Editorial

It has been well documented that changing weather patterns have caused havoc for industries such as agriculture. An overlooked industry that is now experiencing problems due to the changing weather is the fashion industry. The latest victim of climate change is the winter wardrobe. Fashion houses are being forced to ditch traditional seasonal collections for transeasonal garments, leading to a drastic overhaul of fashion show schedules and retail delivery dates.

New York fashion retailers blamed a prolonged "Indian summer" for poor autumn sales. So worried are some fashion houses about the impact climate change on sales they are calling in the climate experts (who could have guessed that scientists would be advising fashion!) American retail giant Liz Claiborne Inc enlisted Radley Horton, a climatologist with the Center for Climate Systems Research at Columbia University, to speak to 30 of its executives on topics ranging from the types of fabrics they should be using to the timing of retail deliveries and seasonal markdowns. Other US fashion retail giants, including Target, have also started using climate consultants to plan their collections and schedule end-of-season sales.

Within Australia, fashion designers are experiencing similar issues. They are increasingly designing transeasonal collections using lighter-weight fabrics for a more temperate climate and readjusting their in-store delivery dates in line with the unpredictable seasons. Defined autumn/winter and spring/summer collections are a thing of the past. Rather than twice a year releases, clothes are being moved in and out of stores depending on the weather.

This highlights a new use for seasonal forecasting and an area that I never thought scientists would be involved in! I am also really looking forward to the fashion section in the IPCC’s next assessment report!

Lee Tryhorn

Further information:
http://www.theage.com.au/articles/2007/10/06/1191091426725.html
http://online.wsj.com/public/article/SB118843034338212804.html

News

A New Science Team for Australia’s Climate Challenges

A new science team is leading Australia’s climate change and weather research. It’s the Centre for Australian Weather and Climate Research – a partnership between two of Australia’s leading atmospheric and oceanographic research agencies; the Bureau of Meteorology and CSIRO. The Centre was established with the intention of ensuring that Australia remains a world leader in climate, weather and oceans research so that it can meet the severe weather and climatic challenges that continue to confront the nation. The two agencies have established an initial five-year collaboration that links scientists based in Melbourne, Hobart, Canberra and Perth. They expect the Centre to deliver a number of advantages including access to a wider range of research skills, more efficient use of resources, as well as increased potential to develop research relationships with government, industry and other research providers. The Centre’s research capabilities cover the sciences associated with:

- Weather and environmental prediction
- Ocean Prediction
- Atmosphere and Land Observation and Assessment
- Seasonal and Interannual prediction
- Ocean Observation and Assessment
- Climate Change.

The core modelling and assimilation capability supporting these activities is itself a new initiative in Australian climate science. Called, the Australian Community Climate and Earth System Simulator (ACCESS), it is an initiative led by the Bureau of Meteorology and CSIRO with strong research partnerships internationally with the United Kingdom Met Office's Hadley Climate Centre and nationally with Australian universities and government research agencies. ACCESS is also strongly supported by the Australian Greenhouse Office. It is expected to be operational by 2009. The agencies expect the Centre will be recognised nationally for its innovation and scientific excellence, and internationally as a world leader in its field, having both an Australian regional focus and exceptionally strong northern hemisphere linkages delivering collaboration benefits. Although the Bureau and CSIRO have different charters, they have worked closely together for many years in a range of partnerships with State and Federal Governments and the private sector. Both have outstanding records in science and science publication including the BLUElink Ocean Forecasting service launched in August. The Foundation Director of the new Centre is Dr Chris Mitchell, most recently the Climate, Weather and Ocean Prediction Theme Leader at CSIRO Marine and Atmospheric Research.

IPCC awarded the Nobel Peace Prize

The Nobel Peace Prize was this year awarded to the Intergovernmental Panel on Climate Change (IPCC) and Albert Arnold (Al) Gore Jr. "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change".

"This is an honour that goes to all the scientists and authors who have contributed to the work of the IPCC, which alone has resulted in enormous prestige for this organization and the remarkable effectiveness of the message that it contains" - says Mr. Rajendra Pachauri, the Chairman of the IPCC.

Through the scientific reports it has issued over the past two decades, the IPCC has created an ever-broader informed consensus about the connection between human activities and global warming. Thousands of scientists and officials from over one hundred countries have collaborated to achieve greater certainty as to the scale of the warming. Whereas in the 1980s global warming seemed to be merely an interesting hypothesis, the 1990s produced firmer evidence in its support. In the last few years, the connections have become even clearer and the consequences still more apparent.

Al Gore has for a long time been one of the world's leading environmentalist politicians. He became aware at an early stage of the climatic challenges the world is facing. His strong commitment, reflected in political activity, lectures, films and books, has strengthened the struggle against climate change. He is probably the single individual who has done most to create greater worldwide understanding of the measures that need to be adopted.

By awarding the Nobel Peace Prize for 2007 to the IPCC and Al Gore, the Norwegian Nobel Committee is seeking to contribute to a sharper focus on the processes and decisions that appear to be necessary to protect the world's future climate, and thereby to reduce the threat to the security of mankind. Action is necessary now, before climate change moves beyond man's control.

Further Information:
http://www.ipcc.ch/press/prpnp12oct07.htm
http://nobelprize.org/nobel_prizes/peace/laureates/2007/

John Church wins Eureka Prize

Dr John Church of CSIRO has been awarded the 2007 University of New South Wales Eureka Prize for Scientific Research. Dr Church developed a way to combine historical data from tide-gauge readings with modern data from satellite altimeters which measure the height of ocean surfaces over most of the global ocean. This led to the discovery that sea-level rise accelerated during the 20th Century.

Dr Church's research has demonstrated that current models of climate change underestimate the rate at which sea levels may rise. He was also the first person to recognise that violent volcanic eruptions can have significant impact on sea level as a result of cooling effects of volcanic aerosols in the upper atmosphere. Dr Church's work on global and regional sea level assessment utilising the satellite-altimeter data is globally recognised for its impact and is contributing to international projects on satellite data calibration.

“Sea level rise is an important issue to society and is central to the current debate about global warming and its impacts,” Dr Church said. Dr Church is an oceanographer with CSIRO Marine and Atmospheric Research and the Antarctic Climate and Ecosystems Cooperative Research Centre and is currently Chair of the Joint Scientific Committee of the World Climate Research Programme. He was co-convening lead author for the chapter on Changes in Sea Level in the IPCC Third Assessment Report. His previous awards include the 2006 Roger Revelle Medal, awarded by the Intergovernmental Oceanographic Commission, and a 2006 CSIRO Medal for Research Achievement.

The Australian Museum Eureka Prizes are Australia’s premier award scheme for outstanding science. Presented annually by the Australian Museum, the prizes reward excellence in the fields of research and innovation, science leadership, school science, and science journalism and communication.

Further Information:
http://www.csiro.au/news/EurekaClimateChange.html

CSIRO scientist wins prestigious ‘Clean Air Medal’

The premier award of the Clean Air Society of Australia and New Zealand (CASANZ) – the ‘Clean Air Medal’ – has been awarded to Dr Peter Manins of CSIRO Marine and Atmospheric Research in Melbourne. Last awarded in 2002, the Medal has only been presented 14 times in the Society’s 40-year history.

Dr Manins received the award for: “Distinction in the atmospheric sciences”, at a dinner at the World Clean Air Congress in Brisbane. “He has been a leader in the development of Australian air-quality science for over 30 years and has been instrumental in many significant research developments, as well as a mentor to numerous young scientists,” CASANZ President Dr Gerda Kuschel said.

Dr Manins is a Chief Research Scientist at CSIRO, with internationally recognised expertise in air pollution meteorology and modelling. He has been an expert advisor on several public infrastructure projects and major industrial developments, including Sydney’s Lane Cove Tunnel.

He also led the major Latrobe Valley Airshed Study in the 1980s and has worked as an international advisor for the World Health Organisation, the UK Science Council and the World Meteorological Organisation. Dr Manins founded CSIRO’s Environmental Consulting Research Unit in 1989 – based on advanced air pollution modelling – and led CSIRO's air pollution program from the mid-1990s.

Further Information:
http://www.csiro.au/news/CleanAirMedal.html

Winner of the 2007 AMOS Student Essay Prize

The Society awards 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. The prize aims to foster and reward excellence in scientific communication, and to encourage articles of general interest to the members. The best three essays submitted are published in the BAMOS.

This year's winner of the inaugural AMOS Student Essay Prize is Helen Duncan for her essay entitled "The Southern Ocean and its Role in the Marine Carbon Cycle" (April issue). The runners up were "Chaos and Causality" by Robert Woodham (June issue), and "A Review of Phytoplankton Growth on the Great Barrier Reef: Does Aeolian Dust Deposition Stimulate Phytolankton Blooms?" by Emily Shaw (August issue). Helen, Emily and Robert submitted terrific essays and the Society would like congratulate each of them on the quality of their work.

2008 AMOS Student Essay Prize
Call for Essays

It's now time to write your entry for the 2008 AMOS Student Essay Prize. *Review essays on any topic in the areas of atmospheric or oceanographic are sought.* If you are an enrolled student and an AMOS member then you are eligible. 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. Entries close 28 February 2008. The Education Committee will read the essays submitted and determine the best three. During 2008, these three will be published in the BAMOS. The best of the three, 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. All honours and graduate students write detailed, usually technical, literature reviews as the introductory chapters of their theses. You may like to draw on your literature review in writing an essay for BAMOS, although the essay should not be simply the introductory chapter from your thesis. The essay must be written with the general reader in mind, and it must not exceed 5000 words.

Report on the Leeuwin Current 2007 Symposium
University of Western Australia, Saturday 22nd September

Alan Pearce

Although the Leeuwin Current was only formally identified and named as such (by George Cresswell and Terry Golding) in 1980, it has become of growing national and international interest because of its unusual nature. A one-day Symposium was held in Perth in 1991 to bring together many of the oceanographers and biologists studying the Current at the time -- the Proceedings of that meeting are still available at $20 for those who may be interested.

A follow-up one-day symposium was organised for 22nd September this year to update progress on Leeuwin Current research over the intervening 16 years. As previously, the symposium was primarily sponsored by the Royal Society of Western Australia (which is again publishing the full Symposium Proceedings), with generous co-sponsorship from the Western Australian branch of the Australian Marine Sciences Association (AMSA), the Australian Meteorological and Oceanographic Society (AMOS), the University of Western Australia (UWA), the Western Australian Marine Sciences Institute (WAMSI) and Murdoch University. Some travel support for interstate PhD's and recent postgraduates was made available through the Australian Research Council Research Network for Earth System Science (ARCNESS).

A total of 105 participants attended the Symposium in the impressive and very adequate University Club at the University of Western Australia. Professor Alistar Robertson, the Dean of the Faculty of Natural and Agricultural Sciences at the University, formally opened the Symposium by pointing out both the growing interest in marine science in Western Australia and the rapidly increasing funding and infrastructure to undertake advanced marine research in this state.

