CSIRO

Future Climate Data for Building Regulation Energy Impact Assessment

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A report prepared for
Energy Partners

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Executive Summary

Energy Partners is doing an assessment of the implications of climate change up to 2050 on the energy standards for building construction in Australia. These standards are based on energy consumption modelling conducted using a standard set of meteorological data called a Reference Meteorological Year. In order to evaluate the likely implications of future climate change on these standards, Energy Partners intend to modify the Reference Meteorological Year according to the projected changes in key meteorological variables for 12 representative sites around Australia. The sites were:

Adelaide, SA
Alice Springs, NT
Brisbane, Qld
Cabramurra, NSW
Canberra, ACT
Darwin, NT
Hobart, Tas
Melbourne, Vic
Mildura, Vic
Perth, WA
Sydney, NSW
Townsville, Qld

In this report, CSIRO provides projected seasonal and monthly change values for the 12 sites for 2030 for a mid-range emissions scenario (A1B), and 2050 for low (B1) and high (A1FI) emissions scenarios. To obtain these data, CSIRO's developmental Climate Futures methodology was used to group regional climate projections from 24 climate models into plausible futures (such as "Hotter, drier and windier"). For all 12 sites, the INM-CM3.0 model was selected as representative of the most likely future and the CSIRO-Mk3.5 model was chosen as representative of the worst case (hottest and driest) future. Having the same models for all sites allows comparisons between sites if required.

The change values provided are suitable for use by Energy Partners to modify the Reference Meteorological Year to represent the most likely and worst case future climates.

1. Introduction

1.1. 1.1 Global Climate Change

In 1988, the United Nations Environment Programme and the World Meteorological Organization established the Intergovernmental Panel on Climate Change (IPCC). This comprises many of the world's experts on climate change, and produces authoritative reviews of our knowledge of climate change. The most recent review includes a summary describing observed climate change and its causes (IPCC 2007).

Our understanding of warming and cooling influences on climate has improved in the past decade, leading to very high confidence that human activities have had a warming effect since the Industrial Revolution, around 1750. The largest human contribution comes from increases in greenhouse gases, such as carbon dioxide, methane and nitrous oxide, whose atmospheric concentrations have increased by 35%, 148% and 18%, respectively. The carbon dioxide increases are due primarily to fossil fuel use and land-use change, while increases in methane and nitrous oxide are primarily due to agriculture.

The Earth's average surface temperature has increased by almost 0.75˚C since the beginning of the 20th Century. The past decade was the warmest on record since at least the 1850s (World Meteorological Organisation 2009). Most of the warming since 1950 is very likely due to increases in atmospheric greenhouse gas concentrations associated with human activities. It is extremely unlikely that this warming is due to natural causes alone. The warming has been linked with more heatwaves, changes in precipitation patterns, reductions in sea ice extent and rising sea levels.

1.2. Climate Change in Australia

Australian-average annual temperatures have increased by 0.9ºC since 1910. Most of this warming has occurred since 1950 (Figure 1), with greatest warming in the east and least warming in the north-west (Figure 2). The warmest year on record is 2005, but 2009 was the second warmest and 2009 marked the end of the warmest decade on record (Australian Bureau of Meteorology 2010a). The number of hot days and nights has increased and the number of cold days and nights has declined (CSIRO and Australian Bureau of Meteorology 2007). The Australian Bureau of Meteorology has assessed the exceptional January-February 2009 heatwave in south-eastern Australia. The conditions from 28 to 30 January set many individual-day and multi-day records (National Climate Centre 2009).

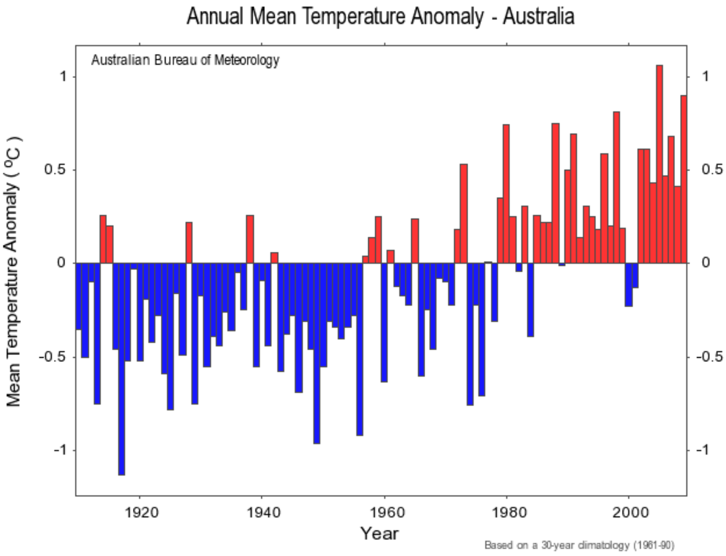

Figure 1: Australian-average annual temperature anomalies from 1910-2009 relative to the average for the 1961-1990 period. Source: Australian Bureau of Meteorology (2010c).

Since 1950, most of eastern and south-western Australia has become drier (Figure 2). In New South Wales and Queensland, rainfall trends partly reflect a very wet period around the 1950s, though recent years have been unusually dry. In south-eastern Australia, the twelve-and-a-half year rainfall average from October 1996 to May 2009 was the lowest within the instrumental period since 1900 (Timbal 2009). In contrast, north-western Australia has become wetter over this period, mostly during summer. Since 1950, the frequencies of very heavy rainfall events (over 30 mm/day) and wet days (at least 1 mm/day) have decreased in the south and east but increased in the north (Figure 3) (CSIRO and Australian Bureau of Meteorology 2007).

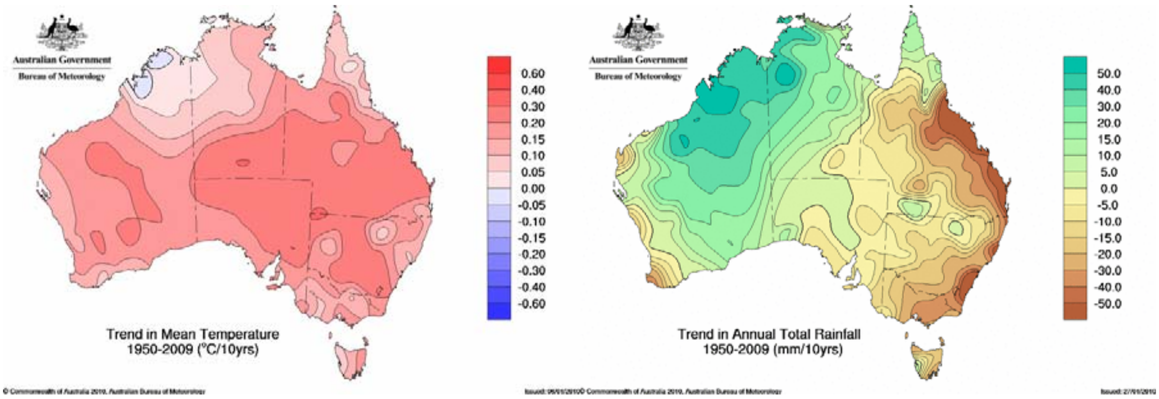

Figure 2: Trends in annual mean temperature and rainfall since 1950. Source: Australian Bureau of Meteorology (2010d).

