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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

Private Bag 80
Hobart Tasmania 7001
Tel: +61 3 6226 7888
Fax: +61 3 6226 2440



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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.

Grose MR, Barnes-Keoghan I, Corney SP, White CJ, Holz GK, Bennett JC, Gaynor SM & Bindoff NL 2010, *Climate Futures for Tasmania: general climate impacts technical report*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

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

ACE CRC 2010, *Climate Futures for Tasmania extreme events: the summary*, Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

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



the summary

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Extreme events in a changing climate

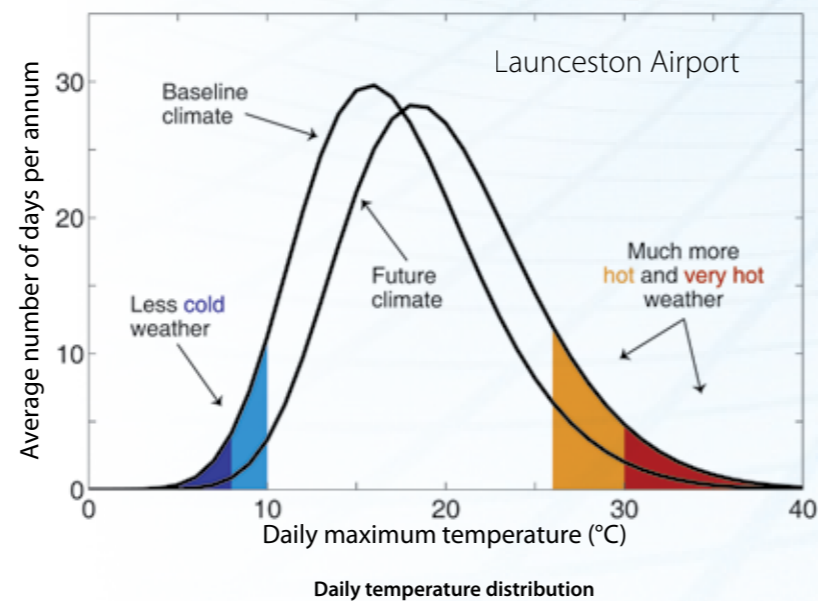
A climate event is 'extreme' when it (or a series of events) occurs with greater intensity, frequency or duration than is normally expected. Every region of the world experiences extreme events from time to time and natural climate variability already produces extreme events in Tasmania. This includes heat waves, cold waves, floods, droughts and storms. Extreme events can have devastating and wide-ranging effects on society and the environment, impacting infrastructure, agriculture, utilities, water resources and emergency planning.

Over the past decade there has been significant research investigating historical trends in climate events and the possible links between extreme events and climate change. The Intergovernmental Panel on Climate Change (IPCC) concluded in its fourth assessment report (AR4) that higher maximum and minimum temperatures, more hot days and fewer cold days, and more intense rainfall events have been observed in the latter half of the 20th century.

The IPCC AR4 evaluated extreme climate events in the context of climate change on a global basis. Climate modelling reported by IPCC AR4 demonstrated that a gradually warming world would be accompanied by changes in both the intensity and frequency of extreme climate events. These changes could occur even with relatively small variations to the mean climate. In other words, a small change in the mean of a climate variable (such as temperature) can cause a disproportionately larger change in the intensity and frequency of extreme temperatures.

Climate Futures for Tasmania examined extreme events in the Tasmanian context to determine how climate change might alter the characteristics of these events in the 21st century.

Changes to the frequency of extreme events



A temperature distribution plot showing a small change in the mean of a climate variable can cause a proportionally larger change in the variability and frequency of extreme events.

Modelling future climate

Global climate models (GCMs) provide the best estimates of global change to our climate to the end of the 21st century. Recent advances in climate modelling techniques have enabled simulations of extreme climatic events at appropriate scales.

Greenhouse emissions scenario

Climate Futures for Tasmania simulated future climate with six downscaled global climate models. Reported in this summary is the A2 (high greenhouse emissions) scenario from the Intergovernmental Panel on Climate Change's Special Report on Emissions Scenarios; the highest emissions scenario for which IPCC GCM projections were available and the best match for recent rates of greenhouse gas emissions.

Dynamical downscaling

Global climate model output, at a resolution of 200 km to 300 km, is too coarse for understanding changes in extreme events that occur at a relatively small spatial scale and are often short in duration. In Climate Futures for Tasmania, GCM output was used in another climate model (CCAM) that creates regional climate information. This process is called downscaling. The downscaling was carried out to a 0.1-degree (approximately 10 km) grid.

Bias-adjustment

All climate model simulations contain biases. Biases are errors that typically 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.

For studying many climate indices, most climate simulations need to be 'bias-adjusted'. This is a standard scientific method for handling consistent differences between observations and simulations. The climate simulations were carefully adjusted to be like observations from the Australian Water Availability Project (AWAP*) dataset. For the very extreme analysis using Annual Recurrence Intervals (ARIs), we used the raw modelling output. The results included in this summary are the A2 emissions scenario, presented as the mean of the six simulations, and the changes assessed against the reference period or baseline period of 1961-1990.

- Climate Futures for Tasmania is the most complete regional climate change study of Tasmania for the 21st century.
- We used dynamical downscaling 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 future climates.
- The dynamical downscaling used in the project is an established technique that uses input from global climate models to generate high-resolution climate simulations.
- The successful validation of the climate simulations gives confidence in projections of future temperature and rainfall, and their use to analyse changes in extreme weather events.

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* AWAP is the Australian Water Availability Project, a joint project between CSIRO and the Bureau of Meteorology.



Changes to extreme events in Tasmania

For Tasmania, the pattern of extreme weather is likely to change across a broad range of climate indices by the end of the century. The emerging pattern of change across these indices represents a consistent and progressive adjustment of the current climate and its weather patterns to a new climate. The new climate will have more hot days and warm nights, more extreme wet days, an increase in more intense rainfall and more dry days. Rain events will intensify, leading to a tendency for increases in both drier and wetter conditions on seasonal and annual periods. This means a reduction in the occurrence of 'average conditions' that we have experienced.

Changes to extreme temperatures

The projections for the high emissions scenario (A2) to the end of the 21st century indicate:

- a reduction in the number of frost days across the island;
- an increase in the number of 'tropical nights' (when the minimum temperature is greater than 20 °C), mainly in the northern and eastern coastal areas;
- an increase in the numbers of warm days and warm spells (a series of warm days), particularly in the central north and midlands, the Derwent Valley and the west coast around Macquarie Harbour;
- cold spells are projected to decrease.

Changes to extreme rainfall events

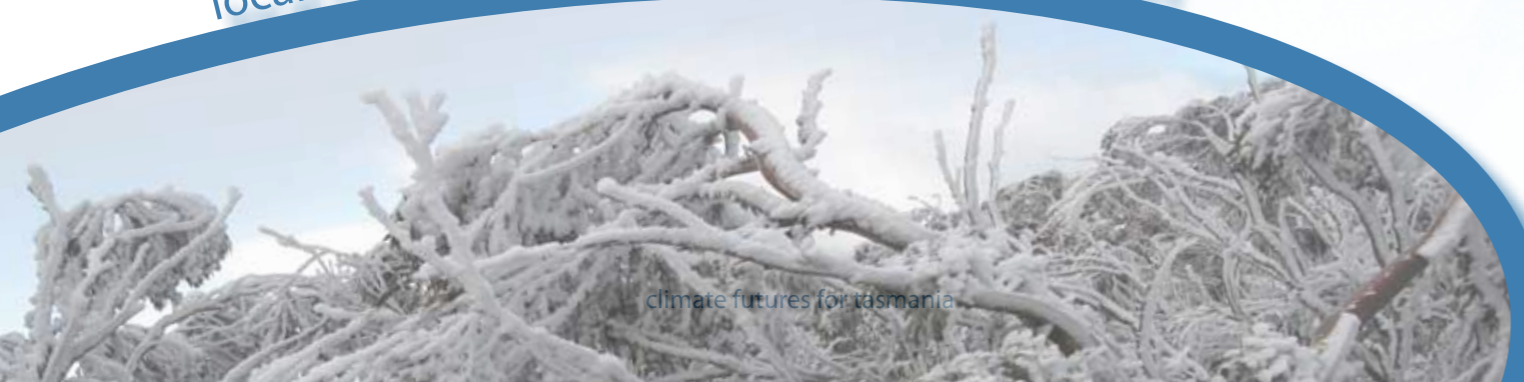
Rainfall projections to the end of 21st century suggest there will be an increase in the number of very wet days, more intense 1-day rainfall totals and significant increases in the 6-minute rainfall rates (particularly in eastern Tasmania).