Invited speakers then addressed a variety of topics to demonstrate the development of knowledge and our understanding of the influence of the Current on the marine fauna and flora of Western Australia, ranging from the source regions in the northwest around to Esperance on the south coast. The programme was:

1) The paleoceanography of the Leeuwin Current. Karl-Heinz Wyrwoll, Ben Greenstein, George Kendrick.
2) Northern sources of the Leeuwin Current and associated circulation on the North West Shelf. Steve Buchan, Nick D'Adamo, Chris Fandry, Susan Wijffels, Catia Domingues.
3) The mean state and seasonality of the Leeuwin Current system between Exmouth and Cape Leeuwin. Chari Pattiaratchi, Mun Woo.
4) Climate variability and biophysical coupling in the Leeuwin Current system off the west coast of Australia. Ming Feng, Anya Waite, Peter Thompson.
5) The Leeuwin Current south of Western Australia -- Cape Leeuwin to the Great

Australian Bight. George Cresswell, Catia Domingues.
6) The influence of the Leeuwin Current on economically important fish and invertebrates off temperate Western Australia. Rod Lenanton, Nick Caputi.
7) Go with the flow - larval fishes and the Leeuwin Current. Lynnath Beckley, Barbara Muhling, Dan Gaughan.
8) Coral communities off far north-western Australia and the influence of the Leeuwin Current. Luke Smith, Jamie Gilmour, Andrew Heyward, Jim Underwood.
9) Influence of the Leeuwin Current on the ecology of the Ningaloo region. Christine Hanson, Dave McKinnon (presented by Anya Waite as Christine was unable to be present).
10) The influence of the Leeuwin Current on the marine biota of the Houtman Abrolhos Islands. John Huisman, Julia Phillips, Dianne Watson, Euan Harvey.
11) Oceanic processes and the recruitment of tropical fish at Rottnest Island. Alan Pearce, Barry Hutchins.
12) The marine environment of the Capes region (Western Australia) and the influence of the Leeuwin Current. Mark Westera, Julia Phillips, Grey Coupland, Alex Grochowski, Euan Harvey (presented by Gary Kendrick).
13) The Recherche Archipelago and the Leeuwin Current. Gary Kendrick, Euan Harvey, Nisse Goldberg, Justin McDonald.
Four posters were displayed and attracted much interest over tea- and lunch-times:
1) Seasonal and Interannual Variations of the Leeuwin Current off West-ern Australia from TOPEX/Poseidon Satellite Altimetry. X. Deng, C. Hwang, R. Coleman and W.E. Featherstone.
2) Evidence for cross-shelf transport of neritic biota during formation of a Leeuwin Current eddy.
David Holliday, Harriet Paterson, Lynnath Beckley, Anya Waite, Ming Feng, Peter Thompson.
3) The good, the bad and the ugly: The Leeuwin Currents influence on seabird reproductive performance at the Houtman Abrolhos. Chris Surman & Lisa Nicholson.
4) Carbonate sedimentation and coral reefs on Australia's western margin: a response to regional climatic gradient and Leeuwin Current flow. Lindsay Collins.

At the end of the day, George Cresswell (the "Father of the Leeuwin Current") closed with some personal reflections on the last 2 decades of Leeuwin Current research, and invited discussion from the audience on future research priorities. A presentation was made by Dr Anya Waite to CSIRO’s Lindsay Pender for his dedicated technical assistance during recent ship surveys of the Leeuwin Current. The final fling was a well-attended "Sundowner" (sponsored by AMSA and AMOS).

The papers will be published in the Journal of the Royal Society of Western Australia during 2008 and (like the 1991 Proceedings) should attract a wide readership. The organising committee comprised Alan Pearce (Royal Society/AMSA/AMOS), Bruce Buckley (AMOS), Euan Harvey/Gary Kendrick (UWA), Mike van Keulen (AMSA), Jane Rosser (Royal Society), Philip O’Brien (RSWA) and Valerie Pearce.

The Proceedings volume will be available for sale at a price probably between $30 and $40; please contact Alan Pearce (alanpearce@iinet.net.au; (08) 9246-2910) for further information.

[Editors Note: This report was previously published in the Australian Marine Sciences Association journal.]

Effects of Climate Change on the World’s Oceans
International Symposium, May 19-23, 2008, Gijón, Spain

Climate change is the most important threat to the Earth. Even if we stabilize CO2 concentrations, the 2007 Intergovernmental Panel on Climate Change Assessment confirms that warming will continue for decades and sea level will continue to rise for centuries. Some direct effects of climate change in the marine environment are already visible, but others need to be defined by enhanced observations, analysis and modelling. We have a rudimentary understanding of the sensitivity and adaptability of natural and managed ecosystems to climate change. An assessment of the consequences of climate change on the World's Oceans has a high scientific and social relevance and is urgently needed.

Although we are beginning to document the local effects and consequences of climate change on the functioning of marine ecosystems, there is no comprehensive vision at the global scale, and only limited ability to forecast the effects of climate change. To close this gap, the Symposium will focus on the major issues of climate change that affect the oceans: oceanic circulation, climate modelling, cycling of carbon and other elements, acidification, oligotrophy, changes in species distributions and migratory routes, sea-level rise, coastal erosion, etc. The Symposium will bring together results from observations, analyses and model simulations, at a global scale, and will include discussion of the climate change scenarios and the possibilities for mitigating and protecting the marine environment and living marine resources.

Further Information:
http://www.pices.int/meetings/international_symposia/2008_symposia/Climate_change/climate_background_3.aspx

Articles

Turning to Meteorology for Teaching and Learning Resources

Rob Willis
Victoria Region, Bureau of Meteorology

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Introduction

Who am I? I prepare information for all walks of life. My work is always a good talking point. My results can be “short of the mark”. Nevertheless, I willingly have my results published for all to see, daily. I am a weather forecaster. As a member of a service industry, a weather forecaster needs to have a thick skin, a well-developed sense of humour and be prepared to withstand the occasional scathing attack from stakeholders and the mass media. Weather is one of the most natural phenomena. The quote, "Everybody talks about the weather, but nobody does anything about it," attributed to Mark Twain, echoes the public attitude to this perfectly natural, yet often confounding raft of phenomena, called weather. In her book, Katherine Anderson (c2005) showed that although weather forecasting has always been a high-risk activity, the outcomes are worthwhile.

Can you imagine how meteorology can link and integrate educative ideas and resources to the secondary school curriculum? This article introduces some teaching and learning ideas and resources through meteorology. I write this article largely from the point of view of a weather forecaster. Because weather is not straightforward, yet is topical on a daily as well as monthly and annual basis, it can be put to good effect as a stimulus context for student interest in and across several areas of the curriculum. The following material provides an outline of several meteorology related contexts that could be used for this purpose from Level 6 of the *Mathematics*, *Science*, and *Humanities — Geography* domains for Victorian Essential Learning Standards or VELS (HREF1) through to various related VCE studies (HREF2).

A quick inspection of the Level 6 VELS indicates there are several collective ideas, which can link meteorology to the curriculum. To this end, I have collected links between the curriculum and meteorology into some rough bundles, some linked through commonality and others through meteorology’s unique ability to highlight a certain aspect of the curriculum. The collective keywords in the context of this article are:
Collaboration *(working together, teams);*
Communication *(getting the message across effectively)**;***
Conceptual Models *(physical processes simplified by isolating the model from the fluid)**;***
Critical Thinking *(thinking logically, in a balanced manner and making distinctions)**;***
Dynamics *(motion described by Newton’s Laws);*

Fluids *(matter which has special properties and can flow but cannot be treated as a solitary solid)**;***
Geography *(study of the earth);*
History *(study of the past particularly people of the past);*
Ideas (*springboards for stimulation acting; this article contains meteorological ideas aimed at stimulating teaching and learning activities);*
Integration of Disciplines, *(mutually supporting links between disciplines)**;***
Issues; Nature *(the natural world);*
Process *(methodology, scheme or procedure for achieving an outcome);*
Probability & Statistics *(the arm of mathematics dealing with chance and likelihood);*
Radiation *(the science of electromagnetic radiation);*
Scaling *(the study of how magnitude and dimension of components of physical processes relate to each other);*
Service *(the ethic of providing a service to a community);*
Thermodynamics *(study of thermal properties of matter).*

One may also inquire how meteorology relates to the other physical sciences. The three fundamental input disciplines into meteorology are chemistry, dynamics and radiation. Mathematics and computing help the three fundamental disciplines “converse” with meteorology. Oceanography and meteorology share their fluid behaviour (and are linked through common theories of dynamics and thermodynamics) as well as their global scale physical coupling and teleconnections, as demonstrated by the mechanism contributing to large effects such as El Niño. Meteorology links also to atmospheric physics, weather forecasting, pollution modelling, and climatology.

Meteorology also relates to many other disciplines and areas of interest, including, economics, risk management, as well as tradition disciplines such as aeronautics, agriculture, fishing, transport, recreation, medicine, geography, politics and history. It is enriching for the student to research the historical context that accompanied progress in meteorology, just as in any other discipline. Finding out about people involved with meteorology through biographies and autobiographies brings the science alive. Meteorology infiltrates many other disciplines and thus can assist the student in integrating subject matter across the curriculum.

Meteorology has many unsolved problems. Visit the Clay Mathematics Institute Millennium Problems websites (HREF3) to see one of the big yet-to-be-solved problems associated with fluid mechanics and the boundary layer of the atmosphere. Rather than reject a problem out of hand, should we consider whether there might be other ways to look at the problem? How we can “manage” a useful solution, even if it is not exact?

Tackling, complex issues and real problems, even if only to make a start in formulation, or develop a partial solution under certain conditions, can be rewarding for the student, providing there is sufficient scope for achievement. If approached as a challenge, the student can test his or her understanding. It becomes useful when one puts a fence around a problem and realises it is not practical to solve it with the available resources at that time. Distraction from the curriculum would not be useful and this needs to be balanced against the stimulation derived from tackling difficult problems.

Background

We cannot proceed without saying something more about the essential weather forecaster. Weather forecasting is an extraordinary data-management job. It seems that it takes more computing power to prepare *numerical weather prediction* guidance for tomorrow’s weather forecast, than it took to place a human on the moon! Very few professionals would make as many decisions in the day’s work as the weather forecaster. Much of the decision-making is experience-based. So strangely, it is often difficult for even the most able forecaster to explain exactly how he or she arrived at the detail of a forecast.

We must bear in mind that, like the oceans, the atmosphere is a fluid. As a fluid, air has rather special physical properties. For example, we are used to applying Newton’s laws to solids. When it comes to a fluid, we have to look at the force per unit volume (often just abbreviated to “force” in the context of meteorology). Fluids tend not to have “holes” or “lumping effects” due to *continuity*. The equations of motion for the atmosphere are known, but turn out to be non-deterministic (non-linear) and combined with the fact that we find ourselves with less-than-ideal starting conditions (observations), this means there are no exact solutions to these equations of motion. Complex interactions and feedback mechanisms make the system intractable.

