Productivity Commission Inquiry into the Barriers to Effective Climate Change Adaptation

Submission by the Bureau of Meteorology

26 July 2012

<u>Enquiries should be addressed to:</u>

Dr Rob Vertessy
Acting Director of Meteorology

Introduction

The Bureau of Meteorology welcomes the opportunity to make this submission to the 2012 Productivity Commission Inquiry into the Barriers to Effective Climate Change Adaptation. We are confining our submission to the matters traversed in Part 6 (Information Provision) of the Productivity Commission's Draft Report dated April 2012. We support in the broad the observations made in Part 6 of the Draft Report. We would however encourage a stronger focus on the merits of enduring environmental intelligence services as a pillar of climate change adaptation, and that is the thrust of our submission to follow.

We define environmental intelligence as *"conclusions drawn from environmental observations and models to guide decisions and actions by governments, businesses and individuals"*.

In a recent presentation given at the Australian Academy of Sciences, Dr Jane Lubchenco, Under-Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration in the United States described the essence of the climate change challenge. She aptly characterized it as "avoiding the unmanageable and managing the unavoidable", highlighting the tandem requirement for mitigation and adaptation strategies.

There are multiple lines of robust evidence to show that earth's atmosphere and oceans are warming as a result of greenhouse gas emissions from the burning of fossil fuels. Significant changes have been recorded already, and further change is now locked in for centuries, whether or not emissions are reduced or even halted in the near term. The rate and magnitude of future changes will be determined by the level of future emissions, and a series of complex environmental feedbacks, but it is now likely that the average temperature of the atmosphere will rise by more than 2°C relative to pre-industrial revolution conditions (ie. beyond the ~1°C rise recorded to date). A rise of 2°C would exceed the commonly quoted "guardrail" level, deemed by experts to be the threshold beyond which dangerous impacts may arise. In this sense, Australia needs to prepare itself to "manage the unavoidable".

Climate change is driving changes in sea levels, ocean chemistry, marine, terrestrial and aquatic ecosystems, agricultural production, water security and the frequency and magnitude of severe weather events. These have the potential to impact profoundly on society, so effective adaptation strategies are vital. All of these changes present particular adaptation challenges for various nations and the many stakeholders within them. Effective climate change adaptation depends strongly on systematic monitoring of such changes and good foresight regarding likely future change. Good foresight implies knowledge of the timing, magnitude and potential impacts. Such knowledge is necessary for effective climate change adaptation, but also vital for informing the design and timing of mitigation strategies aimed at "avoiding the unmanageable".

The better utilisation of currently available environmental intelligence assets, and investments in new ones, could help to identify the most essential and cost effective adaptation options and thus significantly improve the ability of governments, businesses and individuals to reduce the manifold risks posed by climate change.

The role of the Bureau of Meteorology

The Bureau of Meteorology provides Australians with environmental intelligence for their safety, sustainability, well-being and prosperity. In practical terms, this entails providing Australians with the information and related support they need to manage and live within their natural environment, encompassing the atmosphere, oceans, water and land.

Some of the key functions of the Bureau of Meteorology are:

- monitoring and reporting on current environmental conditions
- analysing and explaining historic trends in environmental conditions
- providing forecasts, warnings and long-term outlooks on environmental phenomena that affect the safety, prosperity and resilience of Australians, and
- encouraging the use of of environmental intelligence for social benefit.

Below we elaborate on the different ways in which environmental intelligence provided by the Bureau is of value to Australians, and can support effective climate change adaptation.

Environmental intelligence that keeps us safe

On a 24/7 basis, we provide alerts, warnings and forecasts for cyclones, fire weather, floods, high winds, thunderstorms, hail, tsunami, ocean waves, tidal surges, air turbulence, visibility, volcanic ash, solar disturbances and ultraviolet radiation. In so doing, the Bureau helps protect people on the land, at sea and in the air, across Australia's territory and, in some cases, beyond. As we improve the speed, accuracy and dissemination of our alerts, warnings and forecasts, we reduce the risk of injury and loss of life and contribute to the resilience of Australian communities. In other words, the Bureau is already active in helping the community to adapt to and manage risks to safety and security arising from weather and climate. As noted earlier, an increase in severe weather events is a likely consequence of climate change. Early warning systems have proven time and time again to be the most effective and cost efficient approach to mitigating economic losses and loss of life arising from severe weather.

Environmental intelligence for sustainability

We monitor how our environment is changing over time, providing insight into possible impacts on our climate, food and water security, natural ecosystems and human health. Subtle changes in these parameters can have profound consequences for ecosystems, biodiversity and our food production systems. The Bureau is a 'listening post' for changes in rainfall and temperature, the chemical composition of our atmosphere, surface and groundwater availability, land cover and soil condition, the temperature and chemical balance of our oceans, and pollutants in our air, water, soil and oceans. In the context of this inquiry, such intelligence provides the reference frame. For instance, the Australian Climate Observations Reference Network for Surface Air Temperature (ACORN-SAT), managed by the Bureau, is the definitive data set chronicling the rate and pattern of climate change in Australia.

Environmental intelligence to secure our prosperity

The Bureau provides governments and businesses with environmental intelligence that underpins vital economic decisions. We provide insights into future climate conditions and water availability, trends in water utilisation and trade, ocean temperatures and currents, and changes in Australia's natural capital. These insights inform important investment and planning decisions, adaptation strategies, markets for environmental services, and regulatory and compliance regimes. Ongoing changes in our climate will demand periodic adjustments to planning and regulatory regimes and markets and such adjustments are best founded on sound environmental intelligence.

What more could be done to support climate change adaptation?

Whilst, by international standards, the Australian public is well served by quality environmental intelligence issued by the Bureau and other agencies, the efficacy of climate change adaptation strategies could be enhanced with better information.