These changes are likely to increase the risk of flooding. In particular, the west and north-east coastal regions of Tasmania display a pattern of an increasing number of wet days in winter and early spring and a decrease in summer. In some regions, more intense heavy downpours are likely to be combined with longer dry periods (that is, more time between wet days), as the nature of extreme rainfall events changes across Tasmania.

Historical extreme events in Tasmania

Event type	Description
Hot and cold spells	<p>Although Tasmania does not regularly see extreme temperatures like those seen in many parts of the Australian mainland, it does still experience high temperature events.</p> <p>On 30 January 2009 the Bureau of Meteorology recorded the highest temperature on a single day, with 42.2 °C observed at Scamander in the state's north-east.</p> <p>The lowest temperatures observed in Tasmania were on 30 June 1983 in the central highlands at Butlers Gorge, Shannon and Tarraleah, with recorded temperatures as low as -13.0 °C.</p>
Droughts and dry spells	<p>The last century in Australia was characterised by droughts during the 1900s, the 1930s and the 1940s, interspersed with widespread wet conditions in the 1950s and 1970s (Hennessy et al 2008). In Tasmania, while the areas experiencing long-term exceptionally low rainfall have actually decreased slightly since 1900, the shorter-term period 1998-2007 has seen an above average area of exceptionally low rainfall across the state.</p> <p>Hobart recently experienced its driest seven months on record (January – July 2010), with just 5.8 mm of rain falling in the month of July, compared to an average of 52.0 mm.</p>
Flooding and high rainfalls	<p>The worst flood disaster in Tasmania occurred in northern and eastern regions of the state from 4-6 April 1929. Launceston was particularly affected, resulting in 22 deaths.</p> <p>The state record for the highest rainfall in one day occurred at Cullenswood in the north-east, which received 352 mm of rain on 22 March 1974.</p>
Bushfires	<p>The most devastating bushfire in Tasmania occurred on 7 February 1967. Widespread fires caused 64 deaths (Haynes et al 2008) and destroyed 1400 homes and structures in the south and east of the state.</p> <p>Similar extreme bushfire conditions occurred recently on 12 October 2006, causing bushfires across the Meehan Range to the east of Hobart. Fortunately, these were contained and no lives were lost.</p>

Sources: Bureau of Meteorology, www.bom.gov.au for all events except as noted.
 Haynes K, Tibbits A and Lowe T, 'Local knowledge and gender: re-evaluating the 1967 Hobart bushfire fatalities', Risk Frontiers Quarterly Newsletter, Volume 7, Issue 2, 2008.
 Hennessy K, Fawcett R, Kirono D, Mpelasoka F, Jones D, Bathols J, Whetton P, Stafford Smith M, Howden M, Mitchell C and Plummer N 2008, Drought: exceptional circumstances, *An assessment of the impact of climate change on the nature and frequency of exceptional climatic events*, CSIRO and Bureau of Meteorology, 33pp., <http://www.bom.gov.au/droughtec>.





extreme temperatures

Frost days, summer days and tropical nights

The number of frost days per year (when the overnight minimum is less than 0 °C) is projected to decrease substantially by the end of the century. The greatest decrease is in the central regions of Tasmania, where the highest number of frost events are experienced. An eight-fold decrease in the frequency of frosts at Miena/Liawenee is projected.

The number of 'summer days' (when the maximum temperature is greater than 25 °C) is projected to increase by the end of the century. The increase occurs across Tasmania but the larger increases occur at lower elevations, particularly throughout the midlands. Most regions are projected to experience a 2 to 3 fold increase in the number of summer days.

The number of tropical nights (when the minimum temperature is greater than 20 °C) is also projected to increase, from no tropical nights to up to 20 tropical nights per year. This increase in the number of tropical nights is projected mainly around the northern coastal regions and on Flinders Island.

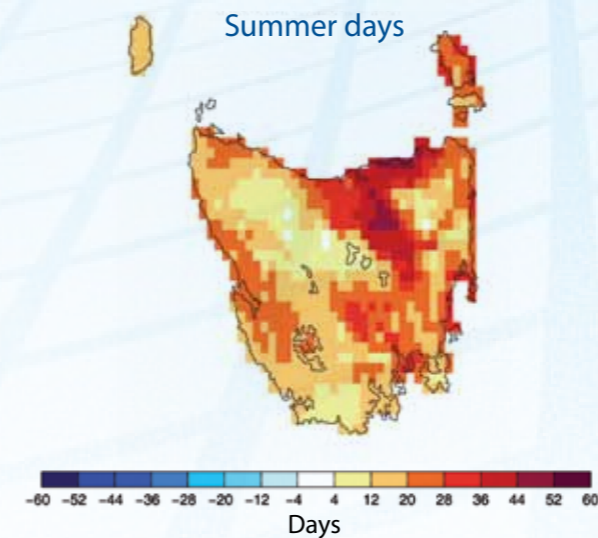
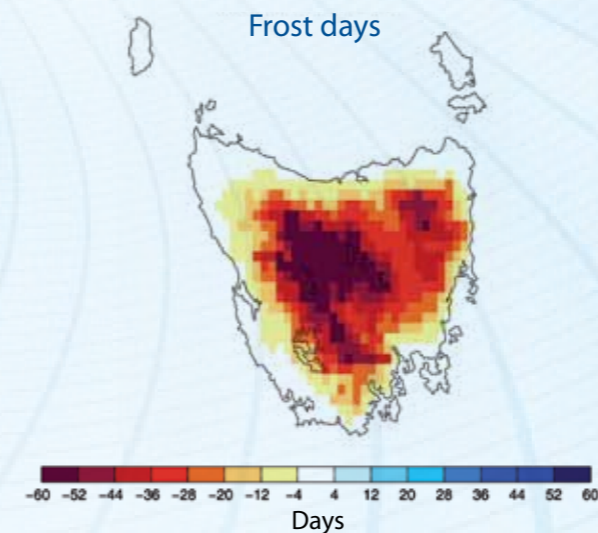
Extreme temperature events

Near the end of the century, annual daily maximum temperatures are projected to increase almost uniformly across Tasmania by between 2.1 °C and 3.3 °C, with a tendency for the larger changes to occur inland. Seasonally, the largest increases (greater than 4.0 °C) tend to occur in the spring and autumn months; the seasons where the daily average temperature is changing fastest. The larger temperature changes in these seasons result in an extension of summer weather.

For Tasmania, our simulations suggest that the mean annual maximum temperatures are likely to increase slightly more than mean annual minimum temperatures.