Students may feel uncomfortable with the fact that there can be no exact solution, a matter that could be explained better to the public as well. There is a need for aligning the public's expectations of weather forecasts with the reality.

Meteorology exposes one to the different "behaviour" of weather elements. For example, the Bureau of Meteorology's Monthly Rainfall Review used to have a prime description of rainfall: "Rainfall, unlike other meteorological elements such as temperature and pressure, is non-continuous in time and space. As a result the statistical description of rainfall occurrence is quite complex". Compare the continuous weather elements (such as temperature and pressure) to the ephemeral nature of clouds, for example. One of the outstanding problems of numerical weather prediction modelling is how to represent most closely the behaviour of clouds. We have to learn how to manage the best solution available to us at the time, under the prevailing circumstances, since extracting an exact solution for our forecast problem is impossible.

We also endeavour to reflect upon the use of our language. Weather forecasts use the term "tends to be" in preference to "is". Rather than attributing causation, the forecaster may prefer to resort to saying, "X is associated with Y". This is a little like real-life in fact, when things **are** complex. We could also attempt to make a distinction between the terms "accuracy" and "precision". The theory of measurement can assist here. The observation may have certain precision associated with it, the forecast for tomorrow's weather, less precision, the outlook for Day 7 less, and the Seasonal Climate Outlook far less precision. These differing time-scales have corresponding differing levels in the confidence placed on them by the weather forecaster. The greater the extension into the future of the prognosis, the less precise it is: so we have less confidence in the "forecast". The rounding of an observed temperature to the nearest 0.2 ºC may be acceptable, the forecasting of temperature to within 2º twenty-four hours ahead may be acceptable (5º or more is deemed a major error), but what about seven days hence? How does the Seasonal Climate Outlook of a couple of months ahead compare?

Despite the vagaries of weather forecasting, associated resources can be a useful source of data, information and stimulation. The teacher has to be aware that meteorology could become a confusing distraction and thus a negative experience for the student. Meteorology involves non-deterministic problems, a large variety of units, and resorts to some non-intuitive solutions to problems. Furthermore, because meteorology defers to many other disciplines, the student of meteorology has to become well versed in a number of different nomenclatures. So, where possible, the teacher is advised to provide careful explanations, simple examples, and use technology to assist in demonstrating the atmospheric processes.

The weather forecasting process – curriculum connections

Firstly, looking over the flow of information with which the forecaster deals every operational shift, let us see what some of the forecasting processes are:

- Assimilation of observations and data;
- Analysis;
- Numerical Weather Prediction guidance comparison and assimilation;
- Applying meteorological knowledge skills and understanding;
- Application of forecast "conceptual models";
- Distillation of information;
- Decision-making;
- Synthesis - formulation of forecast policy;
- Preparation of forecast products;
- Preparation of warnings;
- Weather watch – monitoring observations and diagnostics;
- Amendment of forecasts and warnings;
- Forecast verification; and
- Research.

Note that observations flow dynamically into this scheme.

Forecasters prepare the following groupings of *Basic Products* (which are free to the community because of the perceived "for the public's good"): weather forecasts and weather warnings. These groups are categorised into forecasting regimes of: "Public and Marine" (aimed at the public at large and for ocean going craft and the fishing industry), "Aviation" (tailored for the Australian aviation industry to international standards) and "Severe Weather" (aimed at disaster mitigation).

Once these products have been prepared, they may be transmitted almost immediately to the client or they can be stored temporarily for scheduled transmission. Furthermore, the forecasts and warnings may be reconstituted into other ensembles of products automatically and disseminated to the public by such systems as text-to-speech telephone messages, faxes that can include graphics or, that which may be presented on the Bureau's web-page (HREF4). Basic products can also be manipulated to suit clients who wish to have "value-added" information: the service is tailored specifically for that client and an agreed charge is paid for the extra work involved in presenting the data to the client's specifications.

Routine forecast products are scheduled, but may require amendment at any time. Extra products such as warnings may have to be prepared at very short notice. The forecast verification enables experiential learning to consolidate experience and skill in the forecaster's mind and improve the forecast service. Research can improve forecasts and the service to the community, as well as the forecaster's own ability. Despite this long list of daunting tasks, weather forecasting, a rather specialised job, is one of the most satisfying jobs. Dr John Zillman (Director of Meteorology 1978 – 2003) said in his farewell article in the *Australian Meteorological and Oceanographic Society (AMOS) Bulletin* vol 16 on page 80, "Training completed, I was off to Sydney as Information Officer and to Brisbane as Duty Forecaster (the most enjoyable and satisfying years of my professional career!) …"

The skill of estimation, extrapolation, interpolation and assigning probabilities or likelihoods to events reinforces the theory, and serves as an excellent reality check. These days when technology becomes more and more like the proverbial "black box": the student really needs to develop a healthy interest in checking his or her answers against Nature. Meteorology has many non-intuitive aspects, which add to the intrigue. A good reference on the intrigues of the atmosphere is Craig Bohren's book, *Clouds in a Glass of Beer* (c1987). One example is the fact that moist air is actually less dense than dry air. A quick check of the average molecular weight of the two samples will confirm this for you. This fact is important in appreciating how cloud forms, how precipitation comes about and how convection works. The release of latent heat and the transport of energy about the atmosphere is one of the fundamental driving forces of atmospheric dynamics.

An interesting program on ABC Radio's *Science Show* recently described how face recognition demonstrates pattern recognition. (Refer to the ABC Radio link in the References.) The pattern involves recognising all-important "information" in the changes in detail, beyond the "mean" pattern. The weather forecaster has to analyse a chart by hand about once every three hours. This task is often an excellent opportunity for the forecaster to reflect on the current situation, and glean an enormous amount of information from each chart. The forecaster notes the changes in the many plots of observations. Each plotted observation may display many elements of weather. Similarly, the principle applies when interpreting satellite images or radar images. Data visualisation enables the forecaster to recognise the changes in detail (for example, looped images of Mean Sea Level Pressure (MSLP) charts can assist tracking system translation, the growth and decay. To study the structure of the disturbance in isolation, one moves the image's origin to the centre of a disturbance on each frame, and then the loop of images is reconstituted.

During the 1990s, the Bureau went from a text-based observations and numerical weather prediction display to a *graphics*-based system. The forecasters have the ability to animate the data for visualisation purposes. The Bureau is now investing in techniques to prepare forecasts for its clients in graphical format. As Yogi Berra said, "The future isn't what it used to be!"

Weather forecasting is a balance between the team effort and the individual's thinking processes and experience. On one hand, we encourage forecasters to make distinctions, think consistently, logically, and critically, yet on the other hand, the job is far too great for one individual. The virtue of the team effort is that forecasters share the workload, forecasters learn from each other's experience: collaboration is going to win the day in the end. The Bureau of Meteorology is charged with preparing and disseminating weather forecasts and warnings to the Australian community.

Some researchers attempt to estimate the monetary worth of weather forecasting. The non-pecuniary benefits to the community include the flow-on from disaster mitigation and improvement in the quality of life (through enjoyment of sport and recreation). Tailored weather forecasts serve different communities within Australia too. Thus, different client-oriented weather products tend to use different units. This fact of life is an opportunity for students to practise their skills of converting between units, and applying dimensional checks. Dimensional checks are another approach to seeing how “real” one’s solution is. It may be that too many units will not be instructive, and teachers may balk at this approach if the hurdle is too great for the student. Meteorology and weather forecasting are rich in units!

Scales of motion in the atmosphere

I first met the idea of scaling when studying physics in the late 1960s, in a diagram showing the relationship between thickness of an elephant’s leg (compared to that of a giraffe) and the loading on the “column”. The unifying rule is the greater the load on the “column”, the greater the cross-sectional area of the “column”. Load is proportional to r^2. (Hence, $\mathbf{\log_{10} (Load) = Constant + 2 \times \log_{10} (\mathit{r}).}$ To extend one’s repertoire of examples in scaling, I recommend Bak’s intriguing book, *How Nature Works: The Science of Self-Organized Criticality*, which explores (amongst other examples) the magnitude of earthquakes and their frequency. Earthquakes behave in a similar manner to the relationship between characteristic time and size scales of atmospheric motion.

In terms of magnitude of numbers and logarithms, when one considers the atmospheric phenomena in order of their size and their longevity on a diagram where the *x*-axis is $\log_{10}$ (Characteristic distance in metres) against the *y*-axis being $\log_{10}$ (Characteristic lifespan in seconds) the surprising result is depicted in Figure 1.

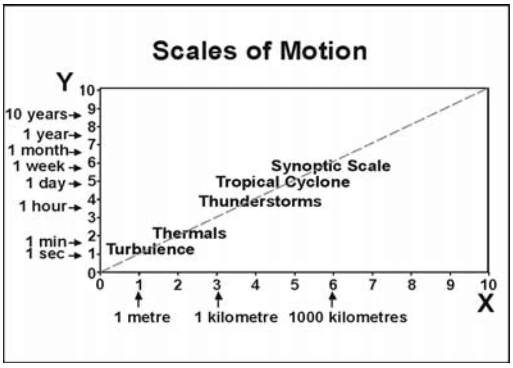

Figure 1 Scales of atmospheric motion

Various types of forecasts interact with their characteristic scales of motion. On the national scale, the National Meteorology and Oceanographic Centre takes hemispheric analyses and applies them to national forecasting guidance products such as the synoptic scale MSLP analysis map. The national guidance provides a setting for the various Regional Forecast Centres (located in capital cities): the Regional Office forecast policy is set in terms of the Public and Marine forecasts. From there, the Aviation Forecaster applies the office policy using his or her autonomy over individual aerodrome forecasts. The time-scales involved in Public and Marine forecasting tends to be from about 12 hours to 24 hours; Aviation forecasting time scales are of the order of 6 hours; in Severe Weather forecasting, the time-scales are about 1-2 hours. Looking at the scales of forecast from the Regional scale to the Aviation or Severe Weather scales, the forecaster has to apply an increasingly intense attention to detail. Aviation forecasters derive most satisfaction from their relative autonomy over their forecasting.

Why are scales of motion important in meteorology? If you were to shoot a missile between Melbourne and Hobart, say, you may notice some error in your aim. Firing a missile over some distance during a considerable time-lapse may be of sufficiently large enough scale to cause the projectile to land somewhere off the line of action. Compare this action to throwing a basketball from one end of the court to the other: we expect no perceptible error, because the scale of motion is so much smaller than the missile example. Similarly, large-scale phenomena such as High Pressure systems (Highs) and Low Pressure systems (Lows) persist longer than short-lived, small-scale phenomena such as thunderstorms, or a willy-willy. Scales of motion assist the student to make appropriate simplification of the physical processes.

A popular misconception about the Coriolis Force demonstrates one favourite application of such interpretation of scales. The Coriolis Force is a force that acts on a body, causing it to tend to accelerate towards the left of its motion in the Southern Hemisphere, and is due to the earth’s rotating frame of reference.

