Technical information supporting the 2023 Projected temperature environmental trend and condition report card

Department for Environment and Water
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Acknowledgement of Country

We acknowledge and respect the Traditional Custodians whose ancestral lands we live and work upon and we pay our respects to their Elders past and present. We acknowledge and respect their deep spiritual connection and the relationship that Aboriginal and Torres Strait Islanders people have to Country. We also pay our respects to the cultural authority of Aboriginal and Torres Strait Islander people and their nations in South Australia, as well as those across Australia.

Acknowledgements

This document was prepared by Graham Green (DEW) and Susan Sweeney (DEW) and technically reviewed by Darren Ray (DEW). Improvements were made to this report and associated report card based on reviews by Amy Ide (DEW), Jennie Fluin (DEW) and Fi Taylor (DEW).

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Summary

The 2023 release of South Australia's environmental trend and condition report cards summarises our understanding of the current condition of the South Australian environment, and how it is changing over time.

This document describes the indicators, information sources, analysis methods and results used to develop this report and the associated 2023 Projected temperature report card. The reliability of information sources used in the report card is also described.

The Projected temperature report card sits within the report card Climate theme. Report cards are published by the Department for Environment and Water and can be accessed at www.environment.sa.gov.au.

1 Introduction

1.1 Environmental trend and condition reporting in SA

The Minister for Climate, Environment and Water under the *Landscape South Australia Act 2019* is required to 'monitor, evaluate and audit the state and condition of the State's natural resources, coasts and seas; and to report on the state and condition of the State's natural resources, coasts and seas' (9(1(a-b)). Environmental trend and condition report cards are produced as the primary means for the Minister to undertake this reporting. Trend and condition report cards are also a key input into the State of the Environment Report for South Australia, which must be prepared under the *Environment Protection Act 1993*. This Act states that the State of the Environment Report must:

- include an assessment of the condition of the major environmental resources of South Australia (112(3(a))), and
- include a specific assessment of the state of the River Murray, especially taking into account the Objectives for a Healthy River Murray under the *River Murray Act 2003* (112(3(ab))), and
- identify significant trends in environmental quality based on an analysis of indicators of environmental quality (112(3(b))).

1.2 Purpose and benefits of SA's trend and condition report cards

South Australia's environmental trend and condition report cards focus on the state's priority environmental assets and the pressures that impact on these assets. The report cards present information on trend, condition, and information reliability in a succinct visual summary.

The full suite of report cards captures patterns in trend and condition, generally at a state scale, and gives insight to changes in a particular asset over time. They also highlight gaps in our knowledge on priority assets that prevent us from assessing trend and condition and might impede our ability to make evidence-based decisions.

Although both trend and condition are considered important, the report cards give particular emphasis to trend. Trend shows how the environment has responded to past drivers, decisions, and actions, and is what we seek to influence through future decisions and actions.

The benefits of trend and condition report cards include to:

- provide insight into our environment by tracking its change over time
- interpret complex information in a simple and accessible format
- provide a transparent and open evidence base for decision-making
- provide consistent messages on the trend and condition of the environment in South Australia
- highlight critical knowledge gaps in our understanding of South Australia's environment
- support alignment of environmental reporting, ensuring we 'do once, use many times'.

Environmental trend and condition report cards are designed to align with and inform state of the environment reporting at both the South Australian and national level. The format, design and accessibly of the report cards has been reviewed and improved with each release.

1.3 Climate change in Australia

Climate affects almost every part of our lives. Communities, industries, landscapes and ecosystems all develop with a tolerance for a range of climate variation. If the climate changes beyond that range of tolerance, then they must either adapt, migrate, transform or decline.

According to the Australian Academy of Science (2015), "Earth's climate has changed over the past century. The atmosphere and oceans have warmed, sea levels have risen, and glaciers and ice sheets have decreased in size. The best available evidence indicates that greenhouse gas emissions from human activities are the main cause. Continuing increases in greenhouse gases will produce further warming and other changes in Earth's physical environment and ecosystems."

The Bureau of Meteorology (the Bureau) and other science agencies employ a range of air, land and marine sensors to track climatic trends across Australia. The Bureau's Australian Climate Observations Reference Network – Surface Air Temperature dataset is based on a network of over 100 stations (Bureau of Meteorology 2023).

Climate change projections, including temperature projections, are periodically improved and updated in line with advancements in climate modelling, and produced for, and incorporated into, international and Australian climate change assessment and reporting, such as the Intergovernmental Panel on Climate Change (IPCC) reports.

