Australian Government
Bureau of Meteorology

Submission to the

Senate Rural and Regional Affairs Transport References Committee

Inquiry into Water Policy Initiatives

November 2005

Contents

Submission to the Senate Rural and Regional Affairs and Transport Reference Committee

EXECUTIVE SUMMARY

The purpose of this submission is to inform the Senate Rural and Regional Affairs and Transport Reference Committee on the role and contributions of the Bureau of Meteorology pertinent to the terms of reference of the Committee's inquiry into water policy initiatives. Particular focus will be on the Bureau's statutory role in monitoring and predicting weather and climate conditions, especially drought monitoring, and also on the Bureau's research program for better understanding of the causes and predictability of climate variability and climate change. Areas where the Bureau could assist with policy implementation are identified, and several other opportunities for improving water use planning, made possible through enhanced meteorological and hydrological services, are highlighted. This submission is particularly addressed at terms of reference (d) and (e) reproduced below:

d) monitoring drought and predicting farm water demand; and

e) the implications for agriculture of predicted changes in patterns of precipitation and temperature.

In these two contexts, the Bureau of Meteorology offers the following perspectives:

- ***Further research and development on climate data, monitoring and prediction systems, and also on related decision-making tools, will allow climate sensitive sectors of the Australian economy to reap the full benefit of the predictability of Australia's variable climate through more effective management of the attendant risks and opportunities.***

  Understanding the nature of Australia's highly variable climate, monitoring that variability and, where possible, predicting it are core activities of the Bureau and are central to both the tactical and strategic management of Australia's natural resources in a long-term sustainable way. Improved monitoring of Australia's climate by the Bureau of Meteorology will flow from its contributions to the Australian Water Availability project and the National Agricultural Monitoring System[1]. There are

[1] The Australian Water Availability Project is being implemented under a National Heritage Trust grant and the National Agricultural Monitoring System is an initiative being implemented through the Primary Industry Ministerial Council to underpin improved assessments of *Exceptional Circumstances*, in particular those induced by drought. Both activities are being coordinated by the Department of Agriculture, Fisheries and Forestry's Bureau of Rural Sciences.

opportunities to improve water policy outcomes through the delivery of enhanced climate information services that grow out from these and other initiatives. Significant improvements in predictive models of the climate system should deliver major benefits for agriculture, e.g. through better predictions of conditions associated with the El Niño/Southern Oscillation (ENSO) phenomenon. The full realisation of such benefits will only be possible through ongoing investment in basic meteorological and related data systems, and in the science and technology that will ensure best use is made of the data.

- ***Climate change is expected to have major consequences for Australian water resources and agriculture, which will present significant challenges for the nation's future prosperity. Uncertainties in climate change science are being reduced. However, there is an urgent need for improved projections of climate into the future as well as for a rigorous detection and attribution effort to determine the extent to which climate anomalies over Australia reflect either or both natural variations and human induced change.***

  Climate change may exacerbate already difficult conditions for Australian agriculture, particularly with regard to the future availability of water for irrigation. Much of the recent global warming is being attributed to human emissions of greenhouse gases, and projections into the future suggest a high likelihood that the warming will continue well into the 21st century. Attribution of other recent shifts or trends in climate to the enhanced greenhouse effect, particularly at regional or local scales, is more problematic although progress is being made. For example, the observed rainfall decline in south-western Australia is most likely due to both the enhanced greenhouse effect and other causes. Future changes in rainfall across Australia are uncertain, although the potential exists for decreases in available soil moisture under a warmer climate. Reducing the uncertainties will require the best quality observational and model data as well as a long-term commitment to advancing climate change science.

- ***The Bureau of Meteorology monitors meteorological conditions conducive to drought and operates a freely available service that provides comprehensive advice on the onset, extent and severity of rainfall deficiencies.***

  This Drought Watch service has been in operation for around 40 years and is a key component for the effective notification of incipient drought, for the provision of accurate advice to decision-makers on drought conditions in progress and, in particular, for the overall management of rural water resources.

- ***There are opportunities to improve rural water usage through the use of products from the Bureau numerical weather prediction systems. The Bureau's existing flood forecasting and warning services could be extended to meet the broader needs of water managers and improvements in earth system simulation, in particular, will open up further opportunities.***

  Numerical weather prediction produces forecasts of elements such as rainfall, temperature and evapotranspiration that can potentially be used to predict and manage rural water usage. The Bureau has a national river monitoring and forecasting service, which is currently directed towards flood forecasting and warning, but has considerable potential to be extended to a more general river forecasting service providing short and medium term water resource outlooks. Improved earth system modelling (e.g. ACCESS, see below) would deliver improved predictions of water availability in terms of river flows for storage management and water allocation as well as for variables such as soil moisture that are valuable to decision-making in many agricultural applications such as crop planning and management.

- ***The Australian Community Climate Earth System Simulator (ACCESS) project will assist in meeting many of the future needs of the agriculture and water sector for climate information, and hence this initiative deserves the support of this and other related sectors; the Bureau of Meteorology also urges them to be active in the development of applications that could draw on the results of ACCESS.***

  The benefits from improved earth system modelling, in addition to those described above, include improved seasonal climate predictions and reduced uncertainties in future climate change projections. The Bureau and CSIRO, with Australian Greenhouse Office support, are embarking on an exciting new approach to climate prediction through the development of ACCESS. The enormous potential of ACCESS to the agricultural and water sector will only be realised if the development of the system has support from this and other related sectors. In particular, the sector should promote the development of applications and support tools that link predictions effectively on a range of time-scales to specific agricultural and related needs.

- ***Large 'public good' benefits accrue from climate research and services, which reinforce the need for adequate funding of strategic research and development, as well as applied research for improved services.***

  Significant social, economic and environmental benefits have already been derived from publicly funded climate research and service developments in Australia, although these benefits have not been fully quantified. Demand for climate information from the agricultural sector, in particular, has risen rapidly over the past decade with the emergence of a better understanding of the link between Australian rainfall and ENSO. Research from the U.S. has calculated that worldwide benefits of better El Niño forecasts to agriculture alone are at least $450 to $550 million (U.S.) per year.

- ***Education and communication activities require investment and need to be tailored appropriately for effective delivery to target communities.***

  There is a need for an expanded national effort on training in climate risk management; current programs have a limited capacity for training on the scale required. The respective roles of extension and communication officers will be pivotal, and investment in the training of these people will be required if the adoption of climate services and the application of climate information are to extend to all industries and regions with the potential to benefit. While improving the accuracy of predictions will be a key factor in increasing the uptake of climate services, communicating climate information in an unambiguous way presents major challenges. There is scope for improving, for example, the communication of probabilities, risks and uncertainties. Increased investment in training is also required to capture the opportunities from existing and future climate services and research and, in addition, to provide clear and comprehensible advice on the added risk that climate change poses for agriculture and water resource management.

Submission to the Senate Rural and Regional Affairs and Transport Reference Committee (SRRATRC)

1. Introduction and purpose

Noting the specific terms of reference of the SRRATRC, the purpose of this submission is to inform the Committee on the pertinent roles and functions of the Bureau of Meteorology, focussing specifically on its activities in monitoring and prediction of weather and climate conditions, in particular drought monitoring, and on those activities relevant to predicting farm water demand. The submission also includes some coverage of research in the Bureau of Meteorology towards better understanding of the causes and predictability of climate variability and change, in order to assist the Committee with its examination of the implications for agriculture of possible changes in patterns of precipitation and temperature.

