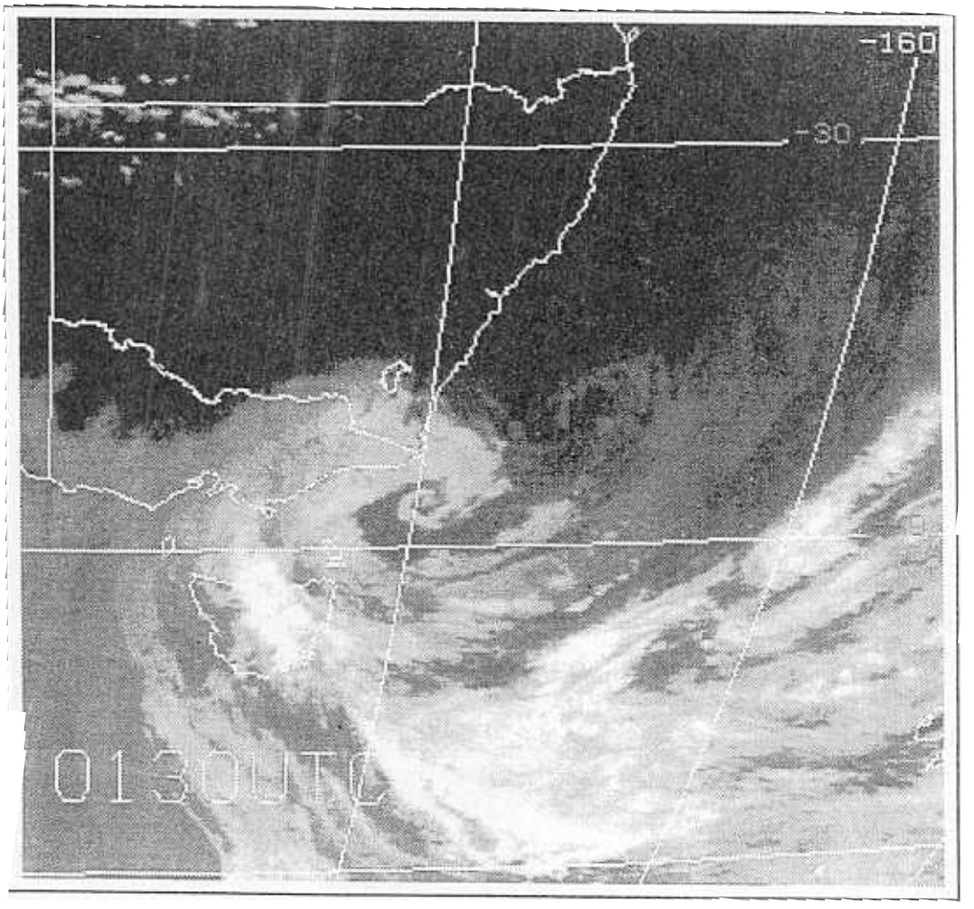
APPENDIX 12

Bureau of Meteorology – "Preliminary Report on Meteorological Aspects of the 1998 Sydney to Hobart Yacht Race"

BUREAU OF METEOROLOGY

Preliminary Report on Meteorological Aspects of the 1998 Sydney to Hobart Yacht Race



February 1999

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8 Search and rescue forecasts issued by the Victorian Regional Forecasting Centre and the Canberra Meteorological Office.

PREFACE

This preliminary report has been prepared in order to provide as much meteorological information as can be made readily available to all those who have a need for background on the meteorological aspects of the 1998 Sydney to Hobart Yacht Race disaster including especially those organisations which need the information to assist in their own assessments of performance during the event.

The report is in two parts. The first consists of an extended Executive Summary that aims to meet the need for a concise overview of the meteorological events and services associated with the 1998 Sydney to Hobart Yacht Race. It includes its own set of figures and attachments. These are repeated in the main body of the report but the numbering is different. Those in the Executive Summary have the prefix "E" to distinguish them from the information appearing in the main body of the report.

The second part of the document is the main body of the report. It is aimed at the more technical reader who requires detailed information on particular aspects of the meteorological situation and/or wishes to examine more closely the services provided for the yacht race by the Bureau of Meteorology during the period from about 23 December through to the end of search and rescue operations on 29 December 1998.

The report has been prepared in the Bureau's Head Office with input from many officers. The lead authors were Ms Clare Richards of the Bureau's Services Policy Branch and Mr John Mottram, an external Meteorological Consultant (and formerly Principal of the Bureau of Meteorology Training Centre), with special assistance from Mr John Bally, Mr Kenn Batt and Mr Geoff Feren from the Bureau's Regional Offices in Tasmania, Sydney and Melbourne, respectively and Dr John McBride from the Bureau of Meteorology Research Centre.

A final more comprehensive report on all meteorological and related aspects of the events surrounding the 1998 Sydney to Hobart Yacht Race will be prepared over the next few months.

PRELIMINARY REPORT ON METEOROLOGICAL ASPECTS OF THE 1998 SYDNEY TO HOBART YACHT RACE

EXECUTIVE SUMMARY

Introduction

Of the 115 yachts that set sail at 1pm on 26 December 1998 in the Sydney to Hobart Yacht Race, only 44 reached their destination. The destruction caused by a storm encountered by the fleet triggered a massive search and rescue operation involving numerous personnel from organisations such as the Australian Maritime Safety Authority (AMSA), the Royal Australian Navy (the Navy), the Royal Australian Air Force (RAAF) and Police. Even so, it resulted in the abandonment of several yachts and the death of six people. It was the most disastrous event in the 54 year history of this yachting classic.

2. The yachts encountered very severe wind and sea conditions before most were half way into their approximately 630 nautical mile journey down the southeast coast of Australia (Fig E1). The worst weather to hit the fleet occurred off the southern NSW coast and in eastern Bass Strait. The Bureau of Meteorology had issued a gale warning (mean wind speeds between 34 and 47 knots) for the southern NSW coast 4 hours in advance of the start of the race and upgraded this to storm warnings (mean wind speeds above 47 knots) for the southern NSW coast and eastern Bass Strait area about one hour into the race (see Attachment E1).

3. This Executive Summary outlines the evolution of the associated weather systems and highlights key meteorological and oceanographic aspects of the event. The advance briefing, and the forecasts and warnings that were provided by the Bureau, are also described. Some of the terminology used in this report is, necessarily, technical and relevant explanatory notes are provided in Attachment E2.

Evolution of weather conditions

4. After a very warm Christmas Day with a north to northeasterly airflow over much of southeastern Australia, the surface weather pattern for 9pm on 25 December 1998 showed a significant cold front crossing the Great Australian Bight towards Tasmania. A prefrontal trough was already located over western Victoria (Fig E2). These features combined during the next day (Boxing Day) and the resultant system intensified as it moved eastwards across Victoria. The surface weather pattern at 9am on 26 December (Fig E3), four hours before the start of the race, showed it would commence in conditions conducive to a fast race with a favouring current, reportedly running at 4 knots, and north to northeast winds of generally 25 to 35 knots prevailing off the New South Wales southern coast.

5. By early morning on 27 December 1998, an upper air jet stream and a substantial cold air mass had moved rapidly northwards over Victoria producing unseasonable snow falls on the Australian Alps in the wake of the surface cold front. In association

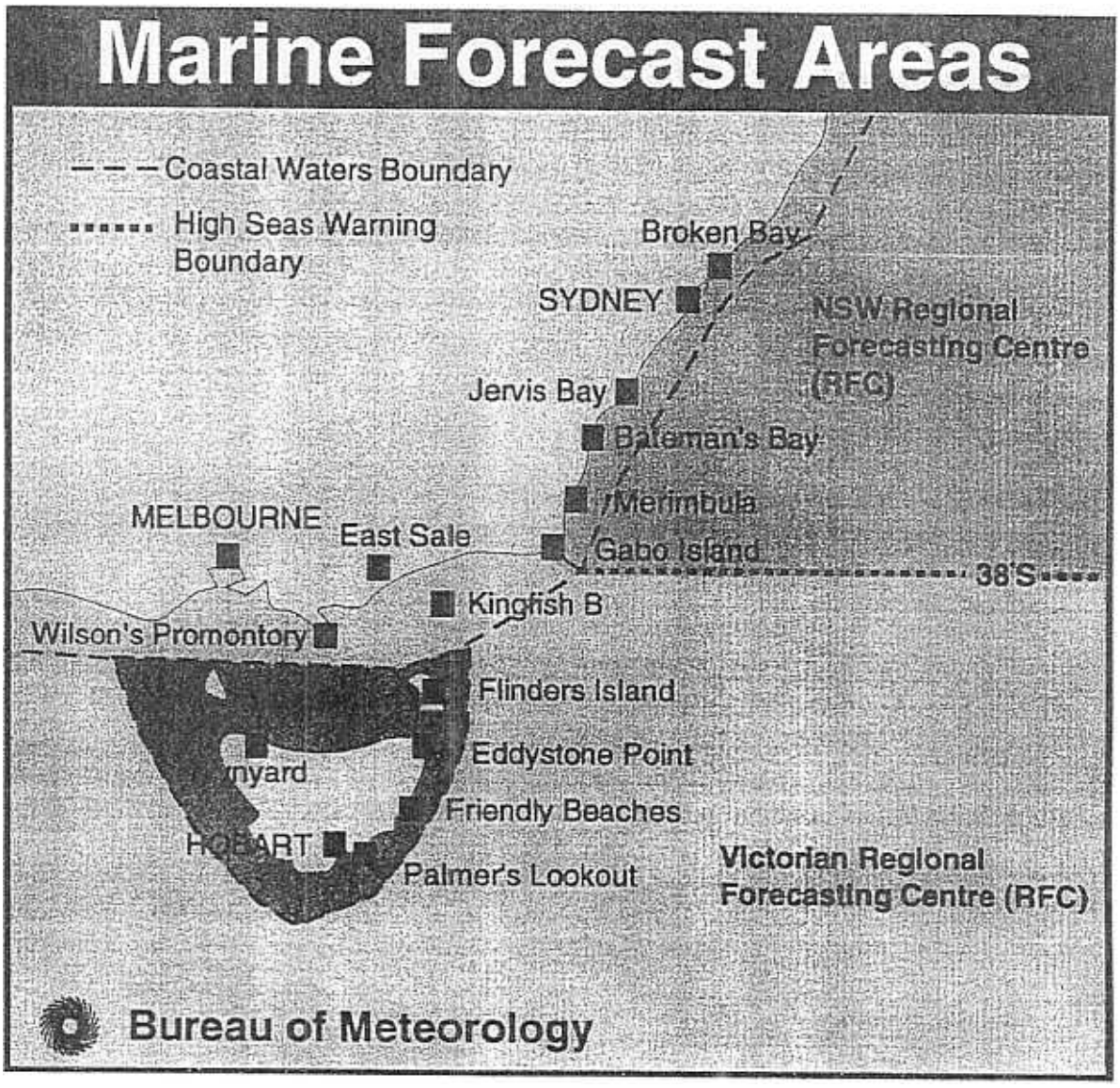

Figure E1: Map of southeastern Australia showing the key coastal locations adjacent to the Sydney to Hobart yacht race course, and the areas of forecast responsibility for the Sydney, Melbourne and Hobart Regional Forecasting Centres. Note that for the special yacht race forecasts, Hobart's area of responsibility is the area from 38°S to Hobart.

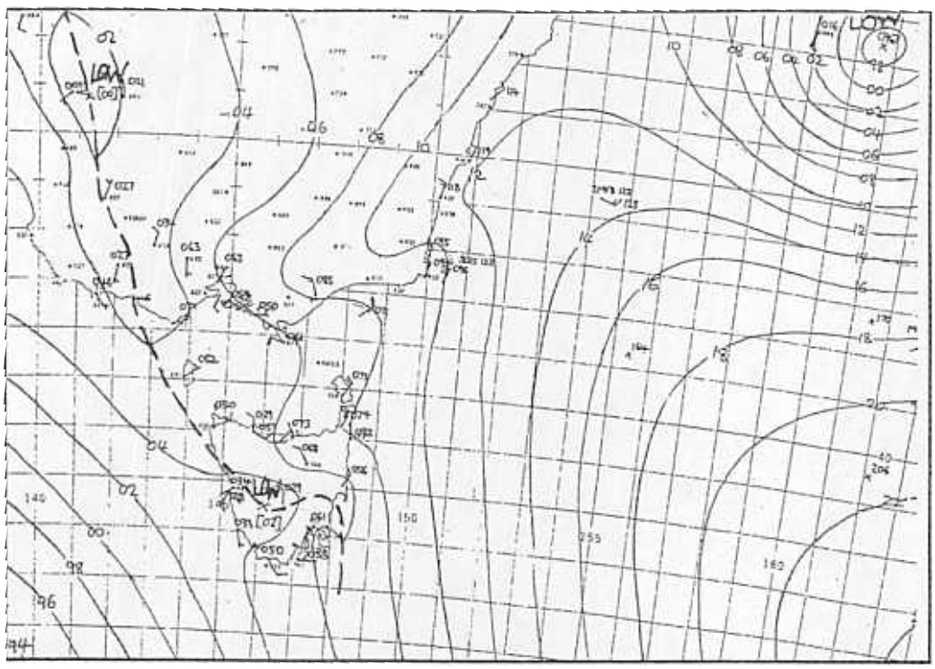

Fig E2. Surface pressure analysis 9pm 25 December 1998
Isobars at 2 hPa intervals (for labelling see Attachment E2)

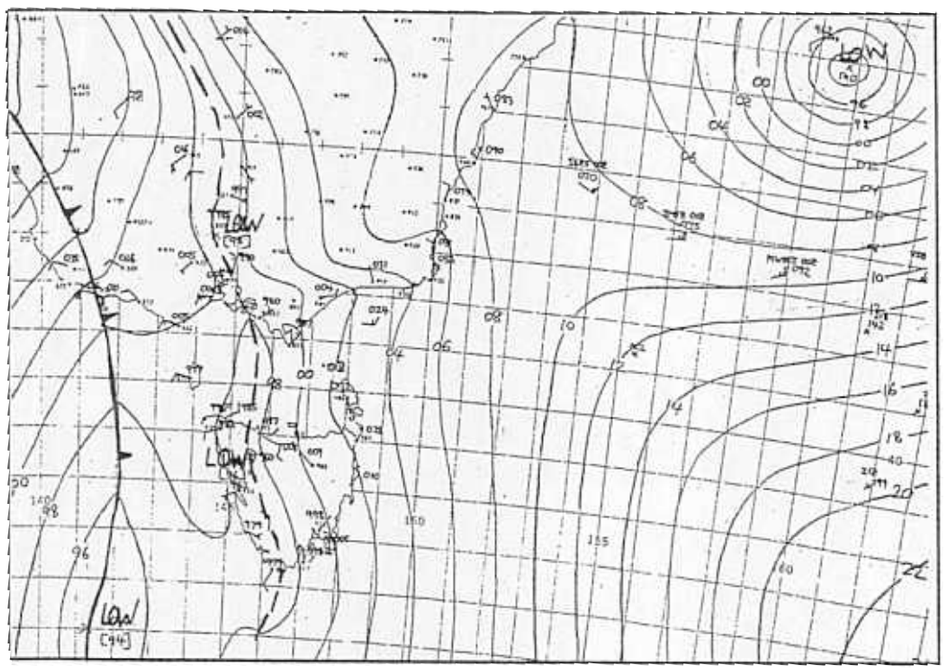

Fig. E3. Surface pressure analysis 9am 26 December 1998
Isobars at 2 hPa intervals (for labelling see Attachment E2)

with this injection of a deep layer of cold air over Victoria, a new small-scale low had begun to form and intensify rapidly over Bass Strait to the south of Wilsons Promontory. This was occurring at the boundary of the interacting very cold and warm air masses which, with the positioning of a strongly curving jet stream in the upper atmosphere, had become a favourable location for the formation of a rapidly intensifying low (as shown schematically in Fig E4).

6. The central pressures in the low, which formed to the south of Wilsons Promontory, dropped rapidly to near 980 hPa. The low initially moved northeastwards but shifted to a more easterly path at a speed near 25 knots by late on the morning of Sunday 27 December. At midday, the low passed to the south of Gabo Island, maintaining its intensity. The path of the low is shown in Fig E5.

7. In association with the low pressure development, west to southwest winds with mean speeds reaching storm force developed and extended over eastern Bass Strait and southern NSW coastal waters. The surface analysis at 3pm Sunday 27 December 1998, when the storm force winds were likely to have been at or near their peak, is shown in Fig E6. A satellite photograph, illustrating the very tight spiral structure of the low pressure system at about the time of this analysis, is shown in Fig E7.

8. By 9am the following day, 28 December, the surface analysis showed the low moving rapidly away towards the southwest of New Zealand (Fig E8) and winds and seas were beginning to moderate for the continuing search and rescue operations.

Wind speeds

9. A preliminary reanalysis of the situation, taking account of all readily available information, including reports obtained to date from yacht crews, observations from the ESSO Kingfish B Platform in eastern Bass Strait, coastal station reports and information from the Navy's Race Relay Ship *Young Endeavour*, as well as the Bureau's normal observation network, strongly suggests that the highest mean winds (for definition, see Attachment E2.) over open waters in eastern Bass Strait and off the southern NSW coast were about 55 to 60 knots. It should be noted that gusts and squalls of considerably higher wind speeds would almost certainly have been experienced by the yachts for short periods of time as mean winds of this magnitude (55 to 60 knots) could be expected to produce gusts of 70 to 75 knots or more on a fairly regular basis. The gusty nature of the winds in Eastern Bass Strait during the critical period of the race is illustrated in the recording of observed winds at ESSO's Kingfish B Platform (Fig E9). A more detailed survey of yacht reports is underway to establish the range of speeds experienced.

10. The reanalysis of events has taken into account that mean winds of up to 79 knots were observed at Wilsons Promontory Lighthouse. The reanalysis has, however, concluded that these winds were unrepresentative of surface conditions because the observations at Wilsons Promontory are measured at an elevation of about 100 metres and are additionally prone to local effects induced by the surrounding topography. According to studies of boundary layer effects, the wind speed recorded at Wilsons Promontory could be as much as 20 to 25 knots higher than that at an elevation of 10 metres.

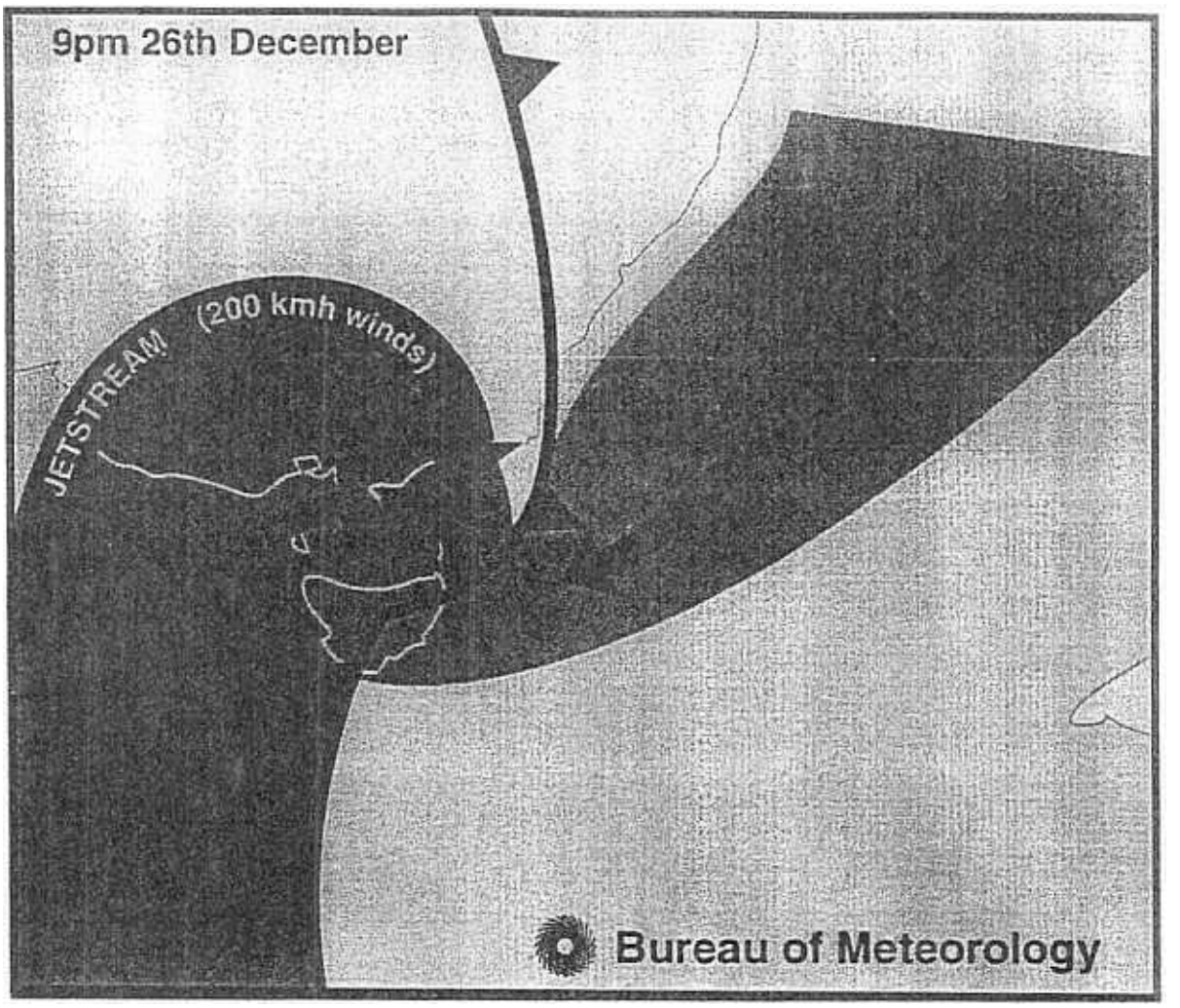

Figure E4: A schematic of the atmospheric conditions suitable for the rapid development of an intense low pressure system in eastern Bass Strait.

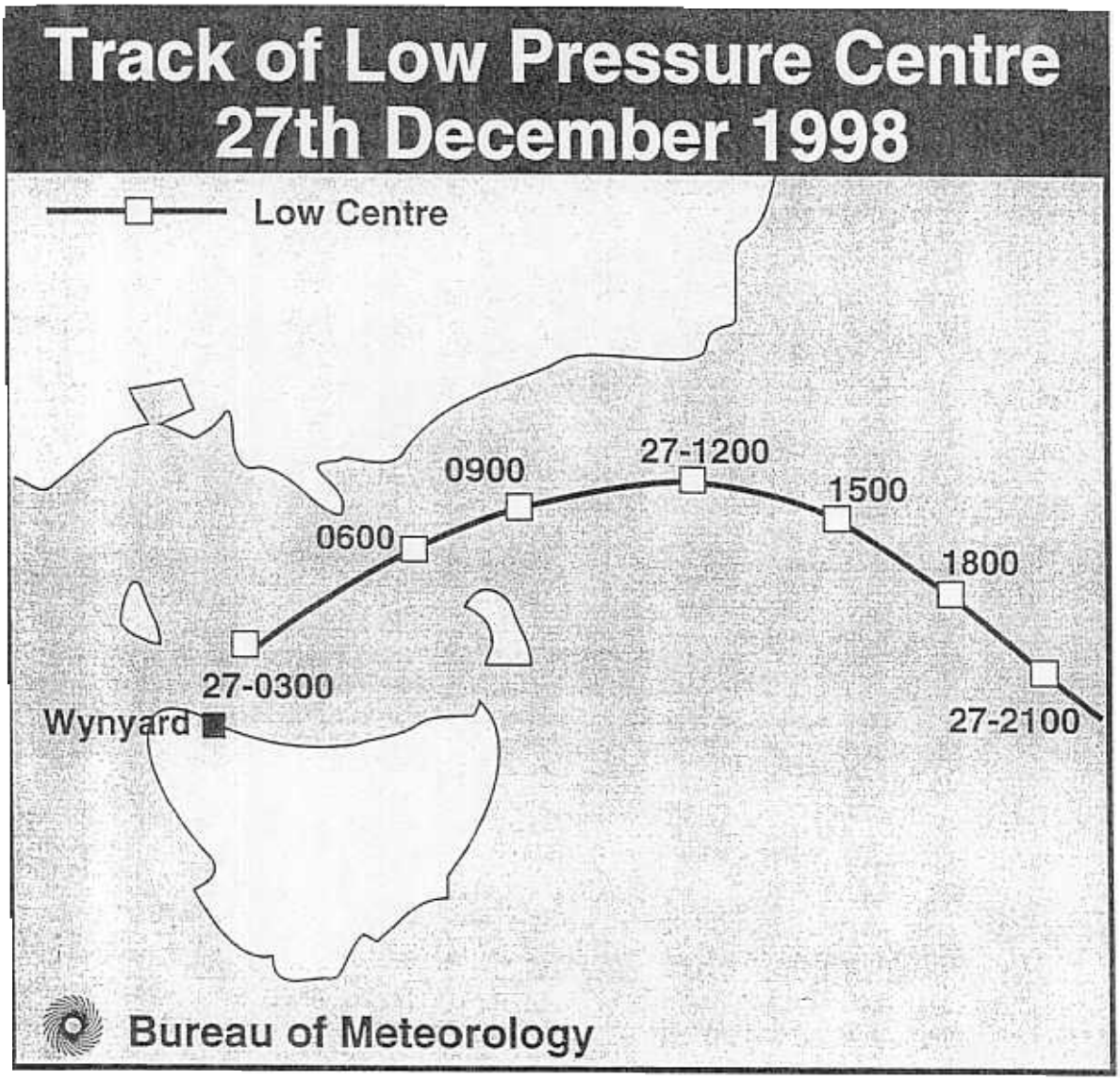

Figure E5: The track of the low pressure system which developed on 27 December 1998 in eastern Bass Strait. Times indicated are in Eastern Daylight Saving Time (EDST) using the 24 hour clock.

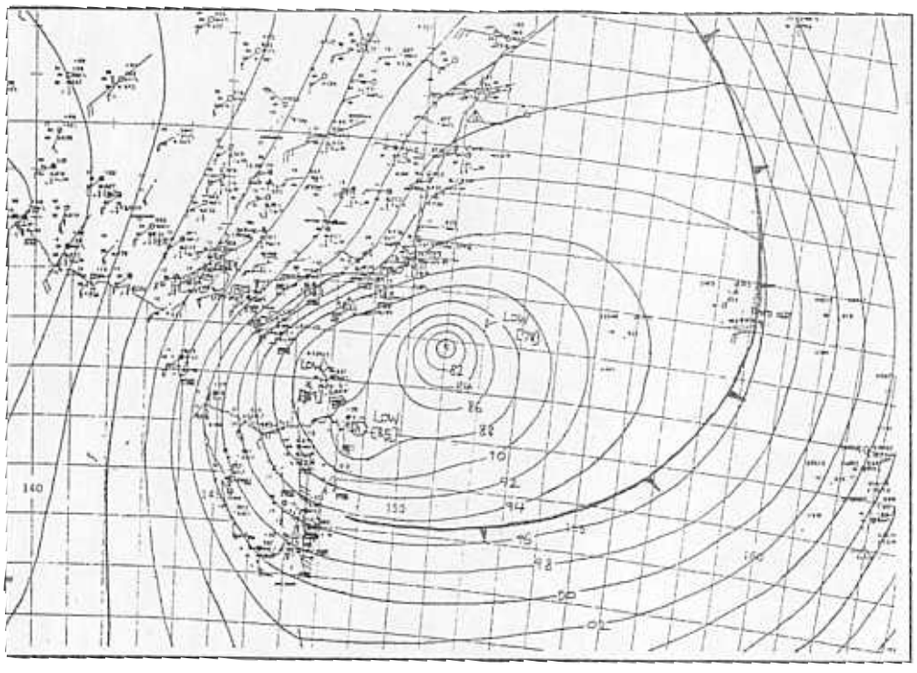

Fig E6. Surface pressure analysis for 3pm 27 December 1998
Isobars 2 hPa intervals (for labelling see Attachment E2)

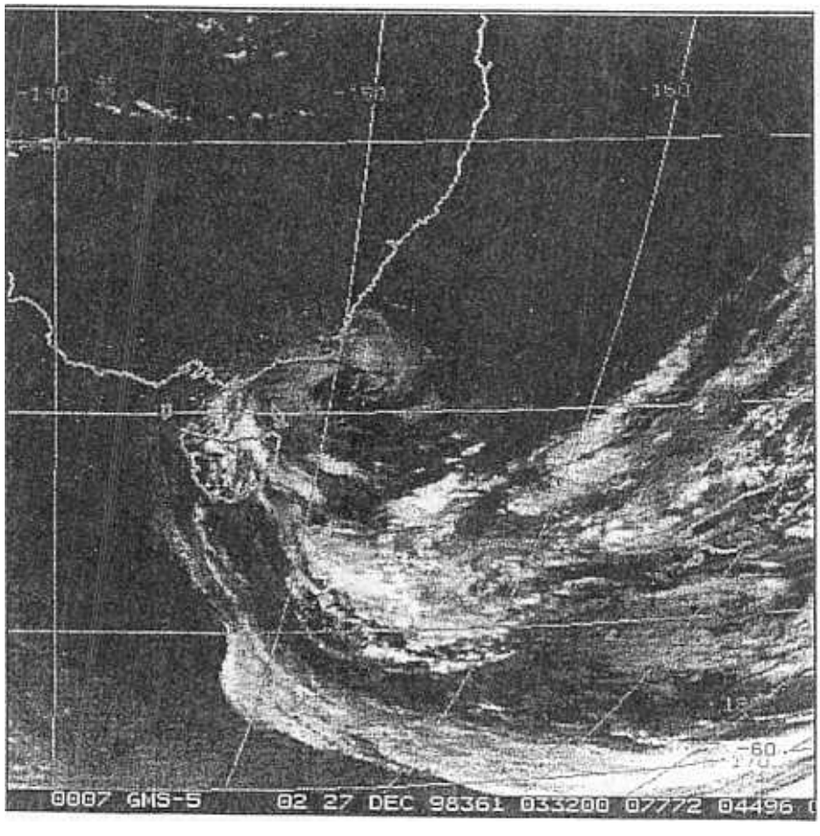

Fig E7. Infra Red (IR) satellite image taken at
approximately 3pm on 27 December 1998

Satellite photograph courtesy of Japan Meteorological Agency (JMA)

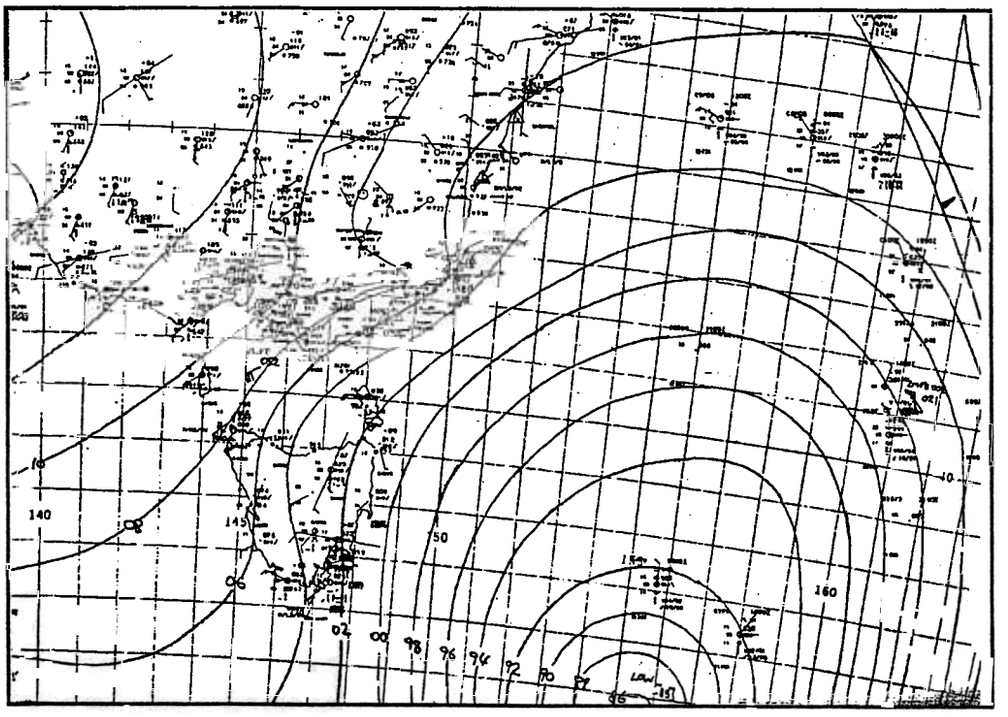

Fig E8. Surface pressure analysis for 9am 28 December 1998
Isobars at 2 hPa intervals (for labelling see Attachment E2)

