

# Editorial

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Welcome to the August edition of the Bulletin of the Australian Meteorological and Oceanographic Society.

This issue contains Part II of John Zillman's history of the Australian participation in the IPCC on page 92. The first part was published in the April edition of the Bulletin, with the second part moved to this issue to make room for the critique of the Great Global Warming Swindle. Despite comments such as those from Ian Plimer, that "it contains schoolboy howlers and a lack of logic intertwined with politics", the critique was generally well received by the Australian public and scientific community.

This issue also contains the last essay in the AMOS student essay competition, this one is written by Emily Shaw and titled "A Review into Phytoplankton Growth on the Great Barrier Reef: Does Aeolian Dust Deposition Stimulate Phytoplankton Blooms?" (page 85).

I would also like to draw attention to the fact that I will be resigning as editor of the Bulletin at the end of the year. AMOS is currently searching for a replacement editor. Australian Meteorological Magazine is also searching for Associate Editors. Please see page 83 for more information on these positions. Members should also check the AMOS website\* for other job opportunities.

## Correction:

The photo of the Pasha Bulker on the front cover of the last issue was actually taken by Murray McKean. We thank him for the use of the photo.

Lee Tryhorn

Further Information:

<http://www.mckeanphoto.com.au>  
<http://www.theage.com.au/articles/2007/07/11/1183833595634.html?from=top5>  
\*<http://www.amos.org.au>

# News

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## Australian to head world science body

An Australian research scientist has been elected to head the international body that guides research into the nature of the Earth.



Dr Tom Beer, a senior scientist with CSIRO Marine and Atmospheric Research and an expert in environmental risk, is now president of the International Union of Geodesy and Geophysics (IUGG).

The IUGG is a union of eight associations in the fields of meteorology, oceanography, vulcanology, seismology, hydrology, geomagnetic science, geodesy and cryospheric science.

"The union fosters collaborative research and information exchange between Earth scientists in 68 countries," Dr Beer said in a statement. "It also encourages the application of this research to (society's) needs, such as mineral resources, mitigation of natural hazards and environmental preservation."

The council of the IUGG also voted in favour of having their next general assembly in Melbourne in 2011. "I am proud that an Australian president is going to be able to host IUGG in Australia, which attracts attendance by some 5,000 Earth scientists from around the world," Dr Beer said.

Further Information:

<http://www.csiro.au/news/ps3ah.html>

## Antarctic polynyas to feel the heat of climate change

Future climate change may affect global ocean circulation because of reduced Antarctic winter sea ice formation in large open water areas known as polynyas\*.

Australian scientists from the Antarctic Climate & Ecosystems Cooperative Research Centre (Antarctic CRC) and the CSIRO used high-resolution climate models to investigate what might happen in the Mertz Glacier Polynya under different future climate scenarios. Their results, to be published recently in the *Journal of Geophysical Research*, indicate that future warming will decrease the formation of sea ice in the polynya, resulting in possible changes to the global ocean overturning circulation. The study contributes to international research in the International Polar Year.

‘Polynyas are extremely important as sea ice ‘factories’’, said lead researcher Simon Marsland. ‘The Mertz Glacier Polynya covers only 0.1% of the sea ice zone, but is responsible for 1% of the total sea ice production in the Southern Ocean and has a significant influence on the global ocean circulation.’

Icy winds blowing off the Antarctic continent cause sea ice to form rapidly on the water surface in the polynya. The winds continually

blow the ice offshore, exposing more water to the subfreezing temperatures, so more ice forms and the process continues. Salt is expelled as the water freezes, forming dense brine that sinks and flows down the continental shelf of Antarctica to form Antarctic Bottom Water – the densest water in the open ocean. This water flows outward from the Southern Ocean and through other ocean basins as part of the global ocean circulation that distributes heat, nutrients and gases around the world.

The sinking water also helps lower atmospheric concentrations of carbon dioxide by carrying dissolved carbon dioxide from the surface to the deep ocean where it may be sequestered for thousands of years.

*\*A polynya is a large body of open water or an area covered by very thin ice that is found in the sea ice in the winter. The name comes from the Russian word for open or hollow. Many recur in the same region over many years. Polynyas may range in size from a few square kilometres to more than 350,000 square kilometres.*

Further information:

[http://www.acecrc.org.au/drawpage.cgi?pid=news\\_events&aid=797504&sid=797050](http://www.acecrc.org.au/drawpage.cgi?pid=news_events&aid=797504&sid=797050)

## Ocean ‘supergyre’ link to climate regulator

New research has confirmed that the current sweeping out of the Tasman Sea past Tasmania and towards the South Atlantic is a previously undetected component of the world climate system’s engine-room – the thermohaline circulation or ‘global conveyor belt’.

Wealth from Oceans Flagship scientist Ken Ridgway says the current, called the Tasman Outflow, occurs at an average depth of 800-1,000 metres and may play an important role in the response of the conveyor belt to climate change. Published recently in *Geophysical Research Letters* the findings confirm that the waters south of Tasmania form a ‘choke-point’ linking the major circulation cells in the Southern Hemisphere oceans.

‘In each ocean, water flows around anticlockwise pathways or ‘gyres’ the size of ocean basins,’ Mr Ridgway says. ‘These gyres are the mechanism that distribute nutrients

from the deep ocean to generate life on the continental shelves and slopes. They also drive the circulation of the world’s oceans, creating currents and eddies and help balance the climate system by transferring ocean heat away from the tropics toward the polar region.’

He says the conventional picture of the Southern Hemisphere mid-latitude circulation comprises basin-wide but quite distinct gyres contained within the Indian, Pacific and Atlantic Oceans. However model simulations had suggested that these gyres are connected.

The CSIRO team analysed thousands of temperature and salinity data samples collected between 1950 and 2002 by research ships, robotic ocean monitors and satellites in the region between 60°S and the Equator. They identified linkages between these gyres to form

a global-scale 'supergyre' that transfers water to all three ocean basins.

The identification of the supergyre improves the ability of researchers to more accurately explain how the ocean governs global climate. Completed as part of the BLUElink ocean forecasting project, this research provides the missing deep-flow connection between the Pacific and Indian Oceans. It has long been known that north of Australia a system of

currents in the ocean's upper 300m, called the Indonesian Throughflow, drains water from the Pacific into the Indian Ocean through the Indonesian archipelago – a process which influences Australian rainfall.

Further information:

<http://www.sciencealert.com.au/news/20071608-16207-2.html>

<http://www.csiro.au/news/OceanSupergyre.html>

### **Wanted – New Associate Editors for Australian Meteorological Magazine**

There are two vacancies for Associate Editors for the Australian Meteorological Magazine. AMOS appoints six of the twelve Associate Editors (the Bureau of Meteorology appoints the other six).

The principal functions of an Associate Editor are as follows:

- To identify reviewers for papers which the Editor considers to be in their subject area.
- To manage the review process for these papers.
- To make recommendations to the Editor, following review and revision, as to whether papers should be accepted for publication.

Depending on their area(s) of expertise, an Associate Editor would normally handle 3-6 papers per year.

Applications are invited from all areas of meteorology or oceanography. In particular, we are looking for an additional Associate Editor (preferably from outside the Bureau of Meteorology) with expertise in one or more areas of climate science, in order to spread the load from the increasing number of papers in that field.

If you wish to apply, or would like to discuss the position further, please contact the Editor, Blair Trewin, at [b.trewin@bom.gov.au](mailto:b.trewin@bom.gov.au), or (03) 9669 4623.

### **Wanted – New Editor for BAMOS**

AMOS is currently searching for someone to take over the role of editor of BAMOS in early 2008. The editor will be responsible for compiling the contents of the Bulletin, including articles and news items. The new editor will initially work with the current editor (Lee Tryhorn) and will have ongoing support from the Editor-in-Chief (Andrew Watkins) and the AMOS Administrative Officer (Val Jemmeson).

Students are particularly encouraged to apply.

For further information please contact either: Andrew Watkins ([A.Watkins@bom.gov.au](mailto:A.Watkins@bom.gov.au)), Val Jemmeson ([V.Jemmeson@bom.gov.au](mailto:V.Jemmeson@bom.gov.au)), or Lee Tryhorn ([Lee.Tryhorn@arts.monash.edu.au](mailto:Lee.Tryhorn@arts.monash.edu.au)).

# Awards

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## Call for nominations for the 2007 Priestley Medal

Nominations are invited for the 2007 Priestley Medal and Council wishes to encourage AMOS members and others to nominate candidates from their own institutions or elsewhere.

The Priestley Medal and the AMOS Medal are the two premier awards given by the Society and are awarded in alternate years. The Priestley Medal commemorates the life-long contributions of Dr C H B Priestley to meteorological and oceanographic research, and is aimed at younger scientists, preferably under the age of 40, for personal excellence in meteorological, oceanographic or climate research carried out substantially within Australia. On the other hand the AMOS medal recognises leadership in meteorology, oceanography, climate and related fields in Australia, and is normally awarded to senior leaders in their field.

The assessment for the Priestley Medal is based primarily on the quality of research publications and the initiation of significant new areas of research. The Award consists of an inscribed medal together with a prize of \$1,000 generously provided by CSIRO Marine and Atmospheric Research to mark the status of the Award and the research achievements of Dr Priestley.

