered with a four-element "boxcar" filter. Output times are 0000 and 1200 h (WST). Wind stress was also calculated from a formula of Large and Pond (1981): $t = r\, C_d\, U^2$ where $10^3\, C_d = 1.2$ for $U < 11$ ms^{-1} and $C_d = 0.49 + 0.065\, U$ for $U > 11$ ms^{-1}, assuming neutral stability. The derived stresses were then filtered in the same manner. Components of filtered wind vectors were calculated in two coordinate sytems: first, northward and eastward; and second, alongshore and onshore. Alongshore is defined as the orientation of the large scale trend of the shoreline, and onshore is defined as being orthogonal to that, towards shore. The positive alongshore direction is towards the top of each figure, and the amount of rotation is indicated in degrees, positive being clockwise. Summary statistics are presented in

Table 4. Summary of wind, temperature and pressure statistics for coastal meteorological stations and offshore met buoys derived from data gathered for the LUCIE period (September 1986 through August 1987) along the coast of Western Australia.

Station Name	Speed (ms^{-1})	Dir'n (°T)	Semi-major axis (ms^{-1})	(°T)	Semi-minor axis (ms^{-1})	Temperature (°C)		Pressure (mb)	
	Mean	Mean	Std.dev.	Dir'n	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Broome	0.62	074	1.9	281	0.9	29.3	3.3	1010.8	4.1
P. Hedland	0.51	148	2.8	293	1.3	25.9	4.4	1011.2	4.9
Mardie	0.96	112	4.0	074	2.0	29.6	4.9	1011.3	4.5
Barrow Is.	2.03	347	5.0	052	2.1	26.4	3.9	1006.0	4.2
Learmonth	2.96	021	3.3	020	1.5	23.9	4.7	1013.0	4.5
Carnarvon	4.31	008	3.3	005	1.9	21.6	3.9	1014.1	4.6
Shark Bay	2.84	004	3.4	018	1.5	23.2	4.1	1013.2	4.5
Geraldton	1.66	358	2.9	006	1.9	18.8	4.6	1012.5	5.0
Dongara*	2.87	006	3.7	323	2.6	22.5	1.4	1016.5	3.7
Jurien	2.32	000	3.6	351	2.5	20.7	3.7	1016.6	4.9
Lancelin	2.89	022	2.3	284	2.2	21.5	3.4	1014.7	3.6
Fremantle	1.48	002	4.2	029	3.4	—	—	—	—
C. Naturaliste	2.56	024	4.3	054	3.5	17.5	3.0	1006.4	5.2
C. Naturaliste*	1.73	357	4.1	336	3.4	18.2	1.8	—	—
C. Leeuwin	2.26	028	6.1	285	3.7	17.6	2.5	1016.3	5.6
Albany	0.62	094	3.8	288	2.9	14.6	3.4	1009.7	6.8
Esperance	0.63	035	3.5	297	3.1	15.6	3.7	1015.5	6.5

* Offshore meteorological buoys — short record, Feb.87–May.87

Table 4 and time series plots of wind vectors, components, air pressure and air temperature are presented in Figures 2 to 8.

Three-hourly ABM observations

Small gaps were first filled by linear interpolation then the data were low-pass filtered with a Lanczos-cosine^2 filter of 40 points (120 hours). The filter, based on the least squares method of Thompson (1983), completely supresses signals at the dominant tidal frequencies and at inertial frequencies at all latitudes south of North West Cape. It has the same characteristics as the low-pass filter used on the current meter data by the LUCIE Group (1988). The output times are 0100 and 1300 GMT (because the original data were recorded at 0900 and 1500 WST), as close as possible to the filtered current meter output times of 0000 and 1200 GMT. Components of filtered wind vectors were calculated following the same conventions as for the twice-daily data, and time series of these are also plotted in Figures 2 to 8. Wind stress was also calculated according to the Large and Pond (1981) scheme. Summary statistics are given in Table 4.

Fremantle Port Authority winds

The raw data are hourly observations of winds. A few small gaps were filled by linear interpolation, then low-pass filtered using the same 120-hour LUCIE filter. Output times are at 0000 and 1200 GMT, and time series plots of wind components are included in Figures 2 to 8. Wind stress was also calculated but not plotted. Summary statistics are given in Table 4.

Offshore buoy observations

The raw data are hourly records of vector-averaged wind speed, relative wind direction, gust speed, wind steadiness, water and air temperatures, air pressure, solar radiation and buoy orientation. Several short patches of bad data were found in the air pressure record of the Dongara buoy data. These were manually edited at the raw data stage by linear interpolation. The Dongara wind speeds were obviously too low after April 25 (the wind speed rotor was badly worn upon recovery), so this section of the record was truncated. A few spikes of bad data in the temperature record during the first deployment period of the Cape Naturaliste buoy were removed and the gaps filled by linear interpolation.

Orthogonal components of the wind velocity and stress vectors were calculated and then filtered, along with air temperature and air pressure, with the 120-hour LUCIE filter. These filtered data are plotted in Figures 2 to 8. Summary statistics are presented in Table 4.

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Figures

Figure 1. Map of Western Australia showing locations of selected Bureau of Meteorology coastal stations (filled circles) and offshore meteorological buoys (open circles).

Figure 2a. Filtered time series of wind velocity vectors (ms^{-1}) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton. The axes have been rotated so that the positive alongshore direction is towards the left side of the page. The amount of rotation is indicated in degrees, positive being clockwise. Two vectors are plotted each day, one at noon and one at midnight.

Figure 2b. Filtered time series of wind velocity vectors (ms^{-1}) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south). The axes have been rotated so that the positive alongshore direction is towards the left side of the page and the amount of rotation is indicated in degrees, positive being clockwise. Two vectors are plotted each day, one at noon and one at midnight.

Figure 2c. Filtered time series of wind velocity vectors (ms^{-1}) from two CSIRO meteorological buoys, offshore from Cape Naturaliste and Dongara. The axes have been rotated so that the positive alongshore direction is towards the left side of the page. The amount of rotation is indicated in degrees, positive being clockwise. Two vectors are plotted each day, one at noon and one at midnight.

Figure 3a. Filtered time series of the alongshore component of wind velocity (ms^{-1}) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton. The positive alongshore direction is towards the left side of the page.

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Figure 3c. Filtered time series of the alongshore component of wind velocity (ms^{-1}) from two CSIRO meteorological buoys, offshore from Cape Naturaliste and Dongara.

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Figure 4a. Filtered time series of the onshore component of wind velocity (ms^{-1}) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton. The positive onshore direction is towards the left side of the page, orthogonal to the alongshore direction.

Figure 4b. Filtered time series of the onshore component of wind velocity (ms^{-1}) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south). The positive onshore direction is towards the left side of the page, orthogonal to the alongshore direction.

Figure 4c. Filtered time series of the onshore component of wind velocity (ms^{-1}) from two CSIRO meteorological buoys, offsore from Cape Naturaliste and Dongara. The positive onshore direction is towards the left side of the page, orthogonal to the alongshore direction.

Figure 5a. Filtered time series of the northward component of wind velocity (ms^{-1}) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton. True north is towards the left side of the page.

Figure 5b. Filtered time series of the northward component of wind velocity (ms^{-1}) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south). True north is towards the left side of the page.

Figure 5c. Filtered time series of the northward component of wind velocity (ms^{-1}) from two CSIRO meteorological buoys, offsore from Cape Naturaliste and Dongara. True north is towards the left side of the page.

Figure 6a. Filtered time series of the eastward component of wind velocity (ms^{-1}) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton. East is towards the left side of the page.

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Figure 6c. Filtered time series of the eastward component of wind velocity (ms^{-1}) from two CSIRO meteorological buoys, offshore

from Cape Naturaliste and Dongara. East is towards the left side of the page.

Figure 7a. Filtered time series of atmospheric pressure (mb) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton. It is necessary to add 1000 mb to the pressure scale.

