Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between CSIRO and the Bureau of Meteorology

Overview of VicCI science plan

Background: key messages from SEACI synthesis report

1. South-eastern Australia (SEA) including Victoria has experienced a range of climate extremes in recent times, including the worst drought of the instrumental record; the Millennium drought (1997–2009), which was broken by Australia's wettest two-year period on record (2010–11).

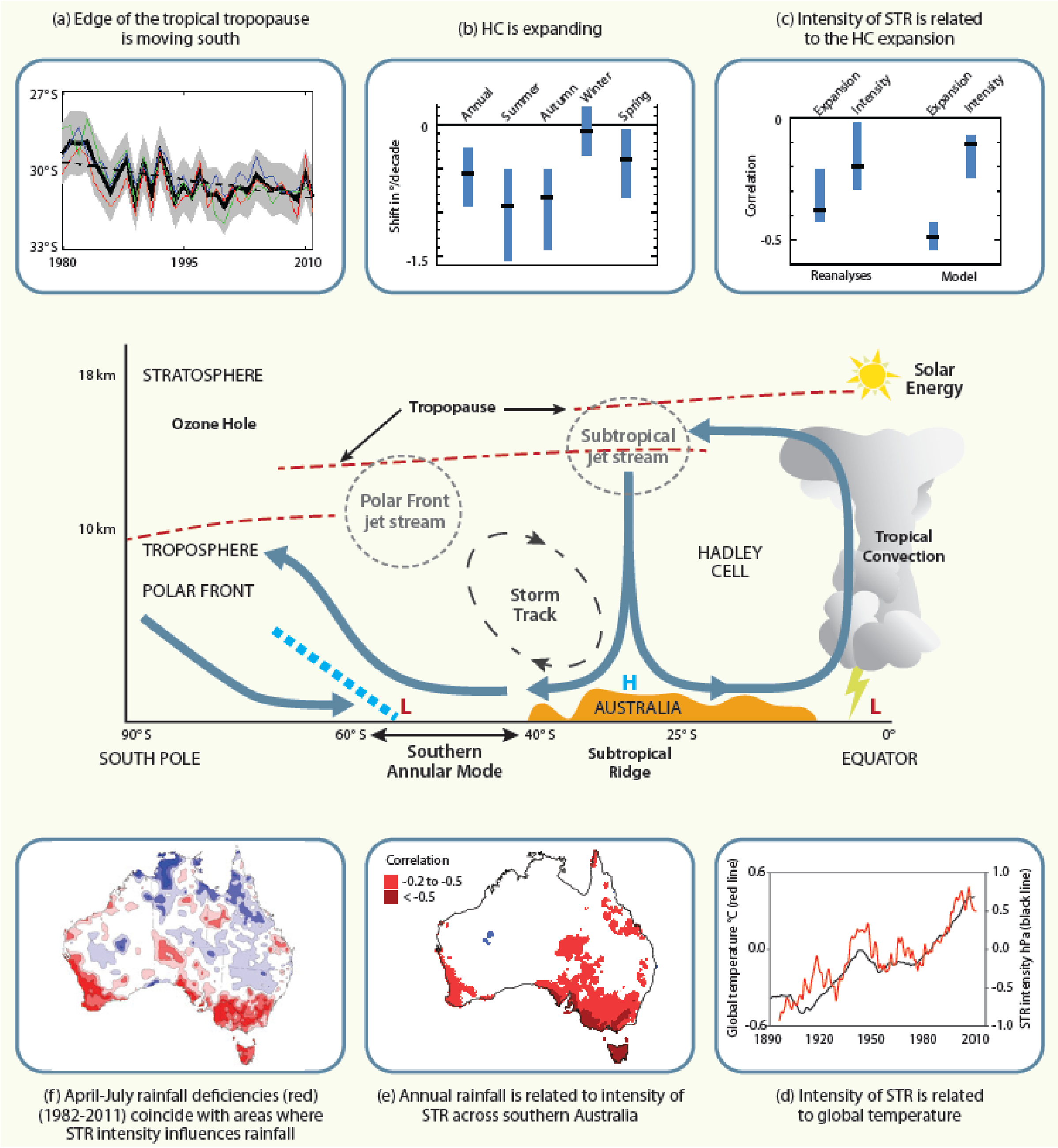
2. The Millennium drought was unusual in terms of its duration, severity and extent. It was unprecedented in terms of being largely restricted to southern Australia and including a large decline in autumn rainfall. The decline in rainfall was found to produce a larger than anticipated decline in runoff. These conditions proved challenging for water management and planning processes.

