Australian Government
Bureau of Meteorology

Collaboration for Australian Weather and Climate Research

A research partnership between CSIRO and the Australian Bureau of Meteorology

CSIRO

Weather and climate forecasting for Australia

Science support for planning and safety in Australian communities

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Importance of a national weather and climate model

Australia's highly variable weather and climate affect every facet of life—from how we spend our recreation time, to when crops are planted; from planning for urban development to management of water supplies.

Extremes of weather and climate occur frequently in Australia and can threaten lives, resources, infrastructure and productivity worth billions of dollars. They also affect our natural environment through impacts on air and water quality and biodiversity.

Managing the impacts of weather and climate—and saving lives, resources and money—relies on being prepared. Preparedness requires accurate forecasts of weather days ahead, reliable outlooks of next season's conditions, and robust projections of climate out to years and decades.

To provide vital weather and climate information, the Australian Government—through the Departments of Environment, Industry and Education—has worked closely with its research agencies to develop a national forecasting system. This system is a major collaborative undertaking, bringing together the climate observations, research and modelling of the Bureau of Meteorology (the Bureau), CSIRO and Australian universities, in consultation with international partners. The result is a weather and climate forecasting system tailored to Australian needs.

This one system has the versatility to predict weather and climatic conditions from hours to many decades ahead. It encompasses phenomena as diverse as the currents in the Southern, Pacific and Indian oceans, droughts from prolonged El Niño conditions, and rainfall from the Asian monsoon. It is specifically designed and set up to perform well in the Australian region.

What is a weather and climate forecasting system?

Forecasting systems are often referred to as earth system models (ESMs) because they incorporate representations of the atmosphere, ocean, land and sea ice. Fundamentally the models describe the flow of heat and water around the earth and between the air, sea, land and ice.

ESMs take the form of computer code that resides in supercomputers. This code drives huge numbers of calculations to provide accurate forecasts for the weather tomorrow and next week, as well as climate outlooks and projections for the months and years ahead.

When used for weather forecasting or seasonal prediction, the models incorporate millions of observations from instruments on land, at sea, in the atmosphere and on satellites to improve their accuracy. For climate projections, the models need to be tested against decades to centuries of historical data. Even ice cores are used, to infer the climate millennia ago.

The Australian ESM is called ACCESS, the Australian Community Climate and Earth System Simulator. The Bureau uses ACCESS for its daily weather forecasting. Results from ACCESS that are familiar to most Australians are the animations of air pressure and land temperatures seen on the Bureau's website, and in a variety of mobile apps and television weather reports.

Forecasting in action

Australia's present forecasting system—ACCESS—has been under development for about ten years, but builds on 50 years of Australian leadership in weather and climate forecasting. The same system delivers weather forecasts over a few days and projections of climate to the end of this century and beyond.

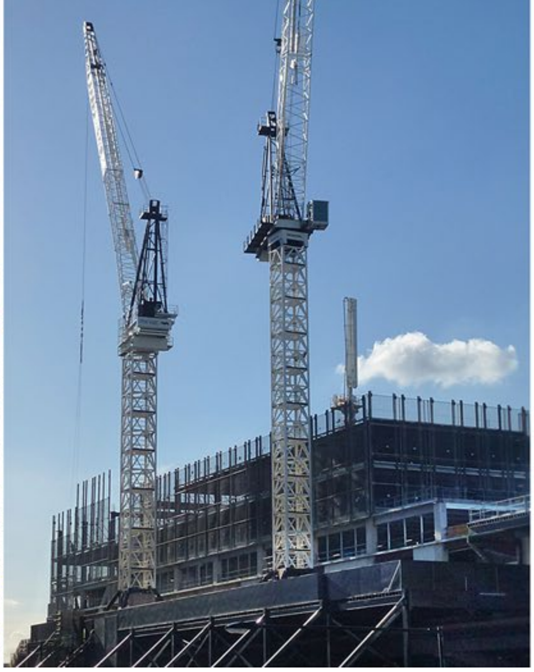
Weather forecasts: Anyone who uses weather forecasts will be aware that they are considerably more reliable than they were ten years ago. Three-day forecasts now have the same accuracy as two-day forecasts did prior to 2009.

Tropical cyclones: Tropical cyclones are challenging to forecasters because they are small and intense. Cyclone tracks are particularly difficult to predict, but are critical in an emergency response. In the last eight years, our forecasts of cyclone tracks have improved by around 25 per cent, with one-day forecasts now accurate to within about 90 km. Tropical cyclone *Yasi* was a memorable and destructive cyclone that crossed the coast of North Queensland in 2011. Bureau forecasts allowed the community and emergency management agencies to plan and make decisions several days ahead of the event.

Fire weather: Forecasts now provide unprecedented detail about fire weather, supporting decisions on deployment of fire crews, community warnings and evacuation. In February 2014, a period of very hot dry northerlies was followed by a strong cool change. Weather simulations provided several days' warning of this extreme event, allowing advance planning by emergency services.

