

Climate change impact across the Southland region

IPCC 6th Assessment Report update - Volume 2:
Atmospheric changes

Prepared for Environment Southland

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Contents

1	Climate variables.....	11
1.1	Air temperature.....	11
1.2	Precipitation	54
1.3	Relative humidity	81
1.4	Solar radiation	89
1.5	Cloud cover	91
1.6	Wind.....	94
1.7	Potential Evapotranspiration Deficit (PED)	112
1.8	Extreme events	116
1.9	Discussion.....	127
2	Glossary of abbreviations and terms	131
Appendix A	FMU change summary	133
Appendix B	Historic rainfall depths.....	159

Tables

Table 1-1:	Projected mean temperature changes (°C, relative to 1995-2014).	11
Table 1-2:	Projected maximum temperature changes (°C, relative to 1995-2014).	19
Table 1-3:	Projected annual changes to average daily maximum temperature (°C).	19
Table 1-4:	Projected minimum temperature changes (°C, relative to 1995-2014).	27
Table 1-5:	Projected annual changes to average daily minimum temperature (°C).	27
Table 1-6:	Projected daily temperature range changes (°C, relative to 1995-2014).	35
Table 1-7:	Projected annual hot day changes (days, relative to 1995-2014).	42
Table 1-8:	Projected changes to the number of annual hot days.	42
Table 1-9:	Projected annual cold nights changes (days, relative to 1995-2014).	45
Table 1-10:	Projected changes to the number of annual cold nights.	45
Table 1-11:	Projected mean temperature changes (°C, relative to 1995-2014).	48
Table 1-12:	Projected changes to annual time spent in heatwave (days).	48
Table 1-13:	Projected growing degree day (base 10°C) changes (days, relative to 1995-2014).	51
Table 1-14:	Projected total rainfall changes (% , relative to 1995-2014).	54
Table 1-15:	Projected wet day changes (days, relative to 1995-2014).	61
Table 1-16:	Projected changes to number of wet days.	61
Table 1-17:	Projected rain days above 10 mm changes (days, relative to 1995-2014).	64
Table 1-18:	Projected changes to number of rain days above 10mm (days).	64
Table 1-19:	Projected very wet day changes (days, relative to 1995-2014).	67

Table 1-20:	Projected changes to number of very wet days.	67
Table 1-21:	Projected rain days as above 50 mm (days, relative to 1995-2014).	70
Table 1-22:	Projected changes to number of rain days as above 50 mm (days).	70
Table 1-23:	Projected maximum annual 1-day rainfall total changes (mm/day, relative to 1995-2014).	73
Table 1-24:	Projected maximum annual 5-day rainfall total changes (mm/day, relative to 1995-2014).	75
Table 1-25:	Projected percentage change factors to rainfall depths per 1 degree of warming.	77
Table 1-26:	Projected annual mean temperature changes for Southland.	77
Table 1-27:	Projected mean temperature changes (°C, relative to 1995-2014).	78
Table 1-28:	Projected changes to number of dry days (days).	78
Table 1-29:	Projected relative humidity changes (% , relative to 1995-2014).	81
Table 1-30:	Projected solar radiation changes (W m^{-2} , relative to 1995-2014).	89
Table 1-31:	Projected cloud cover changes %, relative to 1995-2014).	91
Table 1-32:	Projected average wind speed changes (°C, relative to 1995-2014).	94
Table 1-33:	Projected calm day changes changes (°C, relative to 1995-2014).	103
Table 1-34:	Projected changes to the number of annual calm days ($<1.5 \text{ m s}^{-1}$).	103
Table 1-35:	Projected windy day changes (days, relative to 1995-2014).	106
Table 1-36:	Projected strong wind (99 th percentile) changes (% , relative to 1995-2014).	109
Table 1-37:	Projected PED accumulation changes (mm, relative to 1995-2014).	112
Table 1-38:	Projected probability of annual PED accumulation $>200 \text{ mm}$ changes (% , relative to 1995-2014).	114
Table 1-39:	Projected change in PMP rainfall depth for 12-24-48 and 72 hrs storm duration (°C, relative to DSHG updated PMP rainfall depth under current warming level).	116
Table 1-40:	Historical PMP rainfall depth estimation for 12hr -24 hr- 48 hr and 72 hr storm event duration.	117
Table 1-41:	Timing of the historical maximum annual 1-day rainfall total over the period 1995-2014 for each CMIP6's GCMs.	118
Table 1-42:	PMP magnitude under 1.0°C , 2.0°C and 3.0°C warming for storm duration of 12 hr-24 hr-48 hr and 72 hr.	120
Table 1-43:	Projected meteorological drought frequency changes (days, relative to 1995-2014).	123
Table 1-44:	Projected changes to annual meteorological drought frequency (days).	123
Table A-1:	FMU projected mean temperature changes (°C, relative to 1995-2014).	133
Table A-2:	FMU projected winter mean temperature changes (°C, relative to 1995-2014).	133
Table A-3:	FMU projected spring mean temperature changes (°C, relative to 1995-2014).	133
Table A-4:	FMU projected mean summer temperature changes (°C, relative to 1995-2014).	133
Table A-5:	FMU projected autumn mean temperature changes (°C, relative to 1995-2014).	134

Table A-6:	FMU projected minimum temperature changes (°C, relative to 1995-2014).	135
Table A-7:	FMU projected winter minimum temperature changes (°C, relative to 1995-2014).	135
Table A-8:	FMU projected spring minimum temperature changes (°C, relative to 1995-2014).	135
Table A-9:	FMU projected summer minimum temperature changes (°C, relative to 1995-2014).	135
Table A-10:	FMU projected autumn minimum temperature changes (°C, relative to 1995-2014).	136
Table A-11:	FMU projected maximum temperature changes (°C, relative to 1995-2014).	137
Table A-12:	FMU projected winter maximum temperature changes (°C, relative to 1995-2014).	137
Table A-13:	FMU projected spring maximum temperature changes (°C, relative to 1995-2014).	137
Table A-14:	FMU projected summer maximum temperature changes (°C, relative to 1995-2014).	137
Table A-15:	FMU projected autumn maximum temperature changes (°C, relative to 1995-2014).	138
Table A-16:	FMU projected changes to annual number of hot days (days, relative to 1995-2014).	139
Table A-17:	FMU projected changes to number of winter hot days (days, relative to 1995-2014).	139
Table A-18:	FMU projected changes to number of spring hot days days, relative to 1995-2014).	139
Table A-19:	FMU projected changes to number of summer hot days (days, relative to 1995-2014).	139
Table A-20:	FMU projected changes to number of autumn hot days (days, relative to 1995-2014).	140
Table A-21:	FMU projected changes to annual time spent in heatwave (days, relative to 1995-2014).	141
Table A-22:	FMU projected changes in number of annual cold nights (-, relative to 1995-2014).	142
Table A-23:	FMU projected changes in number of winter cold nights (-, relative to 1995-2014).	142
Table A-24:	FMU projected changes in number of spring cold nights (-, relative to 1995-2014).	142
Table A-25:	FMU projected changes in number of summer cold nights (-, relative to 1995-2014).	142
Table A-26:	FMU projected changes in number of autumn cold nights (-, relative to 1995-2014).	143
Table A-27:	FMU projected changes in number growing degree day (base 10°C) (days, relative to 1995-2014).	144
Table A-28:	FMU projected total annual rainfall changes (% relative to 1995-2014).	145
Table A-29:	FMU projected winter total annual rainfall changes (% relative to 1995-2014).	145

Table A-30:	FMU projected spring total rainfall changes (% , relative to 1995-2014).	145
Table A-31:	FMU projected summer total rainfall changes (% , relative to 1995-2014).	145
Table A-32:	FMU projected autumn total rainfall changes (% , relative to 1995-2014).	146
Table A-33:	FMU projected annual wet day changes (days relative to 1995-2014).	147
Table A-34:	FMU projected changes in winter wet day (days, relative to 1995-2014).	147
Table A-35:	FMU projected changes in spring wet days (days, relative to 1995-2014).	147
Table A-36:	FMU projected summer wet day changes (°C, relative to 1995-2014).	147
Table A-37:	FMU projected changes in autumn wet days (days, relative to 1995-2014).	148
Table A-38:	FMU projected changes in number of rain days above 10 mm (day, relative to 1995-2014).	149
Table A-39:	FMU projected changes in number of rain days above 25mm (day, relative to 1995-2014).	149
Table A-40:	FMU projected changes in number of rain days above 50 mm (day, relative to 1995-2014).	149
Table A-41:	FMU projected changes in maximum annual 1-day rainfall total changes (mm/day, relative to 1995-2014).	150
Table A-42:	FMU projected changes in maximum annual 5-day rainfall total changes (mm/day, relative to 1995-2014).	150
Table A-43:	FMU projected annual dry day changes (day, relative to 1995-2014).	151
Table A-44:	FMU projected winter dry day changes (day, relative to 1995-2014).	151
Table A-45:	FMU projected spring dry day changes (days, relative to 1995-2014).	151
Table A-46:	FMU projected summer dry day changes (days, relative to 1995-2014).	151
Table A-47:	FMU projected autumn dry day changes (days, relative to 1995-2014).	152
Table A-48:	FMU projected PED accumulation changes (mm, relative to 1995-2014).	153
Table A-49:	FMU projected winter PED accumulation changes (mm, relative to 1995-2014).	153
Table A-50:	FMU projected spring PED accumulation changes (mm, relative to 1995-2014).	153
Table A-51:	FMU projected summer PED accumulation changes (mm, relative to 1995-2014).	153
Table A-52:	FMU projected autumn PED accumulation changes (mm, relative to 1995-2014).	154
Table A-53:	FMU projected relative humidity changes (% , relative to 1995-2014).	155
Table A-54:	FMU projected winter relative humidity changes (% , relative to 1995-2014).	155
Table A-55:	FMU projected spring relative humidity changes (% , relative to 1995-2014).	155
Table A-56:	FMU projected summer relative humidity changes (% , relative to 1995-2014).	155
Table A-57:	FMU projected autumn relative humidity changes (% , relative to 1995-2014).	156

Table A-58:	FMU projected wind speed changes (% , relative to 1995-2014).	157
Table A-59:	FMU projected winter wind speed changes (% , relative to 1995-2014).	157
Table A-60:	FMU projected spring wind speed changes (% , relative to 1995-2014).	157
Table A-61:	FMU projected summer wind speed changes (% , relative to 1995-2014).	157
Table A-62:	FMU projected autumn wind speed changes (% , relative to 1995-2014).	158
Table B-1:	Bluff historic rainfall depths across various event ARI/duration combinations.	159
Table B-2:	Fairlight at Cainard Station historic rainfall depths across various event ARI/duration combinations.	159
Table B-3:	Fiver Rivers at Five Rivers Station historic rainfall depths across various event ARI/duration combinations.	160
Table B-4:	Garston historic rainfall depths across various event ARI/duration combinations.	160
Table B-5:	Glenlapa at Round Hill historic rainfall depths across various event ARI/duration combinations.	161
Table B-6:	Gore historic rainfall depths across various event ARI/duration combinations.	161
Table B-7:	Hamilton Burn at Mt Hamilton Road historic rainfall depths across various event ARI/duration combinations.	162
Table B-8:	Hokonui Hills at Lora Station historic rainfall depths across various event ARI/duration combinations.	162
Table B-9:	Invercargill historic rainfall depths across various event ARI/duration combinations.	163
Table B-10:	Lumsden historic rainfall depths across various event ARI/duration combinations.	163
Table B-11:	Mataura historic rainfall depths across various event ARI/duration combinations.	164
Table B-12:	McKellars Flat at Gorge Burn historic rainfall depths across various event ARI/duration combinations.	164
Table B-13:	Milford Sound historic rainfall depths across various event ARI/duration combinations.	165
Table B-14:	Mokoreta at Mt Alexander historic rainfall depths across various event ARI/duration combinations.	165
Table B-15:	Mossburn historic rainfall depths across various event ARI/duration combinations.	166
Table B-16:	Mossburn historic rainfall depths across various event ARI/duration combinations.	166
Table B-17:	Ohai at Wether Hill Station historic rainfall depths across various event ARI/duration combinations.	167
Table B-18:	Otautau historic rainfall depths across various event ARI/duration combinations.	167
Table B-19:	Pourakino Valley at Cascade Road historic rainfall depths across various event ARI/duration combinations.	168
Table B-20:	Riversdale historic rainfall depths across various event ARI/duration combinations.	168

Table B-21:	Riverton historic rainfall depths across various event ARI/duration combinations.	169
Table B-22:	Te Anau historic rainfall depths across various event ARI/duration combinations.	169
Table B-23:	Tuatapere historic rainfall depths across various event ARI/duration combinations.	170
Table B-24:	Waiau River at Clifden historic rainfall depths across various event ARI/duration combinations.	170
Table B-25:	Waikaia River at Piano Flat historic rainfall depths across various event ARI/duration combinations.	171
Table B-26:	Waikaka historic rainfall depths across various event ARI/duration combinations.	171
Table B-27:	Wendon Valley at Waikaka historic rainfall depths across various event ARI/duration combinations.	172
Table B-28:	Whitestone Aquifer at Lynwood historic rainfall depths across various event ARI/duration combinations.	172
Table B-29:	Winton historic rainfall depths across various event ARI/duration combinations.	173
Table B-30:	Woodlands at Garvie Road historic rainfall depths across various event ARI/duration combinations.	173

Figures

Figure 1-1:	Modelled historic annual mean temperature.	12
Figure 1-2:	Projected annual mean temperature changes.	13
Figure 1-3:	Modelled historic seasonal mean temperature.	14
Figure 1-4:	Projected summer mean temperature changes.	15
Figure 1-5:	Projected autumn mean temperature changes.	16
Figure 1-6:	Projected winter mean temperature changes.	17
Figure 1-7:	Projected spring mean temperature changes.	18
Figure 1-8:	Modelled historic annual average daily maximum temperature.	20
Figure 1-9:	Projected annual average daily maximum temperature changes.	21
Figure 1-10:	Modelled historic seasonal average daily maximum temperature.	22
Figure 1-11:	Projected summer average daily maximum temperature changes.	23
Figure 1-12:	Projected autumn average daily maximum temperature changes.	24
Figure 1-13:	Projected winter average daily maximum temperature changes.	25
Figure 1-14:	Projected spring average daily maximum temperature changes.	26
Figure 1-15:	Modelled historic annual average daily minimum temperature.	28
Figure 1-16:	Projected annual average daily minimum temperature changes.	29
Figure 1-17:	Modelled historic seasonal average daily minimum temperature.	30
Figure 1-18:	Projected summer average daily minimum temperature changes.	31
Figure 1-19:	Projected autumn average daily minimum temperature changes.	32
Figure 1-20:	Projected winter average daily minimum temperature changes.	33
Figure 1-21:	Projected spring average daily minimum temperature changes.	34
Figure 1-22:	Modelled historic annual average daily temperature range.	35
Figure 1-23:	Projected annual average daily temperature range changes.	36

Figure 1-24:	Modelled historic seasonal average daily temperature range.	37
Figure 1-25:	Projected summer average daily temperature range changes.	38
Figure 1-26:	Projected autumn average daily temperature range changes.	39
Figure 1-27:	Projected winter average daily temperature range changes.	40
Figure 1-28:	Projected spring average daily temperature range changes.	41
Figure 1-29:	Modelled historic average annual number of hot days.	43
Figure 1-30:	Projected annual hot day changes.	44
Figure 1-31:	Modelled historic average annual number of cold nights.	46
Figure 1-32:	Projected annual cold night changes.	47
Figure 1-33:	Modelled historic average annual heatwave frequency.	49
Figure 1-34:	Projected annual heatwave frequency changes.	50
Figure 1-35:	Modelled historic average annual growing degree days.	52
Figure 1-36:	Projected annual growing degree day changes.	53
Figure 1-37:	Modelled historic average annual total rainfall.	54
Figure 1-38:	Projected annual average total rainfall changes.	55
Figure 1-39:	Modelled historic average seasonal total rainfall.	56
Figure 1-40:	Projected summer average total rainfall changes.	57
Figure 1-41:	Projected autumn average total rainfall changes.	58
Figure 1-42:	Projected winter average total rainfall changes.	59
Figure 1-43:	Projected Spring average total rainfall changes.	60
Figure 1-44:	Modelled historic average annual number of wet days.	62
Figure 1-45:	Projected annual wet day changes.	63
Figure 1-46:	Modelled historic average annual number of rain days (>10mm).	65
Figure 1-47:	Projected annual rain day (>10 mm) changes.	66
Figure 1-48:	Modelled historic average annual number of very wet days.	68
Figure 1-49:	Projected annual very wet day changes.	69
Figure 1-50:	Modelled historic average annual number of rain days (>50 mm).	71
Figure 1-51:	Projected annual rain day (>50 mm) changes.	72
Figure 1-52:	Modelled historic average maximum annual 1-day rainfall total.	73
Figure 1-53:	Projected changes to the average maximum annual 1-day rainfall total.	74
Figure 1-54:	Modelled historic average maximum annual 5-day rainfall total.	75
Figure 1-55:	Projected changes to the average maximum annual 5-day rainfall total.	76
Figure 1-56:	Modelled historic average annual number of dry days.	79
Figure 1-57:	Projected annual dry day changes.	80
Figure 1-58:	Modelled historic annual average relative humidity.	82
Figure 1-59:	Projected annual average relative humidity changes.	83
Figure 1-60:	Modelled historic seasonal average relative humidity.	84
Figure 1-61:	Projected summer average relative humidity changes.	85
Figure 1-62:	Projected autumn average relative humidity changes.	86
Figure 1-63:	Projected winter average relative humidity changes.	87
Figure 1-64:	Projected spring average relative humidity changes.	88
Figure 1-65:	Modelled historic annual average solar radiation.	89
Figure 1-66:	Projected annual average solar radiation changes.	90
Figure 1-67:	Modelled historic annual average cloud cover.	92

Figure 1-68:	Projected annual average cloud cover changes.	93
Figure 1-69:	Modelled historic annual average wind speed.	95
Figure 1-70:	Projected annual average wind speed changes.	96
Figure 1-71:	Modelled historic seasonal average wind speed.	97
Figure 1-72:	Projected summer average wind speed changes.	98
Figure 1-73:	Projected autumn average wind speed changes.	99
Figure 1-74:	Projected winter average wind speed changes.	100
Figure 1-75:	Projected spring average wind speed changes.	101
Figure 1-76:	Invercargill wind rose for a) 2004 (left), and b) 2050 under SSP2-4.5.	102
Figure 1-77:	Invercargill wind rose for a) 2004 (left), and b) 2090 under SSP5-8.5.	102
Figure 1-78:	Modelled historic average annual number of calm days.	104
Figure 1-79:	Projected annual average calm days changes.	105
Figure 1-80:	Modelled historic average annual number of windy days.	107
Figure 1-81:	Projected annual average windy days changes.	108
Figure 1-82:	Modelled historic average annual strong wind speed.	110
Figure 1-83:	Projected annual average strong wind changes.	111
Figure 1-84:	Modelled historic average annual potential evapotranspiration deficit accumulation.	112
Figure 1-85:	Projected annual potential evapotranspiration deficit accumulation changes.	113
Figure 1-86:	Modelled historic annual probability of PED accumulation >200 mm.	114
Figure 1-87:	Projected change in probability of annual PED accumulation >200 mm.	115
Figure 1-88:	Change in PMP rainfall depth with air temperature.	123
Figure 1-89:	Modelled historic average annual meteorological drought frequency.	125
Figure 1-90:	Projected annual meteorological drought frequency changes.	126

1 Climate variables

This report is the second volume associated with the “Climate change impact across the Southland region- IPCC 6th Assessment Report update” report. Volume 2 presents the results of the expected changes across the atmospheric domain.

1.1 Air temperature

1.1.1 Mean temperature

Modelled historic and projected changes to future annual and seasonal mean temperature are illustrated in Figure 1-1 to Figure 1-7. Regional average projected changes are summarised in Table 1-1. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-1: Projected mean temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+1.0	+1.8	+1.2	+2.8	+1.3	+3.4
Summer	+1.1	+1.8	+1.4	+3.0	+1.3	+3.5
Autumn	+1.1	+1.8	+1.2	+2.8	+1.3	+3.5
Winter	+1.0	+1.9	+1.2	+2.8	+1.4	+3.6
Spring	+0.9	+1.6	+1.2	+2.5	+1.2	+3.2

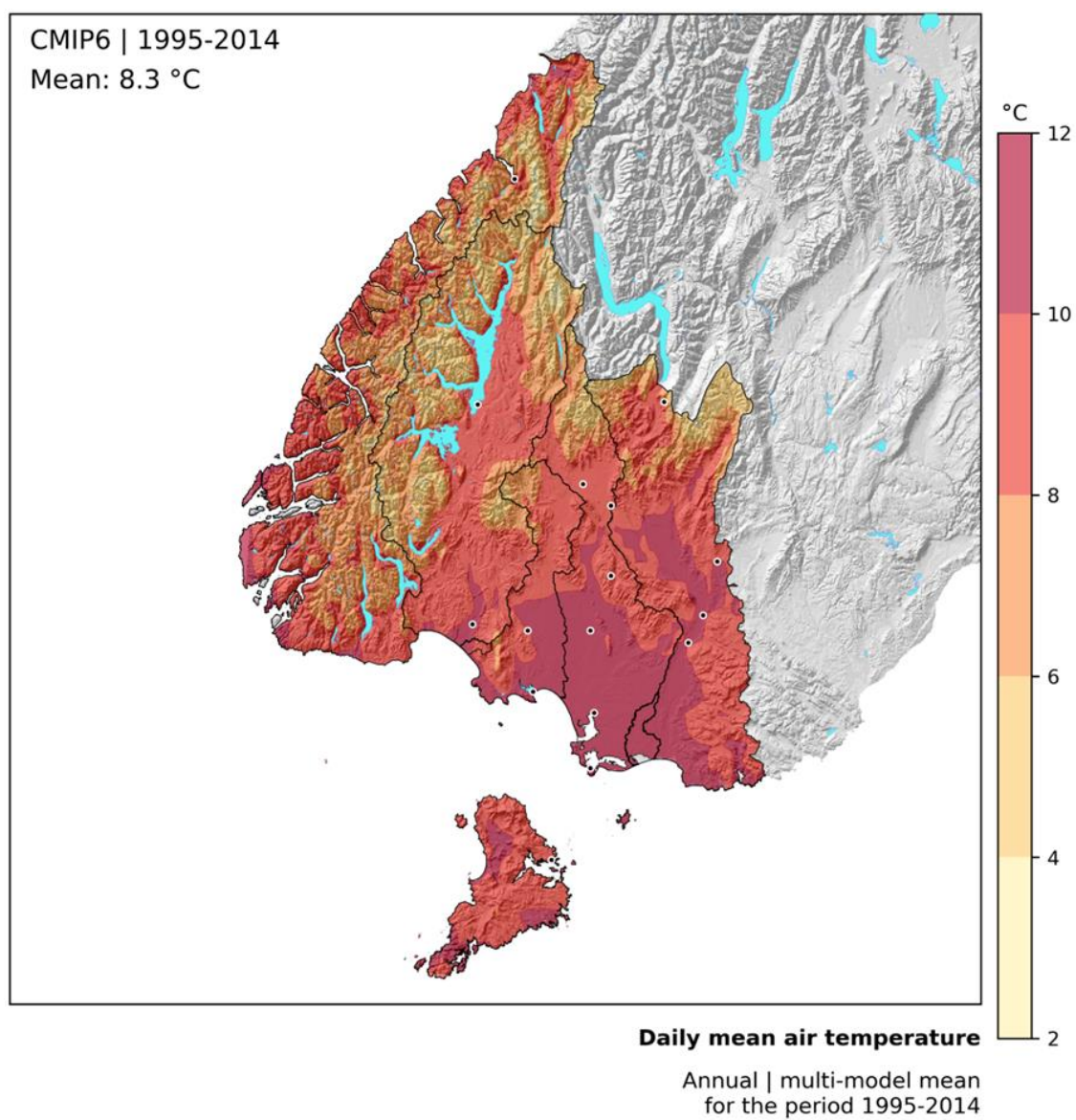


Figure 1-1: Modelled historic annual mean temperature.

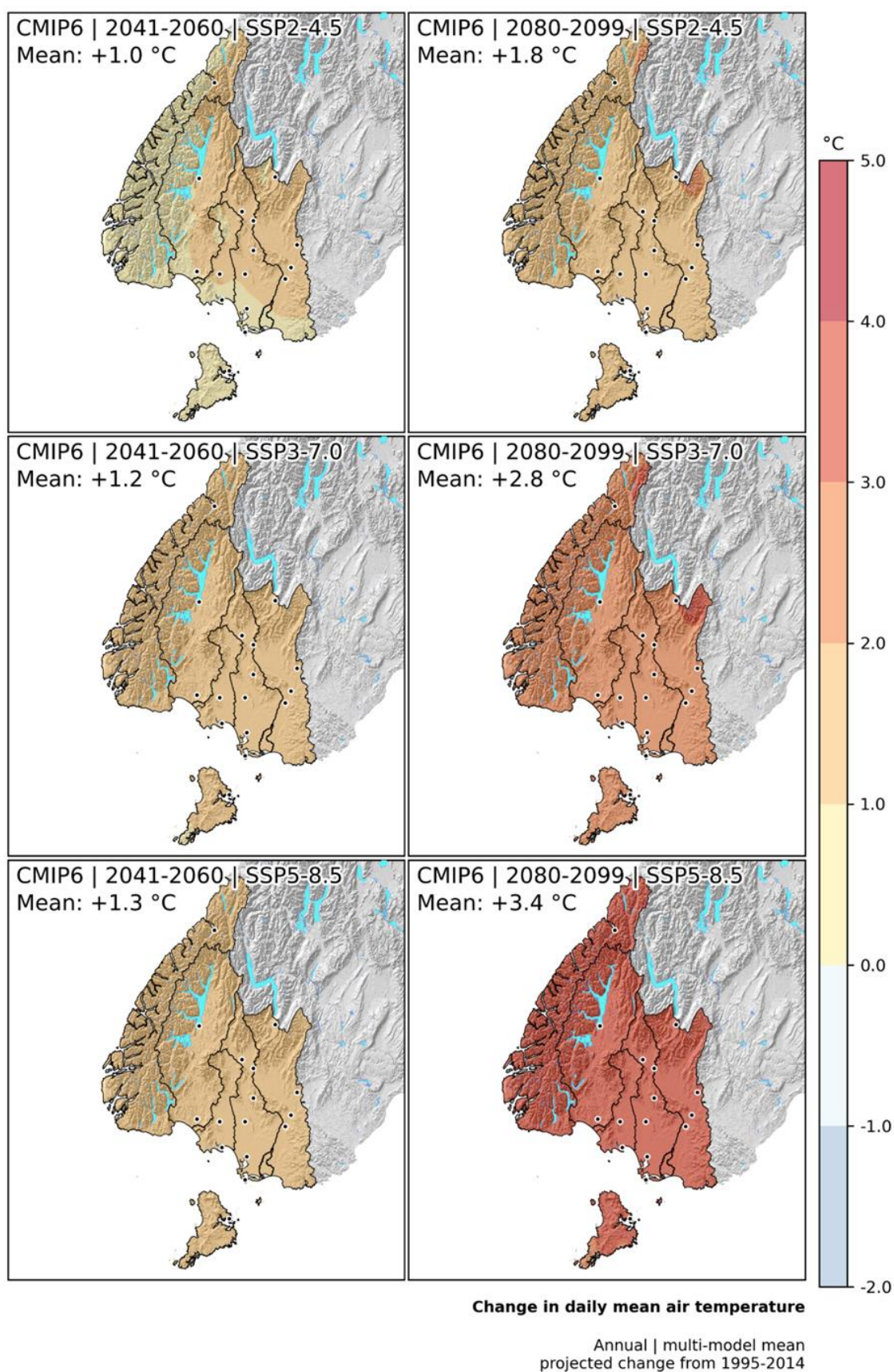
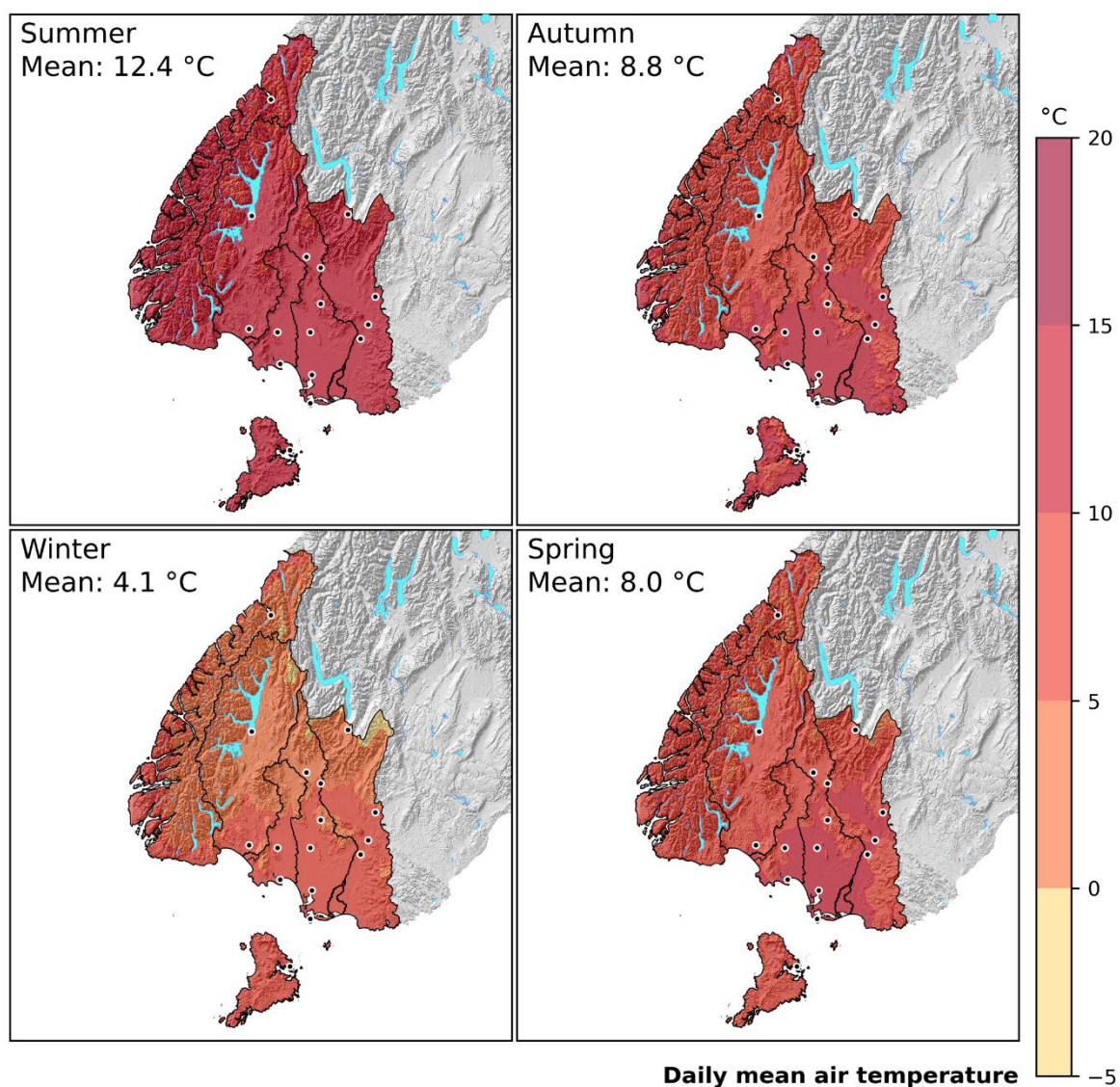


Figure 1-2: Projected annual mean temperature changes.



multi-model mean | for the period 1995-2014

Figure 1-3: Modelled historic seasonal mean temperature.