3. This decline was in sharp contrast to the frequent heavy rain events in the spring and summer of 2010/11, and again in 2011/12, leading to Australia's wettest two-year period on record and caused by consecutive La Niña events, coupled with very warm sea surface temperatures to the north of Australia and in the eastern Indian Ocean. However, across south-eastern Australia, there was a continuation of below average rainfall during the cool season (April to October).

4. This is consistent with the observed long-term reductions occurring in cool season rainfall and stream flow across the region which appears related to changes in the mean meridional circulation (MMC) which acts to transport the solar energy received in the equatorial regions to higher latitudes (next page figure summarises the MMC).

5. Evidence indicates that the MMC is changing: there is an expansion of the tropics, with the Hadley circulation expanding at the rate of approximately 50 km per decade, pushing mid-latitude storm tracks further south and leading to an expanded subtropical dry zone and reduced rainfall across southern Australia. These changes are at least partly attributable to global warming, indicating a possible future climate characterised by continued below average late autumn and winter rainfall across south-eastern Australia. These trends are evident in a range of observational data and can be reproduced by global climate models only when human influences (in the form of greenhouse gases, aerosols and stratospheric ozone depletion) are included.

6. The model simulations also indicate that these trends are expected to continue. The best estimate of the impact of these changes is for reductions in rainfall and runoff across the southern part of south-eastern Australia (south of 33° S latitude) in particular. For example, with 1 °C of global warming, average annual rainfall is expected to decline by 0 to 9 percent (median of 4 percent), and average annual runoff is expected to decline by 2 to 22 percent (median of 12 percent). For 2 °C of global warming, the reductions in both rainfall and runoff are approximately double these.



The mean meridional circulation between the Equator and the South Pole is made of several key components as shown in the central figure. In addition (a) the tropical tropopause is moving south; (b) the Hadley circulation (HC) is expanding; the intensity of the sub-tropical ridge (STR) is related to (c) the Hadley circulation (HC) expansion and (d) the global average temperature; while (e) the annual rainfall deficiency is inversely related to the intensity of the sub-tropical ridge (STR), particularly in that part of the continent (f) where rainfall has declined for the months of April to July over the last 30 years.

Relevant scientific questions at the completion of SEACI leading to VicCI

1. A key outcome of SEACI is the confirmation that the Hadley cell is expanding and this expansion could be playing a key role in the recent climate variability experienced in SEA. Projections of future climate indicate a continued expansion of the Hadley cell, so it is imperative to understand its impact on SEA climate and the mechanism for, and likely limits to, the expansion.

2. SEACI research indicates that the recent expansion of the Hadley cell has been relatively greater over Australia compared to the rest of the hemisphere. And, importantly, the seasonality of the expansion varies between different analyses, with calculations/simulations of the overturning circulation suggesting a summer/autumn expansion, but in situ radiosonde observations showing little seasonality. The seasonality of the expansion (greatest in summer and autumn) bears on the issue of what is driving the expansion and on understanding the observed autumnal rainfall decline and how rainfall may respond to future changes and hence needs to be clarified.

3. Climate model simulations best represent observed recent changes in the MMC, especially its expansion, when ozone depletion and other anthropogenic external forcings are used, suggesting at least a partial human influence of recent changes. However, the expansion in the models is typically much weaker when compared to observations. The effects of stratospheric ozone depletion, often poorly represented in GCMs, may play a significant role in the SH circulation, including the tropics and subtropics. It is thus critical to understand what is actually driving the changes, why the models are underestimating the change and the role of individual anthropogenic forcings (ozone, greenhouse gases, and aerosols) as their future trajectories is likely to be very different.

4. Climate projections from climate models are showing some consistent behaviour (e.g. dry to the south and wet to the north across SEA) and some inconsistent behaviour (the degree of future rainfall change). Some of this uncertainty is linked to the models' ability to represent important teleconnections and climatic behaviour identified through SEACI research. In order to provide guidance as to which models to use for projecting future climate, we need to assess individual models for the capability to simulate these key teleconnections.

5. Evidence is emerging that variations in extra-tropical circulation associated with the Southern Annular Mode (SAM) play a significant role in driving variations of the Hadley circulation, and especially rainfall on the poleward edge of the Hadley circulation. This relationship, which is primarily a summer time phenomenon, is captured in climate models to varying degrees. It is especially associated with ozone depletion, but increased greenhouse gases are also known to drive SAM to its high phase. Understanding the cause of this relationship between SAM and the HC is crucial to understanding the behaviour of the HC in the future.