The Bureau recognises that it is a matter for Governments to determine funding and resource allocation decisions amongst competing priorities. Noting that there are likely to be many productive investments that government could contemplate as part of a climate change adaptation strategy, we see two key areas of new investment where significant benefits could be captured, these being:

1. Improving early warning systems
2. Improving environmental monitoring and analysis

Below, we elaborate on these two areas.

1. Improving early warning systems

Climate change studies indicate that we can expect a higher incidence of severe weather events, particularly heavy rainfalls and very hot days. This increases the odds of more serious flooding, heatwaves and bushfires. These studies also indicate an intensification of our already significant interannual climate variability. This increases the odds of more severe droughts, particularly in southern Australia, and more severe wet seasons, particularly in the north. As noted earlier, early warning systems are an effective and cost-efficient means of mitigating the impacts of such changes.

With respect to severe weather events, the underlying message is that our communities face greater risk, both from the increasing likelihood of weather extremes and from increasing vulnerability arising from population growth and development. This heightened risk profile can be cost-effectively mitigated by improved early warning capability provided by numerical weather prediction systems. These models, already operational within the Bureau, provide forecasts for up to 10 days ahead and are now a mainstay of emergency response systems. There are clear pathways to extract further value from such systems, contingent on increased investment.

Appendix A to this submission outlines how numerical weather prediction systems, such as the ACCESS-based system operated by the Bureau of Meteorology, can be advanced to improve our ability to cope with severe weather events. Key messages in this document are:

1. Scientific knowledge has advanced to the point where we are able to model severe weather events with increasing fidelity.
2. Access to high performance computing capacity is the key to improving weather forecast timeliness, lead time, resolution and certainty.

We would add here that access to high quality observational data from satellites is particularly critical to the quality of severe weather forecasts. Over the last three decades, Bureau forecasts have improved each time new and higher resolution forms of satellite data became available for use in the models. Future improvements in forecast skill will depend heavily on continuing access to better observational data from satellites. For this reason, the Bureau supports the development of a national policy on earth observations from space.

Looking out further in time, benefits can also accrue from early warning systems capable of predicting interannual climate variability arising from medium-term variations in the heat balance of the atmosphere and the oceans. Our initial estimates indicate that about 5% of the variability in Australia's national gross domestic product (GDP) can be attributed to interannual climate variability. This equates to about $58 billion dollars variation in economic activity per year when averaged over the last 10 years (2001-2010). It is anticipated that this sensitivity will increase with further development and climate change. Some of this economic risk can be mitigated by the uptake of forecasts from seasonal climate forecasting systems, even if only slight changes in sectoral behaviour occur.

Seasonal climate forecasting systems look out from 1 to 3 months ahead, and potentially as far as 9 months. Traditional users of the Bureau's monthly-updated seasonal forecasts include farmers making decisions about annual production strategies and emergency management services preparing for fire or flood seasons. The Bureau has recently started to issue seasonal streamflow forecasts, providing guidance on the likely availability of water in major water supply systems across eastern Australia. Many others are now starting to utilize seasonal forecasts to mitigate risks posed by climate variability, including the energy, health, insurance and finance sectors. It appears as though the uptake of seasonal forecasts has been stimulated by the strong interannual climate variability we have experienced over the last decade, indicating that climate change is likely to stimulate further uptake.

Around the world, advanced coupled dynamic modelling approaches that consider interactions of atmosphere-ocean-land-ice processes are now being developed to forecast climate conditions at timeframes from a few weeks to a few seasons ahead. The science and technical capabilities of these advanced coupled dynamic models are maturing rapidly and offer great promise for helping us manage better with interannual climate variability. These new models have many advantages over our current statistical climate forecasting methodologies, not least of which they can account for changes in oceans and the atmosphere that are occurring as a consequence of global warming.

The Bureau of Meteorology is scheduled to implement its first operational climate forecasting service based on a version of a coupled dynamic climate model for Australia later this year. This model, known as the Predictive Ocean Atmosphere Model for Australia (POAMA), has been under development for more than a decade. While this model currently has only low spatial resolution and moderate skill, it will be a modest step forward from the current statistically-based system operated by the Bureau. It is likely to improve the skill of the Bureau's seasonal streamflow forecasting system also. In parallel with the release of POAMA, the Bureau is placing greater emphasis on the utilization of the forecasts by end-users. Based on extensive end-user requirements analysis, we are improving how we deliver seasonal forecasting information to different sectors.

Whilst we envisage improved utilization of seasonal forecasts in the near future, significant skill improvements will be slow to eventuate at the current rate of POAMA development. As a consequence, so too will be the realization of societal benefits. Accelerated development of POAMA could bring significant benefits forward in time. It is noteworthy that our major international trading competitors, in the US, UK, Europe, and Asia, are presently making significant investments in improved seasonal forecasting services.

As with severe weather prediction, access to high performance computing capability is a key to improvements in seasonal forecasting skill. However, in this case there is also a greater requirement for research and development as the science is less advanced.

2. Improving environmental monitoring and analysis

Some reference has been made already to the importance of environmental observations as a vital underpinning to early warning systems, namely numerical weather prediction systems for severe weather and seasonal forecasting systems for interannual climate variability. Beyond these requirements, we see three key areas where improvements in monitoring and data analysis are desirable to support effective climate change adaptation.

2.1 Rainfall intensity, frequency and duration

Accurate estimates of the intensity/frequency/duration characteristics of rainfall are critical to the task of designing structures affected by rainfall and flooding, such as gutters, culverts, drains and bridges. These estimates are also a critical input to hydrologic models used for the assessment of flood risk. Current estimates of design rainfall published in the Engineers Australia handbook Australian Rainfall and Runoff are based on data available up to 1983. Since then the availability of additional rainfall data has increased markedly and new techniques in frequency analysis have been developed. The Bureau is working with Engineers Australia to revise design rainfall estimates for the nation, using a much larger rainfall database and the latest analysis methods. Much of the new data being used was collected by the Bureau from a large number of contributing agencies under the aegis of the *Water Act 2007*, highlighting the value of this important data sharing reform policy.

