Queensland Government

Department of
Environment and Resource Management

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Committee Secretary
Standing Committee on Industry, Science and Innovation Committee
House of Representatives
PO Box 6021
Parliament House
CANBERRA ACT 2600

Dear Committee Secretary

Queensland Climate Change Centre of Excellence Submission to the Inquiry into Meteorological Forecasting.

Thank you for the opportunity for the Queensland Climate Change Centre of Excellence (QCCCE) to make a submission to this Inquiry.

Climate forecasting is a vital tool in managing the challenges of a changing and increasingly variable climate. The Queensland Government has a long history of promoting development and extension of climate forecast information.

The importance of understanding the impact of climate variability on Queensland is discussed and opportunities for using weather forecasts for emergency responses are identified. Whilst the Queensland Government, through the Queensland Climate Change Centre of Excellence (QCCCE) has its own capacity to address climate variability, strong collaboration with national and international institutions is a vital component of that capacity.

The Queensland Government, through the Queensland Climate Change Centre of Excellence, would welcome the opportunity to make a presentation to the Committee in response to this Inquiry. If any further information is required, please contact Mr Ken Day, by email at ken.day@climatechange.qld.gov.au or by telephone 07-3896 9576.

Yours Sincerely

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Submission to the Parliamentary Inquiry into Meteorological Forecasting

Prepared by: Queensland Climate Change Centre of Excellence
on behalf of the Queensland Government
through the Department of the Environment and Resource Management

Contact: Ken Day (ken.day@climatechange.qld.gov.au; tel (07) 3896 9576)

27 April 2009

The Coming Storm - Winslow Homer (1901)

27 April 2009

Submission to the Inquiry into Meteorological Forecasting

Prepared by: Queensland Climate Change Centre of Excellence (on behalf of the Queensland Government through the Department of the Environment and Resource Management).

Introduction

Queensland has one of the most variable climates in the world. The importance of Queensland's climate is unique in terms of the number of urban population centres and agricultural and industrial enterprises in tropical and subtropical climates. Queensland's climate is highly variable, both from place-to-place and from year-to-year. Unexpected weather extremes and annual variations in climate continue to pose challenges for both urban and rural communities. Climate risk associated with extreme temperature, hail and rainfall events are very real in Queensland. Protracted droughts, damaging tropical cyclones and flooding are to be expected and, as such, should be factored into business and regional planning and risk management strategies.

In Queensland, year-to-year climate variability is strongly influenced by the El Niño-Southern Oscillation (ENSO) phenomenon. Decadal and longer time-scale fluctuations also occur (e.g. the wet 1950s, dry 60s, wet 70s, dry 80s). The Queensland Government understands that this longer term variability is linked to both ENSO and a phenomenon known as the Pacific Decadal Oscillation (PDO). As such, to better adapt to Queensland's variable and changing climate, the Queensland Government, local authorities and businesses need to better understand and monitor these processes and bring this information and knowledge to bear in managing for climate variability. Seasonal forecasting is a product of our improved understanding of the climate system, and offers a practical means for government, industry and the community to adapt to climate variability and, ultimately, to better adapt to and prepare for climate change.

Types of forecasting considered in this submission

In addressing the Inquiry's Terms of Reference, and in providing the following background information, the Queensland Government considers three levels of forecasting: 1) meteorological weather forecasting; 2) intra-seasonal forecasting; and 3) inter-seasonal forecasting. A brief interpretation of these terms is given below for clarification. The Queensland Government's interest and involvement in each level of forecasting is also highlighted.

Meteorological weather forecasting

Meteorological forecasting (referred to here as weather forecasting) involves the forecasting of weather conditions and extreme events 'hours' or 'days' in advance. These forecasts are generated by global climate models which are initialised by data from global weather and ocean observation networks. Accuracy of these forecasts declines with increasing lead-times but forecasts up to 14 days in advance are possible. Whilst the Queensland Government makes use of meteorological weather forecasts, the Queensland Government currently depends on the Bureau of Meteorology (BoM) for the development, issuing and interpretation of these forecasts.

Intra-seasonal forecasting
Intra-seasonal forecasting involves forecasting conditions up to a month or so in advance, within a certain part of a season (not the whole season). There is capacity to make intra-seasonal forecasts in Australia based on a phenomenon known as the Madden Julian Oscillation (MJO or '40-day wave'). The MJO is a belt of low pressure that propagates eastward across the equatorial Indian and Pacific Oceans usually taking between 30 to 60 days. Its passing can increase the likelihood of rain in northern Australia in particular. It is possible to forecast the likely timing of the MJO passage across the Australian region and, during this period, heightened prospects of rainfall. The Queensland Government has collaborated with BoM to monitor the MJO and to interpret this information for end-users in terms of the likely timing of the MJO passage and associated rainfall probabilities.

Inter-seasonal forecasting
Inter-seasonal climate forecasting (referred to here as 'seasonal climate forecasting' or 'climate risk assessment'), involves the forecasting of rainfall or temperature probabilities up to nine months in advance for a particular season. Typically, such forecasts are issued at the end of each month, for the coming three-month season. However, more targeted forecasts, with longer lead times, are now emerging.

Seasonal forecasts indicate, for example, whether there is a higher or lower probability than normal of achieving a certain amount of rainfall in a particular season. For example, a typical forecast for a given location might state 'there is a 70% probability of exceeding median rainfall this coming summer'. For this reason, seasonal climate forecasts may also be referred to as 'climate risk assessments'.

Such assessments may be either 'statistical' (i.e. based on a statistical analysis of historical climate), or 'dynamical' (i.e. based on dynamical climate modelling), in the same manner as weather forecasts are generated (as discussed above). In both cases, the predictive power of these forecasts is derived from phenomena such as ENSO, which may have a strong enough influence on seasonal climate locally (and fluctuate slowly enough), to allow some advanced assessment of climate risk.

The Queensland Government has a long history of developing and applying seasonal climate forecasts and has retained a largely independent capacity in this regard. However, the Queensland Government also collaborates widely with national and international agencies in its endeavours.

Use of weather and climate forecasting in Queensland

Seasonal climate forecasts are being used in Queensland in relation to agriculture, and natural resource and water management. For these purposes, statistically-based seasonal climate forecasts have been most commonly used and promoted. However, as seasonal forecasts based on global climate models have become more available, these are now also being incorporated in climate risk assessment. Intra-seasonal forecasts based on the MJO have now been heavily promoted in parts of rural Queensland and there is now a demand for this information. As meteorological weather forecasting has advanced and longer lead forecasts have become available, this information is being factored more into operational planning in Queensland. In all cases, decision makers must be able to easily access such information and have it presented in a way that can be readily incorporated into their business plans.

The Queensland Government's interest in weather and climate forecasting

The Queensland Government has had a long involvement in the development, evaluation and extension of seasonal forecasting in particular its application for the agricultural industries. In fact the history can be traced back to the late 1930s, when the Queensland Government prompted the Federal Government to investigate the potential for developing seasonal forecasting based on the original Southern Oscillation Index developed by Walker and Bliss.

In the mid-1980s, the Queensland Government, through the Queensland Department of Primary Industries, developed a climate databank (now the 'SILO' database) for use by researchers. These data demonstrated the importance of historical rainfall variability in Queensland. In light of the value and importance of such information to the rural community, decision support packages (e.g. RAINMAN) were developed by the Queensland Government in cooperation with BoM, which allowed users to access over 100 years of historical climate data and to explore, for any location in Queensland, the historical relationship between ENSO indices (e.g. the Southern Oscillation Index: SOI) and important climate elements such as rainfall and minimum and maximum temperature. This allowed the public and industry to develop awareness of the availability of this type of climate information and to understand its relevance to their particular enterprise or interests. In addition, operational crop and pasture forecasting systems (e.g. APSIM, AussieGRASS) were developed in the 1990s and these tools now provide information to the National Agricultural Monitoring System (NAMS). These tools value-add to the analysis of historical climate data by translating climate information into more meaningful terms for decision-makers (e.g. crop production, pasture production and streamflow).

