Future directions for Australian climate change science

A workshop hosted by

The Australian Academy of Science

in association with the Department of Climate Change, the Australian Bureau of Meteorology and CSIRO

The Shine Dome, Gordon Street, Canberra 12–13 March 2008

Table of contents

Statement by the President

The recent workshop on *Future directions for Australian climate change science* held on 12 and 13 March 2008 brought together leading climate change scientists in Australia to identify the top research priorities for Australia. These proceedings are a record of the discussions.

The Australian Academy of Science was pleased to host this important workshop at the Shine Dome, in collaboration with the Australian Department of Climate Change, the Australian Bureau of Meteorology and CSIRO. The workshop discussions provided a valuable and timely contribution from Australian climate scientists on how the global climate is changing, and the need for researchers to be able to better monitor and understand the climate so that responses and actions are well-informed.

Australian climate change scientists are recognised for their work in Australia and internationally, including for their contributions to the work of the Intergovernmental Panel on Climate Change, which has assembled much of the collective data on global climate change and future scenarios. The Australian Academy of Science strongly supports the need for a sustainable Australian climate change science program, with the facilities and expertise to provide an improved scientific understanding of the basic processes for determining climate change. This research can then provide the scientific basis to properly understand the impacts for Australia and the region, and to provide reliable advice on appropriate actions by government, industry and the broader community.

The key messages from the workshop speakers included:

- The increasing demands on climate change science and research for Australia and the world to better understand the climate systems, and for the development of appropriate national and global strategies in accord with cyclical and human influences;
- Australia's climate change research needs to be undertaken in collaboration with international research efforts to ensure that our understanding of the climate change impacts for Australia benefits from the global research work;
- Australian climate change research is needed to help inform the policies and strategies by government, industry and the broader community for addressing the impacts of national and global climate change through practical measures for adaptation and/or mitigation; and
- Australians are looking for answers from the research sector to community concerns about the future impacts of climate change on changing weather patterns which could affect our coastline, the Great Barrier Reef, agriculture, water supply and temperature extremes.

The workshop considered that the priorities for climate change research in Australia to address the major challenges required:

- Enhanced capabilities for observing and monitoring climate change on a sustainable basis to understand the more vulnerable aspects of the climate system and the likely thresholds for major changes;

- Significant strengthening of Australian climate modeling systems and capabilities to support the observations, and the need for models to be owned and well understood by the Australian research community;

- Advanced data handling and supercomputing facilities;

- Training and career opportunities for the next generation of climate scientists; and

- The development of a 'National Framework for Climate Change Science' which incorporates interdisciplinary research activities addressing the big challenges that face Australia and the region; essential research infrastructure for observation, modeling and development of climate information systems to inform the development of government policies for adaptation and mitigation; and training and career opportunities for the next generation of scientists.

The Academy was pleased to be associated with this workshop and the initiative by the Department of Climate Change. It provides an overview of the significant research challenges to be addressed for a better understanding of climate change processes, and some priorities for early consideration.

Professor Kurt Lambeck FAA

President, Australian Academy of Science

Workshop objectives

The workshop brought together the Australian climate change science community to express their views about the top research priorities for Australia and to discuss developing a national framework for collaboration.

The workshop was a major step in progressing the recommendations of a review in May 2007 of Australian climate change science, and the Australian Climate Change Science Program. The review was undertaken by Dr Susan Solomon (co-chair of IPCC climate change science Working Group 1) and Professor Will Steffen (Director, Fenner School of Environment and Society, ANU). The review report 'Australian climate change research: perspectives on successes, challenges and future directions' can be found on www.climatechange.gov.au/science/publications

The review concluded that, while Australia makes a substantial contribution to regional and global science, Australian climate change science has reached a critical point where the full capacity and expertise in this country needs to be brought together to meet the climate change challenges before us and support the growing responsibility of leading the science effort in the southern hemisphere.

