

Queensland Climate Change Centre of Excellence  
**KEY PROJECTS and ACHIEVEMENTS**  
2007 – 2008

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## Minister's foreword

Sustainability is the ultimate whole-of-government – indeed, whole of society – issue. Sustainability must be the foundation upon which we build economic strength and natural resilience. It's the beginning and the end of any discussion about society's future.

Sustainability isn't something to be considered in isolation, almost as an afterthought. It must be central to our planning, thinking and acting, as we seek to live in harmony with the planet and leave it in better condition than when we arrived.

What the science of climate change is now demonstrating is just how badly Australia's approach of "borrowing from its past and its future, to sustain its current population and lifestyle" (Foran, 2003) has undermined the planet's systems of support.

Global warming is a symptom of the problem of living unsustainably. Consuming fossil fuels without considering the waste is a sustainability issue. The challenge of climate change, or human induced global catastrophe as it should be known, might be the clarion call that heralds another threat caused by our careless consumption of fossil fuels.

The Queensland Government is committed to working with the community, industry and Commonwealth and local governments to make genuine progress towards sustainability and to tackle climate change. This commitment is reflected in the Queensland Government's *Towards Q2 Tomorrow's Queensland* document. The *Towards Q2* vision frames the government's 2020 vision for Queensland around five ambitions that address current and future challenges. One of these targets – Green – focuses on protecting our lifestyle and environment.

The Queensland Climate Change Centre of Excellence (QCCCE) will play an important role in helping the Queensland Government achieve that target.

The QCCCE was established to ensure that the policies, programs and initiatives of the Queensland Government have access to and are informed by the latest peer reviewed science on climate change and its impacts on Queensland.

The QCCCE will now be broadening its future role to support *Towards Q2* and in response to the current review of the Queensland Government Climate Change Strategy.

This document outlines the key projects and achievements of the Queensland Climate Change Centre of Excellence, within the Environmental Protection Agency's Office of Climate Change.

I would like to take this opportunity to congratulate the team on the science delivered during this time and to acknowledge the efforts of those within the Departments of Natural Resources and Water, Primary Industries and Fisheries and the Environmental Protection Agency in bringing together their climate science expertise to provide this whole-of-government service.



The Honourable Andrew McNamara MP  
Minister for Sustainability, Climate Change and Innovation







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# 1 About the QCCCE

Queensland Climate Change Centre of Excellence

The Queensland Climate Change Centre of Excellence (QCCCE) is part of a specialist whole-of-government work unit, the Office of Climate Change, based within the Queensland Environmental Protection Agency.

## Science, predictability and climate change

Predictability is a resource in itself but one we tend to overlook or take for granted. The ability to predict a range of likely future scenarios allows us to plan and to manage risk. Were we able to do this in relation to climate we could plan and manage risk in any area of human life influenced by climatic events. Hence, considerable resources have been devoted to climate prediction (one field of climate science). Yet even as this science continues to advance, our climate is changing and becoming less predictable.

All sectors will be affected by climate change, particularly water supply, agriculture, human settlements, the natural environment, health and industry, but there are many others. In fact, all aspects of human existence are affected in some way by the climate of our planet. Everyday we make plans on the basis of assumptions about the climate without necessarily being aware that we are doing so.

Human-induced climate change is making our climate less predictable in two senses. Firstly, factors like temperature and rainfall are being pushed outside their recorded historical ranges. Secondly, climate is less predictable because it is more variable, producing more extreme events such as floods and droughts. Any climatic event outside our range of expectations imposes some cost on ecological, social and economic resources.

One important aim of climate science is to understand how and why our climate is changing and hence, increase our knowledge of the range of possible future climates. Basic to this endeavour is the ability to model climate variability and climate change. Models use data from observation combined with mathematical equations to estimate the future climate, either in the form of short-term forecasts or long-term projections.

A further aim is to understand how variations in climate will affect the natural resources and the environment upon which human life and prosperity depend – resources such as water supply, pasture, crops, ecosystems services and so forth. Science is applied in order to manage the risks to human systems from climate variability and climate change.

Finally, once tools are developed to enable us to understand and respond to climate and climate change, these must be packaged and made accessible to potential end-users such as government planners and policy-makers in various sectors, natural resource managers, farmers and other business people, and the community.

## The Queensland Climate Change Centre of Excellence

Established in March 2007, the Queensland Climate Change Centre of Excellence (QCCCE) provides policy advice, information and science on climate change and its impact on the community, the economy and the environment. The Centre carries out scientific work under four themes:

- climate systems research
- climate change impacts and applications
- information and knowledge systems and
- special projects.

The first three themes address the scientific aims listed in the previous section on science predictability and climate change, namely:

- increasing our knowledge of how and why Queensland's climate is changing (climate systems research)
- applying science to understand how climate change will affect the natural resources and the environment upon which human life and prosperity depend, in order to manage



the risks to human systems from climate variability and climate change (climate change impacts and applications)

- packaging and making accessible science-based tools to help end-users understand and respond to climate change and its associated risks (information and knowledge systems).

The fourth theme undertakes special projects and new climate change science in response to emerging trends. It is currently involved in a cloud-seeding research project to assess the potential application of cloud-seeding technology in south-east Queensland.

## The policy context – *ClimateSmart 2050*

*ClimateSmart 2050* is the Queensland Government's policy response to climate change. The strategy was released in June 2007 and outlines a range of measures that target climate change across all sectors in the mid to long term. Significant mitigation actions are already underway in the areas of energy efficiency, promoting the uptake of renewable technologies and investing in new technologies such as geothermal energy production and carbon capture and storage.

*ClimateSmart Adaptation 2007–12* is the government's action plan for building Queensland's resilience to climate change, and sits within the overarching *ClimateSmart 2050* strategy. The policy sets up a framework for a whole-of-government response to managing the impacts of climate change (figure 1). The goal is to enhance Queensland's resilience to these impacts. Specific outcomes sought through climate change adaptation are that Queenslanders:

- understand their climate change risks and vulnerabilities
- consider climate change impacts in their decisions
- take practical steps to enhance their resilience to climate change.

While all sectors of human endeavour are potentially affected by climate change, the priority sectors for action under this policy are:

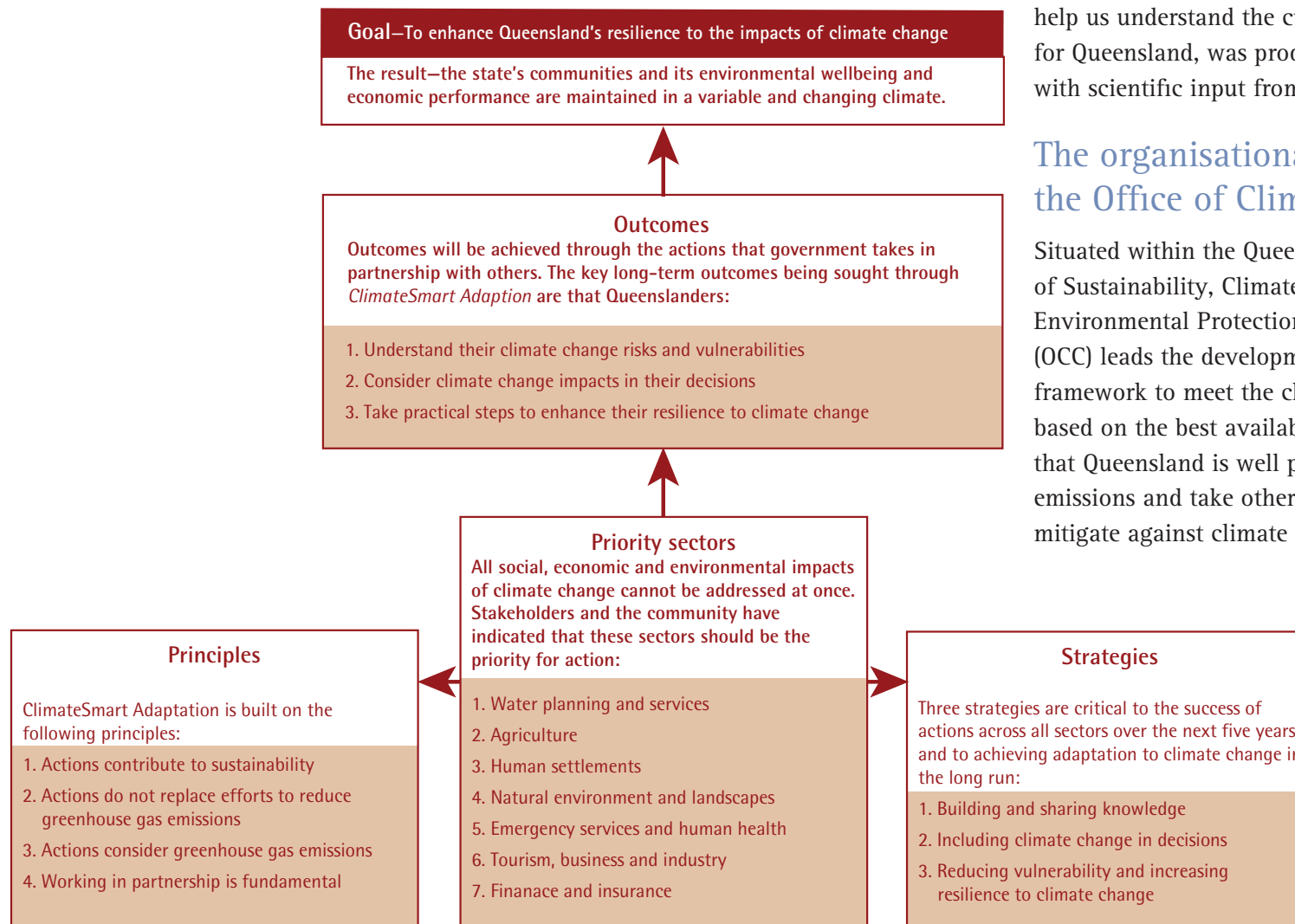
- water planning and services
- agriculture
- human settlements
- natural environment and landscapes
- emergency services and human health
- tourism, business and industry
- finance and insurance.

A series of actions are set out under each of these priority sectors along with actions that run across all sectors. Taking these actions will enable Queenslanders to:

- build and share knowledge
- include climate change in decisions
- reduce vulnerability and increase resilience to climate change.

The *ClimateSmart Adaptation 2007–12* policy can be found on the Queensland Government's climate change website at [www.climatechange.qld.gov.au/response/adaptation\\_plan.html](http://www.climatechange.qld.gov.au/response/adaptation_plan.html)

The Queensland Government's *ClimateSmart* policies are being reviewed to take account of the latest scientific assessments as well as national and international developments in climate change policy. The review process will deliver an updated strategy with a thorough assessment of the likely physical impacts of climate change on Queensland's regions and economic sectors. It will build on *ClimateSmart Adaptation 2007–12* by identifying the climate change adaptation measures and progress undertaken by government, industries and communities to date and recommending priorities for adaptation action.



help us understand the current situation and projected impacts for Queensland, was produced by the Office of Climate Change with scientific input from the QCCCE.

## The organisational context – the Office of Climate Change

Situated within the Queensland Government portfolio of Sustainability, Climate Change and Innovation, the Environmental Protection Agency's Office of Climate Change (OCC) leads the development of a whole-of-government policy framework to meet the climate change challenge. Its work is based on the best available science and information to ensure that Queensland is well positioned to reduce greenhouse gas emissions and take other necessary steps to adapt to and mitigate against climate change. The Office integrates whole-of-government climate change policy functions with the expertise of the Queensland Climate Change Centre of Excellence.

The Environmental Protection Agency works toward a sustainable future by leading climate change policy responses that reduce greenhouse gas emissions and prepare Queensland for the impacts of climate change.

With several strategies in place to meet these priorities, the OCC is acting on the government's commitment to manage climate change and protect the environment.

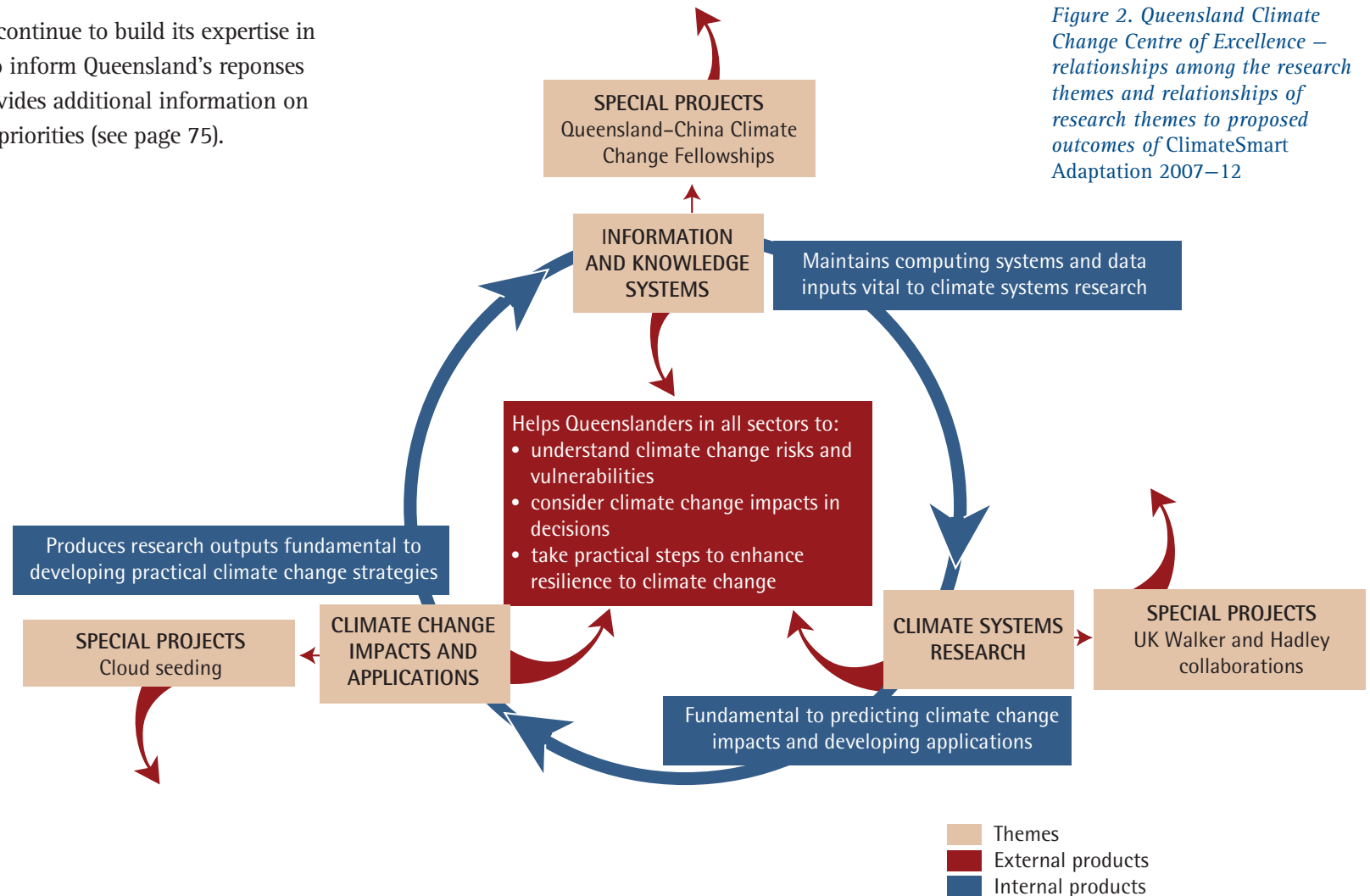
4 *Figure 1. Framework for managing the impacts of climate change, ClimateSmart Adaptation 2007–12*

The QCCCE will provide the scientific base to inform and defend decisions made under the Queensland Government's *ClimateSmart* policies. The recently published report *Climate Change in Queensland – What the science is telling us*, which captures the latest peer reviewed data on climate change to

## Key projects and achievements 2007–2008

This document describes key projects and achievements of the QCCCE from March 2007 to June 2008, aligning these with actions set out in the government's ClimateSmart policies. The projects and achievements are presented by theme. A diagram relating these themes to each other and to desired outcomes of the *ClimateSmart Adaptation 2007–12* is presented in figure 2.

Moving forward, the QCCCE will continue to build its expertise in providing a solid evidence base to inform Queensland's responses to climate change. Chapter 6 provides additional information on the QCCCE's future direction and priorities (see page 75).







# 2 Climate systems research

understanding, forecasting and modelling our dynamic climate

To respond to the challenges posed by global climate change, it is crucial that the scientific community develops a solid understanding of the climate system, enabling scientists to provide reliable climate change projections to support intelligent policy responses. There are many national and international climate science research groups and there is now a large amount of climate change literature available to guide policy development. However, Queensland's climate is unique. The climate processes that affect Queensland must be understood so appropriate policies can be developed. The QCCCE is undertaking research in areas where information or knowledge is not available from other sources, primarily in areas of climate science that relate specifically to Queensland.

The Climate Systems Research (CSR) program aims to increase our knowledge of how and why Queensland's climate is changing. The program addresses three key issues.

- How is Queensland's climate changing?
- What are the causes of these changes?
- What will Queensland's climate be like in the future?



Climate Systems Research is attempting to answer these questions through the following activities:

- attribution studies which link climate change causes such as greenhouse gas emissions, land clearing and ozone depletion, with climate change effects such as warming and rainfall declines
- generating climate change projections which provide policy-makers and planners with realistic, scientifically-based climate scenarios for the future
- seasonal forecasting to help people manage climate variability and assist them in adapting to climate change
- climate modelling to quantify the outcomes of efforts to mitigate climate change.

The theme's key objective is to support the development of scientifically-founded and credible climate change policies. The climate systems research theme provides:

- climate change datasets to enable the impact, adaptation and mitigation studies undertaken by other groups within QCCCE
- climate information to guide policy makers.

Some key concepts in relation to the CSR theme revolve around the use of models and historical data for climate research. Historical data on a range of climate “variables” (quantities that change and can be measured, such as temperature, rainfall and evaporation) have been collected around the world for centuries by weather stations, observatories and ships at sea. As may be appreciated, the actual historical climate database is very patchy in quality and geographical extent as well as through time. However, it is possible to reconstruct a full set of historical climate data using climate models and the incomplete records that exist. This process is called climate “reanalysis”.

*Climate models are based on equations that take into account the relationships among factors such as solar radiation, sea surface temperature and atmospheric pressure...among many others*

Data from the modern records produced by weather stations are also not complete because they have data for just the places where weather stations are located. Getting data for the whole country (or indeed the globe) involves a process called “interpolation”, a mathematical technique used to estimate the climate variables (temperature, rainfall etc) for places between weather stations.

Historical climate data, whether from interpolation or reanalysis or both, can be used in two ways to forecast future climates. First they can be used to make statistical forecasts such as those based on the familiar El Niño-Southern Oscillation (ENSO) phenomenon. Underpinning these forecasts are known relationships between ENSO indicators (such as the Southern Oscillation Index or SOI) and climate variables (for example rainfall and temperature). Statements are made about what is likely to happen based on what has happened in the past. Such forecasts will become less accurate as the climate changes because the past will be a less reliable predictor of the future. Instead we will need to know more about how the many complex factors involved interact to produce climate.

This is the purpose of climate modelling, which makes a different use of historical data to forecast and project likely future climates. Historical data can also be called “observational” data, because it is based on what has already been observed, whereas “projected” data, the output of modelling, is an attempt to demonstrate what is yet to come. Climate models are based on equations that take into account the relationships among factors such as solar radiation, sea surface temperature, atmospheric pressure, the extent and influence of ice and snow among many others. Models are tested against historical data. If we run the models and find that they accurately predict what happened in the past, then we can have some confidence in what they tell us about the future. Because they are based on understanding the physics of climate

and not merely on statistics about what has happened in the past, they are robust to the effects of climate change.

This is why models can be used to project likely future climates under the influence of climate change. Factors contributing to human-induced climate change include increases in greenhouse gases (carbon dioxide, methane and others) as well as aerosols in the atmosphere, depletion of stratospheric ozone and changes in land cover and land use. Global climate models (sometimes called GCMs) can include all these factors in attempting to project the climate of the future. For example, models are typically run using a range of possible future “emissions scenarios”, that is, assumptions about what quantities of greenhouse gases are likely to be emitted in future, as we take a range of possible actions to mitigate climate change.

However, global climate models (such as those used in climate change assessments coordinated by the Intergovernmental Panel on Climate Change or IPCC) are usually too coarse grained to allow impact assessments on the scale needed for governments, industries and communities to realistically manage the risks of climate change. To achieve this, the models need to be “downscaled” using various techniques. While global climate models give climate projections on a grid covering the earth in grid cells of 150–300km across, the downscaled regional models produced by the QCCCE will be able to project future climates for areas as small as 15 to 20 kilometres across. However, this improvement in model resolution by a factor of ten requires the commitment of enormous computer resources both for storage of the huge datasets produced and for doing the calculations involved in running the models.

*Climate systems research team:  
(top to bottom, left column)  
Jozef Syktus (theme leader),  
Allyson Williams, Norman Treloar,  
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# Atmospheric Circulation Reconstructions over the Earth (ACRE)

*Earth and sea surface weather records, newly recovered from ships logs and other historical sources, are the basis of a collaborative international “climate reanalysis” project in which the QCCCE is a partner. The historical weather data are used to generate a detailed reconstruction (reanalysis) of the weather of the last 200–250 years. Partners in the project, along with the QCCCE, are the UK Met Office Hadley Centre, and the US National Oceanic and Atmospheric Administration (NOAA). The climate reanalyses will be immensely valuable for testing the outputs of global climate models, used by the QCCCE to assess the impacts of climate change on Australia’s (and the world’s) environment, society and economy.*

With state-of-the-art climate modelling and super computers, we now have the science to estimate what the past climate was like anywhere on the globe and also to make predictions about future climate under a range of assumptions. But why should we have confidence in future climate projections, upon which we have to rely so heavily? The answer to this question lies in the fact that we use historical weather data to test the models’ ability to simulate past climate, that is, in order to have confidence in future predictions we need to demonstrate that we can simulate the past.