A new body of IFD design rainfall estimates will be released later this year and should significantly enhance confidence in hydrologic design for the current climate regime. However, noting that most structures have long life cycles and that our climate is changing, the challenge remains on how to estimate what future IFD patterns may be. Maintaining continuous, high frequency rainfall measurements will be important for future revisions of rainfall IFD statistics, but so too will be the development of analysis methods for estimating future ones using currently available data. Under-design and over-design can both be costly.

Although different organizations have provided advice on the consideration of climate change in flood studies and investigations have been undertaken for specific areas of Australia, there does not exist a consistent approach on the consideration of climate change in flood studies. The Bureau of Meteorology is working closely with Engineers Australia and a variety of practitioners and academics involved in design flood studies, to develop a robust and consistent national approach.

2.2 River height monitoring for floods

For the Bureau to forecast the timing and magnitude of flooding and to issue warnings, it requires real-time access to rainfall and river height information. Under the current arrangements the Bureau is responsible for measuring rainfall and over 100 State agencies and Councils across Australia are responsible for monitoring river heights. These agencies supply, free of charge, their river height observations to the Bureau so that we are able to use them in our flood forecasting process and to publish real-time river levels online. These products are vital to community safety and pivotal in emergency services response to flood events.

The Bureau is most appreciative of the cooperation it receives from these many data-supplying agencies, noting that they are virtually all struggling with network maintenance costs and that very few are explicitly resourced to monitor river heights for flood management purposes. Nonetheless, we see the need to voice concern about several issues that are limiting the overall extent and quality of flood warning and forecasting services to the community. The problems being experienced today will be magnified in a climate-changed world with more severe flooding, and are thus salient to climate change adaptation policy.

River height observations made by non-Bureau parties are usually gathered for purposes other than flood monitoring and suffer from a range of problems, including:

i. Monitoring network designs that are sometimes ill-suited to flood forecasting and warning requirements;
ii. An inability of most agencies to service monitoring equipment on a 24/7 basis;
iii. A lack funds or expertise to maintain stations to an adequate standard or to upgrade them readily;
iv. An inability to supply data at the temporal currency that the Bureau needs; and
v. The absence of an enduring funding model to extend networks into new areas as circumstances require.

We stress that these problems rarely arise from any lack of goodwill or effort on behalf of the data collecting agencies involved. They almost always arise from either agency funding constraints or institutional arrangements that do not provide for the maintenance of sufficient professional expertise and data management and communication systems. In our view, there are simply too many players with varied responsibilities and capacities, for an adequate, let alone future-ready, national flood monitoring network to eventuate.

Ensuring that citizens receive timely and accurate flood warnings and forecasts should be an important facet of Australia's future climate change adaptation strategy. Noting the criticality of river height observations for flood warning and forecasting services, we recommend government consideration of alternative institutional arrangements and funding models for this important function.

2.3 Monitoring environmental change

In recent years the Bureau has built upon its traditional weather and climate monitoring and forecasting roles to assess a variety of environmental processes and ecosystems that are sensitive to climate change. A range of new Bureau products and services are emerging that can help to support effective climate change adaptation.

In 2007, the Bureau was assigned a new water information function under the *Water for the Future Initiative* and the *Water Act 2007*. As part of this new function, the Bureau is now making regular assessments of water balances for the nation, complementing our climate analysis function. This entails reporting on water availability, water quality, water entitlements and water use, providing a firm foundation upon which to make assessments of the role of climate change in affecting water security. An important aspect of this role is collecting and standardising the diverse primary water data collected by more than 215 agencies involved in this space. Another important aspect is the free dissemination of the harmonised data and derived products generated by the Bureau, providing governments, businesses and individuals with vastly superior insight into water resources than existed prior to the recent severe droughts.

In 2010, the Bureau was assigned a new environmental information function under the *National Plan for Environmental Information Initiative*. This entails establishing plans, standards, relationships, legislation, infrastructure and institutional arrangements to affect a step change in the availability and utility value of environmental information. Whilst we are only in the early stages of this program, the Bureau is already making good headway with several Federal, State and private partners to develop monitoring systems for the Great Barrier Reef (GBR), an ecosystem known to be very sensitive to climate change.

The eReefs project is a $25 million, five-year collaboration that brings together corporate Australia (through the Great Barrier Reef Foundation and its partner BHP Billiton Mitsubishi Alliance), Australia's leading operational and research agencies (the Bureau of Meteorology, CSIRO, and the Australian Institute of Marine Science), the Science and Industry Endowment Fund and Reef Managers (Great Barrier Reef Marine Park Authority). Contributions are also being made by the Australian Government, through Caring for our Country's Reef Rescue Program.

Managers of the GBR face ongoing challenges in the context of water quality, shipping, fishing, coastal development and particularly climate change. eReefs will help decision-makers manage the GBR by providing integrated and interactive information at both a scale and detail that has hitherto been lacking. Operational services scheduled to be launched by the Bureau include a Reef water temperature product and a Reef water quality product, developed by the eReefs research partners. Coupled hydrodynamic and ecologic forecasting systems for the GBR lagoon are also under development and expected to be launched in later phases of the program. A critical complement to this work are the primary coastal observations being made by the Integrated Marine Observing System (IMOS) initiative and the Australian Institute of Marine Sciences (AIMS). Without these observations, reporting and forecasting systems such as eReefs could not operate. We note that many marine and coastal zone observation programs underway in Australia are supported by short-term research programs.

eReefs is emblematic of the kind of environmental monitoring services that the Bureau is aspiring to host under the auspices of the *National Plan for Environmental Information Initiative*. These need to be supported by observation programs that are stable and enduring and this will necessitate arrangements to transition research programs into operational ones. We see merit in directing initial focus to iconic ecosystems that are sensitive to climate change and the prime focus of climate adaptation planning. What is lacking is appropriate institutional arrangements and an investment model to bring such monitoring services to fruition at the pace required by climate change and other environmental pressures. Redressing this deficiency is one of the primary aims of the proposed *National Plan for Environmental Information*.