6. The same relationship bears on the ability to predict regional climate seasonally. There is strong evidence that tropical SSTs during ENSO directly affect the HC, which then affects the SAM. These variations should be highly predictable. But, because SAM is primarily an internal mode of variability, to the degree that the SAM variations determine the poleward extent of the HC, this will reflect on the limits of predictability of HC variations.

7. 2010-11 reminds us that climate in SEA varies markedly on multi-year and decadal time scales. Importantly, the capability to make predictions of seasonal climate variability in SEA varies also decadally, with decades of high skill being associated with high ENSO variability and decades of low skill being periods of quiescent ENSO variations. The relationship of these variations of ENSO predictability with epochs of increased global warming and intensification of the subtropical ridge needs to be explored.

8. Furthermore, there is clear evidence that some specific ENSO events are predictable for 1-2 years (such was the case in 2010 and 2011) but many are only predictable 2-3 seasons in advance. Further, ENSO variability today is acting on a warmer mean state and this warming may have played a role in changing both the behaviour of ENSO and the ENSO teleconnections to SEA (e.g. there is some evidence to suggest that the La Niña pluvial phase may be more intense now than previously). Understanding these changes will provide more confidence for predictions of short term climate variations in the future.

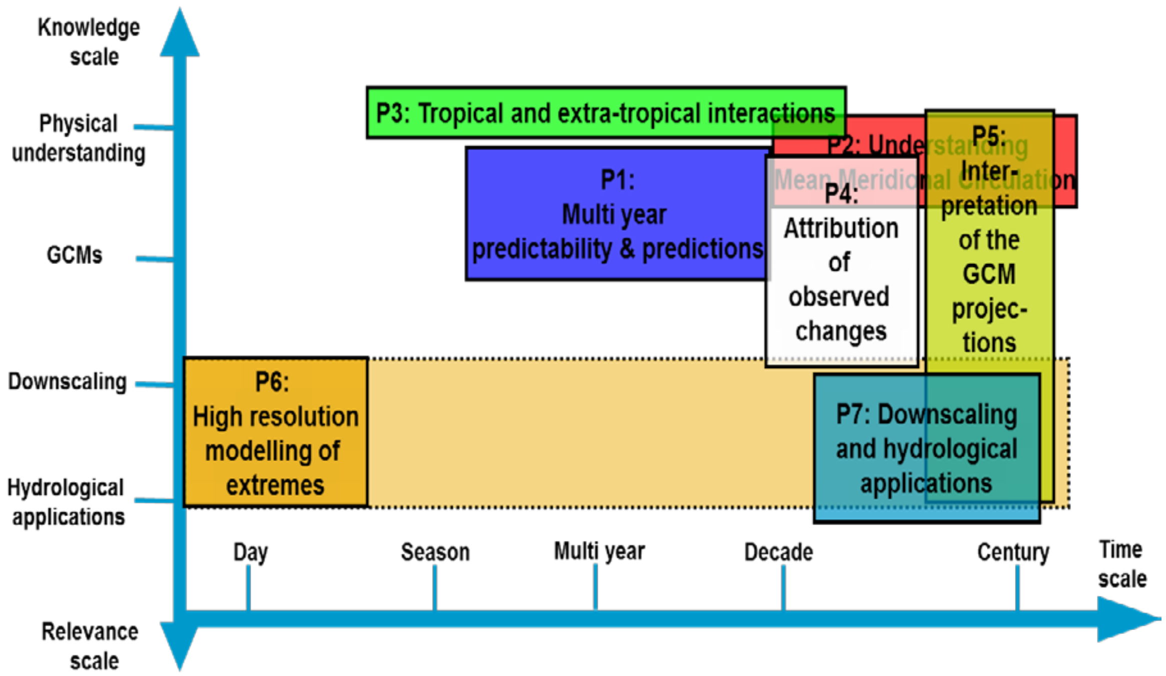
9. In order to increase the relevance of all these findings for water management, information from climate model predictions and projections needs to be successfully integrated with hydrological models. This requires further investigation of model behaviour and methodological choices with a view to identifying ways to improve the reliability and usefulness of runoff projections for mid- to long-term future time horizons (2040 and 2065), which are needed for the next round of Water-Supply Demand Strategies (WSDS) in 2016.