“Climate reanalysis” is a revolutionary technique used in modern climatology to produce an uninterrupted reconstruction of global weather in three dimensions. It involves reprocessing whatever patchy historical land and sea weather observations exist, and feeding these into a numerical weather model to produce short-term forecasts. The output of these forecasts fills gaps in the observation network in time and space. Once the gaps have been filled, the model can be tested to see how well it reproduces further historical observations and so on until an entire historic dataset has been built.

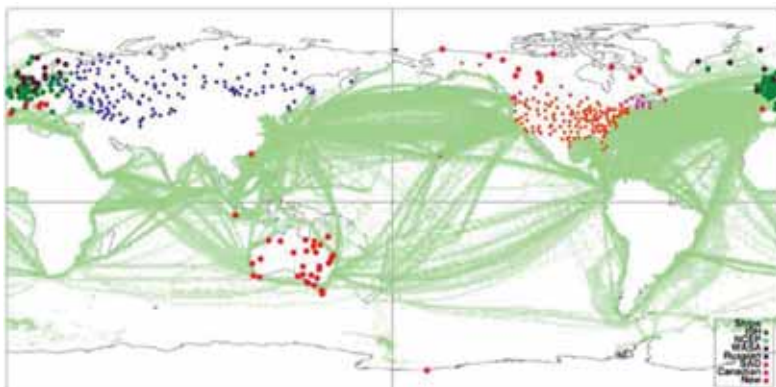
The international ACRE initiative, a collaboration of the Hadley Centre, the NOAA Earth System Research Laboratory (ESRL)/Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado and the QCCCE, is facilitating the recovery, imaging and digitisation of global historical land and sea weather data, covering approximately the past 200 years, to fuel reanalyses which will produce an historical global 3D database of weather variables extending back to the mid-1800s and a dataset for the north Atlantic and European region going back to the mid-1700s. These historical reanalyses are being developed by ACRE’s US partner, NOAA’s ESRL/CIRES. Their first complete reanalysis, which will be released early in 2009, is the 20th Century Reanalysis Project extending the global 3D weather database back to 1892 using similar techniques. These extensions are possible because the models used to make the weather predictions rely only on surface observations and not modern records such as satellite observations, aircraft data and upper level balloon readings that have hitherto been used for reanalyses, such as those produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) or the National Centers for Environmental Prediction (NCEP) in the US. (source <http://www.met-acre.org/wg1-data/imaging-and-digitisation-of-historical-instrumental-weather-observations-in-ship-logbooks>)

*Historical weather records – excerpt from a logbook page of the Discovery, on Mawson’s 1929–31 expedition. This logbook is held in the Australian National Meteorological Library*

(source [http://brohan.org/hadobs/acre/marine\\_digitisation\\_2007-9.html](http://brohan.org/hadobs/acre/marine_digitisation_2007-9.html))

The benefits of having these reanalysis databases of climate variables extending back 200 years or more will be immense. They will give us important insights into climate cycles such as the El Niño Southern Oscillation (ENSO), the Madden–Julian Oscillation (MJO) and the Interdecadal Pacific Oscillation (IPO) – all processes that interact in complex ways to influence Queensland’s climate. They will help us model accurately the interactions of these cycles with human-induced climate change to produce our future climate. These historically extended databases will also test models being used by the Intergovernmental Panel on Climate Change (IPCC) to predict future climates. The result will be more finely tuned models that allow us to make predictions accurate enough to underpin risk management in key sectors such as agriculture and health affected by climate change. The historical datasets will also allow us to assess climate change mitigation and adaptation strategies against relevant and reliable benchmarks.

Perhaps one of the most important outcomes of this project will be the QCCCE’s collaboration and ongoing relationship with the Hadley Centre, a leading international centre for climate change research, and the ready access to extremely valuable data that will result from this collaborative research.



*Land and sea weather data coverage of the earth in 1929*

## WHAT ARE GLOBAL CLIMATE MODELS?

Climate models are our primary tools for anticipating climate change and its likely impacts. Such models use observed data and mathematical equations to estimate the future climate, either in the form of short-term forecasts or long-term projections. In either case, using models to simulate past climate is an important prerequisite to using them to simulate the future, as it enables scientists to test the model outputs against observed, historical climate. Comparison of model outputs and observed climate is critical. It allows scientists to evaluate the potential accuracy of their future climate projections.

Global climate models, such as those used in the various assessment activities coordinated by the Intergovernmental Panel on Climate Change (IPCC), attempt to predict the climate system’s response to human-induced increases in greenhouse gases among other factors. These models are known as fully coupled ocean-atmosphere models. This means that the models include components for simulating both oceanic and atmospheric processes and important connections between the ocean and atmosphere. A description of the initial state of the land, ocean and atmosphere (the initial conditions) is fed into the model and mathematical equations are used to estimate possible future climate states based on a range of assumptions about future greenhouse gas emissions (known as emissions scenarios).

There is considerable difficulty in estimating how future emissions may evolve, and furthermore, not all aspects of the climate system can be accurately modelled. Consequently there is a degree of uncertainty about the accuracy of climate change projections. The level of uncertainty tends to increase with the length of projection (i.e. how many years ahead the model is attempting to predict the climate), and is also dependent on which climate model is used. Climate models differ in many respects (e.g. complexity, resolution) and, although climate models have evolved toward highly complex systems that simulate a vast range of physical and biological processes influencing climate, there is a need to constantly monitor the behaviour of the individual components and their interconnections.

A factor affecting the usefulness of a global climate model for predicting local climate conditions is their resolution, that is, the size of the “grid” on which the calculations are based. Global climate models typically use a grid of 150–300 km, so they will project the same climate for any place within a given “grid cell” up to 300 km across, without reference to local conditions. To get a finer grid with a global climate model (a process called downscaling) requires enormous computer power. In fact, computer power is currently a major limiting factor in downscaling global climate models.

# The Climate of the 20th Century (C20C) project

*The QCCCE is one of many climate centres around the world involved in the Climate of the 20th Century Project, whose ultimate aim is to improve our ability to predict accurately the climate of the future. Through this collaborative effort, all participating groups benefit from the combined modelling efforts, which would not be achievable by any single group. In addition to benefiting from the collaborative effort, Queensland will gain a comprehensive dataset of historical climate simulations for the Australian region. Detailed analysis of the dataset will improve QCCCE scientists' understanding of the key climate processes affecting the Queensland region.*

*Drought in the Sahel region of Africa*



The Climate of the 20th Century project was initiated by the UK Met Office Hadley Centre for Climate Prediction and Research has since expanded into an international project involving climate research centres from around the world, the QCCCE being one such centre. The motivation for the project is to investigate the ability of atmospheric global climate models (AGCMs) to reproduce the major climatic events of the 20th Century, such as the ongoing drought in the Sahel region of Africa, and the drought affecting much of Australia's east coast.

The project focuses on the simulation of atmospheric processes and does not use dynamic ocean models. Rather, the influence of oceanic processes is included

through the use of observational datasets, in particular observed sea surface temperatures and sea-ice extents from the HadISST (Hadley Centre Global Sea Ice and Sea Surface Temperature) dataset.

Many research activities are being conducted under the auspices of the Climate of the 20th Century Project, and all share one common attribute: the use of atmospheric-only models and observational datasets for the oceanic component. The combined benefit of running a large number of modelling experiments is primarily two-fold. Firstly, all participating groups benefit from the combined modelling efforts that would not be achievable by any single group. Secondly, the comprehensive analysis of atmospheric-only models enables researchers to identify potential sources of error in the coupled ocean-atmosphere models. While each participating centre gains its own advantages from the collaboration, the entire modelling community benefits through the advancement of fully coupled models and the consequent improvements in our ability to predict accurately the future climate.

The QCCCE is contributing to this project by investigating the causes and impacts of the major climatic fluctuations and events that affected the Australian region during the 20th Century. The outcome for Queensland, in addition to the collaborative relationships fostered throughout the project and the outcomes of international significance from which everyone gains benefit, will be a comprehensive dataset of historical climate simulations for the Australian region. Detailed analysis of the dataset will improve QCCCE scientists' understanding of the key climate processes that affect Queensland.

# Developing the capacity to predict storms and floods

*Analysing historical data will allow us to predict storms and floods despite increased variability brought on by climate change. This will help us to detect and adapt to future weather patterns.*

**E**xtrême events such as storms and floods have the potential to cause hardship to many sectors of the community. Detecting trends in the potential for storms within the historical climate record can provide insight into some likely outcomes of climate change. Just as Australia-wide weather records from the past have helped us detect trends in temperature and rainfall, they can also be used to detect trends in extreme events.

The Intergovernmental Panel on Climate Change (IPCC) predicts that storm-tracks in sub-tropical and temperate regions of Queensland are likely to move south. This movement will bring changes in wind, rain, and temperature patterns in line with trends observed over the last half-century. In the past, Queenslanders have relied on intense rainfall to fill water storages and recharge water tables and water profiles. A reduction in annual rainfall, continuing recent trends, could mean ongoing water shortages with consequent problems for communities, governments and rural producers.

QCCCE researchers are studying the changes in atmospheric instability that would normally indicate storm potential. Their aim is to discover how best to predict the occurrence and severity of Australian thunderstorms and severe weather including hail, severe wind, rain, flooding and cyclones.

To do this they are using stability indices, indicators of unstable weather conditions calculated using a number of

climate variables. Researchers will identify the best indices for predicting severe weather, look at how good the predictions are, and tease out the signs of climate change within these stability indices.

The ability to predict the occurrence of storms and floods will be crucial to climate change adaptability in the key sectors such as agriculture, water supply and emergency services.

*Storm over Brisbane city*



# Tailoring global climate change projections to the Australian region

*In collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), global climate change projections have been tailored for use in the QCCCE's research and information delivery activities, such as climate risk vulnerability assessments and provision of expert advice to guide policy development. The CSIRO Mk3.5 model has also been extended through this collaboration to include the impact of aerosols (such as soot and dust) on climate change. (The Mk3.5 model is a global climate model, see page 11.) This work will be submitted to the IPCC 5th assessment, making a contribution to the work of this world peak-body dealing with climate change.*

Climate scientists have constructed global climate models to simulate how our climate may evolve in the future. The models typically incorporate a number of components, where each component focuses on the simulation of one or more specific climate processes, along with coupling mechanisms for communicating the interactions between the various processes. The CSIRO Mk3.5 climate model is one such application and features fully-coupled atmospheric, oceanic, terrestrial (land) and cryospheric (ice, snow) components.

The QCCCE undertakes a range of collaborative projects with the CSIRO, and has used the Mk3.5 model to compute global climate projections. The projections span the years 1871–2100 and incorporate 6 repetitions of the model (known as a 6-member ensemble). The datasets were constructed using two distinct, but continuous time periods:

- 1) Simulations spanning 1871–2000 were computed using observational data to guide the model. The climate model was used to simulate the past climate for two reasons. Firstly, historic simulations enable researchers to investigate the mechanisms and processes associated with major climatic events. This work is part of the Climate of the 20th Century Project, which is an international collaborative project approved by the World Meteorological Organization and the Climate Variability and Predictability Programme. Secondly, the 130-year simulation enabled the climate model to stabilise, in

preparation for the simulation of future climate.

- 2) Simulations spanning 2001–2100 were computed using a specific emission scenario to generate projections for the coming decades. The Intergovernmental Panel on Climate Change (IPCC) commissioned a Special Report on Emission Scenarios (SRES) in 1996 to construct a number of emission scenarios, which are essentially estimates of future trends in the emissions of various greenhouse gases. The QCCCE projections are based on one such scenario, the SRES A2 scenario, which is a mid-range emissions scenario.

The Mk3.5 projections have been tailored to the Centre's data requirements. A six-member ensemble was used to reduce noise and thereby enable extraction of climate change signals (by enhancing the signal-to-noise ratio, the uncertainty associated with a projection can be reduced). The projections also feature high-frequency (daily and six-hourly) datasets. Daily outputs allow the construction of daily time-step climate scenarios, necessary for developing computer applications to analyze the impact of climate change. Six-hourly datasets are needed to dynamically downscale the global projections, creating high-resolution scenarios suitable for regional-scale climate risk assessments.

The Mk3.5 projections will support many of the Centre's research and information delivery activities, such as climate risk vulnerability assessments and provision of expert advice to



guide policy development. The availability of in-house datasets greatly facilitates such activities. Furthermore, the datasets being developed through this project are of particular value, as high-frequency and multi-ensemble projections are not readily available elsewhere. Most of the datasets contributed to the IPCC 4th assessment report only include daily datasets for one-, two- or three-member ensembles spanning selected, and in some case discontinuous, periods of time.

While the QCCCE uses the CSIRO model under a license agreement, the collaboration between the two groups has also extended to model development. The QCCCE has assisted the CSIRO with the development of new components for improving the simulation of aerosols and radiative processes (e.g. reflection and absorption of solar radiation by clouds). Aerosols impact on cloud formation and radiative processes, thereby influencing rainfall. The new aerosol simulation model enables interactive simulation of both natural aerosols and those generated by human activity. Major sources of aerosols include mineral dust, marine processes (such as the decomposition of algae to form Dimethyl-sulfide) and industrial and agricultural emissions (such as soot, generated by large-scale burning of forests and grasslands). The improved radiation model independently simulates the radiative processes associated with each of the major individual greenhouse gases. As well, it incorporates into the model the radiative effects of Asian aerosols, dust, greenhouse gases and the depletion of ozone in the stratosphere. Preliminary testing indicates that the improved aerosol and radiation models significantly improve the simulation of rainfall in the Australian region. Further testing is currently underway, and the QCCCE/CSIRO intend to use the model for preparing a joint submission to the upcoming IPCC 5th assessment.

*Burning of forests and grasslands is a major source of aerosols in the atmosphere*

# Management of climate models

*This project gives expert technical support to all QCCCE projects that use climate modelling. Managing a state-of-the-art computing environment is crucial to the computationally intensive business of climate modelling, which is in turn crucial to the Centre's ability to predict future Queensland climates.*

The QCCCE uses global and regional climate models to produce monthly climate forecasts and to predict the effects of climate change at state, regional and local scales. Climate models use data from observation and mathematical equations to estimate the future climate, either in the form of short-term forecasts or long-term projections. The models begin with a description of

the current climate (based on historical data). They then simulate the evolution of the weather system with a set of mathematical equations, taking into account the many factors known to influence climate. These factors include but are not limited to sea temperature, atmospheric pressure differences and solar radiation.

Climate models are numerically intensive computer programs, typically needing a massive investment in both computing and storage hardware. The QCCCE has two Cray supercomputers dedicated to running climate models and a robotic system for storing the output datasets. The QCCCE maintains its own high performance computing (HPC) facilities as it enables the Centre to compute climate change projections tailored to Queensland conditions and to undertake basic research into climate processes that impact directly upon Queensland.

This project manages the installation and operation of the Centre's climate models and their associated datasets. Climate models are complex programs and significant resources are needed to manage their installation and operation. The Centre recently upgraded both its global and regional climate models to allow improved climate change projections for Queensland. The new global model incorporates fully-coupled atmospheric and oceanic components and improved simulation of many physical processes. Fully-coupled components allow the flows and feedback relationships between different model components to be taken into account.

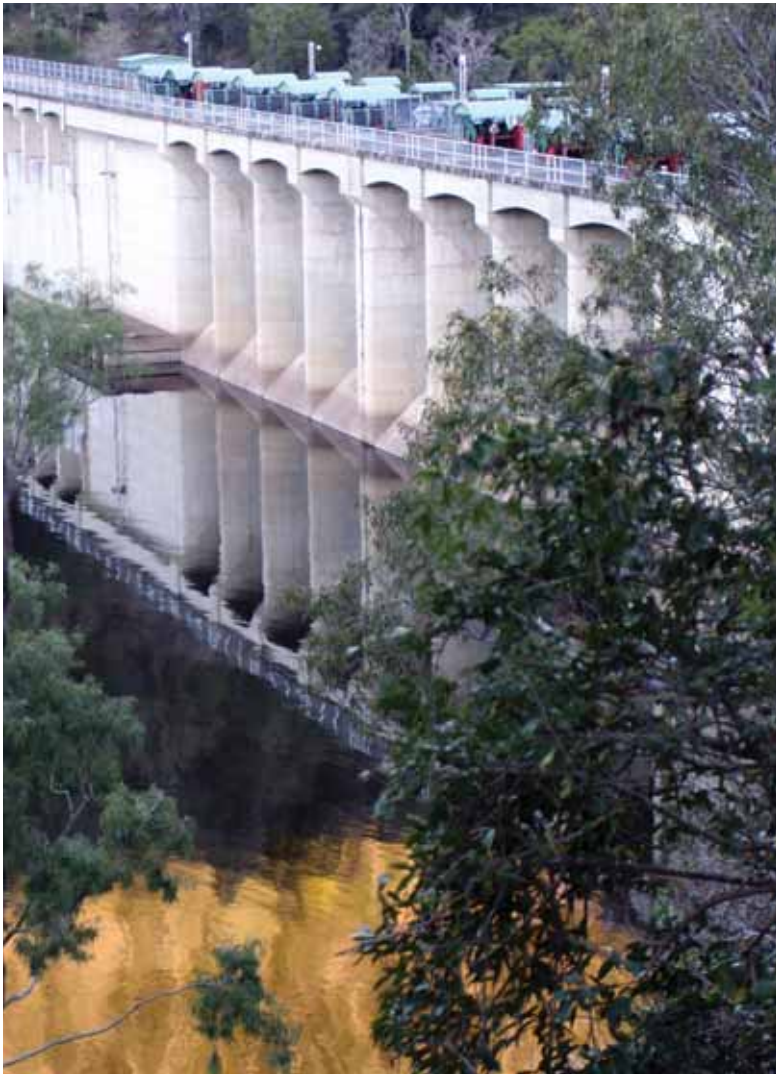
This project involves collaboration with the CSIRO.

*The QCCCE's robotic data storage system in action*



# What has driven the decline in Queensland's rainfall over recent decades?

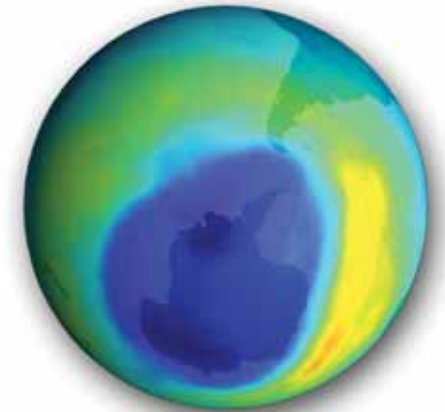
*Climate modelling can be used to investigate the processes contributing to the observed and projected changes in our climate. The QCCCE has recently undertaken an "attribution" experiment to assess the factors contributing to the observed reduction in rainfall along Australia's east coast in recent decades. The research found that ozone depletion strongly influenced the summer climate, while carbon dioxide (CO<sub>2</sub>) levels made their greatest contribution during winter. The depletion of ozone in the stratosphere (by man-made substances such as CFCs) appears to have contributed strongly to recent drying trends across eastern Australia. These results have been used to inform water resources groups responsible for planning Queensland's water infrastructure.*



The global climate system is highly variable and shows natural variability driven by cyclical processes spanning a range of time scales. Examples of cyclical phenomena which influence Queensland's climate include the El Niño Southern Oscillation (ENSO), which drives year to year variability, and the Interdecadal Pacific Oscillation (IPO), which influences variability on a ten-year time scale. A range of other processes also contribute to climate change and variability, including: natural mechanisms, such as solar variability, and human-induced influences, such as stratospheric ozone depletion, changes in land use (mainly deforestation), and increasing concentrations of greenhouse gases and aerosols (pollutants).

The aim of the QCCCE's attribution experiment was to weigh up the contributions of the various factors that may have contributed to observed climate change in Australia. The study focused on the decrease in rainfall across the eastern half of Australia over the past 50 years, and the persistence of dry conditions throughout a recent La Niña period (1998–2001). The unusually dry conditions experienced during this recent La Niña period are of particular concern, as prolonged dry spells have historically been broken by wetter years associated with La Niña events.

The CSIRO global climate model was used to reproduce the climate for the period 1871–2003. Simulations were performed



*Above: the decline in Queensland's rainfall over recent years has been linked with a hole in the stratospheric ozone layer, here shown as a blue area over the Antarctic continent.  
Left: the Somerset Dam*

using both the fully coupled model (incorporating both oceanic and atmospheric components), and also the atmospheric-only model. A "base" simulation was constructed for the analysis period (1871–2003) using the fully coupled model and a minimal set of "forcings" consisting only of observed sea surface temperature (SST) and sea-ice datasets.

The effects of natural and human-induced influences on recent rainfall patterns were then tested by using various combinations of forcing datasets to drive the atmospheric only model. The relative impact of the various forcings, such as solar variability, CO<sub>2</sub> concentrations and ozone depletion, was assessed on the basis of how accurately they reconstructed the climate of the recent dry times compared with the base simulation.

Model simulations driven by combined forcings of observed sea surface temperature, sea-ice, solar variability, increasing CO<sub>2</sub> concentrations and stratospheric ozone depletion, were found to produce the closest agreement between observed and modelled data. Stratospheric ozone depletion strongly influenced the summer climate and the increasing concentration of CO<sub>2</sub> made its greatest contribution during winter. Ozone depletion was found to contribute strongly to large-scale changes in atmospheric circulation, particularly in polar regions, and appears to have contributed significantly to recent drying trends in eastern Australia.

The research outcomes have important implications for water infrastructure planning in Queensland, as the atmospheric conditions driving the recent changes are likely to continue well into the future. The growing population of south-east Queensland is another issue which needs to be examined in the light of these findings.

## WHAT ARE "FORCINGS"?

The term "forcing" refers to any process which has a recognisable impact on the climate system. Forcings can be either natural processes (such as changes in the amount of radiation received from the sun), or human-induced influences (such as the release of polluting greenhouse gases). They can be classified into three categories:

- natural processes, such as the natural variability in solar radiation
- anthropogenic activities, such as land clearing, land use change and production of aerosols (aerosols consist of tiny particles finely distributed throughout the air, such as soil, dust, sea-salt and volcanic ash)
- greenhouse gases, such as carbon dioxide, methane and chlorofluorocarbons.