Under the *Meteorology Act 1955*, the Bureau of Meteorology has certain national responsibilities in respect of the atmosphere, parts of the land, the oceans and phases of the hydrological cycle and, accordingly, plays a key part in the water and agricultural sector on a national scale. The statutory functions of the Bureau include, *inter alia*, the:

- Forecasting of weather and the state of the atmosphere;
- Supply of meteorological information;
- Promotion of the use of meteorological information;
- Provision of hydrological services;
- Promotion and advancement of meteorological science, by means of meteorological research and investigation or otherwise; and
- Furnishing of advice on meteorological matters.

The Bureau performs these functions under the Act in the public interest generally and, in particular, for the purpose, *inter alia*, of assisting persons and authorities engaged in primary production, industry, trade and commerce.

This submission first describes activities of the Bureau of Meteorology in the area of monitoring climate variability and change, including its role in service provision and research. This discussion is relevant to term of reference (e) in that it addresses the need to improve understanding of the characteristics of natural climate variability together with those relevant to future climate change. The following section describes the Bureau's activities in drought monitoring (term of reference (d)), and the final section examines current and proposed new tools that can assist with predicting farm water demand (term of reference (d)).

2. Climate variability and change

Monitoring of Australia's climate and describing those features of climate variability and climate change[2] that are of importance to agriculture and rural water usage are major activities of the Bureau of Meteorology. This section describes the Bureau's role in related research and services provision.

2.1. Seasonal climate variability and prediction

Australia's climate is more variable than that of most, if not all, the world's major agricultural nations (Figure 1). This high variability largely reflects Australia's geographical location and the influence of the El Niño – Southern Oscillation phenomenon (ENSO), which leads to a quasi-regular cycle with effects that can range from widespread meteorological drought in association with El Niño events, to periods of abundant (and even excessive) rainfall in association with La Niña events.

Understanding the nature of Australia's highly variable climate, monitoring that variability and, where possible, predicting it are central to both the tactical and strategic management of Australia's natural resources in a long-term sustainable way. Carrying out these activities requires extensive, global-scale programs for monitoring the atmosphere, oceans, and land surface. Using past observations and statistical modelling, it is possible to formulate seasonal climate outlooks that define the likelihood of a climatic outcome (such as the probability of occurrence above average rainfall or below average temperatures). Recent developments include the construction of complex computer models of the climate system that couple processes in the atmosphere, oceans and land surface. These 'Coupled Climate Models', which are based on mathematical representations of physical and dynamical processes rather than on statistical relationships derived from past records, offer

[2] In the context of this paper, climate variability refers to variations in time in the mean or other statistical properties of one or more climatic variables, which extend beyond the time-frame normally associated with discrete weather events (i.e. beyond about one to two weeks). Climate change, therefore, encompasses climate variability, but the former is more typically reserved for a persistent trend or shift in one or more of the statistical properties of a climatic variable, which extends or is likely to extend over the timeframe of perhaps a century or longer. A 'change' in climate could be due to either natural forcing (e.g. the slowly varying internal dynamics of the oceans or changes in solar or volcanic activity) or due to human activities (e.g. increasing concentrations of greenhouse gases in the atmosphere due to burning of fossil fuels, land use change, etc).

the promise of more accurate forecasts on climate time scales. To capture the essence of the varying and changing climate system with sufficient accuracy for predictive purposes, coupled climate modelling systems require massive computing resources to process huge volumes of information at high spatial resolutions.

Skilful climate forecasts, whether or not from statistical or coupled modelling systems, offer opportunities for improved risk management in the face of climate variability. The effective linking of climate forecasts to agricultural production or farm economic models, would allow climate sensitive industries to move beyond the simple application of fixed climate statistics when planning and making decisions. With a demonstration of sufficient and reliable skill, the availability of climate forecasts would also raise the possibility of a more proactive, prediction-based approach to Exceptional Circumstance policy.

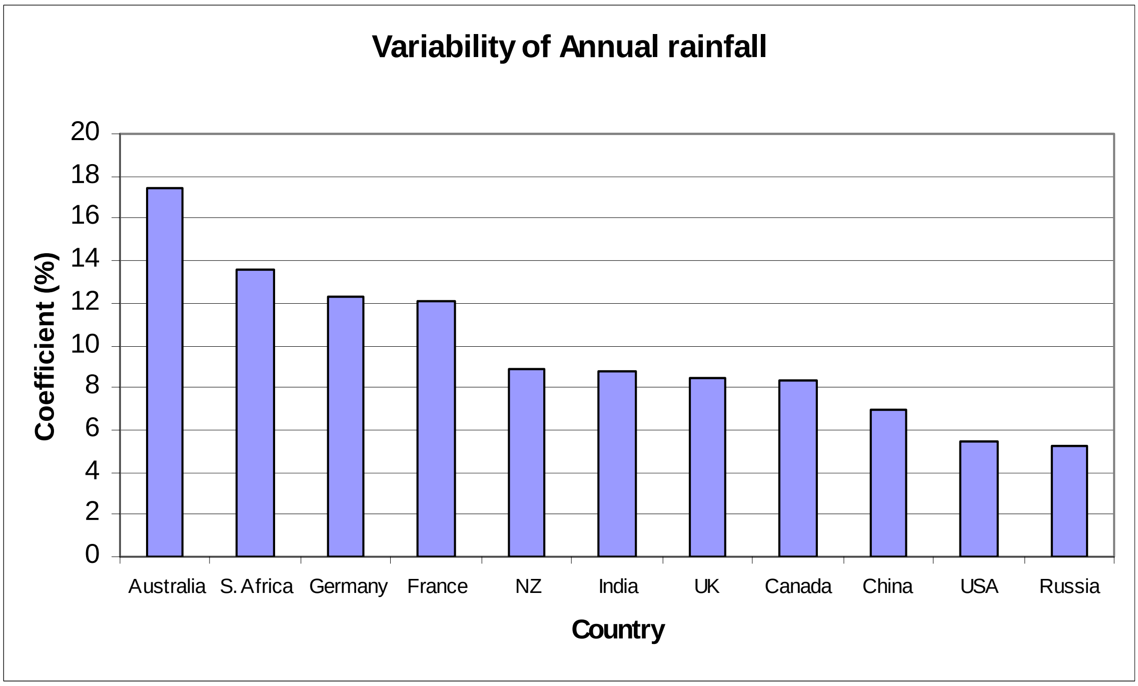

Figure 1. The coefficient of variation of national annual rainfall for Australia and 10 other countries. Values are calculated by dividing the standard deviation of annual rainfall by its mean. (Source: Love (2005))

There are clearly opportunities to improve policy outcomes for rural water management and usage by enhancing and increasing the uptake of existing climate services through:

- Improved climate data - thereby ensuring that climatological risk is better defined, and that water management practices best reflect actual long-term climate expectations;

- Improved climate monitoring - thereby providing the opportunity for improved tactical water management by farmers, allowing active redefinition of climate risk and the opportunity for decisions to reflect current climatic conditions; and
- Improved seasonal prediction, particularly when coupled with decision support tools, which together would expand the prospects for managing both climate risk and opportunity by forewarning of adverse or beneficial climatic conditions.

Benefits from improved climate data

The Bureau's climate services consist of climate data collection, climate monitoring and climate prediction. Climate monitoring and climate prediction are complementary, with the former providing information on the current state of the climate system from which predicted conditions are expected to evolve. Neither is possible without data collection, highlighting the foundation role of meteorological and related observational data. Widespread use is made of data from the Bureau's extensive surface-based observation networks (e.g. more than 7000 daily rainfall stations, nearly 900 daily temperature stations, and some 700 Automatic Weather Stations). It is clear, however, that with a careful targeting of additional resources, greater use could be made of remotely sensed data from satellites in the monitoring and prediction of climate variability in Australia.

