

**AUSTRALIA'S CLIMATE CHANGE SCIENCE
PRIORITIES**

2008 AND BEYOND

**BUREAU OF METEOROLOGY-CSIRO WORKSHOP
REPORT**

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Australia's climate change science priorities 2008 and beyond

Bureau of Meteorology – CSIRO workshop report

SUMMARY

In late 2006, senior researchers from the Bureau of Meteorology and CSIRO met to discuss and determine Australia's future climate change science needs. The group considered the key scientific questions and issues faced by Australia arising from climate change, and the climate change science needed to address these issues.

Participants identified the following key questions:

What is the state of Australia's climate now, and what will Australia's future climate be like, especially climatic extremes including droughts, heat waves, tropical cyclones and floods?

What are the likely impacts of climate change on important sectors such as water resources, agriculture, human health, the environment and infrastructure?

What is the vulnerability of our natural systems, including iconic ecosystems such as the Great Barrier Reef and Kakadu?

What are the implications of climate change on regional security?

How can we best adapt to climate change to ensure the sustainability of our agricultural, environmental, social and other systems?

What are the interactions between climate change, climate variability and extremes?

What constitutes 'dangerous' climate change?

The following scientific research activities are needed to help answer the important questions posed above:

- 1. Improve documentation and understanding of past climatic changes and their impacts*
- 2. Maintain high quality monitoring of the Earth's climate system, especially in the Australian region*
- 3. Improve our understanding of processes important for climate and climate change*
- 4. Improve our capacity to simulate the Earth's climate system*
- 5. Develop better climate change projections for Australia, especially of extreme events*
- 6. Improve estimates of the likely impacts of climate change on Australia*
- 7. Improve climate change risk management through adaptation and mitigation.*

Researchers identified the activities listed below as vital.

- Improve monitoring of global and regional climate and the incorporation of data into climate models, particularly data derived from satellites and other remote sensing tools.
- Improve our ability to monitor and simulate the earth's climate system, extending our capacity beyond the atmosphere, ocean and cryosphere. The Australian Community Climate and Earth Systems Simulator (ACCESS) offers the chance to dramatically improve our capacity to study and project climate in our region.
- Increase the accuracy of regional climate change projections, and projections of extreme events such as droughts, floods, storm surge and tropical cyclones.
- Generate shorter-term projections (say, a decade hence) as well as multi-decadal projections.
- Improve our ability to model the impact of projected climate change on economic, agricultural, hydrological, natural resource and other systems.
- Identify systems that are most vulnerable, and the associated 'tipping points', at which climate change becomes dangerous.
- Maintain strong and productive links with key decision makers and policy makers in the wider community to guide our research and to maximise benefits to Australia.
- Provide targeted climate information needed for effective adaptation and mitigation strategies.

Priorities and opportunities for research in each of these areas are listed in the body of the report.

BACKGROUND

For more than two decades, Australian researchers have made profound contributions to understanding the enhanced greenhouse effect. There have been world-leading atmospheric monitoring programs, assessments of biospheric emissions and uptake of greenhouse gases, oceanic studies, extensive model development and application, advances in our understanding of how the earth's climate system operates, projections of how Australia's climate will change in the decades ahead and numerous examinations of the likely impacts of climate change.

Australia is a unique environment and has its own distinctive human and natural systems. Our climate change research has been aimed primarily at meeting the nation's requirements, while at the same time being a leading force in contributing to understanding how the southern hemisphere influences, and is influenced by, rising atmospheric concentrations of greenhouse gases.

As Australia's resources are limited, science activities must be prioritised to maximise their benefit. A focus must be on distinctive regional processes that drive and influence our climate, as these receive limited attention from overseas groups.

One way of enhancing the value of Australian research is to contribute to, and draw upon, the finest international science. Our researchers collaborate strongly with overseas colleagues. We make regular contributions to the assessments produced by the Intergovernmental Panel on Climate Change. We also draw upon on global research findings and judiciously apply and incorporate climate model advances.

Climate change cannot be addressed in isolation. It is but one component of endeavouring to achieve a sustainable environment. To this end, science needs to have strong links with economic, planning, social sciences and other disciplines, to provide information and advice that will best serve policy makers and stakeholders.

Fundamental questions, which science can help answer, include determining the balance between investment in reducing greenhouse gas emissions and investment in adaptation measures.

INTRODUCTION

The awareness of climate change as an issue in the wider community and the demand for information on climate change from our agencies has increased dramatically in recent times. This growth in demand, together with the emergence of ACCESS, and the likelihood of a joint research facility involving CSIRO and the Bureau, make it timely that our two agencies jointly consider future directions in climate change research.