The usual procedure is for senior members of institutions to nominate candidates and to provide supporting papers. Nominees do not already have to be members of AMOS, but in that case Council hopes that they will consider joining and will provide a successful candidate who is not already a member with a

complimentary membership for the remainder of the year of award. The Committee's preferred form of nomination comprises:

- a) a concise summary of the reasons for the nomination,
- b) a publication list in which the more significant contributions are identified and brief notes written on no more than five of the most important ones (where there are multiple authors to these five the role of the candidate should be explained), and
- c) a listing of the major achievements of the candidate including the initiation of new fields and a curriculum vitae.

If possible, the nominations should include copies of not more than three of the candidate's most significant publications. Where work has been done in a group or has been published with multiple authors, the Committee would appreciate a brief comment on the role of the nominee. The Awards Committee has limited ability to seek additional information to that in the nomination papers and therefore depends on the nomination papers to provide a full and fair account of each candidate.

Further information can be obtained from the Committee chair, Mark Williams of the Bureau's Victoria Regional Office. Nominations with supporting papers should be forwarded to the [Mark.Williams@bom.gov.au](mailto:Mark.Williams@bom.gov.au) by 30<sup>th</sup> September 2007. The Award is normally presented on the occasion of the Priestley lecture at CSIRO Marine and Atmospheric Research.

## Call for nominations for the 2007 Christopher Taylor Award

Christopher Taylor was a Bureau of Meteorology analyst and forecaster from the mid-70s until his untimely death at age 35 in July 1988. He had a natural curiosity in, and an enthusiasm and energy for investigating observed weather phenomena and operational forecasting problems, which was largely carried out in his own time.

The Award carries a prize of \$500 very generously provided by his former wife

Jacqueline Healy, and is open to professional meteorologists for contributions of all kinds to operational forecasting and supporting activities. In the spirit of Christopher Taylor's efforts, the Awards Committee will give extra weight to nominations for operational meteorologists who have either commenced or performed a substantial part of their investigative work, or other contribution to operational forecasting, outside of normal duties. Meteorologists who's normal role is to

support operations either through investigations or the development of operational tools may also be nominated, however a case should be made that the contribution has exceeded the normal expectations of a person working in that position. It should be noted that achievements of a more academic nature are recognised through other AMOS awards. There is also a perpetual plaque held for the year by the appropriate Regional or other office.

Nominations may be made by AMOS members or others, especially senior staff of the Bureau of Meteorology who will be familiar with the work of their regional operational staff. The Awards Committee now seeks nominations with supporting papers by 30th September 2007. Please return completed nominations to [Mark.Williams@bom.gov.au](mailto:Mark.Williams@bom.gov.au).

### **AMOS Student Essay Prize - Call for Essays**

The Society has an annual prize of \$250 for the best essay written by a student and published in the Bulletin of the Australian Meteorological and Oceanographic Society. Review essays on any topic in the areas of atmospheric or oceanographic science are sought by the Society. All enrolled students who are AMOS members are eligible. The prize aims to foster and reward excellence in scientific communication, and to encourage articles of general interest to the members (for publication in the BAMOS). Essays should be sent to Dr Deryn Griffiths, Chair of the AMOS Education Committee, Bureau of Meteorology, NSW Regional Office, PO Box 413, Darlinghurst NSW 1300.

Email: [D.Griffiths@bom.gov.au](mailto:D.Griffiths@bom.gov.au)

**Entries close 28 February 2008.**

All honours and graduate students write detailed, usually technical, literature reviews as

The Awards Committee has limited ability to seek additional information to that given in the nomination papers and therefore depends on these papers to provide a full and fair account of each candidate. The Committee's preferred form of nomination comprises: a summary of the reasons for the nomination, a listing of the achievements of the candidate and a curriculum vitae.

The high quality of nominations in recent years has two implications: first that those are unsuccessful in one year could succeed in a subsequent year, and second that competition is such that nominating papers should be prepared with care to ensure that members of the Awards Committee will be fully aware of the achievements of each candidate.

the introductory chapter of their theses. Students may like to draw on their literature reviews in writing an essay for BAMOS, although the essay should not be simply the introductory chapter their thesis. The essay must be written with the general reader in mind, and it must not exceed 5000 words.

The Education Committee will read the essays and determine the best four. During 2008, one of these four will be published each month in the BAMOS. The best of the four, as determined by the Education Committee, will be awarded the prize, and the winner will be announced in the final BAMOS for the year 2008. Essays of sufficiently high quality that do not make the final four in one year may, at the discretion of the Education Committee, be added to the pool of submitted essays in the following year.

# Articles

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## A Review into Phytoplankton Growth on the Great Barrier Reef: Does Aeolian Dust Deposition Stimulate Phytoplankton Blooms?

Emily Shaw

Griffith School of Environment

### 1. Introduction

The World Heritage listed Great Barrier Reef (GBR) is of great ecological, social and economic importance, with a gross domestic product of approximately AUS\$5.9 billion *per annum*, from tourism, commercial fishing and recreational activity (Access Economics Pty Limited 2005; The State of Queensland and Commonwealth of Australia 2003). However, there is increasing concern as to the effects of declining water quality in the GBR as a result of anthropogenic nutrient enrichment (eg. Baker 2003; The State of Queensland and Commonwealth of Australia 2003). Research has found that the concentrations of plant nutrients have increased significantly over the past century with increases in urban, industrial and agricultural development and that this may be causing the GBR lagoon to become eutrophic (Bell 1991; Bell 1992; Haynes and Michalek-Wagner 2000).

Increased eutrophication is characterised by increased algal growth rate and standing stock, which can have a number of deleterious effects both to the GBR ecosystem and also to human health, through the bioaccumulation of toxins in seafood and through direct recreational contact (Bell 1991; Sellner 1997; Carmichael 2001). In coral reef ecosystems benthic algae compete with coral for space and also compete for light with zooxanthellae, the symbiotic algae present in corals (Bell 1991). Of particular concern, however, is the increase in cyanobacterial blooms (cover picture), as these organisms are able to fix atmospheric dinitrogen and introduce new nitrogen to the system which may promote further blooms of other nuisance phytoplankton, such as dinoflagellates (Bell *et al.* 1999; Hood *et al.* 2004). *Trichodesmium* is a filamentous cyanobacterium that has received much attention since it was suggested by Dugdale *et al.* (1961) that it could fix atmospheric N<sub>2</sub>. Globally, cyanobacteria of the genus *Trichodesmium* are believed to be the most significant organisms contributing to the nitrogen cycle, and in the GBR it has been suggested that new nitrogen introduced by

*Trichodesmium* is at least of the same order as that entering via riverine discharge (Capone *et al.* 1997; Bell *et al.* 1999).

In some parts of the world, for example the North Atlantic Ocean, aeolian dust deposition has been shown to stimulate blooms of *Trichodesmium* by increasing the levels of nutrients within the water column (eg. Michaels *et al.* 1996; Lenes *et al.* 2001; Karl *et al.* 2002). However, in Australia research on aeolian dust delivery of nutrients has generally been very limited in comparison to research on fluvial transport of sediments (McTainsh 1989). Indeed the recent *Reef Water Quality Protection Plan* (The State of Queensland and Commonwealth of Australia 2003) which aims to address the levels of land based pollutants, including nutrients, entering the GBR, addresses only fluvial sources. This report reviews the trends in cyanobacterial growth on the GBR, the factors that affect cyanobacterial growth and the possible effects of aeolian dust deposition on cyanobacterial blooms in the GBR.

### 2. Ecophysiology of cyanobacteria

Cyanobacteria, along with some other phytoplankton, have played a critical role in the evolution of the Earth's atmosphere through oxygenic photosynthesis (Falkowski *et al.* 1998). As a result of the oxidation of water through photosynthesis, the Earth's atmosphere changed from being largely anaerobic to reaching oxygen levels comparable to those of the contemporary atmosphere, a change which occurred approximately 2.2 billion years ago (Blankenship and Hartman 1998; Rye and Holland 1998). Cyanobacteria, and related prokaryotes, were also critical in the evolution of eukaryotic photoautotrophs, as it is believed that the chloroplasts of these organisms formed through endosymbiotic associations with cyanobacteria (Blankenship and Hartman 1998; Falkowski *et al.* 1998).

Although cyanobacteria of the genus *Trichodesmium* are believed to be the most

significant N<sub>2</sub>-fixers in oligotrophic waters (Capone *et al.* 1997), recent research has shown that there are a number of unicellular cyanobacteria that may also be contributing significantly to the nitrogen dynamics of oligotrophic waters (Zehr *et al.* 2001).

### **2.1 Nitrogen fixation and ecophysiology of *Trichodesmium***

In *Trichodesmium*, nitrogen fixation generally occurs diurnally during daylight hours, although it has been observed to occur for short time periods in the dark (Capone *et al.* 1990; Capone *et al.* 1997; Fu and Bell 2003). Nitrogen fixation is catalysed by the nitrogenase enzyme, which is irreversibly inhibited by oxygen and therefore it must occur anaerobically (Capone *et al.* 1997; Karl *et al.* 2002; LaRoche and Breitbart 2005). Unlike other cyanobacteria, *Trichodesmium* does not possess heterocysts, which are specialised cells for the spatial separation of nitrogenase and oxygen (Berman-Frank *et al.* 2001). Instead, *Trichodesmium* use temporal separation of oxygenic photosynthesis and nitrogen fixation during daylight hours in combination with some spatial separation within filaments (Berman-Frank *et al.* 2001). Nitrogen fixation is believed to occur during daylight hours due to its large energy requirement and it has been observed that rates of nitrogen fixation are directly proportional to light intensity (Fu and Bell 2003). *Trichodesmium* has physical adaptations to obtain optimum levels of light, such as photosynthetic apparatus adapted to high light conditions and natural buoyancy (Capone *et al.* 1997; Karl *et al.* 2002).