Benefits from improved climate monitoring

Climate monitoring consists of analysing climate data, with an emphasis on comparisons with the averages and statistics of past observations. Thus, the products of climate monitoring establish the historical context for current climate variability, thereby enabling the definition of exceptional events and, when coupled with agricultural decision support tools, enabling better tactical and strategic management of water supply and farm risks. For example, Abawi (1995) has shown how the risk of rain damage to wheat is substantially elevated when the western Pacific Ocean is warmer than average, a situation that often occurs during Pacific La Niña events. Advance knowledge of such information can be used to modify the time of harvesting, reducing the risk of crop downgrades, and substantially increasing expected farm profit.

Improvements in climate monitoring can be expected over the next few years through the Bureau of Meteorology's collaboration with CSIRO in the Australian Water Availability project, and also in the related development of the National Agricultural Monitoring

System. Both projects are being led by the Bureau of Rural Sciences, with the latter project targeted at streamlining the Exceptional Circumstance process.

Benefits from improved seasonal climate forecasts

Seasonal climate prediction allows for improved risk management in the face of climate variability, by enabling greater preparedness and some advanced warning of the likelihood of adverse or beneficial seasonal conditions. The Bureau of Meteorology is a world leader in the development and public dissemination of seasonal climate forecasts. Three-month outlooks, which give the likelihood of rainfall and temperature being near normal, above normal, and below normal are produced on a rolling monthly basis, and distributed via the Bureau's website and via a more-detailed mailed subscription service.

In 2003, the Bureau of Meteorology launched a new coupled climate model for generating seasonal to interannual climate predictions, called POAMA (Predictive Ocean Atmosphere Model for Australia). Unlike the current seasonal outlook modelling system, which relies on the history of past observations, POAMA is based on mathematical representations of the interactive physical and dynamical processes of the atmosphere, ocean and land surface domains that together control climate variability. Coupled models of the climate system are more likely:

- To capture event types that are outside the range represented by the observed statistics (including severe events and a changing climate);
- To provide longer-lead forecasts; and
- Potentially to provide more accurate and higher spatial resolution forecasts.

Climate change already observed to be underway (as discussed in Section 2.2) means that observations of the past are becoming increasingly less useful as guides to the future, necessitating this shift from historical basis for forecasting to an explicit, physically and dynamically based approach. However, the application of the results of POAMA to agriculture has been slowed by limitations in the resources available to develop a version of the model that accurately represents the atmosphere, ocean, and land processes together with sufficient resolution and accuracy to forecast regional variations in rainfall and temperature at the seasonal time scale. Such a task would severely tax the resources of any existing individual Australian institute (see Section 5). Nevertheless, the further development of POAMA in the right institutional framework offers the opportunity for much more accurate and agriculturally tailored seasonal outlook information. Such an opportunity will only be realised through ongoing investment in basic data and climate science (see Section 6).

Improving agricultural management in a variable climate also offers concurrent opportunities for agriculture to adapt to climate change, since a large fraction of climate change will be manifest in changes in the characteristics patterns of weather and seasonal variability. For example, water conservation measures activated during droughts during the current climatic regime may equally well be applied in the future if, as a consequence of climate change, there are more frequent occurrences of reduced water availability. It is probable that many sectors are already embracing appropriate adaptation strategies for climate change, simply by managing their enterprises well for climate variability. Clearly then, improving the quality of climate information and expanding its uptake would lead to an increase in adaptive capacity.

2.2. Climate change: potential impacts, observations and possible future changes

The findings and issues of most relevance to Australian agriculture with regard to climate change are that:

- Climate change is expected to lead to significant consequences for Australian agriculture and water resources and that this presents major challenges for the future;
- Improvements in climate data and climate science are reducing uncertainties in our understanding of climate change;
- There is an urgent need for a rigorous detection and attribution effort to determine the extent to which recent unusual climate anomalies over Australia reflect either or both natural or anthropogenic climate change; and that
- There is a need for improved climate change projections, in particular for projections that describe in probabilistic terms the possible future evolutions of climate risk and opportunity for agriculture, and which would thereby facilitate the adoption of rigorous risk management practices.

Potential impacts of climate change

A recent Australian Greenhouse Office (AGO) publication reports that climate change may exacerbate already difficult conditions for Australian agriculture, particularly with regard to the availability of water for irrigation (Pittock, 2003). This publication also states that, by the mid-to-late twenty-first century, the net effects of climate change on agriculture are likely to be negative while there may be greater water surpluses in northern Australia where human use is low, in the southern areas where there is already high competition for water between human and natural uses reduction in water supply appears much more likely. IPCC (2001b) conclusions tend to support these assertions while noting that many uncertainties remain.

Climate change poses a major potential threat to the sustainability, and even viability, of much agricultural activity in Australia, and such consequences need to be carefully assessed and in the context of a broad range of policy frameworks such as those related to natural resource management, drought and the determination of Exceptional Circumstances.

At the national level, long-term climate change caused by enhanced greenhouse forcing presents at least three distinct policy relevant issues, which distinguish it from the perspective of climate variations alone. These issues include:

- Uncertainty about both the magnitudes and relative contributions of natural and human induced factors on observed climate change, leading to a less than perfect knowledge of climate risk;
- Uncertainty about the rate and, for some parameters and regions, the direction of future climate change, leading to uncertainty about the optimal adaptation strategies; and
- Uncertainty about changes to national and international competitive advantage in agriculture. For example, drying trends might benefit or disadvantage farmers on the margins of the cropping zone depending on the direction of a shift in rainfall patterns, while farmers on either margin might be disadvantaged by warming trends in the northern hemisphere that offered the opportunity for poleward expansion of cropping regimes in Russia and Canada.

For industries with low inbuilt adaptive capacity, climate change will inevitably require active and possibly imposed adaptation strategies, as incremental management may be insufficient. Recognising the point at which managing climate risk needs to be replaced with structural adjustment is far from precise.

Improved observations and science are reducing uncertainties in climate change

Certain aspects of climate change are now well established; for example, the global surface warming of 0.7-0.9ºC since 1910 and a current surface warming of 0.2-0.3 ºC per decade[3] are well understood and not in serious dispute (IPCC, 2001a, see Figure 2). Much, if not

[3] The range reflects differing definitions of trends

most, of the recent warming is likely due to human emissions of greenhouse gases (IPCC, 2001a; Meehl et al., 2004), with a further projected warming of around 0.5 ºC highly probable, even without further increases in atmospheric greenhouse gases (Meehl et al., 2005). Palaeoclimatic observations from the Northern Hemisphere, e.g. from tree rings, corals, ice cores, etc, reveal that recent global warming is very likely occurring at a greater rate than any temperature change observed in the past millennium and probably over the last 1800 years.

Significant systematic changes over several decades in climate variables such as temperature and frost frequency are being observed across Australia, implying that the climate change, as defined, is already underway. Uncertainty exists, however, in the extent to which the observed changes in climate over Australia may have an anthropogenic origin, although the experience of the 2002 drought suggests that global warming provides a highly plausible cause for its exceptional severity (Nicholls, 2004). Importantly, all projections reviewed by the IPCC (2001a) point to Australia experiencing significant climate change in future years, which would increasingly render historical records less useful for providing analogues from any new and perforce incompletely specified climate. In future years, it is possible that climate anomalies in some regions, which would now be considered exceptional, will become common place.