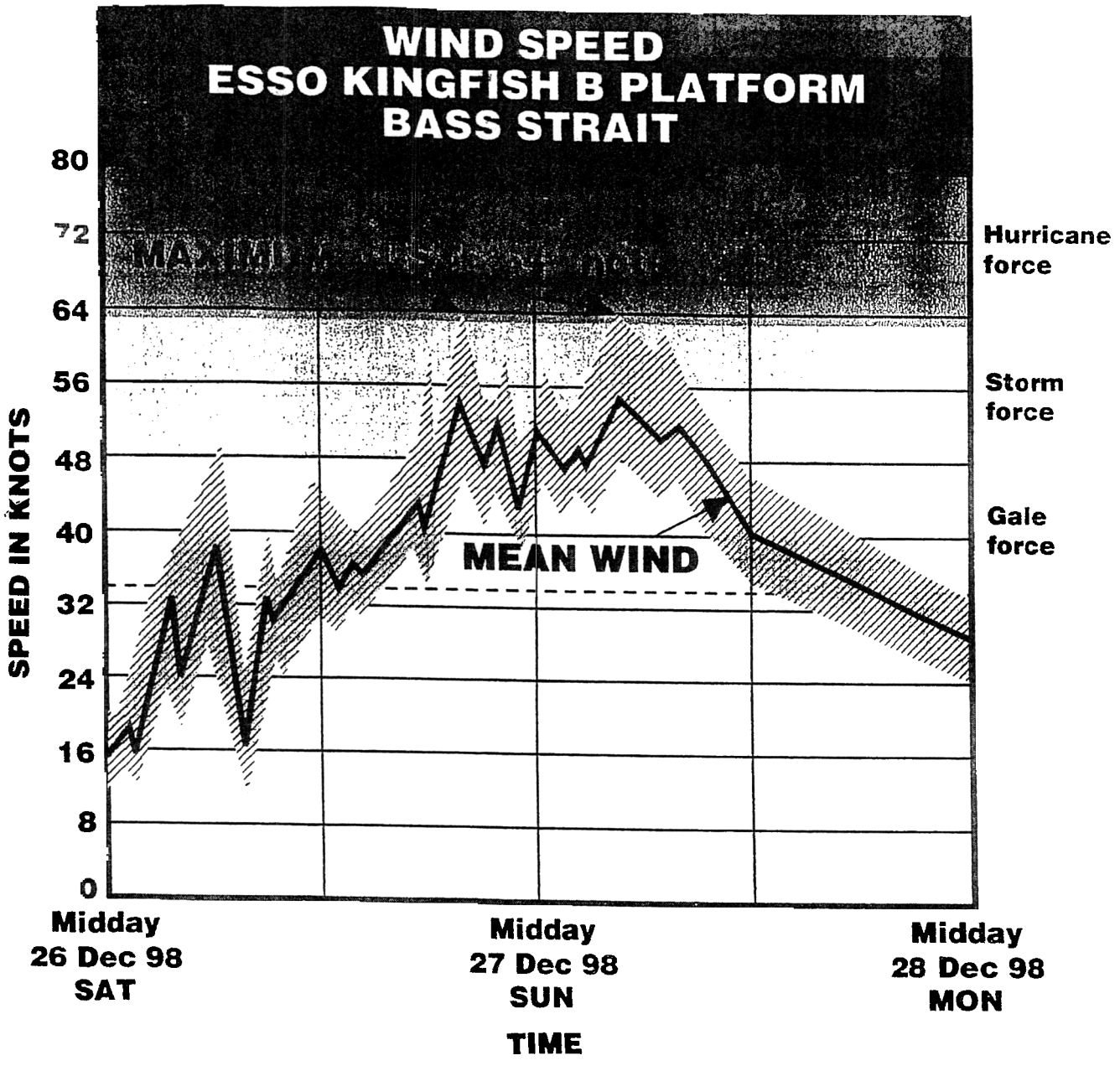

Figure E9: The 10 minute mean winds, and envelope of gusts observed at the Esso Kingfish B platform in eastern Bass Strait (location as given in fig. 1).

Wave heights

11. Although instrument recordings of wind, sea state and ocean current are very sparse, it is apparent that the favourable conditions early in the race deteriorated rapidly as the yachts encountered the storm force westerly winds over southern NSW coastal waters and Bass Strait during Sunday.

12. Significant wave heights of 6 to 7 metres with a few reaching maximum heights of 11 to 12 metres were recorded during Sunday at ESSO Kingfish B Platform (Fig E10). The *Young Endeavour* reported seas of 5.5 metres and a swell of 6 metres (combined effect 8 metres) while located approximately 30 nautical miles east of Gabo Island at 11pm on 27 December 1998. From the limited number of observations received from the yachts so far, many appear to have experienced significant wave heights in the 5 to 8 metre range and maximum waves approximately double these heights.

Services provided and forecasts issued

13. Relevant services provided by the Bureau of Meteorology in the period leading up to and encompassing the yacht race were the usual basic marine weather services, including regular forecasts for the high seas and coastal waters (See Fig E1 for definition of forecast areas), a full 24 hour weather watch, and warnings as required. In addition, the Cruising Yacht Club of Australia (CYCA) sought an additional briefing and some race specific forecasts which were supplied in the public interest. Arrangements with the CYCA also enabled race officials to contact the Bureau's Senior Forecaster at any time

14. A Bureau meteorologist provided a special briefing session for the competitors and organisers of the Race on 24 December 1998. The approximately 250 people who attended this meeting were made aware of the possibility of hazardous weather conditions during the race although the eventual nature and strength of the development were not foreseen at this time. However, soon after 9am on 26 December 1998, about 4 hours before the start of the Race, the Bureau issued a gale warning for the New South Wales coastal waters south from Broken Bay. The gale warning was disseminated through normal channels (e.g facsimile, coastal radio and the Internet) and competitors and organisers were also able to access this information at the Bureau's pre-race briefing stand.

15. The Bureau's New South Wales (NSW) Regional Forecasting Centre (RFC) upgraded the gale warning to a storm warning for the area south of Merimbula at 2.14pm on 26 December 1998, just over one hour into the race. A copy of this warning is included in Attachment E1. The warning was disseminated via the normal channels and, in addition, a Bureau officer from the NSW RFC contacted the Australian Maritime Safety Authority, Eden Royal Volunteer Coastal Patrol and the Sydney to Hobart Race media centre before issuing an updated special race forecast at 2.50pm on 26 December 1998. The updated forecast (see Attachment E1), which included advice that a storm warning was current south of Merimbula, was sent to the *Young Endeavour* which was responsible for relaying forecasts and warnings to the competitors during the official radio schedules. According to the limited number of reports from crews that have been received so far, it appears that in addition to the

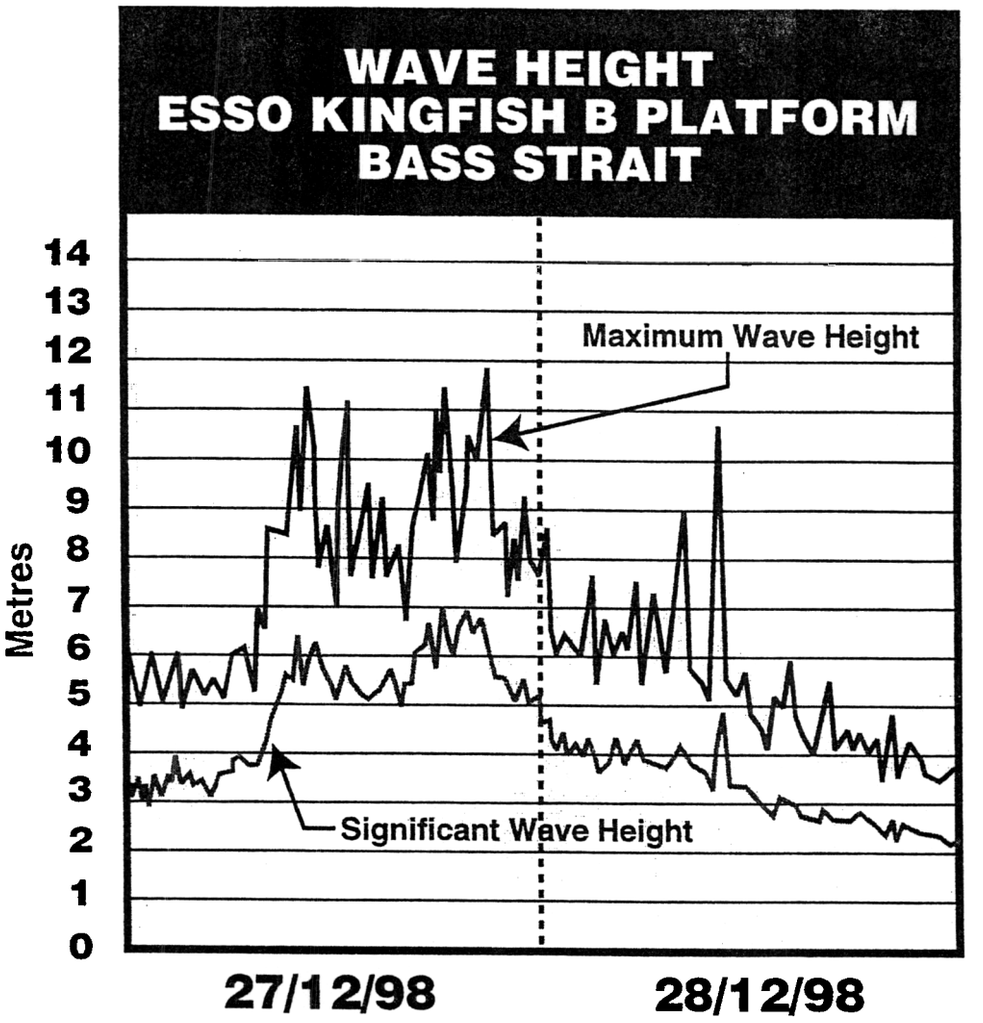

Figure E10: Significant and Maximum Wave Heights (metres) transcribed from recording unstruments located at the Esso Kingfish B Platform, eastern Bass Strait 27 - 28 December 1998 (location as given in Fig 1)

radio schedules some yachts received the details of the warning from other means (ie coastal radio broadcasts). The results of a CYCA survey will provide more detailed information on how and when the crews were made aware of the storm warning.

16. An initial investigation of the relevant meteorological analyses and prognoses has shown that output from the Bureau's high resolution computer model at 1pm on 26 December was an important factor in triggering forecasters to issue the storm warning. The alerting computer forecast output, valid for 11pm on Sunday 27 December 1998, is shown in Figs E11 and E12.

17. After consultations between the Bureau's Victorian and NSW RFCs, storm warnings were promptly issued for coastal waters in eastern Victoria and southern NSW (Attachment E1). Warnings for the high seas were issued soon after. The warnings were issued some 18 to 21 hours ahead of the onset of the storm force winds over the race area.

18. The special race forecast service provided to the Cruising Yacht Club of Australia has, by agreement between the Bureau and race organisers, always been performed by the New South Wales and Tasmanian RFCs. During the event, these offices liaise together and with the Victorian RFC which is responsible for routine forecasts in eastern Bass Strait, forecasts for the high seas in the Tasman Sea and for high seas warnings south of latitude 38 degrees south (See Fig E1).

19. During the search and rescue operations, the Bureau provided particular forecast products on five occasions to AMSA to assist in search planning and rescue efforts. The products originated from the Bureau's Victorian RFC (one on 27 and three on 28 December 1998) and from its Meteorological Office in Canberra (one issued on 28 December 1998). To help define the search areas, the Victorian RFC also provided AMSA with additional information on winds (speed and direction) likely to have already occurred over the search and rescue area and to have influenced the movement of disabled yachts.

20. Storm warnings for both the coastal waters and high seas referred to winds of up to 45 to 55 knots. By international convention these are mean wind speeds. It is known that wind gusts cause large temporary fluctuations about this mean and that maximum gusts of up to 40% above the forecast mean wind are to be expected. Therefore, with a forecast of 45 to 55 knots, regular gusts in excess of 70 knots were to be expected.

21. Storm warnings for the coastal waters mentioned waves of 4 to 7 metres. These refer to significant wave height which is the average height of the highest one third of all waves. Storm warnings for the high seas referred to rough (2.5 to 4 metres) to very rough (4 to 6 metres) seas and moderate (2 to 4 metres) to heavy (greater than 4 metres) swell which would result in a combined significant wave height of at least 7 metres. It should be noted that while forecasts and observations of waves are for the significant wave height, individual waves approaching twice that size must be expected to occur.

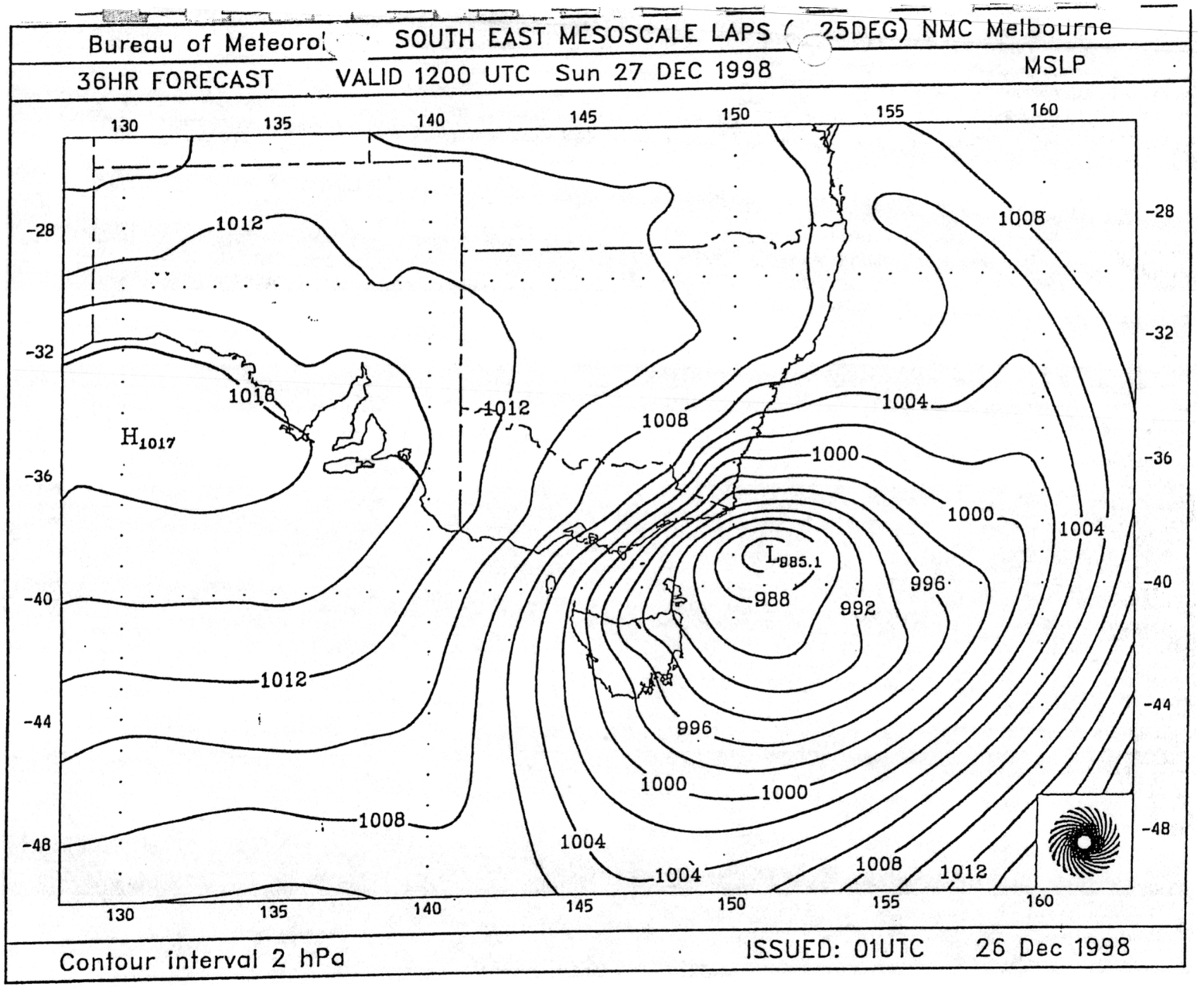

Figure E11. Computer generated prognosis of Mean Sea Level (surface) Pressure for 11pm Sunday 27 December 1998, which became available to forecasters at 1pm on 26 December 1998.

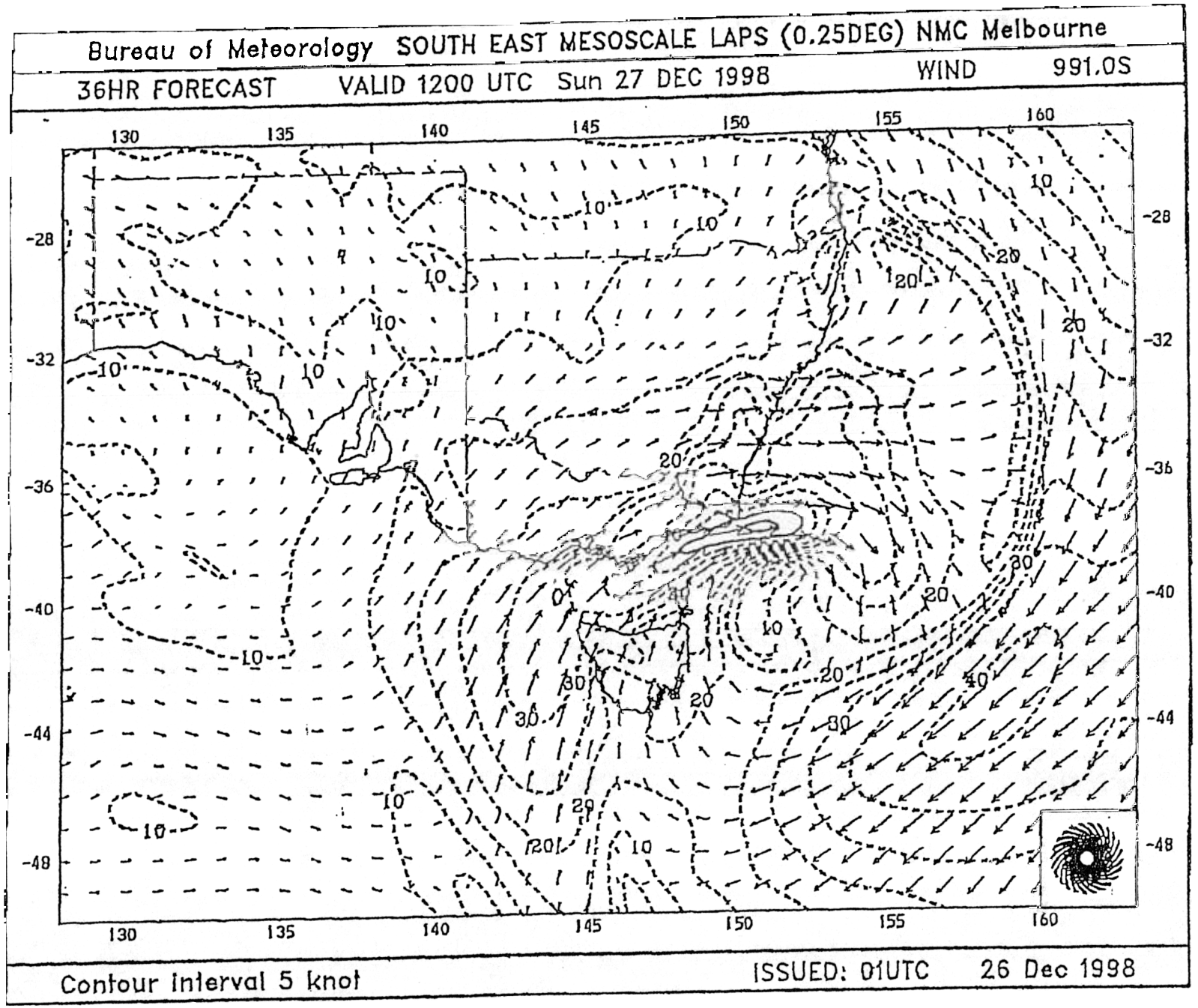

Figure E12. Computer generated prognosis of wind speed in knots (contours) and direction (arrows) for 11pm Sunday 27 December 1998, which became available to forecasters at 1pm on 26 December 1998.

Summary

22. In summary, a preliminary investigation of the meteorological situation surrounding the race and the services provided by the Bureau, indicates that:

- A Bureau briefing provided to race organisers and competitors on 24 December 1998 indicated the possibility of hazardous weather conditions during the race.
- A gale warning was issued soon after 9am on the morning of 26 December for the New South Wales coastal waters south from Broken Bay and was current at the time the race started. The gale warning was transmitted through normal channels and details were also available at the Bureau of Meteorology's pre-race briefing stand for race competitors and organisers.
- The Bureau's Sydney office upgraded the gale warning to a storm warning for the area south of Merimbula at 2.14pm on 26 December, just over 1 hour into the race. Phone contact was made with key authorities to alert them to the warning.
- Output from the Bureau's high resolution computer model at 1pm on 26 December 1998 was an important factor in triggering forecasters to issue the storm warning.
- Storm force winds over the race area appear to have developed some 18 to 21 hours after the first storm warning was issued.
- The storm warnings referred to mean wind speeds of 45 to 55 knots. Under these forecast conditions, gusts of 70 knots would be expected.
- Instrumented observations from Kingfish B and the *Young Endeavour* indicate that the likely highest mean winds were around 54 to 56 knots. Reports received from the yachts so far suggest that the likely maximum mean winds experienced were in the range 55 to 60 knots with frequent gusts to 75 knots.
- Seas of 4 to 7 metres (significant wave height) were generally forecast in the Bureau's storm warnings. Infrequent maximum waves with heights of about 13 metres could be expected under these forecast conditions.
- Several observations received from the yachts so far suggest that waves of 5 to 8 metres, with some individual waves of 15 metres, were experienced.

23. A more complete description of the meteorological conditions, including the range of wind speeds and sea conditions, associated with the Race is expected to emerge as additional information comes to hand from other sources (e.g. surveys being undertaken by the CYCA, and from AMSA) and all available relevant information will be included in the Bureau's final report.

IDW00N01

BUREAU OF METEOROLOGY
NEW SOUTH WALES REGIONAL OFFICE
300 Elizabeth St. Sydney; Ph [02] 9296 1555

Priority Storm Warning Coastal Waters South of Merimbula
Gale Warning Coastal Waters South of Broken Bay
Strong Wind Warning between Broken Bay and Seal Rocks

Issued at 1414 on Saturday the 26th of December 1998

Synoptic Situation

High over New Zealand ridging onto central NSW coast. Low 995hPa near Lord Howe Island is slow moving. Cold front moving east across central Victoria.

Warning

N/NE wind reaching 20/25 knots between Broken Bay and Ulladulla, 25/30 knots south from Ulladulla, ahead of a gusty W/SW change 30/40 knots expected South Coast late tonight, then W/SW 25/35 knots Illawarra and Sydney Coast early Sunday morning, and W/SW 25/30 knots Hunter Coast later Sunday morning. W wind increasing to 45/55 knots offshore south of Merimbula late Sunday afternoon.

Seas 1 to 2 metres, rising to 3 to 4 metres with the change. Swell 1 to 2 metres, rising to 2 to 3 metres after the change.

53.

BUREAU OF METEOROLOGY
VICTORIAN REGIONAL OFFICE

Priority
Storm Warning
for Victorian coastal waters east of Wilsons Promontory

Issued at 1358 on Saturday the 26th of December 1998

West/southwesterly wind change of 20/30 knots extending from the west this afternoon then increasing to 35/45 knots tomorrow morning and 45/55knots late Sunday afternoon. Seas rising to 2 to 3 metres this afternoon, 3 to 4 metres tomorrow morning and 4 to 6 metres late afternoon.

*** CORRECTED VERSION ***

*** This is the corrected version of a warning issued 6 minutes earlier. The correction made is underlined.

Priority
Storm Warning
for Victorian coastal waters east of Wilsons Promontory

Issued at 1352 on Saturday the 26th of December 1998

West/southwesterly wind change of 20/30 knots extending from the west this afternoon then increasing to 35/45 knots tomorrow morning and 45/55 knots late Saturday afternoon. Seas rising 2 to 3 metres this afternoon, 3 to 4 metres tomorrow morning and 4 to 6 metres late afternoon.

ZCZC ID27200 B PROD COTCS CGFCS P1HRDCPY XRYCT CI811 XCYCA CHRFC

40:4:450300141::::2
IDS00N00

BUREAU OF METEOROLOGY
NEW SOUTH WALES REGIONAL OFFICE
300 Elizabeth St. Sydney, Ph [02] 9296 1555

SYDNEY - HOBART YACHT RACE FORECAST 26 - 31 December 1998

Forecasts issued from Sydney covering Sydney > 38S on Weather by fax 1902 935 244

Dec 26 (0500, 1000, 1300) Sydney --> Jervis Bay

27 (0200, 1300) Jervis Bay --> Gabo Island

28 (0200, 1300) Jervis Bay --> Gabo Island

Forecasts issued from Hobart covering 38S --> Hobart on Weather by fax 1902 935 247

Dec 27 (1300) Bass Strait

28 (0200, 1300) Bass Strait & East Coast Tas. from 1300

29 (0200, 1300) Bass Strait & East Coast Tas.

30 (0200, 1300) Bass Strait & East Coast Tas.

31 (0200, 1300) Bass Strait & East Coast Tas.

Coastal Observations are available from 1902 935 813

ISSUED BY THE BUREAU OF METEOROLOGY, SYDNEY
UPDATED at 1450 on Saturday the 26th of December 1998

FOR

AREA: Sydney to Jervis Bay.

SYNOPTIC SISTUATION: A high near New Zealand is ridging onto the central NSW coast. A low 995hPa near Lord Howe Island is slow moving. A cold front is over central Victoria.

WARNINGS: Storm Warning is current south from Merimbula. Gale Warning is current south from Broken Bay.

WIND: North to northeast wind 20/25 knots ahead of a W/SW change 25/35 knots, with stronger gusts, expected near Jervis Bay around midnight-2am and then near Sydney around 3am-5am Sunday. Wind may tend briefly northwest 15/20 knots prior to the change.

WAVES: 1 to 2 metres, rising to 3 metres offshore with W/SW change.

SWELL: 1 to 2 metres.

WEATHER: Scattered showers and thunderstorms developing tonight ahead of the change then clearing tomorrow.

OUT LOOK FOR NEXT 48 HOURS: Winds moderating north of Jervis Bay Sunday night. Gale to storm force W winds south of Jervis Bay expected to moderate Monday evening.

NNNN

Attachment E2

Definitions of meteorological terms used in this report.

Wind
In keeping with maritime conventions wind speed is reported in knots.

Forecast or observed winds refer to the mean wind. In observations, this is the average wind speed and direction recorded over the previous ten minutes and is recorded at the international standard height of ten metres above the sea surface. It is known that wind gusts will cause temporary fluctuations about this mean and that maximum gusts of up to 40% above the reported or forecast mean wind may be observed.

Waves
Forecasts of waves in coastal waters are given in metres and describe the significant wave height which is the average height of the highest one third of the waves. Forecasts for the high seas describe seas and swells using terms like slight, moderate, rough etc. The attached table relates these descriptive terms to the heights they represent. It is important to note that waves higher and lower than the significant wave height occur. Generally, in open water, a wave of 1.86 times the significant wave height can be expected in every thousand waves. For example, maximum wave heights corresponding to significant wave heights of 7, 9 and 11 metres are about 13, 17 and 20 metres respectively.

In the description and forecasting of waves, height refers to the vertical distance between the top of a crest and the bottom of a trough. This should not be confused with the length of the face of the wave which will be considerably longer than the vertical height.

Distances
In keeping with maritime conventions distances are quoted in nautical miles.

Surface Analysis Charts
Isobars (lines which join points of equal pressure) on the surface pressure analysis charts shown in Figs E2, E3, E6 and E8 have been drawn with a 2 hectoPascal (hPa) spacing. The values have been abbreviated according to the following convention:

a) Pressures above 1000 hPa have had the first 2 digits removed, eg the '1012' hPa isobar is written as '12'.
b) Pressures below 1000 hPa have had only the first digit removed, eg the '994' hPa isobar is written as '94'.

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SEA (WIND SEA) AND SWELL STATES
from Bureau publication 'Observing the Weather'

Sea (in open sea)

Height (metres)	Description	Effect
0	Calm (glassy)	No waves breaking on beach.
0 - 0.1	Calm (rippled)	No waves breaking on beach.
0.1 - 0.5	Smooth	Slight waves breaking on beach.
0.5 - 1.25	Slight	Waves rock buoys and small craft.
1.25 - 2.5	Moderate	Sea becoming furrowed.
2.5 - 4	Rough	Sea deeply furrowed.
4 - 6	Very rough	Sea much disturbed with rollers having steep fronts.
6 - 9	High	Sea much disturbed with rollers having steep fronts (damage to foreshore).
9 - 14	Very high	Towering seas.
over 14	Phenomenal	Precipitous seas (experienced only in hurricanes).

Swell

Height (metres)	Description	Length (metres)	Description
0-2	low	0-100	short
2-4	moderate		
over 4	heavy	over 200	long

PRELIMINARY REPORT ON METEOROLOGICAL ASPECTS OF THE 1998 SYDNEY TO HOBART YACHT RACE

1. INTRODUCTION

1.1. Background

Of the 115 yachts that set sail at 1pm on 26 December 1998 in the Sydney to Hobart Yacht Race, only 44 reached their destination. The destruction caused by a storm encountered by the fleet triggered a massive search and rescue operation involving numerous personnel from organisations such as the Australian Maritime Safety Authority (AMSA), the Royal Australian Navy (the Navy), the Royal Australian Air Force (RAAF) and Police. Even so, it resulted in the abandonment of several yachts and the deaths of six people. It was the most disastrous event in the 54 year history of this yachting classic.

The yachts encountered very severe wind and sea conditions before most were half way into their approximately 630 nautical mile journey down the southeast coast of Australia (Fig 1). The worst weather to hit the fleet occurred off the southern NSW coast and in eastern Bass Strait. The Bureau of Meteorology had issued a gale warning (mean wind speeds between 34 and 47 knots) for the southern NSW coast 4 hours in advance of the start of the race and upgraded this to storm warnings (mean wind speeds above 47 knots) about one hour into the race (See Attachments 1 and 2).

