climate futures for tasmania

climate modelling

climate modelling

the summary

local climate information for local communities
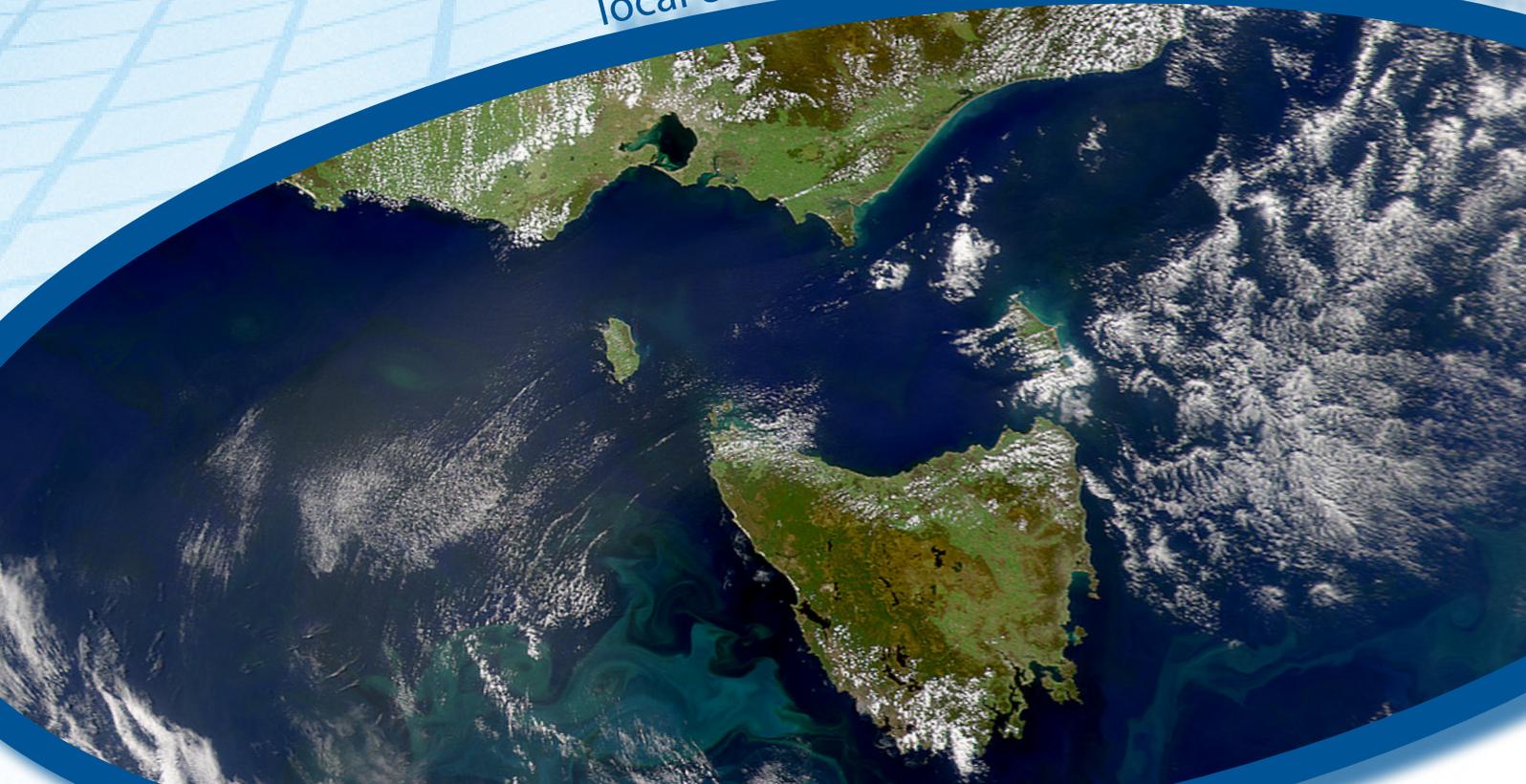
Climate modelling

Global climate models (GCMs) provide the best estimates of global change to our climate to the end of the 21st century. Using more global climate models in a climate modelling study gives a better idea of the range of possible future climate conditions, and the more confident we can be in the projected change in the Earth's climate.

The Intergovernmental Panel on Climate Change (IPCC) considered output from 23 global climate models when compiling its Fourth Assessment Report. Climate Futures for Tasmania used the same multi-model approach. However due to the modest scale of the project relative to the IPCC AR4, we used six GCMs. As the ability to accurately simulate present climate is a useful indicator of how well a model can simulate the future climate, we chose the six models for their ability to reproduce present day rainfall means and variability over Australia.

Generating fine-scale climate projections

Generally, climate information from global climate models has a resolution of 200 km to 300 km. This means that the Earth's surface is divided into grid cells that are 200 km to 300 km along each side. At this resolution, Tasmania is usually represented by one or two grid cells. In each grid cell, climate variables such as temperature and rainfall, and even the topography, have just a single value. This means global climate models do not allow us to understand the regional detail of climate change at local scales, for example they can not distinguish between the east coast and the Tamar Valley. For this level of detail, we downscale information from global climate models using an advanced dynamical model.

