



Australian Government
Bureau of Meteorology

BUREAU OF METEOROLOGY

RESEARCH AND DEVELOPMENT
STRATEGY 2015–2020

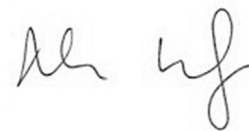
Foreword

I am pleased to present the Bureau's Research and Development Strategy 2015–2020. This strategy formalises our ongoing commitment to world-class research that supports and advances the quality, breadth, timeliness and utility of our products and services for the benefit of all Australians.

This strategy supports the Bureau's Strategic Plan 2015–2020. It targets research outcomes that will deliver the next generation of meteorological, climate and water product and service advances—essential for the future. It will strengthen the relevance and use of our products, reduce production costs, expand investment and allow our staff to focus on functions of higher value, as we work to provide all Australians with environmental intelligence for safety, sustainability, security, well-being and prosperity.

The Research and Development Strategy 2015–2020 has five research themes: scientific computing, Earth observing systems, fundamental processes, modelling and assimilation, and delivery of services from science. These themes reflect the science priorities that will ensure our systems and services continue to advance with users' needs, as they have done for more than 100 years. Recently, these advances have included more detailed and accurate weather forecasts over longer lead times, better warning and prediction of cyclones and other severe weather events, and projections of future climate.

Recognising the vital role that research and development plays in delivering our mission, I commend this strategy to you.



Dr Rob Vertessy
Director of Meteorology and CEO

R&D excellence transforming the Bureau's business

Contents

Summary	4
R&D and the Bureau.....	6
Services from science.....	8
Modelling and assimilation.....	10
Fundamental processes.....	12
Earth observing systems.....	14
Scientific computing	16
Framing the strategy.....	17
Implementing the strategy	18

Summary

The Bureau of Meteorology's research and development (R&D) team is characterised by a relentless drive to solve problems and to wring the greatest value out of ever-evolving technology and data streams. Their visionary belief in a world where broader knowledge creates smarter, better services has powered the Bureau's ability to meet user needs in ways that could barely have been imagined a few short years ago.

R&D is a major driver of advances in the quality, breadth, timeliness and utility of the Bureau's products and services. It contributes directly to the safety, sustainability, well-being and prosperity of all Australians. We have legislated responsibilities to advance meteorological science and to improve understanding of Australia's water resources through research. These scientific endeavours lay the foundation for future improvements in services and products.

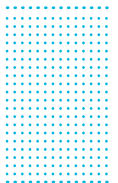
Our national weather, ocean and climate services are supported by world-class modelling and forecasting systems that we have developed. These produce the gridded high-resolution spatial information that has revolutionised production and delivery of forecasts—when and where people want to access them. Similarly, early 2015 national climate projections—the most comprehensive ever released for Australia—were supported by our world-class research on weather and climate processes.

The Research and Development Strategy 2015–2020 sets the direction for R&D investment and reaffirms and clarifies the key contribution science and engineering play in achieving the Bureau's mission. We are driven to be more efficient and effective, to improve products and services—ranging from severe and high-impact event warnings to long-term advice on changes in climate and water resources—and to continue automating routine and standardised tasks.

Our scientists and engineers have a significant and direct role in improving our understanding of physical processes, using this knowledge to produce new and improved services, enhancing the use of our services, reducing production costs, attracting external investors in our science, and in providing solutions that allow Bureau staff to work on functions of higher value to the organisation.

The essential services we provide to all Australians are founded upon broad, deep and active R&D in Earth system observations, modelling and analysis. Our national service suite includes assessments, analysis, forecasts, warnings, and advice on weather, river floods and flows, climate and climate change, ocean and marine conditions, and space weather.

Our overarching goal is to provide
underpinning science and technology
for **environmental intelligence.**



Our overarching goal is to provide underpinning science and technology for environmental intelligence—information on impacts that supports decision-making over timescales from minutes to decades.

In the future we will enhance the utility and use of our products and services—where, when and how users require them—by continuous improvement in our Earth system modelling capability. This must be supported by a better understanding of fundamental physical processes and the use of advanced observational techniques.