Along with light intensity, *Trichodesmium* growth can also be limited by the availability of phosphorus and micronutrients (Arrigo 2005). *Trichodesmium* has the ability to migrate vertically through the water column using gas vacuoles, which is thought to occur to obtain phosphorus from beneath the nutricline (Villareal and Carpenter 1990; Tyrrell *et al.* 2003). Micronutrients, such as iron and molybdenum, are required in much larger quantities in diazotrophs, which are organisms that fix nitrogen, than other phytoplankton as they are required as cofactors of nitrogenase (Howarth and Cole 1985; Paerl *et al.* 1994; Kustka *et al.* 2002). Conversely, cyanobacteria are selected against in high nitrogen eutrophic environments as they have growth rates slower than other phytoplankton, which are able to out-compete cyanobacteria in these environments (Hood *et al.* 2001).

Notably, however, *Trichodesmium* lacks any major grazing pressure (Capone *et al.* 1997).

*Trichodesmium* is present in tropical and subtropical waters where the distribution and occurrence of blooms appear to be controlled by temperature (Karl *et al.* 2002). *Trichodesmium* is generally found at temperatures of at least 25°C (Dugdale *et al.* 1961; Subramaniam *et al.* 2002). However, due to the negative correlation between nitrate concentration and temperature, it is uncertain as to whether temperature or nitrate controls the distribution of *Trichodesmium*, or a combination of both (Karl *et al.* 2002).

## **3. Environmental factors affecting cyanobacterial growth**

### **3.1 Iron limitation**

Iron has been shown to limit cyanobacterial growth in many parts of the world through ecosystem-scale iron enrichment experiments (Behrenfeld *et al.* 1996; Coale *et al.* 1996; Falkowski 1997; Behrenfeld and Kolber 1999). The primary sources of iron in the global oceans are from aeolian dust deposition and oceanic upwelling (Boyd *et al.* 2004). Although oceanic upwelling contributes significantly to the iron budget of the world's oceans, it is believed that this source has no significant effect on cyanobacterial growth as upwellings from beneath the euphotic zone also contain a number of other nutrients, including nitrogen, which selects against the growth of diazotrophic organisms (Karl *et al.* 2002). Therefore aeolian dust deposition is believed to be the major environmental factor controlling cyanobacterial growth in iron-limited environments (Michaels *et al.* 1996; Karl *et al.* 2002). The effects of dust storms on cyanobacterial growth are further evidenced by recorded cyanobacterial blooms following dust deposition events (eg. Lenes *et al.* 2001).

### **3.2 Phosphorus limitation**

In some oligotrophic waters, for example in the North Atlantic Ocean, phosphorus is believed to limit cyanobacterial growth (Sanudo-Wilhelmy *et al.* 2001; Fu *et al.* 2005). However, it is believed that this is unlikely to limit cyanobacterial growth in the Great Barrier Reef lagoon as phosphorus levels are two to three orders of magnitude higher than in the North Atlantic due to anthropogenic enrichment (Fu *et al.* 2005). Although atmospheric precipitation, volcanism of active continental margins, glacier discharge and erosion, coastal abrasion and groundwater discharge supply phosphorus to the World

Ocean, the dominant source of phosphorus enrichment, both in the GBR region and globally, is from fluvial discharge (Froelich 1988; Bell 1992; Baturin 2003). Globally, the level of phosphorus in present-day rivers is believed to be 1.5-2 times the pre-anthropogenic levels, due to deforestation, soil erosion, wide application of phosphatic fertilizers, and discharge of industrial and domestic wastewaters (Baturin 2003).

### 3.3 Physical factors

Physical conditions, such as salinity, wind and oceanic mixing, have all been shown to affect the growth of cyanobacteria (Capone *et al.* 1997; Karl *et al.* 2002). Salinity has been shown to be inversely correlated with cyanobacterial growth rates and is believed to indirectly affect cyanobacterial growth by inhibiting the uptake of molybdenum, a cofactor of nitrogenase (Howarth and Cole 1985). This occurs as sulphate, which is in higher concentrations in more saline waters, is a structural analogue of molybdate and competitively inhibits molybdate uptake (Karl *et al.* 2002).

Oceanic mixing has also been shown to influence cyanobacterial growth and explain observed distributions of *Trichodesmium* (Karl *et al.* 2002; Tyrrell *et al.* 2003). Vertical mixing has been hypothesised to reduce cyanobacterial growth, as it increases the nitrate concentration, selecting against nitrogen fixation (Karl *et al.* 2002). The depth of the surface mixed layer was also found to be one of the main factors correlating with *Trichodesmium* abundance in a study in the Atlantic Ocean, where *Trichodesmium* abundance was greatest in areas with a shallow mixed layer (Tyrrell *et al.* 2003). A shallow mixed layer is hypothesised to be advantageous as it reduces the distance needed to travel to the nutricline to uptake nutrients and therefore lowers the energy requirements for vertical migration (Tyrrell *et al.* 2003). Also, high rates of turbulent mixing and strong wind conditions have been shown to adversely affect *Trichodesmium*, where blooms have been observed to form predominantly in calm conditions and dissipate with the onset on windy conditions and turbulent mixing (Capone *et al.* 1997; Subramaniam *et al.* 2002).

### 4. History of cyanobacterial blooms on the Great Barrier Reef

Knowledge of the spatial and temporal distribution of phytoplankton in the GBR is generally limited compared with other regions

of the world (Revelante *et al.* 1982). The first field surveys yielding information on cyanobacterial blooms on the GBR were from the British Museum's Great Barrier Reef expedition during 1928-29 (Marshall 1933). There is no further documented information until a study by Revelante and Gilmartin (1982) in 1976-77. These studies, however, show that *Trichodesmium* levels were orders of magnitude higher in 1976-77 than in 1928-29 (Bell 1991). From this point onwards, field data from research studies provide information at discrete time periods and usually at small-scale study sites. This research does indicate however, that whilst *Trichodesmium* blooms occur each year, the abundance of *Trichodesmium* is increasing in the GBR (eg. Bell 1991; Muslim and Jones 2003). The only regular monitoring of marine cyanobacteria in Queensland is of *Lyngbya majuscula*, due to the public health risks associated with the toxicity of this species, and this monitoring program has also identified a significant increase in observed blooms along the east coast of Queensland (Albert *et al.* 2005).

The availability of large-scale data on cyanobacterial blooms has increased through the use of satellite data (Behrenfeld and Falkowski 1997). Initially satellite imagery of chlorophyll was used to estimate time and depth integrated productivity (Smith *et al.* 1982). Improvements have since occurred to allow for remote sensing of *Trichodesmium* spp. through the development of a reflectance model for remote sensing based on the optical properties of *Trichodesmium* (Subramaniam *et al.* 1999). These advances in detecting large-scale *Trichodesmium* blooms may allow for levels of nitrogen fixation to be estimated from satellite data and provide information on the contribution of *Trichodesmium* to the global nitrogen cycle (Subramaniam *et al.* 1999).

### 5. Factors influencing dust storms

Dust storms have globally been identified as important events affecting the occurrence of cyanobacterial blooms (Karl *et al.* 2002). On a broad scale, dust storms are primarily controlled by climatic conditions, in particular rainfall (McTainsh *et al.* 1989). Generally the frequency of dust storms increases with decreasing rainfall to a maximum frequency at 100 to 200mm per year rainfall levels, where dust storms are believed to be limited by sediment supply beyond this point (McTainsh *et al.* 1989). Drought has also been identified as an important factor, preceding a number of major dust storm events (eg. Prospero and Nees 1977; Goudie and Middleton 1992;

McTainsh *et al.* 2005). On a smaller scale, soil erodibility and vegetation cover can affect dust storms and accelerated wind erosion can occur if anthropogenic disturbances, for example grazing or land clearing, impact upon these factors (McTainsh *et al.* 1989; McTainsh and Leys 1993). There are two main pathways of dust storms in eastern Australia resulting from climatic controls, the northern pathway being of interest in terms of dust deposition on the GBR. Dust in the northern region is typically sourced from the rangelands of Queensland and northern New South Wales and is carried east by westerly winds that are the result of west-east movement of frontal systems across Queensland (McTainsh and Leys 1993). Dust storms in this region tend to occur from September to November, until the start of the wet season reduces their frequency (McTainsh *et al.* 1998). For example, in October 2002, a major dust storm carried dust from the rangelands of Queensland and northern New South Wales eastward to coastal areas from far north Queensland to southern New South Wales following six months of severe drought in eastern Australia (McTainsh *et al.* 2005).

## 6. Discussion

Cyanobacteria play significant roles in global nutrient cycles, in particular influencing the nitrogen cycle by fixing significant quantities of new nitrogen into the ocean (Capone *et al.* 1997; Arrigo 2005). The input of new nitrogen can then promote growth by nuisance phytoplankton, as seen in Florida with blooms of the toxic dinoflagellate, *Gymnodinium breve*, following *Trichodesmium* blooms (Lenes *et al.* 2001). Whilst globally it is believed that *Trichodesmium* spp. are the most significant nitrogen fixers (Capone *et al.* 1997), unicellular cyanobacteria are also expected to contribute significantly to the levels of new nitrogen (Montoya *et al.* 2004) and further research should be aimed at determining the influence of these species on nutrient cycles within the GBR.

