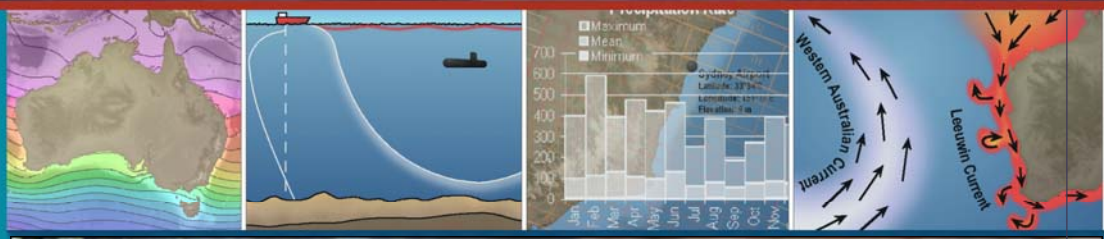
VERSION 2.1

NAXA



DIRECTORATE OF OCEANOGRAPHY AND METEOROLOGY

NAVY

METOC Environment Brief

NAXA

January - December

Author: Climate Services Group

Directorate of Oceanography & Meteorology
Level 2 Bay E201 Building 89/90
Garden Island
Potts Point NSW 2011
Ph (02) 9359 3121
Fax (02) 9359 3120

Version: 2.1
Date last published: 17th September 2008
Product Code: DOM_CSG_MEB_NAXA_Ver 2.1

Cover Photo: Textile Cone Shell. http://www.scuba-equipment-usa.com/marine/JUN05/Textile_Cone_Shell(Conus_textile).html

Data Disclaimer

Monthly means and extreme values of climatological and oceanographic data are compiled from climatological and historical records. This information is presented primarily for planning purposes. Real-time environmental observations should always be used in preference to climatological records. Forecasting services are provided by the Joint Command Centre (JCC) METOPS (02-9359 4130). Further information on current weather and sea conditions can be obtained on the internet from the sites listed in Appendix 6.2.

Copyright

This work is copyright. Apart from any use as permitted under Copyright Act 1968, no part may be reproduced by any process without written permission from the Commonwealth. Requests and enquires concerning reproduction and rights should be addressed to the responsible author body named above.

For Department of Defence Use Only

TABLE OF CONTENTS

Page No.

1 INTRODUCTION 1
1.1 AREA OF INTEREST 1
1.2 SYNOPTIC OVERVIEW 2
1.3 PHENOMENA OF CONCERN 2
1.4 CLIMATE VARIABILITY 2

2 METEOROLOGY 3
2.1 REGIONAL CLIMATE 3
2.1.1 SEVERE WEATHER CONDITIONS 3
2.2 CLIMATE SUMMARIES 4
2.3 ATMOSPHERIC PRESSURE 12
2.4 AIR TEMPERATURE 14
2.5 WINDS 15
2.5.1 LAND AND SEA BREEZES 29
2.6 TROPICAL CYCLONES 29
2.7 PRECIPITATION 32
2.8 THUNDERSTORMS 34
2.9 FOG AND VISIBILITY 36
2.10 CLOUD COVER 41
2.11 RELATIVE HUMIDITY 48

3 OCEANOGRAPHY 50
3.1 SWELL 50
3.2 WIND – WAVES 57
3.3 CURRENTS 62
3.4 TIDES AND TIDAL CURRENTS 65
3.5 INTERNAL WAVES 65
3.6 WATER PROPERTIES 67
3.6.1 SEA SURFACE TEMPERATURE 67
3.6.2 SEA SURFACE SALINITY 69
3.6.3 TSVD PROFILES 71
3.6.4 XBT PROFILES 77

3.7 WATER TURBIDITY 79

4 BIOLOGY 81
4.1 BIOLUMINESCENCE 81
4.2 HUMAN ACTIVITIES 83
4.2.1 FISHERIES 83
4.2.2 SHIPPING 86
4.2.3 MINING 88
4.3 MARINE LIFE 89
4.4 SEAGRASS MEADOWS 92
4.5 DANGEROUS ANIMALS 93
4.6 DISEASES 100

5 GEOLOGY 101
5.1 BATHYMETRY 101
5.2 SEABED TOPOGRAPHY 103
5.3 REEFS 104
5.4 SEISMIC ACTIVITY 105
5.5 BOTTOM SEDIMENTS 106

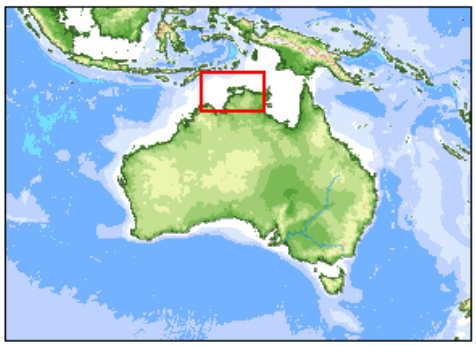
6 APPENDIX 109
6.1 LOCATION OF DOCUMENT ON INTRANETS 109
6.2 USEFUL INTERNET LINKS 109
6.2.1 REAL TIME DATA 109
6.3 ACRONYMS 109

7 REFERENCES 111

1 INTRODUCTION

1.1 AREA OF INTEREST

This document presents a summary of the climate and environmental conditions for the area of latitude 9ºS to 15ºS and longitude 126ºE to 136ºE in which the Northern Australian Exercise Area (NAXA) is located (Figure 1). This document covers the entire year, ie. January to December.



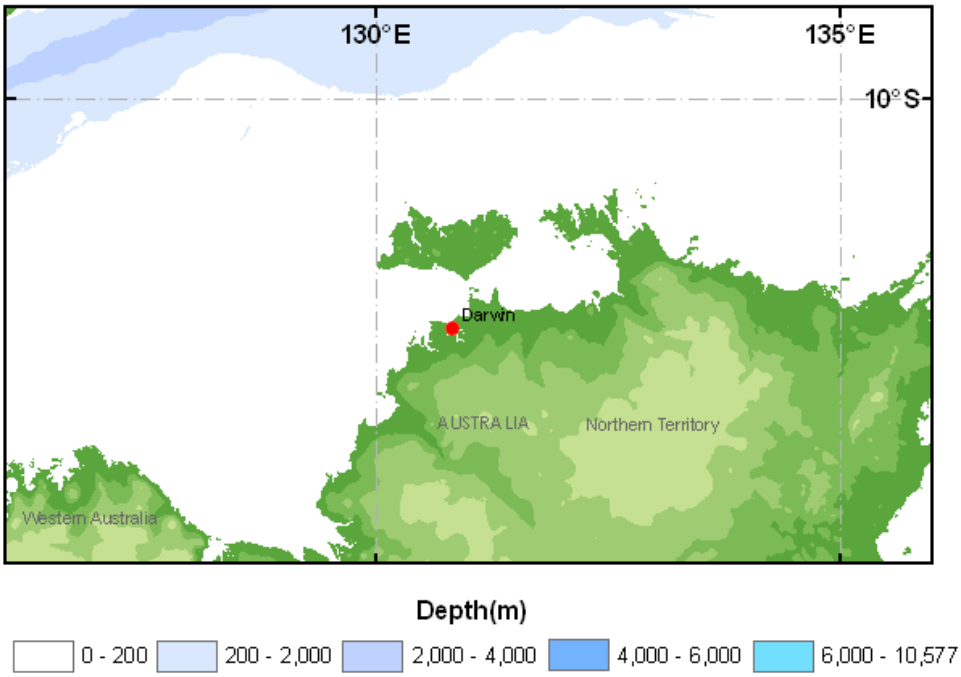


Figure 1: The area in which NAXA is located.
(Source: GEBCO, 2007, DOM, 2007)

1.2 SYNOPTIC OVERVIEW

The NAXA climate is monsoonal. Winter is characterised by SE trade winds with relatively dry conditions, spring and autumn winds are light and variable, while the summer is dominated by the NW monsoon bringing rain and humid conditions with an occasional tropical cyclone. All seasons are hot with little variation.

1.3 PHENOMENA OF CONCERN

- Tropical Cyclones can develop from tropical depressions formed over the Timor and Arafura Seas between November and April. Peak activity extends from January to March.
- After a cyclone in the Northern Territory there could be a risk of contracting Melioidosis from groundwater following heavy rains. Melioidosis is a disease caused by a bacteria in the soil that can be transmitted through open cuts or broken skin.
- Thunderstorms occur on an average of 80 days per year around Darwin, between November and March. Peak activity is during the "build-up" period at the start of the summer wet season.
- Temperature remains high throughout the year, with daily mean temperatures varying around 28ºC in summer and 26ºC in winter.
- Tidal Ranges and Tidal Currents are much greater than normally encountered, with consequent strong tidal streams, which may be a navigation hazard. Some of the estuaries are also noted for tidal "jumps" or "bores", which are dangerous for small vessels.
- The potentially deadly box jellyfish and Irukandji jellyfish season is from October to May, although stings have been reported in all months.

1.4 CLIMATE VARIABILITY

The data presented within this brief is past average conditions. This data will remain valid as long as the climate does not substantially change. There is however a slow shift in the climate from many factors such as natural cycles within the climate, which will result in a gradual change in the weather over an extended period of time.

Some of these changes could include, temperature, wind, and rainfall changes, which could result in variations in sea-level, the frequency or severity of cyclones, and droughts (Sidsnet, 2007).

2 METEOROLOGY

2.1 REGIONAL CLIMATE

The climate of the region is controlled by the behaviour of the inter-tropical convergence zone (ITCZ). This zone is a band across longitudes where southeast and northeast trade winds from the southern and northern hemispheres meet. The zone moves north and south during the year. During November and December the ITCZ moves southwards towards northern Australia.

The climate is monsoonal and marked by seasonal changes in wind and rainfall. The SE monsoon prevails in winter (May to September) imposing relatively dry conditions, while the NW monsoon (December to March) brings the rainy and humid summer season. October to December and March to April are transitional periods between the monsoon seasons.

The amount of rain varies significantly in space and time and from year to year, being largely controlled by the orientation and topography of the coast and the extent of exposure to the monsoons.

South of 5ºS the seasonal trend becomes more definite and air temperature is noticeably lower in winter, while the amount of rainfall is controlled by season rather than local topography. Off northern Australia, hot and humid weather of the "wet" season begins to change to fine, hot and dry conditions associated with SE trade winds (monsoon), which prevail from April onward.

Winds are mainly light to moderate throughout the region, being more constant in direction and stronger in the south. Gales (wind force 7 and more) are rare, however tropical depressions usually form over the Timor and Arafura Seas, some maturing into tropical cyclones, producing winds of gale or storm force. Tropical cyclones normally occur between November and April, but tropical depressions are likely to develop at any time of the year (HO, 1992).

Fog is rare at sea, but haze sometimes may be thick, particularly when SE monsoon blows offshore over the dry interior of the Australian continent during years of drought. Haze and smoke can frequently reduce visibility in coastal waters in the Banda Sea.

Climate summaries are shown in Figure 3 to Figure 9 for meteorological stations around NAXA. While the data from these stations are relevant to the area, the weather will tend to be modified by adjacent land masses and may not accurately indicate weather conditions over the open sea. Wind speeds and directions are also perturbed by the land topography.

The climate summaries are followed by descriptions of the major weather parameters for all months.

2.1.1 SEVERE WEATHER CONDITIONS

Tropical Cyclones can develop from tropical depressions formed over the Timor and Arafura Seas between November and April. Peak activity extends from January to March.

Thunderstorms occur on an average of 80 days per year around Darwin, between November and March. Peak activity is during the "build-up" period at the start of the summer wet season.

Temperature remains high throughout the year, with daily mean temperatures varying around 28ºC in summer and 26ºC in winter.

2.2 CLIMATE SUMMARIES

Figure 3 to **Figure 9** present monthly mean climatic summaries for 7 climate stations situated in the NAXA (see **Figure 2**).

CLIMATIC COMFORT INDICATOR

The climate summaries contain a climatic comfort indicator, which has been generated using mean values of temperature, humidity and wind speed. As a result, this indicator should only be used as a general guide because extreme and unusual weather conditions may bring about climatic comfort conditions that vary from those indicated on the scale, particularly if the weather is very hot and humid or very cold and windy.

The level at which a person becomes affected by the weather conditions depends not only on temperature, humidity and wind speed, but on clothing, accommodation, work environment, occupation, health, fitness, age and the level of acclimatization. Exposure to full sunshine can increase apparent temperature values by up to 8ºC

The climate comfort scale shows the risk of permanent injury or death from situations of extreme cold or heat, with each rating indicating the following:

Table 1: Climatic comfort scale.

Danger Rating		Description of Dangers
	Heat Extreme Danger	heat stroke highly likely
	Heat Danger	heat cramps or heat exhaustion likely and heat stroke possible
	Heat Caution	heat cramps or heat exhaustion possible
	Low Risk	minimal risk of illness
	Cold Caution	little danger for a properly clothed person
	Cold Danger	increasing danger from freezing of exposed flesh or hypothermia
	Cold Extreme Danger	great danger from freezing of exposed flesh or hypothermia

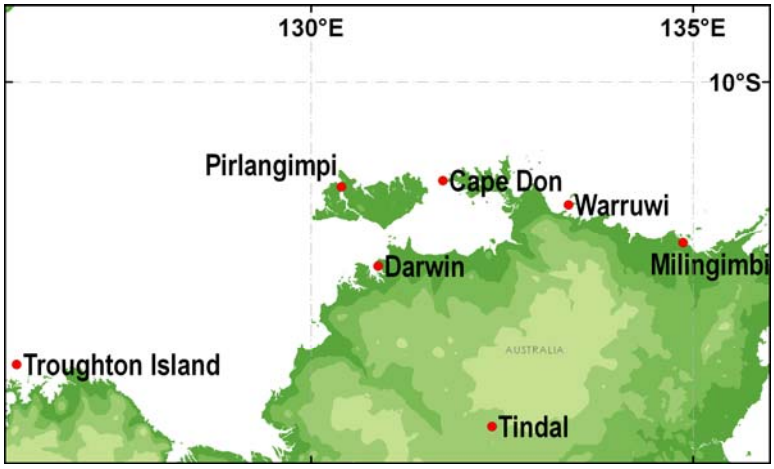


Figure 2: Location of Climate Stations used in climate summaries
(Source: Map from DOM, 2007)

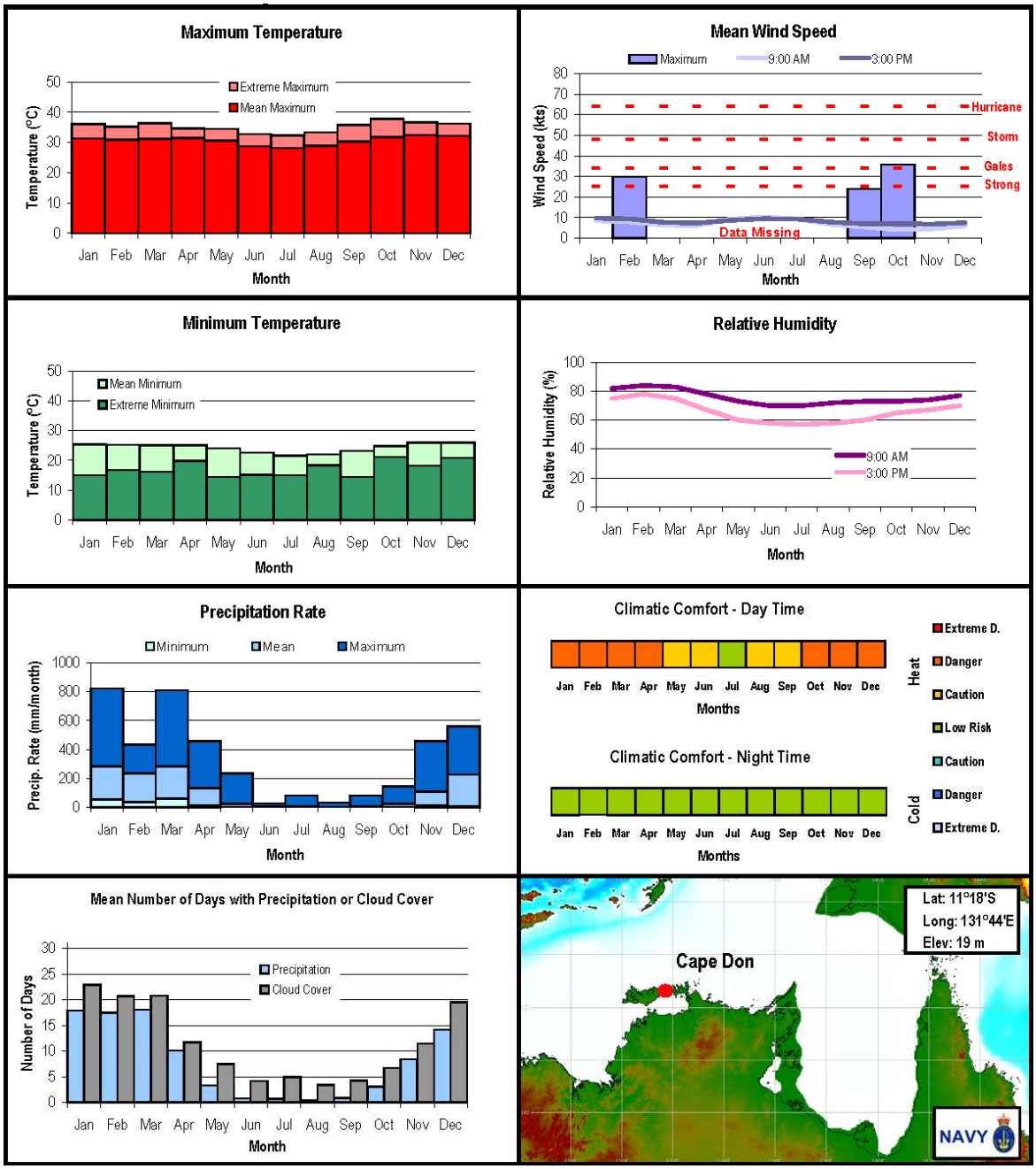


Figure 3: Climate Summary of Cape Don (11º18'S, 131º44'E)
(Source: Modified from BoM, 2002, FCCA, 1996 and GEBCO, 2002)

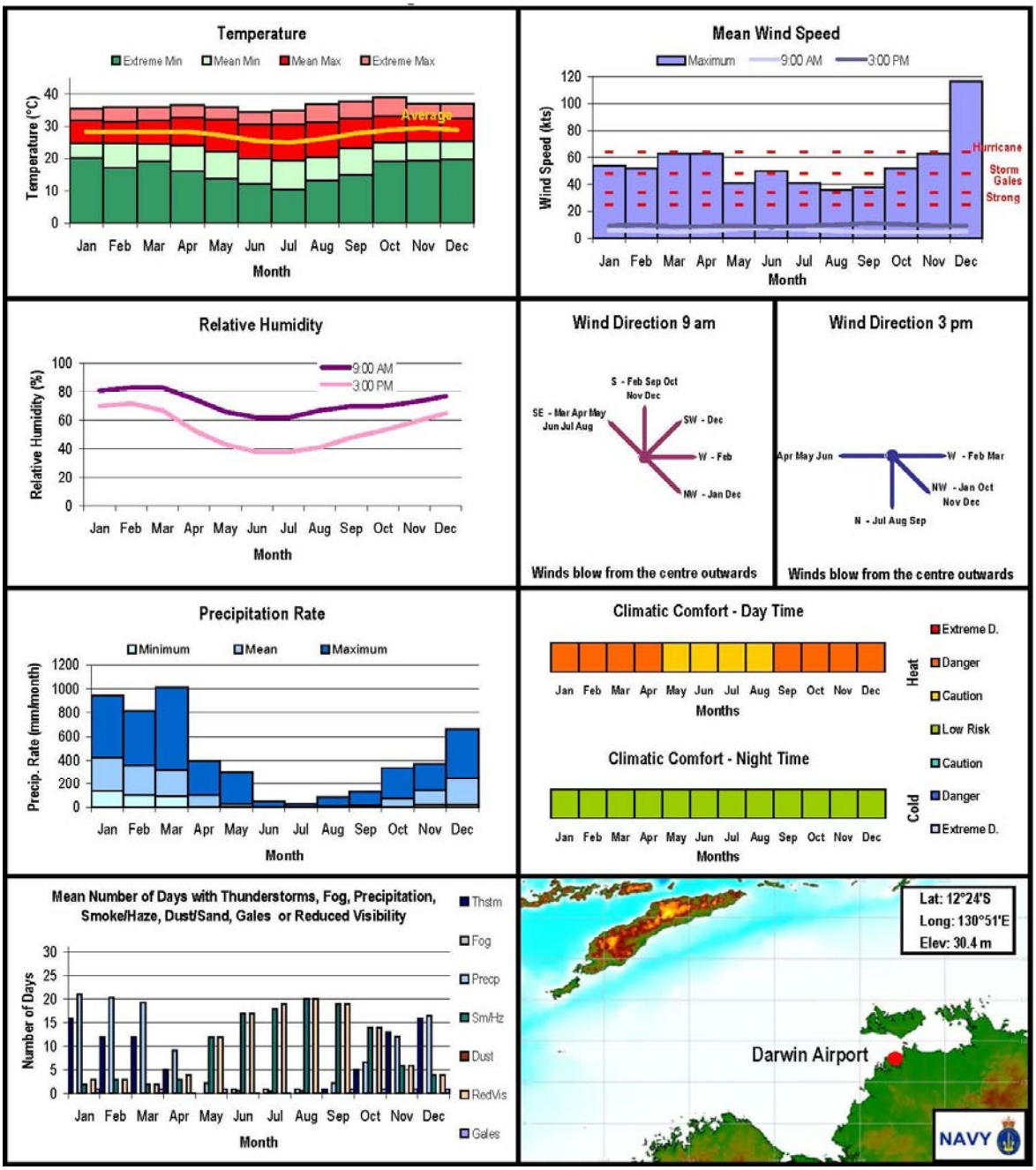


Figure 4: Climate summary for Darwin (12º24'S, 130º51'E).
(Source: BoM, 2008, FCCA, 1996)

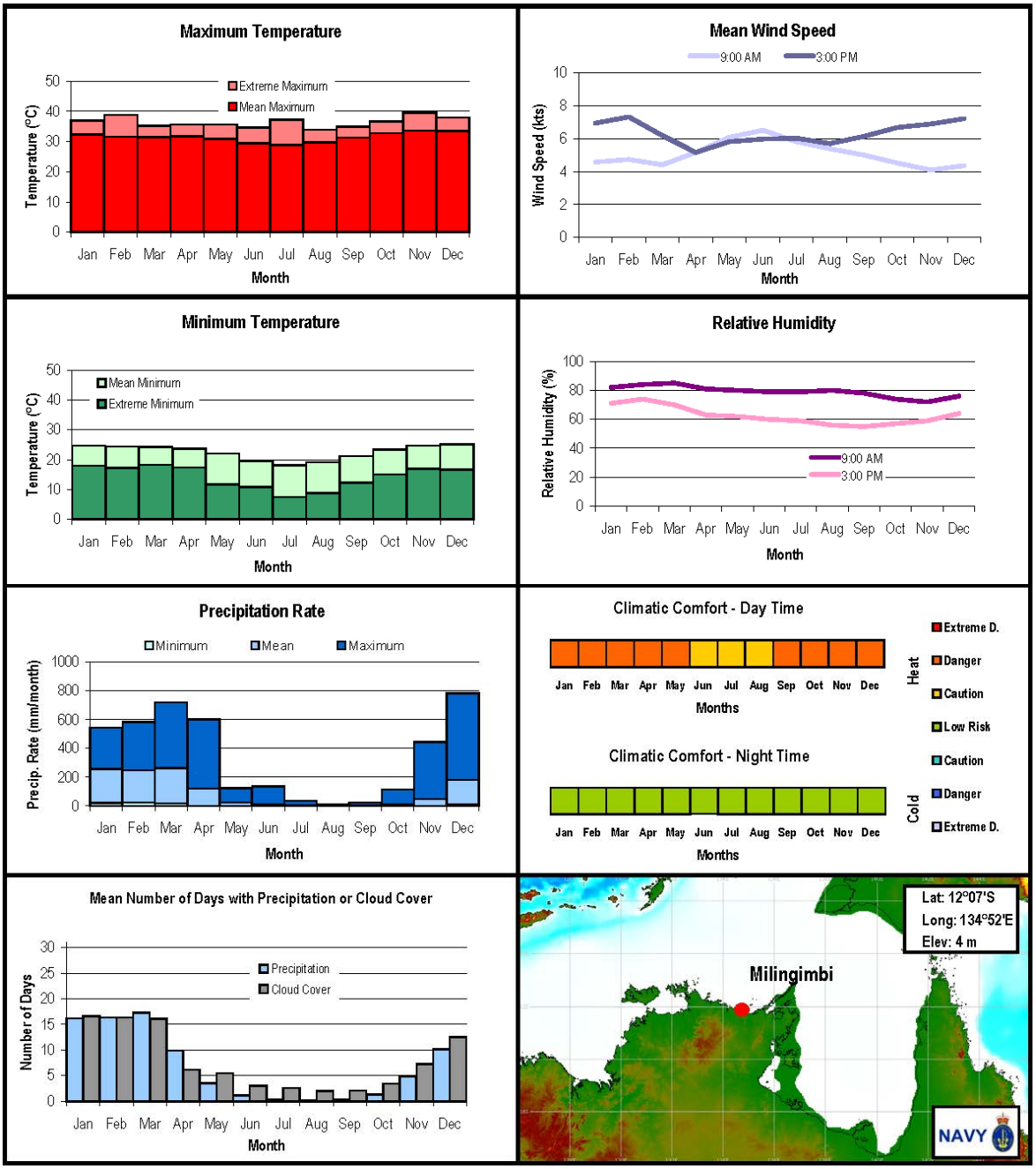


Figure 5: Climate Summary for Milingimbi (12º07'S, 134º52'E)
(Source: Modified from BoM, 2002, FCCA, 1996 and GEBCO, 2002)

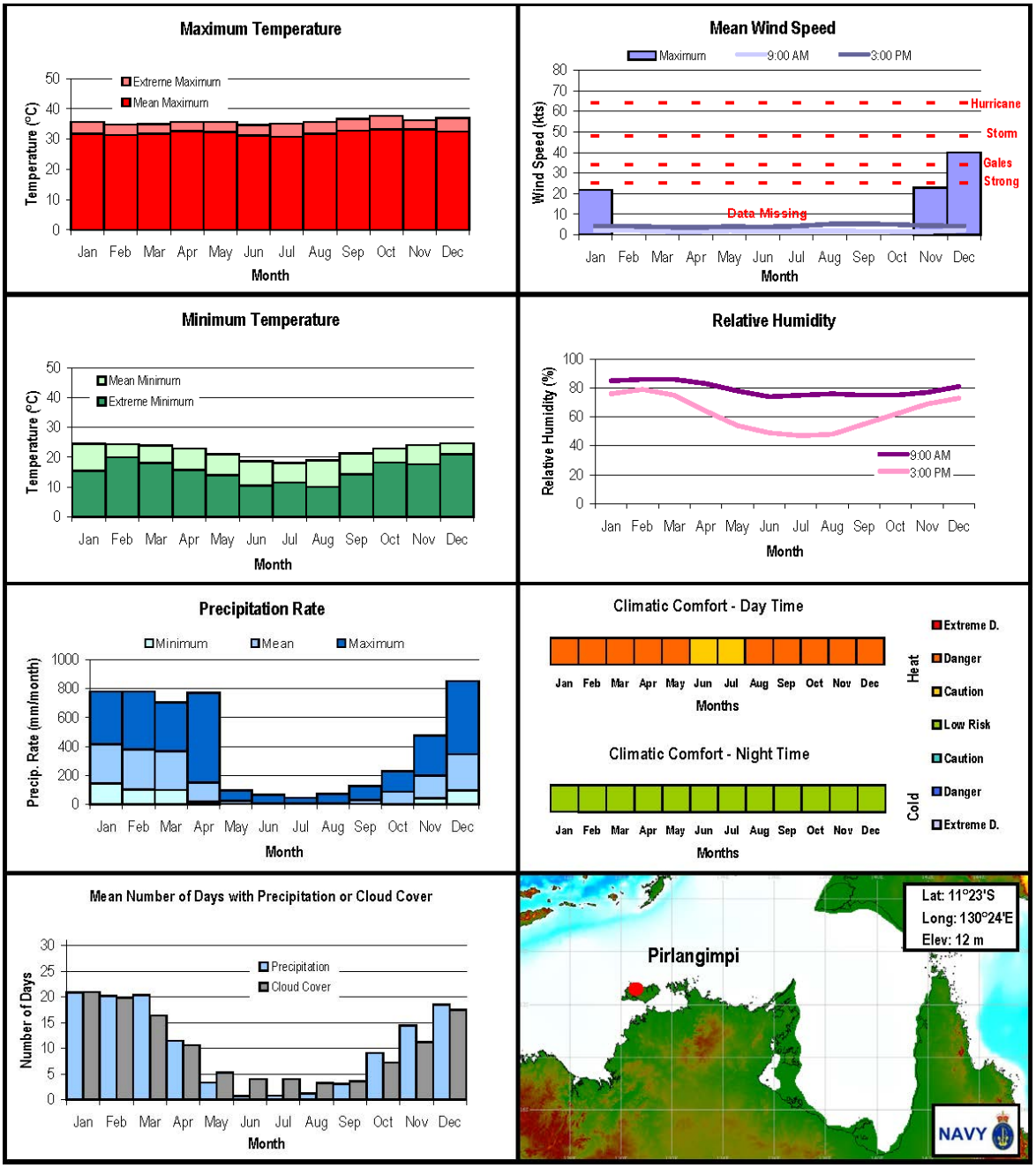


Figure 6: Climate Summary for Pirlangimpi (11º23'S, 130º24'E)
(Source: Modified from BoM 2002, FCCA 1996 and GEBCO 2002)

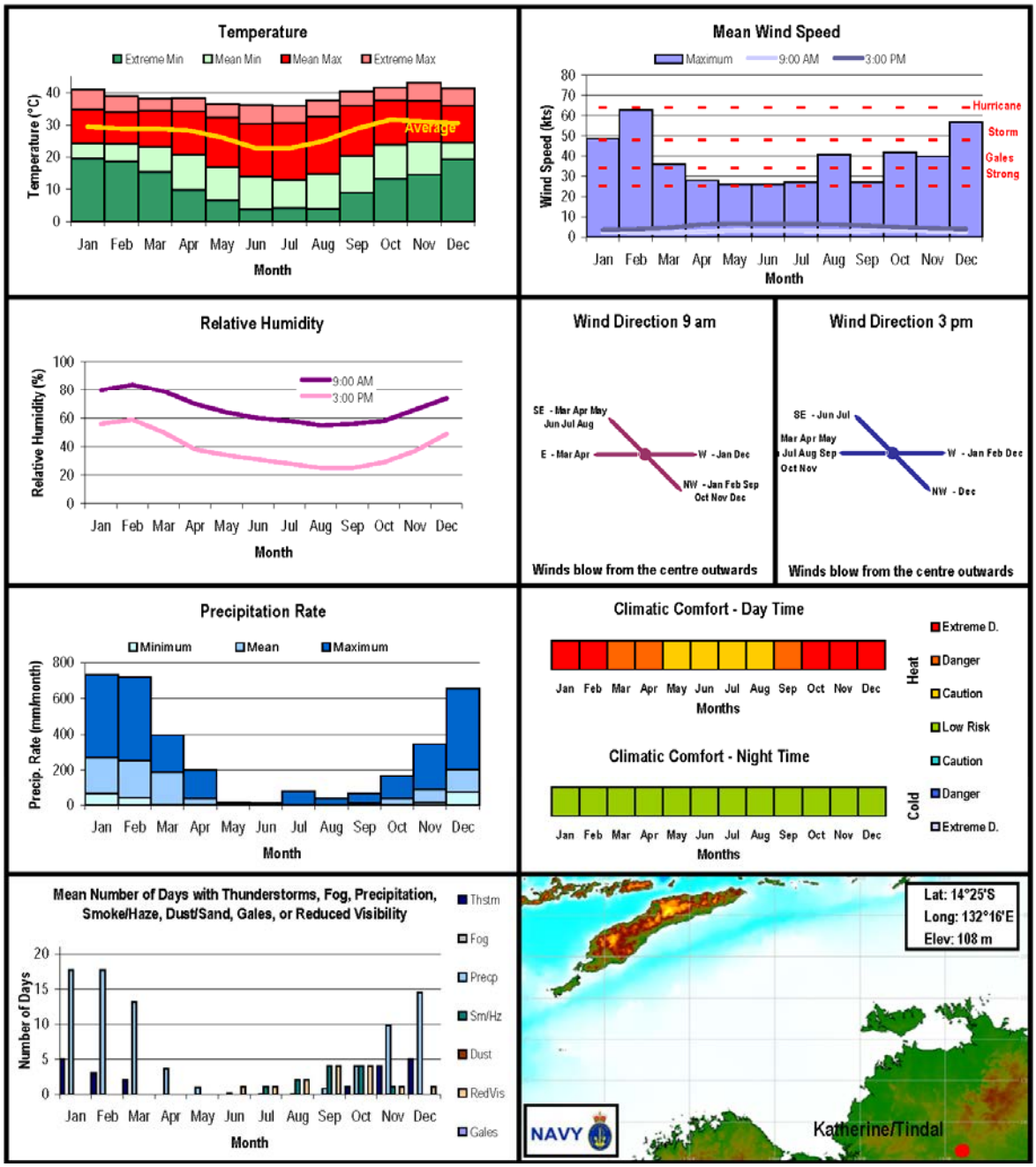


Figure 7: Climate summary for Katherine/ Tindal (14º25'S, 132º16'E).
(Source: FCCA, 1996 and BoM, 2003)

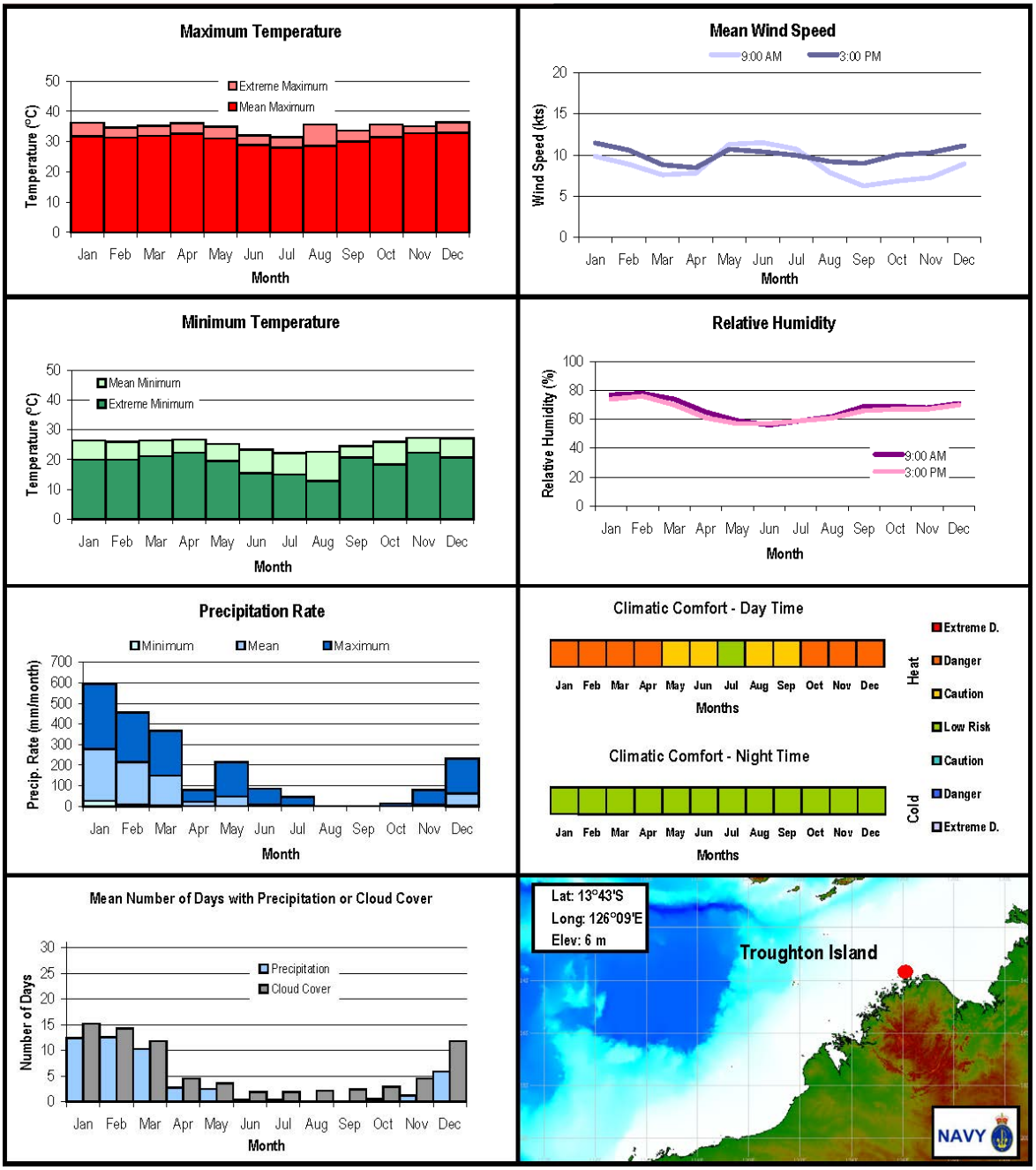


Figure 8: Climate Summary for Troughton Island (13º43'S, 126º09E)
(Source: Modified from BoM, 2002, FCCA, 1996 and GEBCO, 2002)

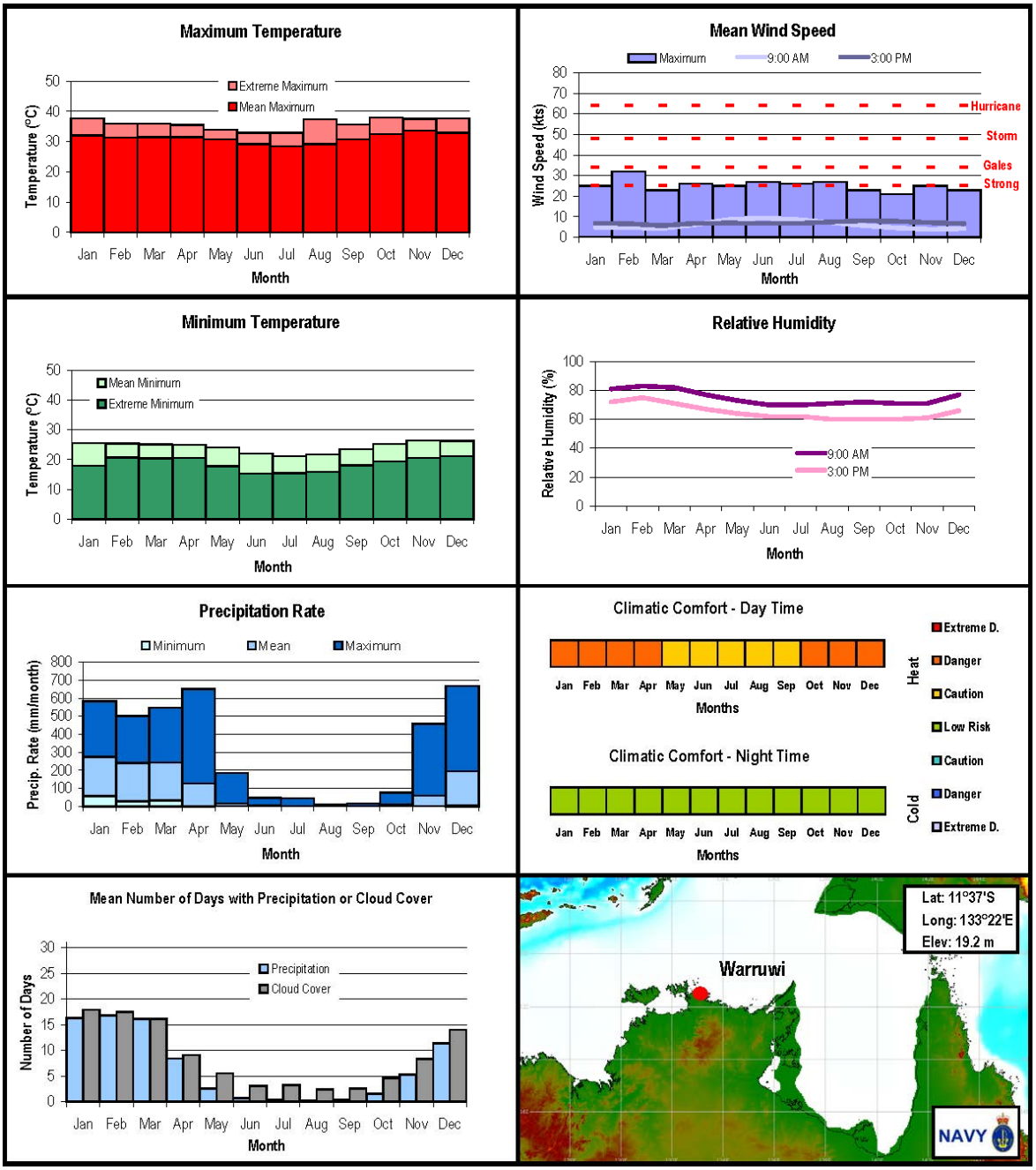


Figure 9: Climate Summary for Warruwi (11º37'S, 133º22'E)
(Source: Modified from BoM, 2002, and GEBCO, 2002)

2.3 ATMOSPHERIC PRESSURE

Mean monthly air pressure ranges from a minimum of around 1006 hPa during summer due to the presence of the ITCZ, to a maximum of around 1014 hPa in winter, as shown in Figure 10 and Figure 11. The standard deviation around the means shown is about 2 hPa. There is a regular diurnal variation of atmospheric pressure with maxima at 1000 and 2200 local time and minima at 0400 and 1600, and an amplitude of 2 to 3 hPa (HO, 1992). A larger range of daily fluctuations may occur when a major depression passes, particularly during the cyclone season from November to April. Any sharp fall in pressure should be carefully monitored as it may indicate the approach of a storm.

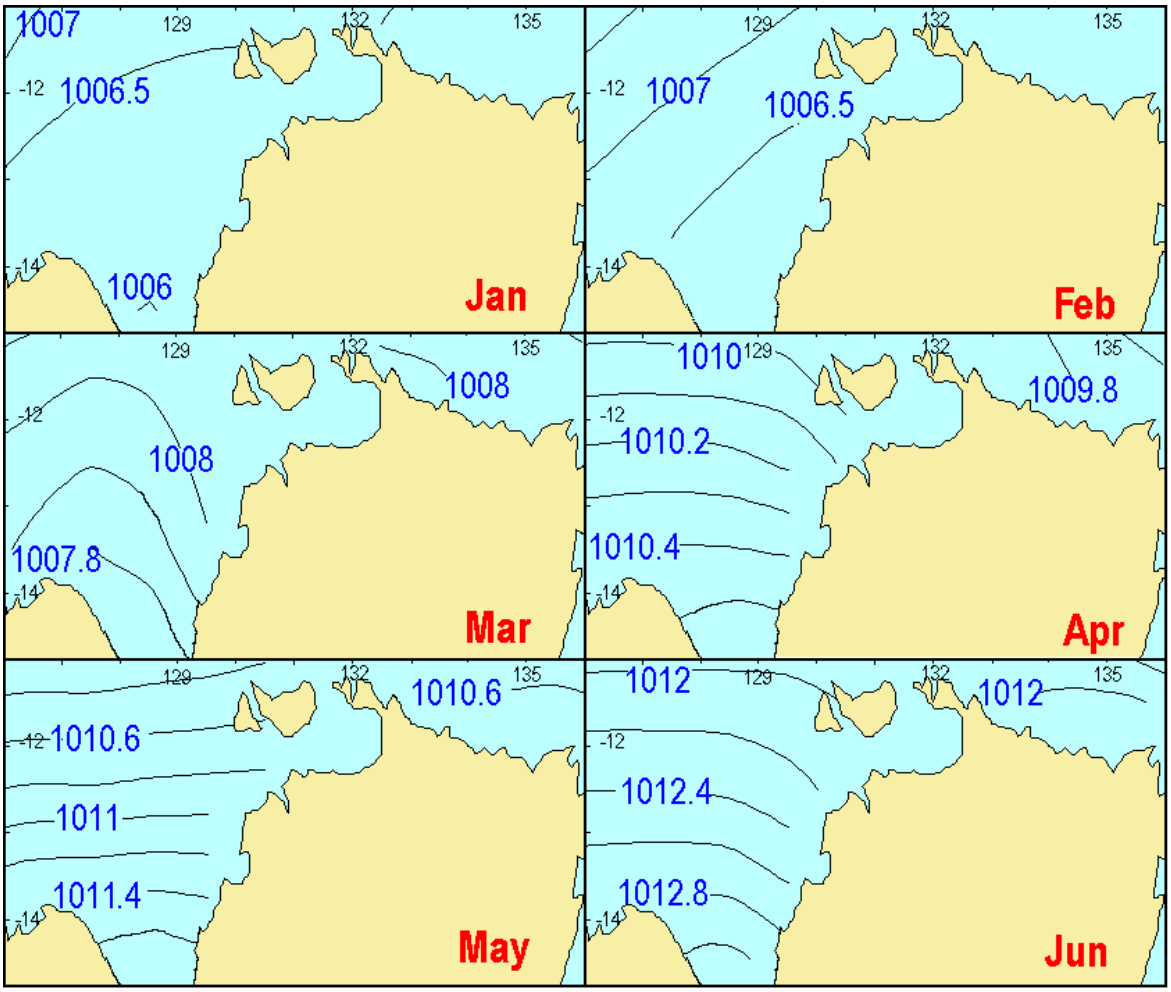


Figure 10: Mean air pressure at sea level (hPa).
(Source: NCDC, 1995)

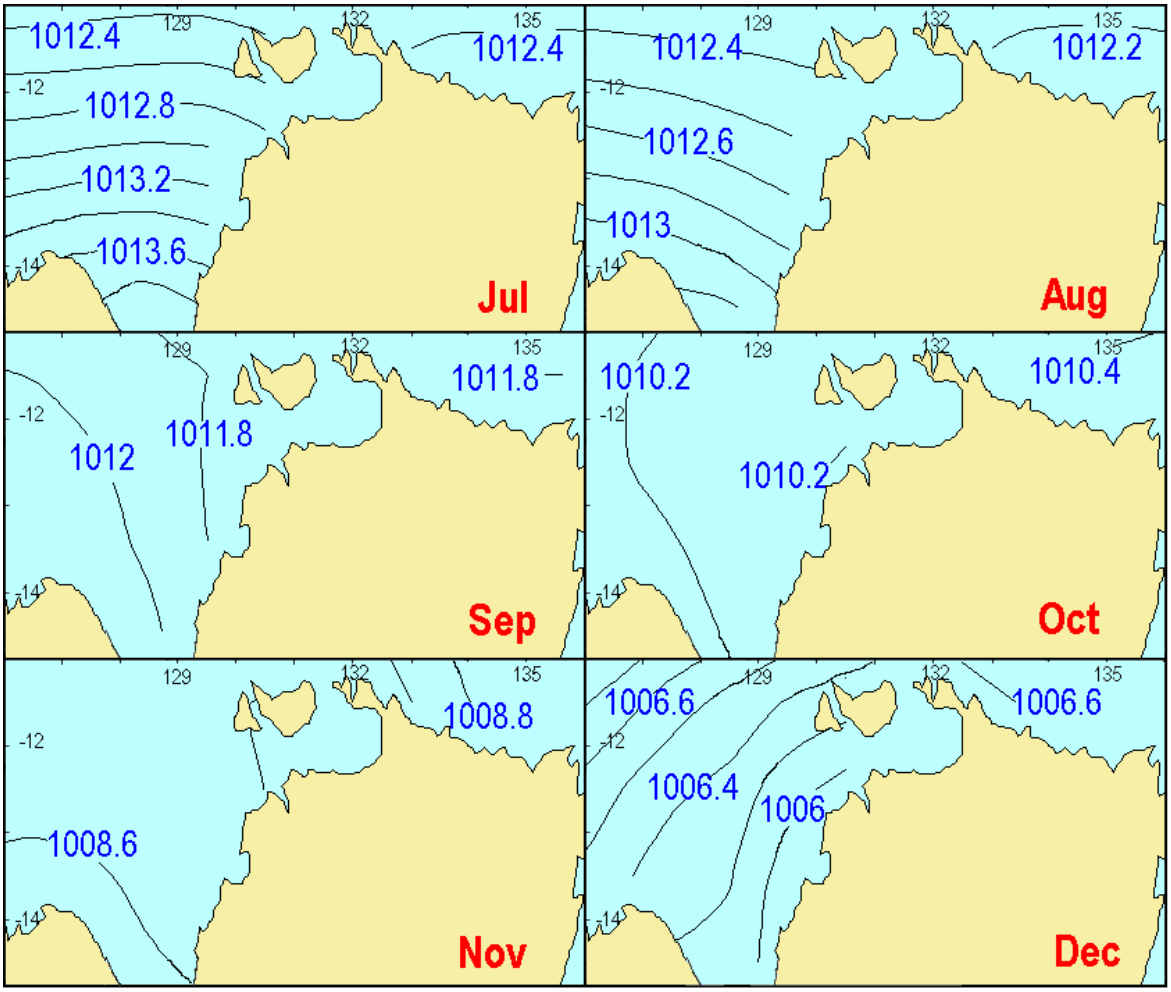


Figure 11: Mean air pressure at sea level (hPa).
(Source: NCDC, 1995)

2.4 AIR TEMPERATURE

Mean monthly air temperatures for five meteorological stations around NAXA are shown in Figure 12 and Figure 13. At sea, air temperatures remain relatively high throughout the year ranging from around 24ºC in July to over 29ºC in summer. The mean temperatures shown have a standard deviation of about 1.2ºC over the sea, but in the coastal zone, daily temperature changes may reach up to 8ºC.

