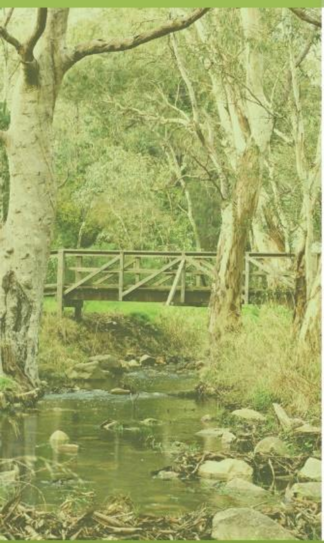
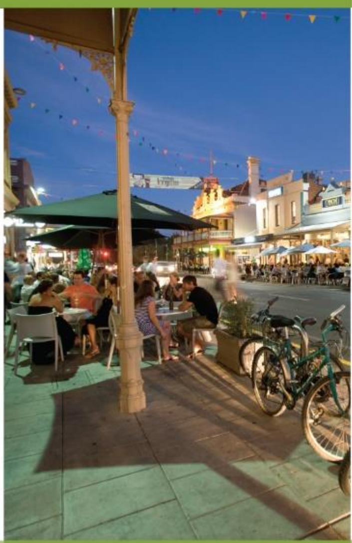
Resilient **East**

Climate Projections Report





URPS

Climate Projections for the Eastern Adelaide Region

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Contents

1 Summary of key points

- While there is natural variability in the climate of the Eastern Adelaide region, climate change will create a different future climate with warmer and drier conditions.
- Climate change planning uses climate projection data to assist with undertaking risk and vulnerability assessments and to assist with selecting adaptation options.
- The Project Steering Group for the Resilient East project has chosen to use projections for the Integrated Vulnerability Assessment based on median climate model outputs to 2050 under a high (emission) concentration pathway.
- Maximum temperatures are projected to increase from baseline conditions by 1.6ºC by 2050 and 2.3ºC by 2070 under the high concentration pathway, while extreme heat could increase from 20 days per year over 35 ºC to 47 days per year by 2090 under the high concentration pathway.
- Rainfall is projected to decline by 7.4% and 11% compared with baseline conditions by 2050 and 2070, respectively, under the high concentration pathway.
- Fire risk and extreme rainfall events are projected to increase in intensity in the coming century.

2 Introduction

2.1 Resilient East overview

Resilient East is a partner project between the Cities of Tea Tree Gully, Campbelltown, Burnside, Unley, Norwood Payneham & St Peters, Prospect, the Town of Walkerville and Adelaide City Council, and the stakeholders and communities that live and work in the Eastern region.

Resilient East is being delivered through three main project phases:

- Preparing the evidence base - Identifying regional values and key decisions with potential to be impacted by climate change, and gathering information to better understand these values, decisions and impacts;
- Undertaking the Integrated Vulnerability Assessment (IVA) – Assessing the exposure, sensitivity, and adaptive capacity of the region to understand vulnerabilities in the face of climate change; and
- Preparing the Adaptation Plan – Identifying priority areas of focus and adaptation options and developing adaptation pathway maps.

2.2 Purpose of this report

Stage 2 of the Resilient East project involves undertaking an Integrated Vulnerability Assessment (IVA) to identify areas which are vulnerable to the impacts of climate change. A key input to the IVA is the set of climate variables which are used in the assessment process.

Climate variables describe various aspects of the future climate such as:

- Maximum and minimum temperature;
- Extreme heat;
- Quantity and seasonality of rainfall;
- Intensity of extreme rainfall events; and
- Frequency and intensity of extreme fire danger days.

Climate projection data is also used to inform identification of adaptation options and development of adaptation pathways which are key elements of the final Adaptation Plan.

This report has been prepared as an input to the IVA process and describes the drivers of climate change, sources of variation in climate projections and what climate the region may experience in the future.