1.4 Projected temperature

The Climate: Projected temperature report card examines decadal timescale temperature outlooks in South Australia under future climate scenarios, according to the Government of South Australia's downscaled climate change projections for South Australia (DEW 2023). The projections were developed by the using the data products of the New South Wales and Australian Regional Climate Modelling project (NARCliM 1.5), conducted as a partnership between the state governments of New South Wales, South Australia and Western Australia, the Australian Capital Territory and the University of New South Wales.

The report card provides textual comments on the trends in projected future temperature, and two graphs. The first graph shows the projected trend in average annual maximum temperature, averaged across the projections of the six NARCliM 1.5 climate model combinations for each of nine South Australian landscape regions: Alinytjara Wilurara, South Australian Arid Lands, Eyre Peninsula, Northern and Yorke, Kangaroo Island, Murraylands and Riverland, Green Adelaide, Hills and Fleurieu, and Limestone Coast. The second is a graph of recent observed and projected future extreme temperatures for Adelaide.

2 Methods

2.1 Indicator

The indicator used for the Projected temperature report card is the projected future change in average annual temperature in the nine landscape regions of South Australia. The projections are derived from the modlling processes described in Section 2.2.

2.2 Data sources, collection and analysis

The NARCliM 1.5 climate projection downscaling project provides climate simulations for 1951 to 2100 on daily and monthly timesteps from six global/regional model combinations and two emissions scenarios. The base dataset is compiled in grid form (netcdf format data files) at grid resolutions of 10 km and 50 km. The part of South Australia to the west of a north-south line passing approximately through Ceduna has simulations of only 50 km resolution. To the east of this line both 10 km and 50 km resolutions are available.

Projections of temperature are included from two Representative Concentration Pathways (RCPs): RCP 4.5 and RCP 8.5, which respectively represent medium and high future greenhouse gas emissions scenarios used in the modelling. These are two of a range of four RCPs, greenhouse gas concentration trajectories adopted by the IPCC for its fifth Assessment Report (AR5) (IPCC Working Group 1 2013).

It should be noted that the time horizon years – 2030, 2050, 2070 and 2090 – are not representing the exact years by which temperature is projected to change by these amounts. Rather, they are marker years, each for a 20-year period spanning the marker year. For example, the temperature change projection for the 2050 time horizon represents the difference in the model projection average annual maximum temperature averaged across the period 2040 to 2059, compared with the model projection average annual maximum temperature averaged across the historic baseline period of 1986 to 2005.

2.2.1 Projected changes in regional average daily maximum temperatures

The first of the two graphs presents projected changes in the average annual maximum temperature (°C) in the nine landscape regions of South Australia centred on the years 2030, 2050, 2070 and 2090, as shown in Figure 2.1. This was prepared using data from the Government of South Australia's downscaled climate change projections (DEW 2023). At each grid point, at each timestep, the trend in annual maximum temperature relative to the 1986 to 2005 period was calculated for each of the six available model combinations. The average trend of all six was then calculated for each grid point. Then, for each landscape region, the mean was taken of the value of all grid points in that region, to reach the final value.