The frequency of extreme temperature days will change

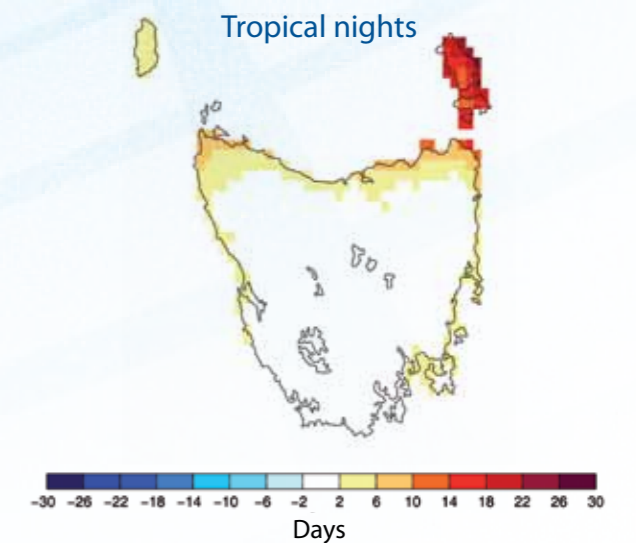
Change to 2070-2099



- Hot summer days and heat waves are projected to increase. The number of summer days warmer than 25 °C is projected to double or triple, relative to what we have experienced.
- Some areas of Tasmania will see 40 additional summer days per year by the end of the 21st century. The largest increases in extreme temperatures are projected to occur in the spring and autumn months, with increases of greater than 4.0 °C. This increase is substantially greater than the projected mean temperature change.
- In the central highlands, the projections show an eight-fold decrease in the number of cold waves.

Extreme temperature indices

The maps show the change by the end of the century to the number of frost days (when the overnight temperature is less than 0 °C) - top left; summer days (when the maximum temperature is greater than 25 °C) - bottom left; and tropical nights (when the minimum temperature is greater than 20 °C) - below.



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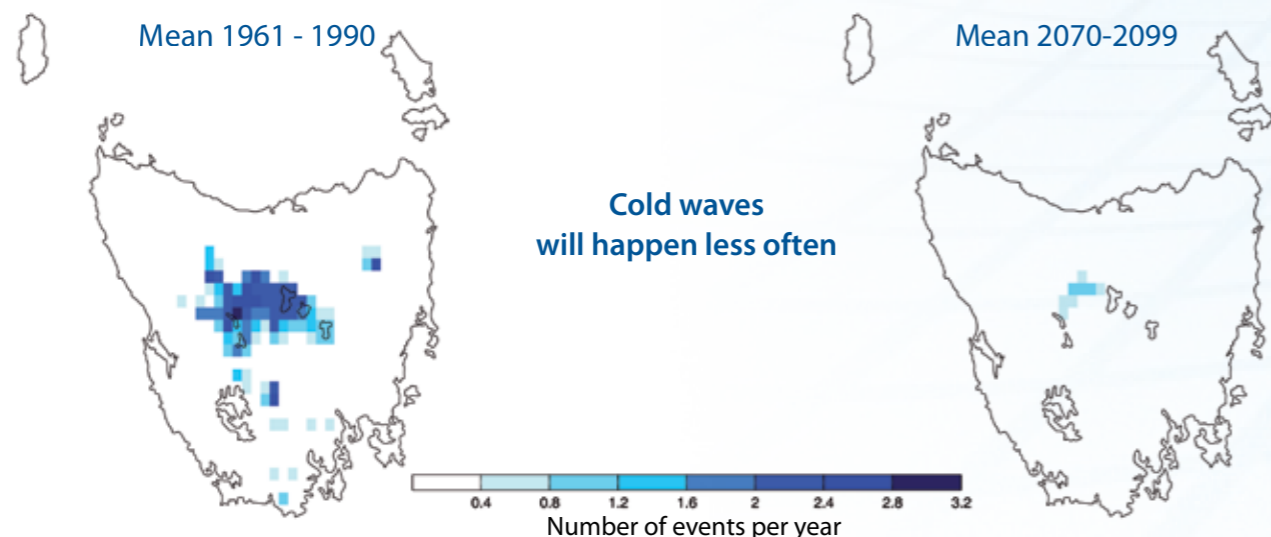
Warm spells, heat waves and cold waves

As well as the projected changes to both the number and intensity of daily temperature events, it is useful to determine changes in multi-day events, particularly heat waves.

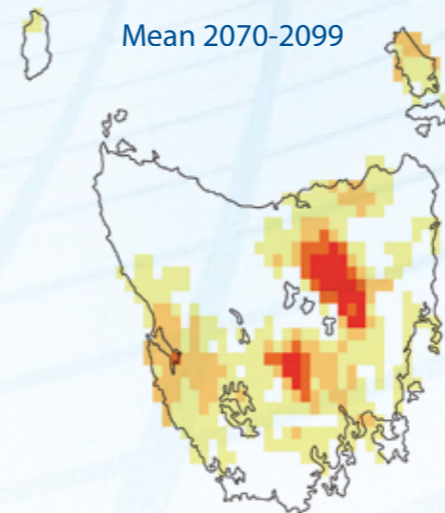
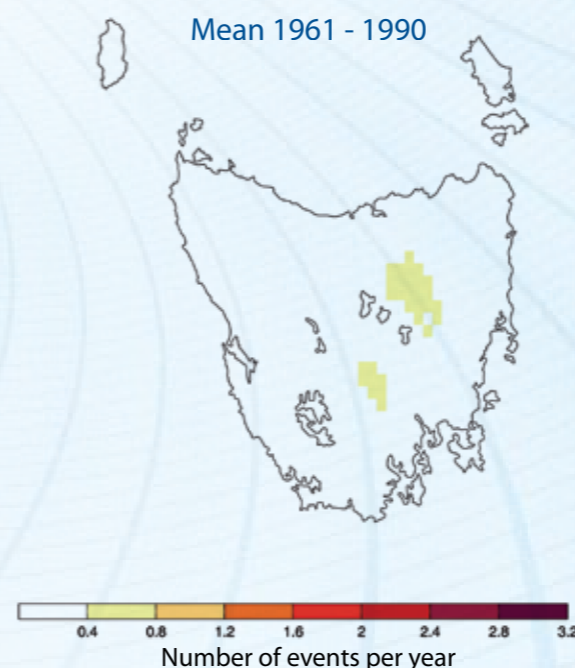
Heat waves are defined as three or more consecutive days where the maximum temperature is above 28 °C. From the midlands through to the north coast, the Derwent Valley and the south-west around Macquarie Harbour are all projected to have significant increases in the number of heat waves. Projections suggest the frequency of heat waves will continue to increase throughout the century and, on average, may occur twice a year, which is about four times more frequently than we have experienced.

Warm spells are defined as three or more consecutive days where the maximum temperature is above 20 °C. There is a significant increase in warm spells by the end of the century. This is particularly apparent in the northern half of Tasmania, where the total number of warm spells per year is likely to increase by as much as four times.

Cold waves are defined as three or more days colder than 5 °C. The projected decline in the frequency of cold wave events at Miena/Liawenee suggests that by the end of the century, they will experience a more than 10-fold reduction in the frequency of cold waves. These changes are consistent with the projected decreases in the frequency of individual frost days.



Heat waves will happen more often



Tasmania is projected to get warmer

The frequency of heat waves will continue to increase throughout the century and, on average, may occur twice a year, which is about four times more frequently than we experience now. Cold wave events are projected to decrease significantly.

Temperature ranges

Throughout the 21st century, increases to daily minimum and maximum temperatures are projected for all locations across Tasmania. However, minimum and maximum temperatures are not projected to increase by the same amount.

The extreme temperature range (the difference between the highest and lowest temperatures per year) increases in most areas of Tasmania, particularly the south-east and west coast, but with small decreases along the north coast. For example, there is a projected increase in the extreme temperature range of around 3 °C for Hobart, whereas Devonport on the north coast shows a projected decrease of 1 °C.

