

METEOROLOGICAL AND RELATED RESEARCH

Meteorological and Related Research delivers research which includes both strategic components, responding to new challenges in the advancement of meteorological, hydrological and oceanographic science in Australia, and in applying that science to the needs of the Australian community, and tactical components, underpinning the Bureau's systems and services.

The Bureau has transformed the way in which it delivers this Major Output through two significant new initiatives developed over the past few years. The first is the establishment with CSIRO of the Centre for Australian Weather and Climate Research (CAWCR) as a jointly operated research operation focussing on weather, climate and earth system science. CAWCR replaces the Bureau of Meteorology Research Centre as the main organisational unit tasked with generating research outputs for the Bureau; its work is complemented by research and development undertaken in the Bureau's Regional Offices and other areas of the Bureau.

The second new initiative, which is an important component of the work of CAWCR, but one which is being carried out in partnership also with the university sector and others, is a major earth system modelling initiative, the Australian Community Climate and Earth System Simulator (ACCESS). ACCESS represents a new generation of modelling and model systems infrastructure which will underpin Bureau services on a range of time scales, offering advanced numerical weather and ocean prediction, seasonal forecasting models, and the ability to simulate future and past climate change, particularly as it manifests in the Australian region.

PLANNED OUTCOME 2007-08

<p>Outcome</p>	<p>Advancement of meteorological science and understanding of the mechanisms of Australian weather and climate.</p>
<p>Objective</p>	<p>To advance the science of meteorology, develop an integrated, comprehensive description and scientific understanding of Australia's weather and climate, develop the application of meteorology in the national interest and improve the operations and services of the Bureau.</p>
<p>Effectiveness indicators</p>	<p>The extent to which Meteorological and Related Research:</p> <ul style="list-style-type: none"> • is recognised for the quality and extent of its contribution to national and international meteorological and related sciences; • contributes to the knowledge base relevant to Australian weather and climate; • is responsive to the Bureau's operational needs and national priorities; • impacts the efficiency and effectiveness of relevant systems and services within the Bureau; • impacts national and international scientific debate within its field(s) of expertise; • is implemented and managed efficiently in the Bureau while maintaining full staff engagement and morale; and • is innovative and policy relevant, nationally and internationally.

OUTPUTS 2007-08

Meteorological and Related Research is one of the Bureau's eight Major Outputs and also constitutes Output 1.2, one of the Bureau's five Output Groups.

This Major Output delivers: original publications in the peer-reviewed scientific literature on Australian and global meteorology, hydrology, climate and climate change, and oceanography; reviews, project reports, conference presentations, and the general build-up of scientific expertise, reputation and influence in the international scientific community; published and unpublished contributions to the development and implementation of new and improved applications of meteorology; and new operational meteorological and related systems and techniques. Outputs also include effective Australian participation in international research programs directed towards improved understanding of southern hemisphere and Australian meteorology and oceanography.

OUTPUT PERFORMANCE 2007-08

Output performance is measured against a number of targets, including quality, quantity and price. The performance against each of these output targets during 2007-08 is provided below.

Quality	Target	Actual
Number of awards	3	6
Number of memberships on eminent scientific panels	12	19
Number of people directly involved in national science fora/working groups	10	12
Number of invitations to present at national meetings/ workshops/conferences including keynote addresses	40	45
High-quality input to possible parliamentary questions	5	5
Percentage of requests for advice met on time	100%	90%
Percentage of scientific integrity of systems and services maintained	100%	100%
Number of responses/advice for extreme events	5	3
Positive response to the National Research Priorities (NRP) report from the Office of the Chief Scientist – number of issues identified no more than one	<2	0
Number of updates to operational systems	10	11
Number of scientists as lead or contributing authors in Intergovernmental Panel on Climate Change and equivalent assessments	5	7
Percentage of staff with management qualifications	5%	3%
Percentage of planning/budget management requests met	100%	100%
Percentage of the annual report to NRP completed	100%	100%
Number of innovations taken up externally	2	1
Quantity		
Number of international visitors	20	19
Number of communications (briefings, media, etc)	25	57
Number of inventions (new technology)	1	1
Number of collaborative projects	75	81
Number of briefs prepared (for Minister, etc.)	12	8
Percentage of research effort to address NRPs	55%	46%
Number of new developments/innovations (tests, trials)	4	5

Quantity (cont.)	Target	Actual
Number of publication articles (peer reviewed)	65	81
Number of publication articles (non-peer reviewed)	90	112
Number of international meetings convened	3	4
Percentage of overall efficiencies generated	2.4%	2.9%
Number of collaborative projects managed	12	14
Number of seminars held (internally organised)	50	76
Percentage of research budget from external sources	30%	26.5%
Price		
Weather, Ocean and Environment Research	-	\$2.570m
Earth Systems and Climate Research	-	\$4.191m
Weather Research	\$6.793m	\$3.966m
Climate Research	\$2.773m	\$2.009m
Ocean Research	\$2.551m	\$0.921m
Hydrology Research	\$0.577m	\$0.354m

Comments on output performance

In recent years Meteorological and Related Research has been delivered through four individual output areas which have contributed to the achievement of the desired outcome: Weather Research, Climate Research, Ocean Research and Hydrology Research. With the establishment of CAWCR during 2007-08 these four were reorganised into two output areas: Weather, Oceans and Environment Research; and Earth System Modelling and Climate Research. The price targets above are those set in the Portfolio Budget Statements 2007-08 for the four output areas that applied at the beginning of the year, while the actual prices are reported partly against these four (for the period before the establishment of CAWCR), and partly against the two new output areas (for the remainder of the year).

