Australian Government
Bureau of Meteorology

RESEARCH AND DEVELOPMENT PROGRAM

ANNUAL HIGHLIGHTS 2014–15

Contents

The Research and Development Program 2014–15

Our research and development (R&D) supports achievement of our organisational mission by providing a strong science capability that enables our weather, climate, water, space and ocean products and services.

The R&D Program objective is to:

'apply advanced scientific knowledge related to weather, climate, oceans and hydrology and meet the current and future system and service needs of the Bureau— with a focus on the development and application of a world class coupled climate and earth system simulator'

Development of the Australian Community Climate and Earth System Simulator (ACCESS) continues to underpin advances in weather forecasting, ocean forecasting and the climate prediction services provided by the Bureau. In collaboration with CSIRO, Australian universities and international agencies (especially the United Kingdom Met Office), the Unified Model that is a core component of the ACCESS Earth system models continues to enhance our ability to predict extreme events that affect Australia.

We are also continuing to improve our understanding of atmospheric processes through modelling and observation. We are applying this knowledge to weather and climate prediction systems for advanced forecasting and environmental services. This includes prediction and monitoring of severe weather and environmental hazards, and seasonal and long-term climate patterns.

Our water information research is undertaken through the Water Information Research and Development Alliance (WIRADA), a co-invested partnership with CSIRO. This alliance continues to deliver the science needed for operational improvements in data exchange, landscape water balance and flow forecasting.

We re-framed our long-term weather and climate research partnership with CSIRO during the year into the Collaboration for Australian Weather and Climate Research (CAWCR). In future CAWCR will focus on research projects involving CSIRO and Bureau scientists working together. CAWCR's mandate is to advance earth-system science, with the express purpose of improving our capability to predict weather and climate for the benefit of Australia and beyond. This is a substantial challenge that can only be achieved through collaboration.

We were also successful in winning a significant role in the new National Environmental Science Programme's Earth Systems and Climate Change Hub, which will undertake research from 2016 under the leadership of CSIRO.

I thank the R&D Program staff for their contributions, successes and support through the last year.

Dr Peter May

Head of Research

R&D governance, strategy and management

This year has delivered some major changes in R&D governance and strategy for the Bureau, influencing both the R&D Program and the broader research and development activities occurring across the organisation.

R&D arrangements in the Bureau

The Director of Meteorology commissioned a review of R&D arrangements in the Bureau in 2014. He sought advice on the effectiveness of the arrangements that we had in place for specifying, conducting and utilising research, including the arrangements for the then Centre for Australian Weather and Climate Research (CAWCR).

Recommendations to the Director by the review author, Dr Sue Barrell, resulted in twenty-three actions. These included establishment of a new CAWCR agreement, an R&D Oversight Board, an R&D Leadership Team and a designated lead for scientific computing. Other actions addressed planning and management of the extensive portfolio of Bureau R&D activity, both within and external to the R&D Program, with major focus on development of a Bureau R&D Strategy.

A new R&D Strategy: Services from science

A Research and Development Strategy 2015–20 was developed to set the direction for R&D in the Bureau. It reaffirms and clarifies the key contributions that science and engineering have in achieving the Bureau's mission. It also recognises and provides a balance between services arising from science and science undertaken for services. The former reflects the new and innovative service directions that arise from scientific efforts, while the latter focuses sharply on the science required to meet organisational business needs.

Our five research themes

Meeting the many demands on our R&D capability requires a cohesive and synergistic approach to our organisation-wide research and development effort. Our R&D integrates knowledge of fundamental processes across our business domains with modelling and assimilation of associated natural phenomena, using low-latency earth observational systems to provide accurate information on current and past conditions. These are brought together within a scientific computing environment that delivers the services required to produce positive outcomes for Australian communities.

Through 2015 I led implementation of the actions arising from the review of R&D arrangements under the oversight of the Deputy Director, Environment and Research, Mr Graham Hawke. A phased approach was taken to implementation of actions, many of which are now part of our ongoing R&D planning and management practices.