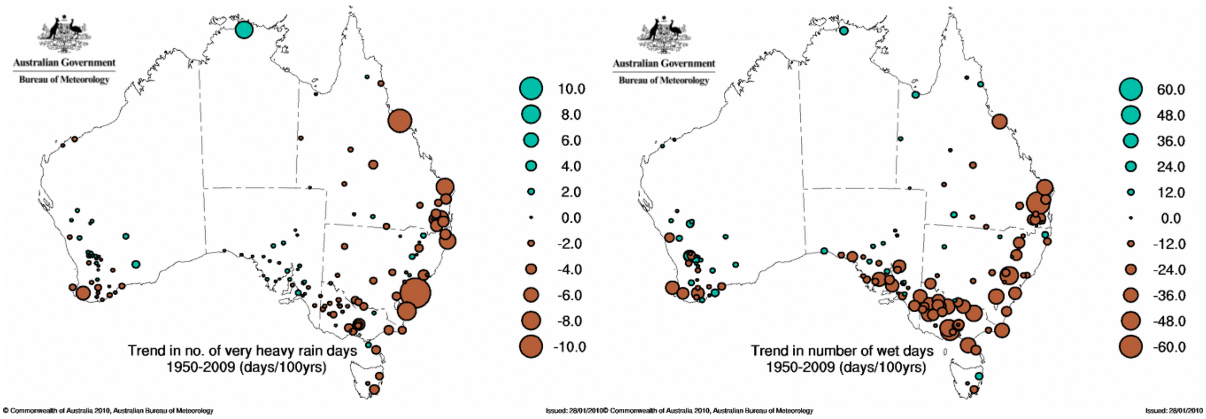

Figure 3: Trends in the frequencies of very heavy rain days (over 30 mm/day) and wet days (at least 1 mm/day) since 1950. Source: Australian Bureau of Meteorology (2010b).

Australian rainfall shows considerable variability from year-to-year, partly due to the El Niño – Southern Oscillation (ENSO). El Niño events tend to be associated with hot and dry years in Australia, and La Niña events tend to be associated with mild and wet years (Power *et al.* 2006). There has been a marked increase in the frequency of El Niño events and a decrease in La Niña events since the mid-1970s (Power and Smith 2007).

Australian average annual wind-speeds have declined over the period 1975-2006 (McVicar *et al.* 2008). The majority of Australia (88%) exhibits a reduction in wind-speed, with 57% of the area having statistically significant decreases, *e.g.* between Adelaide and Cape Otway (Figure 4).

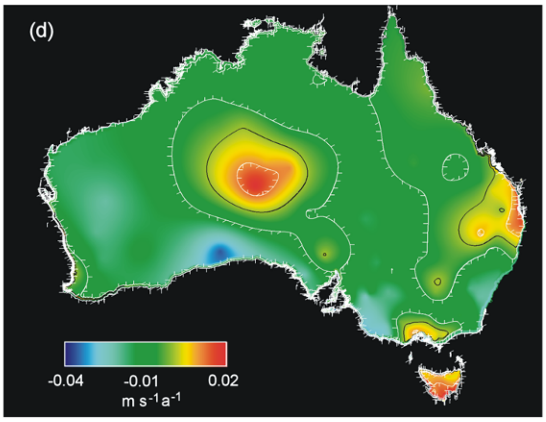

Figure 4: Wind-speed trends from 1975-2006. Black lines show no change and white lines show significant trends with barbs pointing to increased significance. Source: McVicar *et al.* (2008).

1.3. This Study

Energy Partners are conducting a study on the impacts of climate change on building codes for energy consumption.

Energy consumption of buildings is modelled using a standard representative climate data set called a Reference Meteorological Year (RMY). This comprises a 12-month set of hourly data selected from weather observations from a 41 year period centred on 1987. In order to evaluate the effects of climate change, it is necessary to reselect the RMY months or 'perturb' the RMY hourly values by the projected changes in key meteorological variables to create a plausible synthetic future RMY (or ersatz future meteorological year - EFMY).

2. Models, Emissions, Assumptions and Limitations

To provide a basis for estimating future climate change, 40 greenhouse gas and sulphate aerosol emission scenarios were prepared for the 21st century by the IPCC (Nakićenović and Swart 2000), based on a variety of assumptions about demographic, economic and technological factors likely to influence future emissions. The climatic effects of projected changes in emissions can be simulated using climate models, which are mathematical representations of the Earth's climate system based on well-established laws of physics, such as conservation of mass, energy and momentum. CSIRO has access to monthly data for up to 12 climate variables from up to 24 global climate models from 1900-2100 for 3 emission scenarios (A1B, A2 and B2). Some results can also be scaled for the highest emission scenario (A1FI).

The future climate is strongly influenced by inherently uncertain factors, so it is not possible to make definitive climate predictions for decades ahead. However, projections that account for uncertainties can be made by considering the output of computer models of the Earth's climate system and different scenarios for future greenhouse gas and sulphate aerosol emissions. Uncertainties in projected regional climate to 2030 are mostly due to differences between the results of the climate models rather than the different emissions scenarios. In this report, projections for 2030 are given for the IPCC's mid-range A1B emissions scenario while those for 2050 are given for the IPCC's low B1 and high A1FI emissions scenarios (Nakićenović and Swart 2000).

Projections can be created in a number of ways, depending on the intended purpose. Two common examples are described below.

If projections are needed for general communication, with a focus on quantifying the range of possibilities across all available models for one climate variable at a time, then it is appropriate to combine results from multiple climate models. Recently, this has been done using a method that produces probabilistic distributions for future changes in a range of climate variables for Australia (CSIRO and Australian Bureau of Meteorology 2007, Ch 5) and Victoria (Vic DSE 2008).

If projections are needed for a detailed risk assessment, with a focus on internally consistent changes between climate variables, then it is inappropriate to combine multi-model results (CSIRO and Australian Bureau of Meteorology 2007, Ch 6). Projections should instead be based upon individual model results.

However, working with projections from 24 different climate models and multiple emissions scenarios and time scales can be very complex. This can be simplified for a given region by grouping the individual model projections into a set of "Climate Futures" (Whetton *et al.* 2010), such as:

- Warmer, wetter, windier (10 models)
- Warmer, drier, windier (4 models)
- Hotter, drier, calmer (5 models)
- Hotter, much drier, calmer (1 model)
- Warmer, much drier, much calmer (2 models)
- Hotter, much wetter, much windier (2 models)

These can then be used to select Climate Futures that are considered by the client as being relevant for the risk assessment in question. Within those Climate Futures, data from representative models can be derived.

This method for generating model-based projections is designed to extract the underlying multi-decadal trends associated with climate change rather than random yearly-to-decadal climate variability associated with phenomena such as the El Niño Southern Oscillation. This means that projections for 20-year periods centred on 2030 and 2050 describe the average climate, but do not allow for random variability. In reality, changes in average climate will be superimposed on random daily, seasonal and yearly variability that will have significant impacts on extreme events. The extremes in an individual year will be determined by a combination of natural variability and anthropogenic climate change. In this report, when the year 2030 or 2050 is mentioned, this refers to the average climatic conditions for 20 years centred on that year, rather than a single year.

3. Climate Change Analysis

3.1. Data and methods

Projections

For this study, internally consistent Climate Futures were determined in consultation with Energy Partners. The climate variables of interest were (in order of priority) seasonal-mean changes in temperature (particularly summer), humidity, solar radiation and wind speed. In addition, monthly-mean changes were required for minimum and maximum temperature.