3 Explaining climate change projection data

3.1 The Eastern Region

The Eastern Adelaide Region occupies the eastern to north-eastern flank of the Adelaide Plains in South Australia. The Region has a Mediterranean climate and as such experiences natural variability in weather during the year, characterised by hot dry summers and cold wet winters.

Climate patterns vary year to year as well with major climate influences including the[1]::

- Indian Ocean Dipole (IOD), which affects the climate of Australia and other countries that surround the Indian Ocean Basin, and is a significant contributor to rainfall variability; and
- El Niño Southern Oscillation (ENSO), the oscillation between El Niño and La Niña conditions which affects rainfall and temperature in eastern Australia.

The result of these and other climate influences are major variations in rainfall and temperature, especially drought cycles. For example during the period 2006-2010, The Eastern Adelaide region was affected by below average rainfall both locally and in upper River Murray catchments (which generate a significant amount of the water supply for Metropolitan Adelaide), which resulted in major water restrictions for metropolitan Adelaide.

In addition to this natural variability in climate, there are longer term changes in rainfall, temperature and other variables occurring as a result of climate change.

3.2 What is climate change

Climate change is a consequence of the release of greenhouse gases like carbon dioxide, methane and nitrous oxide into the Earth's atmosphere. These gases are produced from a range of natural sources as well as from human activities like energy production, transport, industrial processing, waste management, agriculture and land management. Greenhouse gases trap the sun's energy in the Earth's atmosphere leading to changes in the global climate.

The most authoritative source of information on climate change is the Intergovernmental Panel on Climate Change (IPCC). Every 5-6 years the IPCC produces an Assessment Report which presents the most up to date view of the current state of scientific knowledge relevant to climate change. Climate change modelling results contained in these reports are used across the world for climate change adaptation planning.

[1] http://www.bom.gov.au/climate/enso/history/ln-2010-12/IOD-what.shtml. Accessed 27 October 2014.

The most recent report, Assessment Report 5 (AR5) was released in September 2013. Two major climate change projections projects contain information relevant to the Eastern Adelaide region which draw on the suite of climate models used for AR5.

The Goyder Institute's "Agreed downscaled climate projections for South Australia" project, called SA Climate Ready, provides regional scale summary data for rainfall, temperature, solar radiation, vapour pressure deficit and areal evapotranspiration[2]. SA Climate Ready provides detailed weather station downscaled data along with regional scale trends for NRM regions.

The CSIRO and Bureau of Meteorology project "Climate Change in Australia: Projections for Australia's NRM regions" (CCIA) provides projected climate change data for the following variables at various temporal and spatial scales: temperature, rainfall, relative humidity, point potential evapotranspiration, wet areal evapotranspiration, wind-speed, solar radiation, wind speed and fire weather days, mean and extreme sea-level rise, sea surface temperature, sea surface salinity and ocean acidification. At the time of preparing this report only cluster and sub-cluster scale (multiple NRM regions combined) summary data was available for this project, with more detailed data available in March 2015. The Eastern Adelaide region is part of the Southern and South Western Flatlands East sub-cluster, which covers the Eyre Peninsula, Northern and Yorke, Adelaide and Mount Lofty Ranges and Kangaroo Island NRM regions.

3.3 Sources of variations in projections

It is not possible to "predict" or "forecast" what the future climate might be. Instead, climate models use emission and land use scenarios to develop "projections" that can be used to explore what future conditions may look like.

There is variability between projections and an understanding of the reason behind the variability is needed to assist with determining how best to use climate data in adaptation planning.

Climate projections vary in two main ways as follows.

1. Global climate models (GCMs) are numerical models that explore how physical processes in the atmosphere, ocean, cryosphere and land surface respond to increasing greenhouse gas concentrations. GCMs are used to generate projections for climate variables like temperature and rainfall.

[2] Charles, S.P. and Fu G. (2014). Statistically Downscaled Projections for South Australia – Task 3 CSIRO Final Report, Goyder Institute for Water Research Technical Report Series, Adelaide, South Australia.