1.2. Purpose and Scope of this Report

The purpose of this report is to provide a preliminary analysis of the meteorological conditions experienced during the running of the 1998 Sydney to Hobart Yacht Race and document the forecasts and warnings that were issued at the time by the Bureau of Meteorology. This information is intended for the use of those who are engaged in separate assessments of the events that transpired from 26 December through to the end of the search and rescue operations.

The Report outlines the evolution of the associated weather system and highlights key meteorological and oceanographic aspects of the event. The nature of the advance briefing and the forecasts and warnings that were provided by the Bureau are also discussed.

The report also incorporates all retrospective analyses performed to date, but it should be recognised that additional information is expected to come to hand as a result of surveys being undertaken by the Australian Maritime Safety Authority (AMSA) and the Cruising Yacht Club of Australia (CYCA). Such additional information will be incorporated in the Bureau's final Report of this event.

corresponding to significant wave heights of 7, 9 and 11 metres are about 13, 17 and 20 metres respectively.

In the description and forecasting of waves, height refers to the vertical distance between the top of a crest and the bottom of a trough. This should not be confused with the length of the face of the wave which will be considerably longer than the vertical height.

'King', 'Freak' or 'Rogue' waves are terms used to describe the occurrence when wind waves and/or a combination of swell waves join to form a very high wave. For more information on the formation of waves and factors that affect their behaviour, see Appendix 1.

Isobars are lines joining points of equal pressure and are measured in hectopascals (hPa). The values on the surface pressure analysis charts shown in Figures 2 to 21 have been abbreviated according to the following:

a) Pressures above 1000 hPa have had the first 2 digits removed, eg the '1012' hPa isobar is written as '12'.
b) Pressures below 1000 hPa have had only the first digit removed, eg the '994' hPa isobar is written as '94'.

2. THE METEOROLOGICAL SITUATION 23-29 DECEMBER 1998

This section provides detailed descriptions of the main features on the sequence of synoptic charts shown in Figures 2 to 21. Developments evident in the satellite pictures (Figures 24 to 35) are also discussed and related to the features on the synoptic charts. Weather conditions, the surface winds and the state of the sea are then outlined.

2.1. Detailed Evolution of the Surface Synoptic Pattern

The storm force winds and heavy seas experienced during the 1998 Sydney to Hobart yacht race were the result of a complex low pressure system which developed and rapidly intensified in the Bass Strait region overnight Saturday 26 December and during Sunday 27 December.

The Surface Synoptic Pattern Leading up to the Race

The surface synoptic pattern in the Australian region on 24 December (see Fig 2) shows a high pressure ridge over the Tasman Sea, a low over the Southern Ocean with a major cold front crossing waters south of Western Australia, and a broad region of low pressure over northern Australia and the adjacent tropical oceans associated with the monsoonal circulation. The Tasman ridge was directing a warm north to northeasterly airflow over southeastern Australia, in advance of a low pressure trough and a weakening cold front moving across the eastern Bight.

The slow-moving (blocking) high maintained its position to the south of New Zealand on 25 December, with a north to northeasterly airflow persisting over most of southeastern Australia (Fig 3). Meanwhile, a low pressure system, which had formed just to the south of New Caledonia during the previous two days, was now moving steadily south-southwestwards towards Lord Howe Island and deepening. The central pressure of this system decreased to just below 1000 hPa (Fig 4). The low pressure trough over southwestern Victoria showed little progression over the mainland during the day.

The Surface Synoptic Pattern at the Start of the Race

By early morning on 26 December, the low pressure trough (over southeastern Australia) had developed into a more sharply defined and more mobile system ahead of the approaching cold front (Fig 5). This resulted in a marked transition from a warm northerly airstream in the east, to a cooler west to southwesterly airflow over western areas of New South Wales, Victoria, Bass Strait and Tasmania. Conditions were favourable for the start of the yacht race with north to northeast winds prevailing off the New South Wales coast.

Around this time, a low pressure system formed on the cold front to the southwest of Tasmania and the low just to the east of Lord Howe Island continued to intensify (central pressure decreasing to near 990 hPa) but was slow-moving (Fig 6).

The low pressure trough over Victoria continued a steady eastwards progression and gradually deepened during the late morning and afternoon period of 26 December (Fig

SEQUENCE OF MEAN SEA LEVEL (SURFACE) CHARTS

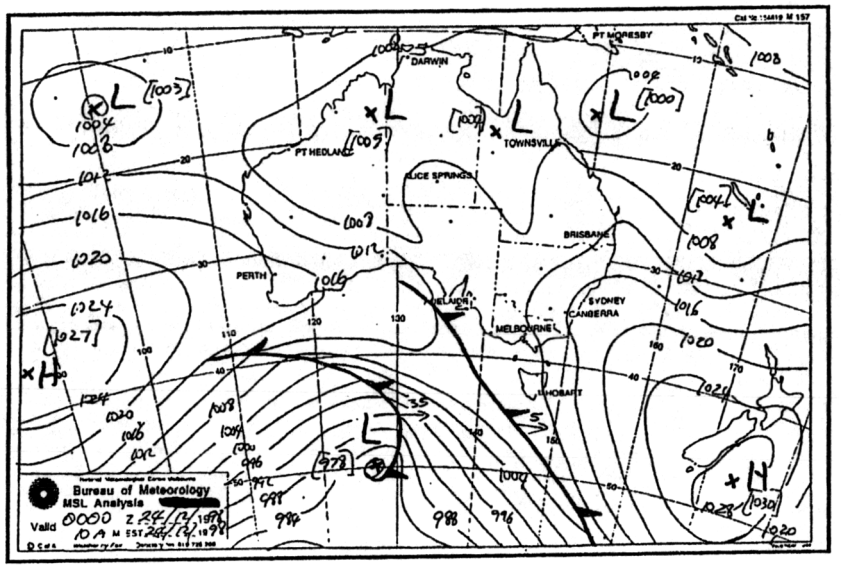

Fig. 2 10am 24/12/98. Isobars at 4 hectopascal (hPa) spacing

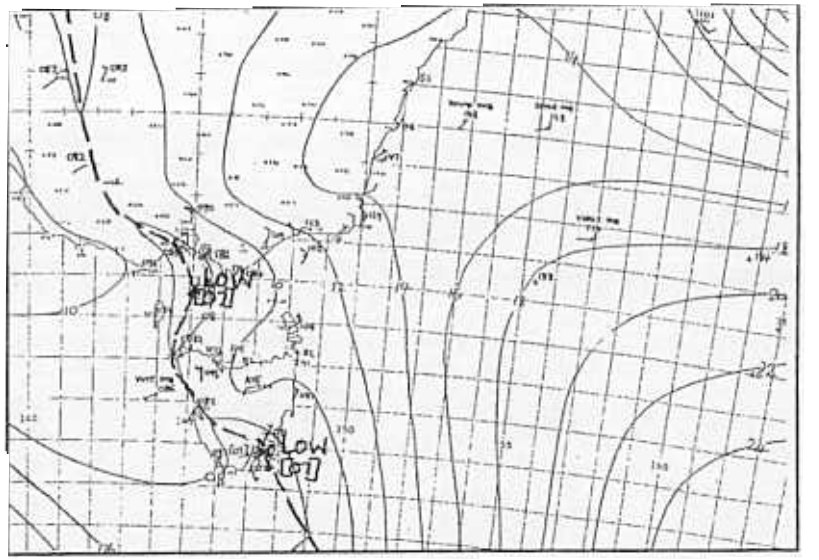

Fig. 3 9am 25/12/98. Isobars at 2 hPa intervals

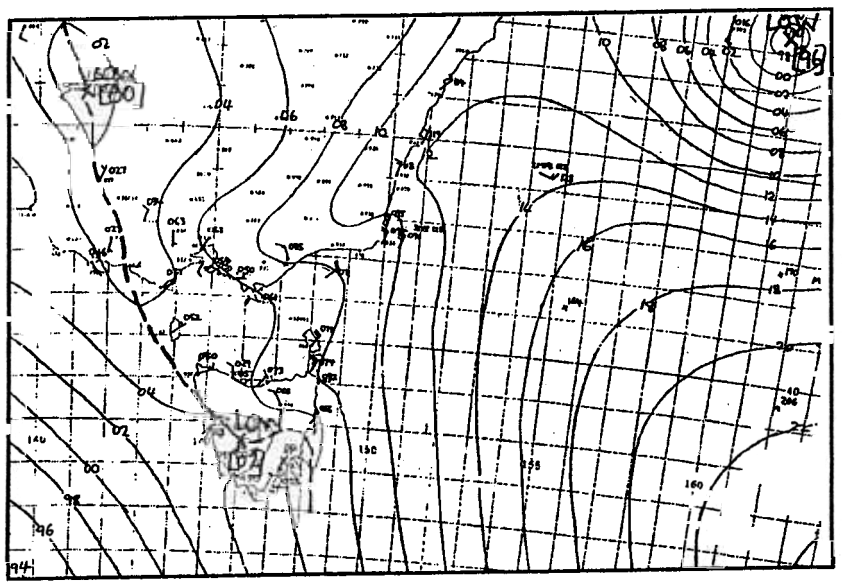

Fig. 4 9pm 25/12/98. Isobars at 2 hPa intervals

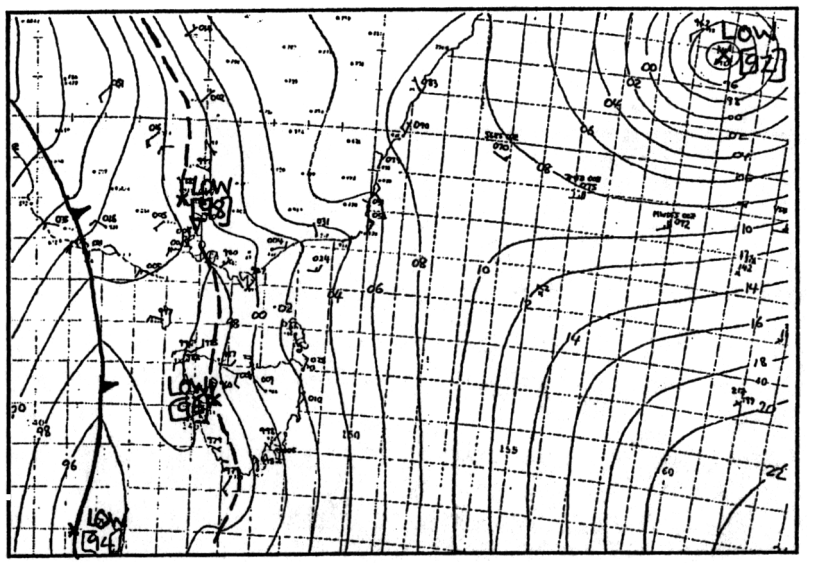

Fig. 5 9am 26/12/98. Isobars at 2 hPa intervals

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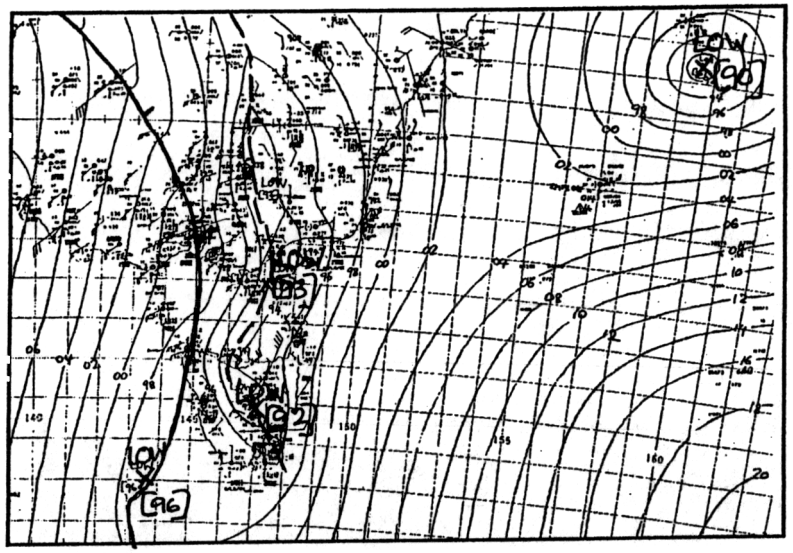
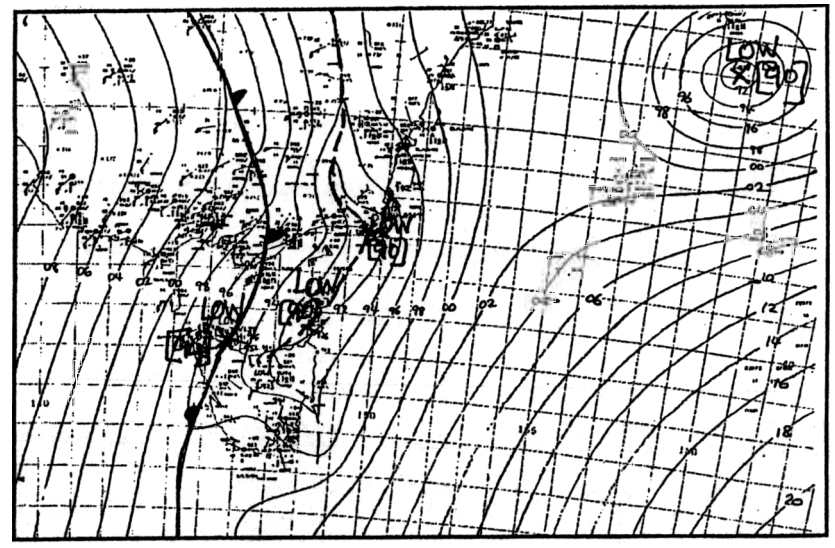
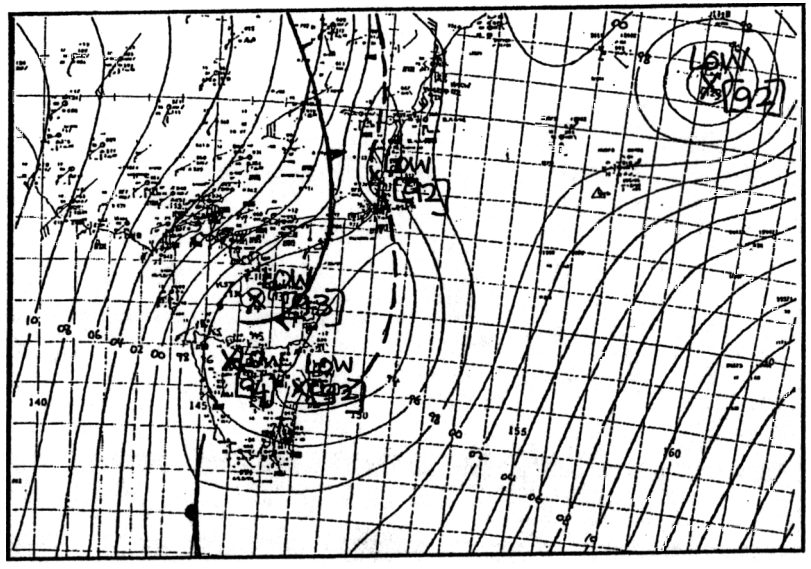
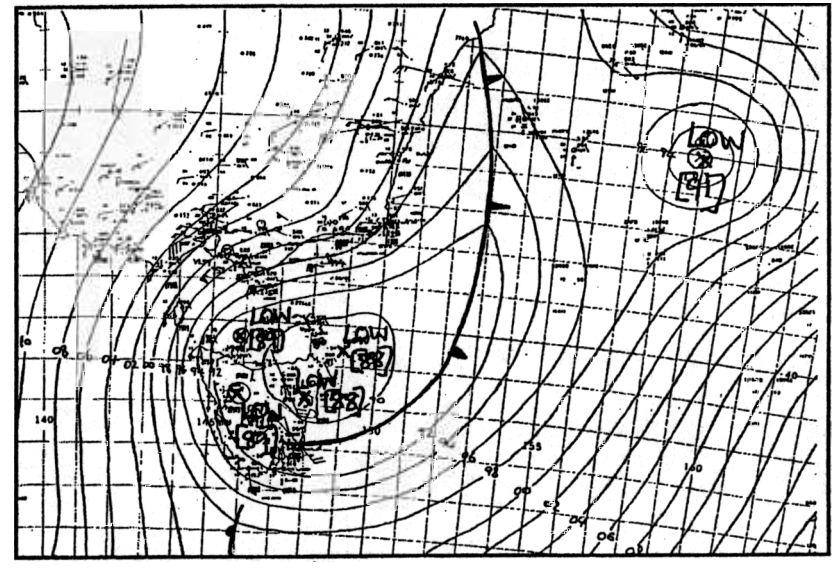
Isobars at 2 hPa intervals









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SEQUENCE OF MEAN SEA LEVEL (SURFACE) CHARTS

Isobars at 2 hPa intervals

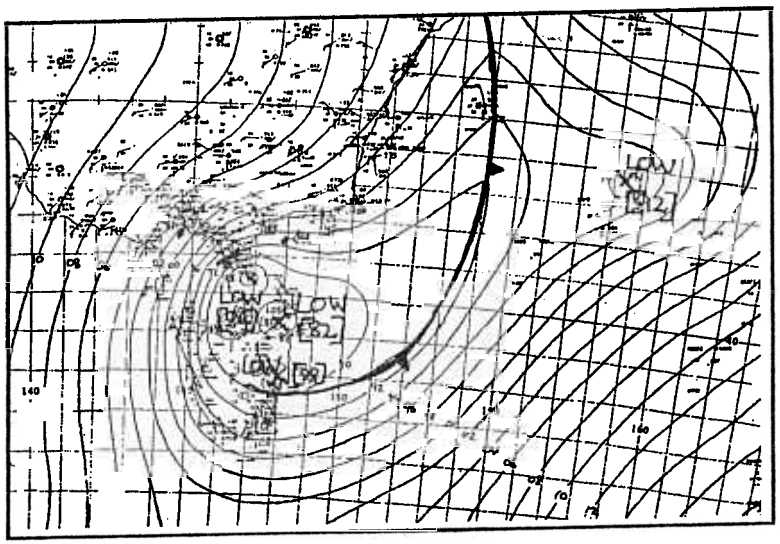

Fig. 10 6am 27/12/98

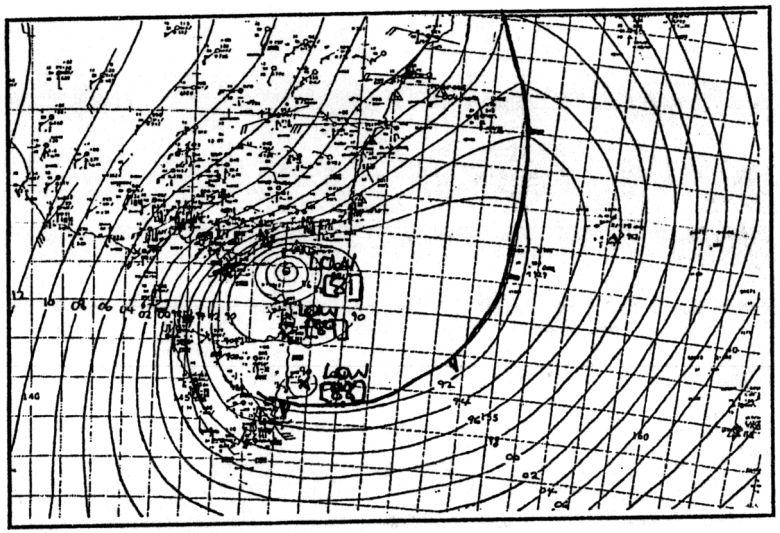

Fig. 11 9am 27/12/98

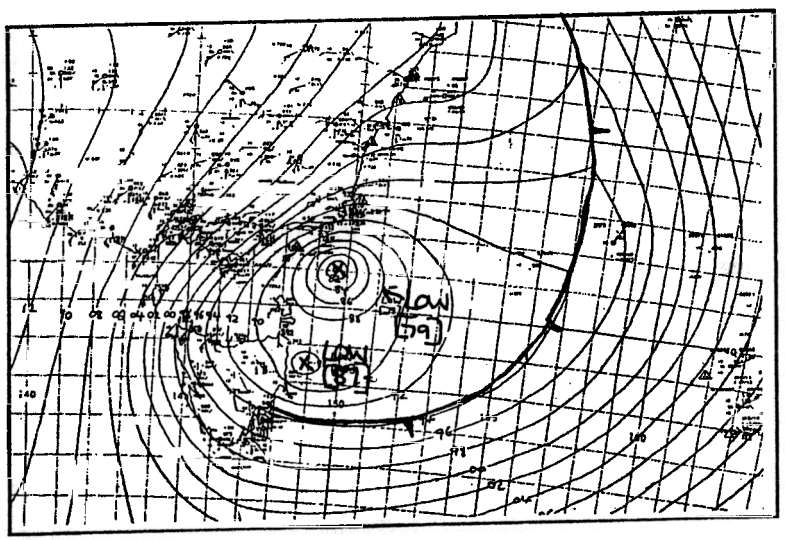

Fig. 12 Midday 27/12/98

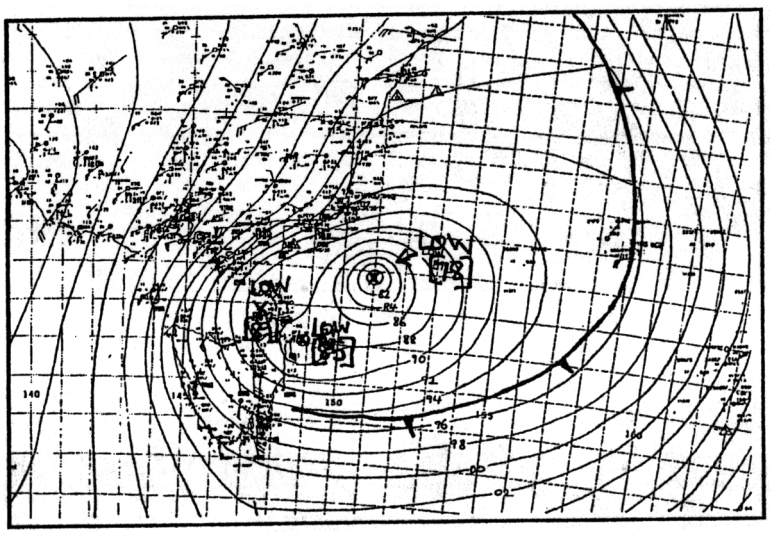

Fig. 13 3pm 27/12/98

SEQUENCE OF MEAN SEA LEVEL (SURFACE) CHARTS

Isobars at 2 hPa intervals

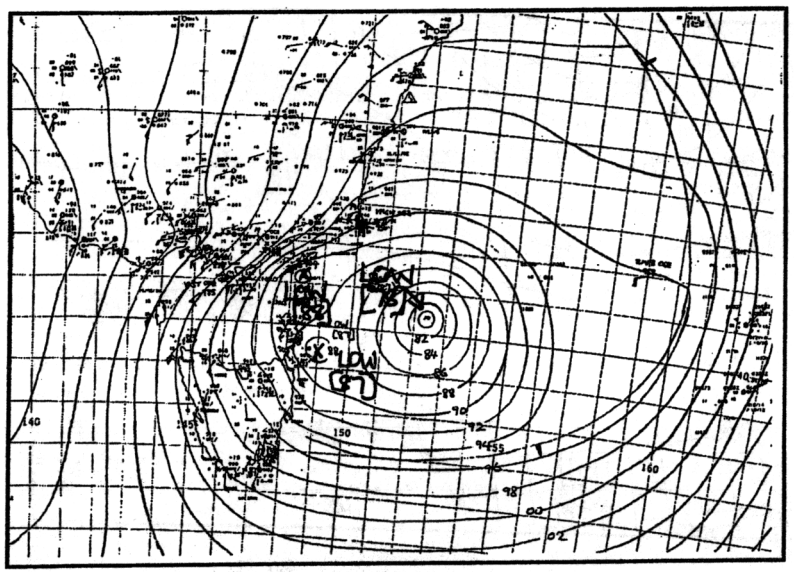

Fig. 14 6pm 27/12/98

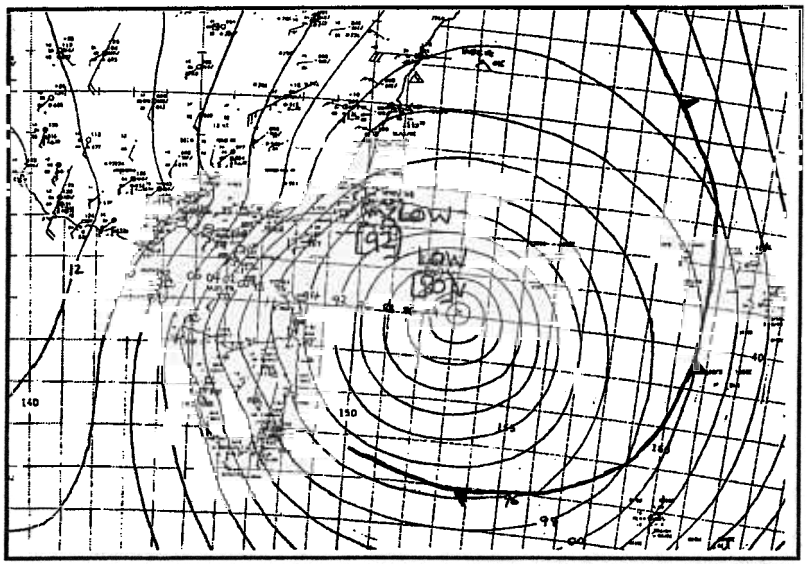

Fig. 15 9pm 27/12/98

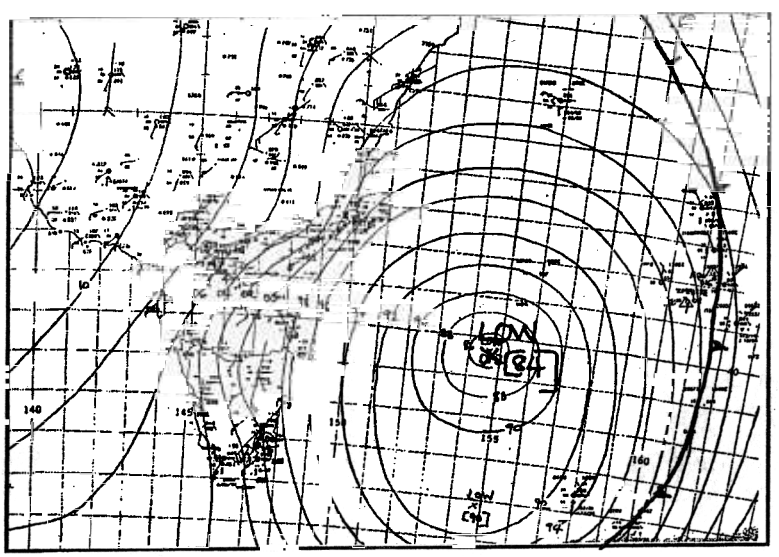

Fig. 16 3am 28/12/98

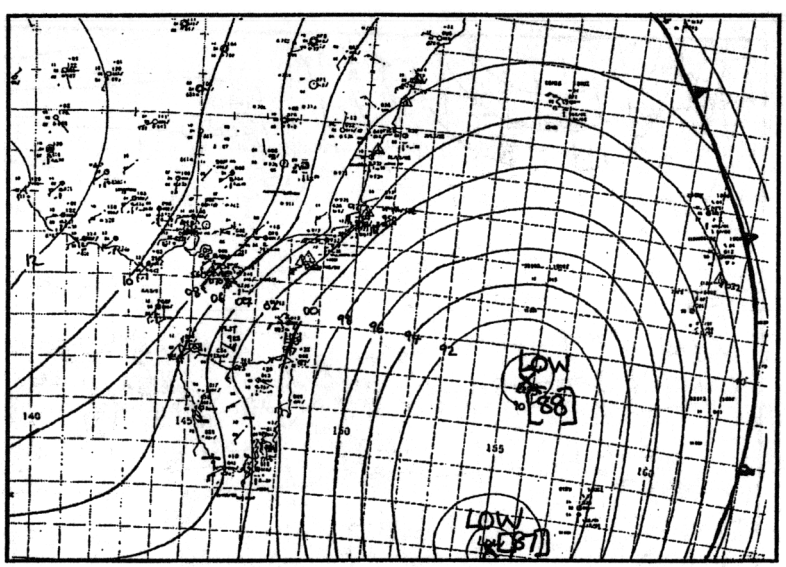

Fig. 17 6am 28/12/98

SEQUENCE OF MEAN SEA LEVEL (SURFACE) CHARTS

SEQUENCE OF MEAN SEA LEVEL (SURFACE) CHARTS

Isobars at 2 hPa intervals

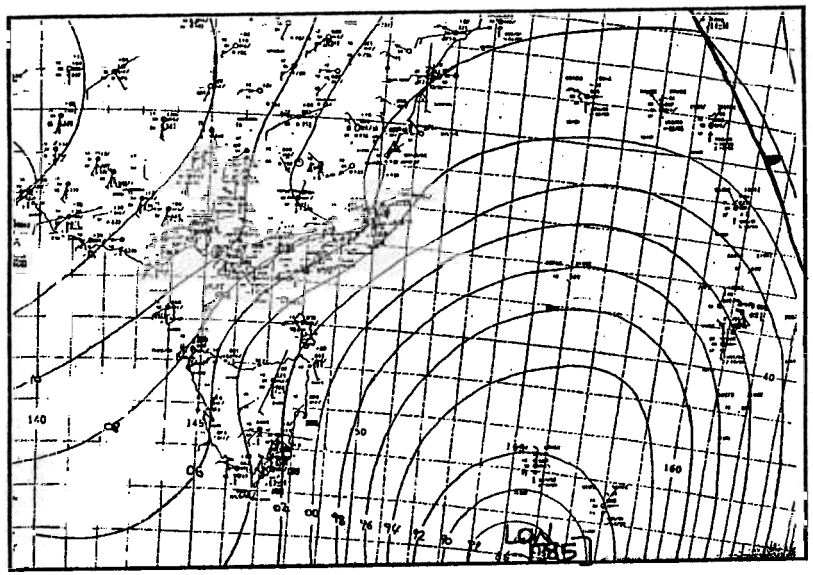

Fig. 18 9am 28/12/98

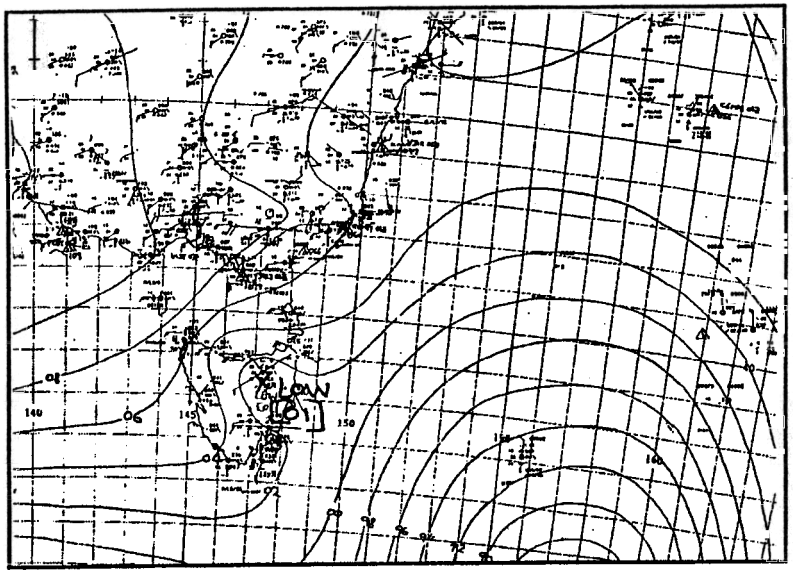

Fig. 19 3pm 28/12/98

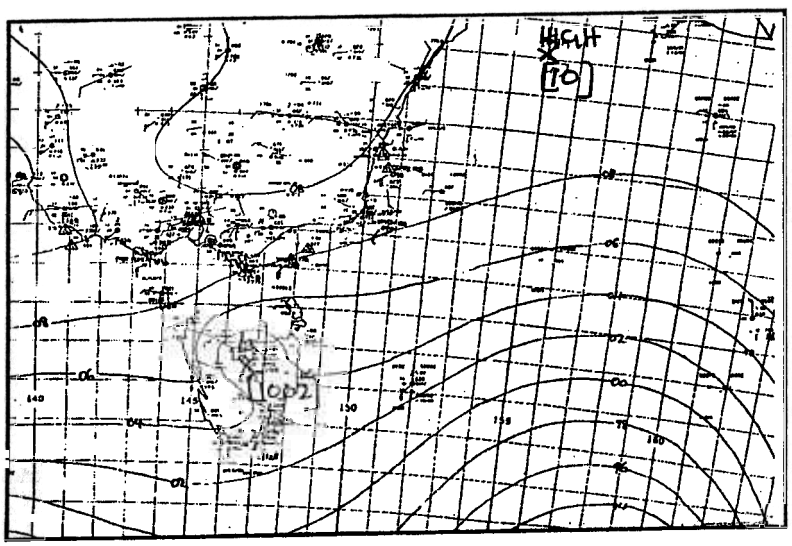

Fig. 20 9pm 28/12/98

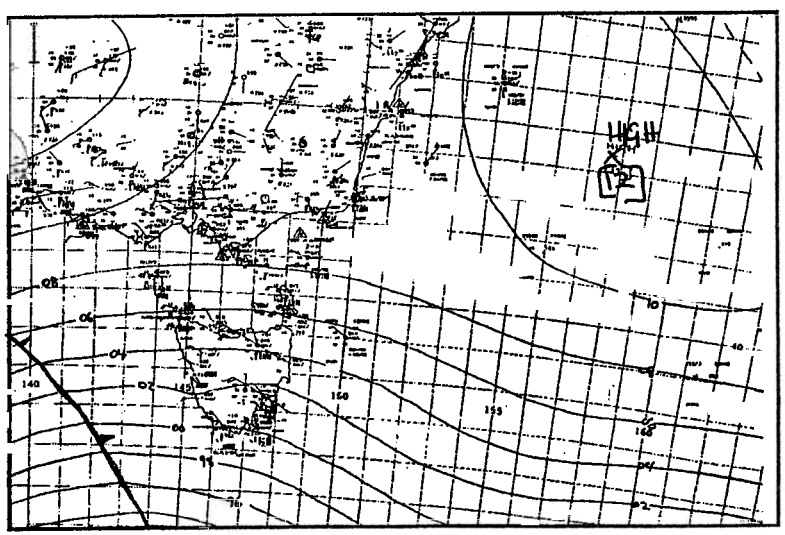

Fig. 21 9am 29/12/98

7). Minimum Mean Sea Level (MSL) or surface pressures over southeastern Australia decreased from near 1000 hPa to near 990 hPa as the trough approached the southern New South Wales coast by the end of the day (Fig 8). The northern section of the cold front also continued to move steadily eastwards across Victoria and the low (which had formed on the front) moved northeastwards to be located over northwestern Tasmania by late afternoon. To the east of the continent, the systems remained slow-moving, with the Tasman low drifting to the south of Lord Howe Island and maintaining intensity.