The targets for published articles were significantly exceeded again this year, even though the combined target for peer-reviewed and other publications had been increased by about 40 per cent compared to that for 2006-07. Peer-reviewed articles included papers published in the prestigious journals *Nature*, *Science* and *Scientific American*.

The number of Bureau scientists who were members of eminent scientific panels, including the number who contributed to the work of the Intergovernmental Panel on Climate Change (IPCC), exceeded the target. CAWCR scientists made significant contributions to the IPCC's recently released Fourth Assessment Report, a key international climate change assessment. CAWCR scientists' roles included those of lead authors and contributing authors for IPCC Working Groups I (The Physical Science Basis) and II (Impacts, Adaptation

and Vulnerability). The value of the work of the IPCC was recognised in October when the IPCC was awarded the Nobel Peace Prize jointly with former US Vice President Al Gore. The quality of the scientific contributions of CAWCR scientists was also recognised through a NASA Group Achievement Award, editor's awards for international journals and educational awards from universities and academies.

A shortfall in the management capabilities of our research staff is indicated by the lower percentage with professional management qualifications compared with the target value. Appropriate management training is becoming more important in contemporary scientific organisations, where complex projects and collaborations are common, and this aspect of performance will be a focus for future staff development.

The number of inventions, new developments and innovations this year exceeded the target. A number of systems that had been in development by Bureau scientists for several years were completed and implemented. These included the Ocean Model Analysis and Prediction System (OceanMAPS), extensions to the Operational Consensus Forecast (OCF) system to produce forecasts on a 5 km grid and to produce ocean forecasts, the POAMA (Predictive Ocean Atmosphere Model for Australia) Ensemble Ocean Data Assimilation System, and the ACCESS numerical weather and climate prediction suite. Details of these innovations are provided later.

The prominence in public debate of issues such as climate change, rainfall declines in southeastern Australia and the Murray-Darling Basin, and cloud seeding probably contributed to a larger-than-expected number of media briefings during the year. Other media activities, communications and briefings included involvement with documentaries on experimental field campaigns, and articles and interviews on the IPCC, the Nobel Peace Prize, Antarctic ocean salinity changes, the Beijing Olympics, and the formation of CAWCR.

The Bureau was also host to a number of visiting scientists, with long-term visitors (staying more than one week) coming from countries including Canada, China, France, South Korea, Spain, the United Kingdom and the US. The regular weekly Bureau research seminar series was supplemented by a larger-than-expected number of seminars provided by such visitors, resulting in the target number for the year being exceeded.

ACHIEVING THE OUTCOME

As noted above, with the establishment of CAWCR, Meteorological and Related Research was reorganised to be delivered through two output areas that contribute to the achievement of the planned outcome: Weather, Oceans and Environment Research; and Earth System Modelling and Climate Research. The contributions reported below reflect the collaborative efforts of all CAWCR scientists, both those employed by the Bureau and by the CSIRO.

CAWCR's integrated research capabilities are organised into seven research groups covering the sciences associated with:

- ACCESS;
- Climate Change;
- Seasonal and Inter-annual Prediction;
- Ocean Observation and Assessment;

- Weather and Environmental Prediction;
- Ocean Prediction; and
- Atmosphere and Land Observation and Assessment.

OVERVIEW OF 2007-08

The key development this year for Meteorological and Related Research was the establishment of CAWCR itself, which came into operation in September and was formally launched at the National Museum of Australia in Canberra in December.

CAWCR involves more than 250 staff located in Canberra, Melbourne (in the Bureau's Head Office in Docklands, and the CSIRO's Division of Marine and Atmospheric Research in Aspendale), Hobart, Brisbane and Perth. The vision of the Centre is 'to be a joint Centre for earth system science recognised for its innovation and scientific excellence nationally and as a world leader in its field,' and the goal is to strategically manage the science capabilities relating to weather, climate and ocean research in Australia's national interest. The partnership between the Bureau and CSIRO will achieve the critical mass of research scientists required to tackle complex research problems, and will provide the mechanisms to resolve duplication and deliver efficiencies in these research areas.

Work on ACCESS formed a major part of CAWCR's achievements during the year. Development of ACCESS is being carried out in association with the United Kingdom Met Office's Hadley Climate Centre, and is based on the Met Office's Unified Model, considered to be at the forefront of the field of climate and weather prediction. The ACCESS initiative is led by the Bureau of Meteorology and the CSIRO, but also relies on strong research partnerships with Australian universities and government research agencies. ACCESS will be used for predicting the weather, improving seasonal climate forecasts and understanding climate change, and will provide information for mitigating natural disasters and for natural resource management. Early numerical weather prediction results confirm that the performance of the local implementation of the Unified Model global prediction system in ACCESS is close to that of the UK Met Office, providing a significant improvement on the Bureau's current operational numerical weather prediction system.

EARTH SYSTEM MODELLING AND CLIMATE RESEARCH

The Earth System Modelling and Climate Research output draws on the work of four of CAWCR's research groups: ACCESS, Climate Change, Seasonal and Inter-annual Prediction, and Ocean Observation and Assessment. The ACCESS research group leads CAWCR in the development of a world-competitive coupled climate and earth system simulator and modelling system. The objective of the Climate Change group is to understand and project future climate change and its impacts so as to inform policy and decision-making and assist the improvement of adaptive responses by the community. The Seasonal and Inter-annual Prediction research group delivers new knowledge and applications that inform policy for managing Australia's environmental resources and decision-making in climate-sensitive industries. The Ocean Observation and Assessment group aims to create the infrastructure and knowledge to monitor, observe and understand the key processes that drive variability and change in Australia's marine and deep ocean waters.