The diurnal range is the difference between daily maximum and minimum temperatures. There is likely to be a decrease in the diurnal temperature range across much of Tasmania throughout most of the year, because daily minimum temperatures tend to increase more than daily maximum temperatures.

The decrease in the diurnal range is particularly strong in winter and early spring. However the diurnal range in summer months increases due to reduced cloud cover. These changes are likely to be accompanied by significantly fewer nights where the temperature drops below freezing (in winter) and more nights where temperatures remain high (in summer). However, it is interesting to note that the central highlands show a projected increase in the diurnal range in every month.

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Extreme rainfall frequencies

In the context of infrastructure and floods, changes to the frequency of high intensity extreme rainfall events are more important than changes to the average rainfall. Most areas of Tasmania show increases in the annual number of very wet days (defined as the wettest 1% of days) with the exception of the central plateau and an area extending from the plateau to the north-west.

By the end of the 21st century, the increase in the number of very wet days is greater in the south-west and north-east, with up to 7 days more per year on average. The increases in wet days are driven predominantly by the number of winter rainfall events, with smaller increases in autumn and spring. Decreases in very wet days occur in all seasons in the central highlands, as well as a decrease in rainfall events in summer in the west of Tasmania.

The overall pattern of change in very wet days aligns well with the annual and seasonal changes to average rainfall. In the latter part of the century, western Tasmania is projected to experience increased annual rainfall in winter and drier summers, while wetter summers are projected for eastern Tasmania. A decrease in average rainfall is projected for the central highlands in all seasons.

Extreme rainfall intensities

Some regions in Tasmania are more prone to intense rainfall than others, and consequently, have greater potential for flooding. The east coast region holds the Tasmanian record for the highest observed one-day rainfall total: 352 mm recorded at Cullenswood in Tasmania's north-east.

Mean annual maximum 1-day rainfall totals are projected to increase across Tasmania, with an increase of up to 35% in some coastal regions.

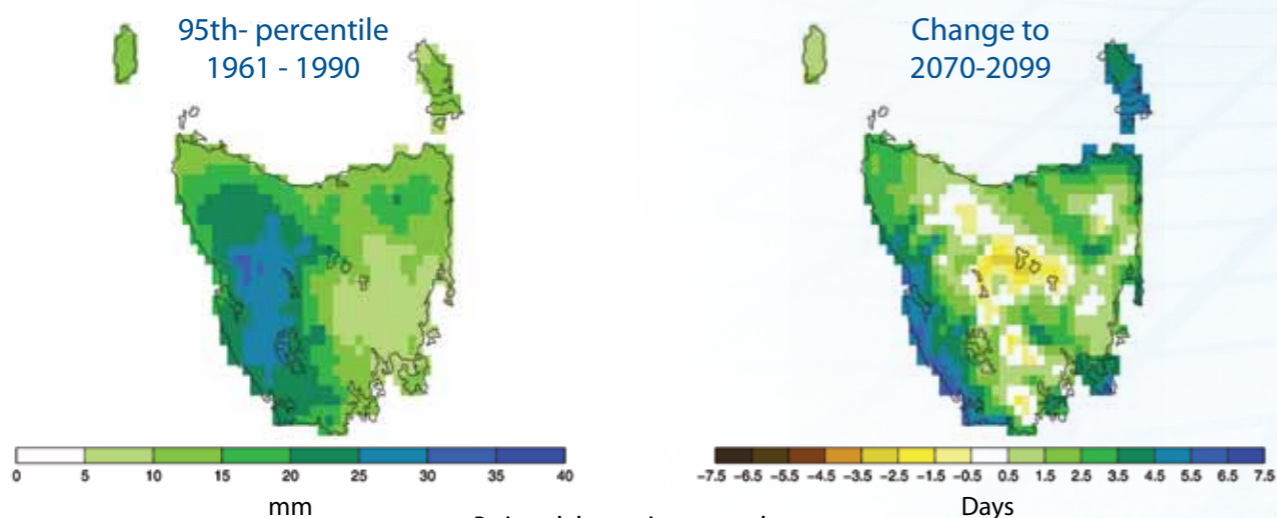
These increases vary seasonally, with particularly large changes in late summer and autumn in the east of Tasmania, and increases in the north and west across the majority of seasons. The projected increase in 1-day rainfall totals show similarity to the spatial pattern to the projected increase in the number of very wet days. This highlights a likely increase in both the frequency and intensity of daily extreme rainfall events in almost all regions, except the central highlands.

Projections for mean annual maximum 5-day rainfall totals show changes that are more varied across Tasmania. Five-day totals decrease in the central highlands combined and increase in the north-east, east and west coast regions. The 5-day rainfall totals (and the relative projected changes) are more closely linked to mean rainfall changes than 1-day rainfall totals.

The 6-minute peak rainfall rate (often referred to as an 'instantaneous' rate) is particularly important in assisting engineers and planners with the design of flood and water infrastructure. Projections suggest an increase in the instantaneous rates across Tasmania annually, particularly in the east. This increase will be especially apparent in late summer, autumn and spring, with up to a 60% increase in some areas of the east coast.

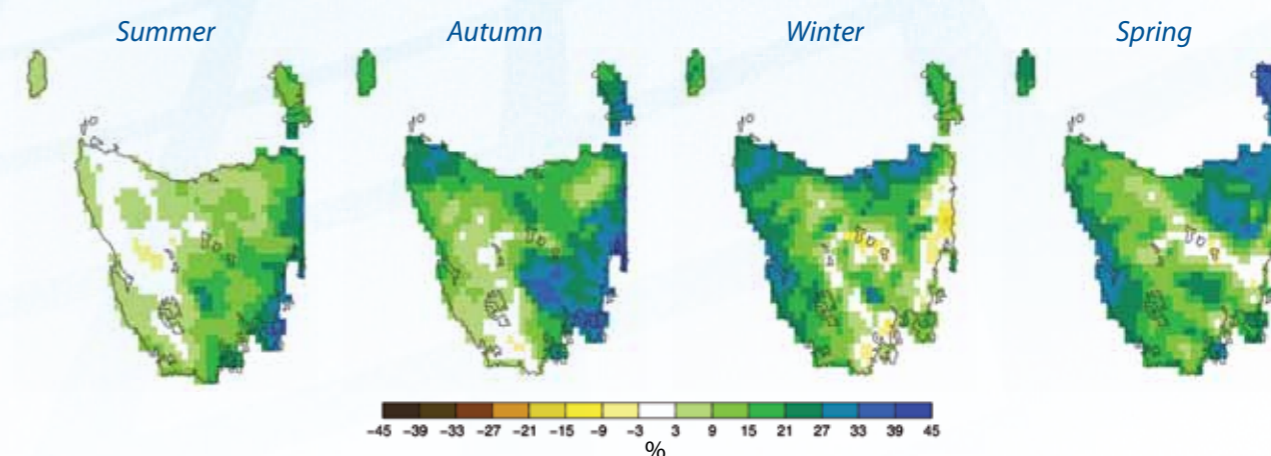
- There will be more frequent and more intense extreme rainfall events mixed together with more dry days. Extreme wet days will increase in the south-west and north-east, with up to 7 days (or about 25% more events) per year. For the central highlands, there are projected decreases in extreme wet days in all seasons.
- The number of rain days across the whole of Tasmania is likely to decrease. This decrease is greatest in the north-west of Tasmania.

More extreme rainfall events will occur



The map on the left shows the amount of rainfall on the wettest days across Tasmania (5% of rain days). That is, on the west coast, the wettest days have in excess of 30 mm. The map on the right shows the change into the future, where the west coast has the biggest increases in the number of very wet days (up to 7 days).