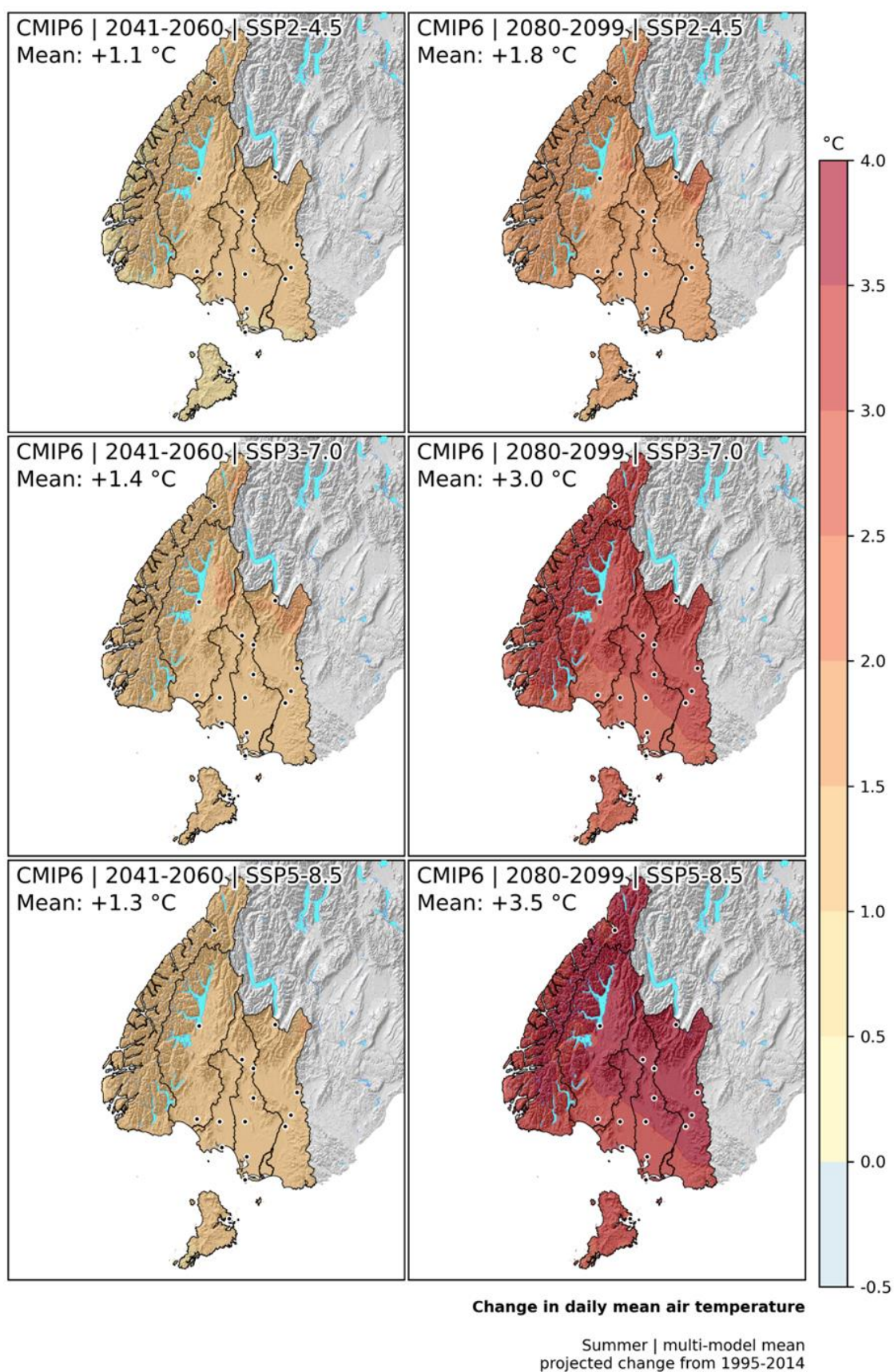


Figure 1-4: Projected summer mean temperature changes.

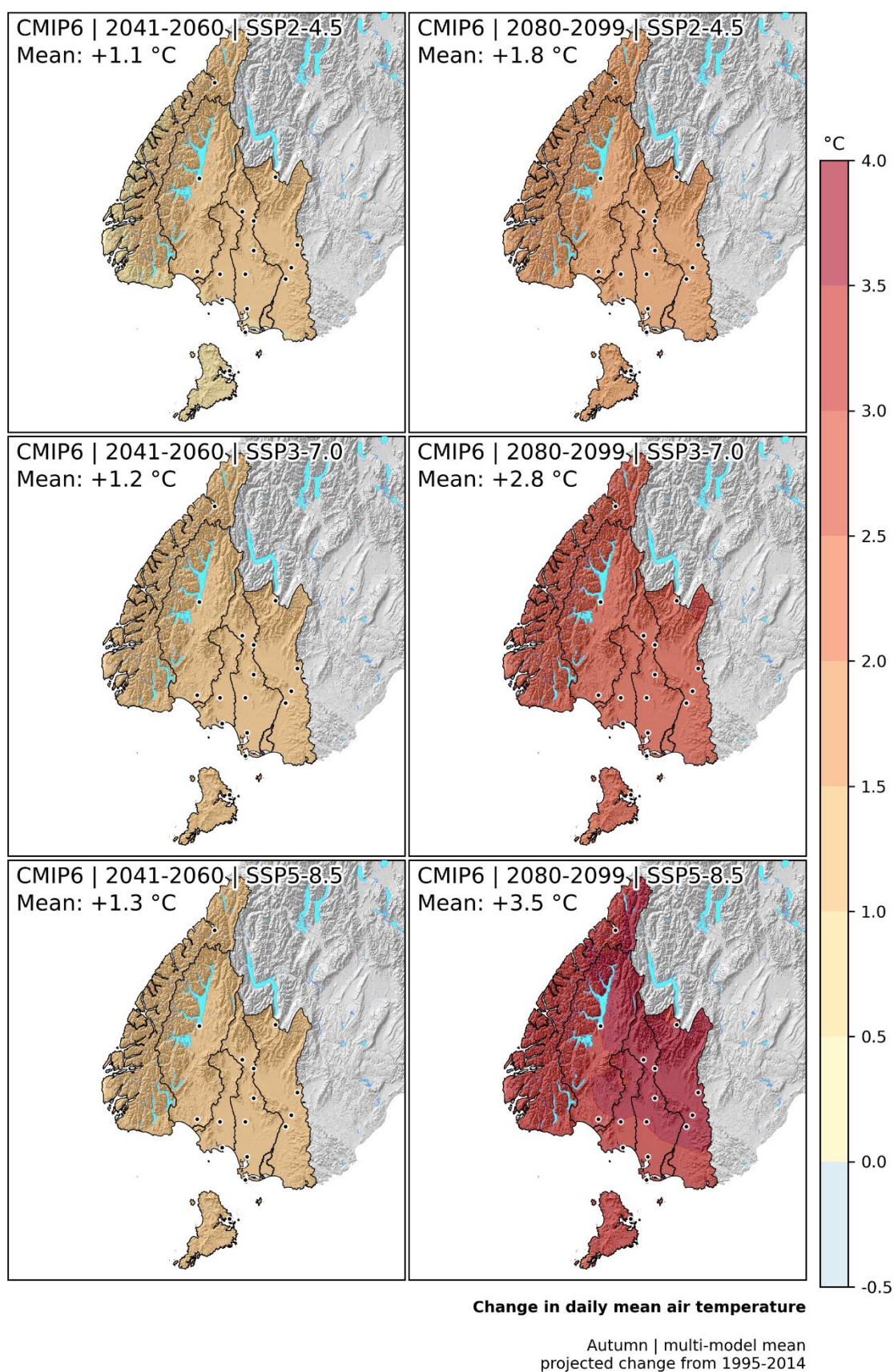


Figure 1-5: Projected autumn mean temperature changes.

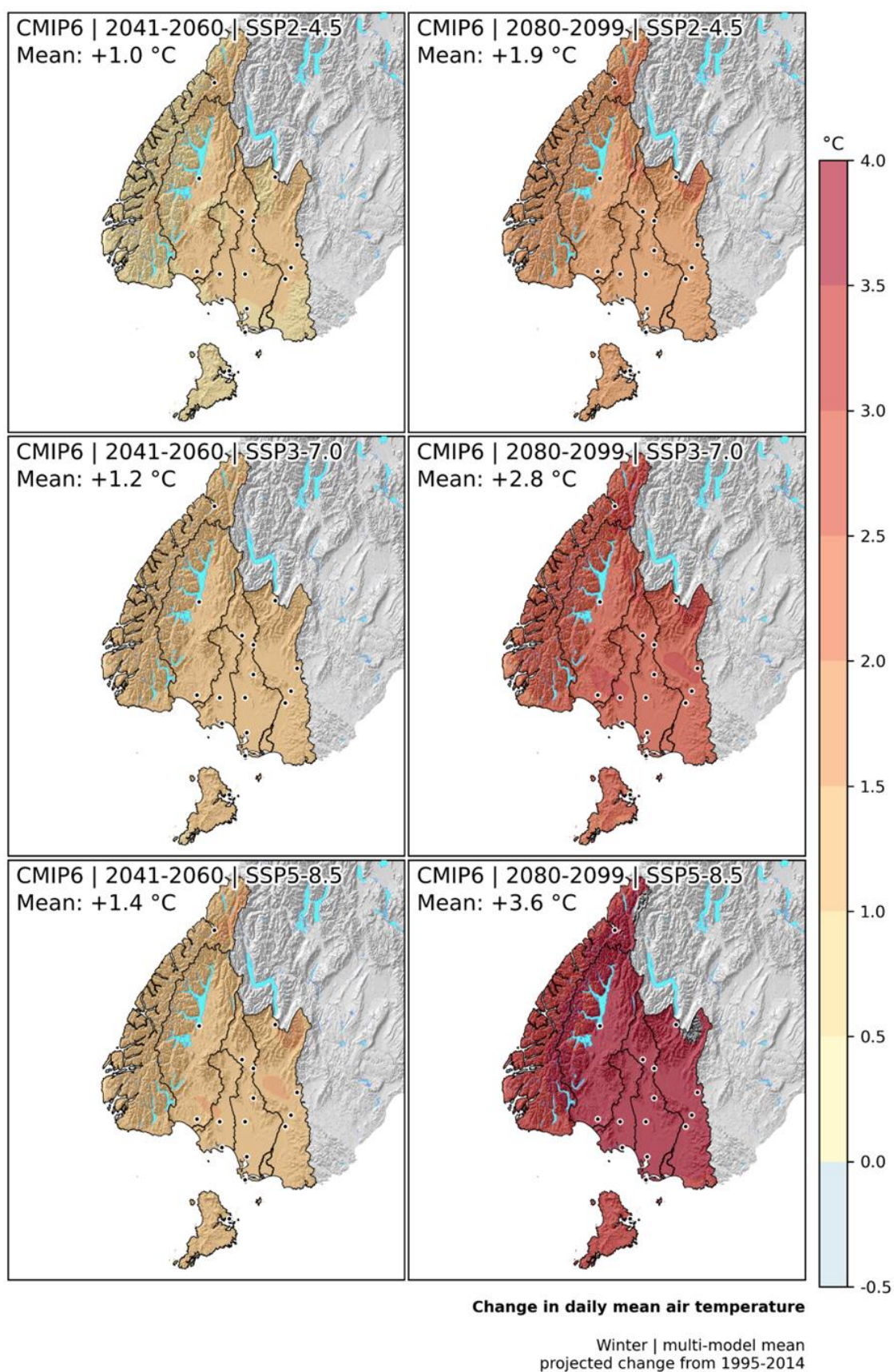


Figure 1-6: Projected winter mean temperature changes.

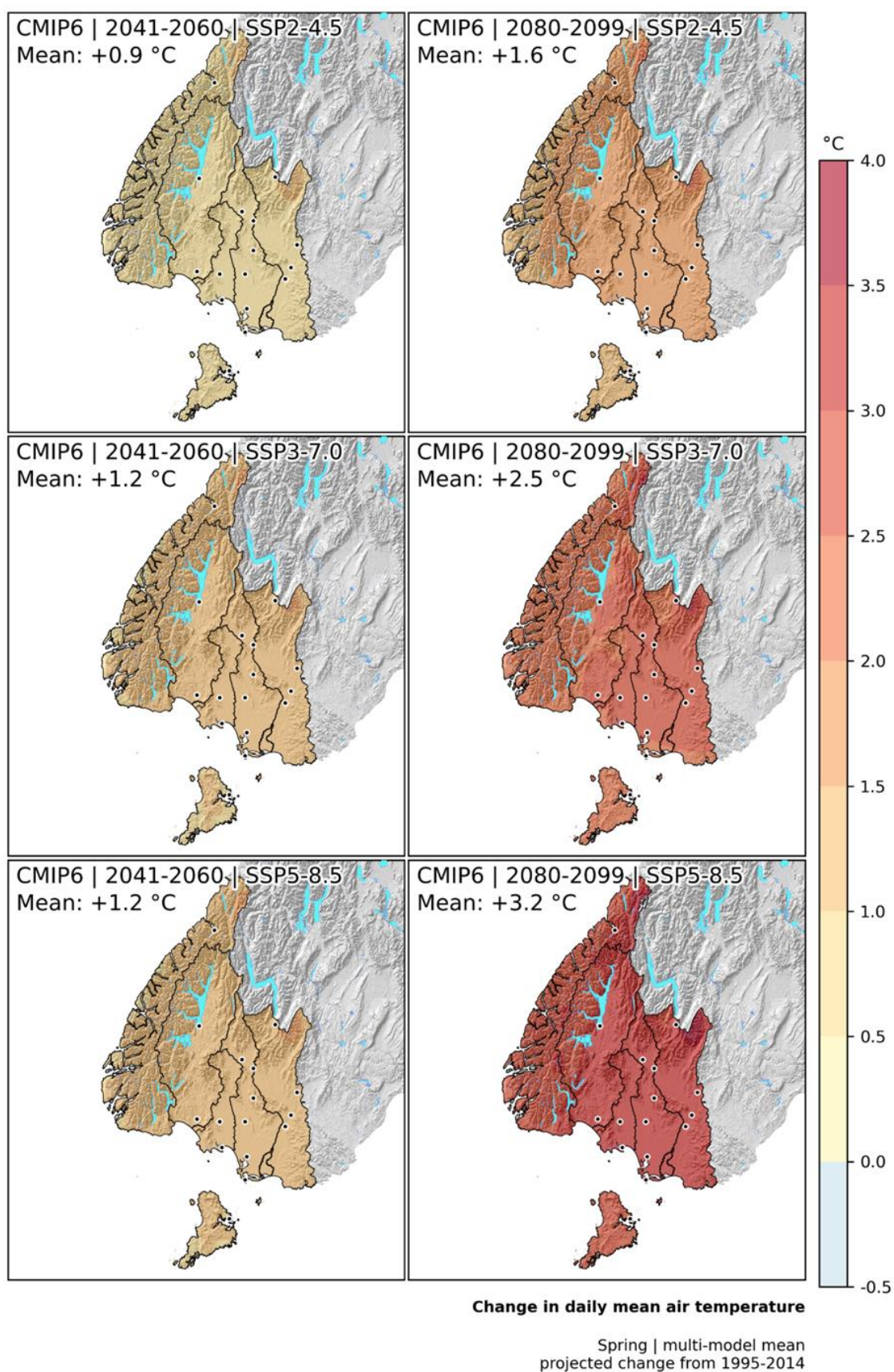


Figure 1-7: Projected spring mean temperature changes.

1.1.2 Maximum temperature

Modelled historic and projected changes to future annual and seasonal average daily maximum temperature are illustrated in Figure 1-8 to Figure 1-14. Regional average projected changes are summarised in Table 1-4, while location-specific projected changes are shown in Table 1-2. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-2: Projected maximum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	1.0	1.8	1.3	2.9	1.4	3.6
Summer	1.2	2.0	1.5	3.3	1.4	3.9
Autumn	1.1	1.9	1.3	3.0	1.4	3.7
Winter	1.0	1.9	1.2	2.9	1.4	3.7
Spring	0.9	1.6	1.2	2.5	1.2	3.2

Table 1-3: Projected annual changes to average daily maximum temperature (°C).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	1.0	1.8	1.3	2.9	1.3	3.6
Riverton	1.0	1.8	1.3	2.9	1.4	3.6
Mataura	1.1	1.9	1.4	3.1	1.4	3.8
Gore	1.1	1.9	1.4	3.1	1.5	3.8
Winton	1.1	1.9	1.3	3.0	1.4	3.7
Lumsden	1.1	1.9	1.4	3.0	1.4	3.8
Te Anau	1.0	1.8	1.3	2.9	1.3	3.6
Otautau	1.0	1.8	1.3	2.9	1.4	3.7
Tuatapere	1.0	1.8	1.3	2.9	1.4	3.6
Oban	0.9	1.6	1.1	2.6	1.1	3.2
Riversdale	1.1	1.9	1.4	3.0	1.4	3.8
Waikaka	1.1	2.0	1.4	3.1	1.5	3.9
Milford Sound	1.1	1.9	1.4	3.0	1.4	3.7
Garston	1.2	2.0	1.5	3.2	1.5	3.9
Mossburn	1.1	1.9	1.4	3.0	1.4	3.8
Bluff	1.0	1.7	1.2	2.8	1.3	3.4

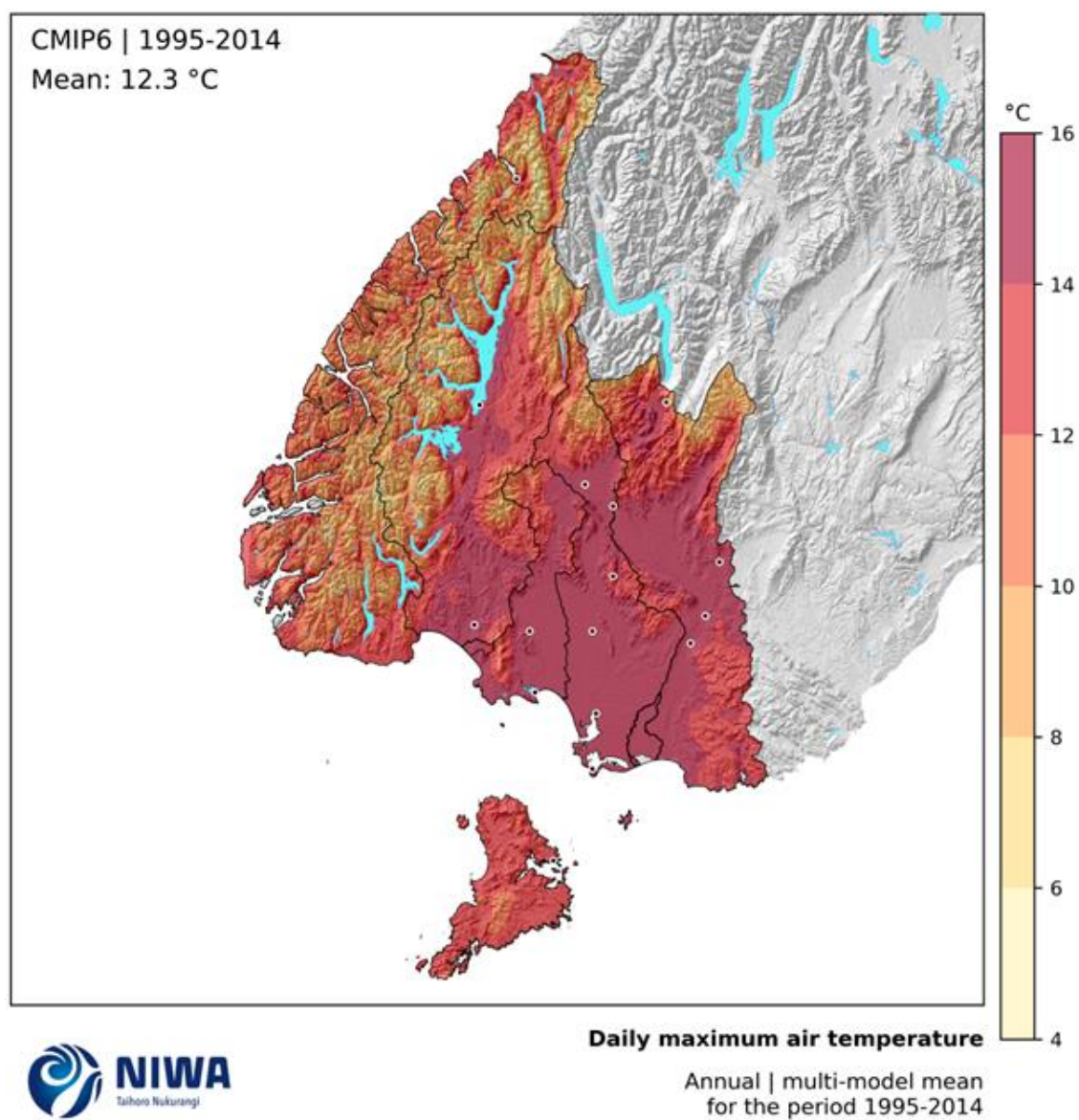


Figure 1-8: Modelled historic annual average daily maximum temperature.

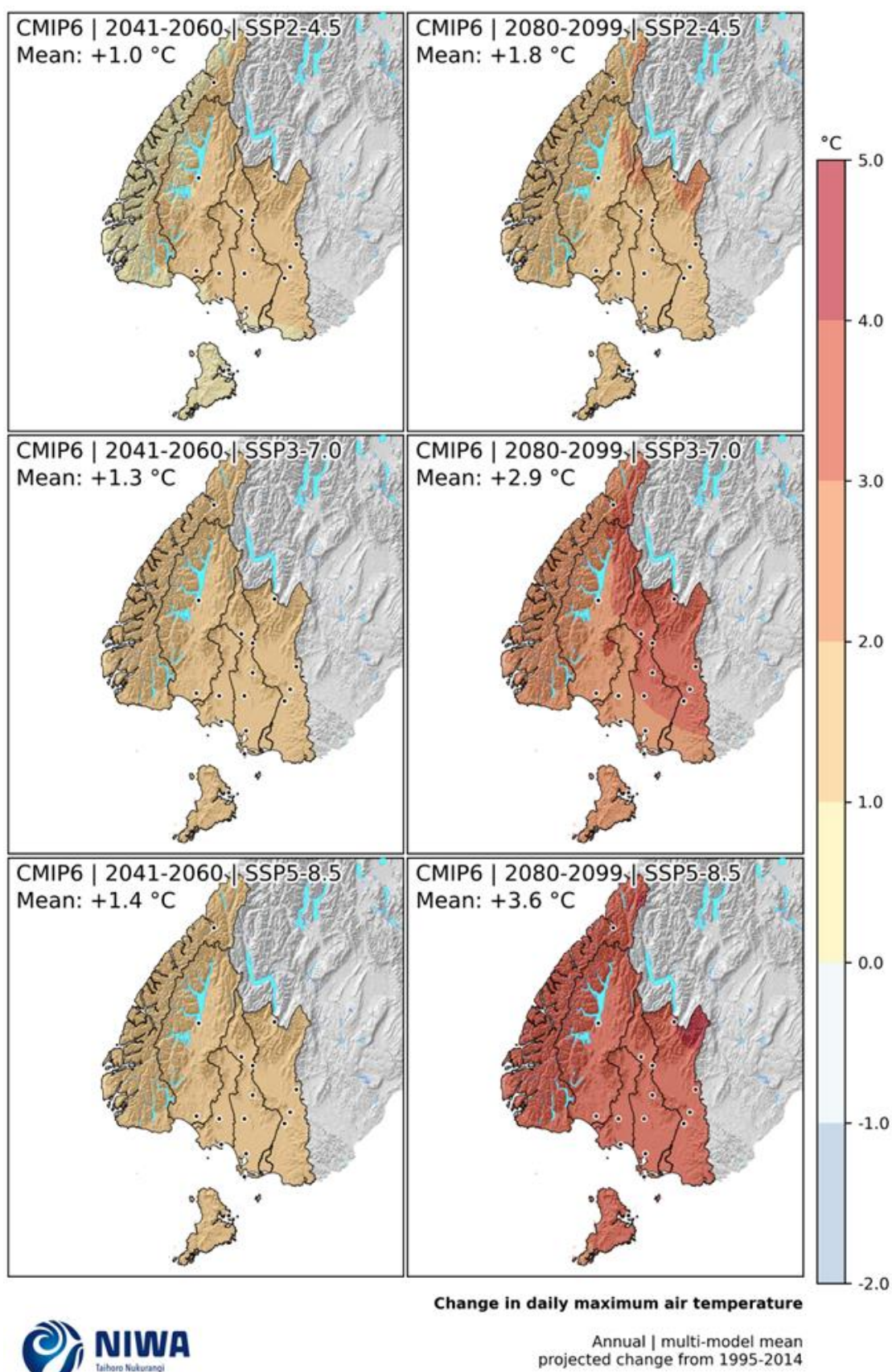


Figure 1-9: Projected annual average daily maximum temperature changes.

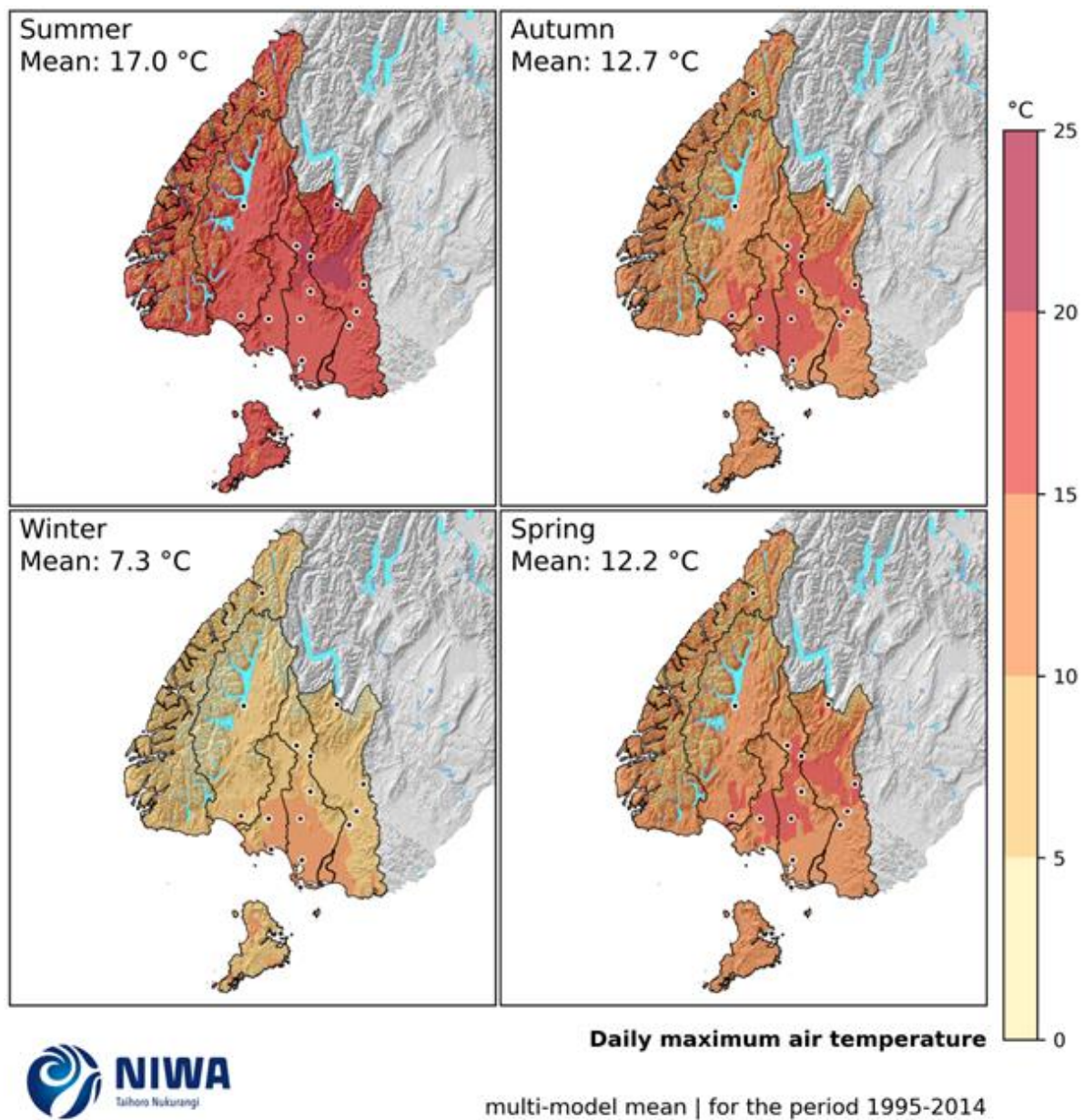


Figure 1-10: Modelled historic seasonal average daily maximum temperature.

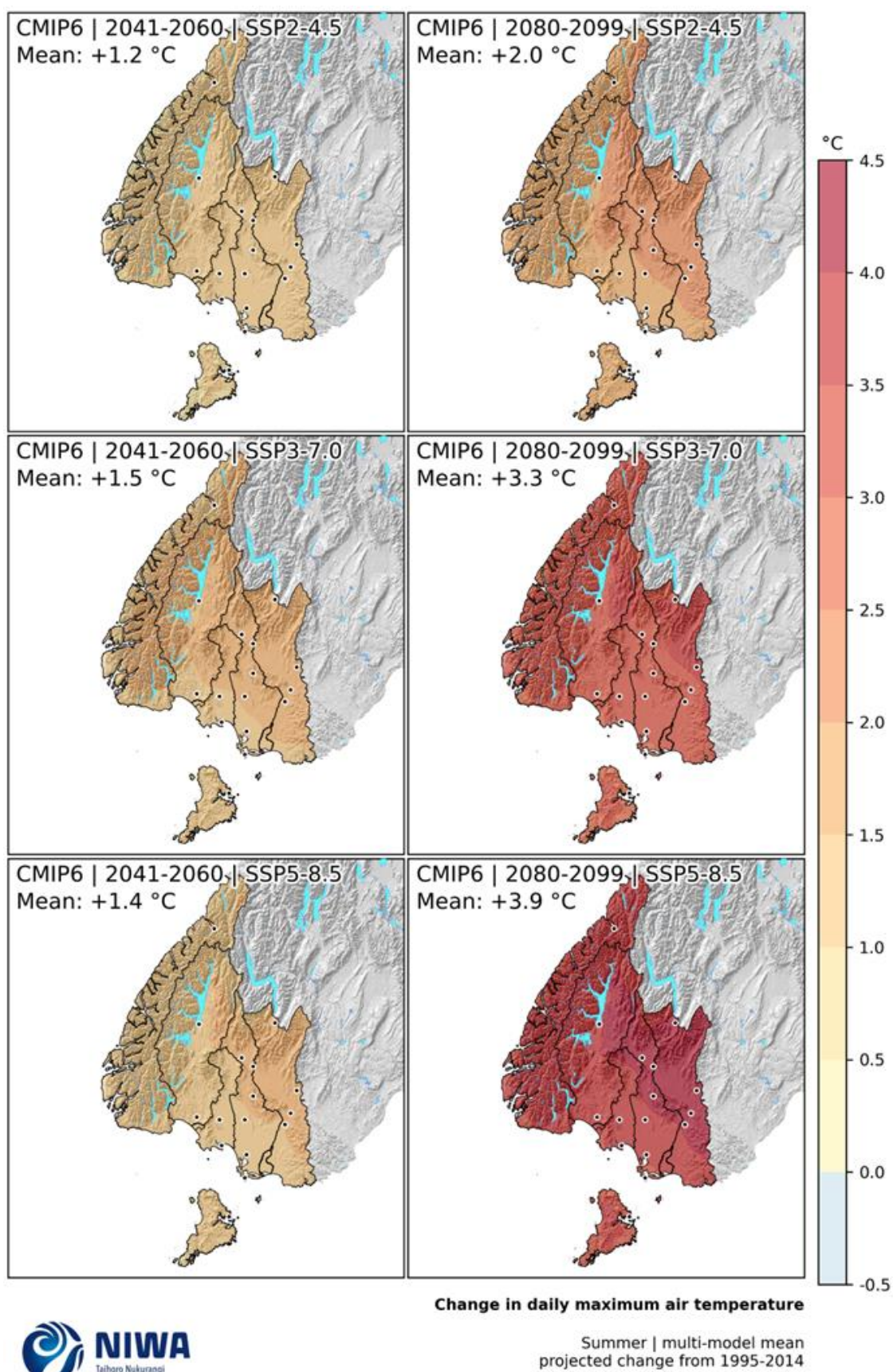


Figure 1-11: Projected summer average daily maximum temperature changes.