We will reduce the unit cost of service production while meeting increasing demand for services, through more efficient service development and delivery. This will flow from new research and innovation, more effective translation of research outcomes into operational services, increased automation and streamlining enabled by our model systems, post-processing and greater supercomputing capability.

We have particular advantages through our strong national and international R&D partnerships. We can bring these to bear on our research capacity through sharing outputs, progress and ideas, as well as to enhance our influence in the research, standards, operational and policy communities.

To achieve these goals during 2015–2020 we will pursue five key strategic themes:

- services from science;
- modelling and assimilation;
- fundamental processes;
- Earth observing systems; and
- scientific computing.

We will focus on realising benefits across three horizons:

1. The near term—when we review, adapt and apply existing knowledge, and target operational deployment within annual business cycles.
2. The medium term (over which most research projects occur)—aligning with multi-year capital and investment plans as well as key partnerships and programmes, such as the Collaboration for Australian Weather and Climate Research (CAWCR), the UK Meteorological Office and the Earth System Science and Climate Change hub of the National Environmental Science Programme.
3. The period at and beyond five years (over which most fundamental research advances occur). This period lays the groundwork for most of the achievements of the shorter timeframes. It also encompasses key modelling and computing developments as well as organisational, societal, government and policy changes.

Our science will be published in high-quality, peer-reviewed journals, enhancing the Bureau's reputation and influence within the science community and—as we focus on science with direct relevance to the Australian community and economy—with policy makers.

We recognise that to retain and develop our R&D capability—our people—we need to ensure a rewarding, engaging and caring work environment. In this, we will focus on R&D that meets our user and stakeholder needs and continues to deliver service outcomes of the highest standard.

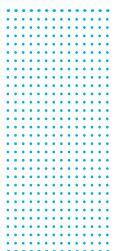
R&D and the Bureau

Our R&D business

The Bureau uses physical process knowledge, advanced modelling, Earth observation capabilities and scientific computing to transform our understanding of the complex natural environment into valuable user-focused services.

We have many national and international partners and partnerships, in research, development and delivering science into service. Through formal representation at national and international levels we contribute valued advice and direction across environmental domains.

We have a significant breadth of organisational business needs that are serviced by our R&D capabilities. These include observations, assessment, prediction, and infrastructure; climate, water and environmental information; weather and other forecasts, warnings and hazards; and operational service areas.



We are working in a dynamic, international operating environment where ‘standing still’ means ‘going backwards’.

To service these needs, and those of the ultimate users of Bureau products and services:

- **our people** draw upon their diverse skills, expert knowledge, professional networks and strong commitment;
- **our research** investigates processes that affect conditions across timescales from minutes to decades, spanning the atmosphere, land, water, marine, and ionospheric domains;
- **our models and modelling systems** cover these domains and include data assimilation, forecast guidance, observing systems, high-performance computing capabilities, assessment and analysis, and prediction and projection; and
- **our development** includes these models, model evaluation and post-processing, our data and observation networks and systems, and the products and services used by us and others to service the needs of all Australians.

Our drivers

We are working in a dynamic, international operating environment where ‘standing still’ means ‘going backwards’. Technology-driven change is affecting capabilities from satellite observations to crowd-sourced observations to low-cost on-sellers of data.

We are driven by increasing demands from a growing population and economy to extend and improve our standard services as well as to provide better warning of high-impact events. We must also strive to lower service production costs within a highly challenging resourcing environment. We must become more efficient and effective, standardising and automating routine procedures so that our staff can focus on work of higher value.

Demands include:

- better and more integrated data and information services to support situation assessments, predictions and projections in weather, climate, water and the environment over a range of time and space scales;
- increased environmental intelligence that extends basic information services to better support decision-making at times and places relevant to users, and also to increase awareness, preparation and understanding of current and future high-impact events;
- provision of longer-term guidance on future events over time frames from days to weeks to decades; and
- improvement of the resolution and definition of services in coastal and ocean areas, to support planning and infrastructure needs associated with extreme events and a changing climate.

Our research themes

Meeting these demands requires a cohesive and synergistic approach, to our organisation-wide research and development effort. This approach integrates knowledge of **fundamental processes** across our business domains with **modelling and assimilation** of associated natural phenomena, using low-latency **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.