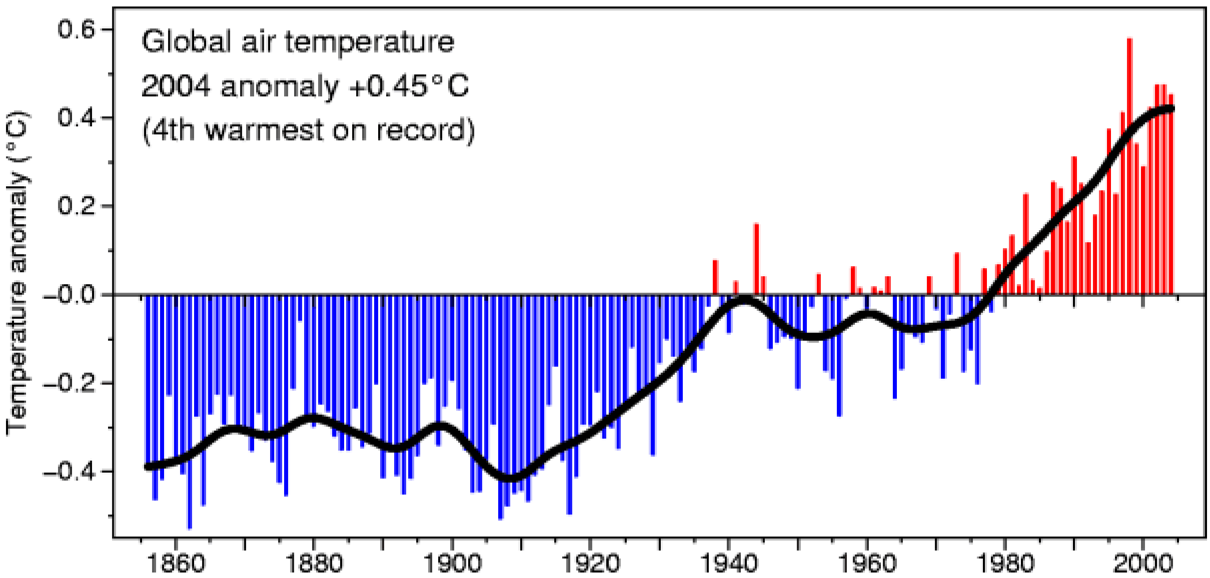

Figure 2. The annual combined global land and marine surface temperature record from 1856 to 2004 from http://www.cru.uea.ac.uk/cru/info/warming/ (Jones and Moberg, 2003).

The Bureau of Meteorology's contributions to knowledge about climate change currently cover the areas of observed climate change, climate science, climate change attribution, and climate change projections. Many activities have been undertaken in close collaboration with other agencies, such as the Australian Greenhouse Office (AGO), CSIRO, and State departments of agriculture/primary industries and natural resources. The AGO's Australian Climate Change Science Program and National Climate Change Adaptation Program provide overarching frameworks.

As noted already, observing climate change requires high quality, long-term climate records; for this purpose, a national Reference Climate Station (RCS) network has been identified to monitor long-term climate trends and variability in Australia. This network is the backbone resource for a number of high-quality datasets used to monitor variations in Australian temperatures and rainfall (Figure 3). Where possible, observations in these datasets have been corrected for discontinuities caused by changes in location, exposure (including the local effects of urbanisation), instrumentation, and observational practice. The datasets are used extensively for research, climate monitoring and reporting, including Australia's State of the Environment Report.

High-Quality Rainfall Network

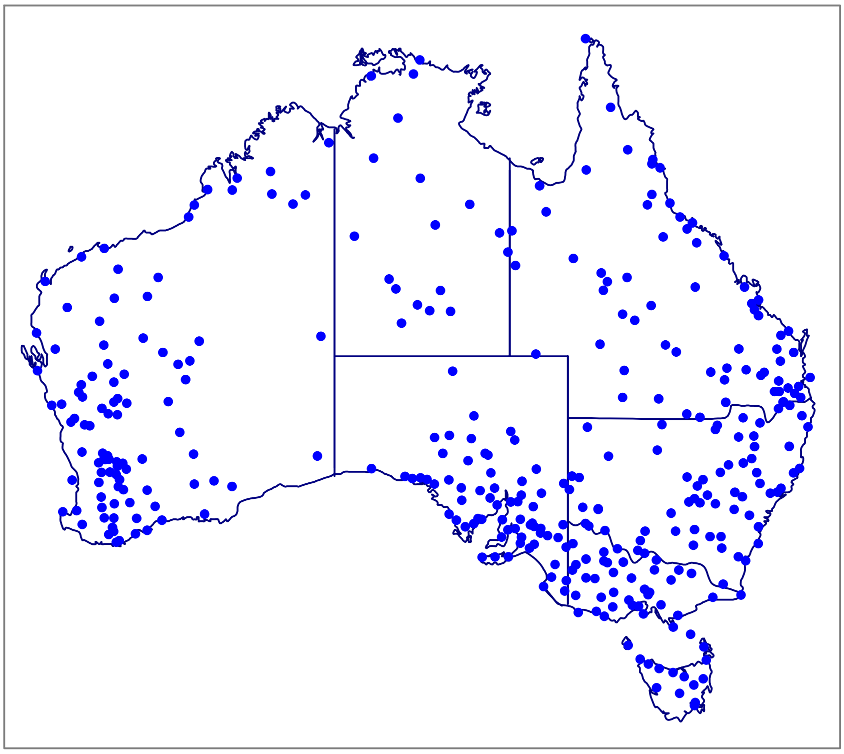

Figure 3. Locations of Australia's high-quality rainfall network used to monitor rainfall trends and variations.

Need for a clearer understanding of the causes of recent climate change over Australia

A key issue for industry and government policy responses to climate change is the cause and hence likely future direction of climate change. In climate science, determining cause is generally termed attribution, i.e. the ability to ascribe the occurrence of an unusual event or epoch to one or more processes operating within or on the climate system that are of either natural or human origin. Such processes may be associated with the injection of volcanic aerosols, slowly varying dynamics of the deep oceans, or increasing concentrations of atmospheric greenhouse gases derived from the burning of fossil fuels. The ability to attribute a climate change depends on several factors; it is somewhat easier, for example, to attribute changes in smoothly varying measures such as temperature, than changes in highly varying measures of climate such as rainfall. Attribution can also be computationally very expensive, and typically requires very advanced physical coupled climate models to be done convincingly.

Despite the difficulties, some progress has been made in attributing observed climate variability and change. While recent global and Australian warming has been linked to increasing greenhouse gas concentrations (IPCC, 2001a; Stott, 2003), attribution of recent rainfall changes has been more problematic, and results are more uncertain. In analysing the rainfall decline in southwest Australia since 1970 (Figure 5), IOCI (2002) concluded that "Most likely, both natural variability and the enhanced greenhouse effect have contributed to the rainfall decrease". More exact attribution of climate change is not beyond climate science, as the physics governing climate variability and change are well understood. However, the effort will require the best quality observational and model data, as well as again a commitment to advancing climate change science.

The case for improved projections of climate change

The future incidence of drought under a changing climate may be strongly influenced by changes to the important modes of interannual variability affecting Australia, such as ENSO. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2001a) projected a range of warming of around 2.5 to 5°C in northern Australia, and 2 to 4°C in southern Australia towards the end of this century. Projected precipitation changes were more equivocal, with general decreases in northern and southern Australia, but with some models showing increases (particularly in the south). The potential exists for less available soil moisture over the continent under a warmer climate. Improved climate modelling capabilities, such as those that will emerge from the ACCESS program (Section 5), will help narrow some of the uncertainties inherent in current projected changes of climate over Australia in coming decades.