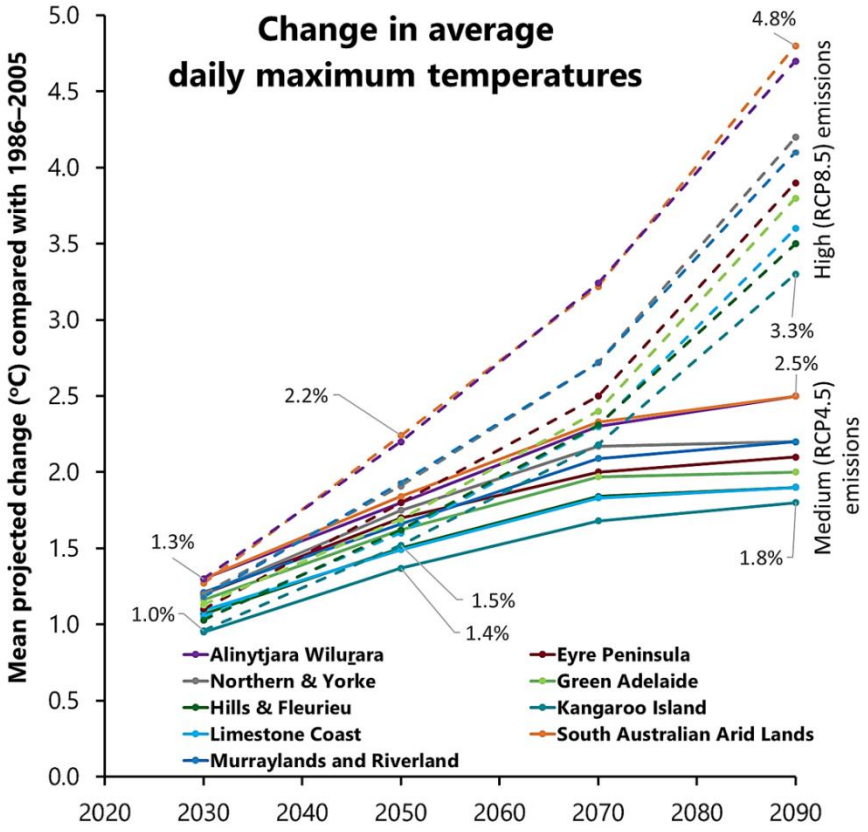


Figure 2.1. Projected temperature report card 'top figure' – projected changes in average annual temperature in South Australian landscape regions

The projected temperature change graph (Figure 2.1) shows the average result of the projections of the six combinations of global and regional climate models for each landscape region, for both medium (RCP4.5) and high (RCP8.5) greenhouse gas emissions scenarios. There is considerable variability among the six model combinations in their projections of temperature change for each region.

The ranges of temperature change described in the text of the report card are simply the range between the highest and lowest mean projected temperature change from the six available downscaled projections, under the medium (RCP 4.5) and high (RCP 8.5) greenhouse gas emissions scenarios in the nine landscape regions.

2.2.2 Change in frequency of days over 40°C in Adelaide

The bottom figure in the Projected temperature report card (Figure 2.2) shows a graph of the average projected frequency of occurrence of days with a maximum of 40°C or more in Adelaide in the period 2020 to 2039 derived from six downscaled NARCLiM1.5 projections, compared with the observed frequency of those days during the 1986 to 2005 baseline period, as derived from the Bureau's ACORN-SAT surface air temperature records for Adelaide (Bureau of Meteorology 2023): http://www.bom.gov.au/climate/data/acorn-sat/#tabs=Data-and-networks.

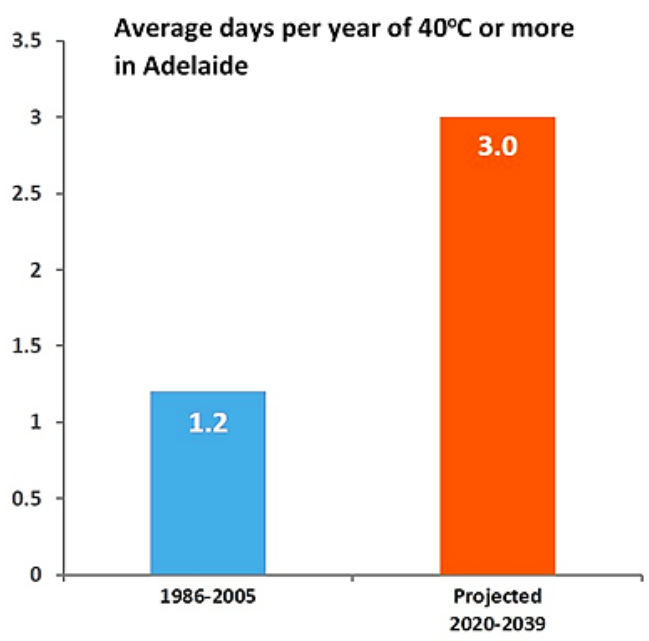


Figure 2.2. Projected temperature report card ' bottom figure' – the projected change in average annual occurrence of days with a maximum temperature of 40°C or more in Adelaide

The data in Figure 2.2. Projected temperature report card ' bottom figure' – the projected change in average annual occurrence of days with a maximum temperature of 40°C or more in Adelaide

are derived from two sources:

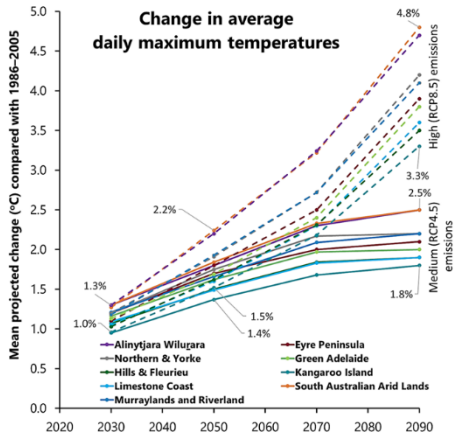
i. The frequency of days of 40°C or more (1986–2005) in the first column is derived from a simple count of the number of days with a daily maximum temperature of 40.0 °C or greater over July to June, in the 20-year period from 1 January 1986 to 31 December 2005 within the historic observation record, drawn from the ACORN-SAT dataset for the Adelaide Bureau of Meteorology station.