A large number of GCMs exist (over 40), however, only a subset are generally used to project the climate for a given location or region. For example, the SA Climate Ready project used 15 GCMs to generate climate projections and refined this to a list of the "best" six based on the ability of the GCMs to reproduce the effects of drivers such as the Indian Ocean Dipole and the El Niño Southern Oscillation.

The CCIA project provides summary information and projected change data using up to 40 GCMs. The number of models vary dependent on the climate variable and concentration pathway of interest, at the resolution of the particular host GCM (~67km to ~333km). 'Application-ready' future climate data is provided to intermediate users (after undergoing on-line training) for 8 GCMs.[3]

Variability exists across the outputs of GCMs and hence projections are often described for the median or 50th percentile model (GCM) output, sometimes described as the best estimate, or the 10th and 90th percentile output.

GCMs can also vary in terms how they represent the sensitivity of the global climate to increasing greenhouse gas emissions, with greater sensitivity resulting in a more rapid increase in temperature per unit increase in greenhouse gas concentrations[4].

2. Representative Concentration Pathways (henceforth concentration pathways), are scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover[5]. Previous IPCC reports referred to the Special Report on Emissions Scenarios (SRES) group of emission scenario descriptions and adaptation planning in Australia typically focused on low (B1), medium (A1B) and high (A1FI) SRES scenarios.

In the IPCC's recent AR5, four RCPs were selected from the published literature and are used as a basis for the climate projections presented in AR5 based modelling as follows[6]:

- RCP 2.5 "Peak and decline scenario" – An emission pathway leading to very low greenhouse gas concentration levels; a so-called "peak" scenario (radiative forcing[7] peaks at approximately 3 W m–2 before 2100 and then declines);

[3] This data will be available in March 2015
[4] Sinclair Knight Merz (SKM) (2013) *Western Adelaide Region Climate Change Adaptation Plan - Stage 1*, City of Port Adelaide Enfield
[5] IPCC, 2013: Annex III: Glossary [Planton, S. (ed.)]. 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 [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[6] Descriptions are based on http://tntcat.iiasa.ac.at:8787/RcpDb/dsd?Action=htmlpage&page=welcome
[7] Radiative forcing is the extra heat the lower atmosphere will retain as a result of additional greenhouse gases, measured in Watts per square metre (W/m^2). http://www.cawcr.gov.au/publications/otherreports/ACCSP_RCP.pdf

- RCP 4.5 “Intermediate, stabilisation scenario”: An emissions pathway where the impact of climate change on the atmosphere is stabilised before 2100 by using a range of technologies and strategies for reducing greenhouse gas emissions (radiative forcing is stabilised at approximately 4.5 W m-2 after 2100);
- RCP 6.0 “Intermediate, stabilisation scenario”: An emissions pathway where the impact of climate change on the atmosphere is stabilised after 2100 by using a range of technologies and strategies for reducing greenhouse gas emissions (radiative forcing is stabilised at approximately 6.0 W m-2 after 2100); and
- RCP 8.5 “High emissions scenario” – An emissions pathway characterized by increasing greenhouse gas emissions over time leading to high greenhouse gas concentration levels.

An overview of some of the main conclusions of AR5 are outlined in Box 1.

Another source of variability in relation to emission scenarios is the timeframe. Scenarios are often considered for 2030, 2050, 2070 or 2090 timeframes[8], with the concentration of greenhouse gases in most cases increasing through time, hence increasing the extent of, for example, warming.

[8] Projection timeframes are based on decadal averages, that is 2050 represents the average of data for the period 2040 – 2059.