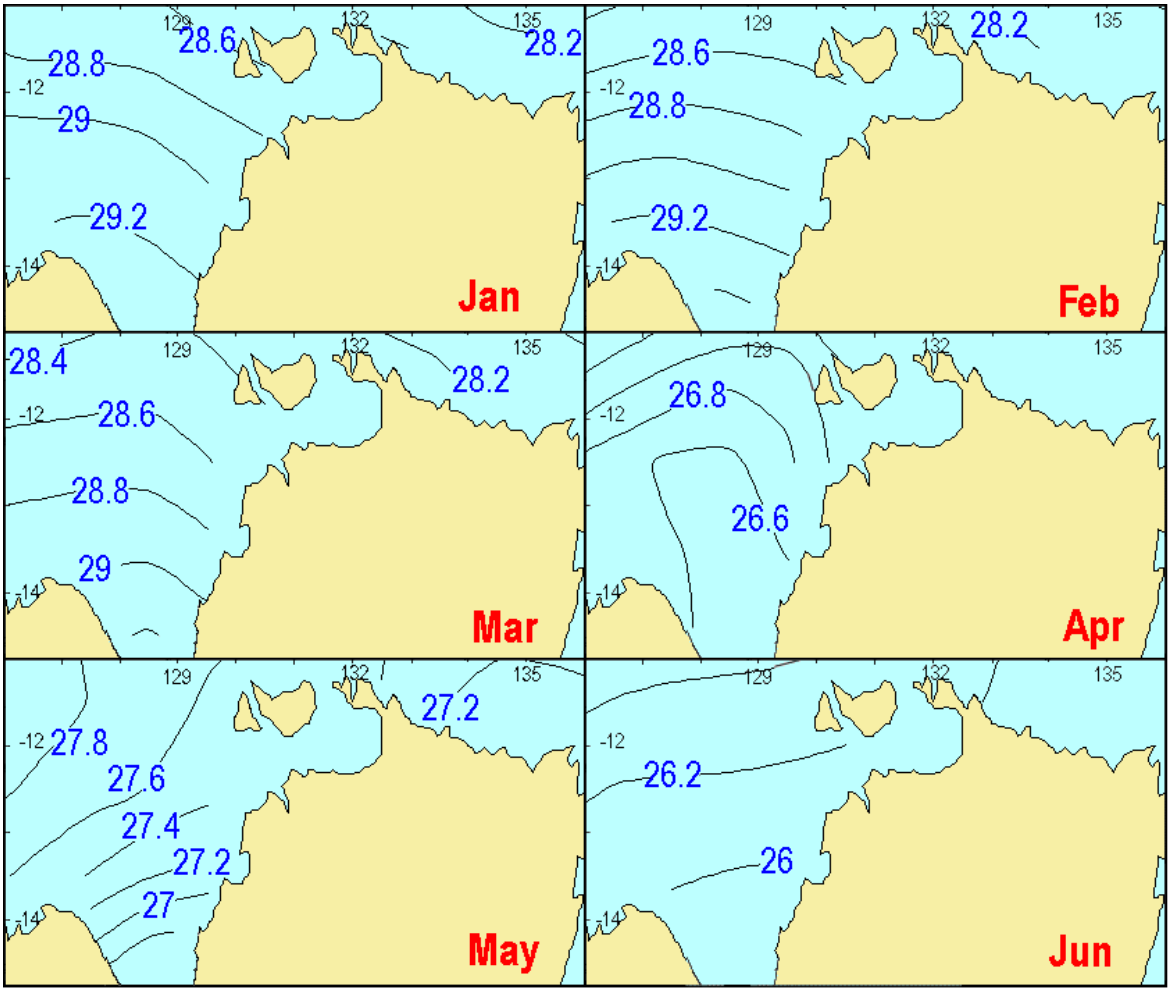


Figure 12: Mean air temperatures (ºC).
(Source: NCDC, 1995)

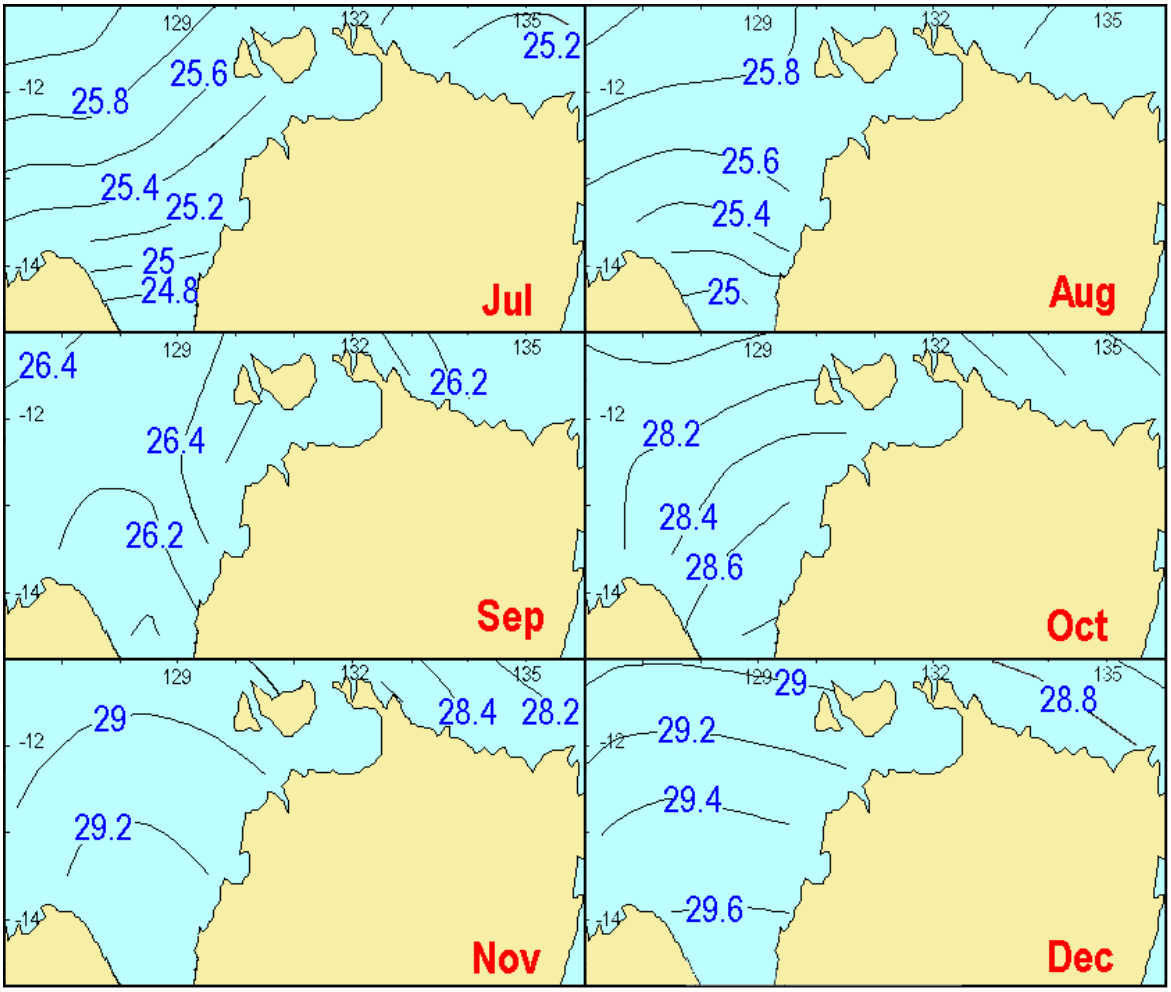


Figure 13: Mean air temperatures (ºC).
(Source: NCDC, 1995)

2.5 WINDS

Seasonal changes in wind directions are shown by the wind roses in Figure 14 and Figure 15. During summer, winds are light to moderate (averaging 8 - 9 kts) from a W and NW direction (NW monsoon). During autumn winds become variable then shift to the E – SE and strengthen (SE monsoon). During spring winds once again become light and variable as the change in monsoon season begins. The transitional periods are from October to December and from March to April, with no abrupt change from one monsoon to the other. For several weeks it is common to experience a period of light and unsteady winds, mainly from the S and interspersed by squalls (HO, 1992).

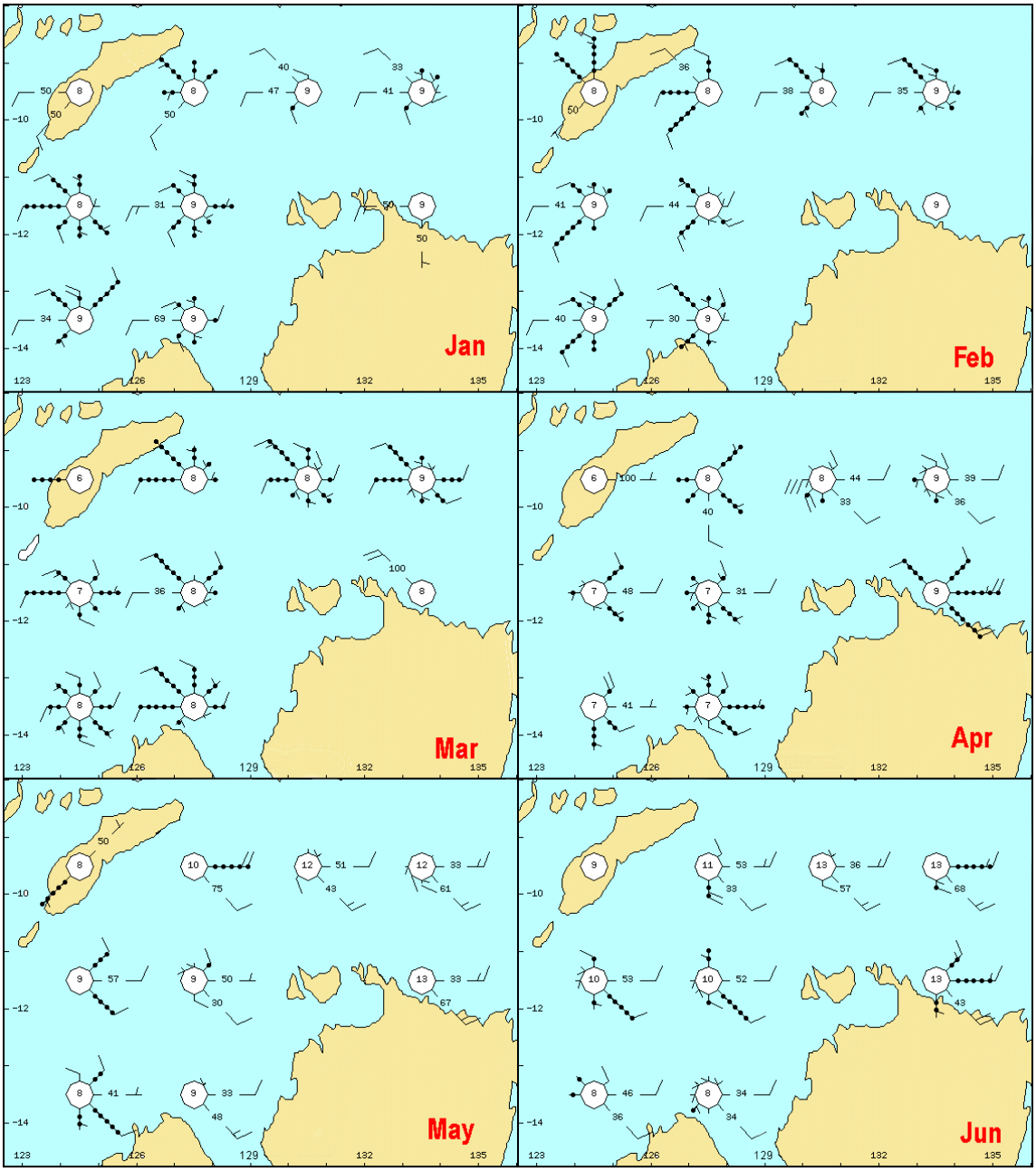
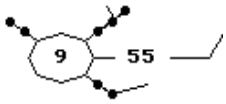


Figure 14: Wind roses (kts).
(Source: NCDC, 1995)

Explanation of Wind Rose



Wind blows from a compass point
Dots on each wind vector indicate 5% frequency increments
Half barb on vector = 5 kts, Full barb = 10 kts
Number in centre of rose shows mean windspeed in knots for month
Number on vector indicates frequency of wind (55% in this case)

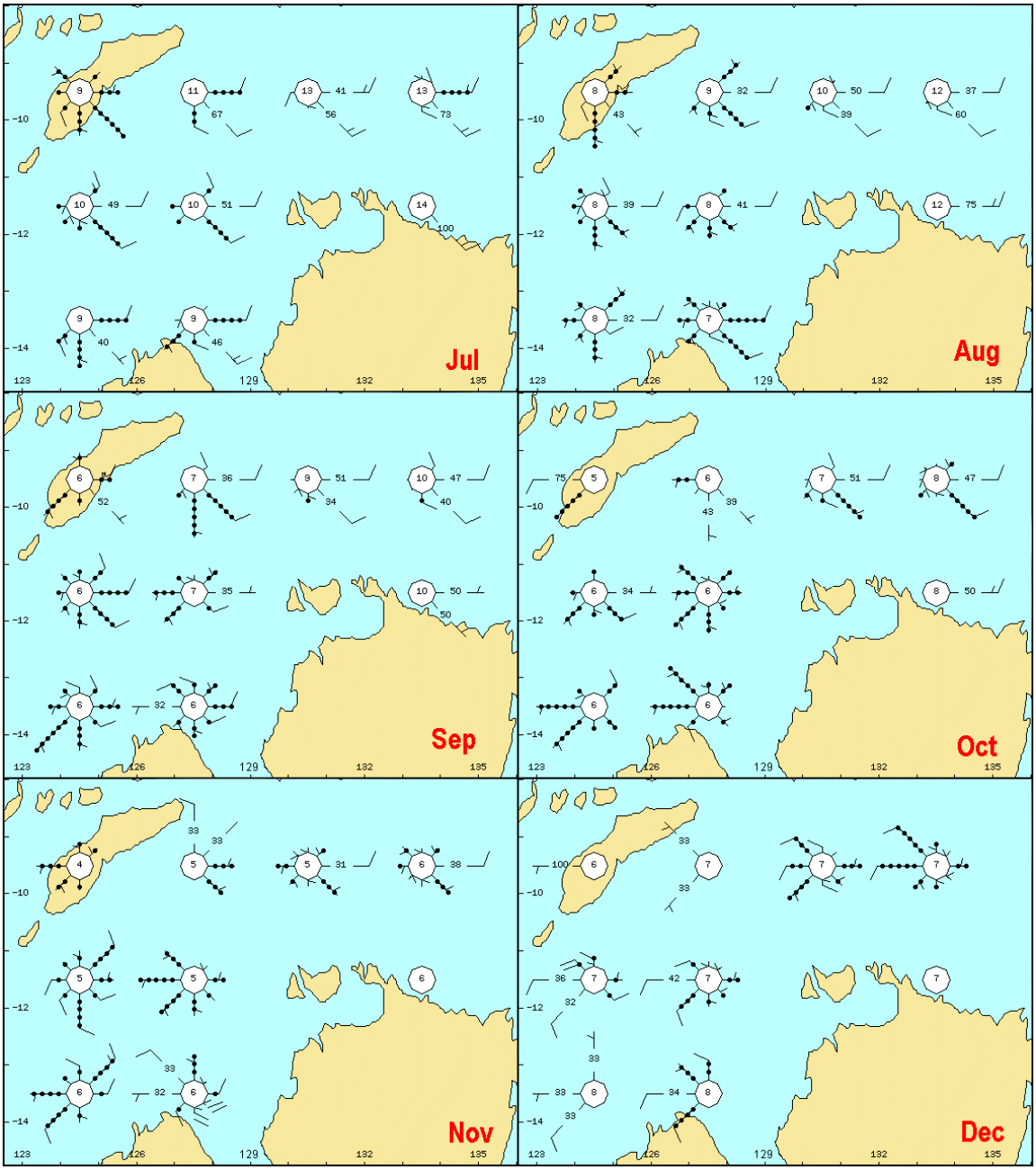
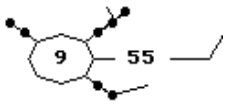


Figure 15: Wind roses (kts).
(Source: NCDC, 1995)

Explanation of Wind Rose



Wind blows from a compass point
Dots on each wind vector indicate 5% frequency increments
Half barb on vector = 5 kts, Full barb = 10 kts
Number in centre of rose shows mean windspeed in knots for month
Number on vector indicates frequency of wind (55% in this case)

Mean wind speeds are shown in Figure 16 and Figure 17. Winds are stronger during the winter and lighter during the transition periods between the monsoons. There is not much variation in wind speed over NAXA, except during winter when stronger winds are present along the Arnhem Land coast.

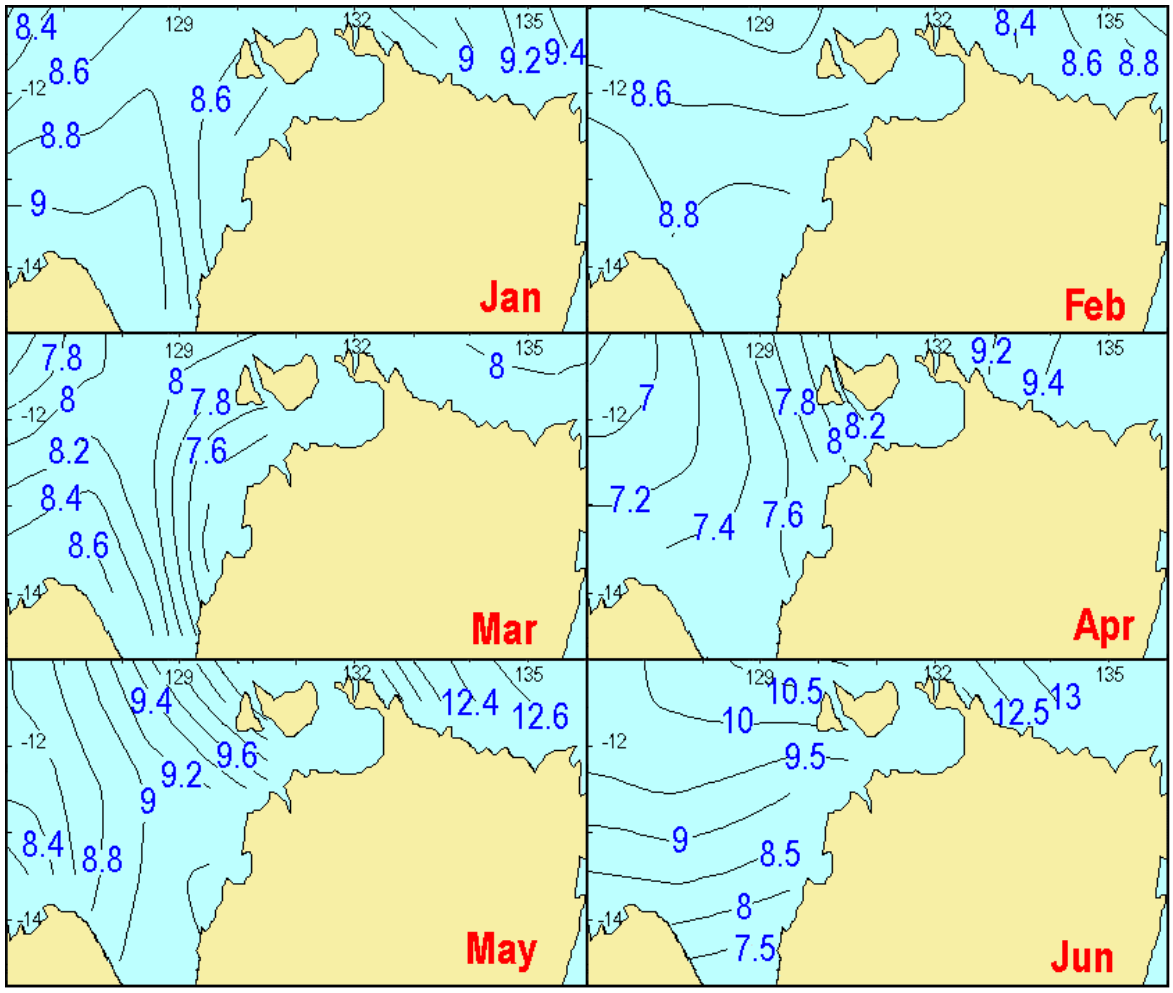


Figure 16: Mean wind speeds (kts), January to June.
(Source: NCDC, 1995)

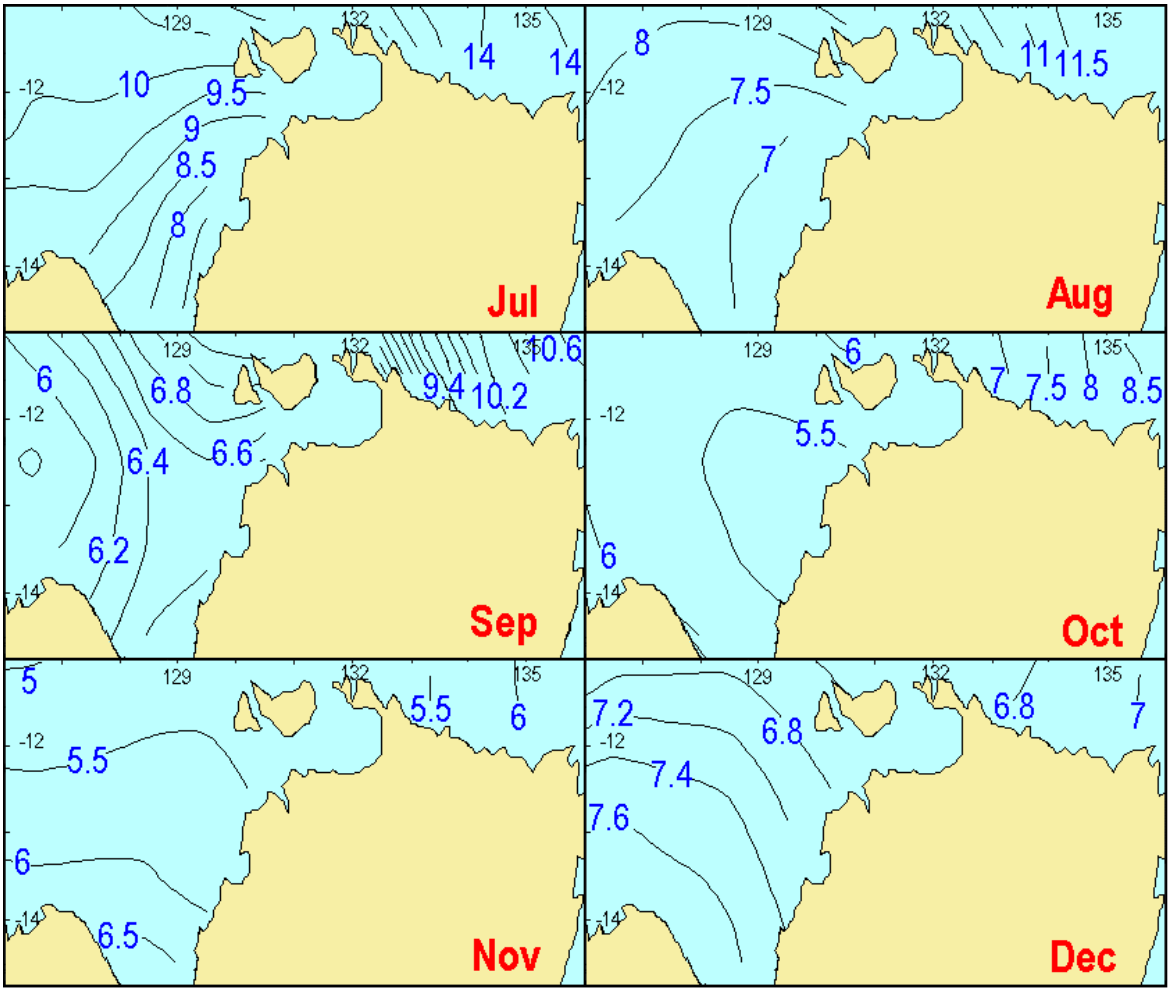


Figure 17: Mean wind speeds (kts), July to December.
(Source: NCDC, 1995)

Frequency distribution of wind speed and direction were obtained from the 2° chart squares; square 1: 9-11ºS, 126-128ºE and Square 2: 11-13ºS, 128-130ºE (**Figure 18**). These are shown in **Figure 19** to **Figure 26**. These plots clearly show the bimodal distribution of the monsoon winds from the W in summer and from the ESE in winter. Wind speed distributions during the summer and winter periods are similar with modal wind speeds of about 10 kts and 2 – 3% of strong winds (25 – 33 kts). Wind speeds are lower during the transition periods with a modal wind speed around 8 kts from March to May and 6 kts from September to November, when the percentage of calms rises to 15%. Gale force winds (>33 kts) are uncommon and confined to summer.

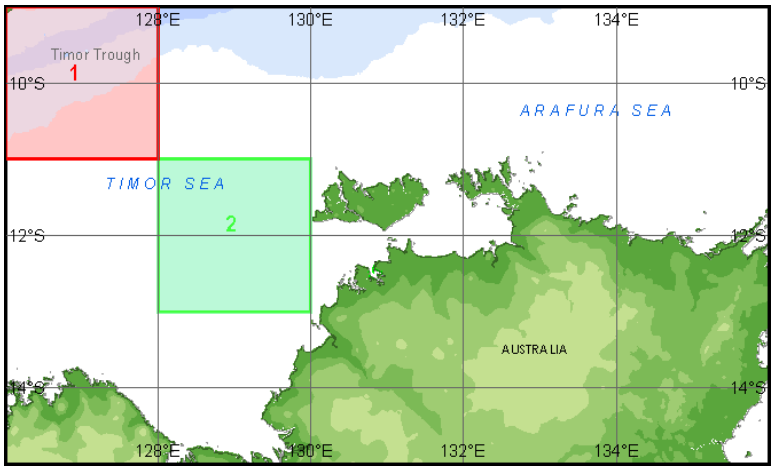


Figure 18: Area selected for GMCA data plots

(Square 1: 9-11ºS, 126-128ºE and Square 2: 11-13ºS, 128-130ºE).
(Source: chart from DOM, 2007)

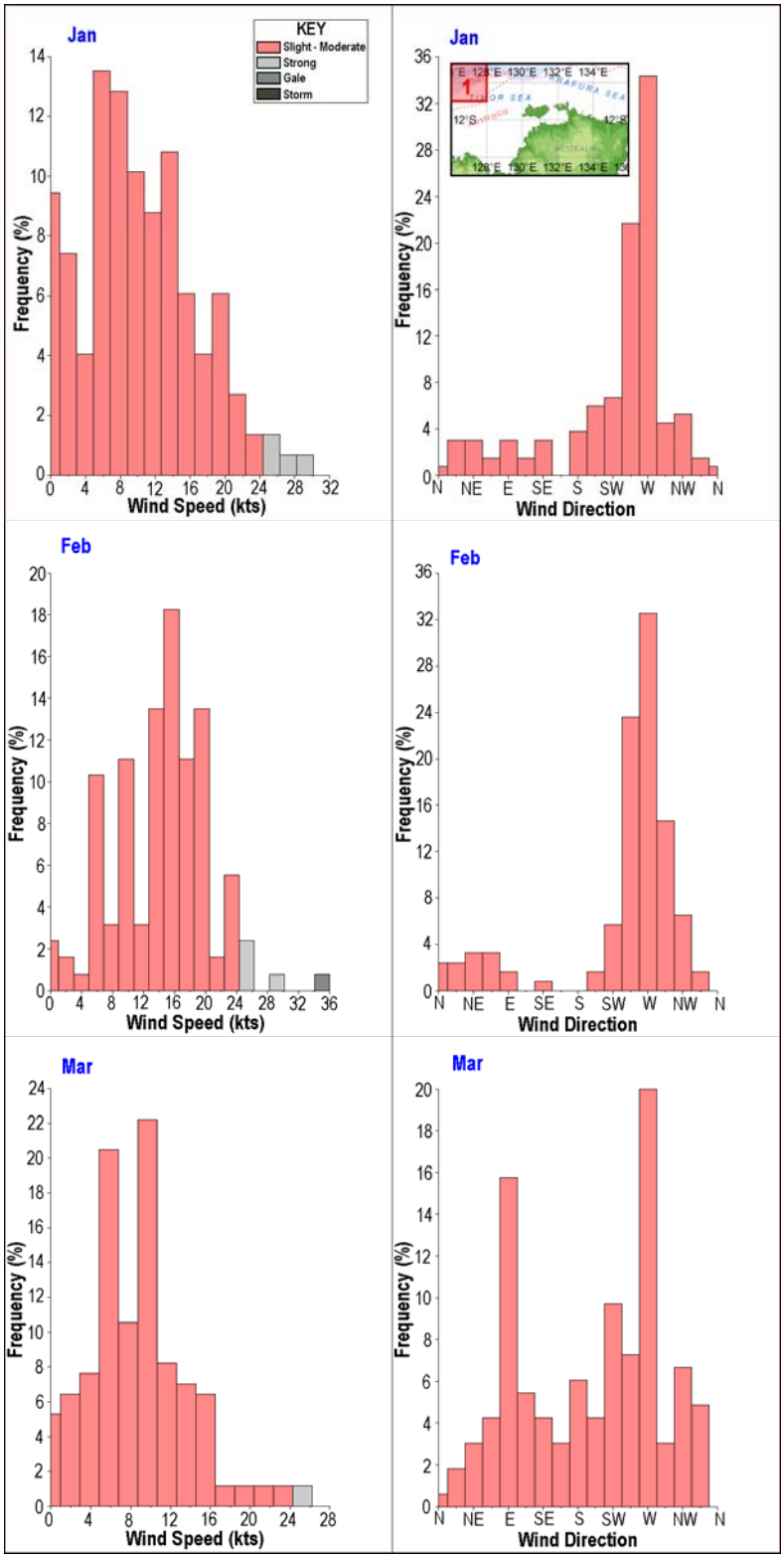


Figure 19: Wind speed and direction frequencies for square 1: 9-11ºS, 126-128ºE. (Source: GMCA, 2008)

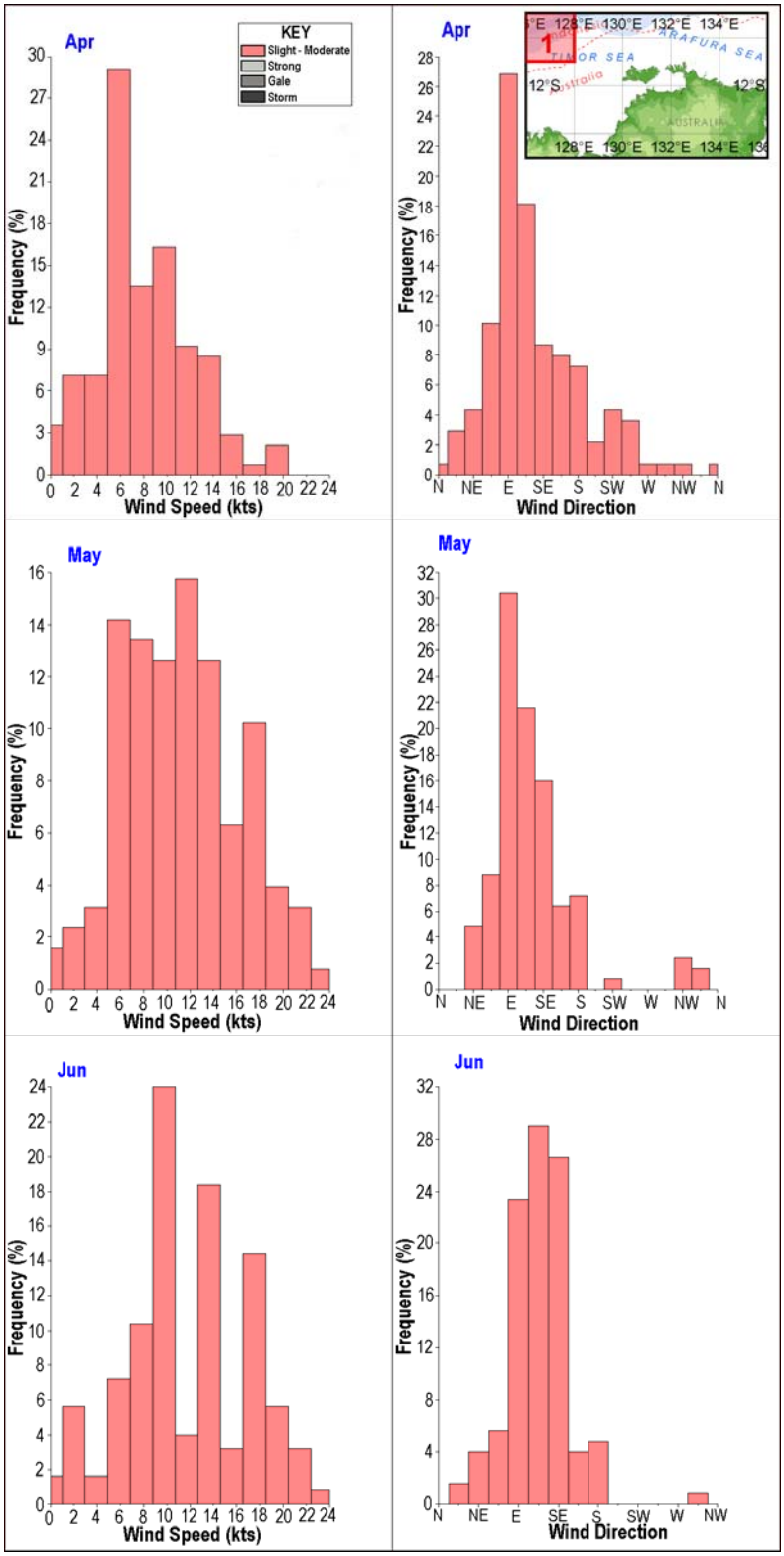


Figure 20: Wind speed and direction frequencies for square 1: 9-11ºS, 126-128ºE (Source: GMCA, 2008)

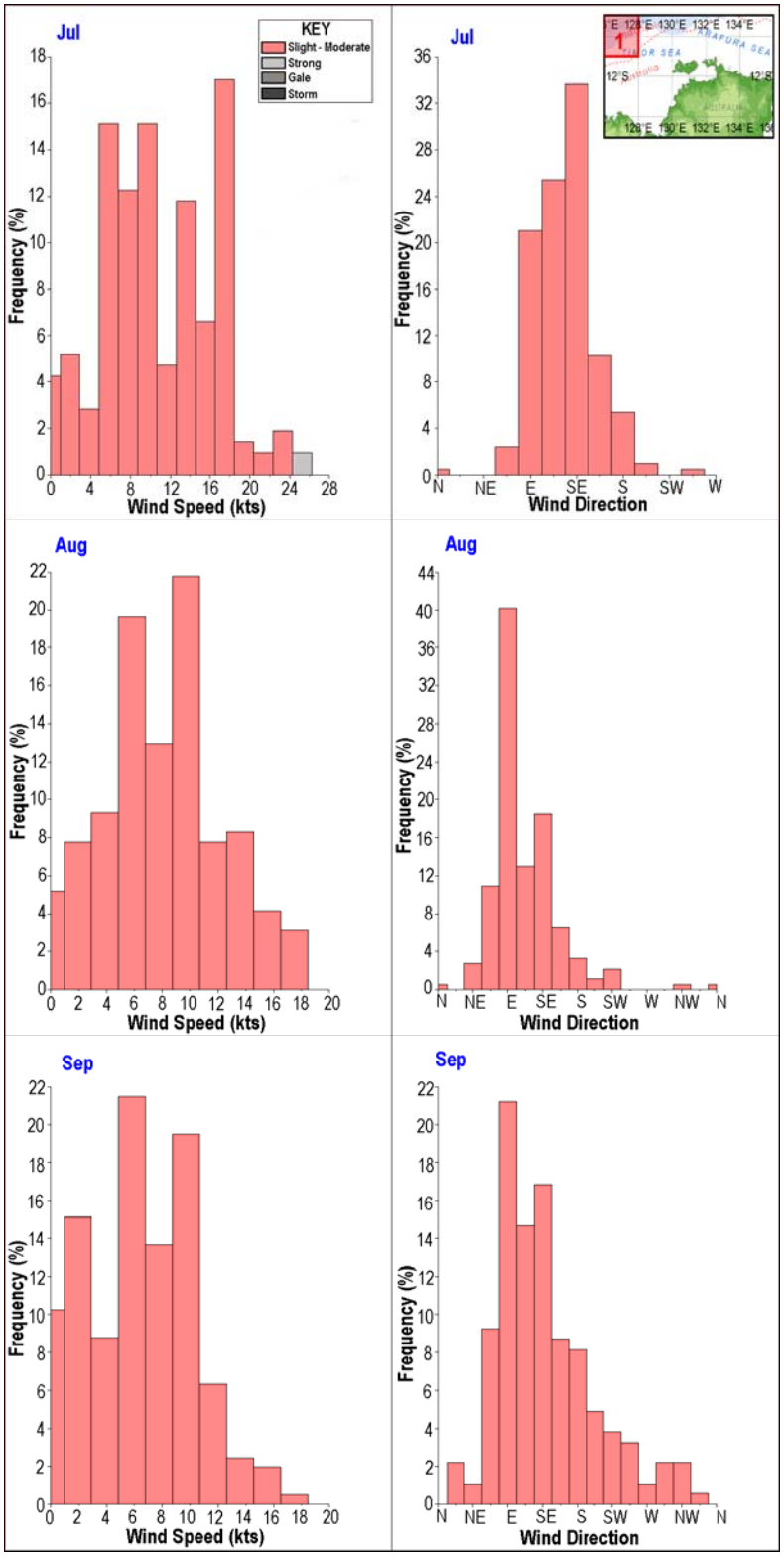


Figure 21: Wind speed and direction frequencies for square 1: 9-11ºS, 126-128ºE (Source: GMCA, 2008)

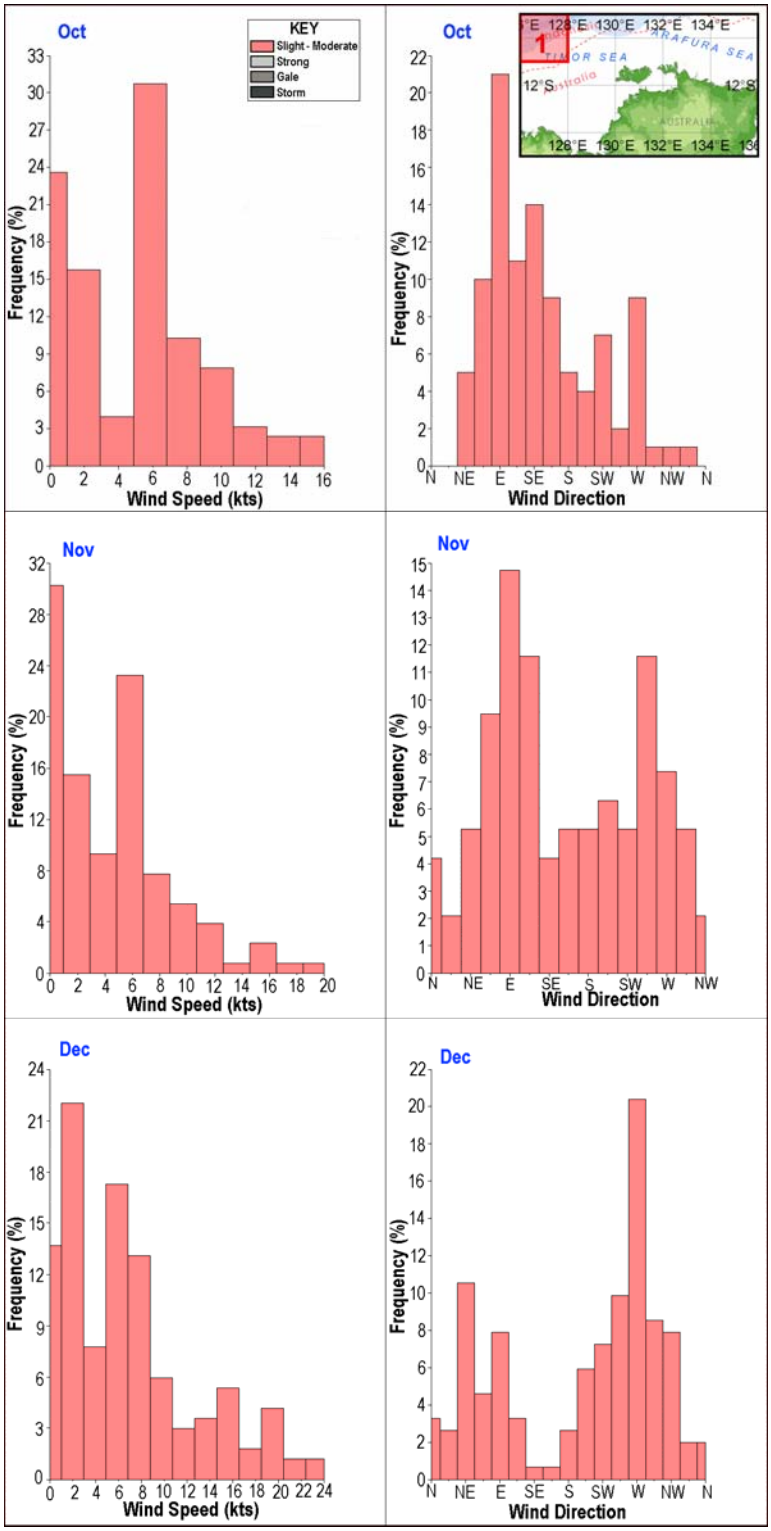


Figure 22: Wind speed and direction frequencies for square 1: 9-11ºS, 126-128ºE (Source: GMCA, 2008)

