CLIMATE CHANGE IMPACTS (CC)

SCIENTIFIC ASSESSMENTS Part III

Commissioner for Environmental Sustainability Victoria

Traditional Owners

The Commissioner for Environmental Sustainability proudly acknowledges Victoria's Aboriginal community and their rich culture and pays respect to their Elders past and present.

We acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life, and how this enriches us.

We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

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Climate Change Impacts

This chapter includes assessments of how Victoria's climate is changing and the associated impacts of those changes. Three key themes are covered: climate, impacts of climate change and management.

The climate theme incorporates a synthesis of the latest data and science on observed and projected surface temperature, rainfall, sea level, snow cover, and observed sea-surface temperature, while also including an update of Victoria's greenhouse gas (GHG) emissions with respect to the targets in the *Climate Change Act 2017*.

The impacts of climate change theme looks at the occurrence and impacts of extreme weather, the extent and condition of climate-sensitive ecosystems, and community awareness of climate risks and associated responsibilities.

The management theme assesses how councils are developing urban forestry plans and considering climate change risks in land-use planning, and also looks at the way agri-businesses are using long-term weather and climate projections. There are direct links to climate change adaptation, which are listed in Appendix A.

Themes in this chapter are covered in greater detail in other chapters. In particular, the Fire chapter includes commentary on the increased bushfire risk associated with climate change, and the Energy and Transport chapters cover GHG emissions from those sectors in greater detail.

Background

Climate research continues to show that temperatures, sea levels and sea-surface temperatures are rising in Australia.[1] Further changes will drive ongoing and significant ecosystem and biodiversity impacts, and will expose Victorians to more frequent and intense droughts, fires, heatwaves, extreme rainfall events and coastal inundation.[2] SoE 2018 reports on the effect climate change is having in these areas, as well as the potential future implications.

Victoria's climate is influenced by a range of factors, including the effect of major ocean–atmosphere phenomena such as the El Niño–Southern Oscillation, which produces El Niño and La Niña events, and the Indian Ocean Dipole. These drivers of climate contribute to large natural year-to-year variations in temperature and rainfall. However, long-term climate change caused by increasing GHG concentrations is occurring at global scales.[3]

The link between increasing GHG concentrations and climate change has been a growing area of focus for environmental policy-makers since countries adopted the *United Nations Framework Convention on Climate Change* in 1992,[4] which was a precursor to the adoption of the Kyoto Protocol in 1997 [5] and the Paris Agreement in 2015.[6]

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1. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
2. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
3. Intergovernmental Panel on Climate Change 2013, 'Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.' Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
4. United Nations 1992, 'United Nations Framework Convention on Climate Change', https://unfccc.int/resource/docs/convkp/conveng.pdf Accessed 4 December 2018.
5. United Nations 1998, 'Kyoto Protocol to the United Nations Framework Convention on Climate Change', https://unfccc.int/sites/default/files/kpeng.pdf Accessed 4 December 2018.
6. United Nations 2015, 'Paris Agreement', https://unfccc.int/sites/default/files/english_paris_agreement.pdf Accessed 4 December 2018.

The challenges associated with mitigating and adapting to climate change impacts are significant. Rising to these challenges will be increasingly important in the coming decades, when the magnitude of climate change is expected to increase. Scientists have produced detailed climate change projections: it is imperative that planning and policy development leverage them to enable decision-making that fully prepares Victoria to manage climate change impacts.

Critical challenges facing Victoria's management of climate change and its associated impacts, now and in the future, include:

- reducing GHG emissions to mitigate the speed and severity of climate change as part of the national and global effort
- developing understanding of the impacts of climate change through better real-time monitoring, trend analysis and predictive capabilities to enable strategic and timely responses to protect the environment and communities
- reducing the health burden associated with heatwaves and other natural disasters
- maintaining/designing vital infrastructure, such as power generation and rail transport, for reliability in the face of changes to the average climate and more frequent and intense weather events
- maintaining secure water supplies across the state as population grows, average rainfall reduces and evaporation increases, leading to less available water
- maintaining the viability of the agricultural sector
- protecting biodiversity from the impacts of climate change
- mitigating the effects of sea-level rise and associated adverse coastal impacts, including more frequent and severe flooding in low-lying coastal areas, dune erosion, loss of coastal ecosystems and reduced public access to coastal environments.

Current Victorian Government Settings: Legislation, Policy, Programs

The *Climate Change Act 2017* took effect on 1 November 2017. It establishes a long-term emissions reduction target of net zero by 2050, with interim emissions reduction targets set for five-year periods from 2021. The Act also requires the government to develop a Climate Change Strategy and Adaptation Action Plans every five years from 2021 for key systems vulnerable to the impacts of climate change. The Act mandates periodic reporting of the following measures:

- standalone reports on the science and data relevant to climate change in Victoria
- annual GHG emissions reports at the end of each interim target period.[7]

To develop the five-yearly emissions reduction targets, the Victorian Government is required to seek expert independent advice. In March 2018, an independent panel of experts released an issues paper that explored the issues relevant to setting interim emissions reduction targets for Victoria for 2021 to 2025 and 2026 to 2030, and trajectories to net zero emissions by 2050.[8]

Climate change responses are being integrated into federal, state and local government policies and strategies across many sectors. Recent notable publications include *Protecting Victoria's Environment – Biodiversity 2037*, which outlines a vision for Victoria's biodiversity in a time of climate change; *Water for Victoria*, the 2016 water plan, which links climate science and adaptation to water management; and the Agriculture Victoria Strategy, which identifies research and capacity-building programs that help farmers adapt to climate change as priorities.[9,10,11]

7. Office of the Chief Parliamentary Counsel Victoria 2017, 'Climate Change Act 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.
8. DELWP 2017, 'Independent Expert Panel: Interim Emissions Reduction Targets for Victoria (2021-2030)', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0019/121924/Issues-Paper_28-03-2018.pdf Accessed 4 December 2018.
9. DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf Accessed 4 December 2018.

Sustainability Victoria is delivering the TAKE2 program, designed to support individuals, government, business and other organisations to help Victoria achieve net zero emissions by 2050.[12] The program requires government agencies to make pledges to act on climate change, while businesses and the community are invited to make their own public commitments to reduce emissions in Victoria. The program is designed to build momentum towards a lower GHG emissions future as well as recognising organisations that are leading the way.

State and Commonwealth agriculture ministers have initiated a work program on climate change. The program covers climate change impacts, managing emissions across the sector and identifying the risks and opportunities of adaptation in agriculture. A national approach to climate change in the agriculture sector will be delivered to the Agriculture Ministers' Forum by May 2019.

In April 2016, the Victorian and Commonwealth governments jointly funded the construction of a Doppler weather radar in the Wimmera, to extend the Bureau of Meteorology (BoM) to provide farmers in the region with more accurate rainfall data.[13]

Note that the government response to climate change includes additional initiatives, which are covered in other chapters, including the Energy, Land, Biodiversity and Water Resources chapters.

10. DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria https://www.water.vic.gov.au/__data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf Accessed 4 December 2018.
11. DEDJTR 2017, 'Agriculture Victoria Strategy', Melbourne, Victoria http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 4 December 2018
12. Sustainability Victoria, 'TAKE2', Melbourne, Victoria https://www.sustainability.vic.gov.au/About-Us/What-we-do/Campaigns/TAKE2 Accessed 4 December 2018
13. Victorian State Government 2016, 'Media Release: Andrews Labour Government puts Wimmera on the radar', Melbourne, Victoria, https://www.premier.vic.gov.au/wp-content/uploads/2016/04/160406-Andrews-Labor-Government-Puts-Wimmera-On-The-Radar.pdf Accessed 4 December 2018

Climate

The climate of Victoria is highly variable and influenced by large-scale climate drivers that occur on interannual timescales in the oceans surrounding Australia, such as the El Niño–Southern Oscillation and the Indian Ocean Dipole.[14] In addition to this natural climate variability, increasing concentrations of GHGs are causing rising surface and ocean temperature and decreasing cool-season rainfall.[15]

Some of the indicators in this chapter refer to different emissions scenarios. Current scenarios are referred to as Representative Concentration Pathways (RCPs). In this report, RCP8.5 is referred to as a 'high emissions scenario', RCP4.5 is referred to as an 'intermediate emissions scenario' and RCP2.6 is referred to as a 'low emissions scenario'. Note that RCP2.6 aligns most closely with the Paris Agreement target.[16]

14. Risbey JS, Pook MJ, McIntosh PC, Wheeler MC, Hendon HH 2009, 'On the remote drivers of rainfall variability in Australia', *Monthly Weather Review*, 137(10), pp. 3233-3253.
15. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
16. CSIRO and BoM 2016, 'Australia's changing climate', https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/176/AUSTRALIAS_CHANGING_CLIMATE_1.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:01 Observed average rainfall		●			↘	DATA QUALITY Good
Data custodian BoM						

Rainfall over Victoria is highly variable from year to year, due to large-scale climate drivers such as the El Niño–Southern Oscillation. But beyond this variability, a drying trend is emerging. Below-average rainfall has been recorded most years since the late 1990s. The main exceptions are 2010 and 2011 (influenced by strong La Niña events) and 2016 (influenced by a strong negative Indian Ocean Dipole). Since the publication of SoE 2013, below-average rainfall conditions have dominated the climate and extended the overall drying pattern affecting the state.

The drying of Victoria's climate has become increasingly apparent since the mid-1990s, with only four of the past 20 years above the 1961 to 1990 average rainfall (Figure CC.1).

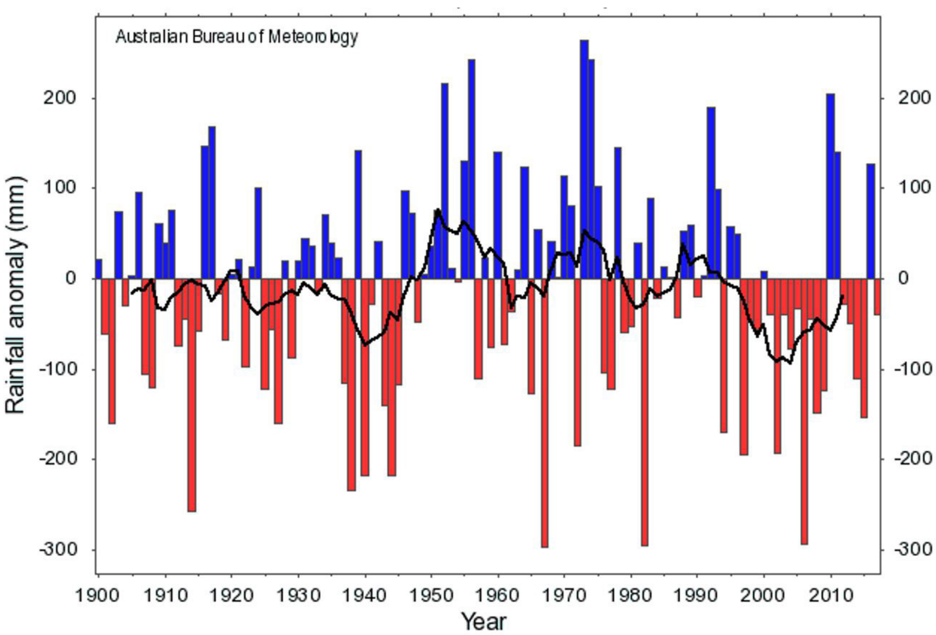

Figure CC.1 Victorian annual rainfall anomaly, 1900–2017

Note: 11-year running averages shown by black curve, Based on a 30-year climatology (1961-1990).

Anomalies calculated with respect to the 30-year climatology period 1961–1990 (average is 660.2 mm per year).

(Data source: BoM, 2018)

This drying mainly affects the cool season, from April to October. Figure CC.2 shows that nearly all of Victoria received below-average to record-low cool-season rainfall, for the most recent 30 years from 1985 to 2015. Therefore the trend for this indicator has been assessed as detiorating. Dry conditions were in part due to increasing GHG concentrations, so they may be indicative of a longer-term change.[17] The dry conditions are also linked to the millennium drought of 1996 to 2010. The decline in cool-season rainfall has particular consequences for agriculture, water resources and water quality.

Warm season (November to March) rainfall was generally above-average in northern Victoria and below-average in southern Victoria for the 30 years from 1985 to 2015 (Figure CC.2).

Rainfall in the coming decades will be determined by both anthropogenic climate change (likely to drive a general continuing decrease in rainfall) and ongoing natural variability. This means that in the short-to-medium term, Victoria may be wet or dry depending on the incidence of drought or wet events.

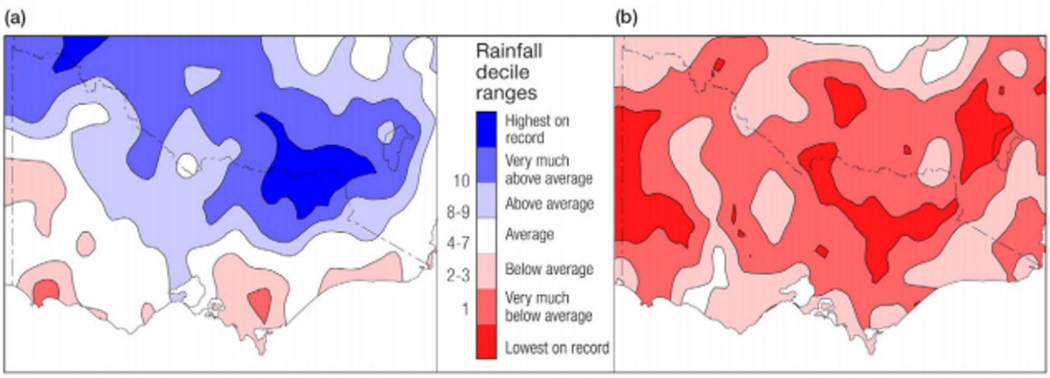

Figure CC.2 Victorian rainfall deciles, 1986–2015[18]

(a) the warm season (November–March)

(b) the cool season (April–October)

Note: Map shows where the rainfall is above-average, average or below-average for the recent period, compared with the rainfall record dating from 1900.

17. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
18. Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:02 Snow cover						DATA QUALITY Good
Data custodian None						

Snow cover in alpine areas is critical to Victoria's highland ecosystem resilience, water supply and winter sport recreation. It is also an important indicator of climate change.

A decline in snow accumulation has been observed at several locations across the Victorian Alps.[19,20] Observations have also shown a decline in the frequency of smaller daily snowfall events (under 10 cm) across the Victorian Alps in the past 25 years.[21] These changes are closely linked to increasing maximum temperatures in winter, indicating the role of anthropogenic climate change in reducing snow cover.[22] Snow depth is also influenced by large-scale drivers such as the El Niño–Southern Oscillation and Indian Ocean Dipole.[23]

In addition to ground-based observations, researchers have recently utilised technology such as satellite remote sensing to observe a reduction in snow cover in the Australian Alps from 2000 to 2014.[24] Remote sensing methods were automated as part of this study and can be consistently used to process remotely sensed imagery, enabling efficient monitoring of Australian snow cover changes.[25]

Projections for snow in Australia are based on global climate models, and high-resolution climate modelling that uses global models as an input. There is very high confidence that as warming progresses, there will be a decrease in snowfall and an acceleration in snowmelt, reducing the snow season, particularly at lower elevations.[26,27,28,29,30]

Snow cover and volume will decline to the extent that only the highest peaks will receive any snow by 2070 to 2099.[31] This is likely to have a significant impact on the region's natural ecosystems, and on winter sport recreation. Figure CC.3 shows the change and projected change in snowfall at two elevations in an area where snow is currently observed. Figure CC.3 also demonstrates that the decreasing trend in snow cover that has been observed since 1950 is projected to continue to 2100.

19. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), pp. 246–252.
20. Timbal B, Ekstrom M, Fiddes S.L, Grose M, Kirono D.G.C, Lim E, Lucas C, and Wilson L, 2016. 'Climate change science and Victoria', Melbourne, Victoria (Bureau of Meteorology).
21. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), pp. 246–252.
22. Ibid
23. Pepler AS, Trewin B, Ganter C 2015, 'The influences of climate drivers on the Australian snow season', *Australian Meteorological and Oceanographic Journal*, 65(2), pp.195-205.
24. Thompson J 2016, 'A MODIS-derived snow climatology (2000–2014) for the Australian Alps', *Climate Research*, 68(1):25–38.
25. Ibid
26. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
27. Di Luca A, Evans JP, Ji F 2017. 'Australian snowpack in the NARCliM ensemble: evaluation, bias correction and future projections' *Climate Dynamics*, 51(1-2) pp. 639-666.
28. Timbal B, Ekström B, Fiddes S, Grose M, Kirono D, Lim E-P, Lucas C and Wilson L 2016, 'Climate change science and Victoria: Bureau Research Report No. 14', *Report issued by the Bureau of Meteorology*.
29. Bhend J, Bathols JM, Hennessy KJ 2012, 'Climate change impacts on snow in Victoria. CAWCR Research Report', Centre for Australian Weather and Climate Research, Melbourne, Victoria.
30. Hennessy KJ, Whetton PH, Walsh KJE, Smith IN, Bathols JM, Hutchinson M, Sharples JJ 2008, 'Climate change effects on snow conditions in mainland Australia and adaptation at ski resorts through snowmaking', *Climate Research*, 35, pp. 255-270.
31. Antarctic Climate & Ecosystems Cooperative Research Centre 2016, 'The Potential Impacts of Climate Change on Victorian Alpine Resorts', Hobart, Tasmania http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf Accessed 4 December 2018.

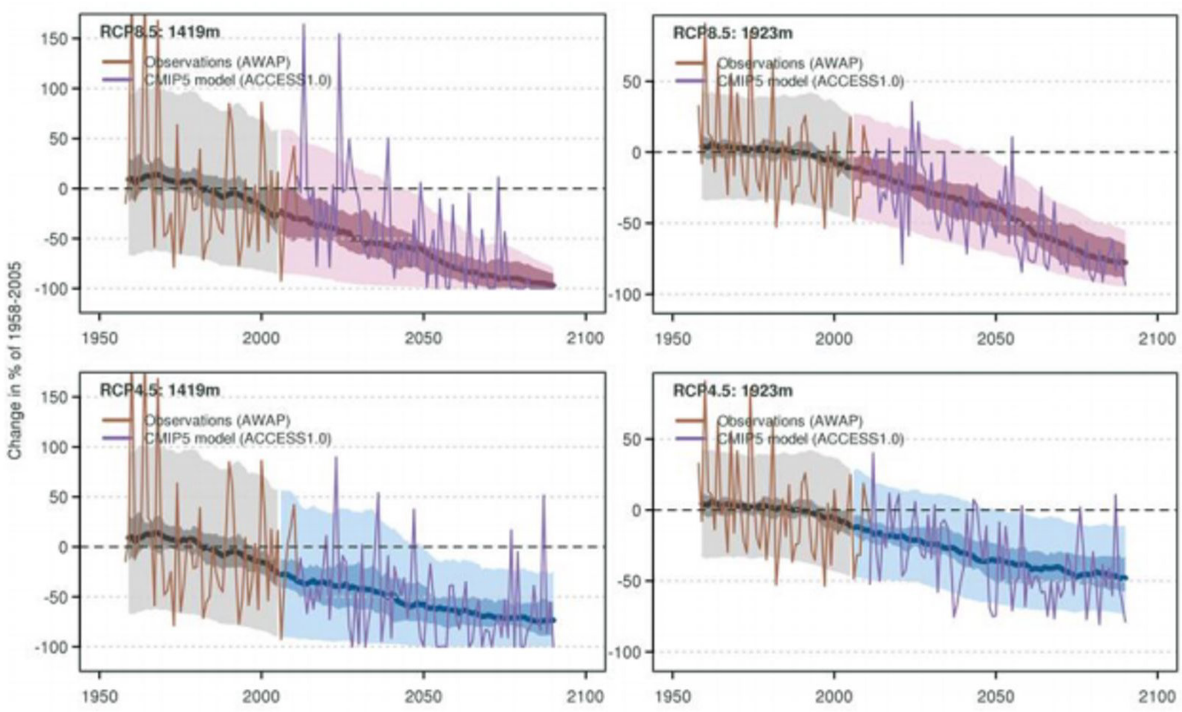

Figure CC.3 Change in snowfall for two grid boxes in the BoM operational 5 km gridded observations[32]

Note: Change corresponds to a lower alpine elevation consistent with the current snowline (left panels) and for the highest elevation in the gridded observations (right panels). Future projections are provided from 2006 onward for high (top row) and intermediate (bottom row) emissions scenarios. Each panel shows the model ensemble median (thick line), the 10th and 90th percentile of annual snowfall (light shading) and the 10th and 90th percentile of the 20-year mean snowfall (dark shading), operational 5 km gridded observations (brown line) and an example of a possible future time series (light purple) from a single model (ACCESS-1.0).[33]

There is a considerable interannual variability in various snow conditions and little research to date on the potential influence of climate change on extreme snowfall events. However, the research that has been conducted for Victoria consistently models a significant reduction in snow cover in the state's alpine locations.

32. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
33. Ibid

Social research suggests that Australian skiers have a higher sensitivity to low snow cover than European skiers, which may heighten the impacts of reducing snow cover on the Victorian ski industry, with Victorian skiers potentially opting to ski in New Zealand or other international alpine regions.[34,35,36]

Man-made snow could be used increasingly as a replacement for natural snow. However, the most prevalent snow-making techniques are expected to become less reliable as temperatures rise, and they will be limited by water availability. The most reliable way to produce snow in the future is likely to involve an expensive, energy-intensive technology known as a 'snow factory'.[37]

34. Pickering CM, Buckley RC 2010, 'Climate Response by the Ski Industry: The Shortcomings of Snowmaking for Australian Resorts', *AMBIO*, 39, pp. 430-438.
35. Behringer J, Buerki R, Fuhrer J 2000, 'Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture', *Integrated Assessment*, 1, pp. 331-338.
36. König U 1998, 'Tourism in a warmer world: implications of climate change due to enhanced greenhouse effect for the ski industry in the Australian Alps', Geographisches Institut, Universität Zürich.
37. Antarctic Climate & Ecosystems Cooperative Research Centre 2016, 'The Potential Impacts of Climate Change on Victorian Alpine Resorts', Hobart, Tasmania http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf Accessed 4 December 2018.

Flora and fauna reliant on snow are unlikely to adapt to the loss of natural snow, and some species are highly likely to be lost. An example is the mountain pygmy possum – an endangered species that is only found in alpine and subalpine regions above 1,400 metres on Mount Buller and the Bogong High Plains in Victoria, and on Mount Kosciuszko in New South Wales.[38] Declining snow cover and earlier snow melting will likely mean the possums awake from hibernation before some of their food sources (for example, bogong moths) are available.[39]

While man-made snow may be able to mitigate the economic effects of a reduced snow cover on the ski industry, it is not expected to ease the stresses on flora and fauna.[40] Snow-making is unlikely to contribute to the survival of snow-dependent flora and fauna, because the area covered by man-made snow is too small, and subject to unusual conditions of management and use, relative to what the species are adapted to. If natural snow is lost, many snow-dependent species will be lost.

38. Museum Victoria, 'Mountain Pygmy-possum', Melbourne, Victoria, https://museumsvictoria.com.au/website/melbournemuseum/discoverycentre/wild/victorian-environments/alps/mountain-pygmy-possum/index.html Accessed 4 December 2018.
39. Broome L, Archer M, Bates H, Shi H, Geiser F, McAllen B, Heinze D, Hand SJ, Evans T, Jackson S 2012, 'A brief review of the life history of, and threats to, *Burramys parvus* with a pre-history based proposal for ensuring that it has a future', *Wildlife and Climate Change: towards robust conservation strategies for Australian fauna*, Royal Zoological Society of NSW, Mosman, New South Wales, pp. 114-126.
40. SGS Economics and Planning 2017, 'Alpine Resort Futures Vulnerability Assessment (Social and Economic)', https://www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0014/215141/Alpine-Resorts-Vulnerability-Assessment-FINAL_Report-Aug-17.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:03 Observed surface temperature			●		↘	DATA QUALITY Good
Data custodian BoM						

Victoria's climate has been warming since the 1950s (Figure CC.4). Since the publication of SoE 2013, every year has been among the top 10 warmest on record for Victoria, with 2014 the second-warmest year on record, behind 2007.[41] The greatest warming, measured as the linear trend across Victoria from 1910 to 2018, has been observed in summer (+0.14°C per decade), with the least warming observed in winter (+0.06°C per decade).[42] The warming has been observed in both maximum (daytime) and minimum (overnight) temperatures. Based on this data, the trend for this indicator has been assessed as deteriorating (warming).

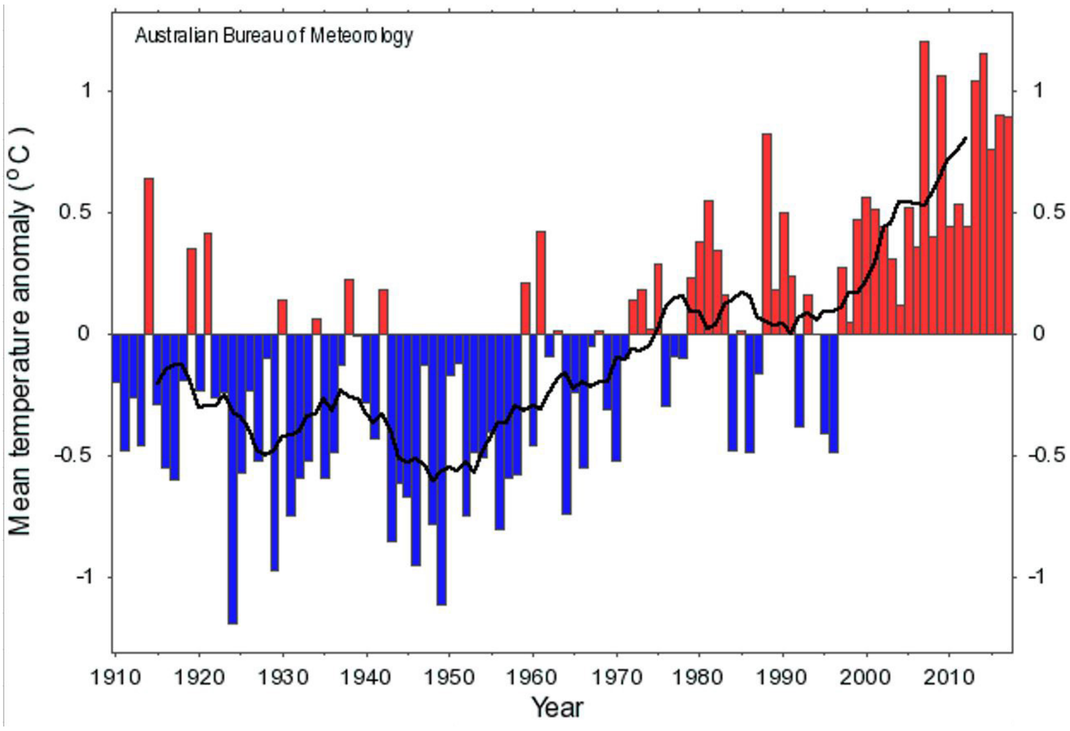

Figure CC.4 Victorian mean temperature anomaly, 1910–2017[43]

Note: 11-year running averages shown by black curve, Based on a 30-year climatology (1961-1990).