In early 2007, the Queensland Government's Climate Change Centre of Excellence (QCCCE) was established. The Centre considers that the use of seasonal forecasting, in a risk management context, is an important component of equipping communities and industry sectors for challenges posed by a highly variable and changing climate. Such work has been a key focus under the Centre's previous existence as the Queensland Centre for Climate Applications, formed in the late 1990s.

As part of the Queensland Government's commitment to reducing the risks from climate variability and climate change, the Queensland Climate Change Centre of Excellence (QCCCE) is responsible for providing a whole-of-government climate science research and information delivery service for Queensland. Such work includes: climate system modelling using global and regional climate models; developing, promoting and interpreting seasonal climate forecasts; providing tools to assist industry better manage climate variability and to assess and adapt to climate change risks; and collaborating with national and international climate institutions.

A range of Queensland agencies now use or provide specialist climate information and decision support tools. For example: the Department of Environment and

Resource Management apply such information to water planning and environmental modelling; the Department of Employment, Economic Development and Innovation promotes seasonal forecasting for cropping and grazing land management; the Department of Community Services utilises weather forecasting data for a number of purposes, in particular operational for hazard risk assessment, management and planning purposes; the Queensland Water Commission is responsible for developing and implementing strategies to assure the short and long term water security of South East Queensland; and Queensland Health utilises climate information as part of its planned responses to extreme weather events and emergency situations.

Improvements in weather and seasonal climate forecasts in terms of increased skill and longer lead time will allow more targeted and applied use of this information and knowledge by government and businesses.

What the Queensland Government has learned in relation to weather and climate forecasting

The active use of seasonal climate forecasting systems by the Queensland Government and its stakeholders has provided some important lessons which are detailed below:

- The Queensland Government has found that the community is more likely to act on information if the scientific basis behind the forecasts (including the ability to assess how forecasts operated in real-time) is understood. The community is also more likely to act on forecasts where a benefit is clear (e.g. avoiding danger/disaster/loss, increasing in profitability) and where the information fits in with existing decision making.

- Major limitations to implementation are likely to include: confusion resulting from the range of available forecasts; lack of understanding of the underlying science; and lack of an accessible track record.

- Stakeholders need clear advice on climate science, including the range of available forecasting systems, their roles and differences.

- The Queensland Government advocates the use of both statistically-based forecasts and forecasts based on global climate models, recognising that both approaches have their limitations.

- Year-to-year variation in Queensland's climate is strongly influenced by the El Niño-Southern Oscillation (ENSO) and decade-to-decade fluctuations in the Pacific Ocean (known as the Pacific Decadal Oscillation or PDO). Queenslanders need to better understand and monitor these processes and to find ways to adapt to this inter-annual and inter-decadal variability.

- The Queensland Government understands that global climate models vary in their ability to model ENSO and its impacts in Queensland.

- Whilst the Queensland Government recognises the potential for global climate models to synthesis climate information and to provide a 'step-change' in forecast ability, the Government cautions that the skill of such models for Queensland will be limited by the extent that they can accurately model important processes such as ENSO and the PDO.

- The Queensland Government believes that practical steps can be taken to improve statistically-based forecast schemes for Queensland: 1) remove indices of little relevance to Queensland (e.g. Indian Ocean sea-surface temperature in BoM's current sea surface temperature scheme); 2) replace these with indices of more relevance to Queensland e.g. an index which is sensitive to fluctuations in the PDO; 3) de-trend climate signals for observed climate change trends; and 4) customise systems to user-needs in terms of lead times and target periods.

- The ENSO signal is weakest in South East Queensland, an important region of the state both economically and in terms of population and water demand.

- Given that fluctuations in the strength of the relationship between ENSO and local climate has 'waxed and waned' over the years, an important question in evaluating the skill of forecasting systems is: how do such systems perform throughout the entire historical record, including periods such as 1920 to 1950 for example, during which the ENSO signal lacks persistence and there is low correlation between the ENSO indices and Queensland rainfall?

- Seasonal climate forecasts need to be translated into terms that can be readily incorporated into management and decision making. The Queensland Government has learnt that a 'transparent' approach leads to a better understanding of the underlying processes, a better appreciation of the probabilistic nature of seasonal climate forecasts, and therefore encourages long-term adoption.

- Although seasonal forecasts are widely adopted in rural Queensland, industry would further benefit from improvements which deliver more accurate forecasts over longer timeframes and forecasts relevant to particular locations.

- The lack of available specialist interpretation for some BoM products limits their effectiveness and uptake in some cases.

- The importance of translating seasonal climate forecasts, through systems modelling, into more meaningful terms for decision-makers (e.g. crop production, pasture production and streamflow).

- Systems analysis provides the basis for developing risk management strategies and for better assessing the impact of climate variability on particular systems (e.g. agricultural and hydrological systems). There are, as yet, untapped opportunities in Queensland for using seasonal climate forecasting in a range of sectors (e.g. open-cut mining). Systems analysis therefore needs to be more broadly applied across sectors impacted by climate variability.

- There is a need for existing systems to produce historical ‘analogue’ years[1] so that they can be readily input into operational system models such as AussieGRASS. Similar issues may arise with global climate models if these are to be used operationally within systems models.

- The Queensland Government has been advised that information currently available on intra-seasonal forecasting based on the MJO is difficult to understand and a demand continues to exist for information previously provided by the Queensland Department of Primary Industries and Fisheries.

[1] Analogue years are those years in history which have similar background climate (e.g. ENSO conditions), to the current period. For example, analogue years may be chosen based on current and historical values of the Southern Oscillation Index.

The Queensland Government's response to the Inquiry's Terms of Reference: key points

Taking into account the Queensland Government's historical and current commitment to seasonal climate forecasting and current use of seasonal climate forecasts, intra-seasonal forecasts and shorter-term meteorological forecasts, below are key points for each of the Inquiry's Terms of Reference that we wish to make.

Key points under Terms of Reference 1

The efficacy of current climate modelling methods and techniques and long-term meteorological prediction systems

Meteorological weather forecasts

- Current weather forecasts are useful for emergency management but, for operational purposes, their efficacy is limited by accuracy, particularly at lead times greater than three days.

- The availability of specialist data is a major limitation to the effective use of weather forecasts and some BoM models are unavailable to emergency services.

- The availability of specialist interpretation for some products limits the effectiveness of some forecasts and interpretative services should be extended to the full range of products provided by BoM.

- The spatial resolution of weather forecasts limits their relevance for some decisions.

Intra-seasonal climate forecasts

- Information based on the passage of the MJO is considered quite reliable and useful for timing both cropping and grazing decisions.

- Information previously available from the Queensland Government continues to be considered more useful and easier to interpret than information currently provided by BoM and internationally.

- The QCCCE is currently working toward restoring this service.

Inter-seasonal climate forecasts

- Current skill levels of statistically-based systems are sufficient to make a long-term difference to rural enterprises in terms of both profitability and sustainability.

- Industry would further benefit from improvements which deliver more accurate forecasts over longer time-frames and forecasts relevant to particular locations.