The review recommended the development of a national framework to provide the structure for collaboration and integration across institutions. The reviewers concluded that a nationally coherent approach to climate change science would enhance synergies between research partners; facilitate more efficient use of scarce research funds; engage new research, management and policy communities needed to design and implement adaptation strategies; and strengthen the global engagement of Australia's scientists in climate change research. The review recognised that a globally networked and effective scientific enterprise is essential to support the global policy process on climate change.

The reviewers saw a pivotal role for a core program, such as the Australian Climate Change Science Program, as a mechanism for integrating the research programs of the major organisations around a set of high-priority, high-level science questions of national importance, and for maintaining links to policy.

The review also pointed to the critical need for an increased and more flexible funding base; the creation of opportunities for young scientists to build stable, long-term career paths; and for the urgent renewal of core infrastructure such as supercomputing for global climate modelling.

Workshop structure

The workshop comprised six sessions over two days. Sessions 1–5 covered broad areas of climate change research, while session six was a more free-ranging session examining funding models, infrastructure support and fostering the next generation of climate change scientists.

Session facilitators were asked to identify teams of research scientists in each area and to nominate a panel member who would speak to each topic. Panel members were asked to consult as widely as necessary among their colleagues with expertise relevant to their topic.

Panel members each gave two-minute presentations, supported by three slides that summarised the issues and implications (local, national and global) arising from research undertaken thus far, and to identify the top research priorities for Australia.

Workshop outcomes

The researchers at the workshop expressed strong recognition of the need for a national climate change science framework that will concentrate research efforts on issues that are important to Australian decision-makers and allow the most efficient use of scarce resources. It was agreed to assemble a small group to prepare a draft framework that will provide a clearer basis for consultation with stakeholders. The Department of Climate Change will be working with key scientists and other stakeholders over the next few months to develop a robust framework driven by policy and stakeholder needs.

Report on Day 1

Professor Michael Dopita, Fellow of the Australian Academy of Science, welcomed participants and introduced the Minister for Climate Change and Water, Senator, the Hon. Penny Wong who opened the workshop.

The first keynote speaker was Dr John Church, Chair of the Joint Scientific Committee of the World Climate Research Programme (WCRP), who spoke about the state of global climate change science and Australia's role. The presentation was based on the WCRP/IGBP report 'Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report' www.igbp.net/documents/resources/Report_58.pdf. He stressed the importance of climate change science to underpin sound decisions on *mitigation* and *adaptation* and to underpin *international negotiations*. Outcomes from the workshop stressed the need for ongoing observations, resolving key scientific uncertainties (for example aerosols, clouds, carbon cycle, ice sheets), completing predictions for the next few decades as well as longer-term projections, much greater computing resources to resolve regional scales, a greater focus on extreme events and an improved Climate Information System to deliver climate information to users.

The second keynote speaker was Professor Will Steffen, Director, Fenner School of Environment and Society, Australian National University. He spoke about the review referred to above to provide a context for following sessions.

Session 1 – Understanding the climate system and climate change

Facilitator:

Dr Chris Mitchell (CAWCR)

Panel members:

Dr Michael Raupach (CSIRO) – Research priorities in the carbon cycle and radiative forcing

Dr Robert Colman (Bureau of Meteorology) – Atmospheric processes – radiation and feedbacks – clouds, water vapour, aerosols and rainfall

Professor Malcolm McCulloch (ANU) – Lessons from the past – thresholds for major 'phase shifts' in the past, where are we now?

Professor Bruce Mapstone (Antarctic Climate and Ecosystems CRC) – The cryosphere

Dr Steve Rintoul (CSIRO) – Ocean processes and climate

Key messages

Demands upon climate change science are set to explode

As people make decisions about the impacts of climate change there will be large and unmet demands on scientific understanding of the major processes within the climate system. Scientists will therefore need to access their 'full toolbox': observations, modelling, process studies and improvements in underlying theory (i.e. theoretical developments are still required). This full toolbox includes palaeoclimatic observations.