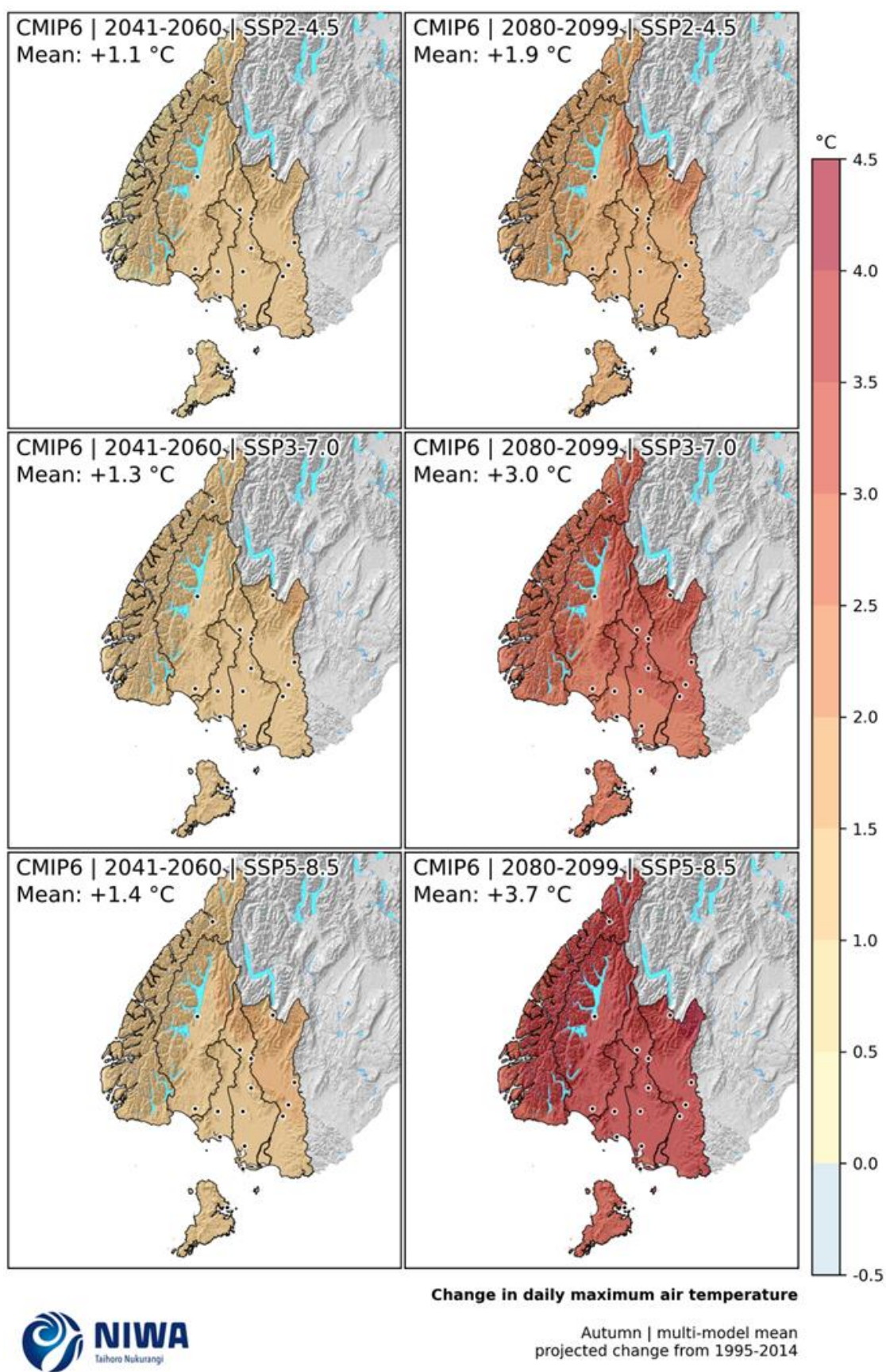


Figure 1-12: Projected autumn average daily maximum temperature changes.

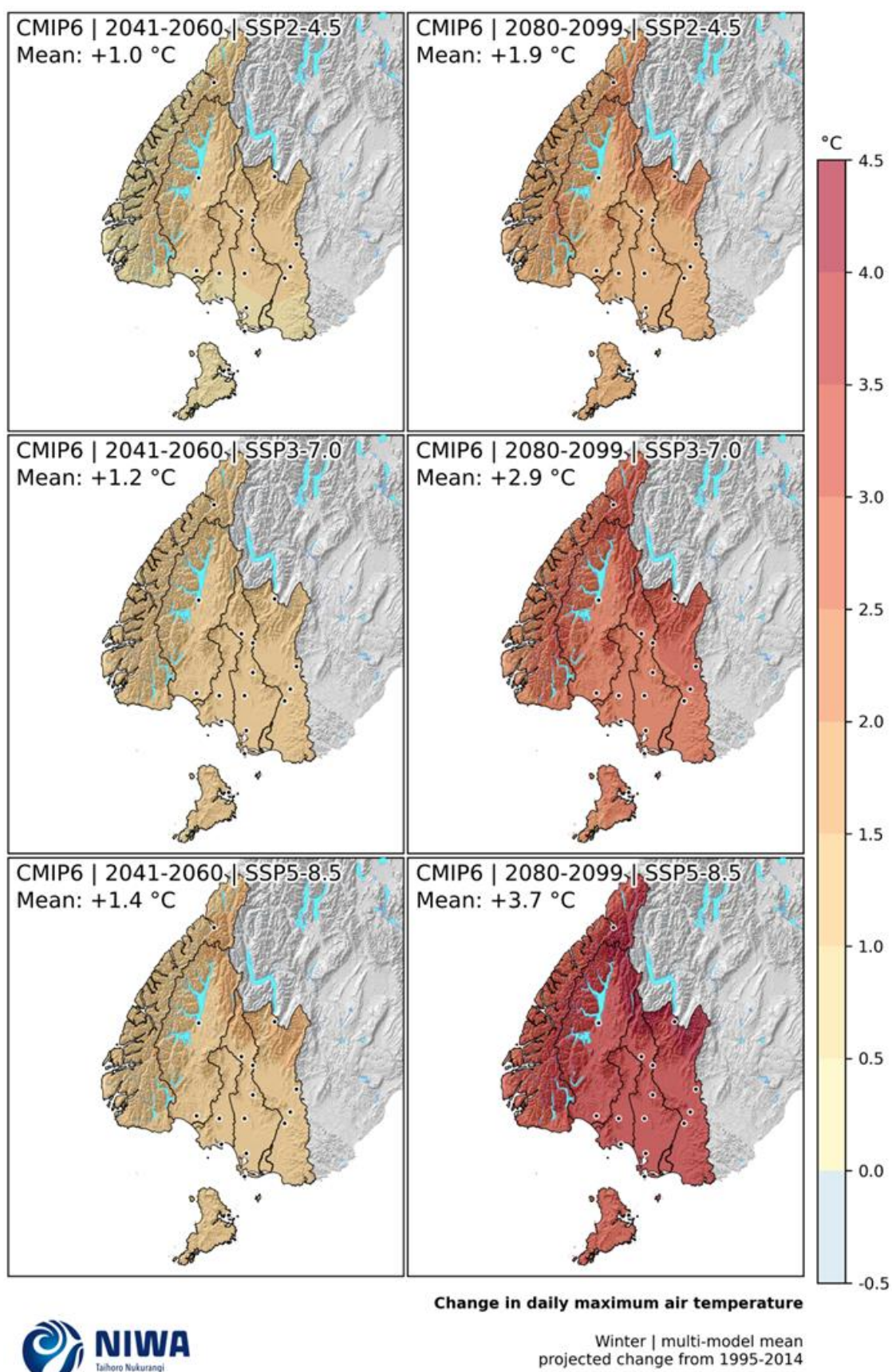


Figure 1-13: Projected winter average daily maximum temperature changes.

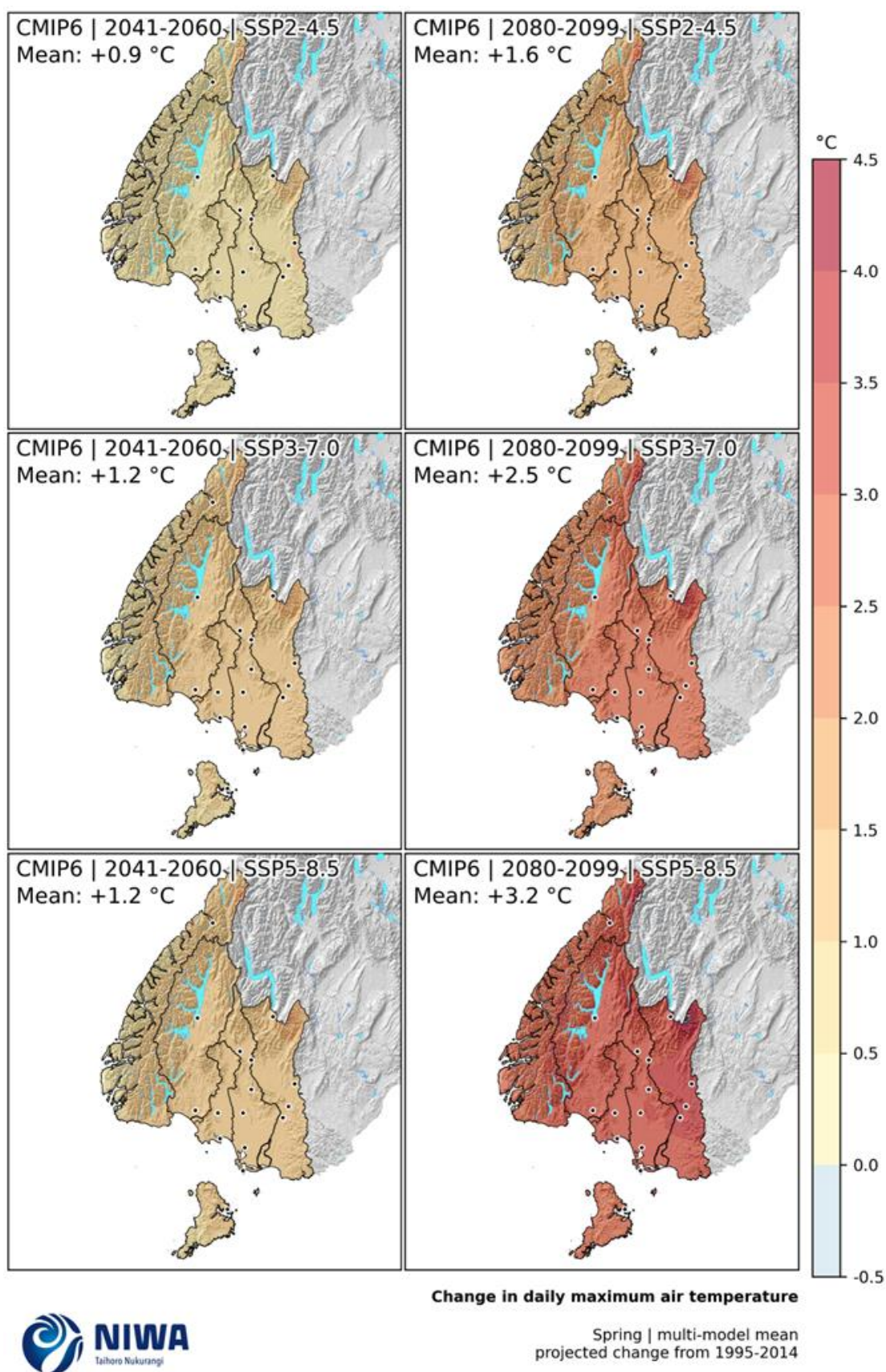


Figure 1-14: Projected spring average daily maximum temperature changes.

1.1.3 Minimum temperature

Modelled historic and projected changes to future annual and seasonal average daily minimum temperature are illustrated in Figure 1-15 to Figure 1-21. Regional average projected changes are summarised in Table 1-4, while location-specific projected changes are shown in Table 1-5. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-4: Projected minimum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+1.0	+1.7	+1.2	+2.6	+1.2	+3.3
Summer	+1.0	+1.7	+1.2	+2.7	+1.2	+3.2
Autumn	+1.0	+1.8	+1.1	+2.6	+1.2	+3.2
Winter	+1.0	+1.8	+1.2	+2.8	+1.4	+3.6
Spring	+0.9	+1.6	+1.1	+2.4	+1.2	+3.1

Table 1-5: Projected annual changes to average daily minimum temperature (°C).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	+0.9	+1.7	+1.1	+2.6	+1.2	+3.2
Riverton	+1.0	+1.7	+1.2	+2.7	+1.3	+3.3
Mataura	+1.0	+1.8	+1.2	+2.7	+1.3	+3.4
Gore	+1.0	+1.8	+1.2	+2.7	+1.3	+3.4
Winton	+1.0	+1.7	+1.2	+2.7	+1.3	+3.3
Lumsden	+1.0	+1.8	+1.2	+2.7	+1.3	+3.4
Te Anau	+1.0	+1.8	+1.3	+2.8	+1.3	+3.5
Otautau	+1.0	+1.8	+1.2	+2.7	+1.3	+3.4
Tuatapere	+1.0	+1.7	+1.2	+2.7	+1.3	+3.3
Oban	+0.8	+1.5	+1.0	+2.4	+1.1	+2.9
Riversdale	+1.0	+1.8	+1.2	+2.7	+1.3	+3.4
Waikaka	+1.0	+1.8	+1.2	+2.8	+1.3	+3.4
Milford Sound	+1.0	+1.8	+1.2	+2.7	+1.3	+3.3
Garston	+1.0	+1.7	+1.2	+2.6	+1.2	+3.2
Mossburn	+1.0	+1.8	+1.2	+2.8	+1.3	+3.4

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Bluff	+0.9	+1.6	+1.1	+2.5	+1.2	+3.2 ¹

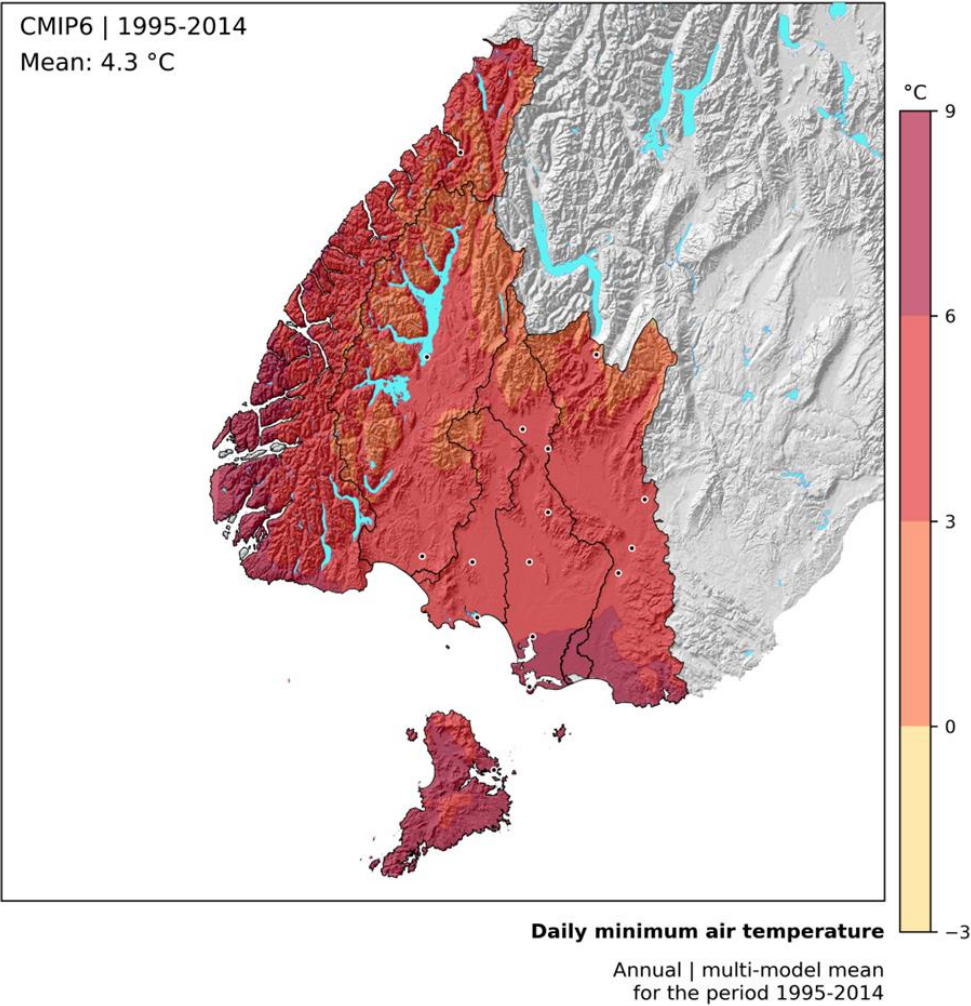


Figure 1-15: Modelled historic annual average daily minimum temperature.

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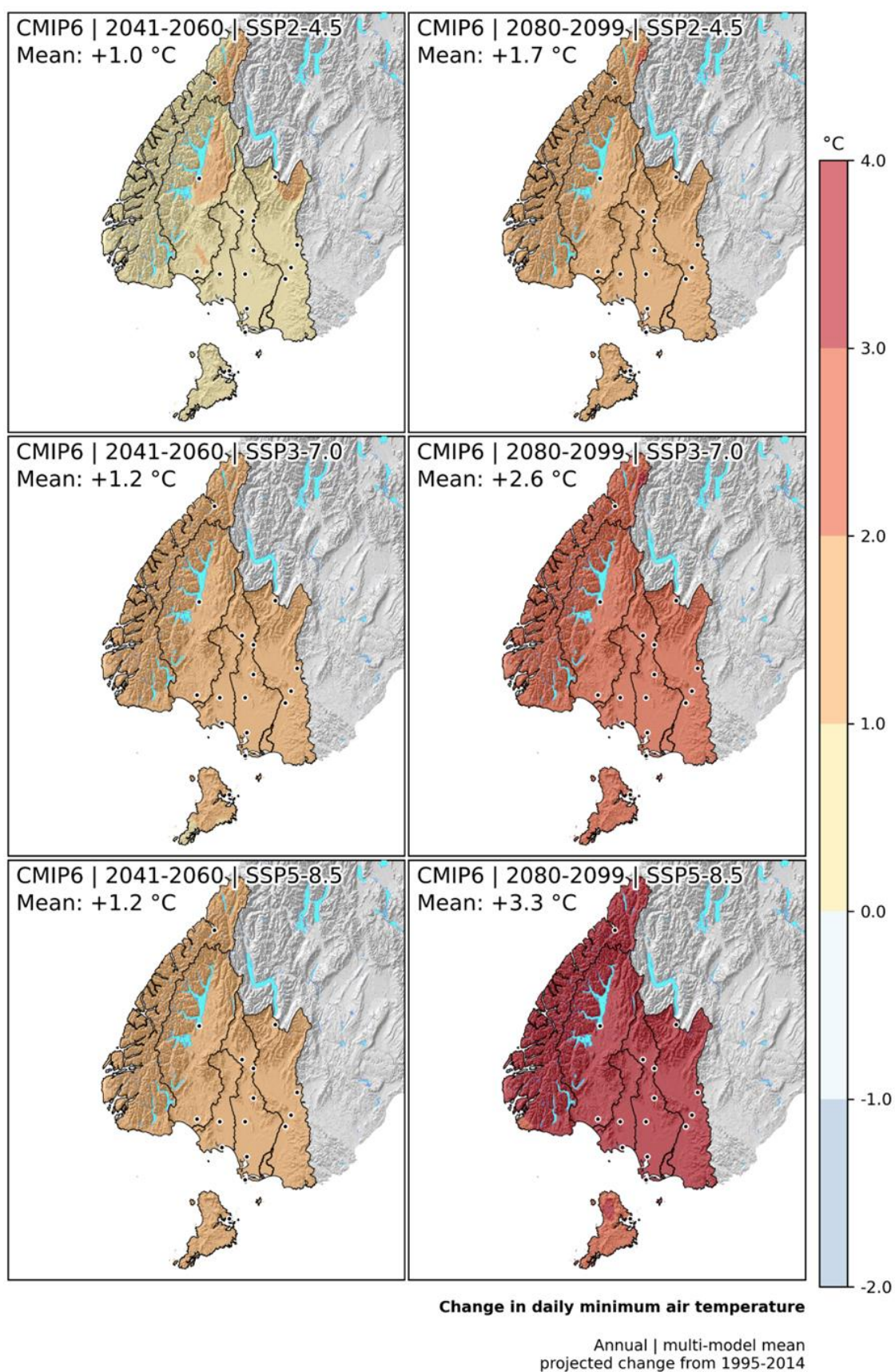
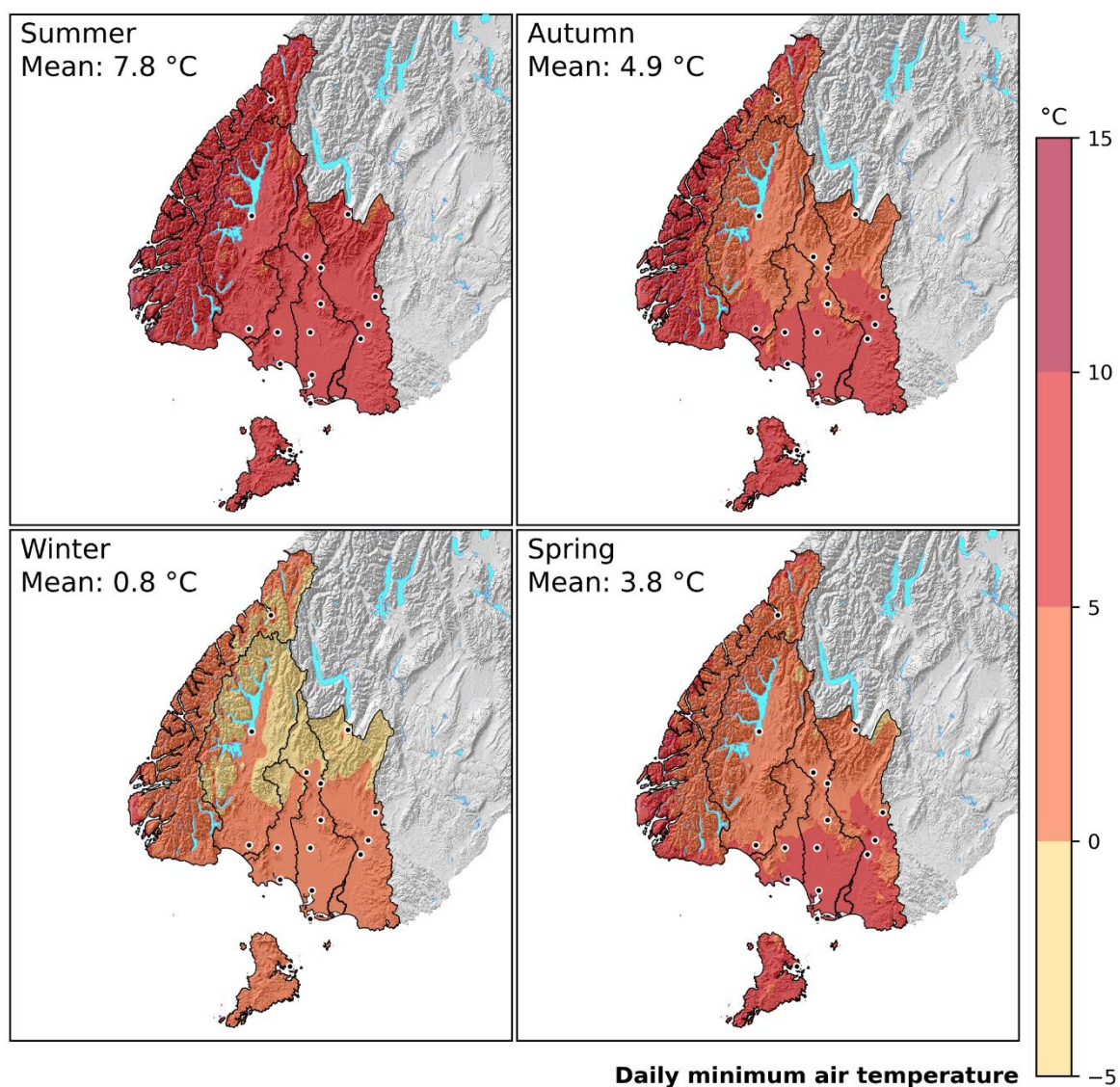


Figure 1-16: Projected annual average daily minimum temperature changes.



multi-model mean | for the period 1995-2014

Figure 1-17: Modelled historic seasonal average daily minimum temperature.

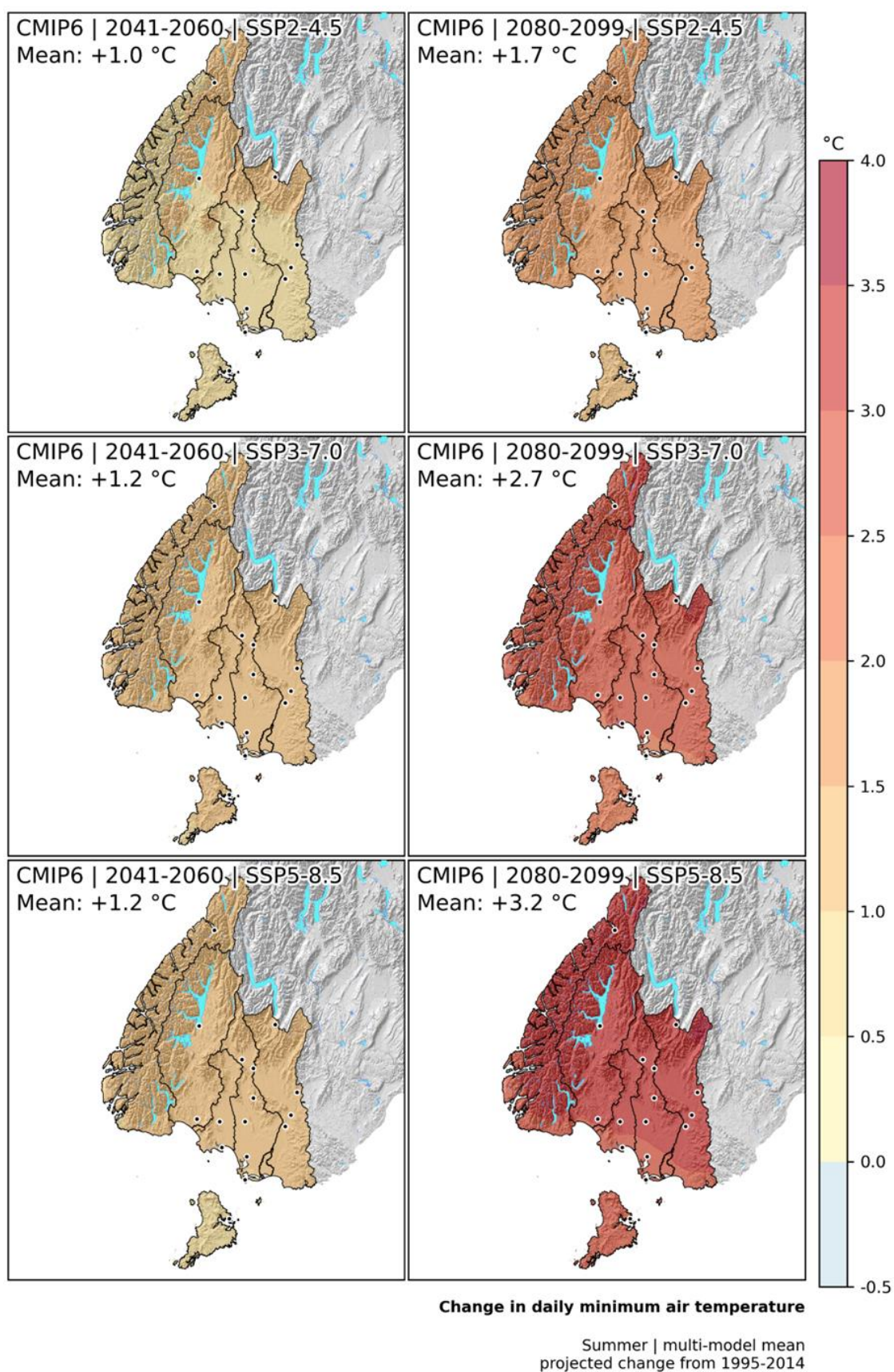


Figure 1-18: Projected summer average daily minimum temperature changes.