Seasonal changes to rainfall intensities Change to 2070-2099



Maximum 1-day rainfall intensities will change across the seasons

The above seasonal maps show the change in the heaviest one-day rainfall in each season. On an annual basis, rainfall intensities increase in all regions of Tasmania. However, seasonally there are differences. For example, on the west coast there is likely to be little change, but in winter, there is significantly more intense daily rainfall.

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Duration of wet and dry spells

In addition to the projected increase in both the number of very wet days and intensity of rainfall events, it is useful to determine if such events are likely to become longer in duration.

Since 1961, the longest dry spells (consecutive days with no rain) are typically in the lower lying areas in the eastern half of Tasmania (on average, each year has up to 24 consecutive days without rain), while the longest wet periods are in the western half of the state (with each year having on average, one spell of 20 days consecutive days of rain).

Towards the end of the century, projections show little change in the total length of either wet or dry spells.

Rainfall ARIs

Characterising extreme rainfall is important for decision-makers and engineers for the maintenance and design of major infrastructure, and for the management of emergencies. Average recurrence intervals (ARIs) are the primary tool used by these people for assessing the risk of future events. An example of an ARI is the size of the 1-in-100 year 24-hour rain event.

- Drier conditions and wetter conditions on 6-month and 12-month intervals are both likely to increase in the coming century. Both cumulative rainfall deficits (drier conditions) and surpluses (wetter conditions) are likely to increase towards the end of the century, with normal conditions likely to occur less often in some regions.

The projected changes of the ARI estimates indicate an increase in the size of rainfall events across Tasmania by the end of the 21st century. The largest increases occur in the north-east (in some regions by as much as 90%), precisely where the most variable and intense rain is already observed. For example, at St Helens the 1-in-200 year rainfall event becomes a 1-in-20 year event by 2085.

Return Periods and ARIs

Return periods or average recurrence intervals (ARIs) are often used to describe infrequent or catastrophic events like earthquakes, floods, large rainfall events and extreme sea-level events. A return period is the average interval of time between extreme events of a certain intensity, magnitude or given height.

The 100-year flood is more accurately referred to as the 1% annual exceedance probability flood, since it is a flood that has a 1% chance of being equaled or exceeded in any single year.

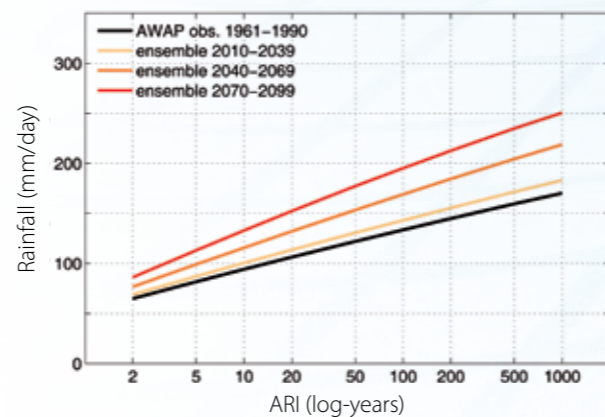
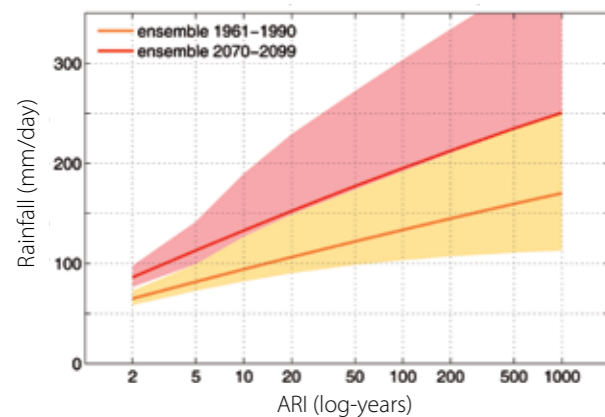
Likewise, an event with a 50-year average recurrence interval has a probability of exceedance of one-in-every 50 years, or a 2% chance of occurring in any one year.

Similarly, a sea-level height expected to be equaled or exceeded every 10 years on average is known as a ten-year sea-level event.

Average recurrence intervals, annual exceedance probabilities and return periods are used by engineers, emergency planners and scientists to assess flood risk, drainage and infrastructure design.

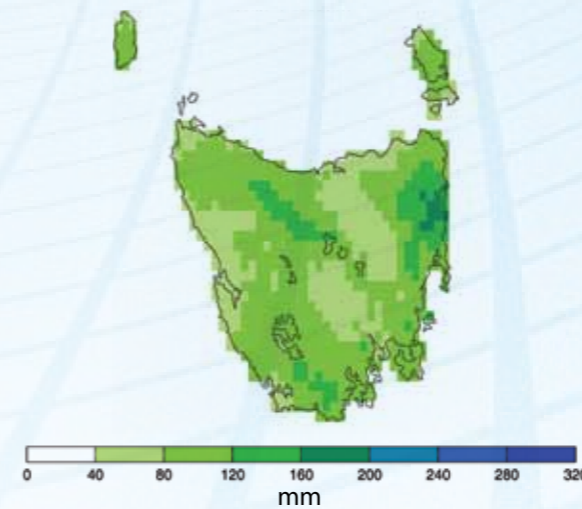
Very rare extreme rainfall events will happen more frequently

St Helens

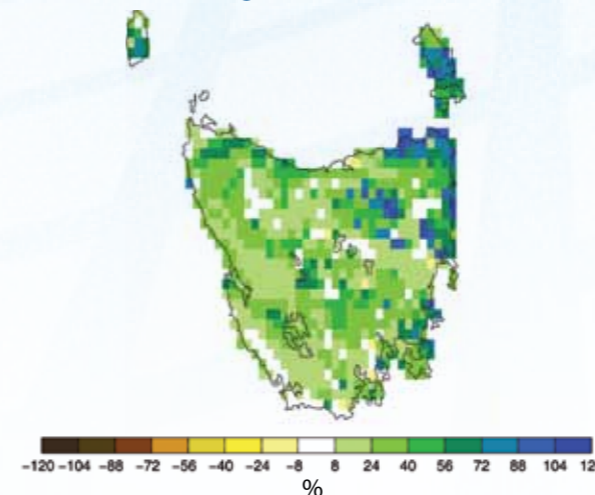


Very rare extreme rainfall events will happen more frequently

1-100 year ARI
Mean 1961 - 1990



Change to 2070-2099



Changes in very high rainfall events

1-in-100 year rainfall events happen rarely. The maps and graphs show the projected changes to these rare events. These most extreme events are projected to become more frequent. For example, at St Helens, the 1-in-200 year rainfall event becomes a 1-in-20 year event by 2085. The colour bands on the graphs on the opposite page indicate the range of possible changes in 1-in-100 year rainfall events.



Flooding in Tasmanian rivers

An important element of studying extreme rainfall events is what this may mean for flooding. Climate Futures for Tasmania also looked at the likely changes to flooding in four major river systems: the Mersey River, Forth River, Huon River and Derwent River. We used our projected changes in extreme rainfalls to assess the likely changes to flood levels and generated new flood inundation maps for Tasmania's State Emergency Service.

The Climate Futures for Tasmania simulations were used to produce a series of design flood hydrographs for the 1:10, 1:50, 1:100 and 1:200 annual exceedance probability (AEP) events for four time periods. The baseline period (1961-1990) is calibrated with historical data, while the three future periods (2010-2039, 2040-2069 and 2070-2099) are based on climate projections. Hydraulic models were run for each of the selected catchments and each of the design floods, and the results were used to generate flood inundation maps for the catchments of the Mersey River, Forth River, Huon River and Derwent River.

