Developments in climatology in Australia: 1946-1996*

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Australian climatology before 1946

Australian meteorological services were concerned with climate from their inception. For instance, H.C. Russell, the NSW Government Astronomer and Meteorologist during the late 19th century, wrote on ‘Physical geography and climate’ and ‘On periodicity of good and bad seasons’. Much of the early work focussed on the description of ‘average’ climate, although interannual variability was recognised and the possibility of predicting these variations was considered.

Even before the formal establishment of meteorological services, climate had been a matter of controversy. As early as 1850 the colonies, especially Victoria, were promoted as having a climate beneficial to sufferers of tuberculosis. This was hotly contested by the Victorian Government Statist.

The Commonwealth Bureau of Meteorology, from its establishment in 1908, was involved in climate questions of public importance. The early editions of The climate and meteorology of Australia, by H.A. Hunt, Commonwealth Meteorologist, included a discussion of influences affecting Australian climate. This focussed on the possible effects of forests on rainfall. The possible ameliorating effects of forests and agriculture on climate was a controversial subject before and after the turn of the century. Later, Griffith Taylor, who was employed as a physiographer by the Bureau from 1909 to 1920, documented the physiography (including the climate) of Canberra, the planned site of the new capital. Taylor was embroiled in acrimonious public disputes after he noted that much of the inland was desert. His book on Australasian geography was banned in Western Australia and he was vilified by the ‘boosters’ – politicians and others who refused to accept that Australia had deserts, or that the environment in any way limited population growth.

The Bureau was also involved in discussions on the Bradfield scheme to launch massive irrigation projects in the Centre. It was claimed that evaporation from the water storages and irrigated areas would lead to increased rainfall of wide areas of the inland, and that temperature changes due to the increased water vapour would ameliorate climate and increase productivity. This idea was based largely on papers published by E.T. Quayle, formerly Senior Meteorologist of the Bureau. A committee organised by the Bureau concluded that there was no evidence that the scheme would lead to amelioration of climate, either by lowering the temperature or increasing rainfall. Quayle, who was a member of this committee, dissented.

So, the early development of climate science in Australia was marked by controversy, as meteorologists tried to depict the true nature of the country’s climate.

Not all of this, however, would be what we might, today, call ‘operational climatology’. This would include real-time monitoring of climate variations and change, and the prediction of variations. The remainder of this paper concentrates on the development of operational climate monitoring and prediction, rather than on descriptive climatology (e.g., Loewe 1948; Radok 1948; Gentilli 1972; Linacre and Hobbs 1977) or the more strategic work undertaken in CSIRO (e.g., Dix and Hunt 1995).

Climate monitoring

As noted above, some early meteorological work had focussed on the marked interannual variations in rainfall. Much of Russell’s works delineated variations in
the nature of years, by listing historical floods or lake levels, for instance. It was recognised very early that routine monitoring was necessary for various political purposes. In 1865, Surveyor-General Goyder of South Australia drew what quickly became known as Goyder's Line. This was to mark the limit to which drought had extended south during that year, to help determine which pastoral lessees might be given financial relief (Andrews 1966). The various colonies had established observing networks to monitor climate variations, especially rainfall which was quickly recognised as the major variable controlling agriculture over much of Australia. Extensive descriptions and tabulations of the year's climate variations were published.

Soon after the establishment of the Commonwealth Bureau of Meteorology, systems were introduced to monitor the rainfall across the entire country. The Bureau's *Monthly Meteorological Report of the Australian Commonwealth* commenced publication in January 1910. These reports included, as well as rainfall and temperature information, charts of tracks of anticyclones and cyclones. Patterns of atmospheric circulation have remained an interest (e.g., Karelsky 1956; Leighton and Nowak 1995). Improved communications and upper air data have led to the routine monitoring of global circulation (e.g., Beard 1996). This was not possible in 1910, but annual rainfall maps were published, and the country was divided into meteorological divisions (Taylor 1910). The stations in each division were averaged to produce what we now call district average rainfalls. These district averages are still prepared and used in monitoring and prediction, despite some well-known deficiencies.