Whilst there is limited documentation on the occurrence of cyanobacterial blooms in the GBR, the data that is available all suggest that the frequency of cyanobacterial blooms is increasing (eg. Bell 1991; Muslim and Jones 2003; Albert *et al.* 2005). Of the number of physical and environmental factors that have been suggested to limit cyanobacterial growth, it is generally believed that the major limiting factors seem to be the availability of either iron or phosphorus, or that there is co-limitation where at least one of the limiting factors is usually iron or phosphorus availability (Mills

*et al.* 2004; Arrigo 2005). Bell (1991) reported that between the Great Barrier Reef expedition in 1928-29 and the studies of Revelante and Gilmartin in 1976-77, *Trichodesmium* levels had increased and that phosphate concentrations had more than doubled in the GBR lagoon, which he attributed to fluvial sources. However, the increase in *Trichodesmium* may not be explicitly related to the increase in phosphate, as riverine discharge outputs a range of macro- and micro-nutrients that could be responsible for the increased *Trichodesmium* growth (eg. Tovar-Sanchez 2006). Furthermore, along with increasing the levels of phosphorus, riverine discharge also increases the level of nitrogen, which selects against the growth of diazotrophs, such as *Trichodesmium* (Karl *et al.* 2002; Moss *et al.* 2005). Also, it has been proposed by Fu *et al.* (2005) that *Trichodesmium* in the Great Barrier Reef lagoon may experience less limitation by phosphorus compared with the Atlantic Ocean due to anthropogenic enrichment of phosphorus in the GBR lagoon.

Iron enrichment from Saharan dust deposition has on a number of occasions been linked to cyanobacterial blooms in the North Atlantic (eg. Michaels *et al.* 1996; Walsh and Steidinger 2001; Lenes *et al.* 2001; Mills *et al.* 2004). Whilst the quantities of aeolian dust deposited in the northern hemisphere exceed that of the southern hemisphere (Duce and Tindale 1991), the amount of iron being transported via aeolian dust from Australia may still be significant as the iron content of Australian soil is 50% greater than the global average (Mahowald *et al.* 2005). Furthermore, although Australia's contribution to the global dust budget is minor, severe dust storms have occurred in Australia, particularly during drought years (Shao *et al.* 2006). For example, the October 2002 dust storm, which was found to be of the magnitude of a moderate northeast Asian dust storm deposited an estimated 2.13 Mt of dust into the ocean. Much of which was deposited off the east coast of Queensland and into the GBR region (Shao *et al.* 2006).

Currently in Australia there is very little research undertaken on aeolian nutrient transport processes in comparison to fluvial processes (McTainsh 1989). As a result of this, management actions to improve the water quality of the GBR and to reduce the occurrence of nuisance phytoplankton blooms have been targeted primarily at addressing land-based pollutants entering the reef via riverine discharge (eg. The State Government of Queensland and Commonwealth of

Australia 2003). From global findings of the significance of aeolian dust deposition in promotion of cyanobacterial blooms, it is apparent that there is a need for research into their effects in the Great Barrier Reef region, particularly as dust storms occur during the dry season and therefore may provide an important source of nutrients in times when the reef would otherwise receive very little nutrients through riverine output. The influence of aeolian dust deposition on cyanobacterial growth in the GBR is likely to increase in the future with global climate change, as it is predicted that drying on mainland Australia will increase, which could be expected to lead to an increase in dust storm frequency (CSIRO 2001; McTainsh et al. 2005).

## 7. References

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## **Australian Participation in the work of the Intergovernmental Panel on Climate Change 1988-2001: Part II.**

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### **The Supplementary Report 1992 and the Special Report 1994**

The 1992 Supplementary Report (SUPP) was prepared to provide the latest assessment of the state of understanding of key issues for input to the final negotiating session of the UNFCCC; and the 1994 Special Report (SPEC) was prepared for the First Session of the Conference of the Parties (COP) to the UNFCCC. The Australian input to both the Supplementary and Special Reports maintained the same broad base as for the First Assessment. The draft Working Group I Supplement, with major input from eight Australian scientists (including several who had not been involved directly in the First Assessment), was circulated to 105 Australian scientists and a full-day workshop was held on 18 December 1991 to review all sections of the report and prepare detailed comments for consideration by the Lead Authors. The consolidated Australian review report also served as the main source document for the Australian delegation to the Third Session of Working Group I in Guangzhou, China on 13-15 January 1992. It was at this session that a member of the Australian Delegation (Dr G B Tucker) proposed (and Working Group I eventually formally adopted) the use of the

term 'projection' rather than 'prediction' for the output of climate models forced by greenhouse gas scenarios - in order to try to reduce the public confusion resulting from the earlier ambiguity in the use of the concept of model 'predictions'. Australia also made a particularly significant contribution to the sea-level, energy and agriculture sections of the 1992 Supplementary Report on the basis of international IPCC Workshops in Perth on sea level rise in February 1990 and in Canberra on agriculture and forestry issues in January 1992.

The major Australian contributions to the writing of the 1994 Special Report were in the areas of:

- The carbon cycle – I Enting, G Farquhar, R Gifford, J Lloyd,
- Other trace gases and atmospheric chemistry – P Fraser,
- Greenhouse gas inventory guidelines – P Cheng, M Howden, R Leng
- Impacts and adaptations – W J McG Tegart, I R Noble, AB Pittock,
- Emission scenarios – J Daley, T Weir.

The Working Group I report on 'Radiative Forcing of Climate Change' was reviewed in a full-day workshop in Melbourne on 27 January

1994 and the agreed comments of the 45 participants were forwarded to the IPCC Secretariat and Lead Authors and subsequently used as the main source document for the Australian delegation to the Fourth Session of Working Group I at Maastricht, Netherlands, on 13-15 September 1994. The Australian review of the Working Group II and III components of the Special Report was assembled from individual expert and agency comments, forwarded to Lead Authors and used as the source material for the subsequent Nairobi Sessions of Working Groups II and III and the Tenth Session of the Panel. The Australian delegation to Nairobi (7-12 November 1994) contributed to the resolution of a number of difficult technical and procedural issues that eventually led to acceptance and approval of the 1994 Special Report.

### **The Second Assessment Report**

Following the signing of the FCCC by 154 countries at the Rio Earth Summit in June 1992 (Zillman, 1992), the IPCC was restructured in November 1992 with new tasks including the preparation of the 1994 Special Report and a new Working Group structure to begin work on the Second Assessment Report (SAR) as follows:

- Working Group I – assessment of science relevant to climate change (essentially the same as for the FAR);
- Working Group II – assessment of impacts and response options (essentially a merger of the former Working Groups II and III); and
- Working Group III – cross-cutting economic and other issues.

The Eighth (Harare) Session of the Panel, which agreed the new structure for the IPCC, also decided to establish a 28-member Bureau including one representative of each of the WMO Regions, with Region V (South Pacific) represented by Australia (Dr Tegart). Following Dr Tegart's retirement from the Australian Public Service in 1993, revised national arrangements were put in place with the present author appointed as Principal Delegate of Australia (and subsequently elected as South Pacific member of the Bureau) and Mr Ian Carruthers of the, by then, Department of the Environment as Alternate. It was agreed that overall co-ordination of Australian involvement in the IPCC and support for Australian delegations would be provided by the Atmospheric Protection Branch of the Department of the Environment with the involvement of relevant officers from

the Bureau of Meteorology. Co-ordination of Australian involvement in the individual IPCC Working Groups was agreed to be handled as follows:

- Working Group I matters to be co-ordinated by the Bureau of Meteorology;
- Working Group II matters to be co-ordinated by the Department of the Environment; and
- Working Group III matters to be co-ordinated by the Department of Primary Industries and Energy.

Under the overall guidance of the IPCC Chairman (still Professor Bert Bolin of Sweden), Working Group Co-chairs (two Co-chairs, one from a developed and one from a developing country, had replaced the single Chairs of the First Assessment), and the IPCC Bureau, Convening Lead Authors (CLA), Lead Authors (LAs) and Contributing Authors were identified and proceeded with the preparation of the SAR which was finalised in December 1995. There was one Australian Convening Lead Author, four Lead Authors and eighteen Contributing Authors responsible for key chapters of the Working Group I component of the SAR as follows:

- Radiative forcing of climate change – I Enting (LA), P Fraser (LA), G Farquhar, R Gifford, J Lloyd;
- Observed climate variability and change – N Nicholls (CLA), J Church, W Drosowsky, A Henderson-Sellers, G Holland, D Karoly, W Kininmonth, T McMahon;
- Climate models (validation) – A Henderson-Sellers (LA), B McAvaney (LA), C Frederickson, K McGuffie, A J Pitman;
- Climate models (projections of future climate) – J R Garratt, H Gordon, A Henderson-Sellers, G J Holland, D Karoly, B McAvaney, J McGregor, P Whetton;
- Terrestrial ecosystems – G Farquhar.

As for previous Working Group I reports, Australia employed a workshop approach for combined peer and country review of the draft of the SAR. The Australian delegation (B Dixon, W Bouma, N Nicholls and J Zillman) to the September 1995 (Madrid) session of Working Group I - which eventually accepted the full report, converted its draft Summary for Policymakers (SPM) into a 'Technical Summary' and, after long and difficult debate, approved a greatly cut down SPM - played an important role in the crafting of the language and strategy that led to eventual late-night approval of the SPM.