10. Very wet episodes in 2010 and 2011 highlighted the potential for larger flooding events in a warming climate. The ability to describe these events requires the use of very high resolution models such as convection-resolving models. To do so, first these models needs to be tested and their ability to simulate the current climate in Victoria evaluated. It is expected that high-resolution experiments will improve spatio-temporal characteristics of rainfall. This, in turn, has the potential to inform the development of improved methodologies for future runoff projections and, potentially, assessments of future flood risk.

VicCI science plan and program structure

This program is tasked over the next 3 years to provide appropriate guidance on climate variability, predictability, and change that will (a) improve predictions of water availability in the short-term (seasonal to interannual timescales) and (b) underpin an improved assessment of the risks to water supplies from changes in climate over the medium to longer term.

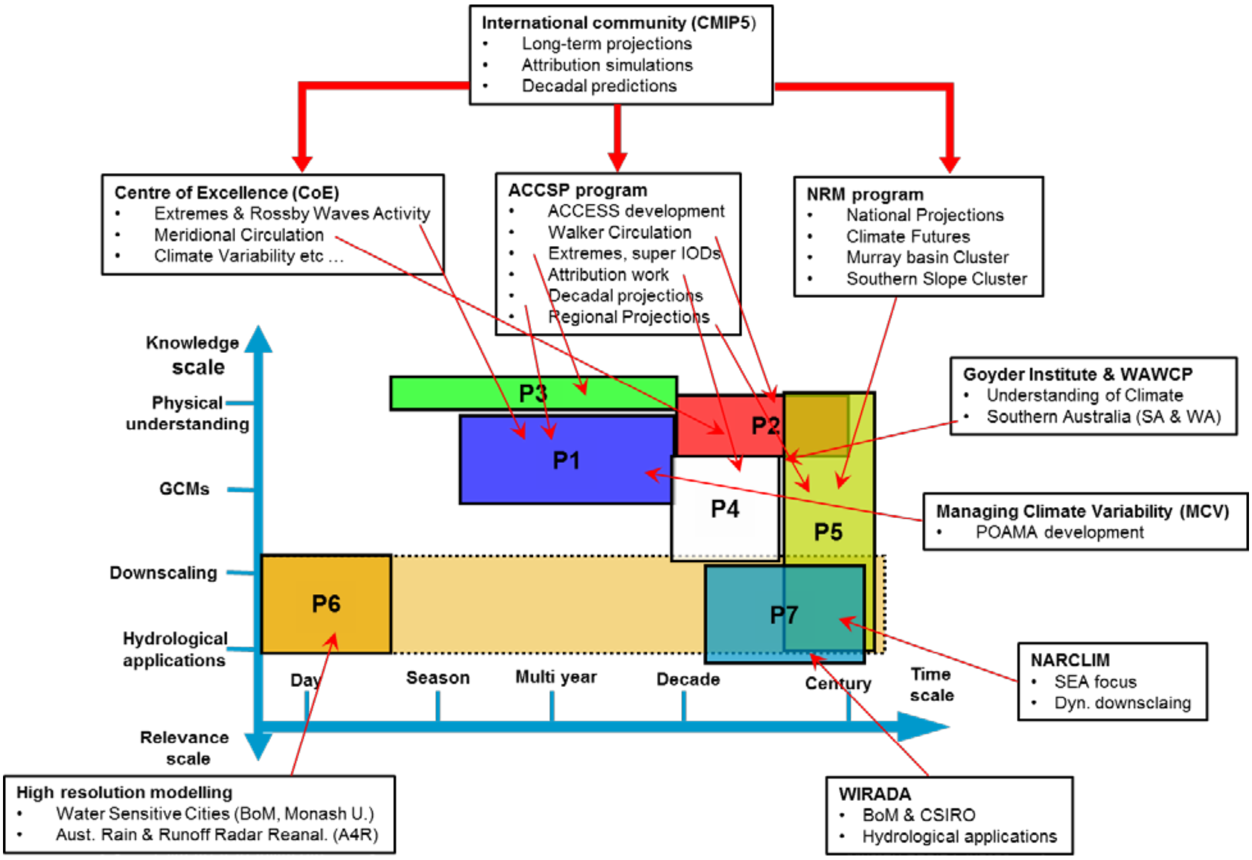
This research is targeted to inform water security outlooks for urban supplies, management of rural water allocations and supplies, and longer term planning aimed at ensuring reliable water supplies decades into the future, and is based on improved understanding of the climate system and its representation by climate models.