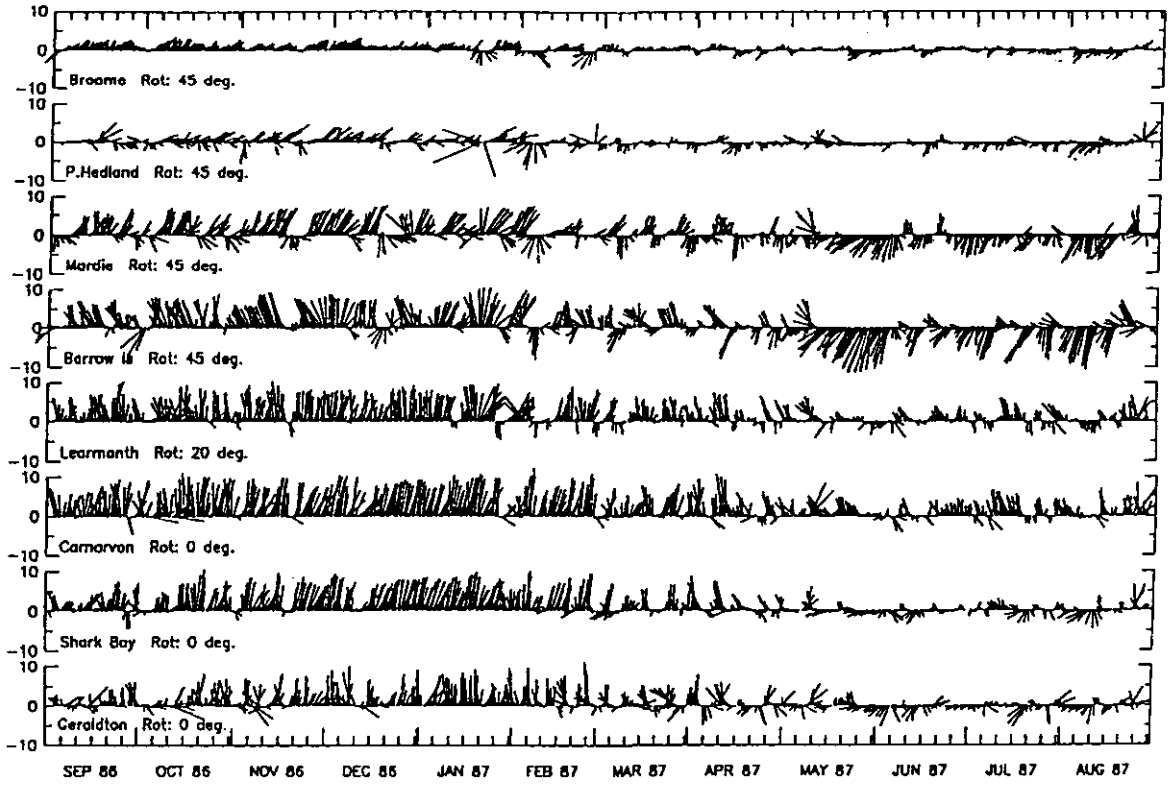
Figure 7b. Filtered time series of atmospheric pressure (mb) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south). It is necessary to add 1000 mb to the pressure scale.

Figure 7c. Filtered time series of atmospheric pressure (mb) from two CSIRO meteorological buoys, offsore from Cape Naturaliste and Dongara. It is necessary to add 1000 mb to the pressure scale.

Figure 8a. Filtered time series of air temperature (°C) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton.

Figure 8b. Filtered time series of air temperature (°C) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south).

Figure 8c. Filtered time series of air temperature (°C) from two CSIRO meteorological buoys, offsore from Cape Naturaliste and Dongara.



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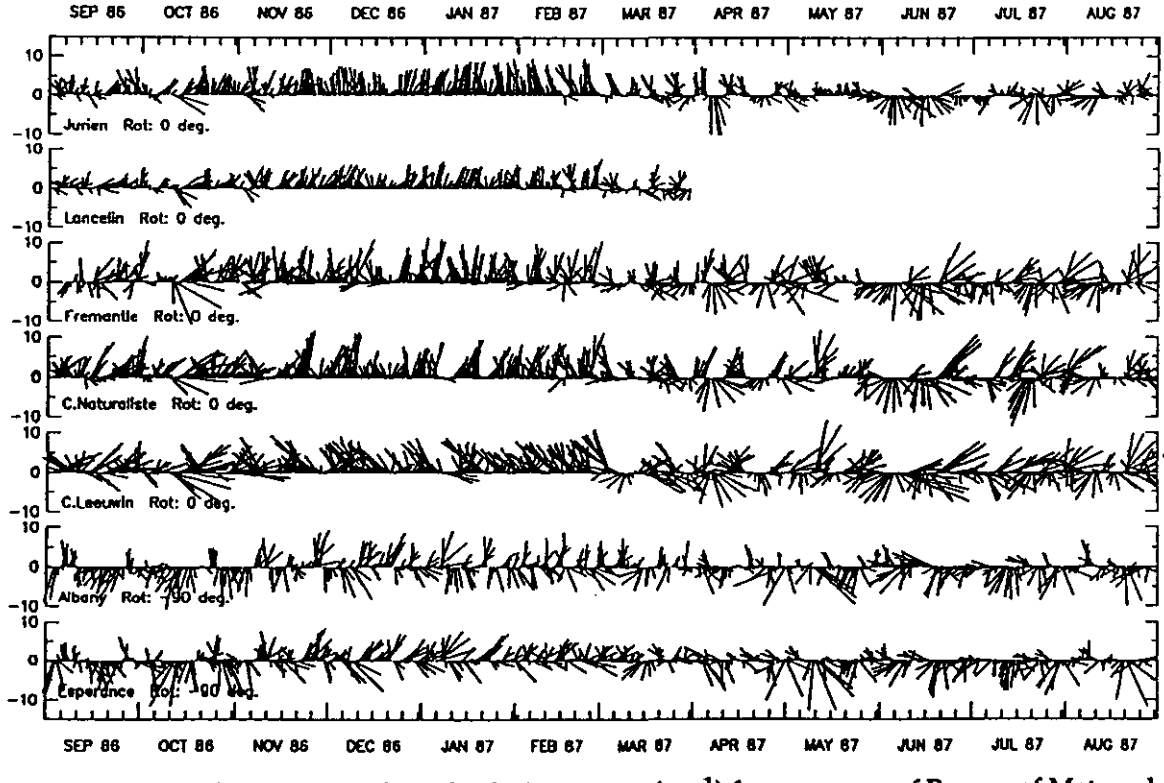