Australian scientists also made a substantial contribution to the Working Group II (Impacts and Response) component of the SAR as Lead Author as follows:

- Impacts on sea ice – I Allison;
- Sea level rise – R McLean;
- Hydrology – B Bates;
- Wetlands and agriculture – J R Freney;
- Plant-soil interactions – M Kirschbaum;
- Marine living resources – H Marchant;
- Health impacts – A McMichael; and
- Modelling of biotic responses – I Noble.

The then Department of the Environment, Sport and Territories (DEST) convened a national workshop in April 1995 to formulate the Australia country response to the draft report.

The main Australian involvement in Working Group III (Cross-cutting economic and other issues) was as a Convening Lead Author (B Fisher) for the chapter on 'An assessment of economic policy instruments to combat the enhanced greenhouse effect'. The Australian delegation to the December 1995 (Rome) session of the IPCC which accepted its four volume 2,000-page SAR and approved its Synthesis Report on a line by line basis, played a substantial role in resolving a number of major definitional and procedural difficulties that arose during the session and in ensuring that the conclusions of the Synthesis Report were firmly based on the underlying reports rather than the product of political negotiation or Lead Author intimidation. That task was not without its challenges (Zillman, 1996).

### **The Third Assessment Report**

With the completion of the SAR and of the protracted and widely consultative process that led to the unanimous election of Dr Bob Watson of the US to succeed Professor Bolin as Chairman of the IPCC, it became necessary to restructure the IPCC Bureau. Agreement was eventually reached on a model which involved representatives from all six WMO IPCC regions on each of the three Working Groups (now dealing with science, impacts and adaptation, and mitigation respectively) so that WMO Region V (Southwest Pacific) now had three members of the enlarged IPCC Bureau – from Australia (Working Group I), New Zealand (Working Group II) and Indonesia (Working Group III). As a Vice-Chair of the Working Group I Bureau and a member of the full Bureau, the author thus carried a special responsibility for the Working Group I Report and shared, with the remainder of the Bureau, the responsibility for assisting

the IPCC Chairman in the preparation of the Third Assessment Report (TAR) as a whole. As far as possible and in consultation with Dr M Manning (New Zealand) and Dr R Sutarnhardja (Indonesia), contact was maintained with all key IPCC government representatives and scientists (including especially Lead Authors) in the Southwest Pacific. The Australian contribution to the Working Group I component of the TAR focussed especially on the input of Australian invitees to a TAR Scoping Meeting in Bad Munstereifel, Germany, the exhaustive Bureau process for identification of potential Lead Authors, the comprehensive writing and review process and the discharge of Review Editor functions for four of the fourteen chapters of the Report.

The Australians carrying Coordinating Lead Author (CLA), Lead Author (LA), Contributing Author and Review Editor (RE) roles for the Working Group I component of the TAR were as follows:

- Technical Summary – J Church, D Karoly, B McAvaney, J Zillman (RE);
- Observed climate variability and change – R Allen, D Collins, D Etheridge, K Hennessy, D Karoly, V Morgan, N Plummer, T Van Ommen;
- Carbon cycle and atmospheric carbon dioxide – G Farquhar (LA), I Enting, R LR Matear, P Rayner;
- Atmospheric chemistry and greenhouse gases – N Derek, D Etheridge, P Fraser, P Steele;
- Aerosols, their direct and indirect effects – R Boers;
- Radiative forcing of climate change – P Forster, L Rotstayn;
- Physical climate processes and feedbacks – A Henderson-Sellers, A Pitman, S Wijffels;
- Global climate models (evaluation) – B McAvaney (CLA), A Pitman (LA), R Colman, M England, G Holland, G Roff;
- Global climate models (projections) – M Dix (LA), P Whetton;
- Regional information (evaluation and projections) – P Whetton (LA), B Bates, J McGregor, K Walsh, J Zillman (RE);
- Changes in sea level – J Church (CLA), K Lambeck (LA), S O'Farrell;
- Detection of climate change and attribution of causes – D Karoly (CLA), J Zillman (RE).
- Climate change scenario development – P Whetton (LA), R Jones, J Zillman (RE).

The Australian impacts and adaptation community were also heavily involved in the writing of the Working Group II component of the TAR as follows:

- Technical summary – H Gitay (LA), R McLean (LA), B Pittock (LA);
- Overview – R Jones, B Walker (RE);
- Methods and tools – R Jones;
- Development and application of scenarios – B Pittock (LA), R Jones (LA);
- Natural and managed ecosystems – H Gitay (CLA), I Noble (LA), M Finlayson, M Howden;
- Coastal zones and marine ecosystems – R McLean (CLA);
- Australasia – B Pittock (CLA), B Bates (LA), M Finlayson (LA), H Gitay (LA), A Arthington, I Cole, B Collyer, S Crimp, K Day, F Glesson, D Griffiths, W Hall, R Jones, S Lakes, R Leigh, V Lyne, K McInnes, G McKeon, D Smith, B Suthurst, K Walsh, B Watson, D White, T Yunon, M Howden (RE);
- Polar regions – H Marchant (LA);
- Small island states – U Kaly; and
- Vulnerability to climate change – B Pittock (LA).

The Australian writing contribution to the Working Group III component of the TAR was limited to one Lead Author role, for the chapter on global, regional and national costs and benefits of mitigation. Several Australians contributed to the TAR Synthesis Report as Lead Authors (H Gitay, I Noble, B Pittock) and Review Editors (S Barrell, I Carruthers, J Zillman). As with the previous Assessment Reports, Australia was strongly represented at the Working Group and Panel sessions, which accepted the full reports and approved their Executive Summaries. The Australian delegations played particularly significant roles in the January 2001 Shanghai Session of Working Group I finalised the Working Group I component of the TAR (Zillman, 2001) and at the October 2001 UK (Wembley) Session of the Panel which accepted the three Working Group Reports and finalised the TAR Synthesis Report.

### **Special Reports, Technical Papers and Guidelines**

As for the Assessment Reports, Australian government representatives and scientists have played a substantial role in the preparation of a number of other IPCC products, especially its Special Reports, Technical Papers (papers based on peer-reviewed Assessment Reports and Special Reports but focussed on bringing the information relevant to a particular issue or

topic together in a single convenient format) and Guidelines such as those for Impact Assessment and Greenhouse Gas Inventories. As a part of this process, Australia has hosted a number of IPCC-related conferences and workshops and prepared a substantial volume of detailed supporting reports.

Two particularly important Australian contributions have been in the area of greenhouse gas inventories and the broad range of issues associated with land use, land use change and forestry:

- Mr Ian Carruthers of the Australian Greenhouse Office of Environment Australia represented Australia on the IPCC Task Force on National Greenhouse Gas Inventories established by the Fourth Session of the IPCC in Vienna in October 1998; and
- Professor Ian Noble of the Australian National University served as one of the three Co-ordinating Lead Authors (with the IPCC's First and Second Chairmen, Prof B Bolin and Dr R Watson) and Professor Graham Farquhar as a Lead Author of the IPCC Special Report on "Land Use, Land Use Change and Forestry" accepted and approved by the difficult and politically charged Sixteenth Session of the IPCC in Montreal in May 2000.

In support of these and the various other information assessing and writing roles of the IPCC, Australia hosted a series of studies and workshops such as the IPCC/OECD/IEA Expert Group meeting on Biomass Burning, Land Use Change and Forestry in Rockhampton in September 1997.

### **Australian Co-ordination, Consultation and Communication Mechanisms**

Following the initial experience of its 'Australian Co-ordinating Committee for the IPCC' and the Bureau of Meteorology's 'IPCC Science Network', the internal Australian co-ordination, consultation and communication on IPCC matters was largely managed through a combination of interagency committees - under the leadership of the Federal Government Environment Portfolio (known for much of the time as 'Environment Australia'), input to and feedback from sessions of the IPCC, its Bureau and its Working Groups, informal reports on Lead Author meetings, and occasional conferences and workshops such as those organised under the auspices of the Australian Academy of Technological Sciences and Engineering (1995) and the National Academies Forum (1996). One particularly significant initiative was a major 1995 Joint Academies Study,

jointly funded by industry and the Federal Environment Portfolio, which drew heavily on Australian Lead Authors for the SAR to provide an Australian-specific assessment of the science (Steering Committee of the Climate Change Study, 1995).

In addition to the large number of seminars and workshops organised by the various science agencies such as the Bureau of Meteorology and CSIRO, the Commonwealth Government's Bureau of Rural (Resource) Sciences issued a regular 'Climate Change Newsletter' featuring IPCC events and, for a while, the Climate Change and Marine Branch of the Department of the Environment, Sport and Territories (DEST) – later to become Environment Australia – issued an occasional newsletter 'IPCC News – Australia'. Further information on Australia's involvement in the IPCC can be found from the back issues of these publications as well as the earlier mentioned biennial reports on 'Climate Activities in Australia' and the long series of Australian delegation reports on the sessions of the IPCC, its Bureau and its Working Groups.