The seven component projects of the research program have strong interconnections. Project 1 is aimed at further improving seasonal climate predictions and exploring the potential for multi-year predictions. Projects 2, 3 and 4 are aimed at better understanding past climatic variability and change in Victoria. Project 5 will use the understanding developed in Projects 1-3 to inform an improved assessment of the utility of climate model projections of future change. Projects 6 and 7 are aimed at developing improved methodologies for producing updated runoff projections and for assessing risks to water supplies from climate change. Project 6 will explore the possibility of obtaining improved information about future changes to convective rainfall and, potentially therefore, improved information about the likelihood and magnitude of extreme events and warm season rainfall. Project 7 will determine the most appropriate methodology(s) for generating a plausible range of improved runoff projections out to ~2040 and 2065 (as required for developing the next round of Water-Supply Demand Strategies in 2016). It will draw on information generated in the first six projects, particularly that of Project 5 and 6, and other relevant international, national and state initiatives, as well as investigating the best ways of bias-correcting dynamically downscaled data from climate models.

Program connections

VicCI is part of a broad landscape of scientific research happening in Australia and overseas aimed at developing an appropriate understanding of the climate system and the implications for policy makers and managers of natural environment and infrastructure impacted by climate variability and change. Therefore, it is in the interest of the program to be aware and take advantage of existing research programs.



The modelling effort of the international community is being channelled as part of the completion of the 5th assessment of the Inter-governmental Panel of Climate Change (IPCC) into the Coupled Model Intercomparison Project, phase 5 (CMIP5). The database is being mirrored in Australia and provides a source of model simulations feeding into all research activities in Australia:

- The Australian Climate Change Science Program (ACCSP): an on-going program underpinning many scientific developments and tools (the Earth System Model: ACCESS, Downscaling work, fundamental research);
- The delivery of national projections for the Natural Resources Management groups (NRM) program due in 2014; and
- Research happening across several Australia Universities as part of the Centre for Excellence for Climate System Science (COeCSS).

VicCI is not alone in focusing on climate variability and change in southern Australia, The Goyder Institute has focused on South Australia since 2011and will continue until 2014, while a new initiative has been announced by the W.A. government (Western Australia Weather and Climate Program – WAWCP) as a successor of the IOCI which was in existence between 2001 and 2012. Similarly, the NSW government has invested in a research program (NARCLIM) to developed high resolution downscaled simulations using the WRF model covering south-eastern Australia.

Other research initiatives are relevant either to help develop capabilities to be used in VicCI (e.g. the MCV program which contributes to the development of the seasonal predictions tool: POAMA) or provide scientific insight into directions tackled by VicCI (e.g. research initiatives using high resolution modelling (Water Sensitive Cities, A4R), or dealing with hydrological applications such as WIRADA).

Expected Outcomes

Expected outcomes from the various projects in the three year program are summarised below.

Improved Short-Term Predictability

1 **Understanding decadal variation of seasonal climate predictability and the potential for multi-year prediction**: Improved understanding of the mechanisms producing multi-year variability in climate, expected changes & impacts, and the role of anthropogenic influences in these changes, and, in turn, improved predictions of future 'short-medium term' climate.

Improved Understanding of Past Climate Variability & Change

2 **Understanding the mean meridional circulation and its relevance to Victoria:** Improved understanding of the mechanisms for an expanding Hadley Cell and associated future impacts.

3. **Understanding subtropical-extratropical interactions and their relevance to Victoria:** Improved understanding of subtropical/extratropical interactions (Hadley Cell/Southern Annular mode), likely future changes and associated impacts.

4. **Evaluation of climate model simulations of current trends in order to attribute observed trends:** Improved understanding of the role of various external forcing factors in driving an expanding Hadley Cell, why climate models underestimate observed changes, and implications for future CC projections.

Improved Understanding of Future Climate & Associated Risks to Water Supplies

5. **Critical assessment of climate model projections from a rainfall perspective:** Improved understanding of which GCMs best capture the behaviour of key mechanisms influencing SEA rainfall, and relationships between these mechanisms and rainfall. This in turn will inform decisions about how best to make use of model projections of future climate and runoff.

6. **Convection-resolving dynamical downscaling**: Assessment of the potential for high-resolution dynamical downscaling experiments to improve on spatio-temporal characteristics of projected future rainfall. This will feed into the development of improved methodologies for future runoff projections (Project 7) and, potentially, provide a methodology for getting better assessments of future flood risk.

7. **Identification and application of improved methodologies for water availability projections:** A recommended methodology for developing updated runoff projections and, potentially, the delivery of these updated projections across the State for 2040 and 2065.