Box 1. What is the evidence that the Earth's climate is changing?[9]

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading international body for the assessment of climate change. The IPCC releases an assessment of the state of scientific knowledge relevant to climate change about every 6 years. Working Group I of the IPCC released its part of the Fifth Assessment Report in September 2013 and made the following conclusions that are relevant to adaptation planning:

- Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the sea level has risen, and the concentrations of greenhouse gases have increased;
- Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 when detailed temperature records began;
- Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010;
- The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. Over the period 1901 to 2010, global mean sea level rose by 0.19 m;
- The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years;
- Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system; and
- Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

[9] Intergovernmental Panel on Climate Change (2013). Summary for Policymakers. 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 [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

4 How will climate change affect the Eastern Region?

4.1 Selecting a projection to use for the Region's Integrated Vulnerability Assessment

As described in Section 3, climate change projections can vary for a number of reasons. However, for the purpose of conducting an IVA, it is not practical or necessary to run the IVA with multiple projections.

The Project Steering Group considered the range of projections that could be used and agreed to base the IVA on data from the median model output, with a timeframe of 2050 and using the high concentration pathway. The decision of 2050 as a timeframe reflects that many of the decisions made by Council, whether planning or infrastructure based, have a timeframe of at least 30 years. The choice of the high concentration pathway was made because this is the emission trajectory on which the Earth is currently tracking (Figure 1).

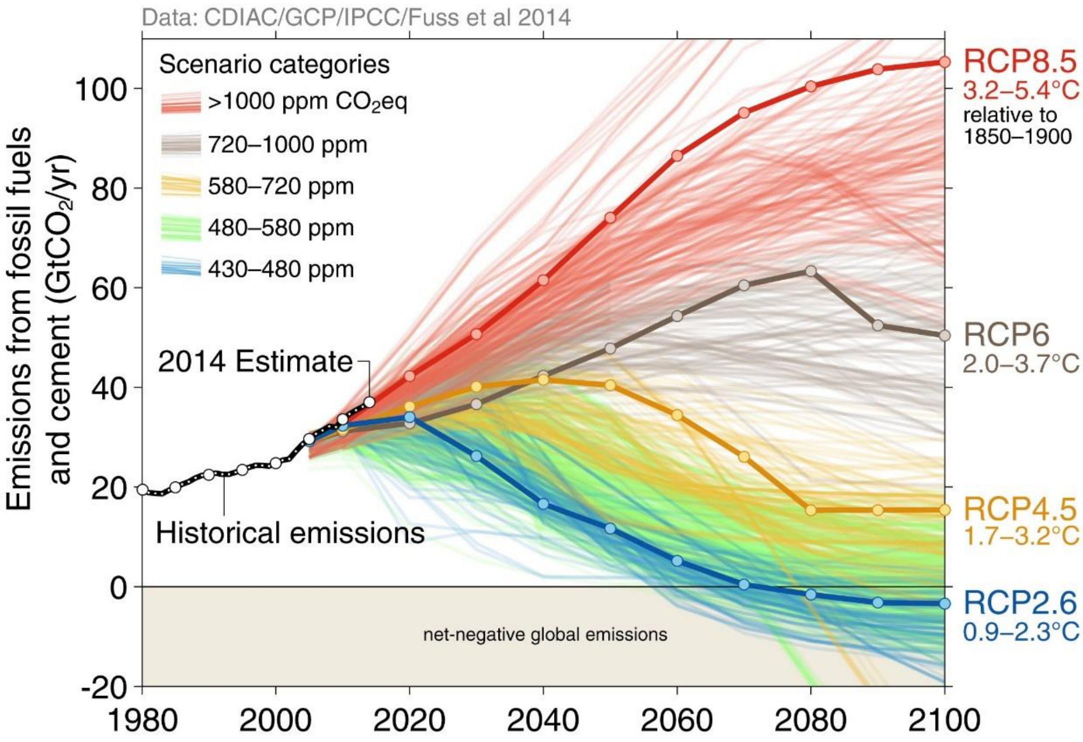

Figure 1: Emissions from fossil fuels and cement production for four RCPs. The historical emissions line is showing to be tracking along RCP8.5 (Source: Global Carbon Budget 2014[10]). The median temperature and rainfall data presented in Section 4.2 is based on the SA Climate Ready information, which is from the average change across 27 weather stations from the Adelaide Mount Lofty Ranges NRM region[11]. However, projections to 2050 are not currently available from SA Climate Ready for rainfall intensity, extreme heat and fire risk so data has been presented for 2090 based on the CCIA project and for 2070 using analyses undertaken for other projects in Metropolitan Adelaide based on IPCC Assessment Report 4 (AR4) model results. These provide a general indication of the trend in these variables for the coming century.