Forcing agents may contribute to global warming, or even global cooling. Their potential to contribute to climate warming may be represented by their net effect on the Earth's total energy budget. For example, the Earth receives approximately 1366 Watts per square meter (a measure of power) from the sun, whereas greenhouse gases have a warming potential of about three Watts/m<sup>2</sup>. While the contribution of greenhouse gases toward global warming is well known, other forcing agents (particularly aerosols) have a tendency to cool the Earth.



# Assessing the impact of climate change on Queensland's regional water resources

*A combination of historical data, climate modelling and hydrological (water) modelling was used to assess the likely impacts of climate change on fresh water resources in three regions in Queensland. The study was commissioned by the Department of Natural Resources and Water (NRW) and is needed to help water managers and other natural resource managers adapt to the impacts of climate change.*

Freshwater resources are vulnerable to the impacts of climate change. Water security, flood and waste-water management, and water quality could all be affected. Climate change impact studies are important as they enable resource managers to identify possible risks and benefits due to climate change, thereby allowing appropriate adaptation strategies to be developed.

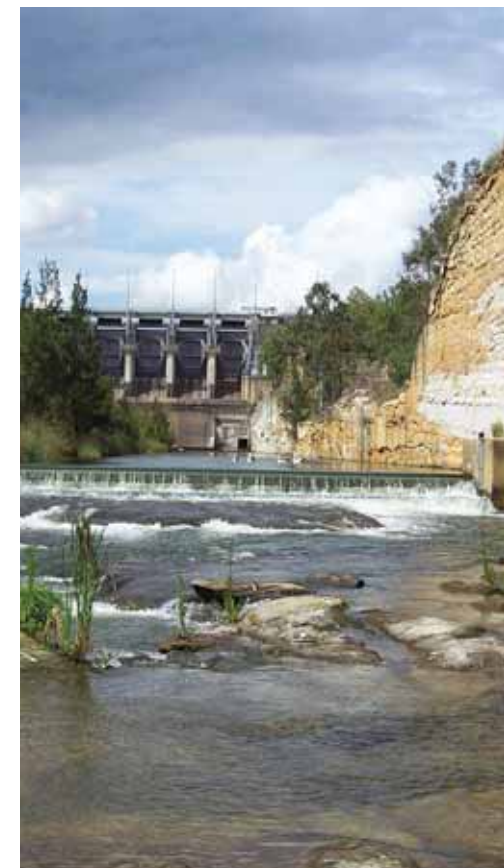
The Department of Natural Resources and Water (NRW) commissioned the QCCCE to identify and quantify the likely impacts of climate change over the next 50 years on water resources in three of Queensland's regions (Wide Bay–Burnett, Mackay–Whitsunday and North Queensland). Advice was also sought as to how these climatic impacts could be incorporated into the assessment of water availability, conservation and demand within each of the regions for the development of the Regional Water Supply Strategies.

Historical climate data from the Bureau of Meteorology's high quality dataset (supplemented by data from the QCCCE's SILO database, see p 59) were analysed for trends in temperature, rainfall and evaporation. Trend information was presented for Australia, Queensland and for each of the three individual regions. The general trend for the last 50 years has been towards a warmer climate for the locations analysed, with some variation between rainfall and evaporation among the three regions.

Global warming is expected to have a greater impact on climatic extremes than on average conditions. Consequently, historical trends in extremes of rainfall and temperature for the three regions were also analysed, along with the incidence of drought and cyclones.

Climate change projections were prepared for each region based upon two emissions scenarios provided by the Intergovernmental Panel on Climate Change's (IPCC's) Special Report on Emission Scenarios (SRES). The A1FI and A1B scenarios were chosen as they have historically been more successful in tracking actual emissions than any of the other major IPCC emissions scenarios. Projections of temperature, rainfall and evaporation were constructed for 2030, 2050 and 2070. Input datasets were provided by CSIRO and the summary projections for individual regions were obtained by spatially averaging the projections for all model grid cells within each region.

NRW assessed water availability within each region using hydrological models driven by the QCCCE's rainfall projections. To minimise uncertainty and improve the forecast quality, rainfall projections were carefully selected from the five global climate models that have been previously identified as being best able to simulate climate in the Australian region.



*Wivenhoe dam, one of Brisbane's main water supply dams*

## CSIRO CONSULTANCY: DELIVERY OF CLIMATE CHANGE PROJECTIONS FOR QUEENSLAND

The Australian Climate Change Science Program released the *Climate change in Australia: technical report 2007* in late 2007. This report was jointly prepared by the CSIRO and the Bureau of Meteorology (who partnered in December 2007 to form the Centre for Australian Weather and Climate Research (CAWCR)) to provide the most up-to-date assessment of climate change in the Australian region. The report describes projections for a range of climate indicators and the underlying datasets constitute a valuable resource for both scientific and policy development groups. The QCCCE has obtained these datasets through a long-standing consultancy arrangement with the CSIRO.

The climate projections provided under the consultancy benefit the QCCCE and its stakeholders through the provision of improved datasets. The updated projections are a major improvement over previous projections for two key reasons:

- 1) The new projections provided are a synthesis of the model results from the fourth and most recent IPCC assessment report. They include not only the range of projected changes in various climate variables, but also the associated probabilities of the projected changes. There is considerable uncertainty in the projections for key indicators, such as rainfall, and furthermore there is a considerable range in the estimates provided by the various climate models. The probability distribution gives the user an estimate of the uncertainty associated with a projection. This is critical for developing cost-effective strategies for dealing with anticipated changes in our climate.
- 2) The additional datasets present projections for each emission scenario separately, in line with the IPCC approach. This separation lets the user tease out the uncertainty associated with future emissions from variations in the projections due to differences in the individual models.

The consultancy products have been used to prepare climate change risk assessments for water supply in three Queensland regions. The QCCCE was engaged by the Queensland Department of Natural Resources and Water to assist with an assessment of the impact of climate change on water resources in the Wide Bay Burnett, Mackay-Whitsunday and North Queensland regions. The Centre is currently preparing climate change projections for thirteen Queensland regions and the consultancy products will also be used to support those analyses.

20 The SEQ Urban Water Research Alliance, to which the QCCCE is a stakeholder, will assess global climate change impacts in SEQ using the CSIRO global model simulations.



# Land clearing triggers hotter droughts: the impact of changes in land cover on regional climate

*Research comparing the modelled effect of land cover change with historical observations suggests that land clearing exacerbates drought and is contributing significantly to climate change. Areas with the greatest extent of historical land-clearing (south-eastern Australia and south-west Western Australia) have become disproportionately hotter and drier than less cleared parts of the country.*

Mapping the rainfall trend across the Australian continent from 1950 to the present reveals a striking correspondence between drier conditions and modification of the land surface by clearing native vegetation and replacing it with crops, pasture or urban development. Mean summer rainfall has decreased by four to 12 per cent in eastern Australia and by four to eight per cent in southwest Western Australia, the regions with the most extensive historical land clearing. Does this mean that land clearing is contributing to climate change in Australia?

Collaborative research between the QCCCE, The University of Queensland, the CSIRO and the University of Colorado suggests that this is indeed the case. Researchers used the CSIRO's Mark 3 climate model to investigate the difference in climate, as measured by factors such as surface temperature, rainfall, near-surface soil moisture and surface wind speed, under pre-European land condition (natural vegetation) and modern-day condition (modified vegetation). Researchers also looked at the impacts of land cover change on drought, comparing modelled summer surface temperatures for pre-European land cover and modern-day land cover under the conditions of the 2002–2003 El Niño-induced drought. This drought had a pronounced impact on the southern half of Queensland (and the whole of south-eastern Australia) resulting in significantly reduced primary production.

The researchers found a close correspondence between annual surface temperature increase and the location of major areas of land cover modification in both summer and winter seasons. The correspondence was less pronounced between land cover modification and rainfall, especially in the winter season. Likewise modelling results showed increases in surface wind speed over regions with extensive land clearing, attributable to the reduced surface roughness of crops and improved pastures compared with native vegetation.

The model results also suggest that land clearing may have magnified the impact of the 2002–2003 drought, especially in southern Queensland and New South Wales, increasing the surface temperature and making the drought hotter and more severe. Abnormally high surface temperatures and low rainfall were experienced throughout the affected areas, and the model reproduced these results when land cover change was factored in.

Careful analysis to see what contribution land clearing has made to local climate shows the impacts include an increase in the strength of surface winds by reducing aerodynamic drag, loss of soil moisture, an increase in the average number of days without rain, reduced stream flows, declines in pasture growth and tree death across large areas.



*Careful analysis of modelled data shows that land clearing has made a contribution to climate change*

## COLLABORATION WITH THE WALKER INSTITUTE (UK)

Queensland relies heavily on industries such as agriculture and tourism which are vulnerable to both natural variations in rainfall, and to potential changes in rainfall due to climate change. Construction of suitable climate change adaptation and mitigation strategies for ensuring the long-term viability of our economy is therefore dependent upon sourcing accurate rainfall projections for the coming decades. Current rainfall projections are considered to be unreliable, partly due to the difficulty in modelling the hydrological cycle, but also due to the range of climate processes influencing Queensland rainfall, such as: tropical cyclone activity, the Interdecadal Pacific Oscillation, the El Niño Southern Oscillation and the Madden-Julian Oscillation.

The QCCCE has engaged the Walker Institute at the University of Reading in a collaborative project to develop an improved understanding of the key processes and phenomena that influence Queensland rainfall on a range of timescales from days to decades. The Walker Institute is an acknowledged world-leader in modelling climate and its impacts, and the QCCCE is providing \$510 000 funding to enable staff at the Walker Institute to investigate these issues on the QCCCE's behalf. The collaboration was initiated by the former Queensland Premier, Peter Beattie, and is expected to deliver improved climate projections for Queensland, as well as a better understanding of how tropical meteorology can be represented in high resolution global climate models.

The collaboration will study climate simulations across several decades to investigate the representation of decadal-scale climate processes. It will also look at datasets of rainfall observations to analyse the behaviour of Queensland rainfall over the past few decades. The assessment will also use datasets developed through the QCCCE's collaborative project with the UK Met Office Hadley Centre for Climate Prediction and Research.



## ENSO, IPO AND OTHERS: BROAD-SCALE (GLOBAL) CLIMATE PATTERNS THAT INFLUENCE QUEENSLAND'S CLIMATE

Queensland's climate is influenced by broad-scale fluctuations in global climate, which operate on different time-scales ranging from months to decades. Whilst we can identify these different patterns (or modes), it is important to remember that the climate system is just one system, so all of these patterns interact and modify one another. Nonetheless, identifying different modes of climate variability helps scientists describe and tease out the dominant climate processes affecting Queensland.

The continuing upward trend in greenhouse gases and resultant trends in climate (e.g. an upward trend in temperature) overlies these shorter-term fluctuations in global climate. These natural short-term climate fluctuations account for the fact that "global warming" does not appear to be continuous. Global temperatures do not necessarily increase year upon year, neither do they increase evenly across the globe. In some places, they may even fall for a period of years due to local influences. However, the overall and continuing trend, both globally and locally, is towards rising temperatures. A case study where the impact of climate change was dampened by natural climate cycles is given on page 25. Some of the broad-scale fluctuations in global climate affecting Queensland are described below.

*The El Niño Southern Oscillation (ENSO)* is an interaction between the ocean and atmosphere primarily in the Pacific Ocean region, which influences global climate and rainfall. Globally, ENSO is the most prominent known source of inter-annual climate variability and its effects are particularly strong in Queensland. El Niño (and its opposite phase, La Niña) is the oceanic component of ENSO, commonly measured by changes in sea surface temperature (SST). The Southern Oscillation (measured by the Southern Oscillation Index or SOI) is the atmospheric component of ENSO. The El Niño phase, lasting up to 18 months, tends to bring dry conditions to eastern Australia whereas La Niña events, of similar duration, tend to bring wet weather. Whilst there can be several years between El Niño and/or La Niña events this is not always the case. El Niño events have occurred "back-to-back", as happened for instance from 1991/92 to 1994/95 leading to protracted drought in Queensland. Likewise, La Niña events can occur back-to-back, for example from 1973/74 through to 1975/76 leading to very wet conditions in Queensland and major flooding. There is certainly no strict pattern to these events so we need to monitor key indicators closely from year to year.

There is concern that climate change may be leading to more frequent El Niño events as observed since the late 1970s, contributing to a down-trend in rainfall in eastern Queensland. The degree to which climate change has influenced this trend as well as other sources of natural variability such as the Inter-decadal Pacific Oscillation (described below) remains a question for further research.

*The Interdecadal Pacific Oscillation (IPO)*, similar to El Niño, is a change in climate related to sea surface temperatures (SSTs). However IPO events tend to last for several years or even several decades. The IPO strongly modulates year-to-year ENSO variability and its effect on Queensland's climate. The wettest periods in Queensland tend to be associated with La Niña events that occur during a "cool" phase of the IPO. On the other hand, when La Niña events occur during a "warm" phase of the IPO, they are less likely to bring wet conditions. Furthermore, "back-to-back" La Niña events (as during the 1970s) tend to occur during a "cool" phase of the IPO and back-to-back El Niño events during a "warm" phase. The IPO has been in a "warm" phase since the mid-1970s, perhaps contributing to the observed increased frequency of El Niño events and the associated down-trend in rainfall. Sea-surface temperatures are currently in a distinct "cool" pattern but it remains to be seen whether this pattern will persist leading to a "cool" phase of the IPO.

*The Southern Annular Mode (SAM)* is a variation in the atmosphere of the high latitudes in the southern hemisphere. The Antarctic Oscillation Index (AOI) is used to monitor SAM (as the SOI monitors ENSO). This index is defined as the difference of zonal (north-south) mean sea level (atmospheric) pressure between 40°S and 65°S. The link between the Southern Annular Mode and Australian rainfall is strongest in southern states but its relationship to the latitude of the Subtropical Ridge (LSTR, see page 24) suggests that it may also have some effect on Queensland's climate.

*The Madden-Julian Oscillation (MJO)* is a planetary-scale climate mode also known as the 40-day wave (although there may be any time between 30 to 60 days between MJO events). The MJO signal is strongest over the tropics but its influence extends to temperate regions. The MJO drives the wet spells in the Australian monsoon that occur about 40 days apart. There is strong year-to-year (interannual) variability in the MJO with this variability being partly linked to ENSO fluctuations.

# How does the Latitude of the Subtropical Ridge (LSTR) impact on Queensland's climate?

*The Subtropical Ridge (STR) is a large belt of high pressure situated around 30°S in the Southern Hemisphere. Variations in the latitude of the STR impact on Queensland's rainfall. A project was conducted to better understand the nature of this variation, its relationship to other climate patterns and its climatic impact. A technique was found for incorporating two dominant influences on Australian rainfall (ENSO and STR) into one season forecasting system and thereby improve seasonal forecasting. Important relationships were also found between LSTR and various climate phenomena.*

While the El Niño Southern Oscillation (ENSO) has received a great deal of attention due to its influence on Queensland's climate, it is important to identify and quantify the effects of other climatic phenomena on rainfall, and consequently on Australia's agriculture, economy and ecology. This will bring greater understanding of climate systems and will also improve systems for managing natural resources and agronomy that use climate information.

The Latitude of the Subtropical Ridge (LSTR) is one such phenomenon needing research to help better understand the complexities of climate variability. The Subtropical Ridge (STR) is a large belt of high pressure situated around 30°S in the Southern Hemisphere. The latitude of the Ridge varies from season to season and from year to year. Its position (north or south) has a strong influence on rainfall along Australia's east coast.

A project carried out by QCCCE scientists aimed to:

- 1) Assess the relationships between the Australian STR, rainfall variability and high-latitude climate patterns, and to assess any trends in the variability of the STR. (High latitudes begin at about 60°S and extend to the south pole. The Australian continent lies between 10°S and 45°S).

- 2) Combine subcontinent-scale (such as STR) and global-scale (such as ENSO) phenomena to improve the skill of seasonal climate forecasts in Australia.
- 3) Create a database of the latest and historical LSTR values to assist with monitoring and forecasting.

The monthly variation (anomaly) of the latitude of the subtropical ridge over eastern Australia (LTSR) is a major regulator of Australia's climate. It was found that LTSR has a significant relationship with seasonal rainfall in Australia. A robust technique was found for incorporating two dominant influences on Australian rainfall (ENSO and STR) into one season forecasting system and thereby improve seasonal forecasting.

Other significant relationships were found between the latitude of the STR and patterns influencing Queensland's climate. The Southern Hemisphere Hadley Cell and meridional circulation changes are associated with changes in LTSR. The Hadley Cell is an atmospheric circulation that carries heat and moisture from the tropics to the northern and southern mid-latitudes.

It was shown that LTSR has a significant relationship with seasonal rainfall in Australia. The study also showed that LTSR was related to a more broadscale climate pattern, the Southern Annular Mode (SAM) and the associated Antarctic Oscillation

Index (AOI) which, in turn, is related to Australian seasonal rainfall (see the box on page 23 for explanations of AOI and SAM).

Longer-term latitudinal shifts in LSTR were also identified, as were possible solar drivers and relationships with other stratospheric phenomena.

As a result of this research, awareness has increased in the climate community (both in Australia and internationally) of the behaviour and role of the STR, the contribution of LSTR to climate variability in Queensland and Australia, and the benefits of using LSTR to improve seasonal forecasting systems. Furthermore, knowledge of the behaviour of the STR improves our understanding of climate change in Australia and provides an additional tool with which to assess impacts of climate change.

Through this research, networks with the Hadley Centre and the University of Southern Queensland have been strengthened.

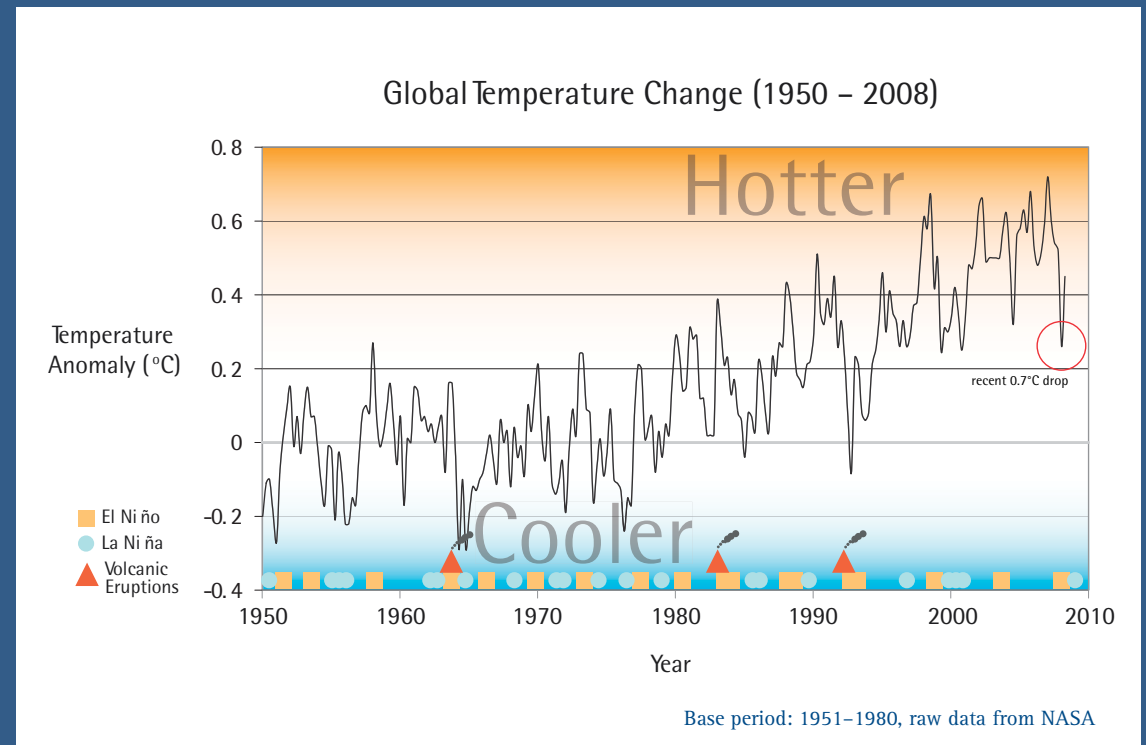


*An electrical storm batters the Gold Coast*

## WHAT HAPPENED TO GLOBAL WARMING?

While 2006/2007 was the second hottest year on record, in 2007/2008 global temperatures plunged by 0.7 degree centigrade sparking a flurry of activity from climate change sceptics. For example on April 23rd 2008, *The Australian* published an article by an Australian geophysicist and astronautical engineer claiming that a lack of sunspot activity had probably caused the dramatic drop in temperature and that we were in all likelihood heading for an ice age.

Climate scientists, however, have a clear understanding of what happened to bring about this rapid temperature drop. Between 2007 and 2008 the El Niño Southern Oscillation (ENSO) made a rapid transition from an exceptionally warm El Niño phase to an exceptionally cool La Niña phase. These transitions are part of the normal climate variability of the planet with similar shifts in phase having occurred at least seven times during the last century. As the graph below indicates, the background trend is still one of dramatic warming.



# Global and regional drivers of climate change and variability in Queensland

*A mechanism has been found that may allow the effects of climate oscillations with timescales of 10–65 years to be teased out from the signal of human-induced climate change, allowing a more accurate forecast of climate change as well as the prediction of severe droughts in Australia.*

Natural variability brings extremes in rainfall, temperature and other climate factors, stressing people and resources at both short time scales (seasonal, interannual) and longer (10 year or decadal timescales and multi-decadal timescales). Climate change is also increasing the frequency of extreme events such as droughts and floods. With our understanding of the El Niño Southern Oscillation phenomenon, we have some insight into natural variability at relatively short timescales. It would be very useful to be able to understand and quantify decadal and multi-decadal natural variability and have sufficient notice of oncoming climate responses to take timely adaptive measures. It would also be useful to be able to tease out these longer cycles from the effects of climate change, to make the climate change signal stand out more clearly from long timescale natural effects which may bring periods of less intense warming, or even cooling, when in the phase that opposes the general global warming trend.