Global climate models used in Climate Futures for Tasmania		
Global Climate Model (GCM)	**Country of Origin**	**Approximate Horizontal Resolution**
CSIRO-Mk3.5	Australia	200 km
GFDL-CM2.0	USA	300 km
GFDL-CM2.1	USA	300 km
ECHAM5/MPI-OM	Germany	300 km
MIROC3.2(medres)	Japan	300 km
UKMO-HadCM3	United Kingdom	300 km

Emissions scenarios

It is very likely that rising greenhouse gases, along with aerosol emissions, stratospheric ozone depletion and other human influences, are responsible for much of the recent global climate change. The extent of future man-made climate change is dependent on the amount of greenhouse gases and other emissions that are released. The most commonly used and accepted set of emissions scenarios comes from the Intergovernmental Panel on Climate Change (IPCC), who outlined the scenarios in their 2001 Special Report on Emissions Scenarios (SRES). These scenarios, commonly referred to as SRES scenarios, are divided into six 'families' - A1FI, A2, A1B, B2, A1T and B1 – and are based on estimated future technological and societal (such as population growth) changes.

Climate Futures for Tasmania used a high emissions scenario (A2) and a low emissions scenario (B1). Using a high and a low emissions scenario provides a reasonable upper and lower range of climate change projections. It is worth noting that these emissions scenarios do not diverge significantly until the middle of the 21st century and thus the change in global mean near-surface temperature is roughly the same across all emissions scenarios up until the middle of the century. Consequently, the choice of SRES emissions scenario does not become important until the latter half of the century.

- Climate Futures for Tasmania has undertaken an extensive modelling program to deliver high quality projections of Tasmania's climate to 2100.

- We used a dynamical downscaling method to generate climate projections over Tasmania at a finer scale than ever before.

- We simulated the complex processes that influence Tasmania's weather and climate, providing a detailed picture of Tasmania's possible future climates. The dynamical downscaling used in this project is an established technique that uses inputs from global climate models to generate high-resolution climate simulations.

Emissions scenarios

Emissions scenarios

Global greenhouse gas emissions scenarios (including carbon dioxide, but also other greenhouse gases such as methane and nitrous oxides). Also shown are the updated likely range of greenhouse gas emissions, post SRES. Source: IPCC AR4

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Choosing a downscaling method

There are two established methods for downscaling global climate model information to a finer scale suitable for regional studies: <u>dynamical</u> downscaling and <u>statistical</u> downscaling.

Dynamical downscaling uses output from a 'host' global climate model as input into either a limited-area climate model or a stretched grid global climate model. Limited area climate models operate over a small part of the globe. Stretched grid global climate models operate over the entire globe, but focus on one small area in particular.

Regional climate models use the same physics as global climate models, and can be just as complex; however, because a regional model focuses on a small area, it provides more detail over that area than a global model, and is much more efficient and economical to run.

Statistical downscaling relates patterns and changes in large scale climate to the local climate. These statistical relationships are derived from historical observations. Once established, the relationships are applied to global climate model projections to produce fine-scale projections of local climate. Statistical downscaling is usually much less complex, and requires much less computing power, than dynamical downscaling.

Statistical and dynamical downscaling produce similar results for present-day climate, but can differ when examining future climate projections.

Statistical downscaling applies historically observed links between large-scale climate variables (from the global climate model) and local climate to a future climate. This is often considered a limitation of statistical downscaling, as these relationships may change in a warmer world. Dynamical downscaling models are complex enough to allow relationships between large-scale climate and local climate to change under future climate according to our understanding of atmospheric processes. A second limitation of projecting a changing climate using statistical downscaling is that the observations being used for the downscaling must span the range of projected future climate responses. In practice, this requires long, reliable observations of both the large and fine-scale climate. Such observational datasets are often not available. Dynamical models rely on our understanding of physical processes in the atmosphere, not only observations of climate.

Dynamical models are complex enough to simulate climate and climate changes at all scales, from global to regional, in a coherent manner. Using dynamical downscaling allows us to demonstrate changes in the local climate of Tasmania, such as changes to the timing, frequency and intensity of weather events – changes that are difficult to detect using statistical downscaling. Dynamical downscaling also maintains the relationships between different climate variables. For example, 'rainy days' will be 'cloudy' and 'cool', or when a 'cold front' passes over Tasmania the 'temperature' drops. This allows us to assess complex changes, for example changes to agricultural production, that involve the interaction of many climate variables (for example, the incidence of frost and available water).

The main constraint of dynamical downscaling is the technical complexity and computational cost. Because of the many benefits of dynamical downscaling, Climate Futures for Tasmania made the technical and financial commitment to use dynamical downscaling to provide the most detailed pictures of Tasmania's future climate possible.