Generally good rains during the two decades after the Second World War meant that monitoring of rainfall fluctuations probably seemed less crucial than in earlier, drier years. The re-establishment of drought conditions in the 1960s led the Bureau of Meteorology to establish a drought watch service (Gibbs 1975). Since 1965 official 'drought statements' have been issued by the Bureau whenever such conditions exist. Aggregate rainfall totals are maintained from the beginning of the drought and maps of the extent of the area covered by the tenth and fifth rainfall percentiles, corresponding with 'serious' and 'severe' drought, are issued monthly. These alerts provide an objective assessment of rainfall deficiency, similar to the Goyder Line of the 19th century, and can be used in determining the need for government assistance.

Gibbs and Maher (1967) advocated the use of deciles to indicate droughts. Gibbs (1963) and others had demonstrated that Australian rainfall is not well-described by a normal distribution, so a non-parametric way of describing rainfall deviations is attractive (except in situations where many climatological monthly rainfall totals are zero, e.g., in deserts). Gibbs and Maher demonstrated that the occurrence of the first decile in annual rainfall corresponded very well with droughts tabulated in Foley (1957), based on newspaper and other reports of effects on crops and livestock. They were surprised (Gibbs 1987) that the drought index for rainfall in a calendar year showed such a close association with drought, irrespective of location in arid, semi-arid or other areas and despite the fact that the wet season occurs at different times of the year and in some places extends from one calendar year to the next. Deciles (and percentiles) are still widely used for monitoring rainfall and preparing drought alerts.

Gaffney (1987) noted a number of shortcomings of the Bureau's drought alert system, some of which had been identified in a drought workshop in 1986 (Royal Meteorological Society, Australian Branch 1986). In particular, defining the start and end of droughts was complicated by the existence of strong seasonal variations in rainfall in some parts of the country. Gaffney proposed establishing specific criteria for droughts in different climatic zones. More complex systems for monitoring drought, taking more than decile rainfall into account, are now being established in various organisations.

Recently, the Bureau has developed a computerised national daily rainfall analysis system, based on the approximately 2000 rainfall reports received in 'real time'. Analyses of daily rainfall totals as well as monthly and seasonal analyses are prepared. These analyses provide more spatial detail than the district average rainfalls, and are available more quickly. The monthly and seasonal analyses can be compared with historical analyses (back to the start of the 20th century) which have been prepared using the same analysis technique. The Bureau's National Climate Centre provides these analyses, as well as analyses of monthly and seasonal temperatures, on the World Wide Web. New forms of drought monitoring and alerts can be based on these improved analysis systems.

Routine monitoring now has extended to the ocean, because of its influence on climate. The important role of the ocean in Australia's climate and economy is illustrated in Fig. 1. This shows the relationship between time-series of the value of Australian crops and sea-surface temperatures (Nicholls 1985) around northern Australia (for May-October, i.e., at the start of the 'crop year'). The figure shows changes in these variables from year to year, to remove trends due to changes in technology. The close relationship is very clear, with a correlation of 0.65 (n = 44; significant at 0.1%). The Bureau has developed an operational system for preparing operational analyses of global sea-surface temperatures, and an objective system for the operational analysis of tropical subsurface thermal structure (Smith
Fig. 1 Australian crop value ($M, 1995/96 values) and May-October sea-surface temperature, averaged over 5-15°S, 120-160°E. First differences (year-to-year variations) are plotted for both variables. The year indicates the start of the crop year (July-June) and also indicates the year to which the May-October sea-surface temperatures apply.

1995). These systems are run operationally and provide much of the detailed information regarding the current behaviour of the El Niño - Southern Oscillation. These analyses, plus analyses of southern hemisphere atmospheric circulation, are published in the Climate Monitoring Bulletin Australia, distributed every month since February 1986. They provide input to the operational seasonal climate prediction.