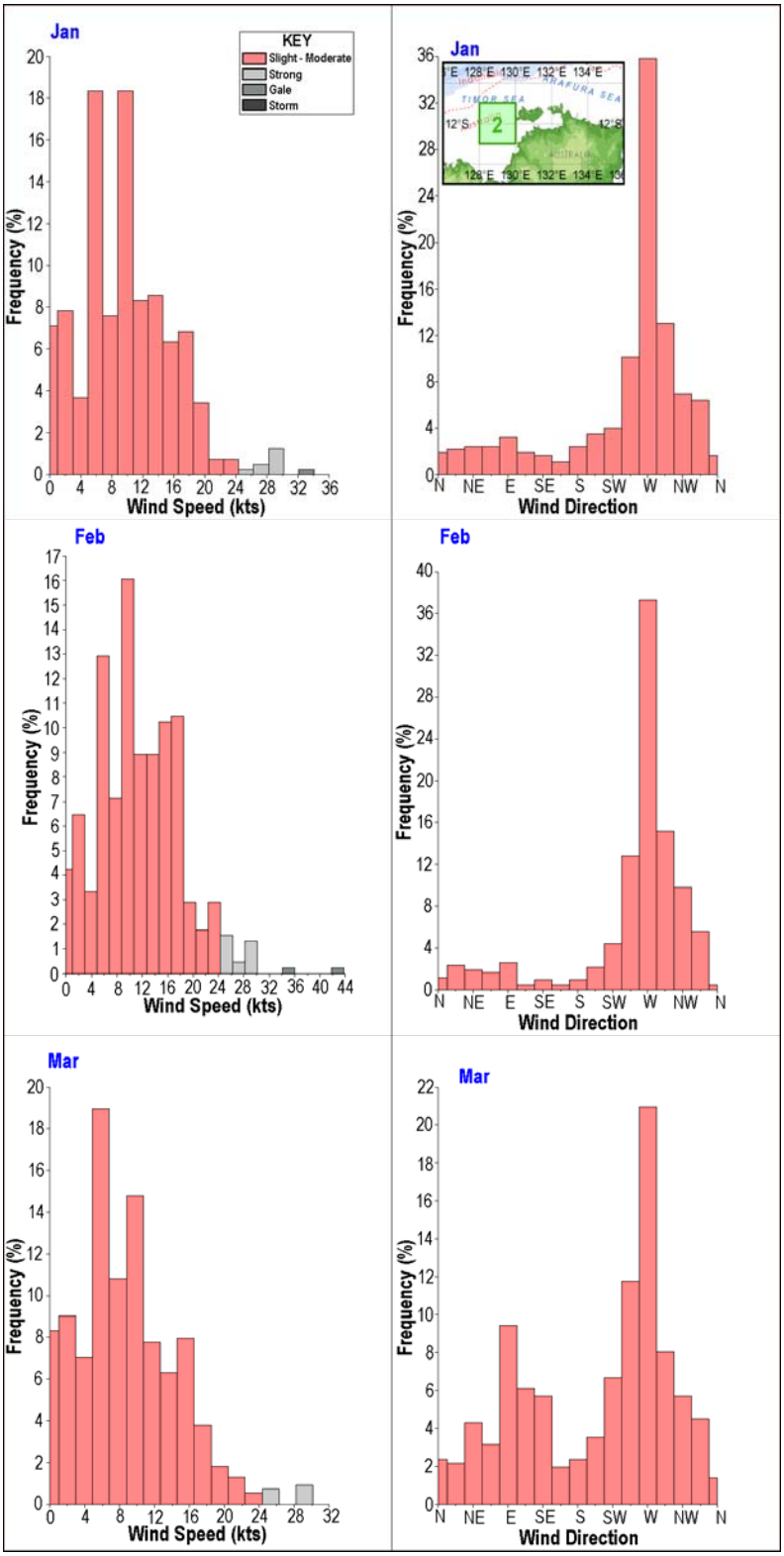


Figure 23: Wind speed and direction frequencies for square 2: 11-13ºS, 128-130ºE (Source: GMCA, 2008)

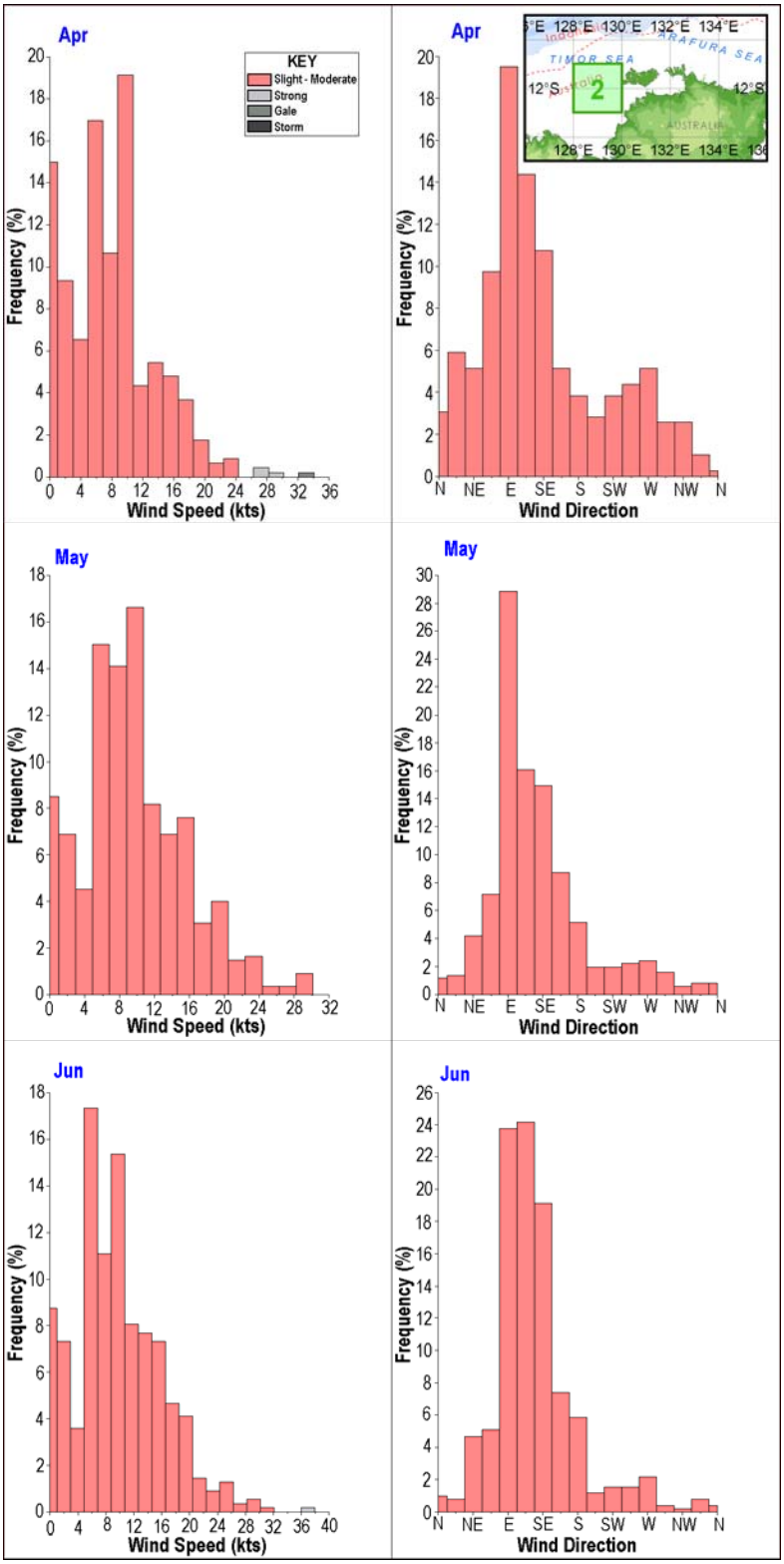


Figure 24: Wind speed and direction frequencies for square 2: 11-13ºS, 128-130ºE (Source: GMCA, 2008)

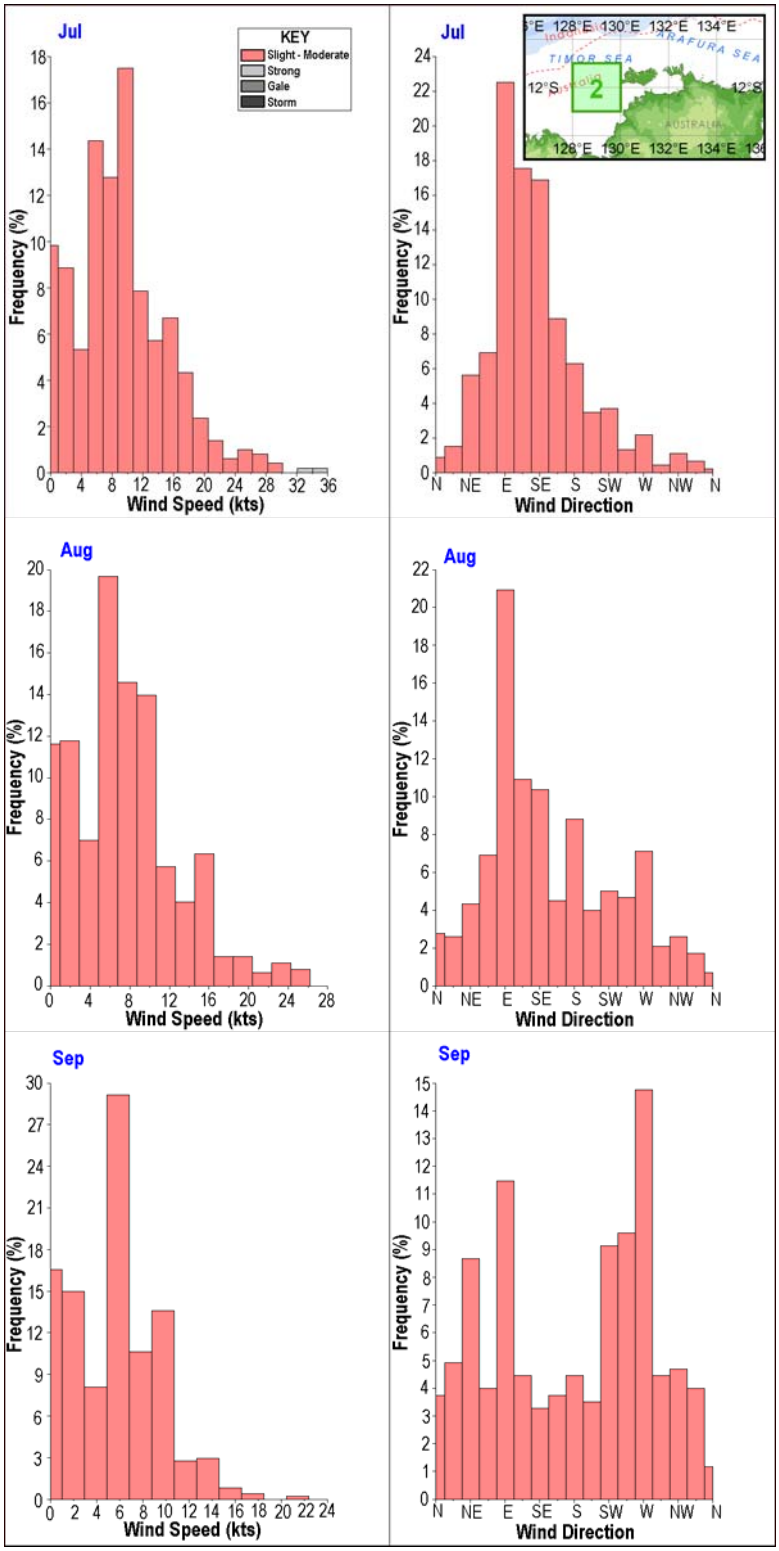


Figure 25: Wind speed and direction frequencies for square 2: 11-13ºS, 128-130ºE. (Source: GMCA, 2008)

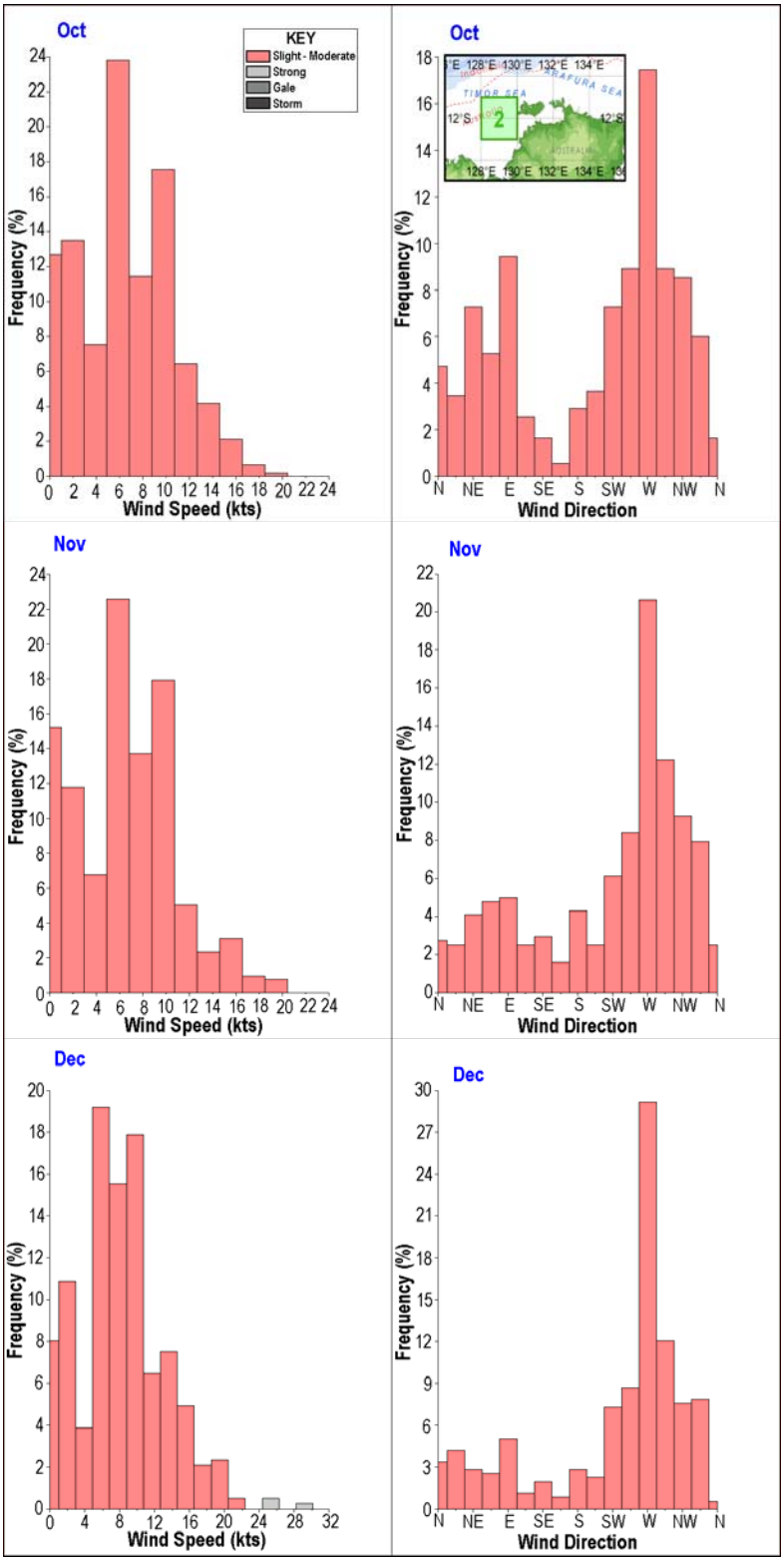


Figure 26: Wind speed and direction frequencies for square 2: 11-13ºS, 128-130ºE (Source: GMCA, 2008)

2.5.1 LAND AND SEA BREEZES

Land and sea breezes are common in the coastal zone, extending from 16 km offshore to approximately 24 km inland (HO, 1992). They are particularly important during calm conditions and transitional periods between SE (winter) and NW (summer) monsoons. Sea breezes blow onshore, commencing around noon and beginning to fade around sunset. Wind speed reaches a maximum strength of 11 to 16 kts in mid-afternoon. Land breezes blow in the opposite direction from around midnight until sunrise and is usually weaker than the sea breeze. Land breezes occur regularly where high ground is located close to the coast, as on the Kimberly coast.

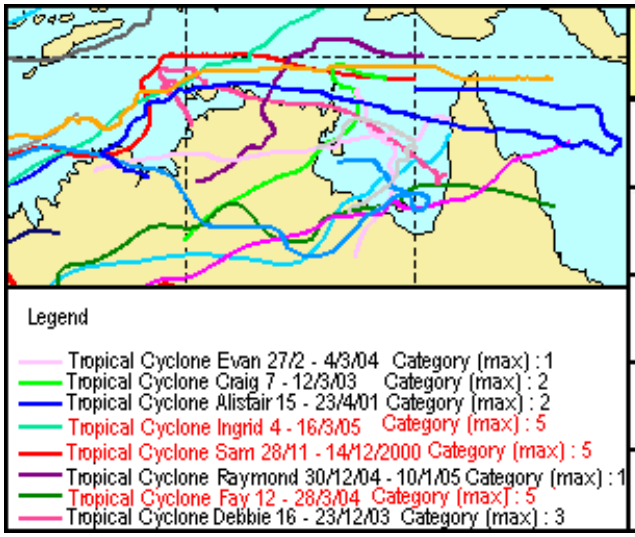
2.6 TROPICAL CYCLONES

Tropical cyclones occur in Australian waters (south of 5ºS) from November to April, with peak activity from January to April, as listed in Table 2.

Table 2: Severe cyclone (>64 kts average max wind speed) occurrence in NAXA from 1842 to 1995. (Source: NMOC/NCDC, 1996)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dec	10	8	11	9	0	0	0	0	0	0	3	5

The average number of cyclones passing within 5º squares of latitude and longitude over the Timor Sea (south of 10ºS) during a decade varies from a maximum of 2.4 in March to a minimum of 0.6 for February (Lourensz, 1981). However, there are significant yearly and long term (decade to decade) variations in cyclonic activities. Tropical depressions can occur at any time of the year (HO, 1992). Figure 27 shows tracks of tropical cyclones passing through NAXA from June 2000 to June 2005.



Cyclone Category	Average maximum wind speed (kt)
1	34 - 48
2	49 - 63
3	64 - 86
4	86 - 108
5	>109

Figure 27: Tracks of cyclones from 2000 – 2005. (Source: BoM, 2008)

Some significant cyclones; cyclone category 3 – 5, in the area include cyclone Thelma, Helen, Monica, Ingrid, Sam and Faye. One of the most intense Tropical Cyclones ever observed around Australia was Cyclone Thelma. **Figure** 28 and **Figure** 29 shows the track and satellite image of 'Thelma,' Thelma formed in the Arafura Sea and intensified rapidly into a category 5 cyclone drifting to the southwest, passing north of Melville Island then across the Timor Sea before crossing the Kimberley coast (BoM, 2003).

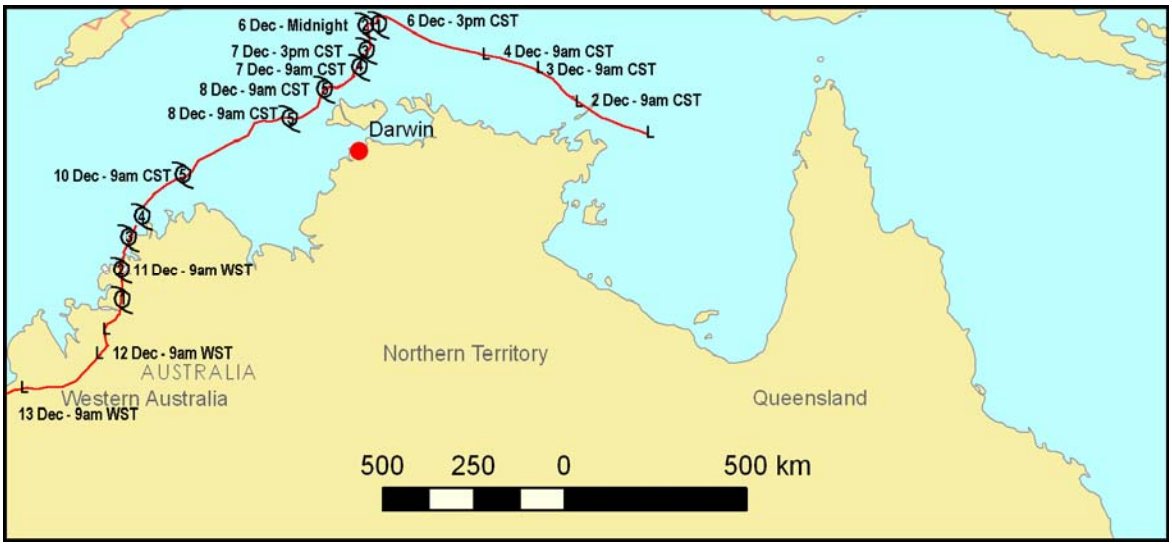


Figure 28: Track of tropical cyclone 'Thelma', December 1998.
(Source: BoM, 2003)

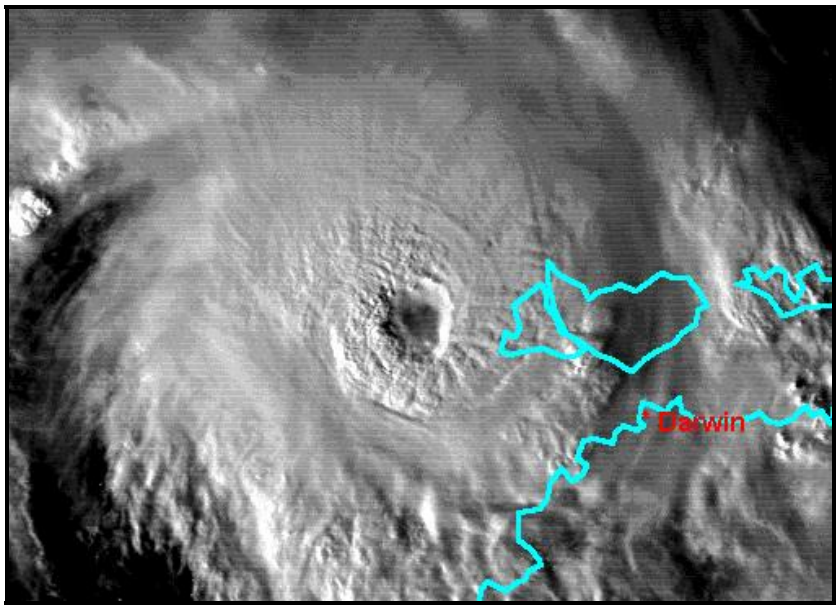


Figure 29: Satellite Image of tropical cyclone 'Thelma', December 1998.
(Source: BoM, 2008)

Severe Tropical Cyclone Ingrid (Figure 30) caused significant impact on the Australian coast in March 2005. It was unusual in that it is the only cyclone in recorded history to impact, as a severe tropical cyclone, on the coastline of three different States or Territories. It crossed the Queensland east coast south of Lockhart River at Category 4; moved across the Gulf into the Northern Territory and impacted on the small islands north of the Arnhem Land coast as a Category 5 cyclone, weakened slightly to Category 4 as it crossed Croker Island and the Cobourg Peninsula; was at Category 3 intensity as it traversed the Tiwi Islands north of Darwin; and finally reintensified to Category 4, before making a final landfall on the West Australian Kimberley coast at that intensity.

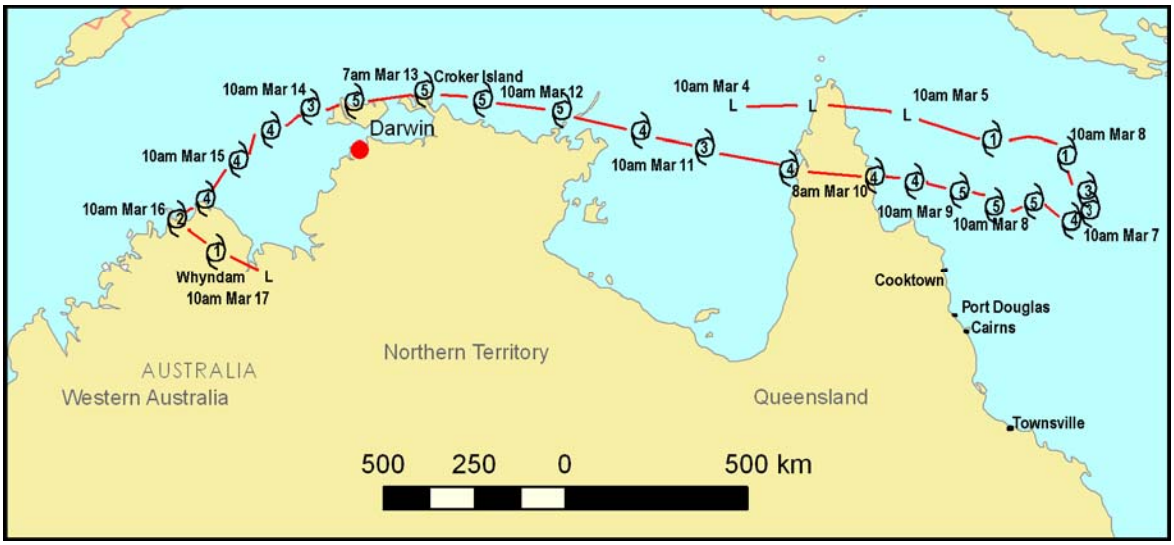


Figure 30: Track of tropical cyclone 'Ingrid', March 2005.

(Source: BoM, 2008)

Tropical Cyclone Fay (Figure 31) intensified reaching peak intensity late on the 21st March 2004 approximately 280 km north northwest of Cape Leveque when wind gusts near the centre were estimated to be about 300 km/h (Severity Category 5). *Fay* continued moving in a general west southwest direction until the 23rd when it abruptly turned to the south southeast toward the west Kimberley coast and weakened to a category 2 system. Early on the 25th *Fay* re-intensified to category 3 and approached to within 90 kilometres of Broome before taking on a more south-westerly track. Broome experienced strong winds with gale-force gusts, some heavy rain and heavy seas but escaped serious damage. *Fay* then headed further away from the coast on the 25th before resuming a general southerly track on the 26th crossing the Pilbara coast between the pastoral stations of Pardoo and Wallal between 8am and 9am on Saturday the 27th as a Category 4 storm with estimated maximum wind gusts of around 235 km/h near the centre. The cyclone began weakening as it moved further inland. It passed close to the Yarrie mine where accommodation units were blown over and some other structural damage occurred. *Fay* appears to have weakened below cyclone strength on Sunday evening between Nullagine and Telfer (BoM, 2008).

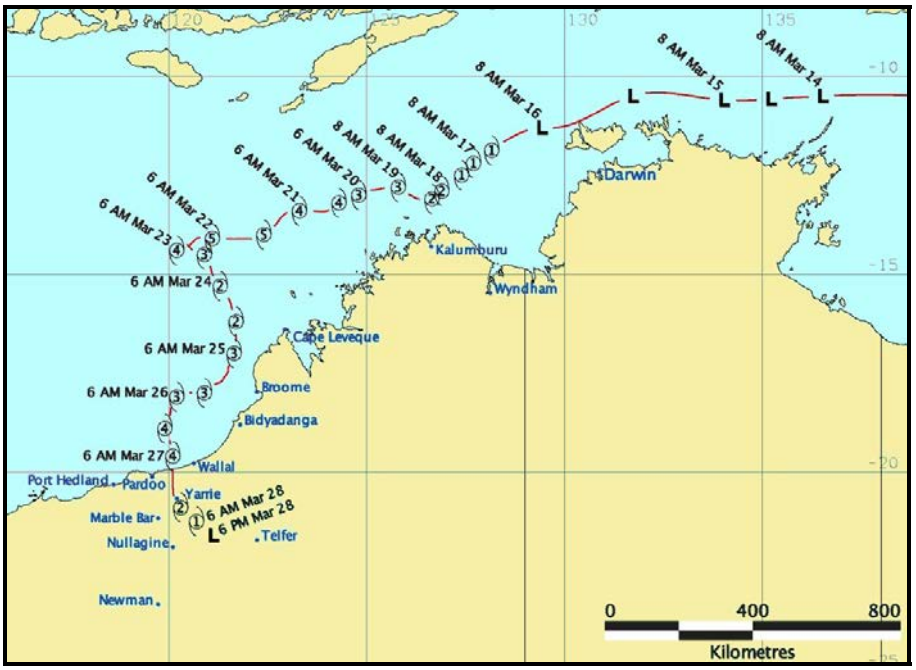


Figure 31: Track of tropical cyclone Fay, March 2004
(Source: BoM, 2008)

Current information and predictions on tropical cyclones in the area can be obtained from the Bureau of Meteorology at http://www.bom.gov.au/weather/nt/cyclone/ or the US Naval Pacific Meteorology & Oceanography Centre at http://www.npmoc.navy.mil/jtwc.html.

2.7 PRECIPITATION

Rainfall is strongly seasonal in northern Australia and most of it occurs from December to March. June to August are the driest months of the year. Over the Timor Sea, rainfall averages are low, approximately 1000 - 1500 mm per year. Most of the rainfall occurs during November to April. From April to September rainfall is low and there may be long periods (several months) with little or no rain at all. The average monthly rainfall at Darwin and other stations are included in Figure 3 to Figure 9. Mean rainfall over the Timor Sea in the exercise area ranges from approximately 13 mm per day during summer to less than 0.5 mm per day during winter, as shown by the satellite sourced data in Figure 32 and Figure 33.

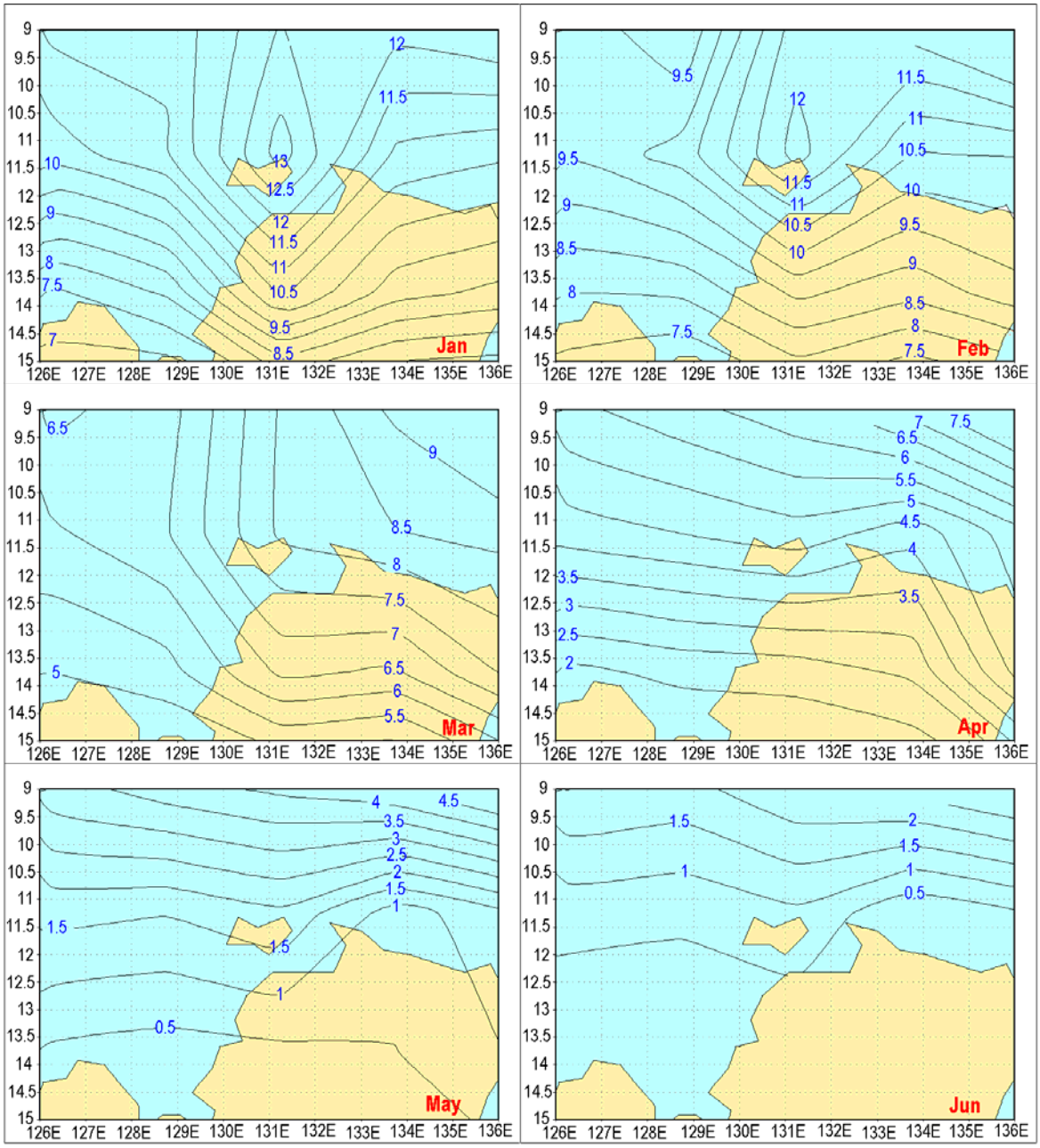


Figure 32: Mean rainfall (mm/day) for January to June.
(Source: ICOADS, 2008)

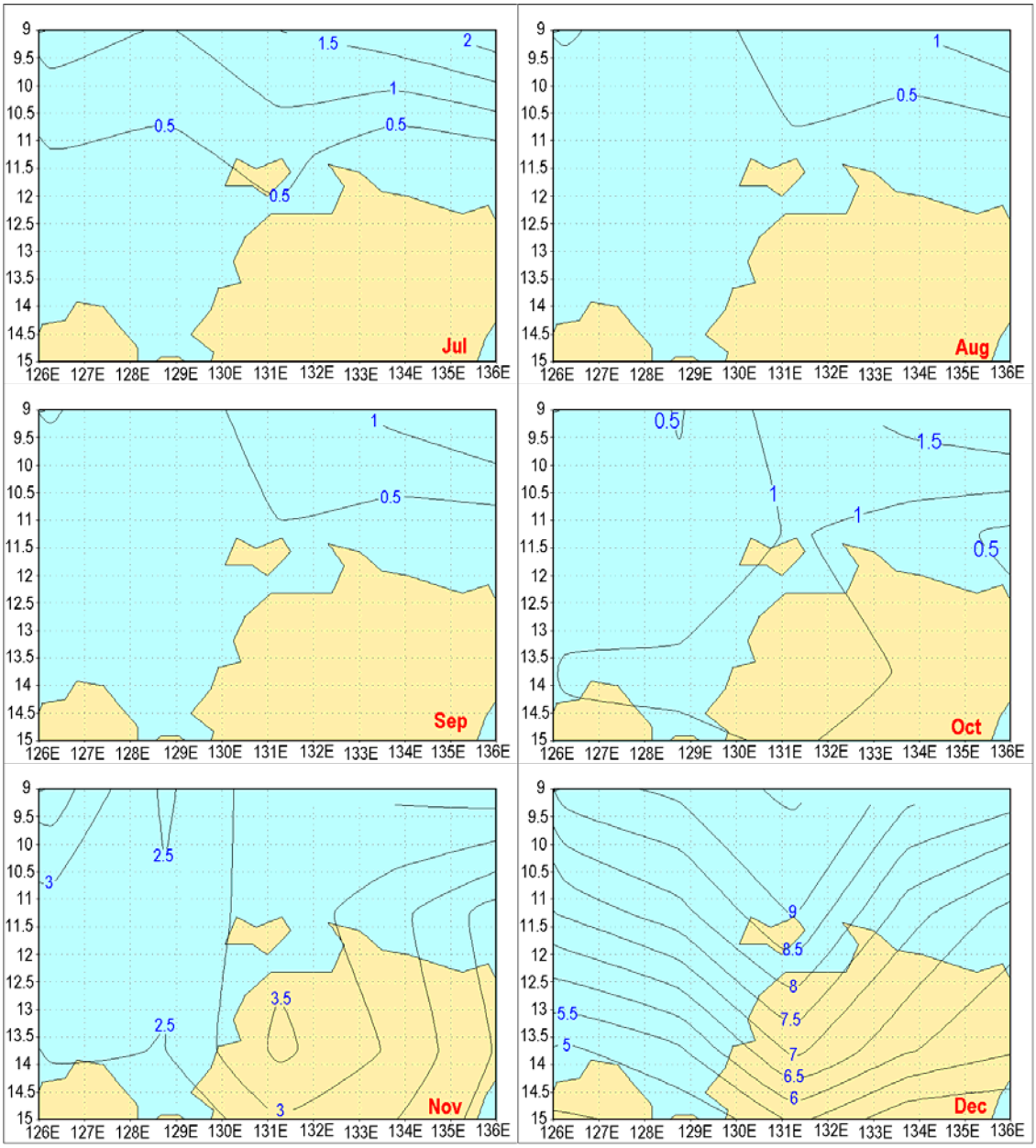


Figure 33: Mean rainfall (mm/day) for July to December.
(Source: ICOADS, 2008)

2.8 THUNDERSTORMS

Thunderstorms occur on an average of 80 days per year around Darwin, between November and March (HO, 1992). In the early part of the wet season in November and early December (known locally as the "build up") the thunderstorms in Darwin and along the coast often result in little rain, despite spectacular displays of cloud, lightning and squalls. The mean number of thunderstorms at other meteorological stations in the region are shown in Figure 3 to Figure 7. The average annual thunder days and lightning flash density in the area is shown in Figure 34 and Figure 35.

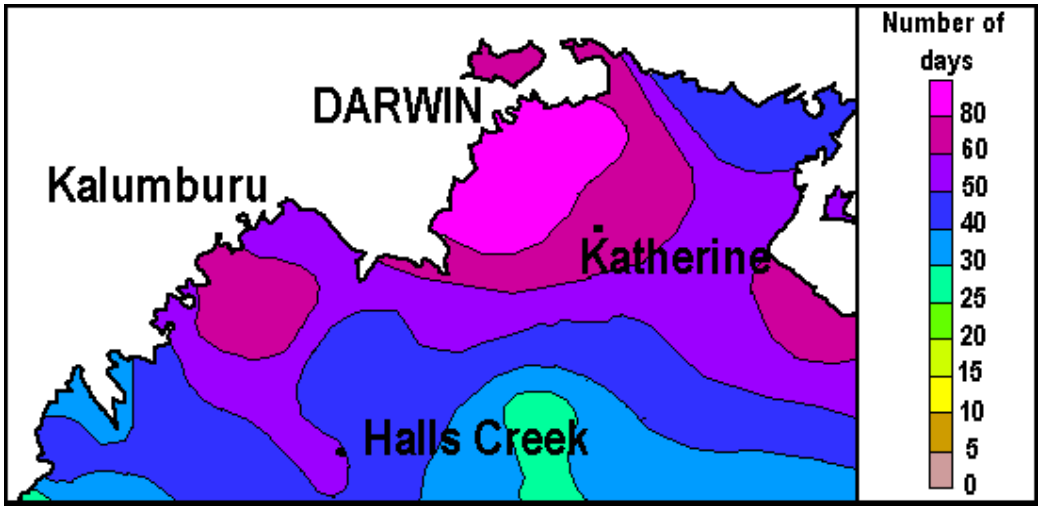


Figure 34: Average annual thunder days.
(Source: BoM, 2008)

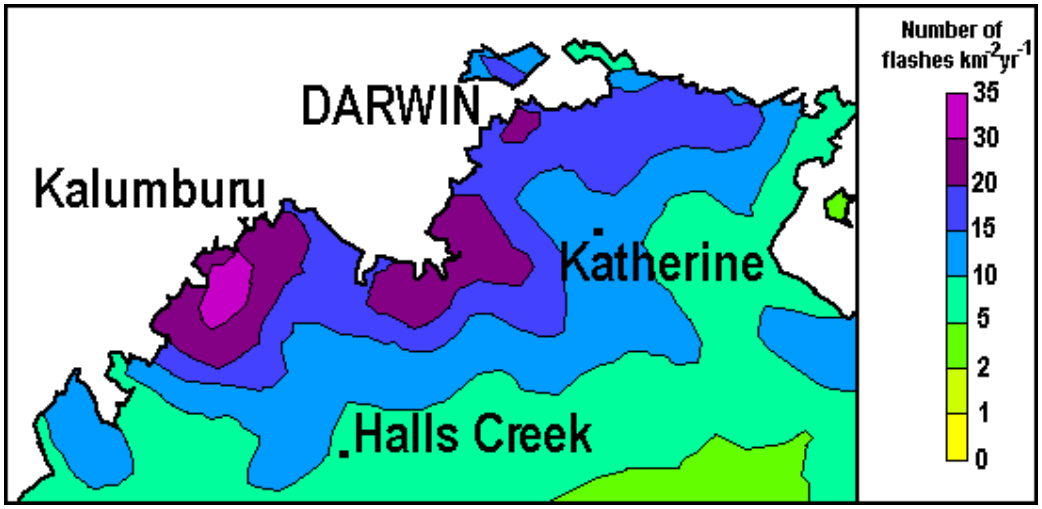


Figure 35: Average annual total lightning flash density.
(Source: BoM, 2008)

2.9 FOG AND VISIBILITY

Visibility is generally good at sea, and sea fog is practically unknown. However, haze, smoke and dust can significantly reduce visibility during the dry season, particularly during the drought years when visibility of 1 to 6 nmiles is normal. The sky may become obscured at some places off the N and NW coast of Australia due to haze (HO, 1992). From June onwards, smoke from bush fires is carried offshore by the prevailing E or SE winds. The Timor Sea is particularly affected and as the year advances, bush fires occur more frequently and haze increases. Haze is at its worst from August to October. Dust raised by strong winds in the dry interior of Australia compounds the haziness, especially in drought years (HD, 1992). Mean number of days with fog, haze and smoke at meteorological stations around NAXA are shown in Figure 3 to Figure 9. Visibility data were obtained from the 2º chart square over the Timor Sea, shown in Figure 18, and are shown as % frequency distribution plots in Figure 36 to Figure 39. Modal visibility is about 20 km over this central part of the Timor Sea throughout the year.