4.2 Climate projections for Eastern Adelaide

4.2.1 Rainfall

By 2050, the SA Climate Ready data suggests that annual median rainfall will decline by 6.8% and 7.4% compared with the baseline[12] under the intermediate and high concentration pathways, respectively (Figure 2). By 2070, the rainfall decline for the intermediate pathway is 5.7% compared with 11% for the high concentration pathway.

The seasonal differences are significant at 2050, with spring projected to experience a 21% decline in rainfall under the high concentration pathway compared with a 3.5% and 4.9% decline in autumn and winter respectively.

By 2070, the projected decline in median annual rainfall is 11% under a high concentration pathway, with reductions as high as 20.6% in spring.

4.2.2 Rainfall intensity

The CCIA project found that there is high confidence that the intensity of heavy rainfall events (maximum 1-day rainfall) will increase in the region and that this holds despite projected decreases in mean rainfall. In contrast, projections of an increase in the return frequency of maximum 1-day rainfall events has low confidence.

Other recent analysis suggests that for each degree of global warming, extreme daily rainfall may increase by 7%[13]. If this was to apply in the Eastern Adelaide region, increasing

[10] Global Carbon Project (2014). Global Carbon Budget 2014. http://www.globalcarbonproject.org/carbonbudget/index.htm. Accessed: 3 February 2015.
[11] A list of weather stations for the AMLR NRM region is contained in the SA Climate Ready User Guide, available on https://data.environment.sa.gov.au/Climate/Pages/Home.aspx.
[12] The baseline period for the SA Climate Ready data is 1986-2005.
[13] Westra, S., Alexander, L. V., & Zwiers, F. W. (2012). Global increasing trends in annual maximum daily precipitation. Journal of Climate Change, 26, 3904-3918.

temperatures could be expected to increase rainfall intensity by nearly 7% in the Eastern Adelaide region by 2030 and at least 10% by 2050 under a high concentration pathway.