Climate prediction

The Bureau of Meteorology has been developing methods for seasonal climate prediction since early this century. The first scientific method for Australian climate prediction was published by a Bureau scientist, E.T. Quayle, in 1910. The prediction technique in this study relied on the phenomenon we now call the El Niño – Southern Oscillation and was subsequently refined (Quayle 1929; Trewartha 1934). Grant (1956) expressed doubts that the statistical relationships identified in earlier works would provide useful forecasts, unless the physical processes underlying these relationships were understood. After this, work on the El Niño – Southern Oscillation languished, with only an occasional paper (most notably, Troup 1965) investigating the phenomenon.

Experimental long-range (monthly) weather forecasts were prepared, for internal assessment, within the Bureau from 1954 to 1971. These were based on an apparent tendency for certain patterns of anticyclonicity to persist for up to a season or longer. An Extended Period Forecasting Section was established as an operational unit of the Bureau in the late 1960s. While its main concern was the regular issue of forecasts up to four days ahead, experimental 30-day forecasts were prepared. These were based on an extension of the methods used in four-day forecasting; a zonal index cycle, blocking patterns, persistence, and the movement of large-scale anomalies. The forecasts were not issued to the public. An analysis of the forecasts revealed that rainfall forecasts were no more accurate than would be expected from chance. Temperature forecasts were slightly (and significantly) more accurate than chance, but not sufficiently accurate to be useful. The experiment was discontinued in 1971.

By the early-1980s, attention had returned to the possible use of the El Niño – Southern Oscillation in prediction. Work on the physical cause of the phenomenon had commenced, and several papers describing patterns and relationships between the El Niño – Southern Oscillation, sea-surface temperature and Australian climate had been published (e.g., Priestley 1964; Pittack 1975; Streten 1981; Coughlan 1979). Some of the earlier (e.g., Quayle) lag relationships had been validated and extended using new data (Nicholls and Woodcock 1981; McBride and Nicholls 1983). New relationships indicating that seasonal temperature, wet-season onset, and even seasonal tropical cyclone activity were predictable, through the El Niño – Southern Oscillation, had been uncovered (Nicholls 1978, 1979; Nicholls et al. 1982). The recognition in mid-1982 that a major El Niño episode was underway led to cautious statements regarding possible implications for Australian rainfall through the remainder of 1982, based on this work (Nicholls 1983). The Bureau's National Climate Centre began preparing and testing monthly Seasonal Climate Outlooks in 1988, and issuing them publicly in 1989.

Simple linear lagged regression, and variants on this, between the SOI (the Southern Oscillation Index, an index of the difference in pressure between Tahiti and Darwin, and a simple measure of the El Niño – Southern Oscillation) and subsequent rainfall provide the basis for the Seasonal Climate Outlooks. Trends and phases (Zhang and Casey 1992; Stone and Auliciems 1992) of the SOI are taken into account (since 1995), as are some patterns of sea-surface temperature (since 1996). The various predictions are combined in a statistically optimal fashion (Casey 1995). Sophisticated time-series methods developed in BMRC (Drosdowsky 1996) are also used to project the SOI into the future. These projections can then be used to find analogues, i.e., years when the SOI has behaved similarly to the current year. Detailed meteorological data from these analogue years can then be used, for instance, in crop models to examine likely crop yields. By the mid-1980s it was clear that the SOI could be used to produce predictions not
just of climate variations, but also of the impact of these variations on the Australian economy and ecology (Nicholls 1988).

Since the 1982/83 El Niño, the influence of this phenomenon on Australian climate has become well-recognised. So much so, that a computer package, 'Australian RAINMAN', has been developed by several organisations, notably the Queensland Department of Primary Industries and the Bureau of Meteorology, to provide information to individual users. This package allows users to investigate the likely consequences of particular phases or trends of the SOI on rainfall at thousands of locations. This information, with readily available real-time SOI values, can allow users to prepare their own seasonal climate forecasts.