I thank research team members and leaders, senior managers and our Executive for their encouragement and support for this work.

Dr Robert Argent

R&D Manager

Research Programs

The R&D Program has three primary functions: Earth systems modelling; weather and climate information; and water research. The first two are undertaken internally through our R&D Program while the third is performed via external research partnerships—the most significant of which is the Water Information Research and Development Alliance (WIRADA).

Earth Systems Modelling (ESM)

Leader: Dr Kamal Puri

Objective: To develop and refine the Australian Community Climate and Earth System Simulator (ACCESS) for use in weather forecasting, ocean forecasting, seasonal prediction and climate prediction services provided by the Bureau.

ESM addresses our high-priority business needs by building a national capability in weather and ocean prediction and in climate and Earth system simulation. This is done through a large involvement in the collaborative national and international development of ACCESS. These developments provide timely and accurate information—including uncertainties—on daily weather and environmental conditions, monthly-to-seasonal outlooks and future climate projections. ACCESS thus informs decision-making across public, government and industry sectors.

To provide the wide range of capability required of the ACCESS framework, we have steadily evolved its use of common component elements across multiple applications. For example, the core atmospheric component (the 'Unified Model') currently drives numerical weather prediction (NWP) and climate applications, and in the future will also underpin our seasonal modelling. R&D development of ACCESS runs the gamut from strategic research (e.g. model parameterisation and initialisation methods) through to preparing robust numerical guidance systems suitable for operational implementation. To meet the needs of a largely coastal population, several modelling application systems are supported under ESM—from high-resolution NWP systems around the major cities, through to global ocean models and, increasingly, high-resolution systems for coastal impacts.

Weather and Climate Information (WCI)

Leader: Dr Beth Ebert

Objective: To advance understanding of atmospheric processes and enhance the ability of the Bureau to observe and predict weather, climate and extreme events that affect Australia. The program delivers new knowledge, advice and applications to assist decision-making for government and weather- and climate-sensitive industries.

WCI combines skills in observing, predicting and understanding high-impact weather and climate, and developing advanced forecasting systems to meet a range of internal and external user needs. R&D areas include seasonal prediction science, climate dynamics, diagnostics, processes and projections, and high-impact weather affecting Australia (including tropical cyclones, bushfire, fog, volcanic ash, thunderstorms and heavy rain). WCI is responsible for scientific development of many of the Bureau's key operational forecasting systems and informing its service methodologies. It provides advanced in-situ and remotely sensed observations, analyses, and related science, and plays a key role in the assessment and demonstration of emerging observing technologies for Bureau application.

Water Research

Objective: To support strategic research and development that enables the Bureau's water information function.

Our Water Research program plans, supports and manages the research required to enable the water information functions defined for us in the Water Act (2007). This research operates across a number of projects conducted by both external partners, as well as internal (Bureau) contributions to research.

The primary vehicle for water research is WIRADA, a co-investment partnership between CSIRO and the Bureau. WIRADA unites CSIRO's research and development expertise in water and information science with the Bureau's operational role in hydrological data management, analysis, and prediction. The three themes of WIRADA research are informatics/data services, water balance modelling, and water forecasting and prediction.

Science achievements

A diverse range of scientific and operational outcomes were achieved in 2014–15, highlighting the contributions made to the Bureau's mission by our scientists and engineers. A selection of our achievements is described below.

Atmospheric modelling and numerical weather prediction (NWP)

Leaders: Mr Robin Bowen, Dr Gary Dietachmayer, Dr Peter Steinle

Program: ESM

Numerical weather prediction

In 2014–15 we focused on evolving the Australian Parallel Suite v2 (APS2) systems to operational standard, and laying the groundwork for APS3 development. At the time of operational handover, a four month trial of APS2 ACCESS-G (Global) over the Australian region demonstrated a gain of 6–8 hours forecast lead-time (for the same accuracy) over the current operational system. Verification against observations was similarly promising, with improvements in screen temperature accuracy of 4 per cent and 10 m wind of 2 per cent.