We need to observe the real world

We now have the potential to observe the time-evolving state of the atmosphere, oceans and terrestrial surface. There is an urgent need for a 'seamless observatory' for monitoring climate change that is established on a sustainable basis.

One very significant outcome from investing in this way is reduced risk of being caught out by catastrophic surprises[1]. Conversely, by not investing in sophisticated monitoring systems there is a much increased risk of being caught out by such surprises. Studies are thus needed to identify the more vulnerable aspects of the climate system to major catastrophic changes and the likely thresholds for such changes.

Much of the time during the session was spent discussing actual observations because the Australian scientific community perceives the current suite to be at risk. There is a need for improved understanding of water vapour, convection, clouds, radiation and aerosols, South Pacific, Indian and Southern Oceans, modes of variability, ocean acidification, sea level rise, and ice sheet response.

Australia's climate change science framework must be internationally engaged and flexible

Any national climate change science framework needs two attributes: the capacity for international engagement, and flexibility. The first attribute partly exists in current programs, the other barely exists at all.

There are three reasons why it is necessary to more effectively and strategically engage with international climate change science: first, much of the science planning is now being done by

[1] In this context catastrophic surprises are major non-linearities such as rapid discharge/collapse of the ice-sheets, sudden changes in ocean circulation or broad-scale precipitation patterns. That is, events associated with a low or undetermined probability, but understood to have global and far-reaching consequences.

international consortia (WCRP is an obvious example, but there are others); second, work will be done by other nations that has a direct and significant impact on Australia, but in which it is not likely that Australia will have a large and direct stake (e.g. studies into the stability of the Greenland Ice Sheet); and third, Australia must be a contributor in order to reap the benefits from international research investments.

The second requirement is for flexibility. In particular the ability to rapidly mobilise climate process teams is required. There are several reasons for this. First, uncertainties in climate processes can only be resolved through the combination of modelling, observations and improved theory (see point 1), and such teams are necessary for integration of these approaches. Second, our experience shows that new, unforeseen issues of great importance continue to arise as we observe climate change unfold around us and as we obtain more understanding. For example, when the current Australian Climate Change Science Programme Strategic Research Agenda was formulated, the rapid drying of southern Australia was not understood as it is today and the risks associated with ocean acidification are only now being recognised. In the future, we expect similar unforeseen challenges to emerge.

Session 2 – Understanding the impacts of climate change

Facilitator:

Professor Ann Henderson-Sellers (Macquarie University)

Panel members:

Dr Mark Stafford-Smith (CSIRO) – Regionalised impact assessment and policy input on responses

Dr Scott Power (Bureau of Meteorology) – Useful, scientifically sound projections of Australian drought

Dr Kathleen McInnes (CSIRO) – Storm surges and coastal damage

Dr Ryan Crompton (Risk Frontiers) – Extreme weather under climate change (presented by Dr Bob Cechet)

Dr Thalik Mallawaarachchi (ABARE) – Agricultural impacts

Dr Tony McMichael (ANU) – Human health impacts and responses

The session discussed how research can best be arranged to inform policy regarding the very broad range of risks of the impacts of climate change – some of which are now inevitable. The aim of the

session was to identify the top national research priorities for impacts in this broad sense and identify Australian research priorities in this area.

Key messages

Understanding the impacts of climate change will require broad system thinking that includes participatory methods and cross-disciplinary integration. We need to identify the most vulnerable areas and improve regional projections.

Drought will be a prime manifestation of climate change

Many Australians will be most affected by climate change through drought. Rural people especially are at the frontline of the impacts of climate change. We need improved projections of how the severity, extent and longevity of droughts will change. This will require a capacity to disentangle better the effects of climate change from those of climate variability. Part of the requirement will be broadening the way in which we assess historic droughts and the way they have changed, taking into account temperatures and rainfall.