Some 50 senior researchers from the Bureau of Meteorology and CSIRO met in Marysville in Victoria on 31 October and 1 November 2006, to discuss Australia's future climate change science needs. The group considered the key issues facing Australia arising from climate change, and the climate change science needed to address these issues. Particular attention was paid to emerging opportunities in climate change research.

Information from the workshop will contribute to planning for the Australian Climate Change Science Program (<http://www.greenhouse.gov.au/science/accsp/index.html>), the National Climate Change Adaptation Program (<http://www.greenhouse.gov.au/impacts/index.html>), and to climate research planning in other programs and in CSIRO and the Bureau generally. The many suggestions documented below provide a valuable list of possible activities and directions. Further prioritisation will occur within CSIRO and the Bureau in the months ahead.

THE KEY CLIMATE CHANGE QUESTIONS FACED BY AUSTRALIA

Our collective experiences and ongoing consultation with stakeholders from government, industry and the community tells us that the vital questions we need to address include:

What is the state of Australia's climate now, and what will Australia's future climate be like, especially climatic extremes including droughts, heat waves, tropical cyclones and floods?

What are the likely impacts of climate change on important sectors such as water resources, agriculture, human health, the environment and infrastructure?

What is the vulnerability of our natural systems, including iconic ecosystems such as the Great Barrier Reef and Kakadu?

What are the implications of climate change on regional security?

How can we best adapt to climate change to ensure the sustainability of our agricultural, environmental, social and other systems?

What are the interactions between climate change, climate variability and extremes?

What constitutes 'dangerous' climate change?

AUSTRALIAN RESEARCH NEEDED TO TACKLE THESE QUESTIONS

We know that the carbon cycle and its strength affects atmospheric concentrations of greenhouse gases. We also know that as climate changes, so too will various components of the cycle. **Science has an important role in assessing the likely future changes to Australian terrestrial and marine environments and their influences.**

We need to gain a clearer picture of the way in which we are influencing climate. This will be achieved, in part, through improved studies that *detect* the presence and strength of the signal of climate change against the eternal background noise of climate variability.

We need to establish the extent to which the climate system is predictable. An improved capacity to explain past changes using assimilation of historical data will be valuable. It would be beneficial to know, for example, why south-eastern Australia is currently experiencing a protracted drought, why there was a step reduction in rainfall in south-western Western Australia and why rainfall has increased in the north-west of Australia.

We need to better estimate the likely timing, rate and extent of climate change. We also need to know the impacts of changing climate on our environment and human systems. Particularly important will be the impact on water resources and on food security, both domestically and internationally. Little work has been undertaken to assess the impact climate change may have on regional stability, such as the possibility of Pacific island refugees and increased resource disputes.

We need to improve our ability to identify **non-linearities within the climate system.** It is most unlikely that climate will change in a steady, consistent manner. There are likely to be jumps, 'tipping points' and thresholds that will be crossed. There will be a hierarchy of feedbacks that will influence rates of change which **will be crucial to developing effective adaptation strategies**

We need to assess the links between **climate variability, climate change and extremes** to establish likely changes to temperature peaks, heatwave duration, rainfall extremes, hail, tropical cyclones,

storm surges and fire risk. Extremes represent the way in which people, animals and plants will strongly experience climate change.

1. Improve documentation and understanding of past climatic changes and their impacts.

We need to improve our understanding of how Australia's climate has varied in the past, including the variability of climate and responses to climate change over past decades. Better knowledge of past, and current, climate will help us assess likely future changes and their impacts.

- Produce high-quality historical datasets with improved spatial and temporal resolution for a larger number of climatic variables, including wind speed. Include non-traditional observations for both the terrestrial and marine environment, such as timing of events and palaeo-climate data.
- Undertake historical reanalysis of Australia's past climate and of phenomena, such as tropical cyclones and hail.

Key opportunities and challenges

- Use palaeoclimatic data to provide proxy evidence for climate variability and abrupt climate change.
- Examine ecosystem indicators, such as native fauna, vegetation, agriculture and fisheries, in detection and attribution studies.
- Better understand climate variability on a range of time-scales, from interannual through decadal and centennial to geological time-scales.
- Apply climate models to investigations of pressing questions, such as determining the likely cause of the current drought.

2. Monitor the Earth's climate system, especially in the Australian region

Monitoring the climate system represents an essential step to understanding climate and the way it is changing in response to anthropogenic and other forcing. Included here is atmospheric, terrestrial and marine monitoring.