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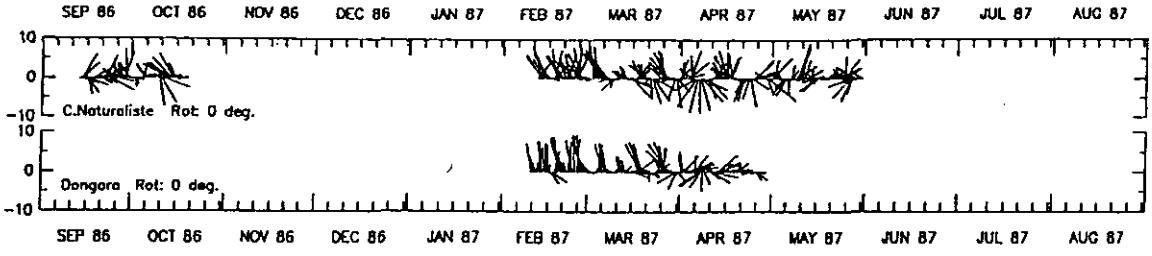
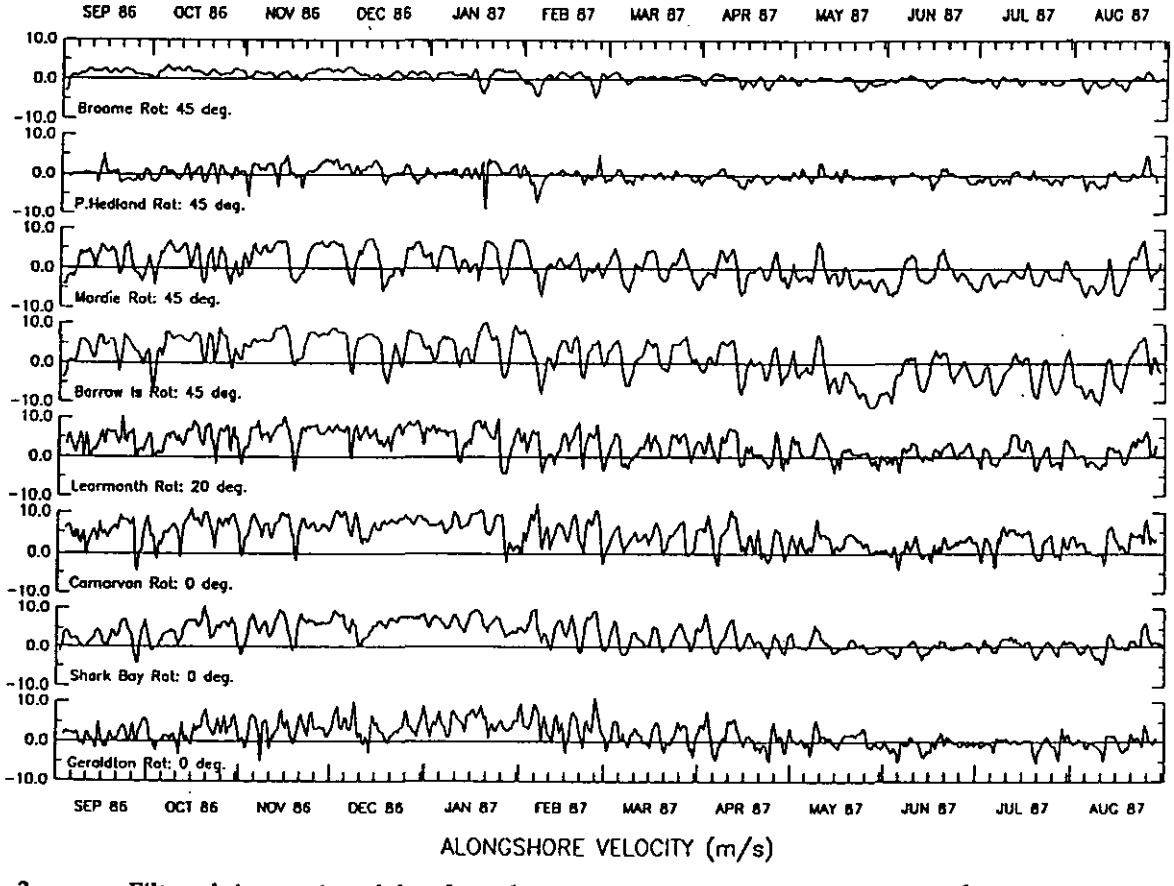


Figure 2c. Filtered time series of wind velocity vectors (ms^{-1}) from two CSIRO meteorological buoys, offshore from Cape Naturaliste and Dongara. The axes have been rotated so that the positive alongshore direction is towards the left side of the page. The amount of rotation is indicated in degrees, positive being clockwise. Two vectors are plotted each day, one at noon and one at midnight.



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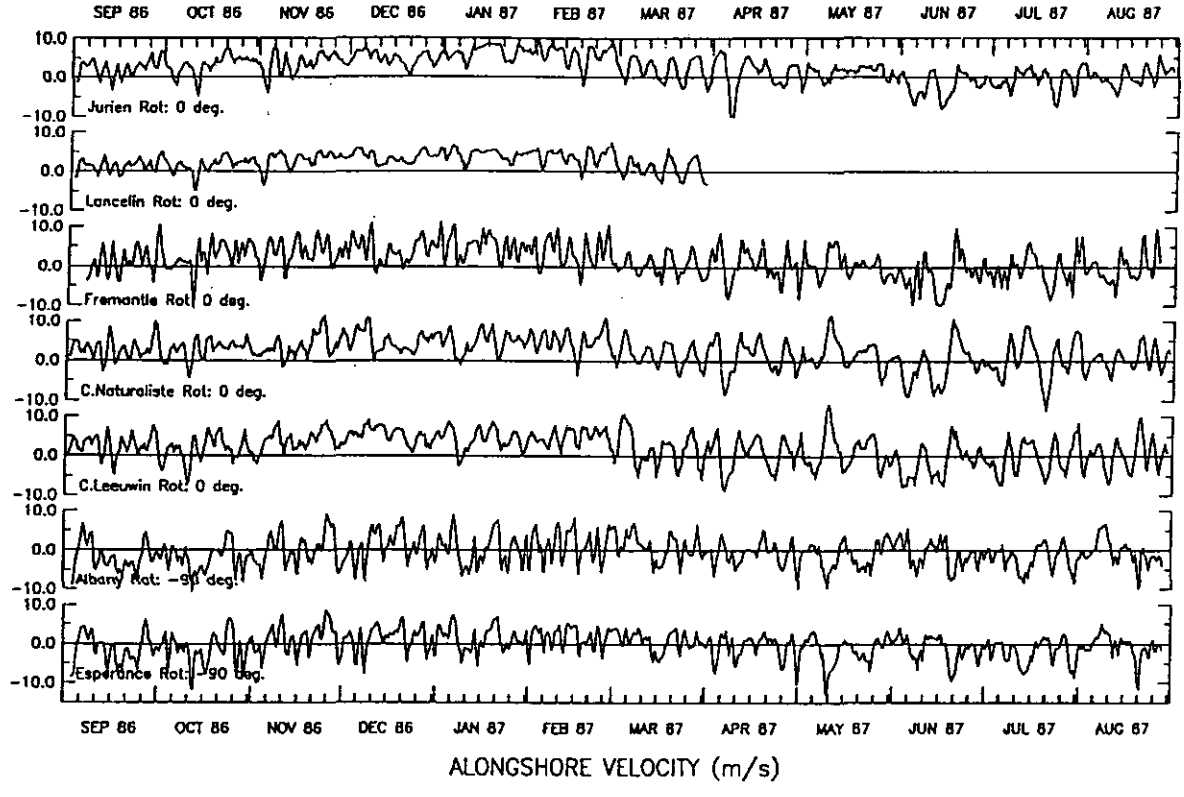

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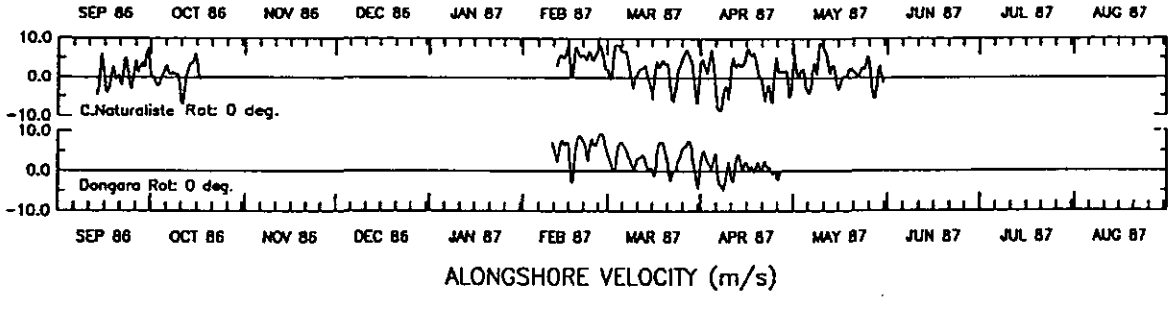