It has been a long-held belief by some scientists that fluctuations in the moon's orbit around the earth may be responsible, through its influence on tides, for long-term fluctuations in the earth's climate. Because such orbital variations can be predicted well into the future, any link between the moon's orbit and the earth's climate offers the hope of very long-range climate forecasts. One QCCCE scientist has developed equations to describe historical fluctuations in the moon's orbit and to predict its future fluctuations. Furthermore QCCCE studies show some correspondence between these equations and fluctuations in

important climate phenomena such as the Interdecadal Pacific Oscillation (IPO) which influence Queensland's rainfall. Some correspondence has also been shown between lunar-tidal cycles and major droughts in Australia over the last 100 years and over the last 300 years in the USA which, in turn, have been previously linked to fluctuations in the broad-scale processes such as the IPO.

A question remains as to whether the observed correspondence between fluctuations in the moon's orbit (and in turn tides) and fluctuations in broad-scale climate phenomenon such as the IPO (and in turn droughts in Australia and the USA) has a physical basis. Certainly processes leading to fluctuations in the IPO are currently not well understood. If there is a physical basis for a relationship between the moon's orbit and broad-scale climate processes such as the IPO, this will prove very useful indeed in terms of understanding historical fluctuations in the earth's climate, providing rainfall forecasts well into the future and, in turn, for modifying climate change projections.

However, it is possible that the moon's orbital fluctuations vary independently from, but at a similar frequency to, broad-scale climate processes such as the IPO, and that overlap in their fluctuations during recent centuries is coincidental. Nonetheless a forecast of the scale and timing of future Australian rainfall and extended drought events has been constructed by the QCCCE on this basis and so far has corresponded well with recent drought conditions across Australia.



## Assessing the value of trees in sustainable grazing systems

*In collaboration with the grazing community, QCCCE researchers investigated how retaining strips of trees (woody regrowth) within pastures affects the production and sustainability of grazing landscapes in southern Queensland. This, and follow-up research, will allow graziers to optimise their mix of grazing and growing trees for carbon storage and other potential benefits. Queensland will benefit from having a more resilient grazing industry and more resilient ecosystems, as graziers are able to manage their land more sustainably in the face of climate change.*

There are about 60 million hectares of grazed woodland communities in Queensland. Historically, tree clearing has been regarded as an important management tool to improve pasture production, based on the observation that trees compete with grass for soil and moisture. With the cessation of remnant tree clearing following changes to State legislation, managers of these grazed woodland communities are now developing plans to manage woody regrowth.

The retention of trees in strips is an option for managing non-remnant woody vegetation in native and sown pastures in Australia. The trees may benefit livestock production either in terms of improved condition of livestock or increased long-term sustainability of the property. Trees may also benefit both graziers and the broader community when managed for their carbon storage value. However, the impact of tree strips on pasture production has not been researched in detail in southern Queensland.

This study aimed to assess the beneficial and competitive effects of trees on surrounding grasslands in southern Queensland and to determine how retaining trees affected

productivity and sustainability. To do this, a preliminary capacity to model impacts of different tree and regrowth regimes on grazing systems was developed.

In this study, the influence of existing tree strips on pasture production was measured intensively on three grazing properties (near Theodore, Mungallala and St George) in southern Queensland during 2004 and 2005. The pasture production measurements indicated that many factors could affect pasture growth across the area between two tree strips. In some cases, the competitive effects of the trees appear to be offset to an extent by the beneficial effects in pasture micro-climate.

The project represents the initial field study in southern Queensland and hence, forms the basis for future studies on this increasingly important topic.

Queensland will benefit from having a more resilient grazing industry, with producers able to adapt their land management regimes to climate change and to national responses to climate change, such as the upcoming carbon trading system. In turn, ecosystems will benefit, as graziers are able to manage their land more sustainably.



# Improving prediction of the northern Australian wet season

*Researchers quantified the relationship between two major climate cycles (ENSO and MJO) to make useful predictions of the onset and duration of the northern Australian wet season.*

Climate variability has important practical, planning and policy implications for the northern Australian grazing industry. Recognising this, the Australian Government (through Land and Water's Managing Climate Variability program) initiated the project Improving Prediction of the Northern Australian Wet Season. Staff from the QCCCE and the then Bureau of Meteorology Research Centre were awarded a contract to develop the wet season forecast, tailored to the needs of northern Australian beef producers.

After consulting producers about what aspects of the wet season they best needed to forecast to assist risk management decision-making, the team developed a forecasting scheme for the onset and duration of the wet.

The project provides predictions of the wet season based on probabilities. These start in May using sea surface temperatures through to July–August when the Southern Oscillation Index (SOI—an indicator of the El Niño Southern Oscillation) is known. Onset, duration and total rainfall amounts can be forecast. Results are available at [www.apsru.gov.au/naws](http://www.apsru.gov.au/naws)

The project thoroughly investigated predicting wet and dry spells within the wet season. Anomalies within the rainfall season are related to the Madden–Julian Oscillation (MJO), a planetary-scale climate cycle that affects rainfall in tropical, sub tropical and temperate regions. In this project, researchers quantified the amount of rain that can be expected with each passage of the MJO, depending on the season. Based on historical rainfall records and the MJO we can also predict when drier conditions will occur.

The team were unable to quantify the relationship well enough to forecast specific wet and dry spells within the wet season to a level that made the predictions useful to graziers. However, the primary effort of the project was to predict the onset and duration of the wet season, as measured by a range of pre-defined thresholds, and this was achieved. It was clearly shown that wet-season onset can be forecast from a series of May–August climate indicators. Another method of data handling produced comparable results for predicting the duration of the wet season.

These forecasts of when the wet season will start, how long it will last and how much rain it will produce can be tailored for any industry in northern Australia affected by weather. For example they could be used to help tourist operators decide when to shut down in spring/summer due to the rains and when they might start up again.



*The stormy onset of the northern Australian wet season is partly determined by the Madden-Julian Oscillation*





# 3 Climate change impacts and applications

assessing and responding to climate change risk across sectors

The QCCCE's climate change impacts and applications team applies climate science in key sectors affected by climate change and variability. The focus is on gaining a practical understanding of climate change impacts, and on developing tools to support stakeholders' adaptation to impacts on their industry or sector. Tools developed under this theme have predictive capability that can be used by primary producers, water supply managers, health service planners and many others, to help make decisions and plan for seasons ahead.

For example, with sufficient advanced knowledge of likely pasture growth in the season ahead, graziers can manage their land more sustainably. Water service managers can plan new infrastructure once they have information about likely future rainfall and how their storages will perform under a range of usage scenarios. With such information, decision-makers are better placed to manage the risks associated with climate change and variability.



*Impacts and applications team:  
 (top to bottom, left row) Yahya Abawi  
 (theme leader), Simon White, David  
 McClymont, Sunil Dutta, Xike Zhang,  
 Simon Vriesema (right row) Greg McKeon,  
 John Carter, Grant Stone, Baisen Zhang,  
 Grant Fraser, David Cobon,  
 Jacqui Balston (not pictured)*

Under this theme, models are developed and used to predict the behaviour of different natural and human systems in the face of climate change. Rather than developing models aimed at understanding climate change *per se*, the models developed in this theme focus on the impacts of climate change and assess options for adapting to those impacts.

The impacts and applications team works on projects in Australia and also in neighbouring countries in the Asia-Pacific region. Much of the work is funded from external sources such as Meat and Livestock Australia (MLA) and the Australian Centre for International Agricultural Research (ACIAR). This external funding brings a range of benefits to Queensland. These include:

- broadening the base of support for climate change research to be applied within the state
- building the capacity of Queensland's climate scientists to apply their work to practical situations involving a range of stakeholders
- developing tools and techniques that can be used in Queensland as well as overseas.

In the case of projects being carried out in other Asia-Pacific countries, the work of the impacts and applications team builds our reputation for cooperative engagement with neighbours in the region, thereby contributing to regional stability in the face of challenges presented by climate change.

This area of the QCCCE's activities has recently been renamed Climate Change Impacts, Adaptation and Mitigation. The change of name brings with it a change in focus as the Centre builds its capacity to provide advice and support across a range of sectors to meet its responsibilities in whole-of-government service delivery.

# Assessing the effects of climate change on Queensland's grazing lands and grassland ecosystems

*The impacts of climate change on Queensland's grazing lands are being assessed with the QCCCE's pasture growth simulation model GRASP. Both the productive capacity of these lands and impacts on their natural ecosystems can be modelled. The output of the GRASP model is being used to support a major extension activity with graziers, providing new tools to help the managers of 85 per cent of Queensland's land surface maintain sustainable production systems in the face of climate change.*

Eighty-five per cent of the land surface of Queensland is managed under grazing. For this reason, Queensland's grazing industry is inextricably linked to the conservation of ecosystems and the vital resources they supply – resources such as drinkable water and productive soils that underpin human survival. Grazing systems are also important to the state's economy, bringing in a high proportion of our primary production income and impacting other sectors such as water supply and tourism. It is important, for these reasons, that our grazing lands are managed sustainably with a view to conserving biodiversity, protecting waterways and preventing run off, erosion and loss of soil, as well as supporting the grazing industry, communities and livelihoods.

The key to sustainable management of ecosystems dominated by grazing (whether by cattle, sheep or native grass eaters such as kangaroos) is to maintain a healthy cover of grasses and other vegetation. This in turn depends on the climate, hence the need to manage grazing systems for climate variability and climate change.

Over the last 30 years, Queensland Government pasture scientists have developed the simulation model GRASP (GRASs Production) which calculates soil moisture, pasture growth, animal production and risks of resource degradation. The model has been developed using data from most of Australia's grasslands and rangelands.

GRASP has been used to calculate the likely effects of climate change on the production of native grasslands and also on problems such as erosion and land degradation. Hence, the GRASP model is an important tool allowing rangeland scientists to estimate the impact of climate change, not only on the grazing industry but also on the natural environment.

In 2004, Meat and Livestock Australia (MLA) commissioned the QCCCE (then Centre for Integrated Natural Resource Science) to develop new software and train pasture scientists in its use. The four-year project, supported by MLA, is coming to an end.

The output of the GRASP model is being used to support a major extension activity with graziers, namely the MLA funded Grazing Land Management Education Package led by the Queensland Department of Primary Industries and Fisheries. The next component of development and use of the model concentrates on assessing the impact of climate change and developing adaptation strategies.

Cooperation between scientists and graziers in the development of climate change adaptation strategies for managing Queensland's vast grazing lands, ensures that these strategies will be effective on the ground, with benefits to the grazing industry and the natural environment.



CLIMATE CHANGE AND NATURAL RESOURCE  
MANAGEMENT IN AUSTRALIA'S GRAZING LANDS –  
LAND & WATER AUSTRALIA FELLOWSHIP

Land & Water Australia (LWA) is a major external funding agency which has supported the work of QCCCE researchers over many years. It invests in scientific research in natural resource management, climate change impacts on agricultural industries and the management of climate variability. LWA has recently developed a program of Fellowships to support scientists in a concentrated effort to address emerging issues over a period of six months. Greg McKeon was awarded an LWA Fellowship in December 2006 with the Fellowship commencing in July 2008.

The purpose of the prestigious Land & Water Australia Fellowship is to enable the Fellow to make a concentrated effort on the agreed topic namely *Climate change and natural resource management in Australia's grazing lands*.

The project will review and document the forces of changing climate and resource management in Australia's grazing lands. The impact of expected climate changes with particular reference to natural resource management issues in Australia's grazing lands will be modelled, simulated and documented. The issues to be examined are livestock carrying capacity, ground and vegetation cover and soil-water balance.

A further aim is to engage selected graziers, industry bodies and resource management agencies. Presentations, feedback and interviews will encourage industry to collaborate in finding ways to reduce emerging climate change impacts and help natural resources to recover.



# Reducing uncertainty in the assessment of the Australian spanner crab fishery

*Research on fluctuations in catch-per-unit-effort in the Queensland spanner crab industry were found to be related to climate factors, including the El Niño Southern Oscillation (ENSO). Catch can be predicted from indicators of ENSO. These preliminary findings can be developed into systems to help the spanner crab industry prepare for and adapt to climate change.*

The Australian spanner crab fishery extends from northern New South Wales to the Gladstone area of central Queensland in shelf waters. The fishery is valued at around \$12 million per year, with Queensland accounting for 85 per cent, and NSW 15 per cent, of the annual catch of approximately 2000 tonnes, most of which is exported live to Asia.

An initial assessment of the sensitivity of spanner crabs to climate variability was carried out in 2001. That study concluded that spanner crab catch-per-unit-effort (CPUE) was correlated with local off-shore climate and also global-scale climate indices. However, these results were interpreted with caution because the sample covered only a relatively brief (13 year) time-span, from 1988 to 2000.

The current project, funded by the Fisheries Research and Development Corporation (FRDC), is the result of attempts by the Spanner Crab Stock Assessment Group (SAG) to develop a robust, reliable and scientifically sound method for monitoring and assessing the status of spanner crabs in Queensland, and represents a logical step in the quest for a better understanding of the population dynamics of this important crab resource.

The project aimed to better understand the reason for fluctuations in commercial catch-per-unit-effort and to improve procedures for monitoring and measuring the spanner crab resource. The climate component is one of many assessment components of the project.

Analysis of the updated data from this study produced results consistent with the earlier study, although the statistical significance varies. Specifically, catch rate (catch-per-unit-effort or CPUE) is influenced by the strength of the eastward component of the ocean current, and salinity. These two climate variables and CPUE are also related to the autumn value of indicators of the ENSO. This means that the annual CPUE can be predicted by the end of autumn.

This study provides the basis for a more thorough climate impact analysis, which will be able to model the effects of climate change on this lucrative Queensland fishery.

*The spanner crab – basis of a lucrative Queensland fishery*



# Seasonal climate forecasting for better irrigation management in Lombok

*Development of climate-based decision-support tools for optimising cropping and irrigation in Lombok, Indonesia has increased the capacity of Lombok rice growers to manage the impacts of climate variability. The technologies developed through this Indonesian experience have already brought benefits to Queensland's cotton growers and other primary producers.*

About 25 per cent of the arable land in Indonesia is under rice irrigation. Crop production (rice and other crops), however, can fluctuate markedly from season to season due to high climate variability associated with the El Niño Southern Oscillation (ENSO) phenomenon. More than 90 per cent of drought in Indonesia has occurred in El Niño years. Analysis of stream flow and cropping data suggests that using ENSO-based seasonal climate forecasts (SCF) ahead of the growing season can improve productivity of irrigated rice in favourable seasons and reduce the risk of crop loss in dry years through tactical adjustment of crops and water allocation.

*Tilling rice fields in Lombok*



This project used QCCCE expertise in climate research to translate seasonal climate predictions into decisions for better cropping and irrigation, and to develop local capacity to manage the impacts of climate variability and change in Lombok, Indonesia. These outcomes were achieved by:

- developing decision-support systems and tools for optimising choice of crop, crop area and irrigation water allocation (decision support tools use the power of computing to help weigh up complex factors involved in decision-making)
- using simulation modelling and scenario analysis to show the benefits of seasonal climate forecasts in irrigation water allocation and cropping decisions
- promoting planning based on seasonal climate forecasts among irrigators, government officials and community leaders
- building local capacity to adapt and use decision-support tools
- conducting a water-balance study of crop management systems
- assessing the impact of water harvesting on irrigation decisions
- analysing the economic impact of water harvesting at the farm and irrigation command levels.



Studying complex agricultural and irrigation systems in Indonesia (a country affected by similar climate phenomena to Queensland) improves our understanding of the impact of climate variability on agricultural systems and enhances the QCCCE capability to model climate variability and change. Several “state of the art” climate software products (*FlowCast*, *CropOptimiser* (see page 42) and *HowLeaky?*) have been further developed through this project. These products have already been used to support Queensland Government policy development on issues such as drought, exceptional circumstances, inflow predictions for the dams of south-east Queensland and crop outlooks for the cotton industry. The project has also enhanced the capacity of QCCCE staff to develop guidelines and deliver training programs in the use of decision-support tools to assist primary producers to respond to climate change and climate variability.

*Hand threshing rice in Lombok*

## CASE STUDY: USING WATER BALANCE MODELLING SOFTWARE TO MAKE DECISIONS ABOUT WATER STORAGE OPTIONS

This case study from Lombok illustrates the use of the software product *HowLeaky?* to test the benefits of water harvesting, both to farmers and to water management planners.

The southern Lombok climate gives farmers three potential cropping seasons. The first is the wet (monsoon) season when there is usually adequate rainfall to produce a crop of rice (the local staple) without irrigation. In the later two seasons rainfall is typically inadequate and must be supplemented from catchment scale irrigation infrastructure (dams) in order to grow a more reliable crop. Crops grown include rice, tomatoes, melons and chillies.

Farmers may have the ability to capture any excess rainfall from the wet season in small on-farm storages called *embungs* from which they hand irrigate small areas of crops in later seasons.

This study used the software *HowLeaky?* to simulate crop growth and components of water balance for a number of crops based on climate data, farming systems and soil types.

Research questions were:

How much run off is available from the first cropping season to use in the second and third seasons (run off is rainfall that does not soak into the ground and could therefore be harvested and stored for the next season)? What is the trade-off between allocating land to larger *embungs* to capture run off in the first season season for irrigation in the second season and losing some cropping land to the *embungs*? And finally, to what extent can catchment scale irrigation demand (from dams) be replaced by this method of farm-scale water management?

*Howleaky?* enabled an assessment of the likely run off volumes for a range of soil types, farming systems and the range of crops commonly grown. Storage size and run off capture (pumping capacity) were assessed as well as the trade-off involved in allocating land to *embungs* instead of crops. While collecting and storing run off can bring benefits to individual farmers, the reliability of this supply varied due to variability between seasons. Total volumes able to be harvested were found to be insufficient to produce any reduction in catchment scale demand.



*Harvesting rice in Lombok*

# Applying climate predictions to adapt to climate variability and change in Pacific Island countries

*Working in Pacific Island countries (through AusAID) QCCCE researchers have developed climate prediction software and implemented risk management and climate adaptation projects in water management, health, renewable energy and agriculture. This has built the QCCCE's capacity in climate adaptation science and fostered strategic alliances with the National Climate Centre and other national and international organisations.*

Climate variability has important practical, planning and policy implications for both Australia and the Pacific Island countries (PIC). Recognising this, the Australian Government (through AusAID) initiated a project *Enhanced application of climate predictions in Pacific Island Countries* in August 2003. The QCCCE was contracted to further develop the climate prediction software SCOPIC (Seasonal Climate Outlooks for Pacific Island Countries) and to conduct training and pilot projects in climate risk management in several of the Pacific Island countries.

SCOPIC was developed to make the Australian Bureau of Meteorology's operational forecast system accessible to Pacific

Island meteorological services. The software produces seasonal rainfall and temperature predictions based on probabilities. This is achieved through statistical analysis of historical data and Sea Surface Temperature anomalies (SSTa) in the Pacific and Indian Oceans. SCOPIC also provides an assessment of forecasting "skill", which is a measure of how reliable the predictions can be expected to be for different seasons and locations. It has a highly graphical user interface and gives flexible user-friendly outputs.

The software is currently being translated into indigenous languages for each of the 10 participating Pacific Island countries. Local meteorology staff in each participating country

*This panorama clearly illustrates why climate change is such an immediate threat in low-lying Tuvalu, one of the Pacific Island countries involved in the SCOPIC project*



have attended multiple training workshops in the use of the software to produce seasonal outlooks.

In the second phase of the project, the QCCCE has been invited to further develop the SCOPIC software through the addition of drought analysis capabilities and enhanced verification tools.

SCOPIC drought-watch will enable Pacific Island weather services to predict and plan for three types of drought, based on the residence times of its three main water sources. (Residence time is the time taken for a storage to go from full to empty based on average demand). Typical residence times for water storages in the PICs are four to six months for rainwater tanks, six to twelve months for wells and five to ten years for shallow fresh groundwater “lenses”. (These freshwater lenses float on top of saltwater beneath a coral island’s porous landmass, providing a reliable water source but one that must be used judiciously to avoid saltwater intrusion).

SCOPIC software is now used for issuing seasonal climate forecasts in all participating Pacific Island countries. The QCCCE is also implementing and leading pilot projects in risk management and climate adaptation in each of the Pacific Island countries, applying seasonal climate forecasting in water management, agriculture, health and renewable energy (see following pages for examples of pilot projects in some of these key sectors).

The research and development undertaken in the SCOPIC project applies directly to the development of climate science and climate impacts and applications in Queensland. It is an important part of building capacity within QCCCE in the assessment of climate impacts on health, agriculture and water management. The tools developed have also been applied locally in the areas of water management and planning and drought assessment for SEQ Water, SunWater and Gold Coast Water dams. The project has fostered a strong strategic alliance with national and international organisations, including the National Climate Centre.

*Building drought analysis capacity in the Solomon Islands*



# The use of seasonal climatic forecasts for managing water supply

*The SCOPIC (Seasonal Climate Outlook for Pacific Island Countries) software based on the Australian Bureau of Meteorology's operational forecast system and developed for use in Pacific Island countries (PIC) has been piloted as a potential tool to assist with climate change adaptation in a number of key sectors. The outcomes of these pilot studies can be applied to climate change adaptation in Queensland. In this study, the software has been trialled to improve water resource management in Fiji.*

Climate forecasting software and decision support tools developed for the PICs, in collaboration with the Australian Bureau of Meteorology, have been piloted in a number of the *ClimateSmart Adaptation 2007–2012* priority sectors. The software applications developed in these PIC pilot projects are applicable to the Queensland situation and in some cases have already been used here.

A water supply management project in Fiji is looking at managing the water demand from Vaturu Dam, the main water supply dam for Nadi and other towns in the relatively dry north-west of the main island of Viti Levu.

Just as in Queensland, there is a strong relationship between rainfall in Fiji and the Southern Oscillation Index (SOI). The island of Viti Levu experiences dry weather from May to October and during this season, droughts are common in the drier north-west sector of the island, especially during an El Niño event. The reliability of fresh water supply during extended dry periods is of major concern in the dry zone of Viti Levu.