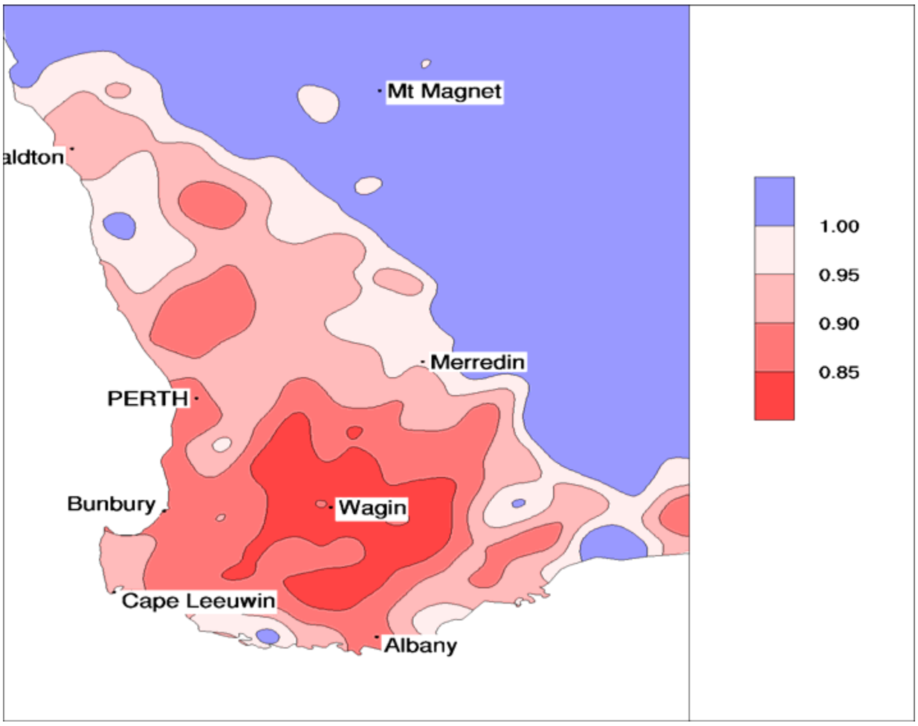

Figure 4. Mean March to October (wet season) rainfall in southwest Australia for 1971-2002 as a ratio of the mean for 1900-1970. This shows the general 10-20% decline in rainfall (~50-200mm) experienced in this region since 1970.

3. Drought Monitoring

The Bureau of Meteorology monitors the extent and severity of drought in terms of rainfall deficiencies; agriculturalists rate the effects of drought on primary industries; hydrologists consider downturns in streamflow and soil and groundwater levels; while sociologists assess drought in terms of social expectations, perceptions and outcomes. Australia has one of the most variable rainfall climates in the world; the strongest cause of year to year fluctuations is the climate phenomenon commonly called El Niño/Southern Oscillation (ENSO). In recent years, the Bureau of Meteorology's greater understanding of the mechanisms behind El Niño and La Niña events (the two extremes of ENSO) has improved its ability to predict seasonal rainfall (as discussed earlier) and thus to help authorities and individuals with information on incipient and ongoing drought.

Monitoring Drought

In general, it is possible to distinguish three types of drought:

a) meteorological drought occurs when rainfall totals over an extended period, e.g. three months or more, fall below an arbitrary but low threshold. In the Bureau of Meteorology's Drought Watch Service, thresholds used are – between the lowest 5th and 10th percentiles of historical records for **serious** rainfall deficiencies (Figure 5 below - orange section) and in the lowest 5th percentile range of historical records for **severe** deficiencies (yellow section in Figure 5 below);

b) agricultural drought occurs when available soil moisture is inadequate to sustain agricultural production. When available, irrigation can be used to forestall agricultural drought or allow production to occur even when the water available from rainfall would be inadequate in most years; and

c) hydrological drought occurs when the supply of water from rivers, streams and dams to service user communities falls to arbitrary but low thresholds. The thresholds may depend to a large extent on the use to which the water is usually directed, e.g. irrigation for agriculture, direct human consumption, power generation etc.

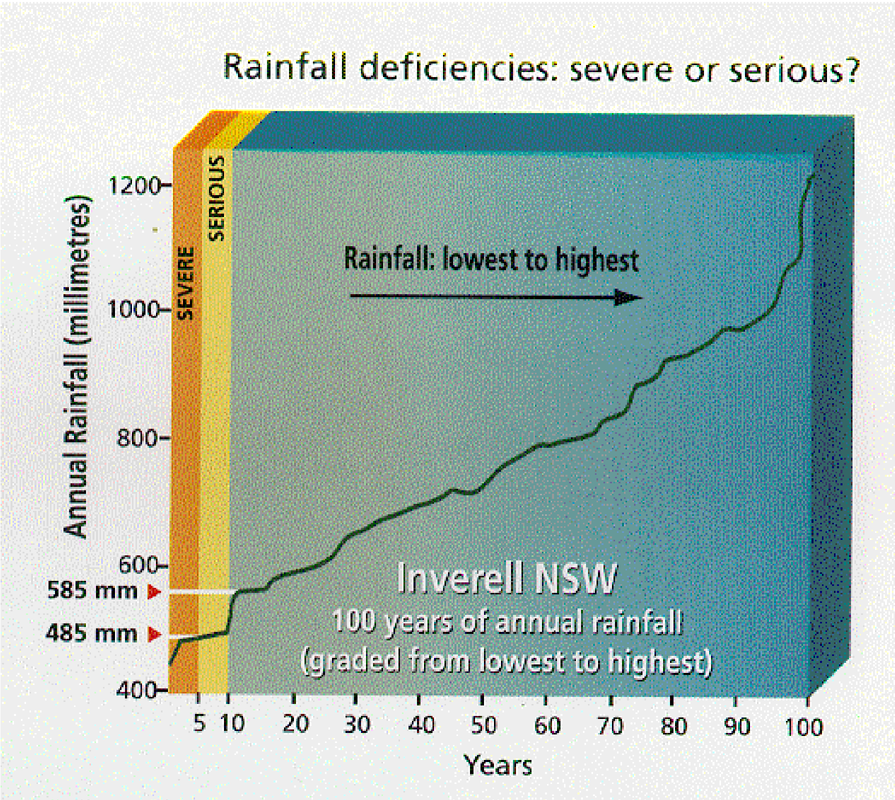

Figure 5. Annual rainfalls for Inverell (NSW) ranked from lowest to highest to illustrate "severe" and "serious" rainfall deficiencies.

The relationships between the three forms of drought are shown schematically below. It should be noted that in the case of irrigated crops, hydrological drought may precede or be coincident with agricultural drought, rather than is the case shown here for rain-fed agriculture.