There is a need to apply modern data analysis and statistical techniques to understand how droughts are actually changing. We must identify synoptic patterns associated with drought, and link these to large-scale circulation changes, as well as discovering the circulation and ocean changes (not just the El Niño) that lead to drought in Australia. We need to understand all the factors that cause most climate models to project decreased rainfall in southern and eastern Australia.

Our coastline is particularly vulnerable

Many factors operating on different time scales will influence the impact of climate on the coastline. Climate change will affect individual storm events such as tropical cyclones just as it will affect longer-term phenomena such as sea level rise. Interacting with these changes are the different modes of climatic variability, such as those associated with ENSO which itself may be affected by climate change. We need better understanding and to reduce uncertainties surrounding all these elements if we are to better project what will happen to our coastal regions.

One area where there is a great demand for more information is shoreline response to climate change. Significant investment is needed to provide better understanding of the climatic processes, such as the regional distribution of sea-level rise, and consequences in order to inform sound coastal management practices and adaptation. There is a lack of historical data and a need to improve the way in which coastal behaviour is modelled. A priority is to increase long-term monitoring of

vulnerable coastlines to improve modelling. Another priority is research that improves modelling of shoreline response to sea level rise, extreme events, and wind and wave changes.

Heat is unhealthy

Temperature extremes, including heatwaves, will affect people's health, as will impacts of weather disasters such as floods, storms, tropical cyclones and bushfires. There is likely to be an increase in infectious diseases, worse urban air pollution, and a greater aeroallergen (spores, pollens) load.

We need to also consider the emotional and mental health of people, especially children, as we grapple to deal with climate change.

Research needs include basic climate-health links; development of disease-specific models for predicting future health risks; improved and higher-resolution scenarios of future climate variability and change; and identifying high-risk groups, with a particular focus on rural and regional Australia.

Session 3 – Australia's modelling agenda

Facilitator:

Professor Christian Jakob (Monash University)

Panel members:

Dr Kamal Puri (Bureau of Meteorology/ACCESS) – Australia's modelling capacity in ACCESS – the Australian Community Climate and Earth System Simulator

Dr Tony Hirst (CSIRO) – Coupled modelling and international context

Professor Andrew Pitman (UNSW) – Terrestrial modelling

Professor Matthew England (UNSW) – Ocean modelling and sea ice

Dr Peter Hurley (CSIRO) – Atmospheric chemistry

Key messages

The session covered various aspects of earth system models, with emphasis on the application to climate change projections for Australia.

Professor Jakob introduced the session by highlighting the various applications of models and the types of models that are required to build a successful climate research program that serves both the

research community and provides state-of-the-art climate projections for the Australian community. Professor Jakob stressed the importance of retaining and, in fact, strengthening modelling expertise in Australia, as a climate research program cannot be based on observations alone. He emphasised the need for a model owned and well understood by the research community. While it is desirable to develop an earth system model in collaboration with international partners, strong local expertise is required for successful application in research and decision making.

The panel members introduced a variety of subjects related to modelling in Australia. Those were the ACCESS project, the international context of earth system models development, ocean modelling, terrestrial modelling, the modelling of atmospheric chemistry and air pollution, and atmospheric modelling.

The panel proposed the following research priorities and associated main areas of research:

1. Improved representation of processes that are key to the global and regional water and energy cycles.

   Main research areas: Atmospheric physics (clouds, convection, boundary layer), aerosols, land hydrology

2. Improved representation of the major modes of climate variability with relevance to the Australian region.

   Main research areas: Atmosphere and ocean dynamics and physics, air-sea and air-land interaction

3. Terrestrial systems: short and long-term feedbacks and mechanisms that contribute to abrupt change in terrestrial systems.

   Main research areas: Soil moisture, carbon cycle, dynamic vegetation, land cover change, snow and land ice, permafrost, ground water

4. An improved ocean circulation model exhibiting a faithful representation of the key ocean processes relevant to Australian climate.