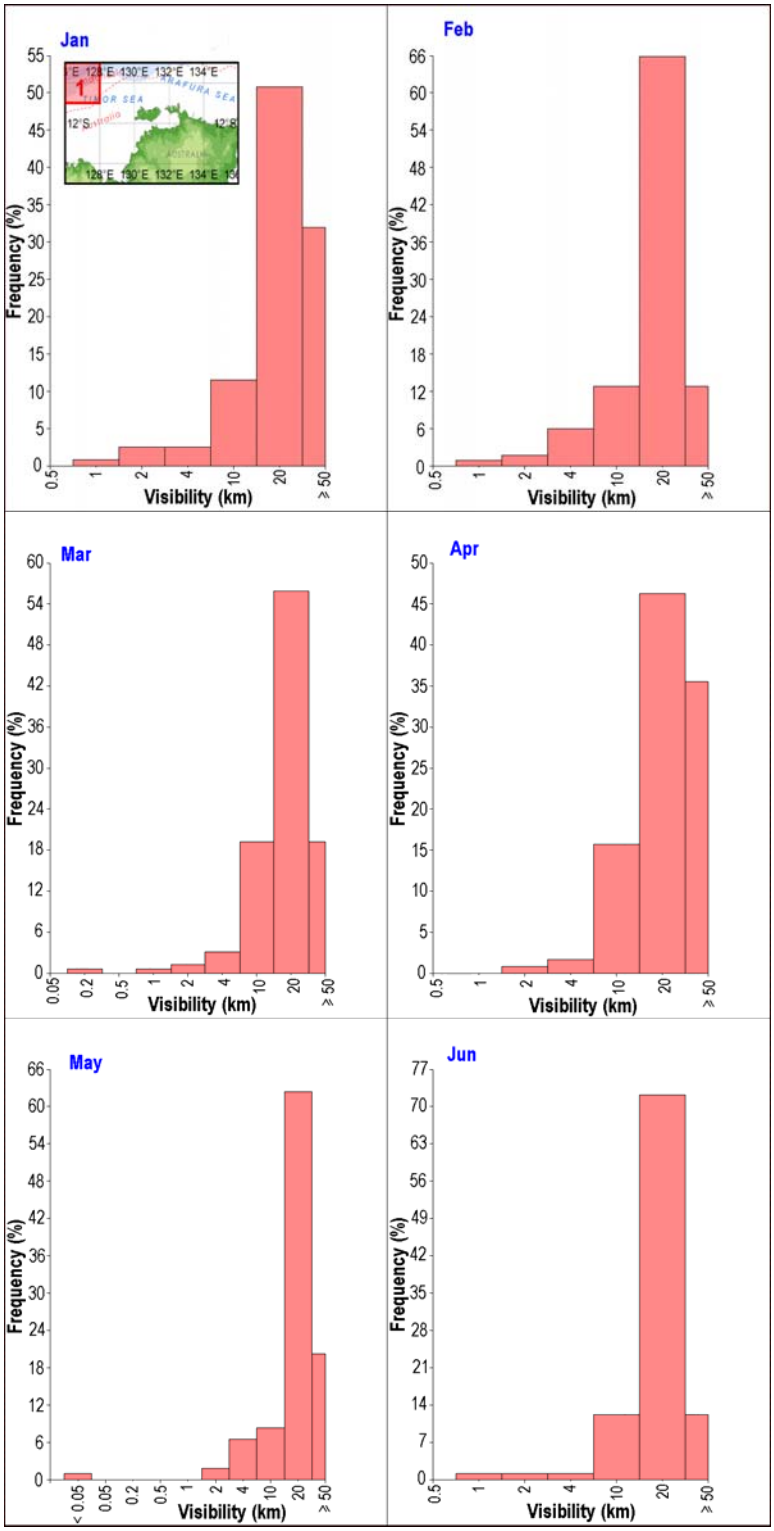


Figure 36: Visibility distance frequencies for square 1: 9-11ºS, 126-128ºE (January to June). (Source: GMCA, 2008)

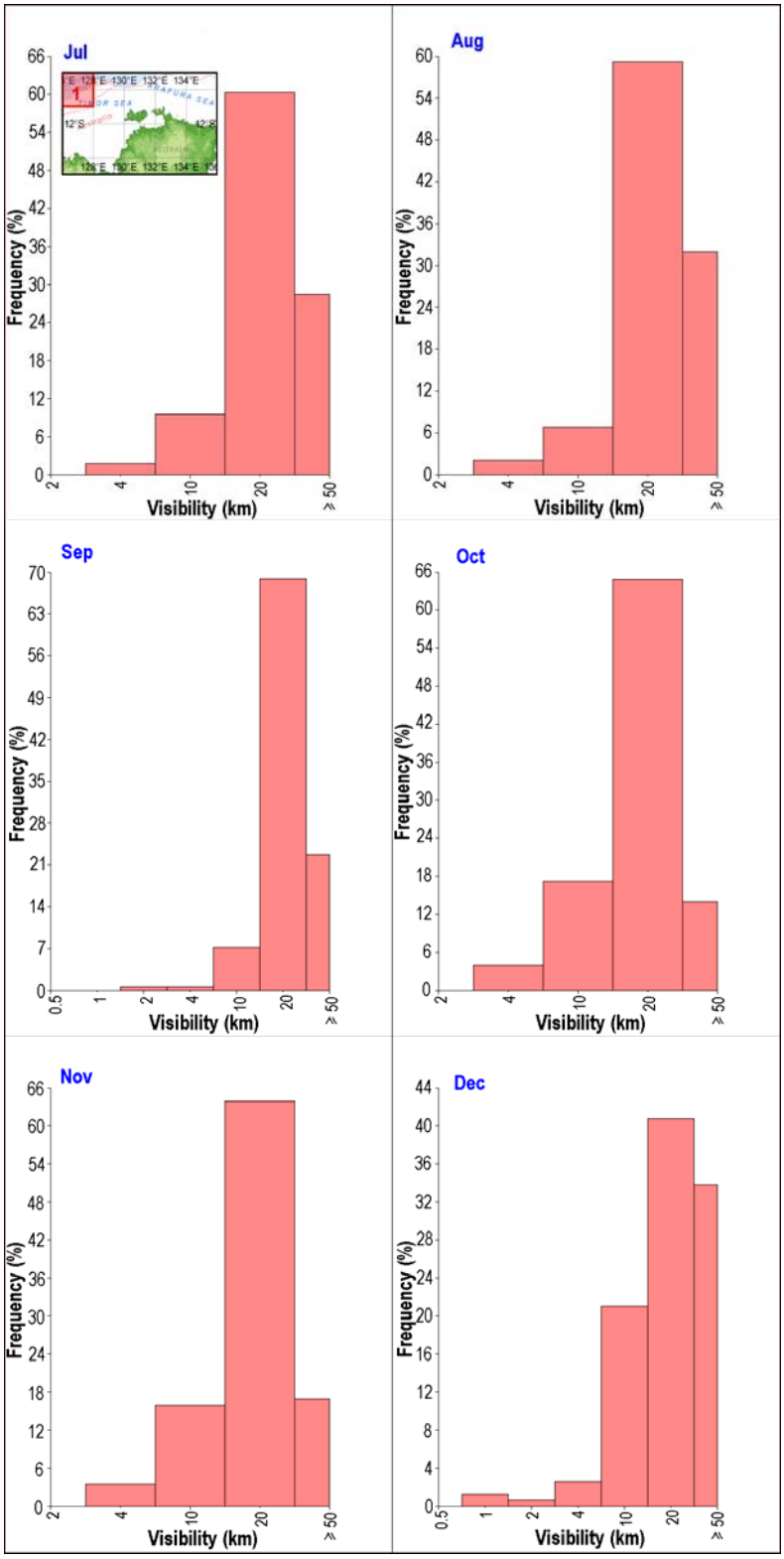


Figure 37: Visibility distance frequencies for square 1: 9-11ºS, 126-128ºE (July to December). (Source: GMCA, 2008)

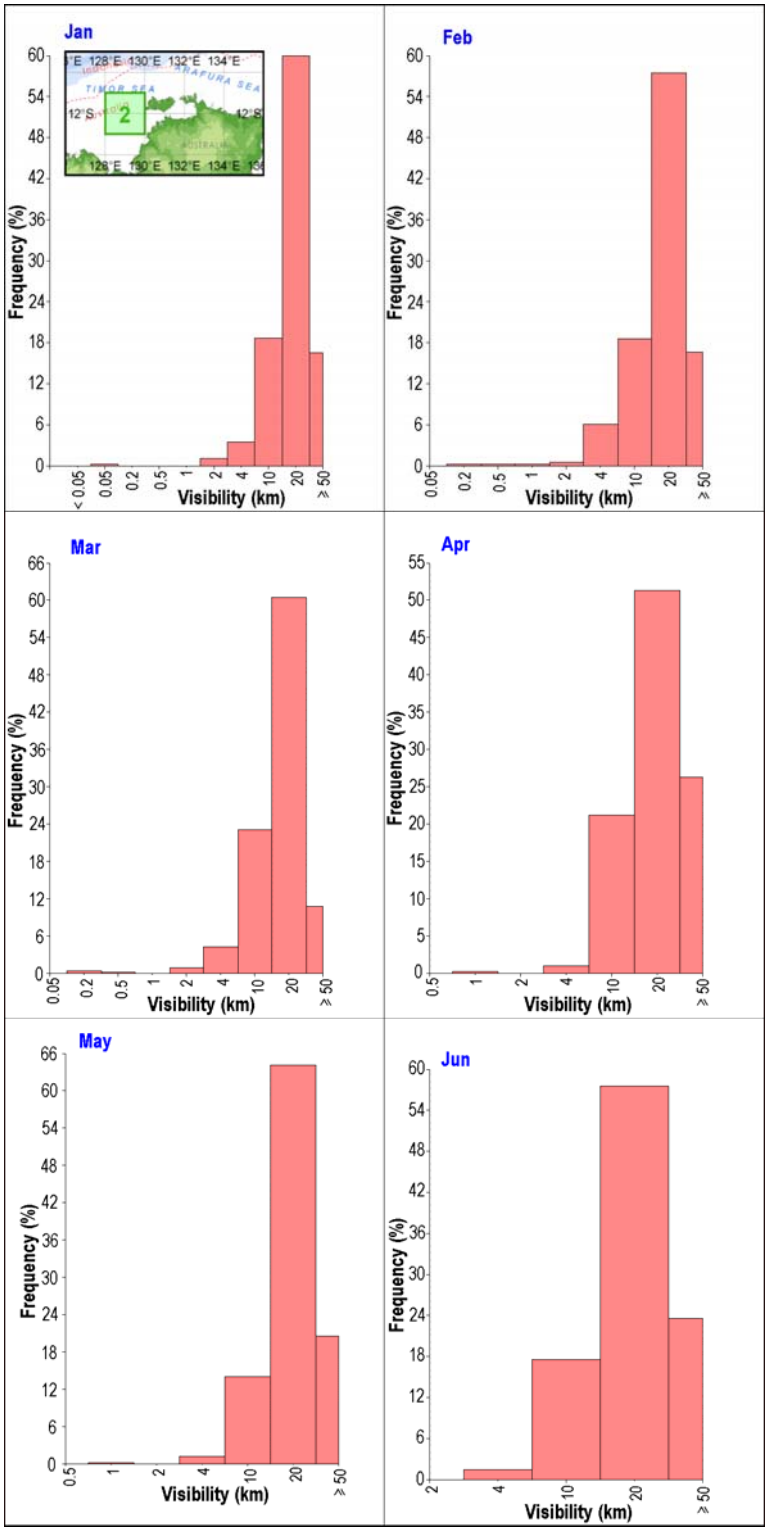


Figure 38: Visibility distance frequencies for square 2: 11-13ºS, 128-130ºE (January to June). (Source: GMCA, 2008)

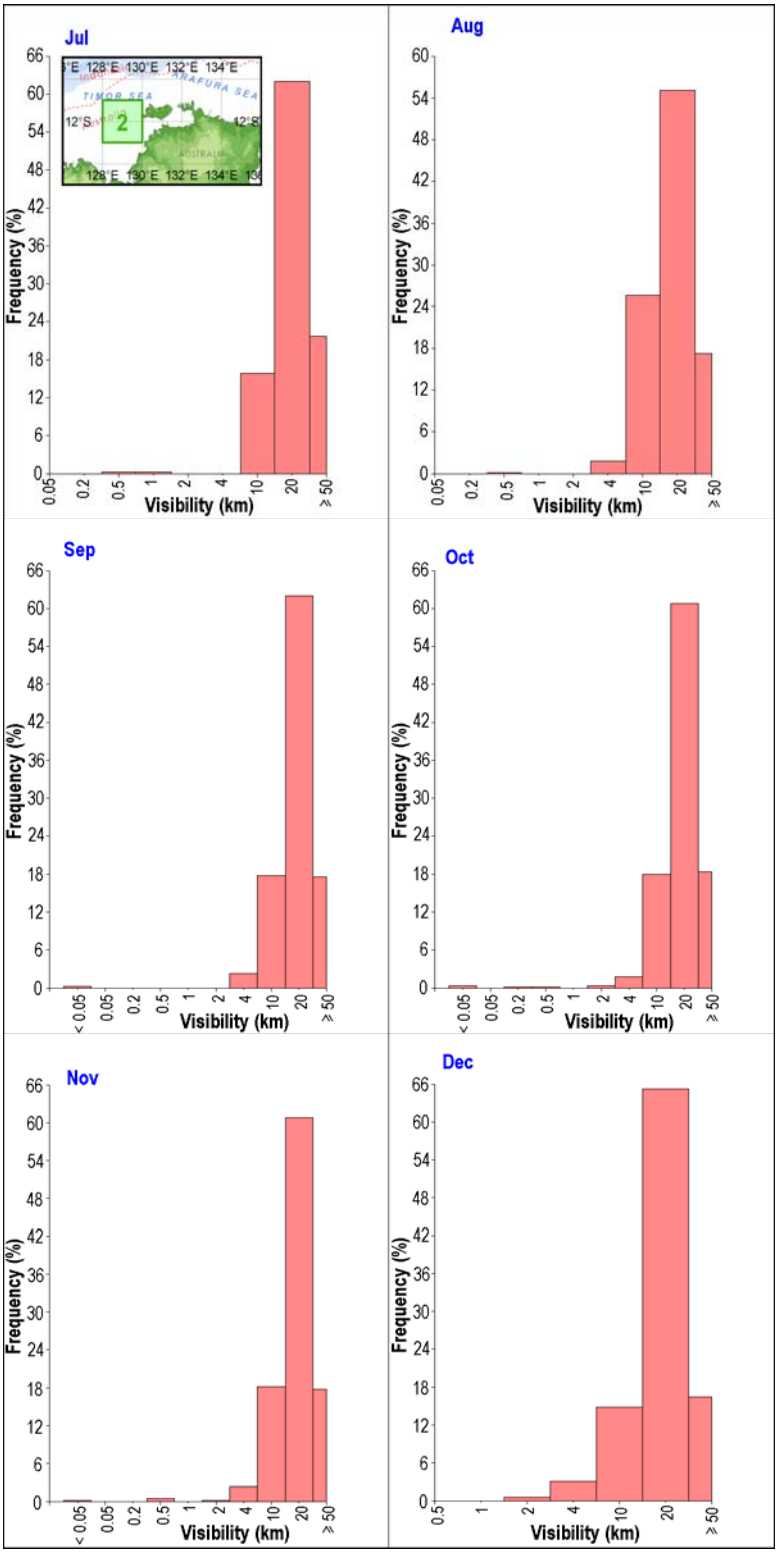


Figure 39: Visibility distance frequencies for square 2: 11-13ºS, 128-130ºE (July to December). (Source: GMCA, 2008)

2.10 CLOUD COVER

Along the north coast of Australia, cloud amount begins to decrease at the end of the "wet" season and the broken skies of the SE trade wind season become frequent. The seasonal variation in mean cloud cover over the open sea ranges from around 5 oktas in summer to around 2 oktas in winter, as shown in Figure 40 and Figure 41.

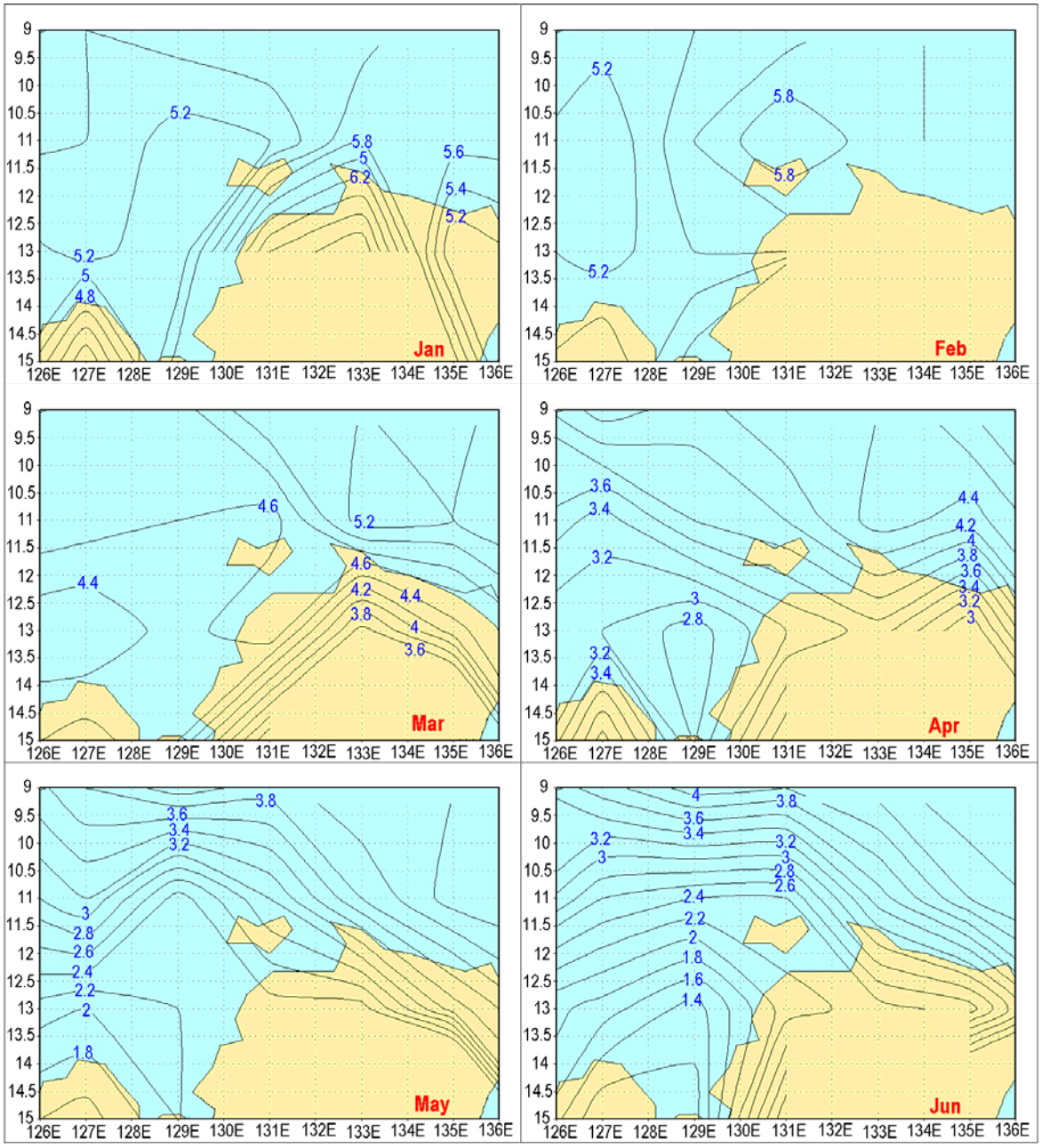


Figure 40: Mean cloud cover (okta) for January to June.
(Source: ICOADS, 2008)

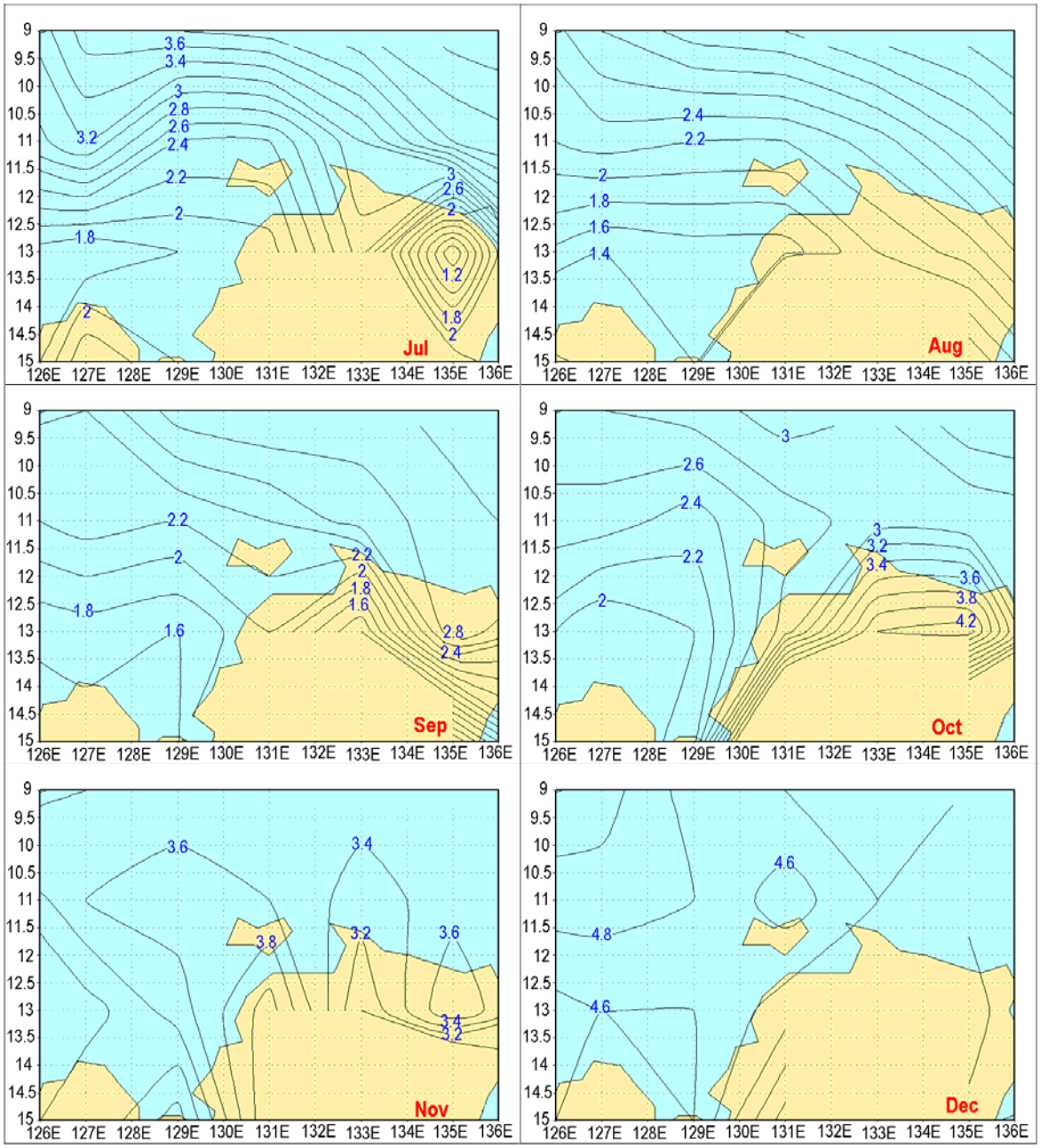


Figure 41: Mean cloud cover (okta) for July and October.
(Source: ICOADS, 2008)

Depending on the local topography and exposure to monsoons, considerable variation in cloudiness occurs in coastal waters. There is also a significant daily variation in the amount of clouds close to the coast which is not so pronounced in the open sea. Usually there is little to no cloud in the early morning along the coast. Small cumulus cloud develops by midday and builds up to heavy cumulo-nimbus cloud by the late afternoon. Then the amount of cloud decreases after the sunset. The appearance of any extensive or unusual cloud formation should be

regarded as possible indications of approaching bad weather, particularly if accompanied by a significant fall in pressure.

Cloud data were obtained from the 2º chart square over the Timor Sea, shown in Figure 18, and are shown as % frequency distribution plots in Figure 42 to Figure 45. The greater cloud cover during the peak of the summer wet season (December to February) is in contrast to the clearer skies of the winter dry season (June to November). There are cloudy skies up to April, the cloud cover decreases from March to April followed by clearer skies in May.

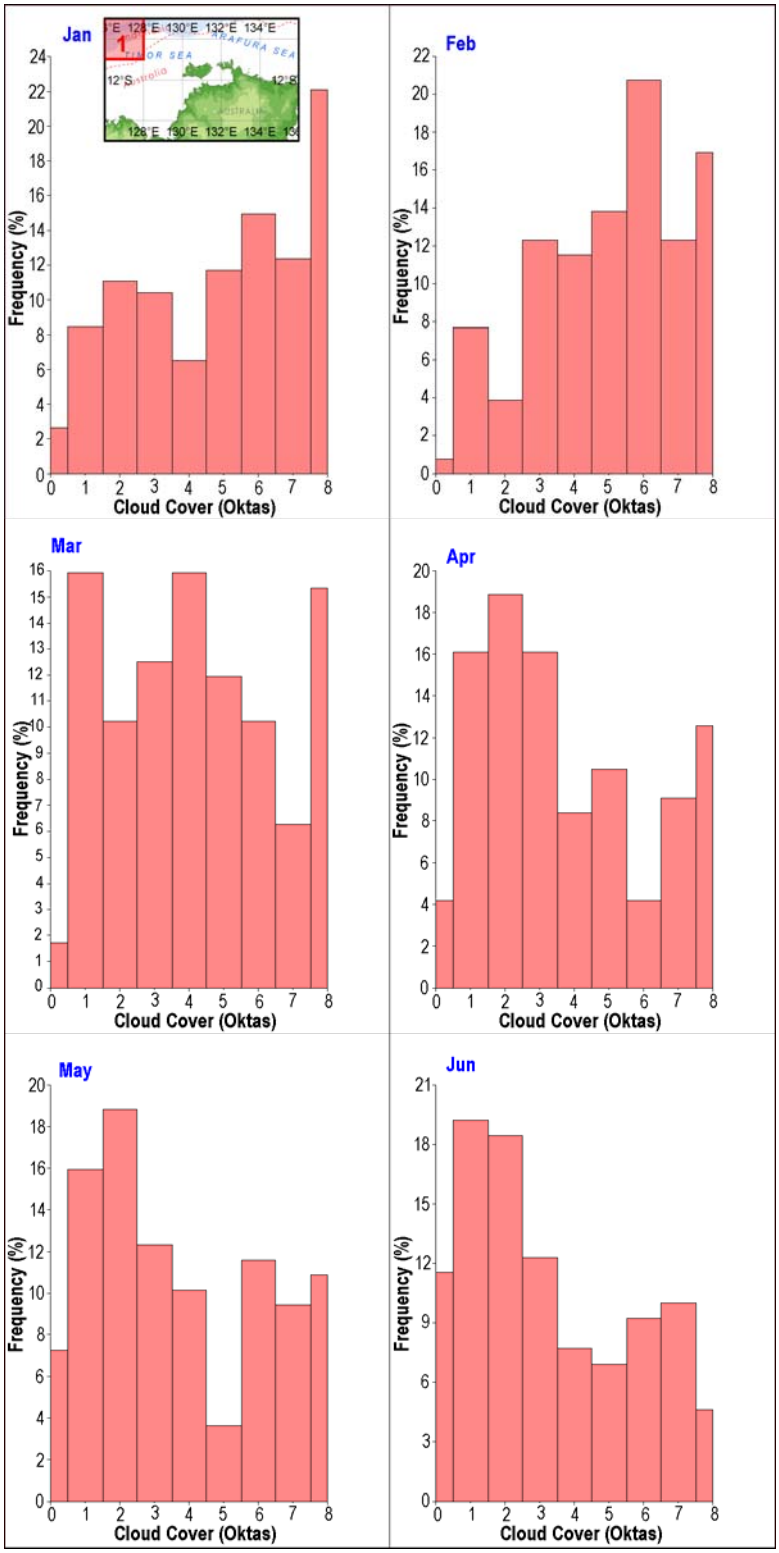


Figure 42: Cloud cover frequencies for square 1: 9-11ºS, 126-128ºE (January to June). (Source: GMCA, 2008)

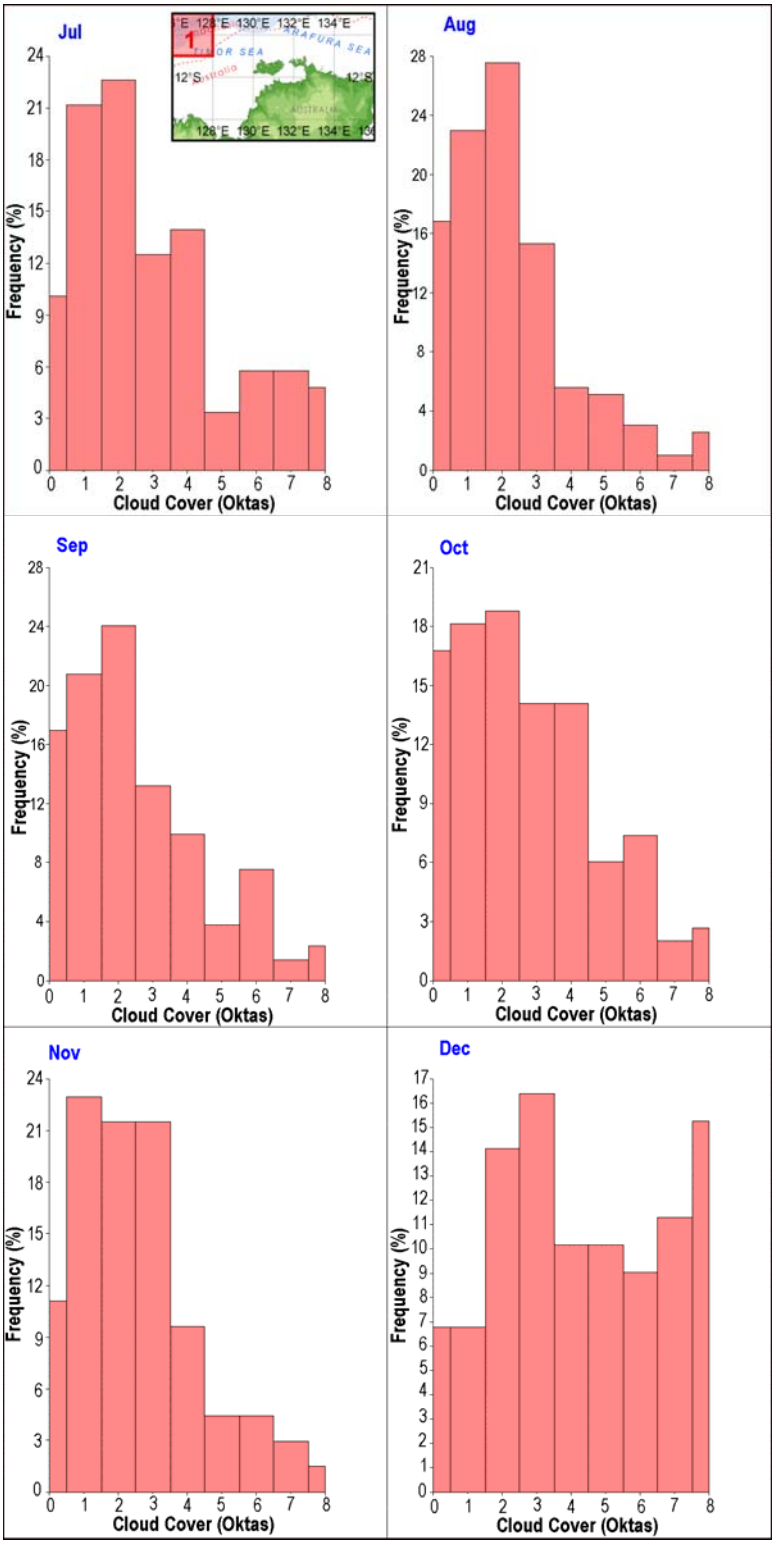


Figure 43: Cloud cover frequencies for square 1: 9-11ºS, 126-128ºE (July to December). (Source: GMCA, 2008)

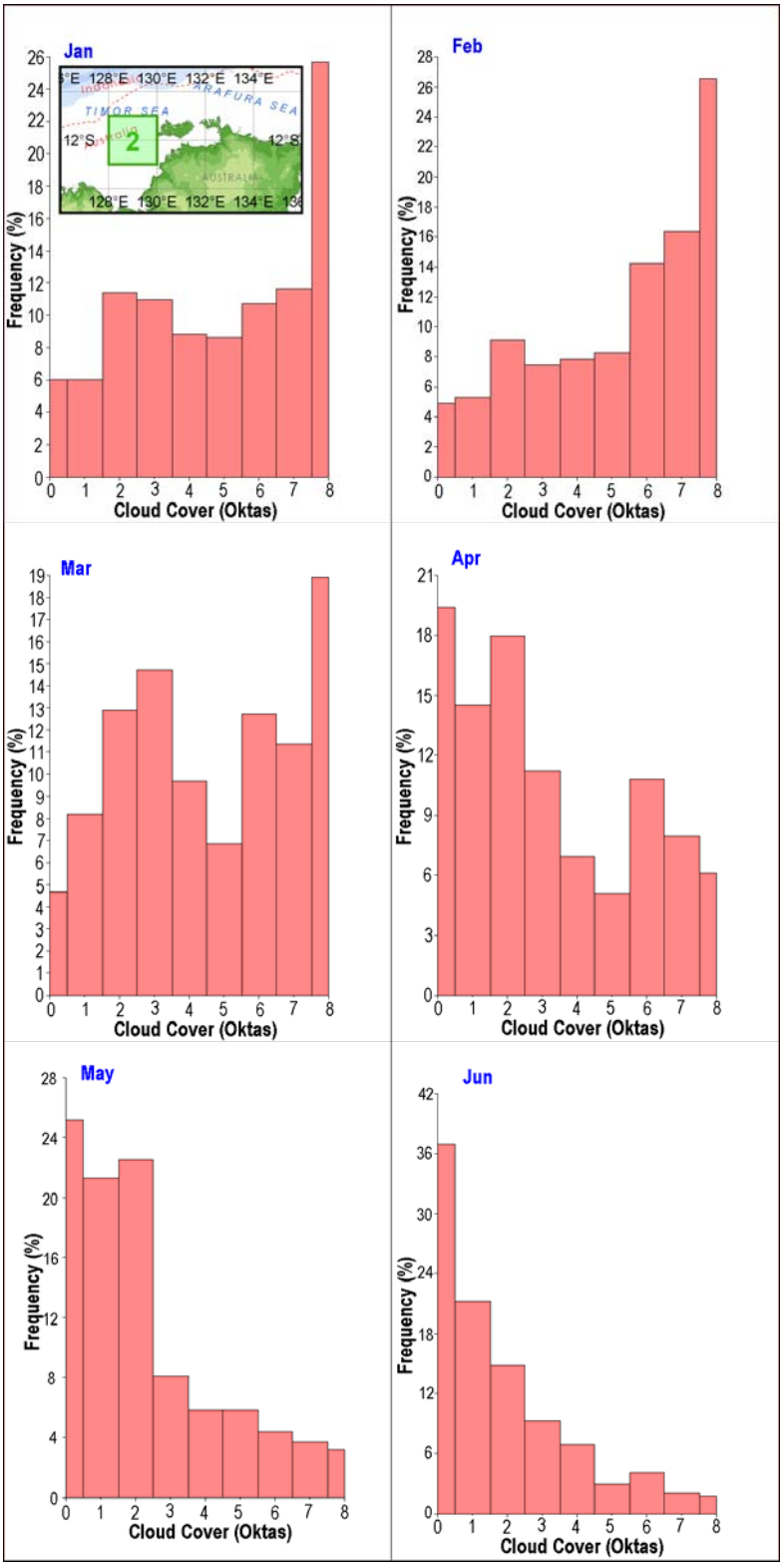


Figure 44: Cloud cover frequencies for square 2: 11-13ºS, 128-130ºE (January to June). (Source: GMCA, 2008)

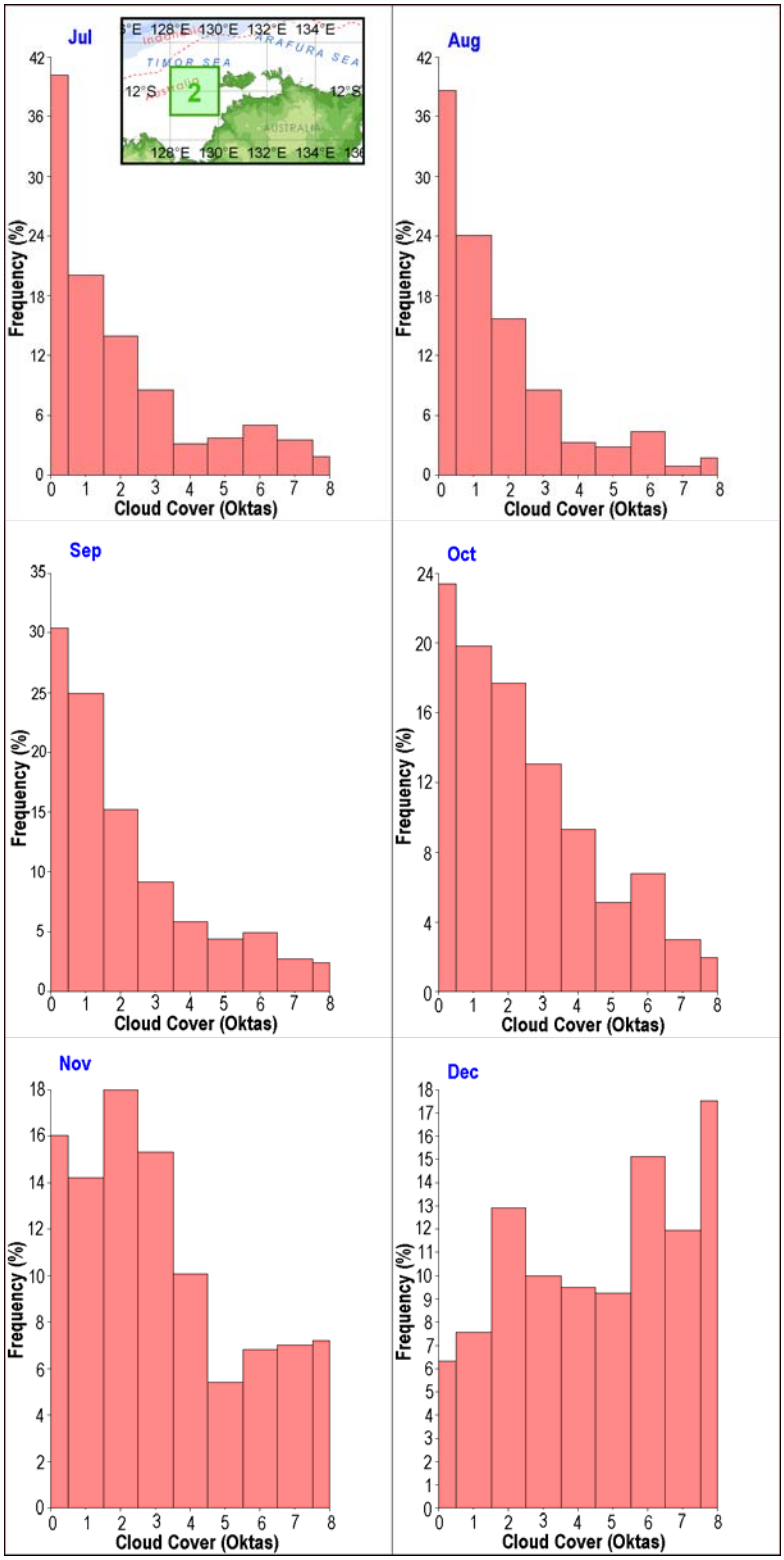


Figure 45: Cloud cover frequencies for square 2: 11-13ºS, 128-130ºE (July to December). (Source: GMCA, 2008)

2.11 RELATIVE HUMIDITY

Relative humidity undergoes a significant diurnal range of variation in the coastal zone, as shown in **Figure 3** to **Figure 9** rising to its maximum around dawn (temperature min) and decreasing to its minimum in the early afternoon (temperature max). These variations along with variability in the strength and direction of land and sea breezes, introduce significant daily variation in the position and height of the evaporation duct near the coasts. Mean monthly relative humidity across the NAXA in the Timor Sea ranges from around 80% in summer to around 60% in winter, as shown in **Figure 46** and **Figure 47**.

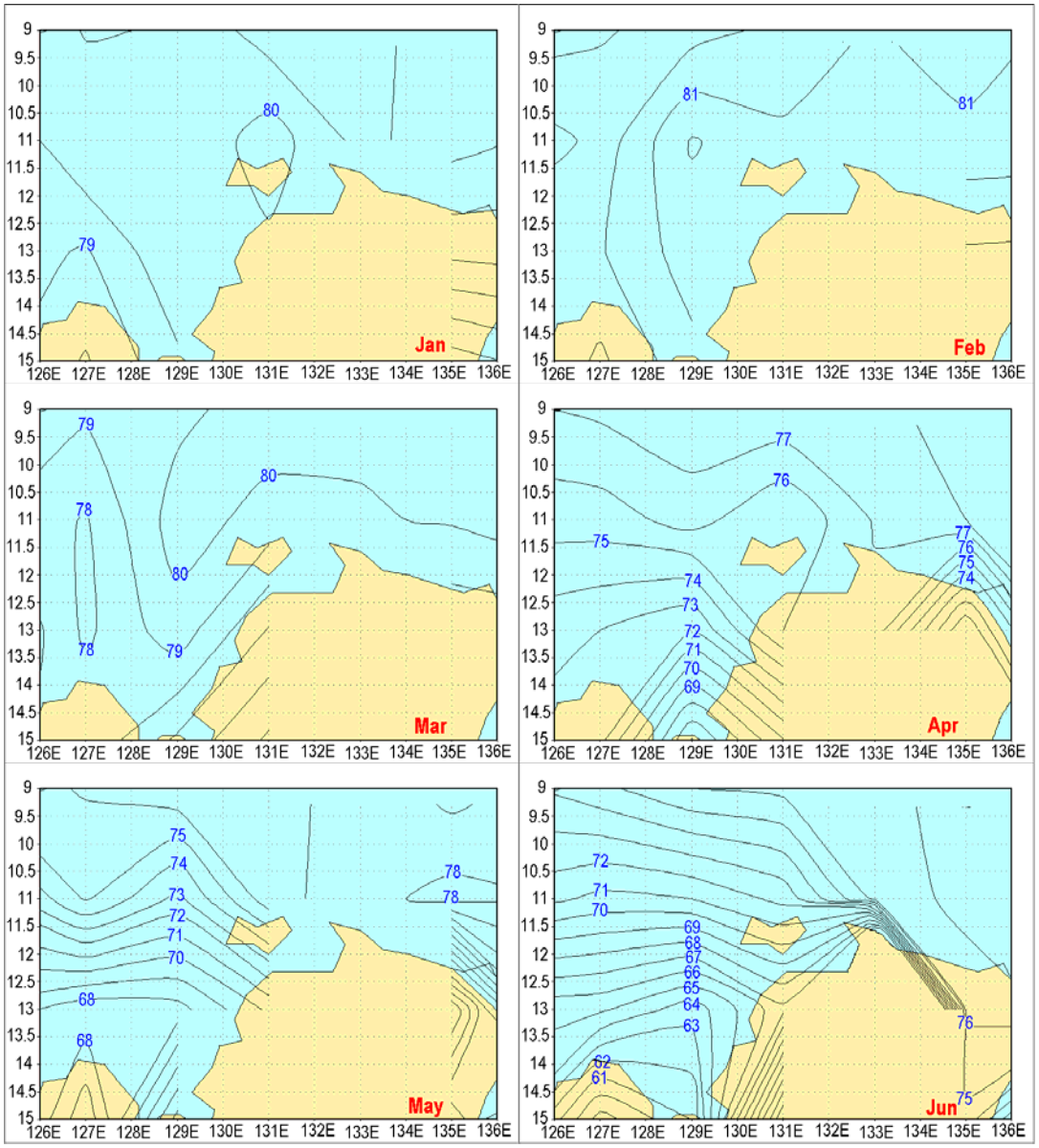


Figure 46: Mean relative humidity (%) for January to June.
(Source: ICOADS, 2008)

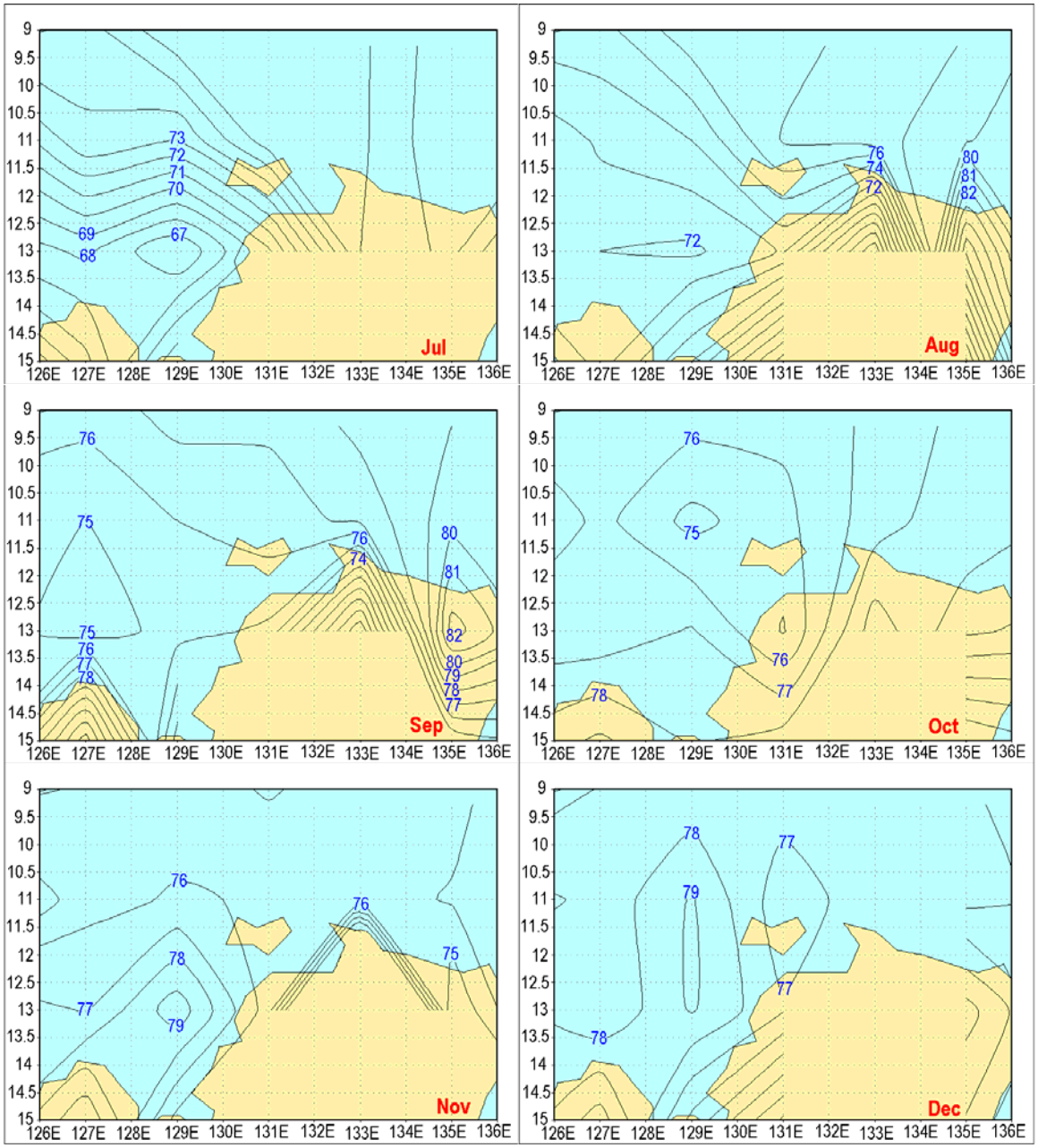


Figure 47: Mean relative humidity (%) for July to December.
(Source: ICOADS, 2008)

3 OCEANOGRAPHY

3.1 SWELL

Seasonal changes in mean significant wave heights for sea and swell combined are shown in Figure 48 and Figure 49. Wave heights are slight to moderate over the NAXA for most of the year. During the May to September period low swell from the Indian Ocean intrudes into the SW corner of the region, but does not go further into the Timor Sea due to attenuation by the shallower water over the continental shelf. Low swell from the W are experienced during the NW monsoon.