Services from science

Our R&D produces science-based products and services to meet our mission by delivering to internal and external users and stakeholders the advice, analyses, assessments, objective guidance, forecasts and warnings they need.

Strategy

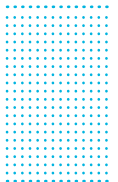
In delivering science into service, our R&D will be directed to producing practical outcomes for users, including decision support and advice. Our priorities are:

- addressing the scale, location, time and context of user and stakeholder decisions and risk-mitigation needs;
- verification and validation—a key characteristic of our authoritative national service—demonstrating how well we have done, the value we are providing, and informing future developments;
- automation and improvements to guidance, forecast processes and diagnostic tools—to support improved service delivery and greater efficiency and effectiveness in the forecast office, enabling an increased focus on decisions and advice;
- providing advice and information on causes of past and future climate and weather extremes; and
- methodical and efficient transition of science and technology outcomes into operations.

Our R&D will include:

- nowcasting, guidance and forecast processes for better high-impact event forecasting;
- forecast verification and post-processing to improve accuracy and inform further research;
- impact prediction capabilities and critical post-event analysis;
- new techniques for service production, such as model output post-processing and decision support, fully capitalising on ensemble model capabilities;
- alerting tools and diagnostic methods to support understanding, analysis and detection of significant events and risks, within the growing volume of data generated by the next generation of forecasting models;
- policy-relevant science on climate and climate change; and
- products and services arising from business development activities.

Our research outcomes will
be more efficiently translated into
products and services.



In five years...

Our research outcomes will be more efficiently translated into products and services. These will, in turn, be more directly targeted to the scale and nature of user and stakeholder needs, bringing together observations and model outputs to provide environmental intelligence.

Through use of a new generation of integrated observations, model guidance and forecast production tools, our weather forecasters will better forecast, interpret and communicate high-impact near-term events. Our forecasts will cover multiple hazards and include predictions and warnings of potential impacts.

Many national services will be probabilistic, discoverable and accessible, providing more quantitative information for risk-based decision making. Forecasting of extremes will include the interrelationship of weather and climate, and many user-relevant variables will have forecast horizons extended to multi-week and seasonal timeframes, presented seamlessly across the weather, land, water and ocean domains.

KEY TARGETS

Our targets for the next five years include:

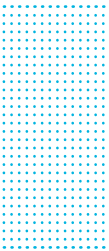
- improved mesoscale guidance products and alerting to support forecasts and warnings of high-impact weather out to 36 hours at 1 km hourly resolution;
- automated routine forecast production, underpinned by accurate guidance, based on statistically post-processed numerical weather prediction (NWP);
- seamless ensemble-based weather and climate applications spanning scales ranging from nowcasts to days to years;
- demonstration of the utility and value of high-resolution ensemble forecasts through a forecast demonstration project;
- more accurate flood forecasting for more than 300 sites across Australia;
- extended inundation prediction capability at select locations for storm surge and tsunami applications;
- more and better tailored services for aviation, defence, agriculture and other key sectors; and
- verification of probabilistic storm forecasts and warnings against gridded analyses of remotely sensed observations.

Modelling and assimilation

R&D in modelling and data assimilation supports process studies and improved use of observations. It also delivers the improvements in assessment and prediction needed for efficient delivery of current services and establishment of new and improved services as well as realising investment benefits.

Improving model resolution and physics, and better use of observations, remain key directions at all timescales. Critical future modelling challenges include important shifts in capability, such as:

- weather forecasting models at ‘convection-permitting’ scales;
- seasonal climate prediction at scales that represent key weather features;
- multi-model ensemble techniques;
- international model comparison studies for long-term climate projections; and
- high-resolution coastal forecasting including during high-impact weather events.



High-resolution ensemble-based Earth system modelling **lies at the heart** of most of the Bureau’s products and services.

Strategy

High-resolution ensemble-based Earth system modelling lies at the heart of most of the Bureau’s products and services.