- Provide ongoing support for the Cape Grim Baseline Air Pollution Station, the radiosonde network and access to remotely-sensed data. In particular, recent remote-sensing products such as those provided under NASA's CALIPSO project provide an unparalleled opportunity to study the atmosphere's composition, including aerosols, cloud base and cloud top heights, boundary layer heights etc.
- Expand the existing surface monitoring network to include ground-based radiation measurements (undertaken in harmony with satellite monitoring) and surface aerosol observations.
- Continue to examine cloud and aerosols, and their links to the hydrological cycle.
- Expand the flux tower network, which will be essential to tracking future, changing fluxes of greenhouse gases.
- Review the value of an ecological network, including, say, six indicator species.

- Establish focus study sites for full terrestrial water balance assessments. This should include *in situ* and remotely-sensed hydrological cycle monitoring (ground water, surface water, evaporation, soil moisture).
- Undertake vegetation and land-use measurement and modelling to categorise the influence of changing climate.
- Assess Australia's anthropogenic greenhouse gas emissions and their drivers.
- Conduct baseline monitoring for climate and climate change, both conventional (e.g. meteorological data and streamflows) and non-conventional (e.g. flowering times, breeding dates, normalised difference vegetation index).
- Use surface data to ground-truth remotely-sensed data.
- Monitor and model changes to thermohaline circulation.
- Continue oceanic observation programs such as ARGO, deep ocean sections, especially in the Southern Ocean, and XPT measurements of boundary currents. Explore the deeper ocean and variables in addition to temperature and salinity.
- Continue to observe the cryosphere.
- Continue ongoing measurement of sea level using both *in situ* and remotely sensed data.
- Conduct ocean data reanalysis.

Key opportunities and challenges

- Employ new datasets – terrestrial, marine, atmospheric, biological, including remotely-sensed data.
- Establish a tropical baseline observatory and a small network of terrestrial carbon dioxide and methane samplers.
- Review and expand the coverage of terrestrial observations, including vegetation condition and species composition; soil properties; water quantity, quality, stores, surface and groundwater.
- Expand measurements in the Coral Sea and Eastern Australian Current.
- Monitor oceanic carbon chemistry, including uptake and release of carbon dioxide, and the chemistry of oxygen, iron and other trace elements. The focus to be on key regions, including the Great Barrier Reef and the Southern Ocean.

3. Improve our understanding of processes important for climate and climate change.

There are a number of climatic processes that have potential to ameliorate or accelerate climatic change. A better understanding of these processes will provide us with stronger insights into likely future changes, including the potential for 'tipping points'. Climatic changes themselves may influence the nature and strength of important climatic processes.

- Improve our understanding of, and our capacity to model, the El Niño – Southern Oscillation, the Indian Ocean Dipole and the Southern Annular Mode, and their influences in a changing climate.

- Determine the role of aerosols, cloud changes and radiation changes in mediating and modulating climate change. This includes establishing the sensitivity of warming to cloud changes and the impact on Australia of the Asian haze.
- Establish major oceanic influences on Australian climate, including the Southern Ocean, boundary currents, and sea-ice-ocean interactions.
- Continue to support studies into tropical convection, monsoons, and tropical cyclones. A wealth of Australian-based data has recently been gathered during the Tropical Warm Pool International Cloud Experiment
- Maintain a focus on the processes which affect glacial melt, changes in Greenland and Antarctica and their impact on sea-level.

Key opportunities and challenges

- Assess the response of the marine and terrestrial carbon cycle to climate change and how changes to the carbon cycle will affect climate.
- Improve understanding of the hydrological cycle
- Determine the impacts of stratospheric ozone reduction on our climate and assess the impact of atmospheric warming on ozone recovery.
- Identify climate thresholds and critical non-linearities.

4. Improve our capacity to simulate the Earth's climate system.

A sophisticated global and regional climate modelling system is needed to develop Australia's modelling capability to provide, amongst other things, high quality probabilistic risk assessments of climate change impacts and adaptation strategies.

- Test the ability of climate models to accurately simulate Australia's past climate at a regional scale (e.g. the rainfall decline observed over southern and eastern Australia, and the rainfall increase over the northwest).
- Apply climate models to investigations of pressing questions, such as determining the likely cause of the current drought.
- Undertake long model runs to provide insights into natural climate variability
- Develop and test land-biosphere and land-surface schemes, improve cloud and aerosol parameterisations, convection treatment, assessments of the terrestrial carbon cycle, fire, dynamic vegetation, nitrogen and phosphorus cycles, ground cover, albedo, dust and aerosols, and hydrology.
- Identify variables that are not included in climate models to improve performance, such as an interactive carbon scheme.
- Reduce climate model uncertainties through understanding and reducing the range of modelled climate sensitivity and feedbacks, with respect to the physics of water vapour, clouds and radiation; the ocean carbon cycle; and natural sequestration.
- Ensure that the assessment of models remains a high priority.