- The skill of dynamical forecasts has rarely been assessed and compared with the skill of statistically based systems. Without an assessment of the track record, the Queensland Government and general public cannot properly evaluate the efficacy of dynamical forecasts.

- Information is now widely available to the community but spread across many locations, with little collation of alternative views of seasonal prospects.

- Collation and synthesis of alternative views would be difficult to achieve, but nonetheless a worthwhile goal.

- Users of seasonal climate forecasts indicate that forecasts, which are generally issued on a rolling monthly basis for the three-month season ahead, are not useful for some key decisions.

- Forecasts targeted at a particular season, issued at progressively shorter lead times, would be preferred to standard rolling three-month forecasts in some cases.

- There has been a relatively high adoption rate of seasonal forecasts in some sectors, particularly rural industries.

- Major limitations to adoption are likely to include: confusion resulting from the range of available forecasts; lack of understanding of the underlying science; and lack of a transparent track record of some forecast schemes.

- Seasonal climate forecasts need to be translated into terms that can be readily incorporated into management and decision making.

Key points under Terms of Reference 2

Innovation in long-term meteorological forecasting methods and technology

- The Queensland Government believes there is scope to improve the skill of seasonal climate forecasts.

- The Queensland Government has developed innovative techniques to improve the skill of statistical climate forecasts addressing issues of lead time and skill at particular times of year.

- The Queensland Government advocates some practical steps to improve the skill of statistically-based forecasts: 1) remove indices of little relevance to Queensland; 2) replace these with indices of more relevance to Queensland; 3) de-trend climate signals for observed climate change trends; and 4) customise systems to user-needs in terms of lead times and target periods.

- The Queensland Government recognises the potential for global climate models to provide a more integrated assessment of the climate system than statistically based systems.

- The Queensland Government has invested in super-computing facilities to run in-house climate models to increase knowledge of the climate system, produce down-scaled climate change projections and seasonal climate forecasts at varying lead times.

- However, global climate models are limited in the extent to which they can accurately model processes such as ENSO, lack transparency and a widely available track record.

- The Queensland Government has been an innovator in terms of improving access to climate data, seasonal climate forecasts and systems modelling at state, national and international levels.

- The Queensland Government has also been an innovator in terms of value adding to seasonal forecasts to make them more relevant to the end-user.

- The Queensland Government has also supported 'Managing for Climate' workshops to help users better understand climate processes, the nature of seasonal climate forecasts and how these can be applied in managing climate risk.

- The Queensland Government has learned that a "transparent" approach to using seasonal climate forecasts leads to a better understanding of the underlying processes, a better appreciation of the probabilistic nature of seasonal climate forecasts and therefore encourages long-term adoption.

Key points under Terms of Reference 3

The impact of accurate measurement of inter-seasonal climate variability on decision-making processes for agricultural production and other sectors such as tourism

- Systems analysis is required to identify management decisions that could be improved by seasonal climate forecasting, the potential impact of seasonal forecasts and responses that currently exist.

- Systems analysis provides the basis for developing risk management strategies and for better assessing the impact of climate variability on particular systems (e.g. agricultural and hydrological systems).

- Simulation studies allow various risk management strategies to be compared over appropriately long time frames.

- Systems analysis and associated simulation studies provide a basis for indicating priorities for research in climate science.

- There are untapped opportunities in Queensland for using seasonal climate forecasting in a range of sectors (e.g. open-cut mining).

- Therefore systems analysis needs to be more broadly applied across sectors impacted by climate variability.

Key points under Terms of Reference 4

Potential benefits and applications for emergency response to natural disasters, such as bushfire, flood, cyclone, hail, and tsunami, in Australia and in neighbouring countries

- Emergency services in Queensland use weather forecasts for a number of purposes including operational response, pre-positioning capability, risk management, planning, community information, reports and profiling expected natural hazard behaviour (e.g. bushfires).

- Providing timely meteorological forecast data allows response strategies to be put in place and allows emergency services to be adequately prepared in terms of staff levels, transportation, pre-positioning of emergency supplies and preparation of evacuation centres.

- Emergency services operations and planning will benefit both from better short-term meteorological forecasts and longer-term seasonal forecasts of tropical cyclone frequency, intensity and propagation.

- Climate trends due to global warming are making weather forecasts a more important tool in managing more frequent extreme events, as well as gradual, longer-term risks, for example:

    - Increasing temperatures due to global warming are increasing the risk of temperature related hazards such as heatwaves vector-borne diseases;

    - changing rainfall patterns affect water supply and quality and increase the risk of water-borne disease; and

    - changing temperature and humidity patterns affect the concentration of air pollutants.

- Improved projections of tropical cyclone intensity, frequency and geographic range under climate change will assist the Queensland Government to better plan infrastructure and more confidently revise building codes.

- As discussed under ToR 1, the efficacy of weather forecasts for emergency response is limited by forecast accuracy, lead-time, spatial resolution, availability and, in some cases, lack of expert interpretation.

Key points under Terms of Reference 5

Strategies, systems and research overseas that could contribute to Australia's innovation in this area.

- Queensland scientists have developed improved statistical climate forecasts building on international efforts to improve global sea-surface reconstructions and extend this information back over 100 years.

- Improvement to the sea-surface data sets has also facilitated a better understanding of processes such as ENSO and the PDO and allowed new indices of these processes to be developed for incorporation into statistical forecast schemes.

- Global climate models will benefit from improvements in underlying data sets used to initialise the models.

- Queensland will benefit from overseas efforts to model tropical systems based on high resolution (sub-15km^2) modelling.

- A number of international research institutions have state-of-the-art seasonal climate forecasting systems based on climate models which are relevant to tropical systems with forecasts available for the Australian region.

- Collaboration with overseas institutions is improving the Queensland Government's access to information, understanding and modelling of phenomena such as ENSO and the PDO.

- Collaboration with overseas institutions is also improving the Queensland Government's access to historical climate data sets such as long-term historical climate reanalysis which will lead to improved interpretation of Queensland's historical climate.

- International agencies such as NOAA provide valuable monthly discussions and information on the current and projected state of ENSO which the Queensland Government incorporates in its advice and planning.

The Queensland Government's response to the Inquiry's Terms of Reference: detailed discussion

Detailed discussion of key points under Terms of Reference 1

The efficacy of current climate modelling methods and techniques and long-term meteorological prediction systems

The Queensland's Government evaluates the effectiveness of weather and seasonal climate forecasting in terms of historical and current skill, access and availability of information, relevance to decision makers and the rate of adoption by the community. The efficacy of current weather and seasonal climate forecasting techniques is discussed with respect to each of these criteria from a user perspective.

Meteorological weather forecasts

Efficacy in terms of historical and current skill

The Queensland Government has found that the operational utility of weather forecasting modelling is heavily dependent on the quality of BoM data and models. Current products offered by BoM have provided good intelligence for emergency management in Queensland. However, for operational purposes, the efficacy of BoM models is limited by accuracy, particularly at longer-lead times (beyond 3-4 days) limiting the operational planning horizon. Improved accuracy out to 14 days would enable detailed planning including: staff levels, transportation and pre-positioning of emergency supplies, preparation of evacuation centres.

Efficacy in terms of access and availability of information

The Queensland Government considers the availability of specialist data a major limitation to the effective use of BoM forecasts. Presently, BoM only provides daily fire weather data to Queensland for the bushfire season. With climate change, bushfires could occur out of season, so availability of weather needs to be expanded to a daily seven day forecast for a 12-month period. Furthermore, BoM has models not accessible to emergency services agencies which could be utilised if available. Detailed analysis of local storm, flood and cyclone events is currently provided by BoM to assist emergency management agencies, especially the State Emergency Service and Emergency Management Queensland. However, the Queensland Government has found that the level of expertise required to interpret BoM data and models is not always available, limiting the effective use of BoM data. Furthermore, limited resources and an operational focus of key government service agencies often impacts on the level of expertise required to interpret national meteorological data (e.g. BoM data) and models.