The assessments suggested that climate change is unlikely to have a significant impact on flooding in large catchments that have significant upstream storages and critical durations of 72 hours or greater (such as the Derwent catchment below Meadowbank). However, as short-duration rainfall events are likely to become more frequent and intense due to climate change, for the catchments studied we projected significant changes to downstream flood levels for small flood prone catchments that do not have significant upstream storages.

Increased discharges are projected in the Forth River (51%), the Mersey River (93%) and the Huon River (36%) for the 1:10 flood. For the 1:200 flood, discharges will increase by 35% for the Mersey River, 42% for the Forth River and 43% for the Huon River. The peak discharge in the Derwent River is not likely to increase significantly due to the long duration of the critical storm events. At sites higher in the catchments the main impact on flood levels was due to changes in rainfall. Downstream sites nearer the river's outlet to the sea will be more significantly affected by the projected rise in sea level at the end of the 21st century.

Project Leader: Dr Fiona Ling

Flood inundation mapping

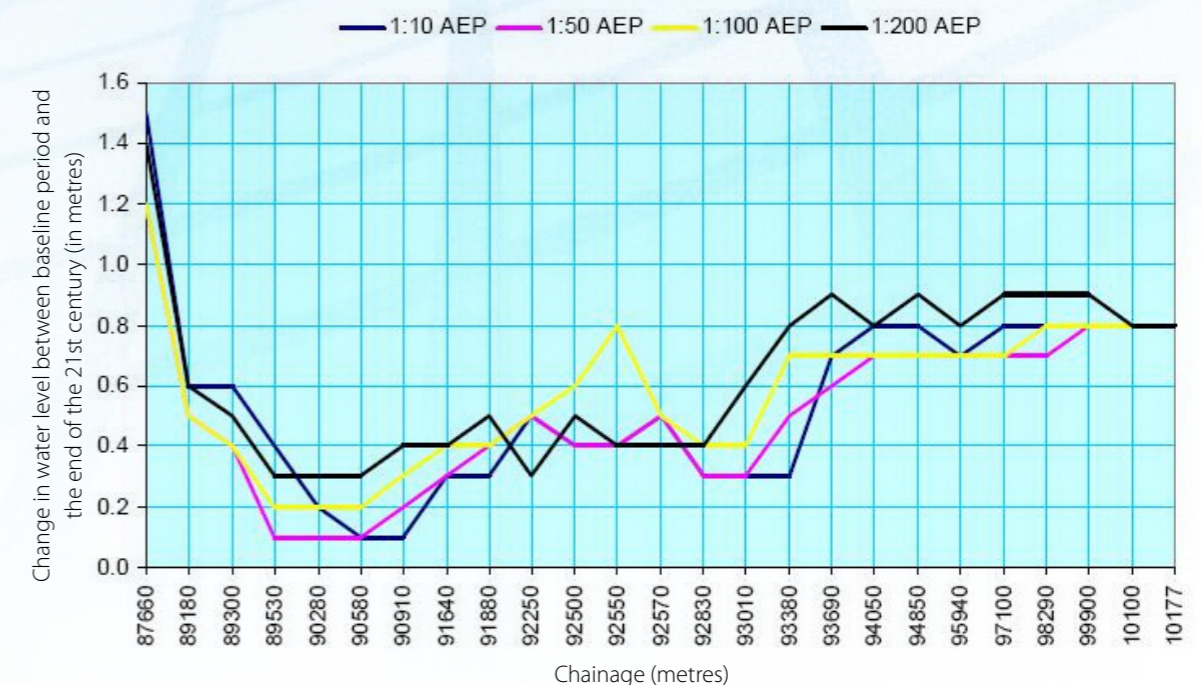


Flood inundation mapping and the changes along the catchment

The flood inundation study produced maps showing the projected changes in flooded areas caused by changes to runoff associated with climate change (above). The flood graph (below) shows increases in flood height in the upper catchment driven by changes to rainfall. Increases in the lower catchment are driven mainly by increases in sea level, and converge to the sea level increase of 0.8 m by 2100.

- Extreme and record rainfall events will become more frequent in the coming century, consistent with a warmer climate. The broad consistency between the estimates of the average recurrence intervals for 24-hour rain events and those from the observations is notable, providing confidence that the future projections to the changed risk of extreme rain events are plausible.
- The projections show a substantially greater frequency of rain events, as recurrence intervals are likely to decrease substantially. In some places, the 1:200 year event becomes a 1:20 year event.
- Changes to flood flows in rivers of the Mersey, Forth and Huon Rivers were found to increase significantly through to the end of the 21st century.
- The peak discharge in the Derwent River did not increase.

Flood heights along the catchment



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Extreme tide and sea-level events

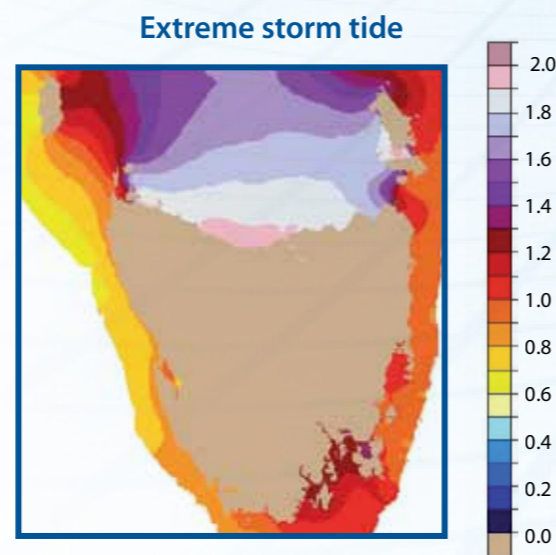
Sea levels have been rising at an increasing rate since the early 1800s. Over the period 1993–2006, mean sea-level trends based on both reconstructed sea level and satellite data have been 3.3 ± 0.4 mm/year; broadly consistent with the rate of rise associated with the IPCC's projections that lead to a globally averaged sea-level increase of 0.82 m by 2100.

Sea-level rise is felt most acutely during severe storm events, when strong winds and lower than normal atmospheric pressure drive storm surges and high waves. The impacts of these events will be greatest when they occur at high tide and such events can cause coastal inundation and erosion.

Similar to extreme rainfall, extreme sea-level events can be characterised by return periods that is, the average amount of time between successive events of a particular magnitude (see page 13 for more information about return periods). Return periods for extreme sea-levels that are a combination of tide and storm surge (storm tides) were evaluated. Such data can be combined with different sea-level rise scenarios for the future to estimate the potential impacts of future sea-level rise.

By studying return periods of extreme sea levels around the Tasmanian coast, Climate Futures for Tasmania found that the main cause of elevated sea levels along the south-east coastline was west-to-east moving cold frontal systems that had a low pressure centre to the south of Tasmania. On the northern Tasmanian coastline, an increase in the non-tidal component of the sea level was most commonly associated with a low-pressure centre located to the west of Tasmania or in Bass Strait, which caused strong northerly winds along the coastline.

Extreme sea-level events that have affected the Tasmanian coast have been hydro-dynamically and statistically modelled to generate storm tide return periods. From this modelling it was found that the largest storm surges (up to 0.7 m) occur on the south-east coast of Tasmania and the smallest (ranging from 0.2 m to 0.4 m) on the northern coast.



Storm tide plot
The above map of 1-in-100 year storm tides (the water level due to a combination of a tide and storm surge that is likely to be exceeded on average once every 100 years) shows that the largest storm tide heights of 2 m occur on the northern Tasmanian coast, with more moderate storm surges on the east and south east coastlines of greater 1 m.