For each of the 12 sites, the Climate Futures approach was used to select one model that was representative of the 'most likely future' (*i.e.* that represented by the greatest number of models) and one that was representative of the 'worst case future' (*i.e.* with the greatest increase in summer temperature). In each case, if the model did not provide all the necessary climate variables it was excluded and the next most representative model was selected. In all cases, projections were obtained for 2030 (A1B) and 2050 (B1 and A1FI). As mentioned in section 2, projections for 2030 are provided for one emissions scenario only, due to the limited variation among global warming estimates under different emissions scenarios over that time period (CSIRO and Australian Bureau of Meteorology 2007). Further, the B1 scenario seems unlikely to be achievable for 2030 due to current emission trajectories (see for example Rahmstorf *et al.* 2007) and inertia in the climate system. The B1 scenario is plausible by 2050 if emissions are rapidly reduced on a path that eventually stabilizes the CO_2 concentration at 550 parts per million by 2100.

Across all sites, the INM-CM3.0 model was selected as representative of the most likely future and the CSIRO-Mk3.5 model was chosen as representative of the worst case future. In some cases, there was no clearly identifiable most likely future. In these instances, a model that produced a mid-range summer temperature change was deemed to represent the most likely future. In other cases, there was no clearly identifiable worst case future. In this instance a model that produced the highest summer temperature change was selected.

In addition, five models (CGCM3.1-T47, IPSL-CM4, GISS-AOM, GISS-EH and PCM) were identified as performing poorly against multiple criteria, while a sixth (GISS-ER) was found to poorly represent variability in the El Niño – Southern Oscillation (Smith and Chandler 2010), which is important for rainfall and humidity in Australia. Consequently, these six models were excluded from the selection.

Climate Variables

The climate variables obtained from the model projections are provided as changes relative to the period 1975 – 2004 (*i.e.* 30 years centred on 1990). This is comparable to the IPCC standard reference period of 1981 – 2000 (a 20-year period centred on 1990). Details of the climate variables, their units of measure and their units of projected change are given in Table 1.

Seasonal change data

These data are derived from the relevant global climate model output, averaged (using an equal area average method) over a 5° latitude-longitude grid-square encompassing the location of interest.

Table 1 Details of the climate variables provided by the model projections.

Variable	Units of measure	Units of change	Notes
Seasonal mean temperature	°C	°C	Temperature at 2 m above the ground
Seasonal mean relative humidity	%	%	
Seasonal mean solar radiation	$W.m^{-2}$	%	Surface downward shortwave radiation (equivalent to 'global radiation')
Seasonal mean wind speed	$m.s^{-1}$	%	Calculated from eastward and northward components at 10 m above the ground
Monthly mean minimum temperature	°C	°C	Minimum temperature at 2 m above the ground
Monthly mean maximum temperature	°C	°C	Maximum temperature at 2 m above the ground

Monthly change data

These data are derived from the relevant global climate model output, where the change value from a single model grid-cell is obtained. Due to processes inherent in the global climate models, which are designed to represent large-scale changes, it is possible for monthly values in individual grid-cells to show large excursions between adjacent months (for example, see Figure 1). Where this occurs, the smoother seasonal mean temperature change values could be used instead.

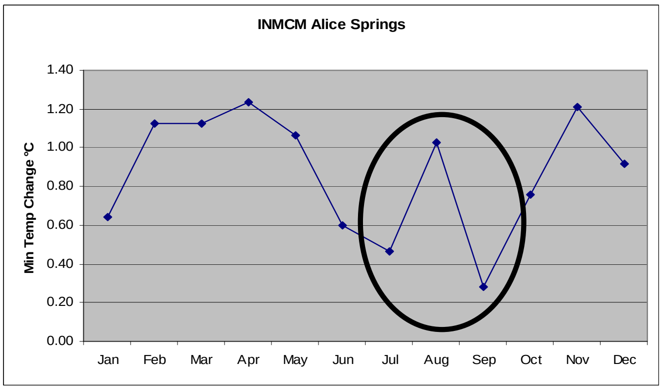

Figure 1 Monthly minimum temperature change values for Alice Springs for 2030 A1B as projected by the INM-CM3.0 model. A large excursion in August is highlighted.

3.2. Projections

Changes in seasonal mean climate variables for 2030 (A1B) and 2050 (B1 and A1FI) for the 12 sites are provided in Tables 2 – 13. Monthly-mean changes in minimum and maximum temperature for 2030 (A1B) and 2050 (B1 and A1FI) for the 12 sites are presented in Tables 14 – 19.

Table 2 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Adelaide.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.97	0.95	0.66	0.75	0.76	0.75	0.52	0.59	2.78	2.73	1.88	2.14
	Humidity	-1.68	-0.65	-0.59	-4.06	-1.32	-0.51	-0.46	-3.19	-4.80	-1.86	-1.68	-11.61
	Radiation	0.26	-0.70	0.26	0.48	0.20	-0.55	0.21	0.38	0.74	-2.01	0.75	1.37
	Wind	1.11	4.06	-5.07	3.51	0.88	3.19	-3.98	2.76	3.18	11.60	-14.47	10.03
Worst Case	Temperature	1.06	1.27	1.04	1.18	0.83	1.00	0.81	0.92	3.03	3.64	2.96	3.36
	Humidity	-1.93	-2.28	-2.96	-2.91	-1.51	-1.79	-2.33	-2.28	-5.50	-6.50	-8.46	-8.30
	Radiation	0.77	1.14	1.44	0.19	0.61	0.90	1.13	0.15	2.21	3.25	4.11	0.54
	Wind	3.58	6.36	-6.67	-1.10	2.81	4.99	-5.24	-0.87	10.22	18.16	-19.05	-3.15

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 3 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Alice Springs.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.91	1.10	0.88	0.93	0.71	0.87	0.69	0.73	2.59	3.15	2.51	2.65
	Humidity	-1.96	-1.21	-3.36	-2.39	-1.54	-0.95	-2.64	-1.88	-5.61	-3.47	-9.59	-6.82
	Radiation	0.10	-0.09	1.47	0.56	0.08	-0.07	1.16	0.44	0.30	-0.25	4.21	1.60
	Wind	-1.02	0.44	2.09	1.77	-0.80	0.35	1.64	1.39	-2.91	1.26	5.98	5.06
Worst Case	Temperature	1.53	1.80	1.58	1.61	1.20	1.42	1.24	1.27	4.38	5.15	4.51	4.61
	Humidity	-6.03	-7.93	-8.12	-7.80	-4.73	-6.23	-6.38	-6.13	-17.22	-22.64	-23.19	-22.28
	Radiation	0.67	2.10	2.11	0.87	0.53	1.65	1.66	0.68	1.92	5.99	6.02	2.48
	Wind	0.99	0.16	0.04	0.69	0.78	0.13	0.03	0.54	2.84	0.46	0.12	1.98

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 4 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Brisbane.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.83	1.01	0.87	0.91	0.65	0.80	0.68	0.71	2.37	2.90	2.48	2.60
	Humidity	-1.64	-1.67	-0.48	-3.47	-1.29	-1.31	-0.37	-2.73	-4.68	-4.76	-1.36	-9.92
	Radiation	0.56	-0.17	0.23	1.69	0.44	-0.13	0.18	1.32	1.59	-0.48	0.64	4.82
	Wind	5.02	5.14	8.13	4.21	3.94	4.04	6.39	3.31	14.33	14.68	23.24	12.03
Worst Case	Temperature	1.37	1.50	1.32	1.38	1.08	1.18	1.03	1.08	3.93	4.30	3.76	3.93
	Humidity	-2.83	-3.61	-3.70	-3.82	-2.22	-2.83	-2.91	-3.00	-8.09	-10.30	-10.58	-10.91
	Radiation	1.49	1.79	1.11	1.22	1.17	1.41	0.88	0.96	4.25	5.12	3.18	3.48
	Wind	2.65	-0.57	-1.26	5.76	2.08	-0.44	-0.99	4.53	7.58	-1.62	-3.60	16.46