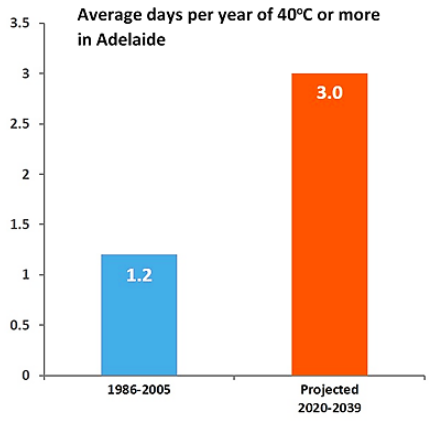
ii. The projected frequency of days of 40°C or more (2020–2039) in the second column was calculated from the average annual number of days with a daily maximum temperature of 40°C or greater at the closest gridpoint to central Adelaide in the NARCliM 1.5 model domain, averaged across the years 2020–2039, derived from the average of the six NARCliM 1.5 global/regional model combinations, as described in Section 2.2.1.

The content of the Projected temperature report card includes a combination of elements of textual information, graphical figures, trand and condition ratings, and summary statements about the projected future temperature in South Australia. The information sources and analyses applied to derive each element of the report card content are summarised in Table 2.1. The method of selection of the trend, condition and information reliability ratings is described in Section 2.3.

Table 2.1. Summary of information sources and analysis

Report card element	Content	Data sources
Trend quote	Average daily maximum temperatures across South Australia are projected to increase by between 1.4 and 2.2 degrees celsius (°C) by 2050 under plausible emissions scenarios.	The range of projected temperature change identified here (1.4 to 2.2 °C) is simply the highest and lowest projected average annual maximum temperature change among the nine landscape regions included in the projected annual temperature graph (top figure) at the time horizon of 2050. The temperature changes illustrated by the graph are drawn from the Government of South Australia's downscaled climate change projections (DEW 2023, www.environment.sa.gov.au/topics/climate-change/climate-science-knowledge-resources).
Trend text	Two scenarios of global atmospheric greenhouse gas concentrations are shown, representing medium (RCP4.5) and high (RCP8.5) emissions (top figure). Under medium emissions, average maximum temperatures could increase by between 1.0°C and 1.3°C by 2030 and by between 1.4°C and 1.8°C by 2050. Changes are even greater under high emissions, with projected increases of between 1.0°C and 1.3°C by 2030 and between 1.5°C and 2.2°C by 2050. Beyond 2050, temperatures are projected to rise considerably more, particularly under a high emissions scenario. With increasing average temperatures, there is a greater occurrence of very hot weather. For example, for Adelaide, the average annual number of days reaching 40°C or more in the 20 years from 2020–2039 is projected to increase to 3 days per year, compared to 1.2 days per year during the 1986–2005 period (bottom figure).	The ranges of annual temperature change described are simply the highest and lowest projected average annual maximum temperature change among the nine landscape regions included in the projected temperature graph (top figure) at the time horizons of 2030 and 2050. The temperature changes illustrated by the graph are drawn from the Government of South Australia's downscaled climate change projections (DEW 2023, www.environment.sa.gov.au/topics/climate-change/climate-science-knowledge-resources) and their mean projections of temperature change in each landscape region at the time horizons of 2030 and 2050. The projected temperature changes are relative to the mean temperature projected by the same models for a historic baseline period of 1986 to 2005. Note, the time horizon years of 2030 and 2050 are not intended to represent the exact years by which temperature is projected to change by these percentages. Rather, they are marker years, each for a twenty year period spanning the marker year. For example, the temperature change projection for the 2050 time horizon represents the difference in the mean temperature in the period 2020–2039, compared with the historic baseline period of 1986–2005. The comment on the projected average frequency of days over 40°C in the period 2020–2039 compared with the baseline period (1986–2005) is a description of the quantities illustrated in the graph in the bottom figure of the report card.
Condition quote	A condition rating is not applicable as this is an assessment of projected temperatures under likely climate scenarios.	The report card condition rating is intended to report on the current status of the reported variable. As the Projected Temperature report card reports only on projected future temperature change, it does not provide an assessment of the current condition of temperature.