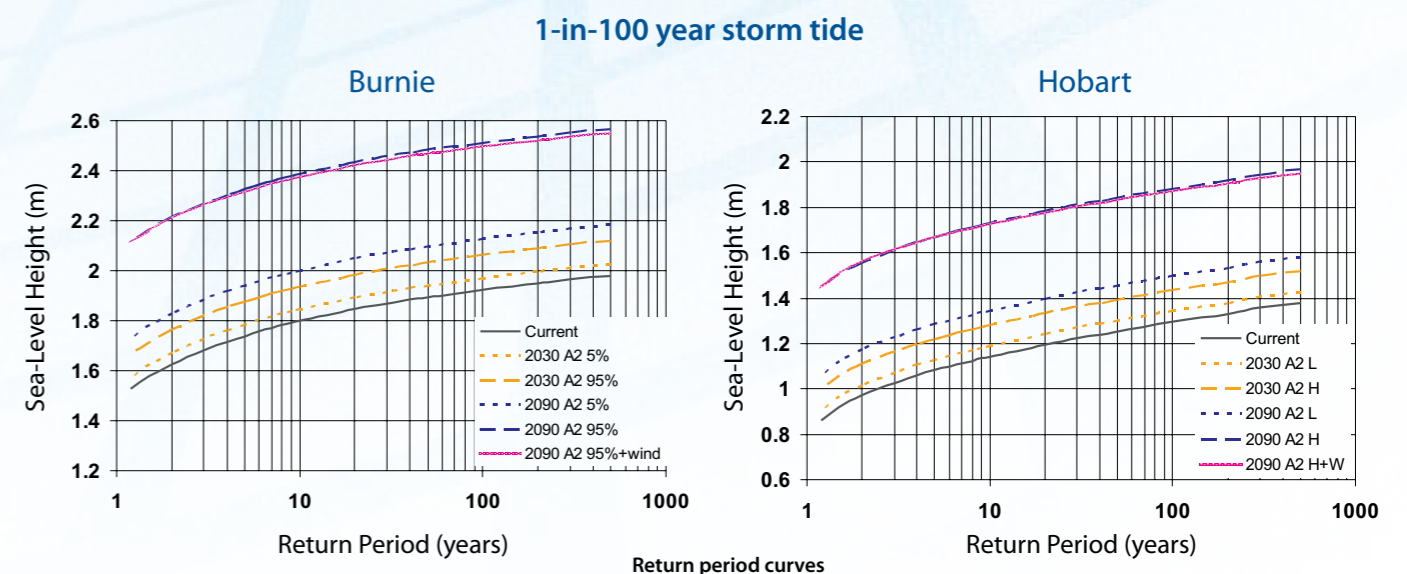
In contrast, tide heights show a range of up to 1.6 m along the north coast, 0.5 m to 0.7 m on the east coast and 0.4 m to 0.5 m on the west coast. Strong tide height gradients occur in the north-east and north-west of the state. The highest values for the 1-in-100 year storm tide height (between 1.9 m and 2.0 m) occur on Tasmania's north coast, owing to the large tidal range within Bass Strait. The 1-in-100 year storm tides along Tasmania's south-east coast range from 1.2 m to 1.4 m.

Projected sea-level rise by 2030 will mean that a 100-year event based on late 20th century conditions will occur at least as frequently as a 1-in-50 year event and may occur as frequently as 1-in-10 years if sea-level rise follows the upper end of the projected range.

By 2090, the impact of the IPCC projected range of sea-level rise will mean that a 100-year event based on late 20th century conditions will occur as frequently as once every 2 to 6 years, depending on location, for the low-end value of sea-level rise and will occur more than once per year if the high-end sea-level rise projections eventuate.

- Extreme sea levels occur when high astronomical tides combine with storm surges to produce storm tides. These events can cause severe coastal inundation and erosion.
- Storm surges along the Tasmanian coast are caused mainly by the west-to-east moving cold frontal systems.
- Around Tasmania, the largest storm tides occur on the northern coastline due mainly to the large tidal range there. The largest storm surges occur on the southeast coast of Tasmania.
- A rise in mean sea level due to global warming of between 5 cm and 14 cm, is projected to occur by 2030 under a high emissions scenario. Such a rise could lead to the water levels associated with a 1-in-100 year storm tide event occurring as frequently as once every 50 years by 2030.

Project Leader: Dr Kathy McInnes



The storm tide return period curves show, for example, that under projected sea-level rise for 2030, an event that is expected to occur on average once every 100 years based on late 20th century conditions, could occur at least as frequently as once every 50 years (see text).

local climate information for local communities





The climate futures LiDAR dataset

Climate Futures for Tasmania generated new high-resolution digital elevation information captured by LiDAR technology. LiDAR stands for Light Detection And Ranging and is an instrument that uses an intense laser light transmitted at an object and detects the laser light reflected by the object.

The new dataset provides digital elevation information in detail up to the 10-metre contour at selected areas of Tasmania's vulnerable coastlines. It can be used to generate topographic overlay maps with 25 cm contours up to 10 metres above sea level. The data covers priority areas of the coastline where life, property and communities may be affected by coastal inundation and storm surges associated with projected rising sea levels and changing weather patterns.

The high resolution height data is used by researchers, planners and local government to identify and assess areas that may be affected or vulnerable to sea level rise, sea inundation, storm or tidal surges. Good quality digital elevation mapping is fundamental to developing appropriate land use planning decisions, building codes, policies and communications. The high quality digital elevation mapping has been used in many complementary research projects and combined with other project outputs for improved modelling in mapping coastal inundation and for emergency response planning.

The Climate Futures LiDAR dataset is publicly available through Tasmania's web-based spatial information service "TheLIST".

Technical specifications

Data captured between 'mean low watermark' and the 10-metre contour.

Horizontal Accuracy: ±25 cm

Vertical Accuracy: ± 25 cm

Point Density: ≥ 1 per metre

Information tiles: 1 km x 1 km tiles with 50 m overlap

Number of tiles: more than 4,200

Total Area Covered: 4,200 km² see map at right

Formats Available: ArcInfo Grid
ASCII point
tiff

Size of dataset: > 500 Gb

Available at: www.thelist.tas.gov.au

Coastal vulnerabilities

The new climate simulations have proven invaluable to extending our knowledge and understanding of the possible impacts of climate change. The innovative and improved resolution datasets are being used by researchers in the School of Geography at the University of Tasmania for applied and adaptation research. These include detailed assessments of the vulnerability of coastal communities in North West Tasmania to sea-level rise, saltmarsh migration pathways in the Derwent Estuary, and storm and sea-level rise inundation mapping around much of Tasmania's coast

One such complementary project, the researchers worked in collaboration with the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) to investigate the risk of the impacts of sea inundation on Tasmania's vulnerable coastlines. They combined the results of the Climate Futures for Tasmania storm surge and tidal outputs derived using the new simulations, with the Climate Futures LiDAR Dataset and sea-level rise projections to assess future flooding impacts on coastlines by storm events and permanent sea-level rise.

- The Climate Futures LiDAR Dataset is a key dataset, which due to its high resolution and precision, enables a substantial improvement in the accuracy of coastal inundation modelling for Tasmania.



The study identified significant areas of low-lying coastal land in Tasmania that are vulnerable to inundation impacts from sea-level rise alone (permanent sea-level rise). Within the study area, the modelling also indicated significant areas of low-lying coastal land vulnerable to flooding by storm events and this vulnerability increases with sea-level rise. The resulting inundation and flooding "footprints" enable rapid identification of multiple asset types potentially at risk, including built and natural assets.