APS2 ACCESS-R (Regional) development included enhanced land-surface characterisation, introduction of improved data assimilation, and computational optimisation to support the very large amounts of data input/output required by the model. As a result forecast lead-times increased by around four hours, and we saw a 10 per cent reduction in 10 m wind errors. Handover to the Bureau National Operations Centre is underway.

Computational optimisation enabled us to develop APS2 ACCESS-C (City) as 1.5 km resolution systems. The move to high-resolution enables the new ACCESS-C to run without the currently used 'parameterised' convection (in 'convection permitting' mode), improving rainfall accuracy in particular.

Preparation for APS3 included improved efficiency of collaboration with the UK Met Office, particularly through greater alignment of our technical infrastructure and the use of shared software repositories. Local introduction of the Unified Model (UM) v10.1 and the Met Office parallel-suite 36 form the basis of an early prototype APS3 ACCESS-G.

One example of the application of NWP systems outside our key operational focus was the evaluation of the potential for ACCESS-R and ACCESS-C to support solar-energy forecasts—including model evaluation against Bureau baseline radiation measurements, and identification of required parameterisation improvements.

Operational advances

- Improvements to operational fog/visibility fields in ACCESS-R;
- upgrading the operational APS1 ACCESS-C system on 5 August 2014—including new high-resolution topography and improved land-surface characterisation;
- adopting an improved high-resolution topography dataset (previously introduced for ACCESS-C) in ACCESS-R, which became operational on 1 December 2014; and
- handing APS2 ACCESS-G over to the Bureau National Operations Centre in May 2015 in preparation for operational implementation.

Marine

Leader: Dr Eric Schulz

Program: ESM

Bluelink

Bluelink3 support was provided through 2014/15, formally ending on 30 June. Our team focused on preparing the new global ocean prediction system, OceanMAPS3, for operational implementation in late 2015. OceanMAPS3 will introduce a global 0.1° resolution system, offering improved forecasts in key areas of interest for stakeholders. A 12-month hindcast performed using the operational observations showed an improvement in performance over the current system. We also completed a defence services project to establish a web-based ocean forecast monitoring and verification framework for the Royal Australian Navy. This included the capability to view ocean forecasts and to verify and assess the forecast performance using internationally agreed inter-comparison standards.

eReefs

eReefs is a five-year project to establish a range of Great Barrier Reef water quality services—in particular, the discharge of nutrients from coastal catchments into the reef lagoon and their circulation within the reef complex. A prototype marine modelling system was established based on a 4 km implementation of the Regional Ocean Modeling System (ROMS) nested within OceanMAPS and driven by atmospheric forcing. The ocean state and circulation are constrained by a daily data assimilation cycle, which uses an ensemble optimal interpolation method based on new assimilation software. Preliminary hindcasts assimilating altimetry, sea surface temperature and in-situ profiles have demonstrated comparable or better performance to that obtained in the region from OceanMAPS.

Storm surge

A four-year project (2013-17) will deliver a storm surge warning system for Australia. In 2014–15 we focused on event-driven storm surge forecasting systems for the tropics. The Queensland system comprises a 2 km-resolution ROMS hydrodynamic model that incorporates a 500 m resolution bathymetric data set for Australia. We established test case scenarios describing historic storm events and associated observation data sets in order to refine and scientifically validate the hydrodynamic model. We also initiated a prototype Tropical system configuration.

Operational advances

The coastal sea level forecasting system was transferred to the Bureau National Operations Centre. This system has been adopted by Melbourne Water and was able to capture the five-day surge event in Port Philip Bay, improving the management of flood water for Patterson Lakes. The Queensland storm surge forecasting system was transitioned to our high-performance computing infrastructure on 1 July 2015, for demonstration during the coming storm season.