   Main research areas: Ocean dynamics and physics, tropical oceans, boundary currents, critical processes: eg ENSO, IOD

5. A seamless prediction system for Australia’s weather and climate.

   Main research areas: Data assimilation, ensemble prediction and projection, the next generation of models – high resolution weather and climate prediction

6. Integration of chemical species and processes into Earth systems models for prediction of global, regional and urban climate change.

Main research areas: Reactive gas and aerosol modelling, integrated atmospheric process modelling (chemistry and physics), emission inventories for models, urban meteorological and air pollution modelling

The panel highlighted the following potential challenges to a successful implementation of the modelling component of a future climate change science program:

- adequately resourcing a sustained basic science program to support modelling
- adequately resourcing a sustained modelling effort in Australia
- supercomputing and data handling
- training the next generation of scientists.

In terms of a sustained modelling effort, much of the discussion focused on supercomputing capacity. However, an equally important issue is the lack of appropriately trained personnel to undertake various aspects of the modelling work. This issue is central to a discussion about the next generation of scientists and opportunities for a career in this field (Session 6 covered some of these issues).

In addition to the research priorities, the panel suggested that the community consider a small number of ’grand challenge‘ projects in the area of modelling in climate change research. Possible examples for such projects, in addition to ACCESS, are a regional reanalysis for Australia and surrounding regions, and high-resolution global climate predictions for the next 30 years, both in support of the attribution of current day regional climate changes and thus decision-making. One question that was raised in various sessions was around the need for community involvement, specifically how do members of the community pose a problem that could be addressed in model experiments and gain access to the analysis of results.

Report on Day 2

Session 4 – Confronting theory and models with observations

Facilitator:

Dr Neville Smith (BoM)

Panel members:

Dr Francis Chiew (CSIRO) – hydrology

Professor Nathan Bindoff (UTAS) – Oceans, sea ice

Dr Helen Cleugh (CSIRO/CAWCR) – Terrestrial

Professor Christian Jakob (Monash)

Dr Neil Plummer (BoM) – Atmosphere

Key messages

The session identified the following conclusions based on Day 1 discussions, and on other documents, such as the report of the international WCRP IGBP meeting on 'Future climate change research and observations', held in Sydney in 2007 (see workshop report web address above).

1. You can observe, and not understand. However, you cannot understand if you do not first observe. A program of systematic observations is needed within the climate change science framework.
2. The observational elements are enabling infrastructure. They allow us to do what we want within the framework. They are not a goal (priority) of themselves.
3. Observing and modelling are coupled within the science program. Models are needed to interpret what we observe, from the simple empirical models to the complex ACCESS. We test models with observations. We confront models and parameterisations of processes with reality. We detect and we predict (the initial value problem).
4. From Session 1, we accept that the observing networks for climate change science are in various states of preparedness and maturity. In some cases it is refinement and supplementation. In others it is a case of sustaining what we know is important and of high impact for climate change science. In others, we have not yet reached the pilot network stage and it is essential that we muster the collective will and commitment to start.
5. There is a balance between sustained observations – essential infrastructure – and targeted campaigns to enhance understanding and test ideas and models. They both must be judged and supported on the basis of their impact (value) to the goals of the science framework.
6. We must improve our performance in making available the information we already have, and that which we collect in the future. The PMSEIC report recommends a climate information system. We have come a long way in the past decade, but we must do far better. Adaptation research, and all other research into impacts that sits alongside, but not within the Australian Climate Change Science Program, demands that we communicate climate change science information and data efficiently and effectively.
7. We need to understand the predictability of the climate system (its modes, its variabilities, and its forcing) and the degree to which it can be predicted (understood, detected and attributed).

It is now important that we transport this uncertainty into adaptation, into impacts research, and into understanding vulnerability. Another question is whether predictability is gained or lost as climate change information is downscaled or applied in other areas, and to what extent is the information useful for decision making.