The fact that BoM provides for service delivery agencies, a hazard-specific interpretative service which tends to favour flood and cyclone events, rather than bushfire, limits the potential effectiveness of BoM data. It can also add unnecessary uncertainty into operational response and planning. Opportunities may be gained from more sophisticated analysis and expanding the interpretive service to include all natural hazards.

Efficacy in terms of relevance to decision makers

The Queensland Government considers the relevance of BoM's forecasts for decision making to be limited by the spatial representation of data and forecasts. Although BoM is moving from point data to a gridded base, the grid squares are too large (with an existing grid base of 37km and 85km). The Queensland Government would prefer that BoM move to a grid of 12.5km x 12.5km or less for all of Queensland, especially for areas with high population density. Further investigation of the QCCCE's 5km x 5km SILO grid will also be investigated for these purposes.

Efficacy in terms of rate of adoption by the community
As noted above, the lack of interpretive comment, scale of outputs, low accuracy, especially at longer lead-times (>3 days) is limiting more widespread adoption of short-term weather forecasts within the Queensland Government.

Intra-seasonal forecasts

Efficacy in terms of historical and current skill
The influence of the MJO depends on the strength of the individual MJO and its interaction with other regional meteorological phenomena. For this reason, the MJO cannot accurately predict quantities of rain, but rather, the time of its approach and passing may be considered a hopeful period. To this limited extent, forecasts based on the MJO are considered both accurate and useful by users for timing of cropping and grazing decisions (below under relevance). From the perspective of service delivery, the lack of a long-term (>100 year) time-series of the MJO limits the assessment of historical skill.

Efficacy in terms of access and availability of information
Until recently the Queensland Government has provided dynamic web content providing operational tracking and interpretation of the MJO and associated rainfall probabilities. In order for QCCCE to now host this system, developmental work is required to upgrade the content to conform with QCCCE's computing systems and web standards. BoM also host information on the MJO on their website but the Queensland Government has been advised that it is not as relevant to end-users (below).

Efficacy in terms of relevance to decision makers
With MJO information temporarily unavailable from the Queensland Government (above), the QCCCE has received requests from the Northern Territory Government and a primary producer in Queensland to reinstate this information as it was found to be more useful and easier to interpret than information provided by BoM, which has more a 'research' focus.

Interviews with graziers in the Longreach district have revealed that many graziers comment that they will often wait for the MJO to pass before making decisions (e.g. to sell livestock). One couple stated that an "empty" MJO (one that doesn't produce rain) is, for them, a bad sign for the season.

Efficacy in terms of rate of adoption by the community
MJO-based forecasts are easy for graziers and farmers to relate to. This, together with its relevance for the timing of specific decisions, has led to quick adoption of the information in northern Australia.

Inter-seasonal forecasts

Efficacy in terms of historical and current skill
The Queensland Government's research has indicated long-term benefits of using climate risk assessments based on the El Niño-Southern Oscillation in cropping and grazing decisions, particularly when applied consistently over many years within a risk management framework. Current skill levels of statistically-based systems are therefore considered sufficient to make a long-term difference to profitability, landscape health and animal welfare.

Although seasonal forecasts are widely adopted in rural Queensland, industry would further benefit from improvements which deliver more accurate forecasts over longer time-frames and forecasts relevant to particular locations. The reliability of current SOI-based seasonal forecast declines beyond three months. Beyond that timeframe forecasts have not been seen as a reliable tool for farm decision making.

The strength of the relationship between ENSO and local climate has 'waxed and waned' over the years. Therefore an important difference between various statistical schemes is the period over which they were developed. The relationship between ENSO and Queensland rainfall, for instance, was quite weak from 1920 to 1950. Thus systems developed on datasets collated since the 1950s (e.g. BoMs operational scheme) do not include the 1920 to 1950 period of low 'skill' and may come out 'looking better' than systems which include that period in the calculation. Furthermore, such systems may not include the high rainfall variability (i.e. extreme wet and dry periods) that occurred from the 1890s to the 1940s. For example, the decade of the 1890s included substantial wet periods as well as extreme drought (i.e. the Federation Drought in eastern Australia – late 1890s to 1902). Thus, an important question in evaluating the skill of forecasting systems is how they would have performed during these periods of extreme rainfall variability.

The Queensland Government considers it is critical to evaluate the likely impact of climate change on statistical systems which, by definition, are based on historical relationships that may or may not hold under climate change. Whilst the Queensland Government does not believe that climate change necessarily invalidates statistical approaches, the Government recognises that adjustments may be needed to account for climate change. This would involve careful consideration on a case-by-case basis. Steps may be needed, for instance, to de-trend sea-surface temperature inputs for any global warming signal. Extra steps may also be needed to interpret outputs. This is an important research question, given the utility and transparency of statistical systems.

Considerable effort has been expended on the 'systems analysis' of enterprises and the potential value of forecasts. Surveys have highlighted the importance of increasing lead-time, so that management decisions could be made well ahead of major rainfall periods (e.g. during the dry season and before the onset of the wet season). Thus, in the Queensland context, with a defined wet and dry season, reliable forecasts of the next wet season at the end of the current wet season would assist Queensland livestock producers in making production decisions. Any improvements in this sense would also improve the utility of seasonal climate risk assessment for water managers and other sectors.

Forecasts based on global climate models are becoming increasingly accessible in the public domain. The Queensland Government, through the QCCCE, produces dynamical seasonal forecasts on this basis (along with statistical assessments discussed above) and contributes these to global multi-model comparisons hosted by the International Research Institute for Climate and Society (IRI) in New York.

A key issue with respect to the skill of dynamical forecasts, is that it has rarely been assessed and compared with the skill of statistically based systems. Dynamical forecasts are attractive, in that they may be able to better integrate the entire climate system (not just the ENSO component for instance). However, without an assessment of the individual track record of each model, the Queensland Government and general public will not be able to properly evaluate the efficacy of these systems.

There are now sufficient years where various statistical schemes and dynamical models have been operating in parallel, to begin to compare skill levels on an operational basis (i.e. 'as issued'). Notwithstanding the difficulties of evaluating statistical schemes over short time periods (around 10 years in this case), the Queensland Government recognises the importance of conducting such studies in order to benchmark alternative systems.

Efficacy in terms of access and availability
The development of the internet has allowed ready access to much of the material, including forecasts (e.g. LongPaddock, BoM's website) and historical data (e.g. SILO). Nevertheless, the information available to the community is spread across a range of websites, with little collation of alternative views of seasonal prospects. We suggest that the collation of alternative views is difficult and would require much discussion as to the appropriate benchmarks and documentation of historical track records.

There is a difference in the rainfall datasets held by QCCCE and those available through BoM. The QCCCE dataset commences in 1890, whilst the BoM dataset commence in 1900. The decade of the 1890s is extremely important in eastern Australia, in that it contains very wet years at the start of the 1890s and the Federation Drought, which commences at some locations in 1896 and lasts until 1902. These wet and dry periods are important in terms of ranking current conditions relative to the past (e.g. the drought in south-east Queensland in the early and mid 2000s). These periods also provide an important historical test for climate forecasting systems given the high variability that occurred in rainfall.