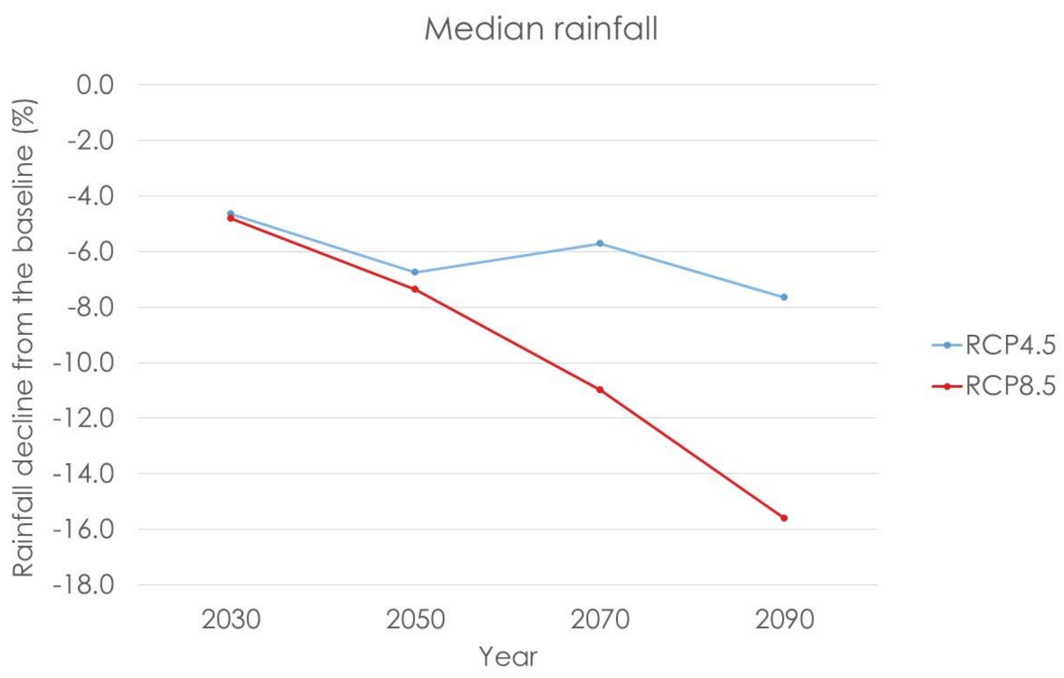

Figure 2: Projected change in median rainfall below the baseline period for 2030 to 2090 for the intermediate and high concentration pathways. Data sourced from Charles and Fu (2014).

4.2.3 Temperature

Surface air temperatures in the region have warmed since national records began in 1910, especially since 1960[14]. Since 1910–2013, mean temperature has risen by 0.7°C.

By 2050, the SA Climate Ready data suggests that annual median maximum temperature will increase compared to the baseline by 1.3ºC and 1.6 ºC under the intermediate and high concentration pathways, respectively (Figure 3). By 2070, the increase in maximum temperature for the intermediate concentration pathway is 1.5ºC compared with 2.3 ºC for the high concentration pathway.

The difference between seasonal changes in maximum temperature by 2050 is limited, with summer, autumn and winter projected to increase by 1.2ºC and spring slighter higher at 1.6ºC

[14] Hope, P. *et al*. 2015, *Southern and South-Western Flatlands Cluster Report*, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekstrom, M. *et al*., CSIRO and Bureau of Meteorology, Australia.

under an intermediate concentration pathway. Under the high concentration pathway summer, autumn and winter increase by 1.5-1.6 ºC and spring by 2.0ºC.

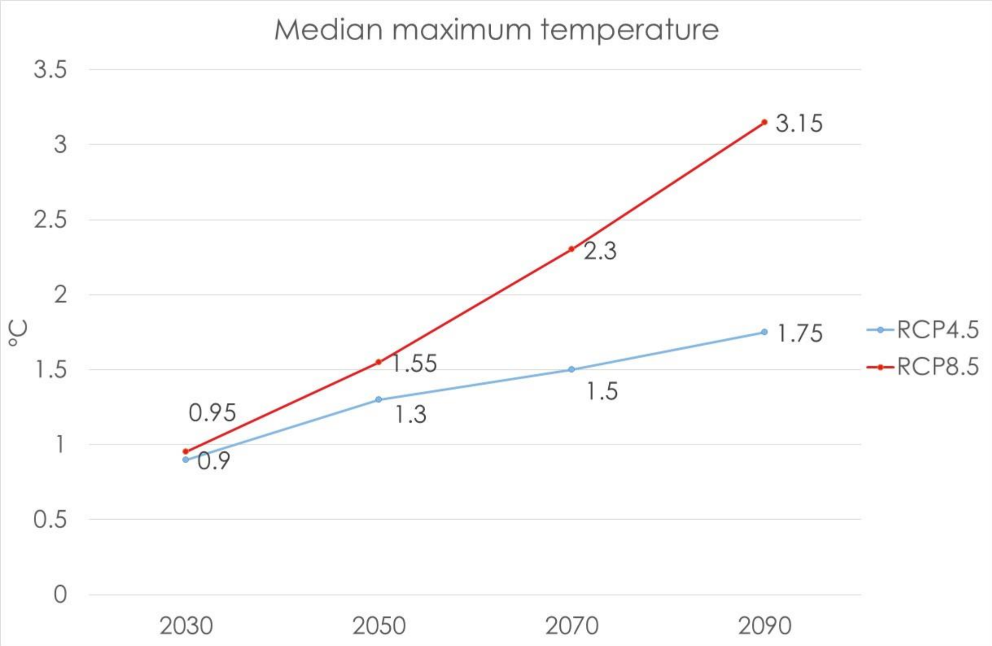

Figure 3: Median maximum temperature rise above the baseline period for 2030 to 2090 for the intermediate and high concentration pathways. Data sourced from Charles and Fu (2014).