Appendix A

Australian Government

Bureau of Meteorology

HIGH-PERFORMANCE COMPUTING FOR NUMERICAL WEATHER PREDICTION

AN ESSENTIAL REQUIREMENT FOR THE FORECASTING OF SEVERE WEATHER EVENTS AND THEIR IMPACT ON THE COMMUNITY

10 April, 2012

1. Forecasting severe weather events

1.1. The demand

The 2010/11 and 2011/12 summers were extraordinary for their extremes of weather and climate, going from a period of unparalleled drought in the southern and south-eastern regions of Australia, to one characterised by floods and extremes of weather. Just as the previous decade introduced new records in temperature and low rainfall, this recent period saw extraordinary downpours and extreme flooding through Queensland and the south-eastern States.

The loss of life and enormous damage to property highlighted the vulnerability of modern society, its infrastructure and communities, as did the drought, heatwaves and bushfires in the preceding few years.

Climate change studies suggest we may expect more extreme patterns of weather and climate variability. Likely early impacts of climate change on communities are the increased frequency and magnitude of extreme rainfall and associated flash flooding and riverine flooding, coastal flooding from storm surges, heatwaves and bushfires. The underlying message is that our communities face greater risk, from the increasing likelihood of extremes, from increasing vulnerability, or from a combination of both.

This heightened risk profile can be mitigated to some extent by improved early warning capability for the onset of severe weather events. This is achieved by the use of numerical weather prediction systems such as the ACCESS-based system operated by the Bureau of Meteorology.

Scientific knowledge has advanced to the point where we are able to model such phenomena with increasing fidelity. Over the last thirty years weather prediction has moved from an uncertain science where prediction at 1-2 days lead time over large regions was a challenge, to the point where 7-10 day forecasts are considered very skilful and local forecasts are routine. Forecast skill is measured by comparing model predictions of temperature, humidity, pressure, wind and rainfall fields with observations of these phenomena. The Bureau systematically collects such verification statistics for every forecast so that it can demonstrate improvements in model accuracy over time.

There are at least three reasons for the increases of forecast skill. First and foremost is the advance in scientific knowledge and that representation of that in the models. Second is the ability to observe and assimilate data into models, particularly from satellites. Third is the enormous growth in computer power which now allows the best global models to run at 10-30 km resolution, and regional models at scales down to 1-4 km. For extreme weather, where the scales of action are often in the 10-30 km range and the complexity of weather is at its most intense, the ability to run models at high resolution with the complexity of the atmosphere addressed in detail is vital.

Most developed countries and an increasing number of developing nations consider numerical weather prediction (that is, numerical computer models of the atmosphere and its evolution in time) as a core capability of their National Meteorological and Hydrological Services. While not every service runs global prediction models, most recognize that timely and accurate forecasts for their region offer distinct social and economic benefits, particularly in terms of timeliness and local relevance.

Timing matters. Every hour of additional lead-time provides further opportunity to reduce vulnerability and exposure to severe weather, saving lives and injuries, and reducing property loss. Seasonal outlooks provide advantage for primary industries and an ability to prepare for possible enhanced extreme weather activity.

There are other natural and man-made disasters that also benefit from high performance computing. For the Australian Tsunami Warning System, an outstanding requirement is the need to generate inundation predictions in real-time, noting that time is again of the essence (minutes matter). For disasters such as the Montara oil spill, ocean prediction systems that forecast surface and subsurface currents come into play.

High performance computing systems enable such outcomes.

1.2. Benefits and impact

The utility value of severe weather forecasting (and related forecast systems mentioned above) essentially increases as the power of high performance computing systems increase. This is because the models improve in terms of:

- *timeliness* – the models can be run more frequently, providing more 'current' results
- *lead time* – the models can be run for longer time windows, providing earlier warning
- *resolution* – the models can be run at finer scale, providing greater relevance to local decision making
- *certainty* – the models can be run many times over (referred to as ensembles), providing probabilities for a range of outcomes.

Six case studies are provided below, each illustrating how these benefits are unlocked when high performance computing constraints are reduced. In each case resolution is shown to be a key determinant in the skill and usefulness/relevance of the forecasts. It is important to note that, since regional and fine scale models are nested in other models of larger domain, there is an interdependence flowing from the global models down to the specialist models such as for tropical cyclones.

These case studies also demonstrate the potential for applications in specific areas. For example, skilful forecasts of extreme heat allow for the development of sophisticated heatwave response strategies. The bushfire model allows for interaction with emergency services, at scales that are relevant for operations. Improved resolution of topography will reduce the need for forecasters to make corrections in these regions. The detailed wind forecasts for TC Yasi open up the possibility of generating impact forecasts ahead of the tropical cyclone.

Seasonal forecasting lags weather prediction in maturity, and faces even more complexity because of the need to consider the ocean and land and their interaction with the atmosphere. Models of seasonal climate variability do not attempt to capture the details of weather since it is unpredictable beyond around 14 days, but instead try to capture the pattern and evolution of "average" weather (climate). This is possible because the coupling of the ocean and atmosphere in the tropics generates joint effects that appear to be predictable on seasonal time scales, perhaps even out to a year and more.

Advanced warning of shifts in climate (for example drier or wetter seasons) provides valuable intelligence for managers in climate-sensitive industries (such as agriculture and energy), for emergency management (as highlighted in the QLD Floods Commission of

Inquiry), and for water management. The utility of forecasts varies with lead-time, region and sector. There is significant value in simply understanding how climate has varied in the past (so-called hind-casts). In some sectors this is on weekly to monthly time scales, and in others it is on seasonal to yearly time scales. For models, both atmospheric and oceanographic information must be taken into account. It is thought that predictability mainly derives from knowledge of the ocean state, but the atmospheric and land states are also important.