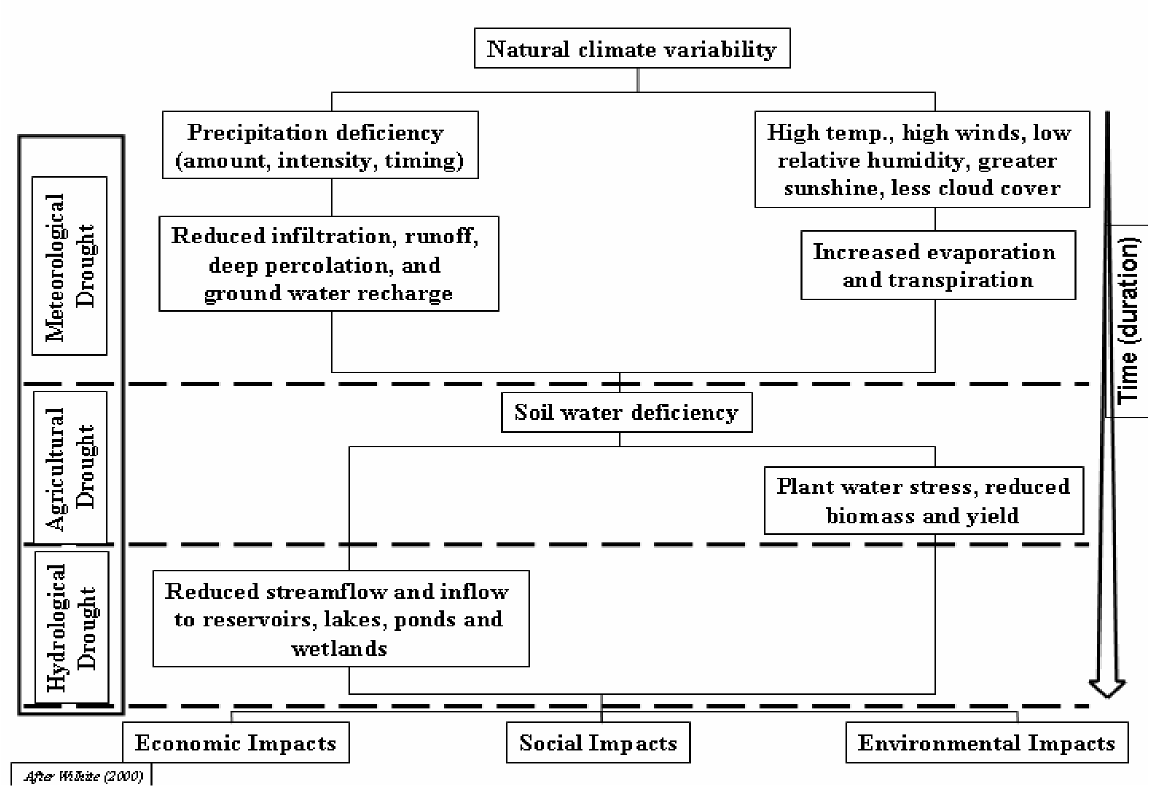

Figure 6. Relationship between various types of drought and duration of drought events (after Wilhite, 2000)

On the basis of monthly rainfall analyses, areas suffering from significant rainfall deficiencies appear in the Bureau of Meteorology's Drought Statement (see below) as well as in the *Monthly Drought Review* publication. If the accumulated rainfall over three successive months lies within the lowest 10 per cent of values for this period on record (at least a serious deficiency), a Drought Watch is commenced and the region is highlighted. This initial dry period stretches to six months for the more arid regions. Consideration is also given to whether an area is usually dry at certain times of the year.

Allowing for seasonal conditions (some areas of Australia are seasonally 'arid'), the Drought Watch may continue for many months; it ceases when adequate rainfall has accumulated. 'Adequate' here is defined as well above average rainfall for a period of one month, or above-average rainfall over a three-month period.

Given that meteorological drought is always a prerequisite for the onset of other, more complex notions of drought, the Bureau of Meteorology's Drought Watch Service provides a consistent starting point for national drought alerts. Since the implementation of Commonwealth Government 'National Drought Policy' initiatives in 1992, the Bureau has expanded its rainfall analysis services. Many of the new products are available through the World Wide Web or Bureau of Meteorology offices.

Drought Statement

Drought Statements, which monitor rainfall deficiencies, are released monthly by the Bureau's National Climate Centre. These statements are found on the Bureau web site at: http://www.bom.gov.au/climate/drought/drought.shtml. In addition, a Weekly Rainfall Update bulletin provides tables and maps of recent rainfall, and includes a discussion of the effects of recent rain on extant rainfall deficiencies. Drought Statements include maps of rainfall deficiencies such as shown in Figure 6.

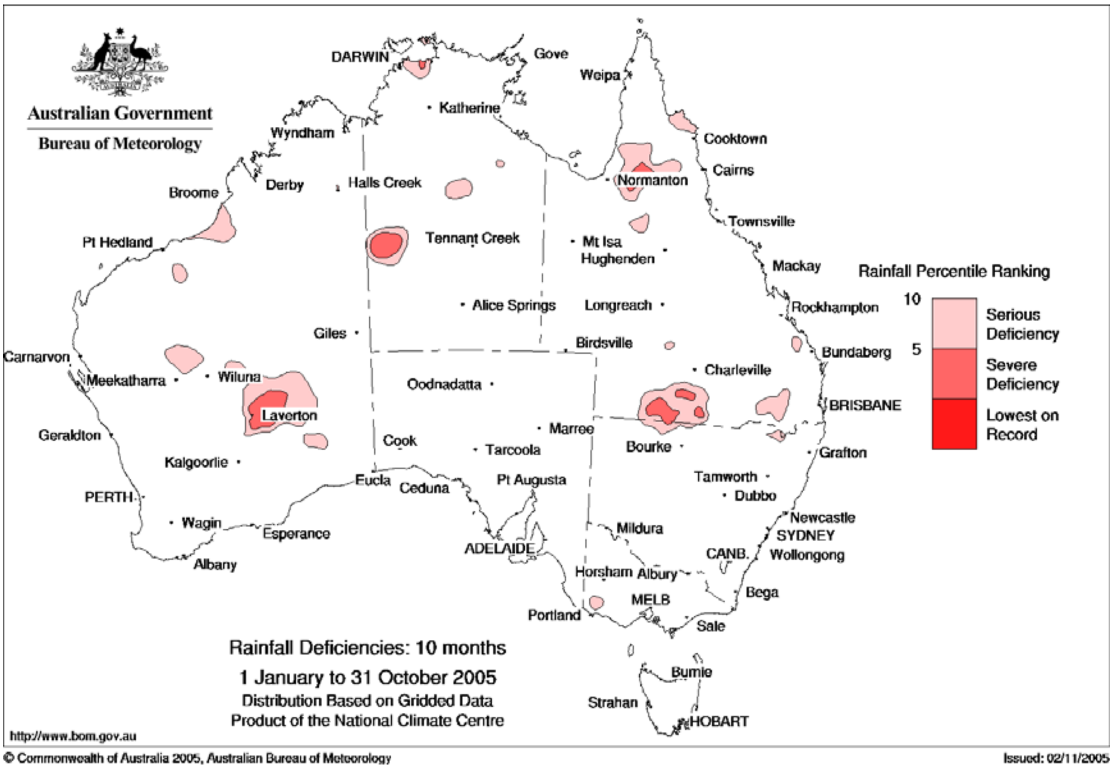

Figure 6. Rainfall deficiencies for 10 months 1 January to 31 October 2005.

4. Rural Water Management and On-Farm Demand

Implementation of the National Water Initiative and the relationship between rural land use and water availability and management requires good information on the current extent and variability (spatial and temporal) of the resource, as well as the ability to understand and predict its variability, both existing and as a result of any long term climate change. The Bureau can contribute effectively to the provision of information through its climate networks and various weather and climate modelling services and to the understanding of the resource through its capability of translating this information into hydrological and water resources products through its Hydrological Services Program.

Weather modelling systems

The Bureau operates a number of numerical weather modelling systems that run at different space and time scales. The system of most use at the farm scale is the Limited Area Prediction System (LAPS). This system generates forecasts (including probabilistic forecasts) of weather elements such as rainfall, temperature and evapotranspiration out to 4 or more days that have the potential to be used to predict on-farm water demand, particularly when linked in with crop modelling systems. Through participation in the Global Energy and Water Experiment (GEWEX) program and as part of the research planned within the new eWater CRC, the Bureau is working to better integrate the outputs of these modelling systems into the operational needs of a range of agricultural and water management enterprises.