Seasonal prediction

Leader: Dr Oscar Alves

Program: ESM

A strategic change: ACCESS-S (seasonal)

Our current seasonal forecasting system, POAMA-2, is low-resolution (250km) and based on old atmosphere, land and ocean models. In a strategic change over the coming two years, we will implement a higher-resolution (60 km), next-generation seasonal forecast system (ACCESS-S). This will be done through a strengthened collaboration with the Met Office, by jointly developing their coupled model under the ACCESS framework. Following detailed evaluation, a new strategy will be implemented through two phases:

1. In 2016, transferring a fast-tracked system (ACCESS-S1) to Bureau operations for six-month forecasting based on Met Office initial conditions, the Met Office GC3 coupled model, local ensemble perturbations and an extended (25-year) hindcast set run locally.

2. In 2018, transferring a complete system (ACCESS-S2) to Bureau operations for forecasts of at least nine months and using the latest available version of the Met Office global coupled model. This will include improvements from Australian science, a locally-developed coupled assimilation scheme based on the Kalman filter, an ensemble generation scheme, and a comprehensive 35-year hindcast set.

Overall, this approach will rapidly move us to the next generation of seasonal forecasts and facilitate future upgrades so as to maintain best practice. It will enable us to keep up with overseas developments, both in terms of resolution and latest physics.

We have implemented the Met Office GC2 coupled model on the National Computational Infrastructure (NCI) supercomputer, and a set of hindcasts are underway to evaluate the model performance. We have also set up real-time access to the hindcasts and forecasts generated by Met Office.

Services and applications

A range of products are now available operationally from POAMA-2. This includes the operational seasonal climate outlook, northern rainfall onset forecasts, hydrological forecasts, and forecasts of ocean temperatures in the Great Barrier Reef. A range of trial products are also available on the POAMA website accessible by registered users, including:

- Australian and global temperature and rainfall forecasts, including tercile probabilities;
- forecasts on the multi-week timescale;
- heatwave products including quintile/decile probabilities, number of extreme days forecasts and probabilities of moderate/severe/extreme heatwaves;
- forecast of the Madden–Julian Oscillation;
- station/region-based forecasts of temperature and rainfall distributions (including major horticultural and agricultural regions and a selected set of trial stations); and
- forecasts of the major climate drivers, including El Niño–Southern Oscillation (ENSO), Indian Ocean Dipole, Madden–Julian Oscillation, Southern Annular Mode, Blocking Index, and the Subtropical Ridge Position.

POAMA-2 hindcasts have also been made available through various datasets and through an OPeNDAP server to several applications groups and projects. Hindcasts were interfaced to a pasture model, Yield Prophet and AusFarm (agricultural systems analysis model). A CSIRO-led project using a crop growth model driven by POAMA-2 hindcasts demonstrated that POAMA-2 can significantly increase farming profitability in a set of case-study farms in eastern Australia.

Observations and high-performance computing

Leaders: Dr Alain Protat, Mr Robin Bowen

Program: ESM/WCI

Field programs: High Ice Water Content

Aircraft cloud radar and in-situ microphysical probes from the Darwin High Altitude Ice Crystals – High Ice Water Content campaign helped characterize the microphysical properties of high ice water content regions in deep tropical thunderstorms. We derived a robust relationship between ice water content, radar reflectivity and temperature, providing an opportunity for real-time use in mitigating this threat to civil aviation. We participated in a second campaign in French Guiana to complement the Darwin dataset. Thirteen cloud microphysics sensitivity simulation tests with the 1.5 km resolution ACCESS model showed that the model is currently advecting too much rain above the freezing level, and that model ice depositional growth is too efficient at removing super-saturation. An additional rain freezing model parameterisation has been included in ACCESS, helping to reduce this model error.