The web-based Coriolis Wind applet at Weather Wise shows how this force works and demonstrates its relationship to the Geostrophic Wind, a conceptual model of balanced flow (discussed below). A scale-appropriate use of the Coriolis Force explains rotations of Highs and Lows. Water running down the plughole, tornadoes, dust devils and willy-willies are too small for the relatively large-scale Coriolis Force to be evident. Although the Coriolis Force is at work in these examples, it is not evident because the other forces at play are far, far greater in magnitude (relative scale).

When forecasts are verified, it is found that for the Public weather and Marine Forecasts, which tend to extend out to of the order of twenty-four hours or more, the statistics wash out evidence of the smaller events, which are often not so important in day-to-day affairs. In the realms of Aviation Forecasting and Severe Weather Forecasting, critical events can last from minutes to hours, say, and are relatively small in scale. These events, such as individual thunderstorms, can have devastating effects on select (unfortunate) portions of the populus. The effects of a thunderstorm on aircraft in flight or worse still, attempting to take off or land, could be fatal. So, the forecast verification has to be tuned to this scale of operation.

Numerical weather prediction guidance does not pick up such small-scale events either, because the time-response for a numerical weather prediction model to react is often too long, and because of the inadequate spatial distribution of data, which the model assimilates. Furthermore, the numerical weather prediction model grid resolution is generally is far too coarse to capture such events.

Conceptual models

Conceptual models assist in the understanding of an isolated aspect of a physical process in the atmosphere without regard to the *continuity* of the fluid. In the atmosphere "everything is connected to everything else". When employing a conceptual model, the weather forecaster makes no pretence of portraying the real atmosphere: the idea of the model is to assist the student to appreciate and understand one process at a time. Boundaries are put around the realism and technical veracity of the model. Some examples will demonstrate this.

Conceptual-model Example 1 Parcel of air

It is useful to construct an idealistic "parcel of air" which is small enough so that the weather elements such as temperature, pressure and moisture content do not vary (significantly) throughout the parcel. We can imagine the cylindrical parcel's axis is vertical. Such a "parcel" is similar to a plastic bag. When the parcel ascends, it expands and cools, and the parcel tends to stretch length-ways along its axis. When it descends, it tends to compress, warm and squash into a "fatter, squatter" parcel in the vertical. This conceptual parcel helps us understand qualitatively such processes as convection, vorticity, advection of meteorological properties with the wind, and helps explain what happens when air moves up against and passes over mountains. When the wind blows, certain thermodynamic properties of the air remain constant. For example, potential temperature is just one such conservative element. If a parcel descends from a height to 1000 hPa level - in the vicinity of the surface - without any condensation of water vapour and without any input or output of energy, the parcel undergoes compression and tends to warm. The temperature that the parcel assumes at 1000 hPa is called the parcel's potential temperature, (θ). The parcel is useful in visualising these ideas. The leap in faith comes when we move from the behaviour of a parcel of air to a large complex atmospheric system. Strangely, certain correspondences do hold quite well (such as vorticity) but are beyond the scope of this article.

Conceptual-model Example 2: Balanced flow - the Geostrophic Wind model

For example, $\mathbf{V}_g$, the Geostrophic Wind is an extremely simple model, which provides an astounding insight into the way in which the surface pressure pattern is related to wind speed and direction. The Geostrophic Wind is a horizontal wind where the horizontal Pressure Gradient Force, **P**, is equal in magnitude but opposite to the Coriolis Force, **C**, (that is $P = C$). (N.B. Here **C** is the approximation for the Coriolis Force's horizontal component when applied to the horizontal wind: refer to Figure 2.)

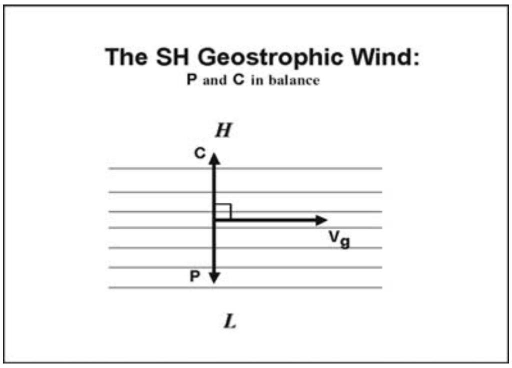

Figure 2 The Coriolis Force and the Geostrophic Wind

Note that the horizontal pressure gradient is the change in atmospheric pressure over a horizontal distance. The vertical pressure gradient is the change in atmospheric pressure over a vertical distance (in the **k** direction, where **i, j**, **k** are 3-D vectors — we take **k** as the unit vector in the vertical direction, and **i** and **j** unit vectors can be thought as the east and north directions respectively). The Geostrophic Wind, $\mathbf{V}_g$, is a wind vector, a different "entity" from **P** and **C**. We ignore friction, setting the frictional force as a zero vector $\mathbf{F} = \mathbf{0}$.

Due to the Earth's rotation, C is a constant multiple of V, written as $C = fV$ where f, the Coriolis Parameter is given by $f = 2 \times \Omega \sin(\Phi)$, and where Φ is latitude.

In the Southern Hemisphere $\Phi < 0$ (by convention) and Ω, the rate of rotation of the Earth, is taken as a constant, and has the value $\frac{2\pi}{24\times60\times60}$ radians per second or, $\Omega = 7.292 \times 10^{-5}$ rad s^{-1}. At 43º South, $f \approx -10^{-4}$s^{-1}. What does f equal when $\Phi = 0$º (at Equator) or, when $\Phi = -90$º (South Pole)?

C always acts perpendicular to the **Left** of **V** in the Southern Hemisphere (plan view).

Clearly, $C = 0$ if either $V = 0$ or $\Phi = 0$

These ideas can be neatly summarised using the notion of vector cross-product where
$\mathbf{C} = -f\,\mathbf{k} \times \mathbf{V}$

Summary of Geostrophic Flow:

- Friction is ignored: $\mathbf{F} = \mathbf{0}$
- Flow is parallel to straight parallel isobars
- **C** balances **P**
- In the Southern Hemisphere, the low-pressure systems are always to the right of $\mathbf{V}_g$
- $V_g = \frac{1}{\upsilon f}\frac{\delta p}{\delta n} V_g$ where $\frac{\delta p}{\delta n}$ represents the change in pressure (p) across the horizontal distance (ideally) normal to the isobars and, where $\rho \approx 1.2$ kg m^{-3} near the surface
- $V_g \propto \frac{1}{\text{isobar spacing}}$

The smaller the isobar spacing, the larger the Geostrophic Wind. The Geostrophic Wind equation is diagnostic, that is, it is not predictive. The use of the Geostrophic Wind relationship is not appropriate in the following situations:

- for small-scale motions, where **C** will be negligible (for example flow out of bathtubs);
- within the boundary layer as **F** can be significant;
- for highly curved flow where we resort to the Gradient Wind Equation; or
- in the tropics, **C** is negligible as f is small and the pressure gradient is "slack" - hence "cross-isobar flow" is more common in the tropics where local effects dominate the wind patterns.

How is the Geostrophic Wind, associated with weather? Deviations of actual winds (observed winds) from the theoretical Geostrophic Wind are associated with vertical motion and accelerations. $\mathbf{V}_{ag}$ is the *ageostrophic* wind: that is, the wind component that is not geostrophic. The web-based Weather Wise applet (below) shows how to calculate the Geostrophic Winds across the globe.

Conceptual-model Example 3: Balanced flow — The Gradient Wind model

The Gradient Wind model is an extension of the Geostrophic Wind approximation. It includes the effect of a trajectory's curvature in balance with the horizontal Pressure Gradient Force and the Coriolis Force. It excludes Friction, so that $\mathbf{F} = \mathbf{0}$. The Gradient Wind, $\mathbf{V}_{gr}$, is a horizontal wind that more closely approximates the observed Gradient Level Winds (generally measured at approximately 3,000 feet above sea level — intended to be above the boundary layer).

The Gradient Wind, $\mathbf{V}_{gr}$, is such that **P**, **C** and $\mathbf{C}_e$ are all in balance in the horizontal plane. $\mathbf{C}_e$ the centrifugal force, which is due to the curvature of the trajectory of the air parcel in the horizontal plane, depends on the *radius of curvature*, R, and the *speed of the parcel* around the curve, V:

$C_e = \frac{V^2}{|R|}$ where $R > 0$ for anticyclonic flow and $R < 0$ for cyclonic flow (another universal convention). Here, $\mathbf{V}_{gr}$, the Gradient Wind is a velocity vector, while **P**, **C** and $\mathbf{C}_e$ are force vectors. **C** depends on $\mathbf{V}_{gr}$, and $\mathbf{C}_e$ depends on V_{gr}.

Figures 3 and 4 show the vector balance for southern hemisphere high (H) and low (L) pressure systems. The Gradient Wind equation is:

$$V_{gr} = \frac{-f \pm \sqrt{f^2 - \frac{4}{R}.\frac{1}{\rho}.\frac{\partial p_h}{\partial n}}}{\left(\frac{2}{R}\right)}$$

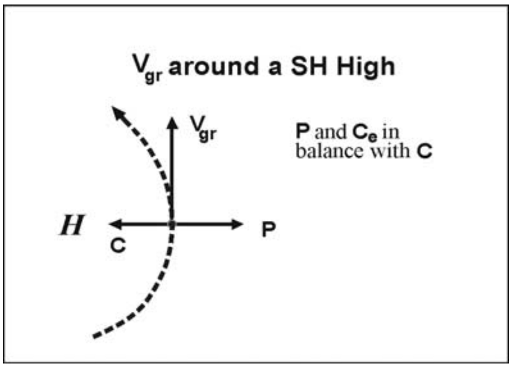

Figure 3 The gradient wind around a southern hemisphere high pressure system

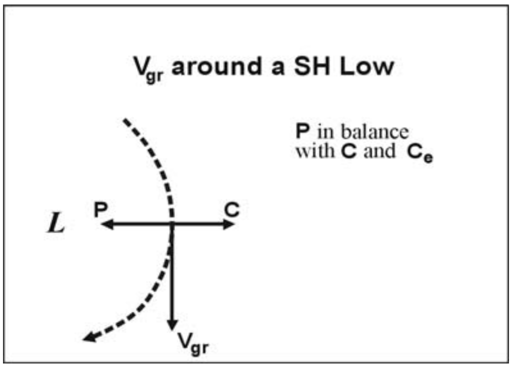

Figure 4 The gradient wind around a southern hemisphere low pressure system

Implications of the Gradient Wind Equation:

- There is a limit to the anticyclonic pressure gradient;
- There is a limit to the radius of curvature for a High; and
- There is no such limit to the radius of curvature for a Low.

In the southern hemisphere plan view, flow around a high-pressure system is anticyclonic, and flows anticlockwise: around a low-pressure system, flow is cyclonic and flows clockwise.

Questions:

1. Having investigated the Geostrophic Wind model, which is greater, the vertical pressure gradient or the horizontal pressure gradient? Another surprise!