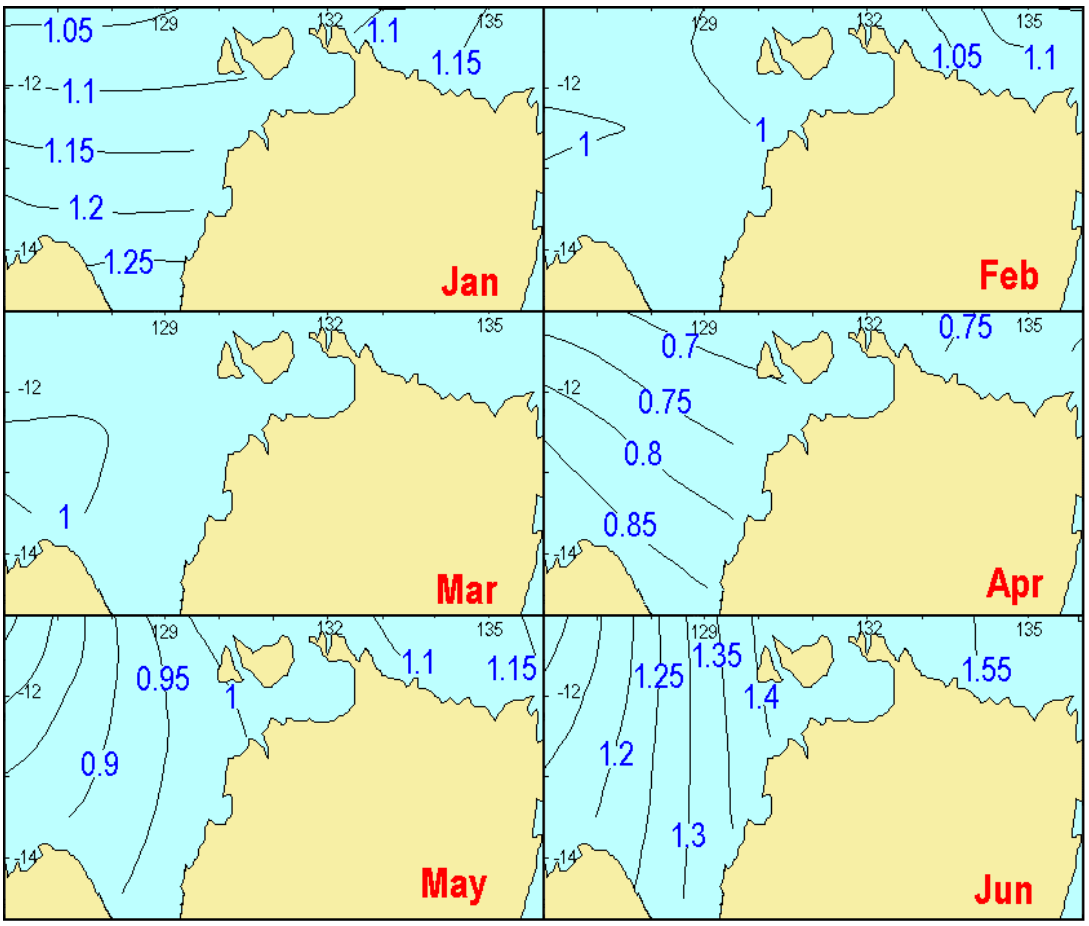


Figure 48: Mean wave height (m) for sea and swell combined.
(Source: NCDC, 1995)

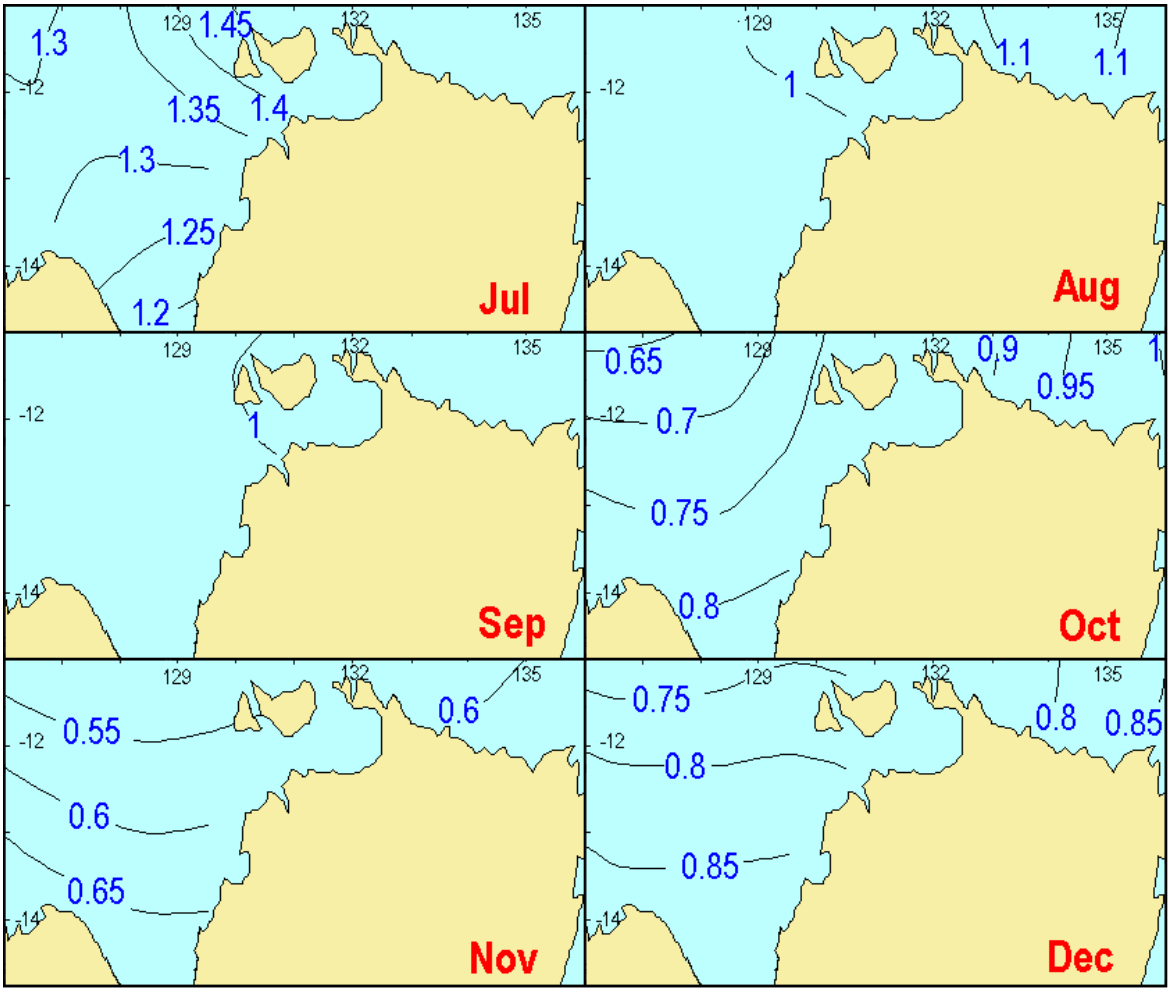


Figure 49: Mean wave height (m) for sea and swell combined.
(Source: NCDC, 1995)

Swell height data were obtained from the 2° chart squares Square 1: 9-11ºS, 126-128ºE and Square 2: 11-13ºS, 128-130ºE (Figure 50) and are shown in Figure 51 to Figure 54.

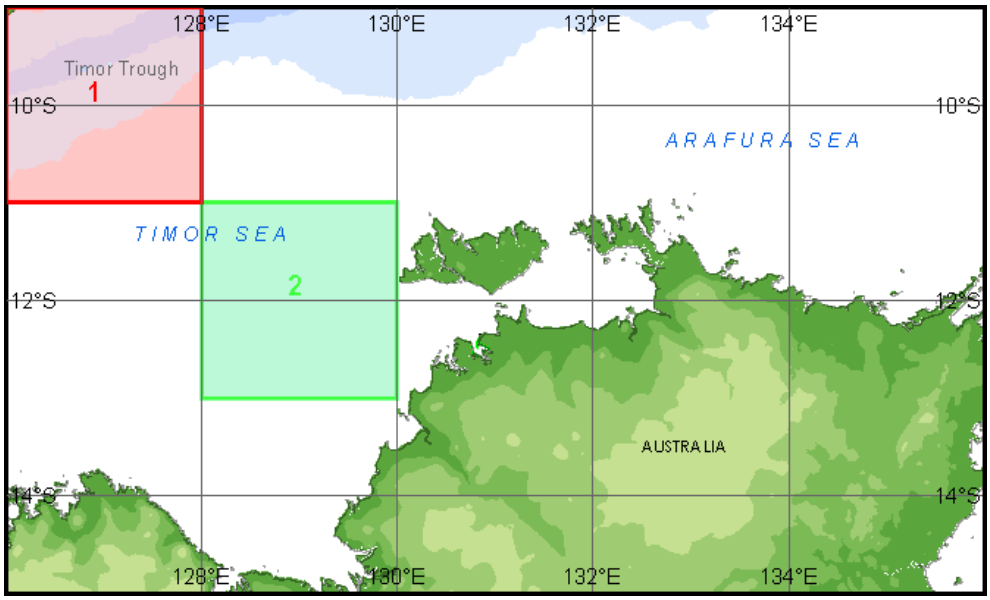


Figure 50: Areas selected for GMCA data plots

(Square 1: 9-11ºS, 126-128ºE and Square 2: 11-13ºS, 128-130ºE).
(Source: Chart from DOM, 2008)

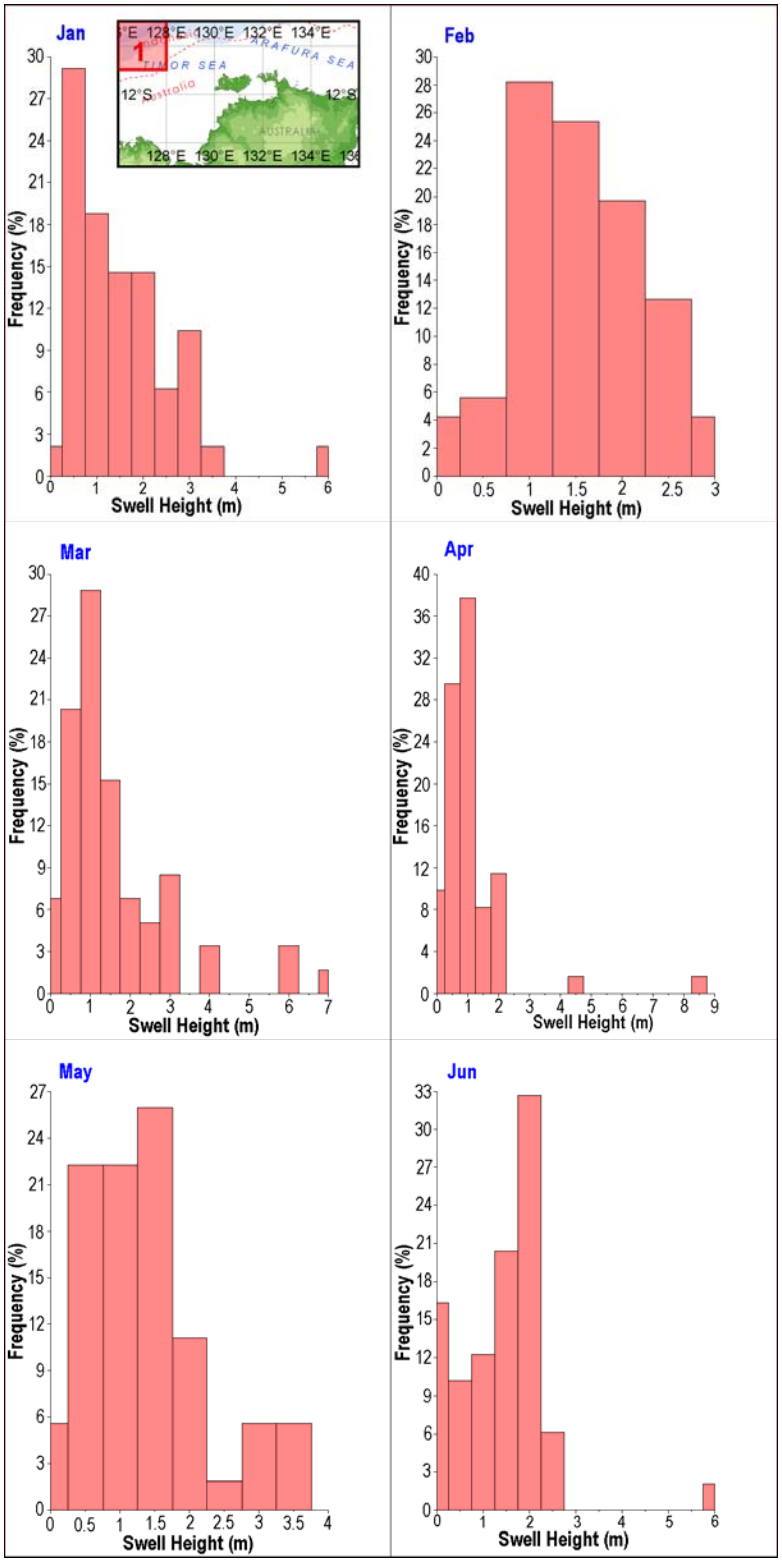


Figure 51: Swell height frequencies for square 1: 9-11ºS, 126-128ºE (January to July). (Source: GMCA, 2008).

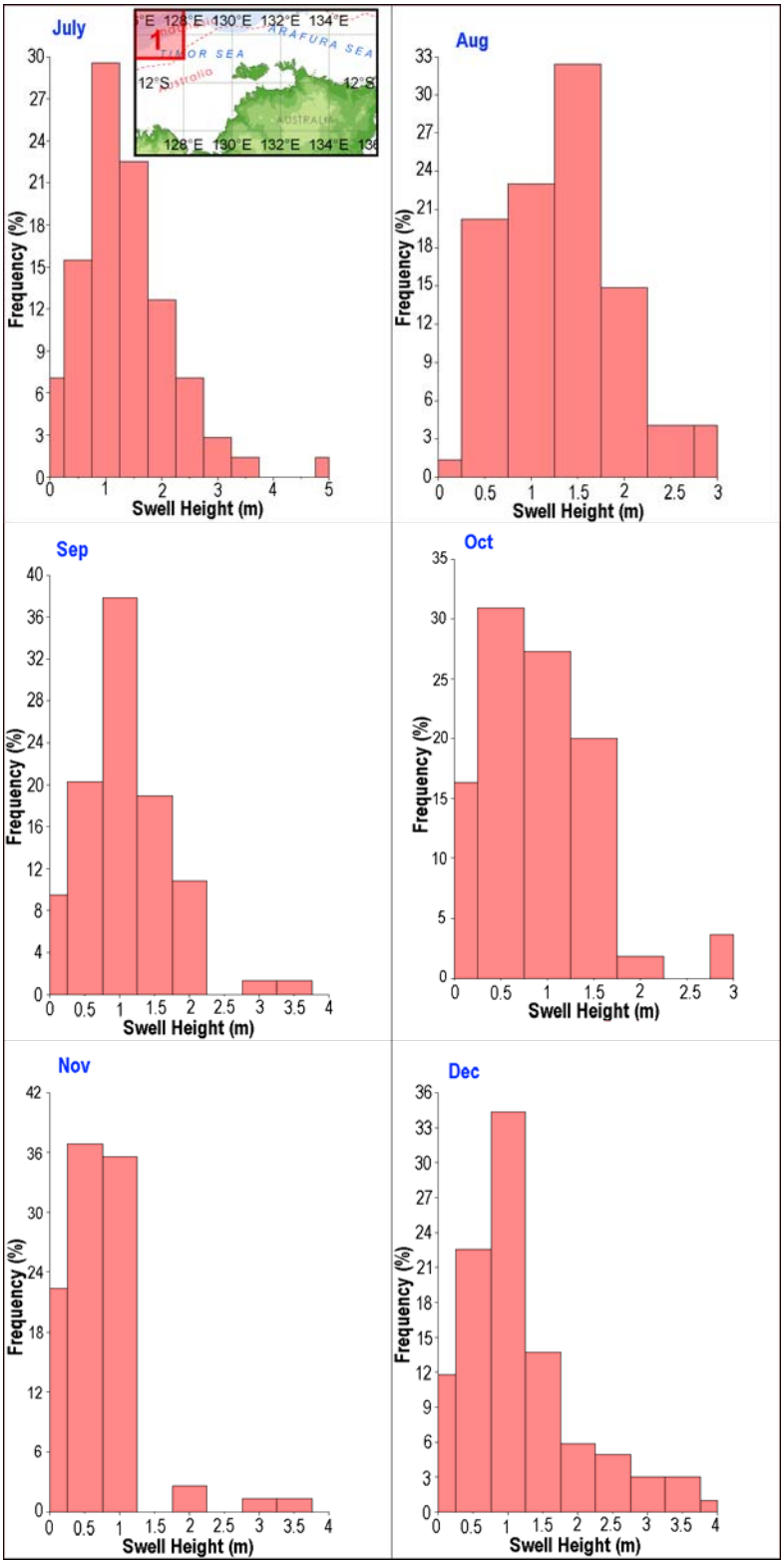


Figure 52: Swell height frequencies for square 1: 9-11ºS, 126-128ºE (July to December). (Source: GMCA, 2008).

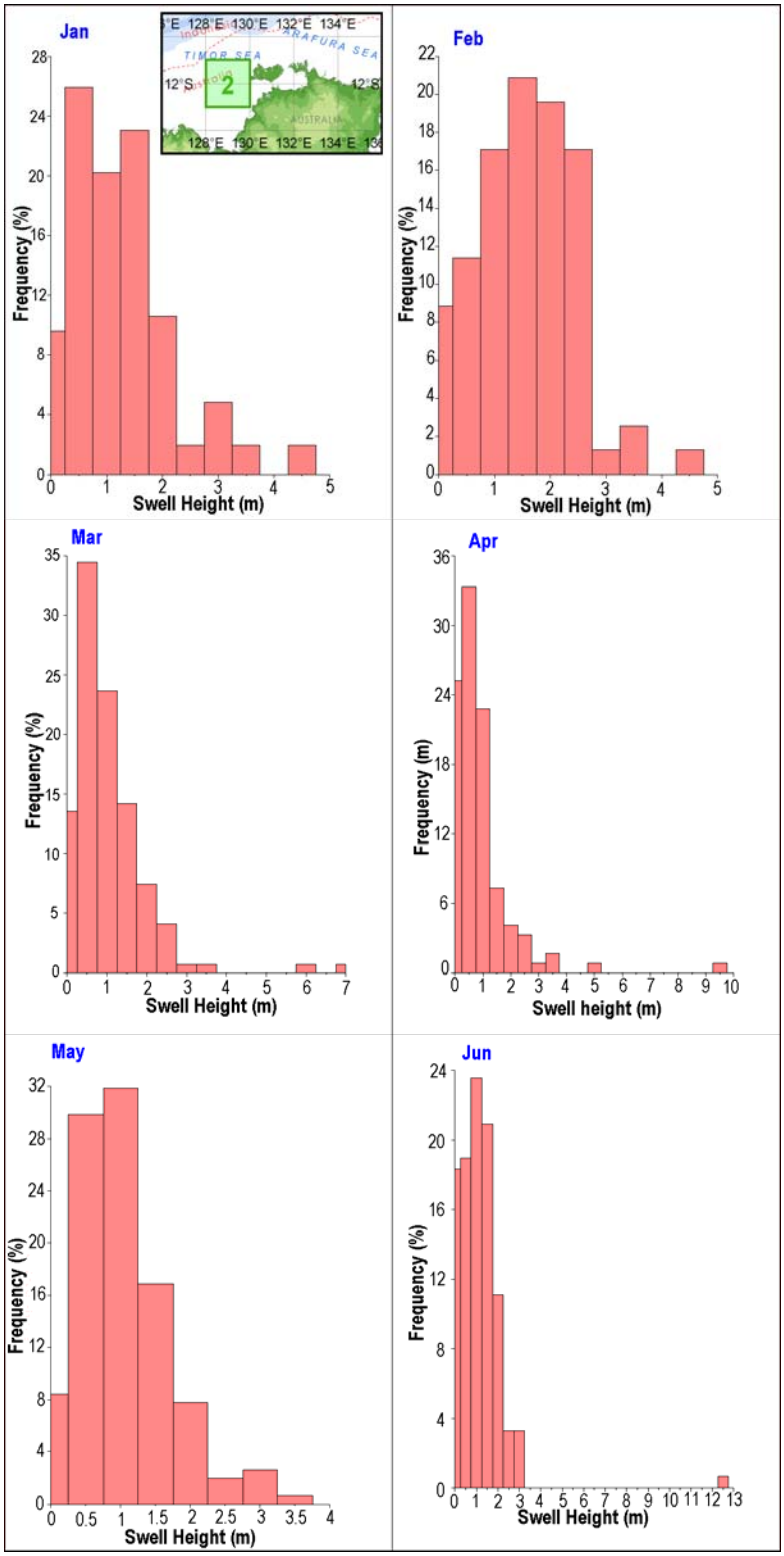


Figure 53: Swell height frequencies for square 2: 11-13ºS, 128-130ºE (January to June). (Source: GMCA, 2008).

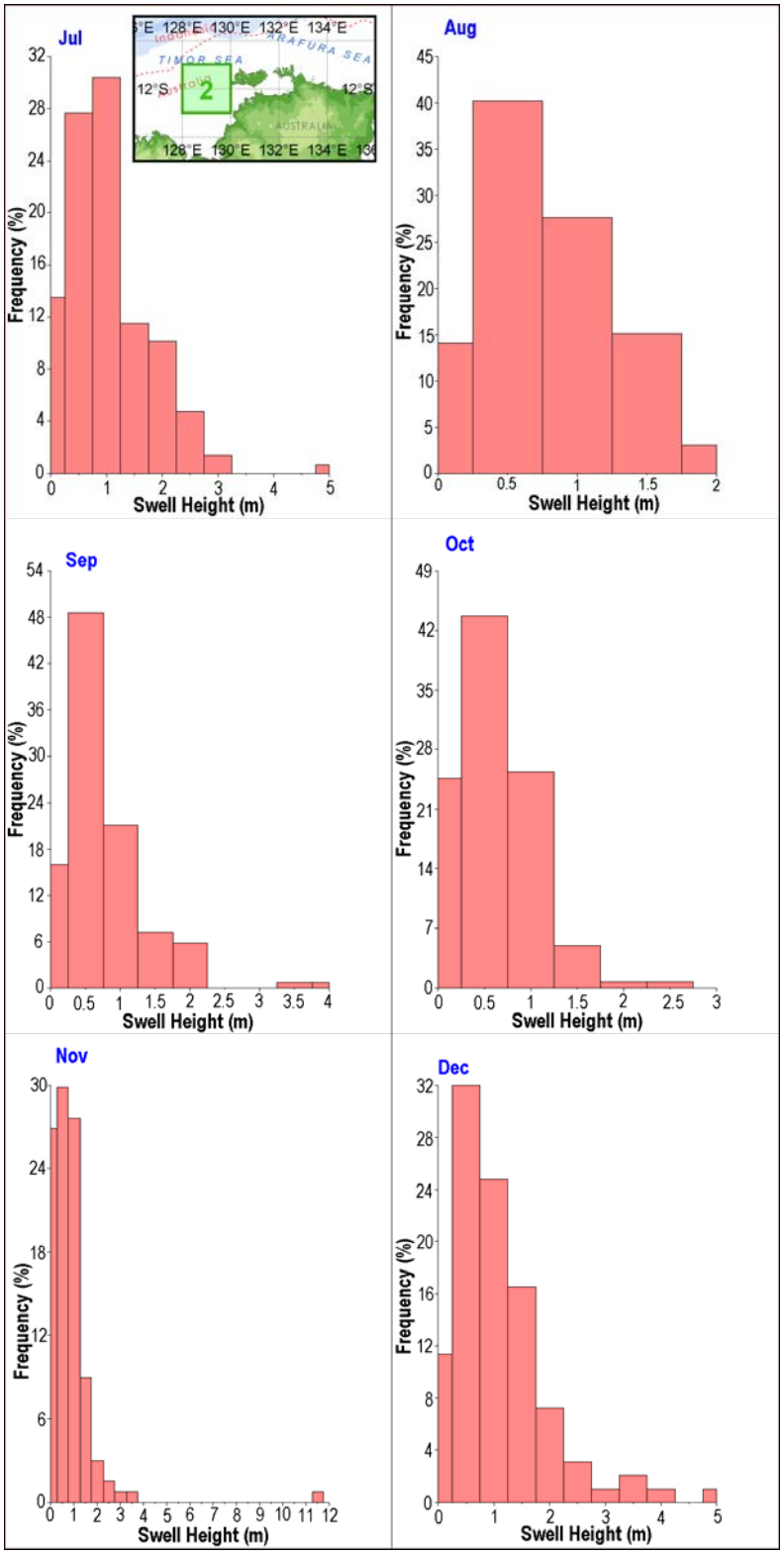


Figure 54: Swell height frequencies for square 2: 11-13ºS, 128-130ºE (July to December). (Source: GMCA, 2008).

3.2 WIND – WAVES

Wave heights are slight to moderate over the NAXA for most of the year. In the northern part of the region wind waves (sea) are higher during the May to September period, due to the fresh and often gusty SE trade winds. Slightly higher wind waves are experienced during the NW monsoon. Wind waves are slightly lower during the months between the monsoons.

Sea (wind waves) were also obtained from the 2° chart squares Square 1: 9-11ºS, 126-128ºE and Square 2: 11-13ºS, 128-130ºE (Figure 50) and are shown in Figure 55 to Figure 58.

Moderate to high seas occur during tropical cyclones from November to April, but this data tends to be excluded from the statistics because ships often avoid these events.

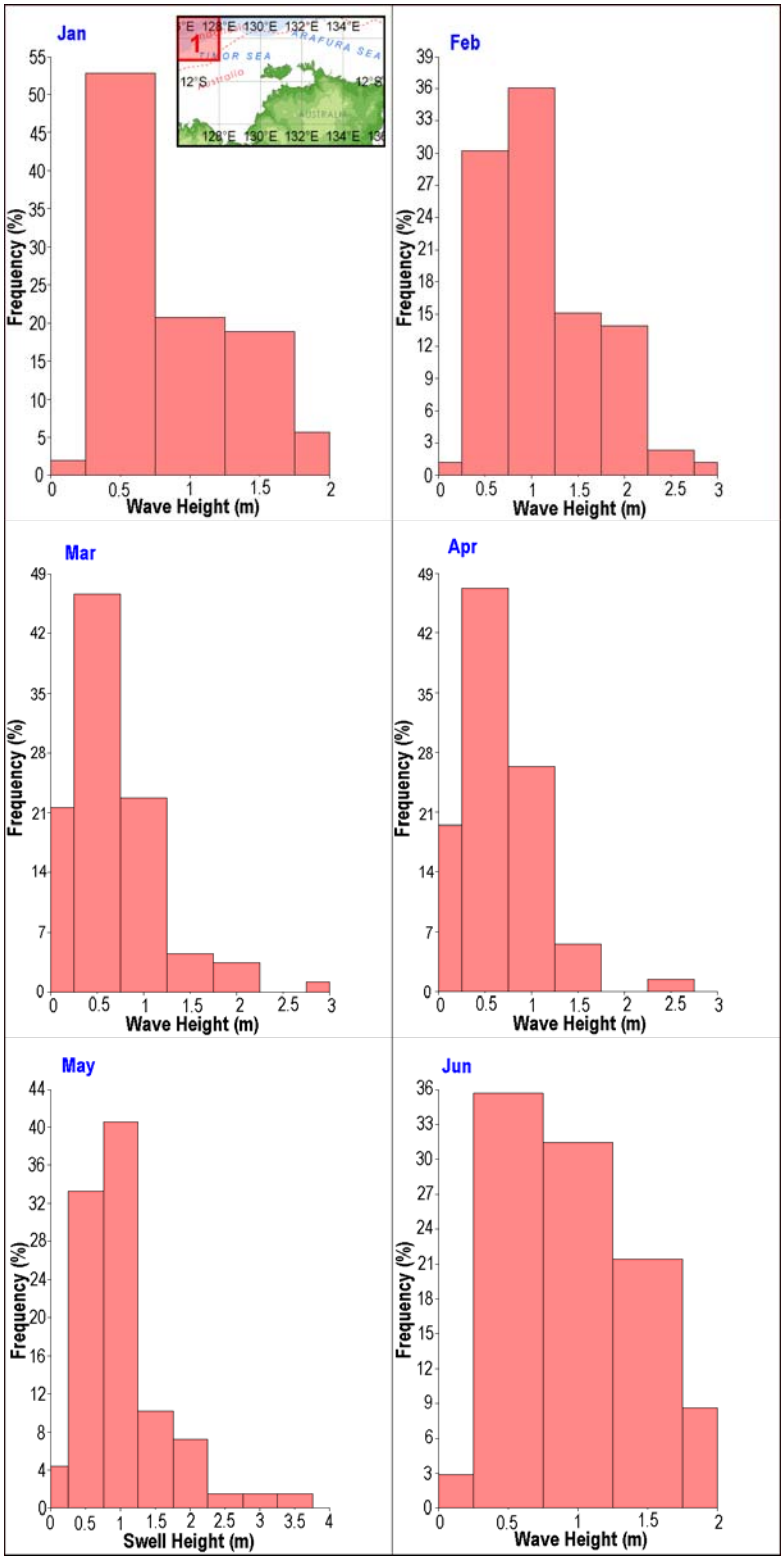


Figure 55: Wind wave height frequencies for square 1: 9-11ºS, 126-128ºE (January to June). (Source: GMCA, 2008).

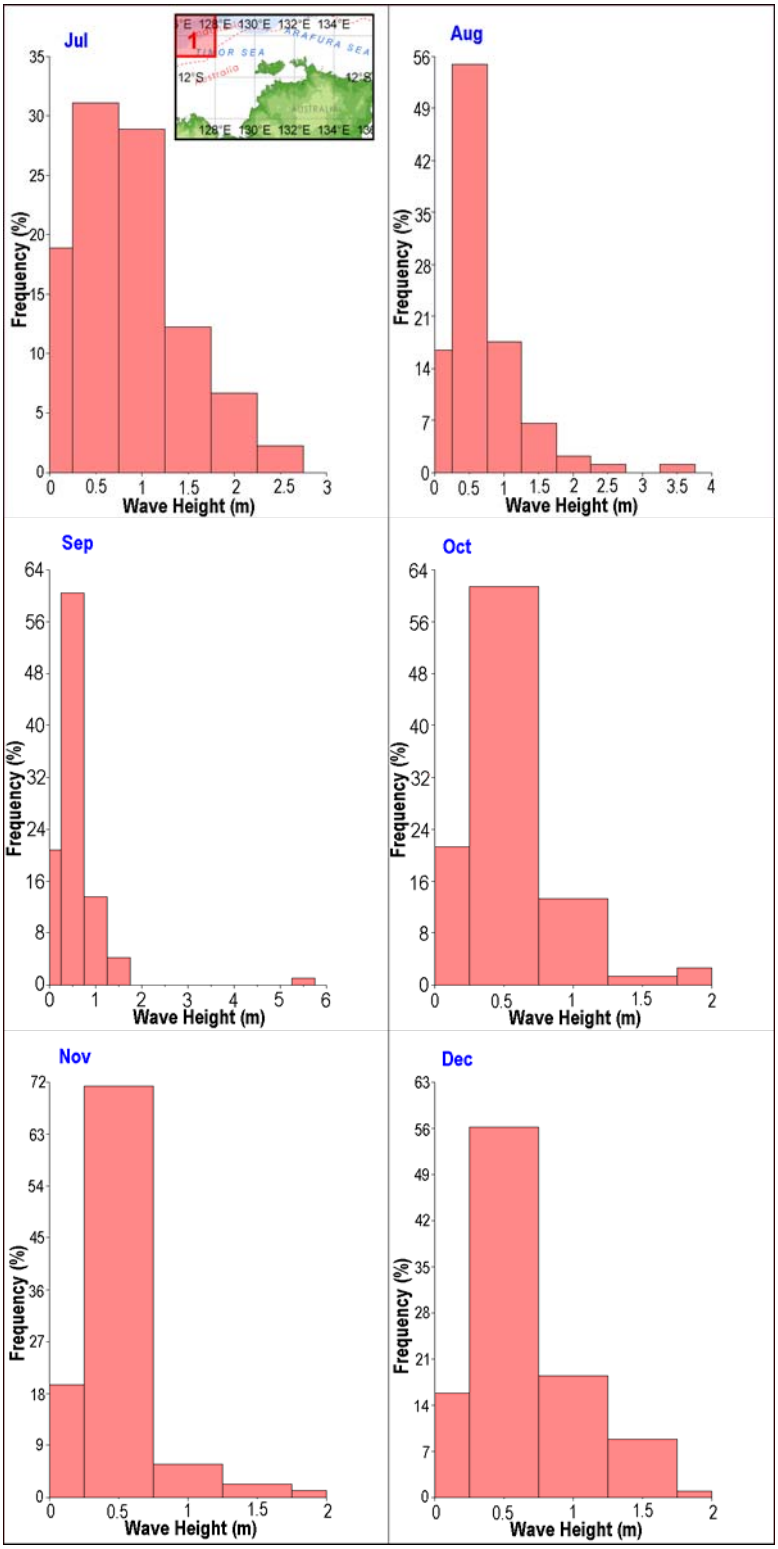


Figure 56: Wind wave height frequencies for square 1: 9-11ºS, 126-128ºE (July to December). (Source: GMCA, 2008).

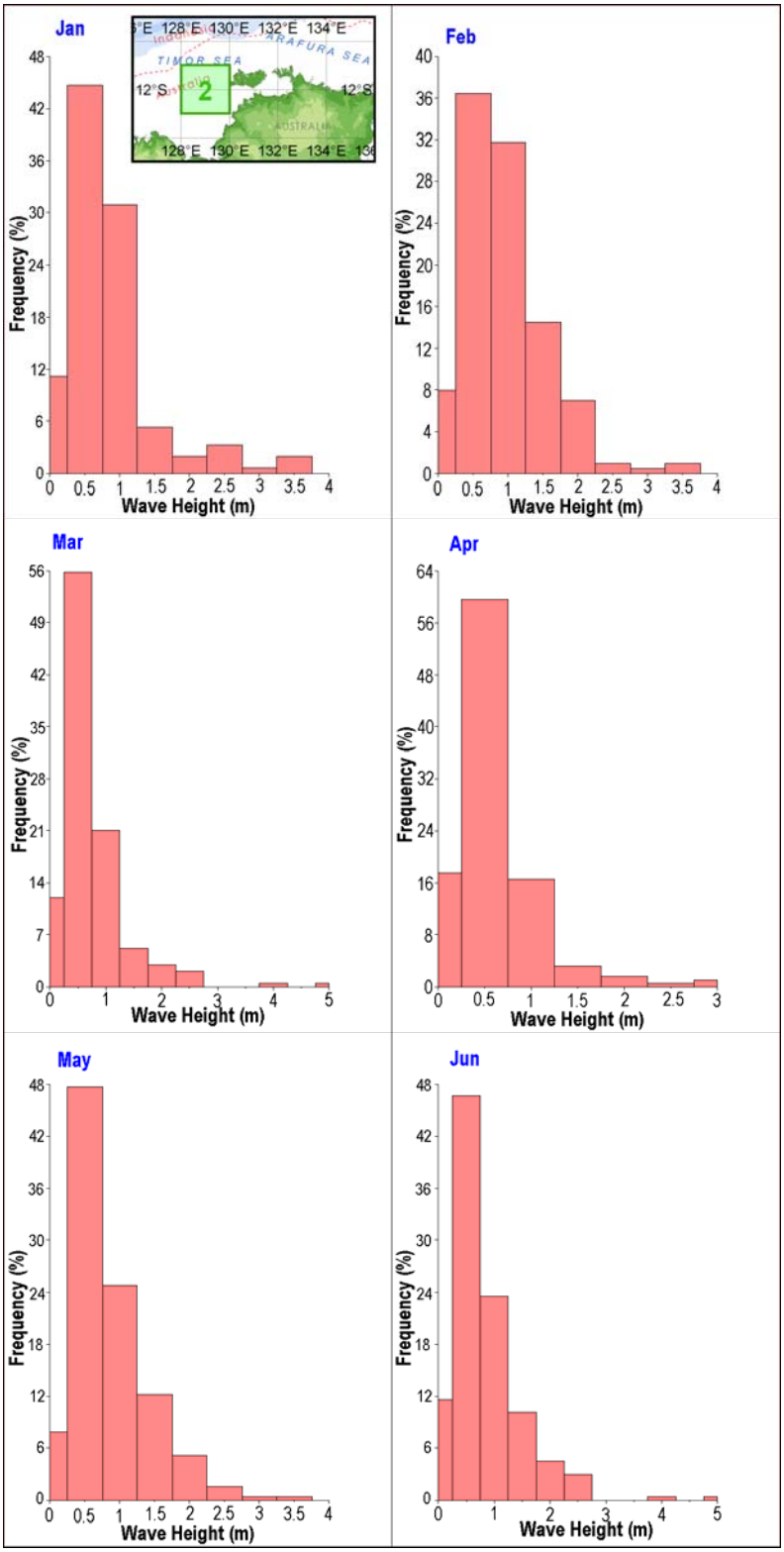


Figure 57: Wind wave height frequencies for square 2: 11-13ºS, 128-130ºE (January to June). (Source: GMCA, 2008).

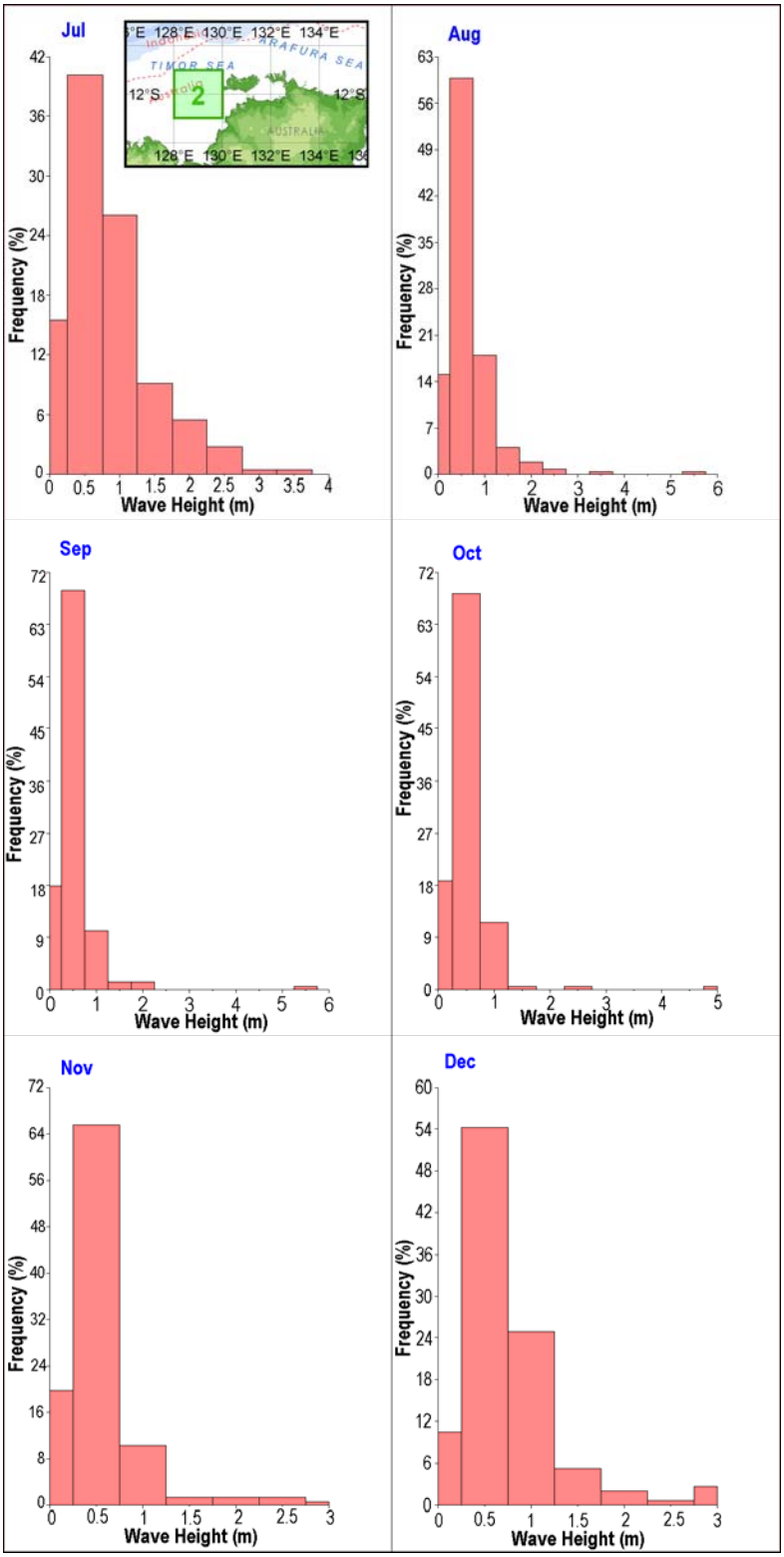


Figure 58: Wind wave height frequencies for square 2: 11-13ºS, 128-130ºE (July to December). (Source: GMCA, 2008).

3.3 CURRENTS

Currents in NAXA show considerable variability, largely due to the variable wind conditions. Over most of the area, the currents reverse seasonally in response to the monsoon wind changes (HO, 1983 and HO, 1992). During the NW monsoon season, December to March, the predominant direction of the current is NE or ENE through the Timor and Arafura Seas and E through Torres Strait. In the SE trade wind season, April to November, the predominant direction is reversed over the area, it becomes W through Torres Strait and WSW through the Arafura and Timor Seas. Throughout the year, the constancy of the current is generally less than 25%, but in some areas it is between 25 and 50%. The mean rate is less than 1 kt, but rates of between 2 and 3 kts setting either E or W have occurred on occasion in both seasons (HO, 1992). The general pattern of the currents around the NAXA area, for each month, is shown in Figure 59 and Figure 60. (Note: 1m/s = 1.984384449 knots).

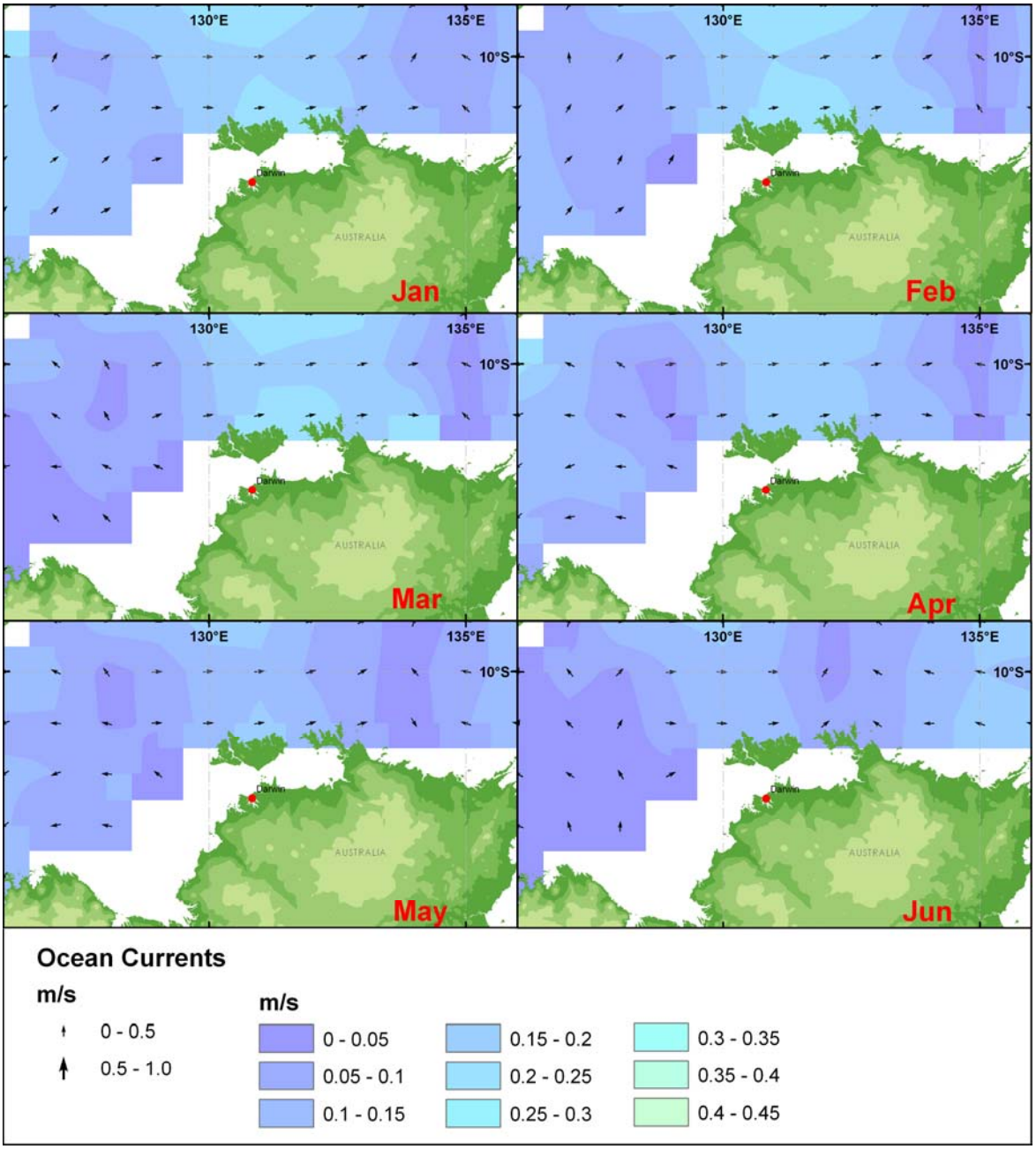


Figure 59: Surface currents (m/s) January – June.
(Source: DOM, 2008)

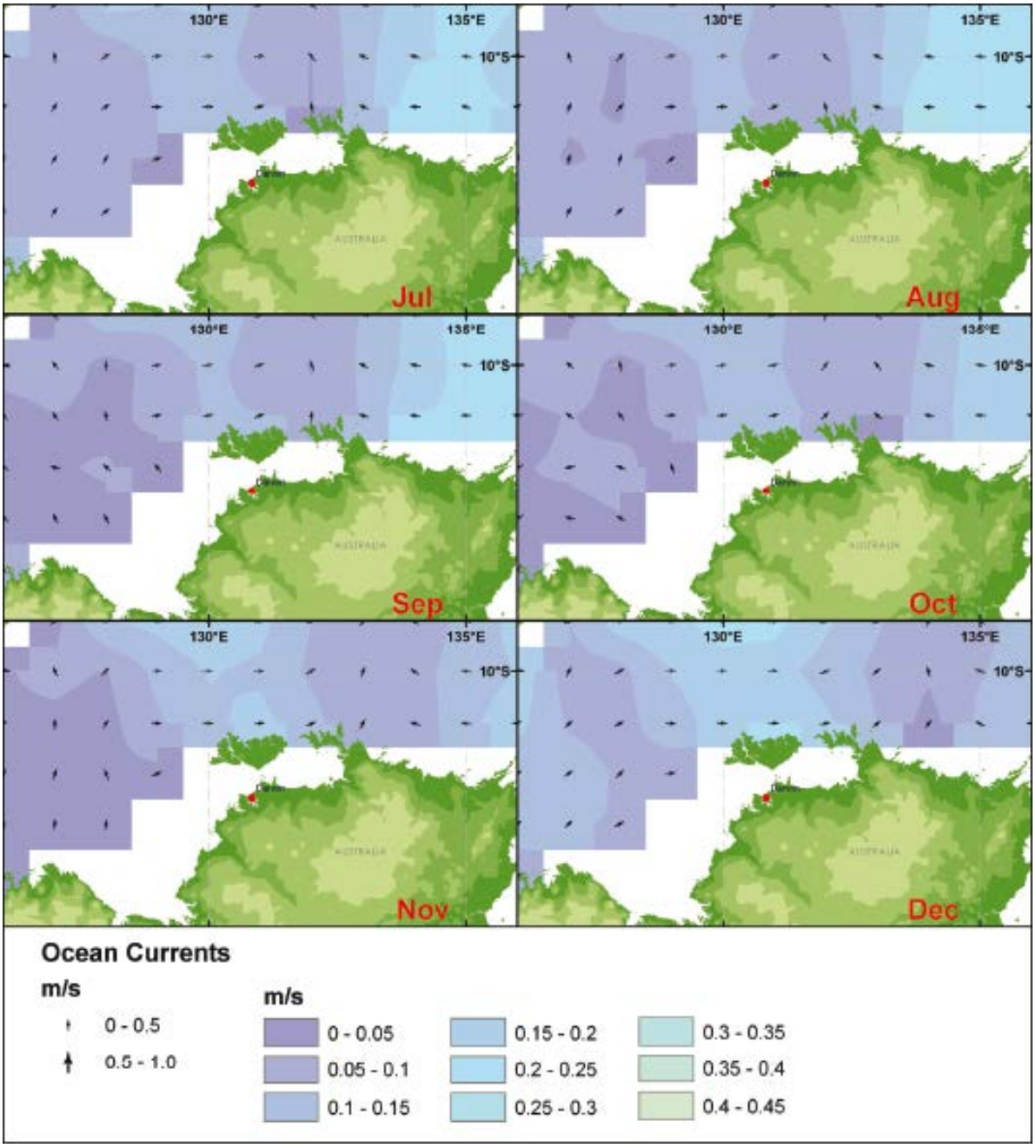


Figure 60: Surface currents (m/s) July – December.
(Source: DOM, 2008)

3.4 TIDES AND TIDAL CURRENTS

Tides throughout the area are semidiurnal and have a strong diurnal inequality (HO, 1983). The maximum tidal ranges through NAXA are shown in Figure 61. Tidal ranges between MHWS and MLWS are about two thirds of those shown. Prediction of daily tide cycles can be made using the computer program for the Australian National Tide Tables, available from the RAN Hydrographic Office. This program will compute tidal information for all ports in and close to Australia. For ports not included in the tide table, such as Surabaya, contact the tidal section of the RAN Hydrographic Office to obtain the tidal constituents, which can be entered into the tidal program (phone 02 4221 8645, or email hts.hydro@navy.gov.au).