From a few grid cells of information to many

From 2-6 grid cells of information...
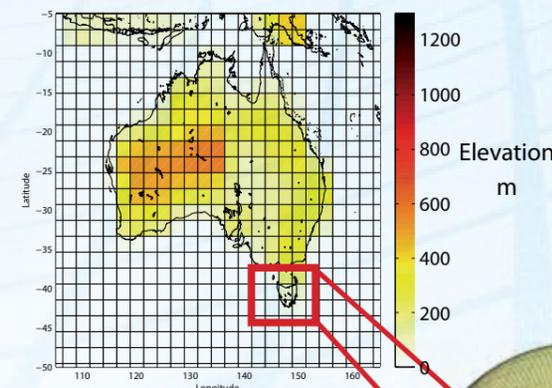
A close-up of how a typical global climate model sees Tasmania
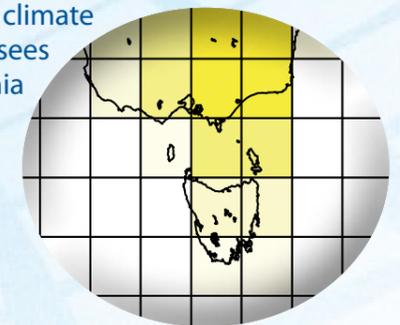
...to more than 720 grid cells of information
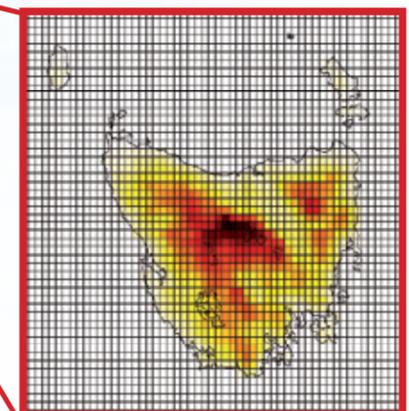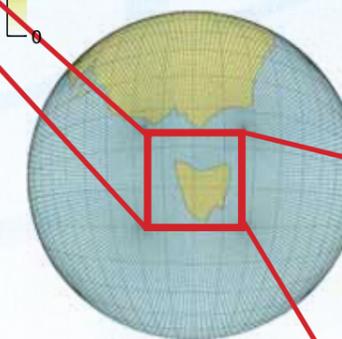
Increasing climate modelling resolution over Tasmania

Climate Futures for Tasmania improved the resolution of climate modelling, from a few grid cells over Tasmania in global climate models, to more than 720 grid cells in the new climate simulations.

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Applying the downscaling method

Tasmania is roughly 350 km by 300 km, the size of a few global climate model grid cells. After carefully weighing up the costs and benefits involved with downscaling to different grid-scales, Climate Futures for Tasmania decided on a final resolution of 0.1 degrees . This corresponds to a grid where each individual cell has side lengths of approximately 10 km. To achieve this resolution we undertook a two-stage dynamical downscaling process using CSIRO's Conformal Cubic Atmospheric Model (CCAM).

The two-stage process used sea surface temperature from the six selected global climate models (for each of the two SRES emissions scenarios) to create intermediate resolution simulations with a resolution of 0.5 degrees (around 60 km) over Australia.

Before we use the modelling output from the global climate models, we bias-adjust the sea surface temperature to bring the modelling output in line with the observed temperatures. These intermediate-resolution simulations are used as input for the simulations with a high-resolution over Tasmania (0.1 degrees or 10 km). We also produce a simulation with very high resolution over Tasmania (0.05-degrees) using the A2 emissions scenario and CSIRO-Mk3.5 as the host global climate model.

The temperature of the sea surface is a major factor in driving global climate systems (such as the monsoons, El Niño or the Roaring Forties), that in turn influence the local climate and weather conditions. Sea surface temperature (and sea-ice concentration in the polar regions) is the only information from the global climate model we use in the downscaling process. By only using information from the ocean surface, we allow the regional climate simulations to create their own pressure, wind, temperature and rainfall patterns in the atmosphere. These patterns occur in response to such local effects as topography. Using the sea surface temperatures from the host global climate model ensures the large-scale climate is the same as the global model.

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Downscaling for a different picture of the future