Major developments 2007-08

- ACCESS, while still in the development stage, has shown dramatic improvements in performance of its global numerical weather prediction system. The skill of the system, as measured by the degree of correlation between predicted and observed quantities, is now equal to that of the UK Met Office Unified Model system. Improvements have resulted from the use of a better model, improved access to a range of remotely sensed data, including from satellites, and incorporation of the four-dimensional variational data assimilation system, a state-of-the-art means of using observations to characterise current atmospheric conditions.
- A number of climate model runs of the Atmospheric Model Intercomparison Project (AMIP) using the ACCESS Unified Model and covering 10 to 20-year time spans have been completed and have shown encouraging model performance for the Australian region. AMIP is a project of the World Climate Research Programme that provides a means of testing and comparing climate models. Work is underway on coupling the ocean/sea-ice model (AusCOM/CICE) and the CSIRO Atmosphere Biosphere Land Exchange model (CABLE) to the Unified Model, allowing modelling of a more complete representation of the climate system rather than of the atmosphere in isolation. An example of output from AusCOM/CICE is shown at Figure 10.
- The inaugural CAWCR Modelling Workshop was held in November, with the theme of Physical Processes and Modelling of the Water and Carbon Cycles. Invited speakers and eminent scientists attended from Australian and international research centres, and keynote presentations were given by Professors Praveen Kumar (University of Illinois), Xu Liang (University of Pittsburgh) and Colin Prentice (Bristol University). The workshop examined the challenges presented in modelling the physical processes involved in the carbon and water cycles from a variety of viewpoints including the acquisition and assimilation of observations, the ecological and physiological processes that modulate the cycles, and how these affect the wider earth climate system.
- CAWCR scientists played a pivotal role in the development of climate change projections for Australia, released as *Climate Change in Australia*, a report co-authored by Bureau and CSIRO scientists, at the Greenhouse 2007 conference in October. The projections were the most comprehensive to date for climate change within Australia, and incorporated the use of probabilistic methods for the first time. Projections were provided of changes in parameters such as temperature, rainfall, severe weather events and sea level to a resolution of two or three hundred kilometres, and in some cases on a finer scale (Figure 11).
- Significant advances were made in understanding of the Walker Circulation, one of the largest and most important global wind systems. It was discovered that the Walker Circulation was weaker during 1977-2006 than at any other time since records began in 1876 and that the same period was more dominated than any other period on record by occurrences of the El Niño phenomenon, which is associated with drought in eastern Australia.

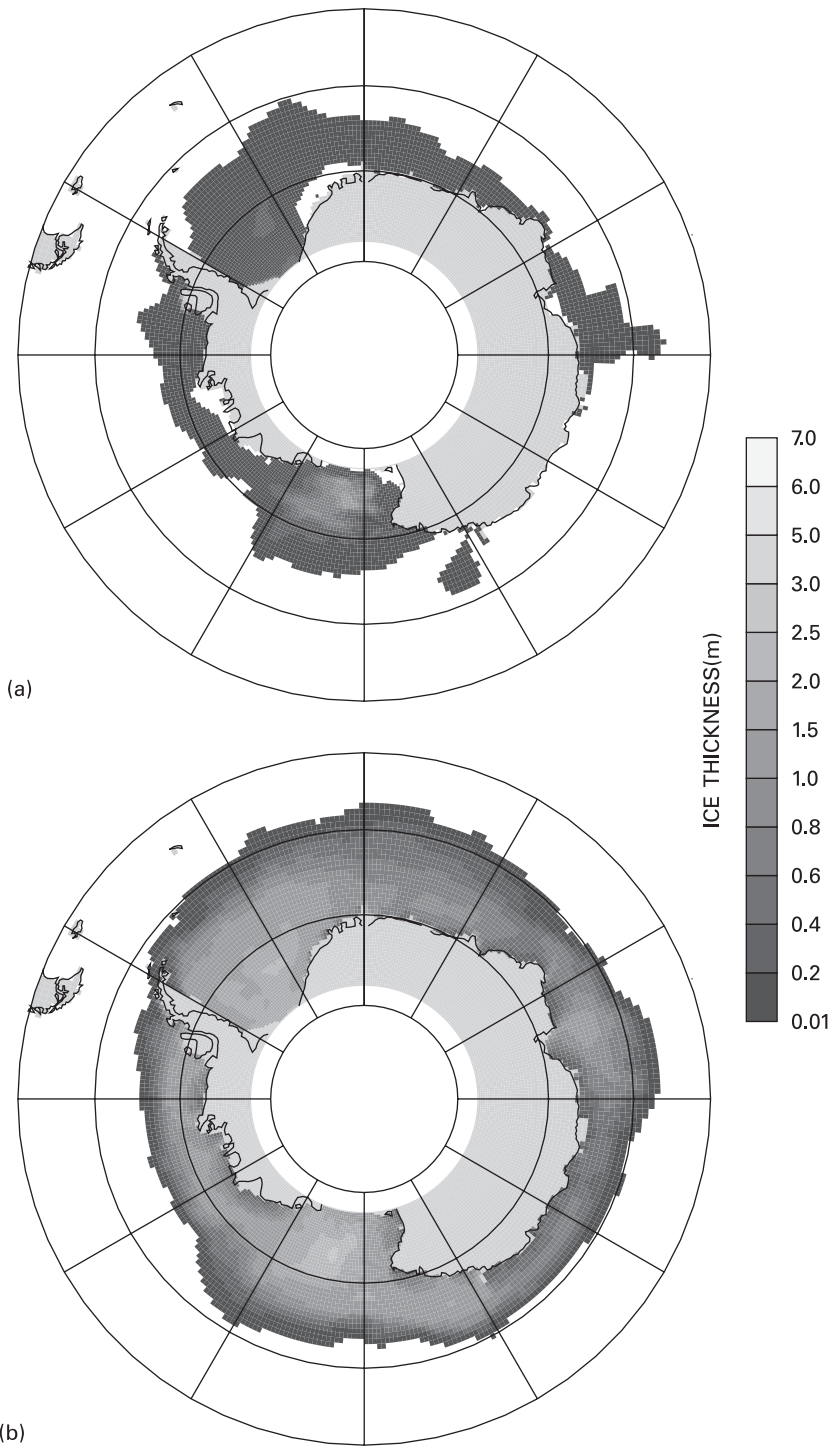


Figure 10. An example of output from the ocean/sea-ice model AusCOM/CICE showing the Antarctic sea ice thickness for (a) February 1983; and (b) August 1983.