Extending services for improved water management

The Hydrological Services Program includes a national river monitoring and forecasting service which is currently directed towards flood forecasting and warning, but has considerable potential to be extended to a more general river forecasting service providing short and medium term water resource outlooks. The river monitoring and forecasting service involves national scale real-time river data collection and the provision of a range of real-time hydrological data and information through the Internet. This information on river flows has the potential to form the basis of a system that can support more efficient operation of water management systems by enabling them to adapt to the continually varying climate and water allocation demands. Such a national river forecasting system also has the potential for assessing the impact of short-to-medium term climate variability as well as much longer-term climate change.

A challenge for the implementation of such a system is the requirement to address issues of consistency of standards in water resource data collection and data management among the growing number of agencies involved. This will require a strong commitment from State jurisdictions and coordination at the national level. The Bureau can play a key role here through its national network of offices, its continuing role in water resources data collection and assessment and, in particular, through its operation of national rainfall and evaporation data networks. Moreover, the Bureau has established links with key state and regional water agencies involved in data collection and resource management as well as links to the international community through World Meteorological Organization (WMO) and UNESCO water programs which enable access to new developments elsewhere. The Bureau is also actively participating in the Australian Water Data Infrastructure Project which has the objective of bringing together spatially diverse sources of water data and information. Furthermore the Bureau's membership of the Executive Steering Committee for Australian Water Resource Information (ESCAWRI), which has responsibility for implementation of Clause 86 of the National Water Initiative dealing with improved coordination, best practice and development of partnerships in water data collection, is also a strategic advantage.

Science for improved water management

To provide fully effective water management, the capability to understand and predict the movement and availability of water within all components of the hydrological cycle and to be able to simulate the impacts of various landscape changes on the distribution and availability of water is essential. The ACCESS project (see Section 5) is a development that provides this capability through full earth-atmosphere simulation. Such simulations can provide predictions of water availability and distribution across space scales ranging from small catchments, through river basins to larger regions and time-scales varying from hours to weeks and longer. Outputs can include water availability in terms of river flows for storage management and water allocation and also variables such as soil moisture that will be valuable to decision-making in many agricultural applications such as crop planning and management. The Bureau's contribution to the Australian Water Availability and National Agricultural Monitoring System projects (see Section 2.1) are also relevant in this regard.

Water Supply System Risk Assessment

The effective management of water supply systems requires an understanding of the reliability of the systems in Australia's variable climate. The Bureau, through its participation in the CRC for Catchment Hydrology (CRCCH), has developed techniques for generating long sequences of climate data that may be used to assess the risk of supply failure of water supply systems. These techniques form the Stochastic Climate Library (SCL) which is one of the components in the Catchment Modelling Toolkit developed by CRCCH (www.toolkit.net.au). Further development of these techniques to include climate change trends in the generated sequences of climate data will be undertaken by the Bureau within the eWater CRC.

5. Integrated Earth System Modelling (ACCESS)

Australia is embarking on an exciting new approach to climate prediction through the development of the Australian Community Climate Earth System Simulator (ACCESS). The enormous potential of ACCESS to the water management and agricultural sectors will only be realised if those sectors:

- Supports the development of ACCESS; and
- Participates in the development of applications that allow predictions, on a range of time-scales, to address the specific needs of the water sector including rural water usage.

ACCESS will be a world-class mathematical model of the earth's climate system that will be used to provide more detailed and more accurate predictions of Australian climate over coming seasons and climate projections for several decades ahead.

The complexity of earth system modelling has increased substantially in recent years and Australia has not been able to keep pace with Europe or the U.S. under previous arrangements. The Bureau of Meteorology and CSIRO will, with Australian Greenhouse Office support, begin the development of a single national system. This collaboration was recently supported by the National Farmers Federation (NFF, 2004). ACCESS will provide a major new focus for climate modelling effort across Australia and will eventually include substantial input from universities and other agencies within Australia. More accurate information about future climate will be of enormous potential benefit to the sector. This potential will only be realised, however, if the sector supports the enormous strategic effort required to develop the system and the application of the predictions to address key issues within the sector. This issue is discussed more generally in Section 6.

Figure 7. Integrated earth system modelling uses complex computer models to examine variations and changes in a range of climatic variables of social, economic and environmental relevance.

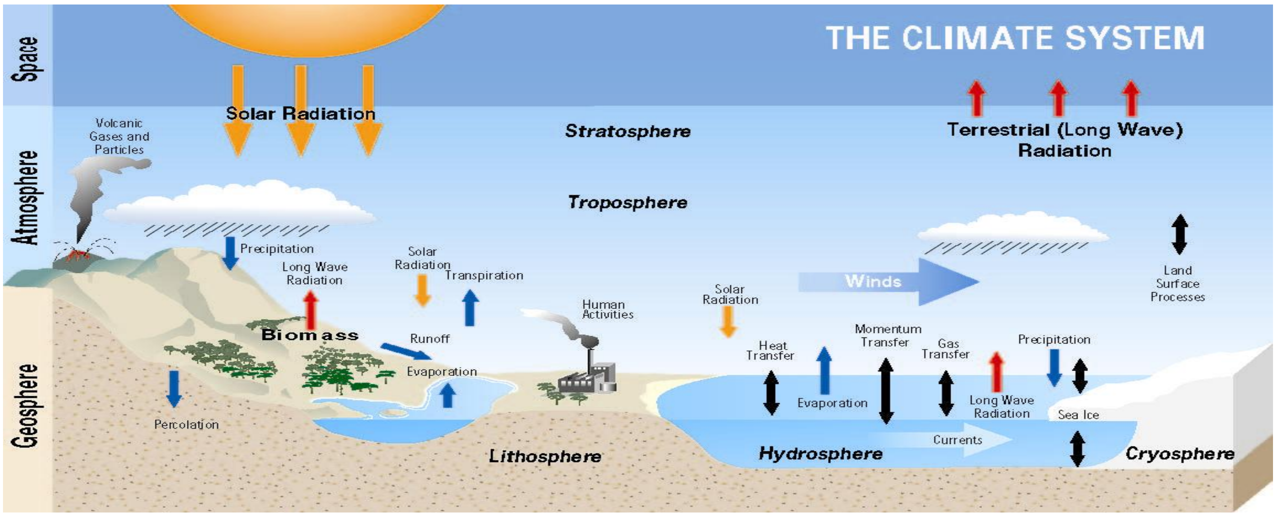

Figure 8. Components of the global climate system, including the atmosphere, hydrosphere, biosphere, cryosphere and lithosphere.

6. Cross-cutting activities

There are a number of cross-cutting issues that will need to be addressed in order to ensure that the opportunities from climate research and services for the agriculture and water industry are fully captured. In doing so, it is important to note that:

- Large ‘public good’ benefits accrue from climate research and services which enforce the need for increased government support;
- Climate services need to be delivered within a risk management framework;
- Education and communication activities require investment and need to be tailored for effective delivery; and
- Significant future improvements in services will only be gained through adequate funding of strategic research and development.

Large ‘public good’ benefits are flowing

The impacts of climate variability (e.g. drought) on agriculture are high. The 2002-03 El Niño-related drought resulted in a 1% drop in Australia’s Gross Domestic Product and earlier droughts have been as severe.

Significant social, economic and environmental benefits have already been derived from publicly funded climate research and service developments in Australia though these have not been fully quantified. Demand for climate information from the agricultural and water management sectors has risen rapidly over the past decade. Many farmers and others in the agricultural industry have adopted seasonal climate outlooks to assist in their decision making and information on climate change is now influencing decisions in government, particularly with regard to future water supplies and related infrastructure. These services, and the underpinning climate research, have been almost entirely publicly funded.