2. The contention is, in comparison to the Geostrophic Wind, "The Gradient Wind is slow around a Low, but it flies around a High". Is this true? One would not expect the outcome, I strongly suspect.

The Gradient Wind model boils down to solving a quadratic equation (well within the grasp of Secondary students). Participants of weather workshops have, without formal training in meteorology, successfully applied the Geostrophic Wind and the Gradient Wind models to actual plotted synoptic charts. If one were to assume that 1° of latitude is worth approximately 111 km across the ground (along a line of longitude) on a MSLP analysis chart using a Lambert Conformal projection, this is sufficiently accurate for the above exercises. Use a map downloaded from the Bureau's website to demonstrate the Geostrophic and Gradient Wind models. The source of greatest error is generally from estimating the radius of curvature (*R*), of the isobars.

Transformations

When changing from one frame of reference to another, such as from one coordinate system in a "fixed" frame of reference to another accelerating frame of reference, with the appropriate transformations, Newton's Laws of Motion still prevail: so-called "apparent" forces can easily be reconciled.

In the Conceptual Models section, we discussed in effect the transformations needed when changing our frame of reference to another (accelerating) frame of reference. Newton's Laws allow the two frames of reference to be easily reconciled through a transformation. The Centrifugal and the Coriolis Forces are manifestations of such change of frame of reference. In the above simplified examples, the calculations are reduced to algebra well within the grasp of the secondary school student.

In meteorology, changing from the coordinate system anchored on the ground (such as a surface observing site) to looking at the world from the point of view of the flow of air, the mathematical transformation, which reconciles different frames of reference, is called "advection". Advection has a physical interpretation that can be useful in forecasting. Firstly, imagine leaning over a bridge that straddles a bubbling brook. You notice a leaf is hurrying down the stream like a small white-water raft, following the flow between stones, boulders, and the banks. If you picture yourself sitting on that leaf, how would the world appear? The origin fixed to the surface of the earth sees the world in a Eulerian manner, with the flow streaming past him or her. Following the flow with the origin fixed to the leaf, one sees the world from a Langrangian point of view. The link between the two points of view, the advection term, represents the flow that the fixed station experiences: the flow transports atmospheric properties such as temperature, moisture content, instability, etc., to that station. The use of advection or transport ideas is a basic approach to anticipating changes at that station in the future.

One further note on the Eulerian point of view: if the horizontal distance does not exceed about 60 km, the “flat-earth” theory holds well for all practical purposes. (Fortunately, we generally do not need resort to spherical coordinates for tackling problems close to our Eulerian origin!)

Transformation Example 1

Most of the public are generally aware how the MSLP analysis map that they see in their newspaper or on television relates to weather. Many people are not aware that the weather forecasting effort depends not only on these “surface charts” (where z = 0) but also upon so-called “upper air charts” which depict observed winds, temperatures and moisture content. These “upper air charts” belong to the *troposphere,* the region between the *tropopause* (at an altitude of ~ 12 km) and the surface. The *troposphere* is where most of the weather occurs. Numerical weather prediction depends on data from various standard pressure levels within the troposphere. We note that atmospheric pressure decreases with height. The upper charts are often analysed in “heights”, technically known as geopotential heights. For the sake of this exercise, we can take a geopotential metre as being essentially equivalent to the SI metre. On the constant pressure surface Highs and Lows, ridges and troughs, behave just as they do on a MSLP pattern. This is the correct interpretation: but this is not intuitive. Lines joining points of equal height on a constant pressure surface (p = constant) are isohypes, and are analogous to the topographic contours we encounter when enjoying an orienteering exercise over and about hilly terrain. This strong analogy is commonly employed in interpreting the MSLP map (z = 0) and the constant pressure level map (p = constant). The most frequently used standard pressure levels used for the constant pressure charts with their typical heights above seal level are:

- 850 hPa (~ 5,000 feet)
- 700 hPa (~ 10,000 feet)
- 600 hPa (~ 15,000 feet - transport aircraft flights)
- 500 hPa (~18,500 feet - notionally halfway up the troposphere)
- 300 hPa (~ 30,000 feet - interstate aircraft flights - polar front jet stream)
- 250 hPa (~ 35,000 feet - jet streams, polar front and the subtropical jet and international aircraft flights)
- 200 hPa (~ 40,000 feet - subtropical jet stream and international aircraft flights)

The International Civil Aviation Organization (ICAO) Standard Atmosphere gives a rough conversion between pressure levels and height in feet. Note that the Aviation Industry worldwide insists on using feet or hundreds of feet for height. Figure 5 shows the transformation from (x, y, z) coordinates to (x, y, p) coordinates graphically.

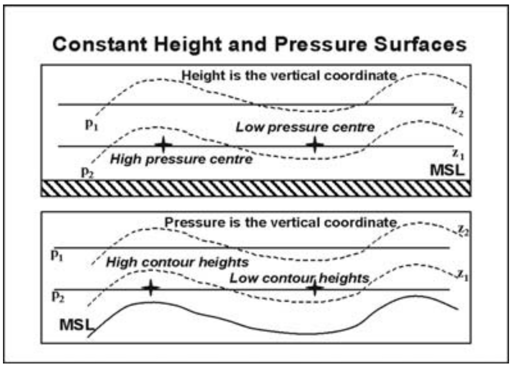

Figure 5 Constant height and constant pressure levels

Transformation Example 2

The aerological diagram, (Skew T – Log P diagram) is craftily designed so that atmospheric thermodynamic processes can be analysed. Typically, we estimate thermodynamic stability by using the temperature and dew point temperature (a measure of moisture content) traces that are derived from a *sonde flight*: a balloon is released with instruments and the on-board transmitter sends back readings at various pressure levels. The aerological diagram has pressure lines, temperature lines and mixing ratio lines (a measure of moisture content). The way these lines are oriented allows the forecaster to compare the observed environment with theoretical lapse rate lines (lines where air parcels have the same potential temperature, θ or θ_{moist}). Areas bounded by the temperature trace and the parcel trajectory, are proportional to the amount of available potential energy. This idea of representing thermodynamic diagrams in this manner was pioneered by J Willard Gibbs, an American thermodynamicist and mathematician.

Using the aerological diagram, one can convert dew point temperature to relative humidity at constant pressure. Access to other representations of aerological or thermodynamic diagrams is via the American Meteorological Society Glossary. The aerological diagram is central to understanding the structure and severity of thunderstorms and other convection.

The International Civil Aviation Organization (ICAO) provides the international benchmark used for analysing the thermodynamic state of the troposphere. Aircraft set their altimeter reference reading using the ICAO equivalent for the Mean Sea Level Pressure, to ensure aircraft fly on separate pressure levels, and ICAO pressure readings at airports assist pilots landing safely. Using the ICAO Standard Atmosphere, one can approximate the pressure and temperature to the height of the *tropopause*. The ICAO atmosphere is based on the International Standard Atmosphere (ISA), (see the below).

This article provides a glimpse of meteorological ideas and resources that could be employed in teaching and learning in the secondary school. Meteorology links not only ideas and resources to mathematics, computing, geography and science especially it assists in integrating ideas and resources across the curricula. With this in mind, AMOS is preparing teaching and learning resources based on meteorology and weather forecasting, (HREF5).

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When does the global warming signal come to dominate interannual temperature variability?

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1. Introduction

For some years, the National Climate Centre has been calculating time series of Australian area-averaged monthly, seasonal and annual rainfall and temperatures.

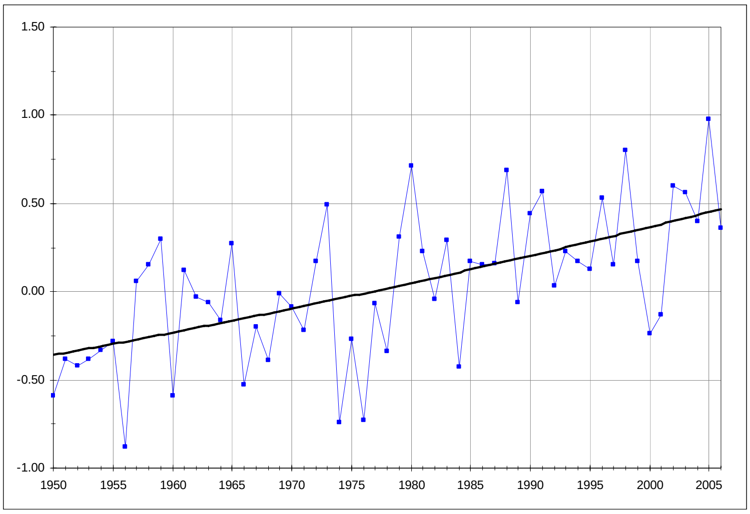

Figure 1: Time series of Australian-averaged annual mean temperature anomalies (1950 – 2006), in °C. The anomalies are calculated relative to the 1961-1990 period. The linear trend line is also shown.

These have been published in the monthly *Climate Monitoring Bulletin – Australia* and more recently on the Bureau of Meteorology's web-site (www.bom.gov.au/silo/products/cli_chg/) along with the underlying time series and updated each month. State and Territorial averages are also available. Figure 1 shows one of those time series, Australian-averaged annual mean temperature anomalies (1950 – 2006), along with the linear trend line. The linear trend line is calculated in the usual way (ordinary least squares linear regression). The anomalies are calculated with respect to the 1961-1990 period. Here, mean temperature (Tmean) is the average of maximum (Tmax) and minimum (Tmin) temperature. While the linear trend line forms a good fit to the data – the quadratic trend line (not shown) is only very slightly different over this period – there remains a considerable fraction of the total variability represented in the residuals. This leads us to ask the following questions:

- How much of the variance in the time series is due to the linear trend and how much due to the residuals, and
- If the fraction of the variance due to the linear trend is less than that due to the residuals, how far into the future does the linear trend have to be extrapolated before the linear trend becomes the dominant effect?

We are interested in these questions for this time series in particular, but also more generally for time series of this type. This article seeks to investigate these questions in the Australian context.

Our motivation is partly ecological: in the presence of a stable climate, it seems reasonable to expect that ecosystems adapt in one way or another to the typical range of interannual climatic variability. (It is also likely that agricultural practices would adapt to this range, in order to be profitable.) In the face of a changing climate, many factors influence the extent to which ecosystems and their components adapt or fail to adapt to the new circumstances, but local extinction of species under such circumstances is far from unknown. It is of course the local-level temperature changes which are ecologically relevant, rather than the regional-level (national/state/territory) changes which are the focus of the present work.

2. National time series

For the purposes of this investigation, we have used the annual and seasonal time series of Australian-averaged maximum, minimum and mean temperatures prepared by the Bureau of Meteorology's National Climate Centre. These time series are based on gridded analyses (Jones and Trewin, 2000) of monthly temperature anomalies, using a network of around 100 high-quality stations[1] around the country (Trewin, 2001). The annual and seasonal values are obtained by aggregation of the monthly data. These time series cover the period 1950 – 2006 (1950/51 – 2006/07 in the case of the summer time series). Each comprises 57 elements, and uses all the available data at the time of writing. The anomalies are calculated with respect to the base period 1961 – 1990, but the choice of base period has little impact on these calculations[2].