2.1.3. Major Developments in the Surface Synoptic Pattern on 26/27 December

The low pressure trough eventually crossed Gabo Island on the evening of 26 December, then extended rapidly up the New South Wales coast overnight and early morning on 27 December, by which time it had merged with the cold front (Fig 9). During this period a considerably broader area of low pressure began to form in the section of the trough centred in the vicinity of northeastern Tasmania.

The explosive development that occurred overnight on 26/27 December was a result of a combination of favourable upper level and surface features. There was very cold air moving up from the south over Victoria (as characterised by snow falls in the Australian Alps), very warm moist air moving southwestwards across the Tasman Sea towards Tasmania, above average sea surface temperatures off the coast of southern New South Wales and eastern Victoria and the presence of a strongly curving upper level jet stream to the north of the surface low centre. These features are shown schematically in Fig 22.

The result was a rapid fall in surface pressures overnight in the northeast Tasmania region (i.e. surface pressures down to below 990 hPa). Several small-scale low pressure centres formed in this general area, the most notable being one which formed approximately 40 nautical miles north of Wynyard, Tasmania, with a second one over eastern Tasmania (see Fig 9). At the same time as this development was occurring the low in the northern Tasman Sea had begun to accelerate southwards ahead of the advancing cold front.

2.1.4. The Surface Synoptic Pattern on 27 December

The Wynyard depression intensified rapidly during the remainder of the morning on 27 December (central pressure dropping to just below 980 hPa). See Figs 10 to 12. While initially moving northeastwards at about 20 to 25 knots the depression then shifted to a more easterly path as it crossed far eastern Bass Strait (Fig 23). At about midday (Fig 12) the low passed to the south of Gabo Island. The cold front associated with this low pressure complex advanced steadily across the Tasman Sea, and by late morning had "captured" the northern Tasman Sea low, which was no longer evident as a separate entity.

Figures 9 to 15 show that, during Sunday 27 December, a storm-force westerly airstream over the eastern Bass Strait region was being maintained by several small scale (mesoscale) low pressure centres embedded in a broad low pressure feature affecting much of southeast Australia. The main low finally moved away towards

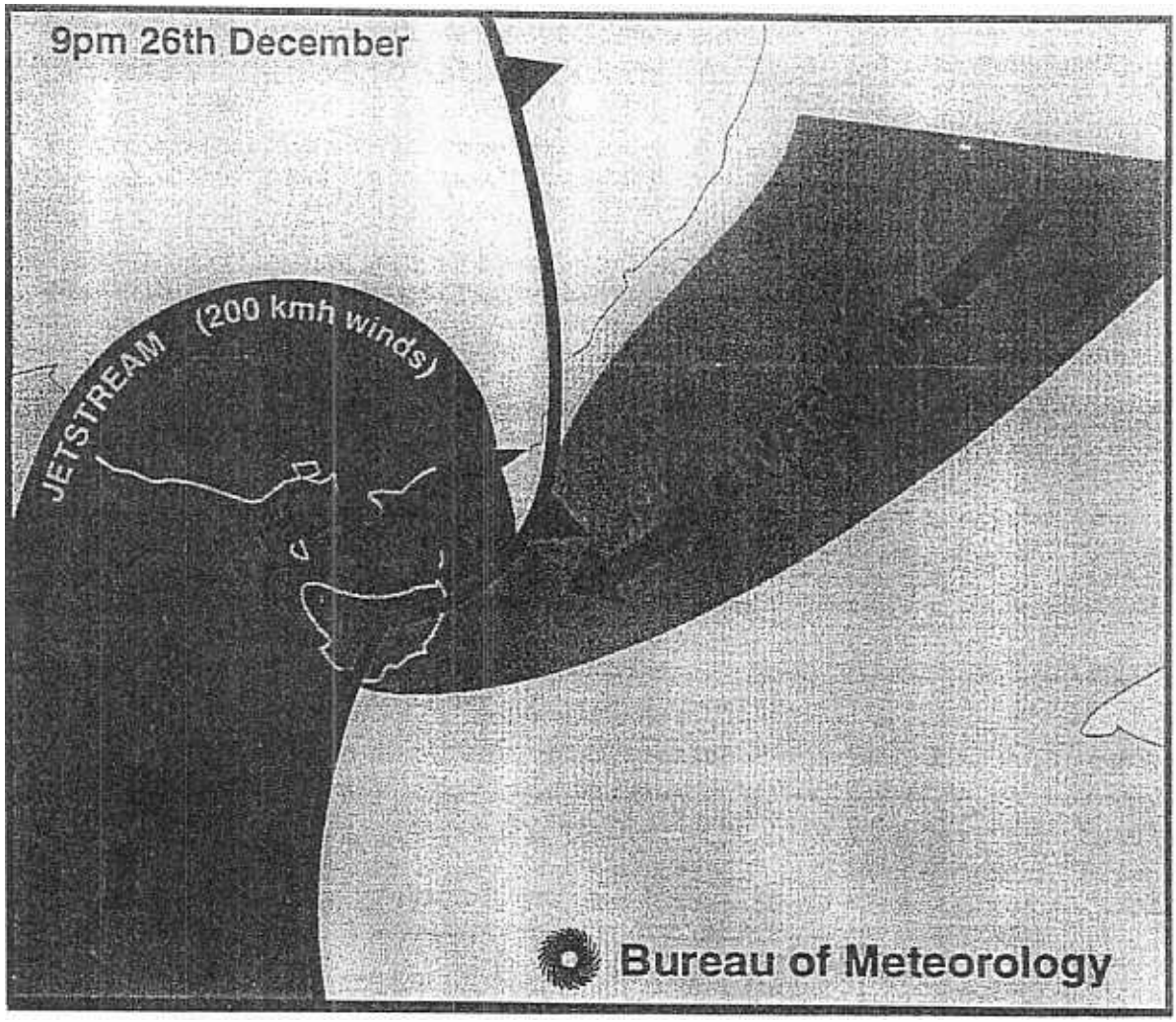

Figure 22: A schematic of the atmospheric conditions suitable for the rapid development of an intense low pressure system in eastern Bass Strait.

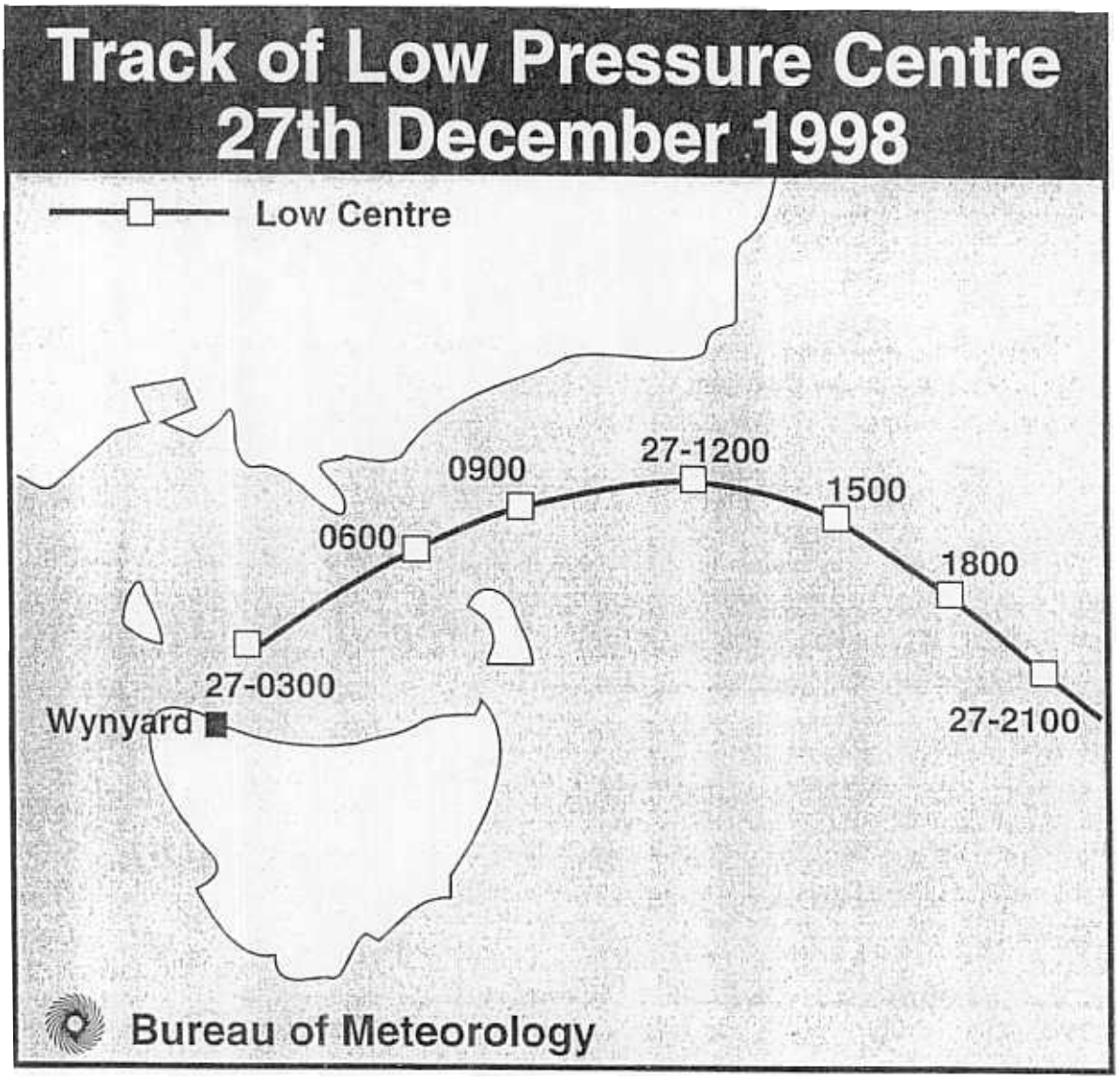

Figure 23: The track of the low pressure system which developed on 27 December 1998 in eastern Bass Strait. Times indicated are in Eastern Daylight Saving Time (EDST) using the 24 hour clock.

southwest New Zealand during the afternoon of 28 December with subsequent moderation of the west to southwest airstream (Figs 16 to 21).

Summary of Surface Synoptic Pattern Developments

In summary, the storm force winds and high seas experienced during the race were part of the circulation around a number of very intense mesoscale low pressure systems, embedded within a parent low system which developed rapidly over the southeast corner of the continent during the 24 hour period beginning from 11pm 26 December. These rapidly developing intense mesoscale systems within the parent low are a well known phenomenon although the development of this particular system was slightly unusual in that it occurred in Bass Strait rather than the more usual location further north along the East Coast.

2.2. Satellite Pictures

The sequence of infrared (IR) satellite imagery available for the period 24 to 29 December (Figs 24 to 35) shows the development of the intense low pressure system as it moved through eastern Bass Strait and into the Tasman Sea.

2.2.1. Features on Satellite Pictures prior to the Race

The dominant features evident on 24 December (Fig 24) were a cold frontal cloudband over the Southern Ocean (with associated cold air well south of Western Australia), and a broad area of cloud over the northeastern Tasman Sea associated with a surface low pressure system.

Figure 25 shows the cold frontal cloudband (and associated cold air field) moving towards the southeast of the continent during 25 December. The cloud mass developing over southeastern Australia (Fig 26) is due to thunderstorms associated with the low pressure trough in that area, whilst the formation of a cloud spiral over the northern Tasman Sea is indicative of the deepening low pressure system in that region.

Satellite Pictures on 26 and 27 December

The cloudbands associated with the cold front and low pressure trough merge over southeastern Australia early on 26 December (Fig 27). The northern section of the resultant cloudband then commences to deform rapidly, adopting a formation (often called a 'comma' cloud) which suggests the development of a surface low pressure system in the Tasmanian region by the end of the day (Fig 28). The vigorous cold air stream in the wake of the front has surged northeastwards across Victoria by this time. Meanwhile, the cloud mass associated with the Tasman Sea low extends southwestwards ahead of the advancing cold front.

The 'comma'-shaped cloudband then moves northeastwards and continues to develop during the morning of 27 December (Fig 29). By late morning a pronounced cloud spiral is forming over eastern Bass Strait (suggesting the presence of an intense surface

Satellite pictures courtesy of Japan Meteorological Agency.

Fig 24. 9am 24 December 1998

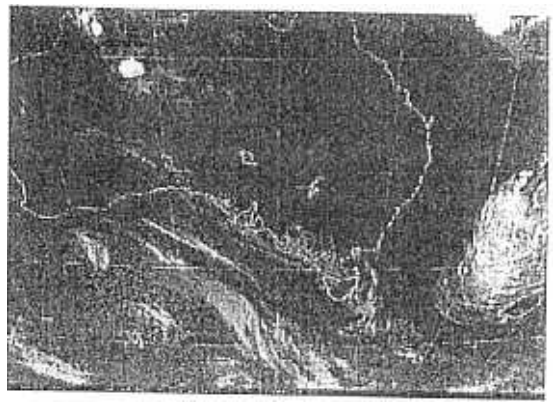

Fig 25. 9am 25 December 1998

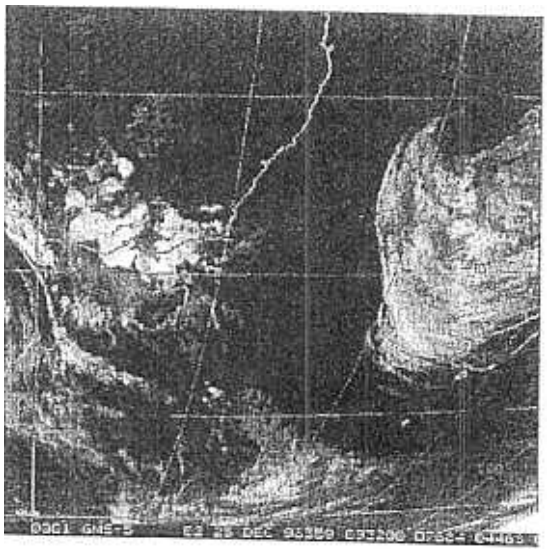

Fig 26. 9pm 25 December 1998

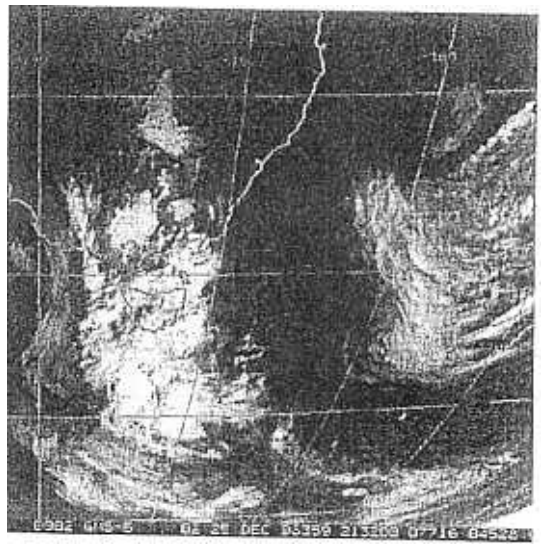

Fig 27. 9am 26 December 1998

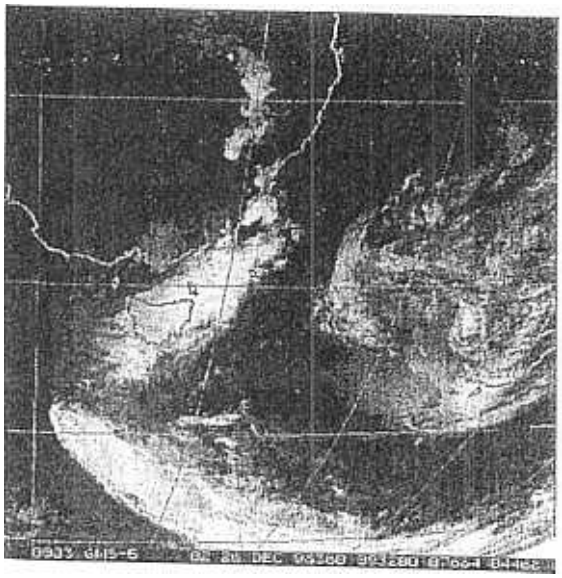

Fig 28. 9pm 26 December 1998

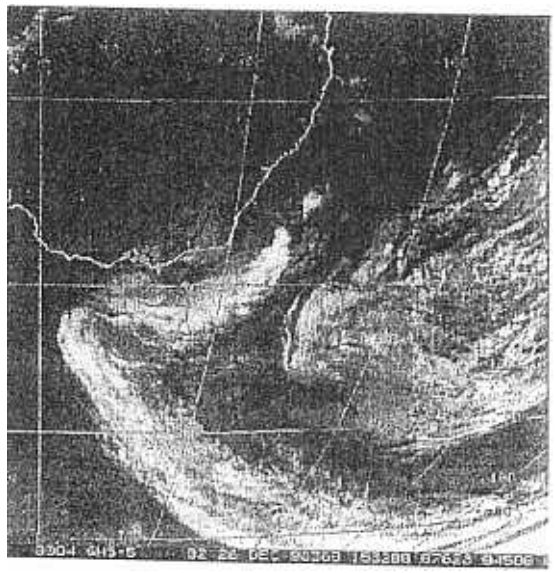

Fig 29. 3am 27 December 1998.

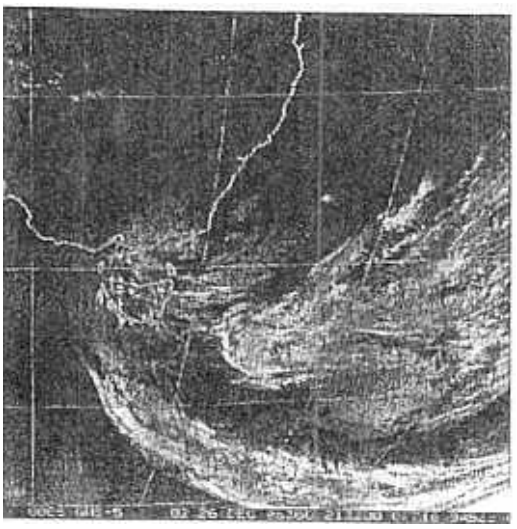

Fig 30 9am 27 Dec mber 99

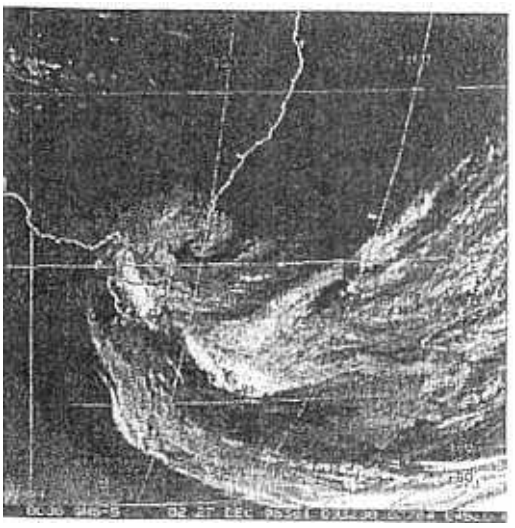

Fig Midday December 99

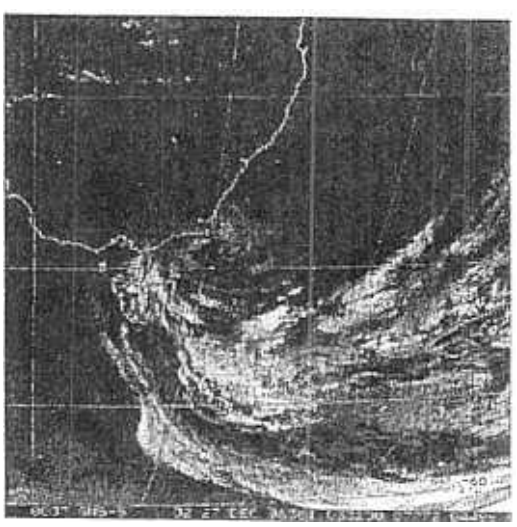

Fig pm December 998

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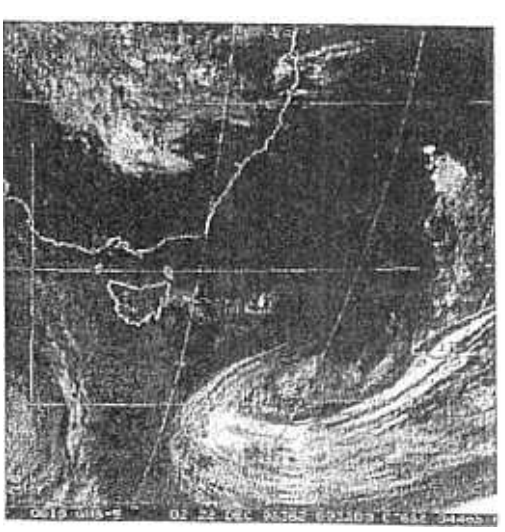


ig 3: cei ber 998

low) (Figs 30 and 31). By this stage, the extensive cloud mass associated with the recently dissipated Tasman Sea low has begun to merge with the frontal cloudband.

2.2.3. Satellite Pictures as Surface Winds Peaked and Abated

The spiralling cloudband associated with the cold front and low pressure complex continue to move steadily eastwards across the Tasman Sea during the afternoon and evening on 27 December (Figs 32 and 33).

This cloud band becomes less organised by the morning of 28 December, due to the temporary weakening of the low pressure complex (Fig 34), then moves rapidly away to the south-southeast (Fig 35). Further west, a second cold frontal cloudband moves rapidly east to northeastwards, eventually crossing Tasmania on 29 December.

2.3. General Weather Conditions

Assessments of the general weather conditions experienced on the Sydney to Hobart course are based, at this stage, on the recorded observations from Bureau coastal stations, which were available at the time, as well as observations from the *Young Endeavour* and on limited information obtained from the competitors, both of which were only available after the event.

Apart from the wind and sea conditions, the main weather elements to affect the race appear to have been heavy precipitation, at least partly due to thunderstorms, and poor visibility. Lightning and thunder were also reported.

Based on observations at the time and post analysis of surface synoptic charts, it is clear that the race commenced in fine weather with good visibility. However, further south, the approaching trough of low pressure was bringing rain and thunderstorms to eastern Victoria and southern NSW. These conditions extended off the coast during the night of 26 December 1998.

By Sunday morning 27 December, the thunderstorms were widespread out to sea.

While reports from some competitors suggest they encountered thunder and lightning and extremely poor visibility at various times (most likely caused by a combination of driving rain and foaming seas), some periods of heavy precipitation not caused by thunderstorms would almost certainly have occurred as well.

A list of selected coastal observations is contained in Appendix 3. It is expected that over the next few months, particularly when more information is received from the yachts via the CYCA, a more definitive picture of the conditions experienced by the competitors will emerge.

2.4. Surface Wind Field

Forecast or observed winds refer to the mean wind. In observations, this is the average wind speed and direction recorded over the previous ten minutes and is recorded at the international standard height of ten metres above the sea surface. It is

known that wind gusts will cause temporary fluctuations about this mean and that maximum gusts of up to 40% above the reported or forecast mean wind may be observed.

The Most Dependable Wind Observations

The most dependable observations of offshore wind have come from the *Young Endeavour* and continuous data recordings from the ESSO Australia Limited, Kingfish B Platform in Bass Strait (see Fig 1 for location). The wind data from Kingfish B, showing two periods of peak winds (maxima around 54 to 55 knots and accompanying maximum gusts to 64 knots) are illustrated in Fig 36.

Surface Wind Behaviour Derived from Post Analysis

According to the post analysed surface synoptic charts, the winds along Victoria's east coast began to increase significantly about 4am on Sunday, reaching storm force by about mid-morning. This is supported by the recordings at Kingfish B that showed storm force winds were first observed shortly after 8am on Sunday.

By 9am, mean winds of up to 79 knots were being observed at the Wilsons Promontory Lighthouse in central Bass Strait. The reanalysis has, however, concluded that these winds were unrepresentative of surface conditions because the observations at Wilsons Promontory are measured at an elevation of about 100 metres and are additionally prone to local effects induced by the surrounding topography. According to studies of boundary layer effects the wind speed recorded at Wilsons Promontory could be as much as 20 to 25 knots higher than that at an elevation of 10 metres.

The storm force winds extended eastward as the main low pressure centre moved through eastern Bass Strait and out to the Tasman Sea. These winds would have reached the area just to the south of Gabo Island about midday Sunday and continued for at least a further 3 to 5 hours before easing slightly.

The surface analyses then show that a second smaller low had moved into eastern Bass Strait by 6pm on Sunday (see Fig 14) and it was this feature that produced another burst of stronger winds. Again this is supported by the observations from Kingfish B. The track of this second low takes the stronger winds to the area east of Gabo Island by about 9pm (Fig 15) where they would have continued for approximately the next 6 to 9 hours before finally easing.

2.4.3. Notable Wind Reports on 27 December

Observations from the lighthouse at Gabo Island, on the eastern tip of Victoria, reported northwest winds of 30 knots at 3pm on Sunday 27 December, westerly winds of 25 knots at 6pm and then southwest winds of 45 knots at 9pm (this was the maximum mean wind reported from Gabo Island during the event). By 6am on Monday morning the winds had eased back to southwest at 28 knots.

Observations recorded by the Navy's race relay ship *Young Endeavour* report 50 knot (storm force) winds at 9pm on Sunday 27th December while located approximately 30

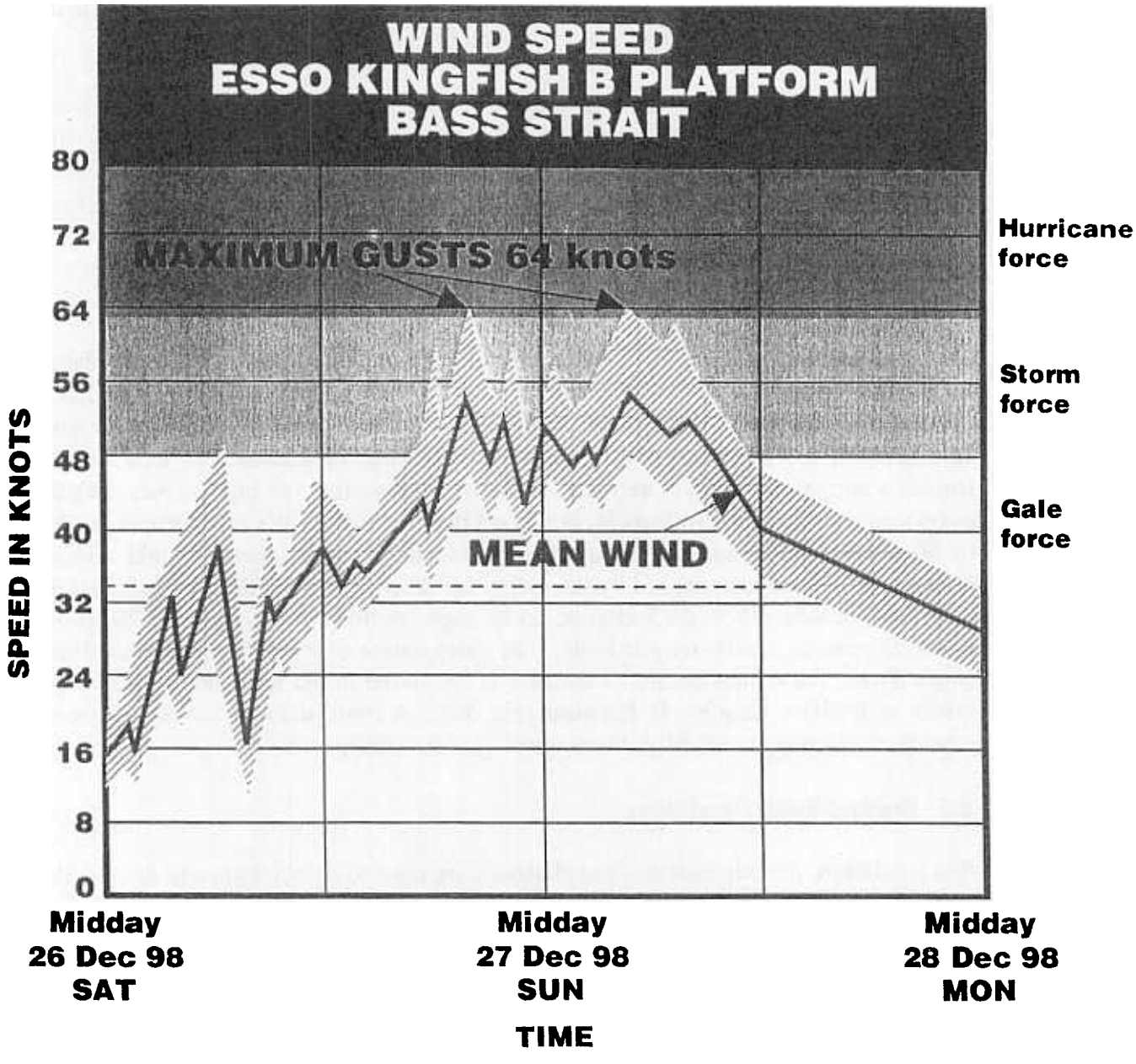


Figure 36: The 10 minute mean winds, and envelope of gusts observed at the Esso Kingfish B platform in eastern Bass Strait (location as given in fig. 1).