Minimum median temperatures show a similar trend to maximums, suggesting an increase compared to the baseline of 1.3ºC and 1.6 ºC under the intermediate and high concentration pathways, respectively (Figure 4). By 2070, the increase in minimum temperature for the intermediate pathway is 1.5 ºC compared with 2.3 ºC for the high concentration pathway.

The difference between seasonal changes in minimum temperature by 2050 is limited, with summer, autumn and winter projected to increase by 1.2ºC and spring slighter higher at 1.6ºC under an intermediate concentration pathway. Under the high concentration pathway summer, autumn and winter increase by 1.5-1.6 ºC and spring by 2.0ºC.

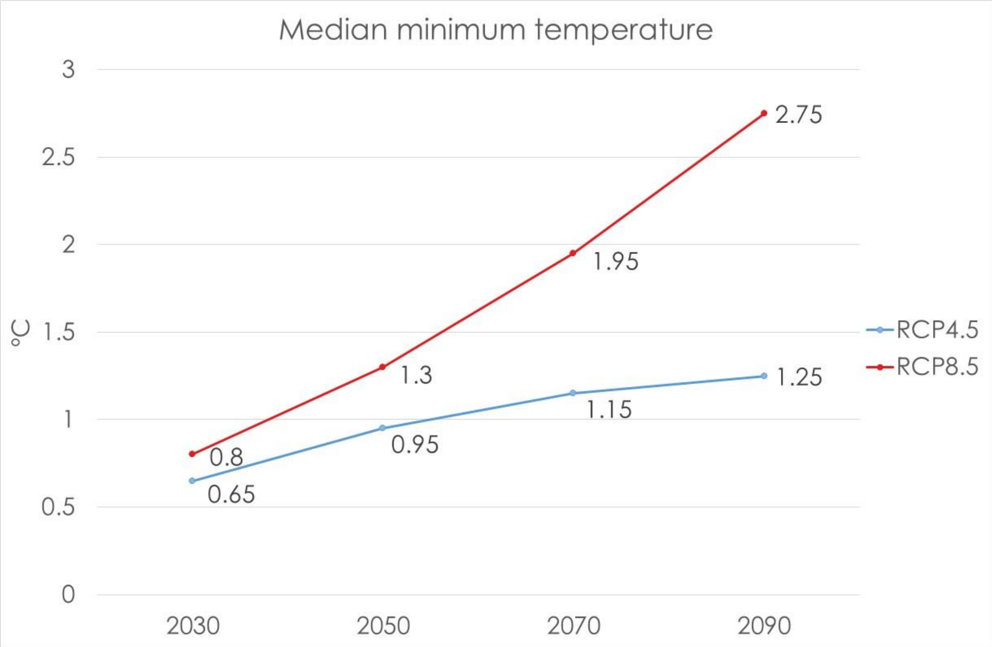

Figure 4: Median minimum temperature rise above the baseline period for 2030 to 2090 for the intermediate and high concentration pathways. Data sourced from Charles and Fu (2014).

4.2.4 Heat extremes

Heat extremes information is not available from the SA Climate Ready project so projections from the CCIA project have been used along with data for the Western Adelaide region (based on Adelaide Airport) produced from the AR4 group of models (CMIP3). Notably, the CCIA project provides data for changes to 2030 and 2090 only at this stage and not 2050.[15]

Heat related extremes are projected to increase at a similar rate as projected mean temperature in the region with a substantial increase in the number of warm spell days[16]. The number of days above 35 °C in Adelaide is projected to increase by about 150 %, but the number of days above 40 °C nearly doubles by late in the century (2090) (Table 1).