For each time series, a linear trend line has been calculated, along with the residuals from that trend line. The variances of the original time series, the linear trend time series and the time series of residuals are all calculated, the variance of the first of these equalling the sum of the variances of the second and third. The fraction of the total variance due to the linear trend is given in Table 1, along with the trend in degrees Celsius per decade.

The linear trend is extrapolated unchanged into the future, together with the assumption that the variance of the residuals remains unchanged. The year at which the variance of the linear trend exceeds the variance of the residuals is also given in the table, provided that year precedes 2100. For each of the five analysis periods represented in Table 1, the linear trend in the mean temperature (Tmean) is not surprisingly close to the average of the linear trends in the maximum and minimum temperatures.

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[1] See www.bom.gov.au/silo/products/cli_chg/temp_trendmaps.shtml for a map of this network, and also the network for the longer annual temperature time series to which we subsequently refer.

[2] The choice of base period has a slight (as opposed to no) impact, because the data are available only to a finite (and limited) precision. Rounding and truncation therefore play a small part, one which has been ignored here.

Table 1: Linear trends in degrees Celsius per decade for annual and seasonal maximum, minimum and mean temperature averaged across Australia, along with the fraction of the variance of the time series which is due to the linear trend. The time series comprise data for 1950 – 2006 (1950/01 – 2006/07 for the summer time series). Years of exceedance are given for the points at which the variances of the extrapolated linear trend time series exceed the variances of the residuals.

Period	Variable	Linear trend (°C/decade)	Fraction of variance due to the linear trend	Year of Exceedance
Annual	Tmax	0.15	0.26	2047
	Tmin	0.14	0.32	2034
	Tmean	0.15	0.36	2026
Autumn	Tmax	0.13	0.09	> 2100
	Tmin	0.11	0.08	> 2100
	Tmean	0.12	0.12	> 2100
Winter	Tmax	0.20	0.26	2045
	Tmin	0.09	0.05	> 2100
	Tmean	0.15	0.22	2058
Spring	Tmax	0.19	0.15	2085
	Tmin	0.21	0.35	2027
	Tmean	0.20	0.26	2046
Summer	Tmax	0.08	0.05	> 2100
	Tmin	0.17	0.35	2027
	Tmean	0.13	0.18	2071

In all fifteen time series, the fraction of the total variance explained by the linear trend is less than 0.5, and in some cases much less. In consequence, if current trends persist it will be quite some time before the linear trend dominates the interannual variability. The results shown in Table 1 show some slight dependence on the end year (2006). Ending the time series at 2005, Australia's warmest year on record at the time of writing, as compared against ending them at 2004 typically served to increase the linear trend and fraction of variance explained by it, and consequently to decrease slightly the year of exceedance, while the further addition of the 2006 data, a cooler year, generally tended to reverse these effects slightly. An exception to this general pattern came with the Spring results. Spring 2006 saw widespread record warmth across southern Australia, particularly with regard to maximum temperature (Tmax) and mean temperature (Tmean). The effects of the addition of Spring 2006 data were therefore similar to the effects of the addition of the 2005 data more generally.

While the monthly time series used to generate the results given in Table 1 are only available from 1950 to the present, annual time series for the three temperature variables are available from 1910 to the present (Della-Marta *et al.*, 2004). Analogous calculations for the longer time series have been performed, with the results given in Table 2.

Table 2: Linear trends in degrees Celsius per decade for annual maximum, minimum and mean temperature averaged across Australia, along with the fraction of the variance of the time series which is due to the linear trend. The time series comprise data for 1910 – 2006. Years of exceedance are given for the points at which the variances of the extrapolated linear trend time series exceed the variances of the residuals. The fraction of the variance due to the quadratic trend line is given in italics.

Variable	Linear trend (°C/decade)	Fraction of variance due to the linear (*quadratic*) trend	Year of Exceedance
Tmax	0.07	0.17 (*0.24*)	> 2100
Tmin	0.12	0.44 (*0.49*)	2019
Tmean	0.09	0.36 (*0.44*)	2038

Table 3: Fraction of the total variance explained by the linear and quadratic trends for the global, northern hemisphere and southern hemisphere annual mean temperature (HadCRUT3) time series.

		Global	Northern Hemisphere	Southern Hemisphere
1910-2006	Linear Trend	0.70	0.60	0.72
	Quadratic Trend	0.72	0.61	0.74
1950-2006	Linear Trend	0.73	0.58	0.79
	Quadratic Trend	0.80	0.76	0.80

This sort of calculation can of course be replicated at the global level, on for example the global annual mean temperature series (HadCRUT3 time series, as of July 2007) compiled by the University of East Anglia's Climatic Research Unit (www.cru.uea.ac.uk/cru/data/temperature/). This time series is available from 1850 to the present, but for purposes of comparison with the Australian data, only data from 1910 to the present is used here. Using the 1950 – 2006 data, the linear trend accounts for 73% of the variance, while the quadratic trend (with a minimum in the mid 1950s) accounts for an astonishing 80% of the variance. Over the longer period 1910 – 2006, the corresponding fractions are 70% (linear) and 72% (quadratic), although it appears that a cubic trend line fits the data rather better than either the linear or the quadratic. The dominance of the trend (however computed) over the interannual variability is stark. These results, along with the corresponding results for the northern and southern hemisphere annual mean temperature time series, are shown in Table 3. While the fractions of the variance explained by the trends for the northern hemisphere are less than those for the whole globe, those for the southern hemisphere are slightly larger than those for the whole globe. This implies that the interannual variability is somewhat stronger in the northern hemisphere than in the southern hemisphere.

In each of the three national annual time series (Tmax, Tmin, Tmean), as in the corresponding global and hemispheric annual time series (Tmean), it is clear that the trends in the second half of the twentieth century are quite different from those in the first half. Accordingly, the fraction of the variance due to the quadratic trend line has also been included in Table 2. The quadratic trend line is computed in the usual way using ordinary least squares regression techniques, but we have chosen not to extrapolate it beyond the range of the data. In each case, the quadratic trend line tends downward at the start of the period with its minimum occurring in the first half of the twentieth century.

For minimum temperature, the fraction of variance due to the linear trend is larger over the longer period (Table 2) than it is over the shorter period (Table 1), but for mean temperature they are about the same. For minimum temperature, the quadratic trend line explains 49% (linear, 44%) of the total variation, indicating that interannual variability might no longer be the dominant effect for much longer.

3. Regional time series

It is not unreasonable to expect that the global warming signal generally should be more apparent within time series that result from averaging over larger spatial regions and longer time periods, than those computed over smaller spatial regions and shorter time periods, simply because of increased averaging of weather noise. (There may of course be striking departures from this idea at individual locations.) Within the Australian context, this has been investigated by looking at regional annual averages (this section) and the underlying gridded analyses (the following section).

Annual time series for each State/Territory, analogous to those used to construct Table 1, have been investigated. As before, these cover the 57-year period 1950 – 2006. The results of the calculations for these regional time series are presented in Table 4.

Table 4: Linear trends in degrees Celsius per decade for annual maximum, minimum and mean temperature averaged across each State/Territory, along with the fraction of the variance of the time series which is due to the linear trend. The time series comprise data for 1950 – 2006. Years of exceedance are given for when the variances of the extrapolated linear trend time series exceed the variances of the residuals.

Region	Variable	Linear trend (°C/decade)	Fraction of variance due to the linear trend	Year of Exceedance
Queensland	Tmax	0.22	0.37	2025
	Tmin	0.23	0.40	2020
	Tmean	0.23	0.49	2008
New South Wales	Tmax	0.20	0.24	2052
	Tmin	0.12	0.19	2068
	Tmean	0.16	0.32	2032
Victoria	Tmax	0.15	0.21	2059
	Tmin	0.04	0.03	> 2100
	Tmean	0.10	0.19	2069
Tasmania	Tmax	0.17	0.33	2032
	Tmin	0.09	0.18	2071
	Tmean	0.13	0.31	2036
South Australia	Tmax	0.21	0.30	2036
	Tmin	0.19	0.40	2019
	Tmean	0.20	0.44	2014
Western Australia	Tmax	0.08	0.07	> 2100
	Tmin	0.11	0.19	2066
	Tmean	0.09	0.14	2090
Northern Territory	Tmax	0.12	0.10	> 2100
	Tmin	0.10	0.07	> 2100
	Tmean	0.11	0.10	> 2100

Three regions (Western Australia, the Northern Territory, Victoria) have linear trends less than or equal to the national trend for all three temperature variables, while two (South Australia, Queensland) have linear trends greater than the national trend for all three variables. The largest fraction of the total variance due to the linear trend occurs in the Queensland annual mean temperature time series, where the linear trend explains 49% of the total variance. Under the previous assumption of no change in the trend and variance of the residuals, the warming signal is projected to become the dominant effect in just a few years.

4. Gridded analyses

The gridded analyses (Jones and Trewin, 2000) used to generate the time series above can themselves be subjected to the type of analyses described here[3]. Annual anomaly grids have been prepared from the underlying monthly anomaly grids for each of maximum, minimum and mean temperature. As before, the base period for calculation of the anomalies is 1961 – 1990, but that has little effect on the results described below. Fractions of the total variance explained by the linear trend are shown in Figure 2 (Tmax), 3 (Tmin) and 4 (Tmean). The period represented is 1950-2006.

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[3] The calculation of the fraction of variance explained necessarily involves the calculation of grid point trends (not shown). These differ to some extent from the trend maps available at www.bom.gov.au/cgi-bin/silo/reg/cli_chg/trendmaps.cgi, because of a difference in methodology (analyses of station trends *versus* trends in station analyses).

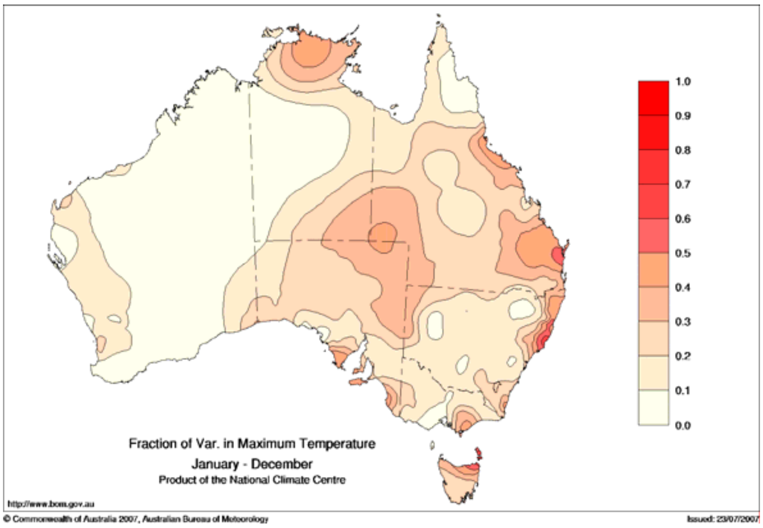

Figure 2: Fraction of the total variance explained by the linear trend in annual maximum temperature anomalies (1950 – 2006).