Report card element	Content	Data sources
Condition text	This assessment draws from rainfall projections presented in the Government of South Australia's Guide to Climate Projections for Risk Assessment and Planning. Each of the graphed projections is the average of 6 projections from a combination of 3 global climate models with 2 regional climate models. The projected changes are relative to temperature during a baseline period spanning 1986–2005 and are in addition to the approximately 0.7°C of warming that occurred between the pre-industrial baseline period of 1850–1900 and recent baseline period of 1986–2005.	As this report card does not report on the condition of temperature, the condition text is replaced by explanatory text on the nature and source of the temperature projections.
Quote	Higher maximum temperatures and more days of 40°C or more are projected for South Australia.	This is a general statement based on both the projected increase in frequency of days with maximum temperature of 40°C or more in Adelaide, illustrated by the graph in the bottom figure, and the increases in average daily temperatures projected for all landscape regions illustrated in the top figure.
Top figure		The temperature changes illustrated by the graph are drawn from the Government of South Australia's downscaled climate change projections (DEW 2023, www.environment.sa.gov.au/topics/climate-change/climate-science-knowledge-resources) and their mean projections of temperature change in each landscape region at the time horizons of 2030, 2050, 2070 and 2090. The projected temperature changes are relative to the mean temperature projected by the same models for a historic baseline period of 1986 to 2005. Note, the time horizon years of 2030, 2050, 2070 and 2090 are not intended to represent the exact years by which temperature is projected to change by these percentages. Rather, they are marker years, each for a 20-year period spanning the marker year. For example, the temperature change projection for the 2050 time horizon represents the difference in the mean temperature in the period 2040–2059, compared with the historic baseline period of 1986–2005.
Bottom figure		The graph of the historic and projected frequency (days per year) of days of 40°C or more in Adelaide was constructed from data from two sources. The baseline period frequency of days of 40°C or more in the first column of the graph is derived from a count of the frequency of days with a daily maximum temperature of 40°C or more in the 20-year period from 1 January 1986 to 31 December 2005 within the historic observation record, drawn from the ACORN-SAT dataset for Adelaide (Bureau of Meteorology 2023). http://www.bom.gov.au/climate/change/acorn-sat/#tabs=ACORN%E2%80%90SAT

Report card element	Content	Data sources
		The projected frequency of days of 40°C or more (2020–2039) in the second column was calculated from the mean annual frequency of days of 40°C or more in 2020–2039, averaged across the six NARCliM 1.5 global/regional model combinations, as described in Section 2.2.1.
Rationale	Climate affects almost every part of our lives. Communities, industries, landscapes and ecosystems all develop with a tolerance for a range of climate variation. If the climate changes beyond that range of tolerance, then they must either adapt, migrate, transform or decline. One example of the impact of a rise in average temperatures is an increase in the occurrence of severe heatwaves. This has important implications for human health, food production and biodiversity.	This is a general comment on the rationale for providing a report on the status of projected changed in temperature in South Australia.
Drivers	According to the Australian Academy of Science, "Earth's climate has changed over the past century. The atmosphere and oceans have warmed, sea levels have risen, and glaciers and ice sheets have decreased in size. The best available evidence indicates that greenhouse gas emissions from human activities are the main cause. Continuing increases in greenhouse gases will produce further warming and other changes in Earth's physical environment and ecosystems."	This statement from the Australian Academy of Science was selected to describe this pressure as it encapsulates a statement of the primary cause of warming, the effects on the Earth's physical environment in the past and future. The statement is drawn from Australian Academy of Science (2015) www.science.org.au/climatechange
What is being done?	Climate change projections, including temperature projections, are periodically improved and updated in line with advancements in climate modelling. Actions in response to the changing climate include those that mitigate South Australia's emissions as part of a global effort to stem further change in the global climate. The Government of South Australia has statewide goals to reduce net greenhouse gas emissions by more than 50% by 2030, achieve net zero emissions by 2050, and achieve 100% renewable energy generation by 2030.	Information on current and future developments in climate change projections modelling and advancements in the science are presented in the Climate Projections Roadmap for Australia Information on the South Australian Government's emissions reduction goals are drawn from DEW's Climate Change web page: Government action on climate change