THRESHOLD	CURRENT	2030, RCP4.5	2090, RCP4.5	2090, RCP8.5
Over 35 °C	20	26 (24 to 29)	32 (29 to 38)	47 (38 to 57)
Over 40 °C	3.7	5.9 (4.7 to 7.2)	9.0 (6.8 to 12)	16 (12 to 22)

Table 1: Projections of extreme heat conditions for Adelaide by 2030 and 2090.

[15] A new definition of extreme heat was recently developed by the Bureau of Meteorology and could be used http://www.bom.gov.au/weather-services/about/heatwave-forecast.shtml
[16] Hope, P. et al. (2015)

Using AR4 based data[17], the incidence of heatwaves also increases in response to climate change. The number of days with temperatures of 35°C or more is projected to increase from 13.4 per year (during the baseline period 1980-1999) to 17.1 per year by 2030 and 35.8 per year by 2070. This equates to a 28% and 167% increase in the number of days over 35°C by 2030 and 2070, respectively.

The number of days with temperatures over 40°C is projected to increase from 1.8 days per year (during the baseline period 1980-1999) to 2.5 per year and 10.8 per year by 2030 and 2070. This equates to a 39% and 500% increase by 2030 and 2070, respectively.

Measuring heat extremes

There are various measures that can be used to assess potential heatwave occurrence. Traditionally, heatwaves are considered to be events with at least two consecutive days of high temperature (i.e. days over 35°C or 40°C), while heatwave-linked Extreme Heat Plans use the measure, "three or more consecutive days where the average daily temperature is equal to or greater than 32°C". The latter takes into account that human health and other issues associated with heatwave events increase where high overnight temperatures provide limited relief from extreme daytime heat loadings.

A new definition of heatwaves was recently developed that accounts for when the long-term resilience of a system to high temperatures is overcome and when a heatwave event is unusual in relation to antecedent conditions (Nairn and Fawcett 2013). Preparation of additional heat extreme statistics to support climate panning in the region should consider. The benefit of using these new metrics should be considered in any additional extreme heat analyses for Eastern Adelaide.

4.2.5 Fire risk

Fire weather was estimated in the CCIA project using the McArthur Forest Fire Danger Index (FFDI). Fire weather is considered 'severe' when the FFDI exceeds 50 and extreme when FFDI exceeds 75.

The CCIA projections suggest an increased fire weather risk in the future. Across the region, general fire weather danger increases by roughly 10 % by 2030, 12 % under RCP4.5 by 2090 and 30% under RCP8.5 by 2090.

The number of days with a 'severe' fire danger rating increases from 12 % (RCP8.5) to 20 % (RCP4.5) by 2030, and from 25 % (RCP4.5) to 65 % (RCP8.5) by 2090. However, these changes represent sub-cluster wide results (i.e. FFDI for the entire Southern and South-Western Flatlands cluster), reflecting the method of aggregating data in this analysis. When taken on its own, the relative change in the number of severe days projected for Adelaide (2090, RCP8.5) is over 200%.

[17] Based on high emissions and median model outputs from SKM (2013) *Western Adelaide Region Climate Change Adaptation Plan - Stage 1*. Sinclair Knight Merz, South Australia.

FFDI calculations are also available from AR4 based analyses, which were generated for the Resilient South project[18]. These found that for Adelaide Airport, days with FFDI ratings in the extreme category are projected to increase fivefold from 2 days per year in 1980-1999 to 10 days per year under the 2070 high emissions scenario.

[18] Resilient South (2014) Climate Change Scenarios Report – Resilient South, prepared by SKM as part of the Resilient South consultancy led by URPS, for the Cities of Onkaparinga, Holdfast Bay, Marion and Mitcham in association with the Government of South Australia and the Australian Government.

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