



## South Eastern Australian Climate initiative

# Answering questions about climate in South Eastern Australia

SEACI was designed to answer key questions for natural resource managers in south-eastern Australia.

Improved understanding of climate change and climate variability will help improve the ability to predict their impacts on water resources, agriculture, communities and the environment over a range of time frames across south-eastern Australia.

The research will provide useful information for developing future plans for water sharing, water allocation and natural resource management. It will also be useful in making decisions about investing in water resource infrastructure.

New methods of climate forecasting will be applied to the forecasting of stream-flow and crop yields across south-eastern Australia. These forecasts have the potential to support adaptation to climate change, more efficient operation of water supply systems, and more informed agricultural decision making.

### What controls the rainfall in south-eastern Australia?

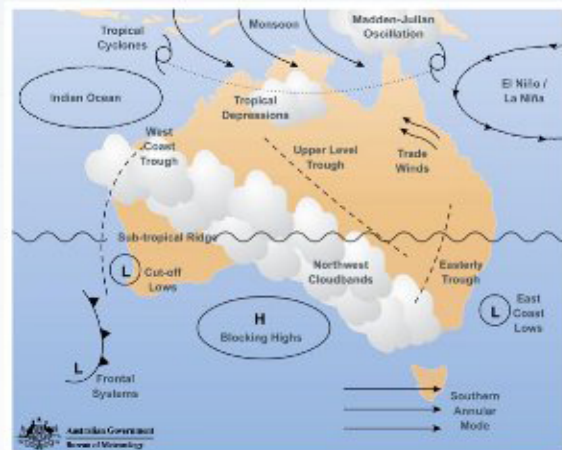
The El Niño Southern Oscillation (ENSO) has a significant effect on the climate of eastern Australia. Major droughts are often linked to ENSO events, when the sea surface temperature rises in the eastern Pacific Ocean and cools in the west around Indonesia. SEACI researchers have also confirmed that warm dry conditions occur in spring during ENSO events.

Variations in patterns of sea surface temperature in the Indian Ocean (known as the Indian Ocean Dipole, or IOD) can be linked to the frequency of north-west cloud bands that bring rain right across south-eastern Australia. SEACI researchers found that the IOD affects the rainfall and maximum temperature in winter and spring, but has no significant impact in summer and autumn.

The Southern Annular Mode (SAM) is a mode of climate variability that affects the north-south movement of the band of strong westerly winds (and associated storms) that dominate the middle to higher latitudes south of Australia. SEACI researchers determined that the SAM has a significant effect on rainfall and minimum temperature in all seasons except autumn.

It was found that the influences of ENSO, IOD and SAM are at their weakest in autumn, the season where the largest rainfall decline has been observed.

Rainfall in south-eastern Australia in autumn and winter is related to the mean sea level pressures over southern Australia. These pressures, in turn, are related to the intensity of the sub-tropical ridge, which is a belt of high pressure located in the mid-latitudes (around 30 degrees south). The sub-tropical ridge is associated with the southern hemisphere Hadley cell, which is a circulation pattern that transports excess heat from the equator towards temperate latitudes. Pressures along the sub-tropical ridge have increased during the 20th century, and this intensification of the ridge appears to be related to global warming. This intensification explains about 70% of the observed rainfall decline in south-eastern Australia.



Understanding the relationship between rising global temperature and the sub-tropical ridge intensification will require additional research. Furthermore, the relationships between changes in the Hadley circulation, the ENSO, IOD and SAM have not yet been clarified and remain active areas of research.

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in all seasons, the effect on rainfall is less certain.

### What controls stream-flow in south-eastern Australia?

Rainfall in river catchments is the main influence on stream-flow variation in our rivers, with a 1% change in mean annual rainfall generally amplified as a 2-3% change in mean annual stream-flow. Other influences on stream-flow include daily and seasonal rainfall distribution, temperature, and evaporation, vegetation and connections between surface and subsurface water.