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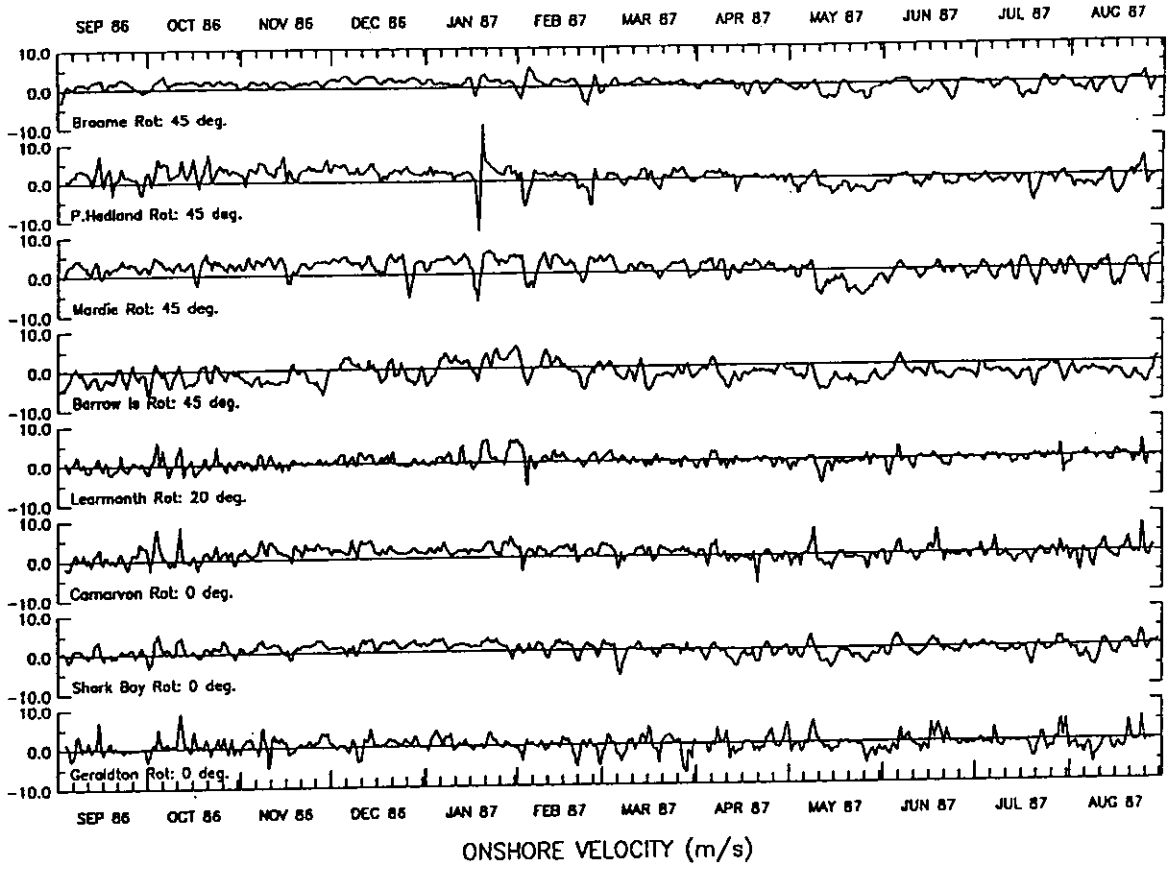

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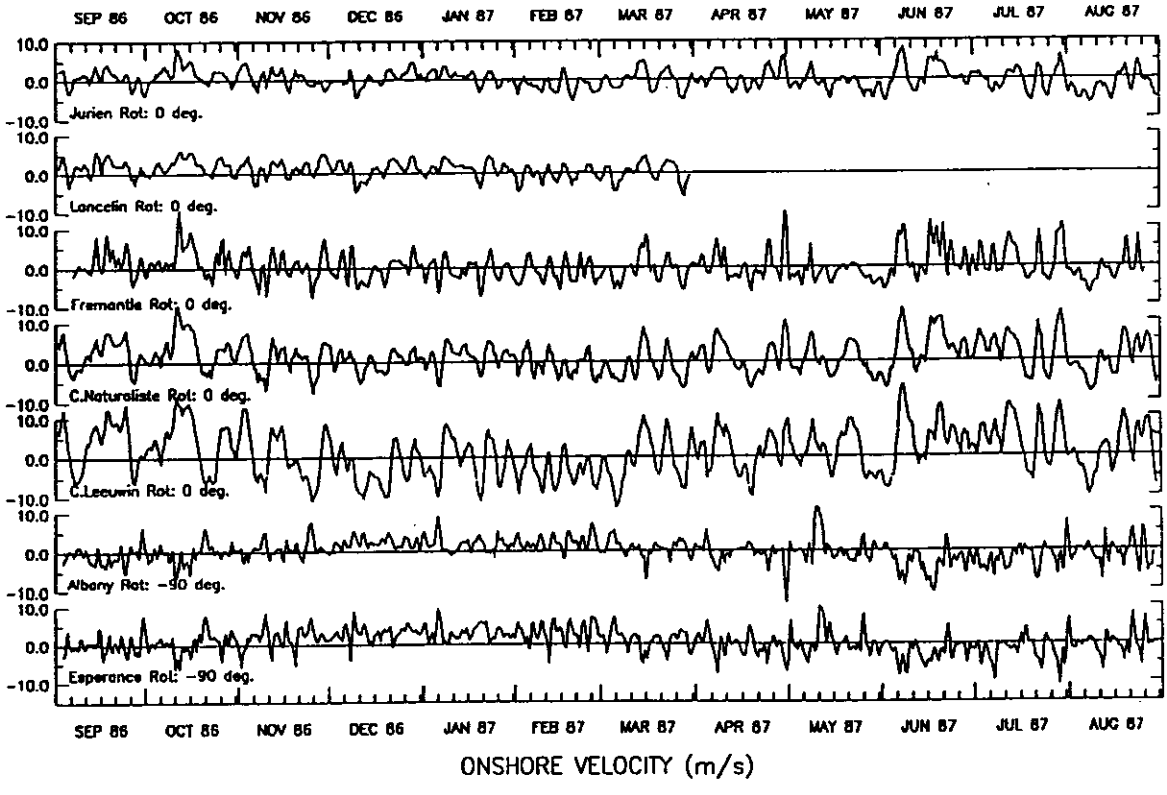

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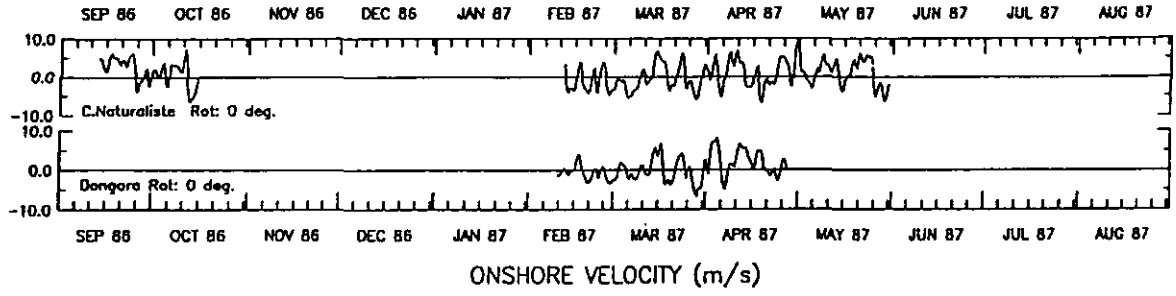