Marine National Facility Research Vessel Investigator

The maiden research voyage of the RV Investigator was successfully completed in early 2015. Three Bureau researchers contributed to the success of this ten-day Southern Ocean journey. Extensive cloud, precipitation and shortwave/longwave radiation data were collected with our bi-static single-polarization Doppler cloud radar, the new dual-polarization weather radar, and our radiation package. These data are complemented by the extensive suite of aerosol measurements collected by CSIRO. This dataset will be used to quantify for the first time errors in cloud radiative forcing estimates from satellite over the Southern Ocean, to evaluate new rainfall products from the NASA Global Precipitation Mission and to assess how well the 12 km-resolution ACCESS-R simulates the cloud–radiation interactions over the Southern Ocean.

Scientific computing, the National Computational Infrastructure (NCI) and the Bureau's new supercomputer

Much of our high performance computing research effort moved to the NCI during the year. ESM staff contributed to the National eResearch Collaboration Tools and Resources (NeCTAR)-funded Climate and Weather System Laboratory project at the NCI, including provision of a web interface. The Met Office unified model (UM) Rose/Cylc scheduling and management infrastructure has been fully implemented at the NCI, and was used in implementing the UK Met Office GC2 system.

In partnership with CSIRO Plant Biosecurity, we developed and implemented a cloud-hosted atmospheric transport modelling service on the NCI infrastructure. This 'software as a service' platform exposes atmospheric transport modelling software to web clients, including providing the service infrastructure for the Tool for Assessing Pest and Pathogen Aerial Spread (TAPPAS) developed by CSIRO and Intersect Australia.

The Science Repository Service run by the Met Office for worldwide collaboration on the UM code, scripts and infrastructure became available in early 2015. Bureau staff and ACCESS collaborators are using this to contribute to joint code development.

Scientific computing experts played a major role in benchmarking and technical evaluation of tenders for the new supercomputer, and also contributed to the ACCESS optimisation project.

Operational advances

Streamlined processes were put in place for transition to operations of ACCESS NWP upgrades. These successfully supported transition of the APS2 global model, and will also underpin transition of the regional and other component systems of APS2.

Forecasting systems and high-impact weather

Leaders: Dr Peter Steinle, Dr Jeff Kepert, Dr Gary Weymouth

Program: ESM/WCI

NexGen Forecast and Warning System

The NexGenFWS rollout project was completed in late 2014 with the introduction of the Graphical Forecast Editor into operations in the Northern Territory. The Graphical Forecast Editor now produces gridded weather forecasts and warnings to seven days at least every 6 km across the whole of Australia. Previously seven-day forecasts had only been available in text form at six capital city locations. The upgraded forecasts and warnings are available to the public in graphical form through the 'MetEye' service on the web, fulfilling the NexGenFWS aims of providing forecasts and warnings where and when people need them. Along the way, the project picked up many competitive local and international awards, reflecting the utility of the upgraded Bureau services and the quality of the project work across a number of Bureau divisions.

Sydney Forecast Demonstration Project

Two key recent developments to improve 0–12 hour forecasts are: high-resolution (1.5 km) NWP systems that make use of radar data; and improved radar quality control, visualization and quantitative rainfall products. These were tested over 70 days in a real-time forecasting demonstration in late 2014, where a parallel mini-forecast office was set up in Sydney to allow operational forecasters and researchers to work closely together to use and evaluate the new products.

Overall the new systems were well received—showing the potential for improved forecasts and warnings of the timing, location and mode of convection; topographic effects on wind, dew point and temperature; and a more realistic depiction of low cloud and fog. The 1.5 km NWP system was judged to be better than existing operational systems on the two most significant events during the demonstration—near record temperatures on 29 September and extreme (87 kt) winds on 14 October.

Further opportunities for improvement were identified—such as incorporating ensemble prediction, improving radar quality control and providing better integration between systems. It was also clear that a demonstration project provides an excellent mechanism for trialling experimental systems— with major benefits arising from the close interaction between the researchers and forecasters.