The unprecedented low stream-flows of the past decade in south-eastern Australia are a result of both consistently lower than average annual rainfall (with no wet years to offset the dry years) and a change in the seasonality of rainfall, with the largest percentage reductions in rainfall occurring in autumn and early winter. This means that catchments are not wetting up as usual in autumn/early winter, so that winter/spring rains do not generate as much run-off. The higher temperature in the last decade also intensifies the impact of the rainfall reduction on stream-flow.

The temperature increase in south-eastern Australia, as in much of the world, is likely to be due, at least in part, to the increasing concentrations of greenhouse gases in the atmosphere. This suggests that as global warming continues, stream-flow in south-eastern Australia could fall independently of whether rainfall increases or decreases. However, changes in rainfall are expected to remain the strongest influence on changes in stream-flow.



### How well can we predict the climate for the coming seasons in south-eastern Australia?

SEACI researchers have improved the accuracy of the Bureau of Meteorology's POAMA climate model. This model is run daily to predict the global climate up to 9 months ahead, and generally yields more accurate forecasts of rainfall and maximum temperature one season ahead than the Bureau's current operational seasonal outlook system, particularly from autumn through to spring. The regions where the model forecast is less accurate than the operational system are generally areas with low seasonal predictability or low seasonal rainfall.

The improved accuracy of the model is largely due to improved atmospheric initial conditions and to its improved ability to predict the occurrence and nature of ENSO events in the Pacific Ocean. Differences in ENSO events have been shown to lead to different impacts on the climate of south-eastern Australia. Events where the warming is greater in the mid-Pacific Ocean, relative to the warming in the east, have been shown to have a greater impact on the rainfall in south-eastern Australia. The model can capture some of these differences, and can predict them up to 3 months ahead.



Research is continuing into the development and application of the POAMA model.

### Are current seasonal climate forecasts of economic value in south-eastern Australia?

As part of the SEACI program, researchers have evaluated the usefulness of seasonal forecasts from a number of global climate models, including POAMA, for on-farm decision-making, e.g. on

fertiliser application in relation to expected rainfall.

Researchers concluded that that the usefulness of many climate models is limited as they cannot accurately represent the regional impacts of ENSO events. Improving their regional accuracy would increase their usefulness.

While global climate models provide a foundation for future improvements in seasonal prediction, useful results can be obtained from forecasts based on the observed statistical relationships between large-scale climate factors such as ENSO. SEACI researchers developed a statistical prediction system for stream-flow in south-eastern Australia which returned useful and accurate predictions when applied to the prediction of stream-flow in the upper

Murrumbidgee and northern Victoria over a 90-year period. The flexibility of the system means that it could include the output of a climate model like POAMA in the future.

### Can we estimate the local climate in south-eastern Australia for the coming decades?

Until now the best estimate of the climate over the next 100 years has been the climate of the past 100 years. However, in south-eastern Australia there have been large variations in the climate record over the past 100 years. Annual rainfall particularly has shown a great deal of variation, with no year in the past decade having rainfall above the long-term mean.

Climate models are now the best tools we have for estimating the local climate in south-eastern Australia for the coming decades. The Intergovernmental Panel on Climate Change (IPCC) has archived the output from over 20 global climate models to support studies of future global and regional climate. Climate change projections for Australia developed by CSIRO and the Bureau of Meteorology through the Australian Climate Change Science Program are available at [www.climatechangeinaustralia.gov.au](http://www.climatechangeinaustralia.gov.au).

SEACI researchers assessed the IPCC models to see how well they simulated the observed climate of south-eastern Australia and found that the output from models selected for their ability to simulate the climate of south-eastern Australia had a different probability distribution to the mean of the output from all models. This difference indicated a shift in the probabilities towards drier conditions in the future.

A global climate model generates output at large scales (e.g. 100 km by 100 km) and, in order to obtain climate projections to drive hydrological models, the output needs to be 'downscaled'. SEACI researchers developed a range of simple scaling methods and statistical and dynamic downscaling methods for this purpose.