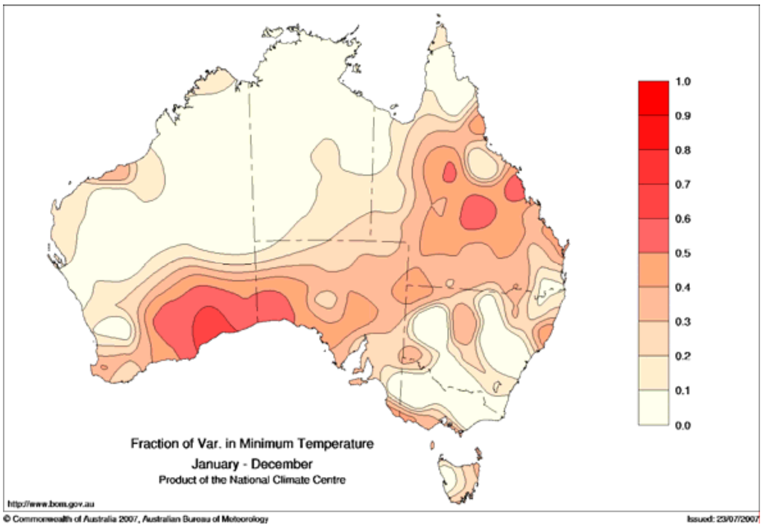

Figure 3: Fraction of the total variance explained by the linear trend in annual minimum temperature anomalies (1950 – 2006).

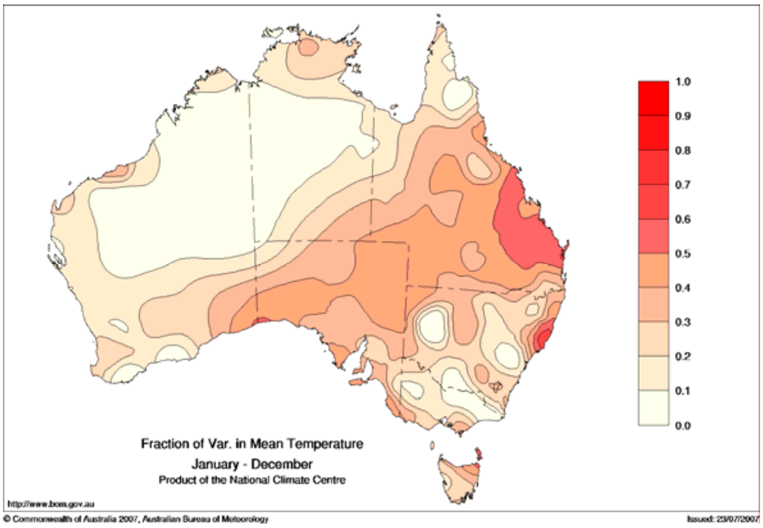

Figure 4: Fraction of the total variance explained by the linear trend in annual mean temperature anomalies (1950 – 2006).

Consistent with the results presented in Table 4, there is considerable regional variation in the extent to which the interannual variation in annual maximum temperature anomalies can be explained by the linear trend (Figure 2). The warming signal is fairly weak in the western half of the country, and indeed there are a few places in southern and north-eastern WA where the trend (not shown) is weakly negative. There are just a few small regions in northeast Tasmania and on the east coast of the continent where the mapped fraction of the variance exceeds 0.5.

The signal in annual minimum temperature (Figure 3) is stronger, particularly in a band stretching from southern Western Australia across South Australia and up into central Queensland. This fairly closely corresponds to the region of greatest linear trend (not shown). The fraction of variance explained by the linear trend exceeds 0.5 in a sizeable area of southeast WA. The signal in annual mean temperature (Figure 4) is fairly similar to that of annual minimum temperature, both being considerably stronger than that of annual maximum temperature.

5. Conclusions

In the Australian time series investigated, the fraction of the overall variance explained by the warming trend, as represented by linear or quadratic trend lines, is significant, even if it has not yet come to dominate the residual interannual variability. That outcome appears to be some way off. At the global level however, as indicated by the University of East Anglia CRU annual mean temperature (HadCRUT3) time series, the warming trend dominates the interannual variability to a very great extent. It seems plausible to expect that as the area over which an annual temperature time series is calculated increases, so too will the dominance of the warming trend, as a general rule. At the local level however, there may be exceptions to this general pattern.

The addition of 2005, as a very warm year, to the time series not surprisingly tended to increase the trends and fractions of variance explained by the trends, with consequent reductions in the years of exceedance. A similar effect was seen on a much lesser scale for those parts of the country (mostly the south) which experienced warm conditions in 2006. If the next few years are not as warm, then the trends will most likely decrease slightly, with the expected effects in the other two statistics.

6. References

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Jones, D.A. and Trewin, B.C. 2000. *The spatial structure of monthly temperature anomalies over Australia*. Australian Meteorological Magazine, **49**, 261-276.

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Significant weather

July 2007

Summary

A strong cold front swept through the south of the continent affecting Western Australia and South Australia, causing strong winds and damage. Light snowfalls were recorded in NSW at the start of the month and again during the middle of the month. Persistent fog in Tasmania caused significant disruption to aviation.

Bushfires occurred in the northwest Top End (NT) during the middle of the month.

Thunderstorms/tornadoes

Victoria

On the 17th a cold front hit Melbourne around the morning peak hour. The SES took 150 storm damage calls across the state, mostly in metropolitan Melbourne. Emerald, Hastings and Sorrento were the worst-affected, mostly for fallen trees.

South Australia

A tornado was reported at Poona, near Coulta, on the Lower Eyre Peninsula on the 4th.

Western Australia

A strong cold front swept through the Southwest Land Division on the 1st followed by secondary development on the 2nd. A low then formed to the south of the state during the 3rd and moved towards South Australia on the 4th. Several severe wind gusts were recorded with Cape Leeuwin recording near storm force mean winds. Tree damage occurred in Kings Park with some moderate property damage in South Perth. A tornado was reported in the NW of the Gnowangerup Shire on the 1st whilst Brunswick Junction reported golf-ball sized hail on the morning of the 2nd.

A cold front moved through the Lower Southwest during the evening of the 23rd. A suspected tornado caused a narrow swathe of damage about 50 metres wide by 2.5 kilometres in length, through Rockingham/Waikiki, south of Perth. About 70 houses sustained damage along this path, with winds ranging from 118-150 km/h. A tornado caused a swathe of damage 10 kilometres south of Meckering.

Wind

Tasmania

A gust of 137 km/h occurred at Hogan Island on the 3rd.

South Australia

Strong to near gale force winds on the evening of the 3rd/4th removed roof tiles and iron sheeting from houses. Numerous trees were blown over or limbs were torn off. Wind gusts were in excess of 90 km/h. Tornadoes were responsible for damage reported from near Millicent and Murray Bridge. The winds caused a rise in sea level of more than a metre which resulted in flooding and damage along the coasts of the Spencer and St. Vincent Gulfs.

Snow

Queensland

A snow flurry, light hail and sleet were reported from the Stanthorpe area on the 8th.

New South Wales

Light snowfalls were recorded on the higher parts of the Central and Northern Tablelands on the 5th and 6th, with 1cm on the ground in Oberon.

Further snowfalls on the Central Tablelands were observed on the 17th. The heaviest falls were in the Black Springs area with 10cm on the ground. Several centimetres of snow was also recorded at Millthorpe and Orange.

Victoria

On the 17th snow was reported in many areas of the state. Ballarat had snow in the main street. Roads were closed in Ballan, Daylesford, Trentham, Woodend and Mt Macedon for several hours due to snow and ice. The Victorian ski fields had their best start to the ski season in several years.

Fog

Tasmania

Persistent fog in Hobart caused significant disruption to commercial aviation with delays, cancellations and diversions on the 4th and the morning of the 5th.

Bushfires

Queensland

On the 5th a large grass fire at the Gap in Brisbane's west threatened houses but was contained before any property loss occurred.

Northern Territory

Three significant fire weather events occurred in the northwest Top End, commencing on the 19th, in the Acacia Hills, Batchelor and Rum Jungle areas. Some caravans and demountable buildings were lost in the first two of these.

A large fire near Tennant Creek in late July burnt approximately 270 square kilometres. There was no significant property loss.

August 2007

Summary

A complex low pressure system towards the end of the month brought strong to gale force winds to the southeast coast and Wide Bay districts of Queensland, resulting in record rainfall totals.

Thunderstorms were reported in Queensland and New South Wales, and windy conditions in most states. Flooding in Tasmania caused significant disruption and damage.

East coast low

Queensland

A complex low pressure system located east of Fraser Island and a large high east of Tasmania between the 21st and 25th brought strong to gale force winds which caused extensive power outages, dangerous surf and torrential rainfall in the Southeast Coast and Wide Bay districts. A 35-metre yacht was torn from its anchor and forced aground at Rainbow Beach on the 23rd. Some very high daily rainfalls concentrated over the Noosa, Maroochy and upper Mary catchments resulted in flash flooding at Tewantin and Noosaville on the 24th. Rainbow Beach set an Australian daily August record for a standard site with 529mm, with even higher totals (772mm at Coops Corner and 689mm at Mt Bilewiliam) from pluviographs.

There were also thunderstorms during the event, with power lines down, roads closed from debris, and damaged crops at Tiaro on the 24th.

Wind

New South Wales

Thredbo recorded gusts of 137 km/h on the 31st, and 131 km/h on the 10th and 30th.

Victoria

Wind gusts exceeded 100 km/h at numerous locations on the 9th, 10th and 31st, with particularly notable values at Mount William (137 km/h on the 10th), Wilsons Promontory (131 km/h on the 31st) and Aireys Inlet (128 km/h on the 31st).

Tasmania

Wind gusts exceeded 100 km/h on several occasions during the month, with notable readings at Hogan Island (150 km/h on the 31st), Mount Read (156 km/h on the 9th), Scotts Peak (152 km/h on the 9th), Maatsuyker Island (135 km/h on the 8th) and Cape Grim (128 km/h on the 31st).

Western Australia

On the 26th the passage of a cold front produced a gust of 122 km/h at Cape Leeuwin, and gusts exceeding 100 km/h at Rottnest Island, Cape Naturaliste and Busselton. No damage was reported.

Flooding

Tasmania

There was widespread flooding on the 10th and 11th. Rivers affected included:

<u>Forth:</u> major flooding with 10 families evacuated. Major roads were closed and a vegetable processing facility was inundated with significant losses.

<u>Huon:</u> moderate flooding with businesses in the main street of Huonville inundated and major roads closed. Peak heights were the highest since August 1975.
<u>Derwent:</u> major flooding in the middle reaches with several road closures, and minor flooding further downstream.
<u>South Esk:</u> moderate flooding in the upper reaches.
<u>North Esk and Ringarooma:</u> major flooding, with 40 homes evacuated at Branxholm, and road and bridge damage estimated at $2-5 million.