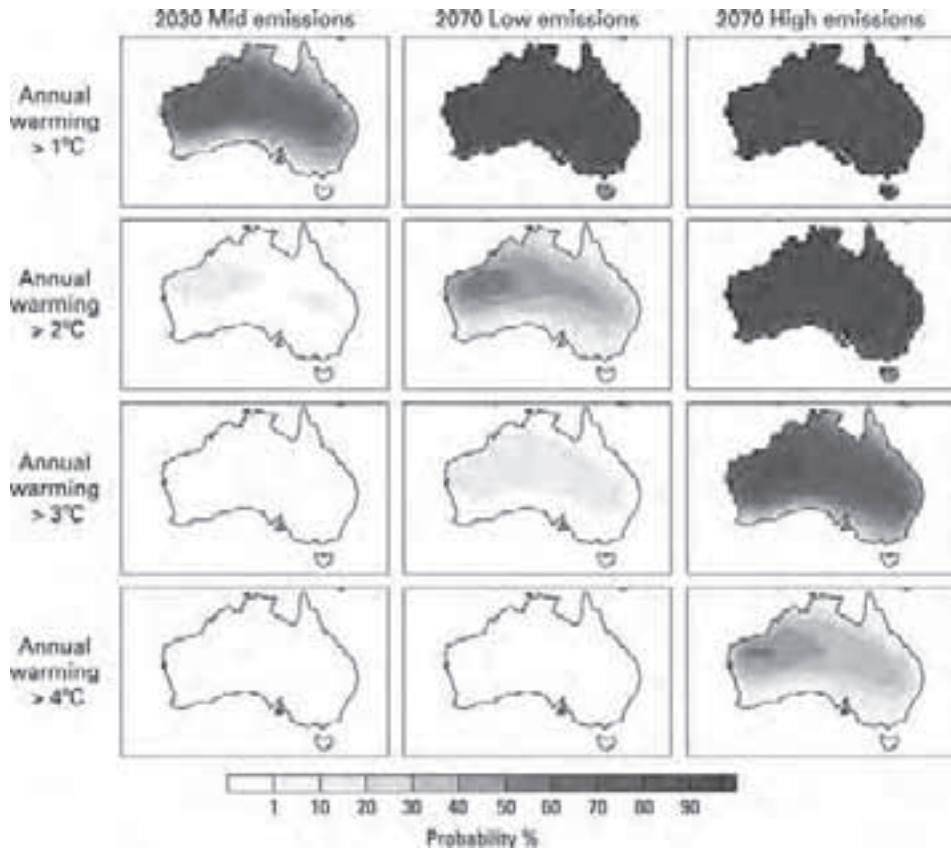


Figure 11. This figure, taken from the publication *Climate Change in Australia*, shows the probability of exceeding various annual warming thresholds for various scenarios, relative to 1990, based on the spread of climate model results.

- A dramatic change was identified in the degree of media coverage of climate change was identified in Australia during 2006 and 2007, as shown by the number of media articles on the topic in major newspapers, suggesting an increase in the level of concern among Australians about the issue (Figure 12).
- Research undertaken as part of the South Eastern Australian Climate Initiative (SEACI), has uncovered a significant relationship between the intensity of the subtropical ridge and global warming of the planet (Figure 13).
- An improved atmosphere-land initialisation scheme for the POAMA seasonal forecast system has resulted in improved prediction of the occurrence of El Niño, improved ability to forecast the different climate impacts on Australia of different El Niño events, and regional climate forecasts with similar skill to that of the National Climate Centre's operational seasonal prediction system, which uses statistical methods.
- The POAMA Ensemble Ocean Data Assimilation System (PEODAS) was developed.

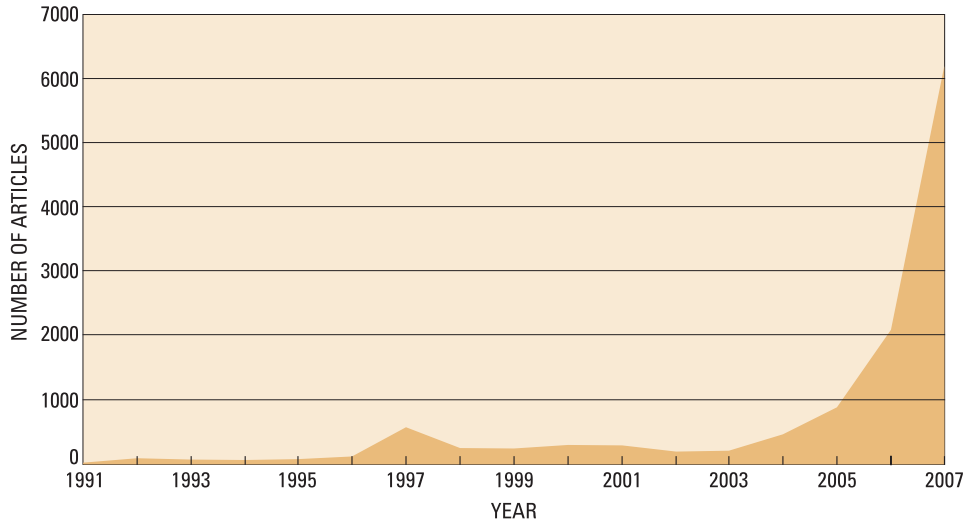


Figure 12. The number of articles on global warming appearing in three major newspapers (The Age, The Australian and The West Australian) continues to increase. The number of articles suggests increased public concern about global warming and climate at the time of the Kyoto Protocol (1997) and from 2004 onwards.