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 5 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Cabramurra*.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.96	0.78	0.69	0.70	0.76	0.61	0.55	0.55	2.75	2.23	1.98	2.01
	Humidity	-1.08	-0.45	-0.64	-3.10	-0.85	-0.35	-0.51	-2.43	-3.10	-1.28	-1.84	-8.84
	Radiation	-0.03	-0.24	0.09	0.90	-0.02	-0.19	0.07	0.70	-0.08	-0.69	0.27	2.56
	Wind	1.22	-7.28	-0.36	2.49	0.96	-5.72	-0.28	1.95	3.48	-20.80	-1.02	7.11
Worst Case	Temperature	1.21	1.27	1.00	1.22	0.95	1.00	0.79	0.96	3.46	3.62	2.86	3.49
	Humidity	-1.68	-2.02	-2.99	-5.26	-1.32	-1.59	-2.35	-4.13	-4.81	-5.76	-8.55	-15.02
	Radiation	0.86	1.74	2.20	1.14	0.68	1.37	1.73	0.90	2.47	4.98	6.30	3.27
	Wind	4.48	-2.43	-2.43	-4.34	3.52	-1.91	-1.91	-3.41	12.81	-6.95	-6.94	-12.41

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.
* Cabramurra falls within the same 5° grid as Melbourne so the change values are identical for both locations.

Table 6 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Canberra.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.93	0.82	0.74	0.75	0.73	0.64	0.59	0.59	2.65	2.34	2.13	2.15
	Humidity	-1.64	-0.47	-0.44	-2.50	-1.29	-0.37	-0.35	-1.96	-4.70	-1.34	-1.26	-7.14
	Radiation	0.04	-0.35	0.11	1.04	0.04	-0.28	0.08	0.81	0.13	-1.00	0.30	2.96
	Wind	3.85	-7.42	-0.66	2.09	3.02	-5.83	-0.52	1.65	10.99	-21.20	-1.88	5.98
Worst Case	Temperature	1.17	1.29	1.12	1.19	0.92	1.02	0.88	0.94	3.34	3.70	3.19	3.41
	Humidity	-0.57	-1.05	-2.85	-3.49	-0.45	-0.83	-2.24	-2.74	-1.62	-3.00	-8.14	-9.98
	Radiation	0.44	0.95	0.92	0.55	0.35	0.74	0.72	0.43	1.26	2.71	2.63	1.56
	Wind	3.20	-0.02	-2.55	-2.16	2.52	-0.01	-2.00	-1.70	9.15	-0.05	-7.28	-6.18

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 7 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Darwin.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.72	0.82	0.72	0.73	0.57	0.64	0.57	0.57	2.07	2.34	2.07	2.08
	Humidity	-0.23	-0.89	-1.01	-0.56	-0.18	-0.70	-0.79	-0.44	-0.65	-2.55	-2.89	-1.60
	Radiation	0.35	0.55	-0.05	-0.01	0.28	0.44	-0.04	0.00	1.01	1.58	-0.16	-0.02
	Wind	-0.43	1.12	1.41	0.87	-0.34	0.88	1.11	0.68	-1.22	3.21	4.03	2.48
Worst Case	Temperature	0.96	0.97	0.93	0.90	0.75	0.76	0.73	0.71	2.73	2.78	2.65	2.57
	Humidity	-0.88	-1.63	-2.19	-1.19	-0.69	-1.28	-1.72	-0.93	-2.52	-4.65	-6.25	-3.39
	Radiation	1.26	1.99	1.01	0.67	0.99	1.56	0.80	0.53	3.61	5.68	2.89	1.92
	Wind	6.01	-1.78	-3.79	2.64	4.73	-1.40	-2.98	2.07	17.18	-5.08	-10.82	7.55

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 8 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Hobart.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.69	0.64	0.62	0.61	0.54	0.51	0.49	0.48	1.97	1.84	1.78	1.75
	Humidity	0.10	-0.11	-0.06	-0.25	0.07	-0.09	-0.05	-0.20	0.27	-0.33	-0.17	-0.72
	Radiation	0.67	-0.45	0.14	0.42	0.53	-0.35	0.11	0.33	1.91	-1.28	0.41	1.20
	Wind	-1.35	-1.97	3.21	3.47	-1.06	-1.55	2.52	2.73	-3.85	-5.64	9.17	9.92
Worst Case	Temperature	0.86	0.91	0.82	0.82	0.68	0.72	0.64	0.65	2.47	2.60	2.34	2.35
	Humidity	-0.55	-0.45	-0.56	-0.89	-0.43	-0.35	-0.44	-0.70	-1.58	-1.28	-1.59	-2.56
	Radiation	0.54	0.41	0.30	0.72	0.42	0.32	0.24	0.56	1.54	1.17	0.86	2.05
	Wind	1.82	-0.33	0.99	-0.96	1.43	-0.26	0.78	-0.75	5.20	-0.93	2.83	-2.74

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 9 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Melbourne*.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.96	0.78	0.69	0.70	0.76	0.61	0.55	0.55	2.75	2.23	1.98	2.01
	Humidity	-1.08	-0.45	-0.64	-3.10	-0.85	-0.35	-0.51	-2.43	-3.10	-1.28	-1.84	-8.84
	Radiation	-0.03	-0.24	0.09	0.90	-0.02	-0.19	0.07	0.70	-0.08	-0.69	0.27	2.56
	Wind	1.22	-7.28	-0.36	2.49	0.96	-5.72	-0.28	1.95	3.48	-20.80	-1.02	7.11
Worst Case	Temperature	1.21	1.27	1.00	1.22	0.95	1.00	0.79	0.96	3.46	3.62	2.86	3.49
	Humidity	-1.68	-2.02	-2.99	-5.26	-1.32	-1.59	-2.35	-4.13	-4.81	-5.76	-8.55	-15.02
	Radiation	0.86	1.74	2.20	1.14	0.68	1.37	1.73	0.90	2.47	4.98	6.30	3.27
	Wind	4.48	-2.43	-2.43	-4.34	3.52	-1.91	-1.91	-3.41	12.81	-6.95	-6.94	-12.41

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.
* Melbourne falls within the same 5° grid as Cabramurra so the change values are identical for both locations.

Table 10 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Mildura.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	1.13	1.04	0.75	0.81	0.89	0.82	0.59	0.63	3.24	2.98	2.13	2.31
	Humidity	-1.57	-1.17	-0.76	-5.60	-1.24	-0.92	-0.60	-4.40	-4.50	-3.33	-2.18	-16.00
	Radiation	-0.24	-0.49	0.14	0.72	-0.19	-0.38	0.11	0.57	-0.69	-1.39	0.41	2.07
	Wind	1.62	3.41	-4.11	4.06	1.27	2.68	-3.23	3.19	4.61	9.73	-11.73	11.61
Worst Case	Temperature	1.31	1.53	1.13	1.36	1.03	1.20	0.89	1.06	3.74	4.38	3.22	3.87
	Humidity	-3.03	-3.24	-4.06	-5.01	-2.38	-2.55	-3.19	-3.94	-8.67	-9.27	-11.60	-14.31
	Radiation	0.65	0.99	1.30	0.12	0.51	0.78	1.02	0.09	1.86	2.83	3.72	0.34
	Wind	3.69	4.99	-5.80	-1.80	2.90	3.92	-4.56	-1.42	10.54	14.25	-16.57	-5.16