2.3 Methods to assign trend, condition and reliablity

2.3.1 Trend

Table 2.2. Definition of trend classes used

Trend	Description
Getting better	Over a scale relevant to tracking change in the indicator it is improving in status with good confidence
Stable	Over a scale relevant to tracking change in the indicator it is neither improving nor declining in status
Getting worse	Over a scale relevant to tracking change in the indicator it is declining in status with good confidence
Unknown	Data are not available, or are not available at relevant temporal scales, to determine any trend in the status of this resource
Not applicable	This indicator of the natural resource does not lend itself to being classified into one of the above trend classes

2.3.2 Condition

Table 2.3. Definition of condition classes used

Condition	Description
Very good	The natural resource is in a state that meets all environmental, economic and social expectations, based on this indicator. Thus, desirable function can be expected for all processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)
Good	The natural resource is in a state that meets most environmental, economic and social expectations, based on this indicator. Thus, desirable function can be expected for only some processes/services expected of this resource, now and into the future, even during times of stress (e.g. prolonged drought)
Fair	The natural resource is in a state that does not meet some environmental, economic and social expectations, based on this indicator. Thus, desirable function cannot be expected from many processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)
Poor	The natural resource is in a state that does not meet most environmental, economic and social expectations, based on this indicator. Thus, desirable function cannot be expected from most processes/services expected of this resource, now and into the future, particularly during times of stress (e.g. prolonged drought)
Unknown	Data are not available to determine the state of this natural resource, based on this indicator
Not applicable	This indicator of the natural resource does not lend itself to being classified into one of the above condition classes

2.3.3 Reliability

Information is scored for reliability based on the minimum of subjective scores (1 [worst] to 5 [best]) given for information currency, applicability, level of spatial representation and accuracy. Definitions guiding the application of these scores are provided in Table 2.4 for currency, Table 2.5 for applicability, Table 2.6 for spatial representation and Table 2.7 for accuracy.

Table 2.4. Guides for applying information currency

Currency score	Criteria
1	Most recent information >10 years old
2	Most recent information up to 10 years old
3	Most recent information up to 7 years old
4	Most recent information up to 5 years old
5	Most recent information up to 3 years old

Table 2.5. Guides for applying information applicability

Applicability score	Criteria
1	Data are based on expert opinion of the measure
2	All data based on indirect indicators of the measure
3	Most data based on indirect indicators of the measure
4	Most data based on direct indicators of the measure
5	All data based on direct indicators of the measure

Table 2.6. Guides for applying spatial representation of information (sampling design)

Spatial score	Criteria
1	From an area that represents less than 5% the spatial distribution of the asset within the region/state or spatial representation unknown
2	From an area that represents less than 25% the spatial distribution of the asset within the region/state
3	From an area that represents less than half the spatial distribution of the asset within the region/state
4	From across the whole region/state (or whole distribution of asset within the region/state) using a sampling design that is not stratified
5	From across the whole region/state (or whole distribution of asset within the region/state) using a stratified sampling design

Table 2.7. Guides for applying accuracy information

Reliability	Criteria
1	Better than could be expected by chance
2	> 60% better than could be expected by chance
3	> 70 % better than could be expected by chance
4	> 80 % better than could be expected by chance
5	> 90 % better than could be expected by chance

2.4 Data transparency

Data transparency for this report card is represented in Appendix A.

3 Results

3.1 Trend

The trend rating for projected temperature was determined to be 'Getting worse' as the projected changes for all the nine landscape regions reported on are for a rise in temperatures in the future. A rise in temperature is assessed to be a trend that is 'getting worse' due to the increased risks of extreme heat events, higher water demand affecting water security and potential impacts to agriculture and ecosystems that may result from higher average temperatures, particularly in regions that already have a warm and arid or semi-arid climate.

3.2 Condition

As this assessment is of projected temperature under future climate scenarios, a condition rating is not considered to be applicable.

3.3 Reliability

The overall reliability score for this report card is 3 out of 5, based on the minimum score for the reliability rating criteria (Table 3.1). Based on definitions in Section 2.3.3, this translates to an overall reliability rating of 'Good'.

Table 3.1. Information reliability scores for projected temperature

Indicator	Applicability	Currency	Spatial	Accuracy	Reliability
Projected average daily temperature	3	5	4	N/A	3

3.3.1 Notes on reliability

The NARCliM temperature projections datasets are less than 3 years old. A currency score of 5 is assigned to these data.