Global climate model

60 km simulation

10 km simulation

Percent change in rainfall

50
40
30
20
10
0   %
−10
−20
−30
−40
−50
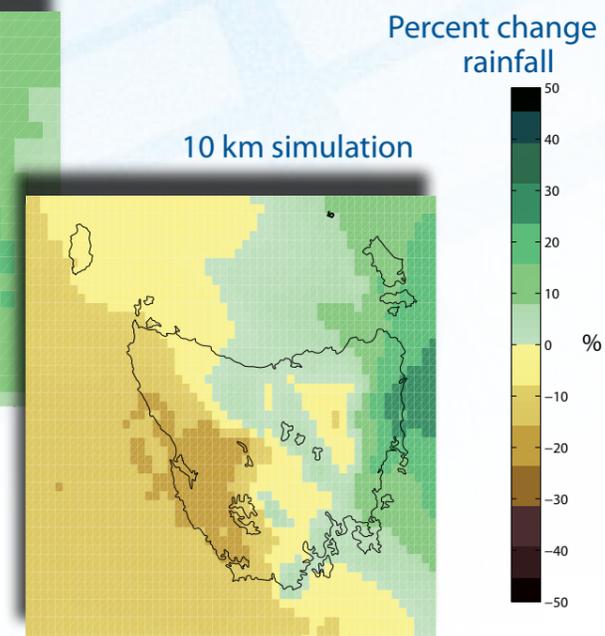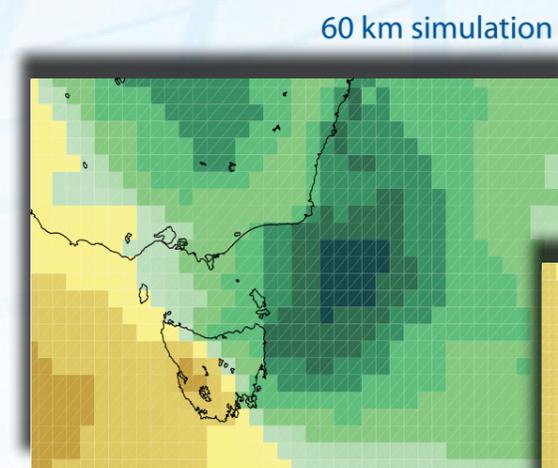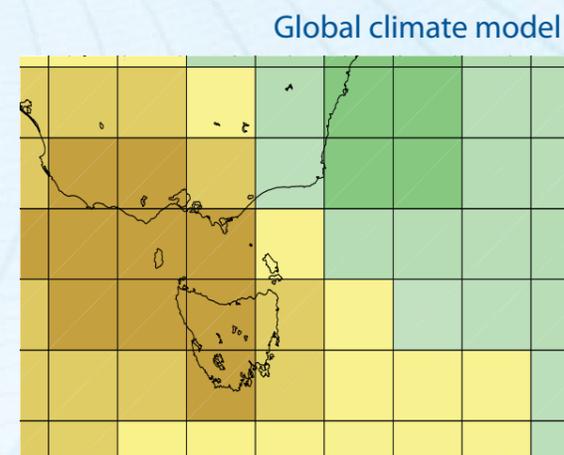
Downscaling can lead to a different story
The global climate model (top image) shows that summer rainfall is projected to decrease in the future. As we downscale from the global climate model (middle and bottom image) projections show an increase in summer rainfall on the east coast of Tasmania. This different projection is due to the improved ability of the downscaled simulations to model drivers of Tasmanian rainfall.

- The suite of simulations took approximately 1300 days of continuous computer time on a 0.82 teraflop computer and required in excess of 75 terabytes of storage. The climate simulations generated by the project occupy more than twice the storage space of the modelling output considered by the Intergovernmental Panel on Climate Change (IPCC) in compiling their Fourth Assessment Report (AR4).

- The end products include 17 simulations of the climate of Tasmania at a resolution of 0.1 degrees (about 10 km) or better. These simulations are all downscaled from global climate models of the kind used in the IPCC Fourth Assessment Report.

- The simulations were run with a time step of only six minutes, with more than 140 variables recorded every six hours of model time. The simulations provide estimates of the Tasmanian climate for both the recent past (1961-2009) and the future (2010-2100). For some variables (such as temperature and rainfall), output is available every three hours.

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Building trust in the simulations

Running a climate simulation to generate a projection of future climate is just like running an experiment. The more often you repeat an experiment and get a similar answer, the more trustworthy the results. To test whether our projections of future climate are realistic, we run many simulations and study the similarities (and differences) in the results.

Just like cars, there are many types of global climate models. Some models are produced in the UK (UKMO-HadCM3), some in the US (GFDL-CM2.0 and GFDL-CM2.1), Japan (MIROC3.2(medres)), Germany (ECHAM5/MPI-OM), Australia (CSIRO-Mk3.5) and several other nations. Using six global climate models allows us to repeat the experiment six times. Where the simulations agree we have increased confidence in our projections. The differences between the simulations allow us to estimate the uncertainty in our projections.