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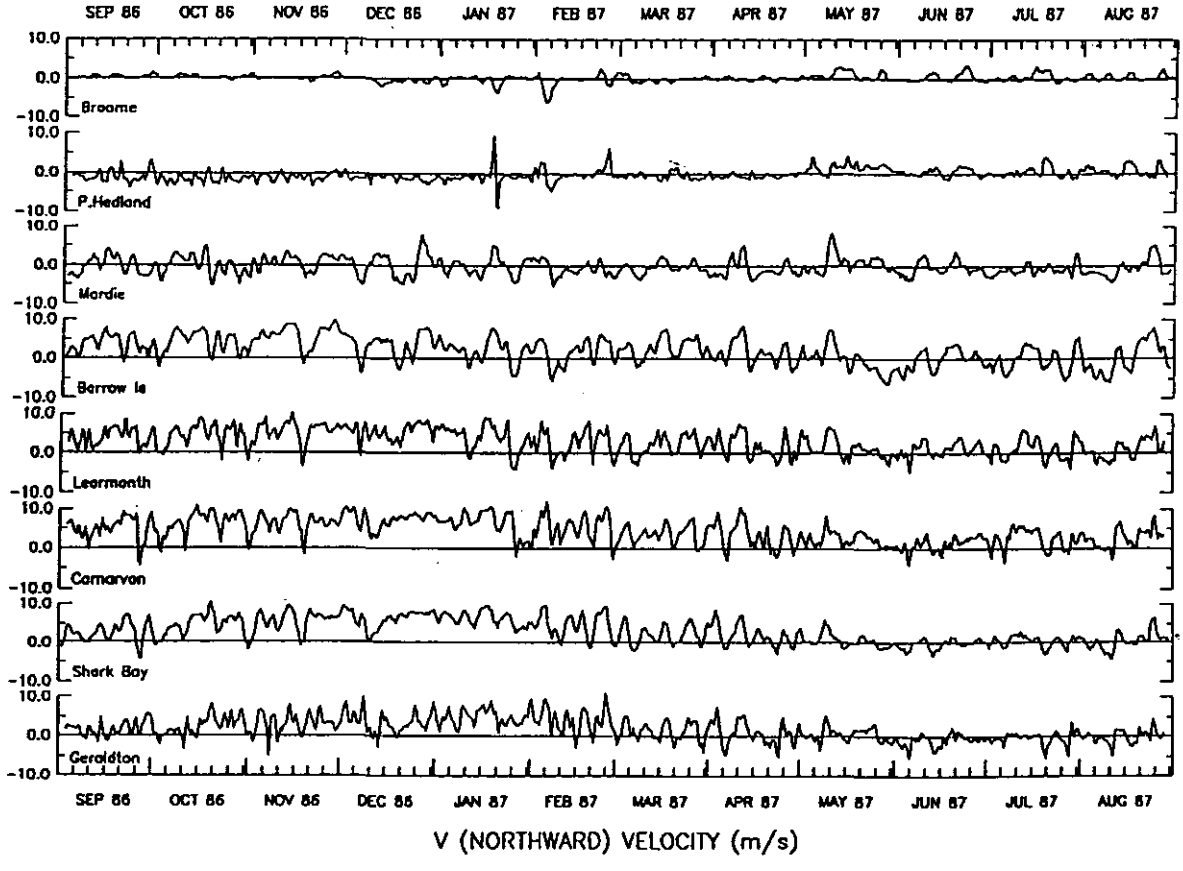

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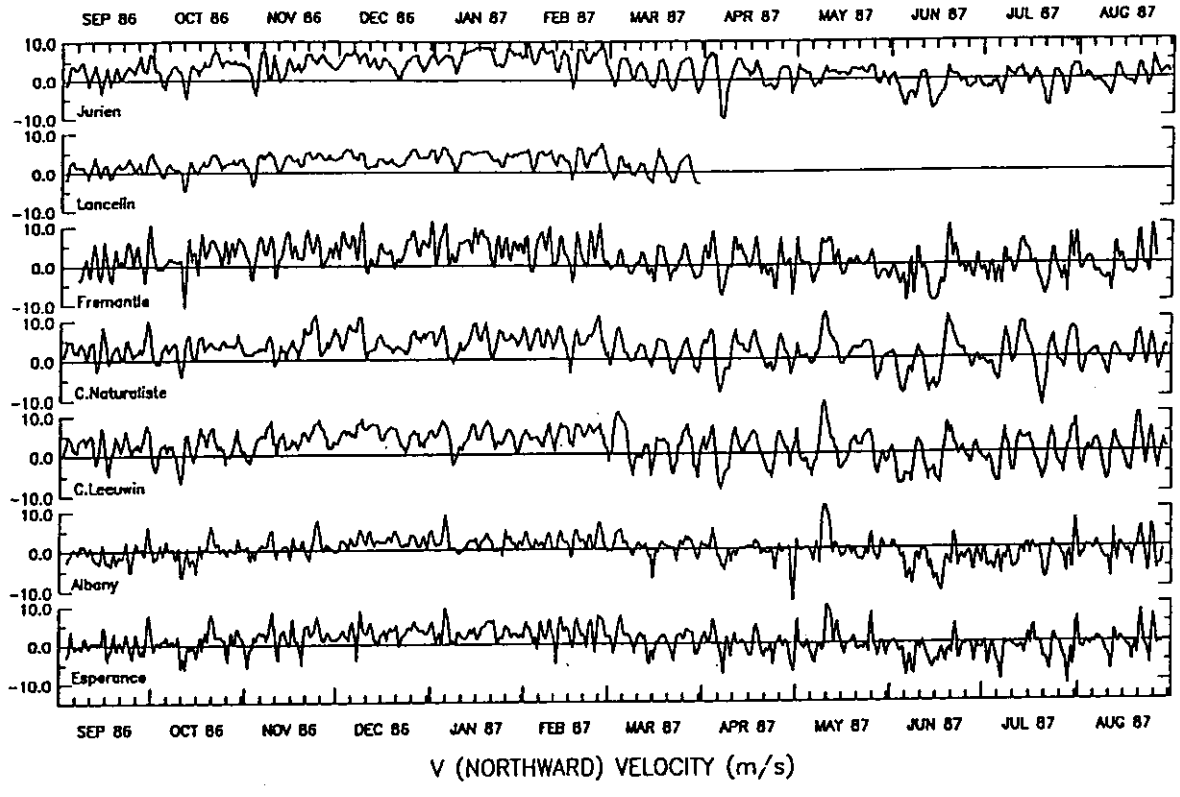

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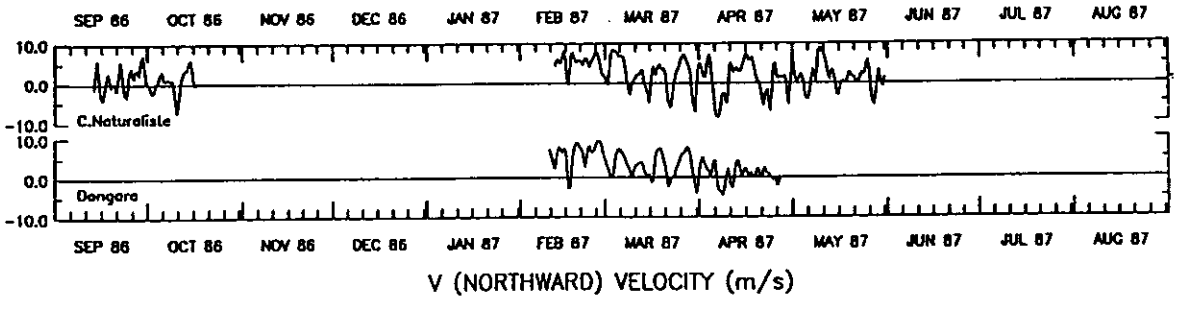