Efficacy in terms of relevance to decision makers
Seasonal climate risk forecasts in Australia are generally issued on a rolling basis for the next three months (e.g. the SOI Phase system, BoM's sea-surface temperature scheme). This rolling three-month forecast at zero lead-time makes it difficult for agricultural managers, particularly pastoralists in Australia managing large properties, to implement key decisions based on the forecast, when the lag between the predictor and predictand is zero. Several surveys of pastoralists in northern Australia indicated that longer lead-times would be useful. These surveys showed that forecasts for the

northern Australian wet season (November-March), issued firstly in June using the April/May SOI phase and reissued each month for the same forecast period counting down from five- to zero-month lead-time, would be most useful for application in management in these regions.

Efficacy in terms of rate of adoption by the community

Despite several years of drought, Queensland has been able to largely maintain agricultural production which can, in part, be attributable to the application of tools by primary producers to better manage climate risk. Queensland has developed a range of tools such as RAINMAN, WhopperCropper, APSIM, APSFarm, Irrigation Optimiser, Nitrogen Calculator, and DROUGHTPLAN that can use the Southern Oscillation Index (SOI) phase system to make forecasts. Other states and territories have similar programs. All of these products require ongoing maintenance and regular updating, and their uptake and availability could potentially be improved by providing training to growers and consultants.

A relatively high rate of adoption of inter-seasonal climate forecasts has been achieved in some sectors and regions. For example, a survey of graziers in Dalrymple Shire in north-eastern Queensland indicated that 52 of the 100 graziers surveyed agreed that they made ‘good use of the Southern Oscillation Index’ for grazing and business management. Other surveys indicate that more relevant forecasts with longer lead-time and higher skill may improve the utility and adoption of seasonal climate forecasts (above).

Rather than lack of access to seasonal climate forecasting information, a major limitation to adoption is likely to be the confusion resulting from the range of the number of available forecasts/climate risk assessment systems. A lack of understanding of the underlying science, and the lack of a transparent track record will also limit the adoption of some systems, even if these systems result in improvement to skill and lead-time (e.g. global climate models, QCCCE’s SPOTA-1 system).

Not only is there a need to tailor or customise forecasts to meet the needs of decision makers and other stakeholders (e.g. a forecast targeting a particular season at a certain lead-time), it is also important to translate seasonal forecast information into terms that can be readily be incorporated into management and decision-making. This may involve systems analysis and the use of models to translate climate information into more relevant information for decision makers (e.g. pasture or crop production rather than rainfall). However, an approach based solely on output from a centralised agency is unlikely to gain trust with stakeholders, therefore reducing the uptake of this information into management systems and decision making.

Terms of Reference 2

Innovation in long-term meteorological forecasting methods and technology

In addressing Terms of Reference 2, we consider only methods and technologies used for seasonal climate forecasting, not short-term meteorological weather forecasts or forecasts based on the MJO as considered under Terms of Reference 1. The QCCCE believes that developments in terms of innovation should concentrate on the following components of seasonal climate forecasting – historical and current skill, access and availability of information, relevance to decision makers and the rate of adoption by the community.

As indicated in the previous section, problems identified in terms of efficacy of seasonal forecasting include:

- lack of skill in certain seasons;
- lack of lead time;
- use of forecasting systems not suitable for Queensland;
- the unknown impact of climate change on the skill of existing seasonal climate forecasting systems;
- lack of capacity to deliver current information;
- a need to value add forecast systems to meet specific needs of community and industry sectors; and
- need for training of advisory staff and community.

Innovation with respect to improving historical and current skill
The Queensland Government recognises that the climate system is predominately chaotic and that there is a limit to how much improvement can be made to the skill of seasonal forecasts. Nonetheless, the Queensland Government believes there is scope for improvement and has always supported and encouraged research into improving seasonal climate forecast both at state, national and international levels.

The Queensland Government, through the QCCCE, maintains an active research program addressing the improvement of lead-time and skill of seasonal climate forecasts, using both statistical and dynamical modelling techniques. For example, using statistical techniques Queensland Government scientists have developed innovative techniques using both the Southern Oscillation Index (e.g. the SOI Phase Scheme) and sea-surface temperature gradients (e.g. the SPOTA-1 – Seasonal Pacific Ocean Temperature Analysis version 1 – scheme) to develop customised climate risk assessments for Queensland addressing issues of lead time, and skill at critical periods. The Queensland Government has also invested in 'super-computing' facilities to run in-house global climate models for producing seasonal climate forecasts, improving our understanding of the climate system and producing downscaled climate change projections.

The Queensland Government believes there are a number of practical steps that can be taken to immediately improve the skill of statistically-based seasonal forecast schemes. Firstly, there is a need to 'weed out' from various schemes indices with least relevance for Queensland (e.g. Indian Ocean sea-surface temperatures includes in BoM's statistical scheme) – this may serve not only to improve the skill of existing systems, but 'make room' for inclusion of more relevant indices (i.e. for a number of practical and theoretical reasons it is well-understood that it is highly desirable to limit the number of indices employed in a statistical scheme). Secondly, the re-engineering existing schemes may provide scope to incorporate indices of persistent processes known to impact on Queensland (e.g. the Pacific Decadal Oscillation). Thirdly, care should be taken to de-trend, as best as possible, both predictors and predictands from climate change trends, should historical relationships be seen to drift. Lastly, as discussed above and elsewhere, there is scope to break away from the traditional seasonal outlook (i.e. issued every month for the next three-month season) and customise seasonal forecasts more to user-needs (e.g. provide a more targeted outlook for next summer at various lead times).

Whilst the Queensland Government acknowledges that there are limitations to statistical schemes and that dynamical models offer a more integrated climate assessment, the Government cautions that the skill of such models for Queensland will be limited by the extent that they can accurately model important processes such as ENSO and the PDO. Furthermore, as discussed elsewhere, the Government recognises that these systems are less transparent than statistical schemes and lack a widely accessible track record, which may limit their uptake by Government and the community.

The Queensland Government will continue to address the challenge of synthesising and interpreting available forecast information for Government and industry. However, until the Queensland Government is convinced of the reliability of global climate models, particularly compared to existing statistical schemes, the Queensland Government has a duty of care to continue to utilise and promote climate risk assessments based on statistical approaches. Nonetheless, the Queensland Government is cautiously integrating output from dynamical models into risk assessments with appropriate caveats given their efficacy has not been fully evaluated (see comments under ToR 1).

Innovation with respect to improving access and availability of information,
As mentioned previously, for scientists, decision makers and other stakeholders to more effectively manage climate risk, there is a need for robust data-sets, targeted forecasts, and supportive interpretation (see response to TOR 1). For example climate forecasts do not reach their potential without good ‘base’ data and translations through models to forecast various outcomes (e.g. water supply, crop production, fuel loads).

For example, as part of the Queensland Heatwave Response Plan, BoM now issues advice to Queensland Health when the ‘heat index’ is forecasted to exceed 36ºC in Brisbane for at least two consecutive days. Queensland Health, in turn, forwards this advice to hospitals and other agencies, and provides public advice on managing heat stress.

The Queensland Government has supported “Managing for Climate Workshops” to help users better understand climate processes, the nature of seasonal climate forecasts, and how to incorporate these into business and risk management frameworks. The Queensland Government has also supported the development of several important national information systems to improve access to information to improve climate risk management. For example, the Queensland Government has developed both the pioneering LongPaddock website and the SILO climate database (discussed in detail below) which have vastly improved access to climate data and forecast information in Australia. The AussieGRASS system, which is underpinned by SILO, has also increased access across Australia to soil water balance and pasture production information and forecasts of pasture growth. The AussieGRASS system is also capable of delivering fuel load forecasts once BoM’s short term forecasts are better incorporated into the SILO system.