### Can we estimate the run-off in catchments of south-eastern Australia for the coming decades?

The run-off in a catchment is largely determined by the rainfall and potential evaporation in the region. It can therefore be estimated from hydrological models driven by the daily rainfall and potential evaporation outputs downscaled from a global climate model.

SEACI researchers downscaled climate projections from a number of global climate models under a mid-range emissions scenario to drive a rainfall-runoff model, and estimated that the mean annual run-off in 2030 is likely to change by between -30% and 0% with a median of -15% in the southern part of south eastern Australia and by between -25% and 20% with a median of -5% in the northern part. However, the reductions in run-off that have been experienced in the southern part of the region over the past decade have been much greater than these projections for 2030. For example, north-western Victoria has experienced



# Outcomes

SEACI was designed to answer the questions that are most critical to natural resource managers in south-eastern Australia.

These pages provide a summary of the main outcomes from the 2006–2008 research program. Detailed research reports are available on the SEACI website at [www.seaci.org](http://www.seaci.org).

## Current climate

How has climate changed?

The last decade has seen a prolonged period of reduced rainfall, especially in autumn. The past eight years (including 2008) have all seen autumn totals below the previous long term average (1961 to 1990). In recent years spring rainfall has also been declining steadily.

Eleven of the past 12 years rank among the 12 warmest years since records began and Australia has experienced warmer than average mean annual temperatures for 17 of the past 19 years.

What is the current climate baseline?

The baseline climate used in many climate change studies is the period 1961–1990. However, for south-eastern Australia this is the wettest period over the last century, and is not representative of the current climate of the region.

SEACI research suggests that in the absence of definite evidence of a permanent climate shift, the current baseline is better defined by using the longest possible climatic record including prior dry period (such as the 1940s) as well as the current dry conditions. However, if it is assumed that most of the recent change in climate is due to a long-term trend (probably global warming) there is also a case for using just the last 10–15 years as a baseline, since this would most likely be more representative of the future than the climate 30 to 40 years ago. Further research to determine the causes of recent climate changes is required.

Can we determine whether shifts in the baseline have occurred, or are likely to occur?

Analysis of climate records and model projections of future climate suggests that the climate baseline is shifting.

While there is strong evidence of increasing temperatures in south-eastern Australia, rainfall is so variable from decade to decade that it is not yet possible to claim that the current dry spell is unprecedented. Evidence does suggest that at least part of the current reduction in rainfall is associated with global warming, via the intensification of the sub-tropical ridge. This is consistent with (but earlier than expected) future projections which show some drying across mid-latitudes associated with global warming.

Further research is required before a confident assessment can be made that the south-eastern

Australia rainfall has permanently shifted due to global warming.

What are the major influences on climate in south-eastern Australia?

The El Niño Southern Oscillation (ENSO) has a significant effect on the climate of eastern Australia. Major droughts are often linked to ENSO events, when the sea surface temperature rises in the eastern Pacific Ocean and cools in the west around Indonesia. SEACI researchers have also confirmed that warm dry conditions occur in spring during ENSO events.

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The sea surface temperature in the Tasman Sea also affects weather systems such as east-coast lows. While SEACI researchers have determined that the Tasman Sea has an effect on temperature in all seasons, the effect on rainfall is less certain.

What are the causes of the dry conditions affecting parts of the study area over the past decade?

The dry conditions of the past decade in south-eastern Australia have led to a large reduction in stream-flow (39%) compared with the reduction in annual rainfall (13%). One of the reasons for the reduction in stream-flow appears to be that the rainfall reduction is mainly in autumn. This means that the land surface is not as moist when the winter rains come, so there is less winter runoff. Furthermore, there have been changes in the

timing and nature of heavy rainfall events, which again affects how much rainfall eventually ends up contributing to stream-flows.