Dynamical methods, using coupled ocean-atmosphere models, can also provide predictions of the likely future behaviour of the El Niño – Southern Oscillation. The Bureau uses a dynamical model of the coupled ocean-atmosphere system in the tropical Pacific to predict the behaviour of sea-surface temperatures related to the El Niño (Kleeman 1996). Forecasts of east equatorial Pacific sea-surface temperatures from this model have been included in the Seasonal Climate Outlooks since 1996. This coupled model does not include all the complex mechanisms involved in the atmosphere and ocean, but retains the larger-scale mechanisms believed responsible for the El Niño – Southern Oscillation. Similar models were first used to predict the 1986/87 El Niño and have been used operationally ever since, although with continual improvements. They have demonstrated some skill in prediction, forecasting the 1991 and (some models) the 1994 El Niño events. They do, however, only forecast ocean conditions, i.e., sea-surface temperatures. These are then interpreted in terms of the El Niño and its statistical implications for rainfall over the areas generally affected by the phenomenon. The Kleeman model, unlike some other models of this type, uses sub-surface ocean temperature data (Smith 1995). The inclusion of these data has led to improved model predictions and the model can provide forecasts of El Niño several seasons ahead.

A new statistical forecast system, which uses global and regional patterns of sea-surface temperature as predictors, has been developed to replace the current operational technique based largely on the SOI. It is expected that the less chaotic nature of the sea-surface temperature fields should allow for improved predictions, partly because less smoothing will be necessary, and also because effects separate from the El Niño – Southern Oscillation may provide skill in areas where the El Niño –Southern Oscillation is of little help. Nicholls (1989) and Drosdowksy (1993a, b) suggest that the sea-surface temperature fields in the Indian Ocean and Indonesian area may provide predictions for some of the areas where the El Niño – Southern Oscillation is not dominant.

More refined statistical techniques are being used to develop systems for operational prediction. A major problem with the development of statistical forecast systems is the short period of data available for development. Typically, only about 50 years of data are available. The shortness of this period means care is needed if 'artificial skill' is not to degrade the accuracy of the forecasts. Such artificial skill arises from attempting to use many predictors to improve the apparent skill on the data used to derive the statistical forecast system. The 'increased' skill then usually disappears when the system is used operationally. In fact, inclusion of extra predictors can actually lead to a degradation of the forecasts. The new systems under development take great care to avoid this problem.

Efforts are underway to refine the content and delivery of seasonal predictions. Potential agricultural users of seasonal climate forecasts have been surveyed to determine what variables should be predicted, and what level of accuracy and lead time is needed. At present, the Bureau of Meteorology only forecasts seasonal rainfall. Yet there is a need for temperature forecasts, and for more specific indices, e.g., the severity of the frost season. Some of these other variables could be forecast using current techniques and predictors, with a small amount of further development. For instance, Stone et al. (1996) suggest that seasonal frost forecasts could be feasible in eastern Australia. Tropical cyclone behaviour is also predictable on seasonal timescales (Nicholls 1992). Coughlan (1979) demonstrated that the El Niño – Southern Oscillation was related to Australian temperatures, implying that seasonal temperature might also be predictable.

The major thrust of research, however, both in Australia and internationally, is the further development of coupled ocean-atmosphere climate models. These coupled models will be much more detailed than the relatively simple models used routinely since the mid-1980s. They are also much more expensive to run. However, rather than simply forecasting El Niño behaviour (e.g., sea-surface temperatures in the east equatorial Pacific), these models could, in theory, be used to forecast rainfall and temperature over land. The representation of the coupling between the ocean and the atmosphere in these models, however, is less than perfect. CSIRO, with BMRC, is developing an improved ocean model (Power et al. 1995). This model, the Australian Community Ocean Model (ACOM), will be used in coupled model development.