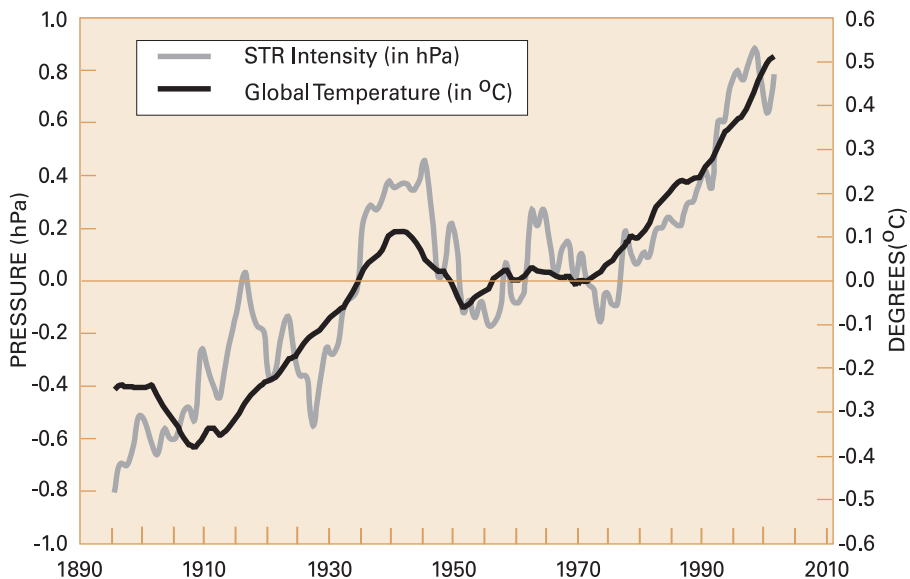


Figure 13. Research has uncovered a significant relationship between the intensity of the subtropical ridge (STR) and global warming of the planet. The subtropical ridge is a broad belt of high pressure between 20°S and 35°S that separates the trade winds of the tropics from the westerlies of the mid-latitudes.

PEODAS assimilates all available observations of currents, salinity and temperature to provide a much improved representation of upper ocean currents compared to the existing scheme used in POAMA.

- Seasonal forecasts of variations of the Leeuwin Current, based on predictions of large-scale variations of the upper Indian Ocean, have been developed using POAMA and shown to be skilful with a lead time of up to nine months.
- Operational predictions of tropical cyclone formation and occurrence up to three weeks ahead for the southern hemisphere tropical Indian and western and central Pacific Oceans commenced under a collaborative project with Meteo France New Caledonia using a statistical scheme developed by CAWCR scientists. The forecasts for the 2007-08 tropical cyclone season showed good skill, based on standard measures for probability forecasts, especially off the Western Australian coast.

Contribution towards outcome

- The numerical weather prediction modelling improvements of the ACCESS suite, and incorporation within it of new remotely sensed data sources, will result in improved weather forecasts and a wider range of forecast products for the Australian community when the ACCESS suite becomes operational.
- Trialling of AMIP-style model runs and enhancements to the ACCESS climate suite are strategic developments to achieve national objectives for Australian regional climate modelling and to ensure a significant contribution by Australia to future work of the IPCC, including the Fifth Assessment Report.
- The CAWCR Modelling Workshop provided a productive forum for exchange of scientific ideas and findings between Australian and international scientists, helping to improve scientific understanding and to drive progress in research into modelling the earth climate system.
- Regional climate projections are an output of advances in the science, and allow policy-makers and stakeholders such as water authorities, farmers and town planners to better plan for future climate regimes in their local area.
- Understanding of atmospheric systems such as the Walker Circulation improves ability to forecast El Niño events and hence has important implications for seasonal forecasting of impacts such as drought.
- Improved knowledge of the level of concern within the community about scientific issues such as climate, climate change and global warming assists in the targeting of research priorities and directions to address community needs.
- This finding of the collaborative SEACI study into the subtropical ridge and global warming is critical to understanding the rainfall decline in southeastern Australia, since the subtropical ridge intensity is very strongly related to rainfall in that region for the greater part of the year.
- The improvements in POAMA led to a improvement in the lead time of its forecasts of one month. It is expected that further upgrades of POAMA will lead to more accurate seasonal forecasts than are possible with the statistical methods used currently, provid-

ing an improved basis for the community's management of a variable and changing climate.

- Improving the representation of ocean currents in POAMA leads to improved seasonal forecasting including of El Niño events.
- Predictions of the Leeuwin Current assist planning in the fisheries industry as well as improving modelling for weather and climate prediction.
- The collaboration with Meteo France New Caledonia brought benefits to both parties, leading to useful predictions for the last tropical cyclone season.

WEATHER, OCEANS AND ENVIRONMENT RESEARCH

The Weather, Oceans and Environment Research output spans three of CAWCR's research groups. The Weather and Environmental Prediction research group aims to improve understanding of atmospheric processes, and develop and apply numerical weather prediction systems to advanced weather forecasting and related environmental services, such as severe weather and air pollution hazards. The objective of the Atmosphere and Land Observation and Assessment group is to develop the techniques and knowledge to monitor, observe and understand atmospheric and land processes, their interaction, and the role they play in the Australian environment. The Ocean Prediction research group aims to describe, model and predict the variability of the oceans and the surface marine environment of the Australian region and, in conjunction with the Ocean Observation and Assessment group, to develop an understanding of the processes and mechanisms that determine the ocean's role in climate and climate change.