Temperatures across south-eastern Australia have also been increasing in recent decades. This will cause greater heat stress on agricultural and natural ecosystems. For example, warmer temperatures may have contributed to increasing evaporation, thereby intensifying the impact of rainfall reduction on stream-flows. An initial analysis has suggested that a 1 degree increase in temperature could account for 15% of the stream-flow reduction over the past 50 years. However, further research on the relative impacts of changes in rainfall and temperature on stream-flows is required.

## Future climate

How is climate likely to change over the next 25–65 years, and what's the likelihood of these changes?

SEACI researchers looked at the results from a number of climate models which provide simulations of future average conditions, inter-annual variability and extreme rainfall, temperature and evaporation events over the region. These results suggest that south-eastern Australia is likely to be warmer and drier in future decades, especially in the winter.

Hydrological modelling, driven by climate model projections under a mid-range emissions scenario, indicates that the mean annual run-off in 2030 is likely to change by between -30% and 0% with a median of -15% in the southern part of south eastern Australia and by between -25% and 20% with a median of -5% in the northern part.

The probabilities of changes in rainfall and temperature are available in the climate change projections for Australia developed by CSIRO and the Bureau of Meteorology through the Australian Climate Change Science Program. They are available at [www.climatechangeinaustralia.gov.au](http://www.climatechangeinaustralia.gov.au).

A key issue requiring further investigation is why the observed changes in climate and stream-flow over the last decade are already greater than those projected by the model for the middle of this century.

How can methods for regional projections be improved so as to provide greater confidence for stakeholders?

While the magnitude of the actual projected changes remains somewhat uncertain, SEACI research suggests that this uncertainty can be reduced by careful selection of the climate models used to prepare the projections. Furthermore, SEACI researchers can provide greater regional detail on future climate projections and this information can also potentially reduce the uncertainties in managing resources.

## Seasonal forecasting

Can reliable methods of forecasting climate 3–12 months ahead be developed for south-eastern Australia?

The coupled atmosphere–ocean–land climate model (POAMA) has been refined during the SEACI program to improve the accuracy of seasonal forecasts. For most of Australia (but especially south-eastern Australia) the model is now more accurate than the current operational seasonal outlook system of the Bureau of Meteorology. The improved accuracy,

especially from autumn through spring, is mostly due to improved atmospheric initial conditions used by the model that were developed during SEACI and by the ability to better capture information about El Niño Southern Oscillation events. Planned improvements in the model are expected to further increase the accuracy of the seasonal forecasts.

Can these new forecast methods be applied to forecast stream-flow and crop yields?

SEACI researchers assessed the economic utility of seasonal climate forecasts from a number of global climate models (including POAMA) for on-farm decision making. The results varied from farm to farm, because of regional differences in soil type. The results also depended on how well each model could predict El Niño Southern Oscillation events.

While global climate models provide the basis of future improvements in seasonal climate prediction, it was found that useful information can be obtained from statistical methods based on the relationship between rainfall and El Niño Southern Oscillation in south-eastern Australia. An improved statistical seasonal climate prediction system applied to the forecasting of stream-flow in the upper Murrumbidgee and northern Victoria was found to be useful for hydrological purposes. This system can be modified to include the output of a global climate model such as POAMA.

# About SEACI

South-eastern Australia is one of the country's most valuable primary production areas. The Murray–Darling Basin alone produces over one-third of Australia's food supply and generates 40% of the nation's agricultural income, with 70% of Australian irrigation occurring in the region.

Over the past 12 years there has been an apparent shift to a warmer and drier climate here, which has had major impacts on our water resources. These changes have come about earlier and to a larger extent than climate change scientists have generally expected.

Understanding climate variability in the region, as well as the longer term climate changes, is critical for the future planning for water resources, agriculture, communities and the environment across south eastern Australia.

## South Eastern Australian Climate Initiative

The South Eastern Australian Climate Initiative (SEACI) was established in 2005 to answer some of the questions about causes and impacts of climate change and climate variability across south-eastern Australia. The SEACI study area incorporates the Murray–Darling Basin, Victoria and southern South Australia, including the agricultural areas of Eyre Peninsula.