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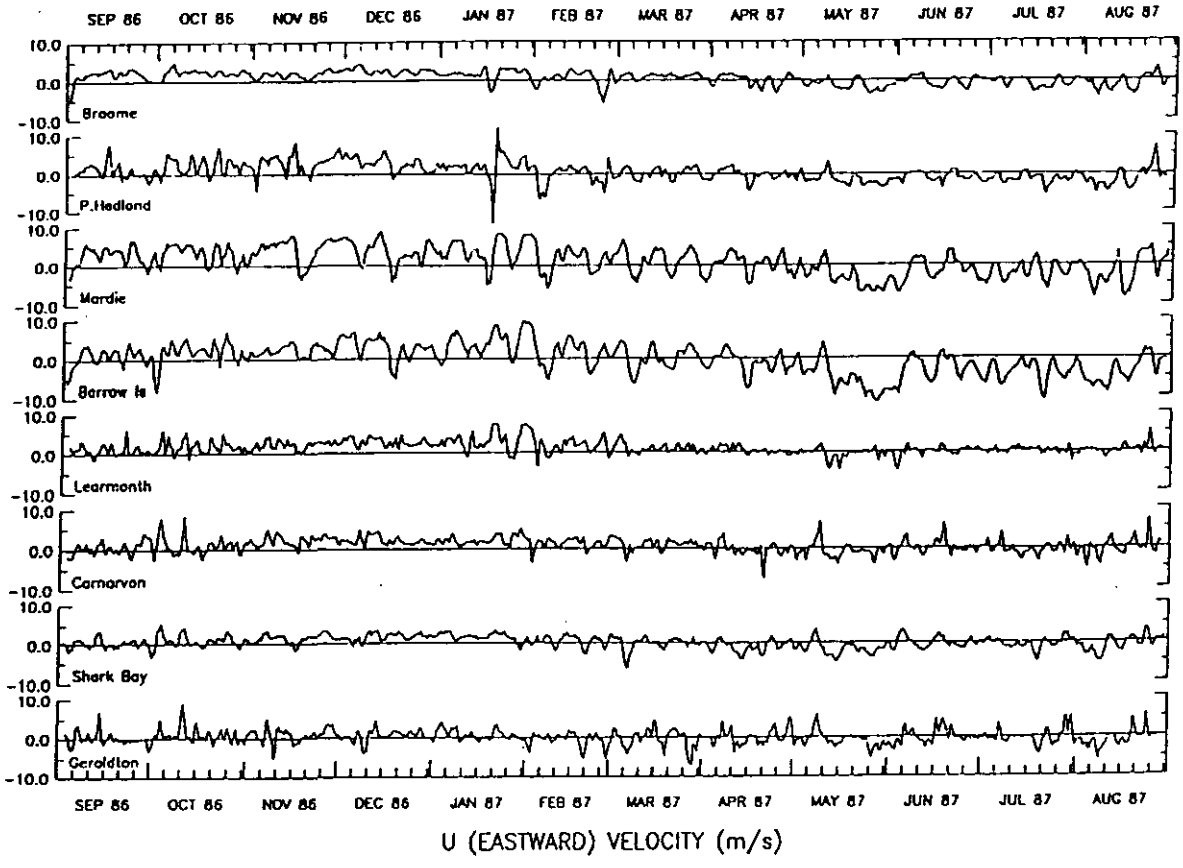

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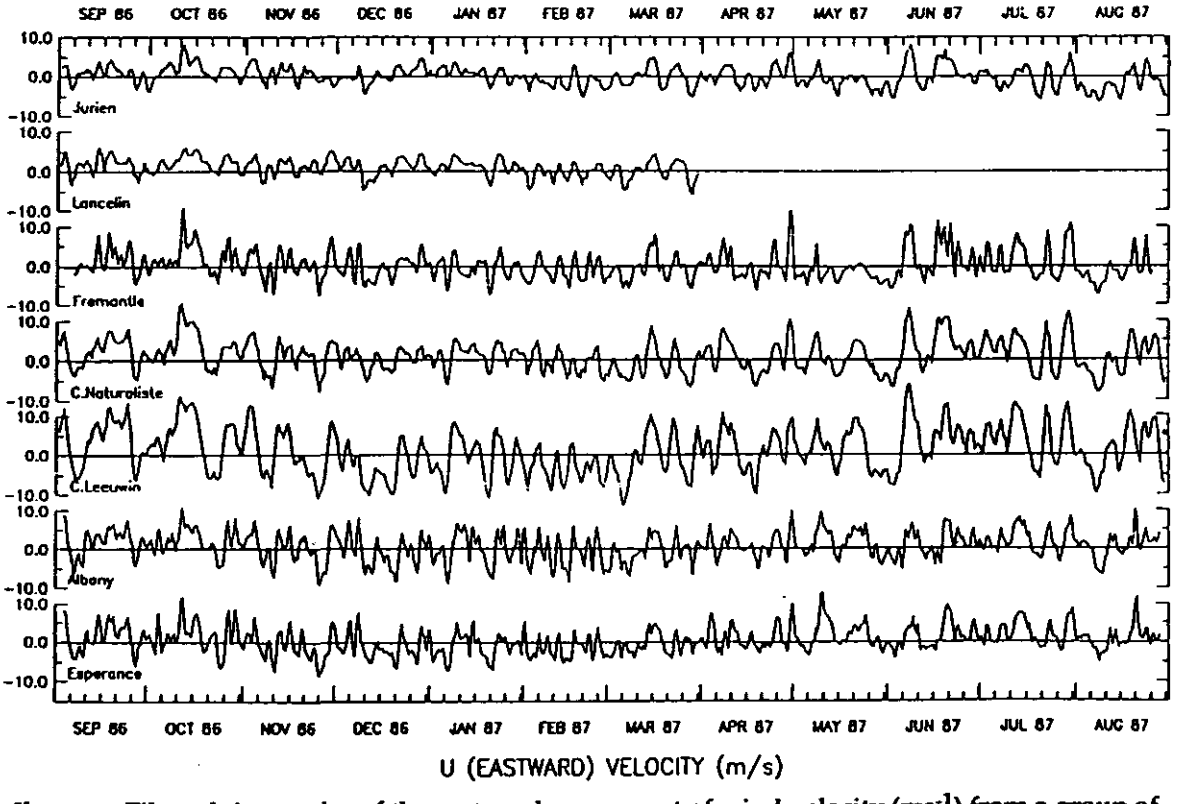

Figure 6b. Filtered time series of the eastward component of wind velocity (ms^{-1}) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south). East is towards the left side of the page.

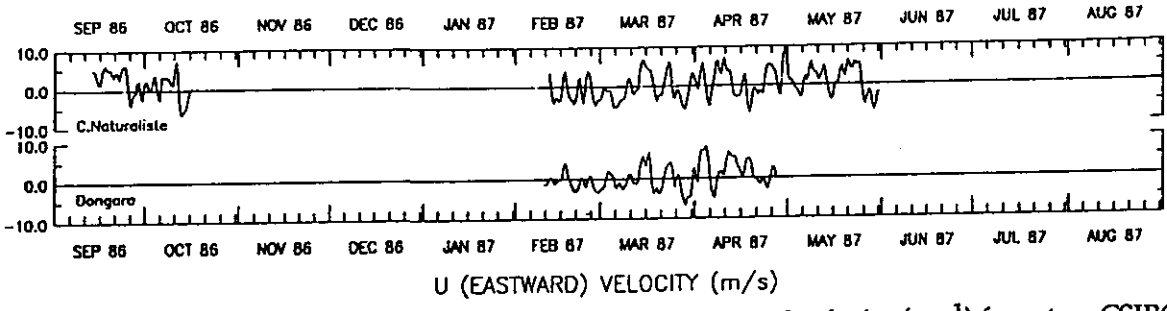

Figure 6c. Filtered time series of the eastward component of wind velocity (ms^{-1}) from two CSIRO meteorological buoys, offshore from Cape Naturaliste and Dongara. East is towards the left side of the page.