There were also several reports of inundation of low-lying coastal areas in the southeast and the west.

Bushfires

South Australia

On the 30th a Fire Ban was issued by the Country Fire Service for several South Australian districts, the first time this has occurred in winter. No major fires were reported.

Northern Territory

A number of significant fires occurred in the northern half of the Northern Territory during August.

A large fire near the Three Ways to the north of Tennant Creek burnt for about a week starting around the 20th, affecting approximately 6,000 square kilometres. Around the same time another large fire near Warrego affected approximately 2,000 square kilometres. There was no significant property loss.

Records set – July 2007 (# - record for any month)

Location	State	Record	Value	Date	Previous record	Year	Years of record
Geraldton	WA	High daily max	29.0	18	28.8	1976	65
		High monthly min	12.4		11.9	1964	65
Northam	WA	High daily max	25.2	18	25.0	2006	98
		High monthly max	19.1		19.0	1977	96
Bidyadanga	WA	Low daily min	3.5#	10	3.9	1967	49
Sandy Cape	QLD	Low daily min	5.2#	2	7.7	1965	51
Amberley	QLD	Low daily min	-4.8	19	-4.5	2002	66
Gympie	QLD	Low daily min	-4.3#	20	-3.0	2002	42
Prospect Dam	NSW	Low daily min	-0.6#	17	0.0	1978	43
Pemberton	WA	High daily min	14.0	30	13.9	1959	51
Cape Naturaliste	WA	High monthly max	18.0		17.9	2006	103
Albany AP	WA	High monthly max	17.1		17.0	1976	43
Katanning	WA	High monthly max	16.4		16.2	1976	113
Norseman	WA	High monthly max	19.5		18.9	1994	56
Meekatharra	WA	High monthly min	10.0		9.9	1996	58
Dalwallinu	WA	High monthly min	8.8		8.2	1964	53
Wongan Hills	WA	High monthly min	8.7		8.3	1992	53
Donnybrook	WA	High monthly min	8.2		8.0	1992	104
Bencubbin	WA	High monthly min	8.8		8.3	1996	57
Corrigin	WA	High monthly min	7.3		7.1	1949	60
Lake Grace	WA	High monthly min	7.7		7.0	1985	52
Kalgoorlie	WA	High monthly min	8.1		7.5	1949	67
Queenscliff	VIC	High monthly rain	140.9		111.7	1951	111
Mackay MO	QLD	Low monthly rain	0.0		0.9	1963	48
Mirboo North	VIC	Low monthly rain	18.2		25.9	1971	86

Records set – August 2007 (* – Australian record; ^ - equal state record)

Location	State	Record	Value	Date	Previous record	Year	Years of record
Bidyadanga	WA	High daily max	38.0	31	37.8	1996	48
Wittenoom	WA	High daily max	34.5	29	34.4	1977	50
Ceduna	SA	High daily max	33.6	30	33.0	1977	67
Kyancutta	SA	High daily max	33.2	30	32.3	1936	77
Adelaide AP	SA	High daily max	29.9	30	27.3	1977	53

Parafield	SA	High daily max	30.4	30	28.2	1977	51
Adelaide (Kent Town)	SA	High daily max	30.4	30	27.8	1982	31
Mount Barker	SA	High daily max	27.2	30	25.5	1977	51
Keith	SA	High daily max	29.2	30	28.6	1982	46
Lameroo	SA	High daily max	29.6	30	29.5	1982	51
Mount Gambier	SA	High daily max	26.6	30	24.8	1995	66
Hillston	NSW	High daily max	30.7	30	30.2	1995	50
Mildura	VIC	High daily max	29.9^	30	29.7	1995	62
Gabo Island	VIC	High daily max	26.4	31	23.9	1958	51
Wilsons Promontory	VIC	High daily max	24.4	30	23.3	1995	51
Laverton	VIC	High daily max	26.8	27	26.4	1982	64
Darwin AP	NT	Low daily max	25.1	17	25.3	1990	67
Cape Naturaliste	WA	High daily min	17.1	19	17.0	1989	51
Ivanhoe	NSW	High daily min	16.4	31	16.1	1969	47
		Low monthly rain	0.2		0.3	1946	124
Wyalong	NSW	High daily min	15.6	31	14.3	1995	43
Hay	NSW	High daily min	15.6	31	14.5	1969	51
Albany Town	WA	High monthly min	10.3		10.0	2006	90
Smoky Cape	NSW	High monthly min	13.2		13.1	1982	69
Nobbys Head	NSW	High monthly min	12.1		11.6	1998	143
Cowra Res Ctr	NSW	High monthly min	6.5		6.4	1998	56
Sydney AP	NSW	High monthly min	11.2		10.7	1998	69
Sydney	NSW	High monthly min	11.7		11.1	1987	149
Riverview	NSW	High monthly min	10.2		9.4	1998	71
Taralga	NSW	High monthly min	4.0		3.4	1998	47
Orbost	VIC	High monthly min	6.5		6.4	1939	67
Cooroy	QLD	High daily rain	251.0	24	91.9	1893	115
		High monthly rain	567.9		167.0	1893	115
Double Island Point	QLD	High daily rain	305.6*	24	81.8	1920	114
		High monthly rain	405.8		250.2	1988	114
Eumundi	QLD	High daily rain	278.0	24	71.1	1969	101
		High monthly rain	572.0		186.7	1978	101
Kenilworth	QLD	High daily rain	106.0	24	94.0	1969	105
		High monthly rain	180.6		136.2	1969	105
Mapleton	QLD	High daily rain	149.0	24	86.2	1989	102
		High monthly rain	375.0		157.2	2002	102
Rainbow Beach	QLD	High daily rain	529.2*	24	97.4	1998	15
Bowraville	NSW	High daily rain	271.0	21	181.6	1949	118
		High monthly rain	405.7		381.9	1949	118
Osterley	TAS	High daily rain	48.4	10	45.0	1991	97
Biggenden	QLD	High monthly rain	101.8		100.4	1971	109
Landsborough	QLD	High monthly rain	204.2		204.0	1916	116
Drake	NSW	High monthly rain	163.1		148.3	1987	116
Gawler	SA	Low monthly rain	6.8		9.4	1994	102
Mannum	SA	Low monthly rain	0.0		2.9	1944	132
Pinnaroo	SA	Low monthly rain	1.8		2.5	1888	105
Berrigan	NSW	Low monthly rain	0.2		0.3	1944	133
Meredith	VIC	Low monthly rain	11.8		21.2	1982	108

Charts From The Past by Blair Trewin

29 July, 1975

The last week of July 1975 saw, for the time of year, one of the most notable warm spells ever recorded in southeastern Australia. After a month which was consistently very warm in northern Australia, exceptionally warm air for the season was drawn southwards as high pressure became established over NSW and the Tasman Sea from the 26th onwards. By the 29th deep low pressure had developed in the Bight with a strong front crossing Western Australia. The front then moved across the continent, reaching the east coast by the 31st.

The major feature of the event was exceptional, persistent warmth through the south-eastern states. July record high temperatures were set between the 27th and the 31st across almost all of Victoria, South Australia apart from the northeast corner, most of Tasmania and much of the southern half of NSW. The 29th saw the most widespread heat, but records were set somewhere on every one of the five days.

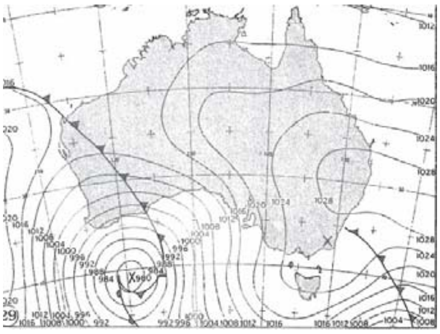
Ceduna's 32.6 on the 29th was 4.2 degrees higher than anything else recorded in July outside 1975, and many other stations were 2-4 degrees above anything else in July before or since, including Canberra (19.7 on the 29th) and Adelaide (26.6 on the 29th). Melbourne (23.1) and Hobart (21.0) also set July records on the 30th. Canberra, Adelaide and Bathurst all had four consecutive days above previous record levels, and many other locations had two or three. Despite the warmth, there was minor flooding in northern Tasmania after highland rainfalls near 50mm on the 29th.

State records for July were set in South Australia, Victoria and Tasmania. The 24.0 at Swansea on the 30th was particularly exceptional; it was not until 2007 that any other July day in Tasmania got within 3 degrees of it. Cook broke the South Australian record by 2 degrees with 34.2 on the 29th, and Robinvale reached 27.1 on the 28th and 29th.

In total contrast, it was exceptionally cold in southern Western Australia, in the wake of a vigorous front which brought severe storms to Perth on the 28th. Many stations in the state's south-west failed to reach 10 degrees on the 29th, and Dwellingup's 6.5 was a state record for July. Much of the south-west had 15-50 mm of rain, with 81.8 at Gooralong and 60.0 at Dwellingup.

The warm spell broke down late on the 30th as a front crossed the south-east, bringing substantial rain with it. Most areas south of a Port Augusta-Horsham-Geelong line had 24-hour falls of at least 20 mm, with up to 80 mm in western Tasmania and 40-60 mm in the Adelaide Hills. Only the south coast of NSW stayed exceptionally warm, with July records at Moruya Heads (24.4) and Nowra (25.4).

The warm spell was a one-off; the remainder of the year was very wet, with the August-December period being Australia's wettest on record. A well-publicised prediction by Lennox Walker during the July warm spell, that the rest of the year would be dry in Victoria and October especially so, came badly unstuck; October 1975 was Victoria's wettest month on record (and remains so today).



Synoptic chart for 29 July 1975 (0000 UTC)

Calendar

2007

November

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

27-29 CAWCR Modelling Workshop, Melbourne, VIC.

2008

January

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

20-24 88th American Meteorological Society Annual Meeting, New Orleans, LA, USA

29th-1st February, 15th AMOS National Conference, Geelong, VIC

February

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

May

19-23 Effects of Climate Change on the World's Oceans, International Symposium, Gijón, Spain

2009

February

9-13 American Meteorological Society Southern Hemisphere Conference, Melbourne

Australian Meteorological Magazine. Vol 56 No.3, September 2007.

Articles:

Suppiah, R., Hennessy, K.J., Whetton, P.H., McInnes, K., Macadam, I., Bathols, J., Ricketts, J. and Page, C.M. Australian climate change projections derived from simulations performed for the IPCC 4th Assessment Report.

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Regular features:

Qi, L. Seasonal climate summary southern hemisphere (spring 2006): weak El Niño in the tropical Pacific - warm and dry conditions in eastern and southern Australia.

Shaik, H.A. and Cleland, S*.J.* The tropical circulation in the Australian/Asian region - November 2006 to April 2007.

Lee, J. Quarterly NWP model performance summary April to June 2007.

Book review:

McBride, J. *Storm World: Hurricanes, Politics and the Battle over Global Warming*, by Chris Mooney.

Further Information:
http://www.bom.gov.au/amm