41. BoM, 'Climate Change and Variability – Time series graphs', Melbourne, Australia http://www.bom.gov.au/climate/change/ Accessed 4 December 2018.
42. Ibid
43. Ibid

All parts of Victoria have warmed, with the most warming in central and southern parts of the state (Figures CC.5 to CC.7). Daytime temperatures have increased uniformly, except in the far west and in parts of Gippsland and the north-east, where there has been a slightly slower increase. Overnight temperatures have warmed the most in southern coastal areas.

There has been no significant upward trend in night-time temperatures during the cool part of the year (April to October).[44] This is likely due to the reduction in rainfall since the mid-1990s, and hence reduced cloudiness, which allows for greater night-time heat loss from the surface.[45] Decreasing rainfall and cloud cover in the cool season appears to have somewhat offset the overall global warming signal in inland parts of Victoria, which explains the lesser night-time warming in this region: clearer night-time skies are generally associated with cooler minimum temperatures.

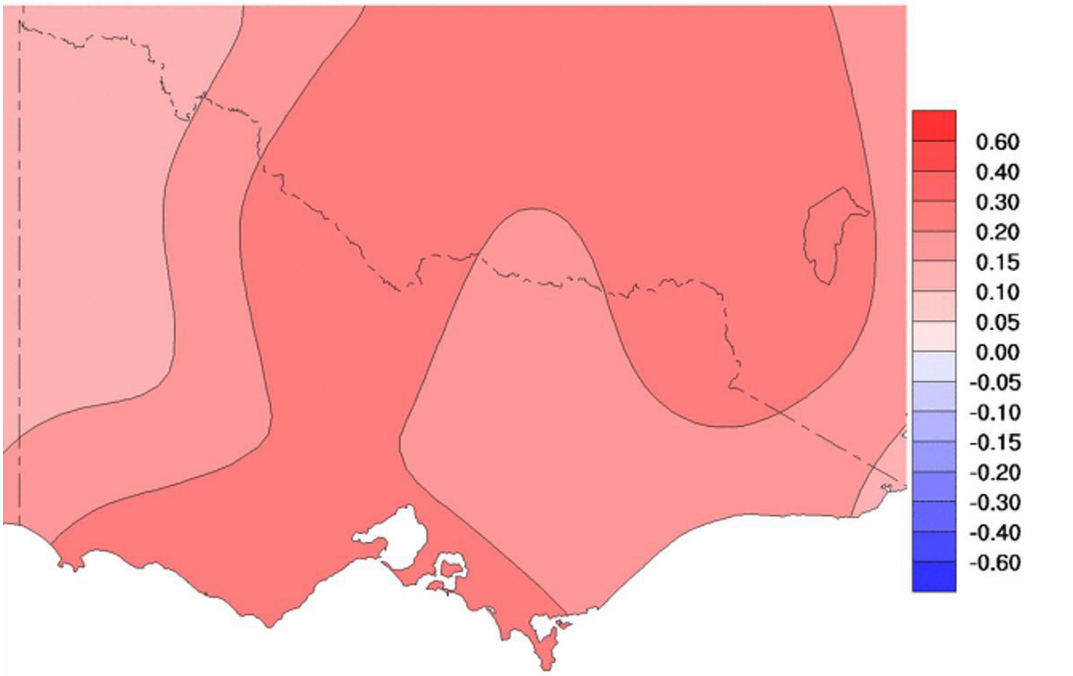

Figure CC.5 Trends in Victorian mean temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

44. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
45. Ibid

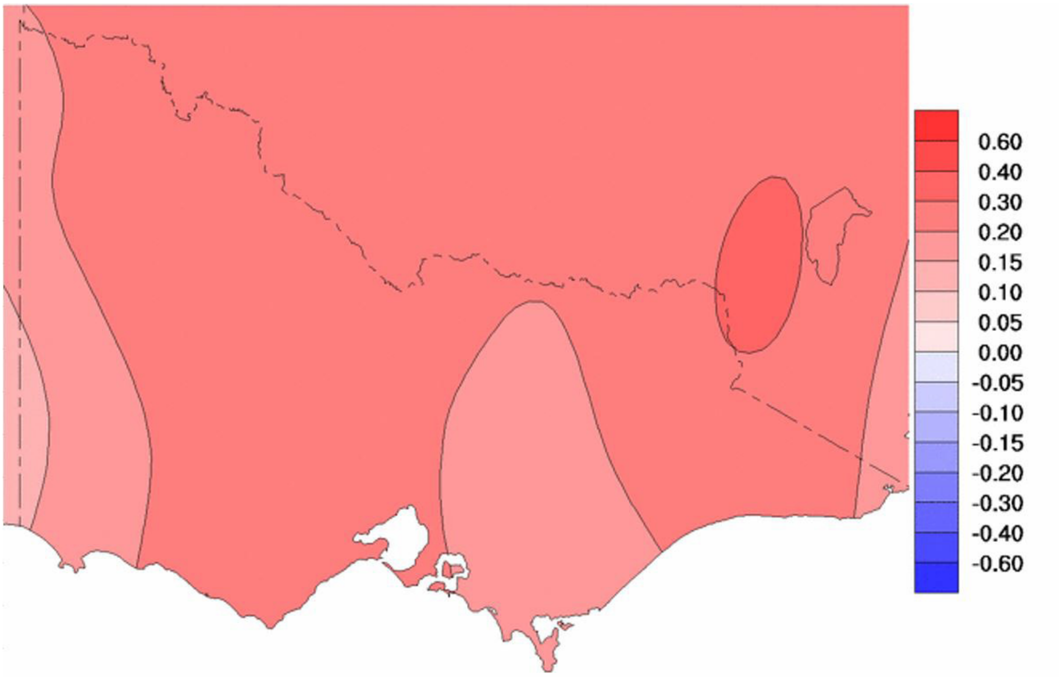

Figure CC.6 Trends in Victorian maximum temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

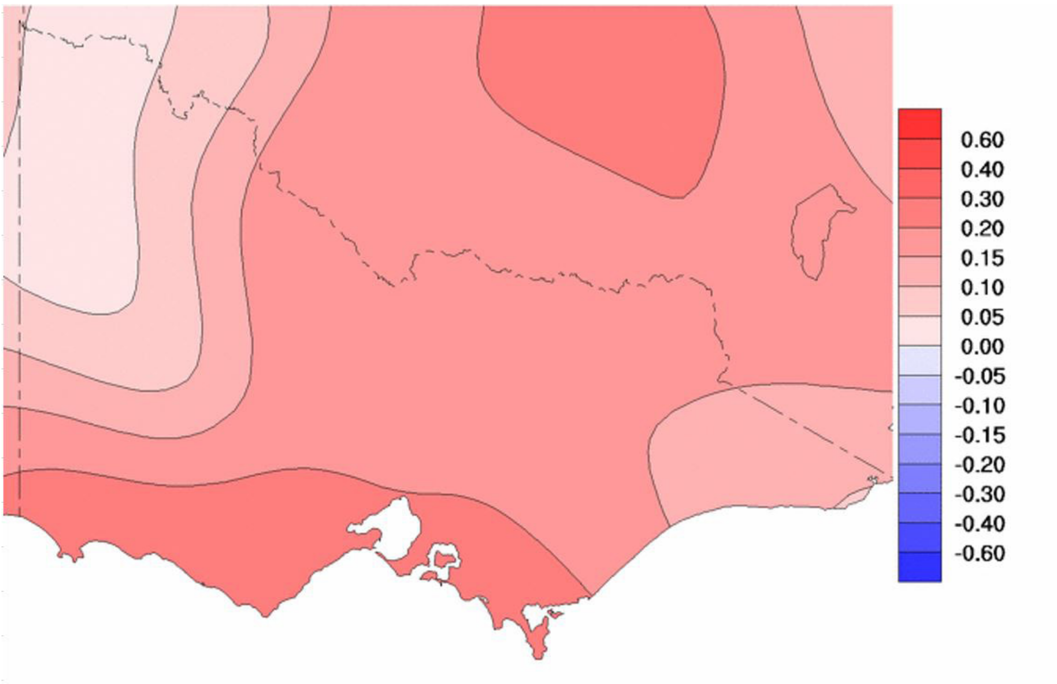

Figure CC.7 Trends in Victorian minimum temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

Climate – Projections

Indicator	Status	Trend	Data Quality
CC:04 Projected changes in temperature	N/A (UNKNOWN / POOR / FAIR / GOOD)	↘	DATA QUALITY Good

Data custodian BoM, CSIRO

Temperatures are expected to be an average of 0.4 to 1.3°C warmer across Victoria by 2030, relative to the 1986 to 2005 baseline. Warming is projected to increase further by 2090, in proportion to the scale of emissions from human activity. From the 1986 to 2005 baseline, Victorian temperatures are expected to increase by 2.5 to 4.5°C in 2090 under a high ongoing emissions scenario, by 1.1 to 2.4°C under an intermediate emissions scenario, and by 0.4 to 1.5°C under a lower emissions scenario, which aligns most closely with the Paris Agreement targets.[46,47] The magnitude of the warming is projected to be slightly greater in the Murray Basin region of Victoria than across the Southern Slopes (Table CC.1).[48]

It is important to note that the projection of a 0.4 to 1.3°C temperature increase by 2030 (relative to the 1986 to 2005 average) is likely to be an underestimate, as the observed average temperature for Victoria from 2008 to 2017 is already 0.6°C warmer than the 1986 to 2005 average.[49]

Increases in the magnitude, frequency and duration of extreme temperatures across Victoria are expected to occur at a similar rate to the rises in average temperature. Frost-risk days (minimum temperatures under 2°C) are projected to decrease across the state, possibly halving in northern Victoria by the end of the century.[50] In the short-to-medium term, other factors, such as an increase in clear nights, may lead to increases in frost risk in some places, but in the long term the warming is expected to drive a decrease in frost risk. A decrease in frost days is expected to help the broadacre agricultural sector, which loses an estimated $120 million to $700 million each year in Australia due to frost events.[51] For more information on extreme heat impacts, see indicator CC:12 (Occurrence and impacts of extreme weather).

Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so an ongoing warming is projected with very high confidence, with the full range of projected change considered plausible.

46. Grose M et al 2015, 'Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.
47. Timbal B et al 2015, 'Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.
48. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.
49. BoM, 'Climate Change and Variability – Time series graphs', Melbourne, Australia http://www.bom.gov.au/climate/change/ Accessed 4 December 2018.
50. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.
51. Crimp SJ, Zheng B, Khimashia N, Gobbett DL, Chapman S, Howden M, Nicholls N 2016, 'Recent changes in southern Australian frost occurrence: implications for wheat production risk', *Crop & Pasture Science*, 67, pp. 801–811.

Table CC.1 Projected temperatures across Victoria

Scenario	Victoria °C
2030 annually averaged warming relative to the climate of 1986–2005 for all emissions scenarios	0.4 to 1.3
2090 annually averaged warming relative to the climate of 1986– 2005 for a low emissions scenario (RCP2.6)	0.4 to 1.5
2090 annually averaged warming relative to the climate of 1986– 2005 for an intermediate emissions scenario (RCP4.5)	1.1 to 2.4
2090 annually averaged warming relative to the climate of 1986–2005 for a high emissions scenario (RCP8.5)	2.5 to 4.5

Note: Data derived from results for the three Victorian regions (Murray Basin, Southern Slopes West and Southern Slopes East) reported by Climate Change in Australia.[52]

52. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:05 Projected changes to average rainfall	N/A	↘	DATA QUALITY Fair

Data custodian BoM, CSIRO

The observed reduction in cool-season (April to October) rainfall in the past 20 years is projected to continue and possibly intensify. While rainfall reduction was more pronounced in autumn during the millennium drought, reductions are expected to be more even across the cool season.[53]

In the short term (until 2030), there is high confidence that natural climate variability will remain the major driver of rainfall changes, compared with the climate of 1986 to 2005.[54] However, by 2090, there is high confidence that cool-season rainfall will continue to decline. There will be no clear leaning towards wetter or drier conditions in the warm season.[55]

Figure CC.8 shows that under a high emissions scenario, Victoria's annual average rainfall at the end of the century is expected to have declined. This decline is expected to be characterised by longer periods of dry weather, interspersed with more frequent extreme rainfall events.[56]

Table CC.2 Projected rainfall across Victoria[57,58]

Scenario	Victoria (annual) %	Victoria (winter) %	Victoria (summer) %
Percentage change in rainfall in 2030 relative to the climate of 1986–2005 for all emissions scenarios	−11 to 5	−17 to 9	−20 to 16
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for a low emissions scenario (RCP2.6)	−19 to 5	−13 to 9	−27 to 8
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for an intermediate emissions scenario (RCP4.5)	−16 to 4	−21 to 7	−24 to 11
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for a high emissions scenario (RCP8.5)	−27 to 9	−38 to 6	−28 to 27

Note: Data derived from the results for the three Victorian regions (Murray Basin, Southern Slopes West and Southern Slopes East) reported by Climate Change in Australia.

53. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
54. Timbal B, Ekström B, Fiddes S, Grose M, Kirono D, Lim E-P, Lucas C and Wilson L 2016, 'Climate change science and Victoria: Bureau Research Report No. 14', *Report issued by the Bureau of Meteorology*.
55. Ibid
56. Australian Climate Change Science Programme 2015, 'Weather extremes and climate change - the science behind the attribution of climatic events', http://www.cawcr.gov.au/projects/Climatechange/wp-content/uploads/2015/11/Weather_Extremes_Report-FINAL.pdf Accessed 4 December 2018.
57. Grose M et al 2015, 'Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.
58. Timbal B et al 2015, 'Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.