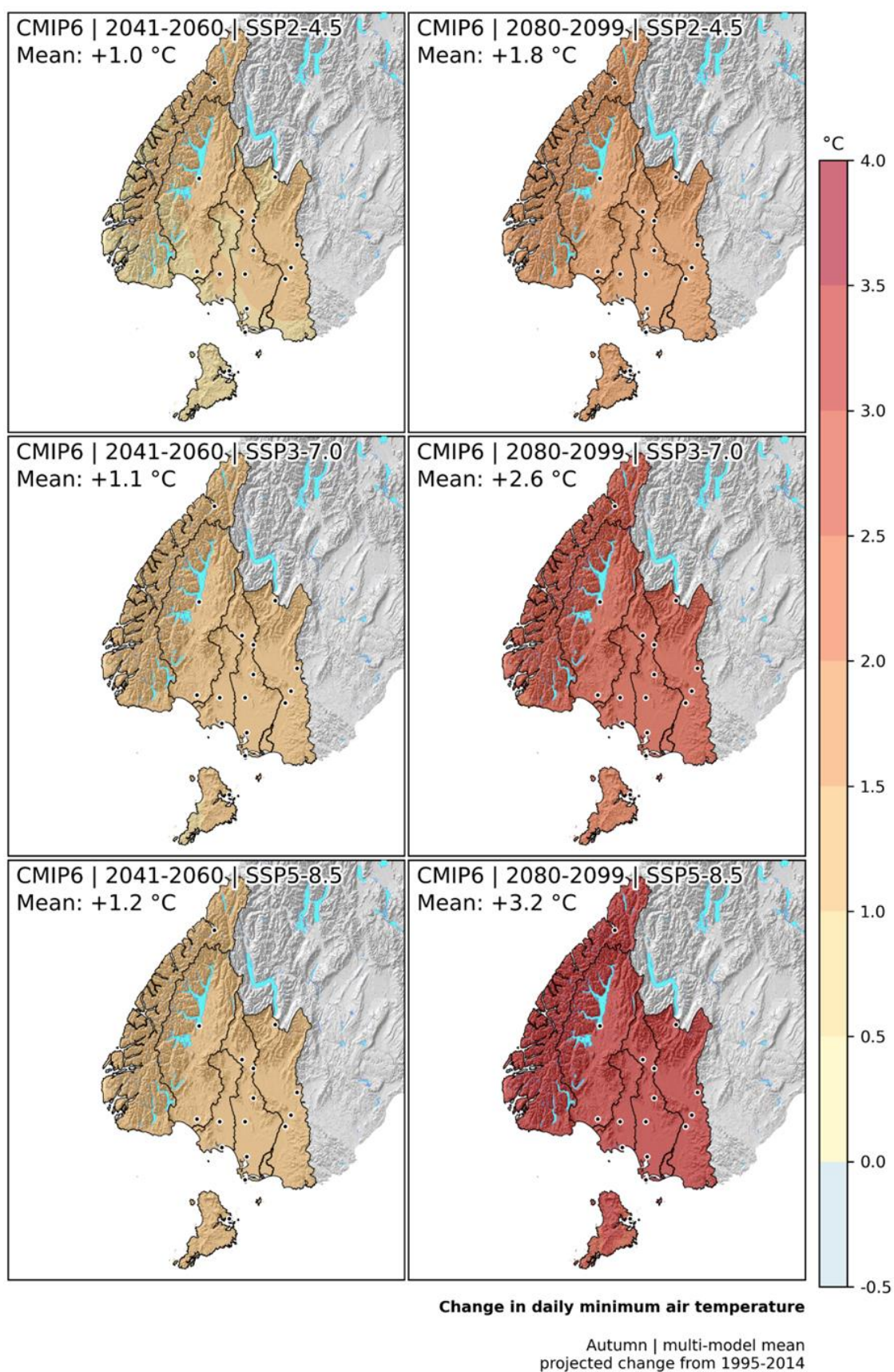


Figure 1-19: Projected autumn average daily minimum temperature changes.

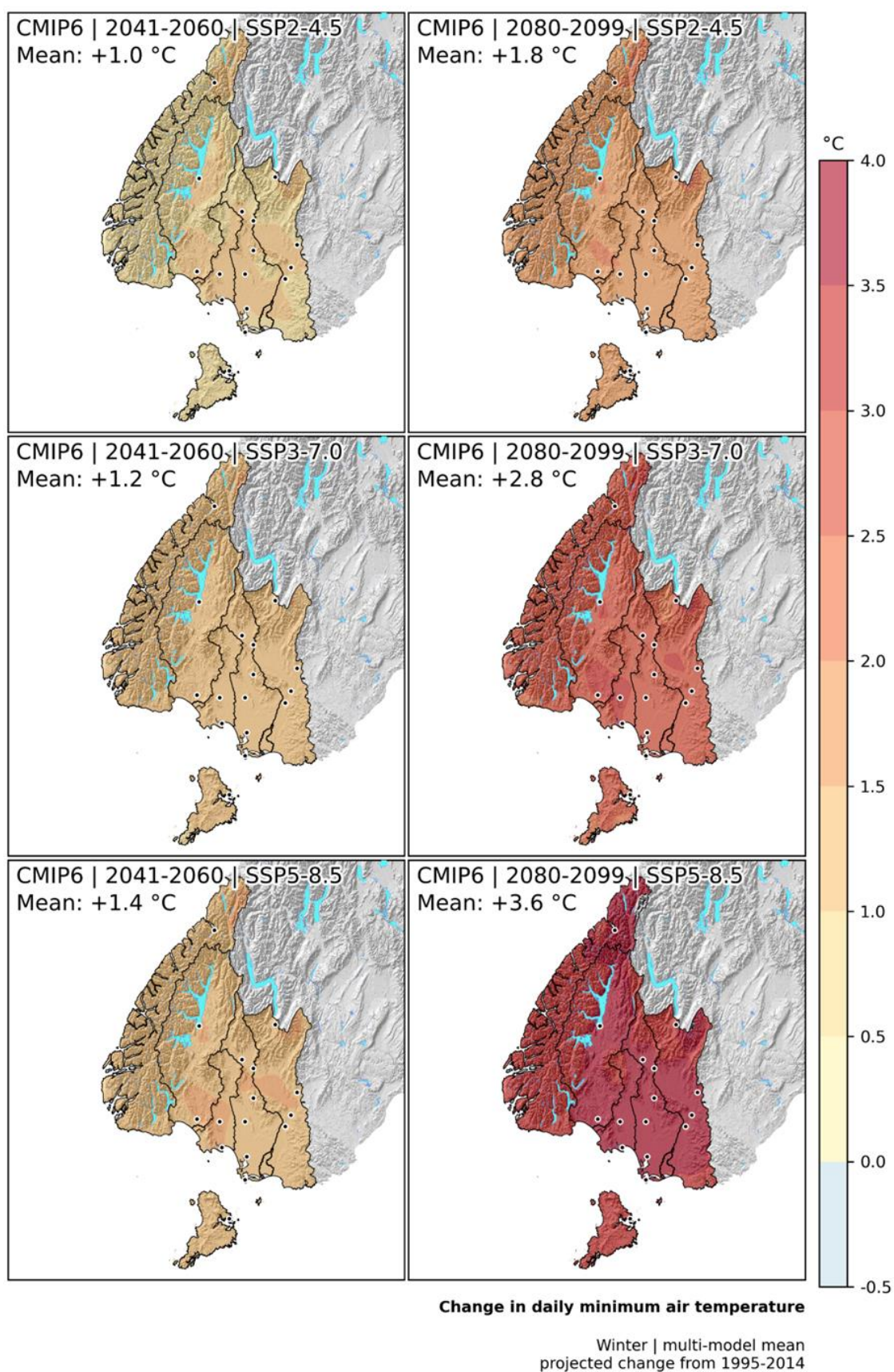


Figure 1-20: Projected winter average daily minimum temperature changes.

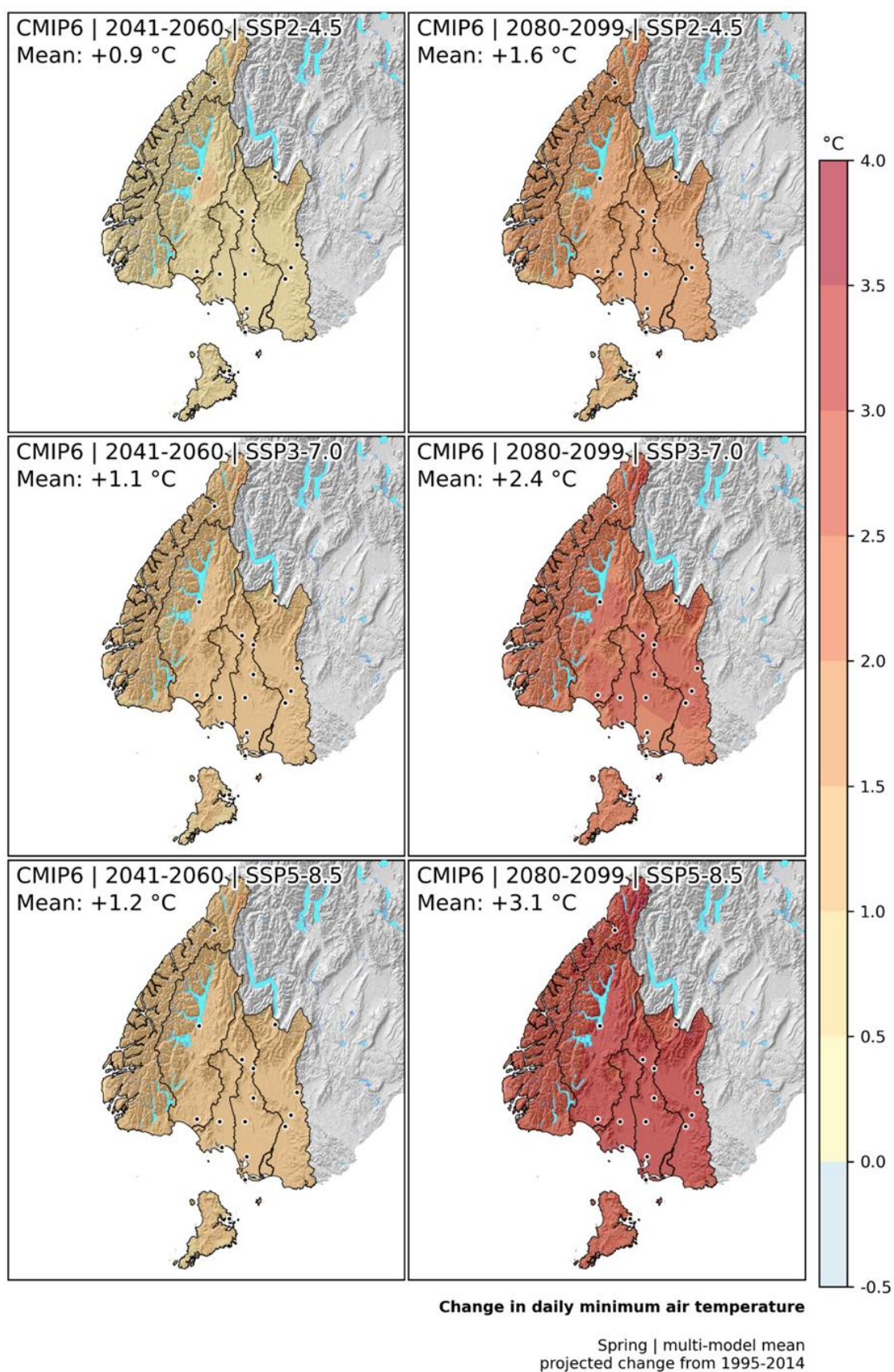


Figure 1-21: Projected spring average daily minimum temperature changes.

1.1.4 Temperature range

Modelled historic and projected changes to future annual and seasonal average daily minimum temperature are illustrated in Figure 1-22 to Figure 1-28. Regional average projected changes are summarised in Table 1-6.

Table 1-6: Projected daily temperature range changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	0.1	0.1	0.2	0.3	0.1	0.4
Summer	0.2	0.3	0.3	0.6	0.3	0.7
Autumn	0.1	0.1	0.2	0.3	0.2	0.5
Winter	0.0	0.0	0.0	0.1	0.0	0.1
Spring	0.0	0.0	0.1	0.1	0.0	0.2

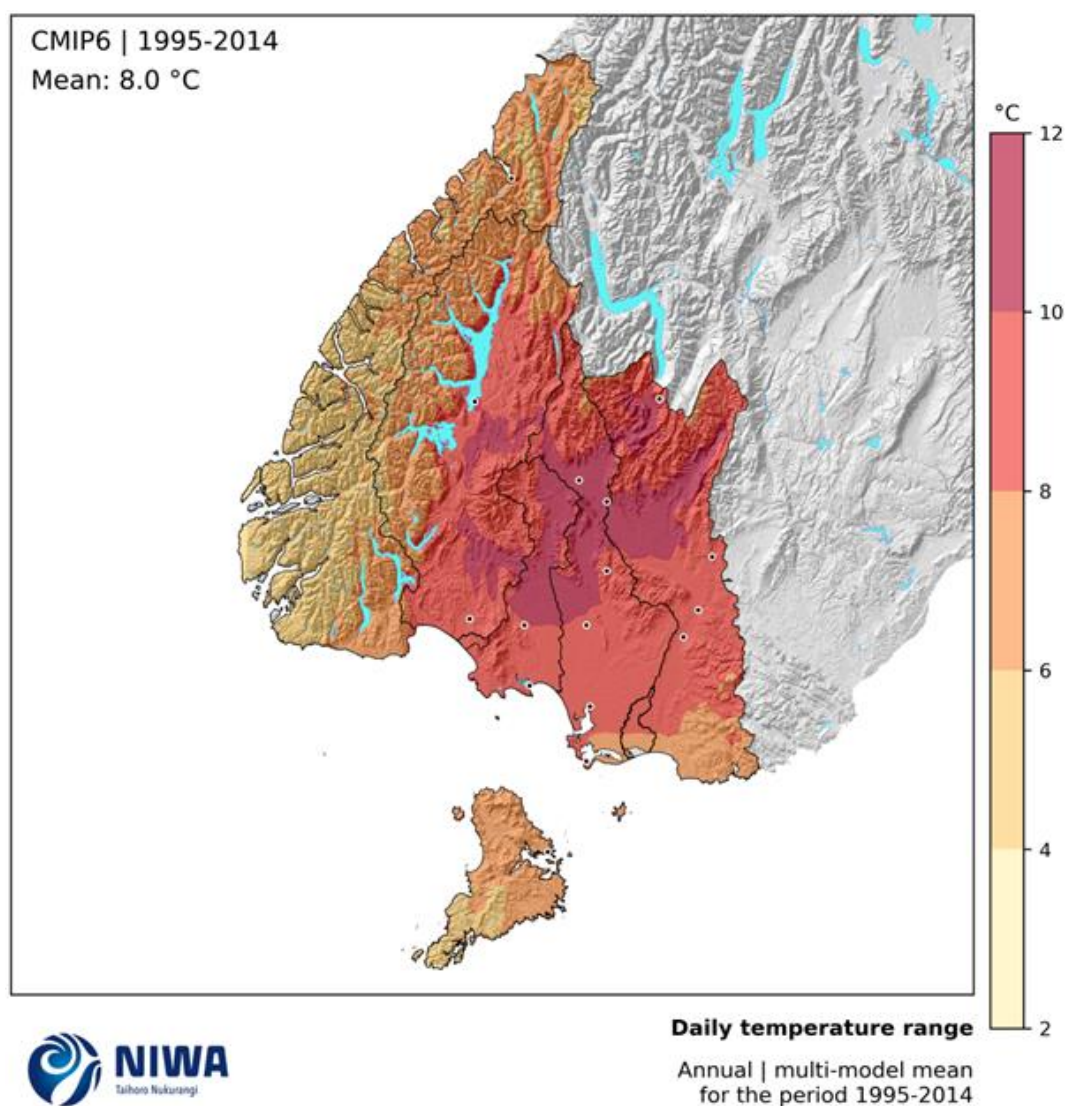


Figure 1-22: Modelled historic annual average daily temperature range.

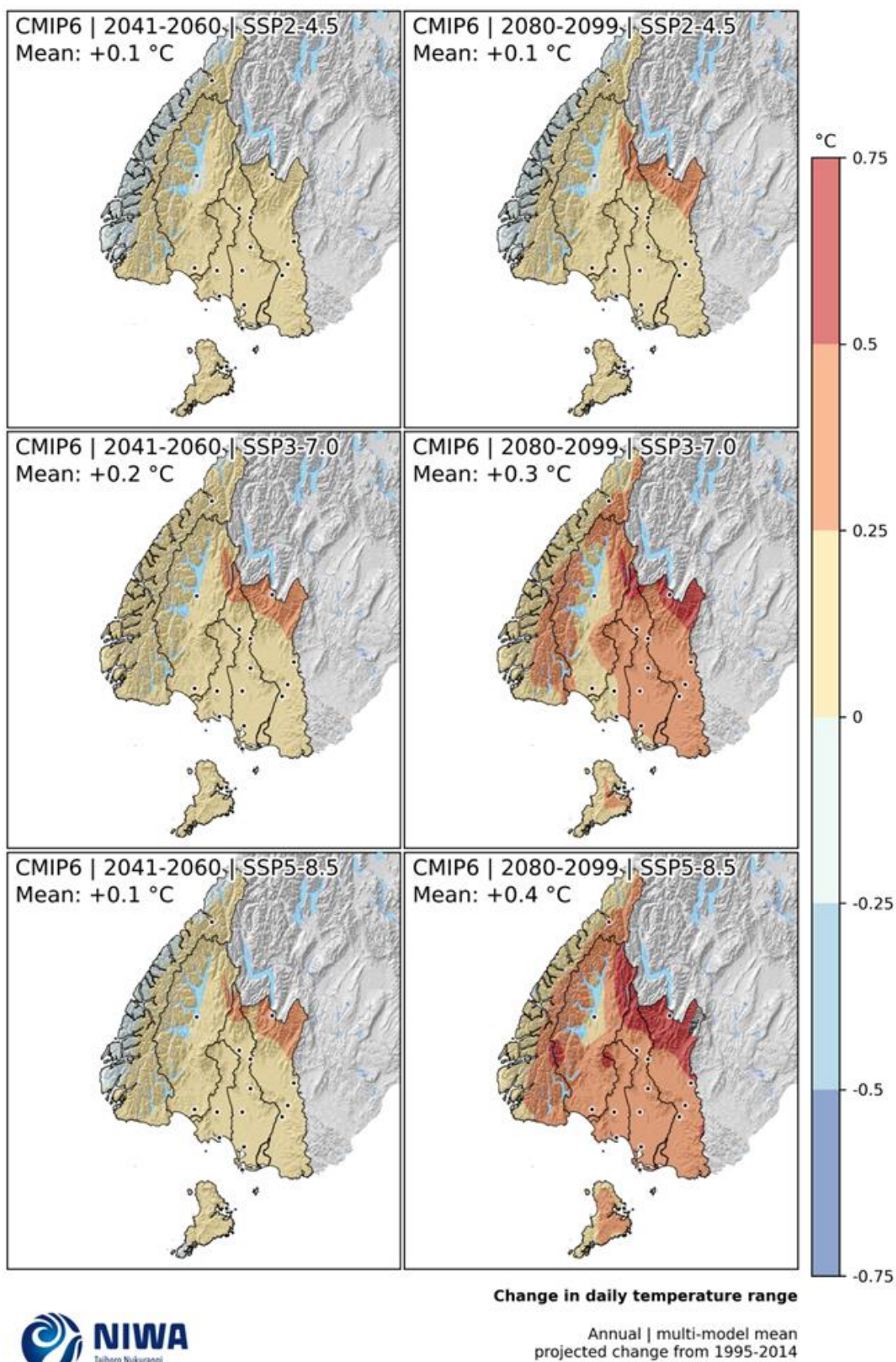


Figure 1-23: Projected annual average daily temperature range changes.

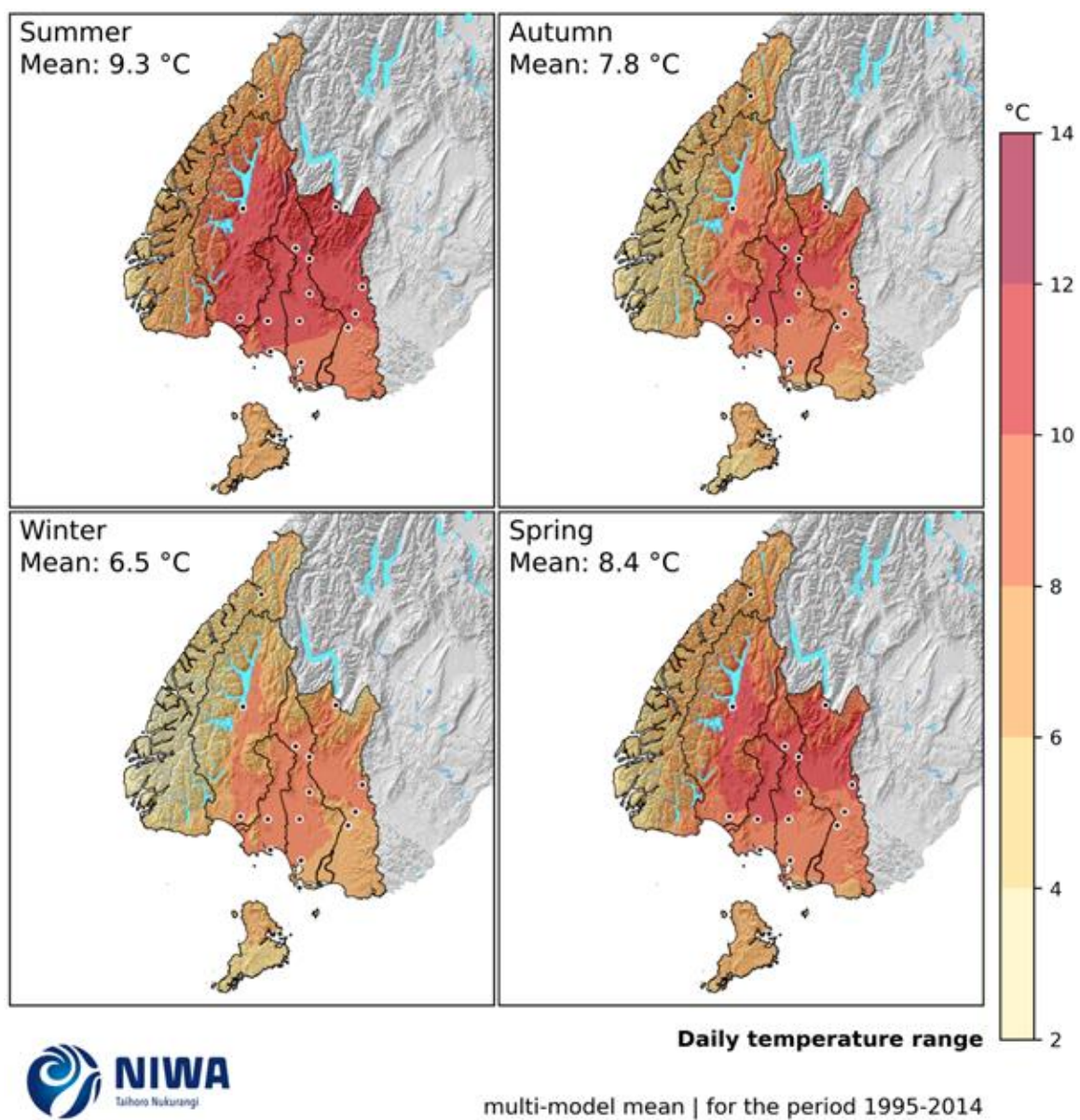


Figure 1-24: Modelled historic seasonal average daily temperature range.

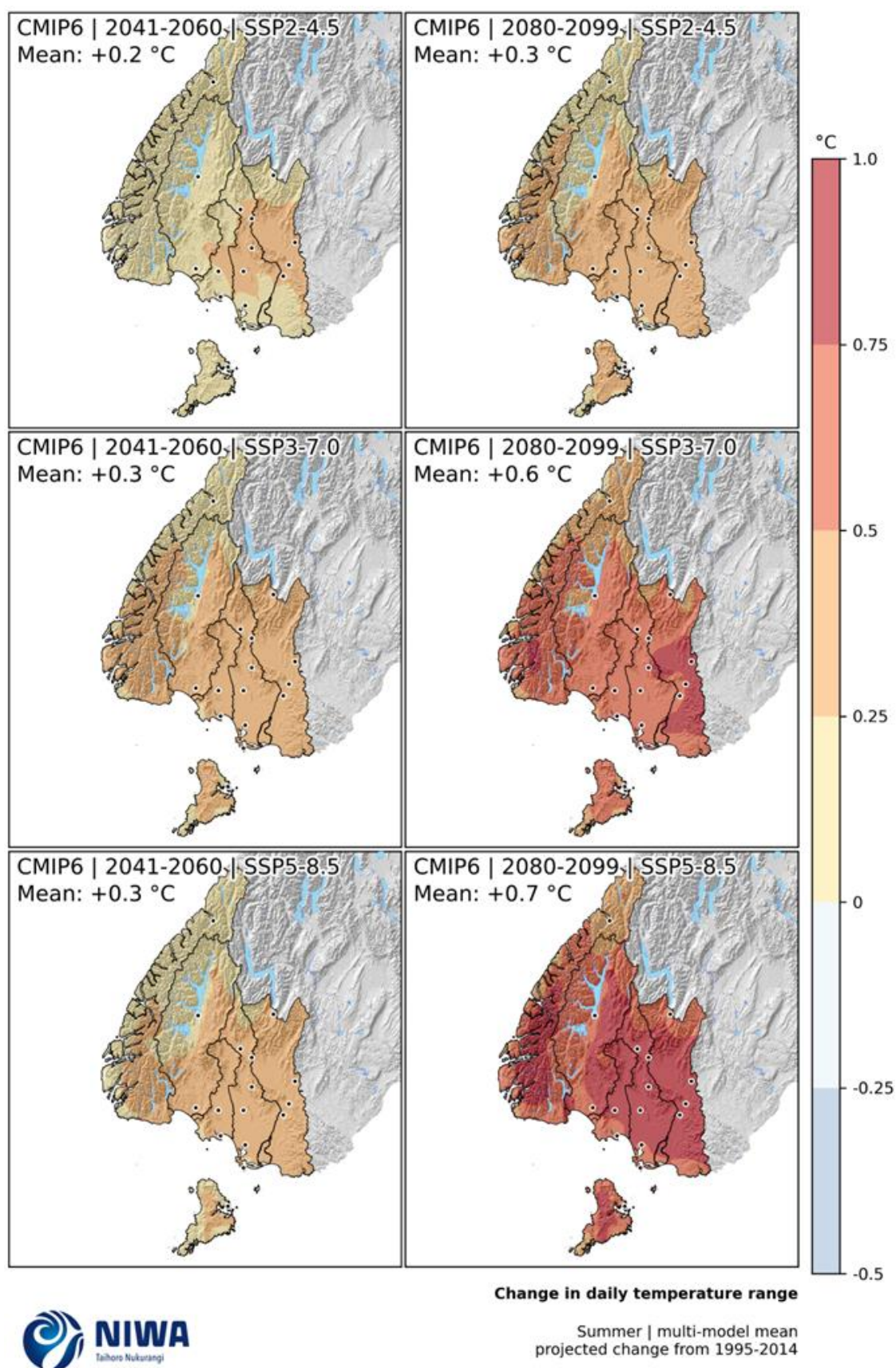


Figure 1-25: Projected summer average daily temperature range changes.

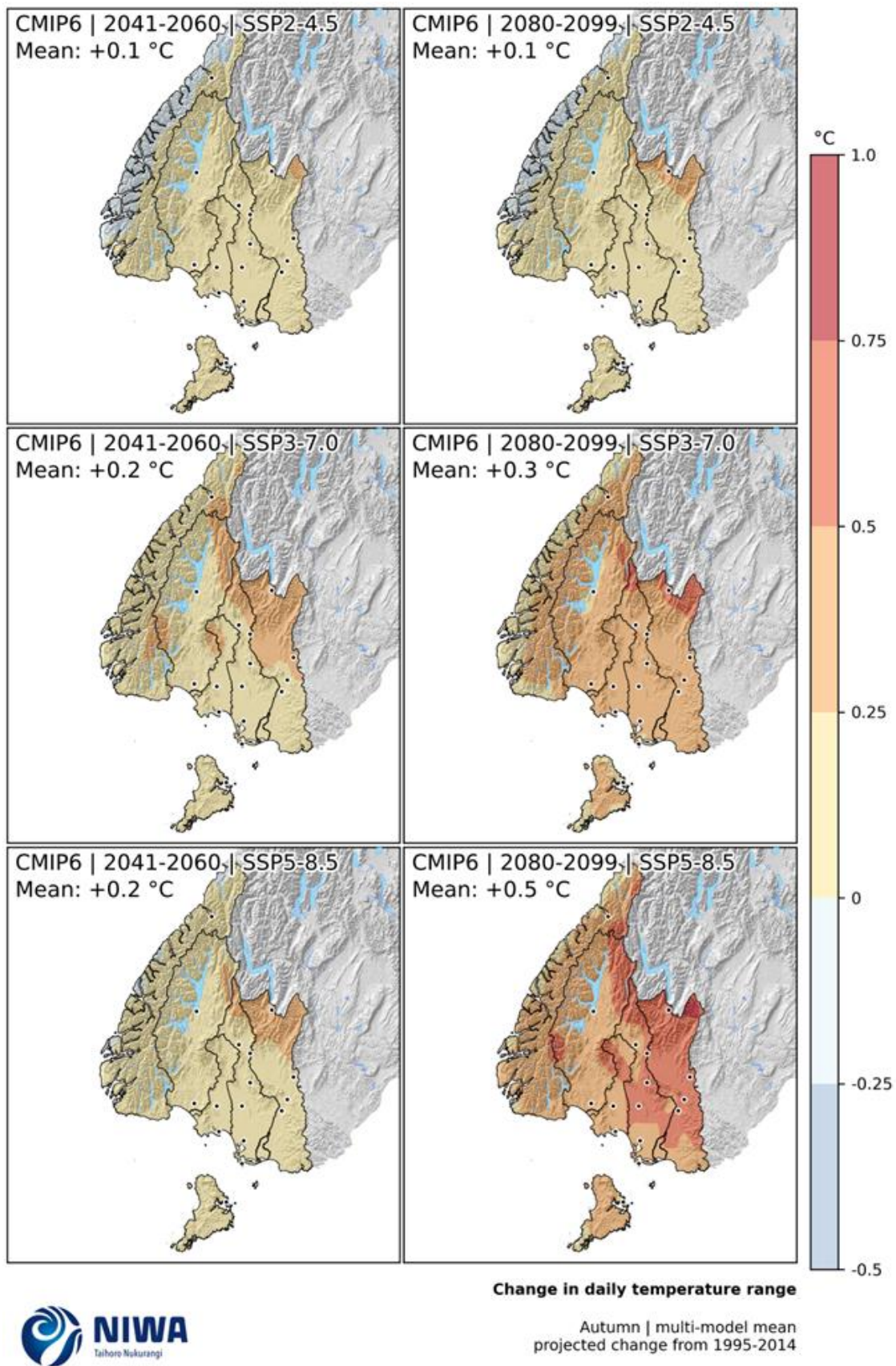


Figure 1-26: Projected autumn average daily temperature range changes.