BUREAU OF METEOROLOGY

nautical miles east of Gabo Island. The observation recorded at about 11pm on Sunday night reports a mean wind of 56 knots while in about the same location. This was the maximum mean wind reported by the *Young Endeavour* as she travelled southwards during Sunday. Note that the observations from the *Young Endeavour* were not available to forecasters during the event.

A number of crews recalled winds in excess of 55 knots. However, in at least some instances, it is likely that these excess wind speeds were not mean winds of the standard 10 minutes duration but were in fact gusts. It should be noted that wind squalls often accompany heavy showers and sustained winds in excess of 55 knots may also have occurred during heavy precipitation.

2.4.4. The Likely Highest Mean Winds

The preliminary reanalysis of the situation, taking account of all readily available information, including reports obtained to date from yacht crews, observations from the ESSO Kingfish B Platform in eastern Bass Strait, coastal station reports and information from the Navy's Race Relay Ship *Young Endeavour*, as well as the Bureau's normal observation network, strongly suggests that the highest mean winds over open waters in eastern Bass Strait and off the southern NSW coast were about 55 to 60 knots. Gusts and squalls of considerably higher wind speeds would almost certainly have been experienced by the yachts for short periods of time as mean winds of this magnitude (55 to 60 knots) could be expected to produce gusts of 70 to 75 knots or more on a fairly regular basis. The gusty nature of the winds in Eastern Bass Strait during the critical period of the race is illustrated in the recording of observed winds at ESSO's Kingfish B Platform (Fig 36). A more detailed survey of yacht reports is underway to establish the range of speeds experienced.

2.5. Sea and Swell Conditions

Sea conditions, in both forecasts and observations, refer to *significant wave height* (the average height of the top one third of all waves) and therefore it is anticipated that waves in excess of the predicted/observed heights will be encountered on a number of occasions. Generally a factor of 1.86 is applied to the predicted wave height to determine the possible maximum wave height. For example, maximum wave heights corresponding to significant wave heights of 7, 9 and 11 metres are about 13, 17 and 20 metres respectively.

2.5.1. Swell, Sea and Current Interactions

The development of a low pressure system near Lord Howe Island and the maintenance of a high pressure system south east of New Zealand on 24 to 26 December (Figs 2 to 7) produced an easterly wind regime which resulted in a swell from the east to northeast over most of the course. This has been confirmed by a constant 2 metre significant wave height recorded at the Manly Hydraulic Laboratory's wave rider buoys at Eden and Bateman's Bay. The subsequent development of the westerly storm force winds associated with the intensifying low pressure system that moved through Bass Strait then superimposed wind generated waves from the west to

southwest. At the time this was occurring the East Australian Current is believed to have been flowing southward at about 4 knots off the NSW coast.

2.5.2. Sea State Reports

Although instrument recordings of wind, sea state and current are very sparse, it is apparent that the favourable conditions early in the race deteriorated rapidly as the yachts encountered the storm force westerly winds over southern NSW coastal waters and Bass Strait during Sunday. Some information on the sea state has been obtained from a few of the yacht crews in Hobart, from media reports, the ESSO Kingfish B platform in eastern Bass Strait and from the *Young Endeavour*. A more detailed survey is underway to establish the sea conditions experienced by the yachts.

The *Young Endeavour* reported seas of 5.5 metres and a swell of 6 metres (combined effect 8 metres) while located approximately 30 nautical miles east of Gabo Island at 11pm on 27 December 1998. From the limited number of observations received from the yachts so far, many appear to have experienced significant wave heights in the 5 to 8 metre range and maximum waves approximately double these heights.

Due to a lack of information on the correlation between wave observations from the Kingfish B platform and waves observed in the far east of Bass Strait and the Tasman Sea, the reports from Kingfish B can serve only as a guide for the Bureau's analysis. Nevertheless, the observations of significant wave heights of around 6 to 7 metres with maximum waves of 11 to 12 metres during the critical period on Sunday 27 December (Fig 37) are consistent with some observations received from the crews near the Gabo Island/eastern Bass Strait area.

2.5.3. Indirect Estimates of the Sea State

Due to the lack of observational data in the region of most interest, sea and swell conditions generated by the Bureau's own computer model have been incorporated into the post analysis of the event (Fig 38). In the model, the state of the sea is represented as an energy spectrum, which is a function of wave frequency and direction at each of the points in the model grid. The wave conditions generated by the wave model are based on the response of the ocean to a given wind field. There is no assimilation of observed wave data into the model at present nor is there any attempt to diagnose interactions between the waves and ocean currents. The wind fields used are those obtained from the lowest level of the operational atmospheric models adjusted to 10 metres.

The model generated significant wave heights of just over 7 metres from the west in the area well to the east of Gabo Island at 11pm on 27 December.

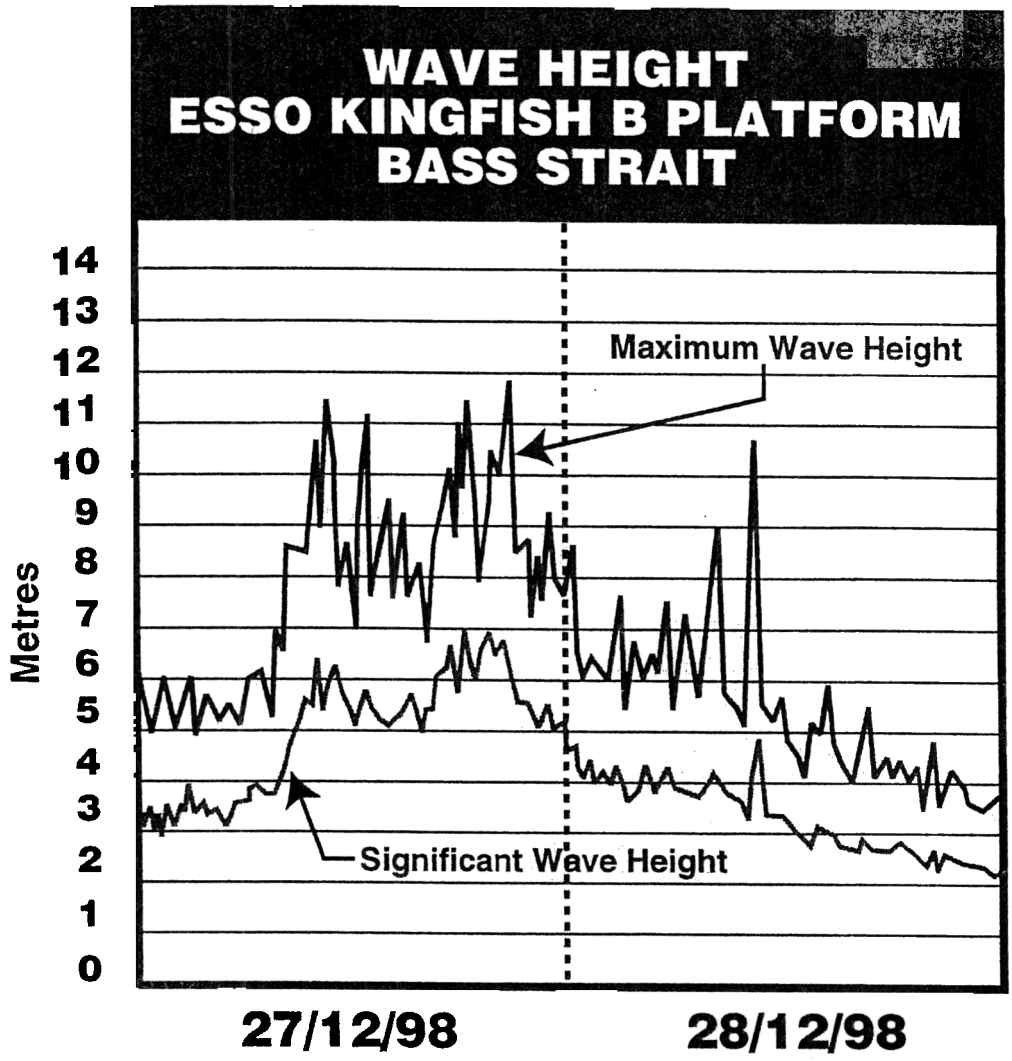
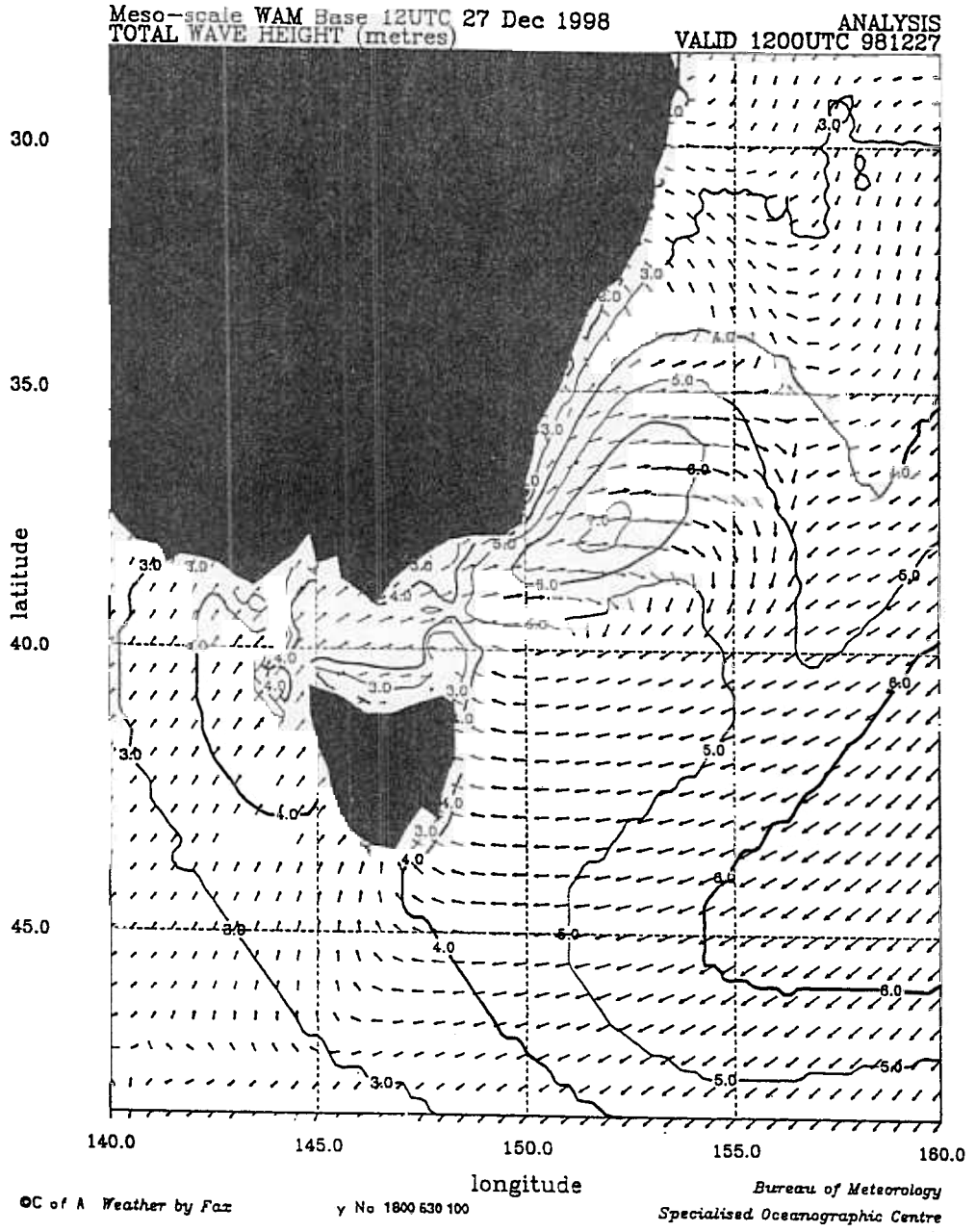


Figure 37: Significant and Maximum Wave Heights (metres) transcribed from recording unstruments located at the Esso Kingfish B Platform, eastern Bass Strait 27 - 28 December 1998 (location as given in Fig 1)

Fig 38. Computer generated analysis of wave heights valid for 11pm 27 December 1998.



3. SERVICES PROVIDED BY THE BUREAU OF METEOROLOGY 15-29 DECEMBER 1998

3.1. The Bureau's Role in Marine Weather Services

The Bureau has a responsibility, under the Meteorology Act 1955, to issue routine forecasts and warnings of weather conditions for, *inter alia,* the purposes of navigation and shipping. As part of its charter, the Bureau provides a suite of routine weather products in the public domain. These products include coastal waters (out to 60 nautical miles from the coast) and high seas forecasts.

A wind warning service is also provided and, for coastal waters, this covers strong winds (mean winds averaging 25 to 33 knots), gale-force winds (mean winds averaging 34 to 47 knots) and storm-force winds (mean winds averaging in excess of 47 knots). For high seas forecasts, warnings are issued for gale-force, storm-force and hurricane-force winds (mean winds averaging over 63 knots - in severe tropical cyclones only).

These forecasts and warnings are made available to the public in a variety of ways that include radio, facsimile, pager and the Internet. The Bureau has produced several publications and pamphlets providing information on marine weather including descriptions of the forecast and warning service and how to obtain marine weather information.

3.2. Services provided to the Cruising Yacht Club of Australia

For many years, the Bureau of Meteorology has provided a pre-race briefing and a special race forecast service to all competitors in the Sydney to Hobart yacht race through the Cruising Yacht Club of Australia (CYCA). The special service has always been provided by the New South Wales/Tasmanian Regional Forecasting Centres (RFCs) of the Bureau with the NSW RFC delivering the pre-race briefing as well as the outlooks leading up to the race. During the event, these offices liaise together and with the Victorian RFC which is responsible for routine forecasts in eastern Bass Strait, forecasts for the high seas in the Tasman Sea and for high seas warnings south of latitude 38 degrees south. For the race, the NSW office prepares race forecasts from Sydney to 38 degrees south and the Tasmanian office south of 38 degrees south (See Fig 1). The schedule of forecasts is shown in the following table.

NSW RFC		
Date	**Time of Issue**	**Area Covered**
Dec 26th	0500, 1000,1300	Sydney to Jervis Bay
Dec 27th	0200, 1300	Jervis Bay to Gabo Island
Dec 28th	0200, 1300	Jervis Bay to Gabo Island
TAS RFC		
Dec 27th	1300	Bass Strait
Dec 28th	0200, 1300	Bass Strait and Tas East Coast
Dec 29th	0200, 1300	Bass Strait and Tas East Coast
Dec 30th	0200, 1300	Bass Strait and Tas East Coast
Dec 31st	0200, 1300	Bass Strait and Tas East Coast

The forecasts were distributed to the CYCA, the Royal Yacht Club of Tasmania and made available generally though the Bureau's Weather-by-Fax and Internet services. It is understood that these forecasts were also relayed to the competitors via the Navy's Race Relay Vessel, the *Young Endeavour*, during the regular radio schedules. For the 1998 Sydney to Hobart Yacht Race, the official radio schedules were at 8.05pm on 26 December and at 3.05am, 2.05pm and 10.05pm on subsequent days up to and including 30 December 1998.

Relevant services provided by the Bureau of Meteorology in the period leading up to and encompassing the yacht race included routine marine products (coastal waters and high seas forecasts and warnings, coastal weather reports, etc.) and specific services for the CYCA. The routine services broadcast on marine radio are twice per day for high seas forecasts and two to three times per day for coastal waters forecasts. Warnings are broadcast on receipt and repeated every two hours while the warning is current. The specific services for the CYCA were provided on a cost-recoverable basis (i.e. the incremental cost to the Bureau of providing the service was recovered from the CYCA) and included pre-race briefings by Bureau staff for the competitors and organisers and special access arrangements for race officials to contact the Bureau's Senior Forecaster at any time.

The relevant warnings issued by the NSW and Victorian RFCs over the period 23 December to 29 December 1998 are included in Appendix 4. Copies of the special race forecasts issued by both the Tasmanian and New South Wales Regional Offices for the 1998 race can be found in Appendix 5.

3.2.1. Meteorological Services Leading up to the Sydney to Hobart Yacht Race

Meteorological services for the CYCA, leading up to and including the Sydney to Hobart yacht race, commenced on Tuesday 15 December 1998 with a general weather briefing delivered by a meteorologist from the NSW Regional Forecasting Centre to all competitors in the Telstra Cup event. (This event is the lead-up series to the Sydney to Hobart yacht race and is contested every other year - alternating with a series called the Southern Cross Cup.) It is understood that the majority of yachts that participate in these series also take part in the Sydney to Hobart race.

The briefing consisted of a general information session that included possible weather problems around the Sydney area as well as information on where and how competitors could obtain weather information. Competitors were also made aware of a number of web sites, including that of the Bureau, and also the Bureau's Weather-by-Fax service where they could obtain the full suite of marine products produced by the Bureau. The information that was provided is listed in Appendix 6.

3.2.2. Outlooks for the Sydney to Hobart Yacht Race

The first formal outlook for the Sydney to Hobart race was prepared at 10.20am on 23 December 1998 (Appendix 5). This was issued primarily for media purposes, and covered the period from Saturday 26 December to Tuesday 29 December. It was

based heavily on the Bureau's computer generated products. The outlook was issued with a qualifier that it was based on limited data and needed to be fine-tuned.

3.2.3. Pre-race Briefing for the 1998 Sydney to Hobart Yacht Race

The official pre-race briefing, held at 9am on 24 December 1998 at the Cruising Yacht Club of Australia, Rushcutters Bay, Sydney, was attended by approximately 250 people. A Bureau meteorologist provided general meteorological and oceanographic information as well as the latest information on likely weather conditions for the race.

The general information provided during this briefing centred around weather conditions along the race course that could pose problems to competitors. A session on where and how weather and oceanographic information could be obtained was also presented. The existence and location of weather related web sites and details on how to access the Bureau's Weather-by-Fax service were highlighted to competitors. Relevant Bureau handouts were also made available (Appendix 6).

Attention was also drawn to two articles, the first written for the December 1998 *Offshore Yachting* magazine (journal of the CYCA) titled "Finding that weather information", which covered essentially where competitors could obtain weather information. The second article appeared in the January 1999 issue of the *Australian Sailing* magazine (available middle of December 1998) and was titled "Cold Front". This article covered cold fronts and their behaviour over SE Australia.

A race weather outlook was also presented (see Appendix 5.) This outlook was issued at 8.30 am on 24 December and covered the period 26 to 29 December. It was based on the latest computer generated prognoses but the various computer models available to NSW forecasters at the time were not conclusive regarding the evolution of weather patterns for the race. The outlook also contained the qualifier that "This outlook is based on limited data and will need to be fine-tuned".

It was added verbally at this briefing that at least one other computer model, namely the European Centre for Medium range Weather Forecasts (ECMWF) computer model, which was run the day before the briefing, was showing signs of a low pressure system forming to the southeast of Gabo Island. Competitors were told to keep an eye on this, especially since there was a trend towards low pressure development in the northern Tasman Sea.

A request was also made to competitors that had the capabilities (20 or so yachts) to send the Bureau observations of actual weather conditions encountered along the course. An electronic mail (e-mail) address was set-up specifically for this purpose, namely, whrsyd@bom.gov.au. They were asked to supply observations in plain language and to include the following:

- Time
- Position
- Average wind speed, direction and maximum gust
- Seas

- Swell
- Other remarks

As observations of wind and sea state in the race area are sparse, these reports would have been extremely useful for analyses and forecasts. Unfortunately, no observations were received.

Competitors' attention was also drawn to possible 'wind opposing current' problems. This was in light of the forecast strong southerly change coupled with 3 to 4 knots of East Australian Current generally setting south. In such conditions, steep breaking seas can develop very quickly.

Another race outlook was issued at 2pm, Friday 25 December. This outlook (Appendix 5) was valid for the period 26 to 29 December and contained details pertaining to areas or sub-divisions over the race area as well the synoptic situation for each day. This outlook was again heavily based on the Bureau's computer model outputs.

3.2.4. Forecasts and Warnings for the 1998 Sydney to Hobart Yacht Race.

On Boxing Day, 26 December, the first special race weather forecast was issued at 4.29am. This was the first issue of the special forecasts that were faxed to the CYCA as well as to the Radio Relay Vessel (Appendix 5).

During the morning of Boxing Day, before the race commencement at 1pm, the Bureau has traditionally maintained a race weather briefing service outside the sailing office of the CYCA. Competitors can avail themselves of the latest race weather and oceanographic information and have the opportunity to talk to Bureau forecasters for any elaboration or explanation that they may require. Approximately 75% of competitors in the 1998 race availed themselves of this service. Crews that approached the stand were handed the latest (9.04am) issue of the special race forecast as well as a comprehensive briefing pack (see Appendix 7). Three meteorologists provided this service on the Bureau's behalf.

The 9.04am issue of the race forecast updated the 4.29am issue by including a gale warning for waters south from Broken Bay. The warning, based on computer model output, was forecasting south to southwest winds with mean speeds in the 30 to 35 knots range with stronger gusts. Competitors were also warned that the strong to gale force SW/W winds would persist south of Jervis Bay over Sunday and would start to moderate over Monday evening.

3.2.4.1. Issue of First Storm Warnings

At about 1pm on 26 December, meteorologists in both the NSW and Victorian RFCs received the latest computer generated prognosis (based on data input at 10am on 26 December 1998) which showed the development of a strong low pressure system in Bass Strait (Figs 39 and 40). The computer prognosis indicated mean winds of 45 to 55 knots were likely to occur over that area, especially in eastern Bass Strait. After consultation between the respective senior forecasters, both offices issued a storm

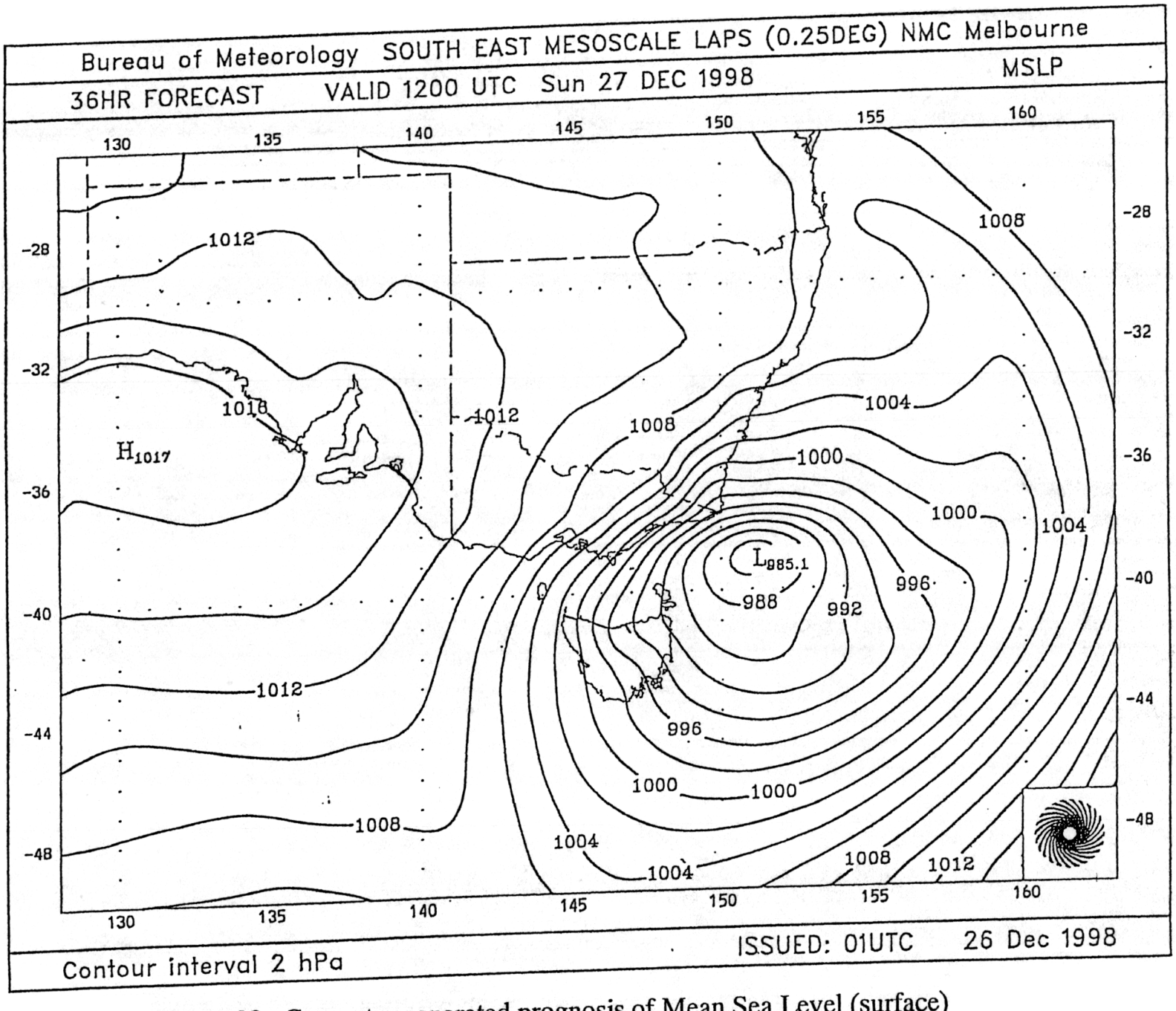


Figure 39. Computer generated prognosis of Mean Sea Level (surface) Pressure for 11pm Sunday 27 December 1998, which became available forecasters at 1pm on 26 December 1998.

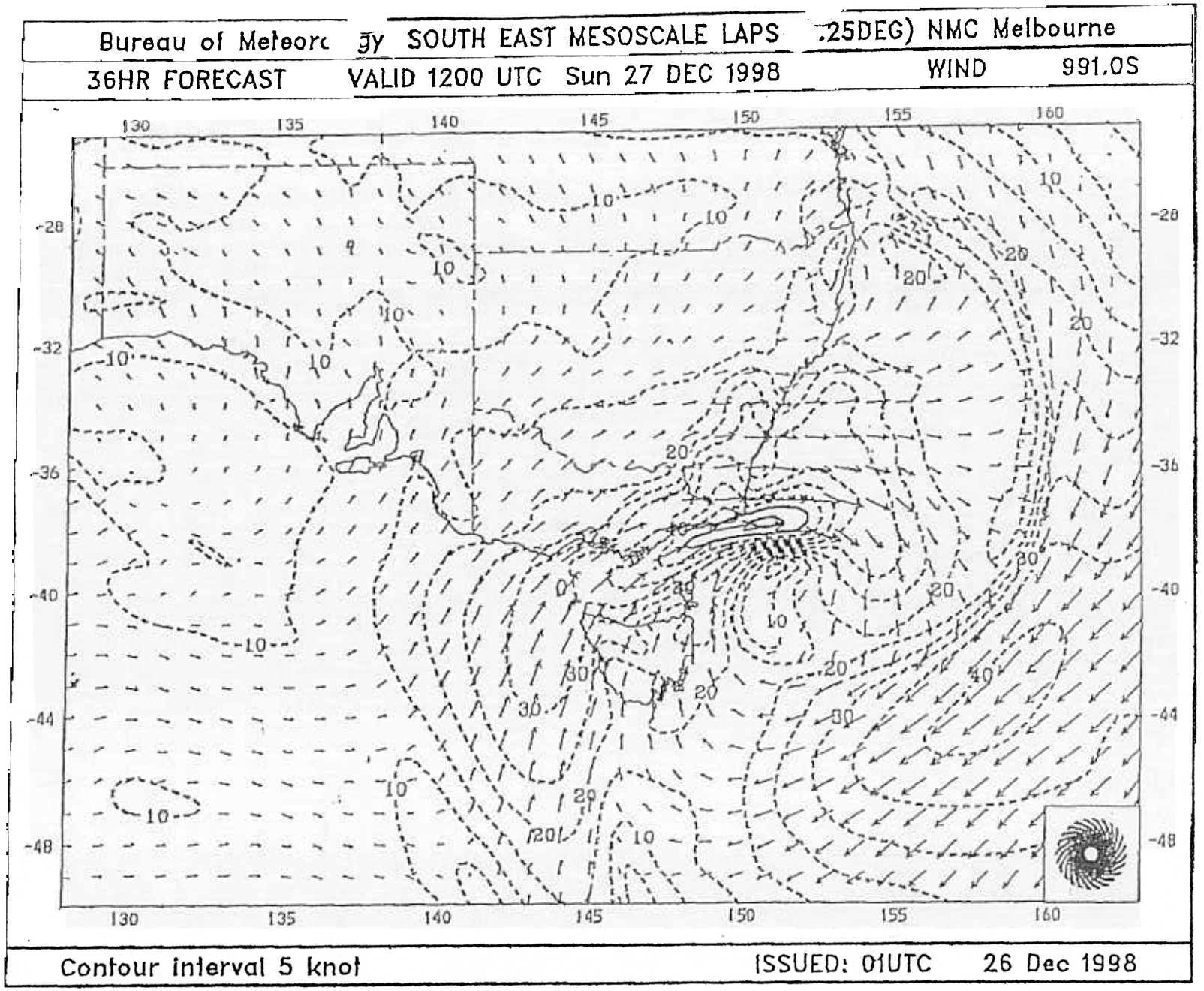


Figure 40. Computer generated prognosis of wind speed in knots (contours) and direction (arrows) for 11pm Sunday 27 December 1998, which became available to forecasters at 1pm on 26 December 1998.

warning. The Victorian warning, issued just before 2pm, covered waters east of Wilson's Promontory and the NSW warning, issued about fifteen minutes later, covered waters south from Merimbula (Attachments 1 and 2).

Upon issuing the storm warning through the normal channels, the Bureau's NSW office also contacted the following:

- AMSA (it was understood that they would contact other authorities, including the Navy)
- Eden Royal Volunteer Coastal Patrol
- Sydney to Hobart Race media centre

The NSW RFC then issued an updated special race forecast at 2.50pm on 26 December 1998. The updated forecast, which included advice that a storm warning was current south of Merimbula, was sent to the *Young Endeavour* which was responsible for relaying forecasts and warnings to the competitors during the official radio schedules. According to the limited number of reports from crews that have been received so far, it appears that in addition to the radio schedules some yachts received the details of the warning from other means (ie coastal radio broadcasts). The results of a CYCA survey will provide more detailed information on how and when the crews were made aware of the storm warning.

3.2.5. Services to AMSA for Search Planning and Rescue

The Bureau of Meteorology is responsible for providing weather forecasts and weather information to assist search and rescue (SAR) operations. The suggested content of forecasts for SAR operations is contained in the *Abridged Final Report of the Twelfth Session of the Commission for Marine Meteorology* which indicates the internationally agreed set of information that should be provided. Additional information can be provided if available and requested.