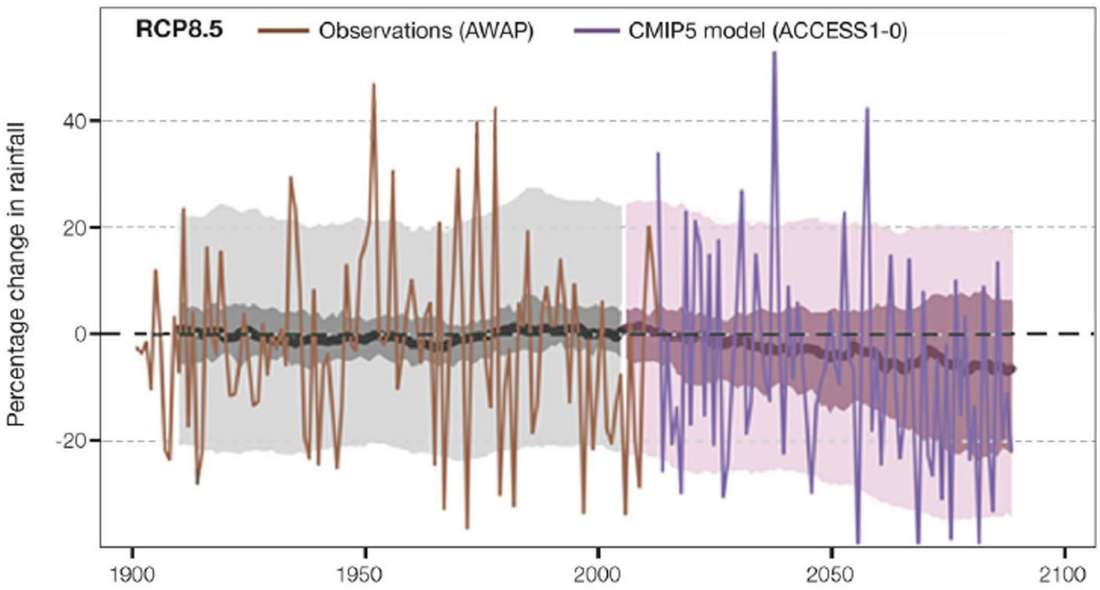

Figure CC.8 Observed annually averaged and simulated historical Victorian rainfall [59]

Note: Observed annually averaged Victorian rainfall (in brown), and simulated historical Victorian rainfall (in grey), with the deeper shade showing the variability across all available CMIP5 models in the 20-year average. Projections of Victorian rainfall from RCP8.5 are in purple, with shading illustrating the spread across all available CMIP5 models. Dark purple shows the median response. One model's output (ACCESS-1.0) is shown to highlight the year-to-year variability observed in all models.[60]

59. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
60. Ibid

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:06 Regional climate projections	N/A	↘	DATA QUALITY Good
Data custodian BoM, CSIRO			

As presented in indicators CC:04 (Projected changes in temperature) and CC:05 (Projected changes to average rainfall), climate projections for Victoria have been provided based on data available for three classified regions in Victoria.

Climate Change in Australia projections are reasonably consistent across the three Victorian regions.[61] There is a very high confidence that average temperatures will continue to increase in all seasons, with more hot days and warm spells, while fewer frosts are projected with high confidence.

In south-west Victoria, generally less rainfall is expected in winter and spring, while in the northern areas of the Murray Basin, and in the south-east of the state, changes to rainfall are not expected to exceed natural variability for another few decades. Despite the likely reductions in average rainfall, increased intensity of extreme rainfall events is projected with high confidence.

In 2015, the Department of Environment, Land, Water and Planning (DELWP) produced local data and fact sheets for Victorian towns and regions, based on the climate projections in indicators CC:04 (Projected changes in temperature) and CC:05 (Projected changes to average rainfall).[62] The fact sheets report on the projected annual number of hot days (over 35°C) and frost days (under 2°C) in selected major Victorian towns and cities, according to different emissions scenarios. These projected hot and frost days are shown in Table CC.3. The number of hot days in most cities and major towns in Victoria is expected to double by 2070, while the number of frost days is expected to halve.

61. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.
62. DELWP, 'Fact sheets about climate change impacts by region', East Melbourne, Victoria https://www.climatechange.vic.gov.au/information-and-resources Accessed 4 December 2018.

Table CC.3 Average number of hot and frost days per year for current, 2030 and 2070 scenarios[63,64,65,66,67,68]

Town	Current hot days	Hot days in 2030	Hot days in 2070 (medium emissions – RCP4.5)	Hot days in 2070 (high emissions – RCP8.5)	Current frost days	Frost days in 2030	Frost days in 2070 (medium emissions – RCP4.5)	Frost days in 2070 (high emissions – RCP8.5)
Ballarat	5	8	10	13	36	25	18	10
Bendigo	13	19	23	29	35	25	20	12
Geelong	6	9	11	13	4	2	1	0
Hamilton	8	11	13	16	20	12	8	4
Horsham	18	25	29	36	33	23	17	10
Melbourne	8	12	14	17	3	1	1	0
Mildura	36	46	54	66	14	9	6	3
Orbost	6	9	11	14	6	3	2	1
Shepparton	15	23	29	37	37	27	21	13
Traralgon	6	9	10	14	20	13	8	3
Wodonga	21	31	39	47	40	29	23	13

63. DELWP 2015, 'Barwon South West', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0020/60743/Barwon-South-West.pdf Accessed 4 December 2018.
64. DELWP 2015, 'Gippsland', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0021/60744/Gippsland.pdf Accessed 4 December 2018.
65. DELWP 2015, 'Grampians', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0018/60741/Grampians.pdf Accessed 4 December 2018.
66. DELWP 2015, 'Greater Melbourne', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0019/60742/Greater-Melbourne.pdf Accessed 4 December 2018.
67. DELWP 2015, 'Hume', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0022/60745/Hume.pdf Accessed 4 December 2018.
68. DELWP 2015, 'Loddon Mallee', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0023/60746/Loddon-Mallee.pdf Accessed 4 December 2018.

Sea Level

Indicator	Status: UNKNOWN	Status: POOR	Status: FAIR	Status: GOOD	Trend	Data Quality
CC:07 Observed sea level			●		↘	DATA QUALITY Fair

Data custodian BoM

Global sea levels rose by about 1.7 mm per year on average last century, with a greater rate of increase observed in recent decades.[69] Victorian tide gauges show the mean sea level has been increasing around the Victorian coastline, with average increases between 1.59 cm and 3.89 cm per decade between 1993 and 2016.[70] Melbourne (recorded at Williamstown), which has the longest continuous record of observations in Victoria, has reported an average increase in mean sea level of 1.97 cm per decade (that is, ~2 mm per year) since 1966.[71] This equates to a total rise of 10.2 cm over the past 52 years, which has been accompanied by increases in the frequency of extreme sea-level events.[72]

Higher maximum annual sea levels increase the hazards of extreme sea levels, such as coastal erosion and flooding, created by natural variability and climate conditions. This is especially the case when large astronomical tides combine with strong winds and low pressures that produce storm surges. There is also significant variability across seasonal-to-interannual timescales associated with drivers such as the El Niño–Southern Oscillation.[73]

The highest sea level recorded in Melbourne between 1966 and 2016 occurred on 24 June 2014, when the Williamstown gauge recorded values of up to 62 cm above Highest Astronomical Tide (the highest sea level that can be reached by astronomical tides).[74] This event occurred in conjunction with a severe storm and caused inundation of many bayside foreshore reserves and coastal infrastructure such as shared-use paths, beach access points and some roads (Figure CC.9).

Figure CC.9 Sand deposited over the bicycle path at Middle Brighton on 24 June 2014

(Photo: Andrew Watkins)

69. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
70. BoM, 'Tide Gauge Metadata and Observed Monthly Sea Levels and Statistics', Melbourne, Australia http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 4 December 2018.
71. Ibid
72. Ibid
73. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
74. BoM, 'Tide Gauge Metadata and Observed Monthly Sea Levels and Statistics', Melbourne, Australia http://www.bom.gov.au/oceanography/projects/ntc/monthly/ Accessed 4 December 2018.

Annual maximum sea levels at Melbourne have increased, on average, at a rate of 3.37 cm per decade between 1966 and 2016 – a total of 17 cm over the period. However, observed trends have been higher in recent years, with 12 cm of the total 17 cm occurring since 1993 at an average of 5 cm per decade. Similar trends have also been observed at Geelong (2.3 cm per decade from 1965 to 2016). Data collected from shorter-term Australian Baseline Sea Level Monitoring gauges from 1993 to 2016 shows increases at Portland (2.7 cm per decade) and Stony Point (4.2 cm per decade).[75]

The frequency of very high sea levels has also increased, with statistically significant increases in the frequency at which the Highest Astronomical Tide is exceeded at Geelong, Melbourne and Portland.

Recent tidal inundation has mainly occurred when observed sea-level rise has coincided with high astronomical tides (for example, king tides or spring tides).

75. BoM, 'Australian Baseline Sea Level Monitoring Project', Melbourne, Australia http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml Accessed 4 December 2018.

Sea Level – Projections

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:08 Projected sea level	N/A	↘	Good

Data Custodian BoM, CSIRO

Sea-level rise is one of the biggest threats associated with climate change to coastal areas. Significant impacts experienced this century are expected to intensify. These include:

- more frequent and extensive inundation of low-lying areas
- loss of coastal habitat, such as roosting and nesting sites for shorebirds and seabirds
- cliff, beach and foreshore erosion
- altered saltmarsh and mangrove habitats.[76]

Thermal expansion of the ocean and melting glaciers and ice caps have been the main causes of rising sea levels worldwide in the past century – a trend that is expected to continue. Australian sea levels are projected to rise for the rest of this century, most likely at a faster rate than for the past four decades.[77] Higher sea-level rise, driven by the accelerated melting and disintegration of ice shelves and ice sheets in Greenland and Antarctica, is also possible, meaning the 'worst case' scenario is sea levels above the high-end of projections presented here.

For Victoria, sea-level projections have been produced for Geelong and Williamstown (Table CC.4). Depending on the emissions scenario, sea levels are likely to rise between 3 cm (low emissions scenario) and 10 cm (high emissions scenario) per decade at Geelong and Williamstown during the rest of this century.

To visualise the possible impacts of coastal inundation, Figure CC.10 shows the areas that would be flooded at Queenscliff in 2100 in a high tide under a high emissions scenario, which assumes a median sea-level rise of 0.74 m.

Table CC.4 Likely ranges for projections of regional sea-level rise (m) relative to 1986–2005 under all emissions scenarios[78]

Locations	2030 m	2050 m	2070 m	2090 m
Geelong	0.06–0.17	0.12–0.33	0.18–0.54	0.22–0.82
Williamstown	0.06–0.17	0.12–0.32	0.17–0.54	0.22–0.81

76. Victorian Coastal Council 2018, 'Victoria's coast and marine environments under projected climate change: Impacts, research gaps and priorities', East Melbourne, Victoria http://www.vcc.vic.gov.au/assets/media/files/Victorian_Coastal_Council_Science_panel_report_WEB.pdf Accessed 4 December 2018.
77. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report – Projections for Australia's NRM regions', https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf Accessed 4 December 2018.
78. Ibid

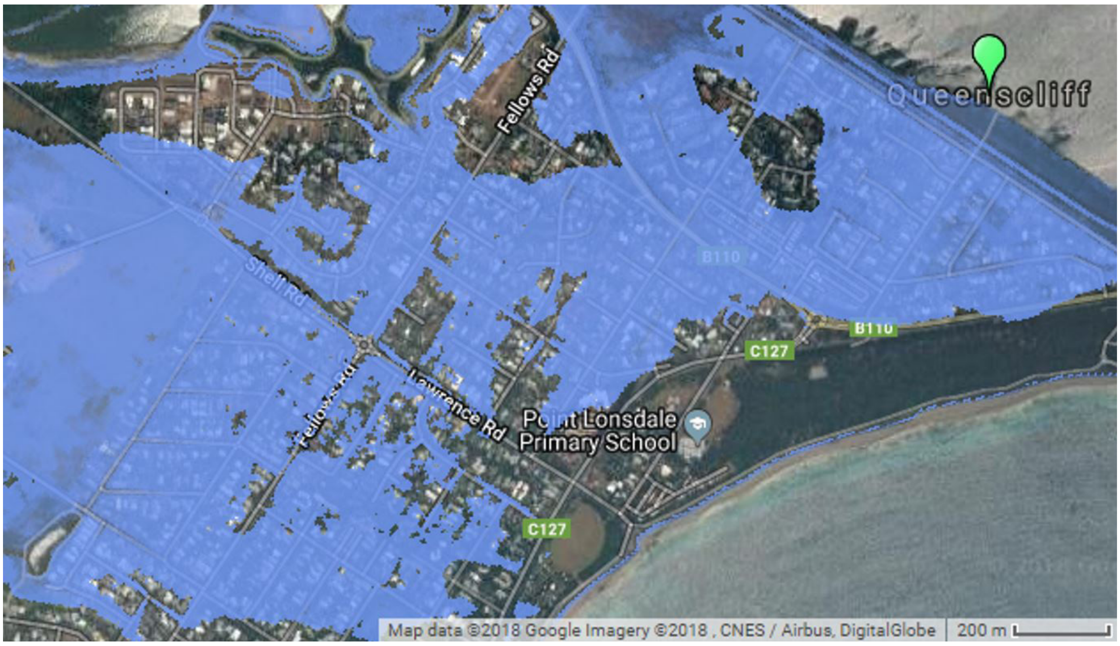

Figure CC.10 Coastal inundation at Queenscliff in high tide and assuming 0.74 m sea-level rise[79]

An increase in mean sea level will result in a larger increase in the frequency of extreme inundation events. For Australia to maintain the current level of exposure of coastal assets to extreme sea levels, protective barriers would need to be raised by at least 0.7 to 1.0 m by 2100 for a high emissions scenario.[80]

79. CRC for Spatial Information and NGIS, 'Coastal Risk Australia', http://www.coastalrisk.com.au/ Accessed 4 December 2018.
80. Climate Change in Australia, 'Projections for Australia's NRM Regions', https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters Accessed 4 December 2018.