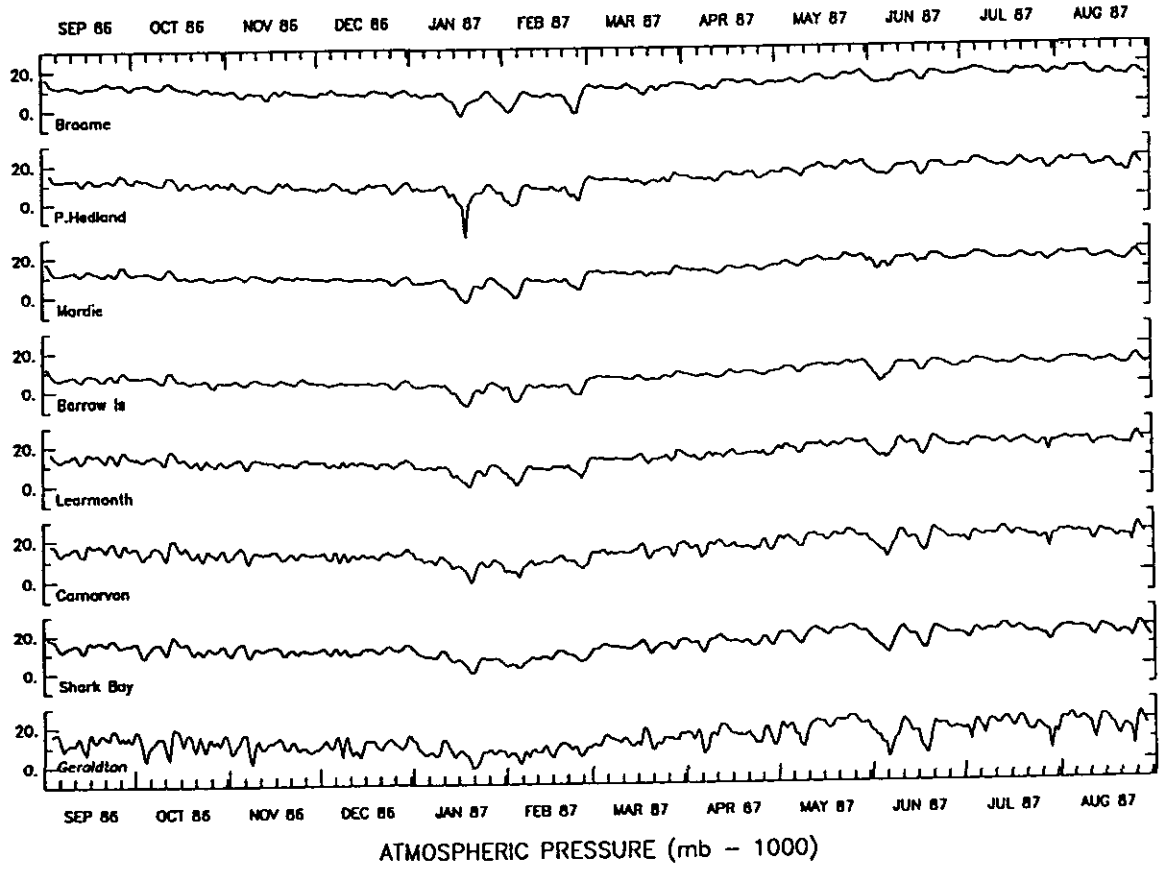

Figure 7a. Filtered time series of atmospheric pressure (mb) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton. It is necessary to add 1000 mb to the pressure scale.

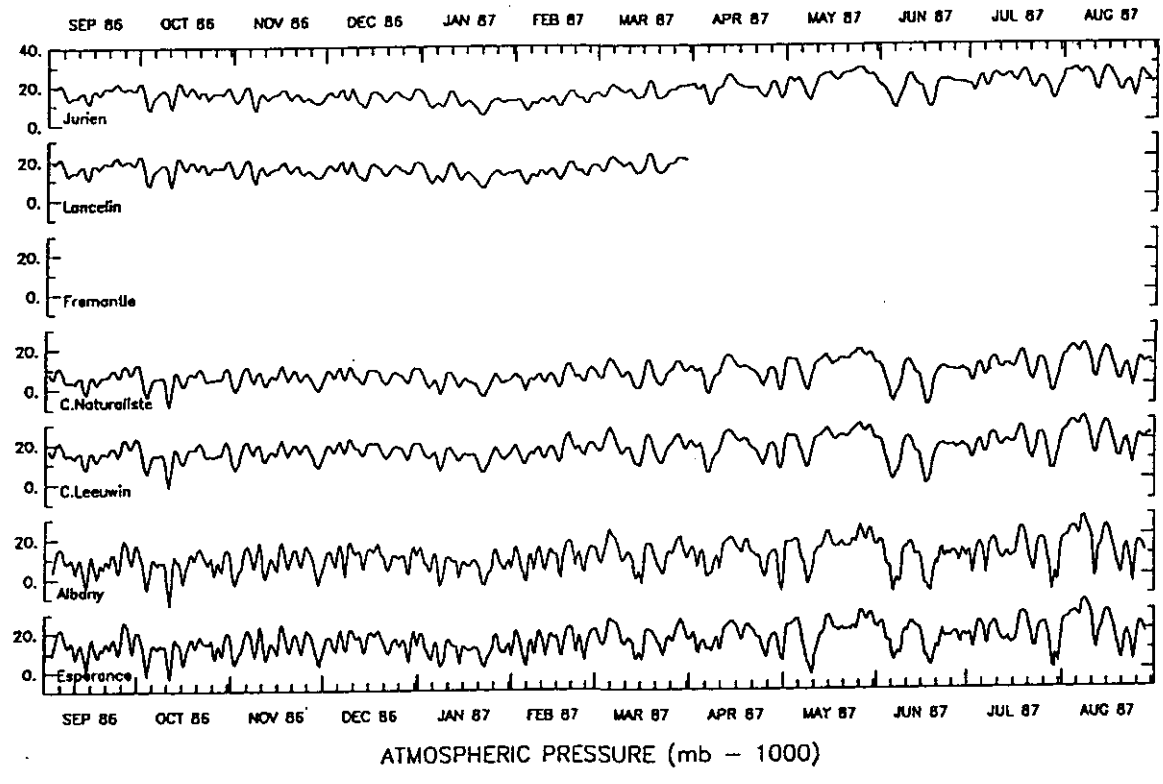

Figure 7b. Filtered time series of atmospheric pressure (mb) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south). It is necessary to add 1000 mb to the pressure scale.

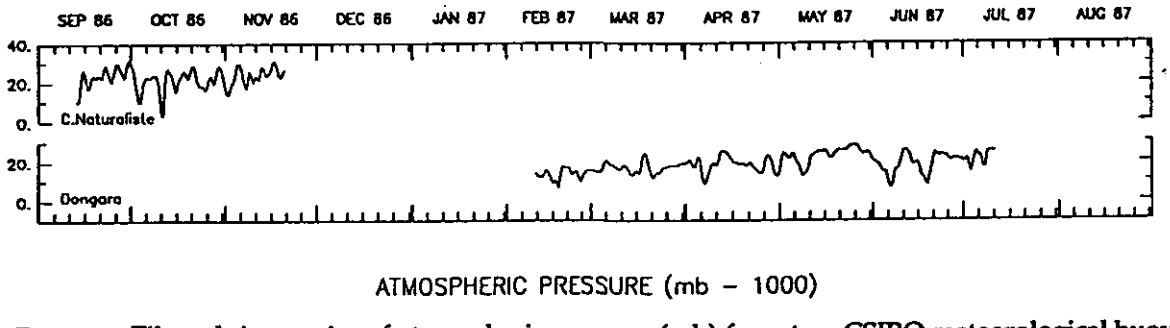

Figure 7c. Filtered time series of atmospheric pressure (mb) from two CSIRO meteorological buoys, offsore from Cape Naturaliste and Dongara. It is necessary to add 1000 mb to the pressure scale.