Tidal ranges along the NW coast of Australia are much greater than normally encountered, with consequent strong tidal streams, which may be a navigation hazard. Some of the estuaries are also noted for tidal "jumps" or "bores", which are dangerous for small vessels.

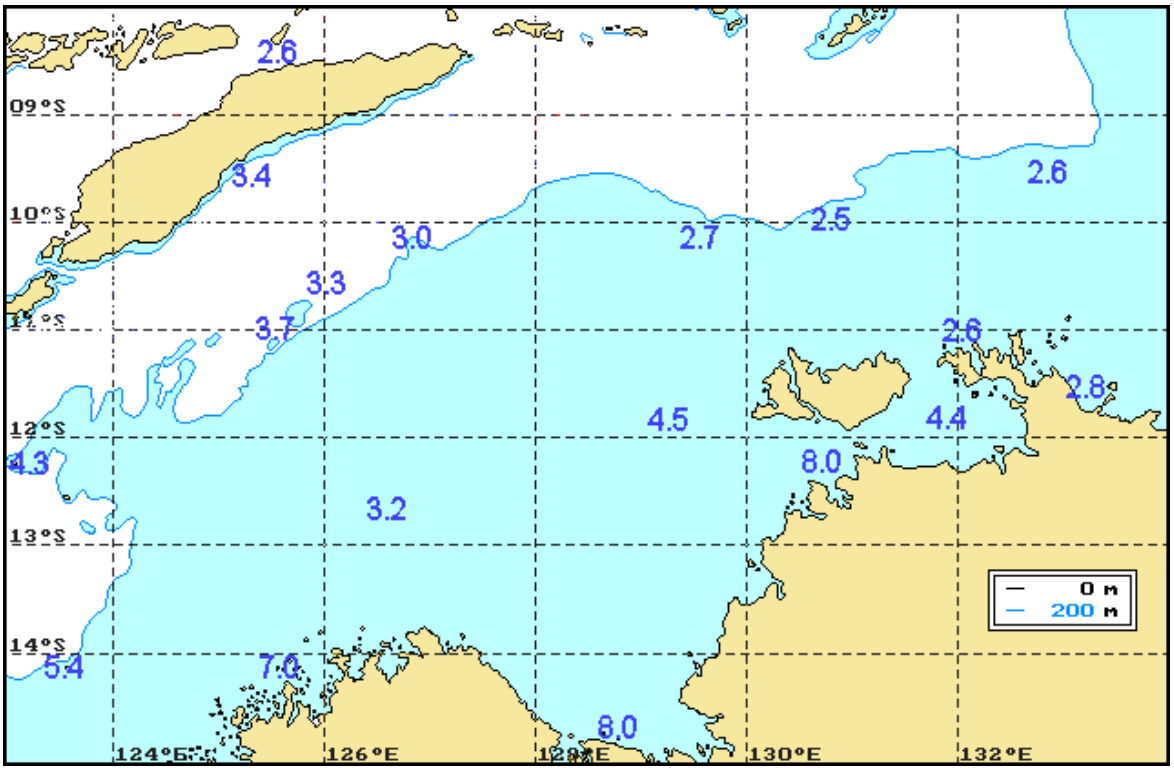


Figure 61: Maximum tidal ranges (m).
(Source: AHO, 2002)

3.5 INTERNAL WAVES

The effects of internal waves can be experienced at the thermocline depth, where the water density changes more rapidly with depth. Submarine navigators should take care where the thermocline depth is close to the bottom. Internal wave heights, periods and lengths are usually much larger than for surface waves. Isotherms have been observed to oscillate with amplitudes of up to 50 m, periods ranging from 10 minutes to 12 hours and wavelengths of 0.2 to 100 km.

Internal waves are often driven by tides, so that the wave period will often be about 12 hours (Holloway, 1997). Internal waves can be detected from the rise and fall of isotherms in thermally stratified water (XBT measurements). Possible mechanisms to generate internal waves include: (a) tidal action; (b) flow impinging on a continental shelf; (c) flow over irregular topography; (d) adjacent flows along water mass boundaries; (e) seismic disturbances; and (f) severe meteorological events.

There is little information on internal wave activity for the NAXA. But the existence of internal waves along the outer shelf near NW Cape (Holloway, 1997), suggests that they will also exist along the edge of the Salhul Shelf, driven by tides. Internal waves also exist around nearby Scott Reef (14°03'S, 121°46'E), a 39km wide island rising nearly vertically in 500m depth on the outer continent of Western Australia. The primary response of the tidal flow past deep oceanic islands is the formation of huge internal waves. These waves reach 60m peak to trough at Scott Reef (Wolanski *et al*.,1998). Divers near Broome have also reported strong surging currents on the bottom due to the approach of tropical cyclones. The existence of well defined thermoclines (and therefore pycnoclines) in NAXA, as detailed in 3.6 WATER PROPERTIES provides the basic prerequisite for the generation of internal waves.

3.6 WATER PROPERTIES

3.6.1 SEA SURFACE TEMPERATURE

Mean sea surface temperatures across NAXA show little variation, especially in summer. The summer sea surface mean temperature range is 28 - 28.4ºC, while in winter it is 24.8 – 26.4ºC, as shown in Figure 62 and Figure 63.

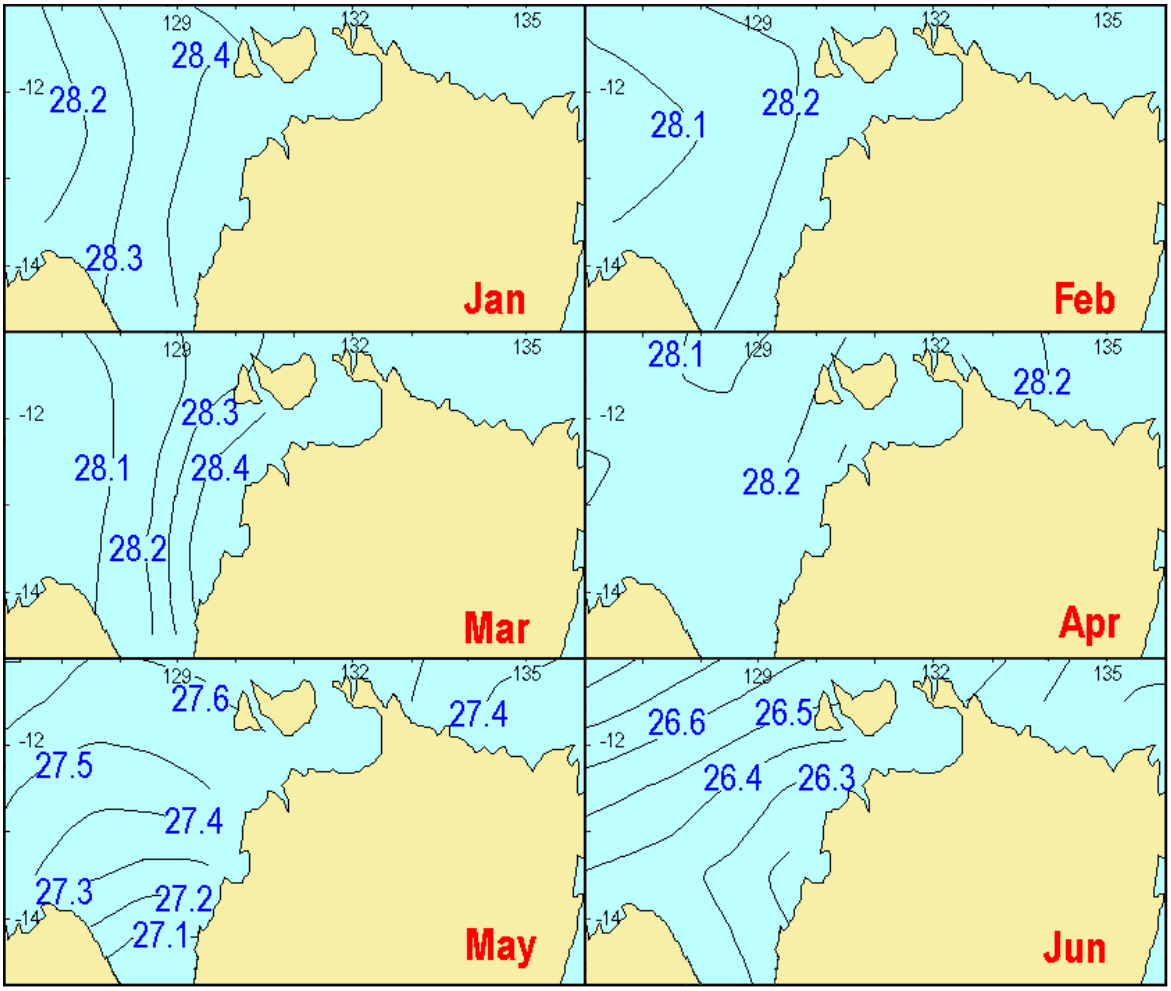


Figure 62: Mean sea surface temperature (ºC).
(Source: NCDC, 1995)

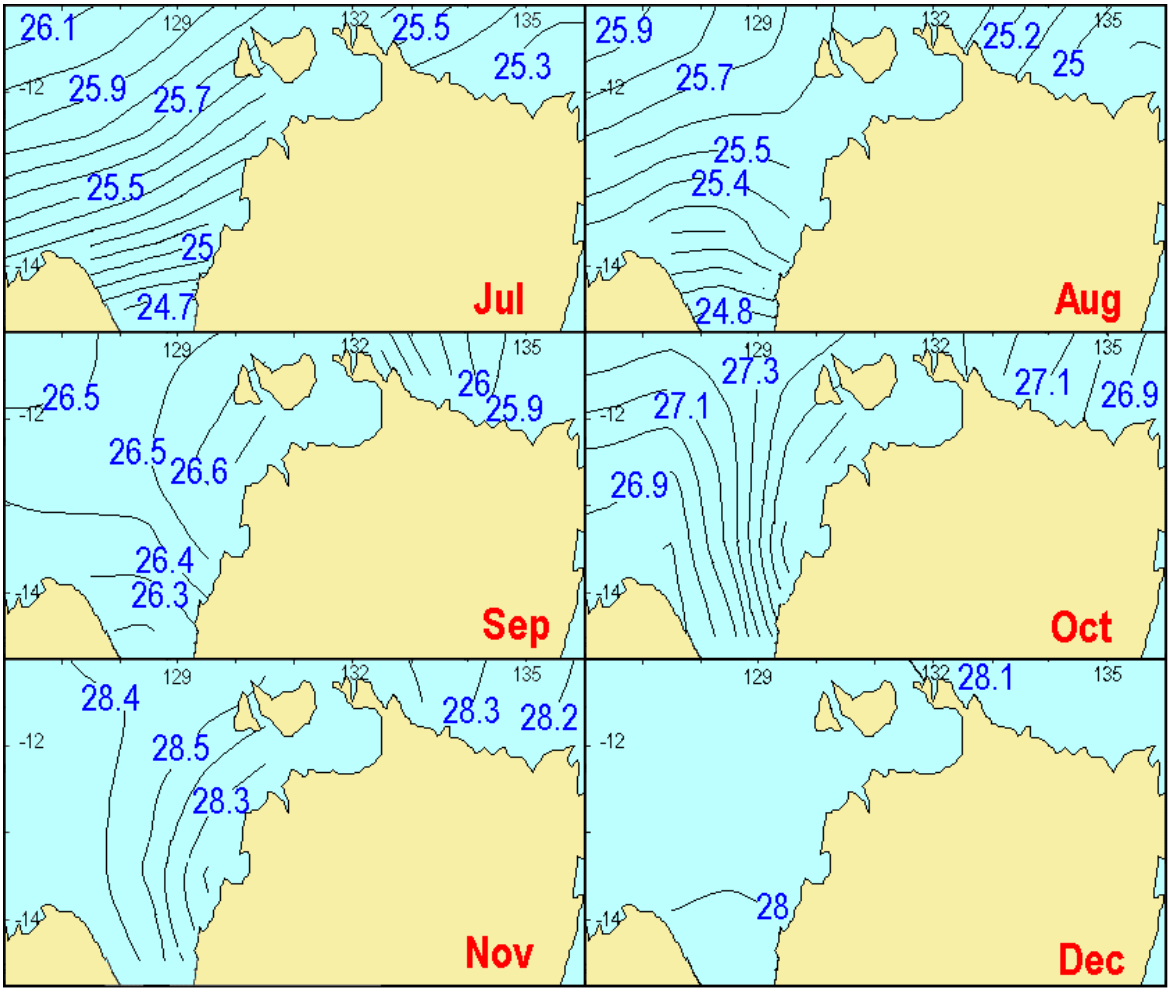


Figure 63: Mean sea surface temperature (ºC).
(Source: NCDC, 1995)

3.6.2 SEA SURFACE SALINITY

There is some seasonal change in surface salinity, with greater salinities in the SW of the area in summer, and lower salinities in the NW from April to July (Figure 64 and Figure 65).

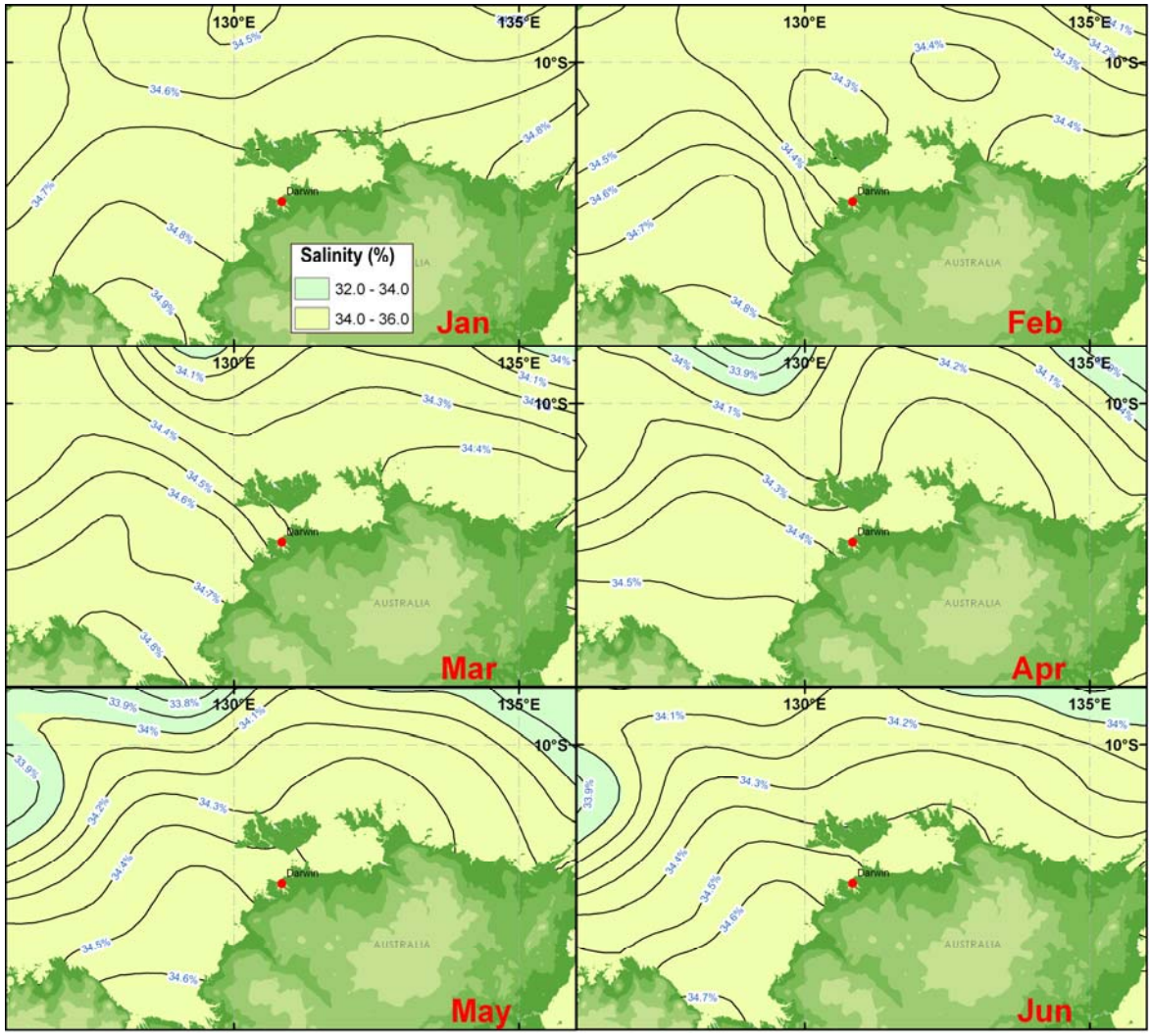


Figure 64: Mean sea surface salinity (%) January to June.
(Source: DODC, 2008)

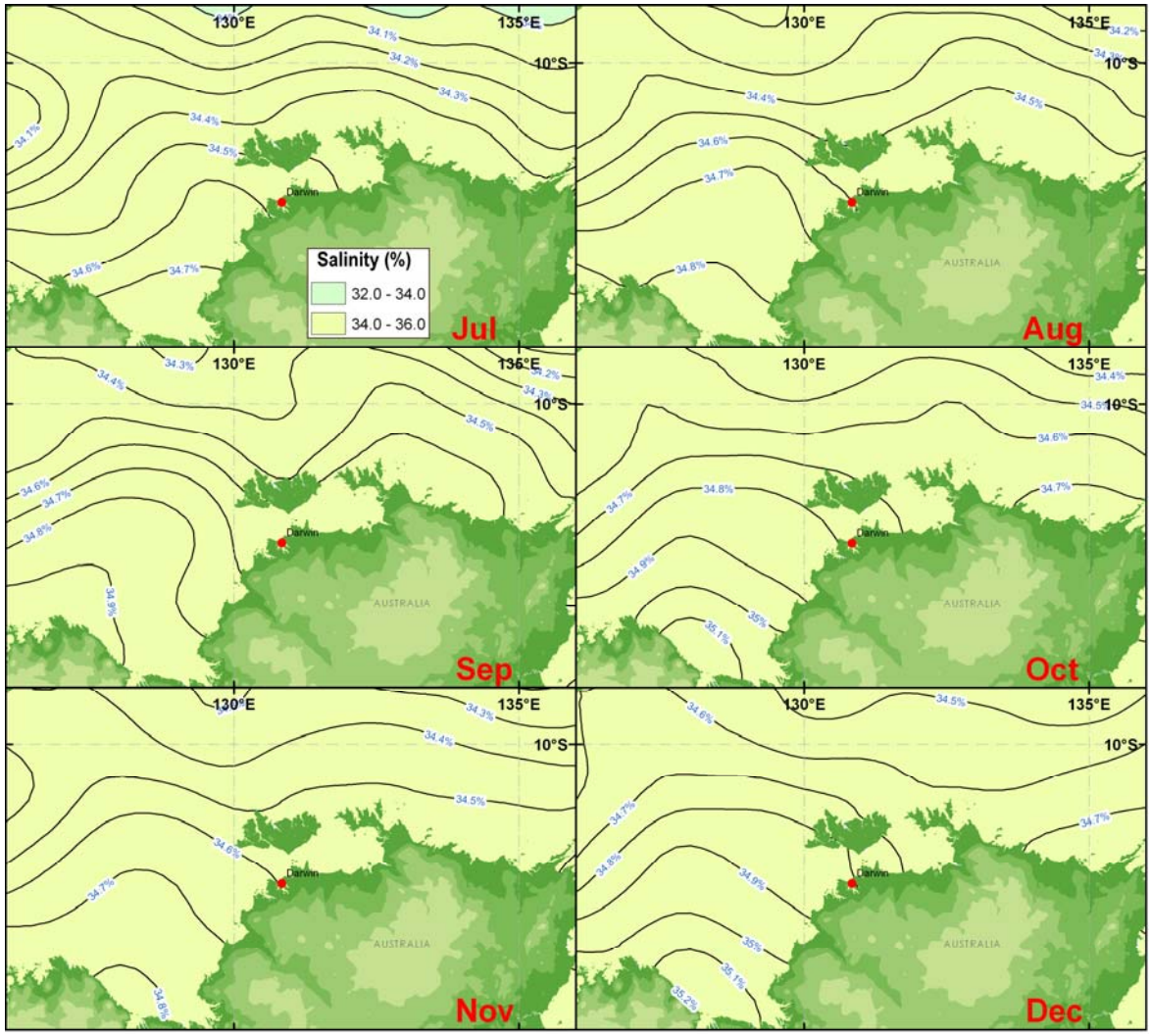


Figure 65: Mean sea surface salinity (%) July to December.
(Source: DOM, 2008)

3.6.3 TSVD PROFILES

Three areas were selected in NAXA for the display of temperature, salinity, sound velocity and density (TSVD) profiles. Two of the areas are shallow in the Timor and Arafura seas, while the third includes deeper water over the Timor Trench, as shown in Figure 66.

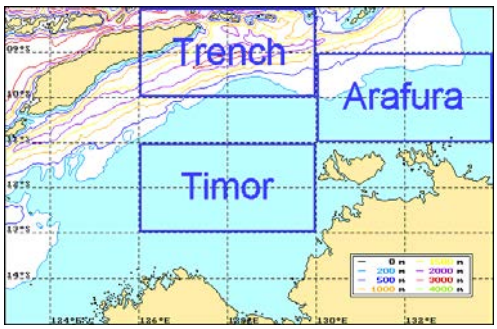


Figure 66: Areas used for the display of TSVD data.
(Source: Chart from GEBCO, 1997)

The data are displayed using *Ocean Data View* (Schlitzer, 2001). Data were extracted for the summer (January – March) and winter (July – September). It can be assumed that the water properties in autumn and spring will be intermediate to summer and winter, except that the mixed layer depths may be shallower in autumn and spring due to slightly lower wind speeds.

Deep temperature, salinity, sound velocity and density (TSVD) profiles from bottle sampling for all year in the Trench area are shown in Figure 67. Since there is little seasonal variation below 450 m, the lower part of these profiles can be used to spline on to seasonal or recent profiles.

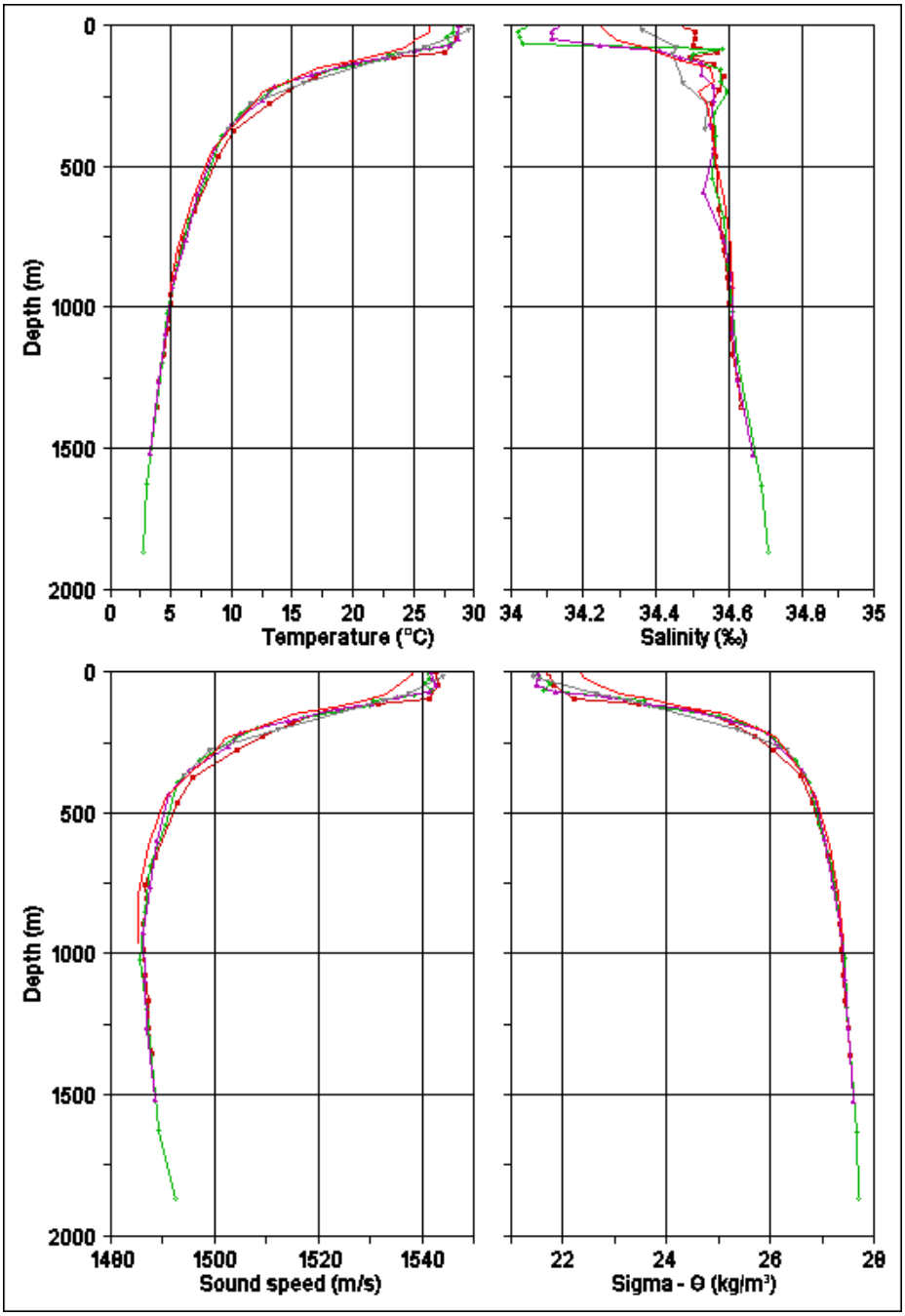


Figure 67: Deep TSVD profiles for Trench area (all year).
(Source: Conkright *et al*., 1998)

Selected profiles from bottle sampling in the Trench area for oceanographic summer (January – March) and winter (July – September) to 450 m are shown in Figure 68 and Figure 69.

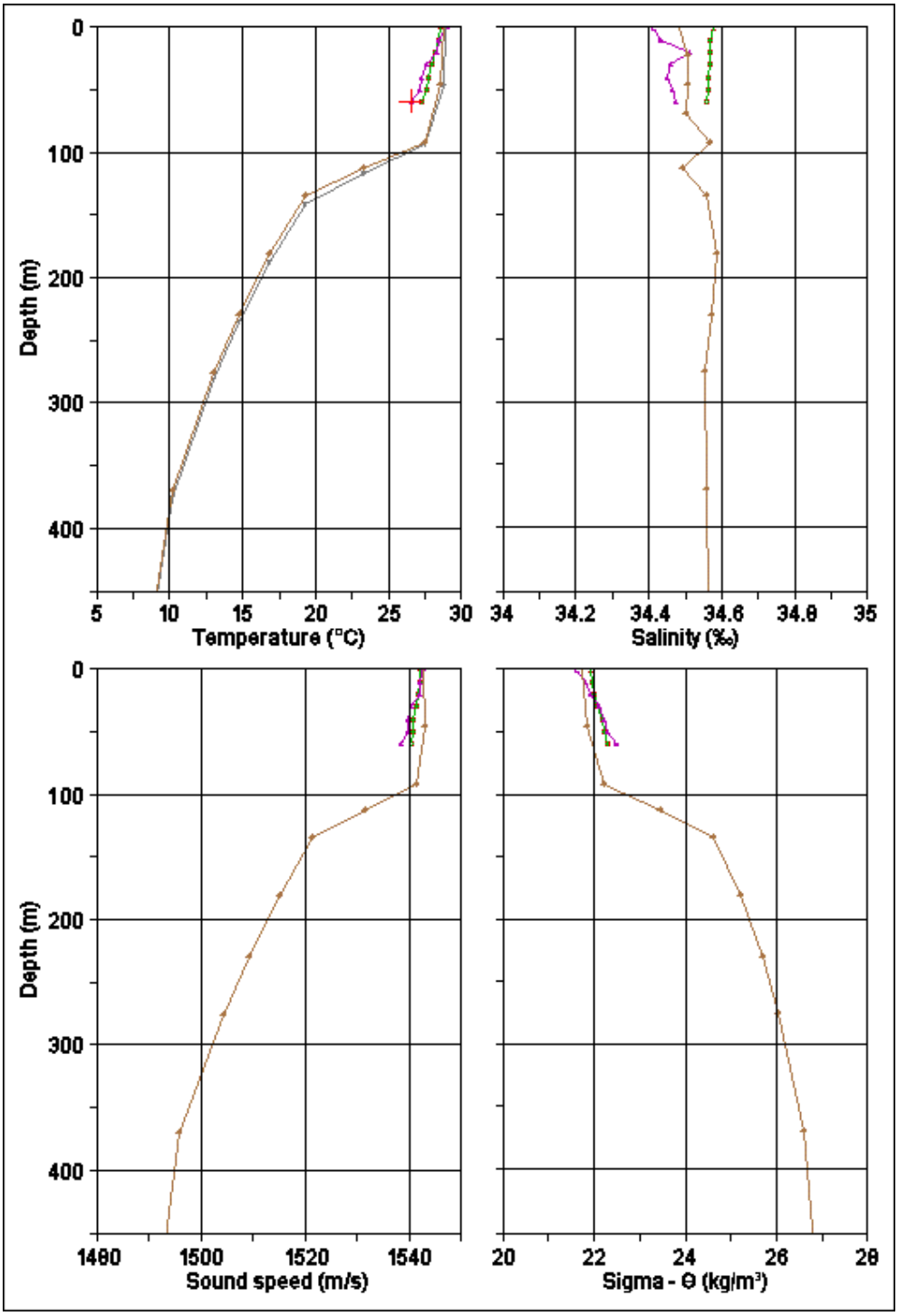


Figure 68: Summer TSVD profiles for Trench area (to 450 m).
(Source: Conkright *et al*., 1998)

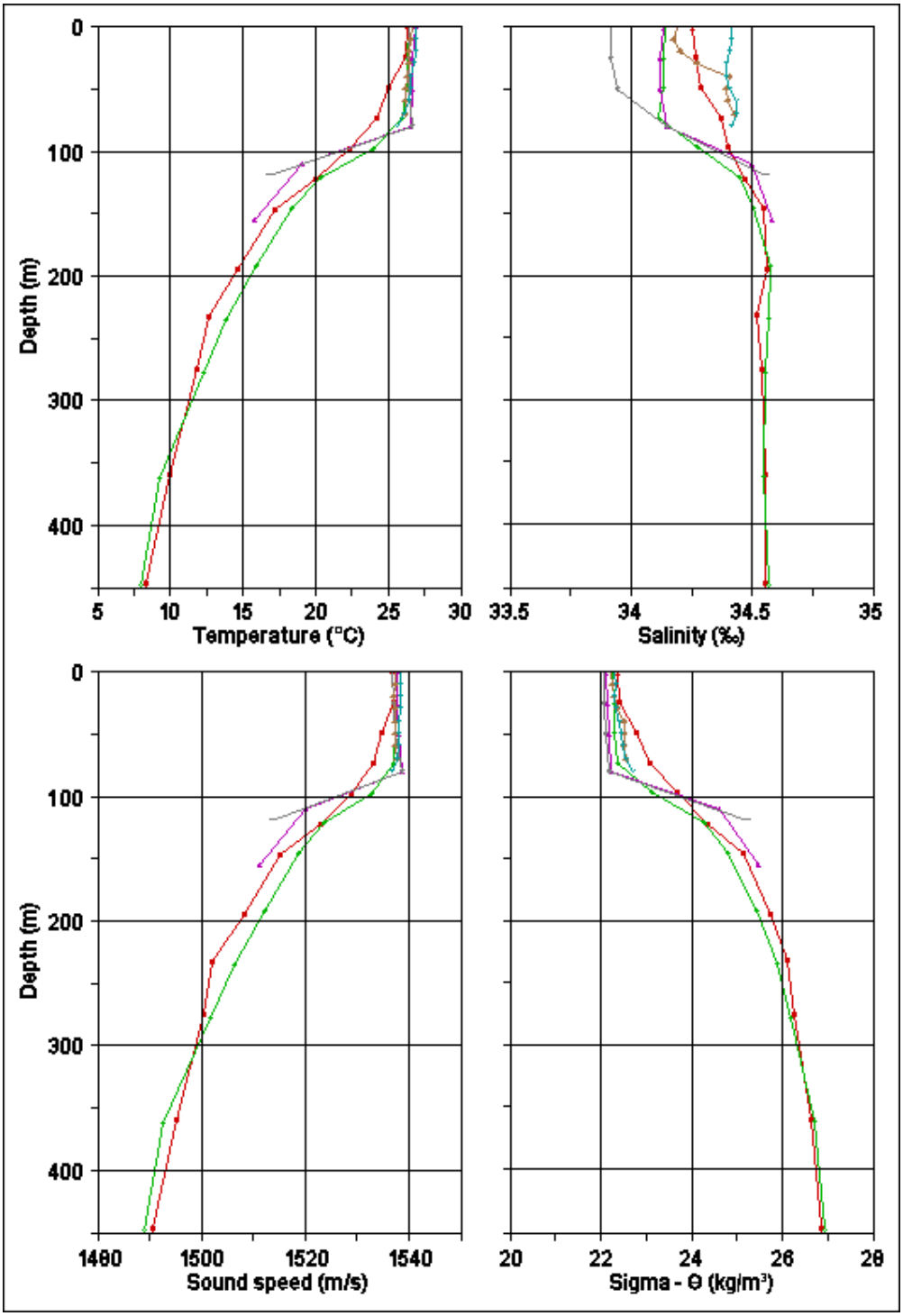


Figure 69: Winter TSVD profiles for Trench area (to 450 m).
(Source: Conkright *et al*., 1998)

Selected profiles from bottle sampling in the Timor and Arafura areas to near the bottom for oceanographic winter (July – September) are shown in Figure 70 and Figure 71. Summer profiles were not available.

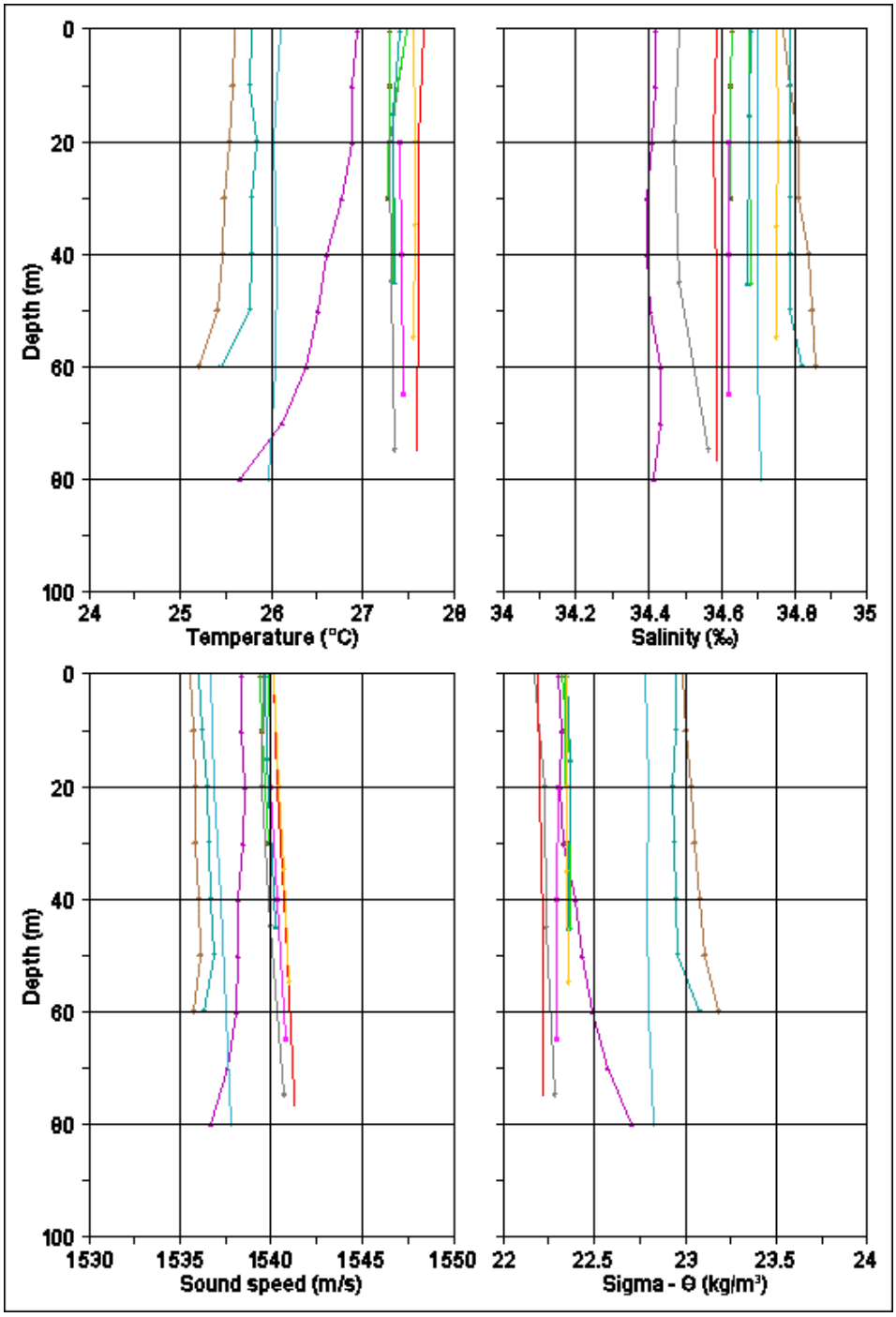


Figure 70: Winter TSVD profiles for Timor area.
(Source: Conkright *et al*., 1998)

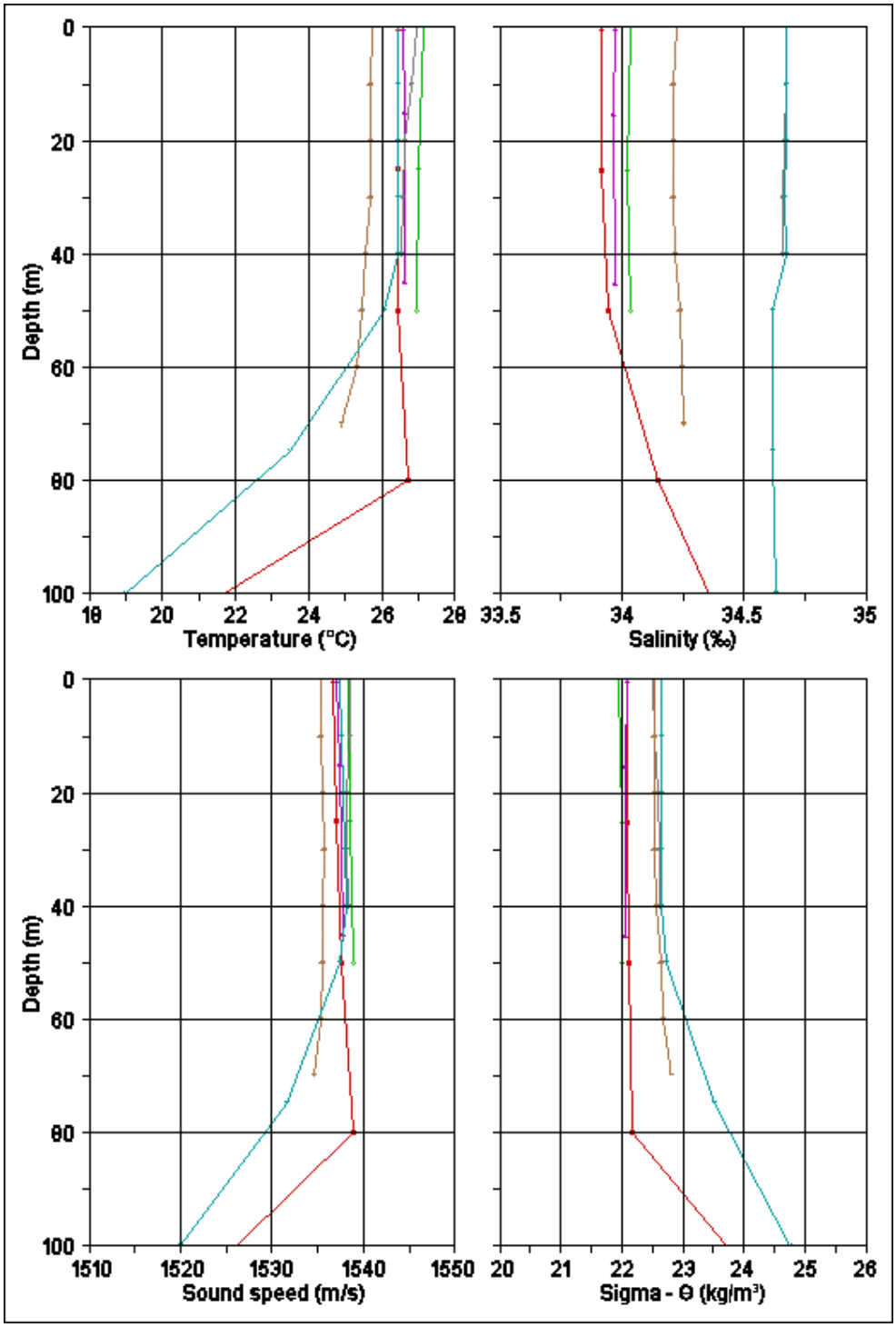


Figure 71: Winter TSVD profiles for Arafura area.
(Source: Conkright *et al*., 1998)

3.6.4 XBT PROFILES

Selected XBT profiles for summer and winter in the Trench, Timor and Arafura areas are shown in Figure 72, Figure 73 and Figure 74. Mixed layer depths in summer for the Trench area can extend to 60 m with an average of 20 m, while greater wind speeds in winter result in mixed layer depths to 70 m and an average of 40 m. In the Timor area mixed layers average 25 m in summer with a maximum around 75 m, and in winter the average is 60 m with a maximum of 120 m, although vertical mixing is often limited by the shallow depth. In the Arafura area mixed layers average 25 m in summer with a maximum of 60 m, and in winter the average is 50 m with a maximum of 90 m. The three areas appear to be similar with surface temperatures of around 30ºC and a mixed layer depth of 25 m in summer, and a surface temperature around 27ºC and a mixed layer depth of 60 m in winter.