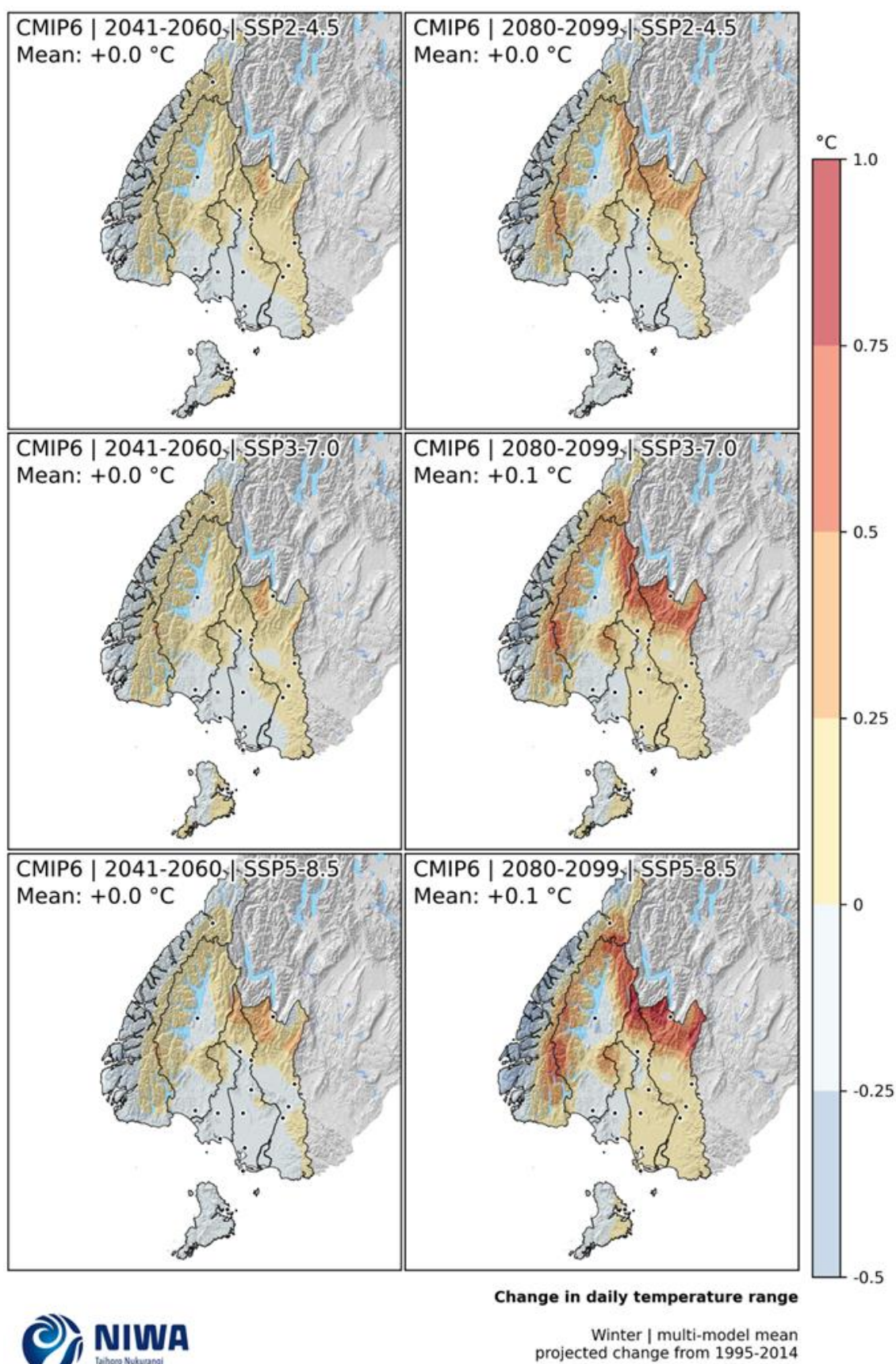


Figure 1-27: Projected winter average daily temperature range changes.

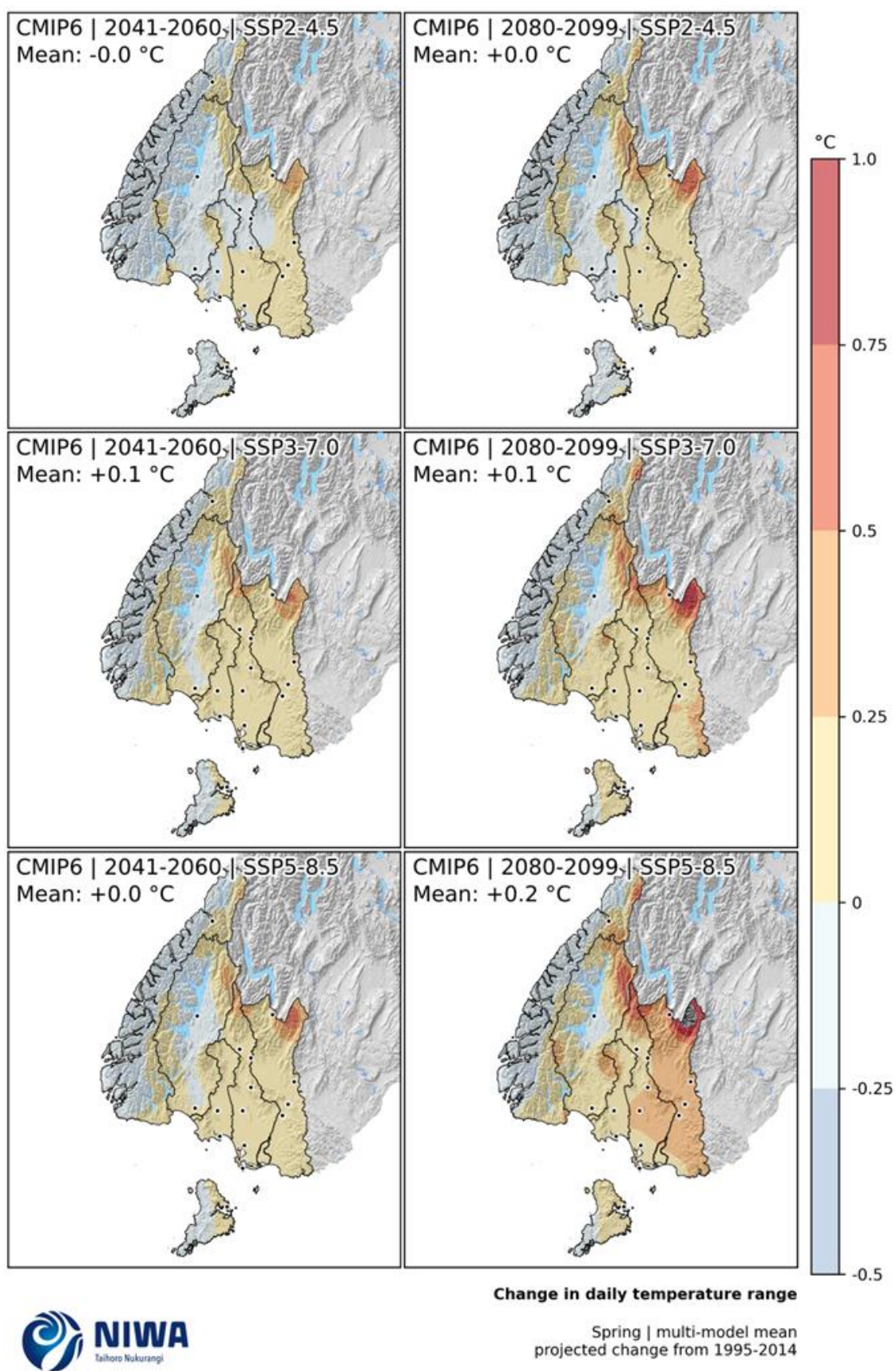


Figure 1-28: Projected spring average daily temperature range changes.

1.1.5 Hot days

Modelled historic and projected changes to future annual hot days are illustrated in Figure 1-29 and Figure 1-30. Regional average projected changes are summarised in Table 1-7, while location-specific projected changes are shown in Table 1-8. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-7: Projected annual hot day changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+3.5	+6.5	+4.8	+14.4	+4.2	+18.8

Table 1-8: Projected changes to the number of annual hot days.

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	6.6	12.0	8.8	25.1	7.8	30.9
Riverton	7.7	13.9	10.5	28.6	9.5	35.3
Mataura	8.7	15.6	12.2	31.7	10.6	40.2
Gore	9.5	16.7	13.4	34.0	11.9	42.7
Winton	9.5	16.8	13.0	33.1	11.6	41.0
Lumsden	10.5	18.8	14.4	36.1	13.2	44.9
Te Anau	5.7	10.9	8.3	26.6	7.4	34.9
Otautau	6.5	11.3	8.6	25.2	7.6	31.9
Tuatapere	8.1	14.0	11.2	29.9	9.9	37.4
Oban	0.6	1.6	0.9	4.0	0.7	6.0
Riversdale	4.0	8.1	5.9	19.3	4.9	26.5
Waikaka	11.4	20.2	15.8	38.0	15.0	46.7
Milford Sound	1.0	3.1	1.4	9.3	1.2	13.7
Garston	7.6	14.3	10.8	30.4	9.6	39.2
Mossburn	8.8	15.9	12.0	32.3	11.1	41.1
Bluff	4.8	9.6	6.8	20.3	5.6	25.7

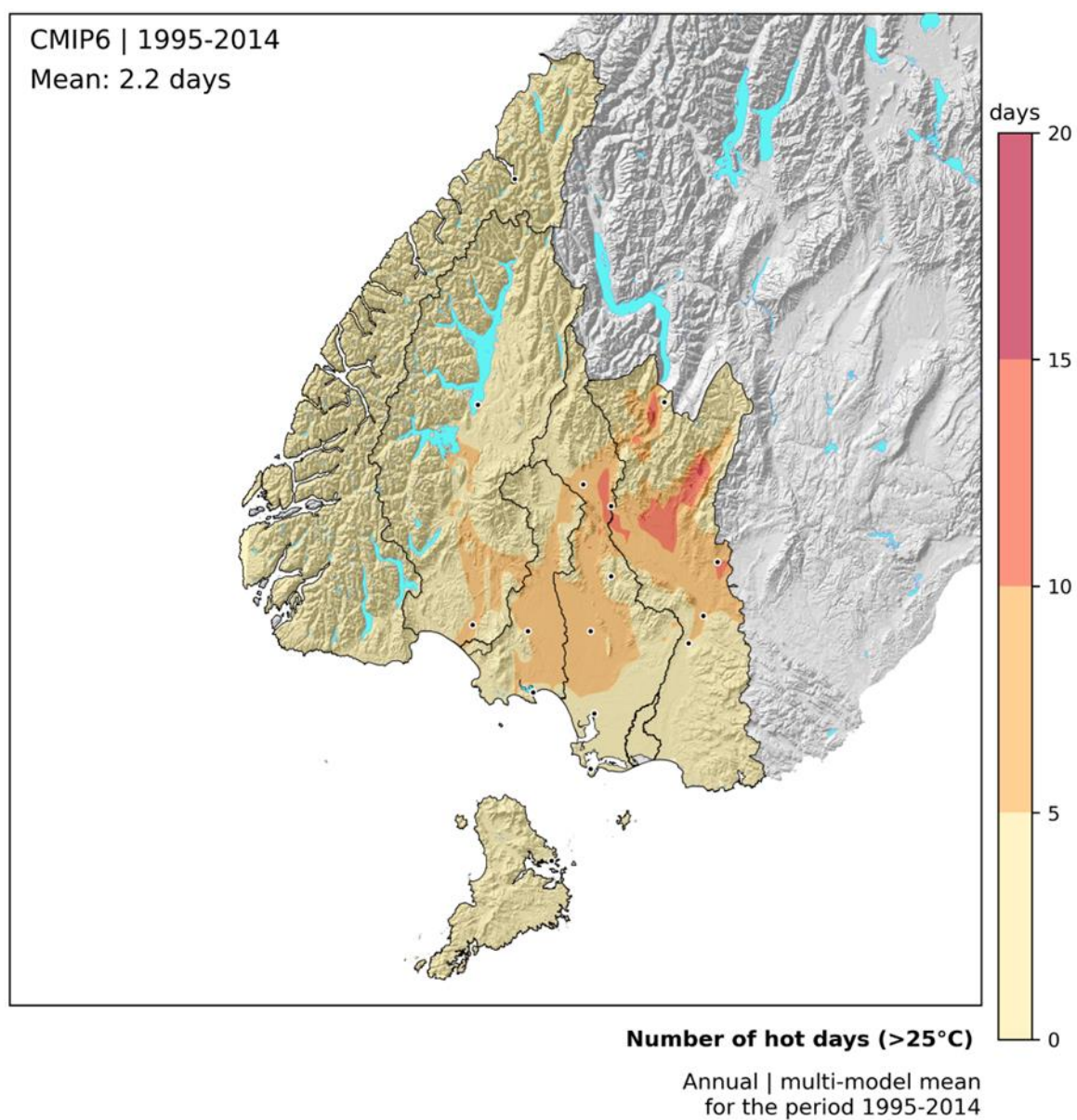


Figure 1-29: Modelled historic average annual number of hot days.

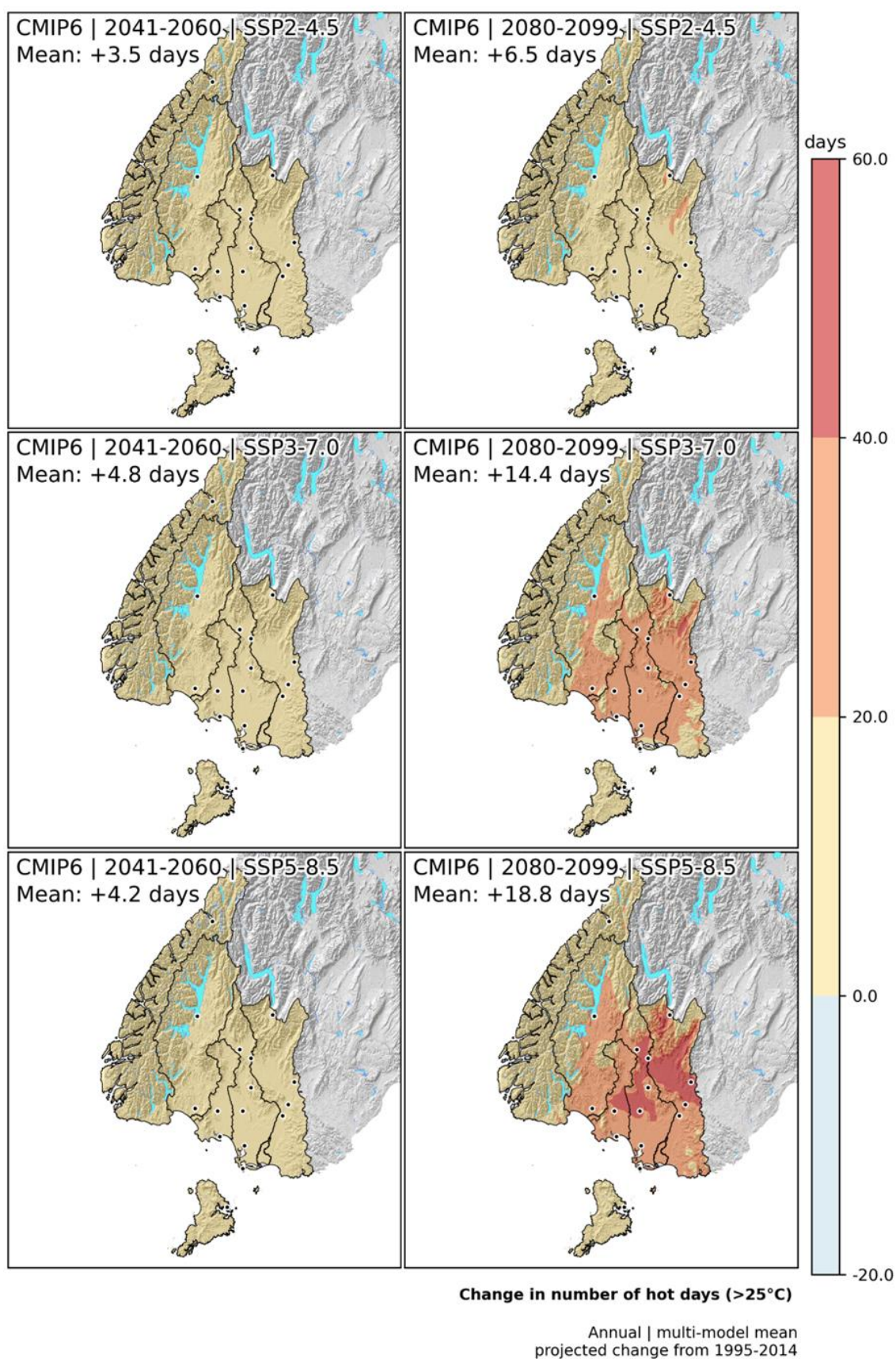


Figure 1-30: Projected annual hot day changes.

1.1.6 Cold nights

By definition, cold nights are associated to cold days, i.e., days for which the minimum air temperature is less than 0°C. Modelled historic and projected changes to future annual cold days are illustrated in Figure 1-31 and Figure 1-32. Regional average projected changes are summarised in Table 1-9, while location-specific projected changes are shown in Table 1-10. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-9: Projected annual cold nights changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	Annual	-15.3	26.9	-18.6	-36.6	-20.4

Table 1-10: Projected changes to the number of annual cold nights.

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	-9.2	-15.0	-10.8	-19.4	-12.0	-21.4
Riverton	-11.0	-18.3	-13.7	-24.4	-15.2	-27.0
Mataura	-10.1	-17.4	-12.9	-22.3	-13.7	-25.0
Gore	-11.7	-19.3	-14.4	-24.7	-15.8	-27.8
Winton	-12.0	-20.4	-14.8	-27.1	-16.6	-30.2
Lumsden	-15.8	-27.3	-19.0	-36.8	-21.1	-43.7
Te Anau	-21.8	-34.7	-25.0	-44.3	-27.2	-50.3
Otautau	-15.8	-26.5	-18.7	-35.8	-21.4	-39.9
Tuatapere	-13.3	-21.6	-16.3	-28.4	-17.4	-31.3
Oban	-6.4	-10.2	-8.1	-12.3	-8.6	-12.9
Riversdale	-18.1	-31.4	-21.9	-43.5	-24.5	-50.7
Waikaka	-13.0	-22.7	-16.0	-29.9	-18.8	-33.9
Milford Sound	-18.7	-30.6	-24.6	-34.7	-25.3	-35.5
Garston	-16.8	-30.0	-20.1	-42.2	-21.7	-53.5
Mossburn	-18.5	-30.8	-21.3	-41.6	-23.8	-49.3
Bluff	-7.1	-12.4	-9.0	-15.8	-9.8	-17.5

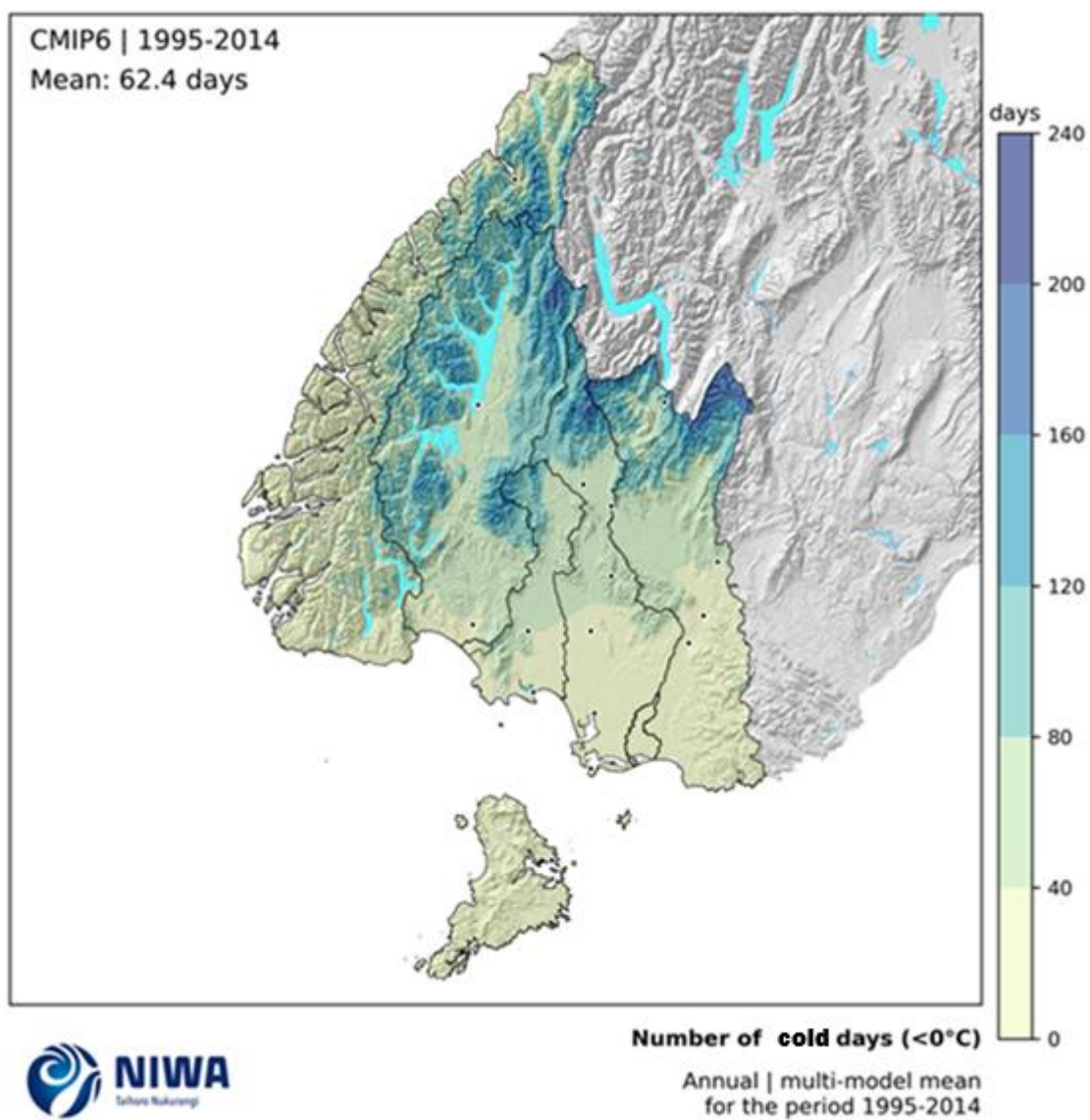


Figure 1-31: Modelled historic average annual number of cold nights.

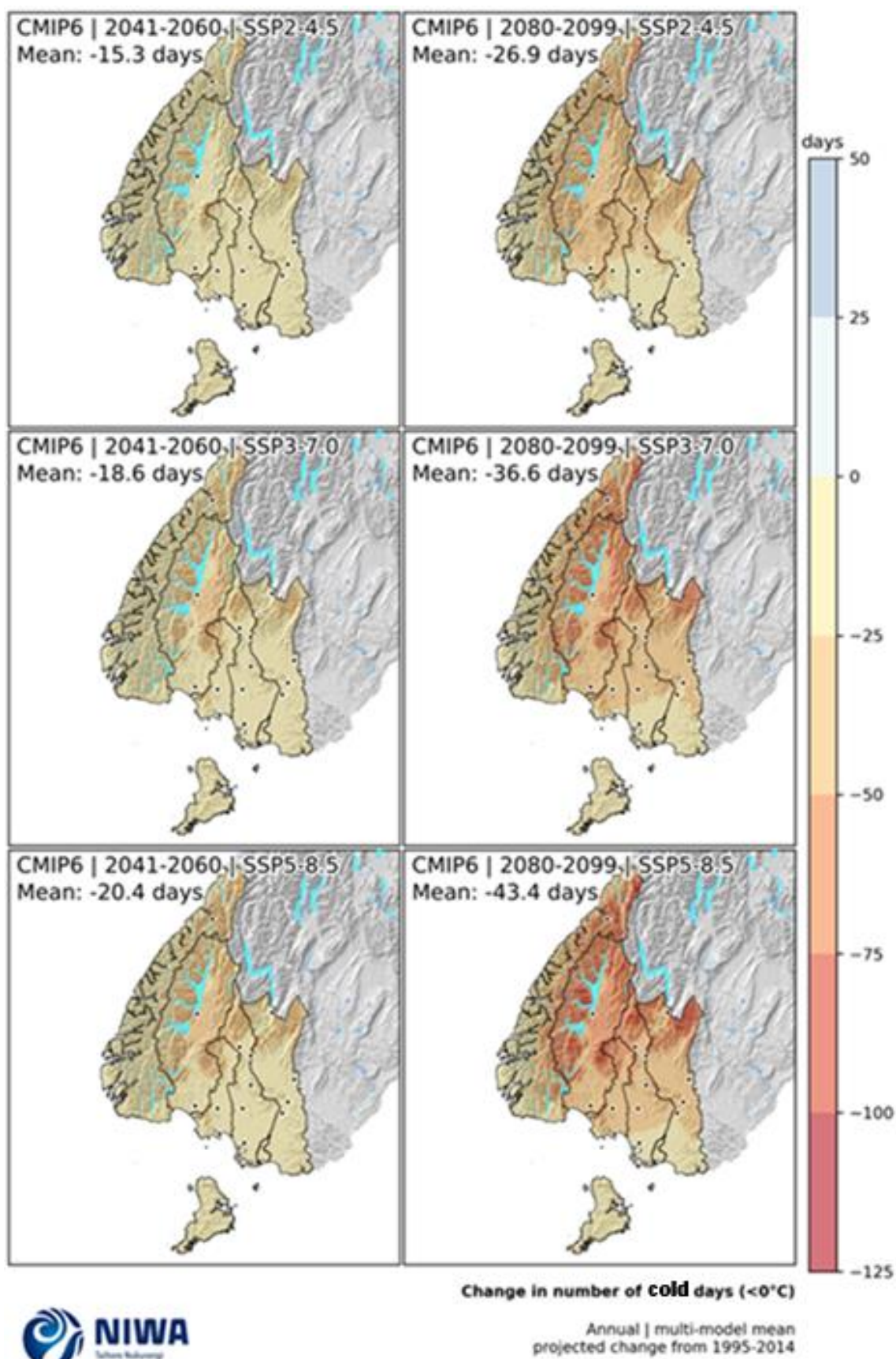


Figure 1-32: Projected annual cold night changes.

1.1.7 Heatwave frequency

Modelled historic and projected changes to future annual time spent in heatwave are illustrated in Figure 1-33 and Figure 1-34. Regional average projected changes are summarised in Table 1-11, while location-specific projected changes are shown in Table 1-12.

Table 1-11: Projected annual time spent in heatwave (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+6.5	+12.4	+9.1	+27.8	+7.7	+35.6

Table 1-12: Projected changes to annual time spent in heatwave (days).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	+4.9	+7.9	+6.3	+18.4	+5.5	+22.1
Riverton	+5.3	+9.3	+6.8	+20.2	+6.3	+24.7
Mataura	+5.8	+10.1	+7.5	+22.9	+6.7	+28.9
Gore	+5.8	+10.3	+7.8	+23.6	+6.7	+29.9
Winton	+5.9	+10.0	+8.2	+23.5	+7.2	+29.3
Lumsden	+7.0	+13.0	+9.5	+29.9	+8.5	+38.1
Te Anau	+6.0	+12.4	+8.5	+30.6	+7.3	+39.3
Otautau	+5.6	+10.4	+7.7	+23.7	+7.1	+29.2
Tuatapere	+6.3	+10.8	+8.6	+24.1	+7.8	+29.8
Oban	+5.3	+11.2	+7.8	+25.1	+5.3	+32.5
Riversdale	+6.9	+12.3	+9.2	+27.8	+8.2	+35.2
Waikaka	+6.1	+10.4	+8.2	+24.4	+7.0	+31.2
Milford Sound	+6.7	+13.6	+9.3	+28.9	+7.9	+37.9
Garston	+8.2	+16.1	+11.4	+33.7	+9.9	+43.4
Mossburn	+7.2	+14.0	+9.9	+31.6	+9.3	+39.3
Bluff	+3.1	+6.2	+4.7	+14.4	+3.1	+18.5

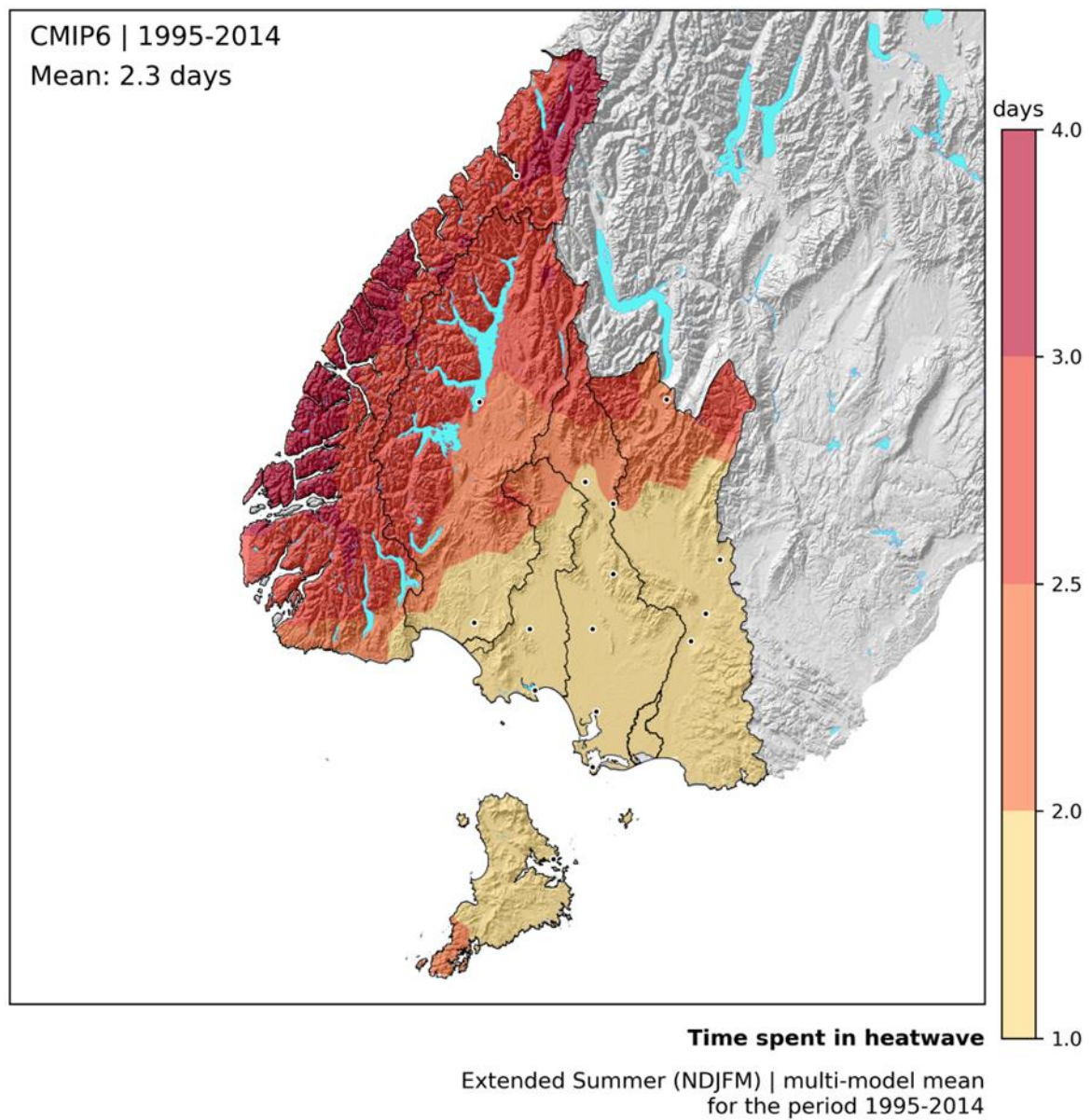


Figure 1-33: Modelled historic average annual heatwave frequency.