Since construction, Vaturu Dam has been the main water supply source for the Nadi–Lautoka region, however with high population growth and expansion of the tourism industry there is concern as to whether the dam will be able to supply these areas without water rationing during extended dry periods, especially under the influence of climate change.

The SCOPIC software package was developed by the QCCCE to enable Pacific Island national meteorological services to provide seasonal climate outlooks for climate sensitive industries. This software is being used to test demand management scenarios for the Vaturu Dam both under current rainfall conditions and under a range of climate change assumptions. One aim was to determine whether a proposal to raise the height of the dam wall could be delayed if the water supply was better managed.

*The Vaturu Dam is the main water supply for Nadi, Fiji*



## **CROPOPTIMISER: A CLIMATE-BASED SOFTWARE PRODUCT TO SUPPORT DECISIONS ABOUT CROP CHOICE AND MIX**

*CropOptimiser* is a climate-based decision support tool for optimising regional crop choices and patterns for different seasonal, climatic, agronomic and social conditions. It was developed to help improve agricultural decision making in Lombok, Indonesia but can be used in any situation where climate variability requires decisions to be made ahead of the growing season as to what crops to plant, how much to plant and when to plant.

Agricultural production in Lombok is predominantly (and socially) rice-based and is highly influenced by climate variability, in part, associated with the ENSO phenomenon (see page 23). Water availability is one of the key issues influencing decisions about crop choice, so the ability to forecast availability for the coming season is highly beneficial to farmers. *CropOptimiser* is designed as a simple to use, stand-alone software product for use by regional managers and advisors of both irrigated and rainfed agricultural systems.

At the regional level, strategies can geographically optimise cropping choice and cropping area, based on the likelihood of available water from climate forecasts to maximise yield and protect market value. This ensures crop survival and avoids overproduction of particular crop varieties, which could affect the market price and demand.

*CropOptimiser* simplifies the process of weighing economic, climatic and social factors to achieve the optimum regional and farm-based crop choice for a coming season.



# Predicting the onset and severity of malaria epidemics in the Solomon Islands

*Software products SCOPIC and FlowCast can be used to model the onset of malaria epidemics in Honiara, based on rainfall between January and March, giving health authorities enough lead time to take preventative action. As the range of the malaria-causing mosquito is predicted to move south into Queensland due to climate change, this ability to use QCCCE-developed software to predict and help prevent malaria will likely be of direct benefit to Queenslanders in the future.*

Honiara, the capital of the Solomon Islands, has also been labelled “the malaria capital of the world” with world’s highest incidence rates of *Plasmodium falciparum* malaria (the most dangerous species) as well as high incidence rates of *P. vivax*. Malaria is a climate dependent disease. Certain temperature and humidity ranges are needed by both the malaria vector (the *Anopheles* mosquito) and the parasite itself (the different species of Plasmodium which infect and destroy red blood cells in the human host). The critical temperature range is 25–29°C. High humidity (around 80 per cent) is also required as are particular rainfall conditions – enough rain in a given period to create pools of stagnant water but not enough for run off, which will flush the mosquito larvae away.

QCCCE scientists have analysed malaria data for the period from 1975 to 2006, supplied by the Solomon Islands Medical Research Institute. During the period 1970 to 1972 while the Solomons were still under the British government and again in 1975 to 1976, mosquito eradication was carried out using DDT. For a time, no significant eradication took place and the incidence of malaria in the Solomons generally increased until 1992–93 when another eradication program was instituted. During the total period covered by the supplied data, there have been two major spikes in malaria incidence, with each one corresponding to consecutive years of epidemics, defined as years when the malaria incidence in the population reached into the upper quartile (the upper quarter of the range of all incidences).

A number of statistical techniques were used to tease out the effect of climate from that of non-climate factors (namely mosquito eradication programs) in causing high rates of malarial infection in the Honiara population. With the effects of eradication factored out, it is possible to see which years would have produced malaria epidemics related purely to climate.

The climate-related incidence of malaria can be modelled using SCOPIC and *FlowCast* software. This allows the incidence to be predicted from the rainfall pattern experienced between January and March in any year. The aim is to give health authorities sufficient lead-time to prepare for, and to some extent mitigate, a potential epidemic, for example by targeting mosquito-spraying campaigns to those areas most at risk.

The ability to model climate-influenced diseases, including malaria, is valuable to Queensland health providers and the planners of health services as well as to the state’s population, especially in view of the fact that malaria is one of the diseases predicted to increase in Queensland as the range of the *Anopheles* mosquito moves southwards under the influence of climate change.

*Housing that cannot be screened against mosquitoes increases exposure to malaria in the Solomon Islands*





## Climate impacts on aquaculture: developing methods and industry awareness

*A study of the impacts of temperature on barramundi in aquaculture ponds developed methods and built links with industry groups. Both will be useful in managing the impacts of climate change on the aquaculture industry.*

The barramundi farming industry of Queensland is growing rapidly with aquaculture production of barramundi already exceeding the wild fishery. In 2005–06 production reached 1745 tonnes (\$14 million). Barramundi growth is marginal at water temperatures less than 22°C and severely curtailed at less than 20°C while prolonged temperatures below 21°C result in reduced feeding. Low temperatures also increase susceptibility to skin infections in the fish. These diseases can inflict stock mortalities of 40 per cent to 100 per cent in grow-out cages or ponds.

The project provided an opportunity for the further improvement of both stock management practices and animal welfare and is seen as a precursor to other uses of seasonal forecasting of temperature threshold analysis, which may benefit the aquaculture industry Australia-wide.

The study assessed the potential for using seasonal climate forecasting to predict winter severity and over-wintering risks to the barramundi farming industry in order to improve stock management practices and animal welfare. Tools developed included a model describing the relationship between aquaculture pond water temperatures and air temperatures and predicting the likelihood of critical minimum temperatures. The project investigated the relationship between low temperature and disease outbreaks. Another important facet was technology transfer to industry through participatory research and publications.

Farmers' awareness of the links between fish disease and climate was raised as was their understanding of the benefits of having a daily farm record-keeping system for monitoring mortalities, disease outbreaks and feeding frequency.

Methods developed in this project are more broadly applicable to understanding the impacts of climate and climate change on the aquaculture industry. Through this project, the QCCCE has also established important links with aquaculture industry bodies including the Australian Barramundi Farmers Association (ABFA) and Australian Prawn Farmers Association (APFA).

## CLIMATE CHANGE IMPACTS ON LIVESTOCK CARRYING CAPACITY ACROSS AUSTRALIA: INPUT TO GARNAUT REVIEW

The Queensland Climate Change Centre of Excellence (QCCCE) contributed to the Garnaut Review by undertaking research into the livestock carrying capacity of Australia under a range of climate change scenarios. The QCCCE is recognised for its research into the relationship between climate and the grazing industry.

In terms of area of land use, grazing is the major activity in Australia. The objective of this project was to calculate the impact of climate change on the livestock (sheep and cattle) component of the Australian economy. Several climate change scenarios were evaluated by the Garnaut Climate Change Review to allow the impact to be assessed at a Statistical Division level (58 in Australia) and also at a state and territory level (eight in Australia). The QCCCE's initial involvement was through a sub-contract with CSIRO Sustainable Ecosystems.

The underpinning scientific research component of the project was to find the best way to calculate the impact of climate change on livestock production. The effects of changes in rainfall, temperature and carbon dioxide on the gross dollar value of production in this agricultural sector of the national economy were examined. The starting point for the QCCCE was the existing "116 point" model which calculates native pasture growth at two locations in each of the 58 Statistical Divisions in Australia. A major issue that emerged during the project was the treatment of the 11 Statistical Divisions that constitute the arid zone of Australia. This zone has over 70 per cent of the land area and 28 per cent of the sheep and cattle numbers (expressed as animal equivalents) and was found to be very sensitive to climate changes. Here, changes in rainfall are greatly amplified in terms of their impact on livestock carrying capacity. As a consequence, an approach was developed to

simulate 80 additional locations within the arid zone to better estimate the impact of climate change in this zone on Australia livestock production as a whole.

This work provided an approach to rapidly estimate climate change impacts on livestock carrying capacity based on any given climate change projection. The benefit to Queensland of the research carried out under this project is that grazing, and climate change impacts on grazing, will be considered in the review in a way that will help to achieve the best possible policy outcomes for this important statewide industry.



*Professor Ross Garnaut delivers the findings of his climate change review*

# Adaptation to climate change in regional natural resource management

*Climate change projections were constructed for each of four targeted regions of Queensland to investigate possible impacts of climate change on grazing production and the flow of water through the environment. In each region vulnerable components of natural resource systems were examined under various climate change scenarios. Understanding how these vulnerable natural resources performed under the stress of (modelled) climate change will help Queensland's natural resource managers to prepare for the range of likely future climates.*



*Queensland's desert channels*



*Steers grazing in the Nogoa River catchment*

Climate change and increasing levels of atmospheric carbon dioxide may have significant impacts on the productivity and management of Queensland's natural resources and grazing systems, especially in climatically marginal areas. This project aimed to identify and quantify the potential impacts through selected case studies. The research results will help natural resource management (NRM) and grazing industry bodies in regional Queensland with strategic adaptation to climate change. The five case studies were:

- 1) impact of climate change on production and natural resources management indicators in a grazing/beef production system in the Fitzroy Basin
- 2) impacts of climate change and land use on the amount of sediment in the rivers of Nogoa sub-catchment of Fitzroy Basin. This sediment may impact on downstream environments such as the Great Barrier Reef
- 3) impact of climate change on flooding flows and inundation areas in Queensland's desert channels. Changes in these may significantly impact on agricultural production and biodiversity conservation in the region
- 4) impact of climate change on streamflows and irrigation water availability in Queensland's Murray-Darling Basin
- 5) impact of climate change on flows to water storage and water supply in south-east Queensland's western catchments area.

The research approach in these case studies included constructing climate change projections for each targeted region using seven to nine global climate models which were forced by different emission scenarios and levels of climate sensitivity. These projections were used, in turn, to drive models of grass/beef production and the catchment sediment and flows of water through the environment. The purpose of modelling these onground factors of interest to natural resource managers is to quantify climate change impacts on each system studied. The most vulnerable components of each region's natural resource systems were identified and case studies designed to investigate climate change impacts on these components.

The results from the case studies will be used to help develop tools and processes that enable regional NRM organisations to include climate change into their planning, priority setting and action. So far four papers have been published and presented in the 17th International MODSIM Conference in 2007 and the International Grassland and Rangeland Congress 2008.

Benefits to Queensland include knowledge and tools that can be used in adapting to future climate change. Areas where adaptation is particularly important are in biodiversity conservation, water management and agriculture (where water is an essential resource). The findings of the five cases studies are given in the box on page 47.

## ADAPTATION TO CLIMATE CHANGE IN REGIONAL NRM – WHAT WAS FOUND?

Case studies were carried out to investigate impacts of climate change on key natural resources in four areas of Queensland. The project involved projections of future climates as well as modelling climate impacts on agricultural production, flooding inundation, catchment sediments and river flows in the environment. A fuller description of the research and its overall significance for Queensland is given on page 46. Some findings of the case studies are summarised here.

A number of global climate models were run with different emission scenarios and levels of climate sensitivity. Dry, average and wet climate change outcomes were examined reflecting the fact that the mean annual temperature will be warming, evaporation will increase and rainfall is more likely to reduce. Here, some aspects of projected climates for 2030 are compared with the climates of 1990 for each case study.

### *Climate change in the Fitzroy basin (Nogoa subcatchment)*

- By 2030, the mean temperature will increase by 0.9 to 1.4°C, annual rainfall will change in the range from 9 per cent decrease (or -9 per cent) to 2 per cent increase. Evaporation will increase by 2 per cent to 10 per cent in the region.
- A dry scenario will mean reduced runoff, reducing the risk of erosion, but also reducing the amount of water flowing into watercourses and dams.
- A dry scenario will increase the variability of annual pasture growth. Higher variability will make it more difficult to manage stocking rate sustainably.
- A dry scenario will cause a reduction in grass cover of about 10 per cent by 2030.
- A dry climate change scenario will increase risk of low annual livestock weight gain (LWG) per hectare compared to 1990.
- In the Fitzroy Basin, land use patterns have already changed in response to climate change. For example, in the period from 1970 to 2000 cropping land doubled at the expense of grazing land in the Nogoa sub-catchment. These changes in land use influence natural resources. One of the greatest issues of concern is sediment loads in rivers, as they are eventually deposited into waters around the southern part of the Great Barrier Reef.

### *Impacts on water flows in Queensland's desert channels*

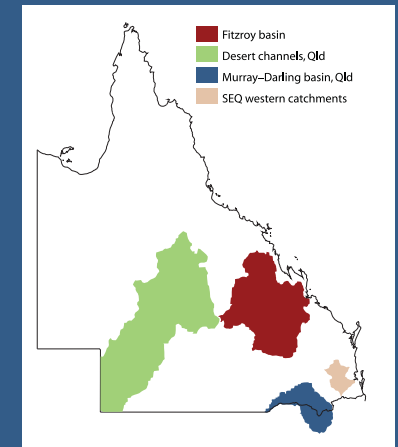
- The mean temperature of the Desert Channels region will increase by 1.0 to 1.7°C, annual rainfall will change -4 per cent to 1 per cent and evaporation will increase by 3 per cent to 9 per cent by 2030 in the region compared with 1990.
- In average and dry years, the length of time water holes persist during drought periods and the length of time water holes remain connected to each other will be reduced. This, in turn, will have consequences for the plant and animal life that rely on these water sources.
- Climate change will extend the lengths of long periods of no flow in the desert channel.

### *Impacts on the Queensland Murray-Darling Basin*

- By 2030, the mean temperature will increase by 0.9 to 1.3°C, annual rainfall will change by -6 per cent to 3 per cent and evaporation will increase by 2 per cent to 10 per cent in the region.
- The change in mean annual flow for the MacIntyre Brook River ranges from approximately -25 per cent to +9 per cent by 2030. For the Dumaresq River the change is from -25 per cent to +6 per cent.
- Irrigators between the Inglewood and Whetstone weirs along MacIntyre Brook River, are likely to have significantly less water in the dry season and which may reduce agricultural production. The same is likely for Dumaresq River in the dry climate change scenario.
- For Queensland irrigators along the Dumaresq River the dry climate change scenario will reduce the average cropping area by 28 per cent. This reduction is caused by less rainfall (6 per cent) and less water allocation.
- For the MacIntyre Brook River the environmental flow requirement is 2ML/day. With a dry scenario, 2030, will bring more long periods of flow below 2ML/day compared to 1990. This could lead to increased drying of the river bed, reducing the speed of water order deliveries and inhibiting the migration of fish species in the river system among other detrimental impacts on aquatic and land ecosystems.

### *Impacts on south-east Queensland Western Catchments*

- By 2030, the mean temperature will increase by 0.8 to 1.2°C, annual rainfall will change by -5 per cent to 2 per cent and evaporation will increase by 2 per cent to 8 per cent in the region
- By 2030, the annual streamflow for the Brisbane River downstream of Mt Crosby Weir will be reduced 28 per cent in the dry scenario and increased by 14 per cent in the wet scenario. Average annual inflows into Somerset, Wivenhoe and Mt Crosby storages will decrease by 12, 16 and 21 per cent respectively if climate change is accompanied by drying, however will



increase by 7, 9 and 10 per cent respectively, for the wet climate change scenario.

- “Demand may rise by up to 35 per cent by 2030. Water planning in South East Queensland (SEQ) undertaken by the Queensland Water Commission indicates that following establishment of the Water Grid and completion of planned infrastructure to 2012, additional urban and industrial supplies are not anticipated to be required prior to 2028, unless SEQ experiences another drought as severe as the current drought. This forecast is after taking into account the provision of reduced system yields which are 20 per cent below the previous forecasting methodology (Historic No Failure Yield) to account for climate variability and a further reduction of 10 per cent in assumed yield to reflect a mid range climate change scenario. The proposed planning framework for SEQ also includes a drought response plan which ensures that SEQ would not run out of water under any climate change scenario.” (QWC, pers. comm., 2008)

# Interactions between soil, rainfall, land management and resilience to climate change

*Research into how rainfall infiltrates into landscapes will give us better insight into what makes land resilient to the effects of climate change. The outcome of this research can be incorporated into an existing model of grass production (GRASP) allowing infiltration rates and hence climate change resilience to be modelled for all Queensland's grasslands and grazing systems.*



In the face of climate change, the goal posts for assessing the sustainability of land management practices have moved. Practices which may have been marginally sustainable in the past may no longer be viable due to the potential impacts of climate change, including shorter wet periods of higher daily rainfall intensities interspersed with longer dry periods. The capacity of grazing lands to remain sustainable under such changing climatic forcings will depend greatly on the resilience of the specific land type (which is a function of the soil and vegetation attribute). Resilience – the ability of a resource to “bounce back” when pushed to its limits – is an important mechanism for coping with climate change. In relation to the condition of Queensland's natural resources, an important and recurring question is “how good must the condition of this resource be now in order to be resilient to predicted climate change?” If we knew this, we would be able to manage our resources optimally to withstand climate change, farm sustainably and maximise return on investments. Failure to identify the resilience of different grazing systems can lead to land degradation and resource collapse.

Grazing landscapes in good condition, and therefore with high resilience, have good ground cover and tussock health, good litter and high infiltration rates. Infiltration rate refers to the proportion of rainfall that soaks into the ground and can therefore be used to grow pasture and other vegetation.

Rainfall that does not soak in runs off, potentially causing erosion and reducing the water quality of creeks and rivers further down the catchment. This is of particular importance in catchments that flow into the Great Barrier Reef zone.

In this project, funded by Meat and Livestock Australia, infiltration rate can be seen as an indicator of resilience. Independent of land condition, land type (a combination of soil and vegetation type) is a factor in determining infiltration rate, so it is necessary to examine these two factors in combination to understand the infiltration capacity (and hence resilience) of a given landscape. Additionally, landscapes in good condition with a high density of healthy grass tussocks optimise the amount of carbon that can be stored in the surface soil layers.

A major aim of the project was to investigate the interactions between land condition, soil properties and vegetation in determining rainfall infiltration rates in native grasslands. A major aim of the project was to investigate the interactions between land condition, soil properties and vegetation in determining rainfall infiltration rates in native grasslands. Along with land condition, soil type and vegetation type, grazing practices, in particular stocking rates and stock movements around a property, also influence infiltration rate. While soil type is given for any particular property, vegetation and land condition can



be managed through altering grazing practices. Hence, grazing practices have an important influence in determining how much rainfall infiltrates the soil or runs off the soil surface.

To investigate these relationships, field measurements of infiltration rates and land condition were taken across a range of historical grazing trial sites in Queensland. Laboratory analyses of soil samples were also undertaken. Relationships between soil type, land condition and infiltration rate were extracted from the data. These provide the basis for testing (“ground-truthing”) the ability of GRASP (see page 33 ) to model infiltration processes. Enabling GRASP to be developed in this way was a further aim of the project. By incorporating a new understanding of infiltration processes into the GRASP model, landscape resilience on the one hand, or vulnerability to degradation on the other, can be extrapolated to all Queensland grazing lands through modelling.

Incorporating these processes into GRASP will give new insight into how we can sustainably manage our natural resources and, in turn, recommend appropriate land management strategies under climate change. The GRASP model forms the basis for a diverse range of applications including the State Government’s Rural Leasehold Land Strategy (Delbessie, see page 60) and also the Queensland Department of Primary Industries and Fisheries’ Grazing Land Management workshops.

As well, the science behind using GRASP to model infiltration can be applied to modelling other variables involved in mitigating and adapting to climate change. One important example is soil carbon, which needs to be accurately modelled in order to incorporate agriculture and forestry into Australia’s proposed emissions trading scheme (ETS). Knowledge is currently lacking about how carbon behaves in soils and vegetation under various conditions – a problem that urgently needs to be addressed before this important carbon-managing sector can be properly taken into account.

*Far left: taking field measurements and gathering soil samples. Left: stocking rates influence land condition and infiltration rate*

# Industry engagement in developing a tool to assist with adaptation to climate change

*With the involvement of graziers and other regional participants, a tool is being developed to help regional stakeholders plan their adaptation strategies to potential climate change impacts. The tool uses a risk management approach and can be adapted for use in any industry or sector. A key feature is the participatory nature of the process used to tailoring the tool for each industry.*

The grazing risk matrix is a tool to assess climate change impact, risk and adaptation potential for the Queensland grazing industry. As 85 per cent of Queensland's land area is managed by graziers, the ability of this industry to adapt to climate change has important implications for the sustainability of Queensland's natural resources and for all Queenslanders.

The risk management approach involves identifying potential impacts relevant to decisions being made (in this case by graziers), understanding the likelihood and potential consequences of those impacts and developing appropriate responses. This information is collected at workshop-style gatherings.

The first step in developing a "grazing risk matrix" is to determine how climate and climate-related factors of importance to the grazing industry might change in the future. Firstly climate factors (such as temperature) and climate-related factors of potential importance to the grazing industry (such as bushfire frequency) are identified. Next, the way these factors might change in the future is considered. For example, the number of days with temperature greater than 35°C is likely to increase. These changes are then ranked in order of confidence that each will occur. For example, there may be more confidence that temperature will increase than rainfall will decrease. Each "change factor" is finally colour-coded according to the level of certainty of occurrence.

The next step in the process is for participants to nominate a list of environmental, social and economic factors of interest to the grazing industry that may be impacted by the above-mentioned climate change factors (e.g. pasture growth, rural population and prices relative to CPI). These "industry" factors are combined with the above "change" factors in the form of a matrix – an ordered list of "change" factors form the "rows" of the matrix and the list of "industry" factors form the "columns".

The cells in this matrix are filled with likely impacts of climate change. For example, the effect of higher minimum temperatures (a feature of climate change that we are highly confident will occur) on animal diseases (a factor of interest to graziers) is that there will be an increased incidence of disease. For some cells, interactions are complex and can be filled with quantitative information using modelling tools such as GRASP. Other cells are filled subjectively based on knowledge of climate change science and industry knowledge shared among those at the workshop. If participants lack knowledge, scientists can contribute to filling in the gap, whereas, if participants have good understanding then the scientists are the receivers of information. This process emphasises the importance of local knowledge about historical climate and the potential impacts of a changing climate on industry.