### Conclusion

Australian Government representatives and Australian scientists and other experts made a major contribution to the work of the IPCC and to the content of its reports during its first thirteen years and laid a strong foundation for the even more broadly-based Australian contribution over the period 2001-07 to its Fourth Assessment Report (AR4). The Australian influence has probably been strongest in helping to avert a northern hemisphere bias in the content of the IPCC reports and ensuring that the conclusions in the Summaries for Policy-Makers are based fully on the peer-reviewed science in the full reports and, as far as possible, kept free from non-scientific bias based on the political or policy interests of IPCC Member governments or other stakeholders. The IPCC process has been strongly supported by Australia, both through contribution to the IPCC Trust Fund from the Australian Government (through the Australian Greenhouse Office) and by the Australian science community. By the same token, its reports although critically questioned

by some, (eg Paltridge, 2004; Kininmonth, 2004), have been largely accepted by the Australian climate community and by the Australian Governments as a basis for national policy development and international negotiation.

### Acknowledgements

As Principal Delegate of Australia to the IPCC from 1994-2004, and on behalf of Dr W J McG Tegart who carried that role from 1988 to 1994, it is appropriate that I place on record our, and the various responsible government agencies', appreciation to the several hundred Australian scientists in various fields, including both greenhouse believers and non-believers, who ensured the comprehensiveness and integrity of the Australian contribution to the IPCC assessment process, through their roles as Lead Authors and reviewers and, most importantly, as the authors of the research publications on which the IPCC assessments ultimately depend.

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# Significant weather

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May 2007

## Summary

Thunderstorms and winds were features of the month. Victoria, Tasmania, South Australia and Western Australia reported tornadoes. A strong cold front moving across the Bight late in the month produced cold and windy conditions in South Australia and Victoria. In contrast, Queensland experienced a hot spell at the start of the month, which saw many new daily maximum records broken.

## Thunderstorms/Tornadoes

### *New South Wales*

On the 9th at Avalon very heavy rain (94mm in 2 hours) caused local flash flooding.

A thunderstorm with heavy rain and 4cm hail caused minor damage at Pooncarie on the 16th.

### *Victoria*

On the 3rd a microburst associated with a thunderstorm produced an estimated wind gust to 140 km/h at Woodend. Trees were uprooted in the area and part of the Woodend Library roof was torn off. A severe thunderstorm produced 40mm of rain in less than 15 minutes at Hoppers Crossing resulting in localised flash flooding. On the same day, a thunderstorm produced a gust to 139 km/h at Mt Hotham.

On the 14th a tornado was sighted near the You Yangs. It lasted for several minutes as it crossed farmland with an estimated diameter of 50-100 metres. No damage was reported.

On the 17th a severe thunderstorm produced large hail to 4cm in diameter at Heathmere near Portland. Damage to spouting and security lights and shed roofs were reported.

### *Tasmania*

A tornado in Burnie on the 3rd caused damage to property.

### *South Australia*

On the 21st several houses were damaged and trees were blown down or snapped off at Moana due to a tornado.

A strong front passed over the southern agricultural areas of the state on the 29th, resulting in severe wind gusts. Squally conditions were recorded by the Cape Willoughby AWS where the peak gust was 128 km/h. In the Adelaide region numerous trees were downed or limbs snapped off particularly in the southern suburbs.

### *Western Australia*

On the 26th there was minor damage associated with a weak tornado in Ocean Reef that demolished fences.

## Wind

### *New South Wales*

At Thredbo storm force winds averaging 98 km/h and gusting to 146 km/h were recorded on the 29th.

### *Victoria*

On the 29th a vigorous cold front associated with an intense low moved across the State during the day, producing gale force northerly winds and widespread severe wind gusts. The highest gusts recorded were in the Alpine region with Mt Hotham recording a gust of 148 km/h. Damage was reported across most of Victoria, particularly Melbourne's eastern suburbs, Ballarat and Gisborne.

### *Tasmania*

Notable wind gusts were reported on the 4<sup>th</sup> (150 km/h at Scotts Peak), the 6<sup>th</sup> (154 km/h at Maatsuyker Island), the 9<sup>th</sup> (154 km/h at Mt. Wellington), the 19<sup>th</sup> (154 km/h at Hogan Island) and the 30<sup>th</sup> (157 km/h at Maatsuyker Island and 152 km/h at Scotts Peak).

## Temperature

Mean temperatures were the highest on record for May for Queensland, NSW, Victoria and Tasmania. Many site records were set, especially in the first week of the month, with state/territory records in Queensland and the Northern Territory (see tables).

## June 2007

### Summary

In the middle of the month the combination of a high pressure system over the Great Australian Bight and a deep low off the New South Wales coast driving southeast winds across Queensland, and a broad upper trough across central Australia, led to an exceptional number of record low maximum temperatures in locations across the state. Frequent upper trough activity led to many rainfall records in a normally dry time of the year for Queensland.

There were several low level snow events in New South Wales during the month due to numerous outbreaks of upper cold pools of air while Victoria reported frosts.

In New South Wales and eastern Victoria heavy rain caused severe flooding with many new long term rainfall records set.

### Wind

#### *New South Wales*

Notable wind gusts included those on the 9<sup>th</sup> (135 km/h at Norah Head, 124 km/h at Newcastle) and 27<sup>th</sup> (115 km/h at Green Cape).

#### *Victoria*

Notable wind gusts included those on the 27<sup>th</sup> (120 km/h at Mount Buller) and 28<sup>th</sup> (137 km/h at Mount Hotham).

#### *Western Australia*

On the 22nd/23rd a cold front crossed the Lower West Coast in the afternoon. Rottnest Island registered maximum wind gusts to 113 km/h. There were isolated reports of tree and roof damage and a boat broke its moorings in Busselton.

### Snow

#### *New South Wales*

There were several low level snow events in New South Wales during the month due to the numerous outbreaks of upper cold pools of air, often causing road closures. These included:

8<sup>th</sup>-9<sup>th</sup> (Upper Hunter and Northern Tablelands; 6cm near Tamworth, 5cm at Guyra)

14<sup>th</sup> (Southern Tablelands; 15cm at Bungendore, 20-30cm from hills SE of Canberra)

19<sup>th</sup> (Central Tablelands; 14cm at Black Springs, 12cm at Katoomba)

26<sup>th</sup> (Monaro; 10-15cm at Michelago)

### Flooding

#### *New South Wales*

The worst flooding in the Hunter Valley in 52 years occurred with many new long term rainfall records set. There was major flooding in Hunter River from 8th to the 13th and Paterson/Williams River from the 8th to the 10th. Moderate flooding occurred in the Wyong, Colo and Nepean Rivers. Ten people drowned in the flood waters including 5 in one family when the Pacific Highway was washed away at Somersby on the Central Coast. Over 4,000 people were evacuated from Maitland after a levee burst. Many roads were closed and major property damage and high stock losses were reported. A 76 000 tonne bulk ore carrier was blown onto Nobbys Beach in storm force winds on the 8th. Severe flooding, one of the highest levels ever recorded, was reported in the main business district of Newcastle from thunderstorms with heavy rain (164.6mm in 6 hours at Nobbys Head). Hundreds of cars were stranded or swept away. Many shops and businesses were flooded.

Ferry services were cancelled on Sydney Harbour. Cremorne wharf collapsed and sank due to large waves on the harbour. Severe beach erosion occurred at many Sydney beaches due to huge swells up to 14 metres high. High winds blew beach sand hundreds of metres inland. Over 200,000 homes lost power in the Sydney-Newcastle area due to flooding and high winds. Many thousands more lost phone lines when telephone exchanges were flooded. A natural disaster was declared in Hunter and Central Coast with the damage bill estimated close to \$1 billion.

#### *Victoria*

Major flooding occurred in parts of Gippsland from the 28<sup>th</sup> onwards as a result of extremely heavy rain, especially in upland areas north of the Latrobe Valley. Rivers to experience major flooding included the Macalister, Mitchell and Avon, whilst the Gippsland Lakes were also

severely affected. Many properties were inundated and there were numerous evacuations and road closures.

### Temperature

It was Australia's coldest June on record, with the mean temperature anomaly of -1.54°C

breaking the 1982 record (-1.42). Northern Australia was especially cold, with records being set at many locations in Queensland and the Northern Territory. Tennant Creek's maximum of 8.0°C on the 20<sup>th</sup> was the furthest north that a sub-10 maximum has ever occurred in Australia.