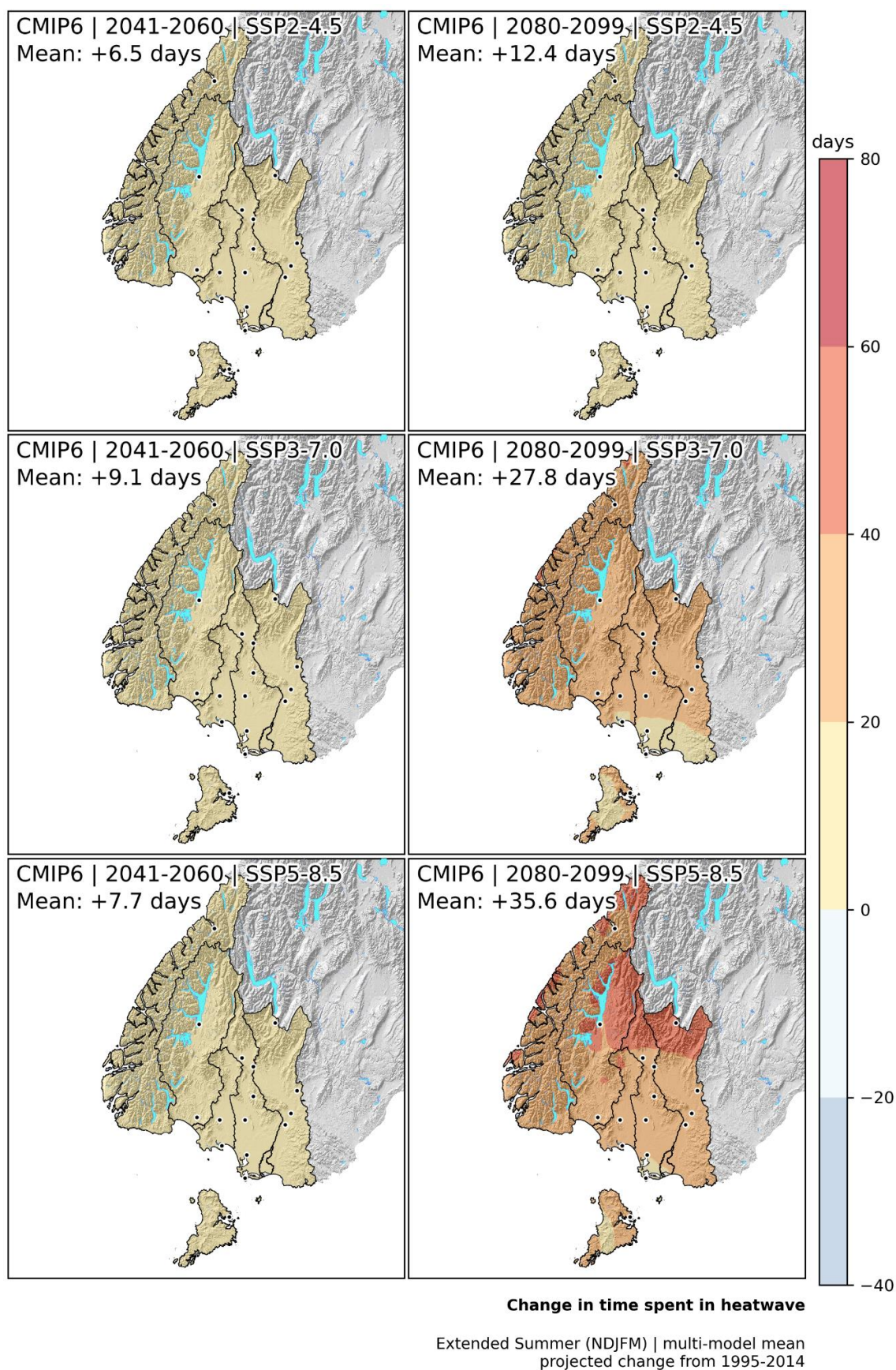


Figure 1-34: Projected annual heatwave frequency changes.

1.1.8 Growing degree days

Modelled historic and projected changes to future annual growing degree days (GDD) are illustrated in Figure 1-35 and Figure 1-36. Regional average projected annual and monthly changes are summarised in Table 1-13. FMU average projected changes at annual time scale are summarised in Appendix A.

Table 1-13: Projected growing degree day (base 10°C) changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+160	+294	+206	+512	+205	+647
January	+32	+50	+41	+86	+35	+104
February	+28	+49	+36	+86	+35	+98
March	+25	+46	+29	+70	+29	+88
April	+15	+28	+17	+46	+20	+62
May	+6	+12	+8	+27	+9	+36
June	+1	+3	+2	+8	+2	+13
July	+1	+2	+1	+5	+1	+10
August	+2	+5	+2	+11	+3	+17
September	+5	+11	+6	+20	+7	+29
October	+9	+18	+13	+33	+13	+45
November	+17	+32	+23	+53	+24	+67
December	+20	+41	+29	+71	+28	+82

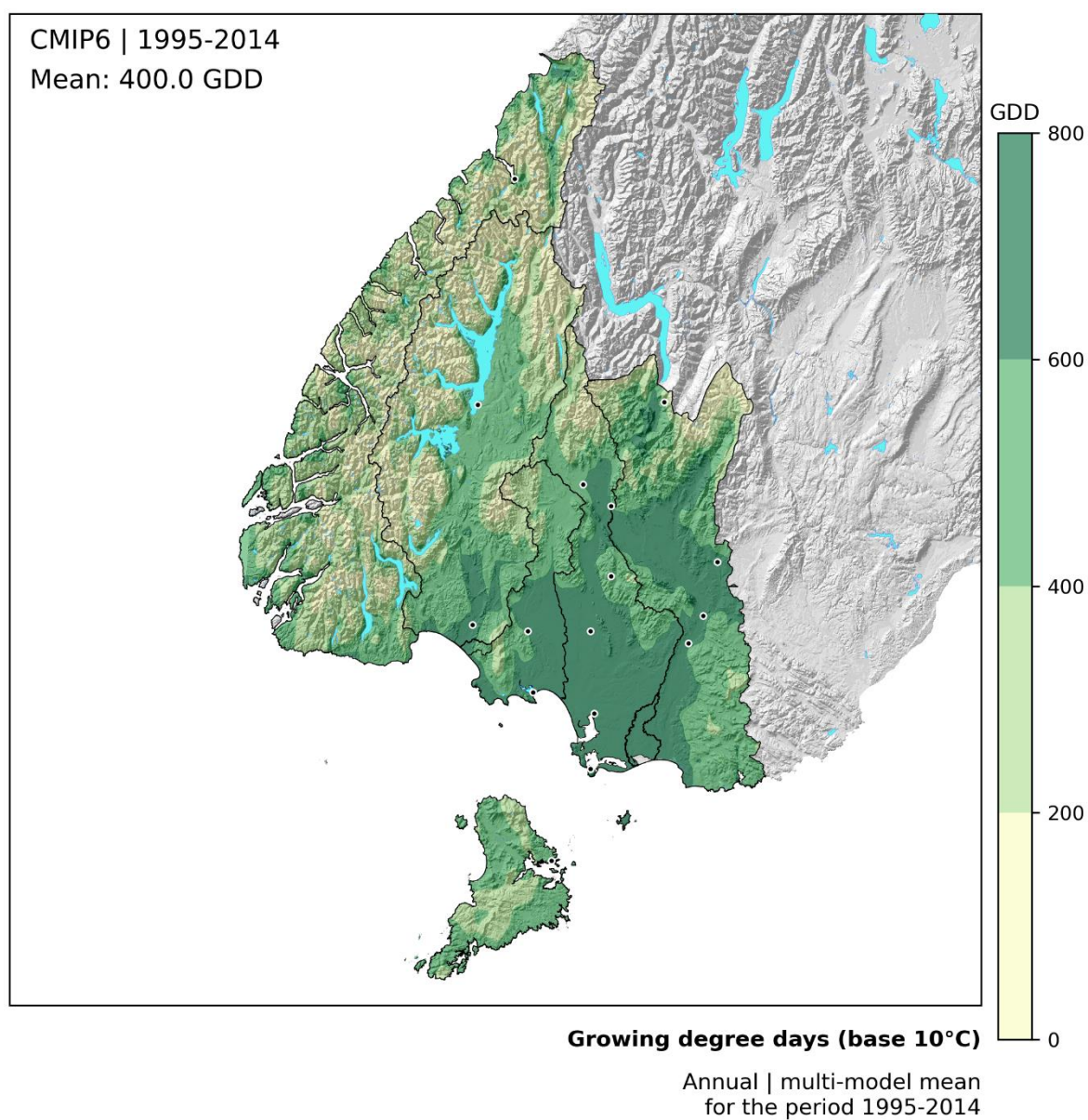


Figure 1-35: Modelled historic average annual growing degree days.

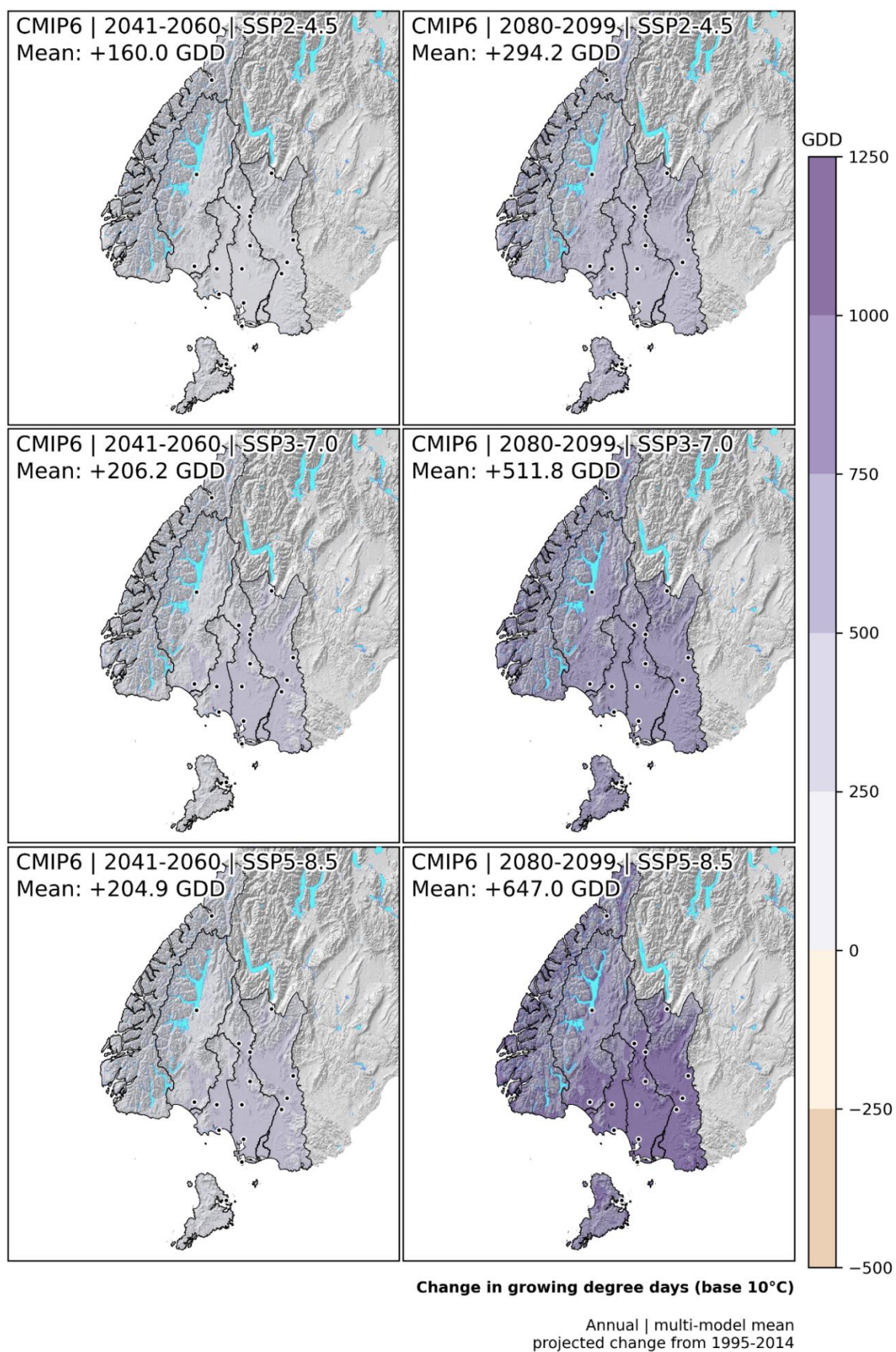


Figure 1-36: Projected annual growing degree day changes.

1.2 Precipitation

1.2.1 Total rainfall

Modelled historic and projected changes to future annual and seasonal rainfall are illustrated in Figure 1-37 to Figure 1-43. Regional average projected changes are summarised in Table 1-14. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-14: Projected total rainfall changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+4.2	+8.0	+4.3	+8.1	+4.6	+12.3
Summer	+1.9	+4.6	+4.0	+4.2	+2.2	+8.4
Autumn	+2.1	+6.6	-0.8	+1.5	+1.0	+2.1
Winter	+6.4	+11.0	+8.7	+14.7	+9.1	+24.2
Spring	+6.9	+10.4	+6.9	+12.8	+6.9	+15.6

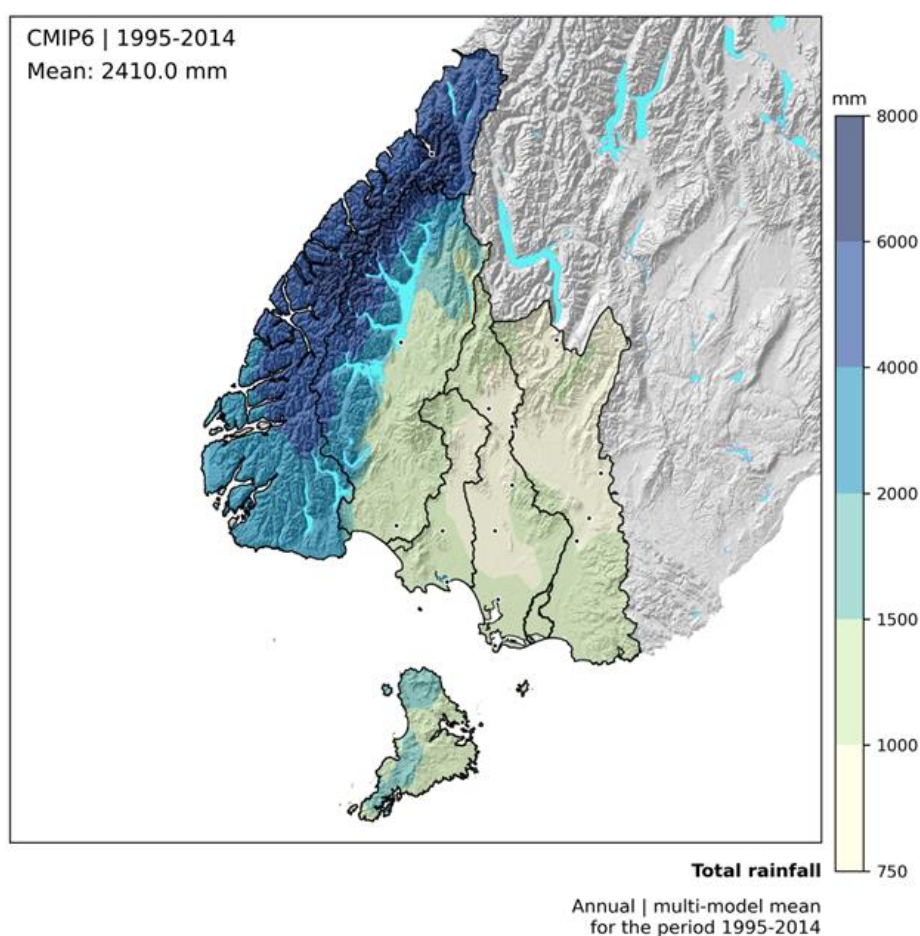


Figure 1-37: Modelled historic average annual total rainfall.

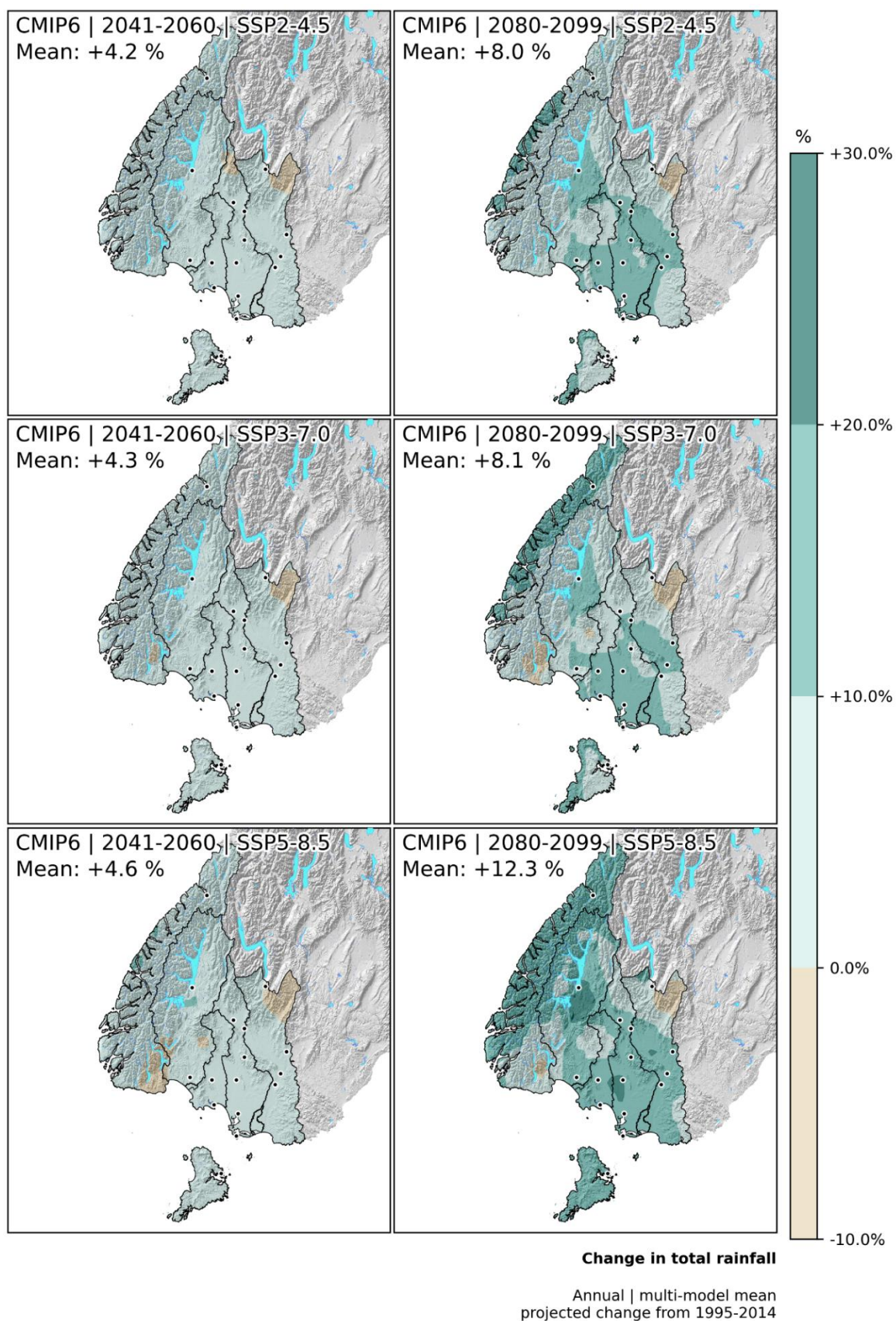


Figure 1-38: Projected annual average total rainfall changes.

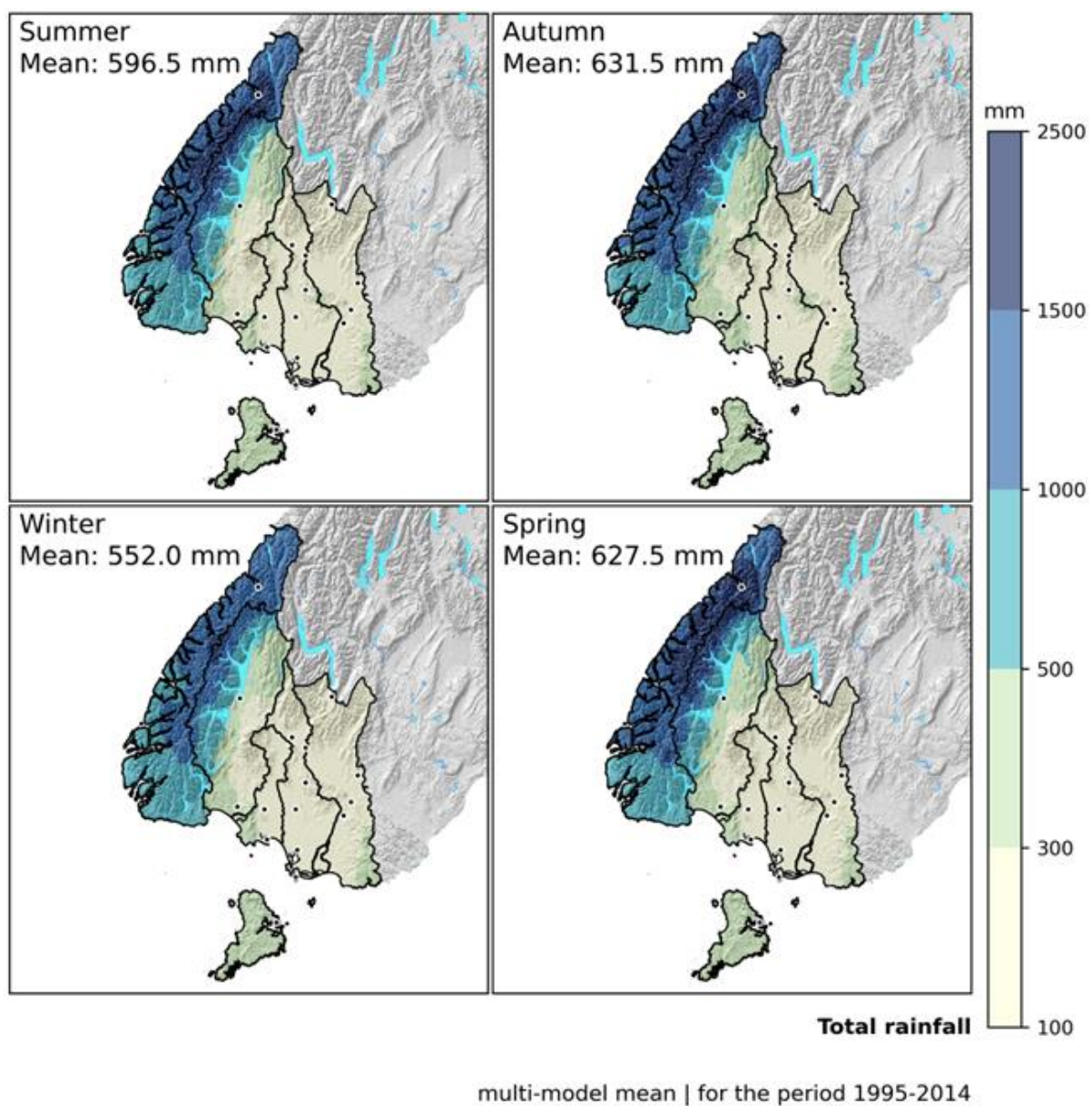


Figure 1-39: Modelled historic average seasonal total rainfall.

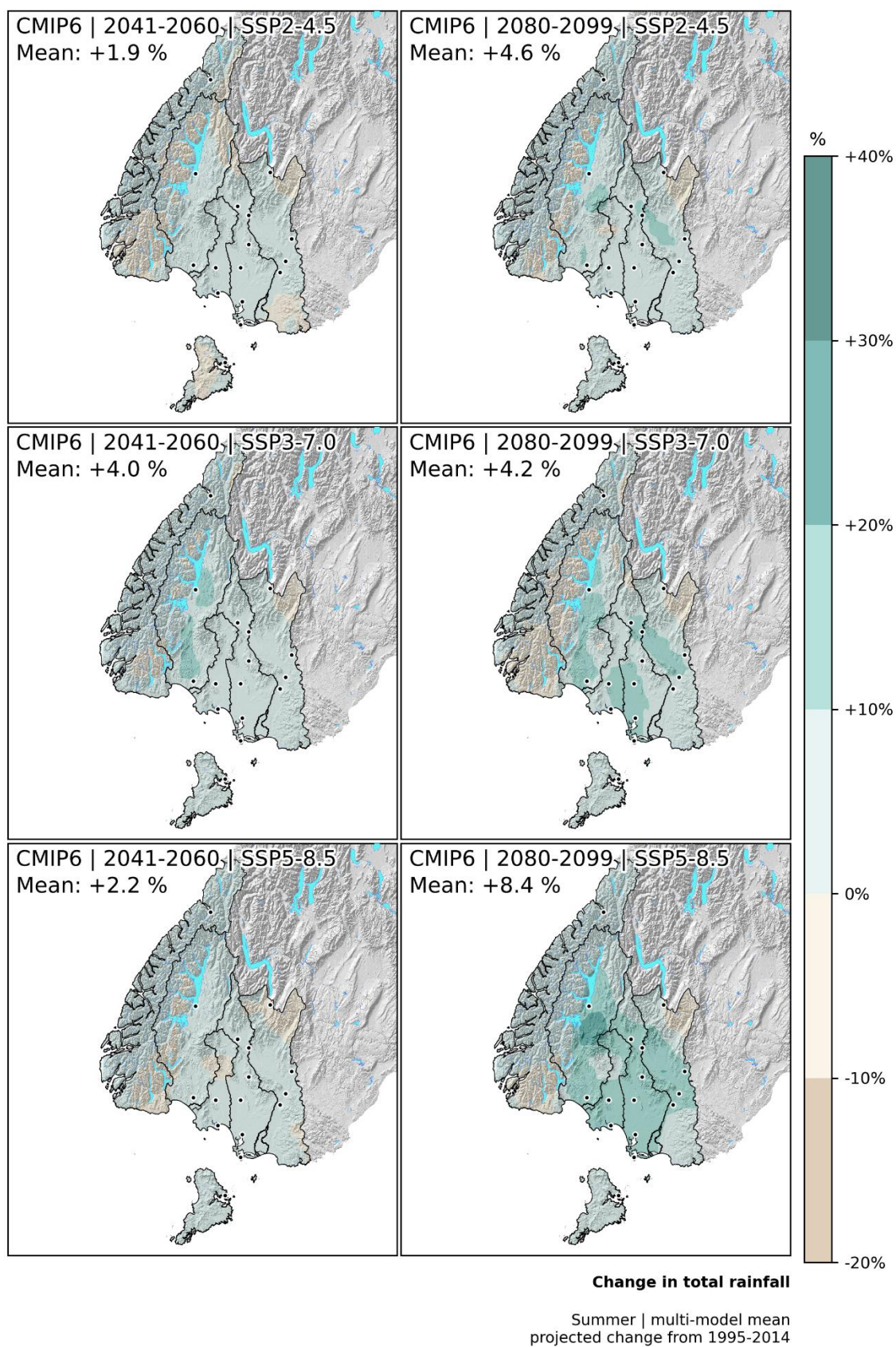


Figure 1-40: Projected summer average total rainfall changes.

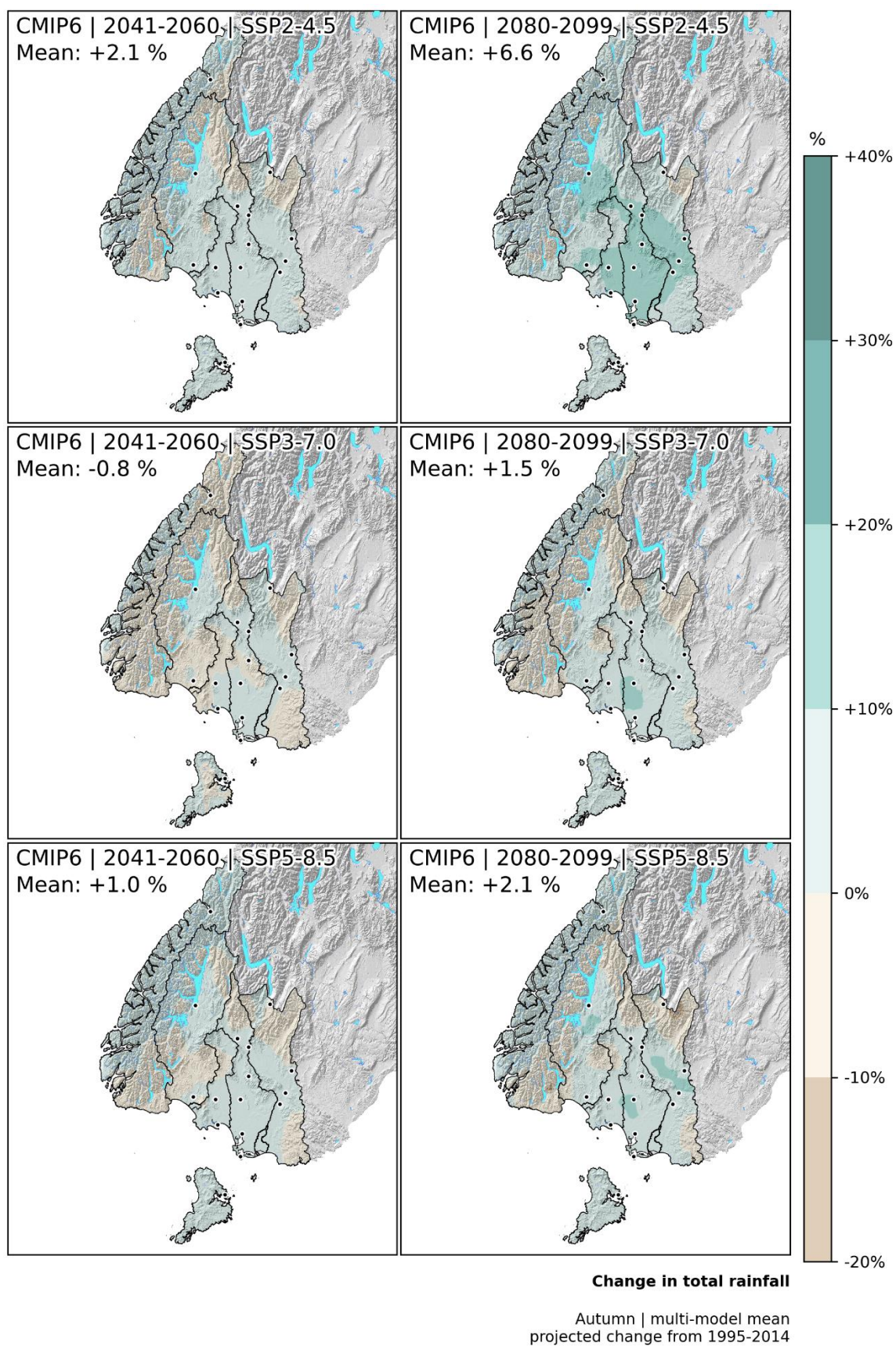


Figure 1-41: Projected autumn average total rainfall changes.