Comparing observations and simulations - rainfall

Gridded observations
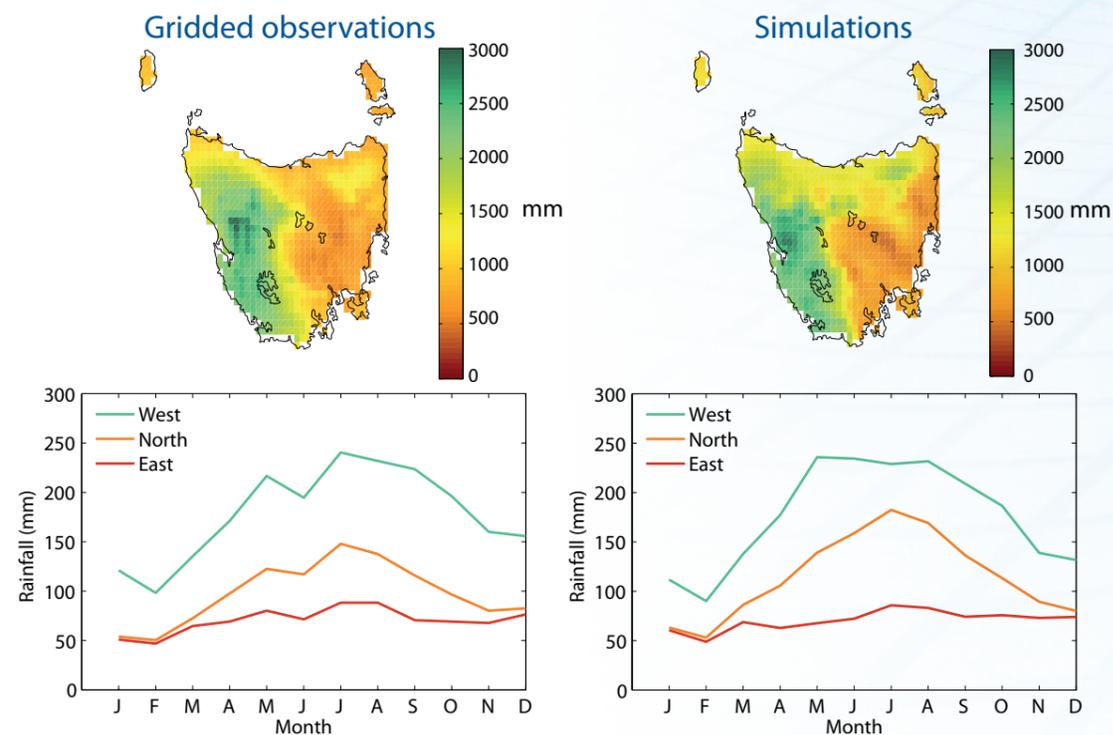
Simulations

Global climate models do not know anything about the current climate aside from the composition of the atmosphere and radiation from the sun. They generate a completely simulated climate, that is, no observations of the current weather or climate have been used to steer them. The downscaled simulations only know the bias-adjusted sea surface temperature from the global climate models. They are not told about past weather and thus, there is no direct link between the simulations and the observed records. This means that we can test the skill of our model in simulating a realistic climate by comparing the simulations representing the recent past with observations in the same period.

The dynamically downscaled simulations have a high level of skill in reproducing the recent climate of Tasmania across a range of climate variables.

Comparing our simulations to observations (the Bureau of Meteorology's AWAP* dataset) for the period 1961-2007, shows that the central estimate (the average of the six simulations) of statewide daily maximum temperature is within 0.1°C of the observed value of 10.4 °C. The simulated average annual rainfall of 1385 mm is very close to the observed value of 1390 mm.

The maps of Tasmania (at left) show that the simulations reproduce the spatial pattern of rainfall over the state. For example, high rainfall in the south-west and a drier east coast and Derwent Valley.

Similarly, the dynamically downscaled models reproduce the different seasonality in climate variables (for example, rainfall) in different regions of Tasmania. The graphs show the monthly rainfall in three regions of Tasmania. The simulations reproduce the wet winters and drier summers on the west coast and the consistently low rainfall throughout the year on the east coast.

The downscaled simulations have reproduced the spatial variability of rainfall, temperature and other climate variables across Tasmania with much greater accuracy than in the global climate models or previous studies.

To test the credibilty of the simulations we:

• Compare the downscaled modelling output with the original output from the global climate model, for example, annual statewide mean temperature. This confirms that we maintain consistency with large-scale climate variables.

• Compare the downscaled simulations to the observed data. This includes temporal checks (annual, seasonal and daily), spatial checks (west coast versus the midlands) and tests for variability.

• Check the internal consistency of climate drivers. For example, we evaluate the strength of the large-scale pressure patterns such as the Southern Annular Mode and atmospheric blocking, and important ocean effects such as the sea surface temperature of the East Australian Current. In short, this is checking it is raining in the right places, for the right reasons.

• Examine what drives the changes to the climate into the future and ensure this is consistent with our knowledge of climate dynamics and processes. For example, the effect of an increase in mean pressure patterns leads to changes to the dominant westerly winds, like the Roaring Forties.

• Use the climate modelling outputs as inputs into biophysical or hydrological models. By showing that our simulations generate similar results to observed records when used in biophysical or hydrological models, we gain further confidence.

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* AWAP is the Australian Water Availaibilty Project, a joint project between CSIRO and the Bureau of Meterology. See box on next page for further details.

Bias-adjusting the simulations

Global and regional climate models cannot provide all the information that is needed about climate change. Climate indices, biophysical models and hydrological models are essential tools for measuring the impacts of a changing climate on areas such as agriculture and water management, and evaluating adaptation strategies. Climate indices include simple thresholds of crop requirements, such as mean annual temperature or rainfall ranges, and more complex calculations, such as growing degree days and chill hours. Biophysical models include those that simulate crop or pasture growth, or the distribution and dynamics of weeds, pests and diseases. Hydrological models are used to estimate water yields from catchments. Biophysical and hydrological models are driven by climate modelling output.

All climate model simulations contain biases. Biases are errors that occur consistently and predictably. Often these biases are caused by the model's resolution. For example, the 10 km resolution of the Climate Futures for Tasmania simulations means that steep ridgelines may not be captured, so the resulting rain shadow on the downwind side of the ridge is not represented in the simulation. The lack of resolution leads to the model consistently under/over estimating the rainfall at some locations. When considering climate trends, and for most places where climate modelling output is used as input to other tools, the small biases in our climate simulations have little impact. However, in applications such as agricultural and hydrological modelling, these biases could result in unrealistic estimates of future change.

For these applications, climate simulations need to be bias-adjusted; a standard scientific method for handling consistent differences between observations and simulations. This involves scaling the climate modelling outputs so that for the period 1961-2007 the absolute range and frequency of simulations matches the observations. The bias-adjustment process assumes that the biases in the climate models are constant throughout the length of the model run (1961-2100).