High-impact weather

We continue to conduct high-resolution, post-event case studies of significant fire events, with the aim of helping to understand meteorological factors that may have contributed to the fire severity. We investigated two cases in which mountain wave activity contributed to strong winds over a fire and hence its rapid spread. We have also extended our numerical model of bushfire plumes to study the problem of ember transport. Ember transport, and consequent spot fire formation, is a major contributor to fire spread and has been observed more than 30 km

ahead of a fire. We are developing a better understanding of spotting, which will lead to better ways of predicting this mode of fire spread.

We began a new project to extend our existing tropical cyclone prediction model from three to five days range, to provide better warnings for industry and the public. As part of this project, we have connected a wave model to the tropical cyclone model, so for the first time have the capability to provide good quality wave forecasts in tropical cyclone situations. We are also investigating methods of bias-correcting tropical cyclone structure in coarse-resolution models, so that ensemble prediction systems can be processed to provide better-calibrated probabilistic forecasts.

Climate studies and climate change

Leaders: Dr Harry Hendon, Dr Scott Power

Program: WCI

Climate change in Australia: Natural Resource Management regional projections

In early 2015 the Bureau and CSIRO released new projections for Australia that provide national and regional information on how the climate may change to the end of the 21st century. The outcomes of the Natural Resource Management Projections R&D program included the public release of a national technical report, eight regional reports, eight regional brochures and a website providing access to the reports, datasets, information and tools for utilising projections data. These projections are the most comprehensive ever released for Australia, and have been prepared with an emphasis on informing impact assessment and planning in the natural resource sector. Information has been drawn from simulations based on up to 40 global climate models. This research has confirmed that most of the changes observed over recent decades will continue into the future.

Australian Climate Change Science Programme (ACCSP)

Climate science highlights for the year, conducted under seven different ACCSP projects, included a new method for evaluating cloud feedbacks in ACCESS; experimentation with ACCESS to improve understanding of La Niña events affecting Pacific Ocean rainfall, evidence showing that Pacific warming has emerged from background variability and that this is due to increasing greenhouse gas concentrations, new methods for understanding the range of tropical rainfall projections, improved understanding of the mechanisms responsible for tropical cyclone development, improved understanding of the factors causing spring 2014's record Australian temperatures, and an initial investigation of long-term lightning trends.

Victorian Climate Initiative

We investigated the relationship between the sub-tropical ridge and rainfall across south-eastern Australia, focussing on representation of this relationship in global climate models. All climate model simulations showed that the sub-tropical ridge will intensify and move south under a future high-emissions scenario, confirming likely further reductions in Victoria's cool season (April to October) rainfall. The skill of global climate models in capturing extended periods of drought (e.g. the millennium drought—over ten years without a 'wet' month) was also investigated. The models show expected associations between key climate drivers during 'no-wet' spells, and suggest that frequencies of 'no-wet' spells in the 21st century will be similar to those in the 20th century. However, the longest simulated 'no-wet' spell in either the past or future century was around 6.5 years, shorter than the millennium drought, highlighting an area for further investigation.

Seasonal prediction science

ENSO is the most predictable component of the Australian climate system and the most important driver of rainfall variability across Australia. ENSO predictability is found to be highest during decades of high ENSO variability. The Inter-decal Pacific Oscillation (IPO) was shown to affect ENSO variability, and the swing to the cold phase of the IPO since 1999 can account for recent reductions in ENSO variability and predictability. However, impacts of ENSO on Australian climate also increased in this period. The recent upward trend in ocean temperatures in the tropical Indian Ocean and western Pacific, due in part to the swing to the cold phase of the IPO since 1999, was found to have significantly amplified (10–30 per cent) the springtime rainfall anomaly over eastern Australia during the 2010–11 La Niña event. Projected warmer sea surface temperatures in the tropical Indian and western Pacific Oceans may increase the risk of extreme rainfall in eastern Australia during future La Niña events. However we can also can also expect epochs of reduced impact of La Niña events when the IPO is in a warm phase. Although swings in the IPO are not predictable, persistence of the IPO is long and therefore its impact can be included in seasonal forecasting models. As a consequence, the extreme rainfall in spring 2010 was shown to be largely predictable at least one season in advance.