1.3. Operational change

A primary motivation for increased computer power is the potential to generate estimates of the uncertainty (error growth) in weather forecasts. The “butterfly effect” says that miniscule differences in the weather state now can manifest as substantial change in the weather days into the future. A similar effect is present for seasonal forecasts. In order to quantify this effect or, equivalently, to provide probabilities for the range of possible climate or weather outcomes, it is usual to generate an ensemble of forecasts, each distinguished by small variations in the initial state and/or minor changes in the model assumptions (the butterfly) but with different weather/climate outcomes as the forecast evolves. These are often run at slightly coarser resolution to allow many ensemble members to be generated. The overall utility value of forecasts is enhanced by such a probabilistic approach allowing informed decision-making and better assessment of risk. These are significant additional computational burdens but the estimates of uncertainty allow informed decision making and better assessment of risk (that is, the likelihood of an event is also forecast).

Errors in forecasts, particularly at fine scales and/or for rapidly evolving storms, can grow significantly over 12 hours (the current default cycle for the Bureau’s weather forecast updates). More frequent updating (say, around every 4 hours) would ensure the most up-to-date information is always available in extreme weather conditions, and allows for event-specific models to be initiated in special circumstances. Examples include for a tropical cyclone approaching landfall, a special high-resolution run to capture fronts for bushfires, or, as in Fukushima, a simulation of the trajectory of a sudden radioactive release.

While empirical models were the mainstay of early seasonal forecasting systems, dynamical models of the ocean and atmosphere are increasingly the norm. Here the challenge is to have sufficient computing power to represent the complex interaction of the ocean and atmosphere, but at relatively coarse scale compared with weather prediction (typically 80-120 km), and to undertake integrations over long periods, typically 9-12 months (compared with 7-10 days for weather prediction.

A unique challenge for seasonal forecasting models is that they still possess systematic errors (biases) that can confound and mask the signal we are trying to predict. The usual treatment is to undertake a number of hind-casts for the recent past (typically from around 1980), and to use these to identify and remove bias. This adds to the computational cost but adds value in terms accuracy and certainty.

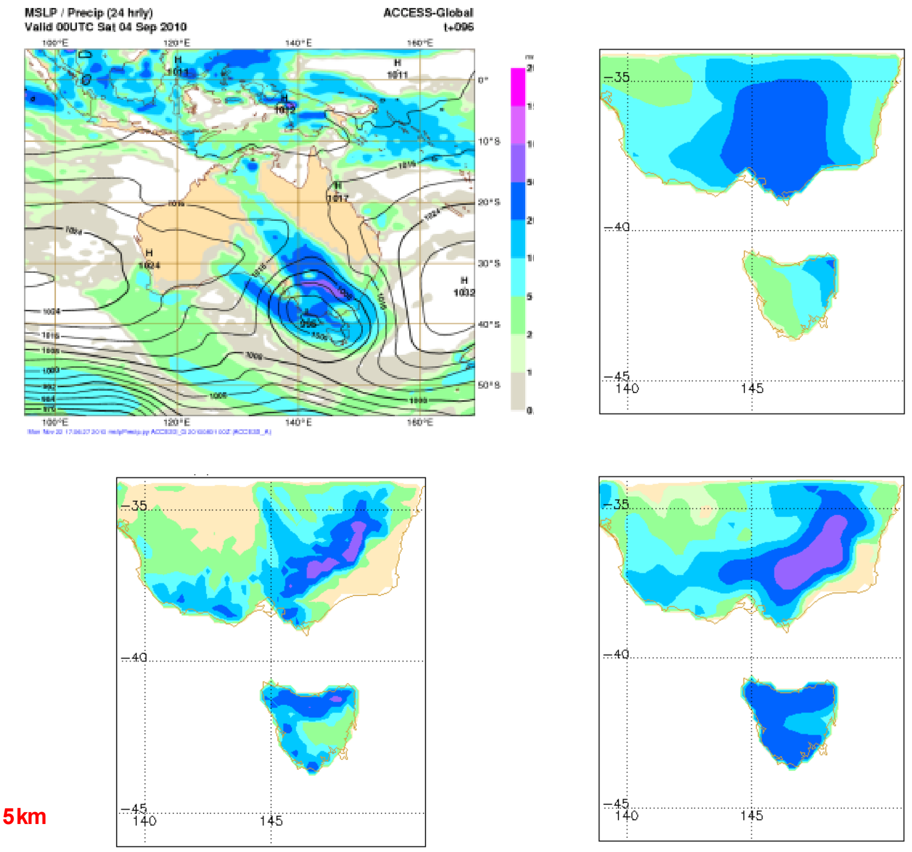
There is also significant value in re-analysing past weather systems. Modern weather prediction systems could be applied to past events such as Cyclone Tracy, to better understand the evolution and spatial structure of the systems, and to generate detailed digital representations of variables such as wind speed and rainfall for planning purposes. For some sectors, such as the re-insurance industry and emergency planning sector, access to detailed statistics of past events, generated through a single modelling system would lead to more accurate assessments of risk.

2. Case Studies

2.1 Case Study 1: Eastern Victoria Flooding September 2010

Severe flooding occurred in eastern Victoria early in September 2010. The ACCESS model is able to forewarn of the likelihood of extreme rainfall several days in advance (Figure 1, top left panel shows the 4 day forecast). Resolution matters. The top right and bottom left panels contrast 80 km and 5 km forecasts, respectively, which can be compared with the independent rain gauge analysis (bottom right).