Climate Futures for Tasmania bias-adjust modelling output for daily minimum and maximum temperature, rainfall, solar radiation and potential evaporation for each downscaled simulation and each emissions scenario (A2 and B1) for the period 1961-2100. These simulations are a valuable resource for any climate change research in Tasmania using biophysical or hydrological models, or other applications where modelling output needs to be closely aligned to observations. The bias-adjusted simulations are available at www.tpac.org.au.

Observed climate dataset - AWAP

Climate Futures for Tasmania used the Australian Water Availability Project (AWAP) data to evaluate project modelling output against the observed climate.

The AWAP data uses observations from the Bureau of Meteorology to create a gridded dataset over the whole of Australia. It contains a range of observational data, including maximum daily temperature, minimum daily temperature, daily rainfall, solar radiation and potential evaporation, produced on a 0.05-degree grid.

To allow direct comparison with the Climate Futures for Tasmania modelling output, the AWAP data for Tasmania is interpolated to the same 0.1-degree grid used in the simulations.

- The bias-adjusted modelling output can be used confidently in biophysical, agricultural and hydrological modelling applications to assess the impacts of climate change.

- Our bias-adjusted simulations contain the modelling output of five key variables: daily maximum temperature, daily minimum temperature, rainfall, solar radiation and potential evaporation.

- Some examples of results generated using bias–adjusted modelling output are viewable on 'TheLIST', and the outputs themselves can be obtained from the Tasmanian Partnership for Advanced Computing (TPAC) data portal:

  www.thelist.tas.gov.au

  www.tpac.org.au

Using bias-adjusted data: impacts on agriculture

An increase in available heat and changing rainfall will have a profound effect on pastures and crops. These impacts may be beneficial or detrimental, depending on the species. We calculate agricultural indices from the projections and use the biophysical models, DairyMod* and CLIMEX*, to describe the impacts of a changing climate on agriculture.

For example, irrigated ryegrass yields at many locations are projected to increase 20% to 30% by 2040 but then decline to current levels due to projected increases in the number of hot days during summer months.

Using bias-adjusted data: changes to runoff

Tasmanian river flows are realistically simulated using climate projections as direct inputs to hydrological models. Runoff in Tasmania's catchments is projected to change spatially and seasonally during the 21st century.

Changes to rainfall are often amplified in changes to runoff: for example, projected rainfall in the central highlands decreases by up to 15%, but runoff decreases by up to 30%.
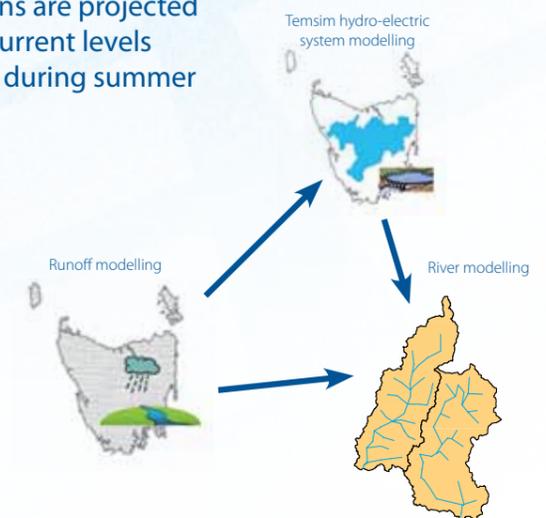
Temsim hydro-electric system modelling

Runoff modelling

River modelling

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* DairyMod was developed by researchers at the University of Melbourne and funded by Meat & Livestock Australia, Dairy Australia and AgResearch (New Zealand). CLIMEX was developed by researchers at CSIRO Entomology and is distributed by Hearne Scientific Software.

Using the simulations

While the new climate simulations are invaluable, their full potential is not realised unless researchers and policy makers use them in their research, business planning and decision making processes. Therefore, to make sense of the mathematically complex simulations, an intermediate step is required to extract and interpret the simulations for particular geographic areas, industry sectors or applications. The project team demonstrated how to analyse and use the new climate information in a selection of disciplines; Tasmania's weather, water catchments, agriculture and climate extremes.

Through working with other researchers and scientists, complementary studies demonstrated the use of the modelling outputs in applied and biophysical models to generate customised information for specific sectors. Below are some examples of these complementary studies.

Impacts on dairy pasture growth

The Tasmanian Institute of Agricultural Research used the climate modelling outputs in agricultural biophysical models like APSIM, DairyMod and GrassGro to assess the likely changes in pasture and crop production due to climate change. These biophysical models provide an assessment of forage supply and also allow for the assessment of adaptations within the farming systems in response to a changing climate. Having a sense of the likely changes in the amount and the seasonality of forage supply will help farmers decide on the appropriate local responses and adaptation options. The use of whole-of-farm system models also allows for differing adaptations to be explored both now and into the future with the new climate information.

Project Contact: Dr Richard Rawnsley

Impacts on the oyster industry

The National Adaptation Research Network for Marine Biodiversity and Resources supported a study into climate adaptation options for the Australian edible oyster industry. The network researchers used the Climate Futures for Tasmania simulations to inform them of the likely changes to climate conditions that impact the oyster industry; these include extreme flooding events impacting oyster harvesting operations and heat waves. The study titled "*Climate Change Adaptation in the Australian Edible Oyster Industry: an Analysis of Policy and Practice*" identifies the key collective actions and opportunities for adaptation in the industry.