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 11 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Perth.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.78	0.83	0.70	0.75	0.61	0.65	0.55	0.59	2.22	2.37	2.01	2.15
	Humidity	-0.30	0.78	-0.44	-1.39	-0.23	0.61	-0.35	-1.09	-0.84	2.23	-1.27	-3.96
	Radiation	-0.43	-1.15	0.07	0.10	-0.34	-0.91	0.06	0.07	-1.23	-3.29	0.21	0.27
	Wind	-0.96	3.67	-4.04	-0.35	-0.76	2.88	-3.17	-0.28	-2.75	10.48	-11.54	-1.00
Worst Case	Temperature	1.15	1.35	0.99	0.92	0.90	1.06	0.78	0.72	3.29	3.87	2.83	2.63
	Humidity	-1.26	-1.86	-1.26	-0.77	-0.99	-1.46	-0.99	-0.60	-3.60	-5.31	-3.59	-2.19
	Radiation	0.31	0.67	0.69	0.22	0.24	0.53	0.55	0.17	0.89	1.92	1.98	0.62
	Wind	0.71	-1.50	-5.70	-2.72	0.56	-1.18	-4.48	-2.13	2.02	-4.27	-16.29	-7.76

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 12 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Sydney.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.94	0.97	0.85	0.90	0.74	0.76	0.66	0.71	2.69	2.76	2.42	2.56
	Humidity	-2.08	-0.91	-0.16	-4.10	-1.64	-0.71	-0.13	-3.22	-5.95	-2.60	-0.46	-11.71
	Radiation	0.07	-0.53	-0.18	1.34	0.06	-0.42	-0.14	1.05	0.20	-1.52	-0.51	3.83
	Wind	7.02	0.24	-4.98	2.49	5.52	0.19	-3.92	1.96	20.07	0.69	-14.24	7.12
Worst Case	Temperature	1.32	1.46	1.22	1.36	1.04	1.15	0.96	1.06	3.78	4.17	3.49	3.87
	Humidity	-1.82	-2.33	-3.70	-4.55	-1.43	-1.83	-2.91	-3.57	-5.19	-6.65	-10.57	-12.99
	Radiation	0.80	1.48	1.05	0.82	0.63	1.17	0.83	0.64	2.29	4.24	3.00	2.34
	Wind	2.44	1.06	-3.40	-0.15	1.92	0.83	-2.67	-0.12	6.97	3.01	-9.71	-0.43

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 13 ***Seasonal-mean changes in temperature, relative humidity, solar radiation and wind speed (relative to 1990) for two time periods and three emissions scenarios for the 5° grid encompassing Townsville.***

		2030 A1B				2050 B1				2050 A1FI			
		Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr
Most Likely	Temperature	0.78	0.85	0.81	0.78	0.61	0.67	0.64	0.62	2.22	2.44	2.32	2.24
	Humidity	-0.37	-1.53	-0.31	-0.26	-0.29	-1.20	-0.24	-0.21	-1.06	-4.37	-0.87	-0.75
	Radiation	0.31	0.18	-0.14	0.00	0.25	0.14	-0.11	0.00	0.90	0.52	-0.40	0.01
	Wind	1.28	1.72	3.07	2.18	1.01	1.35	2.42	1.72	3.66	4.91	8.78	6.24
Worst Case	Temperature	1.08	1.05	1.02	0.94	0.85	0.83	0.80	0.74	3.08	3.01	2.90	2.68
	Humidity	-1.74	-1.89	-1.69	-1.04	-1.37	-1.48	-1.33	-0.82	-4.98	-5.39	-4.84	-2.97
	Radiation	0.63	1.38	0.62	0.49	0.49	1.09	0.48	0.39	1.79	3.95	1.76	1.41
	Wind	1.60	-0.68	-1.53	1.62	1.26	-0.54	-1.20	1.27	4.58	-1.95	-4.37	4.63

NB. The Most Likely Climate Future is represented by the INM-CM3.0 model. The Worst Case Climate Future is represented by the CSIRO-Mk3.5 model.

Table 14 Monthly change values relative to 1990 for minimum temperature for 2030 (A1B) for 12 sites.

Climate Future	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Most Likely (INM-CM3.0)	Adelaide	0.97	1.42	0.89	0.78	0.63	0.36	0.42	0.39	0.26	0.26	0.37	0.68
	Alice	0.64	1.12	1.13	1.24	1.06	0.60	0.47	1.02	0.28	0.76	1.21	0.91
	Brisbane	0.48	0.83	1.02	0.77	0.89	0.86	0.70	0.85	0.44	0.82	0.53	0.65
	Cabramurra	1.02	1.45	1.04	0.54	0.70	0.54	0.59	0.54	0.42	0.10	0.16	0.79
	Canberra	0.91	1.44	1.10	0.58	0.80	0.61	0.64	0.60	0.40	0.20	0.19	0.81
	Darwin	0.68	0.67	0.74	0.75	0.77	0.65	0.67	0.67	0.62	0.72	0.73	0.73
	Hobart	0.62	0.72	0.58	0.60	0.64	0.57	0.62	0.52	0.56	0.50	0.60	0.57
	Melbourne	0.98	1.21	0.81	0.55	0.62	0.50	0.53	0.47	0.44	0.23	0.31	0.69
	Mildura	1.06	1.69	1.10	0.76	0.76	0.38	0.42	0.45	0.20	0.20	0.29	0.81
	Perth	0.57	0.86	0.57	1.55	1.15	0.95	0.65	0.30	0.55	0.59	0.66	1.11
	Sydney	0.69	1.28	1.12	0.66	0.95	0.76	0.69	0.70	0.41	0.50	0.32	0.79
	Townsville	0.71	0.89	0.92	0.80	0.82	0.76	0.76	0.86	0.77	0.85	0.73	0.84
Worst Case (CSIRO-Mk3.5)	Adelaide	0.92	1.00	1.01	1.09	1.00	0.82	0.84	0.83	0.90	1.03	0.99	0.93
	Alice	1.12	1.60	1.77	1.61	1.78	1.32	1.36	1.51	1.34	1.96	1.61	1.64
	Brisbane	1.11	1.17	1.16	1.21	1.30	1.20	1.07	1.17	1.00	1.15	1.17	1.20
	Cabramurra	1.29	1.28	1.49	1.43	1.21	0.95	0.86	0.97	0.98	1.32	1.32	1.39
	Canberra	1.30	1.25	1.46	1.45	1.25	1.00	0.88	1.02	1.03	1.31	1.29	1.35
	Darwin	0.94	0.86	0.84	0.96	1.04	1.04	0.89	0.90	0.86	0.86	0.92	0.93
	Hobart	0.91	1.01	0.94	1.01	0.96	0.90	0.87	0.79	0.79	0.84	0.92	0.89
	Melbourne	1.12	1.22	1.26	1.14	0.91	0.80	0.95	0.90	0.83	1.14	1.18	1.17
	Mildura	1.13	1.37	1.47	1.54	1.23	0.87	0.99	1.00	1.09	1.30	1.41	1.25
	Perth	1.22	1.28	1.45	1.45	1.33	1.15	0.89	0.95	0.96	0.99	0.86	1.22
	Sydney	1.40	1.26	1.40	1.42	1.30	1.15	0.99	1.13	1.10	1.30	1.25	1.27
	Townsville	0.93	1.08	0.97	1.00	1.04	1.04	0.95	0.97	0.80	0.90	0.90	0.94

Table 15 Monthly change values relative to 1990 for minimum temperature for 2050 (B1) for 12 sites.