Major developments 2007-08

- The CP2 polarimetric radar was commissioned at Redbank Plains in southeast Queensland as a test facility for development of applications for severe weather (e.g. flash flood) warning, and for basic research on cloud physics and quantitative rainfall estimation. The facility hosted the Queensland Government's southeast Queensland cloud seeding research project as its first major experiment.
- Improvements to the CSIRO land surface model, CABLE, which will be part of ACCESS, demonstrated the potential for better modelling of evapotranspiration, and hence better estimates of soil water availability and runoff.
- A system to calculate atmospheric winds at different heights from images produced by the Japanese geostationary satellite MTSAT-1R was implemented. These wind estimates are now produced within the Bureau and are used operationally in its numerical weather prediction suite, and have been shown to improve forecasts, including tropical cyclone forecasts, in the Australian region.
- Analyses of global data by scientists from CAWCR and collaborators at MIT, the University of California and the University of Bristol suggest that increases in the methane concentrations measured at Cape Grim, Tasmania, and elsewhere around the globe, after eight years of near-zero growth in atmospheric methane, are, at least in part, due to methane releases in the high latitudes of the northern hemisphere, a predicted result of Arctic warming (Figure 14).

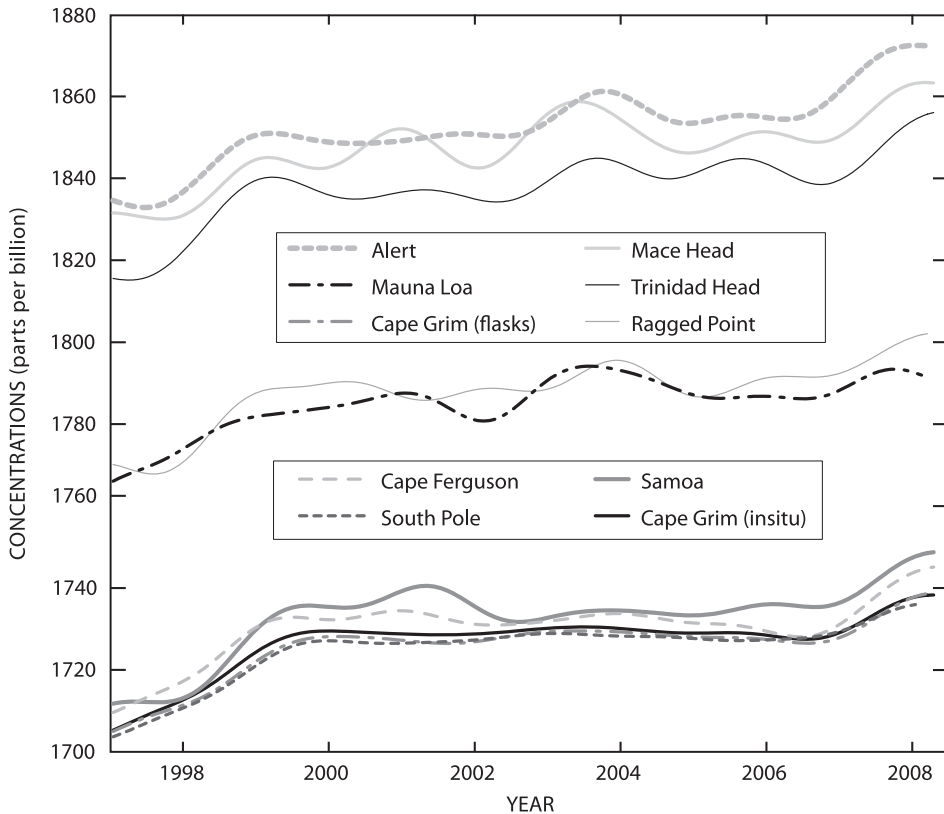


Figure 14. The graphs show time series of atmospheric methane concentrations at various locations around the world with the seasonal cycle filtered out. Significant features are the period from 1999, where concentrations were almost stationary, followed by the significant upward trend since 2007.

- The Operational Consensus Forecast (OCF) technique, developed within the Bureau and used in its forecast offices for several years to provide forecast guidance for parameters such as temperature and rainfall, was applied to a set of 10 global wave models to produce forecasts of significant wave height, peak wave period and wind speed. Significant improvements in the forecast skill of all these parameters were obtained, compared to that provided by the existing forecast guidance system, also based on numerical weather prediction models.
- The OCF system, which could previously be applied to produce forecasts only at specific locations where there were observation stations, was extended to produce hourly forecasts on a five-kilometre grid over Australia in order to provide input to the Graphical Forecast Editor (GFE) system being developed by the Bureau (Figure 15).
- A Real Time Forecast Verification system was developed to provide forecasters with real-time feedback on the accuracy of automated radar-based nowcasts (very short-range