Project Contact: Dr Peat Leith

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Impacts on ecosystems

Scientists from the Tasmanian Department of Primary Industries, Parks, Water and Environment used the new climate information to assess the potential impact of climate change on Tasmania's natural environments. Their report "*Vulnerability of Tasmania's Natural Environment to Climate Change: An Overview*" is the first step in better understanding the possible impact. The report helps guide the formulation of policy and management responses in Tasmania's terrestrial, freshwater and marine systems.

Project Contact: Dr Louise Gilfedder

- More than 50 complementary studies have used the new climate information to determine the impacts of climate change on ecosystems, built-environment, agriculture and other aspects of the natural environment in the Tasmanian region.

Impacts on hydropower generation

Future changes in rainfall and evaporation are likely to have a significant impact on power generation potential, but by how much and when is a challenging question for hydropower generators. Hydro Tasmania is using the climate modelling outputs as inputs to their power generation systems-model, Temsim, to investigate the potential impact to generation across the entire system throughout the century; a period that encompasses lifecycle planning for significant engineering structures.

The analysis of future yields can then be used to target where future changes to plant refurbishment and storage management may be required to limit the impacts of climate change on hydroelectricity generation. The results of this work have already indicated that climate change is a credible risk to Hydro Tasmania's business. Hydro Tasmania is already implementing adaptive management strategies in its high level planning and in its storage operation as a direct response to changing inflows to the hydropower storages.

Project Contact: Dr Fiona Ling

Impacts on infrastructure

Infrastructure and buildings are sensitive to changes in one or more climate variables, and sometimes to a combination of climate variables. Assessing the vulnerability of different infrastructure types, in different locations against a multitude of possible future changes in climate variables can be complex and challenging. Just having the new climate simulations does not give the answers required for planning and adapting infrastructure for climate change.

Engineering firm, Pitt & Sherry, has developed the ClimateAsyst® tool to help infrastructure managers and planners identify what climate change impacts are critical to specific infrastructure. Acting as an interface between the complex climate simulations and the end-users' world, the ClimateAsyst® tool allows the infrastructure manager to identify and select the appropriate climate variables and interpret them against their own assets or planned locations for future assets. The tool provides a snapshot assessment in a GIS format with links to documentation and building code standards.

Project Contact: Sven Rand

Climate modelling program

6 GCMs (Sea surface temperatures as input)

GCMs to 60 km

2-stage
downscaling
process

Stage 1
0.5º grid ~ 60 km

Stage 2
0.1º grid ~ 10 km

60 km to 10 km

Re-grid from CCAM*
grid to limited area
regular grid

Output to TPAC*
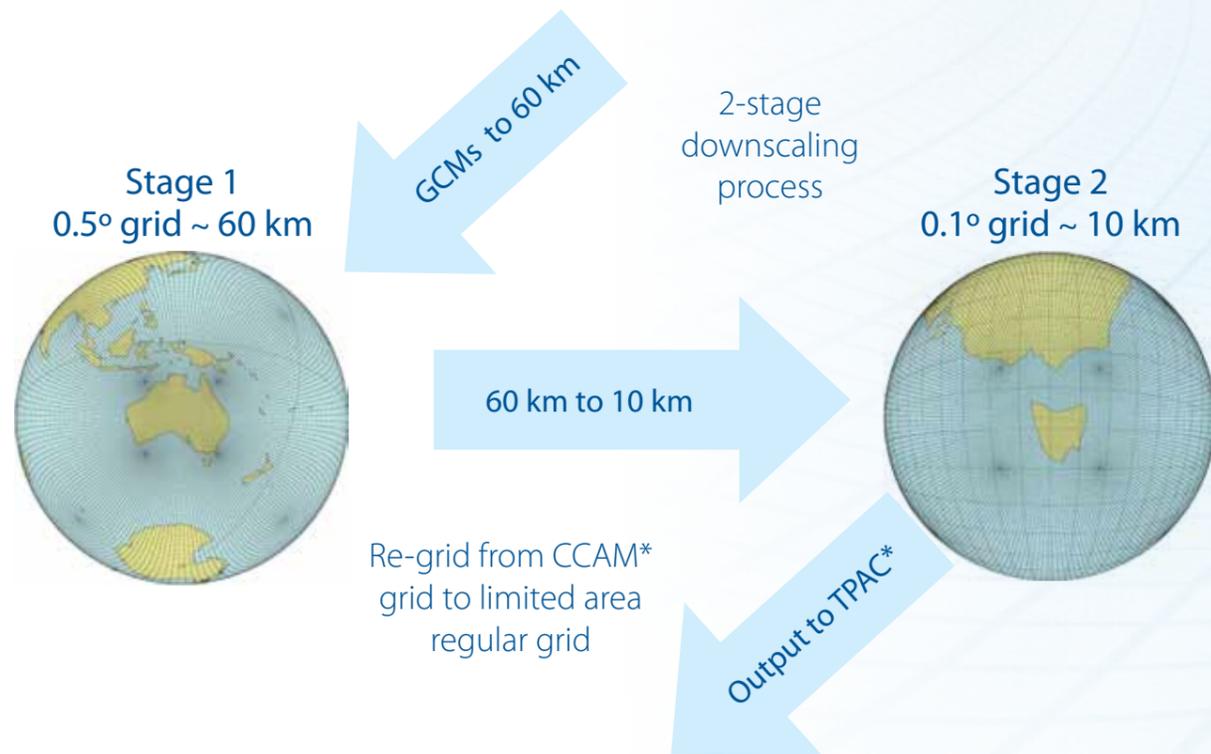
6 downscaled-GCMs with 2 IPCC emissions scenarios
providing
12 simulations covering 1961 - 2100