Reanalysis data and model outputs are important for researchers examining extreme events, such as tropical cyclones, strong winds and downpours. Similarly, reanalysis data are necessary for regional-scale modelling. Fusing observations and model results will improve predictions and diagnoses of abrupt events.

There is an imbalance between expenditure on monitoring the ocean compared with that for monitoring terrestrial systems. More support is needed for aerosol measurements and greenhouse gas changes in the tropics.

There was a strong desire for bringing together CAWCR, the universities and necessary infrastructure under a single decade-long science plan.

Session 5 – Projections, predictions and uncertainty

Facilitator:

Professor David Karoly (University of Melbourne)

Panel members:

Dr Roger Jones (CAWCR CSIRO) – Global emissions to global climate projections to regional climate projections

Dr Scott Power (CAWCR Bureau of Met) – Decadal climate predictions to 2030

Dr Bertrand Timbal (CAWCR Bureau of Met) – Downscaling

Dr Penny Whetton (CAWCR CSIRO) – Impact relevant climate change scenarios for users

Assoc Professor James Ball (Engineers Australia & UTS) – User perspective on uncertainties in climate change scenarios

What climate risks need to be managed by when?

Climate information required includes assessments of daily to decadal climate variability, a measure of the rate of change, the sensitivity of climate to atmospheric changes, and generation of regional climate change projections. Greenhouse gas emission policies will depend on reduction of uncertainties regarding aerosols and atmospheric chemistry, land use and land cover, changes to the carbon cycle, and determination of how rapidly the land, oceans, ice and ecosystems will respond to changes.

There is a need for future climate data sets for impact assessments. There is a clear need for improved, more efficient provision of quality data sets to researchers, who have a growing need to integrate observed data with model projections for many applications.

The decade to come

Information on our climate, regionally and globally, over next 5, 15 and 30 years is in high demand and likely to be a feature of the next IPCC report. Significant resources are required, including computing time and researchers, but decadal predictions will eventually become commonplace internationally. However, Australia currently has no capacity for delivering these predictions.

There is a need to combine natural variability and climate change signals to produce probability functions for risk management. That is, the full range of natural variability must be added to the climate change signal.

Our own backyards

Much work is needed on downscaling large-scale climate model output to enhance its value and application. There are merits in dynamical downscaling using regional climate models, as well as in statistical downscaling, in incorporating uncertainties associated with sensitivity of models to different emission scenarios and in evaluating the uncertainties associated with the two approaches.

Session 6 – Capacity, infrastructure, funding and the next generation of scientists

Facilitator:

Professor David Griggs (Monash University)

Panel members:

Dr Greg Ayers (CSIRO) – science capacity – expertise, training, support staff

Dr Geoff Love (Bureau of Meteorology) – infrastructure – observing systems, computing capacity, research vessels

Professor Amanda Lynch (Monash University) – the next generation of scientists

Mr Paul Holper (CSIRO) – communication of climate change science

Priorities include ocean, atmosphere and terrestrial observation networks, training and ensuring strong, stable career paths for the next generation of climate researchers and reducing the gap between an ARC postdoc and a tenured position.

There is need for a major upgrade to the HPC computing facility. Significantly increased support is needed for oceanographic and atmospheric observations, which lie at the heart of determining how rapidly changes to our natural systems are occurring, their vulnerability and what changes we will experience in future. Australia continues to play a vital role in monitoring changes to the Southern Ocean – we are acknowledged southern hemisphere research leaders. There must be support for research vessel measurement programs.

Climate change is the foremost environmental issue of our times. The Australian Climate Change Science Program and other science collaborations must have an effective communication element. Our nation's capacity to prepare for, and respond to, climate change depends on a sound and up-to-date knowledge of the changes, stresses, vulnerabilities and projections.

Communication is essential within the program, and to main stakeholders – namely, government, industry and the community. Program findings underpin numerous activities at Commonwealth and state level, including impact and vulnerability studies, adaptation programs and mitigation efforts. Targeted information dissemination is vital.