During the search and rescue operations for the yachts, the Bureau provided five forecast products to AMSA to assist in search planning and rescue efforts. The products (see Appendix 8) originated from the Bureau's offices in Melbourne (one on 27 and three on 28 December) and Canberra (one issued on 28 December).

On three occasions AMSA requested additional information on winds (speed and direction) likely to have already occurred at specified locations and times. These forecasts are commonly referred to as "hindcasts" and are used to help define the search areas. The Victorian Regional Forecasting Centre provided this information.

4. ASSESSMENT OF THE PERFORMANCE OF THE FORECAST AND WARNING SERVICES

4.1. Description of the Forecast and Warning Process

The production of meteorological forecasts and warnings begins with collection of data that describe the current state of the atmosphere. These data come from a wide array of sources and include:

- Weather reports from human observers, automatic weather stations, ships at sea and buoys.
- Measurements of the upper atmosphere from instrument packs carried aloft by weather balloons and from aircraft reports.
- Data received from weather satellites including satellite images of the atmosphere as well as vertical temperature cross sections of the atmosphere from satellite based sounders and upper atmospheric winds measured by observing cloud displacements.
- Data from other sources such as weather radar and surface based profilers.

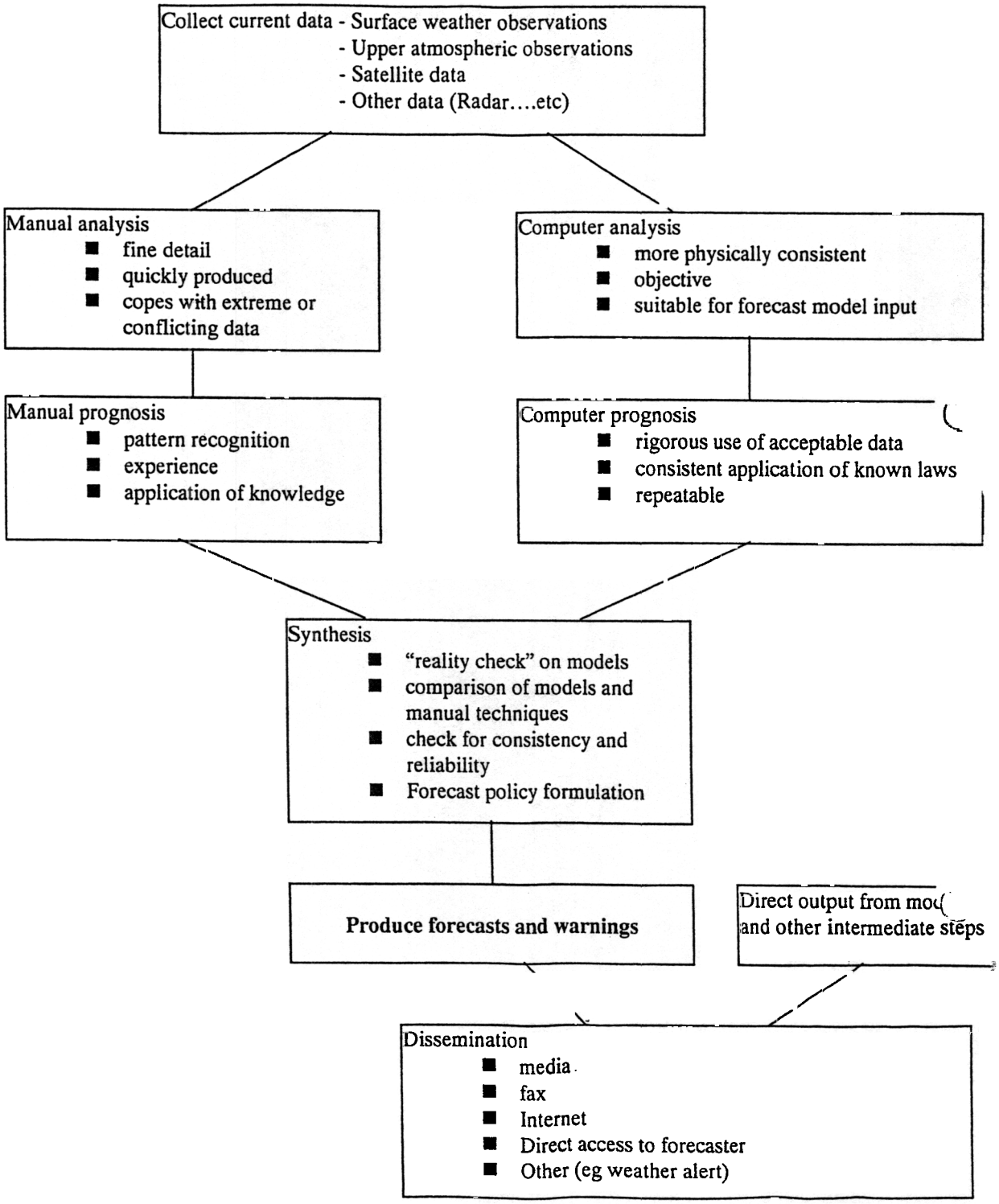
This large volume of data must be sorted and arranged into a comprehensible form before it is useful for predicting the evolution or prognosis of future weather patterns in map form. A number of times each day, the latest collection of data is processed via parallel manual and computer based paths that result in weather analyses and prognoses. (See schematic on following page.)

The manual path involves viewing data on a range of displays, plotting data on weather maps and the preparation of hand drawn analyses. Manually drawn weather maps are usually complete an hour or so after observations are made and often show a level of detail and capacity to cope with extreme data values and discontinuities that is still unavailable in computer weather analysis. Manual weather analysis makes good use of the ability of human forecasters to pick out important patterns in large volumes of data and to integrate different data types. Having analysed the data, human forecasters will recognise weather patterns and use their experience and knowledge of meteorology to predict the likely evolutions of those patterns.

The parallel computer based path uses mathematical models of the atmosphere translated into computer code running on a supercomputer to simulate the behaviour of the real atmosphere. At least twice each day, collected weather data are assimilated by the computer models to produce computer analyses of the atmosphere. These have the advantage of being forced by the construction of the model to be always consistent with the physical laws or mathematical equations that describe atmospheric flow on a rotating earth. As such, they form a suitable starting point for the computer prognosis of future weather patterns over areas ranging from the globe to more limited area domains. Global models have the advantage of being able to make predictions several days in advance but operate at a relatively coarse resolution. Limited area models are able to include more detail but are limited in their forward prediction extent.

The following diagram outlines the various steps in the forecast process.

The Forecast Process



Computer based prognoses make rigorous use of the available data, consistently apply the known physical laws describing atmospheric evolution, are repeatable and show useful forecast skill 4 or 5 days into the future. On the other hand, they cannot use some types of data, cope poorly with small weather systems and conflicting data and take several hours to produce.

Weather forecasters in Australia have routine access to the chart output from at least six different computer models from various centres around the world. In most weather situations, the simulated atmosphere is finely balanced between several different paths of evolution. The different mathematical formulations of individual computer models and the slightly different observational data sets available to each model inevitably results in differing assessments of future atmospheric evolution and associated detailed weather occurrence.

One of the most important tasks for each weather forecasting office is to continuously evaluate the performance of the various prediction models and to compare their predictions with the manual analysis of the current weather situation. A synthesis of the manual and computer analyses and prognoses forms a reality check on the computer simulations and helps the forecaster choose between the alternatives presented by computer simulation and manual techniques. The forecast policy for the offices emerges out of this process and forms the basis for the production of a consistent set of forecasts for particular areas and localities and other weather products.

These products are usually generated according to a fixed schedule, but forecasts are amended and important warnings are produced and updated whenever the need arises. This requirement to issue products to a fixed schedule, and to insert additional warnings and special products during an event such as the Sydney to Hobart Yacht Race adds substantially to the pressure of the manual forecasting task. Products are disseminated through the media and some are directly faxed to clients. Many products are also available via poll (demand) fax services (Weather-by-Fax) and through the Internet. Fax and Internet access has also made practical the dissemination of some of the products generated during the intermediate steps in the forecast process such as the unedited charts produced by various computer weather models.

Forecasts for the yacht race followed standard international practice, as explained in the Bureau's *Marine Weather Services* information sheet which is generally available to the public and handed out at the race weather briefing for both the Telstra Cup and Sydney to Hobart races (Appendix 2).

4.2. Performance of the Numerical Weather Prediction System

Computer modelling of the atmosphere has been in a constant state of development since the first operational systems were produced in the 1960s. Developments in computer technology have meant that the speed with which the new computers are able to calculate terms in the complex equations that describe the atmosphere's evolution has increased dramatically. During this time, computer modellers have gradually increased the physical representativeness of the equations being used and the computational resolution of the calculations performed. As a consequence, the performance (or "accuracy") of the computer output has gradually improved.

4.2.1. Computer Models used by Bureau Forecasters

The following models are used by the Bureau of Meteorology:

ECMWF - this is a 'global' model created by the European Centre for Medium range Weather Forecasts.

GASP - Global Assimilation and Spectral Prognosis. This is a Bureau of Meteorology produced 'global' model.

JMA - 'global' model produced by the Japan Meteorological Agency

LAPS - Local Area Prediction System. This is a Bureau of Meteorology produced 'regional' (local) area model.

MesoLAPS - identical to LAPS but capable of higher ("mesoscale") resolution over more restricted spatial domains. A Bureau of Meteorology system.

U/NSW - this model is produced by Professor Lance Leslie of the University of New South Wales and can be 'run' in 'global', 'regional' and 'local' modes.

UKMO - this is a 'global' model produced by the "Met Office" in the United Kingdom.

US - this is a 'global' model produced by the National Centers for Environmental Prediction in the United States.

4.2.2. Outputs from Operational Computer Forecast Models

The computer weather forecast model output is summarised in Attachment 3. It shows that on Wednesday 23 December, three days before the start of the race, the different computer models were forecasting different possible evolutions of the weather pattern. The ECMWF model was forecasting a ridge of high pressure and moderate to fresh northeasterly winds over the waters around Gabo Island for Sunday. Other models were suggesting that a low would develop somewhere between Gabo Island and the southern Tasman Sea with southeast to southwesterly winds of about 25 to 40 knots likely to affect the race.

By Thursday 24 December, the models were generally on different tracks with the ECMWF model indicating the formation of a low to the east of Tasmania, implying southwesterly winds at about 30 knots for the Gabo Island area for Sunday evening. Some other models, including the Bureau's GASP model, were forecasting a high pressure system very close to Gabo Island for Sunday evening, implying light and variable winds.

On Friday 25 December, the models were starting to agree on the development of a low pressure system over the Tasman Sea, though they differed in its exact location. However, the Bureau's GASP model and the UKMO model both forecast a ridge of

high pressure just off Mt Gambier, near western Bass Strait, and the US aviation model persisted with a centre of high pressure over Gabo Island. Taken as a group, the models were firming on a prediction of southerly or southwesterly winds near Gabo Island by Sunday, with strengths probably between 15 and 30 knots, but there were still significant differences between them.

By Friday evening, the GASP and UKMO models were predicting stronger southerly or southwesterly winds, up to 35 or perhaps 40 knots, for the Gabo Island area for Sunday. The limited area (but often very accurate) LAPS model available at about 1am on Saturday morning was, however, only forecasting wind speeds near Gabo Island of about 25 knots.

4.2.2.1. Key Computer Model Forecasts

Real consensus between the models did not occur until about noon on Saturday 26 December. The global models (ECMWF, JMA, GASP, UKMO and US) became available during Saturday morning and were all forecasting the development of a deep low which would be about 220 nautical miles southeast of Gabo Island by Sunday night. They were forecasting southwesterly winds of around 45 knots, near the high end of the gale force range. Shortly after, the LAPS model output became available and forecast the low to develop much closer to Gabo Island which would mean stronger (about 50 knots) winds. At about 1.00pm the same day, the much higher resolution "MesoLAPS" model predicted a deeper low of 985 hPa central pressure only about 80 nautical miles off Gabo Island with westerly winds of 55 knots (Figs 39 and 40). The Bureau's wave model display, using the winds modelled by MesoLAPS, became available about 2.30pm and forecast waves just over 8 metres high in eastern Bass Strait on Sunday night (Figs 41 and 42).

4.2.2.2. Additional Computer Model Forecasts

Later runs of the GASP and UKMO models available on Saturday evening 26 December maintained forecasts of 50 knot winds, slightly lighter than the earlier MesoLAPS model output. It is considered that this slight apparent decrease of forecast wind was most likely a consequence of the GASP and UKMO models' slightly coarser resolution, rather than any change in the predicted severity of the event.

The next run of the MesoLAPS model, available at about 1am on Sunday 27 December continued to forecast a low developing over eastern Bass Strait and moving eastwards over the Tasman sea but predicted a less deep central pressure (990hPa) and slightly lighter (45knots) winds over the area south of Gabo Island by Sunday night.

On Sunday morning, the real time observational data plotted on manually analysed charts provided the most useful basis for forecasting an event that was nearing peak intensity. From this point on, the weather forecast models were useful mainly as an aid for predicting the general abatement of conditions.

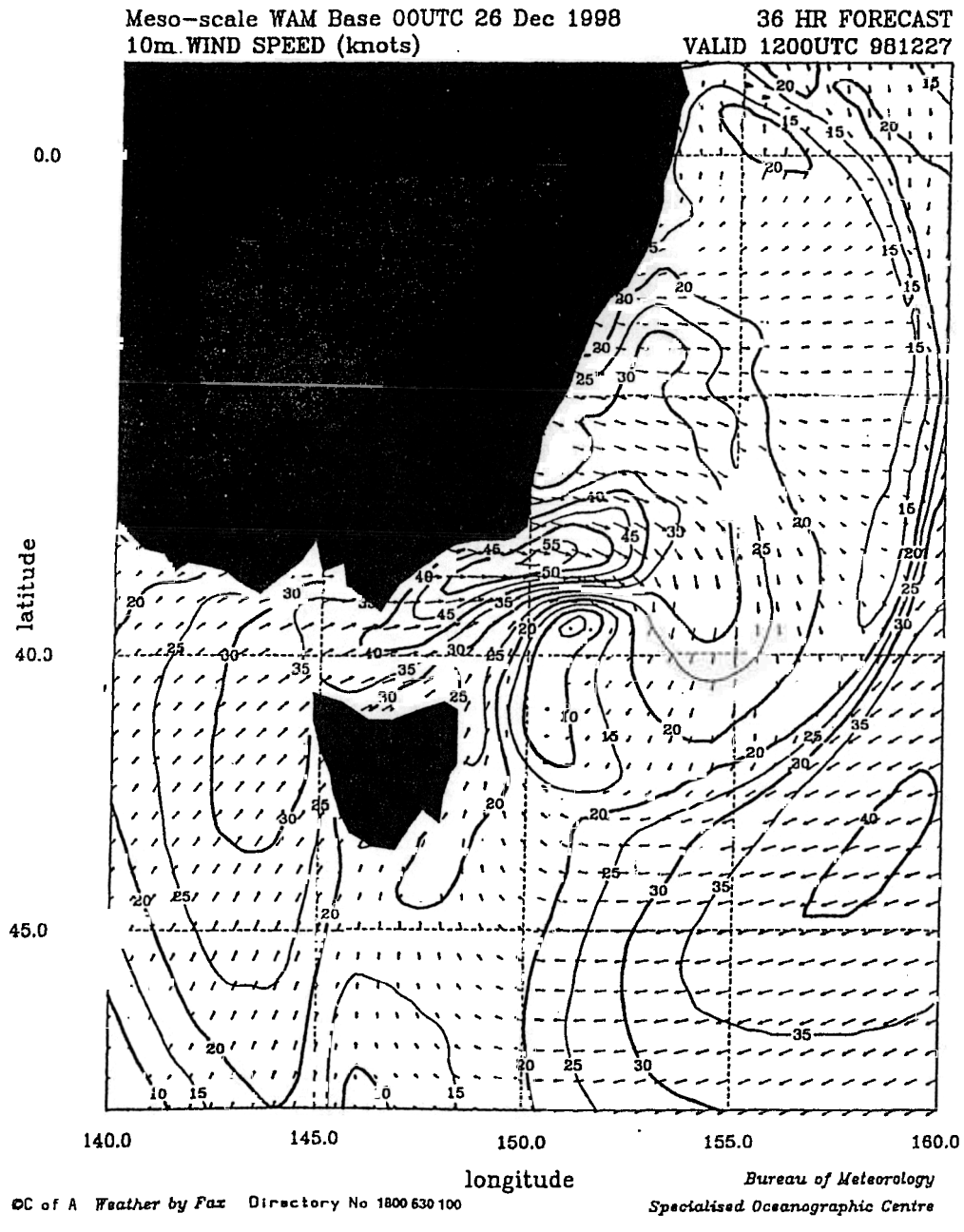


Fig 41. Computer generated prognosis of wind speed (contours) and direction (arrows) valid for 11pm Sunday 27 December 1998. Note this output is from the Bureau's wave model.

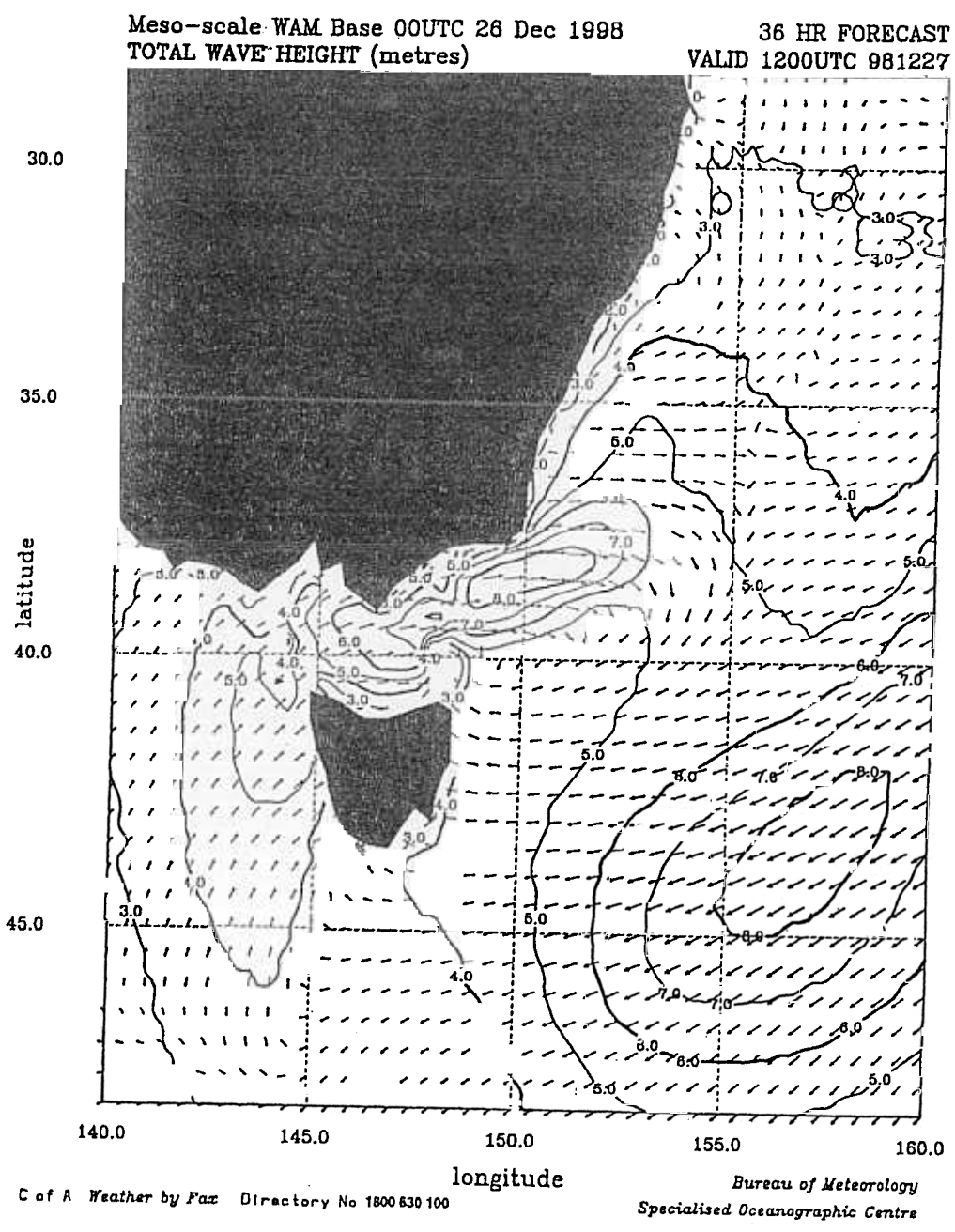


Fig 42. Computer generated prognosis of Total (significant) Wave Hei[illegible]netres) valid for 11pm Sunday 27 December 1998.

4.3. Storm Warnings Issued by the Bureau

An initial investigation of the relevant meteorological analyses and prognoses has shown that output from the Bureau's high resolution computer model at 1pm on 26 December was an important factor in triggering forecasters to issue the storm warning. The alerting computer forecast output, valid for 11pm on Sunday 27 December 1998, is shown in Figs 39 and 40.

The warnings were issued some 18 to 21 hours ahead of the onset of the storm force winds over the race area.

4.3.1. Contents of Storm Warnings Issued

Storm warnings for both the coastal waters and high seas referred to mean winds of up to 45 to 55 knots. It is known that wind gusts will cause temporary fluctuations about this mean and that maximum gusts of up to 40% above the forecast mean wind may be observed. Therefore with a forecast of 45 to 55 knots regular gusts of around 70 knots were likely.

Storm warnings for the coastal waters referred to waves of 4 to 7 metres significant wave height (average height of the highest one third of all waves). Storm warnings for the high seas referred to rough (2.5 to 4 metres) to very rough (4 to 6 metres) seas and moderate (2 to 4 metres) to heavy (greater than 4 metres) swell which would result in a combined significant wave height of at least 7 metres. It should be noted that while forecasts and observations of waves are for the significant wave height, individual waves approaching twice that size can be expected to occur.

4.3.2. Other Surveys and Post-Event Investigations

Separate investigations and assessments are currently being undertaken by the CYCA and AMSA. The investigation being conducted by the CYCA includes a survey of the crews which deals, amongst other things, with the weather aspects of the event.

The results of this survey and the outcomes of the investigations will enable a more complete description of the meteorological conditions associated with the race to be determined, and will be incorporated in the Bureau's final Report of this event.

5. SUMMARY

In summary, a preliminary investigation of the meteorological situation surrounding the race and the services provided by the Bureau, indicates that:

A Bureau briefing provided to race organisers and competitors on 24 December 1998 indicated the possibility of hazardous weather conditions during the race.

A gale warning was issued soon after 9am on the morning of 26 December for the New South Wales coastal waters south from Broken Bay and was current at the time the race started. The gale warning was transmitted through normal channels and details were also available at the Bureau of Meteorology's pre-race briefing stand for race competitors and organisers.

The Bureau's Sydney office upgraded the gale warning to a storm warning for the area south of Merimbula at 2.14pm on 26 December, just over 1 hour into the race. Phone contact was made with key authorities to alert them to the warning.

Output from the Bureau's high resolution computer model at 1pm on 26 December 1998 was an important factor in triggering forecasters to issue the storm warning.

Storm force winds over the race area appear to have developed some 18 to 21 hours after the first storm warning was issued.

The storm warnings referred to mean wind speeds of 45 to 55 knots. Under these forecast conditions, gusts of 70 knots would be expected.

Instrumented observations from Kingfish B and the *Young Endeavour* indicate that the likely highest mean winds were around 54 to 56 knots. Reports received from the yachts so far suggest that the likely maximum mean winds experienced were in the range 55 to 60 knots with frequent gusts to 75 knots.

Seas of 4 to 7 metres (significant wave height) were generally forecast in the Bureau's storm warnings. Infrequent maximum waves with heights of about 13 metres could be expected under these forecast conditions.

Several observations received from the yachts so far suggest that waves of 5 to 8 metres, with some individual waves of 15 metres, were experienced.

A more complete description of the meteorological conditions, including the range of wind speeds and sea conditions, associated with the Race is expected to emerge as additional information comes to hand from other sources (e.g. surveys being undertaken by the CYCA, and from AMSA) and all available relevant information will be included in the Bureau's final report.

IDW00N01

BUREAU OF METEOROLOGY
NEW SOUTH WALES REGIONAL OFFICE
300 Elizabeth St. Sydney, Ph [02] 9296 1555

Priority Storm Warning Coastal Waters South of Merimbula
Gale Warning Coastal Waters South of Broken Bay
Strong Wind Warning between Broken Bay and Seal Rocks

Issued at 1414 on Saturday the 26th of December 1998

Synoptic Situation

High over New Zealand ridging onto central NSW coast. Low 995hPa near Lord Howe Island is slow moving. Cold front moving east across central Victoria.

Warning

N/NE wind reaching 20/25 knots between Broken Bay and Ulladulla, 25/30 knots south from Ulladulla, ahead of a gusty W/SW change 30/40 knots expected South Coast late tonight, then W/SW 25/35 knots Illawarra and Sydney Coast early Sunday morning, and W/SW 25/30 knots Hunter Coast later Sunday morning. W wind increasing to 45/55 knots offshore south of Merimbula late Sunday afternoon.

Seas 1 to 2 metres, rising to 3 to 4 metres with the change. Swell 1 to 2 metres, rising to 2 to 3 metres after the change.

BUREAU OF METEOROLOGY
VICTORIAN REGIONAL OFFICE

Priority
Storm Warning
for Victorian coastal waters east of Wilsons Promontory

Issued at 1358 on Saturday the 26th of December 1998

West/southwesterly wind change of 20/30 knots extending from the west this afternoon then increasing to 35/45 knots tomorrow morning and 45/55knots late Sunday afternoon. Seas rising to 2 to 3 metres this afternoon, 3 to 4 metres tomorrow morning and 4 to 6 metres late afternoon.

*** CORRECTED VERSION ***

*** This is the corrected version of a warning issued 6 minutes earlier. The correction made is underlined.

Priority
Storm Warning
for Victorian coastal waters east of Wilsons Promontory

Issued at 1352 on Saturday the 26th of December 1998

West/southwesterly wind change of 20/30 knots extending from the west this afternoon then increasing to 35/45 knots tomorrow morning and 45/55 knots late Saturday afternoon. Seas rising 2 to 3 metres this afternoon, 3 to 4 metres tomorrow morning and 4 to 6 metres late afternoon.

Attachment 3: Summary of We ..er Forecast Model Output Operati ..y Available in the Lead-up to the Race

Winds noted in each panel are the strongest mean winds which could reasonably have been forecast from the printed model output, for the area just offshore from Gabo Island at the times the model runs were valid (between 4am and 11pm, local time, on Sunday the 27th December 1998). Winds measrured in knots (kn).

Run	ECMWF	JMA	GASP	UKMO	US (aviation)	LAPS	MesoLAPS	U/NSW
+120 valid Sunday, 27th at 12UTC (11pm Sun EDST)	avail Wed at noon High pressure ridge > NE'ly20kn	Low(1000) 400km E of Gabo > SSW'ly 40kn	avail Wed at 6am High pressure ridge over Bight, Low(995) over S'rn Tasman Sea > SW'ly 20kn	avail Wed morn Low(1001) over Gabo > Var winds, SSE'ly developing 25kn	Not Available	Not Available	Not Available	Not Available
+96 valid Sunday, 27th at 12UTC (11pm Sun EDST)	avail Thur at noon Low(992) 600km E of Tas > SW'ly 30kn	High over the Vic highlands > light/ variable	avail Thur at 6am High over Gabo > light/ variable	avail Thur morn Complex trough over the Tasman sea > SE'ly 25kn	Not Available	Not Available	Not Available	Not Available
+72 valid Sunday, 27th at 12UTC (11pm Sun EDST)	avail Fri at noon Low (988) in the S'rn Tasman > WSW 30kn	Low(998) 400km ESE of Hobart > SW'ly 35kn	avail Fri at 6am High west of Bass Strait > SSW'ly 15kn	avail Fri morn High near Mt Gambier, Low(1006) 200km E of Sydney > SE'ly 30kn	High over Gabo > light/variable	Not Available	Not Available	Not Available
+60 valid Sunday, 27th at 12UTC (11pm Sun EDST)	Not Available	Not Available	avail Fri at 6pm Low(999) 500km E of Hobart > SSW 35kn	avail Fri evening Low(1001) 400km E of Gabo > S'ly 40kns	Not Available	Not Available	Not Available	Not Available
+48 valid Sunday, 27th at 12UTC (11pm Sun EDST)	avail Sat at noon Low(993) 400 km SE of Gabo > SW'ly 45kn	Low(995) 400km E of Hobart > SW'ly 45kns	avail Sat at 6am Low(993) 400km E of Flinders > SW'ly 45kns	avail Sat morn Complex low(994) E of Tasmania > SW'ly 40kns	Low(995) 250km E of Hobart > WSW'ly 45kn	avail Sat 1am Low(998) over the S'rn Tasman > SW'ly 25kn	Not Available	Not Available
+ 46 valid Sunday, 27th at 10UTC (9pm Sun EDST)	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	avail 8am Sat spot winds Bateman's Bay SSW 28kn Eden SW 35kn

Run	EC	JMA	GASP	UKMO	US (aviation)	LAPS	MesoLAPS	U/NSW
+36 valid Sunday, 27th at 12UTC (11pm Sun EDST)	Not Available	Not Available	avail Sat at 6pm Low(991) 100km E of Flinders > WSW'ly 50kn	avail Sat evening Low(989) 150km E of Hobart > WSW'ly 50kn	Low(993) 100km E of Hobart > WSW'ly 50kn	avail Sat 1pm Low(989) 150km SE of Gabo > WSW'ly 50kn	avail Sat 2pm Low(985) 150km SE of Gabo > WSW'ly 55kn	Not Available
+ 30 valid Saturday, 26th at 21UTC (5am Sunday EDST)	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	Not Available	avail 8am Sat spot winds Bateman's Bay S 33kn Eden SW 43kn
+24 valid Sunday, 27th at 00UTC (11am Sun EDST)	Not Available	Not Available		Not Available	Not Available	avail Sat 12pm Low(993) 300km SE of Gabo > WSW'ly 30kn	avail Sat 1pm Low(991) 100km E of StHelens > W'ly 40kn	Not Available
+24 valid Sunday, 27th at 12UTC (11pm Sun EDST)	avail Sun at noon Low(989) 500 km E of Hobart > WSW'ly 45kn.	Low(989) 500km E of Hobart > SW'ly 45kn	avail Sun at 6am Low(991) 600 km E of Hobart > S'ly 45kn	avail Sun morn Low(987) 600km SE of Gabo > SW'ly 50kn	Complex Low(992) E of Tasmania > SW'ly 45kn	avail Sun 12am Low(992) 400km SE of Gabo > SW'ly 45kn	avail Sun 1am Low(990) 400km E of StHelens > W'ly 45kn	Not Available

Notes :

- ECMWF - this is a 'global' model created by the European Centre for Medium range Weather Forecasts.
- GASP - Global Assimilation and Spectral Prognosis. This is an Australian produced 'global' model.
- JMA - 'global' model produced by the Japan Meteorological Agency.
- LAPS - Local Area Prediction System. This is an Australian produced 'regional' (local) area model.
- MesoLAPS - as the name suggests, this is a 'mesoscale' model and is produced in Australia.
- U/NSW - this model is produced by Professor Lance Leslie of the University of New South Wales and can be 'run' in 'global', 'regional' and 'local' modes. On this particular occasion, this model was 'run' in regional mode.
- UKMO - this is a 'global' model produced by the "Met Office" in the United Kingdom.
- US - this is a 'global' model produced by the National Centers for Environmental Prediction in the United States.
- Model validity times are in UTC. 12 UTC is 11pm Eastern Summer time. 00UTC is 11am Eastern Summer Time.
- Availability times vary from office to office and a affected by network traffic and other delays. The times quoted are approximate only.
- Positions of systems are stated for descriptive purposes only. They have been estimated off small scale printed charts and are accurate to about 25% of quoted distance.
- Central pressure of systems is in hectoPascals to the nearest unit, taken from printed charts as operationally available.
- Implied wind speed is estimated off small scale printed charts using a geostrophic wind scale and corrected by up to 30% for isobar curvature and reduced by 10% for surface friction. These values can be expected to be within about 20% of the actual modelled near surface winds. The exceptions to this procedure are the winds taken from LAPS a[illegible] Mesolaps which were actual modelled winds read [illegible]f printed wind vector charts.
- The term 'run' refers to when the model cal[illegible]ations were begun. ie to 'run' a computer progra[illegible]

APPENDIX 1

The formation of waves.