One problem is the difficulty the atmospheric part of the coupled models has in simulating rainfall on the spatial scales important for users, despite their general success in simulating atmospheric variability (Nicholls
1996). Model experiments with specified sea-surface temperature anomalies have a long history in the Australian region (Simpson and Downey 1975; Voice and Hunt 1984). We have run our climatic model, forced by observed sea-surface temperatures from 1949 to 1991, and compared rainfall simulated by the model with the observed rainfall (Frederiksen et al. 1995). We ran the model five times, with the same sea-surface temperatures. The only difference between the model runs was that slightly different starting atmospheric conditions were used. The difference between the model runs illustrates the ‘noise’ in the model. In fact, to get much agreement with observed rainfall, we need to average all five runs. This is ‘ensemble’ averaging. Our results indicate that we would need to run our models five or more times, with predicted sea-surface temperatures, or in coupled mode, and do routine ensemble averaging to reduce the inherent noise in the simulations. The ensemble averages of precipitation show some skill in simulating Australian precipitation, at least over northern Australia. In higher latitudes the models are less successful.

In these atmospheric model experiments, the model does very well in simulating the SOI. The SOI can, then, probably be predicted without the need to run expensive ensembles. If so, we could use the coupled ocean-atmosphere models to predict large-scale indices such as the SOI, then use statistical relationships between these forecast indices and the variables we really want to predict (e.g., rainfall at Emerald). Alternatively, we could use the coupled models to predict sea-surface temperatures, then use ensemble runs of an atmospheric model forced with predicted sea-surface temperatures to prepare predictions of rainfall and other variables of interest. Considerable thought and testing is needed to select the best strategy for using models in seasonal climate prediction.

**Climate change**

A number of studies have examined the Australian climate record for longer term variations or changes. O'Mahony (1961) examined rainfall data for periodicities, and found only the 2-3 and 7-year periods associated with the Southern Oscillation. A shift to lower rainfalls in eastern Australia early this century is described in Gentilli (1971), while Kraus (1963) and others noted the return to higher rainfall around the middle of the century. Gani (1975) found no evidence that the climate had become more variable over the 60 years from 1915 to 1974.

The possibility that human influences could affect climate at a local level was recognised last century in Australia. The debate over whether ‘rain follows the plough’ was as intense as in the USA. By the mid-20th century attention was turning to the climatic effects of cities (Handcock and Nailon 1963; Royal Meteorological Society Australian Branch 1978). The Australian debate about the climatic influence of forests was mentioned earlier.

Monitoring Australian climate for evidence of climate change has been underway since at least the late 1970s (e.g. Coughlan 1979). In recent years, the National Climate Centre has released, each year, a time-series of east Australian average temperatures, to provide information on whether the climate is changing. Recently, a ‘high-quality’ dataset of stations which have passed extremely rigorous quality-control testing (Lavery et al. 1997) has been used to prepare spatial averages of rainfall for this monitoring. The data from these stations are believed to be capable of detecting even small changes in climate (Nicholls and Lavery 1992; Nicholls and Kariko 1993). They have been used to prepare time-series of all-Australia mean rainfall, as well as means for each State and various regions. A high-quality temperature dataset has also been produced (Torok and Nicholls 1996) and used to prepare spatial averages of annual mean minimum and maximum temperatures, and is now used as the basis for the regular annual monitoring of Australian mean temperature. Figure 2 shows the annual average maximum and minimum temperatures, and rainfall, averaged across Victoria, for each year from 1910 to 1992. Minimum temperatures have increased gradually since about the middle of the century. Maximum temperatures have remained relatively stable, while rainfall increased quite suddenly in the middle of the century.