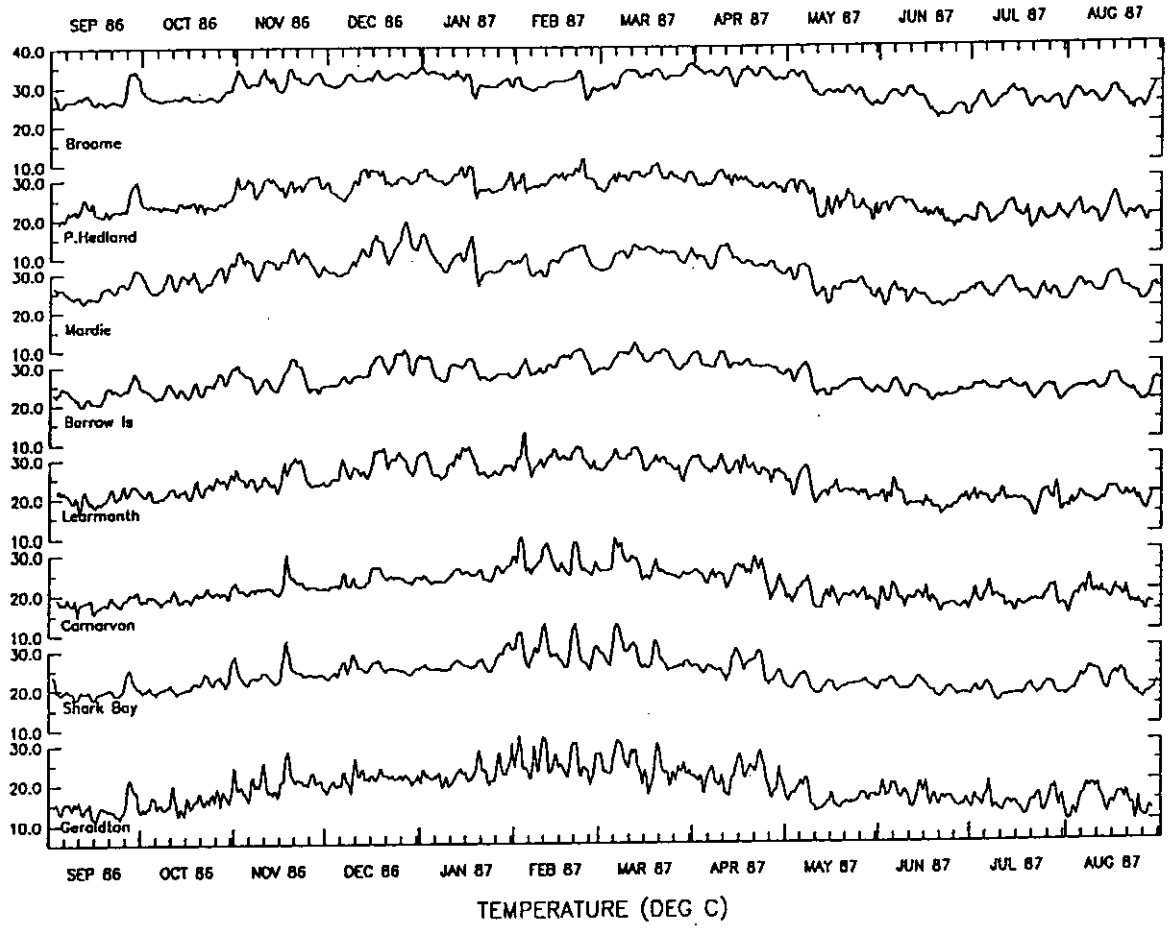

Figure 8a. Filtered time series of air temperature (°C) from a group of Bureau of Meteorology stations, Broome (in the north) to Geraldton.

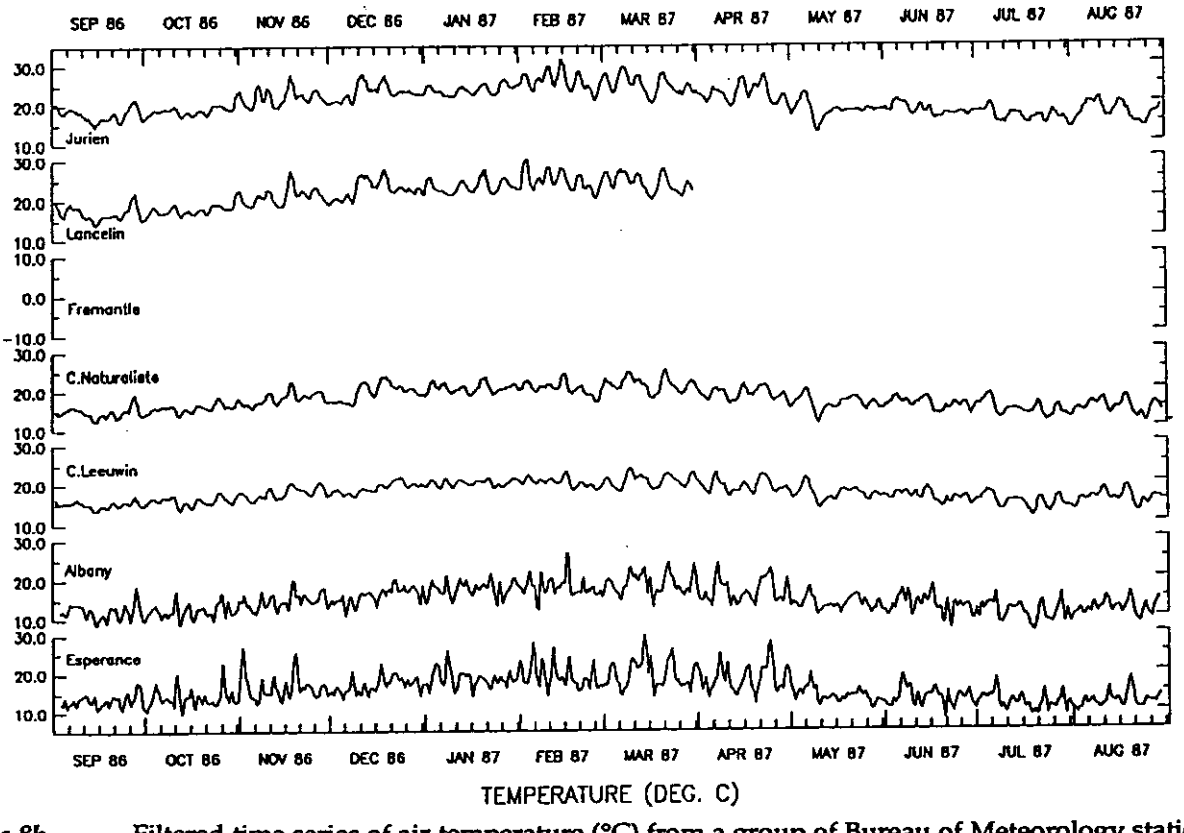

Figure 8b. Filtered time series of air temperature (°C) from a group of Bureau of Meteorology stations, Jurien to Esperance (in the south).

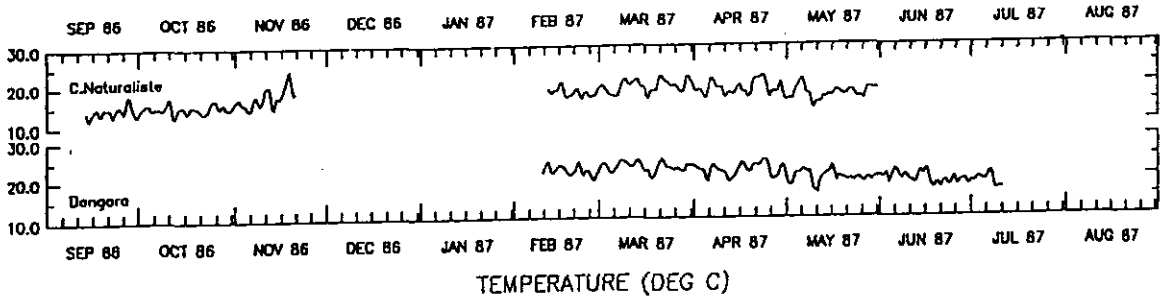

Figure 8c. Filtered time series of air temperature (°C) from two CSIRO meteorological buoys, offsore from Cape Naturaliste and Dongara.

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ISBN 0 643 04830 8