Our priorities are to:

- improve weather, climate, hydrological, ocean and ionospheric representation, prediction and coupling, with higher spatial resolution and longer lead times, and with better quantification of uncertainty;
- improve data assimilation in all domains and also for coupled models; and
- participate in the international community of Earth system model developers and users, including our highly valued partnership with the UK Met Office and other Unified Model contributors.

Our R&D will include:

- numerical prediction and ensemble-based uncertainty estimation;
- model products that are seamless across timescales, geography and domain;
- seasonal forecasting improvements;
- atmosphere-land-sea-ice and coupled ocean-atmosphere and land surface modelling;
- verification analysis and benchmarking, including the frontier area of high-resolution ensemble forecasts; and
- improvements in ‘downstream’ modelling applications, such as dispersion modelling.

In five years...

We will provide analyses, predictions and projections in more detail, with greater accuracy and with better quantification of uncertainty, integrated across atmospheric, land, water, and marine systems.

Our unified modelling system (ACCESS) will provide meso-scale to global atmospheric predictions and will span nowcast, day-to-multiweek, seasonal, multi-year, and climate timescales. We will explore coupled numerical prediction, with the potential to unify our global weather and ocean approaches, and we will produce hydrologically-relevant, ensemble-based precipitation estimates at ‘convection-permitting’ scales.

KEY TARGETS

Our targets for the next five years include:

- implementing high-resolution ensemble systems;
- implementing a high-resolution (1 km) wave model around the Australian coast;
- coupling ACCESS NWP with ocean and wave models;
- implementing a coastal forecast system for the Great Barrier Reef region;
- implementing a global coupled model ensemble system for lead times from ten days to six months;
- increasing numerical weather model and seasonal forecast model spatial resolution by up to four times;
- improving ACCESS-G forecast lead time by six-to-ten hours, with a commensurate improvement for the regional-scale ACCESS-R model;
- reducing tropical cyclone track and intensity errors by up to 20 per cent;
- implementing a real-time tsunami model forecast capability, including data-fusion techniques; and
- maintaining the international competitiveness of our global and seasonal ACCESS prediction systems, as well as the Ocean Modelling, Analysis and Prediction System (OceanMAPS).

Fundamental processes

Research into processes, dynamics and physics provides foundation knowledge upon which our modelling capabilities are evaluated and our services are based, and through which improvements are made—especially in relation to high-impact events and extremes. This research also underpins our ability to explain the cause of severe weather and climate events and future changes in their frequency, intensity, duration and size.

Strategy

We are a valued contributor to, and a beneficiary of, the international community of researchers working on fundamental Earth system processes, and we target research that aligns with national and international strategic priorities.

We will prioritise R&D efforts on:

- improved understanding of the physical, dynamical and other drivers of variability and extremes of Australian weather, hydrology, climate, land surface, sea-ice, ionosphere, coastal and open ocean domains;
- better understanding the effects of global climate change on climate drivers in the Australian region;
- using observations and models to increase process understanding, improve modelling and further underpin operational forecasting and climate advice;
- contributing to high-value field programs; and
- strategic research addressing key uncertainties in prediction and projection.

This includes involvement in local and international programs that use operational and research data streams and infrastructure such as the Integrated Marine Observing System, the Marine National Facility's RV Investigator and the National Computational Infrastructure.

Our R&D will include:

- high-impact weather;
- land, ocean, atmosphere, and sea-ice interactions;
- rainfall, especially extreme values;
- radar studies for cloud properties and their evolution;
- coastal and ocean dynamics;
- climate variability and change; and
- high-quality long-term reference data sets.

In five years...

We will have greater insight into the key processes that cause or contribute to environment-related impacts on Australian society.

KEY TARGETS

Our targets for the next five years include:

- improved understanding of the fundamental drivers of high-impact weather events such as droughts, tropical cyclones, fire weather, heatwaves, east coast lows, and severe thunderstorms;
- improved understanding of key processes driving climate change and variability in the Australian region;
- understanding the processes responsible for significant model biases, such as those in Maritime Continent region rainfall, Madden–Julian oscillation propagation and Southern Ocean global model sea-surface temperature and shortwave radiation;
- developing capability in atmospheric boundary layer, sea-ice and ocean interaction science to support model coupling;
- understanding and explaining the variability, distribution and change of Antarctic sea ice;
- closer engagement with users and stakeholders, such as emergency services, fire agencies, agriculture, water agencies; and
- leading or contributing to the authorship of at least 40 papers per year on foundational scientific advances, published in peer-reviewed literature or presented at international workshops or conferences.