Climate Future	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Most Likely (INM-CM3.0)	Adelaide	1.06	1.55	0.97	0.85	0.69	0.39	0.46	0.43	0.28	0.29	0.41	0.74
	Alice	0.70	1.23	1.23	1.35	1.16	0.65	0.51	1.12	0.30	0.83	1.32	1.00
	Brisbane	0.52	0.91	1.12	0.84	0.97	0.94	0.77	0.93	0.48	0.90	0.58	0.71
	Cabramurra	1.11	1.59	1.14	0.59	0.76	0.59	0.65	0.59	0.46	0.11	0.18	0.86
	Canberra	1.00	1.57	1.20	0.64	0.87	0.67	0.70	0.65	0.44	0.22	0.20	0.89
	Darwin	0.74	0.73	0.81	0.82	0.84	0.71	0.74	0.73	0.68	0.79	0.80	0.79
	Hobart	0.68	0.79	0.64	0.66	0.70	0.62	0.67	0.57	0.61	0.54	0.66	0.62
	Melbourne	1.07	1.33	0.88	0.60	0.68	0.55	0.58	0.51	0.48	0.25	0.33	0.75
	Mildura	1.16	1.85	1.21	0.83	0.84	0.42	0.45	0.49	0.22	0.22	0.32	0.89
	Perth	0.62	0.94	0.63	1.69	1.26	1.04	0.71	0.33	0.60	0.65	0.72	1.21
	Sydney	0.75	1.40	1.22	0.72	1.04	0.83	0.75	0.76	0.45	0.55	0.35	0.86
	Townsville	0.78	0.98	1.01	0.88	0.89	0.83	0.83	0.94	0.84	0.93	0.80	0.92
Worst Case (CSIRO-Mk3.5)	Adelaide	1.01	1.09	1.10	1.20	1.09	0.90	0.92	0.91	0.99	1.13	1.08	1.01
	Alice	1.23	1.74	1.94	1.76	1.95	1.45	1.49	1.65	1.47	2.14	1.76	1.80
	Brisbane	1.22	1.28	1.26	1.32	1.43	1.31	1.17	1.27	1.10	1.25	1.28	1.31
	Cabramurra	1.41	1.39	1.62	1.56	1.32	1.03	0.94	1.06	1.07	1.44	1.44	1.52
	Canberra	1.42	1.37	1.60	1.59	1.37	1.10	0.96	1.12	1.13	1.44	1.41	1.47
	Darwin	1.03	0.94	0.92	1.05	1.14	1.14	0.97	0.98	0.94	0.94	1.01	1.01
	Hobart	1.00	1.11	1.02	1.10	1.05	0.98	0.95	0.87	0.86	0.92	1.01	0.98
	Melbourne	1.22	1.33	1.38	1.24	0.99	0.87	1.04	0.98	0.91	1.24	1.29	1.28
	Mildura	1.24	1.50	1.61	1.68	1.34	0.95	1.08	1.09	1.19	1.42	1.54	1.36
	Perth	1.33	1.40	1.58	1.58	1.45	1.26	0.98	1.03	1.05	1.08	0.95	1.33
	Sydney	1.53	1.38	1.54	1.55	1.42	1.26	1.08	1.23	1.21	1.43	1.36	1.39
	Townsville	1.02	1.18	1.06	1.09	1.14	1.14	1.03	1.06	0.87	0.99	0.98	1.03

Table 16 ***Monthly change values relative to 1990 for minimum temperature for 2050 (A1FI) for 12 sites.***

Climate Future	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Most Likely (INM-CM3.0)	Adelaide	2.36	3.45	2.16	1.88	1.53	0.88	1.03	0.96	0.63	0.64	0.90	1.64
	Alice	1.55	2.73	2.73	3.01	2.58	1.45	1.13	2.49	0.68	1.84	2.94	2.22
	Brisbane	1.16	2.01	2.49	1.87	2.16	2.09	1.71	2.07	1.06	2.00	1.28	1.59
	Cabramurra	2.47	3.52	2.53	1.31	1.69	1.32	1.44	1.32	1.03	0.24	0.39	1.91
	Canberra	2.21	3.50	2.67	1.41	1.94	1.49	1.55	1.45	0.98	0.48	0.45	1.97
	Darwin	1.64	1.63	1.80	1.83	1.87	1.59	1.63	1.62	1.51	1.75	1.77	1.76
	Hobart	1.51	1.76	1.41	1.46	1.55	1.38	1.50	1.26	1.36	1.21	1.46	1.39
	Melbourne	2.37	2.95	1.96	1.34	1.51	1.21	1.28	1.14	1.07	0.56	0.74	1.67
	Mildura	2.58	4.11	2.68	1.85	1.86	0.93	1.01	1.09	0.50	0.49	0.71	1.98
	Perth	1.38	2.08	1.40	3.77	2.80	2.31	1.57	0.74	1.33	1.44	1.60	2.70
	Sydney	1.67	3.11	2.72	1.61	2.31	1.84	1.67	1.69	1.00	1.22	0.77	1.92
	Townsville	1.73	2.17	2.24	1.94	1.98	1.83	1.84	2.08	1.87	2.06	1.78	2.05
Worst Case (CSIRO-Mk3.5)	Adelaide	2.24	2.43	2.44	2.66	2.42	1.99	2.05	2.02	2.20	2.50	2.41	2.25
	Alice	2.72	3.88	4.31	3.92	4.33	3.22	3.30	3.68	3.26	4.75	3.92	3.99
	Brisbane	2.71	2.84	2.81	2.94	3.17	2.90	2.60	2.83	2.44	2.78	2.85	2.91
	Cabramurra	3.12	3.10	3.61	3.46	2.93	2.30	2.09	2.35	2.37	3.20	3.19	3.38
	Canberra	3.17	3.04	3.55	3.53	3.04	2.44	2.13	2.49	2.51	3.19	3.13	3.28
	Darwin	2.28	2.08	2.05	2.32	2.53	2.53	2.15	2.18	2.09	2.08	2.24	2.25
	Hobart	2.22	2.46	2.28	2.45	2.34	2.18	2.12	1.92	1.92	2.05	2.24	2.17
	Melbourne	2.72	2.95	3.06	2.76	2.21	1.93	2.32	2.17	2.02	2.77	2.87	2.84
	Mildura	2.75	3.34	3.58	3.74	2.98	2.10	2.40	2.42	2.65	3.15	3.43	3.02
	Perth	2.96	3.11	3.51	3.51	3.23	2.79	2.17	2.30	2.33	2.40	2.10	2.96
	Sydney	3.39	3.06	3.41	3.45	3.15	2.79	2.40	2.74	2.68	3.17	3.03	3.08
	Townsville	2.26	2.62	2.36	2.42	2.52	2.53	2.30	2.36	1.93	2.20	2.19	2.29

Table 17 Monthly change values relative to 1990 for maximum temperature for 2030 (A1B) for 12 sites.