The projected changes in temperature are determined from a combination of large scale modelling of climate systems and statistical modelling of historic weather at a location. The projections of future temperature change that result from these modelling processes are mostly based on indirect indicators of the measure of future temperature. An information applicability score of 3 is determined for these data.

The projected changes in temperature are determined from a combination of large scale modelling of climate systems and regional scale dynamic models that take account of landscape and topographic features covering the whole of South Australia as well as large scale climate systems that are representative of areas covering more than the whole state. A spatial representation score of 4 is determined for the future temperature projections.

As the projected changes in temperature are modelled projections of future changes in temperature under scenarios of future greenhouse gas concentrations, the accuracy of the data cannot be compared against measurement. As a result, the accuracy assessment of the projections is considered to be not applicable (N/A).

4 Discussion

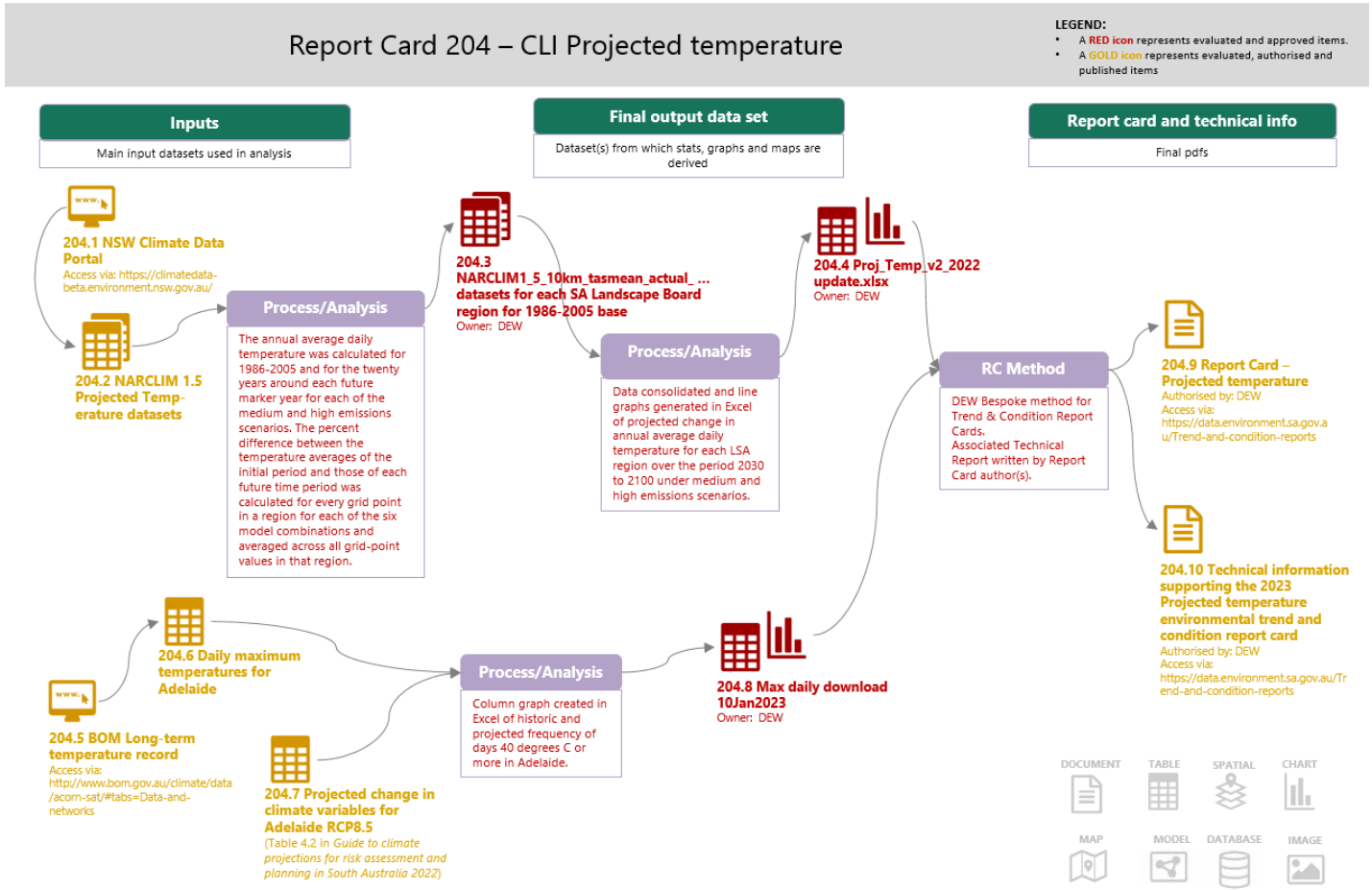
4.1 Trend

The trend rating for projected temperature was determined to be 'Getting worse' as the projected changes for all the nine landscape regions reported on are for an increase in temperature in the future.