Monitoring climate extremes (e.g., droughts), to determine whether the climate is becoming more

![Fig. 2. Annual mean maximum and minimum temperatures (full lines), and annual rainfall (broken lines), averaged over Victoria. Thin lines indicate yearly values; thick line is the result of applying a weighted least squares smoother. Temperature data from Torok and Nicholls (1996); rainfall data from Lavery et al. (1997).](image-url)
extreme or variable, has commenced recently. Karl et al. (1995) found little consistency in patterns of change in temperature variability for Australia since 1961, apart from statistically significant decreases in interannual variability in spring, especially in temperate regions. Suppiah and Hennessey (1996) found an increase in the frequency of extreme rainfall events at a majority of stations in northern Australian summers since 1910. Few of the increases were statistically significant. Stone et al. (1996) report an apparent decrease in the number of frosts affecting inland eastern Australia during the twentieth century. Neil Plummer (National Climate Centre) is now coordinating a study to monitor changes in a variety of indices of extreme weather and climate.

There has been considerable focus on the possible causes of any changes in Australian climate, as well as the possible consequences for the future. In 1975 the Australian Academy of Science, at the request of the Australian Government, established a committee to report on whether the climate was changing. The Committee (Australian Academy of Science 1976) concluded that there was no evidence that the world was on the brink of a major climatic change. They also noted the existence of a new factor in climatic change, namely that 'man's activities are now developing on a scale and in direction, that could have an appreciable effect on the climate within decades'. These 'activities' included the enhancement of the 'greenhouse effect', through increases in carbon dioxide content in the atmosphere, and increases in particulate matter in the atmosphere. Pearman (1978) noted that a doubling of the atmospheric concentration of carbon dioxide could lead to an increase of 2-3°C in global temperature. Tucker (1981) reviewed the current state of knowledge regarding the possible climate effects of increased carbon dioxide production and concluded that 'it seems inevitable that life on earth will be affected by changing atmospheric carbon dioxide concentrations but it is too soon yet to give more than a general indication of the size of the effects and of their net beneficial or deleterious nature'. Since then, Australian involvement in international programs and studies (such as those of the Intergovernmental Panel on Climate Change) and national programs (e.g., Pearman 1988) has attempted to address the question of a human impact on global climate in more depth, as well as looking at its southern hemisphere implications (Giambelluca and Henderson-Sellers 1996). Despite this work, major uncertainties still remain (e.g., Houghton et al. 1996).

The current state and future of climatology

Public and political interest in climate has never been higher. This is perhaps best demonstrated by comparing Australian representation at the first World Climate Conference held in Geneva in 1979 (when W.J. Gibbs was the sole Australian), with the 25-person (but still only one atmospheric scientist) delegation to the second Conference of the Parties for the Climate Convention held in July 1996, also in Geneva. This heightened public interest reflects greater understanding of the climate (e.g., effects of enhanced greenhouse gases, El Niño – Southern Oscillation), improved (faster) monitoring of climate change and variations, and better systems for dissemination of climate information (televison, World Wide Web), as well as increased recognition of the impact of climate variations on society and the economy. All these developments mean that climate science is now ‘operational’ in the same sense as operational short-range weather monitoring and prediction. Many of these developments are leading to competition in climate science. Many organisations now have the technical capabilities and computing power to monitor and predict climate variations. Harnessing the skills of various organisations with an interest in operational climatology should lead to benefits for Australia, as well as for the individual organisations.

The changes in operational climatology can be demonstrated through examining responses to various El Niño – Southern Oscillation episodes. Before the 1972/73 episode, understanding of the effect of the El Niño – Southern Oscillation on Australia was limited, although earlier scientists had studied the problem. Studies in the 1970s and 1980s documented its effects, but even the 1982/83 event caught Australia by surprise, partly because systems were not in place to allow the rapid monitoring of the El Niño – Southern Oscillation phenomenon. By the El Niño events of the early 1990s, a routine seasonal climate prediction service, based on the earlier work on the El Niño – Southern Oscillation, had been established, and routine monitoring was possible. By this time, for instance, buoys moored across the equatorial Pacific allowed the daily monitoring of surface and subsurface temperatures. As well, computer models (as well as statistical models) capable of predicting some aspects of the phenomenon were in place. All this means that we now truly have an ‘operational climatology’ capability, analogous to the operational short-range weather prediction, with real-time climate monitoring, scientifically based prediction and rapid dissemination of these products.