Sea Temperature

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:09 Sea-surface temperature	POOR	↘	Good

Data custodian BoM, CSIRO

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by GHGs.[81]

Globally, the temperature of the ocean near the surface (upper 75 m) has been steadily increasing, by about 0.11°C per decade from 1971 to 2010.[82] The sea-surface temperature has warmed across the Australian region, with the greatest warming since 1950 around the south-east and to the south-west of Australia (Figure CC.11).

The ocean off the south-east coast of Australia, including the region near eastern Bass Strait, is one of the world's most rapidly warming locations, with a strengthening of the East Australian Current adding to the overall warming trend.[83, 84]

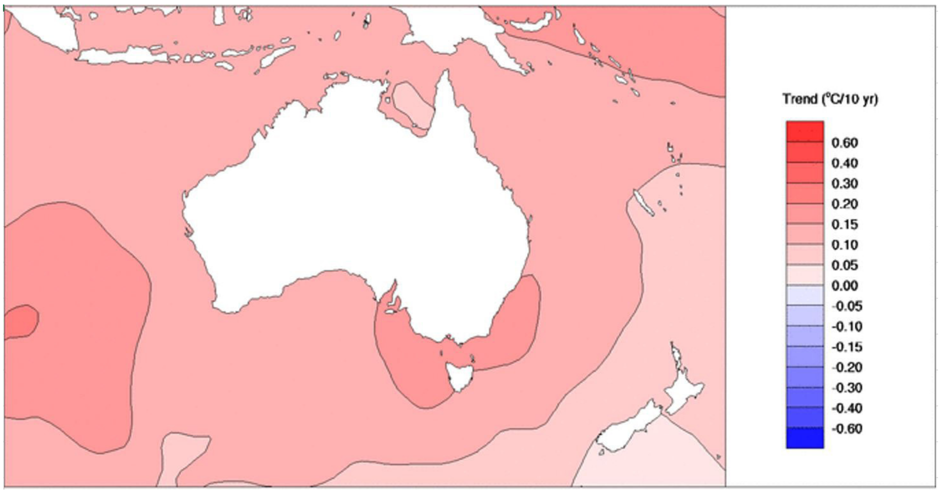

Figure CC.11 Trends in annual Australian region sea-surface temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

81. Rhein M, Rintoul SR, Aoki S, Campos E, Chambers D, Feely RA, Gulev S, Johnson GC, Josey SA, Kostianoy A, Mauritzen C, Roemmich D, Talley LD, Wang F 2013, 'Observations: Ocean. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
82. Ibid
83. Hobday AJ, Pecl GT 2014, 'Identification of global marine hotspots: sentinels for change and vanguards for adaptation action', *Reviews in Fish Biology and Fisheries*, 24(2), pp. 415-425.
84. Ridgway KR 2007, 'Long-term trend and decadal variability of the southward penetration of the East Australian Current', *Geophysical Research Letters*, 34(13).

Record-warm sea-surface temperatures have been observed in the Australian region in recent years, with 2016 the warmest year on record.[85] In the southern region (30°S–46°S, 94°E–174°E), recent years have also been warmer than average, with every year since 2010 in the top 10 warmest years on record for the region (Figure CC.12).

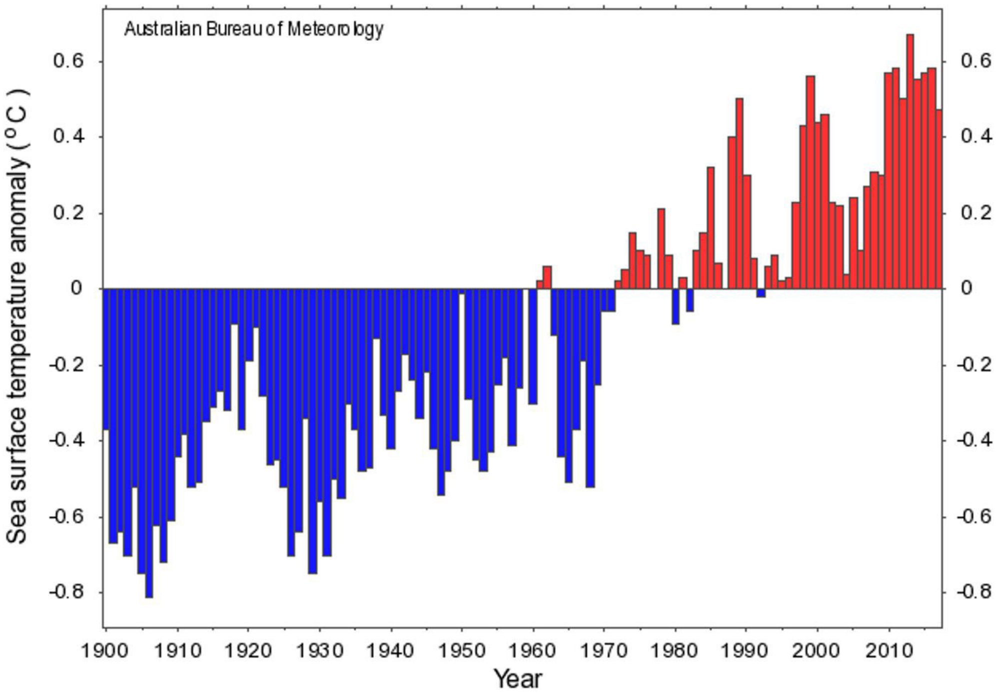

Figure CC.12 Australian sea-surface temperature anomaly – Southern Region, 1900–2017 [86]

Background warming of the oceans has led to an increased frequency of marine heatwaves.[87] Over the summer of 2015 to 2016, an extreme heatwave was observed to the south-east of Victoria in the Tasman Sea. The intensity and duration of the heatwave was increased by climate change and linked to outbreaks of Pacific Oyster Mortality Syndrome in Pacific oysters off the coast of Tasmania.[88] Background warming and the warmer and less nutrient-dense water from the East Australian Current has led to other impacts in the region, such as an almost complete loss of cold-water kelp forests off Tasmania's east coast.[89]

85. BoM, 'Climate change and variability', Melbourne, Australia http://www.bom.gov.au/climate/change Accessed 4 December 2018.
86. Ibid
87. Oliver ECJ et al 2018, 'Longer and more frequent marine heatwaves over the past century', *Nature Communications*, 9.
88. Oliver ECJ, Benthuysen JA, Bindoff NL, Hobday AJ, Holbrook NJ, Mundy CN, Perkins-Kirkpatrick SE 2017, 'The unprecedented 2015/16 Tasman Sea marine heatwave', *Nature communications*, 8.
89. Bennett S, Wernberg T, Connell SD, Hobday AJ, Johnson CR, Poloczanska ES 2016, 'The 'Great Southern Reef': social, ecological and economic value of Australia's neglected kelp forests', *Marine and Freshwater Research*, 67(1), pp.47-56.

Greenhouse Gas Emissions

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:10 Annual greenhouse gas emissions Data custodian DELWP	Stable for land sector and Unknown for marine and coastal ecosystems	↗	DATA QUALITY Good

Despite a relatively small population, Australia is the world's 13th biggest GHG emitter, ahead of countries such as the United Kingdom and France.[90] Australia's contribution is even more significant at a per capita level: no other country from the Organisation for Economic Co-operation and Development emits more GHGs per person than Australia.[91] Victoria's annual per capita emissions are lower than the national figure of 22 tonnes CO_2-e per person (in 2016), and Victorian per capita emissions have dropped from 24 tonnes CO_2-e per person in 1990 to 18 tonnes CO_2-e per person in 2016 (Figure CC.13).[92]

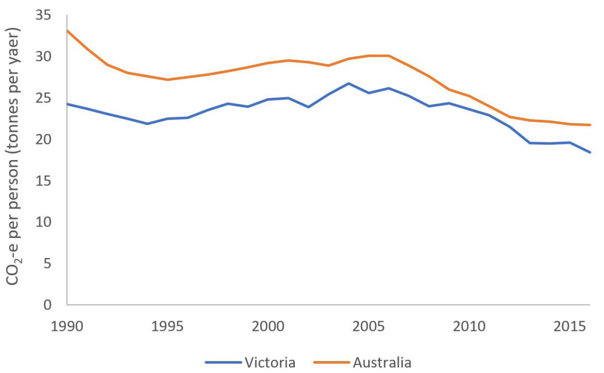

Figure CC.13 Victorian and Australian per capita annual GHG emissions, 1990–2016, including land use, land-use change, and forestry (LULUCF)

(Data source: DELWP, 2018)

In Victoria, carbon dioxide is the most significant GHG, contributing 79% of total emissions in 2016.[93] The majority of carbon dioxide emissions come from industry, transport and energy generation. Emissions of methane and nitrous oxide in 2016, mainly from land management and agriculture, also made contributions of 14% and 4% respectively to the total GHG emissions.[94]

The Victorian Government has committed to reducing the state's emissions by 15 to 20% of 2005 levels by 2020.[95] In 2016, the state's total net GHG emissions were 10.8% lower than in 2005 (but 7.3% higher than in 1990) (Figure CC.14). The reduction on 2005 levels means this indicator has been assessed as improving.

Reductions since 2005 are largely due to improvements in energy efficiency, higher electricity prices (which have reduced electricity demand) and a decline in manufacturing activity.[96,97] There was a 3.5% reduction between 2015 and 2016 alone, primarily because of an increase in carbon sequestration from the land sector, and a reduction in emissions from the generation of electricity.

90. World Resources Institute, 'Climate Analysis Indicators Tool (CAIT) Climate Data Explorer Historical emissions', Washington, DC, http://cait.wri.org/historical Accessed 4 December 2018.
91. Organisation for Economic Co-Operation and Development, 'OECD.stat Greenhouse gas emissions', Paris, France, https://stats.oecd.org/Index.aspx?DataSetCode=AIR_GHG Accessed 4 December 2018.
92. DELWP 2018, 'Victorian Greenhouse Gas Emissions Report 2018', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0033/395079/Victorian-Greenhouse-Gas-Emissions-Report-2018.pdf Accessed 4 December 2018.
93. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia http://ageis.climatechange.gov.au Accessed 4 December 2018.
94. Ibid
95. Department of Environment, Land, Water and Planning, 'Emissions reduction targets', Melbourne, Victoria, https://www.climatechange.vic.gov.au/reducing-emissions/emissions-targets Accessed 4 December 2018.
96. DELWP 2017, 'Independent Expert Panel: Interim Emissions Reduction Targets for Victoria (2021-2030)', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0019/121924/Issues-Paper_28-03-2018.pdf Accessed 4 December 2018.
97. DELWP 2018, 'Victorian Greenhouse Gas Emissions Report 2018', East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0033/395079/Victorian-Greenhouse-Gas-Emissions-Report-2018.pdf Accessed 4 December 2018.

By 2020, net GHG emissions in Victoria are expected to have dropped by 18% relative to 2005 levels.[98] The closure in March 2017 of the Hazelwood power station, which emitted about 15 Mt CO_2-e per year, is expected to be the biggest contributor to the reductions between 2005 and 2020.[99]

For further discussion, see the Energy chapter.

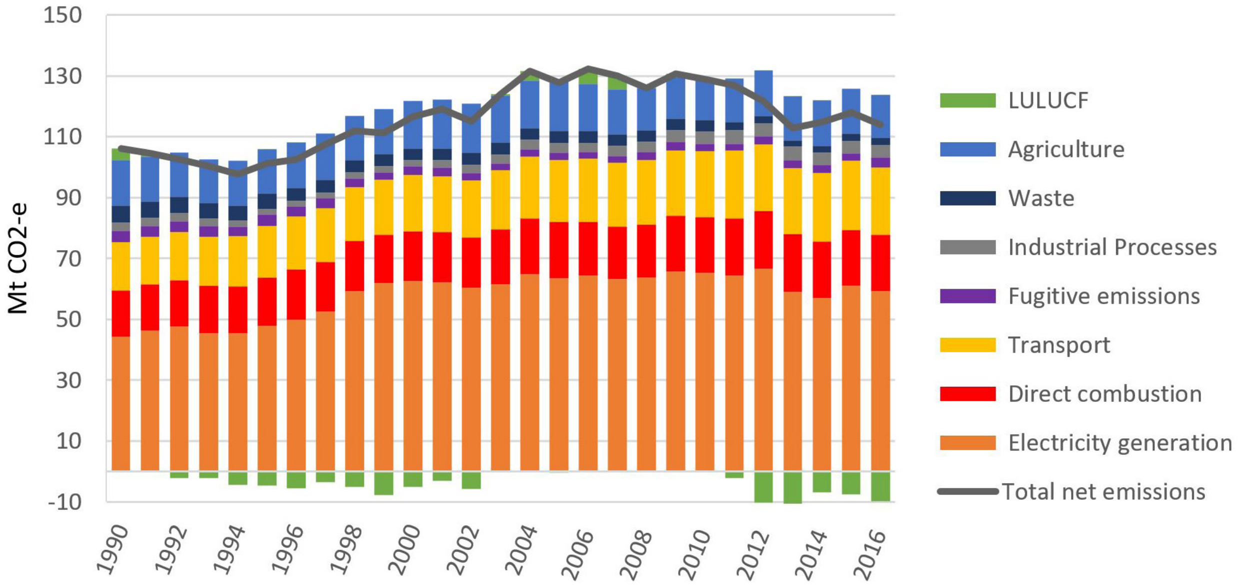

Figure CC.14 Victoria's annual GHG emissions, 1990–2016

(Data source: DELWP, 2018)

The highest contributor to GHG emissions in Victoria in 2016 was the production of electricity, which was responsible for 52% of the state's total emissions (Figure CC.15). The transport sector had the second largest share (20%) and the greatest increase since 1990. The direct combustion of stationary fuels had the third largest share (15%) followed by the agriculture sector (12%). Carbon sequestration from Victoria's land sector offset 9% of total emissions in 2016.