Once the matrix is filled with comments, contents of cells in the matrix are graded (and colour coded) as to the risk associated with their occurrence on a scale of extreme, high, medium and low. Two dimensions of risk are taken into account when assigning grades. First, the likelihood that the impact will occur (taking into account confidence in climate change projections among other factors) and, secondly, how serious the consequences would be on a scale of minor, moderate, major, severe and catastrophic.

This process is repeated for potential positive impacts of climate change (such as increased pasture growth due to higher carbon dioxide levels) then a similar exercise is conducted to develop a matrix of adaptations (i.e. management decisions a grazier may make) to each of the potential negative and positive impacts.

The primary purpose of this exercise is to identify climate change impacts and develop adaptation strategies. However, there are other benefits. Due to its participatory nature, and due to the straightforward design of the grazing risk matrix

tool, this process offers an effective way to share knowledge of the likely effects of climate change and to encourage graziers to begin to take action.

A proposed development of the grazing risk matrix is to use bioeconomic modelling to fill some of the matrix cells with more quantitative information. Bioeconomic modelling will help discover biological responses to regional climate change scenarios. These responses will be further analysed in a series of case studies, with the work being done in collaboration with scientists from the Queensland Department of Primary Industries and Fisheries and CSIRO.

The results of the modelling will feed back into the grazing risk matrix to provide “quantitative” information to better inform both scientists and graziers of the risks and potential adaptations related to climate change for Queensland’s grazing lands.

This risk assessment approach can be used on a regional basis and across a broad range of other industries and fields, for example transport, tourism and health sectors.







# 4 Information and knowledge systems

improving access to climate change information

Information is a key resource in times of uncertainty and rapid change. The QCCCE's information and knowledge systems theme is developing information products to communicate climate change impacts and scenarios to the community, business and governments, to support planning and decision-making and to engage these sectors in adapting to climate change. This theme also develops and maintains robust information management systems, information infrastructure and data security protocols.

The theme has five integrated components:

- 1) information management – generation of reports and advice, systems documentation and archive for reproducibility
- 2) data management – observed and climate model datasets



*Information and knowledge systems team:  
 (top to bottom, left column) Ken Day (theme leader), Alan Peacock, Alan Beswick, David Ahrens, Neil Flood, Dorine Bruget  
 (right column) Tracy Van Bruggen, Andrej Pankov, Simon Lovell, Greg Kociuba, David Owens*

- 3) operational systems – forecasting tools, spatial modelling and data processing
- 4) computing infrastructure – provision of resources, systems management
- 5) information products and communication.

The information and knowledge systems theme does not focus on major project-based research activities but fulfills a support function for most research projects undertaken within the QCCCE. It also provides an operational home for some of the research developed in other themes and continuously improves existing operational products. The QCCCE products, SILO, AussieGRASS Environmental Calculator and Seasonal forecast systems, have been recognised as world class applied science.

Many outputs of the information and knowledge systems theme are delivered on “operational” timeframes, in the sense that they are continually and regularly refreshed as new data is assimilated, then made available to users in various formats but especially on line through the QCCCE’s website, the Long Paddock ([www.longpaddock.qld.gov.au](http://www.longpaddock.qld.gov.au)).

An example of such a product is the SILO database which services the climate data needs of the scientific community within and external to the QCCCE, offering a complete set of climate data – maximum and minimum temperature, rainfall, evaporation and several other measures, available for approximately 350,000 locations throughout Australia, for every day of the past 120 years. This information is updated daily (see page 59 for more information about SILO).

## ASSISTING QUEENSLAND'S PRIMARY PRODUCERS WITH 'EXCEPTIONAL CIRCUMSTANCES' APPLICATIONS

The main business of the information and knowledge systems theme is service delivery. This theme develops, packages and distributes a range of tools and services to assist internal (state government) and external stakeholders to understand and adapt to climate change and climate variability. The assistance the QCCCE provides to primary producers applying for 'Exceptional Circumstances' (drought) relief is an example of such a service.

Current Federal Government policy encourages primary producers and other sections of rural Australia to adopt self-reliant approaches to managing the risks stemming from climatic variability. However government policy also recognises that there are 'exceptional circumstances' which are beyond normal risk management. The QCCCE assists the Queensland Department of Primary Industries and Fisheries to prepare Exceptional Circumstances (EC) submissions for Queensland regions. Submissions to the Commonwealth are required either when seeking EC status for a particular region or when current EC status is under review. The QCCCE conducts a climatic assessment for regions in question, ranking current seasonal conditions with historical conditions and presenting this information as detailed regional maps.

Furthermore the QCCCE also contributes maps and time-series information for all of Australia to the National Agricultural Monitoring System (NAMS). The NAMS is a website containing climatic, agronomic and production information for Australian agriculture. The NAMS was developed to help provide a consistent, streamlined approach to the EC process. This is achieved by generating reports using agreed data for EC applications. These reports

provide the basis of the EC application, with interpretation and supporting information provided by local, state and territory governments communities and industry groups.



# AussieGRASS – Environmental Calculator

*The AussieGRASS “environmental calculator” was developed to help graziers to take the known relationship between the ENSO and Australian drought into consideration when managing grazing lands. The environmental calculator has been further developed into a variety of products that assist land managers to monitor pasture growth, pasture utilisation, ground cover, soil moisture and potential flow to streams among other variables of interest. It is maintained as an operational computer application by the QCCCE’s information and knowledge systems theme. Output of the environmental calculator is regularly updated and is available on the Long Paddock website.*

**E**ighty-seven per cent of Queensland’s land area is occupied by native and naturalised grasslands, shrublands and woodlands. The sustainable management and conservation of this vast natural resource hinges on management decisions regarding livestock numbers. The choice of target carrying capacity for a property and the year-to-year management of stocking rates are critical for conserving these natural ecosystems. This challenge is made more difficult by the strong year-to-year and decade-to-decade variation in rainfall in Queensland, largely driven by fluctuations in the El Niño Southern Oscillation. On top of this, Queensland faces an era of unprecedented climate change.

The extreme year-to-year and decade-to-decade variability of rainfall in Queensland can make it challenging to keep stock numbers in tune with prevailing seasonal conditions and to plan for future conditions. Protracted dry periods, sometimes lasting several years, are difficult to manage and sequences of wet summers can give a false expectation of longer-term carrying capacity. As it is, livestock numbers in Queensland have tended to increase during wet decades and have been slow to fall with the inevitable return to average or below average seasons, a situation that leads to wide-spread land and pasture degradation.

Following such a scenario in north-eastern Queensland during the 1980s, it was recognised that, had the tools been available to put existing climate knowledge to use, land managers could have foreseen the high risk of land and pasture degradation and taken appropriate action. To provide such a tool, based on the Southern Oscillation Index, simulated pasture growth and reported livestock numbers, the Australian Grassland and Rangeland Assessment by Spatial Simulation (AussieGRASS) project was subsequently developed.

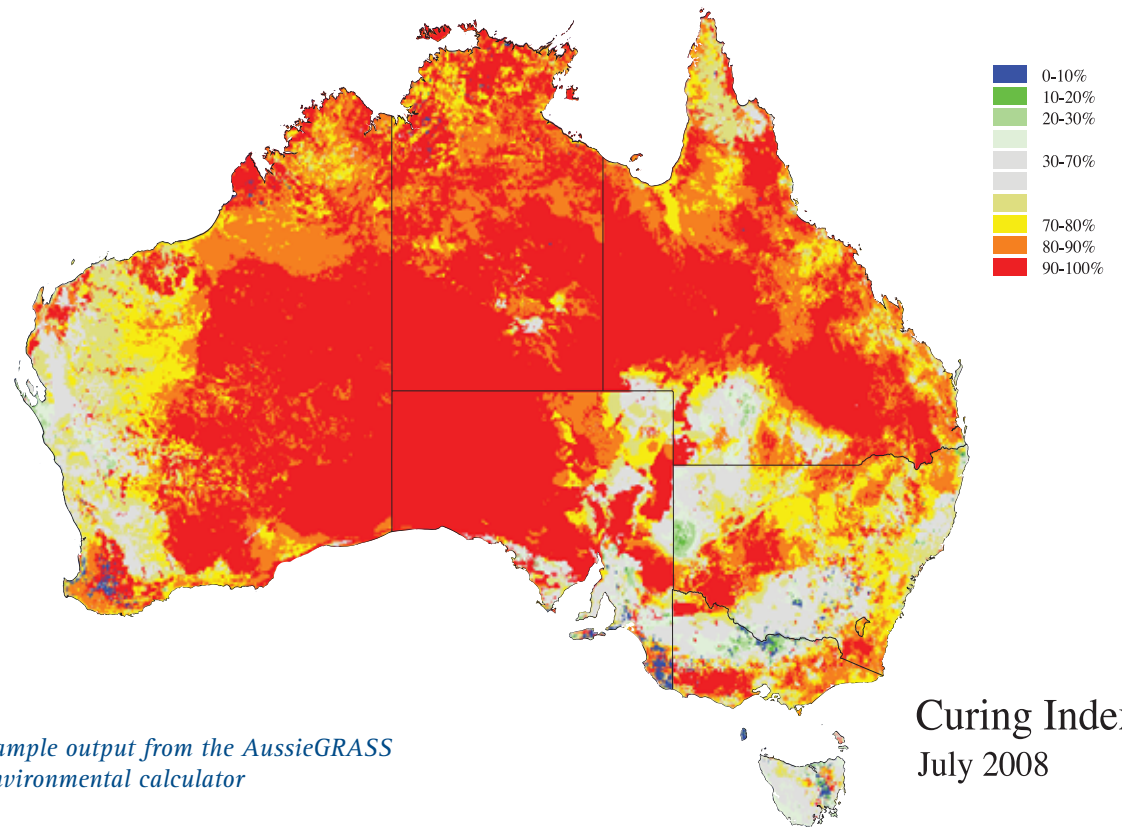
AussieGRASS was an innovative project, widely acclaimed and supported at both state and national levels, providing policy officers and land managers with information critical for monitoring the condition of Australia’s extensive natural grasslands and rangelands and for assessing and managing climate risk. This recognition facilitated a decade of continual innovative development to serve a wide and growing range of client needs and, in so doing, contribute to the sustainable and productive management of natural resources in our variable climate.

The focus of the AussieGRASS project was the development, validation and near real-time operation of a national grassland modelling framework. This modelling framework is now known as the “environmental calculator” and is a means of analysing current and emerging issues of critical importance to policy



and resource management in Queensland, including drought and Exceptional Circumstances, landscape water balance, climate change impacts, carbon stocks in vegetation and soils, and impact of grazing on groundcover and sediment loss.

QCCCE researchers have upgraded and continue to maintain and operate the AussieGRASS environmental calculator. Products are made available in near-real time and for the season ahead and are updated on a monthly basis on the QCCCE's LongPaddock website ([www.longpaddock.qld.gov.au](http://www.longpaddock.qld.gov.au)) and the Bureau of Rural Science's National Agricultural Monitoring System (NAMS) website ([www.nams.gov.au](http://www.nams.gov.au)). The continued use of these products by landholders will improve the prospects for long-term sustainable use and conservation of our vast natural grasslands, shrublands and woodlands. The AussieGRASS environmental calculator will also continue to be an important tool for studying climate change impacts, adaptation and mitigation responses in Queensland – a vital component of the information and knowledge base underpinning the QCCCE's research and extension activities.



# Using the environmental calculator, AussieGRASS, to investigate the effects of increased atmospheric carbon dioxide on ecosystems

*AussieGRASS, an “environmental calculator” that assists land managers to monitor pasture growth, pasture utilisation, ground cover, soil moisture and other variables is being adapted to address urgent questions about how the increase in atmospheric CO<sub>2</sub> affects plant growth and hence ecosystems. This knowledge is needed to understand how ecosystems services may be affected by climate change.*

One important climate change matter urgently needing research is the effect of increased carbon dioxide (CO<sub>2</sub>) on plant growth and hence on natural systems (ecosystems). Will production (both natural and agricultural) increase? Will increases be uniform across different types of natural and agricultural systems? If not, how will these differences affect the natural balance of the ecosystem? These and many related questions need urgent answers.

Exploring links between increasing CO<sub>2</sub> levels and ecosystems is important because ecosystems perform services that maintain the planet within livable limits for the human species. Ecosystem responses to increased CO<sub>2</sub> are of particular importance to Queensland’s agricultural and pastoral industries.

The modelling framework AussieGRASS environmental calculator uses output from the modelling program GRASP (GRASS Production) to produce maps of a number of variables important to Queensland’s primary industries. GRASP models plant growth and water balance in the Australian landscape. Both GRASP and AussieGRASS were developed by QCCCE scientists prior to 2007.

It is currently possible to produce outputs from the AussieGRASS environmental calculator that address water supply, greenhouse emissions (e.g. methane), land degradation and rangelands economic issues.

QCCCE researchers are extending the capabilities of AussieGRASS to test the responses of the ecosystem to elevated levels of CO<sub>2</sub>. This new use for the AussieGRASS software will help to answer important questions about the direct response of the natural environment and its complex interrelationships to increased levels of CO<sub>2</sub>.



# Managing and extending the SILO database

*In the early 1990s scientists, now with the QCCCE, set up a world-class climate database, SILO. The Centre now manages and maintains this database, the output from which is highly valued and much sought-after by agencies throughout Australia, including the research arm of the QCCCE itself.*

The QCCCE receives daily climate data from all Australian weather stations via the Australian Bureau of Meteorology (BoM). The SILO database does the following tasks for the QCCCE in order to maintain the Centre's basic climate data sets:

- collects climate data from BoM and ingests it into the local database
- orchestrates interpolation of most recent climate data coming from about 4500 weather stations across Australia. Interpolation is the process by which data is generated in a regular .05 degree grid across Australia, producing about 350,000 grid squares from the original 4500 points. The interpolated data is either used as grids or to replace data missing from the BoM raw data sets
- stores climate files for use by AussieGRASS. (The application AussieGRASS environmental calculator uses advanced spatial simulation techniques and the QCCCE's supercomputing facilities to assess and monitor the condition of Australia's grazing lands).

SILO services the climate data needs of scientists both nationally and internationally, offering a complete set of climate data – maximum and minimum temperature, rainfall, evaporation and several other measures, available for approximately 350,000 locations throughout Australia, for every day of the past 120 years – a formidable and very valuable data set. The SILO data is much in demand because

of its wide usefulness and recognised very high quality. Major client groups include:

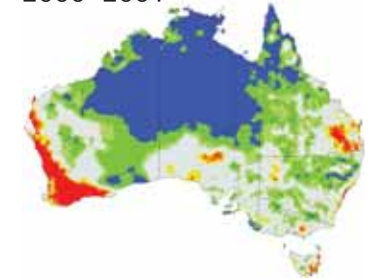
- Queensland Government departments
- the CSIRO
- Cooperative Research Centres (including the CRC for Irrigation Futures and CRC for Cotton Catchments)
- state government departments in NSW, VIC, SA and WA
- universities
- Commonwealth Government agencies, including the Bureau of Regional Sciences (BRS)
- consultants
- individual researchers.

SILO provides custom data analysis for *ad hoc* requests to the QCCCE most recently in relation to developing climate information for Queensland Regional Water Supply Strategies assessments.

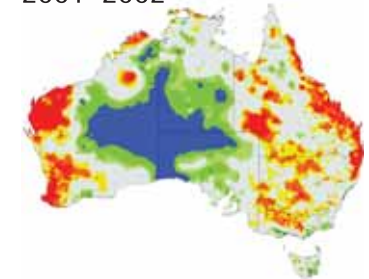
As well as servicing external clients, the SILO database is vital to the function of the QCCCE in providing high quality Australia-wide weather data for use in modelling and other Centre activities.

*SILO data was used to construct these yearly maps of Australia's rainfall anomaly. Red areas indicate lower than average rainfall, while blue areas map places where the rainfall was higher than the average for the base period (base period = entire record from 1890 to date)*

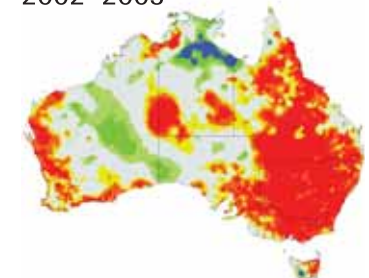
2000–2001



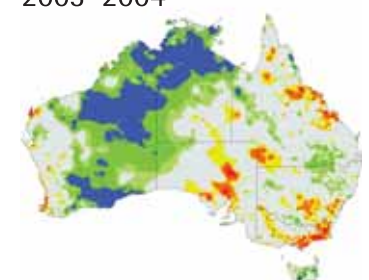
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2002–2003



2003–2004



# Providing managers of Queensland's rural leasehold lands with tools to assess land condition and to adapt to climate change

*The Delbessie Agreement (the State Rural Leasehold Lands Strategy) came into effect in 2008 to guide the management of rural leasehold land in Queensland. Following this agreement, the QCCCE was commissioned by the Queensland Department of Natural Resources and Water to provide information to help assess and monitor the condition of leasehold land. This information also increases land managers' capacity to adapt to climate variability and change. To meet these requirements, property-scale information and decision-support tools such as FORAGE and PaddockGRASP have been developed by the QCCCE, based on existing tools such as AussieGRASS and GRASP (both described elsewhere in this document). The QCCCE's provision of services under the Delbessie Agreement demonstrates the broad applicability of the Centre's information and knowledge systems and the capacity of the Centre to develop customised climate products.*

Two-thirds of Queensland's land surface is under leasehold tenure. The Delbessie Agreement (the State Rural Leasehold Lands Strategy) was signed in December 2007 at Delbessie – a property north of Hughenden and came into effect in January 2008. The agreement provides a framework for the sustainable use of the State's leasehold land – particularly that defined as 'rural' leasehold land – and documents the changes and challenges to managing it.

The Department of Natural Resources and Water (NRW), Agforce Queensland, and the Australian Rainforest Conservation Society collaborated in developing the agreement, taking into account the aspirations of leaseholders, conservation and Indigenous groups and rural industry.

The agreement includes measures to balance profitable use of land with maintaining healthy land condition, and to improve land managers' capacity to adapt to emerging issues such as climate change.

The QCCCE has been commissioned to provide key information to help in the assessment of land condition and to assist land managers' capacity to adapt to climate variability and change.

The QCCCE is preparing fact sheets to raise awareness of the various products available from the Centre as well as those under development.

One product being developed specifically to meet the aims of Delbessie is FORAGE – an internet-based framework used to generate and distribute property-scale information about climate as well as pasture as an indicator of land condition. Clients will be able to request, via the web, reports on rainfall, pasture and ground cover, based on outputs from the AussieGRASS environmental calculator or based on satellite imagery.

Also at a property scale, the QCCCE is improving access to the PaddockGRASP decision-support system, which allows detailed modelling of pasture growth – both historically and projected for the year ahead based on state of the El Niño-Southern Oscillation phenomenon (ENSO). This modelling tool, in the hands of trained users, allows detailed assessments to be made of the impacts of various stocking policies in the face of variable and changing climatic conditions. The QCCCE has provided training in the use of the GRASP model (which underpins





PaddockGRASP) through a recent series of workshops (see page 33) funded by the Meat and Livestock Association.

Building on the AussieGRASS environmental calculator, the QCCCE is also preparing graphs of key environmental variables over time, such as rainfall and pasture growth. These will be prepared at regional scales to provide a broader scale perspective of both past and present seasonal conditions. These graphs will be made available on the QCCCE's Long Paddock website.

A further product under development by the QCCCE, specifically for Delbessie, is a "Seasonal Conditions Report" – a simple email report which tracks current seasonal conditions across Queensland, based on maps of rainfall, pasture growth and ground cover. This report provides probabilities of likely future conditions based on the current state of the ENSO phenomenon.

The commissioning of the QCCCE to provide fundamental land and climate information to support the Delbessie Agreement demonstrates the broad applicability of the QCCCE's information and knowledge systems and the capacity of the Centre to develop customised climate products.

# Developing new tools for producing Queensland's seasonal climate outlooks

Queensland's seasonal climate is strongly influenced by the El Niño Southern Oscillation (ENSO) phenomenon. Seasonal forecasting currently uses the historical relationship between the Southern Oscillation Index (SOI: an atmospheric measure of ENSO) and Queensland's rainfall to make statistical statements about likely rainfall at a lead time of just three months. The QCCCE has developed alternative forecasting systems that have longer lead times (for example SPOTA-1) including systems based on the use of global climate models that will better incorporate the effects of climate change.

*SPOTA-1 gives climate forecasts eight months earlier than the SOI and explains 30 per cent more of the variation in Queensland's rainfall*

To adapt to climate change, Queensland needs industries with the capacity to adjust their operations based on climate risk assessments. One big question regarding the future climate of Queensland is whether climate change is manifesting in more frequent El Niño events. While anecdotal evidence

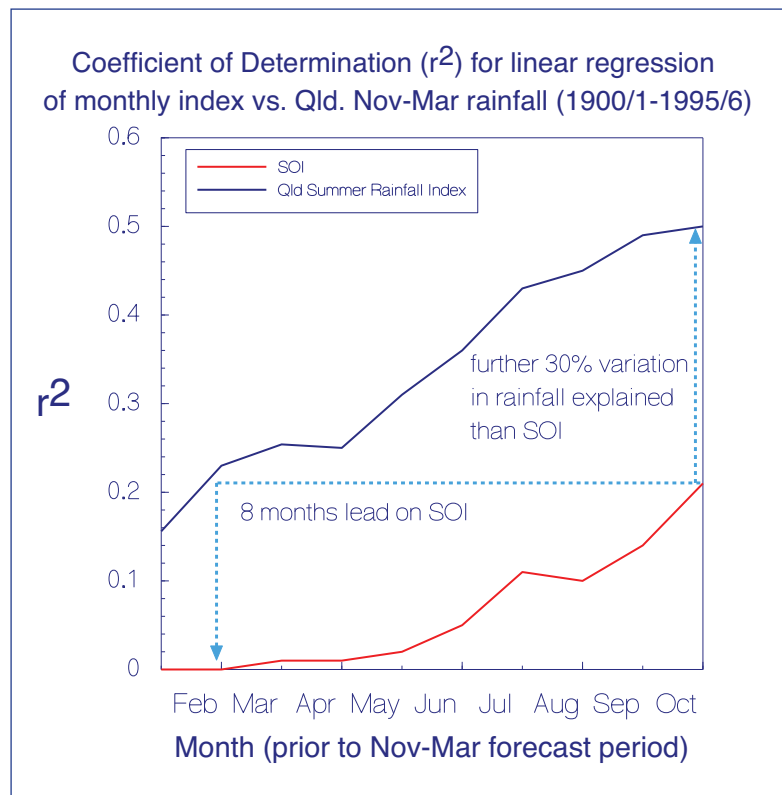
and some scientific studies suggest such a connection, this remains an hypothesis for now. Research and continued monitoring will eventually tell whether climate change is increasing the frequency of El Niño events or whether some other long-term climate cycle is responsible for this apparent trend or, indeed, whether this increasing frequency is just 'natural variability' and therefore not long-lasting.