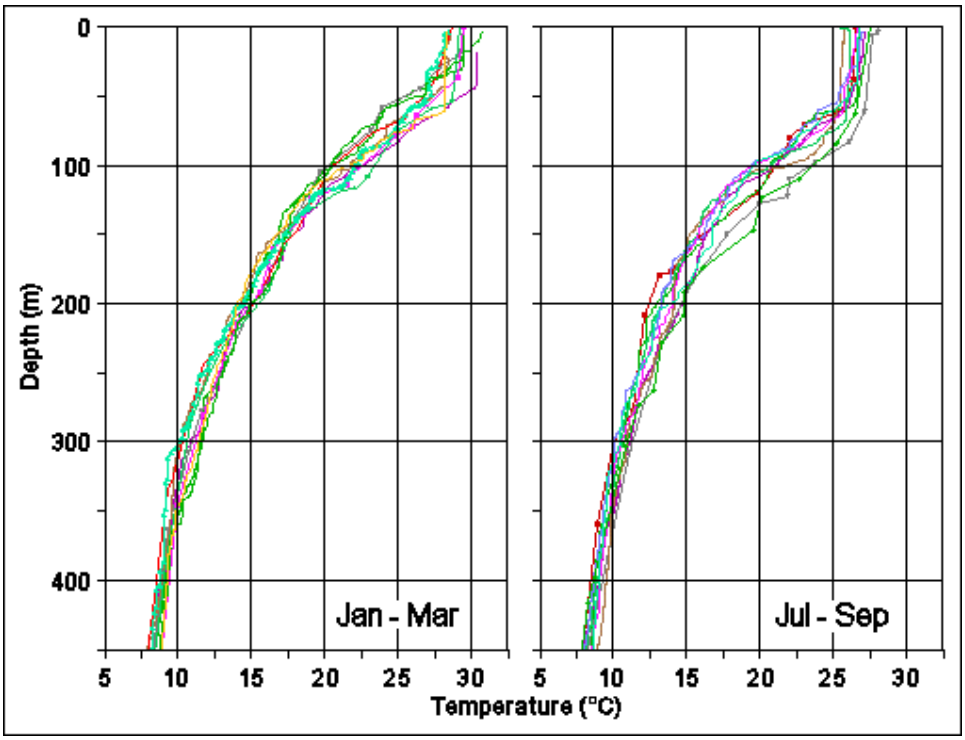


Figure 72: XBT profiles to 450 m for Trench area.
(Source: Conkright *et al*., 1998)

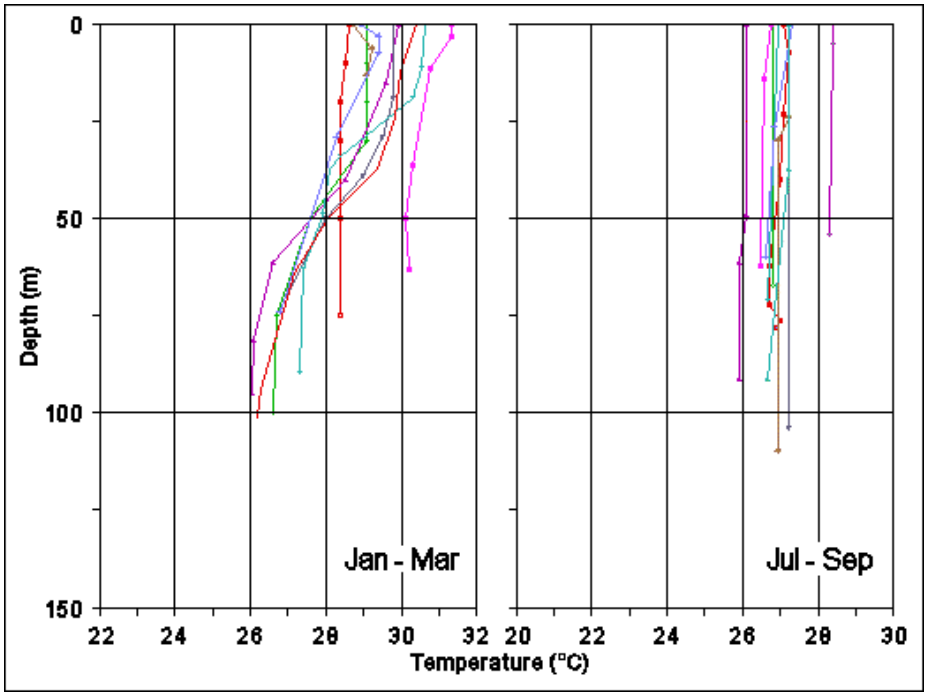


Figure 73: XBT profiles to 150 m for Timor area.
(Source: Conkright *et al*., 1998)

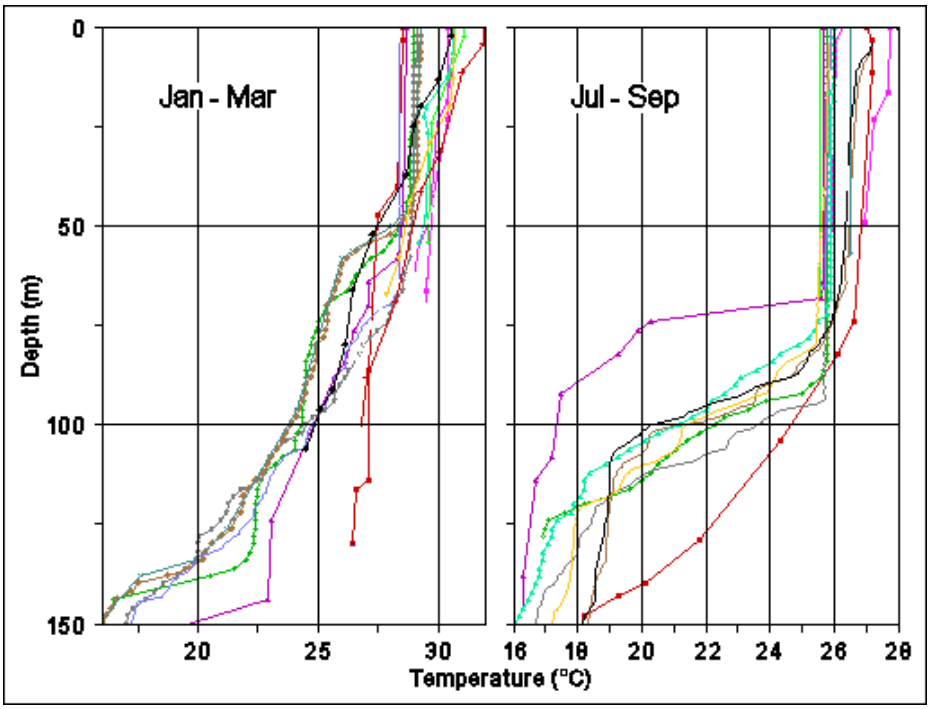


Figure 74: XBT profiles to 150 m for Arafura area.
(Source: Conkright *et al*., 1998)

3.7 WATER TURBIDITY

Water transparency is the product of a number of factors: water depth, wind, sediment type and nutrient flux, which all vary with distance and time. In general, water transparency will be greater in deeper water, where in mid ocean the Secchi disc depth can reach around 50 metres. If the water depth is less than 50 metres strong winds can cause turbulence and resuspension of fine sediments and organic detritus. Vertical mixing by winds and currents also increase the flux of nutrients (from decaying detritus on the bottom or in deeper water) into surface waters promoting phytoplankton growth and consequent decreased transparency. Runoff from land will reduce water transparency due to sediments, detritus and dissolved organic matter.

Water transparency can be expressed in a number of ways, one of which is the Secchi disc depth. The Secchi depth measurement is carried out by lowering a 300 mm white disc into the water and noting the depth in metres at which it disappears from sight, which is a useful water transparency guide for clearance divers. There is little Secchi disc data for the Timor Sea region, but it is possible to estimate Secchi disc depths from data on phytoplankton concentration because phytoplankton is the main light absorber in the open ocean. The images in Figure 76 are adaptations of NASA satellite images of water colour formed by processing data from the Nimbus-7 Coastal Zone Color Scanner from 1978 to 1986. Since this is a long term average image the actual Secchi disc depths may vary from a half to twice the values shown. Close to the coast the presence of suspended sediments makes the estimates of Secchi disc depths in less than 5 m unreliable.

Note that water transparency is reduced in the August-September period, when the SE trade winds cause greater nutrient flux from deeper water in the ocean and thus more phytoplankton growth. In shallower coastal areas the SE winds will also resuspend sediments and detritus, thus reducing water transparency.

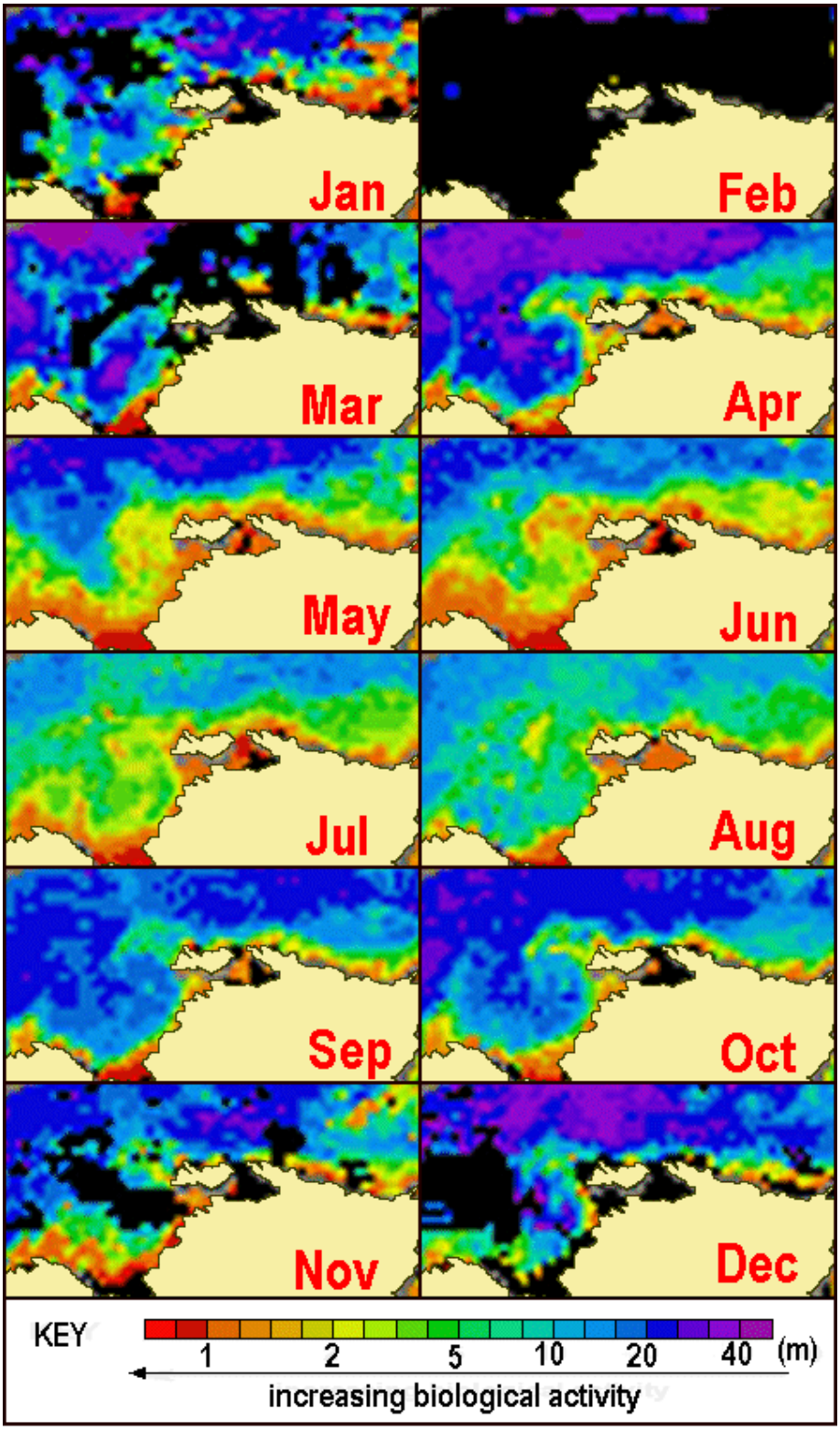


Figure 75: Seasonal change in Secchi disc depths (m).
(Source: NASA, 1999)

4 BIOLOGY

4.1 BIOLUMINESCENCE

Bioluminescence (phosphorescence) is the production of light in the sea from the excitation of a few species of plankton, and jellyfish. Bioluminescence occurs in three main forms: Sheet type, often appearing as a diffuse glow extending over a large area; Spark type, occurring as innumerable flickering points of light; and Globe type, appearing as glowing balls of light. The sheet type, described as “milky sea” or “sea fire”, observed at night most frequently in the open sea. Glowing type is also common. Excitation of the bioluminescent organisms can be caused by breaking waves, bow waves, propellers, wake, rain and moving fish. If strong enough, bioluminescence can be observed at night by ships, aircraft and satellites for as long as one hour after the transit of a vessel. Currents moving past a fixed object such as a moored buoy can also cause bioluminescence around and in the wake if the organisms are present. Occasionally, bioluminescent organisms become attached to an underwater moving object making its outline visible. In general, bioluminescence is a common occurrence throughout the year in tropical regions, particularly in inshore or shallow waters where biological activity is high.

Bioluminescence is most common in July and August (HO, 1980). Most observations from the Timor Sea indicate that bioluminescence occurs in the form of “flashing patches” and “disturbed water luminescence”, while “sheet” (milky sea) and “glowing balls” types are less common. The sparkling patches mostly occur along bow-waves due to mechanical excitation by vessels.

Phytoplankton provides the base of the food matrix in the ocean, so that the numbers of zooplankton, which includes bioluminescent organisms, are directly related to phytoplankton productivity. The images of ocean colour in Figure 76 can be used as an indication of biological activity and the relative probability of bioluminescence. The images indicate that the NW shelf is a productive area and that bioluminescence would be common, particularly during the SE trade wind season.

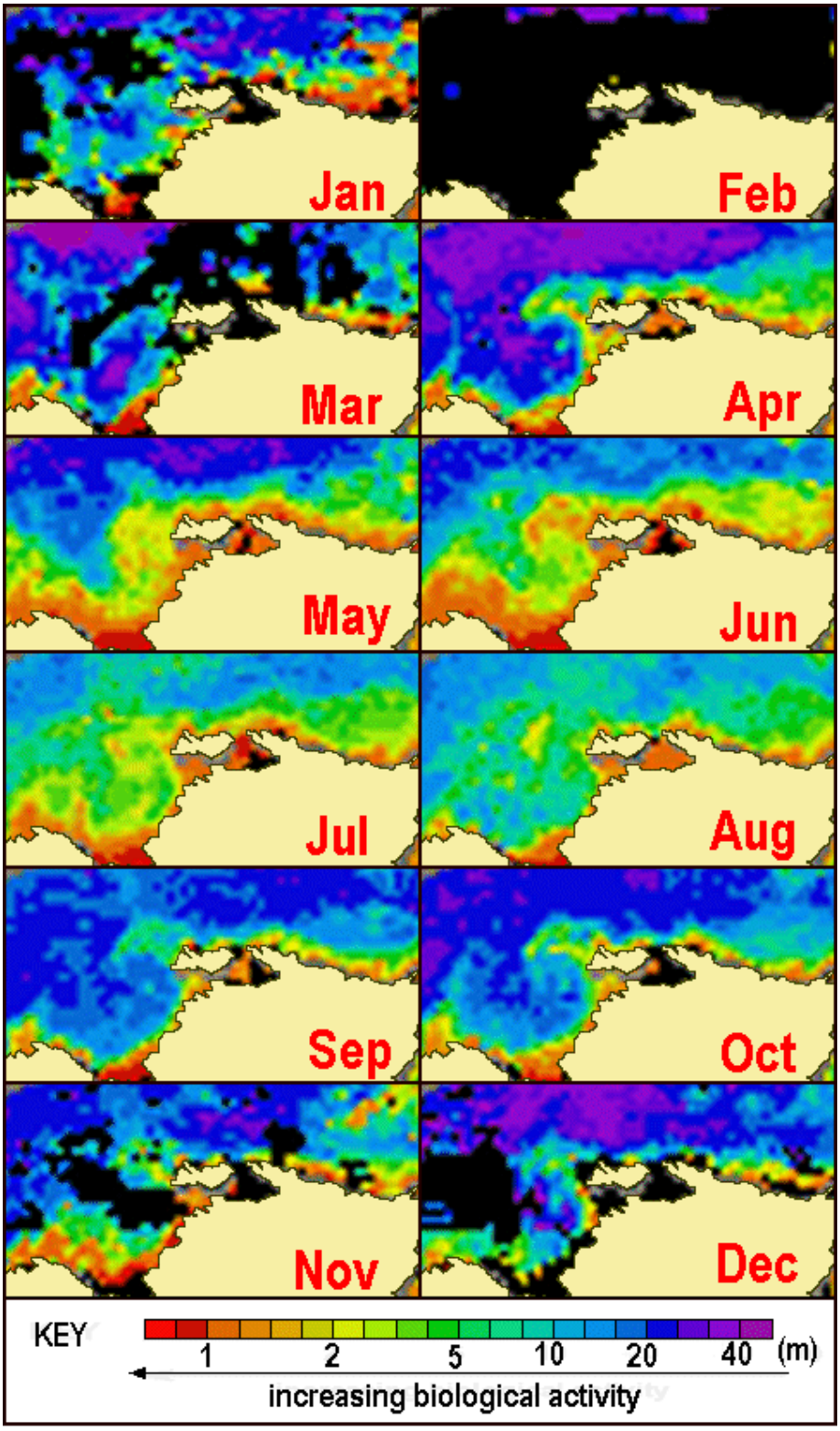


Figure 76: Monthly change in Secchi disc depths (m).
(Source: NASA, 1999)

4.2 HUMAN ACTIVITIES

4.2.1 FISHERIES

WILD CAPTURE FISHERIES

The Northern Territory's aquatic resources are shared between a variety of user groups including commercial, recreational, indigenous fishers, fishing tour operators and the wider community. Management plans have been developed for the Mud crab, Barramundi and Spanish mackerel fisheries. Other fisheries are managed by a combination of regulations, gazettal notices and licence conditions (NT Government, 2008). Wild capture fisheries managed by NT Fisheries include:

- Barramundi
- Mud crab
- Spanish Mackerel
- Off-shore Net and Line
- Timor Reef
- Finfish Trawl
- Trepang
- Demersal
- Coastal Line
- Coastal Net
- Aquarium
- Bait Net
- Mollusc
- Squid Jigging

COMMERCIAL FISHING

Within the bounds of the Australian fishing zone (AFZ) there are numerous managed fisheries (Figure 77). The fisheries relevant to NAXA are listed in Table 3. Indonesia claims an economic exclusion zone 200 nm around the archipelago. Some fishing grounds extend beyond the AFZ and are managed jointly by various countries. Commercial fishing fleets in Australian waters tend to consist of larger well organised vessels, while in Indonesian waters most of the vessels are small, and numerous. There are over 30,000 small vessels in the waters off Malaysia, and similar numbers would apply in Indonesia.

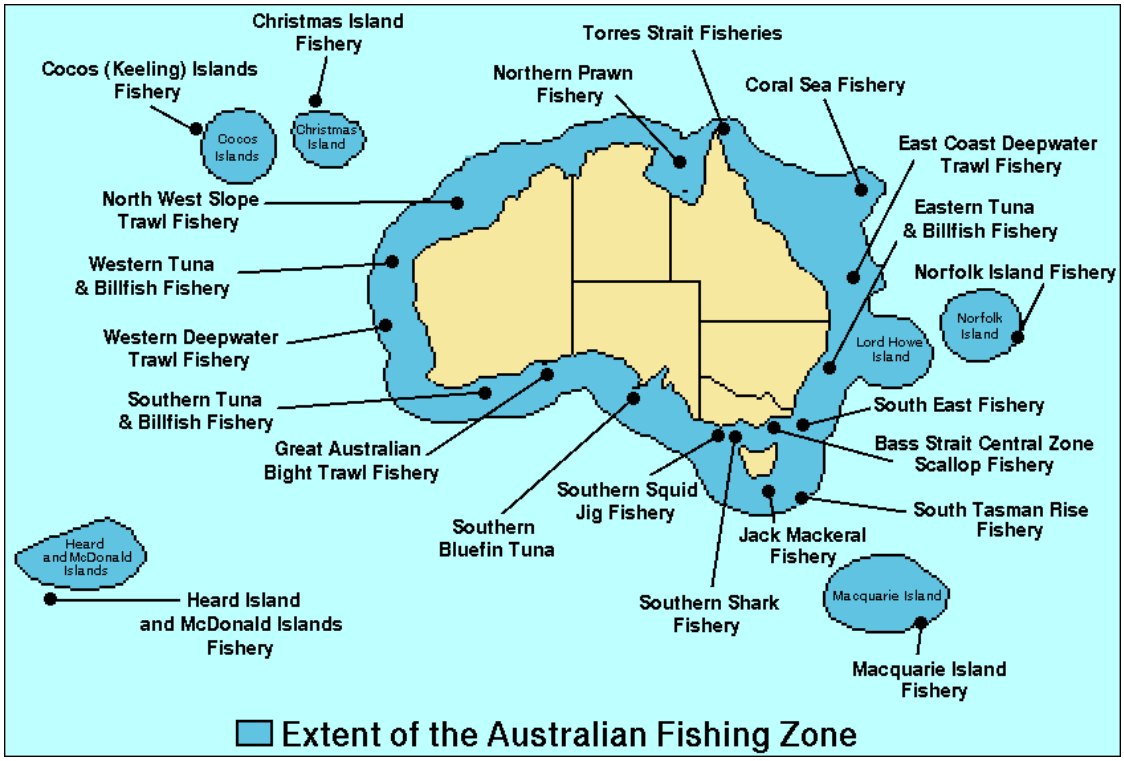


Figure 77: Fisheries within the area.
(Source: AFMA, 2007)

Table 3: Details of fisheries within the area
(Source: AFMA, 2007)

Fishery Name	Extent	Principal Species	No. SFR[1] or fishing permits & management plans	Fishing methods[3]
Northern prawn	Cape York - Cape Londonderry	Banana, tiger and endeavour prawns, scampi, squid, scallops and bugs	SFR - 52 (as of August 2007), NPF mgt Plan (1995, amended 2006)	otter trawl
Western tuna and billfish	Cape York - around the west coast, then east to 141ºE	Yellow fin, bigeye and albacore tuna, broadbill swordfish	permits - 110, includes 1 high seas only permit, WBTF mgt plan (amended 2006)	pelagic longline, purse seine, minor line (hand line, rod and reel, troll, polling)
Western skipjack fishery	from 200 m to the AFZ limit, west of 142°30'E	Skipjack tuna	permits - 13	purse seine, pole, longline and line
Southern bluefin tuna[2]	see Figure 51	southern bluefin tuna	SFR - 98 (as of May 2007), SBT mgt plan	purse seine (for farming), pole, pelegic longline, trolling

Notes for Table 4.

[1]Statutory Fishing Rights

[2]Australia jointly manages fishing grounds in international waters with Japan and New Zealand through the Commission for the Conservation of Southern Bluefin Tuna (CCSBT). For more AFMA information see http://www.afma.gov.au

[3]Fish are caught in the following ways:

- Otter trawl method - a net, towed behind the boat, travels over the sea floor and 'otter' boards keep the mouth of the net open.
- Handline - a line with one or more lures or baits are attached.
- Troll - a method where handlines are towed behind a slow moving boat.
- Demersal trawl - trawl gear is designed to take species on or near the sea bed.
- Purse seine - a net is set around an area of water, the base is then 'pursed' to enclose the area. Used for catching fish for fish farms.
- Pole and line (polling) - fishers use a pole with a barbless lure, or baited barbless hook, to hook and swing the fish onto the boat.
- Pelagic longline - has a mainline attached to branch lines. Baited hooks or lures are attached to these lines. Floats on the sea surface are attached to keep the lines off the seafloor.

RECREATIONAL FISHING

Amateur fishers within the Northern Territory do not require a licence. However, recreational fishers will currently need a temporary licence for recreational fishing activities conducted on and over aboriginal granted land and adjoining waters. There is no requirement for a vessel used for amateur fishing to be registered, but the vessel is required to carry the correct safety equipment. An amateur fisher cannot sell, trade or barter their catch. Popular species include Saratoga, Reef Fish, Mud crabs, Game fish and Barramundi. Size and catch limits apply, refer to: http://www.nt.gov.au/dpifm/Fisheries/index.cfm?header=Fishing%20Controls%20and%20Advice.

INDIGENOUS FISHING

Subsistence fishing in the Northern Territory forms an important part of Aboriginal people's culture as well as a traditional source of protein. Under section 183 of the Fisheries Act Regulations, coastal Aboriginal communities and Land Trusts established to hold title to land under the Aboriginal Land Rights (Northern Territory) Act and may hold a licence to fish and sell fish within areas specified, for the benefit of their community. An Aboriginal coastal licensee cannot hold a commercial fishing licence in conjunction with this licence (NT Government, 2008). Aboriginal coastal licenses allow for the use of amateur fishing gear, including amateur dragnets that are the most common fishing method used with this type of licence.

The most prevalent species of finfish taken by indigenous fishers are mullet, catfish and barramundi. The most important non-fish species are mussels and mud crabs. Indigenous

fishers also harvest a range of species that cannot be taken by non-Indigenous people. These species include turtles, dugongs, crocodiles and mangrove worms (NT Government, 2008).

The Tiwi Islands (Bathurst and Melville Island) of the Northern Territory are Aboriginal owned and administered by the Tiwi Land Council. Whilst the public have legal rights to access fish and waters within rivers, creeks and the intertidal zone of Aboriginal owned land, permits are required to go ashore (NT Government, 2008).

4.2.2 SHIPPING

Numerous shipping routes cross the area north west of Australia and south of Indonesia. Most of these routes are shown in

Figure 78. There are some routes crossing the area that are not shown, such as the iron ore routes from Port Hedland to Asia. Several routes start from points A, B, C, D and E, and south of the Christmas and Cocos Islands then follow great circles across to South Africa and around the Cape of Good Hope. A number of great circle routes commence from points B and C to Mauritius, Reunion and East African ports (HO, 1987). The more frequently used north-south routes through the Indonesian islands are through the Straits of Lombok, Alas and Alor, due to the depth of water and less hazards. Oil rig tenders and tankers will also be present in the areas near the oil and gas area in the Timor Sea and the adjacent NE Indian Ocean.

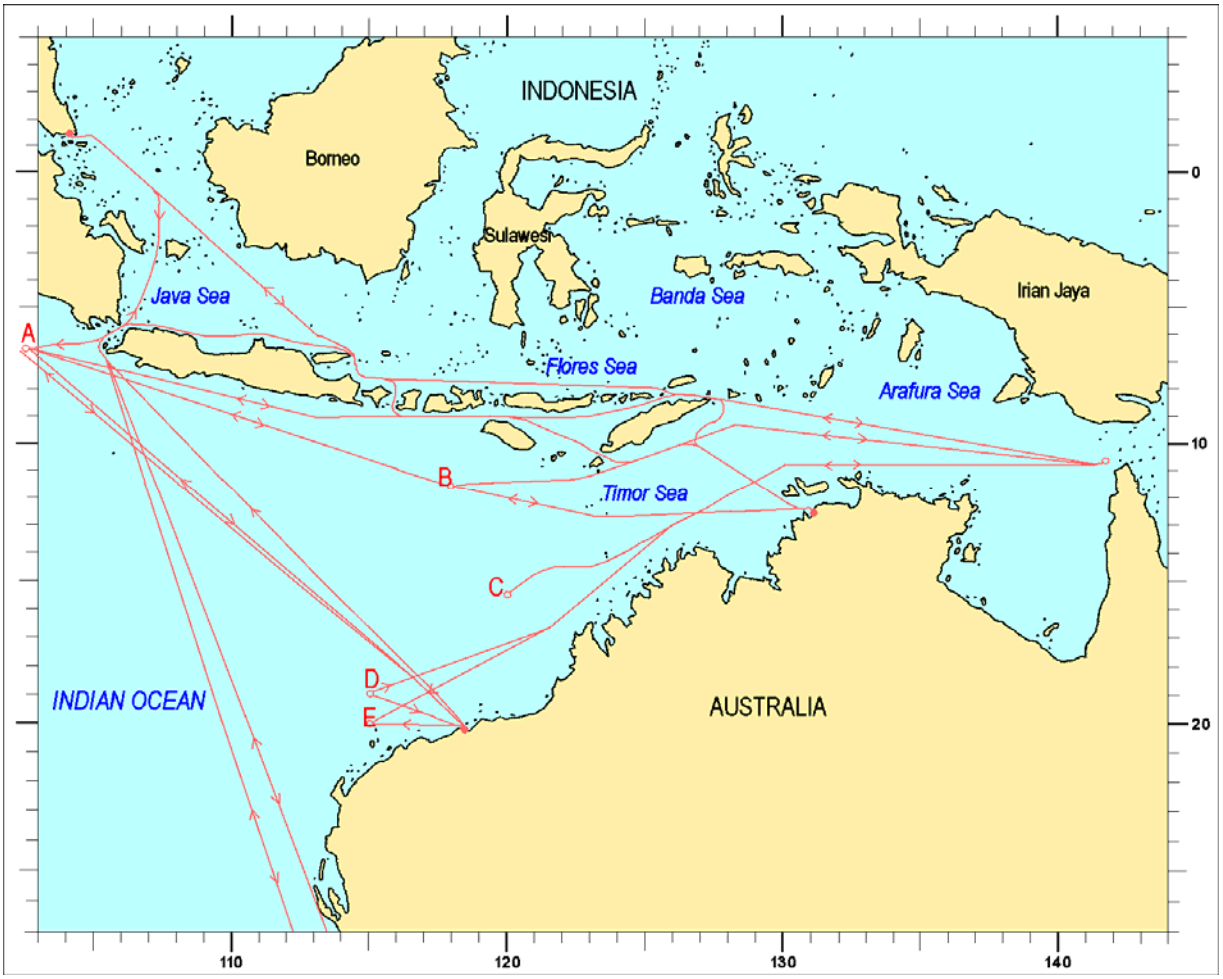


Figure 78: Shipping routes north west of Australia.
(Source: HO, 1987)

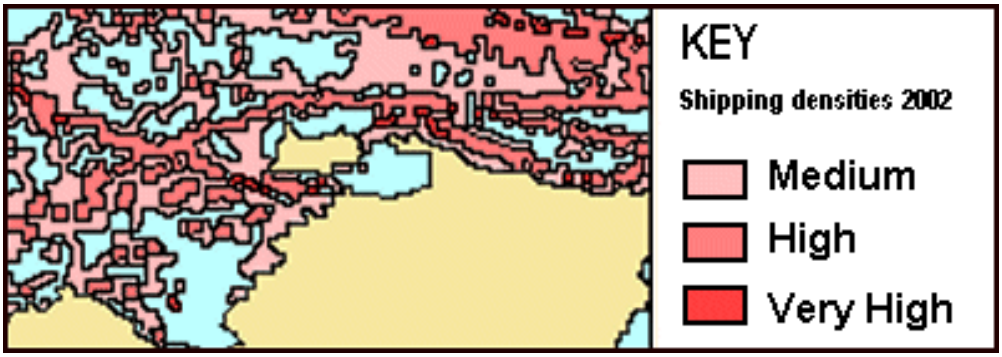


Figure 79: Shipping density in NAXA.
(Source: CSIRO, 2002)

4.2.3 MINING

Figure 80 shows the location of oil and gas fields and the potential oil fields in the Timor Sea as published in 2008. For the latest information on oil wells and submarine cables, Aus chart 314 should be consulted. The chart shows the positions of each oil well, with the prohibited area around them. Information on exploration drilling, which is an ongoing activity in this region, is published in the "Weekly Summary of Navigational Warnings". There are five producing oilfields in the Timor Sea: Jabiru, Challis, Elang/Kakatua, Laminaria/Corallina and Buffalo, which are marked in red in the figure. The Bayu-Undan pipeline, now supplies gas annually to the Northern Territory. The Northern Territory gas use could thereby increase more than sixfold within the next two decades, lifting the NT's share of total Australia use from 2.3 per cent to almost seven per cent by 2020 (Chemlink, 2008).

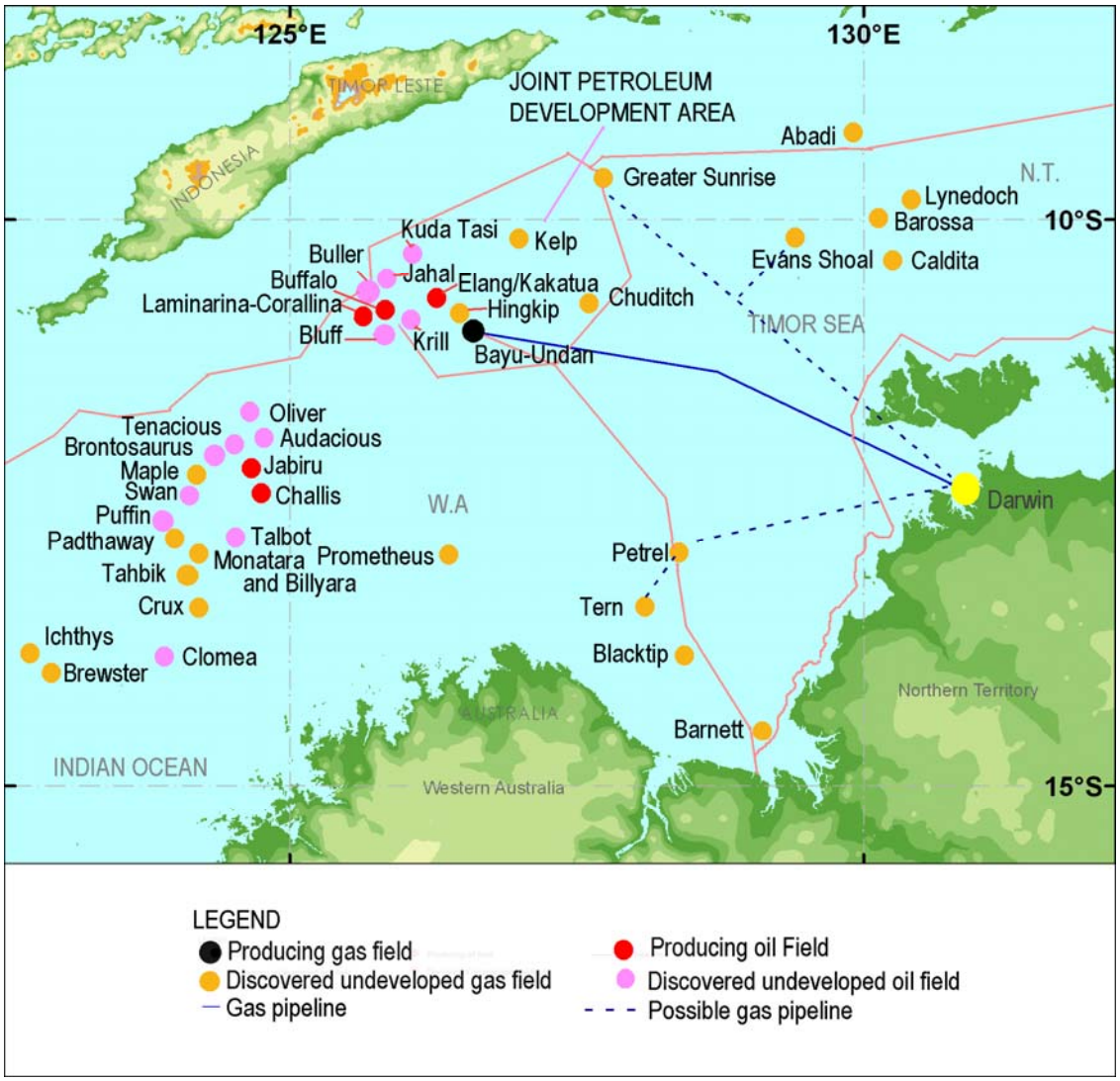


Figure 80: Oil and gas fields and pipelines in the Timor Sea.
(Source: Map produced using data from DOM, 2007 Chemlink, 2008, N.T. Government, 2008)

4.3 MARINE LIFE

The Northern Territory is typified by species rich, highly diverse marine communities with national and international conservation significance. The territory has the largest area of mangroves in Australia and these provide important breeding, feeding and nursery habitats for a range of valuable marine and freshwater species. Coral reef and seagrass meadows are critical feeding habitat for dugongs and turtles while intertidal mudflats and coastal saltmarshes provide important habitat for migratory seabirds.

Many endangered or threatened animals live in the region, including species of sawfish, sea snakes, pipefish, seahorses, sharks and rays. Six species of marine turtles (Green, Olive Ridley, Hawksbill, Leatherback, Flat Back and Loggerhead) (Figure 81) live in northern waters and most are listed as vulnerable, endangered or critically endangered (NT Government, 2008).

Figure 81: Endangered Turtles found in NAXA
(Source: National Geographic, 2008, ABC, 2008, Townsend, 2008)

The Dugong (Figure 82) is the most abundant marine mammal in inshore waters of northern Australia. The Dugong is listed as vulnerable to extinction internationally; however, it is not listed as endangered in Australia. It is fully protected from any commercial or recreational utilisation within its range in Australian waters. The Dugong has a significant cultural and dietary role for many indigenous Australian peoples and is subject to indigenous utilisation within these roles (NT Government, 2008).

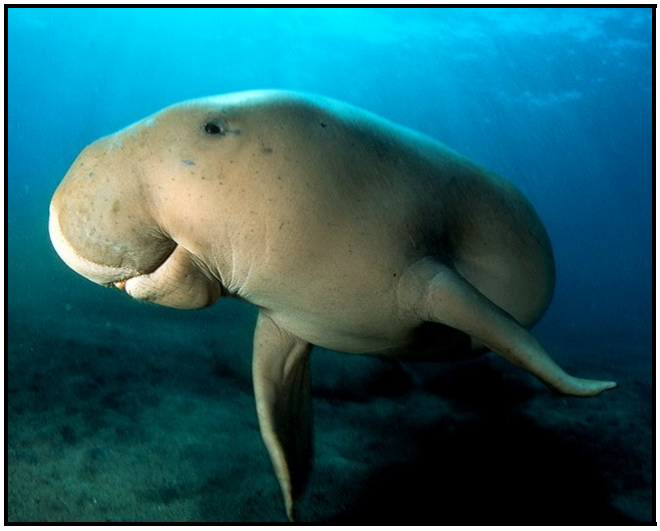


Figure 82: Dugong
(Source: National Geographic, 2008).

Humpback whales, Killer whales (Orca) (Figure 84) and the Sei whale (Figure 83) have been sighted off the Northern Territory. The Sei whale is a moderately large (15-16 m length) baleen whale. The Sei whale is listed as a vulnerable species, its distribution is unpredictable, generally found in deep waters. They are rarely recorded in Australian waters (NT Government, 2008).

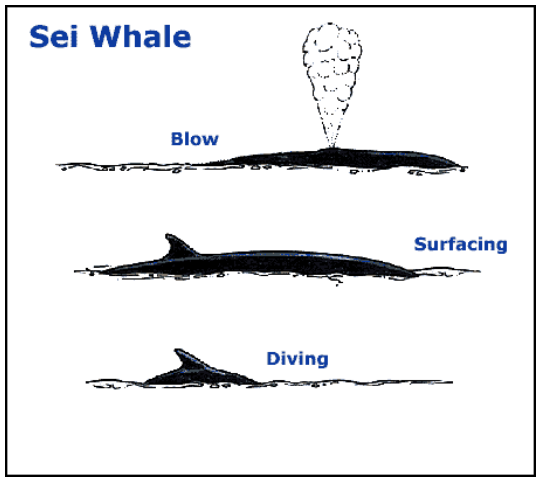


Figure 83: The Sei Whale.
(Source: ABC, 1998)

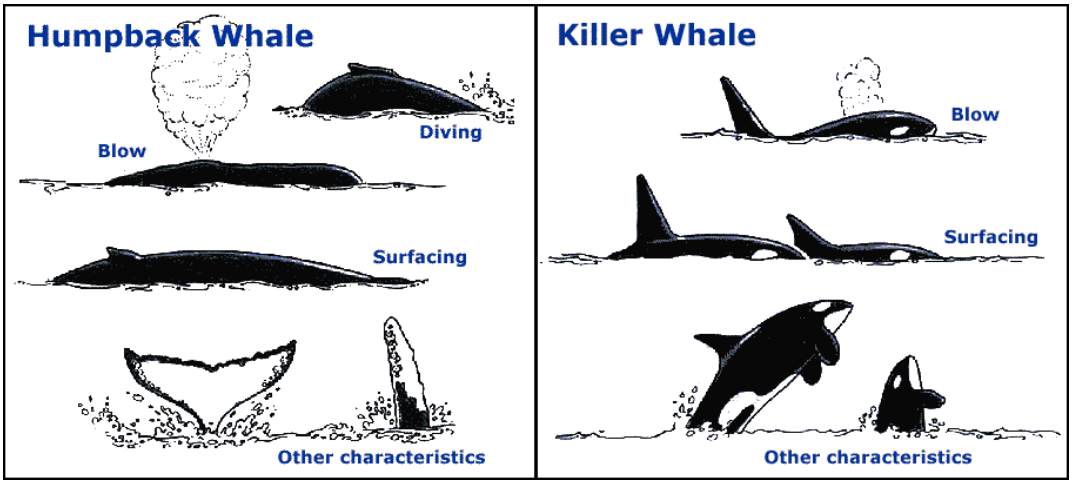


Figure 84: Humpback whale and Killer whale.
(Source: ABC, 1998)

The majority of humpbacks in Australian waters migrate north to tropical breeding grounds from June to August, and south to the Southern Ocean feeding areas from September to November. The exact timing of the migration period can change from year to year and may be influenced by water temperature, the extent of sea-ice, predation risk, prey abundance and location of feeding ground. Humpback whale stranding has been observed on the Napier peninsula, Northern Territory (Australian Government, 2008).

The whale shark (Rhincodon typus) (Figure 85), is also found off the Northern Territory. The whale shark, which is listed as vulnerable, is the world's largest fish and reaches a length of up to 18 m (CSIRO, 2008). Despite its huge size, the Whale Shark is not a threat to people. There are about 300 tiny, hooked teeth in both jaws. Whale Sharks feed by filtering small crustaceans, squid and fishes from the water using filtering screens on the gills (Australian Museum, 2008).

Figure 85: Whale Shark with fish.
(Source: National Geographic, 2008)

Marine environments in the NT are relatively pristine and thought to be primarily impacted by natural disturbances such as cyclones. Increased anthropogenic activities at local and regional scales now threaten many habitats and species (NT Government, 2008).

4.4 SEAGRASS MEADOWS

A Northern Territory seagrass meadow survey found there to be an area of just over 42,000 hectares of intertidal seagrass. Combined with data from previous surveys it is estimated that at least 70,000 hectares of intertidal and shallow sub-tidal seagrass are present in the survey region. The survey region described is the intertidal and shallow sub-tidal seagrass communities from Van Diemen Gulf to Castlereagh Bay, Northern Territory, and from Gove to Horn Island, Queensland (NT Government, 2008).

Seagrass surveys on the Northern Territory coast and the Gulf of Carpentaria found that *Halophila* meadows (Figure 86) were the major intertidal meadow types for this region. In the areas surveyed, seagrass communities were concentrated in the Caledon and Blue Mud Bay regions in the north, Numbulwar, and the Borroloola/Sir Edward Pellew Island group in the south. Previous studies have also identified significant areas of seagrass at Groote Eylandt (Poiner *et al*., 1987). The dominant cover type for the region was meadows with aggregated seagrass patches (Figure 87).

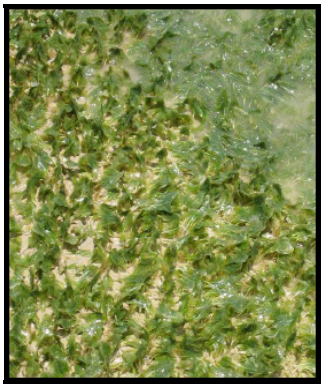


Figure 86: *Halophila ovalis.*
(Source: Roelof et al., 2005)

Figure 87: Aggregated seagrass patches (aerial view).
(Source: Roelof et al., 2005)

The *Halophila* meadows in Caledon Bay had particularly high dugong feeding activity, while the seagrass meadows from Limmen Bight to the Sir Edward Pellew Island Group had high numbers of feeding flatback turtles (50+ on some meadows) and several dugongs. Seagrass meadows are also found in the Fog Bay – Bynoe Harbour region, these are not widespread and were patchy in nature, dominated by the pioneer species *Halophila* sp. and *Halodule* sp. However, some meadows had extensive dugong feeding trails, indicating that the area may be an important feeding ground (Roelof *et al*., 2005).

4.5 DANGEROUS ANIMALS

As a result of the coral reefs, various marine creatures within the area can cause painful injury or even death by stinging. These include starfish, sea ferns, corals, jellyfish, sea urchins, sting rays, sea snakes, conus snails and some reef fish. Larger sharks may also present a danger. Many of the most significant animals are listed below. For further information see http://www.toxinology.com/index.cfm and www.emedicinehealth.com.

Note: the information provided in this section is a guide only. It is suggested that before the exercise that you consult a reliable source such as your medical personnel.

Dangerous and potentially deadly animals found in the area include:

- Box jellyfish (sea wasps)
- Irukandji (jellyfish)
- Saltwater Crocodile
- Blue-ringed Octopus
- Sharks
- Stone fish
- Scorpion fish
- Stingrays
- Redback spider
- Snakes
- Cone shells

Box jellyfish, also called sea wasps and marine stingers, live primarily in coastal waters off Northern Australia and throughout the Indo-Pacific. The box jellyfish season is from October to May, although stings have been reported in all months. Swimming in the sea near the coast and around river mouths, estuaries and creeks should be avoided during this season. Box Jellyfish are pale blue and transparent in colour and difficult to see. They get their name from the cube-like shape of their bell. Up to 15 tentacles grow from each corner of the bell and can reach 3 meters in length. Each tentacle has about 5,000 stinging cells, which are triggered not by touch but by the presence of a chemical on the outer layer of its prey. Their venom is considered to be among the most deadly in the world, containing toxins that attack the heart, nervous system, and skin cells. (National Geographic, 2008).

Figure 88: Box Jellyfish
(Source: National Geographic, 2008)

Irukandji (Carukua barnesi) inhabits Northern Australian waters roughly from the end of October to early May. This is a deadly jellyfish, which is only 2.5 centimetres in diameter, which makes it very hard to spot in the water. The initial sting of the jellyfish is usually not very painful. But about 5 - 45 (usually 30) minutes after being stung, the person starts to have a severe backache or headache and shooting pains in their muscles, chest and abdomen. They may also feel nauseous, anxious, restless and vomit.

Figure 89: Irukandji
(Source: BBC, 2003)

Saltwater Crocodiles are found in brackish water around coastal areas and in rivers. They are also present in freshwater rivers, billabongs and swamps. Fear of this species is not unfounded, with a number of people injured or killed each year, although in most cases these tragedies can be avoided with

increased awareness. The saltwater crocodile is also the world's largest living reptile in terms of mass. Adult males can reach sizes of up to 6 meters (Britton, 2002).

Figure 90: Saltwater Crocodile.
(Source: Virginmedia, 2008)

Blue-ringed Octopus range from four to six centimetres long, with arms reaching lengths of 7 to 10 centimetres. The group is named for the iridescent blue markings that dot their bodies; however these are usually only seen when the octopus feels threatened and is about to attack. They inhabit depths from intertidal flats down to 50 m. They tend to hide in crevices or under rocks during the day, and emerge at night (Australian Institute of Marine Science, 2008).