<b>Records set – May 2007</b> (* - state record; # - record for any month)							
Location	State	Record	Value	Date	Previous record	Year	Years of record
Daly Waters	NT	High daily max	38.6*	5	37.8	1942	38
		High monthly max	34.9		34.1	1958	38
Timber Creek	NT	High daily max	38.6*	4	37.7	1987	27
		High monthly max	35.5		35.1	1988	27
Brunette Downs	NT	High daily max	38.1	6	37.6	1988	43
		High monthly max	32.7		32.2	1988	41
Tennant Creek AP	NT	High daily max	36.4	4	35.5	1988	38
Yuendumu	NT	High daily max	34.8	4	33.0	2002	39
Mount Isa AP	QLD	High daily max	37.1	4	35.3	1988	41
		High monthly max	31.1		29.9	1986	41
Georgetown	QLD	High daily max	36.8	4	36.7	1961	98
		High monthly max	34.0		32.2	1988	114
Toorak RS	QLD	High daily max	38.8*	3	37.0	2005	31
		High monthly max	33.3		30.7	2005	29
		High monthly min	16.7		16.0	2004	26
Richmond PO	QLD	High daily max	37.0	4	36.8	1903	114
		High monthly min	17.6		17.0	1958	115
Clermont	QLD	High daily max	35.0	4	33.4	2003	46
Tambo	QLD	High daily max	34.4	4	34.0	1964	50
Taroom	QLD	High daily max	34.7	4	33.8	2003	51
		High monthly max	27.9		27.3	1973	55
Barcaldine	QLD	High daily max	35.2	4	34.1	2003	46
		High monthly min	16.3		16.1	1989	89
Isisford	QLD	High daily max	36.4	4	34.2	1995	51
		High monthly min	15.8		14.9	1983	91
Longreach AP	QLD	High daily max	36.2	4	34.2	2003	42
		High monthly max	30.3		28.8	1986	42
Camooweal	QLD	High daily max	38.2	4	37.1	1988	66
		High monthly max	32.2		31.9	1988	100
Urandangi	QLD	High daily max	37.8	3	37.5	1988	49
		High monthly max	30.5		30.4	1986	66
Winton	QLD	High daily max	36.8	6	35.6	1964	51
		High monthly max	31.2		30.5	1946	69
		High monthly min	16.9		16.8	1989	69
Amberley	QLD	High daily max	33.3	5	32.8	1943	66
		High monthly max	27.3		26.5	1973	66
Gatton	QLD	High daily max	33.7	5	31.6	2005	42
		High monthly max	27.2		26.9	1923	84
Gympie	QLD	High daily max	32.8	5	31.6	1973	43
Stanthorpe	QLD	High daily max	27.3	4	26.0	1973	45
Surat	QLD	High daily max	33.0	4	32.4	1973	46
Cobar MO	NSW	High daily max	29.6	8	29.5	1985	46
		High monthly min	11.7		11.3	1989	45
Casino	NSW	High daily max	32.7	5	31.8	1973	42
Smoky Cape	NSW	High daily max	29.5	4	28.0	1973	51
		High monthly max	23.7		23.6	1958	69
		High daily max	29.8	4	29.6	1973	57
Scone SC	NSW	High daily max	28.7	8	28.0	1973	43

Townsville	QLD	High monthly max	22.8		22.3	1973	47
Mackay MO	QLD	High monthly max	29.4		29.2	1996	67
Windorah	QLD	High monthly max	25.5		25.4	1973	48
Lady Elliot Island	QLD	High monthly max	28.6		28.0	1958	72
Rockhampton	QLD	High monthly max	26.3		25.9	1973	68
Gladstone	QLD	High monthly max	28.4		28.0	1946	68
		High monthly max	28.1		27.8	1973	50
		High monthly min	18.9		18.8	1973	50
Cape Moreton	QLD	High monthly max	24.0		23.6	1958	94
		High monthly min	19.1		18.5	1989	95
Double Island Point	QLD	High monthly max	24.4		23.8	1998	64
		High monthly min	19.6		19.3	1973	64
Mitchell	QLD	High monthly max	26.9		25.8	1993	87
Mungindi	NSW	High monthly max	25.8		25.3	1938	84
Katoomba	NSW	High monthly max	16.5		15.9	1939	73
		High monthly min	8.6		8.3	1989	73
Parkes	NSW	High monthly max	21.4		21.3	1939	97
Riverview	NSW	High monthly max	21.9		21.6	1947	69
Bombala	NSW	High monthly max	18.1		17.8	1999	84
Eddystone Point	TAS	High monthly max	17.8		17.3	2002	49
Cape Bruny	TAS	High monthly max	16.2		15.4	1999	82
		High monthly min	10.5		10.3	1939	83
Hobart	TAS	High monthly max	17.3		16.9	1980	126
		High monthly min	9.9		9.4	1999	125
Grove	TAS	High monthly max	17.2		16.6	1999	53
		High monthly min	7.6		6.9	1973	52
Bushy Park	TAS	High monthly max	17.1		17.0	1939	73
Cleve	SA	High monthly min	12.0		11.7	1990	67
Adelaide	SA	High monthly min	12.1		11.6	1988	31
Mount Barker	SA	High monthly min	9.8		9.7	1975	107
Lameroo	SA	High monthly min	9.9		9.8	1988	93
Mount Gambier	SA	High monthly min	10.5		9.8	1988	66
Robe	SA	High monthly min	13.1		12.4	1975	123
Cape Borda	SA	High monthly min	12.8		12.5	1975	60
Burketown	QLD	High monthly min	21.0		20.5	2004	108
Grenfell	NSW	High monthly min	10.1		9.6	1989	91
Ouyen	VIC	High monthly min	10.1		9.9	1958	71
Melbourne	VIC	High monthly min	12.6		11.6	1988	153
Laverton	VIC	High monthly min	11.5		9.8	1988	63
Ballarat	VIC	High monthly min	8.2		8.0	1974	99
Cape Otway	VIC	High monthly min	12.4		11.9	1919	143
Howlong	NSW	High daily rain	57.8	18	48.6	1978	123
Eldorado	VIC	High daily rain	67.2	18	64.5	1918	114
Princetown	VIC	High daily rain	56.0	29	40.6	1904	106
Tibooburra PO	NSW	High monthly rain	94.0		92.8	1893	119
<b>Records set – June 2007</b>							
Location	State	Record	Value	Date	Previous record	Year	Years of record
Georgetown	QLD	High daily max	34.8	4	34.4	1973	99
		High monthly rain	100.6		85.8	1927	136
Darwin	NT	Low daily max	22.7	20	24.2	1963	67
Victoria River Downs	NT	Low daily max	15.1	21	16.6	1993	42
		Low monthly max	24.5#		26.4	1985	39
		High daily rain	56.4	20	20.8	1913	117
		High monthly rain	96.2		27.5	1923	117
Brunette Downs	NT	Low daily max	10.8#	21	13.9	1978	43
Tennant Creek AP	NT	Low daily max	8.0#	20	12.8	1993	38
		Low monthly max	19.9#		21.6	1985	38
		Low monthly min	9.8#		10.2	1977	38
Burketown	QLD	Low daily max	13.4	21	15.9	1904	110

Croydon	QLD	High daily min	23.5	5	23.2	1998	45
		Low daily max	14.6#	21	18.4	2000	46
		Low monthly max	25.6#		26.1	2000	83
Mount Isa AP	QLD	Low daily max	9.4#	20	13.0	1978	41
		Low monthly max	20.4		21.8	1985	41
		High daily rain	54.8	18	28.4	1998	41
Richmond PO	QLD	High monthly rain	111.8		29.0	1998	41
		Low daily max	11.2	21	13.0	1978	114
		Low monthly max	21.1#		22.8	1893	115
Townsville	QLD	High monthly rain	164.3		109.5	1935	115
		High daily min	23.0	4	22.7	2002	67
		Low daily max	13.9#	21	14.6	1971	67
Ayr DPI	QLD	Low monthly max	22.9#		23.6	1989	67
		High monthly rain	111.4		106.8	1967	67
		Low daily max	12.4#	21	15.3	1958	52
Collinsville	QLD	Low monthly max	21.9#		23.3	1989	52
		Low daily max	11.0#	21	13.4	1958	50
		Low monthly max	21.0#		22.8	2000	49
St. Lawrence	QLD	Low daily max	11.9#	21	12.8	1971	51
		Low monthly max	20.7#		22.2	2000	67
		Low daily max	11.8#	21	15.0	1961	48
Mackay MO	QLD	Low monthly max	19.8#		19.9	2000	47
		Low daily max	12.3	21	12.5	2000	46
		Low daily max	9.2#	20	12.0	1978	43
Clermont Springsure	QLD	Low monthly max	18.7		20.1	1950	56
		Low daily max	7.3#	20	11.3	1957	51
		Low monthly max	18.1#		18.5	1949	76
Taroom	QLD	Low daily max	9.6#	20	10.2	2000	51
		Low monthly max	18.3		18.9	1989	55
		Low daily max	7.8#	20	13.8	1986	45
Barcaldine	QLD	Low monthly max	18.8#		20.1	1913	90
		High daily min	18.5	5	18.4	1996	42
		Low daily max	8.3#	20	13.1	1986	42
Longreach AP	QLD	Low monthly max	19.7#		20.6	1989	42
		Low daily max	9.8#	20	12.2	1957	68
		Low monthly max	21.2		22.0	1949	100
Camooweal	QLD	Low daily max	9.1#	20	13.9	1978	49
		Low monthly max	19.4		20.3	1950	69
		Low daily max	9.6#	20	12.2	1957	51
Winton PO	QLD	Low monthly max	20.6#		21.6	1985	70
		Low daily max	9.0#	20	11.1	1956	118
		Low monthly max	19.3		19.7	1891	119
Lady Elliot Island Sandy Cape	QLD	Low daily max	14.4#	20	16.5	1995	50
		Low daily max	13.5	21	14.7	1978	51
		Low monthly max	20.0		20.1	1928	99
Cape Moreton Double Island Point	QLD	Low daily max	12.3#	20	13.2	1978	51
		Low daily max	11.6#	20	14.7	1961	47
		Low daily max	12.3	20	12.9	1978	42
Gatton	QLD	Low daily max	12.6	20	13.4	1973	42
		Low daily max	11.9	20	13.9	1965	51
		Low monthly max	20.2		20.6	1913	99
Stanthorpe	QLD	Low daily max	6.4	20	6.7	1972	45
		Low daily max	4.9*	20	6.0	2005	38
		Low daily max	10.1	20	12.0	1995	46
Applethorpe Surat	QLD	Low monthly max	17.2		17.4	1949	61
		Low daily max	9.5	20	11.1	1959	51
		Low daily max	10.1	20	11.8	1975	51
Bollon	QLD	Low daily max	6.6	19	7.7	1981	46
		Low monthly max	14.0		14.3	1989	46
		Low monthly min	3.8		4.2	1982	46
Quilpie	QLD	Low daily max	10.1	20	11.8	1975	51
		Low daily max	6.6	19	7.7	1981	46
		Low monthly max	14.0		14.3	1989	46
Cobar MO	NSW	Low monthly min	3.8		4.2	1982	46