Whatever the case, Queensland's rainfall pattern is strongly linked to the ENSO. Indeed this global climate pattern has a stronger

relationship with the climate in Queensland than in any other part of the world. Therefore, developing the capacity of our industries to adjust their operations to ENSO-based seasonal forecasts is a sensible precaution to adopt. In fact, model simulations show that we could already have been adjusting to the ENSO signal and would be economically better off for having done so.

The current Queensland Government forecast uses the SOI Phase System. This system provides a three-month look ahead into likely conditions based on historical probabilities. The Southern Oscillation Index (an atmospheric measure of ENSO which measures the gradient in air pressure between Darwin and Tahiti) explains about 20 per cent of the summer rainfall variation in Queensland and, at certain times of the year (particularly winter and spring), can be used to make a statistical statement about likely rainfall over the next three months or so.

Agricultural industries typically need to make management decisions with longer lead times. For example, in the Queensland grazing industry, stocking rate decisions must be made well in advance, based on estimates of the likelihood of good or poor rainfall in the main summer pasture growing season (November to March). The QCCCE is currently evaluating longer-lead forecasts as an alternative to the SOI Phase System, to make forecasts more useful in planning for and adapting to climate change and climate variation.



## APPLICATION OF THE SEASONAL PACIFIC OCEAN TEMPERATURE ANALYSIS (SPOTA-1)

One important application of the seasonal forecasts produced by SPOTA-1 is the prediction of Queensland's dam water levels. QCCCE scientists are working with SunWater to develop on-line seasonal forecasts of future storage levels. This information is being prepared for major water storages in Queensland and, when released, will be available on the SunWater website.

Probabilities of future storage levels are calculated each month for up to 12 months in advance. The probabilities are based on current storage levels and the current state of the El Niño Southern Oscillation. Both the SOI and SPOTA-1 are used to get the most accurate possible predictions. This new information will allow water users to better estimate likely future allocations.



QCCCE scientists are working with SunWater to develop on-line seasonal forecasts of future storage levels

The first approach is a statistical procedure based on Seasonal Pacific Ocean Sea Surface Temperatures (SPOTA-1). This climate risk assessment tool targets Queensland's summer rainfall, providing both increased "skill" and lead times to the SOI. SPOTA-1 gives new understanding of how the Pacific Ocean affects Queensland's rainfall at year-to-year and also at 10-year-long (decadal) time scales. It gives regularly updated climate forecasts for summer up to nine months in advance, available from the Long Paddock website ([www.longpaddock.qld.gov.au](http://www.longpaddock.qld.gov.au)). Queensland's graziers already use this tool to help make informed business planning decisions.

The second alternative approach being investigated uses Global Climate Models and recognises that, as the planet warms and other climate changes occur, the statistical relationships derived from historical data and used to make seasonal forecasts with SOI and SPOTA-1, may begin to drift. In the future, to account for climate change, additional scientific support may be required to modify or replace the historical statistically-based systems that have proved so useful since 1988.

The current limiting factor with the use of global models to produce seasonal forecasts is computer power. Computer power is needed to run the very high resolution climate models most useful for seasonal forecasts. While global models typically have grid cell resolution of up to 300km, which is not fine-grained enough to produce useful regional forecasts, the QCCCE has (since 1998) been producing seasonal forecasts based on regional climate models with 75km grid cells over Australia and 15km grid cells over Queensland.

*The QCCCE produces seasonal forecasts for Queensland based on regional climate models*



# Communicating climate change and engaging Queenslanders in climate change adaptation action

*Through communication and community engagement, the QCCCE reaches the broader Queensland community to raise awareness of climate variability and change. This includes collaborating with people from a range of sectors impacted by climate change to investigate potential economic, social and environmental impacts. Through this process of communication and collaboration, Queensland communities are able to better understand, prepare for and adapt to changes in our climate.*

QCCCE staff continue to engage with the broader Queensland community to raise awareness and increase understanding of the causes of climate variability and change.

This has included engaging community and industry groups to develop, promote and deliver timely and applicable climate science based information, products and services. This engagement involves working with the community, local government, industry and other agencies to develop suitable response adaptation strategies.

This consultative process enhances the capacity of Queensland communities to make informed responses to climate change as it affects issues such as human health, water supply and infrastructure, emergency services, mines and energy, natural resource and catchment sustainability, food security and production.

Community engagement activities over the last 12 months have included:

- climate variability and change workshops with community and industry groups as diverse as the Northern Gulf Resource Management Group, local Landcare groups, AgForce, Queensland Farmers' Federation, Queensland Murray–Darling Committee Inc, primary and secondary schools, assisting students investigating “Climate Change: Fact or Fiction” for entry to this years “Ekka Show Camp”, the Siemens Summer School, the Australian Independent Retirees Association, local agricultural production groups, local environmental groups, and local councils
- Cloud Seeding Research Project community awareness presentations to local governments and community groups (including SEQ Catchments Ltd)
- joint Managing for Climate and Weather workshops with the Bureau of Meteorology
- development and maintenance of the Centre’s internationally recognised Long Paddock internet site, which has also been instrumental in the presentation of easy to access and easily understood climate information.



- The site contains:
  - a daily track of the SOI calculation
  - a weekly El Niño advisory bulletin which gives the monthly SOI values; commentary on sea surface temperature trends, national and international climate models; and seasonal prospects for rainfall and perhaps frost
  - monthly seasonal climate forecast maps of rainfall probability for Queensland, Australia, and the entire world – the world maps can be used by producers
    - to anticipate market price movements from global drought and rainfall predictions
  - tables of monthly SOI data
  - SOI phase graphs
  - monthly sea surface temperature maps of the globe
  - monthly simulation model updates which give a district and state perspective of agriculture, grazing and water systems
  - the current drought declaration status of Queensland as a map and tables.



*The QCCCE works with the community, local government, industry and other agencies to develop suitable response adaptation strategies*

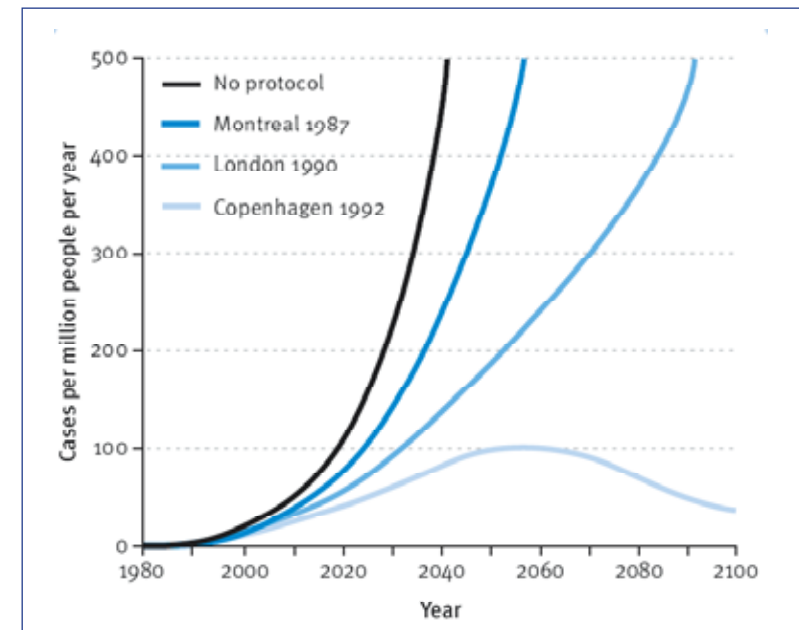
# Contributing to State of Environment reporting

*The Queensland Climate Change Centre of Excellence contributed the climate change sections in the State of the Environment Queensland 2007 report on climate change issues affecting the atmosphere. The report documents the condition of the environment under several broad categories, to assess the impact of climate change on the state's natural resources and the adequacy of current legislation and policies to manage the pressures on our environment.*

The “Climate and greenhouse” section of *State of the Environment Queensland 2007* reported on the major changes occurring in Queensland climate, which are now known to be principally driven by human activities. Trends in a number of key climate indicators were described, such as increasing average temperatures (1°C increase across Queensland over the last century), and declining rainfall over most of the state. Other key indicators of the state's performance on climate change issues were also described, including the increase in per-capita emissions (4.9 per cent from 1999 to 2004, mainly driven by an increase in energy demand), and the significant decrease in emissions from land use, land change and forestry. The decline in the latter may have been aided by the introduction of the *Vegetation Management Act 1999*, demonstrating that government policy can be a useful instrument in mitigating climate change.

The “Stratospheric Ozone depletion” section described the effects the various man-made gases have been having on the natural and cyclical processes involved in creating and destroying ozone in the stratosphere. The stratosphere forms the upper part of the atmosphere and lies about 10–50km above the Earth's surface. Emissions of various man-made gases that destroy ozone, such as chloroflourocarbons (CFCs), have risen steadily since the industrial revolution, followed by a rapid increase in the latter half of the 20th Century.

As a result of these emissions, the concentration of stratospheric ozone has decreased and the State of the Environment report documented the consequent impacts on human health and the environment. Key findings included revised estimates of when the ozone layer would recover, and the expectation that the current elevated rates of skin cancer (due to ozone depletion) would not begin to decline until the middle of the 21st Century. The report did, however, note that various international activities aimed at regulating the use of ozone depleting substances were having a significant impact and that many such substances have now been phased out.



Increase in Queensland's per capita greenhouse gas emissions from 1999 to 2004 was largely driven by an increase in energy demand

## Development of a high performance computing infrastructure

*As climate models become ever more complex, computer-intensive and accurate, the QCCCE must keep its computer system at the cutting edge of development. This infrastructure allows the Centre to produce projections of future Queensland climates that are reliable and fine-grained enough to use in managing the risks of climate change on regional and local scales.*

The Centre needs a new high performance computing (HPC) system, as existing systems are not adequate to run the latest generation of climate models. A project is underway, in collaboration with NRW, to get the best possible system for the Centre.

A benchmark suite of applications and datasets has been constructed to put available systems through their paces. Through a tender process, selected vendors are invited to submit system proposals. The benchmark suite will enable the HPC vendors to demonstrate the performance of their systems and allow the selected system to be tailored to the Centre's computing and storage requirements. The use of benchmark applications will ensure the Centre achieves optimum value for money, and also guarantee that the new system has the capacity to perform the Centre's planned climate modelling work. Therefore this activity is vital to the success of the Centre, as it underpins the climate modelling that will support many of the Centre's current and future projects.

## Management of datasets from the Intergovernmental Panel on Climate Change (IPCC)

*The QCCCE maintains an archive of climate model datasets to meet its obligation to analyse climate change impact on Queensland. Storing such datasets involves a considerable investment in computer hardware.*

The QCCCE is responsible for analyzing the impact that climate change may have on various aspects of Queensland's industry, economy and society. To fulfill this obligation the Centre must have access to a broad range of climate model projections. Datasets from multiple models ensure climate change impact analyses are based on the best available science, and are not adversely affected by deficiencies in any one model. The QCCCE maintains an archive of climate model datasets from various modelling inter-comparison projects and international collaborative ventures, such as the assessments of the IPCC.

Climate model datasets are typically of the order of terabytes for each set (a terabyte is 1000 million bytes of data or "bits of information"), depending on a range of factors such as model resolution (in both space and time), and also the length of the dataset. Storing such datasets requires a considerable investment in both storage hardware and network infrastructure. The QCCCE maintains a number of high performance disk arrays and two tape storage systems for hosting its climate data archive.

*One of the QCCCE's Cray computers, soon to be replaced by a new high performance computer system*



*Storing climate model datasets requires a considerable investment in both storage hardware and network infrastructure*







# 5 Special projects

assessing cloud seeding technology for sub-tropical Queensland

The special projects theme responds to emerging trends in climate science through strategic and innovative projects and new climate change science initiatives.

# Researching cloud seeding techniques to augment stream in-flows to the dams of south-east Queensland



*The Queensland Cloud Seeding Research Project (CSRP) is investigating whether cloud seeding is a viable option to increase rainfall and consequently stream flow into south-east Queensland's main water storages – the Somerset and Wivenhoe Dams. Even a modest increase in rainfall could significantly increase dam levels due to increases in sub-soil moisture levels, allowing more rain to run off rather than soak into the ground.*

While early analysis of the first season's trials indicate an increase in cloud droplet size and rain cell duration, further analysis and research is required to determine if south-east Queensland would benefit from an operational cloud-seeding program.

Due to increasing demands on water supplies and the negative effects of climate variability and change, Queensland frequently suffers severe water shortages. Recent scientific advances have resulted in cloud seeding being considered as a means of enhancing rainfall throughout south-east Queensland.

Cloud seeding is a weather modification technique that can be used to increase rain and snowfall. Experiments with different seeding techniques have been carried out in various Australian locations since the 1940s, including Queensland during the 1960s.

Based on recent scientific advances in "warm cloud" seeding techniques, a research project was developed during 2007 to investigate the potential for warm cloud seeding in the Somerset and Wivenhoe catchments. (See page 71 on *How cloud seeding works* for an explanation of different cloud seeding techniques).

The aim of the CSRP is to determine if benefits can be achieved in terms of increased rainfall and gains in water storages. Even a modest improvement in rainfall over the dam catchments can

increase sub-soil moisture levels and in turn dam in-flows. The outcomes of this project will help inform a decision on investing in long-term capability in cloud seeding for Queensland and will contribute to national level interest on this issue.

The objectives of the CSRP are to:

- establish the amenability of south-east Queensland clouds to cloud seeding
- assess the potential of cloud seeding on a catchment scale in south-east Queensland
- investigate the meteorology and climatology of the south-east Queensland including the level of pollutants and aerosols in the atmosphere .

The field program for 2007–08 finished at the end of March 2008. The field program for 2008–09 is due to commence during September 2008. Due to the large volume of aircraft sensor and radar data collected, scientific analysis will continue for some time after the field program is completed.

Preliminary results from season one have also resulted in:

- an improved understanding of the "background" climatological conditions for south-east Queensland
- new developments in understanding cloud chemistry, cloud physics and microphysical processes related to cloud seeding

*Cloud seeding research project team: top to bottom, David McRae, Li Fitzmaurice, David Cameron (not pictured), John Mullins (not pictured)*

- improved radar and software systems that will have benefits beyond the cloud seeding research program in improving severe thunderstorm warnings for south-east Queensland.

While further analysis and research is required to discover whether south-east Queensland atmospheric conditions will support an operational cloud-seeding program, Queensland's CSRP is building the Centre's research capacity and expertise in areas such as cloud physics, radar technology, project management and atmospheric research. This will be valuable in future state, national and international collaborations investigating possible climate change adaptation strategies.

The project is delivered with technical support and advice from the CSIRO, the Australian Bureau of Meteorology, the University of Southern Queensland and the National Centre for Atmospheric Research (USA).

## HOW CLOUD SEEDING WORKS

The aim of any cloud seeding is to increase the growth rates of small cloud droplets (either as ice or liquid) into large and heavy rain drops that fall out of the cloud and reach the ground. There are two basic types of cloud seeding.

1. Cold cloud seeding or glaciogenic seeding involves the introduction of ice nuclei such as silver iodide or a cooling agent such as dry ice to encourage the formation and growth of ice crystals. Silver iodide is used as it has a similar structure to ice crystal and has been found to be highly efficient. The ice crystals then grow in size until they become heavy enough to fall and melt into raindrops.
2. Warm cloud seeding or hygroscopic seeding involves the introduction of extremely moisture absorbent material such as salt or other hygroscopic particles into the base of convective clouds. In convective or warm clouds, water vapour tends to condense around particles such as dust, smoke and pollution present in the air to form cloud droplets. These particles are called cloud condensation nuclei or CCN.

Warm cloud seeding increases the amount of CCN in a cloud, which in turn increases the rate at which cloud droplets turn into rain.

While warm cloud seeding is the primary method used in south-east Queensland the potential for cold cloud seeding is also being investigated.



# The Queensland–China Climate Change Fellowship Program

*A group of delegates from the Yellow River Conservation Commission visit the QCCCE's Toowoomba office*

The Queensland–China Climate Change Fellowship Program is a joint initiative of the Queensland Government and the Ministry of Science and Technology, Beijing, the People's Republic of China.

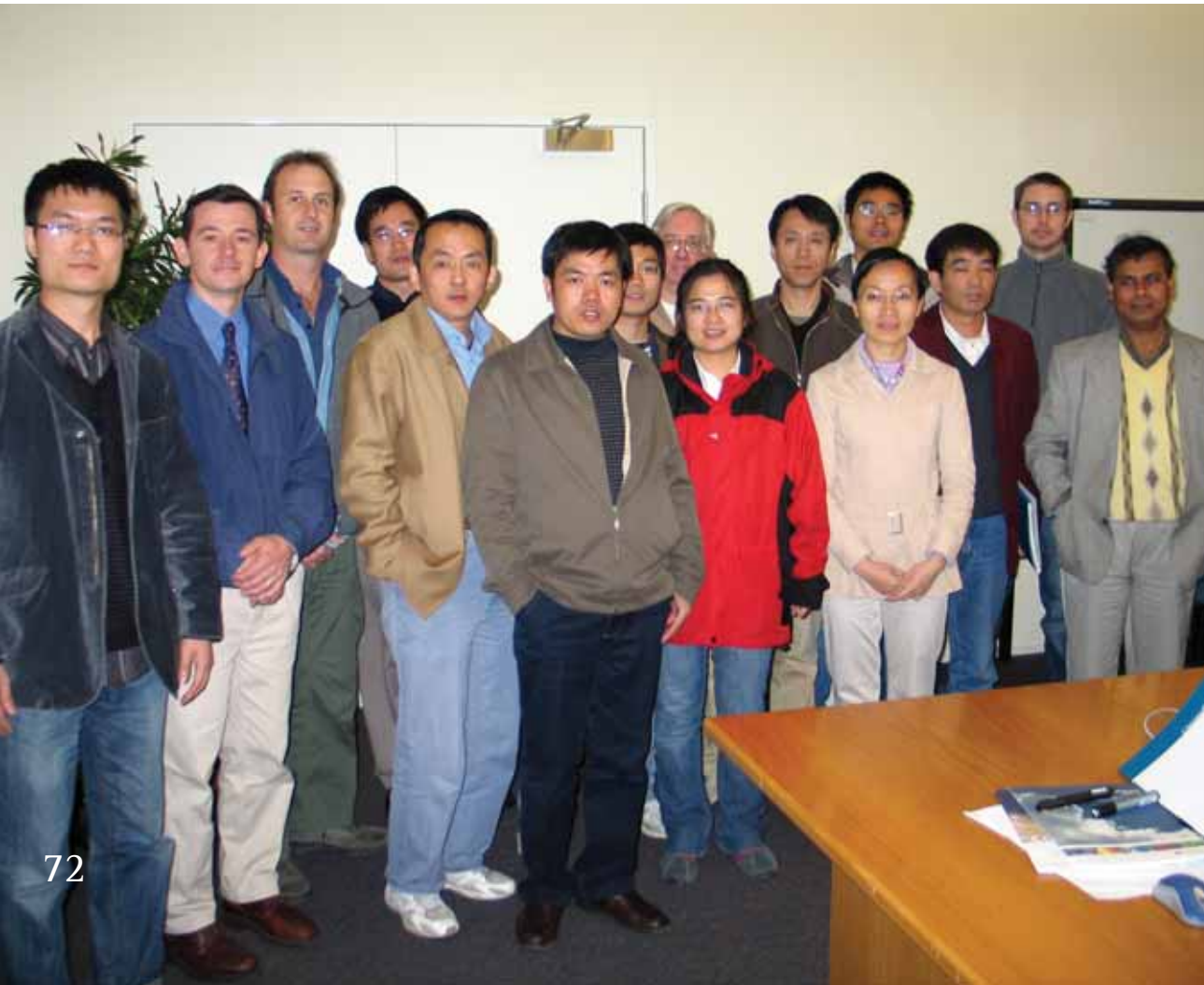
Through the Fellowship Program Queensland and Chinese researchers and other professionals will be able to participate in a short-term reciprocal exchange to develop projects, share knowledge and ideas, cultivate strategic links and improve mutual understanding of climate change, its potential impacts, mitigation strategies and adaptation responses.

The QCCCE works closely with International Collaborations in the Department of the Premier and Cabinet to manage the Climate Change Fellowship Program.

Six Fellowships are offered each year (three to Queensland scientists and three to Chinese scientists). Applications for the first year of the Fellowship Program (to be awarded in 2008) closed on Monday, 30 June 2008. Eleven applications were received from Queensland scientists. Three Queensland recipients have been selected and will be matched with Chinese researchers interested in pursuing related climate change science.

To be eligible applicants need to be:

- a citizen of either Australia or China
- be employed by a Queensland and or Chinese Government state and local agency, research or educational institution (including universities, research institutes) or private industry or be currently studying at a Queensland or Chinese education institution
- be nominated by their home organisation to participate in the exchange.