- Undertake long model runs to provide insights into natural climate variability.
- Engender better linkages between climate model designers and users.
- Model future greenhouse gas emissions

Key opportunities and challenges

- Develop a comprehensive Earth system model (ACCESS).
- Improve climate models for regional scales, especially for simulations of the next 10-20 years.
- Develop ice sheet and sea-ice models that reveal how sensitive Australia's climate is to changes in Antarctica.
- Develop and test applications such as land-surface modelling for better and more sophisticated agricultural modelling, and improve the coupling between climate and hydrological models
- Provision of advice regarding managing rapid climate change
- Model changes associated with various adaptation strategies.
- Develop cross-sectoral socio-economic modelling to address key questions relating to climate change.

5. Develop better climate change projections for Australia, especially of extreme events

Climate change projections provide one of the most tangible and well-used outputs from Australian climate change research. Surveys in late 2006 reveal a strong demand for regional, clear, probabilistic projections covering time scales from a decade hence. Many of the impacts of climate change will be felt through changes in the frequency of extreme climate events, such as heat waves, heavy rainfall, wind gusts, tropical cyclones, storm tides, fire risk, drought and hail. The community look to us for information on likely changes to both average conditions and extremes, and for the best available estimates of the likely timing, rate and extent of climate change.

- Generate shorter-term projections. There is value in assessments for 2010 as well as for 2100.
- Establish the extent to which the climate system is predictable and use this to improve short-term projections.
- Use dynamical and statistical downscaling techniques to provide regional-scale projections for 2010 and beyond.
- Use ensemble projections to provide probability density functions, including the likelihood of climatic extremes.
- Determine what will happen to climatic extremes, including drought, fires, tropical cyclones, heat waves, frosts and floods.
- Determine how weather systems, including tropical cyclones and tornadoes and storms, will change in the future.
- Develop more effective ways to communicate the meaning, value, accuracy and limitations of projections.

Key opportunities and challenges

- Develop a model evaluation framework, establishing which models best predict recent past climate. Improve the capacity to link what has occurred in the observed record with what will occur in the future (model data fusion).
- Investigate the possibility of rapid climate change – when, where, why and how might it occur

6. Assess the likely impacts of climate change on Australia

Increasingly, researchers will work with professionals with expertise in particular sectors, to apply climate change projections. There is a strong need for well-coordinated impact assessments on a wide variety of natural and human systems.

- Define the vulnerability of Australian systems and identify ‘tipping points’. Give special attention to vulnerable systems including coral reefs, urban and rural water supplies, forests, the marine and terrestrial biosphere, and aquatic environments. Define what constitutes ‘dangerous’ for these systems.
- Undertake ‘Free Air CO₂ Enrichment’ experiments examining the response of plants to higher carbon dioxide concentrations, taking temperature rises and rainfall changes into account.
- Examine climate-induced productivity changes in Australian agriculture, and international productivity changes affecting Australian commodity exports.

Key opportunities and challenges

- Examine the impact of ocean acidification on corals and marine biota.
- Develop a coherent national capability to conduct integrated assessments in identified key areas. Develop a more complete and integrated assessment of likely climate change impacts through fostering interactions between science and other relevant disciplines and the community.

7. Improve climate change risk management through adaptation and mitigation

Climate change researchers are increasingly being called upon to provide information that will inform and underpin planning programs for adaptation to likely future climate change. Mitigation projects may also need observational and modelling tools to verify reductions in greenhouse gas emissions.

- Explore and model the likely future emissions of species that will change due to various mitigation strategies, including moves to a low carbon economy and to a hydrogen economy.
- Contribute to Australian carbon accounting science, including assessing carbon fluxes, mitigation strategies and their likely impacts through input to mitigation strategies.
- Contribute to assessments of global carbon trading, including defining property rights to carbon, emissions verification, climate sensitivity and atmospheric lifetime of greenhouse gases.
- Maintain strong links with key stakeholders, decision-makers, policy-makers and intermediaries in the wider community to ensure that their needs help drive our research.

- Form partnerships when this is the best way of providing the information and data we produce.
- Provide strong advocacy for the need for effective, professional communication of climate change science advances and applications, to stakeholders, collaborators and the public.

Key opportunities and challenges

- Identify and evaluate adaptation and mitigation strategies, including examining any unintended consequences. Link impact assessments to adaptation and mitigation options as integrated response packages, taking into account changes in the environment, demographics; health, markets, political complexion of governments, energy and social factors.
- Provide advice and monitor specific mitigation measures such as geosequestration.

Participants

The following staff from the Bureau of Meteorology and CSIRO participated in the workshop and hence have contributed to this report:

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