98. Ibid
99. Ibid

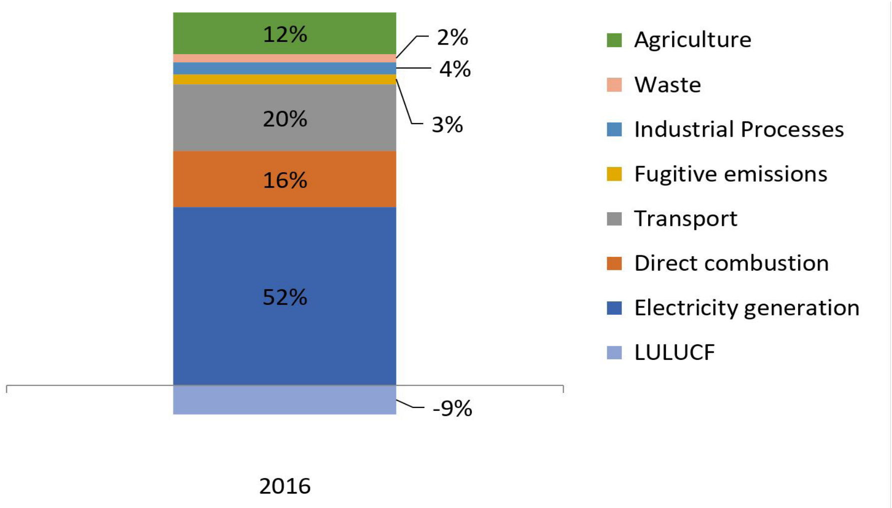

Figure CC.15 Sector GHG emissions percentage contributions in Victoria, including LULUCF, in 2016

(Data source: DELWP, 2018)

Figure CC.16 compares 2016 emissions by sector with emissions in 1990, and the baseline year of 2005 (against which Victoria's emission reduction targets are assessed).[100] Emissions from the electricity, direct combustion, transport and industrial processes sectors all increased between 1990 and 2016. Direct combustion, transport, fugitive and industrial processes emissions were higher in 2016 than in 2005, whereas emissions from other sectors were lower.

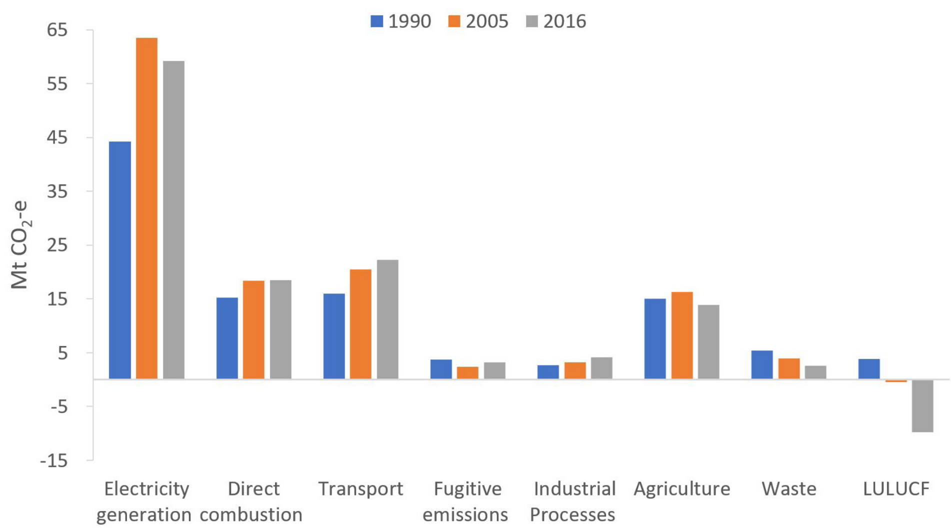

Figure CC.16 Sector GHG emissions in Victoria in 1990, 2005 and 2016

(Data source: DELWP, 2018)

100. Office of the Chief Parliamentary Counsel Victoria 2017, 'Climate Change Act 2017', Melbourne, Victoria http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf Accessed 4 December 2018.

Transport emissions have grown by 39% in the past 26 years. The sector had the highest proportional increase in emissions in Victoria over this period (Figure CC.17). Road transportation is the major source of emissions from this sector, accounting for 90% of transport emissions in 2016. This is a result of the use of motor vehicles as the main mode of transport for passengers and freight. For further detail about energy and GHG emissions, see the Energy and Transport chapters.

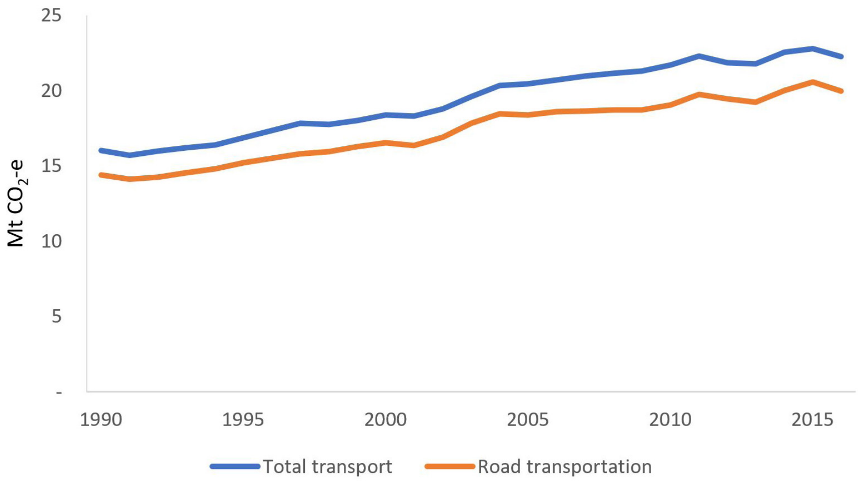

Figure CC.17 Transport GHG emissions in Victoria, 1990–2016

(Data source: DELWP, 2018)

Carbon Storage

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:11 Victorian ecosystem carbon stocks Data custodian DELWP	Stable for land sector and Unknown for marine and coastal ecosystems	→	DATA QUALITY Fair

This indicator looks at the important role ecosystems play in the global carbon cycle and global GHG balance by storing carbon in both trees and soil. Carbon stocks in Victoria are vulnerable to climatic variation and bushfires, which have temporarily decreased carbon stocks in some areas. This has important implications for the management of Victoria's carbon stocks with the ability of forests to take up carbon vital for the mitigation of climate change.

Victoria's forests store a considerable amount of carbon, but carbon stocks are likely to be impacted by climate change, with increased periods of drought and fire risk. Figure CC.18 shows declines in land sector carbon stocks from 2002 to 2003, and 2006 to 2007, directly attributable to bushfire events – although there has been a consistently upward trend in land sector carbon stocks since 2007.[101] The y-axis of the graph in Figure CC.18 has been enlarged to show changes in greater detail, and it is important to note that despite the consistent increase in carbon stocks, the growth from 2007 to 2016 has only been 1%. Based on this small increase, the trend for land sector carbon stocks has been assessed as stable. The growth has been due to net growth of carbon stocks in forests, which is currently occurring at a rate of nearly 2% per year. There has been a decay of carbon stocks in non-forests.

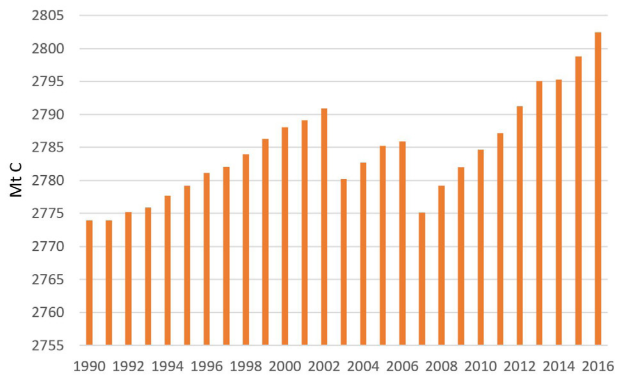

Figure CC.18 Victorian land sector carbon stocks, 1990–2016[102]

Carbon stored in coastal and marine ecosystems is referred to as 'blue carbon'. Potential blue carbon stocks have been estimated at 1,000,000 t in the Port Phillip and Westernport catchment.[103] For further detail on blue carbon, see the Marine and Coastal Environments chapter.

101. Australian Department of the Environment and Energy, 'State and Territory Greenhouse Gas Inventories 2016', Canberra, Australia http://www.environment.gov.au/system/files/resources/a97b89a6-d103-4355-8044-3b1123e8bab6/files/state-territory-inventories-2016.pdf Accessed 4 December 2018.

102. Ibid
103. Carnell P et al 2015, 'The distribution and abundance of 'Blue Carbon' within Port Phillip and Westernport', Deakin University, Melbourne, Victoria.

Impacts of Climate Change

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:12 Occurrence and impacts of extreme weather		●			↘	DATA QUALITY Good

Data custodian BoM, CSIRO, DHHS, EMV

Extreme weather affects the frequency and intensity of natural disasters in Australia. The types of natural disasters that occur in Australia are many and varied, ranging from severe thunderstorms, hail storms and floods to heatwaves, bushfires and droughts.

Research has found that heatwaves cause more deaths than any other natural disaster in Victoria,[104] with another study estimating there will be an extra 400 deaths per year in Victoria by 2050 due to heatwaves, if no adaptation measures are taken.[105] A warmer climate has coincided with an increase in the number of extreme heat events in Victoria. There has been a significant increase in the number of days per year when Victorian temperatures are unusually warm (Figure CC.19) – defined as those above the 99th percentile of each month from the years 1910 to 2015.[106]

This century has not seen a year without at least one extreme heat event, compared to the start of the record, which contains many years without extreme events. As described in indicator CC:06 (Regional climate projections), the number of hot days (over 35°C) per year in most cities and major towns in Victoria is expected to double by 2070.

The Department of Health and Human Services (DHHS) operates a heat health alert system.[107] During the summer of 2016 to 2017 (between the start of November 2016 and the end of March 2017), DHHS issued 23 heat health alerts for six days of extreme heat across multiple districts. In the summer of 2015 to 2016, DHHS issued 33 heat health alerts for 10 days of extreme heat.[108] The impacts of extreme heat can be catastrophic, particularly during multiday heatwaves with oppressive overnight weather. In Victoria, during a January 2009 heatwave, there were 374 'excess' deaths (over what would be expected). The majority of those deaths occurred in people aged 75 and older. There were also an estimated 167 excess deaths during a January 2014 heatwave.[109, 110]

Heat stress can also significantly affect tree-dwelling and nocturnal wildlife such as possums, koalas and birds, while grey-headed flying foxes are particularly prone to heat stress.[111]

Increased probability of extreme rainfall events in a given season can be predicted with reasonable accuracy months in advance when La Niña, negative Indian Ocean Dipole and high Southern Annular Mode align in spring. These predictions can be used for improved management of Victorian water resources.

BoM predicted the extreme rainfall across eastern Australian in spring 2010 up to one season in advance.[112] BoM also issues more immediate flood watches and warnings for most major rivers in Australia. A flood watch provides early advice of potential flooding, while a flood warning is issued when flooding is occurring or expected to occur. From July 2015 to June 2017, BoM issued

104. Steffen W, Hughes L, Perkins S 2014, 'Heatwaves: Hotter, Longer, More Often', Climate Council of Australia Limited, Potts Point, New South Wales.
105. Keating A, Handmer J 2013, 'Future potential losses from extremes under climate change: the case of Victoria, Australia', Victorian Centre for Climate Change Adaptation Research, Melbourne, Victoria.
106. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf Accessed 4 December 2018.
107. Department of Health and Human Services 2017, 'Heat health alert system', Melbourne, Victoria.
108. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
109. Department of Human Services 2009, 'January 2009 Heatwave in Victoria: an Assessment of Health Impacts', Melbourne, Victoria.
110. Department of Health 2014, 'The health impacts of the January 2014 heatwave in Victoria', Melbourne, Victoria.
111. DELWP, 'Heat stress in wildlife', East Melbourne, Victoria https://www.wildlife.vic.gov.au/wildlife-emergencies/heat-stress-in-wildlife2 Accessed 4 December 2018.
112. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.

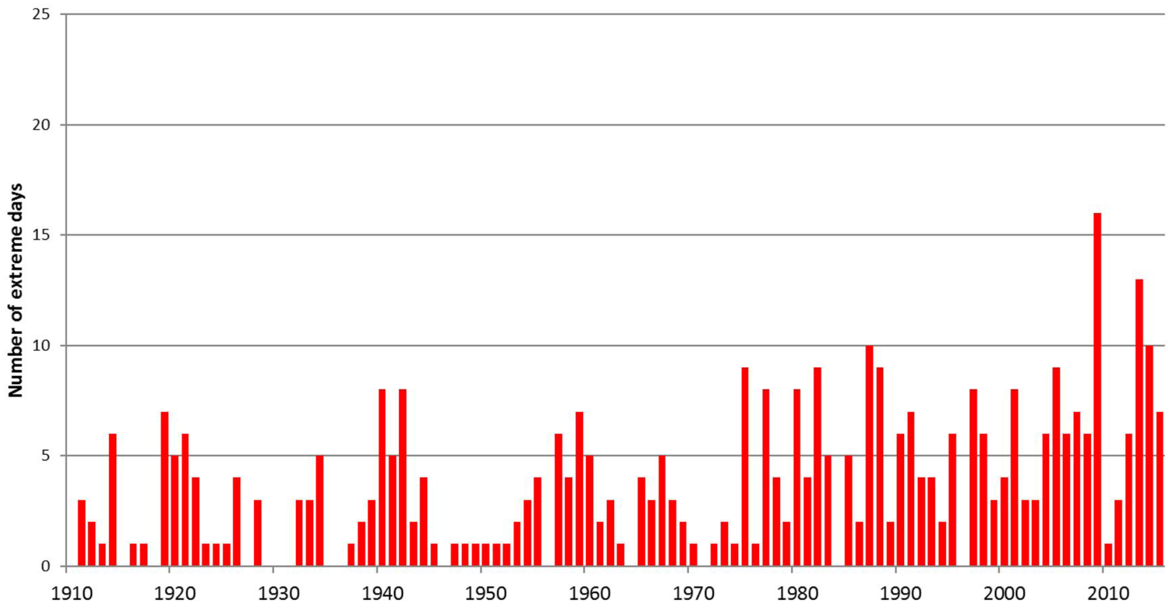

Figure CC.19 Days per year when Victorian averaged daily mean temperature is 'unusually warm' – above the 99th percentile of each month, 1910–2015

(Data source: BoM)

nearly 1,300 flood watches and flood warnings for Victoria. About two-thirds of these flood watches and warnings were issued in spring 2016, when substantial amounts of rain fell across the state and led to flooding.[113] No trend on flood watches and flood warnings could be determined based on the limited period of this dataset.