Changes in technology have meant changes in the organisations undertaking ‘operational climatology’. In 1946 climate monitoring was labour-intensive. Even with the introduction of computers in the 1960s, the costs of archiving and analysis and display meant that it would have been very expensive for other organisations to duplicate the climate monitoring functions undertaken by the Bureau of Meteorology. Now, however, the
feasibility of remote access to data archives, along with faster (and cheaper) computing and communications, has meant that many organisations can duplicate the role of the Bureau, while adding their expertise to the field of climatology. Agricultural organisations, for instance, can utilise their knowledge of aspects of drought other than rainfall shortages in monitoring drought. The future of operational climatology offers the prospect of many organisations in the field, tailoring their products to suit their specific customers.

There are, however, threats to this new picture of climate science. All these ‘new’ climate organisations will still rely on the availability of a quality-controlled network of climate stations. The colonial meteorologists, with very limited resources, managed to establish excellent observing systems across the country, although these did use a variety of instrumentation and observing practices. Hunt, the first Commonwealth Meteorologist, within a couple of years of taking office, had consolidated the observational program, standardising instrumentation, exposure and observing practices. By the 1960s Australian climate data was in excellent shape, but by 1976 the Academy committee on climatic change felt it needed to warn that the ‘maintenance and improvement of (the Australian climate) data bank is of national importance’.

Two decades later and climate data across the world is under increasing threat. So Karl et al. (1995) observe that ‘Even after extensive re-working of past data, in many instances we are incapable of resolving important aspects concerning climate change and variability. Virtually every monitoring system and dataset require better data quality, continuity, and homogeneity if we expect to conclusively answer questions of interest to both scientists and policy-makers...the continued degradation of conventional surface-based observing systems in many countries (both developed and developing) is an ominous sign with respect to sustaining present capabilities into the future’. This has occurred at the same time as public and political interest in climate has risen. This situation recalls the situation with Queensland weather observations around the turn of the century. Clement Wragge had established a superb observing system throughout Queensland in the last decades of the 19th century. But a severe drought at the turn of the century led to its dismantling, because of reduced Government funds. We must ensure that our future capability to monitor, predict and understand the climate is not similarly undermined, just as the need for climate information peaks.

For much of the past 50 years, operational climatology in Australia has been the equal of that anywhere in the world. Especially during the 1960s the data archiving was superb, in world terms, as was the operational use of these data in maintaining a national drought watch system. Resource limitations, and a greater focus on daily weather prediction, during the 1970s and 1980s somewhat diminished the Australian efforts in climatology. We are now not in the lofty position we once were, relative the rest of the world. For instance, apart from major cities, daily meteorological observations prior to 1957 have not been digitised. Yet these historical daily observations are of crucial importance for assessing if and how the climate has changed. Without these observations we are unable to determine whether the climate is becoming more or less extreme, as we perturb the atmosphere with enhanced greenhouse gases and aerosols.

In some areas, however, Australian operational climatology still leads the world. In operational seasonal climate prediction, and climate variability monitoring, the systems we have in place, within the Bureau of Meteorology and elsewhere, are at the forefront of the science, and research funders have recognised the opportunities to enhance the current capabilities. Australian expertise in these areas is sought internationally by other organisations and countries eager to apply similar technologies to the monitoring and prediction of climate. The international role of Australian operational climatology owes much to the vision of W. Gibbs and, before him, to the colonial meteorologists and H.A. Hunt.

References