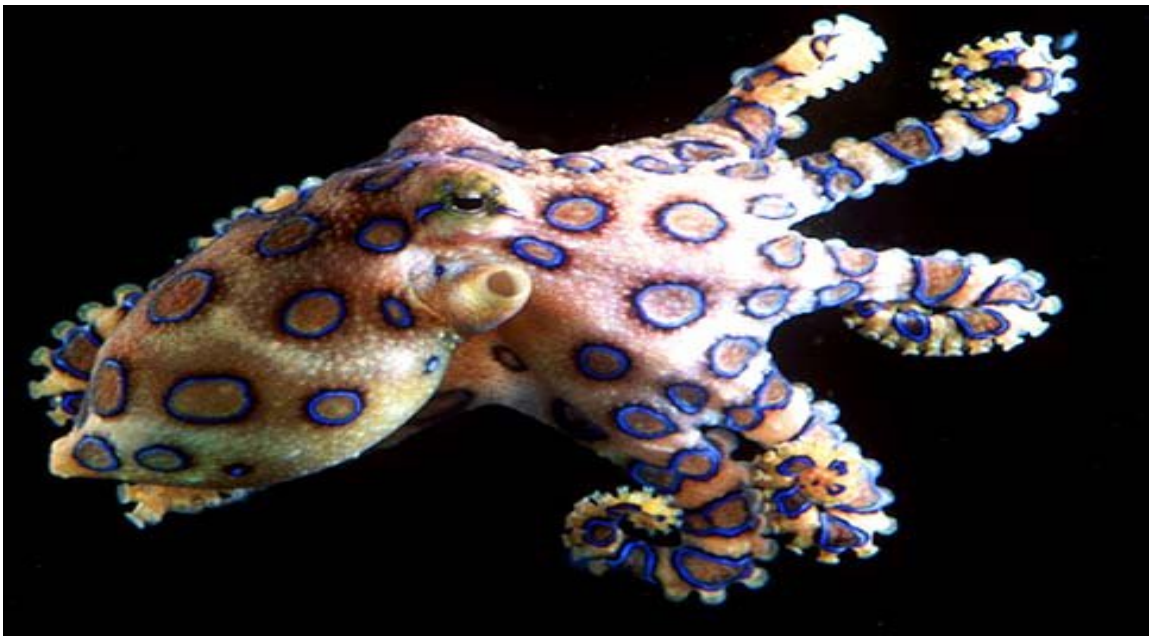


Figure 91: Blue Ringed Octopus.
(Source: Brown University, 2008)

The three sharks most dangerous to people in the tropical regions of Australia are: Bull Sharks, Tiger Sharks and Great White Sharks. Shark habitats range from open ocean waters to coastal waters, rivers and coral reefs. The Bull Shark also inhabits fresh water and is considered to be a very dangerous shark because of its aggressive nature and liking for shallow habitats. Research suggests that sharks undergo daily activity rhythms culminating in greater activity between sunset and well into the night. Generally sharks will only attack humans if provoked or mistaken for food (Australian Institute of Marine Science, 2008).

Figure 92: Three potentially dangerous sharks (others may also present dangers)
(Source: AASharks, 2008; Sharkzone, 2008; and Shark Attack Photos, 2008)

Stonefish are usually a mottled greenish-brown colour with its skin having many stone-like appendages which gives it an almost perfect camouflage against the background it prefers. The most striking feature of this species is its' spines, a row of 13 grooved hypodermic-like projections along its back, each capable of piercing a sandshoe. Stonefish can live out of water for many hours and grow to about 30 cm in length. Its main habitat is on coral reefs, near or about rocks, or it just lies dormant in the sand or mud (Australian Institute of Marine Science, 2008).

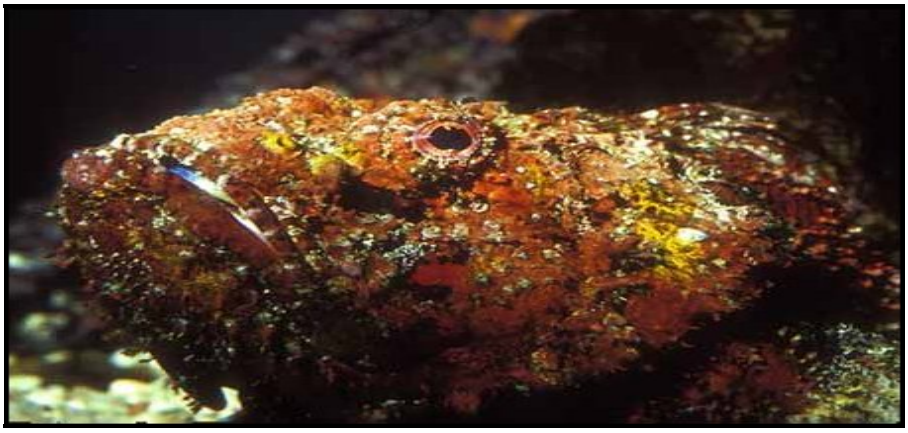


Figure 93: Stonefish.
(Source: National Museums Liverpool, 2008)

Scorpion fish have long spines on the dorsal and contain enough poison to kill. They inhabit every area of Australia and prefer coral reefs (YES Australia, 2008).

Figure 94: Scorpion Fish.
(Source: Dkimages, 2008)

Stingrays are found on the sea bottom and only attack if they have been stepped on or threatened (Australian Venom Research Unit, 2008).

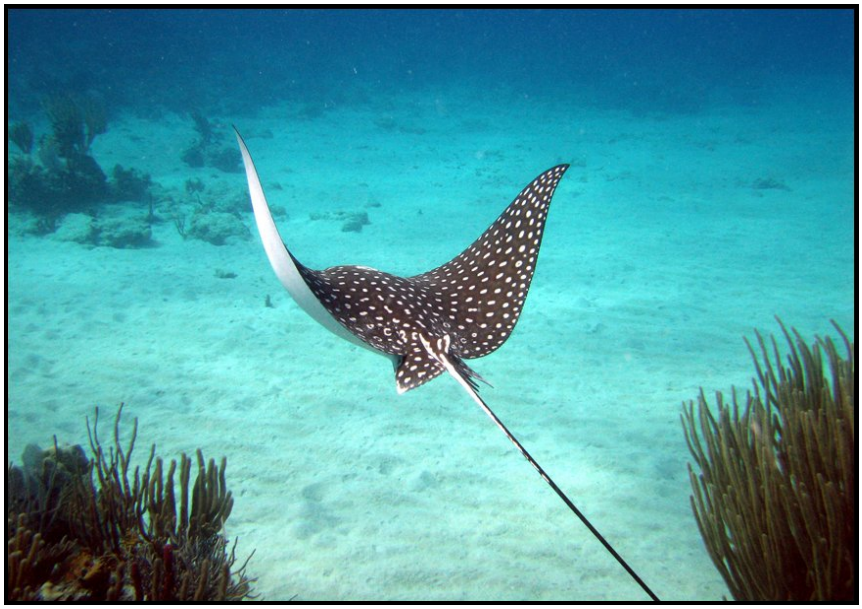


Figure 95: Stingray.
(Source: Swimatyourownrisk, 2008)

The Redback spider bite is found all over Australia, especially in urban areas (AVRU, 2008).

Figure 96: Redback Spider.
(Source: AVRU, 2008)

Venomous snakes found in the Northern Territory include Death Adder, Red-bellied Black Snake, Taipan, Eastern Brown Snake and King Brown Snake. Encounters rarely occur due to their nocturnal and shy behaviour. All native snakes are protected in the Northern Territory (NT Government, 2008).

Figure 97: Eastern brown Snake.
(Source: Australian Museum, 2008)

Several Cone Shell species are capable of stinging humans with painful and potentially fatal results.

Figure 98: Textile Cone Shell.
(Source: Scuba Equipment USA, 2008)

4.6 DISEASES

Before travelling to the Northern Territory, seek advice from your medical personnel about vaccinations and check the website http://www.nt.gov.au/health/ for any health alerts. Four to six weeks before travelling, precautions should be taken such as ensuring vaccinations are up to date such as measles, pertussis (whooping cough), Haemophilus influenzae type b (Hib), Pneumococcal disease, Hepatitis and Tuberculosis (check with medical personnel). These diseases are present in some isolated communities. Scabies infections have increased with poor living conditions in some indigenous communities; this is a mite that can be treated with lotion. Precautions should also be taken when drinking any water from isolated community water supplies ie. boiling water if necessary.

Viral Infections that occur in the area include Ross River Fever and Barmah Forest viruses, which are spread by mosquitoes, can be diagnosed by blood tests and have similar symptoms. Ross River Virus is found throughout Australia, Papua New Guinea, parts of Indonesia and the western Pacific Islands. In the Northern Territory, the main risk season is from December to March inclusive with the highest risk period in January when large numbers of mosquitoes result from either high tides or increased rainfall (NT Government, 2008). Epidemics usually follow heavy rains or after high tides which inundate salt marshes or coastal wetlands. Between 70–90 per cent of people infected with RRV have slight or no symptoms. Between 10–30 per cent of these develop an illness, which may include a rash, general effects and rheumatic symptoms. The disease can cause incapacity and inability to work for two to three months. About one-quarter of patients have rheumatic symptoms that persist for up to a year (Australian Government, 2008).

After a cyclone in the Northern Territory there could be a risk of contracting Melioidosis from groundwater following heavy rains. Melioidosis is a disease caused by a bacteria in the soil that can be transmitted through open cuts or broken skin. (Northern Territory Government, 2008).

5 GEOLOGY

5.1 BATHYMETRY

The Arafura and Timor Seas cover a wide portion of Australia's northern continental shelf. Water depths in the Arafura Sea over the Arafura Shelf, which extends from Cape York Peninsula westward to 130ºE, range between 30 and 90 m. The Northwest Shelf consists of the submerged continental shelf area off the Northwestern coast of Australia and includes the Sahul Shelf and the Joseph Bonaparte Gulf. The Malita Valley is a narrow channel that serves as principal outflow of the Bonaparte Depression during sea-level low stands. The Timor Trough lies between the Sahul Shelf and Timor, with depths of 3,000 m (Figure 99).

The Timor Sea over the Sahul Shelf extends westward from 130ºE to the shelf edge, with depths ranging from tidal reefs to 200 m. The edge of the Sahul Shelf between 123ºE and 130ºE is studded with shoals and reefs ranging from above-water reefs to shoals with depths of up to 30 m. These shoals and reefs are known collectively as Sahul Banks (Figure 100). Caution should be exercised in this area due to probable uncharted dangers (HO, 1992). The Sahul Shelf is a recently drowned part of the Australian continent, with old shorelines, river channels and a large lake defined by the detailed bathymetry.

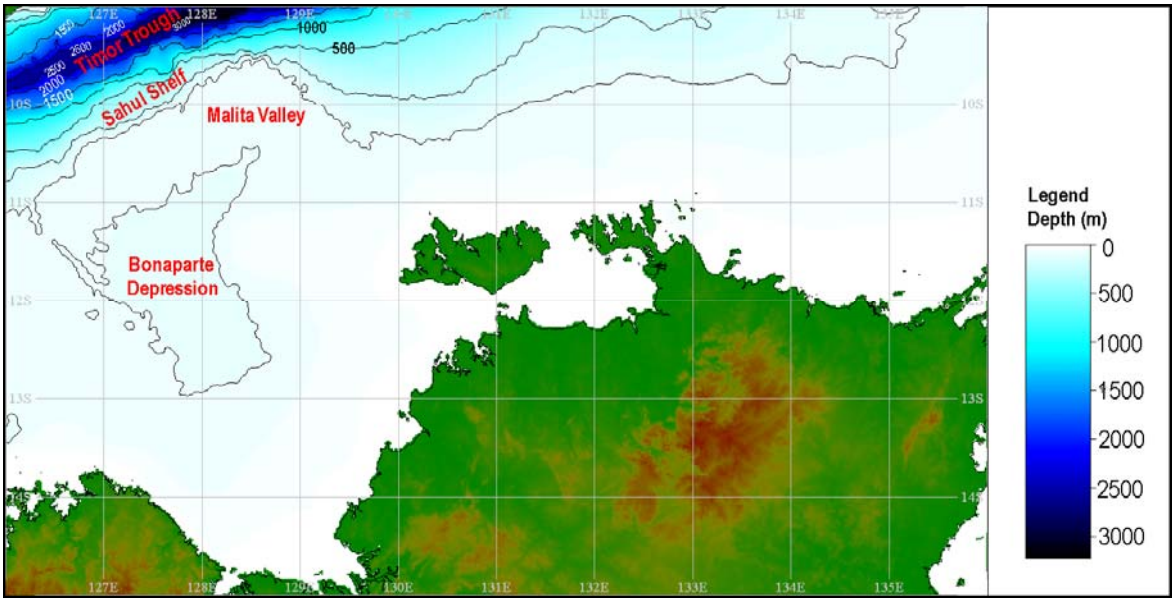


Figure 99: Bathymetry (m) of the area.
(Source: GEBCO, 2003 and Yokayama *et al*. 2001)

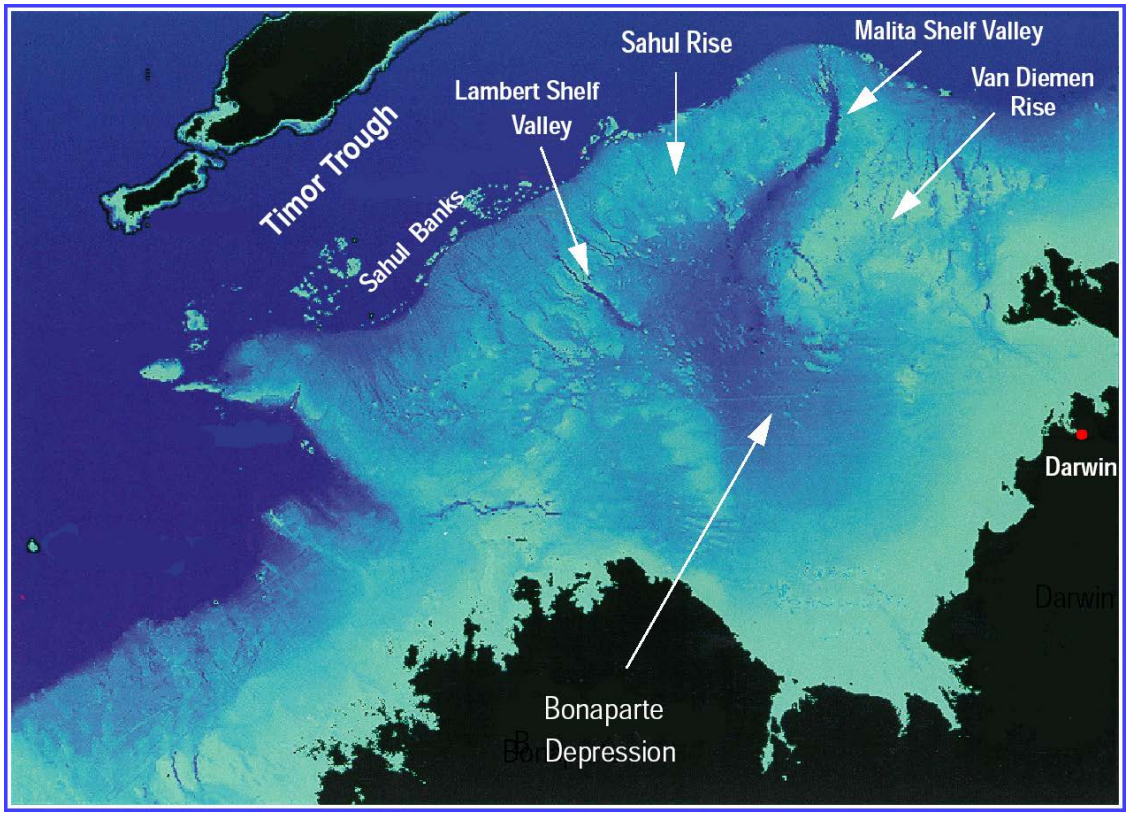


Figure 100: Topography of the Sahul Shelf.
(Source: AGSO, 1997)

5.2 SEABED TOPOGRAPHY

In addition to sediment types, grain sizes and thickness, the slope and roughness of the seafloor are important determinants for the performance of acoustic sensors. Seafloor slopes and relief for NAXA are shown in **Figure** 101 and **Figure** 102.

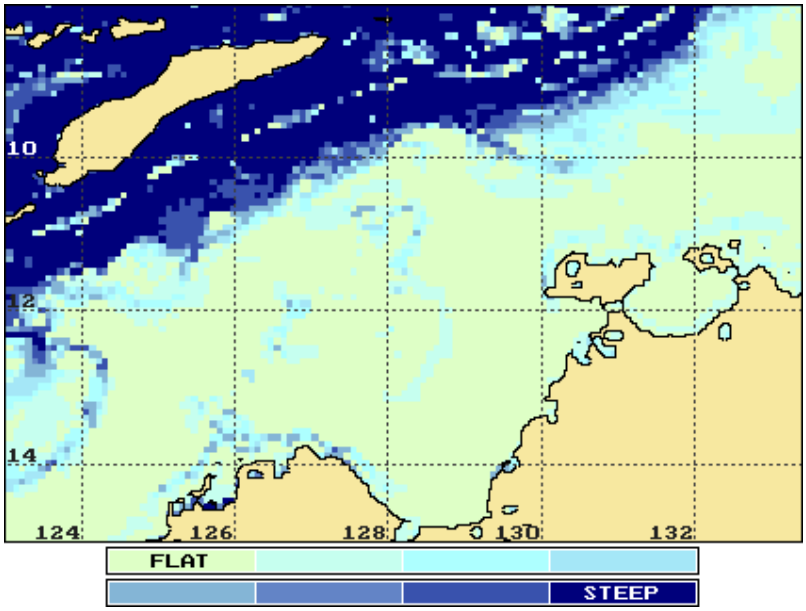


Figure 101: Seafloor slopes.
(Source: WADER, 1998)

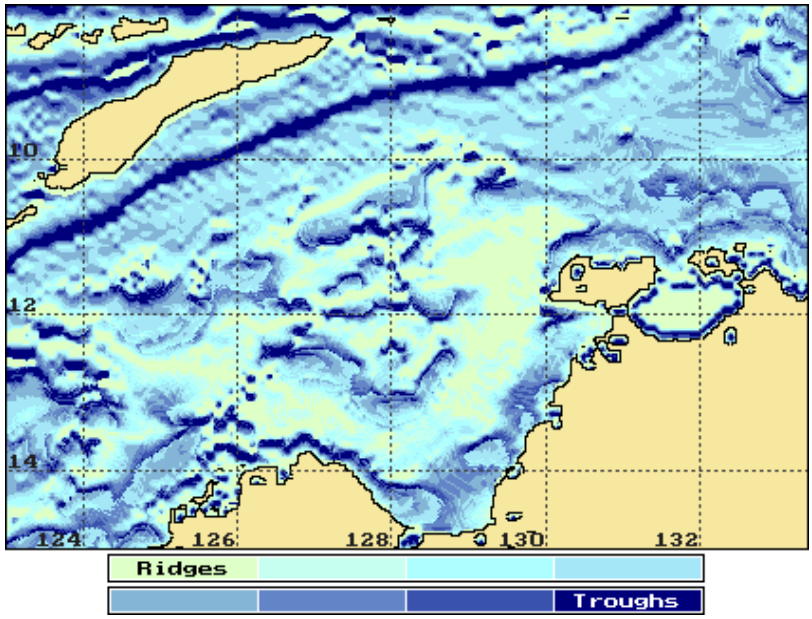


Figure 102: Seafloor relief.
(Source: WADER, 1998)

5.3 REEFS

Cobourg Marine Park shown in **Figure 103**, latitude 11º21'S, longitude 132º11ºE, has an area of 229000km^2 and is protected because of the coral, mangrove, littoral and marine ecosystems (Reefbase, 2008). Approximately 250 species of coral have been recorded along the NT coastline, including Kelloway Reef, Bynoe Harbour (**Figure 104**) and off Casuarina Beach, Darwin. However, these species rarely form large reef systems, due to the lack of clear water. Small coral reefs, dominated by branching 'staghorn' corals (from the Acroporiidae family), have been recorded on the Cobourg Peninsula. Massive corals (mainly from the Faviidae family) are also common, particularly in Darwin Harbour, along the Arnhem coast, and in Popham Creek on Cobourg Peninsula. Coral communities in the NT are diverse and in pristine condition, with some coral colonies reaching the maximum size for their species (NT Government, 2008).

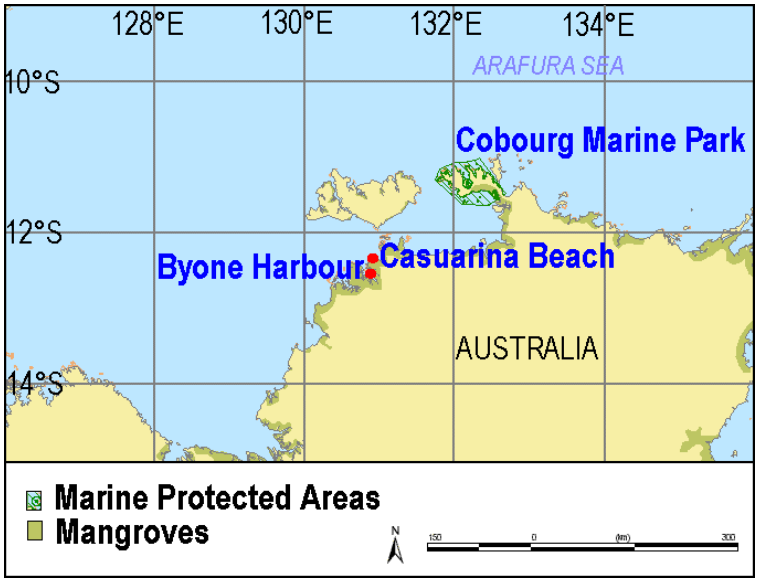


Figure 103: Marine Protected Areas within NAXA.
(Source: Reefbase, 2008)

Figure 104: Kelloway Reef corals, Bynoe Harbour.
(Source: NT Government, 2008)

5.4 SEISMIC ACTIVITY

There are numerous active volcanoes and seismic areas to the north of NAXA in Indonesia, as indicated by Figure 105. Eruptions and earthquakes under the sea or near the coast may cause tsunamis. While tsunamis are not normally dangerous for ships at sea they can cause abnormal tides and tidal currents near the coast. No records of tsunami runup are available for the NW coast of Australia, although it is expected that the wide continental shelf will progressively reduce the energy of any long wave-length waves from deeper water before reaching the Australian coast. Volcanic eruptions can also produce volcanic ash, which can be potentially deadly to people in aircrafts and also affects visibility, this is most likely to occur in the NW monsoon. The Darwin Volcanic Ash Advisory Centre tracks and forecasts ash movements, this is on the website: http://www.bom.gov.au/info/vaac/advisories.shtml.

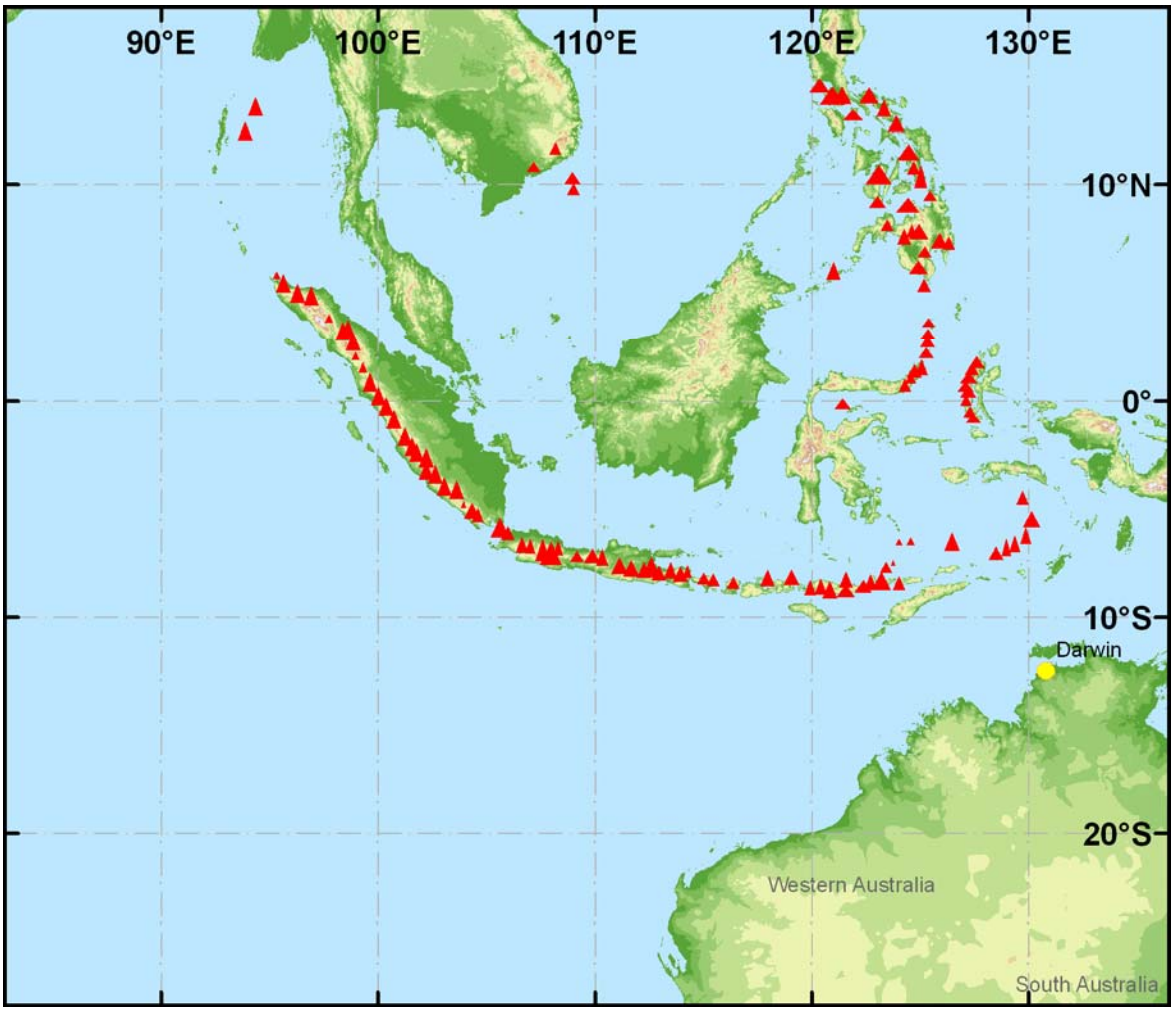


Figure 105: Volcanoes, active in the last 10,000 yrs.
(Source: Smithsonian Institute, 2003, map from DOM, 2007)

5.5 BOTTOM SEDIMENTS

Bottom sediments in the continental shelf areas of the Timor and Arafura Seas mainly consist of sand with varying amounts of clay and some silt, as shown in Figure 106 and Figure 107. The sediments of the region have been reviewed in detail by Harris *et al*. (1991). Close to reefs and shoals there will be patches of gravelly sand and stones. The amount of clay and silt (mud) in the sediments increases towards the central part of the Bonaparte Depression, while gravelly and sandy bottom is common over its shallow surrounding banks and rises. In the deep trough to the south of Timor the sediment is silty-clay, and although it is not shown in the Arafura diagram this fine grained sediment type will continue to the NE in the deeper waters south of Tanimbar Island.

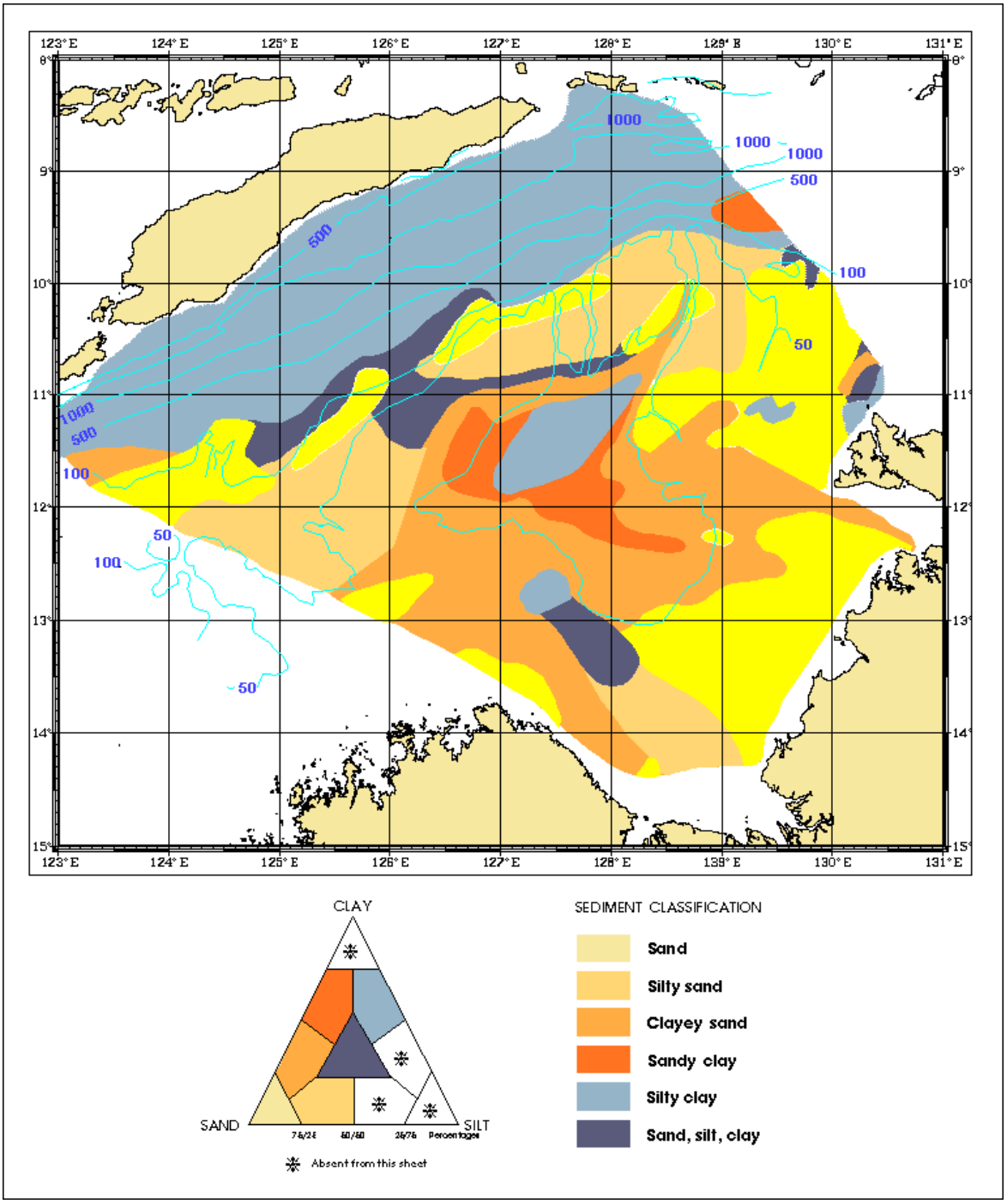


Figure 106: Sediments in the Timor Sea.
(Source: Van Andel and Veevers, 1967; and Jongsma, 1974)

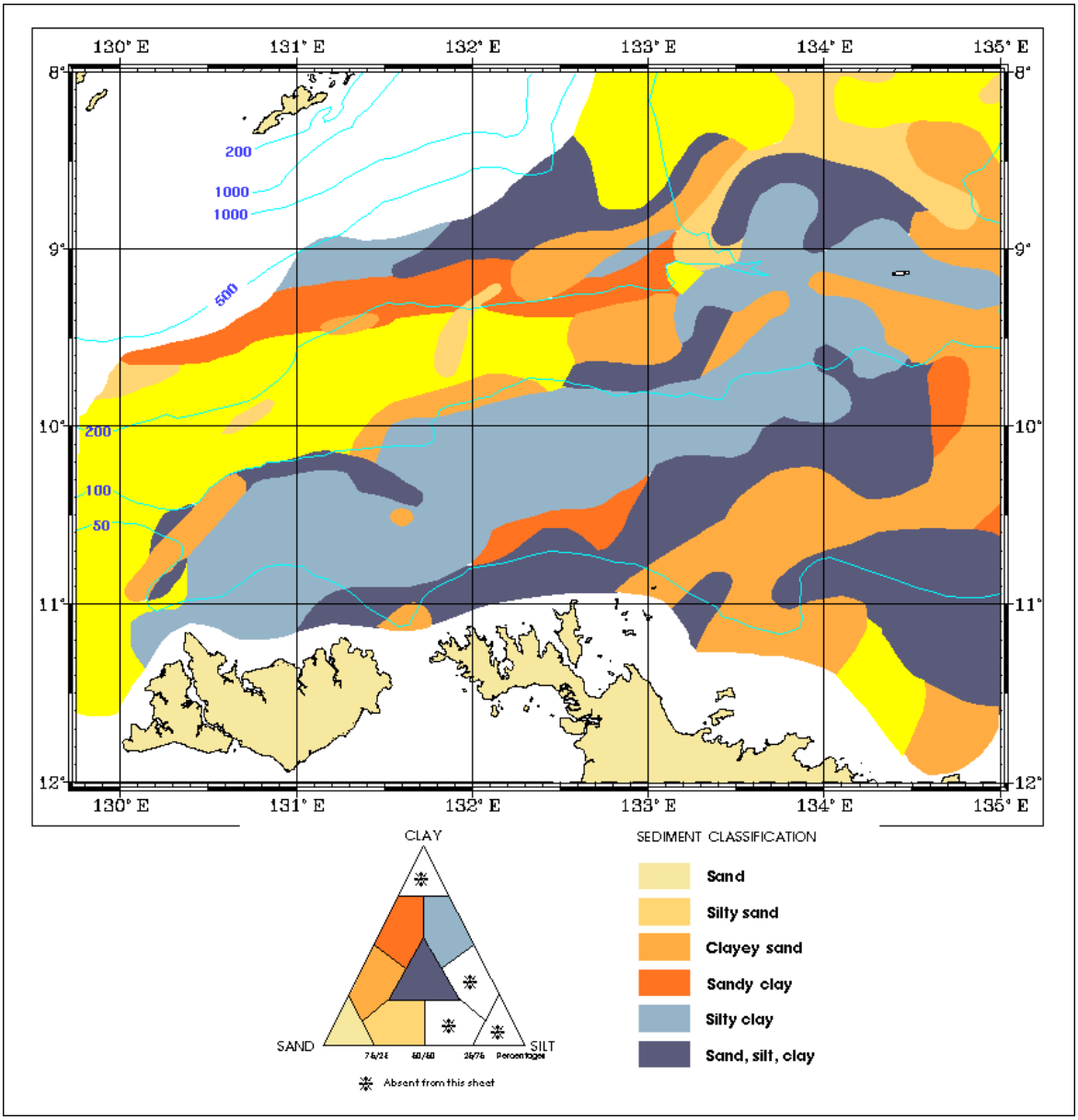


Figure 107: Sediments in the Arafura Sea.
(Source: Van Andel and Veevers, 1967; and Jongsma, 1974)

6 APPENDIX

6.1 LOCATION OF DOCUMENT ON INTRANETS

DRN http://intranet.defence.gov.au/navyweb/Sites/DOM

DSN http://web.ppt.ear.dsn.mil.au/metoc/index.htm

Then click on Climate Products > Mega Briefs

6.2 USEFUL INTERNET LINKS

Although we endeavour to present as much available information as is possible at the time of writing, some information is beyond the scope of these briefs. The following website may provide further useful information.

6.2.1 REAL TIME DATA

Falling Rain Genomics Inc is a commercial venture that provides basic daily weather information for numerous locations around the globe. Link – http://www.fallingrain.com/world/index.html

6.3 ACRONYMS

AFMA	Australian Fisheries Management Authority
AFZ	Australian Fishing Zone
AGSO	Australian Geological Survey Organisation
AHO	Australian Hydrographic Office
BoM	Bureau of Meteorology
CIRES	Co-operative Institute for Research in Environmental Sciences (US)
DCS	Ducting Climatology Summary
FCCA	Federal Climate Complex, Asheville (US)
FWOC	Fleet Weather and Oceanographic Centre
GEBCO	General Bathymetric Chart of the Oceans

GMCA	Global Marine Climatic Atlas (US)
HO	Hydrographic Department (UK)
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
ITCZ	Intertropical Convergence Zone
MO	Meteorological Office (UK)
NASA	National Aeronautics and Space Administration (US)
NAXA	Northern Australia Exercise Area
NCDC	National Climatic Data Center (US)
NMOC	Naval Meteorology and Oceanography Command (US)
NOAA	National Oceanic and Atmospheric Administration (US)
TSVD	Temperature, Salinity, Sound Velocity and Density
XBT	Expendable bathythermograph

7 REFERENCES

AASharks, 2008. http://www.aasharks.com/types-of-sharks/great-white-shark.htm

Australian Broadcasting Corporation (ABC), 1998. http://www.abc.net.au/oceans/whale/char.htm

Australian Broadcasting Corporation (ABC), 2008. http://www.abc.net.au/reslib/200711/r197853_755137.jpg

Australian Fisheries Management Authority (AFMA), 2000. http://www.afma.gov.au

Australian Geological Survey Organisation (AGSO), 1997. Chart from 30º arc second bathymetric database in "Big bank shoals of the Timor Sea, an environmental resource atlas", Eds: A. Heyward, E. Pinceratto and L. Smith. Australian Institute of Science and BHP Petroleum.

Australian Government, 2008. http://www.health.gov.au/internet/wcms/publishing.nsf/Content/cda-cdi2901a16.htm Department of health and aging, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=38

Australian Hydrographic Office (AHO), 2002. *Seafarer Charts and Tides (electronic versions)*. Australian Hydrographic Service, Commonwealth of Australia.

Australian Museum, 2008. http://www.amonline.net.au/fishes/fishfacts/fish/rtypus.htm

Australian Venom Research Unit (AVRU), 2008. http://www.avru.org/compendium/biogs/A000042b.htm

BBC News, 2003 *Hope for lethal jellyfish cure.* http://news.bbc.co.uk/2/hi/health/2713211.stm

Bowles Lt. Col. D.E. and Swaby Col. J.A., 2006. *A Field Guide to Venomous and Medically Important Invertebrates Affecting Military Operations: Identification and Treatment.* Version 2. USAF Institute for Operational Health

Britton A., 2002 Croco*dilians Natural History and Conservation,* Florida Museum of Natural History, http://www.flmnh.ufl.edu/cnhc/csp_cpor.htm#habi

Bureau of Meteorology (BoM), 2003. http://www.bom.gov.au

Cato, D.H., 1995. Unpublished data provided to RAN.

Cato, D.H., 1995b. *The ambient noise in the ocean.* Lecture notes for a course in "Basics of Underwater Acoustics". ADFA, November 1995. 21pp.

Cato, D.H., 1991. *Songs of humpback whales: The Australian perspective*. Mem. Qld. Mus. 30(2): 277-290.

Cato, D.H. and McCauley, R.D., 1997. *Ambient Sea Noise*. In: Investigation of a proposed tracking range near Exmouth, DSTO, Maritime Operations Division, draft report ed. B.D. Scott.

Chemlink (2008) www.chemlink.com.au/ntchem.htm

Conkright, M.E., Levitus, S.,O'Brien, T., Boyer, T.P., Stephens, C., Johnson, D., Stathoplos, L., Baranova, O., Anotov, J., Gelfeld, R., Burney, J., Rochester, J. and Forgy, C., 1998. *World ocean database 1998.* CD-ROM data set documentation. National Oceanographic Data Centre, Silver Spring, MD.

Cooperative Research Centre (CRC), Reef Research Centre (2008) http://www.reef.crc.org.au/discover/plantsanimals/irukandji/index.html

CSIRO (2008), http://www.marine.csiro.au/LeafletsFolder/51wshark/51.html

CSIRO (2002), http://www.marine.csiro.au/nddq/ndd_search.Browse_Citation?txtSession=365

DOM, 2008. Map created in Arc GIS using GEBCO (2003) data.

Ducting Climatology Summary (DCS), 1992. Database Ver 2.0. Naval Command, Control and Ocean Surveillance Centre, San Diego.

Federal Climate Complex Asheville (FCCA), 1996. International Station Meteorological Climate Summary. CDROM Ver. 4.0., USA.

General Bathymetric Chart of the Oceans (GEBCO), 2003. *Digital atlas*. British Oceanographic Data Centre.CDROM

Global Marine Climatic Atlas (GMCA), 2003. http://waves.ncdc.noaa.gov

Harris, P.T., Baker, E.K. and Cole, A.R., 1991. *Physical sedimentology of the Australian continental shelf: with emphasis on late Quaternary deposits in major shipping channels, port approaches and choke points*. Ocean Sciences Institute Rep. No. 51. The University of Sydney:

Holloway, P., 1997. *Internal waves*. In: *Investigation of a proposed tracking range near Exmouth*. DSTO, Maritime Operations Division, draft report, ed. B.D. Scott.

Hydrographic Department (HO), 1980. *Indonesia Pilot, Vol. III. (1st edition)*. NP 35. U.K. Hydrographer of the Navy: Taunton, Somerset.

Hydrographic Department (HO), 1983. *Indonesia Pilot, Vol. II (NP 34, 1st Edition).* Hydrographer of the Navy, Taunton, Somerset, UK.

Hydrographic Department (HO), 1987. *Ocean Passages for the World. (NP. 136, 4th Edition)*. UK Hydrographer of the Navy, Taunton, Somerset.

Hydrographic Department (HO), 1992. *The Australian Pilot, Vol. V. (NP17, 7th edition).* UK Hydrographer of the Navy, Taunton, Somerset.

International Comprehensive Ocean-Atmosphere Data Set (ICOADS), 2008.. Data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at http://www.cdc.noaa.gov/

Intergovernmental Panel on Climate Change (IPCC) 2007. *Climate Change in Australia Technical Report, Ch 5.* http://www.climatechangeinaustralia.gov.au,

Jenner, K.C.S., M.N.Jenner & K.A.McCabe (2001). Geographical and temporal movements of humpback whales in Western Australian waters. *APPEA journal*. Page(s) 749-765.

Jongsma, D., 1974. *Marine geology of the Arafura Sea*. Bureau of Mineral Resources, Bulletin 157.

Lawrence, M.W. and Prenc, S., 1989. *Bottom bounce propagation north west of Australia*. DSTO Technical Report.

Lourensz, R.S., 1981. *Tropical cyclones in the Australian region: July 1909 to June 1980*. AGPS, Canberra.

Meteorological Office (MO), 1967. *Quarterly surface current charts of the South Pacific Ocean.* Her Majesty's Stationary Office, London.

National Geographic, 2008 http://animals.nationalgeographic.com

National Climatic Data Centre (NCDC), 1995. *US Navy Marine Climatic Atlas of the World.* CD- ROM, Ver 1.1. National Climatic Data Centre

Naval Meteorology and Oceanography Command, National Climatic Data Centre (NMOC/ NCDC), 1996. *Global Tropical and Extratropical Cyclone Climatic Atlas* (GTECCA),CD-ROM, Ver 2.0

National Aeronautics and Space Administration (NASA), 1999. http://seawifs.gsfc.nasa.gov

National Geographic, 2008.
http://animals.nationalgeographic.com/staticfiles/NGS/Shared/StaticFiles/animals/images/primary/dugong.jpg,
http://animals.nationalgeographic.com/staticfiles/NGS/Shared/StaticFiles/animals/images/1024/whale-shark-with-fish.jpg

Northern Territory Government, 2003. http://www.otd.nt.gov.au

Northern Territory Government, 2008p. http://www.nt.gov.au/health/cdc/fact_sheets/RRV.pdf,
http://www.nt.gov.au/health/news/2008/news_05_01_groundwater_health_risk_warning.shtml,
http://www.nt.gov.au/nreta/wildlife/marine/pdf/coralreefs.pdf,
http://www.nt.gov.au/nreta/wildlife/marine/research.html,
http://www.nt.gov.au/nreta/wildlife/marine/education.html#marine,

http://www.nt.gov.au/nreta/wildlife/animals/threatened/pdf/mammals/sei_whale_dd.pdf,http://www.nt.gov.au/nreta/wildlife/programs/public/closed.html

Reefbase, (2008) http://www.reefbase.org/gis_maps/default.aspx

Roelofs A., Coles R., and Smit N., (2005) *Survey of intertidal seagrass from Van Diemen Gulf to Castlereagh Bay, Northern Territory, and from Gove to Horn Island, Queensland.* Report to the National Oceans Office, Department of Primary Industries & Fisheries, CRC Reef Research Centre, Biodiversity and Conservation, NT Department of Infrastructure, Planning and Environment. http://www.nt.gov.au/nreta/wildlife/marine/pdf/seagrasssurvey_intro.pdf.

Schlitzer, R., 2001. *Ocean Data View*. http://www.awi-bremerhaven.de/GEO/ODV

SCUBA Equipment USA, 2008. http://www.scuba-equipment-usa.com/marine/JUN05/Textile_Cone_Shell(Conus_textile).html

Sharkzone, 2008. http://www.sharkzone.com/shark-pictures/

Shark Attack Photos, 2008. http://www.sharkattackphotos.com/Bull-shark.jpg

Smithsonian Institute, 2003. http://www.volcano.si.edu/gvp/

State Government of Victoria, 2008. http://www.health.vic.gov.au/ideas/diseases/rrv_facts

Townsend Sara 2008. James Cook University (JCU). http://www.jcu.edu.au/school/tbiol/zoology/herp/NthQldHerps/NthQLDHerps-turtles.shtml

Virgin Media, 2008. http://www.virginmedia.com/travel/galleries/animals.php

WADER, 1998. Version 5.72, *Ocean Acoustic Developments Ltd* 1993-1998. Cornwall, UK.

Wikipedia, 2008. http://en.wikipedia.org/wiki/Influenza

Wolanski, E. and Deleersnijder, 1998. *Island generated internal waves at Scott Reef, Western Australia.* Australian Institute of Marine Science. http://www.aims.gov.au/ibm/reports/scott/scott_short.html

World Health Organization (WHO), 2008. http://www.who.or.id/eng/php/index.php

Yokoyama,Y. Purcell, A. Lambeck, K. and Johnston, P., 2001 'Shore-line reconstruction around Australia during the Last Glacial Maximum and Late Glacial Stage Research School of Earth Sciences', *Quaternary International* 83–85 (2001) 9–18 , The Australian National University, Canberra, ACT 0200 Australia.

Zann, LP (compiler), 1995. *Our sea, our future: major findings of the State of Marine Environment Report for Australia*. Ocean Rescue 2000 Program, DEST, Canberra.