Earth observing systems

Research into observing systems, platforms and networks makes our analysis, modelling, forecasting and warning procedures more robust and feeds into nowcast and forecast improvement directly and through data assimilation. It also realises benefits from investment in observations, and informs future observing system changes and opportunities.

Strategy

We operate Australia's largest Earth system observing network and benefit greatly from partner observing systems across the country and the globe.

Our R&D priorities are:

- greater and more efficient use of remotely sensed information sources;
- increasing the efficiency and value of our observing networks;
- providing timely and effective feedback on observing data quality; and
- increasing the value of observations in forecast guidance, verification and in model improvement and evaluation.

We will have a national observing system that is more **flexible and robust** 

Our R&D will include:

- use of advanced sensors and platforms, especially next-generation satellite observations, dual-polarisation weather radar, cloud radar, lidar, and unmanned autonomous vehicles;
- increasing use of all observations in forecast verification;
- quantifying the value of observed data to numerical prediction systems, with feedback into observing network design;
- deriving geophysical quantities for use in data assimilation systems and by forecasters in real time;
- improving the integrity of the Bureau's observation dataset, including verifying remotely sensed data;
- integrating observations and model outputs into hybrid and blended products to meet nowcasting and public information needs; and
- using research and operational datasets to support fundamental process studies, provide input into advanced verification systems and improve products and services.

In five years...

We will have a national observing system that is more flexible and robust, more readily able to evolve and integrate new data streams and platforms, able to provide more direct and tangible improvements to our services, and for which the value of proposed changes are readily quantified in terms of service outcomes.

KEY TARGETS

Our targets for the next five years include:

- robust tools for quantifying the value of observations and specific observing system components to numerical prediction systems;
- operational assimilation of radar-derived quantities, new satellite data and global navigation satellite system observations into high-resolution and rapid-update cycling numerical prediction systems;
- development of advanced applications integrating Himawari satellite data and other sources for storm detection and quantitative rainfall estimation;
- development and validation of operational products from our upgraded radar network, including better data quality control, calibrated and attenuation-corrected reflectivities, and assimilation of Doppler-derived winds;
- observation programmes to support high-value applications in the aviation, maritime, defence, emergency management, and agriculture sectors; and
- exploration of further integration of third-party data and products in Bureau R&D and operations.

Scientific computing

Scientific computing enables modelling, effective service delivery, efficient running of operational and research model suites, automated processing and next-generation computing. Advances in modelling and observations are driving a revolution in computing resource and data volume requirements.

Strategy

Scientific computing underpins all of our R&D activity. Our priorities are:

- computing optimisation, especially high-performance computing (HPC);
- improving scientific computing work processes and transitioning research outputs to operations;
- engaging research communities through shared scientific platforms and data-sharing; and
- enhancing the tools and technologies that support research scientists working more efficiently.

Our R&D will include:

- optimising HPC resources;
- investigations in graphics processing unit (GPU) based massively parallel computing, multi-threaded execution, big data, cloud computing, linked data, automated monitoring, increased reliability, architectures and machine learning, and
- streamlining through streamlining through standardisation of coding, code management and release practices.

In five years...

Model development will be more streamlined, reducing developer intervention and improving development efficiency. We will take advantage of international developments in HPC to deliver improved observation and data-management systems, and in-model development and operation.

We will also accommodate step-changes in data volumes arising from resolution increases, new satellite data streams, international model comparison studies, and the increased national adoption of our products and services.

KEY TARGETS

Our targets for the next five years include:

- meeting operational update cycle timelines for new numerical systems;
- automation and verification to support the development and evaluation of new services;
- processes to efficiently develop, document and transition systems into operations with minimal support;
- automated monitoring for streamlined operations; and
- full adoption of standard methods for coding, code management, release management, automated testing and issue tracking.