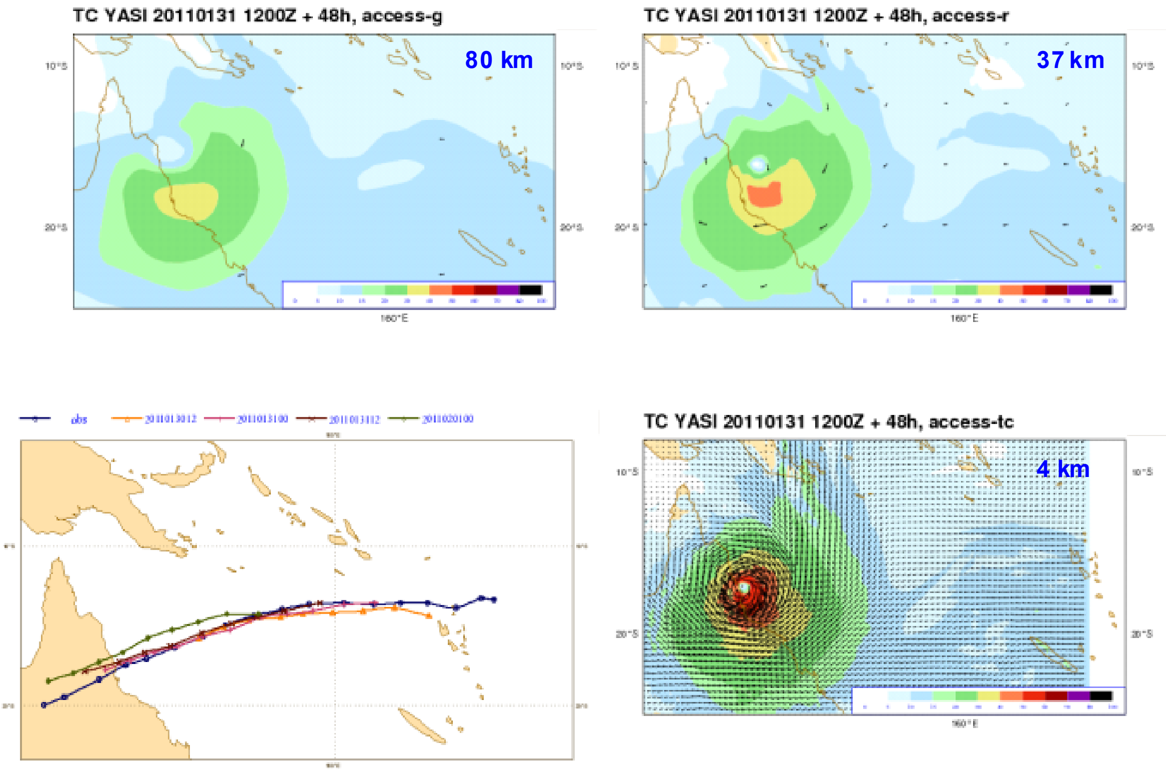
Figure 1. Extreme rainfall September 2010



2.2 Case Study 2: Tropical Cyclone Yasi

The second case study focuses on tropical cyclone Yasi in early February 2011. Again we show the impact of resolution on a 2-day forecast, going from the 80 km global ACCESS model at the time (top left), the regional ACCESS model (top right), to a 4 km resolution model run post the event (bottom panels). The bottom left panel shows forecasts beginning at 1200 on 30 Jan and then every 12 hours until 1 Feb. There is an excellent track forecast with the 4km version of ACCESS and very encouraging skill in the intensity of the forecast (bottom right), with the model getting down to ~950hPa (observed was ~925hPa). At present this model can only run operationally at 12 km. The use of ensembles (running the forecast several times with slightly different initial conditions) gives additional information on the strike probability and opens up the possibility of developing impact scenarios.

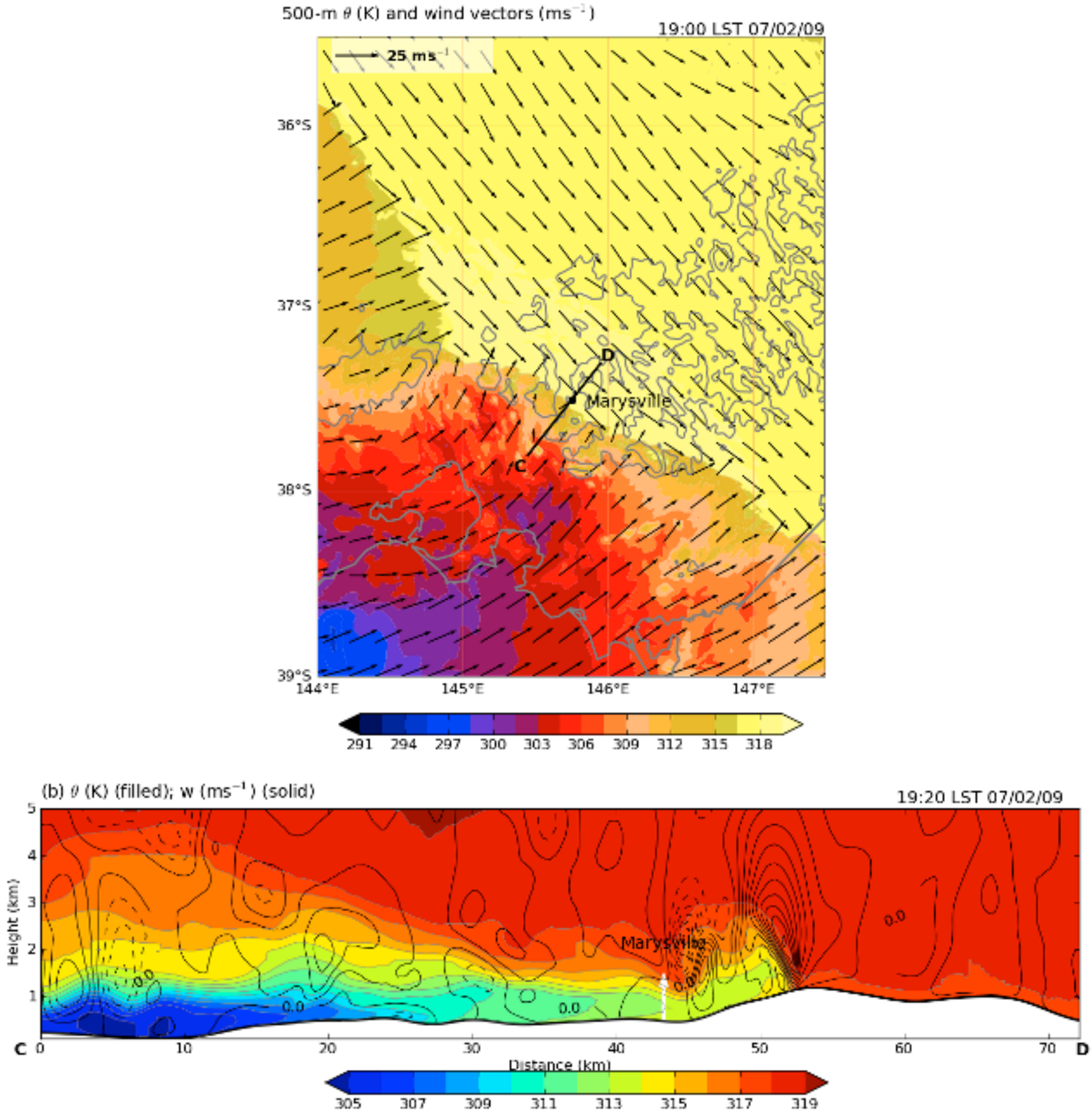
Figure 2. Models of tropical cyclone Yasi.