Project Leader: Dr Richard Mount

The climate futures LiDAR dataset

The LiDAR mapping covers areas that may be affected by coastal inundation and storm surges associated with projected rising sea levels and changing weather patterns (shown in pink). These areas included Storm Bay, the Tamar Estuary, the north-west coast, the northern Tasmania coastline and parts of the east coast.

local climate information for local communities





Severe wind gusts in a changing climate

Severe winds pose a significant risk to Tasmania's major cities and communities, particularly along coastlines that are vulnerable. Historically, residential and other low-rise buildings in Australia regularly suffer wind damage. The personal and community costs, economically and emotionally, are enormous. Across Australia, wind damage from tropical cyclones, thunderstorms and synoptic windstorms cost hundreds of millions of dollars annually.

Although severe wind damage is more often associated with tropical cyclones, Tasmania does experience severe wind events: the 'Roaring 40s' bring severe synoptic winds from the Southern Ocean; spring/summer thunderstorms are caused by the frontal boundary between hot winds from the north and cold south/south-westerly winds from polar low-pressure systems; and topographic effects increase the horizontal winds. These are important elements in determining the severe wind hazard and risk to Tasmanian communities, both now and in a changing climate.

For Climate Futures for Tasmania, Geoscience Australia led the research into severe wind hazard and risk. Working closely with Tasmania's State Emergency Service, detailed modelling of severe wind hazard, exposure, vulnerability and risk was done for the present and future climates of Tasmania. The study generated new maps of severe wind hazard for Tasmania incorporating the downscaled global climate simulations from Climate Futures for Tasmania. The maps are part of a new web-based spatial information system and will be used with other data already available from 'TheLIST', such as aerial photography, cadastral parcels and road maps. The new assessment tool can also be interrogated by the Tasmanian State Emergency Service during emergency management planning. The new hazard assessments will be used when determining future wind loadings for revising building codes.

Wind hazard

New modelling and analysis techniques were used to develop a revised understanding of the regional wind hazard across Tasmania. The wind hazard maps were generated for Tasmania for current climate and also for two climate change scenarios (a high emissions scenario and a low emissions scenario). Based on the highest scenario, only modest increases in wind hazard are projected by 2100.

The revised estimates of regional wind hazard show significant detail previously not available, with high hazard associated with elevated regions and low hazard in major valley regions such as the Derwent and Tamar Valleys.

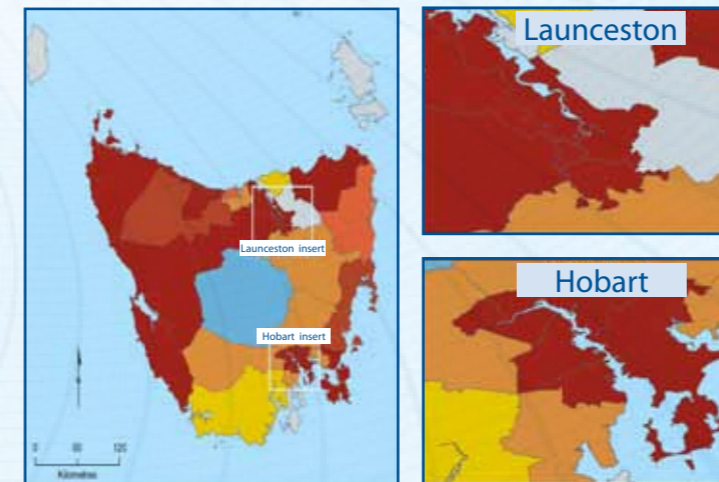
Local climate information for local communities



climate futures for tasmania

severe wind hazard and risk

Change in wind risk
Percentage change to 2090



Change in wind risk
Only small increases in wind risk are projected by 2090 in populated settlement areas of Tasmania.

Change in annualised loss (%) High emission scenario, 2090	
< -5%	10% - 15%
-5% - 0%	15% - 20%
0% - 5%	20% - 25%
5% - 10%	> 25%

- The new modelling and analysis techniques were used to develop a revised understanding of the regional wind hazard across Tasmania. The revised estimates of current regional wind hazard show significant detail not previously available.
- High wind hazard is associated with elevated regions, northern coastal areas and the Bass Strait islands, whereas low hazard is found in major valley regions such as the Derwent and Tamar Valleys.
- Tasmania has a new web-based severe wind hazard and risk tool available to emergency services to make decisions about where and whether to adapt to future wind hazard and risk.
- For future regional wind speeds based on the higher emissions scenario (A2), the current building code (design wind speeds) for the major residential-settlements will in general be adequate to 2100.

The revised hazard estimates for the major population centres in Tasmania (both current climate and also for the climate change scenarios) are generally below the regional wind speeds specified in the Australian standards; for current climate generally 10%-20% below the design wind speeds, confirming the conservatism of the current design standard. The level of hazard is only of concern for sparsely populated parts of the northern coastal region and Bass Strait islands towards the end of the 21st century.

Wind risk

Wind risk was assessed using the new wind hazard maps in association with a database describing Tasmania's residential buildings that included important information such as building age, roof type and wall cladding. Using the high emissions scenario, modest increases in wind risk of up to 25% are projected for Tasmania by 2090. However, Tasmania's severe wind risk levels remain well below those experienced in the northern part of the Australian continent, where high wind hazard is mostly associated with tropical cyclones.

The modest increase in future wind risk during the 21st century is mainly attributed to the current legacy buildings that were constructed prior to the implementation of the wind loading for the current building code (AS4055) in the early 1990s.

Project Leader: Bob Cechet



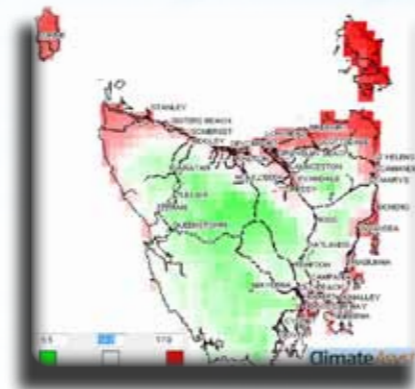
Impacts on infrastructure

With the future climate for Tasmania likely to be hotter, with an increase in extreme rainfall events and longer dry spells in between, the impacts to infrastructure could be significant.

A critical step in adapting to climate change is building capacity with infrastructure managers, businesses, planners and local government to use the new information in their business systems and planning processes. Tasmanian engineering firm Pitt & Sherry worked in partnership with Climate Futures for Tasmania to develop a risk assessment tool that helps access and use the new climate change information in an engineering context.

ClimateAsyst® is a risk assessment tool that helps identify climate change impacts of importance to local infrastructure. The tool allows the operator to identify and select the relevant climate variables and see how the projected future climate may impact current assets or locations for future assets. Infrastructure managers and planners can manipulate the new climate information in a GIS format and overlay their asset knowledge to see what risks they may be facing in the future. The climate change decision support tool links important engineering documentation and standards relevant to the selected asset/climate variable combination (for example, current Australian standards, early century, mid-century and late century timeframes).

Project Leader: Sven Rand



- Pitt & Sherry's ClimateAsyst® tool has extended the use and application of the Climate Futures for Tasmania simulations to Tasmania's local governments.
- ClimateAsyst® draws together the new climate simulations with updated engineering/technical analysis and research relevant to specific infrastructure types and climate change hazards into a one-stop-shop for infrastructure managers.
- Decision makers are taking practical advantage of the Climate Futures for Tasmania simulations by using the interpreted results routed through the ClimateAsyst® to design and build replacement infrastructure.

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 heat waves, 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 extreme events component of research. Please refer to the various full reports for detailed methods, results and references, or contact the respective project leaders.

The Climate Futures for Tasmania project complements climate analysis and projections done at the continental scale for the Fourth Assessment Report of 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.

local climate information for local communities