Waves

Understanding waves

The effect of wind on water varies from the tiny ripples on a pond to the mighty rollers of the Southern Ocean. All ocean waves, other than those caused by movements of the sea floor and tidal effects, owe their origin to the generating action of the wind.

As waves move across the ocean, only the shape and energy of the wave moves forward; the water particles remain behind.

When you observe the sea surface you will, in general, notice a complicated pattern of crests and troughs, with waves of different shapes moving in different directions. There is considerable interaction between individual waves - faster moving waves overtake slower waves and they often combine to either reinforce or cancel each other. On occasion, when two or more crests interact, an abnormally high wave can develop (a king or rogue wave) which can be very dangerous.

Some terms to understand

Wind waves (local seas) are waves produced by the local prevailing wind.

Swell waves are waves that have moved well away from the area where they were generated, and have settled into a regular travelling pattern.

Wavelength (L), expressed in metres, is the horizontal distance between successive crests.

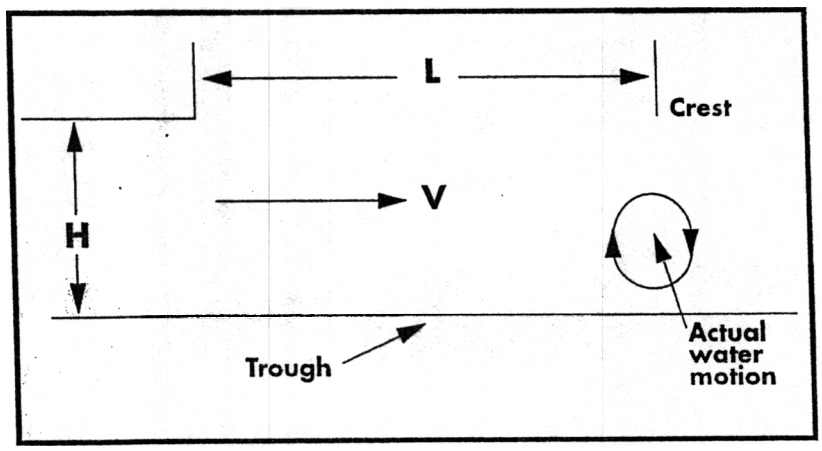
Wave period (T), expressed in seconds, is the time between successive crests.

Wave height (H), expressed in metres, is the vertical distance between the top of a crest and the bottom of a trough.

Significant wave height is the average height of the highest one-third of the waves. It is about equal to the average height of the waves as estimated by an experienced observer.

Wind duration is the time over which the wind has been blowing.

Wind fetch is the distance upstream from the point of observation over which the wind blows with constant speed and direction.



A simple wave of wavelength L, wave height H, and velocity V.

Wind waves (local seas)

Wind waves are produced by the local prevailing wind. They travel in the direction of the prevailing wind, i.e. a northerly wind will produce southerly moving waves.

The height of wind waves depends on :

- the strength of the wind
- the time the wind has been blowing
- the fetch.

The higher the wind speed, and the longer the duration and fetch, the higher the wave and the longer the period. Wind waves are steeper than swell waves, with shorter periods and wavelengths. The sea appears more confused than for swell waves alone.

The tables below show the significant wave height for various wind speeds, durations and fetches. For example, with a fetch of 40 nautical miles, a wind of 25 knots and a duration of about 6 hours, a significant wave height of 1.9 metres is expected. For longer fetches, a 40 knot wind blowing for 6 hours will give waves averaging 3.8 metres.

It is important to note that waves higher and lower than the average can occur. Generally, in open water, a wave of 1.86 times the significant wave height can be expected in every thousand waves. If the significant wave height is 3.8 metres, with a period of 7.7 seconds, then a wave of 7 metres can be expected every two hours or so.

Wave height as a function of wind speed and fetch distance (in nautical miles) for differing durations.

Fetch (Duration)	Wind speed	Wave height *m*	*ft*	Fetch (Duration)	Wind speed	Wave height *m*	*ft*
Fetch 10	10 kn	0.3	1.0	*Fetch* 30	10 kn	0.5	1.5
(2-3 hrs)	15	0.5	1.8	(5-7 hrs)	15	0.9	2.8
	20	0.8	2.7		20	1.3	4.2
	25	1.1	3.7		25	1.7	5.5
Fetch 20	10	0.4	1.2	*Fetch 40*	10	0.5	1.8
(4-51/2 hrs)	15	0.8	2.5	(6-81/2 hrs)	15	0.9	3.1
	20		3.7		20	1.4	4.7
	25	4	4.7		25	1.9	6.1

Note: A range of wind duration for wave height development is given. The lower the wind speed, the longer the duration required to develop the wave height. The longer duration applies to the lower wind speeds and the shorter duration applies to the higher wind speeds.

Wave height and period as a function of wind and duration for unlimited fetch.

	Duration 3 hours			Duration 6 hours			Duration 12 hours			Duration 24 hours		
Wind speed	Wave height *m*	*ft*	Period sec	Wave height *m*	*ft*	Period sec	Wave height *m*	*ft*	Period sec	Wave height *m*	*ft*	Period sec
10 kn	0.4	1.2	2.3	0.5	1.6	2.6	0.6	1.9	3.0	0.7	2.2	3.4
	0.6	2.0	3.1	0.9	2.8	3.7	1.1	3.7	4.2	1.4	4.5	4.8
20	0.9	3.1	3.9	1.3	4.3	4.6	1.9	6.0	5.3	2.3	7.5	6.2
25	1.3	4.2	4.5	1.9	6.1	5.4	2.5	8.3	6.4	3.4	1.0	7.4
30	1.8	5.8	5.2	2.4	8.0	6.2	3.4	11.0	7.3	4.5	4.6	8.5
40	2.7	8.7	6.3	3.8	12.5	7.7	5.3	17.5	9.2			
50	3.7	12.0	7.4	5.4	17.7	9.0						

Swell waves

Swell waves are wind-generated waves that have moved away from their area of formation. They may originate in the heavy seas created by a deep low pressure system offshore. As they move away, they become more rounded and regular in height and period and are often detected thousands of kilometres from their source area. As the swell travels, its height decreases and its period and wavelength increase, because short waves have too little energy to enable them to travel long distances against the action of friction. Swell waves are long waves in comparison with the wind waves and may have wavelengths from 30 to 500 times their wave height.

The characteristics of swell waves depend on their size and shape at the outset and the distance travelled. These factors, however, are seldom able to be determined with any degree of confidence.

The most common swell direction along the NSW coast is southerly and these swells are produced by the low pressure systems which pass to the south of the continent. In summer and autumn, lows and tropical cyclones in the Coral Sea can generate large northeast swells.

Waves approaching the coast

Sea waves and swell approaching the coast are progressively modified by the decreasing water depth. They slow down, their direction of motion may change and their shape steepens. As water depth may vary along the wave, different sections of the wave may travel at different speeds. Waves with longer wavelengths (such as swell) sense the sea bottom first and slow down and steepen further from shore. Hence the cry from the surfer, 'out the back', when a bigger set of waves appears.

A line of waves approaching the shore at an angle will be slowed at the end closest to shore, and the line will wheel around towards the shallower water and become parallel to the shore before breaking. This is also why waves bend around headlands and travel into sheltered bays.

As a wave moves toward the shore, the depth of water becomes so shallow that the wave steepens until it collapses or breaks. The critical depth is about 1.3 times the wave height. Therefore a 1 metre wave will break at a water depth of about 1.3 metres. On a gradually shelving beach the bigger waves will break further out.

In contrast to an unbroken wave, where the water does not move with the wave, a broken wave is a moving turbulent wall of water. Its energy is dissipated by turbulence, frothing water up onto the beach.

Tides and tidal currents

Tides are produced by the gravitational attraction of the moon (and to a lesser extent the sun). Tides move around the earth as it revolves each day and the height of the tide varies because the sun, moon and earth are in constant motion relative to each other.

The tidal rise and fall in sea level in a partially enclosed area forces water to flow in and out of that area. Hence quite strong currents may be generated by the tides at entrances to inlets, bays, harbours, river mouths and around reefs.

The predicted tide heights published in the Australian National Tide Tables assume average weather conditions. Hence if the weather conditions, especially wind and pressure, are unusual, the actual tides can be different. A wind blowing strongly onshore will pile up the water and cause the high tide to be higher than predicted, while winds blowing offshore will have the reverse effect. In addition, a difference in barometric pressure of 10 hPa from the average can cause a difference in tide height of 0.1 m. Low pressure will tend to raise sea level and high pressure will tend to depress it.

Along the NSW coast there are normally four tides (two high and two low) each day. The tidal variation is moderate and fairly uniform; the difference between high and low tide is around 1 to 1.5 m, though the range can reach 2 m.

Ocean currents

Ocean currents are large-scale movements of water in the oceans and result from a combination of the rotation of the earth, the distribution of land masses and the saltiness and temperature of the water.

The east Australian current

The major current off the NSW coast is the east Australian current, which brings warm water from the Coral Sea into the cooler Tasman Sea. The surface of the Coral Sea is about 50 cm above that of the Tasman Sea (at the latitude of Eden) and the water flows down this slope, close to the coast at first. Often, near Sugarloaf Point, the current separates from the coast and forms slow-moving eddies of warm water, which rotate anticlockwise.

These large eddies, which can be more than 300 km in diameter, wander along quite complex paths during lifetimes that can exceed a year. The current in the eddies can reach a speed of 4 knots. Between the eddies and the coast generally lies water which has upwelled from a depth of 200 m or more and can be 5°C cooler than the water of the eddies. Across this zone there is frequently a colour change, from a deep, clear blue in the east Australian current to a more cloudy, phytoplankton-rich green in the upwelled waters. Between the eddies and the coast the direction and strength of the current depend on several factors and are highly variable.

Sometimes small clockwise-rotating eddies form which cause 30-40 km sections of the continental shelf to experience north-ward-flowing currents. Such a situation was recognised in 1985 by the CSIRO's Division of Oceanography, from satellite infrared images, in time to advise the southbound participants in the Sydney to Hobart Yacht Race.

Since 1983 the Naval Weather Centre, Nowra, has been producing weekly oceanographic charts of the sea-surface temperature in the Tasman Sea by pooling data collected by the navy, merchant shipping, satellite monitoring and research activities. These charts clearly show the location of the warm eddies and of strong changes, or 'gradients', in sea-surface temperatures.

Meteorologists studying east coast lows believe that these regions of strong temperature gradient are important both for intensification and movement of these storm systems.

Further information on the east Australian current may be obtained from Dr George Creswell at the CSIRO Division of Oceanography, Marine Laboratories, GPO Box 1538, Hobart 7001.

The forecast description of sea state

The Bureau of Meteorology forecasts the wave height of sea and swell in metres. The figure given is an average for deep water in the particular area covered by the forecast. Some local knowledge of how different wind directions and speeds affect the sea where you are heading is very important because of the large variability that can occur along the coastline.

This variability is a result of many effects such as coastal topography, local winds, shapes of bays, sea bottom topography, and tides. It is not possible, therefore, to cater for all these variations in the coastal waters forecasts.

Another difficulty is that where a strong wind passes over an opposing current, steep breaking seas can develop very quickly. When there is an east coast low, heavy rainfall over the land can cause the coastal rivers to flood. Hence the rough conditions generated by the strong easterly winds can be amplified near river estuaries by the strong opposing flow of the flooding river. Broken Bay, the estuary of the Hawkesbury River, can be especially dangerous.

As sea and swell are independent, it is important to realise that even though the weather conditions may indicate light winds, with consequently smooth or slight seas, there may in fact be a moderate or heavy swell which has been generated further out over the ocean, often from a weather system no longer shown on the latest weather maps.

Observing Wind with the Beaufort Scale

The Beaufort scale is a simple scale that can be used to estimate wind speed accurately without the need for instruments. It is based on observations of the effects of wind on waves, trees and a small fishing boat. (The term 'smack' used in the Beaufort scale pertains to a small one-masted yacht with mainsail and jib.)

Beaufort number	Wind speed† kn	km/h	Description	On land	At sea near the coast	At sea far from land	Probable wave height*
0	0	0	Calm	Calm; smoke rises vertically.	Calm.	Sea like a mirror.	0 m
1	1-3	1-5	Light air	Wind direction shown by smoke-drift but not wind vanes.	Fishing smack just has steerage way.	Ripples with the appearance of scales are formed, but without foam crests.	0.1 m (0.1)
	4-6	6-11	Light breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind.	Wind fills the sails of smacks which travel at about 1-2 mph.	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break.	0.2 m (0.3)
3	7-10	12-19	Gentle breeze	Leaves, small twigs in constant motion; wind extends light flag.	Smacks begin to careen, travel about 3-4 mph.	Large wavelets; crests begin to break; foam of glassy appearance; perhaps scattered white horses.	0.6 m (1)
4	11-16	20-28	Moderate breeze	Raises dust and loose paper; small branches are moved.	Good working breeze, smacks carry all canvas with good list.	Small waves, becoming longer; fairly frequent white horses.	1 m (1.5)
5	17-21	29-38	Fresh breeze	Small trees in leaf begin to sway, crested wavelets form on inland waters.	Smacks shorten sail.	Moderate waves, taking a more pronounced long form; many white horses are formed (chance of some spray).	2 m (2.5)
	22-27	39-49	Strong breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas hard to use.	Smacks have double reef in mainsail; care required when fishing.	Large waves begin to form; the white foam crests are more extensive everywhere (probably some spray).	3 m (4)
	28-33	50-61	Near gale	Whole trees in motion; inconvenience felt when walking against the wind.	Smacks remain in harbour and those at sea lie-to.	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	4 m (5.5)
	34-40	62-74	Gale	Breaks twigs off trees; generally impedes progress.	All smacks make for harbour, if near.	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks along the direction of the wind.	5.5 m (7.5)
9	41-47	75-88	Strong gale	Slight structural damage occurs (chimney-pots and slates removed).		High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple, tumble and roll over; spray may affect visibility.	7 m (10)
10	48-55	89-103	Storm	Seldom experienced inland; trees uprooted; considerable structural damage occurs.		Very high waves with long overhang crests; the resulting foam, in great patches, is blown in dense white streaks along the direction of the wind; the surface of the sea takes on a white appearance; the tumbling of the sea becomes heavy and shock-like; visibility affected.	9 m (12.5)
11	56-63	104-117	Violent storm	Very rarely experienced; accompanied by widespread damage.		Exceptionally high waves (small and medium-sized ships might be for a time lost to view behind the waves); the sea is completely covered with long white patches of foam lying along the direction of the wind; everywhere the edges of the wave crests are blown into froth; visibility affected.	11.5 m (16)
12	over 63	over 117	Hurricane			The air is filled with foam and spray; sea completely white with driving spray; visibility very seriously affected.	14 m

† Units are not exact conversions because of established 'Number' conventions.

* Figures in brackets indicate the probable maximum height of waves in metres.

APPENDIX 1.

SEA (WIND SEA) AND SWELL STATES
from Bureau publication 'Observing the Weather'

Sea (in open sea)

Height (metres)	Description	Effect
0	Calm (glassy)	No waves breaking on beach.
0 - 0.1	Calm (rippled)	No waves breaking on beach.
0.1 - 0.5	Smooth	Slight waves breaking on beach.
0.5 - 1.25	Slight	Waves rock buoys and small craft.
1.25 - 2.5	Moderate	Sea becoming furrowed.
2.5 - 4	Rough	Sea deeply furrowed.
4 - 6	Very rough	Sea much disturbed with rollers having steep fronts.
6 - 9	High	Sea much disturbed with rollers having steep fronts (damage to foreshore).
9 - 14	Very high	Towering seas.
over 14	Phenomenal	Precipitous seas (experienced only in hurricanes).

Swell

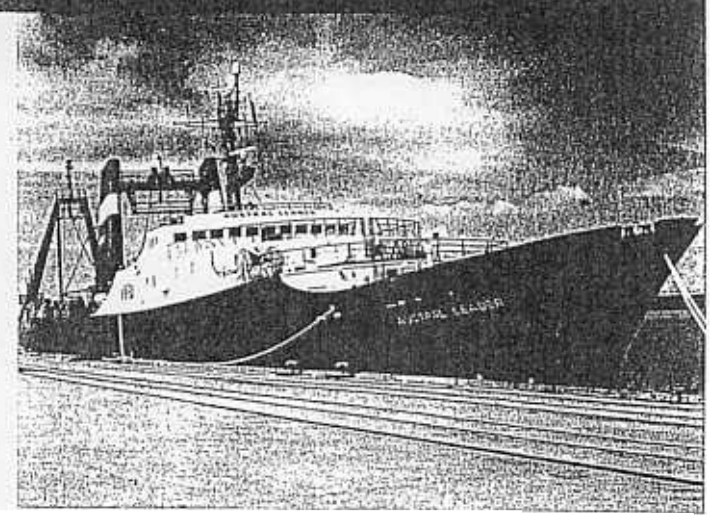
Height (metres)	Description	Length (metres)	Description
0-2	low	0-100	short
2-4	moderate	100-200	moderate
over 4	heavy	over 200	long

APPENDIX 2

Marine Weather Services information sheet.

A guide to Australia's marine forecasts and warnings

MARINE WEATHER SERVICES



Marine Forecasts and Warnings

Routine coastal waters and high seas forecasts and warnings are produced by the Bureau of Meteorology and broadcast by Telstra marine radio and are available from a variety of other sources.

Routine Coastal Waters Forecasts are for areas within 60 nautical miles (nm) of the coast (see map for coastal waters sections). They are issued by Regional Forecasting Centres in each capital city several times daily and monitored for changes which may occur.

Routine High Seas Forecasts are issued twice daily by the Regional Forecasting Centres in Perth, Darwin, Brisbane and Melbourne for the areas beyond the coastal waters surrounding Australia.

Warnings for Coastal Waters are issued whenever strong winds, gales, storm or hurricane-force winds are expected. The initial warning attempts to achieve a 12 to 24-hour lead-time and warnings are renewed every 6 hours.

Warnings to Shipping on the High Seas are issued whenever gale, storm or hurricane-force winds are expected. The initial warning attempts to achieve a 12 to 24-hour lead-time and warnings are renewed every 6 hours.

NOTE: Australian and International practice refers to weather system positions for marine use in DEGREES and TENTHS of a degree. For example 25.4 South is the latitude of twenty five decimal four degrees south, NOT twenty five degrees four minutes south. To convert the decimal to minutes, multiply by 60, i.e. 0.4 degrees = 24 minutes.

Winds

Winds flow in order to more evenly distribute heat between the equator and polar regions. Wind direction and speed are determined by the patterns of highs, lows and fronts seen on weather maps and by local effects such as sea-breezes and thunderstorm downdrafts. When the isobars (lines of equal pressure) around highs and lows become more closely spaced, then winds increase. That is, the higher (or tighter) the pressure gradient, the stronger the wind speed.

Stronger wind speeds are associated with tropical cyclones, lows and cold fronts. Sudden squalls are associated with thunderstorms, heavy showers or the passage of a cold front or low pressure trough and can happen in clear skies (e.g. the Southerly Buster in NSW). The very strongest winds are caused by tropical cyclones, deep mid-latitude low pressure systems and tornadoes/water spouts.

Definitions and Terminology

Wind speed mentioned in forecasts and coastal observations is measured as the average speed over a 10-minute period. Gusts may be 40 per cent stronger than the speed. *Note :10 knots = 18.5 km/h. and 10 km/h = 5.4 knots.*

Wind direction is given in the 16 compass points and is the direction the wind is coming from. A knot (kn) is the unit given to a speed of one nautical mile per hour.

Strong wind: 25 to 33 kn (remembering this is a 10-minute average) **Gale force:** 34 to 47 kn **Storm force:** 48 to 63 kn **Hurricane force:** more than 63 kn.

Wave height is vertical distance between the top of crest and bottom of trough.

Wind (or sea) waves are generated by the local prevailing wind and vary in size according to the length of time a particular wind has been blowing, the fetch (distance the wind has blown over the sea) and the water depth.

Swell waves are the regular longer period waves that were generated by the winds of distant weather systems. There may be more than one set of swell waves travelling in different directions, causing a confused sea state.

Sea state is the combination of wind waves and swell.

The **forecasts of wave and swell height** are meant to represent the average of the highest one-third of the waves. Hence some waves will be higher and some lower than the forecast wave height.

King/Freak waves occur when wind waves and/or a combination of swell waves join to form a very high wave. Shape and depth of the seabed is also important.

UTC (Universal Time Coordinate): time references in warnings for high seas are given in UTC. Australian Eastern Standard Time is UTC + 10 hrs. Western Standard Time is UTC + 8 hrs.

Forecast & Warning Delivery Systems

Coastal Marine Radio

Telstra operates marine radio transmitters around the Australian coastline with marine (Coastal and High Seas) forecasts and warnings broadcast at scheduled times on the following frequencies: **2201, 4426, 6507, 8176, 12365 kHz, and VHF Channel 67** (*Some centres only. Check with Telstra Maritime*)

Broadcast schedules can be obtained from the Bureau's Weather By Fax and Internet services (see reverse side) or from Telstra's Customer Service Centre on 1800 810 023. When a weather warning is issued it will be broadcast when first received, and then at scheduled broadcast times.

Public Broadcast Radio/TV Stations

The Bureau distributes coastal waters forecasts and warnings to the ABC and commercial networks (both city & country stations). Broadcasting of these varies between stations.

Recorded Telephone Services

The Bureau operates a number of recorded services via Weathercall for coastal waters forecasts and warnings. Call costs for 1900 services are 75c per minute - higher from mobile & public phones. Check your local telephone directory, dial 1900 155 346 or poll Weather By Fax on 1902 935 254 for a list of your local numbers. Services are:

- **Local Waters Forecasts:** Supplied for capital city boating.
- **Severe Weather Warning Service:** Marine and land based warnings.
- **Marine Forecasts:** Full coastal waters forecasts and latest actual reports.

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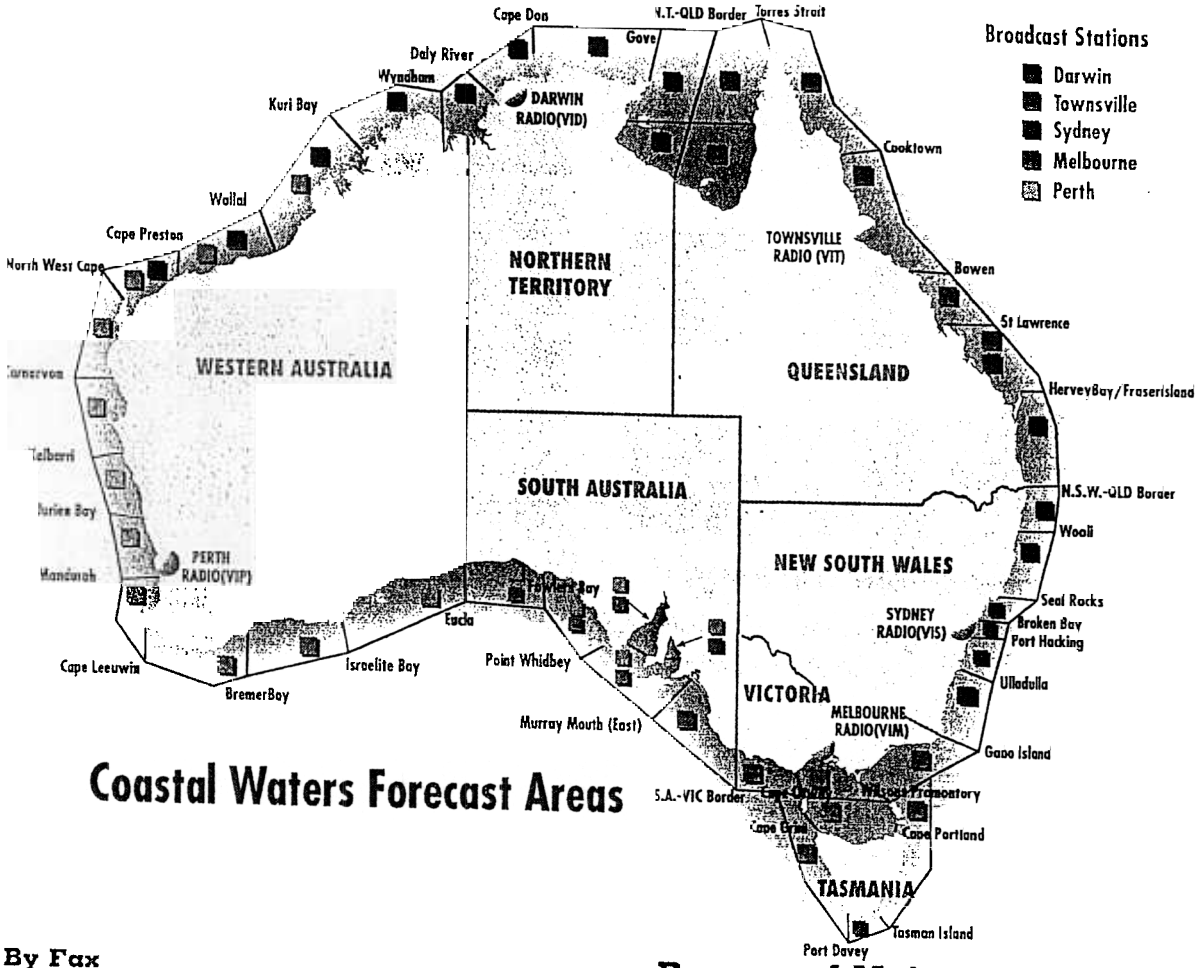

Coastal Waters Forecast Areas

Weather By Fax

The Bureau of Meteorology uses the Telstra polling fax system (Infofax) and provides around 200 fax products, including weather charts (updated 3-hourly), satellite photos (updated hourly), weather radar reports, the latest warnings, routine coastal waters forecasts and the latest actual reports Call costs for fax products are 60cents per minute, higher from mobile or satellite phone.

Set your Fax in 'Poll Receive' mode and dial 1800 630 100 for a Free Main Directory. This system can also be accessed through a personal computer or lap-top using a modem. Access is also available via Seaphone and Inmarsat.

AXM/AXI HF Radio Fax

HF Radio Fax transmits a range of weather charts and warning summaries on a 24-hour schedule which can be obtained via Weather By Fax (includes Coastal Radio) on 1902 935 046, on the Bureau's World Wide Web site or by phoning one of the Bureau's capital city offices. AXM/AXI does not transmit routine forecast text or satellite pictures.

This system is operated by the Royal Australian Navy on behalf of the Bureau of Meteorology using two HF radio transmitters at Canberra and Darwin. Reception requires a marine fax unit attached to your HF radio or a Personal Computer connected through a HF demodulator.

Satellite Communications

Telstra's Satcom services and Inmarsat can be used to access faxed marine weather forecasts and warnings through the Infofax system. Contact Optus MobileSat for details an access to voice and fax data. As part of the Global Marine Distress & Safety System (GMDSS) Telstra transmits via Satcom-C a complete range of marine safety information, including weather warnings, free of charge.

Internet

Information about the range of Bureau of Meteorology forecast and warning products is available on the Internet via the World Wide Web. The address of the Bureau's Home Page on the Internet is: ***http://www.bom.gov.au.*** The menu includes the latest satellite photo, weather maps, marine forecasts and warnings and a range of educational pages. Enhanced marine, satellite and weather radar products using passwords are also available via credit card facilities from the Bureau's Home Page.

Bureau of Meteorology Contacts

Brisbane:	Tel: 07 3239 8700	Sydney:	Tel: 02 9296 1555
Melbourne:	Tel: 03 9669 4915	Hobart:	Tel: 03 6221 2000
Adelaide:	Tel: 08 8366 2600	Perth:	Tel: 08 9263 2222
Darwin:	Tel: 08 8920 3800		

Wind, Waves, Weather Booklet

A more detailed explanation of meteorological systems and local weather effects is available for a number of sections of the Australian coastline in a Bureau of Meteorology Boating Weather Series booklet entitled *Wind, Waves, Weather.* Contact Bureau office in your capital city for details on availablity.

Safety Hints

1. Know the local factors that influence sea conditions and know where to reach shelter quickly.
2. Learn how to read the weather map (pamphlet available).
3. Be aware that the weather map in the morning newspaper was drawn the day before.
4. Always check the latest forecast and warnings before going to sea and know what conditions exceed your safety limits.
5. Beware of rapidly darkening and lowering cloud – squalls may be imminent.
6. When at sea, listen to the weather reports on public or Telstra marine radio.
7. Be flexible – change your plans if necessary.

BUREAU OF METEOROLOGY
DEPARTMENT OF THE ENVIRONMENT

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APPENDIX 3

Observations from selected coastal observing sites.