Paull (2002) discussed the considerable value and benefits of seasonal climate forecasts to Australia. The estimated total benefit of these forecasts and climatic risk assessment to grazing industries alone, from 1991/92 to 2002/03 was in the range of $600M to $1200 million (Queensland Centre for Climate Applications, 2002).

Research from the U.S. suggests a very high benefit-cost ratio for climate services. For example, the latest *Economic Statistics for NOAA* (NOAA, 2005) provides the following:

- Benefits to U.S. agriculture by altering planting decisions have been estimated at $265 to $300 million (U.S.) annually, throughout El Niño, normal, and La Niña years.

- Worldwide agriculture benefits of better El Niño forecasts are at least $450 to $550 million (U.S.) per year.
- An analysis of NOAA's operational El Niño forecasting system comparing forecast systems costs with anticipated benefits in just the U.S. agriculture sector yielded an estimated annual rate of return on that investment of between 13 to 26 percent.

Climate in a broader risk management framework

The concept of 'climate risk management' is increasingly used to describe the strategies to minimise stakeholder risks due to climate variability, including climate change. There is evidence to suggest that climate training and services are most effectively delivered when they are included within a risk management framework and this requires a multi-disciplinary systems approach (MCV, 2005). Climate-related risk management should be better linked to extension programs that deal with broader aspects of business and NRM risk management. This is particularly important when considering the implications for agriculture of predicted (uncertain) changes in patterns of precipitation and temperature (term of reference (e)).

Education and communication: investment and tailoring

A good deal of climate science R&D is already in the public domain but is not being fully utilised by the sector because of: limited funding for extension activities; lack of collaboration sometimes (e.g. between federal agencies and State government departments); or through a lack of associated education opportunities (e.g. for individuals within the sector).

The Bureau has a role in public education and this includes outreach activities in assisting farmers and other end users in better using climate services, particularly seasonal outlooks. Extensive information services are also available through the Bureau's popular web site (see http://www.bom.gov.au/climate/) and through regular media statements (see http://www.bom.gov.au/climate/ahead/rain_ahead.shtml). Several State government departments of primary industries and natural resource management have been successful in working with the agricultural community to improve adoption of climate services, including application tools. Australia's efforts in climate services have been innovative and, in many respects, have led the world.

MCV (2004) called for the development of an expanded national effort in training in climate risk management and noted that the current Managing Climate Variability R&D

program of Land and Water Australia has limited capacity for training on the scale required: "The key to success will be industry ownership and leadership to endorse the value of training in climate risk management."

Understanding the information needs of end-users in order for them to make tactical and strategic decisions for their industry and region is essential for improving uptake. Extension officers, within a broad risk management context, have been successful in integrating climate services into the farmer's 'tool-kit'. Farmers' preferences for learning are primarily through interactions with people rather than models, highlighting the importance of extension and communication officers (MCV 2005). Investment in training these people will be required if the adoption of services and applications are to extend to industries and regions so far untapped.

Communicating climate information still presents major challenges, which reinforces the need for more tailored training of end users. In terms of the factors contributing to the poor communication of seasonal outlooks, there is scope and a very pressing need for improvement in communicating probabilities, risks and uncertainties. There are challenges in communicating the distinguishing features of weather, climate variability and climate change. Improved communication and consultation both between researchers/climate information providers and with end-users are also required. However, improving forecast accuracy still holds the key to significant uptake of climate outlooks and so investment in strategic research is also a priority (as discussed earlier and further below).

While a large majority of the public believes that climate change is occurring and that it is an issue to be concerned about, overall public understanding is not high. This is at least partly a result of the media's journalistic norms of balanced reporting, i.e. for every group or individual providing evidence of climate change, the media 'balances' this with comment from an individual or group who is more sceptical. While scepticism is important in the climate change debate it is also important to be mindful that a very large majority of climate scientists believe in the evidence for climate change and foresee significant climate change for Australia in the future.

For many years the Bureau has collaborated with Australian and State government departments and directly with farmers and related groups to assist them to more prudently use climate information. While this has generally been in the area of climate variability, and more specifically seasonal outlooks, there is a need for water management and agriculturally relevant climate change information – in effect the application of extension activities to communicate future projections. As climate change adds another risk factor for agriculture and water management, increased investment in training is required to improve the opportunities from existing and future climate research and services.

Investment in strategic R&D is critical for better outcomes

Strategic and applied research in meteorology has been of great benefit to the agricultural sector (e.g. through provision of increasingly accurate weather forecasts) and its benefit to water management is increasingly being recognised. However, it is becoming increasingly difficult to capture the necessary funds for strategic research. Such funds are required, for example, for the development of complex mathematical computer-based climate models (such as for POAMA and ACCESS), for greater utilisation of existing data sources for use in seasonal climate outlooks, and for climate change projections.

Support behind significant investment in climate models is provided by the National Farmers Federation (NFF 2004): "… it is imperative that significant and immediate research investment be focused on the development of more accurate Global Climatic Models (GCM) with longer predictive lead times and forecast horizons. This investment is particularly important given the possible effects of climate change on Australian agriculture."

Applied research (e.g. linking the outputs from climate models with decision-making tools) should have a path to widespread adoption available, e.g. through improving services widely used by the sector. However, applied research that is unlikely to lead to improved service outputs and outcomes, especially if it has an ineffective adoption pathway, should be given lower priority.

Meeting some of the needs of the water management and agriculture sectors requires multi-agency involvement and funding for such collaborative activity is often absent, short-term or insufficient to resource important strategic multi-agency activities (e.g. in the integration of climate information with agricultural and other risk management tools). Most of this research needs to be strategic and non-commercial in nature. Multi-agency collaboration is usually still required beyond the life-time of a specific project and funding is often unavailable to support collaboration as an ongoing activity.

Finally, R&D Corporations need to be familiar with the core expertise in relevant agencies to ensure that they fund research in an efficient manner e.g. by reducing duplication and enhancing collaboration.

7. Conclusions

This submission sets out where the Bureau of Meteorology can contribute to the development and implementation of policies for underpinning the National Water Initiative and especially rural water usage as described in the terms of reference. In particular the submission has focussed on two of the terms of reference; (d) and (e).

The Bureau of Meteorology wishes to inform the Committee of its key role in assisting in this area and to *inter alia* the following issues and recommendations:

- Improved seasonal to interannual predictions will require developments with climate data, monitoring and prediction systems and also decision-making tools in order for end users to manage effectively the ongoing and future risks and opportunities posed by climate change and variability.
- Climate change is expected to have significant consequences for Australian agriculture and rural water usage, which will present major challenges for the future sustainability and, in some cases, the viability of some agricultural and water resource enterprises. Uncertainties in the climate science are being reduced. However, there is an urgent need for improved projections of climate into the future as well as for a rigorous detection and attribution effort to determine the extent to which recent unusual climate anomalies over Australia reflect either or both natural and anthropogenic climate change.
- There are opportunities through the Bureaus numerical weather prediction systems to improve the management of on-farm water demand and research is underway in this area.
- The Bureau’s Hydrological Services also have a role to play, particularly in assisting with the information needs of the National Water Initiative.
- The Australian Community Climate Earth System Simulator (ACCESS) project will assist in meeting many of the future challenges of the agriculture and water management sectors and we urge that the sector supports the initiative and be active in the development of applications in the future.
- Large ‘public good’ benefits accrue from climate research and services which enforce the need for adequate funding of strategic research and development as well as applied research for improved services.
- Education and communication activities require investment and need to be tailored for effective delivery.

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