2.3 Case Study 3: Black Saturday Bushfires February 2009

This case study demonstrates the power of resolution for modelling fire weather and the potential for running special “models on demand”. The model is run at super-fine resolution in order to better represent the evolution of the front through Marysville. This run incorporates detailed topographic information and provides much greater detail in the wind directions, including changes; vital information for fire fighters and emergency services. It provides an accurate prediction of the cool change and major change in wind direction, and a much more accurate depiction of the severity of the event in terms of high temperatures.

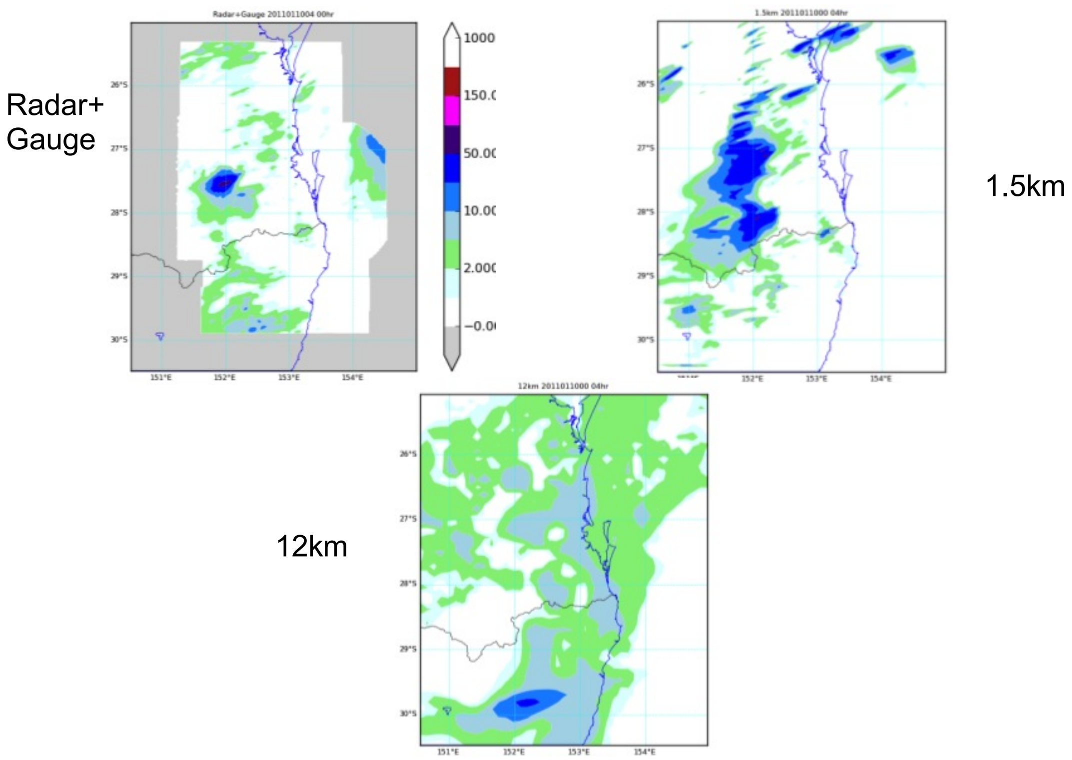
Figure 3. High-resolution (0.5 km) forecasts for 7 February 2009 (work with the University of Melbourne).



2.4 Case Study 4: Toowoomba Extreme Rainfall Event

This case study shows an experiment with a fine resolution ACCESS model to test the extent to which the detail of intense rainfall events might be captured. Shown are two four-hour forecasts for the severe rainfall in Toowoomba on 10 January, one at the resolution of the regional ACCESS model (12 km, bottom) and one at 1.5 km (top, right). The rainfall inferred from radar measurements is shown top left. Thunderstorms are small-scale and short-duration systems and their predictability is short (few hours), so it is not possible to forecast location or timing of events precisely. The 1.5 km version of ACCESS with latent heat nudging (based on radar-gauge rainfall) and assimilation of radar winds provides an indication of the severe event in the region around Toowoomba. The 12 km operational ACCESS-A provides no such indication. Ensembles have the potential to provide probabilities for severe storms.