With increased nutrient runoff from land practices, warmer temperatures and reduced flows, the prevalence of algal blooms is expected to increase. A recent example of such an event is the blue-green algae event in the Murray River in February 2016.[114]

Environmental conditions that encourage mosquito breeding, such as heavy rainfall, floods, high tides and warm temperatures, can lead to outbreaks of Ross River virus, a disease spread by mosquitos that can cause joint inflammation and pain, fatigue and muscle aches.[115] The recent wetter rainfall years have been linked to increased incidences of Ross River virus. A record number of notifications of Ross River virus infection were recorded in 2017 (mostly during January and February) associated with a wetter 2016 in Victoria.[116] A similar spike was recorded in the early months of 2011, coinciding with heavy rainfall during the summer of 2010 to 2011.

There is a clear trend towards more dangerous weather conditions for bushfires in south-east Australia, including significant increases in the frequency and magnitude of extreme conditions in some regions. The Forest Fire Danger Index (FFDI) is used throughout Victoria by fire agencies to plan and manage resources in response to the risk of bushfires. The FFDI is based on temperature, rainfall, humidity and wind speed. FFDI patterns have changed over recent decades, with the strongest increases in fire danger generally in summer and spring. Changes to the springtime pattern indicate a shift towards an earlier start to the fire season. These changes are attributable, at least in part, to increasing temperatures associated with anthropogenic climate change.[117]

113. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
114. Emergency Management Victoria 2016, 'Year in Review 2015-16', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/EMV-Year-in-Review-2015-2016.pdf Accessed 4 December 2018.
115. Department of Health and Human Services 2018, 'Ross River virus disease', Melbourne, Victoria https://www.betterhealth.vic.gov.au/health/ConditionsAndTreatments/ross-river-virus-disease?viewAsPdf=true Accessed 4 December 2018.
116. Australian Department of Health, 'National Notifiable Diseases Surveillance System', Canberra, Australia http://www9.health.gov.au/cda/source/cda-index.cfm Accessed 4 December 2018.
117. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', *Journal of Applied Meteorology and Climatology*, 57(2), pp. 221-234.

Currently, natural disasters cost Victoria an estimated $1 billion per year, on average. Population growth, concentrated infrastructure density and migration to more vulnerable parts of the state means this expense is forecast to grow by 3.4% per year. By 2050, the estimated cost is expected to be $3.2 billion. This projection does not include the impacts of climate change, so the actual cost is likely to be much higher.[118]

Since publication of SoE 2013, notable natural disasters due to extreme weather have included:

- January 2014 heatwave. Across four consecutive days from 14 to 17 January 2014, Melbourne recorded maximum temperatures above 41°C, while other parts of the state recorded temperatures of 45°C or more on three consecutive days. There were an estimated 167 excess deaths during the heatwave – a 24% increase in mortality. By contrast, during a heatwave in January 2009, a 62% increase in mortality was observed. The introduction of a heatwave plan for Victoria in 2011 may have contributed to the decrease in estimated excess mortality in 2014.[119]
- December 2015 and January 2016 bushfire in Wye River. A fire that started by lightning strike in the Otway National Park near Lorne broke containment lines during strong northerly winds on Christmas Day, travelling rapidly towards coastal townships. During the next week, communities from Wye River, Separation Creek, Kennett River, Grey River and Wongarra were evacuated and the Great Ocean Road was closed. The fire remained active until 15 January 2016; 116 properties were destroyed.[120]
- Spring 2016 floods. Extensive rainfall was experienced across the state on 8 September 2016, with significant impacts to communities on 13 and 14 September 2016. Widespread flooding occurred in the following catchments: Barwon South West, Grampians, Loddon Mallee, and Hume, and parts of the Metropolitan Regions. The cost of damage to essential public assets was estimated to be more than $115 million.[121]
- November 2016 epidemic thunderstorm asthma event. Epidemic thunderstorm asthma is thought to be triggered by an uncommon combination of high grass-pollen levels and a certain type of thunderstorm. On the evening of 21 November 2016, a severe thunderstorm moved from Geelong and passed through Melbourne. An epidemic thunderstorm asthma event, unprecedented in size and severity, occurred immediately following the storm. The event was associated with a 681% increase in asthma-related admissions to all Victorian public hospitals in the 30 hours from 6 pm on 21 November 2016. It is thought to have contributed to the deaths of 10 people.[122, 123, 124]

118. Deloitte Access Economics 2017, 'Building resilience to natural disasters in our states and territories', Sydney, New South Wales https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-building-resilience-natural%20disasters-states-territories-161117.pdf Accessed 4 December 2018.
119. Department of Health 2014, 'The health impacts of the January 2014 heatwave in Victoria', Melbourne, Victoria.
120. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
121. Ibid
122. Department of Health and Human Services 2017, 'The November 2016 Victorian epidemic thunderstorm asthma event: an assessment of the health impacts – The Chief Health Officer's Report, 27 April 2017', Melbourne, Victoria.
123. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, https://files-em.em.vic.gov.au/public/EMV-web/OpsReview2017.pdf Accessed 4 December 2018.
124. The Age, 'Coronial investigation uncovers tenth thunderstorm asthma death', https://www.theage.com.au/national/victoria/coronial-investigation-uncovers-tenth-thunderstorm-asthma-death-20171018-gz3j59.html Accessed 4 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:13 Extent and condition of key climate-sensitive ecosystems Data custodian DELWP, Parks Victoria	UNKNOWN	?	DATA QUALITY Fair

Some ecosystems are more sensitive to a changing climate than others. Vulnerable ecosystems include those in the mountains, along the coast, in cool-temperature rainforests and in freshwater and wetlands. Species such as seagrass, and certain fish, birds and plants, are particularly sensitive to a changing climate. Changes in the extent and condition of these ecosystems could serve as an indicator of changes in climate risk to natural ecosystems.[125]

As climate change intensifies, existing pressures on Victoria's biodiversity will be amplified and new threats will emerge. The primary climate change impacts expected to affect biodiversity are:

- increased frequency and severity of some types of extreme weather events
- increased frequency and intensity of bushfires and drought
- rising sea levels
- changes in ocean temperatures, currents and ocean acidification
- changes to waterway flows, levels and regimes
- shifts in the range, distribution, abundance and seasonality of species, particularly in association with phenology changes
- changes in the range, distribution and impacts of introduced plants and animals, including the introduction of new pests taking advantage of a changed climate.[126]

Victoria has been experiencing biodiversity loss, partly due to reduced resilience under climate change. An example of this is repeated fires in the Victorian alpine region inhibiting the regrowth of alpine ash trees.[127] The increase in fire danger weather in recent decades has been linked to anthropogenic climate change.[128] At a national level, changes to phenology are now being measured, with the plant and flowering cycle starting earlier by 9.7 days per decade.[129] Earlier and prolonged flowering of Victoria's plants has been linked to an increase in the occurrence of asthma, hay fever, allergic conjunctivitis and eczema.[130]

Recent research has found climate change is likely to exacerbate the impacts of invasive terrestrial and inland aquatic species.[131] See the Biodiversity chapter for discussion of how climate change has been found to be contributing to ecological declines at some Ramsar sites.

125. Australian Department of Industry, Innovation, Climate Chance, Science, Research and Tertiary Education 2013, 'Climate Adaptation Outlook: A proposed national adaptation assessment Framework', Canberra, Australia https://www.environment.gov.au/system/files/resources/e70b19e5-e378-499b-8ae3-cbb42875328c/files/climate-adaptation-outlook.pdf Accessed 4 December 2018.
126. DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', East Melbourne, Victoria https://www.environment.vic.gov.au/__data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf Accessed 4 December 2018.
127. Bassett OD, Prior LD, Slijkerman CM, Jamieson D, Bowman DMJS 2015, 'Aerial sowing stopped the loss of alpine ash (Eucalyptus delegatensis) forests burnt by three short-interval fires in the Alpine National Park, Victoria, Australia', *Forest Ecology and Management*, 342, pp. 39-48.
128. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', *Journal of Applied Meteorology and Climatology*, 57(2), pp. 221-234.
129. Chambers LE et al 2013, 'Phenological Changes in the Southern Hemisphere', *PLoS ONE*, 8(10).
130. Commissioner for Environmental Sustainability 2012, 'Climate Change Victoria: the science, our people and our state of play', Melbourne, Victoria.
131. White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', *Arthur Rylah Institute for Environmental Research Technical Report Series No. 287*, DELWP, Heidelberg, Victoria.

Surveys of species richness and species' ecological attributes at multiple sites (including Ramsar) over different years conclude that native fauna have little if any predictable resilience to significant changes in crucial environmental factors. Examples of this research include a 2015 study that found the majority of bird species in floodplain forest in south-eastern Australia declined substantially during drought conditions between 1998 and 2009, with only a very small minority increasing in prevalence by 2013 after the drought broke and rainfall increased.[132]

A 2018 study found bird species in locations with high vegetation greenness are more resistant to severe drought.[133] This research discusses the effectiveness of prioritising conservation investments in areas with locally high vegetation productivity to increase the resistance of bird species to extreme drought.[134]

Efforts to ensure the ecological health of Corner Inlet by protecting the broadleaf seagrass species *Posidonia australis* is an example of recent work to protect Victoria's biodiversity against the impacts of climate change. Corner Inlet is the only area of Victoria where *Posidonia australis* forms. A native purple sea urchin species – *Heliocidaris erythrogramma* – had been multiplying at Nooramunga Marine and Coastal Park in Corner Inlet. The sea urchin species was eating the seagrass at Coastal Park and creating bare patches that were expected to increase in size without management action.[135] Parks Victoria undertook work to reduce the number of sea urchins in the affected area, most notably working with the Victorian Fisheries Authority and a dedicated group of volunteers to snorkel through the shallow waters and hand-cull more than 57,000 urchins.[136] This work was deemed successful, with evidence of seagrass returning in the areas where the urchins were culled.[137] The distributional range of black sea urchins is also believed to be expanding, driven by climate-related changes to the East Australian Current.[138]

Another example of research of a climate-sensitive ecosystem can be found in Victoria's alpine region, where Arthur Rylah Institute have been mapping alpine sphagnum bogs across their 10,000 km^2 range in the high country for more than a decade.[139] Alpine sphagnum bogs contribute to plant and animal diversity in Australia's high country and provide significant benefits to the environment by storing carbon and filtering out sediments, nutrients and pathogens from water.[140] Alpine sphagnum bog mapping has been produced as a spatial dataset. This dataset is a key resource for land managers that are mitigating and adapting to the challenges posed by climate change and other threats, especially increased fire, deer and feral horses.[141] However, very few vegetation communities are mapped as comprehensively as alpine sphagnum bog, so this degree of informed land management is not available for other parts of the state.[142] The value of alpine sphagnum bog mapping was shown during the 2018 Tamboritha fire, when Parks Victoria accessed mapping to minimise damage to bogs during fire suppression activities, preserving the internationally significant Caledonia Fen.[143]

132. Selwood KE, Clarke RH, Cunningham SC, Lada H, McGeoch MA, Mac Nally R 2015, 'A bust but no boom: responses of floodplain bird assemblages during and after prolonged drought', *Journal of Animal Ecology*, 84(6), pp. 1700-1710.
133. Selwood KE, McGeoch, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology*, 55(2), pp. 641-650.
134. Ibid
135. Crockett P, Johnson K, Brenker M, Ierodiaconou D, Carnell P 2017, 'Undaria pinnatifida in Port Phillip Bay Marine Sanctuaries: Removal strategies and interactions with the native algal canopy', *Parks Victoria Technical Series No. 113*, Parks Victoria, Melbourne, Victoria.
136. Parks Victoria, 'Protecting seagrass meadows from sea urchin attack', Melbourne, Victoria, http://parkweb.vic.gov.au/about-us/news/protecting-seagrass-meadows-from-sea-urchin-attack Accessed 4 December 2018.
137. Ibid
138. Victorian Fisheries Authority, 'Sea urchin', https://vfa.vic.gov.au/about/publications-and-resources/status-of-victorian-fisheries/sea-urchin Accessed 4 December 2018.
139. Arthur Rylah Institute, 'Alpine Sphagnum bogs: if we map them we can manage them', Heidelberg, Victoria, https://www.ari.vic.gov.au/research/wetlands-and-floodplains/alpine-sphagnum-bogs-if-we-map-them-we-can-manage-them Accessed 4 December 2018.
140. Ibid
141. Ibid
142. Ibid
143. Ibid

Further research completed since SoE 2013 shows birds are more resistant to severe drought in locations with high vegetation productivity.[144] Floodplains are potential refuge areas for biota during drought, as they have greater water availability through shallow groundwater and flooding.[145] The white-naped honeyeater (*Melithreptus lunatus Vieillot*), grey currawong (*Strepera versicolor Latham*) and golden whistler (*Pachycephala pectoralis Latham*) are examples of species that have shown a tendency to use floodplain forests for drought refuge.[146] Vegetation greenness is an important factor for biodiversity due to a more reliable water availability and sheltering from topography, with the provision of environmental water an important part of this process.[147, 148]

144. Selwood KE, McGeoch, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology*, 55(2), pp. 641-650.
145. Selwood KE, Thomson JR, Clarke RH, McGeoch MA, Mac Nally R 2015, 'Resistance and resilience of terrestrial birds in drying climates: do floodplains provide drought refugia?', *Global Ecology and Biogeography*, 24, pp. 838–848.
146. Ibid
147. Selwood KE, Clarke RH, McGeoch MA, Mac Nally R 2017, 'Green Tongues into the Arid Zone: River Floodplains Extend the Distribution of Terrestrial Bird Species', *Ecosystems*, 20(4), pp. 745-756.
148. Horner GJ, Cunningham SC, Thomson JR, Baker PJ, MacNally R 2016, 'Recruitment of a keystone tree species must concurrently manage flooding and browsing', *Journal of Applied Ecology*, 53, pp. 944–952.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:14 Community awareness of climate risks and associated responsibilities Data custodian Sustainability Victoria	Good (for awareness of climate risks and mitigation) and Unknown (for adaptation to climate change)	?	DATA QUALITY Fair

Victorians' knowledge and awareness of climate change and its associated risks is an important marker of the state's successful climate change adaptation and mitigation. Public engagement and participation are crucial to create change to address global problems such as climate change.[149] This indicator also describes current actions of Victorians to reduce the effects of climate change.