Climate Future	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Most Likely (INM-CM3.0)	Adelaide	0.79	1.07	0.70	0.87	0.62	0.67	0.73	0.78	0.85	0.88	0.87	0.72
	Alice	0.78	0.93	0.97	1.12	0.88	0.80	0.74	1.48	0.90	1.12	1.01	0.86
	Brisbane	0.54	0.71	0.88	0.68	0.69	0.69	0.66	0.87	0.70	1.05	0.75	0.67
	Cabramurra	1.00	1.06	0.84	0.86	0.83	0.76	0.74	0.80	0.89	1.02	1.21	0.93
	Canberra	1.00	1.06	0.87	0.88	0.84	0.77	0.76	0.85	0.91	1.09	1.25	0.97
	Darwin	0.67	0.61	0.73	0.71	0.70	0.68	0.61	0.62	0.59	0.62	0.62	0.64
	Hobart	0.66	0.78	0.63	0.65	0.61	0.60	0.60	0.64	0.58	0.59	0.65	0.58
	Melbourne	0.82	0.94	0.72	0.77	0.71	0.68	0.69	0.70	0.77	0.81	0.89	0.70
	Mildura	0.87	1.09	0.84	0.96	0.72	0.77	0.80	0.90	0.98	1.07	1.04	0.81
	Perth	0.66	0.74	0.72	0.77	0.41	0.60	0.75	0.68	0.92	0.77	0.78	0.73
	Sydney	0.85	0.96	0.89	0.85	0.81	0.77	0.75	0.90	0.90	1.16	1.17	0.90
	Townsville	0.67	0.66	0.82	0.70	0.63	0.66	0.55	0.70	0.55	0.75	0.53	0.59
Worst Case (CSIRO-Mk3.5)	Adelaide	1.01	1.23	1.14	1.24	1.22	1.00	1.06	1.09	1.19	1.13	1.15	1.04
	Alice	1.10	1.89	2.04	1.85	2.11	1.84	1.85	1.77	1.43	2.16	1.77	1.74
	Brisbane	1.20	1.33	1.34	1.38	1.41	1.22	1.23	1.34	1.19	1.31	1.38	1.36
	Cabramurra	1.19	1.16	1.57	1.57	1.51	1.29	1.27	1.47	1.66	1.59	1.58	1.62
	Canberra	1.22	1.09	1.52	1.55	1.52	1.29	1.28	1.49	1.66	1.57	1.56	1.60
	Darwin	0.96	0.88	0.88	0.97	1.07	1.00	0.85	0.84	0.83	0.90	0.99	0.97
	Hobart	0.97	1.12	1.03	1.10	1.01	0.94	0.89	0.84	0.87	0.98	1.09	1.01
	Melbourne	1.20	1.46	1.41	1.51	1.37	1.13	1.18	1.29	1.47	1.55	1.49	1.43
	Mildura	1.16	1.66	1.59	1.64	1.52	1.18	1.32	1.38	1.49	1.38	1.49	1.45
	Perth	1.25	1.40	1.62	1.56	1.49	1.22	1.05	1.15	1.16	0.99	0.89	1.32
	Sydney	1.44	1.20	1.48	1.55	1.56	1.31	1.34	1.52	1.61	1.53	1.48	1.45
	Townsville	0.96	1.19	1.05	1.03	1.22	1.13	1.08	1.07	0.87	1.06	1.05	1.14

Table 18 Monthly change values relative to 1990 for maximum temperature for 2050 (B1) for 12 sites.

Climate Future	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Most Likely (INM-CM3.0)	Adelaide	0.87	1.17	0.77	0.95	0.68	0.73	0.79	0.85	0.93	0.96	0.95	0.79
	Alice	0.85	1.02	1.05	1.22	0.97	0.87	0.81	1.61	0.98	1.23	1.11	0.94
	Brisbane	0.59	0.77	0.97	0.75	0.76	0.75	0.72	0.95	0.76	1.14	0.82	0.73
	Cabramurra	1.09	1.16	0.91	0.94	0.91	0.83	0.81	0.88	0.97	1.11	1.32	1.02
	Canberra	1.09	1.15	0.95	0.96	0.92	0.84	0.83	0.93	1.00	1.19	1.36	1.06
	Darwin	0.73	0.66	0.80	0.78	0.76	0.74	0.67	0.67	0.64	0.67	0.68	0.70
	Hobart	0.72	0.85	0.69	0.71	0.67	0.66	0.65	0.70	0.63	0.64	0.71	0.64
	Melbourne	0.89	1.02	0.78	0.84	0.77	0.74	0.75	0.76	0.84	0.89	0.97	0.77
	Mildura	0.95	1.19	0.91	1.04	0.78	0.84	0.88	0.98	1.07	1.17	1.14	0.89
	Perth	0.72	0.81	0.79	0.84	0.45	0.66	0.81	0.74	1.01	0.84	0.86	0.80
	Sydney	0.93	1.05	0.97	0.93	0.89	0.84	0.82	0.99	0.98	1.26	1.28	0.98
	Townsville	0.73	0.73	0.89	0.76	0.68	0.72	0.60	0.76	0.60	0.82	0.58	0.65
Worst Case (CSIRO-Mk3.5)	Adelaide	1.10	1.34	1.25	1.35	1.33	1.09	1.16	1.19	1.30	1.23	1.26	1.14
	Alice	1.20	2.06	2.23	2.02	2.30	2.01	2.02	1.93	1.57	2.36	1.94	1.90
	Brisbane	1.31	1.45	1.47	1.51	1.54	1.34	1.34	1.46	1.31	1.43	1.51	1.49
	Cabramurra	1.30	1.26	1.71	1.71	1.65	1.41	1.39	1.61	1.81	1.74	1.72	1.77
	Canberra	1.34	1.19	1.66	1.69	1.66	1.41	1.40	1.63	1.82	1.72	1.70	1.75
	Darwin	1.05	0.97	0.96	1.06	1.17	1.09	0.93	0.92	0.90	0.99	1.08	1.06
	Hobart	1.06	1.22	1.13	1.20	1.10	1.02	0.97	0.91	0.95	1.08	1.19	1.10
	Melbourne	1.31	1.60	1.54	1.65	1.50	1.24	1.29	1.41	1.61	1.69	1.63	1.56
	Mildura	1.27	1.82	1.74	1.79	1.66	1.29	1.44	1.51	1.62	1.51	1.63	1.59
	Perth	1.37	1.53	1.77	1.71	1.63	1.33	1.15	1.26	1.27	1.08	0.98	1.45
	Sydney	1.58	1.32	1.62	1.69	1.70	1.43	1.46	1.66	1.76	1.67	1.62	1.58
	Townsville	1.05	1.30	1.14	1.13	1.33	1.23	1.18	1.17	0.95	1.16	1.15	1.24

Table 19 Monthly change values relative to 1990 for maximum temperature for 2050 (A1FI) for 12 sites.