4.2 Condition

As this assessment is of projected temperature under future climate scenarios, a condition rating is not considered to be applicable.

5 Appendix A: Managing environmental knowledge chart for Projected temperature



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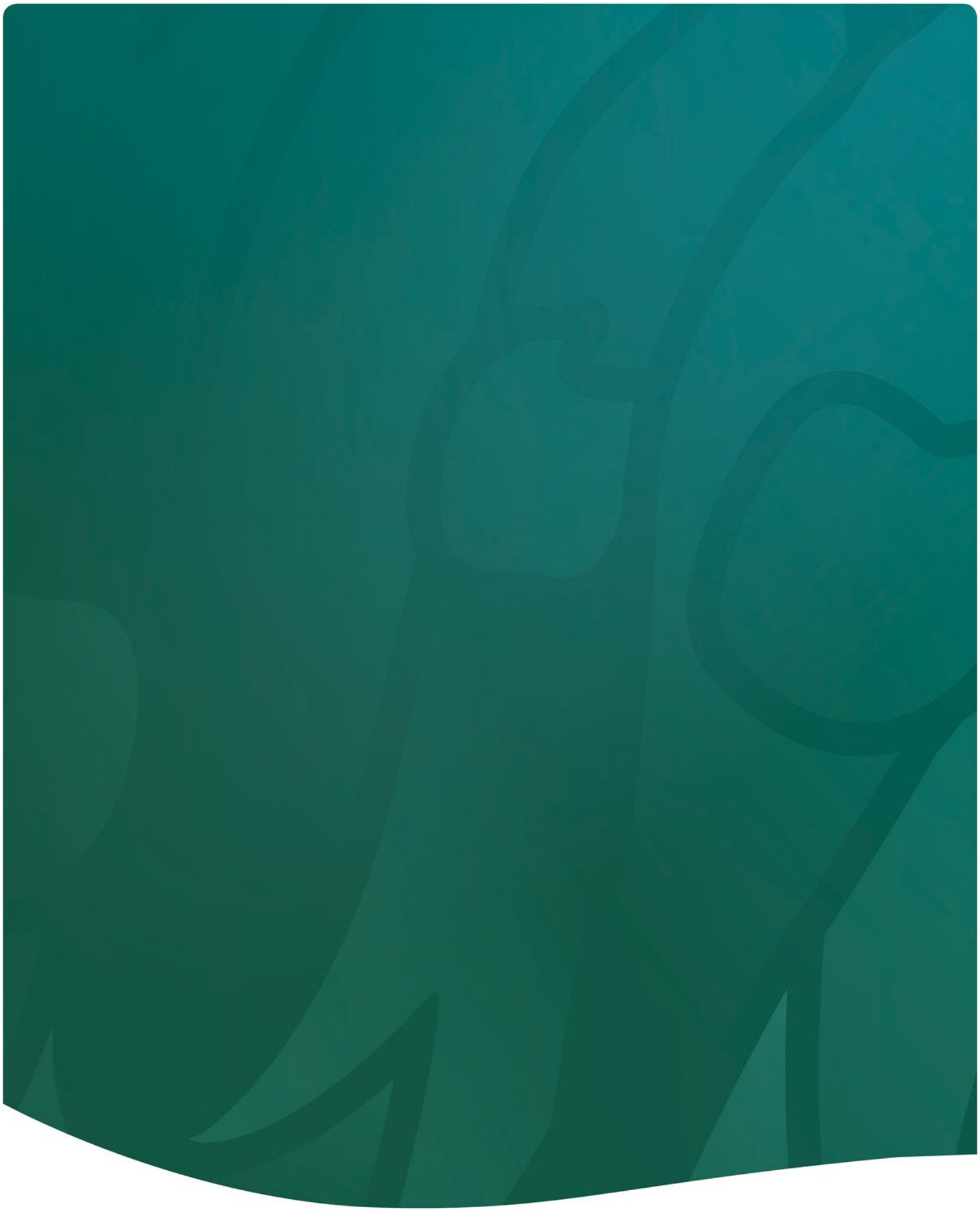

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