12 Bias-adjusted simulations for biophysical,
agricultural and hydrological
modelling applications

* CCAM, Conformal Cubic Atmospheric Model
* TPAC, Tasmanian Partnership for Advanced Computing

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Climate change

There is overwhelming scientific evidence that the earth is warming and that increased concentrations of greenhouse gases caused by human activity are contributing to our changing climate.

Change is a feature of the 21st century global climate. The need to understand the consequences and impacts of climate change on Tasmania and to enable planning for adaptation and mitigation of climate change at a regional level has been recognised by both the Tasmanian and Australian Governments.

Increased temperatures are just one aspect of climate change. Global warming also causes changes to rainfall, wind, evaporation, cloudiness and other climate variables. These changes will not only become apparent in changes to average climate conditions but also in the frequency and intensity of extreme events such as heatwaves, flooding rains or severe frosts.

While climate change is a global phenomenon, its specific impacts at any location will be felt as a change to local weather conditions. This means we need regional studies to understand the effects of climate change to specific areas. Climate Futures for Tasmania is one such regional study, producing fine-scale climate change projections that will allow for the analysis of climate impacts at different locations within Tasmania, and of changes to seasonality and extreme events.

The Climate Futures for Tasmania project is the Tasmanian Government's most important source of climate change information at a local scale. It is a key part of Tasmania's climate change strategy as stated in the Tasmanian Framework for Action on Climate Change and is supported by the Commonwealth Environment Research Facilities as a significant project.

This project has used a group of global climate models to simulate the Tasmanian climate. The project is unique in Australia: it was designed from conception to understand and integrate the impacts of climate change on Tasmania's weather, water catchments, agriculture and climate extremes, including aspects of sea level, floods and wind damage. In addition, through complementary research projects supported by the project, new assessments were made of the impacts of climate change on coastal erosion, biosecurity and energy production, and the development of tools to deliver climate change information to infrastructure asset managers and local government.

As a consequence of this wide scope, Climate Futures for Tasmania is an interdisciplinary and multi-institutional collaboration of twelve core participating partners (both state and national organisations). The project was driven by the information requirements of end users and local communities.

'The Summary' is an at-a-glance snapshot of the Climate Modelling Technical Report. Please refer to the full report for detailed methods, results and references.

The Climate Futures for Tasmania project complements climate analysis and projections done at the continental scale for the Fourth Assessment Report from the Intergovernmental Panel on Climate Change, at the national scale in the Climate Change in Australia Report and data tool, as well as work done in the south-east Australia region in the South Eastern Australia Climate Initiative. The work also complements projections done specifically on water availability and irrigation in Tasmania by the Tasmania Sustainable Yields Project.

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Climate Futures for Tasmania is possible with support through funding and research of a consortium of state and national partners.

Enquiries

Find more information about Climate Futures for Tasmania at:

climatefutures@acecrc.org.au

www.acecrc.org.au

To access the modelling outputs:

www.tpac.org.au

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Technical Reports

Bennett JC, Ling FLN, Graham B, Grose MR, Corney SP, White CJ, Holz GK, Post DA, Gaynor SM & Bindoff NL 2010, *Climate Futures for Tasmania: water and catchments technical report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

Cechet RP, Sanabria A, Divi CB, Thomas C, Yang T, Arthur C, Dunford M, Nadimpalli K, Power L, White CJ, Bennett JC, Corney SP, Holz GK, Grose MR, Gaynor SM & Bindoff NL 2011, *Climate Futures for Tasmania: severe wind hazard and risk technical report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

Corney SP, Katzfey JJ, McGregor JL, Grose MR, Bennett JC, White CJ, Holz GK, Gaynor SM & Bindoff NL 2010, *Climate Futures for Tasmania: climate modelling technical report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

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Holz GK, Grose MR, Bennett JC, Corney SP, White CJ, Phelan D, Potter K, Kriticos D, Rawnsley R, Parsons D, Lisson S, Gaynor SM & Bindoff NL 2010, *Climate Futures for Tasmania: impacts on agriculture technical report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

McInnes KL, O'Grady JG, Hemer M, Macadam I, Abbs DJ, White CJ, Bennett JC, Corney SP, Holz GK, Grose MR, Gaynor SM & Bindoff NL 2011, *Climate Futures for Tasmania: extreme tide and sea level events technical report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

White CJ, Grose MR, Corney SP, Bennett JC, Holz GK, Sanabria LA, McInnes KL, Cechet RP, Gaynor SM & Bindoff NL 2010, *Climate Futures for Tasmania: extreme events technical report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

Citation for this document

Project reports and summaries are available for download from: www.climatechange.tas.gov.au