Climate projections: The Intergovernmental Panel on Climate Change (IPCC) published its Fifth Assessment Report in late 2013. In preparation for the report, more than 20 international institutions ran ESMs to simulate the climate at least through the twentieth century, to test the behaviour of the models, and then through the twenty-first century to assess the climate's response to various scenarios for greenhouse-gas emissions. Based on comparisons with historical climate, Australian simulations rank amongst the best of international climate models and are particularly accurate over Australia.

The collection of all the simulations, called CMIP (Climate Model Intercomparison Project) forms a very large and important dataset. It is now being analysed by climatologists around the world, to help us understand the dynamics and implications of climate change. Multiple model runs (called an 'ensemble') provide far more accuracy and information than single models. As active participants in CMIP, Australian scientists understand the strengths and limitations of the projections, and are positioned to provide expert advice to policy and decision-makers.



Broader applications and benefits for Australia

As development continues, weather and climate forecasts will become more accurate. The result will be more tailored and timely weather and climate information. The new challenge is to improve seasonal forecasts, from weeks out to months. Even more challenging will be predictions out to years.

Weather and climate-related risks occur across a range of timescales:

- short-term (e.g. floods, fires, storms);
- seasonal (e.g. cropping and stocking decisions, bushfire preparedness); and
- multi-decadal (e.g. coastal protection, water storage, construction).

Agriculture

Improved short-term, multi-week and seasonal forecasts will enhance farmers' ability to make the right business decisions. Climate projections from years to decades inform longer-term land management decisions and provide planning information on the changing frequency of high-impact events such as floods, droughts, tropical cyclones and bushfires.

In Australia's variable climate, limited water resources serve not only agriculture but also settlements, industry and the environment. Improved seasonal forecasts will help water authorities, industry and the community to better manage water use, while climate projections will inform planning for long-term water supply.

Industry and infrastructure

Weather and climate events influence business and industry efficiency and profitability.

The annual economic impact of weather and climate events is estimated at around 5 per cent of Australia's gross domestic product. In 2011, natural disasters alone are estimated to have resulted in a $9 billion fall in national production.[1]

Better information and more accurate forecasts lead to better decision-making, which may help mitigate losses.

Investment in infrastructure requires planning far into the future. Engineering design of infrastructure must incorporate such climate issues as rising sea level and increasing frequency or severity of storms.

Damage to public infrastructure across the eastern states of Australia due to the 2011 floods cost approximately $6–7 billion.[2]

Access to the latest information and forecasts for weather and climate allows business and industry to plan more effectively and make decisions that can reduce the economic impact of changing or extreme weather.

Recent World Bank studies suggest that the avoidable damage related to infrastructure from early warning systems with lead times of 24 hours, 48 hours and up to seven days could be around 5, 10 and 15 per cent, respectively.[3]

Energy generation, transmission and use are all affected by the weather. Depending on its source, energy generation can be sensitive to wind, rain, hail, ice, cloud, temperature, storms, drought, run-off and evaporation. Transmission lines and related infrastructure can be



affected by bushfires, floods, tropical cyclones and other extreme weather events, causing disruption to supply and necessitating significant repair or replacement costs. Energy use during extremely hot days can place excessive demand on generators.

The heatwave event of January 2009 caused financial losses of approximately $800 million due to power outages, transport disruption and associated responses.[4]

Tailored forecasts of temperature, humidity, precipitation, wind speeds and cloud cover are now available. They can assist in predicting demand for heating, cooling and lighting, and in turn aid decisions about power generation. They can also precipitate protective action in the case of extreme weather. Longer-term forecasts can help with network and infrastructure planning, including for non-carbon-based generation.

National security

The Bureau delivers critical services to Australia's national security by providing detailed forecasts for land, sea and air operations, including services in support of defence operations both within Australia and overseas. Bureau staff are co-located at Defence Headquarters Joint Operations Centre (HQJOC) in Canberra as well as several defence bases throughout the country. The Bureau also trains Navy meteorologists in weather forecasting. Critically, Bureau forecasts are produced without any dependence on overseas models or systems. This ability to apply state-of-the-art modelling capability for foreign operations results in greater safety and effectiveness for ground and sea operations.

At longer timescales climate-related threats to national security have been widely acknowledged by the US military. For example, from the 2014 Quadrennial Defense Review:

The impacts of climate change may increase the frequency, scale and complexity of future missions, including defense support to civil authorities, while at the same time undermining the capacity of our domestic installations to support training activities.[5]

Planning Australia's national security into the middle of this century will require understanding of regional climate.

Marine and coastal

Globally, Australia claims the third largest marine jurisdiction of any country, returning significant and rapidly growing economic value to the nation. Maritime security is a major national issue.

The ocean currently contributes $44 billion annually to the Australian economy through industries including oil and gas, tourism, and fishing. This is expected to grow to $100 billion by 2025. In 2009–10 Australian ports exported nearly 950 million tonnes by sea, valued at $179 billion.[6]

Tropical cyclones, winds and storms affect marine activities, while longer-term changes to ocean temperatures, currents and acidity levels are likely to affect marine industries and the environment.