Climate Future	Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Most Likely (INM-CM3.0)	Adelaide	1.93	2.61	1.71	2.11	1.50	1.63	1.77	1.89	2.07	2.13	2.12	1.75
	Alice	1.89	2.26	2.34	2.71	2.15	1.94	1.81	3.58	2.18	2.72	2.46	2.10
	Brisbane	1.31	1.72	2.15	1.66	1.68	1.66	1.60	2.12	1.70	2.54	1.82	1.62
	Cabramurra	2.42	2.58	2.03	2.09	2.01	1.83	1.80	1.95	2.15	2.47	2.93	2.26
	Canberra	2.42	2.57	2.10	2.13	2.04	1.87	1.83	2.08	2.21	2.65	3.03	2.35
	Darwin	1.62	1.47	1.77	1.73	1.70	1.65	1.49	1.50	1.42	1.50	1.51	1.56
	Hobart	1.61	1.90	1.53	1.57	1.48	1.47	1.45	1.55	1.40	1.42	1.58	1.41
	Melbourne	1.98	2.28	1.74	1.87	1.72	1.65	1.67	1.70	1.88	1.97	2.17	1.71
	Mildura	2.12	2.65	2.03	2.32	1.74	1.87	1.95	2.18	2.37	2.59	2.54	1.97
	Perth	1.60	1.81	1.75	1.87	0.99	1.47	1.81	1.64	2.24	1.86	1.90	1.78
	Sydney	2.08	2.33	2.16	2.06	1.97	1.86	1.83	2.20	2.18	2.81	2.85	2.18
	Townsville	1.62	1.61	1.98	1.70	1.52	1.59	1.34	1.69	1.34	1.83	1.29	1.44
Worst Case (CSIRO-Mk3.5)	Adelaide	2.45	2.98	2.78	3.00	2.96	2.42	2.58	2.65	2.90	2.73	2.80	2.52
	Alice	2.67	4.59	4.95	4.49	5.12	4.47	4.49	4.29	3.48	5.23	4.31	4.23
	Brisbane	2.92	3.22	3.26	3.35	3.43	2.97	2.98	3.25	2.90	3.17	3.35	3.30
	Cabramurra	2.90	2.81	3.80	3.80	3.66	3.12	3.09	3.57	4.02	3.86	3.83	3.94
	Canberra	2.97	2.64	3.68	3.76	3.69	3.14	3.12	3.62	4.03	3.82	3.78	3.88
	Darwin	2.33	2.15	2.13	2.36	2.60	2.43	2.07	2.05	2.00	2.19	2.40	2.35
	Hobart	2.35	2.72	2.50	2.67	2.45	2.27	2.16	2.03	2.11	2.39	2.64	2.44
	Melbourne	2.92	3.55	3.42	3.67	3.34	2.75	2.88	3.14	3.57	3.76	3.63	3.46
	Mildura	2.82	4.04	3.86	3.99	3.68	2.87	3.20	3.35	3.61	3.35	3.62	3.53
	Perth	3.04	3.40	3.93	3.79	3.63	2.96	2.56	2.79	2.82	2.40	2.17	3.21
	Sydney	3.51	2.92	3.59	3.76	3.79	3.18	3.24	3.69	3.91	3.70	3.60	3.52
	Townsville	2.34	2.90	2.54	2.51	2.96	2.73	2.61	2.60	2.12	2.57	2.56	2.76

4. Applying the projections

Projected seasonal and monthly changes are calculated relative to a 30 year period centred on 1990. This is close to the time period from which the Reference Meteorological Year (RMY) is derived (40 years centred on 1987). Accordingly, the change values can be applied directly to the RMY without additional processing.

4.1. Seasonal change data

Temperature

Since temperature change values are expressed in degrees Celsius, temperature values in the Reference Meteorological Year (RMY) can be scaled up for a selected future time-frame by simply adding the corresponding change value. However, it is anticipated that Energy Partners will use the monthly minimum and maximum change values in preference to the seasonal mean changes as this captures any change in diurnal temperature range that is projected by the model.

Relative humidity, solar radiation and windspeed

Relative humidity (%), solar radiation ($W.m^{-2}$) and windspeed ($m.s^{-1}$) change values are expressed as percentage change. Thus to modify a value from the RMY for a selected future time period, the projected percentage change should be added. In the case of relative humidity, applying a percentage change to a value that is expressed in percentage is potentially confusing, so an example is provided below.

Relative humidity value (hypothetical) for Sydney on 15 July from RMY: 50%

Projected winter change for Sydney in 2050 under the A1FI emissions scenario (Table 12): -10.57%

Projected relative humidity value for 15 July in the 2050 RMY = 50 + (50 × -0.1057) = 44.71%

4.2. Monthly change data

Maximum and minimum temperature projections are provided as monthly change values. It is understood Energy Partners have devised a method for applying these to reselect appropriate historical months (if they exist) or scale the hourly RMY temperature values in a way that reflects the diurnal temperature range projected by the climate models.

If the scaling method is to be applied, we would suggest applying the change in maximum temperature for the relevant month to RMY data for 2 pm and the change in minimum temperature to RMY data for the sunrise hour, with linear interpolation of the scaling factor in between.

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References

Australian Bureau of Meteorology (2010a) *Annual Australian Climate Statement 2009*, viewed 2 March 2010. http://www.bom.gov.au/announcements/media_releases/climate/change/20100105.shtml.

Australian Bureau of Meteorology (2010b) *Australian Climate Extremes - Trend Maps*, viewed 2 March 2010. http://www.bom.gov.au/cgi-bin/climate/change/extremes/trendmaps.cgi.

Australian Bureau of Meteorology (2010c) *Australian Climate Variability and Change - Time series graphs*, viewed 2 March 2010. http://www.bom.gov.au/cgi-bin/climate/change/timeseries.cgi.

Australian Bureau of Meteorology (2010d) *Australian Climate Variability and Change - Trend Maps*, viewed 8 April 2010. http://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi.

CSIRO and Australian Bureau of Meteorology (2007) *Climate change in Australia : technical report*, http://www.climatechangeinaustralia.gov.au/technical_report.php.

IPCC (2007) 'Summary for Policymakers.' **in** *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Eds. S Solomon, D Qin, M Manning, Z Chen, M Marquis, KB Averyt, M Tignor and HL Miller) (Cambridge University Press: Cambridge).

McVicar TR, Niel TGV, Li LT, Roderick ML, Rayner DP, Ricciardulli L, Donohue RJ (2008) 'Wind speed climatology and trends for Australia, 1975–2006: Capturing the stilling phenomenon and comparison with near-surface reanalysis output.' *Geophysical Research Letters* **35**, L20403. doi:10.1029/2008GL035627.

Nakićenović N, Swart R (2000) (Ed.) *Special Report on Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*. (Cambridge University Press: Cambridge, United Kingdom and New York, NY, USA).

National Climate Centre (2009) 'The exceptional January-February 2009 heatwave in south-eastern Australia.' Special Climate Statement 17. Australian Bureau of Meteorology, Melbourne. http://www.bom.gov.au/climate/current/statements/scs17c.pdf.

Power S, Haylock M, Colman R, Wang X (2006) 'The Predictability of Interdecadal Changes in ENSO Activity and ENSO Teleconnections.' *Journal of Climate* **19**, 4755.

Power SB, Smith IN (2007) 'Weakening of the Walker Circulation and apparent dominance of El Niño both reach record levels, but has ENSO really changed?' *Geophysical Research Letters* **34**, L18702. doi:10.1029/2007GL030854.

Rahmstorf S, Cazenave A, Church JA, Hansen JE, Keeling RF, Parker DE, Somerville RCJ (2007) 'Recent Climate Observations Compared to Projections.' *Science* **316**, 709-. 10.1126/science.1136843.

Smith I, Chandler E (2010) 'Refining rainfall projections for the Murray Darling Basin of south-east Australia—the effect of sampling model results based on performance.' *Climatic Change*. DOI 10.1007/s10584-009-9757-1.

Timbal B (2009) 'The continuing decline in south-east Australian rainfall – update to May 2009.' *CAWCR Research Letters* **2**, 4-11.

Vic DSE (2008) 'Climate change in Victoria: 2008 summary.' Victorian Department of Sustainability and Environment, Melbourne. http://www.climatechange.vic.gov.au/CA256F310024B628/0/A97991409E91EFDECA25747F000CD954/$File/DSE+state+summary+WEB.pdf.

Whetton PH, Hennessy KJ, Bates B, Kent D (2010) Regional projections and model evaluation: benefits of 'representative future regional climates' In 'Proceedings of the IPCC Model Evaluation Workshop'. Boulder, Colorado, USA. January 2010.

World Meteorological Organisation (2009) *Press Release No.869: 2000-2009, The Warmest Decade*. http://www.wmo.int/pages/mediacentre/press_releases/pr_869_en.html.