Meteorological Observations at SYDNEY AIRPORT AMO

Site Number 066037 • Locality: SYDNEY AIRPORT • Opened Jan 1929 • Still Open • Latitude 33°56'28"S • Longitude 151°10'21"E • Elevation 6m

	Air Temperature	Relative Humidity	MSL Pressure	Wind	Rainfall	Present Weather	Past Weather
	°C	%	hPa	knots	mm	description	description
Saturday 26 December 1998							
3 am	21.0	85	1009.1	NW 4		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 am	19.9	89	1008.6	WNW 4		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
9 am	23.5	66	1008.3	NW 4		Cloud forming or developing	Cloud generally dissolving or becoming less well developed
12 pm	26.6	55	1005.6	NNE 13		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
3 pm	26.5	53	1001.6	NE 18		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 pm	25.3	56	998.1	NNE 20		Cloud forming or developing	Cloud generally dissolving or becoming less well developed
9 pm	23.0	70	996.9	N 18		LIGHTNING seen but no thunder heard	Cloud unchanged or cloudless
12 am	23.2	69	996.6	N 4	0.0	Cloud generally dissolving or becoming less well developed	Cloud generally dissolving or becoming less well developed
Sunday 27 December 1998							
3 am	19.7	40	997.8	SW 15		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 am	16.2	31	1000.9	SW 27		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
9 am	17.8	29	1002.6	WSW 16		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
12 pm	23.1	17	1000.9	WNW 17		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
3 pm	26.3	14	999.4	W 17		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 pm	26.5	15	999.1	W 19		SMOKE from bush or industrial fires	Cloud generally dissolving or becoming less well developed
9 pm	23.4	20	1002.1	W 14		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
12 am	20.8	26	1002.6	W 9		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
Monday 28 December 1998							
3 am	19.7	32	1002.4	WSW 12		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 am	18.5	42	1004.2	WSW 13		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
9 am	23.0	34	1006.1	W 9		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
12 pm	26.8	33	1005.9	ESE 10		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
3 pm	25.7	42	1005.5	ENE 17		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 pm	24.3	53	1005.4	NE 15		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
9 pm	22.2	64	1007.7	NE 7		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
12 am	21.4	75	1008.7	ENE 4		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
Tuesday 29 December 1998							
3 am	20.9	79	1007.4	NE 5		Cloud forming or developing	Cloud unchanged or cloudless
6 am	21.0	83	1008.0	Calm		Cloud unchanged or cloudless	Cloud unchanged or cloudless
9 am	24.3	60	1008.8	NE 9		Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 pm	25.8	49	1008.4	NE 5		Cloud unchanged or cloudless	Cloud unchanged or cloudless
3 pm	27.2	45	1005.6	NE 13		Cloud generally dissolving or becoming less well developed	Cloud generally dissolving or becoming less well developed
6 pm	26.9	58	1004.6	NNE 16		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
9 pm	24.0	75	1007.0	N 10		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
12 am	22.2	87	1008.7	ESE 3		HAZE of very small particles	Cloud generally dissolving or becoming less well developed

Meteorological Observations at NOWRA RAN AIR STATION

Site Number 068076 • Locality: NOWRA • Opened Jan 1942 • Still Open • Latitude 34°57'02"S • Longitude 150°32'09"E • Elevation 109m

	Air Temperature	Relative Humidity	MSL Pressure	Wind	Rainfall	Present Weather	Past Weather
	°C	%	hPa	knots	mm	description	description
Saturday 26 December 1998							
3 am	16.2	100	1008.9	W 2			
6 am	15.0	100	1008.9	NW 2			
9 am	22.1	76	1007.9	NE 2			
12 pm	25.6	65	1004.8	E 11			
3 pm	26.5	67	999.8	ENE 14			
6 pm	22.8	77	997.7	SSE 8			
9 pm	21.3	86	996.7	WSW 2			
12 am	19.8	41	997.7	NW 13			
Sunday 27 December 1998							
3 am	15.7	46	998.8	WNW 14			
6 am	12.1	59	999.8	W 10			
9 am	15.8	45	999.8	WNW 21			
12 pm	20.8	32	998.8	W 22			
3 pm	23.2	30	997.7	WNW 20			
6 pm	23.4	29	997.7	WNW 22			
9 pm	20.2	35	1000.8	WNW 16			
12 am	19.1	41	1001.8	NW 13			
Monday 28 December 1998							
3 am	17.4	48	1001.8	WNW 15			
6 am	16.2	53	1003.6	NW 14			
9 am	21.0	47	1005.8	WNW 12			
12 pm	26.4	40	1005.8	N 4			
3 pm	24.9	48	1004.8	E 12			
6 pm	23.6	60	1005.8	E 14			
9 pm	20.4	87	1007.9	E 6			
12 am	20.0	89	1008.9	ENE 4			
Tuesday 29 December 1998							
3 am	17.7	98	1007.9	WSW 2			
6 am	16.4	99	1007.9	NNW 1			
3 pm	27.6	61	1004.8	ENE 12			
6 pm	25.3	69	1004.8	SE 10			
9 pm	21.2	91	1008.9	S 12			
12 am	20.0	95	1010.9	S 3			

M o olo c Ob 'v:tion: t MORUYA .EAD P LOT 'TAT'ON

69018 • Locality: MORUYA HEADS • Opened Jan 1875 • Still Open • Latitude 35°54'38"S • Longitude 150°09'06"

	Wind (knots)	State of Sea	Height of Wind Waves	Height of Swell Waves	Length of Swell	Direction of Swell
Saturday 26 December 1998						
3 am	Calm	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Short	
6 am	N 2	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Short	E
9 am	NNE 10	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Short	NE
12 pm	NE 22	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	NE
3 pm	NE 28	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	NE
6 pm	ENE 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
9 pm	NNE 10	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Short	NE
Sunday 27 December 1998						
3 am	W 15	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	
6 am	W 8	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
9 am	W 8	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
12 pm	WNW 15	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
3 pm	WSW 22	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
6 pm	WSW 22	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
9 pm	WNW 14	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
Monday 28 December 1998						
3 am	WSW 2	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	
6 am	W 2	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
9 am	NE 2	Smooth (wavelets)	0.1 - 0.5m	Moderate (2 to 4m)	Average	NE
12 pm	ENE 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	NE
3 pm	ENE 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	E
6 pm	ESE 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	E
9 pm	ENE 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	
Tuesday 29 December 1998						
3 am	SE 4	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	
6 am	SSW 5	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	E
9 am	SSW 4	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	E
12 pm	SSE 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	E
3 pm	SSE 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	E
6 pm	S 12	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	SE
9 pm	S 14	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	

Meteorological Observations at MORUYA HEADS PILOT STATION

Site Number 069018 • Locality: MORUYA HEADS • Opened Jan 1875 • Still Open • Latitude 35°54'38"S • Longitude 150°09'06"E • Elevation 17m

	Air Temperature	Relative Humidity	MSL Pressure		Rainfall	Present Weather	Past Weather
	°C	%	hPa		mm	description	description
Saturday 26 December 1998							
3 am	19.0	92	1009.6		0.0	MIST	Cloud unchanged or cloudless
6 am	17.7	94	1008.2		0.0	Cloud unchanged or cloudless	MIST
9 am	22.2	77	1007.4		0.0	Cloud forming or developing	Cloud forming or developing
12 pm	23.1	76	1004.5		0.0	Cloud unchanged or cloudless	Cloud forming or developing
3 pm	22.6	79	999.6		0.0	HAZE of very small particles	Cloud forming or developing
6 pm	20.0	92	995.3		4.4	Slight or Moderate THUNDERSTORM with RAIN or SNOW	Slight or Moderate THUNDERSTORM with RAIN or SNOW
9 pm	19.4	92	995.7		2.4	LIGHTNING seen but no thunder heard	Slight or Moderate THUNDERSTORM with RAIN or SNOW
Sunday 27 December 1998							
3 am	16.0	46	997.8		0.2	LIGHTNING seen but no thunder heard	Slight RAIN SHOWER
6 am	14.5	55	998.5		0.0	Cloud unchanged or cloudless	LIGHTNING seen but no thunder heard
9 am	16.8	40	999.1		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 pm	21.4	35	996.8		0.0	Cloud forming or developing	Cloud unchanged or cloudless
3 pm	22.5	35	996.3		0.0	Cloud forming or developing	Cloud forming or developing
6 pm	22.3	37	997.3		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
9 pm	19.7	43	998.5		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
Monday 28 December 1998							
3 am	16.1	70	1001.1		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
6 am	16.0	70	1003.0		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
9 am	19.4	63	1005.4		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 pm	23.2	58	1005.7		0.0	Cloud forming or developing	Cloud unchanged or cloudless
3 pm	23.5	63	1005.7		0.0	Cloud unchanged or cloudless	Cloud forming or developing
6 pm	20.6	74	1006.7		0.0	Cloud forming or developing	Cloud forming or developing
9 pm	19.3	81	1008.4		0.0	Heavy continuous DRIZZLE	Distant PRECIPITATION reaching the ground more than 5km away
Tuesday 29 December 1998							
3 am	18.9	89	1008.7		0.6	Distant PRECIPITATION reaching the ground more than 5km away	Heavy continuous DRIZZLE
6 am	17.2	94	1008.8		0.2	MIST	Heavy intermittent DRIZZLE
9 am	17.9	91	1009.6		0.0	MIST	MIST
12 pm	21.4	78	1008.5		0.0	HAZE of very small particles	MIST
3 pm	21.8	77	1006.9		0.0	HAZE of very small particles	HAZE of very small particles
6 pm	20.7	81	1007.1		0.0	Distant PRECIPITATION reaching the ground more than 5km away	HAZE of very small particles
9 pm	20.4	87	1010.2		0.0	HAZE of very small particles	Distant PRECIPITATION reaching the ground more than 5km away

Meteorological Observations at MONTAC _ ISLAND LIGHTHOUSE

Site Number 069017 • Locality: MONTAGUE ISLAND • Opened Jan 1949 • Still Open • Latitude 36°15'18"S • Longitude 150°13'30"E • Elevation 52m

	Air Temperature	Relative Humidity	MSL Pressure	Wind	Rainfall	Present Weather	Past Weather
	°C	%	hPa	knots	mm	description	description
Saturday 26 December 1998							
3 am	20.2	100	1008.7	N 10			
6 am	20.3	99	1007.5	NNE 14			
9 am	21.6	82	1006.9	N 12			
12 pm	23.0	74	1004.2	NE 21			
3 pm	22.4	79	999.2	NE 29			Moderate intermittent RAIN
6 pm	19.6	94	995.0	ENE 37	3.0	Slight intermittent RAIN	Moderate intermittent RAIN
9 pm	20.6	86	994.7	NNE 29			Moderate intermittent RAIN
12 am	18.3	76	995.7	W 16	6.0	RAIN within past hour	
Sunday 27 December 1998							Moderate intermittent RAIN
3 am	15.0	53	997.3	WSW 11			
6 am	14.5	55	997.6	WNW 20			
9 am	16.8	34	997.1	W 26			
12 pm	21.2	28	995.4	WNW 23			
3 pm	20.7	34	995.6	WNW 29			
6 pm	19.4	38	996.1	W 30			
9 pm	19.1	47	997.7	WNW 15			
12 am	19.1	46	999.1	W 18			
Monday 28 December 1998							
3 am	18.3	52	1000.5	WNW 10			
6 am	17.9	62	1002.7	W 6			
9 am	21.4	56	1004.9	SSE 7			
12 pm	21.1	58	1005.6	E 11			
3 pm	21.0	64	1005.6	ESE 15			
6 pm	18.6	78	1006.5	SE 14			
9 pm	17.1	87	1008.4	ESE 14			Moderate intermittent RAIN
12 am	16.7	96	1009.7	ESE 11	3.0	RAIN within past hour	
Tuesday 29 December 1998							Moderate intermittent RAIN
3 am	15.9	97	1008.5	SSE 13	4.0	RAIN within past hour	Moderate intermittent RAIN
6 am	16.3	97	1008.4	S 11	1.0	Slight intermittent RAIN	Moderate intermittent RAIN
9 am	17.4	92	1009.1	SSW 12	0.2		
12 pm	19.8	80	1008.4	S 10			
3 pm	20.5	76	1006.9	S 10			
6 pm	20.4	82	1007.1	S 11			
9 pm	19.3	83	1010.3	S 23			
12 am	18.2	76	1011.8	S 20			

Meteorological Observations at GABO ISLAND LIGHTHOUSE

Site Number 084016 • Locality: GABO ISLAND • Opened Jun 1859 • Still Open • Latitude 37°34'11"S • Longitude 149°54'53"E • Elevation 15.2m

	Wind (knots)	State of Sea	Height of Wind Waves	Height of Swell Waves	Length of Swell	Direction of Swell
Saturday 26 December 1998						
3 am	NNE 18	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	NE
6 am	NNE 22	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	NE
9 am	NNE 23	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Short	NE
12 pm	NNE 30	Rough	2.5 - 4m	Moderate (2 to 4m)	Average	NE
3 pm	NE 28	Rough	2.5 - 4m	Moderate (2 to 4m)	Average	NE
6 pm	NNE 38	Rough	2.5 - 4m	Moderate (2 to 4m)	Average	NE
9 pm	SW 22	Rough	2.5 - 4m	Moderate (2 to 4m)	Average	NE
Sunday 27 December 1998						
3 am	SW 28	Rough	2.5 - 4m	Moderate (2 to 4m)	Average	SW
6 am	SW 14	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	SW
9 am	W 17	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	SW
12 pm	28	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Long	SW
3 pm	NW 30	Very Rough	4 - 6m	Moderate (2 to 4m)	Long	SW
6 pm	W 25	Very Rough	4 - 6m	Moderate (2 to 4m)	Long	SW
9 pm	SW 45	Very Rough	4 - 6m	Moderate (2 to 4m)	Long	SW
Monday 28 December 1998						
3 am	SW 38	Very Rough	4 - 6m	Moderate (2 to 4m)	Long	SW
6 am	SW 28	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	SW
9 am	SW 33	Rough	2.5 - 4m	Heavy (>4m)	Short	SW
12 pm	SW 30	Very Rough	4 - 6m	Moderate (2 to 4m)	Long	SW
3 pm	SW 33	Very Rough	4 - 6m	Moderate (2 to 4m)	Long	SW
6 pm	SW 26	Rough	2.5 - 4m	Moderate (2 to 4m)	Average	SW
9 pm	SW 15	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	SW
Tuesday 29 December 1998						
3 am	W 5	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	SW
6 am	W 3	Smooth (wavelets)	0.1 - 0.5m	Moderate (2 to 4m)	Average	SW
9 am	Calm	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Long	S
12 pm	ENE 10	Smooth (wavelets)	0.1 - 0.5m	Moderate (2 to 4m)	Short	S
3 pm	SSE 2	Smooth (wavelets)	0.1 - 0.5m	Low (<2m)	Short or Average	S
6 pm	SSW 13	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Short	S
9 pm	SW 8	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Short	S

Meteorological Observations at GABO IS[illegible]D LIGHTHOUSE

Site Number 084016 • Locality: GABO ISLAND • Opened Jun 1859 • Still Open • Latitude 37°34'11"S • Longitude 149°54'53"E • Elevation 15.2m

	Air Temperature	Relative Humidity	MSL Pressure		Rainfall	Present Weather	Past Weather
	°C	%	hPa		mm	description	description
Saturday 26 December 1998							
3 am	19.0	91	1005.9		0.2	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
6 am	19.0	88	1005.4		0.0	Cloud forming or developing	Cloud forming or developing
9 am	22.0	72	1005.3		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 pm	22.1	73	1002.0		0.0	Cloud forming or developing	Cloud forming or developing
3 pm	21.4	81	998.6		0.0	Cloud forming or developing	Cloud forming or developing
6 pm	19.5	88	991.3		0.0	Cloud forming or developing	Cloud forming or developing
9 pm	14.8	97	996.2		9.8	Heavy THUNDERSTORM with RAIN or SNOW	Violent RAIN SHOWER
Sunday 27 December 1998							
3 am	12.2	74	996.1		29.0	LIGHTNING seen but no thunder heard	Heavy THUNDERSTORM with RAIN or SNOW
6 am	12.8	57	995.8		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
9 am	16.6	46	994.8		0.0	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
12 pm	14.8	60	993.8		0.2	Slight RAIN SHOWER	Slight RAIN SHOWER
3 pm	15.0	63	993.5		0.0	Distant PRECIPITATION reaching the ground more than 5km away	Distant PRECIPITATION reaching the ground more than 5km away
6 pm	14.0	72	994.4		0.0	Cloud forming or developing	Cloud forming or developing
9 pm	14.0	72	995.4		0.0	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
Monday 28 December 1998							
3 am	14.0	79	999.7		0.0	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
6 am	14.0	78	1003.0		0.0	Cloud forming or developing	Cloud forming or developing
9 am	15.5	74	1005.3			Cloud forming or developing	Cloud forming or developing
12 pm	17.2	71	1005.5		0.2	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
3 pm	16.3	71	1005.5		0.0	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
6 pm	16.1	73	1006.4		0.0	Cloud forming or developing	Cloud forming or developing
9 pm	15.5	77	1009.0		0.0	Cloud forming or developing	Cloud forming or developing
Tuesday 29 December 1998							
3 am	15.0	74	1008.5		0.0	Cloud forming or developing	Cloud forming or developing
6 am	15.0	79	1008.8		0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
9 am	16.7	76	1009.7		0.0	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
12 pm	18.3	75	1008.3		0.0	Cloud generally dissolving or becoming less well developed	Cloud generally dissolving or becoming less well developed
3 pm	19.3	76	1008.1			Cloud forming or developing	Cloud unchanged or cloudless
6 pm	18.1	76	1002.5			Cloud generally dissolving or becoming less well developed	Cloud generally dissolving or becoming less well developed
9 pm	17.0	70	1011.8		0.0	Cloud forming or developing	Cloud unchanged or cloudless

Meteorological Observations at POINT HICKS (LIGHTHOUSE)

Site Number 084070 • Locality: POINT HICKS • Opened May 1962 • Still Open • Latitude 37°48'13"S • Longitude 149°16'25"E • Elevation 25m

	Wind (knots)	State of Sea	Height of Wind Waves	Height of Swell Waves	Length of Swell	Direction of Swell
Saturday 26 December 1998						
6 am	NNE 16	Slight	0.5 - 1.25m	Low (<2m)	Long	SE
9 am	ENE 6	Calm (rippled)	0 - 0.1m	Low (<2m)	Long	SE
12 pm	NE 7	Smooth (wavelets)	0.1 - 0.5m	Low (<2m)	Long	SE
3 pm	ENE 4	Smooth (wavelets)	0.1 - 0.5m	Low (<2m)	Long	SE
Sunday 27 December 1998						
6 am	W 17	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	SW
9 am	W 35	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	SW
12 pm	W 40	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	SW
3 pm	W 36	Very Rough	4 - 6m	Heavy (>4m)	Short	SW
Monday 28 December 1998						
6 am	W 34	Very Rough	4 - 6m	Heavy (>4m)	Short	SW
9 am	WSW 25	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	SW
12 pm	WSW 22	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	SW
3 pm	WSW 22	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	SW
Tuesday 29 December 1998						
6 am	NNW 3	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	S
9 am	NNE 1	Smooth (wavelets)	0.1 - 0.5m	Moderate (2 to 4m)	Average	S
12 pm	S 4	Smooth (wavelets)	0.1 - 0.5m	Moderate (2 to 4m)	Average	S
3 pm	S 6	Smooth (wavelets)	0.1 - 0.5m	Moderate (2 to 4m)	Average	S

Meteorological Observations at POINT H S (LIGHTHOUSE)

Site Number 084070 • Locality: POINT HICKS • Opened May 1962 • Still Open • Latitude 37°48'13"S • Longitude 149°16'25"E • Elevation 25m

	Air Temperature	Relative Humidity	MSL Pressure		Rainfall	Present Weather	Past Weather
	°C	%	hPa		mm	description	description
Saturday 26 December 1998							
6 am	20.5	77			0.0	Cloud forming or developing	HAZE of very small particles
9 am	24.2	73			0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 pm	28.9	57			0.0	Cloud forming or developing	Cloud forming or developing
3 pm	20.9	92			5.2	Cloud unchanged or cloudless	Heavy THUNDERSTORM with RAIN or SNOW
Sunday 27 December 1998							
6 am	12.3	77			12.6	Cloud forming or developing	Heavy THUNDERSTORM with RAIN or SNOW
9 am	13.6	70			0.0	Moderate intermittent RAIN	Moderate intermittent RAIN
12 pm	13.0	81			1.8	Cloud unchanged or cloudless	Moderate or heavy RAIN SHOWER
3 pm	11.0	100			0.2	Slight RAIN SHOWER	Slight RAIN SHOWER
Monday 28 December 1998							
6 am	13.8	91			7.4	Cloud unchanged or cloudless	Slight RAIN SHOWER
9 am	14.3	90			0.0	Cloud unchanged or cloudless	Slight intermittent DRIZZLE
12 pm	15.2	87			0.0	Cloud generally dissolving or becoming less well developed	Cloud unchanged or cloudless
3 pm	16.7	82			0.0	Cloud generally dissolving or becoming less well developed	Cloud generally dissolving or becoming less well developed
Tuesday 29 December 1998							
6 am	14.0	93			0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
9 am	16.9	85			0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 pm	20.2	80			0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless
3 pm	20.6	80			0.0	Cloud unchanged or cloudless	Cloud unchanged or cloudless

Meteorological Observations at MALLACOOTA

Site Number 084084 • Locality: MALLACOOTA • Opened Jan 1974 • Still Open • Latitude 37°35'57"S • Longitude 149°43'39"E • Elevation 22m

	Air Temperature	Relative Humidity	MSL Pressure	Wind	Rainfall	Present Weather	Past Weather
	°C	%	hPa	knots	mm	description	description
Saturday 26 December 1998							
3 am	20.4	81	1007.1	NNE 11			
6 am	20.0	76	1005.5	N 12			
9 am	24.1	57	1005.1	N 13			
12 pm	26.4	48	1001.4	NNE 17			
3 pm	24.0	62	998.4	NNE 12			
6 pm	20.3	86	992.8	NNE 15	0.8	RAIN within past hour	Moderate intermittent RAIN
9 pm	14.2	92	996.4	WSW 12	15.0	Slight intermittent RAIN	Moderate intermittent RAIN
12 am	12.1	83	997.5	W 13	19.0	RAIN within past hour	Moderate intermittent RAIN
Sunday 27 December 1998							
3 am	11.9	66	996.7	W 13			Moderate intermittent RAIN
6 am	11.9	56	996.0	W 7			
9 am	16.9	42	995.0	W 9			
12 pm	12.6	71	993.9	WNW 18	0.6	Slight intermittent RAIN	Moderate intermittent RAIN
6 pm	13.2	79	995.2	W 12	0.2		Moderate intermittent RAIN
9 pm	12.7	76	996.1	W 21	0.8		Moderate intermittent RAIN
Monday 28 December 1998							
3 am	13.6	73	1000.9	W 16	0.2	RAIN within past hour	Moderate intermittent RAIN
6 am	13.5	75	1003.0	W 15			
9 am	15.7	65	1005.9	WSW 14			
12 pm	17.8	59	1006.5	WSW 15			
6 pm	16.9	63	1007.2	SW 10			
12 am	14.8	74	1010.2	WNW 3			
Tuesday 29 December 1998							
3 am	14.3	77	1008.9	WNW 4			
6 am	14.0	82	1009.1	WNW 3			
9 am	16.7	73	1009.8	NE 6			
12 pm	17.9	73	1008.9	E 10			
3 pm	17.3	75	1008.4	S 9			
6 pm	17.0	71	1009.7	S 8			
12 am	15.6	74	1013.1	W 4			

Meteorological Observations at EAST SALE AIRPORT

Site Number 085072 • Locality: EAST SALE • Opened Apr 1943 • Still Open • Latitude 38°06'30"S • Longitude 147°07'48"E • Elevation 4.6m

	Air Temperature	Relative Humidity	MSL Pressure	Wind	Rainfall	Present Weather	Past Weather
	°C	%	hPa	knots	mm	description	description
Saturday 26 December 1998							
3 am	20.6	70	1003.8	S 2			
6 am	19.2	85	1003.8	W 5	0.6	Slight RAIN SHOWER	Slight RAIN SHOWER
9 am	20.0	84	1000.4	E 11	1.0	Distant PRECIPITATION reaching the ground more than 5km away	Slight RAIN SHOWER
12 pm	22.4	80	998.3	S 7	0.4	SHOWER of RAIN within past hour	Slight RAIN SHOWER
3 pm	22.1	80	993.2	S 6	1.0	Slight or Moderate THUNDERSTORM with RAIN or SNOW	Slight or Moderate THUNDERSTORM with RAIN or SNOW
6 pm	13.4	93	996.6	W 16	11.0	Slight or Moderate THUNDERSTORM with RAIN or SNOW	Slight or Moderate THUNDERSTORM with RAIN or SNOW
9 pm	12.1	83	999.3	W 20	3.0	SHOWER of RAIN within past hour	Slight or Moderate THUNDERSTORM with RAIN or SNOW
12 am	11.2	82	1000.2	W 20	1.0	RAIN within past hour	Moderate intermittent RAIN
Sunday 27 December 1998							
3 am	10.6	73	998.6	WNW 17			Moderate intermittent RAIN
6 am	10.2	78	996.7	NW 21	0.4	Slight RAIN SHOWER	Slight RAIN SHOWER
9 am	10.8	89	996.8	WNW 28	5.0	Slight continuous RAIN	Slight RAIN SHOWER
12 pm	11.4	87	998.2	W 36	3.0	Slight RAIN SHOWER	Slight RAIN SHOWER
3 pm	13.0	76	998.9	W 39	1.0	Slight RAIN SHOWER	Slight RAIN SHOWER
6 pm	12.8	74	1000.2	W 34	0.0	Distant PRECIPITATION reaching the ground more than 5km away	Slight RAIN SHOWER
9 pm	12.1	81	1003.4	W 33	0.0	Slight RAIN SHOWER	Slight RAIN SHOWER
12 am	12.2	81	1004.9	W 27			
Monday 28 December 1998							
3 am	11.9	83	1004.8	W 27			
6 am	12.0	78	1006.9	W 22		Cloud forming or developing	Cloud generally dissolving or becoming less well developed
9 am	14.3	64	1008.8	W 21		Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 pm	16.5	52	1008.7	W 23		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
3 pm	18.3	50	1007.6	WSW 22		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 pm	18.5	50	1007.3	WSW 13		Cloud generally dissolving or becoming less well developed	Cloud generally dissolving or becoming less well developed
9 pm	13.5	72	1009.1	WSW 4		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
12 am	13.5	75	1010.0	W 7			
Tuesday 29 December 1998							
3 am	13.0	84	1009.1	W 5			
6 am	10.8	96	1008.6	Calm		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
9 am	16.2	62	1009.7	W 5		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
12 pm	20.0	50	1009.5	WSW 9		Cloud forming or developing	Cloud generally dissolving or becoming less well developed
3 pm	22.4	47	1008.5	W 11		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
6 pm	20.6	49	1008.9	WSW 10		Cloud unchanged or cloudless	Cloud generally dissolving or becoming less well developed
9 pm	17.3	62	1011.8	W 7		Cloud unchanged or cloudless	Cloud unchanged or cloudless
12 am	13.7	74	1013.6	WNW 6			

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5096 • Locality: WILSONS PROMONTORY • Open Jan 1872 • Open • Lat 39° 07' 47" S • Lon 146°

	Wind (knots)	State of Sea	Height of Wind Waves	Height of Swell Waves	Length of Swell	Direction of Swell
urday 26 December 1998						
3 am	NNW 23	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Short	E
6 am	NNW 2	Slight	0.5 - 1.25m	Moderate (2 to 4m)	Average	
9 am	NNE 16	Slight	0.5 - 1.25m	Heavy (>4m)	Average	E
12 pm	NE 29	Moderate	1.25 - 2.5m	Heavy (>4m)	Average	E
3 pm	WSW 26	Moderate	1.25 - 2.5m	Heavy (>4m)	Average	SE
6 pm	WSW 45	Rough	2.5 - 4m	Heavy (>4m)	Average	SE
9 pm	WSW 53					
Sunday 27 December 1998						
3 am	W 41					
6 am	WSW 71	Rough	2.5 - 4m			
9 am	WSW 79	Very Rough	4 - 6m	Heavy (>4m)	Short	W
12 pm	W 66	Rough	2.5 - 4m	Heavy (>4m)	Short	W
3 pm	W 57	Rough	2.5 - 4m	Heavy (>4m)	Short	W
6 pm	W 58	Rough	2.5 - 4m	Heavy (>4m)	Short	W
9 pm	WNW 48	Very Rough	4 - 6m	Heavy (>4m)	Short	W
ember 1998						
3 am	WNW 33	Rough	2.5 - 4m	Heavy (>4m)	Short	SW
6 am	WNW 29	Moderate	1.25 - 2.5m	Heavy (>4m)	Short	S
9 am	WNW 28	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Long	SW
12 pm	W 35	Moderate	1.25 - 2.5m	Heavy (>4m)	Short	S
3 pm	W 36	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Long	SW
6 pm	WNW 28	Moderate	1.25 - 2.5m	Heavy (>4m)	Short	S
9 pm	WNW 25	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Long	W
ember 1998						
3 am	WSW 17	Rough	2.5 - 4m	Moderate (2 to 4m)	Long	W
6 am	WNW 12	Moderate	1.25 - 2.5m			W
9 am	W 19	Moderate	1.25 - 2.5m	Heavy (>4m)	Short	E
12 pm	WNW 24	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Average	SE
3 pm	WNW 30	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Long	SW
6 pm	WNW 27	Moderate	1.25 - 2.5m	Moderate (2 to 4m)	Long	SW
9 pm	WNW 16	Moderate	1.25 - 2.5m	Heavy (>4m)	Short	SE

Meteorological Observations at WILSONS PROMONTORY LIGHTHOUSE

Site 085096 • Locality: WILSONS PROMONTORY • Open Jan 1872 • Open • Lat 39°07'47"S • Lon 146°25'28"E • Height 88.7m

	Air Temperature	Relative Humidity	MSL Pressure		Rainfall	Present Weather	Past Weather
	°C	%	hPa		mm	description	description
Saturday 26 December 1998							
3 am	24.5	35	1002.0		0.2	SQUALL within past hour	Slight or Moderate THUNDERSTORM with RAIN or SNOW
6 am	23.5	51	1001.4		0.4	RAIN within past hour	Moderate intermittent RAIN
9 am	23.4	54	998.7		0.2	THUNDERSTORM within past hour, with thunder heard	Slight or Moderate THUNDERSTORM with RAIN or SNOW
12 pm	20.4	73	995.1		0.2	SHOWER of RAIN within past hour	Slight RAIN SHOWER
3 pm	15.0	93	994.3		4.0	Slight or Moderate THUNDERSTORM with RAIN or SNOW	Slight or Moderate THUNDERSTORM with RAIN or SNOW
6 pm	12.0	100	992.4		15.4	Slight or Moderate THUNDERSTORM with RAIN or SNOW	Heavy THUNDERSTORM with RAIN or SNOW
9 pm	13.2	76	992.6		1.8	Slight RAIN SHOWER	Slight or Moderate THUNDERSTORM with RAIN or SNOW
Sunday 27 December 1998							
3 am	12.5	82	992.0		0.8	Moderate or heavy RAIN SHOWER	Moderate or heavy RAIN SHOWER
6 am	12.0	96	983.9		7.6	Moderate or heavy RAIN SHOWER	Moderate or heavy RAIN SHOWER
9 am	12.5	85	984.9		2.0	Slight continuous RAIN	Heavy continuous RAIN
12 pm	12.0	94	990.1		1.0	Slight continuous RAIN	Slight continuous RAIN
3 pm	12.5	91	992.1		1.6	Slight continuous RAIN	Slight continuous RAIN
6 pm	12.8	93	995.2		1.4	Slight continuous RAIN	Slight continuous RAIN
9 pm	13.2	91	1000.3		0.4	Heavy continuous DRIZZLE	Slight continuous RAIN
Monday 28 December 1998							
3 am	12.8	88	1002.7		0.2	Slight intermittent DRIZZLE	Heavy continuous DRIZZLE
6 am	12.0	94	1004.6		0.6	Moderate continuous RAIN	Moderate continuous RAIN
9 am	11.5	88	1006.0		0.0	Slight intermittent RAIN	Moderate intermittent RAIN
12 pm	14.0	63	1005.8		0.0	SQUALL within past hour	Slight intermittent RAIN
3 pm	15.2	60	1006.2		0.0	SQUALL within past hour	SQUALL within past hour
6 pm	14.3	69	1006.1		0.0	Slight intermittent DRIZZLE	Slight intermittent DRIZZLE
9 pm	13.6	74	1006.9		0.0	SQUALL within past hour	Slight intermittent DRIZZLE
Tuesday 29 December 1998							
3 am	13.6	75	1006.7		0.2	DRIZZLE within past hour	Slight DRIZZLE mixed with RAIN
6 am	12.8	79	1006.6		0.0	Distant PRECIPITATION reaching the ground more than 5km away	Slight intermittent DRIZZLE
9 am	14.1	78	1007.9			DRIZZLE within past hour	Slight DRIZZLE mixed with RAIN
12 pm	16.0	65	1008.1		0.2	SQUALL within past hour	Moderate intermittent RAIN
3 pm	14.8	81	1008.1		0.2	RAIN within past hour	SQUALL within past hour
6 pm	15.2	66	1008.5			SQUALL within past hour	SQUALL within past hour
9 pm	14.4	73	1010.1		0.0	Distant PRECIPITATION reaching the ground more than 5km away	SQUALL within past hour