The SILO system deserves special mention in this context, due the wide-reach of the information and possibilities for innovative use of this rich data-source for improving climate risk assessment. SILO data is based on observations provided to the Queensland Government courtesy of BoM. However SILO data differs from other available data in that it is:

- spatially and temporally complete, covering Australia on a 0.05 degree (approximately 5km) grid and is available for every day from 1/1/1889 to present;
- spatial data for any region in Australia can be provided in over twenty formats to support popular geographical information systems and custom models; and
- point data, for any one of 281,963 locations around Australia is available in 15 formats, supporting a variety of models.

Additional opportunities exist for future development and collaboration with BoM on SILO. For example, through the use of BoM data, SILO is capable of incorporating 7-day predictions into the system to extend SILO's application to a wider range of sectors and industries. In addition to agriculture, examples of other sectoral applications include:

- the tourism industry (e.g. peak holiday periods);
- mining (e.g, flooding of coal mines and coal stock piling);
- the electricity industry (e.g assessment of anticipated peak load requirements);
- primary industries; (e.g. afforestation and reforestation activities);
- main roads (e.g optimum construction periods and location);
- rail system (e.g. bridge construction and maintenance periods);
- pest management (e.g. agricultural chemical applications);
- human and animal health (e.g. heat day indices, mosquito breeding cycles and malaria outbreaks);
- building and construction (e.g. penalty contracts and number of wet days); and
- the meat industry (e.g. matching labour to continuity of animal supply).

In addition to the above, regional climate change projections could also be incorporated.

Innovation with respect to improving relevance to decision makers

For inter-seasonal climate forecasting to effectively support the development of future policy or operational responses, decision makers must have a clear understanding of the needs and demands of the regional industries, the climatic factors of importance and the factors that affect effective uptake of proposed solutions. For example, adaptation responses to climate variability (and climate change) should be applicable to key industries (as opposed to sectors), be cost-effective, practical, and technically sound and provide achievable outcomes. In many cases adaptation responses are generally broad policy measures directed at large sectors, for example agriculture. Ideally climate forecasts should be structured according to the needs of the industry. For example, in contrast to the cropping industry, long term meteorological forecasts for the horticultural industry are insufficient (i.e. shorter lead times of up to a week are necessary).

The development of the SOI Phase system in the early 1990s improved the relevance of SOI-based forecasts for the cropping industries, by capturing additional skill through month-to-month change in the SOI, particularly at the end of autumn, prior to the planting season for winter crops. Like other contemporary schemes, the SOI Phase system provides a rolling monthly forecast for the three-month season ahead. Queensland Government scientists have modified this system to increase its relevance for grazing and sugar industries which are particularly reliant on summer rainfall. The modified system forecasts target a particular period and are issued with lead-times that countdown to the forecast period. Queensland Government scientists, in the late 1990s also developed an innovative system called SPOTA-1 (Seasonal Pacific Ocean Temperature Analysis version 1) which targets summer (November to March) rainfall at lead times counting down from seven months. .

Innovation with respect to increasing the rate of adoption by the community.

Innovations with respect to increasing the rate of adoption by the community should concentrate on the need for continuous training of both advisory staff and the community. To assist better decision making, the contextual information that supports climate forecasting must be able to be understood by the business managers. The Queensland Government has provided "Managing for Climate Workshops", as stated above, to help users better understand climate processes, the nature of seasonal climate forecasts and how to incorporate these into business and risk management frameworks. Such workshops could be extended beyond the agricultural sector. However, broader communication mechanisms should also be in place to disseminate targeted, useful, easy to understand, but risk cognisant climate forecasts that are applicable for a range of business purposes, through a range of mediums and communication processes (via the internet, message alert systems, workshops, preparation of case studies, extension programs). Such networks (including government departments, councils, community and catchment groups) provide the necessary link between climate forecasting and the development of policy responses, in order to support management systems and decision making. It also provides an essential feedback loop to ensure those on the ground responsible for implementing such solutions can influence their future development.

An emerging need is to educate the next generation of research and advisory staff. In this respect, educational institutions have a role in incorporating climate information into practical courses, and in turn, current practitioners have a role in providing source of reference material and texts.

There is no doubt that adoption of seasonal climate forecast information by the community has been facilitated by high-profile 'gurus' and climate champions. It is hoped that there will, in future, be less reliance on individuals and a more effective main-stream, broad-based promotion of seasonal climate forecasting. This will probably now be inevitable given the increased public awareness of climate-related issues.

It is difficult for national institutions to deal closely with a potentially large Australia-wide user-base, hence the need for partnerships with state agencies. These partnerships need to progress from a provider-user relationship to one which recognises the vital contribution that state agencies can play in both developing, value adding and extending climate information. Whilst each state may be at a different level in this regard, increased rates of adoption can only be expected by empowering state agencies and, to a greater extent, rewarding winners and funding the national role out of state initiatives (AussieGRASS and SILO are good examples of initiatives that would have further benefited the nation with ongoing federal funding support).

The lessons learned in Queensland (see introductory statements) should be taken into account. This may mean the transparent approach to extending climate information based on analysis of the historical record and the development of probability distributions based on climate analogues will continue to have a vital role in community education, even if there is a heavier reliance in future on "black box" forecasts from global climate models.

The Queensland Government believes there will be a continuing need and role for local interpretation of seasonal forecasts, both by the BoM regional office and the Queensland Government through QCCCE. As a practical measure to improve relevance of information to decision makers, the QCCCE recognises the importance of strengthening communication with the BoM regional office and collaboration with other state agencies. For example, through the exceptional drought periods in South-East Queensland this decade, the QCCCE has collaborated with water authorities, in particular SunWater, Department of Natural Resources and Water and the Water Commission to develop customised inflow and dam-level 'forecasts' bringing together the knowledge, data and skills of all agencies concerned

With respect to rural industries, enhanced seasonal forecasting and decision support tools to assist producers in incorporating this information in their production decisions are an essential component in assisting producers become better prepared for drought. As such, improving primary producers' drought preparedness and their capacity to manage the risks associated with drought and climate change is the emphasis of the current review of drought policy. Ministers at the Primary Industries Ministerial Forum meeting of 19 September 2008 agreed that to improve drought policy greater emphasis needs to be placed on:

- providing farmers with user-friendly climate projections and season-to-inter-annual forecasts, particularly for specific rural sectors and at a local scale;
- enabling farming families and communities to plan and prepare for the social impacts of drought;
- improving the delivery of existing and future drought social support services (counselling, information, events) to farming families and communities; and
- ensuring that drought policy supports productivity growth of the sector.

Ministers at the 13 February 2009 meeting of the Primary Industries Ministerial Forum then agreed, subject to budget consideration, to implement a range of principles including:

- assistance for farm businesses to prepare for future climate change and drought, including to support farm planning and business training;
- to implement risk management, natural resource management and drought preparedness strategies; and
- improved research and development including seasonal forecasting.

Therefore, there is a clear direction that supports greater investment by the appropriate agencies in enhancements to seasonal forecasting and the application of these forecasts to farm production decision making.

Terms of Reference 3

The impact of accurate measurement of inter-seasonal climate variability on decision-making processes for agricultural production and other sectors such as tourism

The Queensland Government addresses the issue of 'impact' in terms of **potential** historical and current skill of seasonal forecast systems and **potential** uptake and use of available information.