Sustainability Victoria commissioned a social research study, conducted over 2016 and 2017, that aimed to gain baseline data on Victorian residents' attitudes, beliefs and behaviours in relation to climate change.[150] The results of this study have been used to inform the assessment of this indicator.

The study suggested most Victorians accept that climate change is influenced by human activities. More than 90% of those surveyed agreed there is some level of human causation. The other respondents believed that either climate change is due entirely to natural processes or there has been no climate change.

Nearly 80% of respondents were concerned about climate change. Their main areas of concern were:

- water shortage and drought (72% of respondents were concerned about this)
- crop failures (71%)
- severe bushfires (68%)
- air pollution (68%)
- heatwaves (67%)
- severe storms and floods (65%)
- coastal erosion (51%).

Most respondents (78%) supported the Victorian Government's target of net zero GHG emissions by 2050. Even more (84%) supported the associated targets of 25% of power to be generated by renewable energy sources by 2020 and 40% by 2025.

The survey results also point to the opportunity and incentive for businesses to act on climate change, with nearly three-quarters of respondents preferring to buy goods and services from businesses that show they care about climate change.

149. Weaver C et al 2014, 'From global change science to action with social sciences', *Nature Climate Change*, 4, pp. 656-659.
150. Sustainability Victoria 2017, *'Victorians' perceptions of climate change'*, Melbourne, Victoria http://www.sustainability.vic.gov.au/-/media/SV/Publications/About-Us/Research/Victorians-perceptions-of-climate-change/Victorians-Perceptions-of-Climate-Change.pdf Accessed 4 December 2018.

Management

Indicator	Status: UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies Data custodian: Resilient Melbourne, The Nature Conservancy			●		↗	DATA QUALITY Fair

Rezoning and infill development are resulting in less green space and higher population densities across major population centres in Victoria, particularly in inner and middle Melbourne. On Melbourne's fringes, new suburbs are being built on arable land and areas of remnant native vegetation. Where rain once soaked easily into permeable soils, reducing peak streamflows and the risk of flash floods, hard surfaces such as roofs and roads now dominate. These same hard surfaces, unshaded by vegetation, also absorb the sun's heat and contribute to daily inner metropolitan temperatures that can peak up to 7°C higher than those in surrounding rural areas.[151]

This urban expansion is occurring in the context of climate change, which is likely to cause greater impacts from heatwaves, droughts and extreme rainfall. While the effects of these phenomena will be widespread, they can disproportionately affect those already vulnerable, including older residents, people who are unwell, and the financially disadvantaged.

Urban forestry planning is an emerging area of research in Victoria. Of the 32 councils in metropolitan Melbourne, 13 councils have developed, or are developing, urban forestry strategies. Some regional councils, such as Geelong and Ballarat, have also developed urban forestry strategies. The need for these plans and strategies is clear: some of Melbourne's local government areas already have among the lowest urban tree canopy ratios in Australia.[152]

The development of urban forestry plans by some councils is encouraging. But work by The Nature Conservancy and Resilient Melbourne on a Melbourne Metropolitan urban forest strategy is expected to bring widespread benefits that cannot be achieved by individual councils, suburbs, infrastructure operators or neighbourhoods in isolation. The strategy is expected to be launched in 2019.

Discussion of green infrastructure was prominent throughout Infrastructure Victoria's 30-year infrastructure strategy, released in 2016.[153] Green infrastructure is described in that strategy as the network of natural and built landscape assets, including green spaces and water systems within and between settlements. The strategy noted that the delivery of green infrastructure can often be ad hoc and opportunistic. It recommended an increase in the amount and quality of green infrastructure in urban settings over the next 30 years and the production of a statewide green infrastructure plan in partnership with local government, leveraging opportunities to unlock restricted public land held by, for example, water or transport authorities.[154]

151. AM Coutts, J Beringer, S Jimi, NJ Tapper 2009, 'The Urban Heat Island in Melbourne: Drivers, Spatial and Temporal Variability, and the Vital Role of Stormwater', https://www.clearwater.asn.au/user-data/resource-files/Urban_Heat_Island_in_Melbourne2009.pdf Accessed 4 December 2018.

152. Horticulture Australia Ltd 2014, 'Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment', Sydney, New South Wales.

153. Infrastructure Victoria 2016, 'Victoria's 30-year infrastructure strategy', Melbourne, Victoria, http://www.infrastructurevictoria.com.au/sites/default/files/images/IV%2030%20Year%20Strategy%20WEB%20V2.PDF Accessed 4 December 2018.

154. Ibid

In addition to a range of amenity and biodiversity benefits, a greener Melbourne means:

- shadier, cooler metropolitan areas
- lower flood risk for people and assets
- less storm water and nutrients entering waterways, including Port Phillip Bay.

A greener environment also benefits human health. Research has shown that greener cities can reduce mortality, improve general health and wellbeing, increase physical activity and reduce violence.[155, 156]

155. Kondo MC, Fluehr JM, McKeon T, Branas CC 2018, 'Urban Green Space and Its Impact on Human Health', *International Journal of Environmental Research and Public Health*, 15(3), 445.
156. Bowen KJ, Parry M 2015, 'The evidence base for linkages between green infrastructure, public health and economic benefit', *Paper prepared for the project Assessing the Economic Value of Green Infrastructure*.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
CC:16 Considering climate change risks in land use planning (including in the coastal zone) Data custodian DELWP	Generally Poor for inland councils and Fair for coastal councils	?	DATA QUALITY Fair

This indicator is designed to report on management actions to reduce the impacts of climate change. DELWP has supplied data that categorises each Victorian council's incorporation of climate change into land-use planning decisions. The data was generated by making qualitative assessments of publicly available corporate governance documents. Figure CC.20 shows that 14% of all Victorian councils integrate climate change into land-use planning at a level considered high or advanced, while 65% of councils consider climate change at only a basic level, or not at all, during land-use planning. There is a strong pattern when comparing inland and coastal councils, with coastal councils three times more likely to have an intermediate, high or advanced consideration of climate change in land-use planning than inland councils (Figure CC.20).

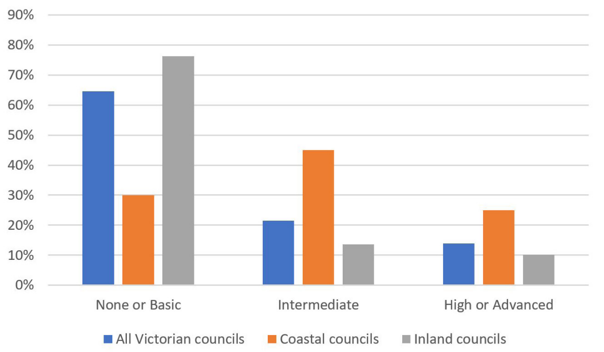

Figure CC.20 Percentage of Victorian councils that integrate climate change into land-use planning

Note: Results are shown by council type (coastal or inland) and level of integration (none or basic, intermediate, high or advanced).

(Data source: DELWP, 2018)

Further information on the integration of climate change into land-use planning was generated as part of DELWP's engagement with local governments during the development of the *Victorian Climate Change Adaptation Plan 2017–2020*.[157]

There is strong agreement across local councils, particularly coastal councils, that land-use planning needs to be informed by up-to-date climate science. As part of this feedback provided by councils, DELWP commissioned a Victorian Coastal Hazard Assessment that analysed the likely impacts of anticipated climate change on the Victorian coastline.[158] The assessment provided ratings for vulnerability to coastal erosion, sea-level rise and storm surge across Victorian coastal areas and coastal priority assets.

Council planners have also expressed strong support for regulatory change to allow for better consideration of climate change impacts in land-use planning.[159] Despite the absence of quantitative data, this support suggests that councils are already aware of the importance of climate change considerations in land-use planning.

The links between climate change and land-use planning extend to the alpine regions. As discussed in indicator CC:02 (Snow cover), a decline in snow accumulation has been observed at several locations across the Victorian Alps, with further reductions expected this century. The alpine resort community is already adapting to the changing landscape, with more focus on year-round activities to ensure long-term business viability. These activities include the development of mountain-biking and walking trails. There have also been developments of other sustainable operations including water recycling and treatment systems, waste recovery processes, renewable energy systems and programs to protect the sensitive alpine ecosystems.

157. Department of Environment, Land, Water and Planning 2016, 'Local Government Engagement on Victoria's Climate Change Adaptation Plan 2017 – 2020', Melbourne, Victoria, https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0015/73050/2017-Local-Government-Input-in-Adaptation-Plan_final.pdf.

158. Spatial Vision 2017, 'Victorian Coastal Hazard Assessment 2017', https://www.coastsandmarine.vic.gov.au/__data/assets/pdf_file/0021/122709/VCHA2017_R1_Victorian_Coastal_Hazard_Assessment_2017_Final_R1.compressed.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:17 Percentage of agri-businesses using long-term weather and climate change projections Data custodian DEDJTR						DATA QUALITY Fair

This indicator aims to provide a measure of agricultural management actions to adapt to a changing climate.

Victoria has a large agricultural sector, valued at more than $13 billion. There are almost 31,000 farm businesses employing about 80,000 people and operating across more than 12 million hectares of farmland.[160] The agricultural industry is sensitive to changes in climate: Victorian agriculture yields are generally forecast to decline in coming years in the absence of climate change adaptation measures.[161]

Understanding climate variability can assist growers to take financial advantage of better-than-average years and manage risk in drier years. Since 2005, Agriculture Victoria has published a newsletter explaining climate conditions to primary producers. The newsletter, distributed to more than 3,000 subscribers, helps farmers to make better use of seasonal climate forecasts. As of 2018, Agriculture Victoria is also providing seasonal climate updates for Victoria on YouTube.[162]

The number of subscribers to the newsletter has increased nearly fivefold during the past decade, indicating the value of the information provided in the newsletter. DEDJTR conducts periodic surveys of the newsletter readers, and the last survey in 2016 found that more than half of subscribers share the newsletter with others, which increases its reach and value. More than 90% of respondents also ‘strongly agreed’ or ‘somewhat agreed’ that the newsletter improved their ability to make decisions to manage seasonal risk, and improved their knowledge and understanding of seasonal climate variability. The main management decisions made due to information provided in the newsletter included changing sowing plans and crop types, changing nitrogen and urea application, and changing stocking numbers.

These results should be interpreted with caution: businesses subscribing to the newsletter and participating in the survey may be more proactive than others in the agricultural sector. Nonetheless, the survey results are a sign of the sector’s increasing ‘climate literacy’ and decisiveness in relation to climate change. In the future, the newsletter survey could be supplemented by a broader study to provide a more holistic understanding of how Victorian agricultural businesses are adapting to climate change.

159. DELWP 2016, ‘Local Government Engagement on Victoria’s Climate Change Adaptation Plan 2017 – 2020’, East Melbourne, Victoria https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0015/73050/2017-Local-Government-Input-in-Adaptation-Plan_final.pdf Accessed 4 December 2018.
160. DEDJTR 2017, ‘Agriculture Victoria Strategy’, Melbourne, Victoria http://agriculture.vic.gov.au/__data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 4 December 2018.
161. Victorian Department of Environment and Primary Industries 2013, ‘Climate Change Adaptation in Agriculture: Technical Report’.
162. DEDJTR, ‘The Very Fast Break’, https://www.youtube.com/channel/UClDCIlI7gRZhUs03opGqH1g Accessed 4 December 2018.

Future Focus

Improve localised climate projections

Localised climate projections at a finer spatial resolution, and more accurate rainfall projections, are required to improve management outcomes. Greater detail in climate projections can improve the proactive planning for many natural assets and sectors, including agriculture, with rainfall projections a particularly valuable tool for long-term policy development. An excellent example of this is the runoff projections that have been produced at river-basin level in indicator WR:02 (Projected runoff to dams and catchments). Rainfall projections are currently associated with reasonably large uncertainties (relative to other climate variables such as temperature) and reducing these uncertainties would enhance environmental management, planning and outcomes.

Recommendation 2: That DELWP, in coordination with research partners, conduct further analysis to improve localised climate projections (particularly in agricultural regions). These projections would aim to reduce the uncertainties associated with rainfall projections as a minimum.

Note: refer to Recommendation 15: Monitoring and reporting on the targets for Victoria's energy transition regarding obligations under the *Climate Change Act 2017.*