Framing the strategy

Strategic setting

Our Research and Development Strategy is informed by and contributes to the Bureau of Meteorology Strategic Plan 2015–2020 and other Bureau strategies such as the Observing System, Marine and Information and Communication Technology strategies. Our R&D aligns closely with national scientific priorities such as the National Research Priorities for a Sustainable Australia and the National Strategy for Disaster Resilience, as well as leading international directions from the World Weather Research Programme and the World Climate Research Programme Grand Science Challenges.

Our R&D effort is targeted towards improving environmental intelligence for all Australians, founded upon the Bureau of Meteorology's role as both a leader and a partner within many national and international scientific endeavours.

Science and services

The strategy 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 focus and approach are influenced by global scientific trends and drivers; global directions in data, modelling, computing and private-sector service delivery; policy developments for growing and securing Australia; episodic national-scale climatic events; societal trends in data, information and mobility; and our need to train and retain a highly skilled workforce.

Principles

The way that we undertake our research and development reflects our R&D principles, which are:

- relevance to business and government;
- service- and operations-focused;
- work we are best-placed to undertake;
- collaborative;
- internationally linked;
- high quality; and
- accessible and open.

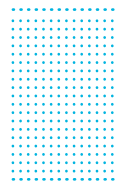
Implementing the strategy

The strategy will be implemented through the decisions it informs on our R&D capability, programme and project commitments, vehicles for research, and our partnerships, under the stewardship of the Bureau R&D Oversight Board.

Recognising the significant lead times required to develop and evolve research capability, we will use this strategy and our R&D investment model to inform workforce planning and to shape our next generation of scientific capability.

We will measure the success of this strategy through specific metrics, including user satisfaction, outputs, and the nature and scale of the changes required to keep the strategy fresh and relevant.

The strategy will be updated in 2020 to ensure ongoing alignment with Australian Government and Bureau priorities, in addition to international trends and directions.



We will measure the success of this strategy through specific metrics...to keep the strategy **fresh and relevant**.

Vehicles for research

In implementing the strategy we will choose a mix of vehicles that align with our R&D investment model, and that balance investment efficiency and service-delivery effectiveness over the range of time horizons required by different scientific efforts.

These vehicles include:

- our R&D branch, along with other Bureau internal capability;
- collaborations and alliances such as the Collaboration for Australian Weather and Climate Research (CAWCR), the Water Information R&D Alliance (WIRADA) and the Unified Model consortium;
- externally funded R&D;
- Australian Government and other research centres and hubs, such as the Australian Research Council's (ARC) Centre of Excellence for Climate System Science, the National Environmental Science Programme's Earth System Science and Climate Change Hub, and Cooperative Research Centres for Bushfire and Natural Hazards (BNH CRC) and Antarctic Climate and Ecosystems (ACE CRC);
- cross-agency activities under Memoranda of Understanding and Heads of Agreement;
- ARC Linkage and other research grants; and
- innovation partnerships.

Partners

The capability to execute our R&D Strategy lies not only with our scientific cohort, but also with the whole of the Bureau and our national and international investors and partners. This is especially apparent in large-scale activities such as observation systems, numerical prediction, and forecast methods and processes where user demands far exceed the capabilities of any one organisation or Bureau branch, and collaborative partnerships are commonplace.

We also partner with investors who wish to transition research outcomes into operational products that meet specific business needs and provide societal benefits.

In all our partnerships we bring a unique southern hemisphere perspective as well as scientific strengths in areas such as data assimilation, extremes and high-impact events, and high-performance computing.

Our partners include:

- our staff, across all Bureau business areas;
- the UK Met Office, the US National Oceanic and Atmospheric Administration, and the meteorological agencies of Japan and Korea.
- the Australian Commonwealth Scientific and Industrial Research Organisation;
- business, industry and consultants;
- universities and research centres;
- Commonwealth and State investors and companion departments; and
- other international bodies and agencies, in research, policy and operations.

From this strategy we will develop an R&D Stakeholder Engagement Plan, to be renewed annually. It will prioritise and detail the approach we will take with different partners, investors and users to ensure our R&D is targeted and delivering the outcomes planned and benefits desired.



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