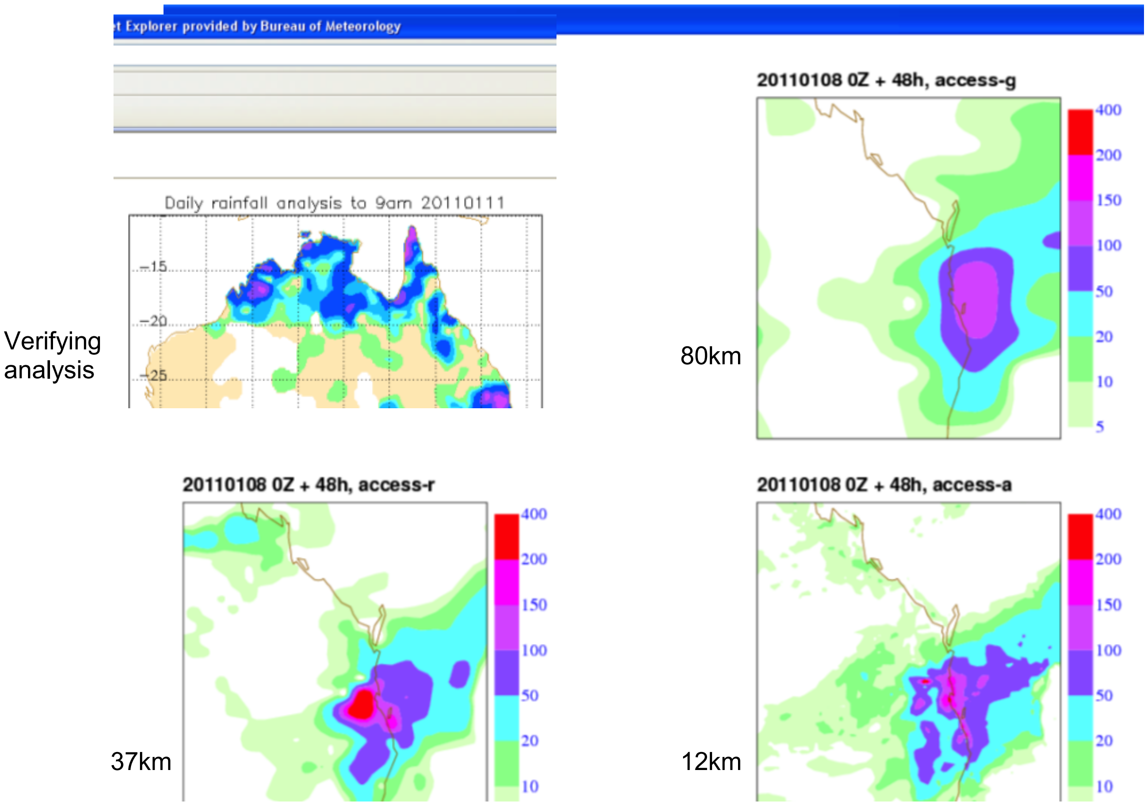
Figure 4. High-resolution experimental forecasts for the Toowoomba rainfall event.



2.5 Case Study 5: Brisbane Floods 2011

Experiments with the ACCESS global and regional models indicate an ability to give warning 6 days ahead of this particular major rain event. Higher resolution runs generate more realistic patterns of rainfall. Higher resolution models with ensembles provide more detailed and specific information, suitable for downstream applications and usable by third parties for integration with other geospatial data to aid decision-making.

Figure 5. Southeast Queensland extreme rainfall as depicted by different resolution models.



2.6 Case Study 6: Ensembles

AGREPS (an ACCESS-based version of the Met Office ensemble technique) has been implemented and is being run in experimental mode in the Bureau. With such technology we can generate likelihood maps for weather impacts. An example of an Extreme Forecast Index (EFI) is shown below. These provide a very powerful visual diagnostic for decision makers in advance of severe weather.

Figure 6. Four of 25 ensembles from an experimental tropical cyclone model run at 37 km grid resolution. The TC Yasi predictions vary in both intensity, track and timing and so provide and indication of the likelihood of particular outcomes.

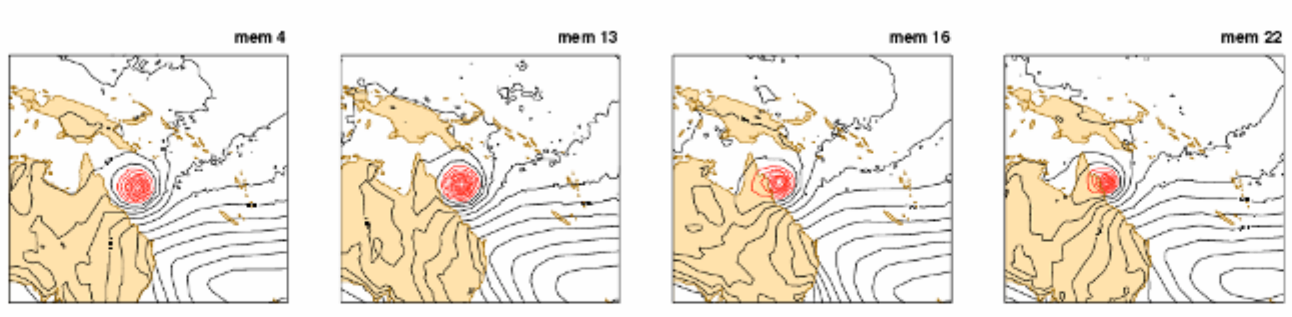


Figure 7. EFI values for 24h total rainfall, 10m wind gust and 2m temperature. EFI identifies areas where the ensemble forecast distribution is significantly different from the climatological distribution.