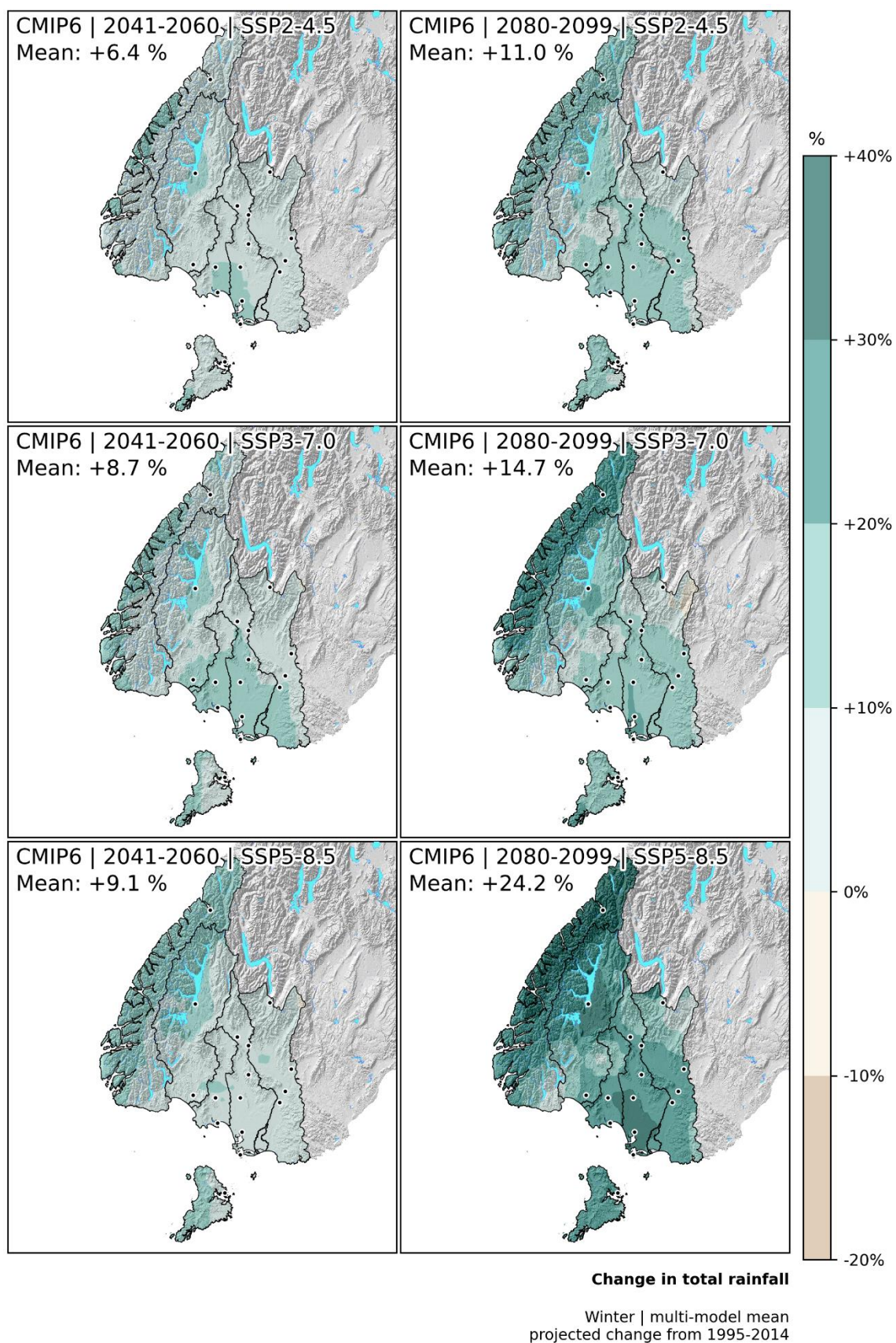


Figure 1-42: Projected winter average total rainfall changes.

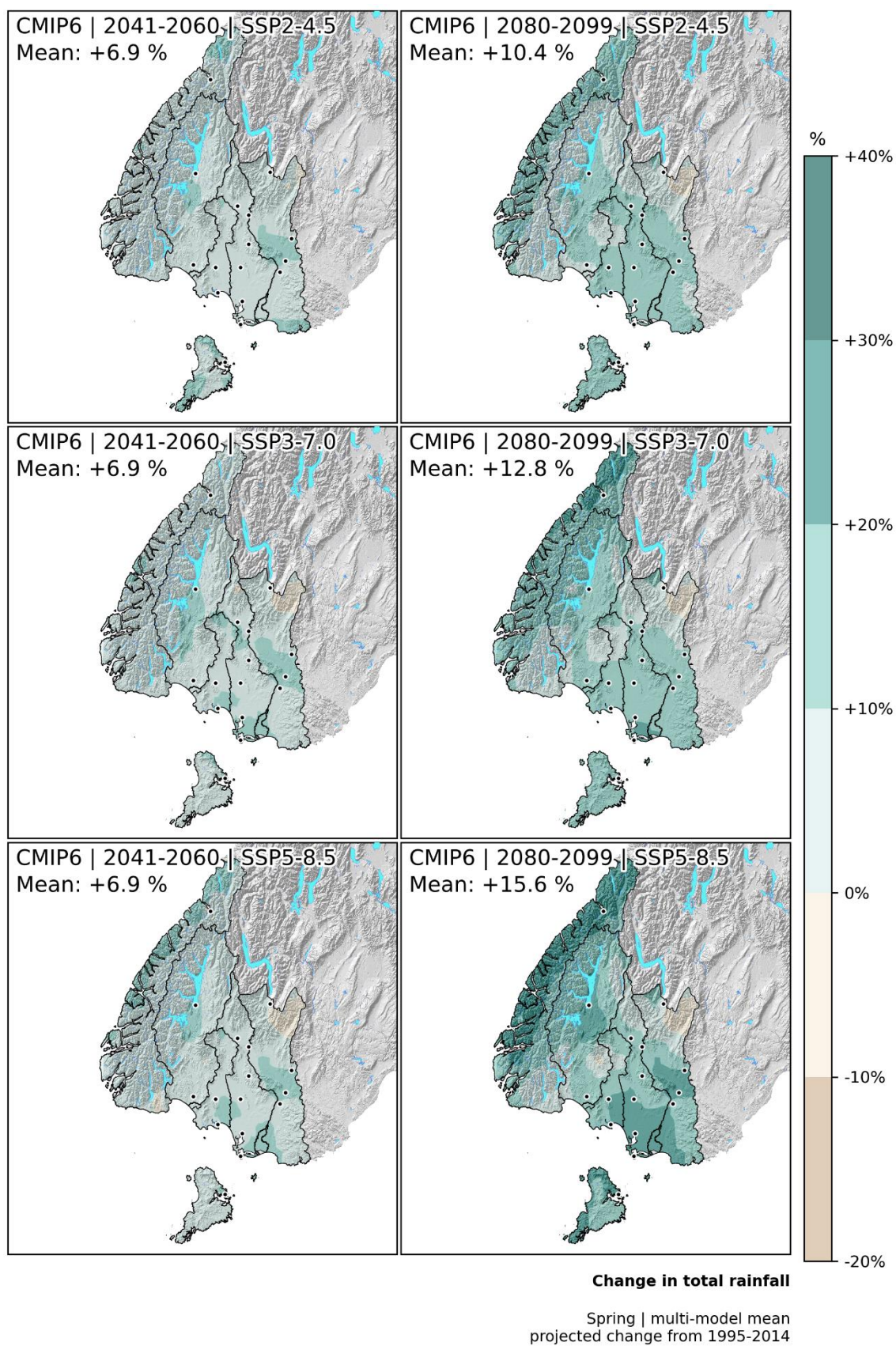


Figure 1-43: Projected Spring average total rainfall changes.

1.2.2 Wet days

Modelled historic and projected changes to future annual wet days are illustrated in Figure 1-44 and Figure 1-45. Regional average projected changes are summarised in Table 1-15, while location-specific projected changes are shown in Table 1-16. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-15: Projected wet day changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+0.3	+0.4	+0.2	-2.5	+0.4	-2.0

Table 1-16: Projected changes to number of wet days.

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	1.7	2.5	0.9	-1.8	0.5	-1.2
Riverton	2.3	1.5	0.8	-2.0	0.3	-2.3
Mataura	2.2	1.4	0.9	-3.0	1.2	-2.4
Gore	0.8	1.6	0.6	-3.2	0.4	-1.9
Winton	0.0	0.8	-0.6	-2.6	-1.0	-2.1
Lumsden	-0.8	0.2	-0.3	-3.1	-2.1	-4.1
Te Anau	-1.8	-1.3	-0.6	-3.6	-1.9	-2.3
Otautau	2.1	1.8	1.6	-2.1	0.0	-1.7
Tuatapere	1.6	1.1	1.6	-2.0	1.1	-2.0
Oban	-0.3	0.3	-1.0	-3.9	-0.1	-4.5
Riversdale	0.4	1.6	0.8	-2.5	0.1	-2.3
Waikaka	-0.6	0.0	-0.2	-2.9	0.2	-2.4
Milford Sound	-0.4	2.0	-1.2	0.8	0.3	2.0
Garston	-1.6	-2.1	-0.6	-6.0	-0.5	-5.3
Mossburn	-0.2	0.2	0.2	-3.8	-0.5	-3.9
Bluff	2.3	2.7	1.0	-1.3	1.1	-1.1

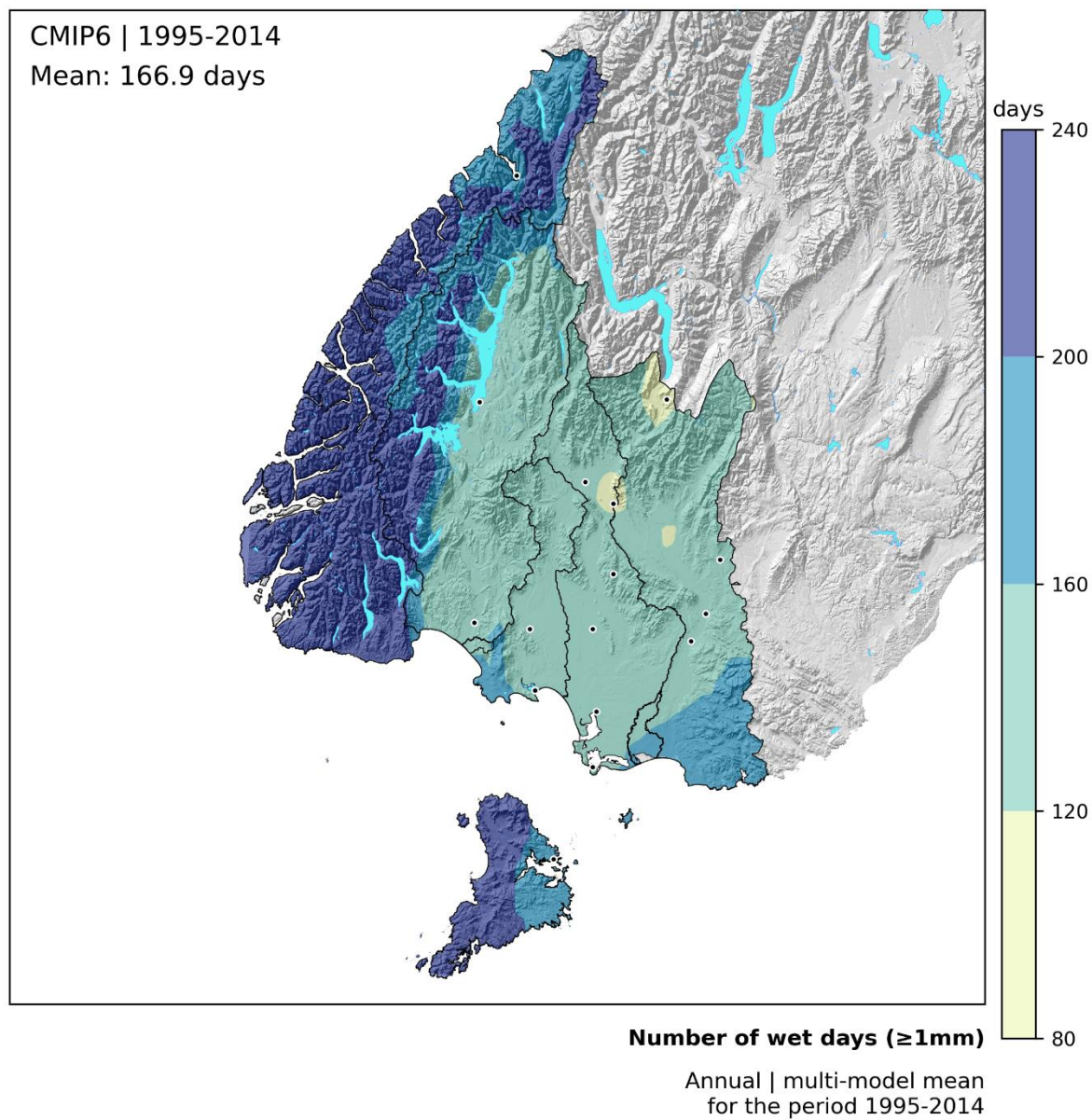


Figure 1-44: Modelled historic average annual number of wet days.

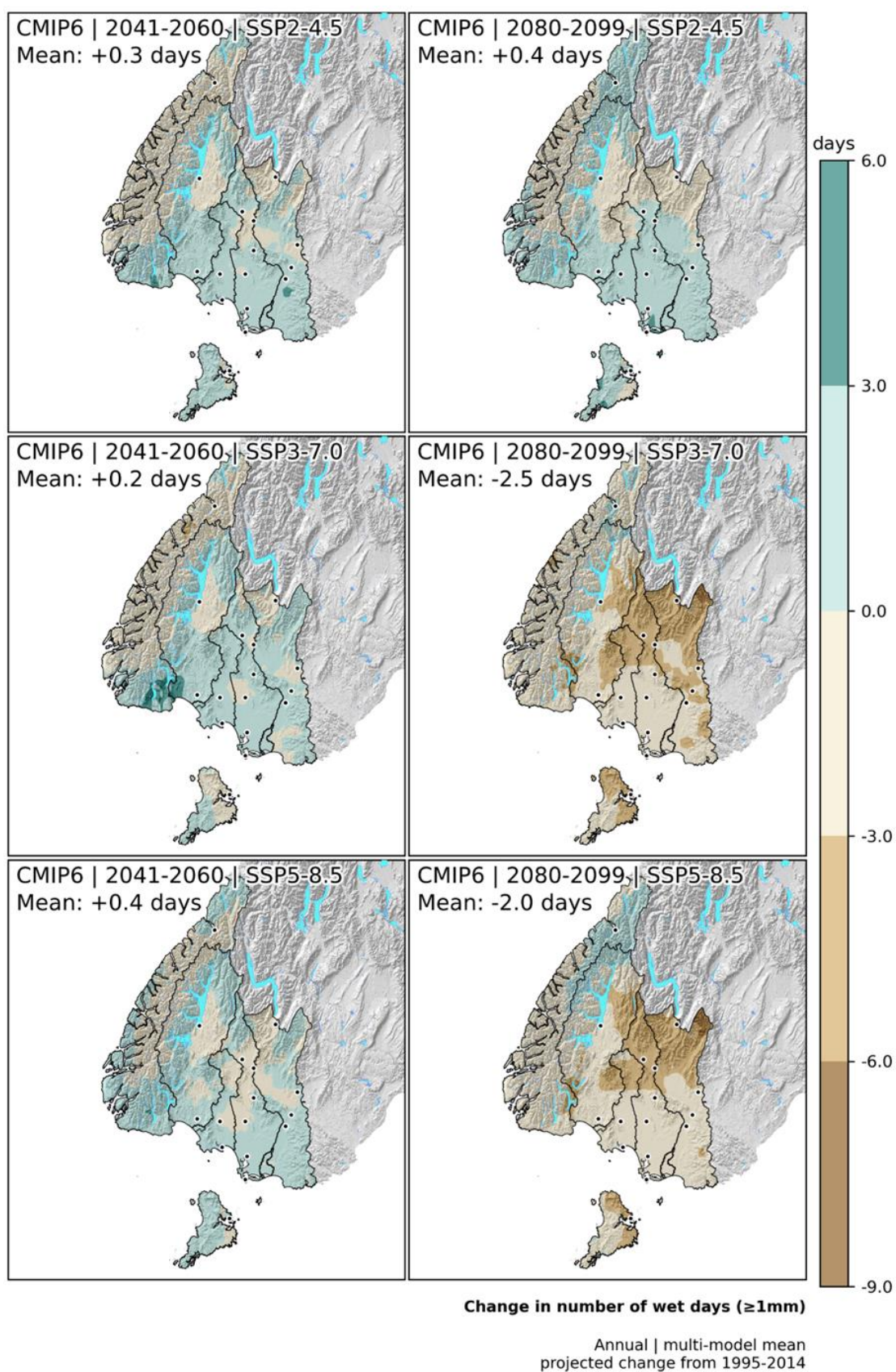


Figure 1-45: Projected annual wet day changes.

1.2.3 Rain days above 10mm

Modelled historic and projected changes to future annual rain days (>10 mm) are illustrated in Figure 1-46 and Figure 1-47. Regional average projected changes are summarised in Table 1-17, while location-specific projected changes are shown in Table 1-18. FMU average projected changes at annual time scale are summarised in Appendix A

Table 1-17: Projected rain days above 10 mm changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	2.1	3.5	1.6	2.8	1.9	4.5

Table 1-18: Projected changes to number of rain days above 10 mm (days).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	3.2	5.1	2.3	6.6	2.0	8.0
Riverton	3.2	5.4	2.8	5.8	1.9	7.7
Mataura	3.2	4.6	3.0	4.8	1.8	7.3
Gore	3.4	5.2	3.2	5.7	3.4	8.3
Winton	3.5	5.4	3.2	6.8	3.0	9.1
Lumsden	1.5	3.8	2.2	3.2	1.7	4.9
Te Anau	3.0	5.0	4.1	5.2	3.2	8.2
Otautau	2.9	5.2	2.9	5.5	2.5	7.7
Tuatapere	2.1	4.1	1.8	4.0	1.4	5.6
Oban	2.5	5.1	3.0	4.7	3.1	7.2
Riversdale	2.0	4.3	2.7	3.7	1.3	6.1
Waikaka	2.0	4.3	2.1	4.6	2.5	6.2
Milford Sound	2.4	3.7	0.7	3.8	3.2	5.6
Garston	-0.5	0.8	0.2	-0.3	-0.8	0.5
Mossburn	2.0	3.7	2.9	3.2	2.2	4.8
Bluff	3.1	5.2	2.8	6.8	2.1	8.5

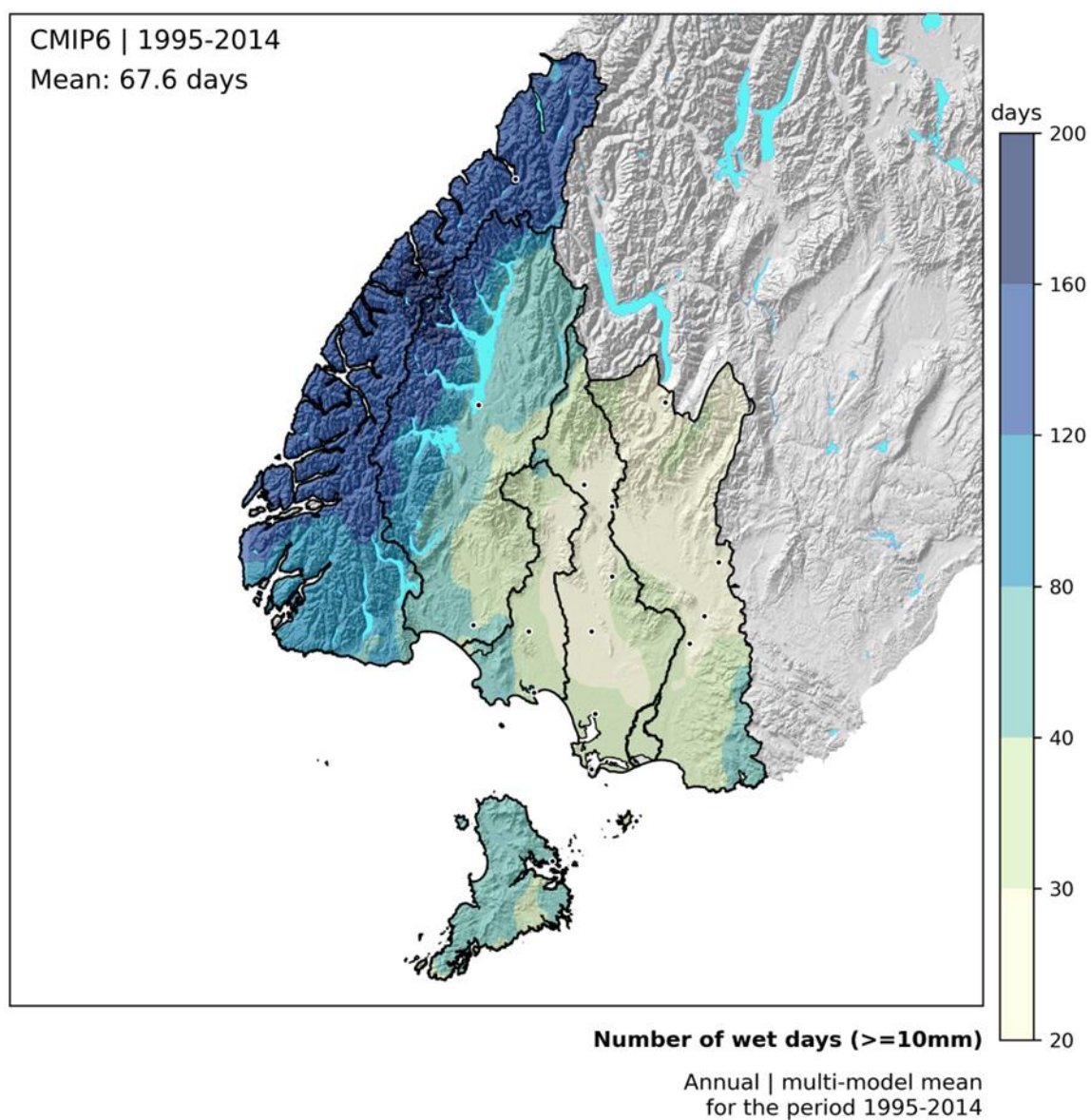


Figure 1-46: Modelled historic average annual number of rain days ($\geq 10\text{mm}$).

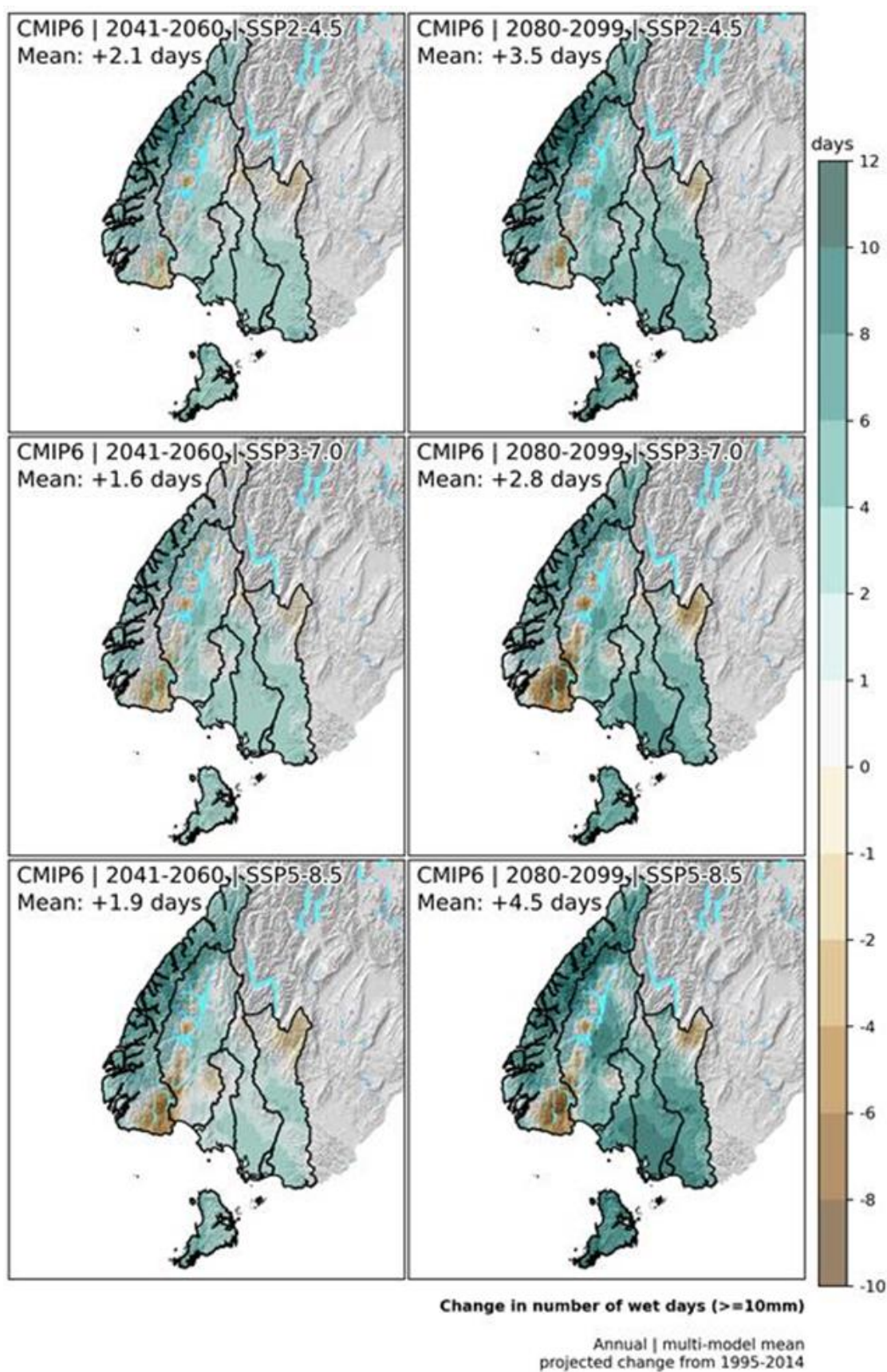


Figure 1-47: Projected annual rain day (>10 mm) changes.

1.2.4 Very wet days

Modelled historic and projected changes to future annual very wet days are illustrated in Figure 1-48 and Figure 1-49. Regional average projected changes are summarised in Table 1-19, while location-specific projected changes are shown in Table 1-20.

Table 1-19: Projected very wet day changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+1.5	+2.7	+1.5	+3.2	+1.9	+4.5

Table 1-20: Projected changes to number of very wet days.

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	0.9	2.0	1.6	3.0	1.4	3.7
Riverton	1.3	2.3	1.8	3.0	1.4	3.9
Mataura	0.6	1.6	1.0	2.1	0.9	2.7
Gore	0.6	1.6	0.8	2.1	0.9	2.8
Winton	0.9	2.0	1.3	2.5	1.2	3.1
Lumsden	1.1	2.1	1.1	2.1	1.0	2.8
Te Anau	2.0	3.4	2.8	4.5	3.0	6.1
Otautau	1.2	2.5	1.8	3.1	1.4	3.8
Tuatapere	1.2	2.8	1.9	3.2	1.5	4.0
Oban	1.2	2.3	1.5	2.8	1.7	3.8
Riversdale	0.8	1.7	1.0	2.0	0.8	2.7
Waikaka	0.7	1.4	0.7	1.9	0.8	2.6
Milford Sound	3.1	5.1	1.7	5.8	3.3	7.5
Garston	0.5	1.1	0.8	1.6	0.5	1.3
Mossburn	1.1	1.9	1.3	2.1	0.9	2.7
Bluff	1.2	2.4	1.6	3.3	1.4	4.2

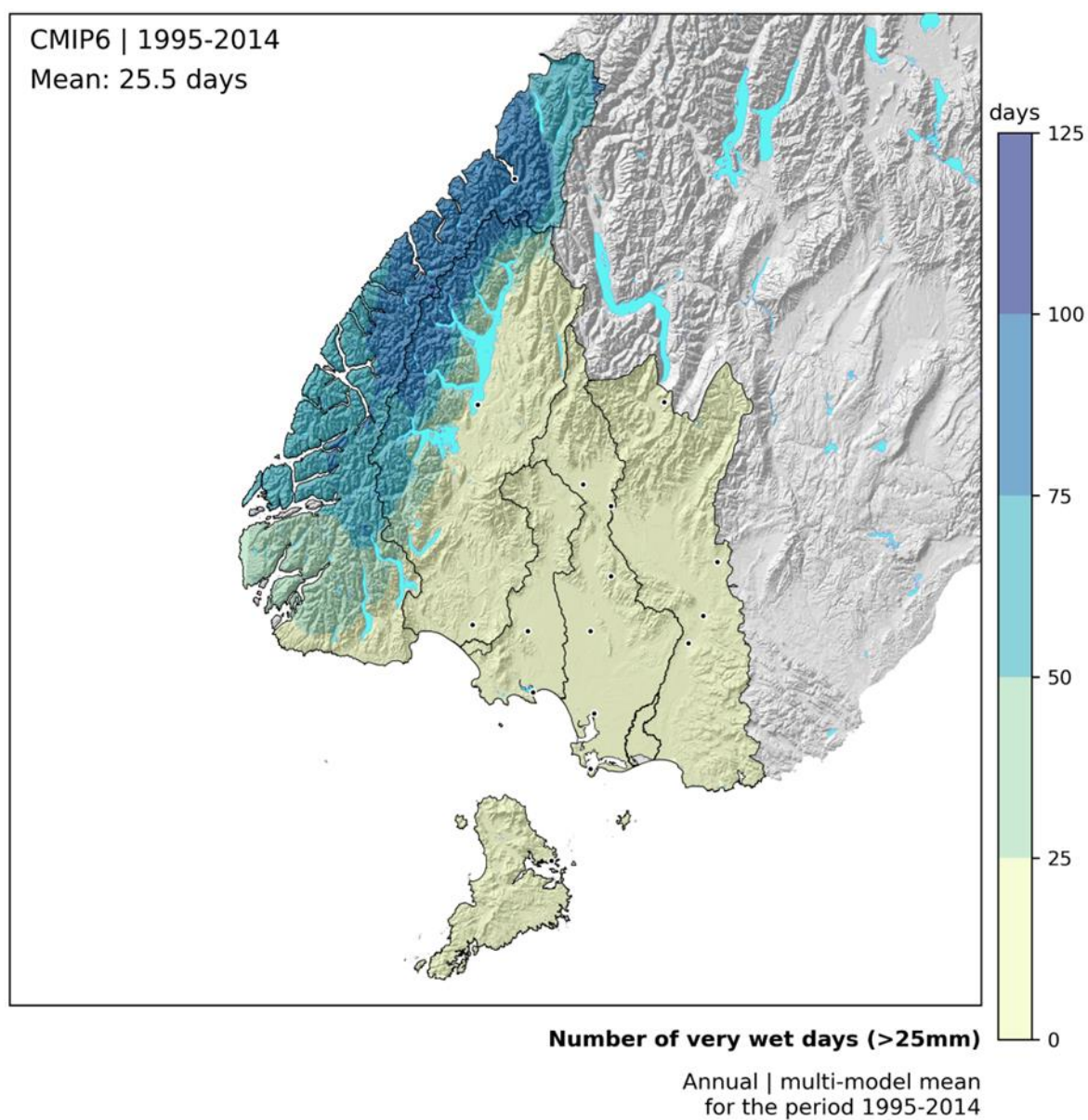


Figure 1-48: Modelled historic average annual number of very wet days.