An important task in evaluating the role of meteorological climate forecasting is to identify those management decisions that could be improved by additional information on the behaviour of the climate system. To achieve this understanding requires a systems analysis of the particular enterprise or activity. A systems analysis would involve identifying the decisions that are made by managers, responses that are currently taken and identifies the impacts of seasonal climate variability on the enterprise. Such a systems analysis provides a basis for the development of risk management strategies and allows the impact of inter-seasonal climate variability on decision-making to be better assessed.

In agriculture and hydrological systems, a range of approaches have been successfully adopted to manage for climate variability. For example, in grazing enterprises in the natural grazing lands of Australia, year-to-year climate variability has had major impacts on pasture growth, forage availability, animal production, surface soil cover, risks of degradation, and opportunities for resource restoration. Successful graziers have adopted a range of strategies including: conservative continuous grazing with appropriate destocking in extreme droughts; or responsive strategies involving more frequent adjustments of stock numbers to match forage supply. These strategies rely on some knowledge of historical climatic variability.

Simulation studies and grazier surveys suggest that management decisions can be improved with seasonal climate forecasting. Simulation studies using grazing system models have evaluated potential production using examples where perfect knowledge of future pasture growth or future regional rainfall was available. Although these studies have been conducted mainly for a single location (Charters Towers, north-east Queensland), nevertheless they suggest that there is substantial benefit from adopting flexible grazing management including knowledge of the coming season. These benefits were in terms of the gross value of the production (beef) without greatly reducing resource condition (e.g. soil loss).

Similar studies have been conducted for agricultural systems which indicate the potential value of seasonal forecasts in terms of crop production, reliability of planting, and financial return of linking agricultural decision-making to future knowledge of the climate system.

We conclude that decision-making is likely to be improved with knowledge of inter-seasonal climate variability by the following actions: (1) conducting a systems analysis of enterprise/activity identifying key decisions and the impact of climate variability; (2) determining those decisions that could be influenced by existing meteorological and climate forecasting information; and (3) identifying those decisions which could be improved if skill in forecasting was increased. The latter component would provide a basis for indicating priorities for research in climate science.

Whilst the Queensland Government has investigated the potential impact of seasonal forecasts in grazing and farming enterprises, the potential in other areas has not been fully explored. There are undoubtedly untapped benefits from seasonal climate forecasting to be realised.

For example, BHP have successfully used seasonal climate forecast information to tactically alter their scheduling of coal production and stockpiling at the Goonyella Riverside mine (central Queensland). In 1998, after considering the outlook provided by the Queensland Government, the mine manager decided to implement a change to the mining operation. The climate outlook provided a likelihood of a much wetter summer, so the mine manager invested in a program of accelerated stockpiling of coal at the mine surface. This was a contingency for expected downtime at the mine due to wet weather. The rain did arrive and the mine was waterlogged, however, the company was able to maintain its orders during this period, whereas their competitors were unable to do so.

Another potential benefit of seasonal climate forecasting in minimising the impact of climate variability is in the reduction to the interruption of freight/transport due to weather events which may cause product spoilage and loss of supplier contracts.

At a regional level, the Queensland Water Commission (QWC) is responsible for developing and implementing strategies to assure the short and long term water security of South East Queensland. An essential input into the development of such strategies is accurate information on historical climate variability and reliable forecasts for both climate variability and climate change. Although the region is small, SEQ encompasses an area which experiences diverse climatic conditions which adds to the complexity of the planning task and associated complexity of climate forecasting within the region.

More specifically, climate forecasts are used as key inputs into models for both demand forecasting and supply forecasting, both on a regional and sub-regional basis. The weather has a major impact on the way people use domestic water, particularly outdoor water use; and clearly it is the single most important factor in determining the sustainable yields of surface water supplies in the region. The climate forecasts also affect the outputs of the models that are used to develop operational protocols.

During the preparation of the SEQ Water Strategy, QWC found there was a lack of information on climate change forecasts for the region that could confidently be used to adjust modelled water supply yields. This is an area of great uncertainty that QWC recognises as a significant risk for the region's water security. Whilst outside the scope of the current inquiry, we make this statement here, as it illustrates an important point in relation to the future effective engagement with government agencies and industry sectors on climate related issues – it will no longer be possible to discuss seasonal forecasting without also addressing climate change issues.

We have mentioned in our introductory remarks the potential value of short- and long-term forecasts to health and emergency services in Queensland. These are explored further under the following Terms of Reference (ToR 4).

Terms of Reference 4

Potential benefits and applications for emergency response to natural disasters, such as bushfire, flood, cyclone, hail, and tsunami, in Australia and in neighbouring countries

Extreme events such as floods, droughts, heat waves, cyclones and storm surges are of particular importance for Queensland. Short and long-term meteorological forecasting will become increasingly important to incident and disaster management planning as well as proactive deployment capability, particularly if there are adverse consequences of climate change. In that respect, to ensure a continuing effective emergency response and in order to remake its policy and planning settings, emergency services need to know how the risk base may be changing.

The Queensland Government utilises BoM's weather forecasting data and models for a number of purposes: operational response; pre-positioning capability; risk management; planning; community information; reports; and profiling expected natural hazard behaviour (e.g. bushfire). As discussed earlier, the operational utility of weather forecasting modelling is heavily dependent on the quality of BoM data and models. For operational purposes, the efficacy of BoM data and models is limited by several factors including veracity of existing data, scale (granularity) of data, availability of specialist data and expert interpretation which have been expanded under the previous Terms of Reference.

In terms of benefits and applications for emergency response to natural disasters, the Queensland Government finds meteorological weather forecasts most useful for emergency response and have provided good intelligence for Emergency Management Queensland. However, as discussed under ToR 1, the accuracy of the forecasts degrades rapidly beyond 3-4 days, which limits the planning horizon during operations. Improved accuracy out to 14 days would enable detailed planning including: staff levels, transportation and pre-positioning of emergency supplies, preparation of evacuation centres.

Emergency services operations and planning will benefit both from better short-term meteorological forecasts and longer-term seasonal forecasts of tropical cyclone frequency, intensity and propagation. Improved tropical cyclone modelling will also improve understanding of likely changes in tropical cyclone activity under global warming including changes to frequency, intensity and geographic range. Such improvements will help the Queensland Government better plan infrastructure and revise building codes with more certainty. Therefore the Queensland Government recognises the importance of research into the processes that influence tropical cyclone formation, intensification and propagation, including the influence of ENSO and the PDO on these factors.

During the 20th century, heatwaves caused more deaths in Australia than any other natural hazard except disease, yet remains one of the least-studied and most underrated hazards (Emergency Management Australia, 2004). From 1994 to 2004 (excluding 1999), heatwave conditions have been experienced in south-east Queensland on two or more days every year. Recent heatwaves in south-east Queensland and their impacts include:

- January 2000: 22 recorded deaths and 350 injuries costing an estimated $2 million dollars (Audit of the Queensland Disaster Management System 2004-05); and
- February 2004: 12 recorded deaths and 221 heat related hospitalisations (preliminary data: State Coroner and Queensland Health, Health Information Centre).

Providing timely meteorological forecast data allows services to be adequately prepared and timely response strategies to be put in place for emergency situations.

Of equal interest to emergency response is the benefit and application of climate data to more chronic environmental hazards affected by climate. These include:

- increasing temperatures that change the breeding cycles of disease vectors (eg. speeding up the maturation of mosquitoes);
- changing rainfall patterns that affect water supply and quality and increase the risk of water-borne diseases; and
- changing temperature and humidity patterns affecting the concentration of air pollutants.