The program also has a role to play in education, through provision of scientifically-sound information through web sites and publications to primary and secondary school students, their teachers and to universities.

Internationally, the program is Australia's foremost contribution to the science assessed by the Intergovernmental Panel on Climate Change. Thus, the program contributes to the science assessed by the IPCC, as well as to the communication of its findings following the release of major reports.

A draft structure for a national framework for climate change science

The final session of the workshop was drawn together from the panel sessions and an open discussion about the next steps in developing a national framework for climate change science. It was agreed that a group be formed to carry this forward and that group should be broadly representative workshop attendees and linked to the Department of Climate Change and the Australian Academy of Science.

In this session six major areas of activity around which a national framework could be organised were identified.

Research activities and infrastructure

Integrated research projects around a small number of grand challenges

These are highly interdisciplinary studies organised around big issues and challenges that face Australia and the region. Examples include:

- Prediction of regional Australian climate for the next 2 to 3 decades
- Drought and drying in eastern Australia (described in more detail below)
- Sea level rise and coastal vulnerability
- Australia's oceanic environment, especially the Southern Ocean and the tropics
- Carbon dynamics of the Australian continent.

Exploratory activities, 'blue sky' research and fast-response teams

- Exploratory activities are 'over-the-horizon' research projects that position us to be able to tackle the grand challenges of the future. Examples include: (i) integrating the human dimensions into Earth system modelling and analysis, and (ii) role of urban centres in the climate system.
- Blue sky research supports our brightest researchers to follow their own ideas and instincts to generate new knowledge and approaches that are not merely extensions of the current situation.
- Fast-response teams address urgent issues on a time-scale of 6 months to 5 years, generating policy-relevant information on critical topics. Examples include a synthesis of understanding of the dynamics of large ice-sheets, and an assessment of atmospheric circulation changes over Australia and their impact and prospective impact on Australia's climate.

Research infrastructure

- Modelling/ACCESS – with an initial challenge perhaps to build a 20–30 year climate prediction scheme in addition to the current projection capability.

- Australian Climate Change Earth Observatory – focus and integrate the current broad spectrum of observation activities. Development of a focused and coherent terrestrial and oceanic component is a high priority. Long-term continuity of observations is critical.
- Climate Information System – much of the information in a CIS needs to be informed by, or even driven by, the policy and user communities. A CIS would provide an excellent link to the adaptation and mitigation research communities.

Enabling activities

People

*D*eveloping the next generation of climate researchers and providing for ongoing renewal, flexibility and mobility in the system. This will include establishing strong career paths, especially for young graduates.

Institutions

Overcoming the constraints that make it difficult to collaborate.

Funding

Enhancing the funding base for climate research – sufficient, sustained and flexible funding is essential.

Example of a grand challenge

Drying trends in eastern Australia

Such a theme would need an integration of models (both global and regional), observations, process studies and information systems. Component projects that would be required to address the grand challenge include:

- coupled reanalysis of the climate system
- prediction of climate on decadal time scales
- ENSO behaviour – understanding and modelling – and ocean circulation more generally
- behaviour of the hydrological regime through time, including provision of palaeo data
- influence of aerosols on rainfall, both as cloud condensation nuclei and via impacts on atmospheric circulation.
- changes in atmospheric circulation, convection and storm tracks
- role of human-driven land cover change in the observed drying trend
- changes in actual evapotranspiration and soil moisture
- role of vegetation in a drying climate, including the effects of elevated CO_2
- changes in patterns of extreme events – frequency and intensity – such as droughts punctuated by flooding rains, and bushfires
- drought, drying and rural health
- modelling activities, including downscaling

- adaptation approaches in agriculture
- impacts on biodiversity
- urban water supplies
- impacts on human settlements
- disaster management
- building an overall risk management framework involving both mitigation and adaptation.