Australian fisheries are our fifth largest food-producing industry, worth more than $2.2 billion annually to our economy.[7]

Information on ocean responses to weather and climate (such as waves and storm surges) will help predict the impact of these events on coastal and marine

environments and industries, informing management decisions.

Approximately 85 per cent of Australians live within 50 km of the coast.[8]

Rising sea levels and more frequent extreme weather combine to increase beach and shoreline erosion, potentially affecting millions of people and billions of dollars worth of infrastructure. Storm surges lead to inundation of coastal regions, affecting infrastructure, industry, communities and the environment.

More than $226 billion in commercial, industrial, road and rail, and residential assets could be threatened by exposure to inundation and erosion hazards at a sea level rise of 1.1 m by 2100.[9]

Improved understanding and projections of climate, including sea level changes, will support planning decisions to maximise benefit and minimise risk and economic loss.

Emergency services

Emergency services work to protect lives and property in times of extreme weather. Timely information ensures that physical and human resources are safely deployed when and where they are needed.

Victoria's 2009 Black Saturday bushfires took 173 lives. The total cost of these fires is estimated to be more than $4 billion.[10]

The 2010–11 Queensland floods caused the death of 33 people and more than 78 per cent of the State was declared a disaster zone. Over 2.5 million people were affected, at an estimated cost to the Queensland economy in excess of $5 billion.[11]

Emergency services will benefit from short-term forecasts through to long-term climate projections. Local forecasting of wind shifts and temperature changes during a bushfire transforms fire-fighting tactics, leading to much-improved protection of fire crews, lives and property.

Ten-day weather forecasting will provide warning of severe weather, enabling communities and emergency services to better prepare for flooding or extreme fire danger.

Monthly and seasonal forecasts support strategic activity like managing water flows to reduce the impact of flooding rains, or controlled burning to protect homes and other infrastructure.

Climate projections enable long-term planning and investment to manage changes in the frequency and severity of extreme winds, rainfall, fire danger and heat.

What next?

ESMs are being improved continuously, as we see from the increased accuracy in weather forecasts over the last ten years. The models are mostly limited by the size of the computers on which they are run. The Bureau will install a new machine in 2016, 20 times greater in capacity than the current one, and planning has started for expansion of the National Computational Infrastructure.

The Bureau's new supercomputer will give more accurate weather forecasts, and will begin a new phase for seasonal predictions. It will also initiate work on multi-year predictions. While predictions on timescales from months to years use the same ESMs as weather forecasts, the models are set up and run quite differently. The results are also interpreted differently. Researchers in the Bureau, CSIRO and the Australian Research Centre of Excellence for Climate System Science are working with international colleagues to develop useful and reliable predictions out to months and beyond.

Meanwhile, Australian scientists are already preparing for the IPCC's next global CMIP. The results from this project will be published around 2019, taking advantage of six years of improvement in modelling and computer technology. CMIP is a massive international exercise, aimed at providing the best climate projections under a variety of assumptions about the continued emission of greenhouse gases.

Who supports the system?

The development of Australia's weather and climate forecasting system was initiated by the Australian Government through the Australian Climate Change Science Program, and led by the Bureau of Meteorology and CSIRO. In maintaining and developing the system, the Bureau and CSIRO have nurtured strong links to university research groups—in particular the Australian Research Centre of Excellence for Climate System Science. The Bureau and CSIRO have also collaborated with many international science agencies to ensure not only the best use of resources, but also the ongoing growth of Australia's national capacity and international research standing.

The Bureau and CSIRO have a formal partnership called the Collaboration for Australian Weather and Climate Research (CAWCR), with the modelling-system development as its core activity. Their principal university collaboration is through the Australian Research Centre of Excellence for Climate Systems Science, which involves the Universities of New South Wales, Melbourne, and Tasmania, the Australian National University (ANU) and Monash University. The ANU also hosts Australia's National Computational Infrastructure, within which the models are developed and run for research. The main international collaborators are the UK Met Office and the US National Oceanic and Atmospheric Administration.

Development of the modelling system is supported nationally by the:

- Department of the Environment, through the Bureau of Meteorology and the National Environmental Science Programme (incorporating the previous Australian Climate Change Science Programme);
- Department of Industry, through CSIRO; and
- Department of Education, through the Australian Research Council Centre of Excellence for Climate System Science, the partner universities, and the National Computational Infrastructure (under the National Collaborative Research Infrastructure Strategy).

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[11] Queensland Floods Commission of Inquiry (2012).

Image credits

Front cover

- left—checking soil condition (Grains Research and Development Corporation);
- right—Pluto LNG gas plant, Western Australia (Woodside); and
- bottom—fire researchers record bushfire behaviour (CSIRO).

Page four: baled hay (Bureau of Meteorology); construction site (Bureau of Meteorology); power lines (Bureau of Meteorology).

Page five: farmer checks a water meter at Mildura (Bureau of Meteorology); trawlers moored at Trinity Inlet, Cairns (Great Barrier Reef Marine Park Authority).

Page six: cleaning up after floods in Brisbane (Debra Kolkka); fighting a bushfire (NSW Rural Fire Service).

Page seven: the earth from space (NASA).

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