Research in the three and a half year, \$7.5 million program is being undertaken by CSIRO and the Bureau of Meteorology. The program is managed by the Murray–Darling Basin Authority, which also provides funding, along with the Victorian Department of Sustainability and Environment, the Commonwealth Department of Climate Change, and the Managing Climate Variability Program.

Building on the existing knowledge available from many other climate programs, both in Australia and internationally, SEACI aims to deliver a better integrated understanding of climate change and climate variability across south eastern Australia. Information collected through SEACI research will support a wide range of planning, management and policy decisions for agriculture, water, natural resources and climate change risk management by communities, industry and governments.

## Climate variability and climate change in south-eastern Australia

The climate of south-eastern Australia is highly variable, spanning cool humid uplands in the east, arid and semi-arid country in the west, inland sub-tropical areas in the north, and temperate mallee in the south-east. As well as the differences in climate between zones, there are large seasonal and annual differences in temperature, rainfall and evaporation within zones. There are also differences over periods of several years.

This variability is reflected in stream-flows across the region, which has historically been subject to both extreme floods and droughts. For example, the Murray River system provides water to irrigators, communities and the natural environment in the southern part of the Murray–Darling Basin. In 2006, the driest year of the current drought, total inflows into the Murray River were less than 600 gigalitres – less than 1% of the record 60,000 gigalitre (GL) inflow in the massive flood of 1956.

While farmers and land and water managers have largely adapted to this variability, climate change is expected to result in changes to both long-term average rainfalls and temperatures, and also the frequency and severity of floods, droughts and fires. These changes are likely to have significant social, economic and environmental consequences.

Climate variability refers to shorter term (e.g. daily, seasonal, annual, cycles of several years) variations in climate, including the fluctuations associated with El Niño (dry) or La Niña (wet) events.

Climate change refers to long-term (decades or longer) trends in climate averages, such as the global warming that has been observed over the past century, and long-term changes in variability (e.g. in the frequency, severity and duration of extreme events).

# Research

There are three research themes in the SEACI program looking at current climate conditions, future climate projections, and seasonal forecasting.

## Research theme 1: Characterisation and attribution of current climate

South-eastern Australia has been getting drier since the mid-1990s. This trend may be associated with the climatic trends observed in south-western Australia since the mid-1970s. The apparent trends in rainfall and stream-flow appear to be unusual when compared with historical records covering a period of about 100 years.

To better understand the current climate, it is necessary to understand the major influences on climate over a range of time-scales, the relationships between these influences, and whether they have changed over time.

SEACI researchers have assessed the current level of knowledge about climate variability and climate change over south-eastern Australia by assembling and reviewing information throughout published literature and databases, and by analysing meteorological records for specific sites. They have also conducted experiments with global climate models to determine what factors have caused recent climate trends and shifts.

## Research theme 2: High-resolution climate projections and impacts

A question of particular importance for water managers in south-eastern Australia is how climate change may affect future stream-flows. SEACI researchers have used climate modelling to determine the extent to which climate in south-eastern Australia is likely to change under enhanced greenhouse conditions. The aim is to improve estimates of likely future changes in average climate, climate variability, and the likelihood of extreme events such as storms, and associated impacts on stream-flows.

## Research theme 3: Seasonal forecasts

A seasonal climate forecast indicates how rainfall or temperature in a coming season is likely to be different from the average weather calculated over a long period, such as 30 years. Because the climate system is so complex, it is impossible to exactly predict the future seasonal climate, so climate forecasts are generally expressed as the probability that rainfall or temperature will be below normal, near normal, or above normal.

SEACI researchers have investigated whether reliable seasonal forecasts (3–12 months ahead) can be developed for south-eastern Australia, and whether these can be applied to forecast stream-flow and crop yields. The researchers evaluated the performance of existing systems which forecast rainfall and temperature, developed and evaluated new forecasting systems, and developed and tested ways of improving forecasts of stream-flows and crop yields.