Water research through WIRADA

WIRADA Director: Dr Robert Argent

Program: Water research

Informatics: data services

Our informatics research focussed on international standards development and Linked Data. The standards work delivered three proposed international water data markup language standards: GroundwaterML2.0; WaterML2.0 part 2 (covering ratings, gaugings and sections); and TimeseriesML. These are being adopted internationally by water information agencies, and provide a foundation for effective and efficient exchange of water data and information. Linked Data standards and technologies are the foundation of future web-based data services. We used Linked Data technologies to publish current water observations and link these with previously unconnected web-based data sources.

Australian Water Resources Assessment Modelling System (AWRAMS)

We implemented an improved landscape component of AWRAMS across continental Australia. When tested against peer models, it performed better than other continental-scale models and similar to or better than individually-calibrated ‘lumped’ conceptual models, supporting more timely and efficient catchment-scale rainfall-runoff modelling for all of Australia. The AWRAMS river system component was implemented across the Murray–Darling Basin and other National Water Account regions. Although calibrated regionally, rather than at river reach scale, performance within various Murray–Darling Basin catchments was found to be comparable to that of the models used for Murray–Darling Basin planning.

Flow forecasting

We have made major scientific advances in both short-term and seasonal forecasting areas. Short-term forecasting improvements included: increased accuracy of rainfall forecasts as input to hydrological models; improved estimates of rainfall uncertainty; a better understanding of relative performance of alternative rainfall-runoff models; improved estimation of hydrological model errors; and a better and more functional version of the model suite used for short-term forecasting (Short-term Water Information and Forecasting Tools v2). Seasonal flow forecasting research focused on the science needed to increase accuracy, extend lead time, distribute forecasts into shorter time periods, and expand the number of sites across Australia for which reliable seasonal forecasts can be made. Achievements this year included further development of the Forecast Guided Stochastic

Scenarios model and major improvements in merging statistical and dynamic-based forecasts, offering us a forecast product that is more accurate and easier to interpret and communicate.

Operational advances

We have implemented WIRADA science to expand its prototype deterministic short-term streamflow forecast service to an additional 51 catchments across Australia. It now includes 114 forecast locations in 62 catchments spread throughout all States and territories across Australia. The current service is available to 150 registered users for testing, and will be available to the public in September 2015.

In the past year we have implemented an operational AWRAMS that is platform-independent, efficient, functional, and easy to maintain. This system underpins the Bureau's water information services, which are mandated through the *Water Act 2007* and include the National Water Account. It also sets a strong foundation for us to develop further enhanced water information products and services such as the Water in Australia situation report.

Partnerships and additional highlights

R&D in partnership

Our R&D capability lies with our scientific cohort, other Bureau staff and our national and international partners. This is especially apparent in large-scale activities such as observation systems, numerical prediction, and forecast methods and processes. In these, user demands far exceed the capabilities of any one organisation or Bureau branch, and collaborative partnerships are essential.

Internationally, our major partners include the UK Met Office, the US National Oceanic and Atmospheric Administration, and the meteorological agencies of Japan and Korea. Nationally, we continue to work closely with Australia's environmental research sector—especially CSIRO and the Australian Research Council Centre of Excellence for Climate System Science.

We also benefit from national research infrastructure programs—particularly those providing high performance computing (National Computational Infrastructure) and underpinning observational capability (The Integrated Marine Observing System and the Terrestrial Ecosystem Research Network).

Additional highlights

This report details many of the science and service highlights of 2014–15. A selection of additional individual, team and other highlights is given below.