Recipients were selected on the feasibility of the application and relevance and value of the application in addressing:

- perceived research needs or gaps in knowledge regarding the environmental, economic and social impacts of climate change
- informing the applicant's respective government's response to climate change
- fostering an interchange of knowledge and skills which benefits Queensland and Chinese institutions, government and the broader community
- contributing to the future work of the applicant by advancing their knowledge, skills development and professional linkages.

The 2008 Fellowship recipients will be working on the impacts of climate change on the management of grazing lands and native grasses in Queensland and China, the impacts of climate change on water resource planning, allocation and cleaner development.





# 6 Future directions for the QCCCE

The Queensland Climate Change Centre of Excellence (QCCCE), as an integral part of the Office of Climate Change, will continue to strengthen the state's leadership in climate change issues. It will be an ongoing focal point for the provision of Queensland-specific climate change science and will provide information on the impacts of climate change on the community, the economy and the environment.

The QCCCE will continue to build its expertise in providing a solid evidence base to inform Queensland's responses to the challenges of climate change. Since its formation, the QCCCE has provided the Queensland Government with the internal capacity to ensure that government policies, programs and initiatives are informed by the most reliable and up-to-date climate science, providing an understanding of the key drivers of Queensland's climate as well as information on the likely climate change impacts in Queensland.



*Directorate: (top to bottom, left column) Lynne Turner (Director), Paul Pinjuh, Susan Fahir, (right column) Anthony Corcoran, Karen Taylor, Christine Phillips*

Historically, the Queensland Government's climate science expertise has addressed the issues of climate variability arising in the agricultural and water resource management sectors. These remain important areas for government attention, and the Centre's activities will continue to provide data and information to support agencies with portfolio responsibilities in these areas. Moving forward, the QCCCE will engage actively with other agencies to ensure appropriate consideration of climate change issues across a range of sectors. The Centre will work to improve whole-of-Queensland Government climate science and information service delivery.

The QCCCE was formed in March 2007 and opportunities remain to enhance some aspects of organisational performance. Additional effort is required to further develop and build the climate science expertise, skills and knowledge of our people, the team as a whole and key partners. This will help to ensure that targeted, high-quality information, advice and support is available to the Queensland Government, industry sectors, business and the community to better understand and manage the risks associated with a changing climate.

Key activities in the 2008–09 financial year will include:

- 1) The provision of the most up-to-date climate change scenarios, where possible downscaled to be regionally relevant, to support education, communication, research and planning for the impacts of climate trends and climate change on Queensland. These scenarios will be compiled into the *Climate Change in Queensland: 2008*, prepared in partnership with the CSIRO and will be available to download at [www.climatechange.qld.gov.au](http://www.climatechange.qld.gov.au)
- 2) Informing targeted impact studies on priority sectors and whole-of-government issues such as considering climate change in the review of the south-east Queensland Regional Plan.
- 3) The implementation of the second season of field operations for the Cloud Seeding Research Program.

- 4) Building regional capacity and understanding of the impacts of climate change in the Pacific Island countries to better enable them to adapt to climate change.
- 5) Broadening the QCCCE's expertise and capacity to provide climate change scientific advice. This extended scientific capacity will focus on meeting the *Towards Q2* targets and supporting the priority sectors and projects identified through the review of the Queensland Government *ClimateSmart 2050* strategy, to commence in September 2008. The QCCCE has commenced projects to provide seasonal climate assessments, climate change information, analyses and projections to sectors other than agribusiness. Examples include assessing the impact of climate change on Queensland's regional water resources and producing regional climate change projections in collaboration with CSIRO. QCCCE will also cooperate with CSIRO to prepare climate model projections for the next IPCC assessment report (Fifth Assessment Report). Biosequestration will be another priority area, with QCCCE broadening its scope to focus on a range of potential projects to isolate and store carbon using biological processes.

Over coming years, the QCCCE will continue to:

- maintain and develop high quality climate datasets and biophysical models, and support the consideration of climate change in the modelling tools and decision-making processes of others
- provide information on the impacts of climate change scenarios on biodiversity, natural resources, community infrastructure and social services
- provide up-to-date information on impacts and adaptation to local governments, industry and communities
- ensure productive linkages with key stakeholders and collaborators in the delivery of climate science information products.

The QCCCE will continue to build its relationships with key national and international climate science organisations. Examples include the CSIRO, the Australian Bureau of Meteorology, the UK Meteorology Office Hadley Research Centre, the Walker Institute at Reading University, the European Centre for Medium Range Forecasting (ECMWF), key agencies within the United Nations (for example the UN World Meteorology Organisation Commissions for Climatology and Hydrology) and the International Research Institute for Climate and Society.

Ultimately, the value of the QCCCE will be assessed on the extent to which the Centre's climate science capability was able to inform decision-making processes and assist Queenslanders to better understand, manage for and adapt to climate change. The Centre's activities moving forward will remain focused on meeting this important challenge.

*The QCCCE team, June 2008*







# Appendices

## Appendix 1 Key collaborations and *ClimateSmart* actions addressed by QCCCE projects

Project	Page	<i>ClimateSmart</i> Actions	Key Collaborations	Contact person
<b>Theme 1 Climate systems research</b>				
Atmospheric Circulation Reconstructions over the Earth	10	2 (details of all <i>ClimateSmart</i> are given after this table)	Hadley Centre for Climate Change	Jozef Syktus
The Climate of the 20th Century Project	12	1, 2	Hadley Centre for Climate Change, (Meteorological OFFice, UK)	Jozef Syktus
Developing the capacity to predict floods and storms	13	1,2	Hadley Centre for Climate Change, (Meteorological Office, UK),	Allyson Williams allyson.williams@climatechange.qld.gov.au
Tailoring global climate change projections to the Australian region	14	1, 2	CSIRO	Jozef Syktus
Management of climate models	16	2	CSIRO	Stephen Jeffrey stephen.jeffrey@climatechange.qld.gov.au
What has driven the decline in Queensland's rainfall over recent decades?	17	1	CSIRO	Jozef Syktus
Assessing the impact of climate change on Queensland's regional water resources	19	1, 3,15	NRW, Australian Bureau of Meteorology (ABoM), CSIRO	Jozef Syktus
Delivery of climate change projections for Queensland	20	1, 2	CSIRO	Jozef Syktus
Land clearing triggers hotter droughts	21	1, 2	CSIRO	Jozef Syktus
Collaboration with Walker Institute	22	1, 2	Walker Institute for Climate System Research (Reading University, UK)	Jozef Syktus
The latitude of the subtropical ridge	24	2, 3, 4, 6, 11, 25, 28	University of Southern Queensland	Allyson Williams
Global and regional drivers of climate change and variability in Queensland	26	3,4		Norman Treloar norman.treloar@climatechange.qld.gov.au
Assessing the value of trees in sustainable grazing systems	27	4, 11, 45, 48	MLA, Rural industries research and development corporation (RIRDC)	Greg McKeon
Improving prediction of the northern Australian wet season	29	1, 2, 14, 22, 24, 25, 26, 28, 45, 48	Centre for Australian Weather and Climate Research (CAWCR), National Climate Centre, ABoM (NCC)	Alexis Donald alexis.donald@climatechange.qld.gov.au
<b>Theme 2 Climate change impacts and applications</b>				
Assessing the effects of climate change on Queensland's grazing lands and grassland ecosystems	33	4, 23, 25, 28, 43, 44, 45, 49	Meat and Livestock Australia (MLA), QDPI&F, CSIRO	Greg McKeon greg.mckeon@climatechange.qld.gov.au
Climate change and natural resource management in Australia's grazing lands	34	4, 23, 25, 28, 43, 44, 45, 48, 49	Land & Water Australia Ltd (LWA)	Greg McKeon

Project	Page	ClimateSmart Actions	Key Collaborations	Contact person
Reducing the uncertainty in the assessment of the Australian spanner crab fishery	35	4, 25, 28, 44, 45, 49	Southern Fisheries Centre QDPI&F, Spanner Crab Stock Assessment Group (SAG), Fisheries Research and Development Corporation (FRDC – funding)	Allyson Williams
Seasonal climate forecasting for better irrigation assessment in Lombok	36	4, 15, 25, 51	Australian Centre for International Agriculture Research (ACIAR – funding), The University of Mataram (Indonesia), Latrobe University	Yahya Abawi yahya.abawi@climatechange.qld.gov.au
Using water balance modelling software to make decisions about crop choice and mix	38	2, 4, 8, 15, 51, 55	ACIAR	Yahya Abawi
Applying climate predictions to adapt to climate variability and change in Pacific Island countries (PICs)	39	2, 4, 8, 25, 51, 55	NCC (ABoM), National Institute for Water and Atmospheric Administration (US), East West Centre, meteorological centre in the participating PICs , funding from AusAID through ABoM	Yahya Abawi
The use of seasonal climate forecast for managing water supply	41	2, 4, 8, 15, 51, 55	ABOM, funding from AusAID through ABoM	Yahya Abawi
<i>CropOptimizer</i> : A climate-based software product to support decisions about crop choice and mix	42	2, 4, 8, 25, 51, 55	Australian Centre for International Agricultural Research (ACIAR – funding), The University of Mataram (Indonesia), Latrobe University	Yahya Abawi
Predicting the onset and severity of malaria epidemics in the Solomon Islands	43	2, 4, 8, 51, 57	ABOM, Solomon Islands Medical Research Institute, funding from AusAID through ABoM	Yahya Abawi
Climate impacts on aquaculture: developing methods and industry awareness	44	4, 25, 28, 44, 45	QDPI&F (Walkamin and Townsville)	Allyson Williams
Climate change impacts on livestock carrying capacity across Australia	45	2, 6	CSIRO, Garnaut Climate Change Review	Greg McKeon
Adaptation to climate change in regional natural resources management (including case studies)	46	1, 3, 4, 15, 21, 24, 25, 45, 48, 49, 50	Land & Water Australia (LWA)	Xike Zhang xike.zhang@climatechange.qld.gov.au
Interactions between soil, rainfall, land management and resilience to climate change	48	22, 24, 25, 45, 48	Meat and Livestock Australia (MLA)	Grant Fraser grant.fraser@climatechange.qld.gov.au
Developing a tool to help industries learn about and adapt to climate change impacts	50	4, 22, 23, 24, 25		Grant Stone grant.stone@climatechange.qld.gov.au
<b>Theme 3 Information and knowledge systems</b>				
Assisting Queensland’s primary producers with “Exceptional Circumstances” applications	55	4, 22	QDPI&F	Ken Day ken.day@climatechange.qld.gov.au
AussieGRASS Environmental Calculator	56	4, 6, 7, 15, 22, 23, 24, 25, 44, 45, 48, 49, 50		Ken Day
Using AussieGRASS to investigate the effects of increased atmospheric carbon dioxide on ecosystems	58	25, 45, 48		John Carter john.carter@climatechange.qld.gov.au

Project	Page	ClimateSmart Actions	Key Collaborations	Contact person
Managing and extending the SILO database	59	1, 2, 3, 4, 7, 15, 21, 25, 29, 30, 45, 48	ABoM	Alan Beswick alan.beswick@climatechange.qld.gov.au
Providing managers of Queensland's rural leasehold lands with tools to assess land condition and adapt to climate change	60	25, 45, 48	DNRW	Ken Day
Developing new tools for producing Queensland's seasonal climate outlooks	62	4		Ken Day
Application of Seasonal Pacific Ocean Temperature Analysis (SPOTA-1)	63	4		Ken Day
Communicating climate change	64	6, 7		Ken Day
State of the Environment Report	66	6		Stephen Jeffrey
Development of a high performance computing infrastructure	67	1		Stephen Jeffrey
Management of datasets from the Intergovernmental Panel on Climate Change (IPCC)	67	1		Stephen Jeffrey
<b>Theme 4 Special projects</b>				
Researching cloud seeding techniques to augment stream in-flows to the dams of south-east Queensland	70	15, 16, 19	National Centre for Atmospheric Research (NCAR) USA, CSIRO, ABoM, University of Southern Queensland (USQ)	David McRae david.mcrae@climatechange.qld.gov.au
The Queensland-China Climate Change Fellowship Program	72	2	Department of Premier and Cabinet, Chinese Ministry of Science and Technology	Lynne Turner Lynne.turner@climatechange.qld.gov.au

### ClimateSmart Adaptation 2007–12 Actions

A list of climate change adaptation actions, extracted from *ClimateSmart Adaptation 2007–12* action plan for managing the impacts of climate change, is given below. Please refer to the original document for the list of agencies responsible for carrying out each action. Those listed for action by the QCCCE are followed by an asterisk.

1. Prepare regional-scale climate change projections for priority areas, to offer more localised information for planning and decision making. 'Downscale' the broad climate change projections currently provided to enable assessments of the impacts of climate change.\*

2. Access the best available climate change science, projections and data by maintaining and enhancing national and international research collaborations with agencies such as: • CSIRO • Bureau of Meteorology • International Research Institute for Climate and Society • Hadley Centre of the UK Met Office.\*

3. Prepare a climate change vulnerability assessment of Queensland's regions and sectors.\*

4. Build the capacity of priority sectors to avoid, reduce and manage the impacts of climate change by:

- identifying critical information gaps in the understanding of climate change impacts
- communicating scientifically based information about climate trends, climate change projections, and potential impacts through various means (internet, regional briefings, interviews)
- developing decision-support tools for risk assessment, including tools for determining the costs and benefits of adaptation options
- facilitating sector-based risk assessments and response plans.

5. Support research into climate change impacts through the Growing the Smart State–PhD Funding Program, and ensure research findings are communicated to the relevant areas of government and the community.
6. Develop and disseminate public information materials about the potential impacts of climate change and recommended responses. Provide more specific information for vulnerable groups within the community as required and develop and implement stage 1 of the ClimateSmart Living campaign educating residents about the impacts of climate change.\*
7. Develop a web portal to provide a single point of access to:
  - Queensland Government climate change information and science
  - tools for self-assessment of risk and vulnerability to climate change.\*
8. Qualitatively assess what core Queensland Government business is at risk from climate change and propose possible responses.\*
9. Explore ways of incorporating climate change in the terms of reference for environmental impact statements and other relevant assessment processes.\*
10. Contribute to the establishment of the national meta-database of climate change information, research, and adaptation actions.\*
11. Establish a network for Queensland climate change professionals to transfer knowledge, skills and experience, and to help build capacity in adapting to climate change.\*
12. Develop performance indicators for meaningful reporting on the progress of actions in *ClimateSmart Adaptation 2007– 2012*.\*
13. Contribute to the implementation of the Council of Australian Governments National Climate Change Adaptation Framework.\*
14. Contribute to collaborative climate change actions on biodiversity, agriculture, coasts and water being undertaken through the Natural Resource Management Ministerial Council.\*
15. Integrate climate change considerations and new projections into:
  - decisions about water infrastructure
  - water-quality management of dams and reservoirs
  - water planning (including water resource plans, resource operations plans, and regional water supply strategies) and water-quality improvement programs.
16. Diversify water-supply sources to reduce dependency on vulnerable supplies. This requires:
  - considering climate change in regional water security plans
  - investigating the potential of less climate-dependant water supply options.
17. Promote water-use efficiency by encouraging and supporting:
  - lower water consumption through water-efficient technologies and practices
  - installation of water-efficient devices through rebate or subsidy schemes
  - the development and adoption of better water-saving devices.
18. Further explore the use and management of recycled water on state-controlled roads in construction sites.
19. Continue with the joint NRW–AGO–BoM project to assess required changes to Probable Maximum Precipitation (PMP) estimates due to climate change.
20. Continue to apply water management strategies in government-owned buildings, including fitting water-efficient devices.
21. Integrate downscaled and regional climate change projections into hydrological models for water planning and assessment of changes in flood risk for urban and infrastructure planning.\*
22. Continue to work with the agribusiness sector to have climate change considerations included in farm management systems and whole-of-property risk planning.\*
23. Explore opportunities to continue the climate workshops held for the agricultural sector.\*
24. Continue research and development into farming practices affected by changed conditions to enhance market competitiveness.
25. Develop commodity-specific forecasting models for climate change scenarios at a regional scale. Assess the impacts of climate change on farm performance and quantify management options for climate risk (both climate variability and climate change).\*
26. Implement actions to fulfil Queensland's responsibilities in the *National Agriculture and Climate Change Action Plan*.
27. Undertake literature reviews/desktop research to determine suitable plant varieties (e.g. wine-grape varieties) for Queensland regions in a changed climate.\*
28. Maintain and build national research and development partnerships such as the Agricultural Production Systems Research Unit, to generate knowledge of the impacts of climate change on various agricultural commodities, and to assess adaptation options.\*

29. Improve understanding about the risks and impacts of climate change to coastal Queensland:

- continue storm-tide and wave monitoring systems
- improve projections of inundation and flooding due to changes in sea level and extreme events
- work with local government to identify and map areas most at risk from storm tides
- integrate the information gained into advice and tools (e.g. digital elevation modelling of coastal Queensland).

30. Contribute to the development of a Queensland Local Government Climate Change Management Strategy.\*

31. Ensure regional planning activities under the *Integrated Planning Act 1997* draw together state and local government responses to climate change, including the:

- 2010 review of the SEQ Regional Plan
- Far North Queensland Regional Plan.

32. Incorporate changes in flood risk due to climate change in the proposed State Flood Risk Management Policy, local government floodplain management plans and relevant state guidelines.

33. Update the *Queensland Urban Drainage Manual* as needed to reflect changes in hydrology associated with climate change.

34. Periodically review physical infrastructure to determine:

- the extent to which climate change may affect operational performance
- whether measures are needed to ensure system durability, safety and reliability.

35. Review the effectiveness of existing planning tools in addressing the increased risks from climate change, including the:

- *State Planning Policy 1/03: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*
- *State Coastal Management Plan*
- local government planning schemes.

36. Review planning guidance given to local government on shoreline erosion management to ensure it integrates climate change, and establish an associated grants scheme.

37. Promote and ensure continual improvement in climate-sensitive design in the building sector through:

- the *Smart and Sustainable Housing* program;
- the *ClimateSmart Living* program;
- updating building codes as required.

38. Review the capacity of Queensland's existing energy infrastructure to cope with climate change.\*

39. Work with energy suppliers and network managers to ensure networks can cope with increased peak demand during higher temperatures and more heatwaves.

40. Include climate change considerations in programs designed to improve the appeal and amenity of public transport.

41. Advance *Smart Travel Choices for SEQ* to encourage the community to replace some of their car journeys with walking, cycling or public transport, and help traffic and freight move more efficiently.

42. Incorporate the latest technical information, such as the Australian Rainfall and Runoff Data, in risk assessment prior to designing and planning roads, bridges and other transport infrastructure subjected to flood and heat stress.

43. Review available options and mechanisms to manage the impacts of climate change on Queensland's at-risk ecosystems.\*

44. Identify critical information gaps in the understanding of the impacts of climate change on biodiversity, and identify the priorities for research.\*

45. Develop climate change information and advice in a form that can be effectively included in conservation and natural resource management programs such as:

- protected-area planning, design and management
- corridor and landscape planning
- species management and planning
- private land conservation initiatives
- regional natural resource management planning
- pastoral leasehold land management
- water-quality improvement planning.\*

46. Continue to implement Queensland's responsibilities in the *National Biodiversity and Climate Change Action Plan*, including review of the plan during 2007.\*

47. Work with the Great Barrier Reef Marine Park Authority to implement joint initiatives that address climate change in the Reef region.\*

48. Undertake qualitative assessments, monitoring and modelling of the likely impacts of climate change on vegetation types, grazing land and cropping land. Advise and help landholders to manage changing landscapes.\*

49. Work with regional NRM (natural resource management) bodies to:

- communicate the best available information about climate change projections and potential impacts
- ensure climate change issues are considered in the next review of regional NRM plans and investment strategies.\*

50. Improve models for sediment movement and salinity intrusion in coastal and riverine environments to ensure they incorporate:

- sea-level rise
- increases in rainfall intensity
- changes to sediment supply
- impacts on engineering, nourishment and other management measures.\*

51. Build the capacity of disadvantaged communities to effectively respond to the potential social and economic impacts of climate change.\*

52. Continue to provide planning and emergency management advice on storm tides, and investigate whether measures are adequate for the next 30 years.

53. Ensure that reviews of local disaster management plans include relevant climate change issues.

54. Implement actions from the 2006 Cyclone Summit, namely:

- provide households in a cyclone-prone area from Fraser Island to Cape York with the *Preparing for cyclones* booklet
- undertake a feasibility study of a mass alert system that uses SMS and email to advise the community about approaching natural disasters
- assist local governments in cyclone-prone areas with funding to prepare long-term shoreline erosion management plans
- hold a yearly 'Cyclone Preparedness' summit
- provide extra funding to help local councils rebuild after natural disasters
- deliver the *Cyclone Recovery and Renewal – Economic and Business Strategy* in North Queensland, including a natural disaster resilience kit for business operators
- carry out the *Improving Indigenous Communities' Resilience to Natural Disasters* project.

55. Extend 'preparedness and awareness' programs to communities where the risk of extreme climatic events has increased.

56. Review the *Queensland Heatwave Response Strategy* to ensure it appropriately considers climate change.

57. Continue to invest in the prevention of mosquito-borne diseases, which includes:

- disease surveillance and response
- mosquito surveillance and control
- public education and awareness campaigns
- management strategies for emerging risks due to climate change.

58. Through the Queensland Tourism Strategy, develop an online Best Practice Sustainable Tourism package that includes advice for businesses on:

- best practice in environmental tourism and cultural heritage management
- best practice in sustainable tourism infrastructure design
- sustainable tourism principles and their commercial application
- reducing waste, water use and energy consumption to decrease greenhouse gas emissions
- identifying and responding to climate change impacts
- benchmarking suitable accreditation programs.\*

59. Review and update the ecoBiz program to ensure it promotes adaptation to climate change.

60. Continue to support energy- and water efficiency innovations through the Queensland Sustainable Energy Innovation fund and the ecoBiz program.

61. Work with the insurance and finance sector to develop a better understanding of the risks and potential costs of climate change.\*

62. Identify, evaluate and create momentum for investment and business opportunities for Queensland from climate change.



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