The assessment and management of these indirect health impacts of climate change will benefit from long-term meteorological forecasting and modelling.

The Queensland Government has co-invested with National ICT Australia (NICTA) to support its Queensland node – the NICTA Queensland Research Laboratory (QRL). The NICTA QRL operates a strategic project known as Safe Applications for Emergencies (SAFE) within which there are several primary research activities whose successful application could be critical in managing natural and other disasters.

As part of its *SAFE Information* research, the QRL has developed a Tsunami Warning Markup Language (TWML). The TWML aims to improve upon the manner and form in which bulletins from tsunami warning centres, such as the Pacific Tsunami Warning Centre in Hawaii, are distributed. The language is designed to maximise opportunities for interoperability with a variety of systems and NICTA anticipates it will be used in conjunction with standards that support the exchange of information in emergency situations.

The QRL has developed a similar language for cyclone warnings. To date the QRL has had preliminary discussions with the Pacific Tsunami Warning Centre regarding the future application of its TWML technology.

A wireless mesh network for public safety and disaster recovery applications has been developed as part of QRL's *SAFE Networks* research. Known as 'NICTA SafeMesh', the technology allows the rapid deployment of a temporary broadband network within minutes in areas where static communication means have been disabled by natural disasters such as cyclones or bushfires. The rapid deployment of such a network is vital to effective emergency management and could assist save many lives, providing first responders with a means to share crucial information via voice, video and data communication.

As a wireless mesh network, 'SafeMesh' has a 'self-healing' capability should any of its nodes be incapacitated, can support a wide range of services (voice, video, web etcetera) and is secure and cost-effective.

Terms of Reference 5

Strategies, systems and research overseas that could contribute to Australia's innovation in this area.

The Queensland's Governments Climate Change Centre of Excellence (QCCCE) evaluates the effectiveness of seasonal climate forecasting in terms of historical and current skill, access and availability of information, relevance to decision makers and the rate of adoption by the community. It is in these areas that QCCCE will provide examples of where overseas work is contributing and could contribute further.

Strategies, systems and research overseas to improve historical and current skill
As discussed, there are two fundamentally different approaches currently used to provide seasonal climate forecasts. Statistical systems are based on historical relationships between climate variables of interest and persistent climate 'signals' such as provided by the El Niño-Southern Oscillation phenomenon as measured, for example, by the Southern Oscillation Index and sea-surface temperatures. Global Climate models are used both for meteorological weather forecasting and long-term inter-seasonal forecasts. All of these approaches are dependent on the international effort to improve historical and real-time data sets to increase skill levels as follows:

Statistical schemes
Statistical schemes are reliant upon on: 1) accurate historical records of key climate elements; and 2) a reliable way to monitor these elements in real-time. Indices such as the Southern Oscillation Index have proved particularly valuable as they have a long historical record and capture much of the atmospheric dynamics of ENSO. In the 1980s Queensland scientists recognised the value of improving the historical SOI record and much has now been achieved to create a useful historical time-series back to the 1900s. Similarly Queensland scientists were able to immediately take advantage of newly developed historical global sea-surface temperature information extending back to 1890 in the development of a new long-lead experimental statistical forecast scheme called SPOTA-1 (Seasonal Pacific Ocean Temperature Analysis Version - 1). Historical and real-time sea-surface data was initially obtained from the British Atmospheric Data Centre BADC) until the real-time feed of data ceased. Subsequently QCCCE has sourced the information from the US (Reynold's data from NOAA). Improvement to the historical sea-surface data sets also allow statistical schemes to incorporate other sea-surface temperature modes e.g. the Pacific Decadal Oscillation (PDO).

Global climate models
Global climate models project forward based on physical calculations of ocean and atmospheres dynamics. However, these projections are highly dependent on model

'initialisation' (i.e. the initial inputs to the model based on current observed atmospheric and upper-ocean conditions). The accuracy of global climate model forecasts will increase with improvements in real-time monitoring networks. Queensland will be a major beneficiary of this international effort to improve direct and remotely sensed data networks. For example, the TOGA network of floats measuring surface and sub-surface ocean conditions transmitted via satellite is providing an incremental improvement to real time global ocean data collections. Such real-time data is most valuable to improving global climate models – without equivalent historical data, either actual or reconstructed, historical statistical relationships can't be developed.

Apart from improvements to the underlying data sets, increased accuracy and resolution can be expected from global climate models as computing power improves – allowing finer resolution models to be run operationally with less dependency on model parameterisation to overcome scale deficiencies. Realistically, for Queensland, improvements to short term (monthly-to-seasonal) forecasts will come with high resolution modelling of tropical systems, orographic effects etc. which will typically require high resolution (sub 15 km^2) modelling.

The Queensland Government through the QCCCE, has long recognised the potential value of global climate modelling to improve climate risk assessment. The QCCCE has contributed to the international effort by running in-house seasonal forecasts and contributing these, on a monthly basis since 1998, to the International Research Institute for Climate and Society (IRI USA). This forecast contributes to multi-model global and regional seasonal condition outlooks publicly disseminated via the web. The QCCCE is now in a position to make a major contribution to assessing the value of these seasonal forecasts by evaluating their performance during the 1998-2009 period.

The QCCCE is also actively collaborating with a number of international centres such as, in the UK, the UK Met Office Hadley Centre, The Walker Institute, in the USA institutions such as the IRI, University of Colorado and National Oceanic Atmospheric Administration, and in China the Chinese Academy of Sciences, to promote research of particular relevance to Queensland, in particular improving understanding and modelling of phenomena such as ENSO, the Pacific Decadal Oscillation and to improve historical climate data sets by contributing to the international ACRE (Atmospheric Circulation Reconstructions of the Earth) project.

There are a number of international research institutions that have state-of-the-art seasonal climate forecasting systems based on climate models. The forecasts produced by these centres are global in coverage and therefore could be used in Australia. In particular the following organisations have world class climate forecast systems of interest: the European Centre for Medium-Weather Forecasting (ECMWF), and the UK Met Office in Britain, National Centre for Environmental Predication (NCEP part of NOAA) and the International Research Institute for Climate and Society (IRI) in the United States.

Strategies, systems and research overseas to improve access and availability of information

Whilst the QCCCE can facilitate access and availability of information across government and industry sectors through, for example, tools and information systems mentioned in this submission or listed in the attached inventory, one of the problems faced by users may now, in fact be the oversupply of information and certainly the sometimes contradictory nature of this information. As such the Queensland Government through the QCCCE recognises the important role of maintaining an understanding and synthesis of available information. Critical to this mix of information is that provided at a national level by BoM and an international level, in particular NOAA's "El Niño/Southern Oscillation (ENSO) Diagnostic Discussion" (http://www.cpc.noaa.gov/products/analysis_monitoring/enso_advisory/). However, the Government also keeps its own counsel by maintaining its own in-house statistical and dynamical modelling capacity.

Strategies, systems and research overseas to improve relevance to decision makers

The Queensland Government depends on international and national agencies to provide real-time assessments of the ocean-climate system, but relies on its own in-house capacity and that of the Brisbane Office of BoM for local interpretation of relevance to decision makers.

Strategies, systems and research overseas to improve rate of adoption by the community

The rate of adoption by the community will improve as the accuracy and utility of forecasts improves and through education programs that improve background understanding of the science behind the forecasts. The Centre views the development of education programs as more a local and national responsibility. Nonetheless, the Centre recognises the important role that international institutions, which focus on local application of seasonal forecasts (e.g. The International Research Institute for Climate and Society) can play in promoting education programs, including train-the-trainer programs and provision of useful content and is watchful of overseas programs.