- Dr Kamal Puri was awarded a 2015 Australian Public Service Medal for outstanding public service in meteorological science.
- Dr Beth Ebert received the RH Clarke Award at the 2015 Australian Meteorological and Oceanographic Society Conference.
- The Nowcast Data Service Trial (developed by the Radar Applications Team to provide a web interface to high spatial resolution radar rainfall estimates and short-term rainfall forecasts) was selected by the Smart Water Fund as a highlight, showing the great work and return on investment obtained from the fund over its 12 years of operation.
- The ACCESS Coupled Model documentation paper for the CMIP5 submission (Bi et al., 2013, Aust. Met. Oceanog. Journal) was noted in Web of Science as a 'highly cited paper'—as of November—December 2014, the paper received enough citations to place it in the top 1 per cent in the Geosciences field.
- The eighth CAWCR Annual Workshop was held 10–12 November 2014, with the theme 'Coasts and extremes'. Session topics included tropical cyclone dynamics and climatology, storm surge and coastal inundation, coastal adaptation, coastal ocean modelling and coincident extremes.
- We contributed forecasts and hindcasts from the current operational seasonal prediction system to the World Meteorological Organization 'Sub-seasonal to Seasonal' prediction project.
- We hosted the fourth International Radio Occultation Working Group workshop, which was well attended by leading radio occultation scientists and program managers from Australia and 15 other countries. Attendees included satellite providers, scientific data processors, weather services, space weather services and climate monitoring scientists.

- We hosted the 2015 International Symposium on Environmental Software Systems, with more than 60 delegates from 14 countries. Delegates praised both the quality of the scientific program and the symposium arrangements.

- Dr Alan Seed organised and chaired the second Workshop on Heuristic Nowcasting, held in Munich 30–31 August 2014. The workshop was by invitation only and was attended by 25 leading scientists in the rainfall nowcasting field.

- Dr Kamal Puri attended the meeting of the Korea Institute of Atmospheric Prediction Systems Science Advisory Committee in October 2014, and the meeting of the Met Office Science Advisory Committee in November 2014, in his capacity as member of both committees. He made an invited presentation on UM Partnerships at the Met Office Science Advisory Committee meeting.

- Dr Peter Steinle was invited to co-chair the World Meteorological Organization Nowcasting and Mesoscale Weather Forecasting Research Working Group.

- Dr Julie Arblaster was invited to serve on the National Committee for Earth System Science of the Australian Academy of Science.

Glossary

ACCESS	Australian Community Climate and Earth System Simulator
ACCESS-C	City-scale ACCESS model
ACCESS-G	Global-scale ACCESS model
ACCESS-R	Regional-scale ACCESS model
ACCESS-S	Seasonal timeframe ACCESS model (stages: ACCESS-S1, ACCESS-S2)
APS	Australian Parallel Suite (version 1, 2 and 3 – APS1, APS2, APS3)
AWRAMS	Australian Water Resources Assessment Modelling System
CAWCR	Collaboration for Australian Weather and Climate Research (formerly the Centre for Australian Weather and Climate Research)
CMIP5	Coupled Model Intercomparison Project, phase 5
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ENSO	El Niño–Southern Oscillation
ESM	Earth System Modelling (research program)
GC2, GC3	Global Coupled model, version 2 and 3 (future versions: GC4, GC5)
IPO	Inter-decal Pacific Oscillation
NASA	US National Aeronautics and Space Administration
NCI	National Computational Infrastructure
NexGenFWS	Next Generation Forecast and Warning System
NWP	Numerical Weather Prediction
OceanMAPS3	Ocean Modelling, Analysis and Prediction System, version 3
OPeNDAP	Open-source Project for a Network Data Access Protocol
POAMA	Predictive Ocean Atmosphere Model for Australia (version: POAMA-2)
R&D	Research and Development
ROMS	Regional Ocean Modeling System
RV	Research Vessel
UM	Unified Model
WCI	Weather and Climate Information (research program)
WIRADA	Water Information Research and Development Alliance

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