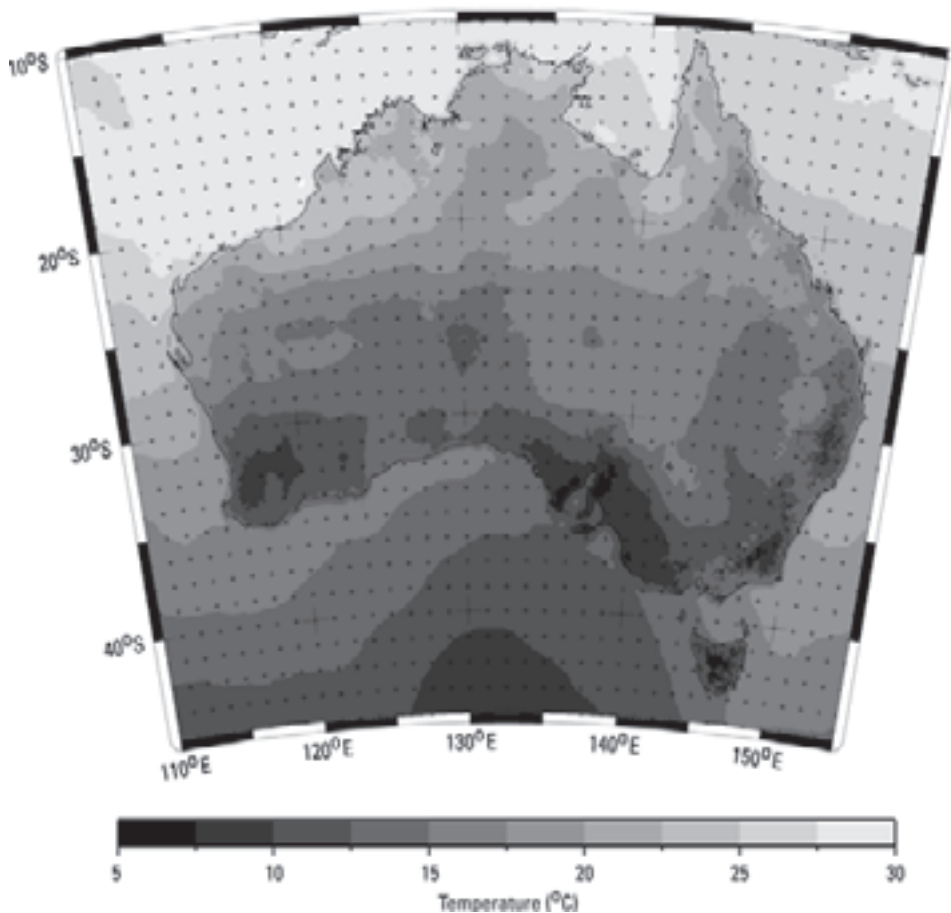


Figure 15. The gridded Operational Consensus Forecast system has been extended to produce hourly forecasts on a five-kilometre grid over Australia in order to provide input to the Graphical Forecast Editor system being developed by the Bureau. This figure shows the gridded forecast for 16 May.

forecasts). Real Time Forecast Verification is an important component of the Beijing 2008 Olympics Forecast Demonstration Project run under the auspices of the World Meteorological Organization's World Weather Research Programme, in which Bureau scientists are participating.

- Instruments providing high-quality observations for the determination of air-sea fluxes were installed on the national research vessel *Southern Surveyor*. These observations were part of the Bureau's involvement with the Integrated Marine Observing System, a distributed set of equipment and data-information services. The data gathered are automatically transmitted to the Bureau for quality control and dissemination to the scientific community.
- An analysis of observed sea-level variability from the Bureau's coastal tide gauge net-

work demonstrated how the sea-level variability at different frequencies can be amplified or attenuated by the local bathymetry and topography.

- The Bureau's operational ocean forecast system OceanMAPS was officially launched on 2 August. A major outcome of the BLUElink project, which was initiated in 2002 as a joint Bureau of Meteorology, CSIRO and Royal Australian Navy research project, OceanMAPS is a global ocean forecasting system with high horizontal resolution in the Australasian region. Analyses and forecasts of parameters such as ocean temperature, salinity and currents up to seven days ahead are available via the Bureau's website.

Contribution towards outcome

- The CP2 radar is a valuable tool for understanding fundamental atmospheric processes, particularly those associated with cloud structure and thunderstorms, precipitation and hail. As a test facility, it will support a variety of research and development projects and experimental field campaigns aimed at improving forecasting techniques, particularly for weather associated with severe convective storms.
- CABLE model improvements enhance the scientific understanding of land-surface processes, and hence are expected to improve the performance of ACCESS in climate simulations and hydrological applications.
- Incorporation of new data derived from satellite measurements into numerical models improves forecast accuracy, and has particular relevance to applications such as tropical cyclone track forecasting.
- The IPCC has identified the causes of variations in methane growth rates as a priority area of research. Improving our understanding of changes in concentrations of greenhouse gases such as methane helps fulfil Australia's international commitments by contributing to the work of the IPCC.
- Extension of the OCF system to wave height and ocean wind forecasts will improve the accuracy of marine forecasts.
- Extension of the OCF system to produce forecasts for every point on a five-kilometre grid will assist the Bureau in providing automated forecast guidance for any location in Australia.
- The Real Time Forecast Verification system will be central to the measurement of very, short-range forecast performance during the Beijing Olympics, where it should help forecasters make best use of the information available to them. In the longer term it will assist the improvement of the Bureau's thunderstorm forecasts by providing researchers with feedback on how to improve their nowcast algorithms.
- The Bureau's involvement in the Integrated Marine Observing System provides researchers with a wide array of observational marine and oceanographic data, which are used in research covering short-range to climate time-scales. The *Southern Surveyor* project therefore contributes both to meeting the needs of marine climate research in Australia, and to fulfilling Australia's role in international programs of ocean observing.
- A better understanding of measurements from tidal gauge networks including the operation of local influences is important for assessing whether a location is useful for

tsunami detection and warning purposes, and also provides guidance for future expansion of the sea-level observing network.

- The forecasts from OceanMAPS are used by stakeholders such as the Royal Australian Navy, commercial shipping and recreational boating. The operational use of OceanMAPS provides the Australian community with services based on leading-edge ocean prediction science and applications.