Ivanhoe	NSW	Low daily max	8.2	19	8.3	1965	47
Glen Innes PO	NSW	Low daily max	3.7	20	4.3	1998	46
Eddystone Point	TAS	Low daily min	-0.4#	22	0.1	1973	50
Geraldton	WA	High daily min	19.2	7	19.1	1988	65
Innisfail	QLD	High daily min	22.9	6	22.4	1990	51
Pemberton	WA	High monthly max	17.4		17.3	2006	62
Halls Creek	WA	Low monthly max	23.3#		24.4	2000	60
Keith	SA	Low monthly max	13.9		14.0	1989	53
		Low monthly min	2.2#		2.4	1972	53
Cardwell	QLD	Low monthly max	22.6		23.4	1944	97
Rockhampton	QLD	Low monthly max	20.6#		21.7	1989	68
Gladstone	QLD	Low monthly max	20.7#		21.5	1989	49
Tibooburra PO	NSW	Low monthly max	14.8#		15.4	1956	98
Giles	WA	Low monthly min	4.7		5.0	2000	51
Grove	TAS	Low monthly min	0.5		0.7	1983	52
Oenpelli	NT	High daily rain	71.4	18	31.8	1933	96
		High monthly rain	73.4		41.2	1973	96
Chillagoe	QLD	High daily rain	64.0	7	59.2	1939	106
		High monthly rain	105.0		95.3	1950	106
Willow Tree	NSW	High daily rain	98.0	9	62.0	1993	127
Branxton	NSW	High daily rain	193.4#	9	191.5	1949	145
Denman	NSW	High daily rain	153.0	9	128.3	1930	125
		High monthly rain	301.0		216.7	1930	125
Dungog	NSW	High daily rain	197.0	8	117.1	1949	108
Muswellbrook	NSW	High daily rain	111.8	9	93.2	1930	120
		High monthly rain	267.6		257.6	1950	120
Nobbys Head	NSW	High daily rain	209.8	9	190.3	1975	144
		High monthly rain	495.8		485.7	1950	144
Williamtown	NSW	High daily rain	147.0	9	111.5	1964	60
		High monthly rain	414.2		324.5	1951	60
Cassilis	NSW	High daily rain	110.0	8	82.6	1930	131
Binnaway	NSW	High daily rain	54.0	9	47.8	1923	104
Woods Point	VIC	High daily rain	101.0	28	80.0	1980	117
Gabo Island	VIC	High daily rain	90.2	27	88.9	1952	147
Mount Wellington	VIC	High daily rain	318.6*	28	28.2	2005	5
Warmun	WA	High monthly rain	80.5		76.9	1939	99
Jerrys Plains	NSW	High monthly rain	298.6		288.4	1950	123
Bruthen	VIC	High monthly rain	327.8		308.8	1998	124
Lindenow	VIC	High monthly rain	284.2#		239.2	1978	108
Walebing	WA	Low monthly rain	14.0		20.2	2001	117
Mount Barker	WA	Low monthly rain	31.8		36.6	1987	121
Arthur River	WA	Low monthly rain	22.5		24.4	1893	112
Burnie	TAS	Low monthly rain	22.2		27.3	1949	63
Longford	TAS	Low monthly rain	2.0		3.3	1930	116
Launceston AP	TAS	Low monthly rain	8.2		11.7	1934	75

# Charts From The Past by Blair Trewin

23 June, 1950

June 1950 was an exceptionally wet month along large parts of the east coast of Australia. After what had already been a wet start to the year, a La Niña, the first of several in rapid succession in the 1950s, became established by mid-year. June saw a succession of five east coast lows, in a month that had a lot in common with June 2007. (In addition to the wet east coast, it was dry in much of western Victoria and Tasmania, and very cool in the tropics, but with no extremes to match 2007).

The five lows brought consistent rain to eastern NSW and south-eastern Queensland. Sydney had its wettest month on record with 643mm, 642 of which fell in the three weeks from 7 to 27 June. During this time it rained on all 21 days, with 25mm or more on 10 of them (including 8 in 10 days from 8-17 June) and a peak of 105.2mm on the 16<sup>th</sup>.

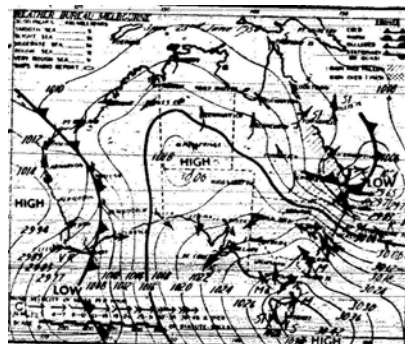
The fifth low in the sequence formed near Fraser Island on the 22<sup>nd</sup>, then drifted slowly south to near Kempsey on the 25<sup>th</sup> before moving into the Tasman. Sydney was only modestly affected (57mm in five days), but further north there were spectacular rainfalls in the easterly flow on the low's southern flank. On the 23<sup>rd</sup> the heaviest rain was in southern Queensland, with 368mm at Springbrook and 200 or more at several stations in the Gold Coast hinterland and southern Brisbane.

By the 24<sup>th</sup> the rain had become still heavier and its focus had moved to the northern coast of NSW. The heaviest falls of all were in the ranges near the coast. Dorrigo received 970mm

in three days from 23-25 June (and 1329mm in eight), including an Australian June record of 636mm on the 24<sup>th</sup>. Four other stations exceeded 400mm, and 19 topped 200. The rain eased a little the next day (although with numerous stations still exceeding 100mm), before tapering to light falls by the 26<sup>th</sup>.

Not surprisingly, such extreme rainfalls, on top of an already wet month, led to extreme flooding, especially in the Clarence and Macleay river systems. Grafton had its worst flood on record, with 75% of the town's 4000 dwellings inundated to some degree, whilst Kempsey and Maitland were also severely affected. (Illustrating that it was an earlier era, the 'Sydney Morning Herald' referred to evacuees in a Maitland church hall as "living like Chinese coolies"). The Clarence River forced a new outlet to the sea at Yamba. Four lives were lost on land. There were also severe winds in places, with the 648-ton freighter 'Bangalow' driven ashore at Coffs Harbour. Production in the Hunter coalfields was severely disrupted, leading to gas rationing in NSW and Victoria. To cap off an already difficult week, the Korean War (which at the time was widely believed to be the opening of World War III) broke out on the 26<sup>th</sup>.

Whilst it did not compare with the situation on the east coast, a front also brought heavy rain to the west coast of Western Australia, with 95mm at Busselton. In contrast, Melbourne was hit by what was reported as its worst fog for 15 years, with numerous transport disruptions.



*Synoptic chart for 23 June 1950 (1500 AEST)*

# Calendar

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**2007**

**September**

3-7, Royal Meteorological Society Conference, Edinburgh, Scotland.

10-14, 4<sup>th</sup> European Conference on Severe Storms, Fourth Edition of the European Conference on Severe Storms, Trieste, Italy.

**October**

2-5 GREENHOUSE 2007: The Latest Science and Technology, Sydney, NSW.

2-6 JCOMM Scientific/Technical Symposium on Storm Surges Seoul, Republic of Korea

31- 1<sup>st</sup> November, Making Science Global: Reconsidering the Social and Intellectual Implications of the International Polar and Geophysical Years, Washington, D.C.

**November**

12-14 In hot water: preparing for climate change in Australia's coastal and marine ecosystems, Science symposium, Brisbane, QLD.

**2008**

**January**

9-11, Catchment-scale Hydrological Modelling & Data Assimilation International Workshop Melbourne, VIC

20-24 88<sup>th</sup> American Meteorological Society Annual Meeting, New Orleans, LA, USA

29<sup>th</sup>-1<sup>st</sup> February, 15<sup>th</sup> AMOS National Conference, Geelong, VIC

**February**

7-8 Living with climate change: are there limits to adaptation? Royal Geographical Society, London, England.

## Australian Meteorological Magazine. Vol 56 No.2, June 2007.

**Articles**

*McCaw, L., Marchetti, P., Elliott, G. and Reader, G.* Bushfire weather climatology of the Haines Index in south-western Australia.

*Sun, Z., Li, Y., Zeng, X., Luo, Z., Wu, J. and Liu, J.* Parameterization of solar radiation at the surface under cloudless conditions and its validation against observations.

*Kirono, D.G.C. and Jones, R.N.* A bivariate test for detecting inhomogeneities in pan evaporation time-series

*Power, S. and Nicholls, N.* Temperature variability in a changing climate.

**Regular features**

*Murphy, B.F.* Seasonal climate summary southern hemisphere (winter 2006): El Nino develops late but drought already severe.

*Lee, J.* Quarterly numerical weather prediction model performance summary: January to March 2007.

**Book Review**

Turner. Remote Sensing from Air and Space by Olsen.

Further Information:

<http://www.bom.gov.au/amm>