RESEARCH RELATED ACTIVITIES

SCIENTIFIC PUBLICATIONS

The publication of scientific and technical results is a vital element of research and development work in the Bureau of Meteorology. During 2007-08 a total of 207 peer-reviewed papers were published by CAWCR scientists in books and international journals, and 138 internally reviewed research reports were produced.

Research staff are continually involved in the peer review of scientific research carried out across the Bureau, in addition to acting as reviewers for work from other organisations and peer-reviewed journals. CAWCR staff operate the editorial office and oversee the publication of the *Australian Meteorological Magazine*, a journal on southern hemisphere atmospheric, ocean and related sciences which is published by the Bureau in cooperation with the Australian Meteorological and Oceanographic Society. Scientists from CAWCR also serve on the editorial board of the *Australian Meteorological Magazine* and other international scientific journals.

The inaugural CAWCR Modelling Workshop publication, on the theme 'Physical Processes and Modelling of the Water and Carbon Cycles', was produced and distributed ahead of the workshop in November, and is also available on the Bureau's website.

COLLABORATION

The Bureau is involved in two major collaborative research efforts – CAWCR itself, and ACCESS - as well as a number of smaller joint initiatives.

Meteorological and oceanographic research in Australia is carried out by the Bureau and CSIRO, a number of university groups and, to a lesser extent, by other government departments and agencies and the private sector. In recent years, the Bureau and CSIRO, as the two major agencies engaged in atmospheric research, have worked closely together to ensure that plans for atmospheric and related research are coordinated effectively, and to identify joint research activities and areas of collaboration at the project level. This close collaboration culminated this year in the formal establishment of CAWCR, with research now performed by integrated Bureau/CSIRO research teams.

ACCESS forms the central core of CAWCR, and as an initiative involving the Bureau, CSIRO and the university sector, it is further strengthening the already effective collaboration within Australia on earth system modelling. The Bureau already has a formal agreement with the UK Met Office allowing Australia to use the UK Unified Model, a high-powered computer-based climate and weather prediction program, and to adapt it for Australian conditions. This collaboration will allow Australia to maintain a world-class climate, weather

and earth system modelling capability. A two-way exchange of knowledge under the agreement is underway, with, for example, plans for tropical modelling expertise developed within Australia to be incorporated into the Unified Model. During 2007-08 once again several Australian scientists undertook placements in the UK Met Office to further modelling developments.

Smaller collaborative research initiatives in which the Bureau is involved include Bureau contributions to the Australian Research Council Earth System Science Network. Collaborative research is also sponsored by the Department of Climate Change (which now encompasses the former Australian Greenhouse Office), principally within the Australian Climate Change Science Programme, and by the Royal Australian Navy. The Australian Tsunami Warning System involves extensive collaboration with Geoscience Australia and researchers in Indian Ocean countries, the US and Japan. The GFE project encompasses collaboration with the Global Systems Division of the US National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory as well as with other parts of NOAA. Research on climate model ensembles and multi-model ensembles is being undertaken within the Asia-Pacific Economic Cooperation (APEC) Climate Network. The China-Australia Climate Action Partnership provides an umbrella arrangement for collaboration with China on land use and arid climates. CAWCR scientists have taken a lead role in the development of a range of nowcasting products and systems which will be deployed at the Beijing Olympics in August 2008 via the Forecast Demonstration Project, and in training forecasters from the China Meteorological Agency in their use.

Even minor collaborations can have important outcomes. Examples include: a study with Birds Australia and universities on the relationship between bird breeding and climate change; application of POAMA seasonal forecasts of ocean temperatures along the east coast of Queensland by the Great Barrier Reef Marine Park Authority to the prediction of coral bleaching in the Great Barrier Reef; and a project with the National Institute of Water and Atmospheric Research in New Zealand on temperature extremes.

Collaborations are enhanced through outputs such as publications and seminars, many of which involve research partners. CAWCR hosts a regular seminar series at the Bureau on topics of broad scientific interest which is open to the public as well as Bureau staff. Of more than 75 seminars hosted in 2007-08, at least 25 were given by CAWCR scientists and the remainder by invited experts and collaborating scientists.

COOPERATIVE RESEARCH CENTRES

To further improve the coordination of meteorological and related research in Australia and to provide support for the strengthening of programs in meteorology at Australian universities, the Bureau participated in several multi-agency agreements for the operation of research centres in meteorology and related disciplines under the Government's Cooperative Research Centre (CRC) program. During 2007-08, the Bureau participated in:

- the CRC for Antarctic Climate and Ecosystems, with the University of Tasmania, the CSIRO, and the Australian Antarctic Division as core partners, and six other supporting partners;
- the eWater CRC at the University of Canberra with more than 40 other participants, in-

cluding a range of industry, government (national, State and local) and university partners; and

- the Bushfire CRC with nineteen other core participants, including emergency and fire authorities at State and Federal levels, and Australian and New Zealand universities.

NATIONAL RESEARCH PRIORITIES

The Bureau of Meteorology aligns with, and works to, the National Research Priorities (NRP) in a manner consistent with its statutory responsibilities under the Meteorology Act. The resources and priorities for the Research and Systems Division of the Bureau and CAWCR are allocated within that context, with little freedom or discretion to tackle NRP that are not within the Bureau of Meteorology's core mission.

The Bureau's major contribution to the NRP relates to An Environmentally Sustainable Australia due to its close relationship to the Bureau's functions and objectives. A total of 30.8 per cent of research funding is devoted to supporting this priority. The NRP of Safeguarding Australia continues to increase in relative importance for the Bureau of Meteorology because of the strong collaboration with the Royal Australian Navy and the evolving role of the Bureau in support of national infrastructure. A total of 15 per cent of the Bureau's research resource supports this priority. The implementation of ACCESS led to a re-alignment and focusing of resources and activities in Frontier Technologies as well as Critical Infrastructure.