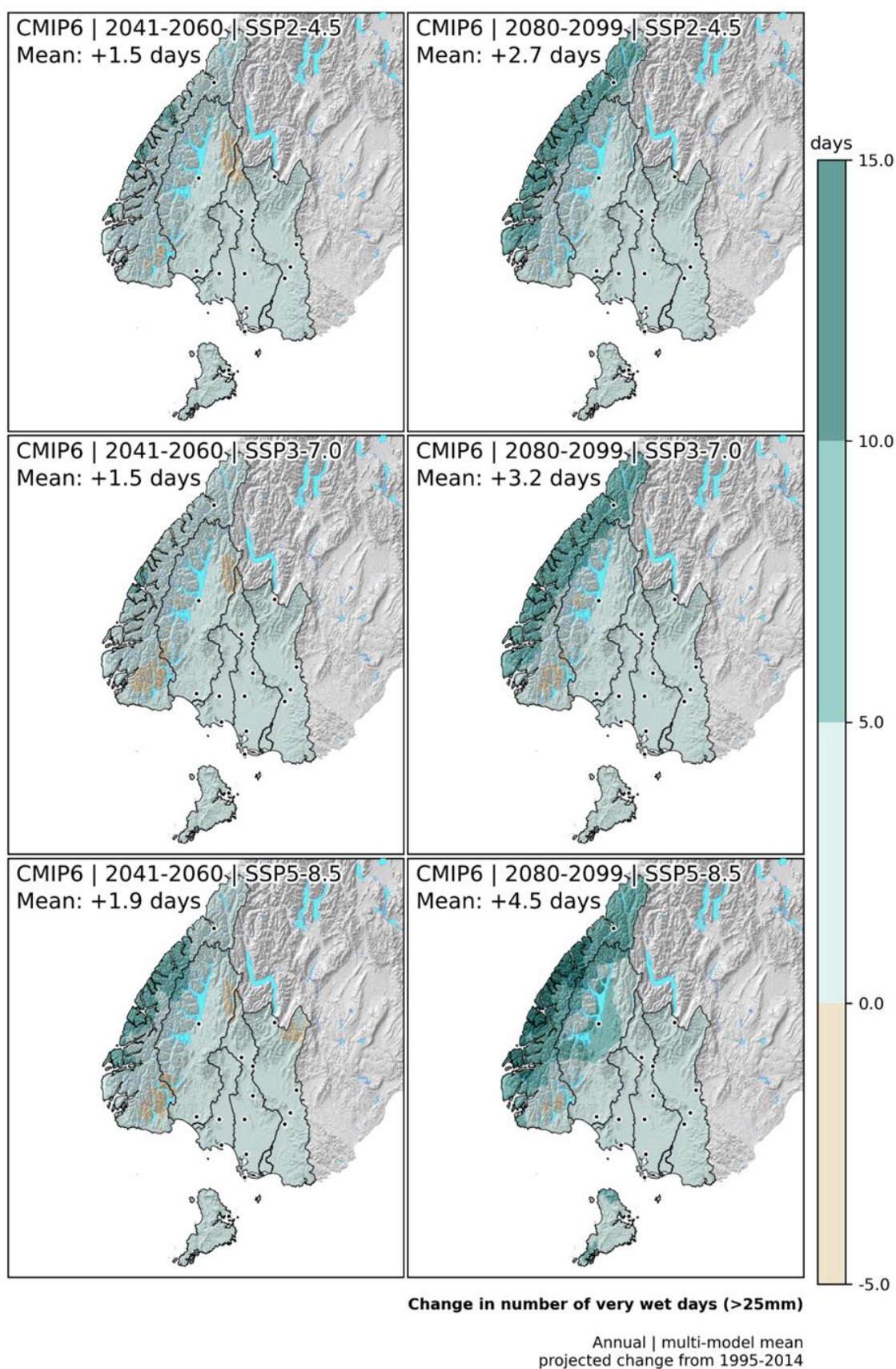


Figure 1-49: Projected annual very wet day changes.

1.2.5 Rain days above 50 mm

Modelled historic and projected changes to future annual rain days (>50 mm) are illustrated in Figure 1-50 and Figure 1-51. Regional average projected changes are summarised in Table 1-21, while location-specific projected changes are shown in Table 1-22. FMU average projected changes at annual time scale are summarised in Appendix A.

Table 1-21: Projected rain days as above 50 mm (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	0.7	1.4	0.8	1.8	1.0	2.7

Table 1-22: Projected changes to number of rain days as above 50 mm (days).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	+0.1	+0.3	+0.1	+0.5	+0.2	+0.6
Riverton	+0.2	+0.4	+0.2	+0.5	+0.4	+0.7
Mataura	+0.2	+0.3	+0.2	+0.3	+0.2	+0.5
Gore	+0.2	+0.3	+0.2	+0.4	+0.3	+0.6
Winton	+0.1	+0.3	+0.1	+0.4	+0.2	+0.6
Lumsden	+0.2	+0.4	+0.2	+0.4	+0.2	+0.6
Te Anau	+0.4	+1.0	+0.6	+1.0	+0.7	+1.9
Otautau	+0.2	+0.5	+0.2	+0.5	+0.2	+0.8
Tuatapere	+0.3	+0.5	+0.3	+0.6	+0.3	+0.8
Oban	+0.1	+0.2	+0.2	+0.5	+0.3	+0.7
Riversdale	+0.3	+0.4	+0.2	+0.5	+0.2	+0.7
Waikaka	+0.2	+0.4	+0.2	+0.4	+0.2	+0.5
Milford Sound	+2.3	+4.6	+2.0	+6.5	+3.2	+8.1
Garston	+0.1	+0.2	+0.1	+0.4	+0.1	+0.4
Mossburn	+0.1	+0.4	+0.3	+0.6	+0.3	+0.7
Bluff	+0.1	+0.4	+0.2	+0.5	+0.3	+0.7

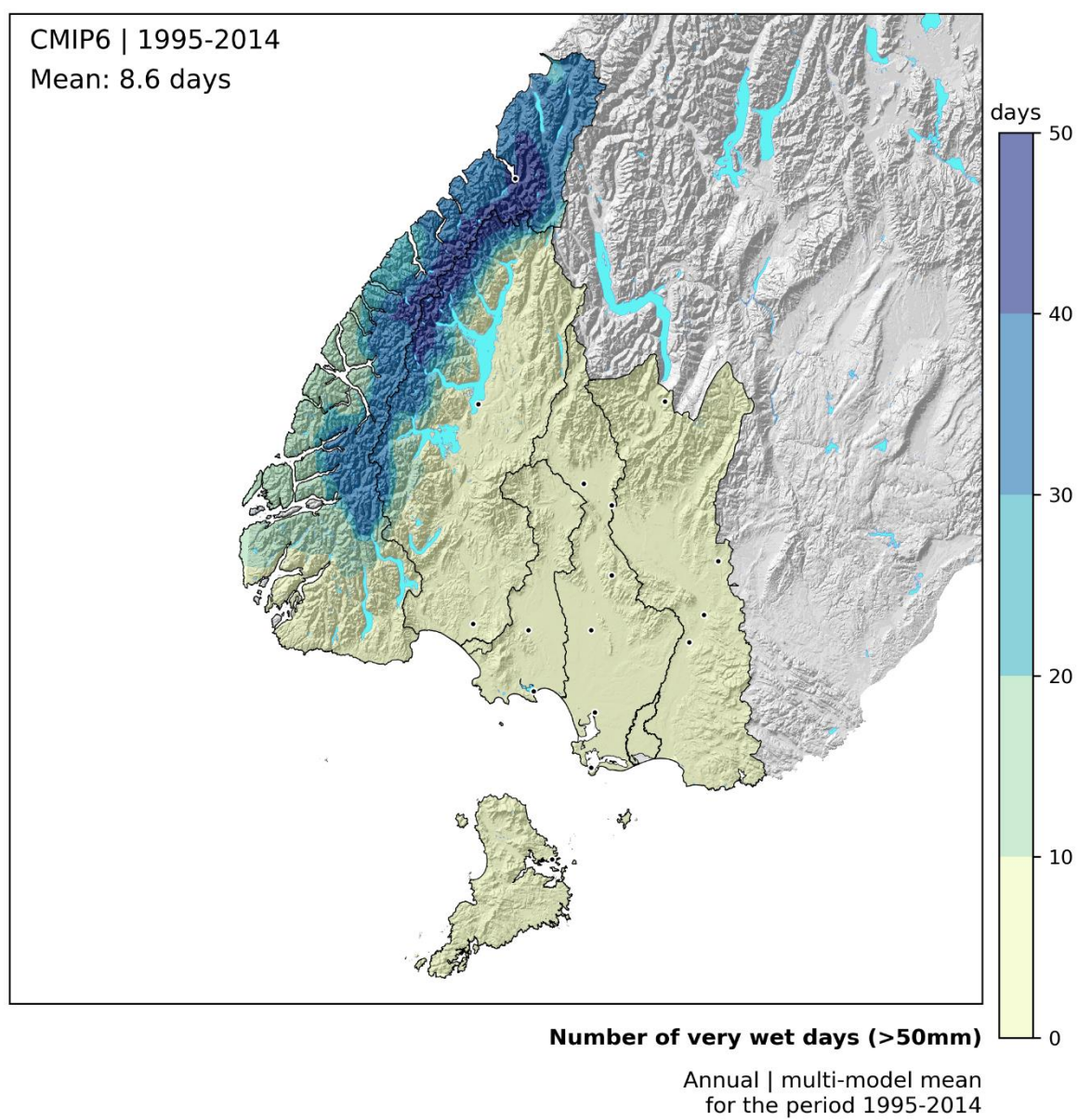


Figure 1-50: Modelled historic average annual number of rain days (>50 mm).

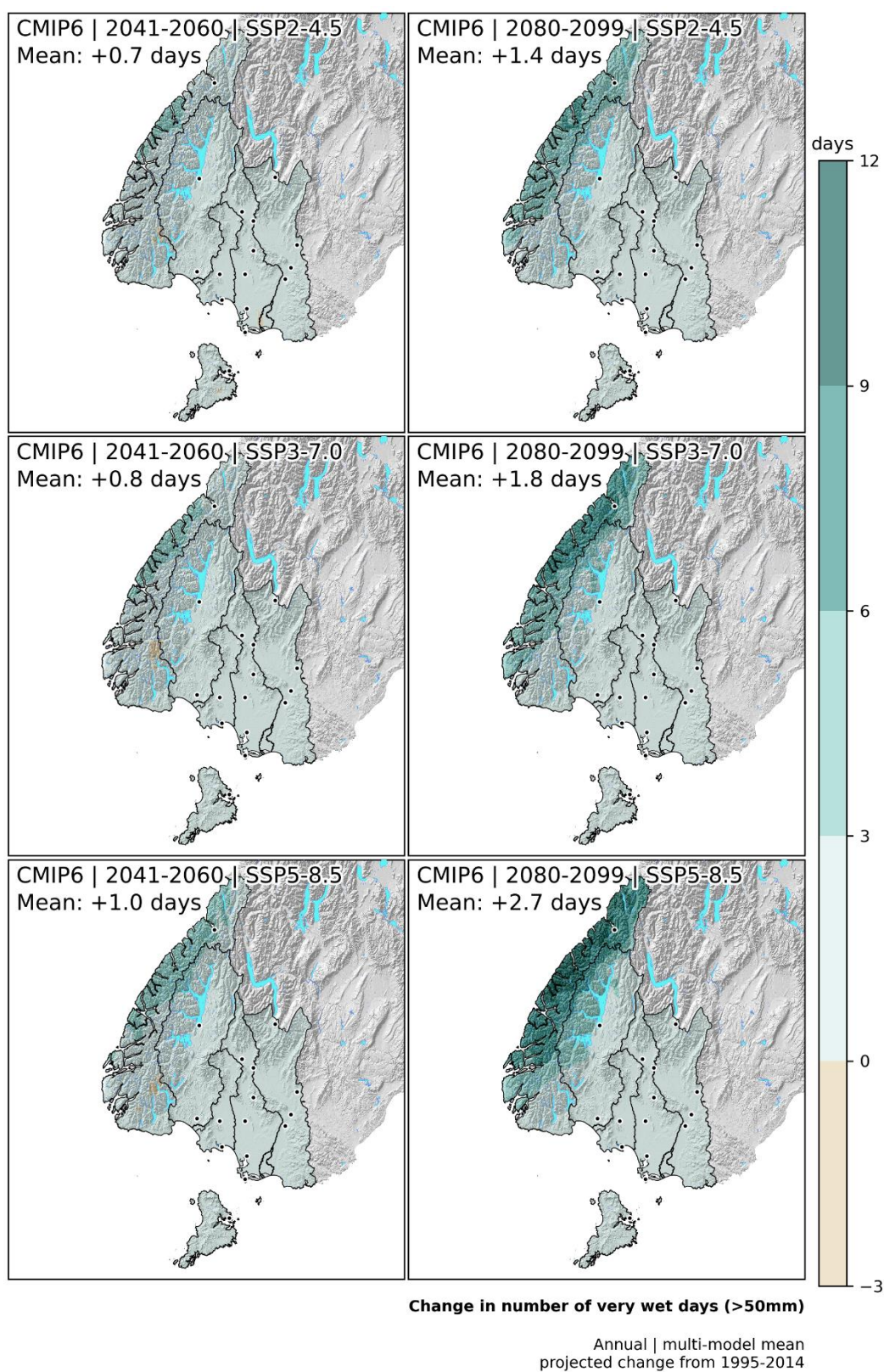


Figure 1-51: Projected annual rain day (>50 mm) changes.

1.2.6 Maximum annual 1-day rainfall total

Modelled historic and projected changes to future maximum annual 1-day rainfall totals are illustrated in Figure 1-52 and Figure 1-53. Regional average projected changes are summarised in Table 1-23. FMU average projected changes at annual time scale are summarised in Appendix A.

Table 1-23: Projected maximum annual 1-day rainfall total changes (mm/day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+6.3	+13.2	+8.4	+15.7	+10.8	+22.2

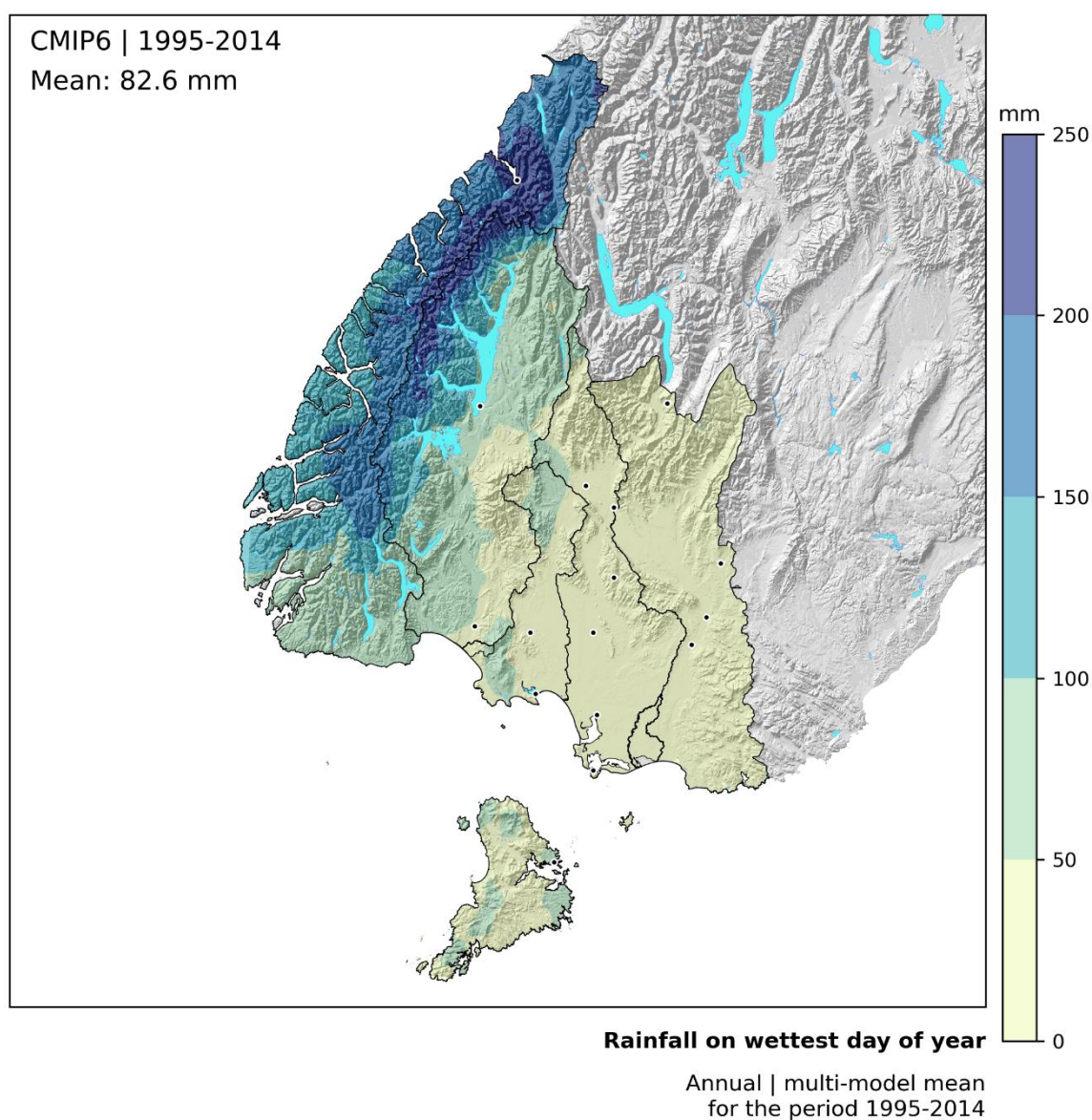


Figure 1-52: Modelled historic average maximum annual 1-day rainfall total.

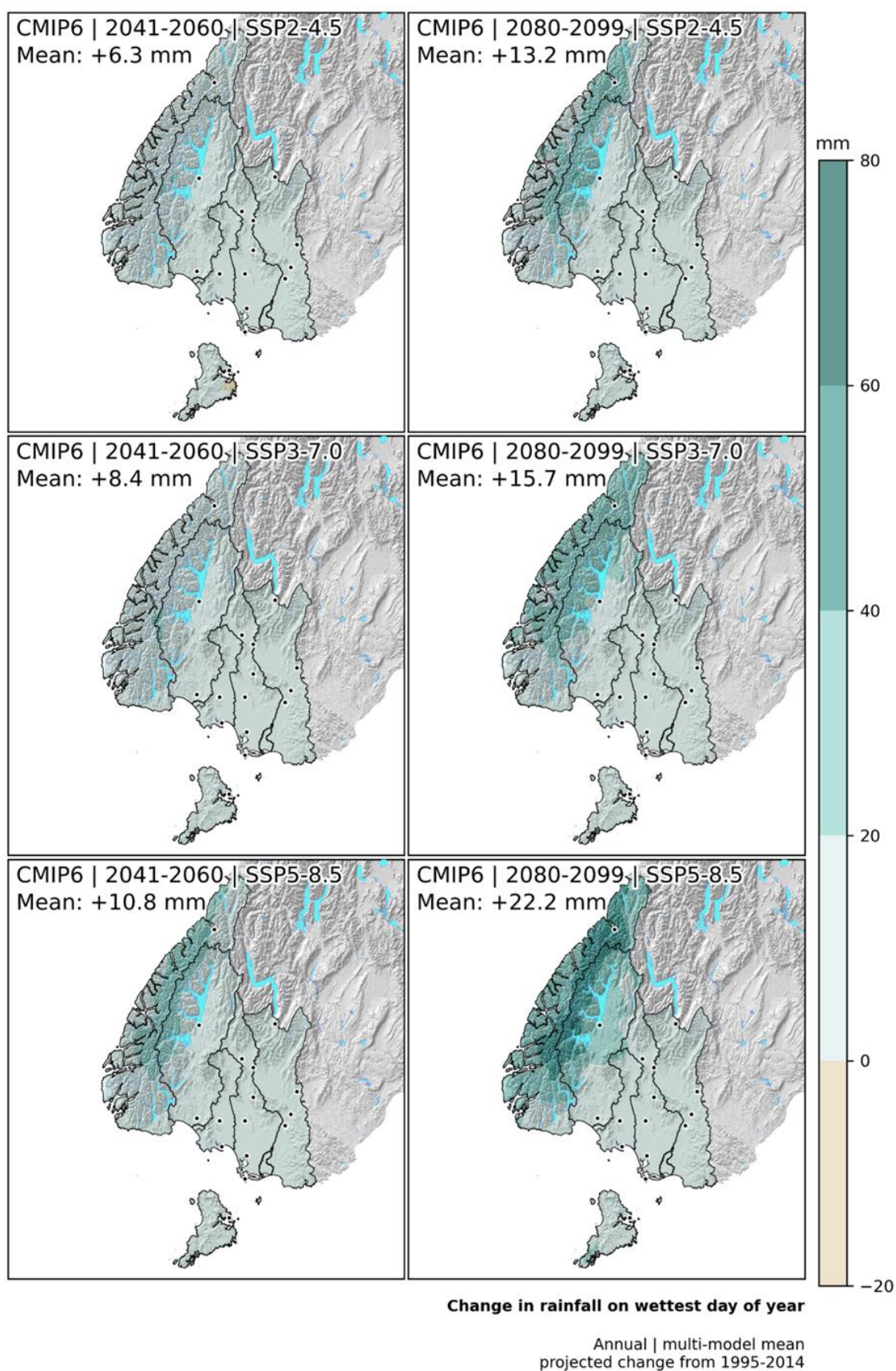


Figure 1-53: Projected changes to the average maximum annual 1-day rainfall total.

1.2.7 Maximum annual 5-day rainfall total

Modelled historic and projected changes to future maximum annual 5-day rainfall totals are illustrated in Figure 1-54 and Figure 1-55. Regional average projected changes are summarised in Table 1-24. FMU average projected changes at annual time scale are summarised in Appendix A.

Table 1-24: Projected maximum annual 5-day rainfall total changes (mm/day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+10.1	+12.5	+8.7	+17.4	+10.9	+25.6

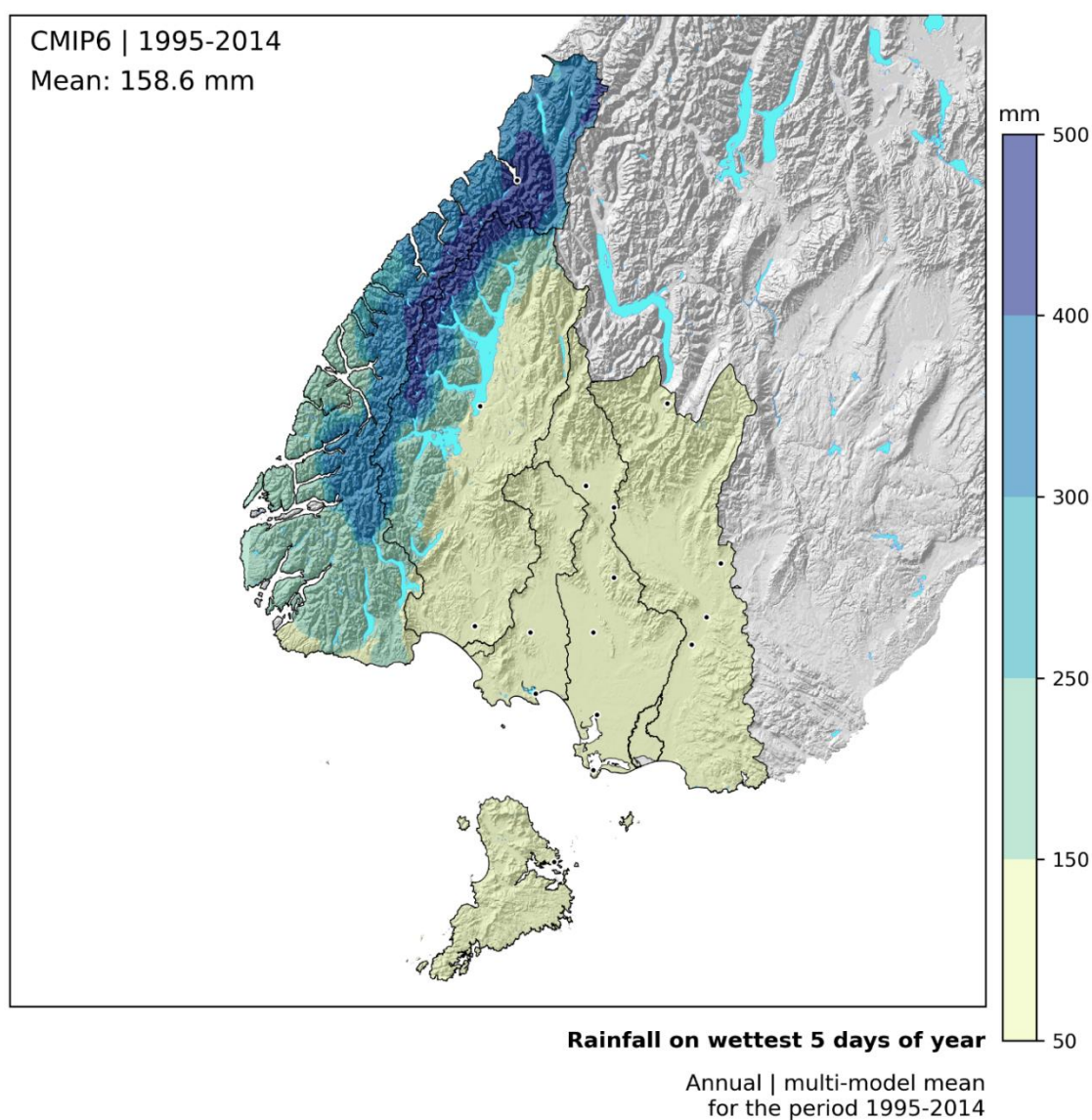


Figure 1-54: Modelled historic average maximum annual 5-day rainfall total.

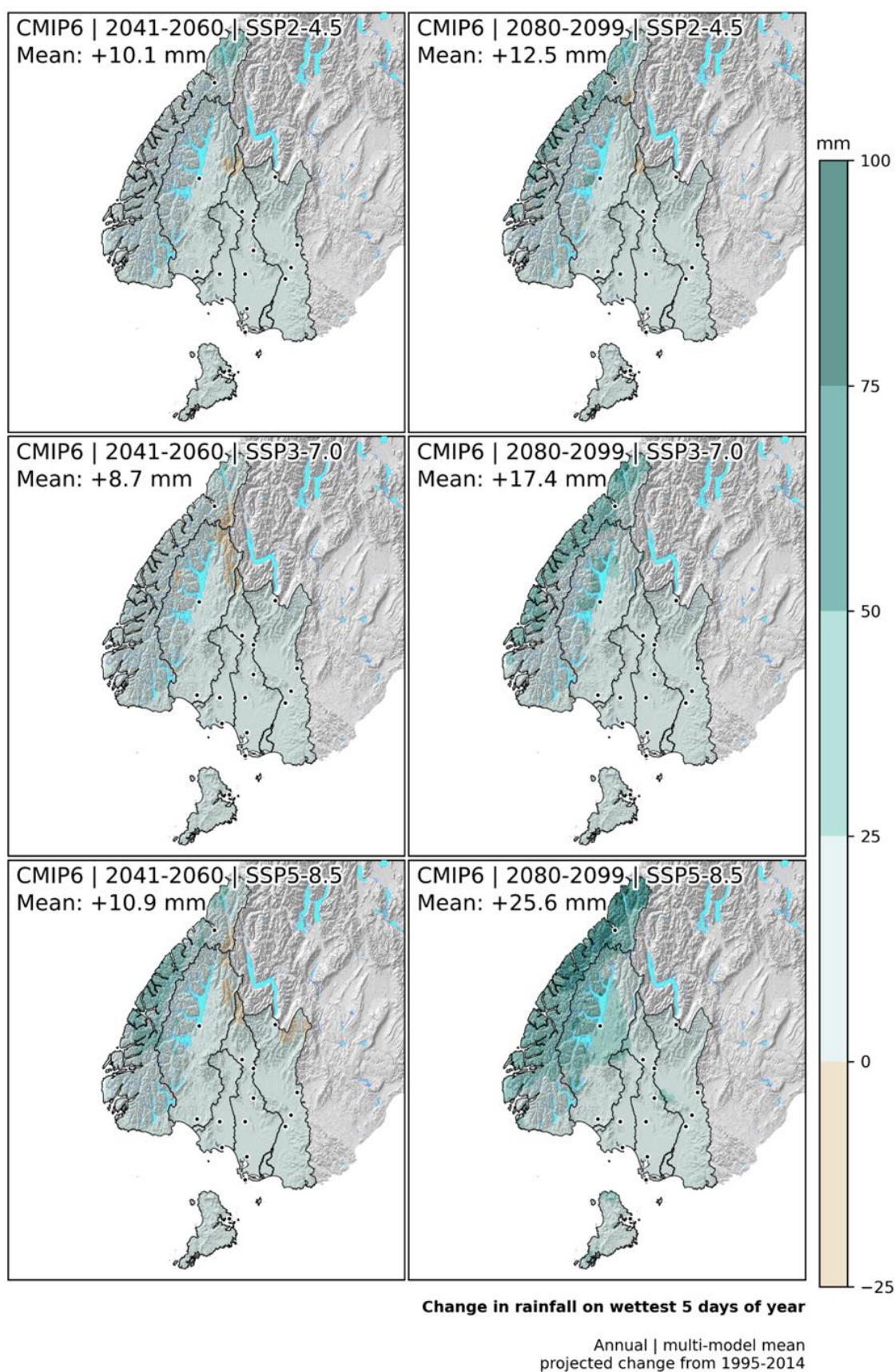


Figure 1-55: Projected changes to the average maximum annual 5-day rainfall total.

1.2.8 Rainfall intensity

Carey-Smith et al. (2018) present New Zealand's future changes to rainfall depths for event durations/average recurrence intervals (ARI) spanning 1-120 hours/2-100 years. Per degree of warming, the percentage change factors for rainfall depths ranged from 4.8% to 13.6%, with greater increases for shorter duration/higher ARI event combinations (Table 1-25). This analysis was based on CMIP5 and can be expected to be updated for CMIP6 in the near future.

To understand the projected changes to rainfall intensity, we propose a three-step approach:

1. Take the historic rainfall depth for a given event duration/ARI combination at your location of interest (See Appendix B).
2. Determine the projected temperature increase for a given SSP scenario and future period (Table 1-26) and use this to calculate the percentage change factor.
3. Apply the percentage change factor to the historic rainfall depth to calculate the projected rainfall depth.

Table 1-25: Projected percentage change factors to rainfall depths per 1 degree of warming.

Source: Carey-Smith et al. (2018).

DURATION/ARI	2 YR	5 YR	10 YR	20 YR	30 YR	40 YR	50 YR	60 YR	80 YR	100 YR
1 HOUR	12.2	12.8	13.1	13.3	13.4	13.4	13.5	13.5	13.6	13.6
2 HOURS	11.7	12.3	12.6	12.8	12.9	12.9	13.0	13.0	13.1	13.1
6 HOURS	9.8	10.5	10.8	11.1	11.2	11.3	11.3	11.4	11.4	11.5
12 HOURS	8.5	9.2	9.5	9.7	9.8	9.9	9.9	10.0	10.0	10.1
24 HOURS	7.2	7.8	8.1	8.2	8.3	8.4	8.4	8.5	8.5	8.6
48 HOURS	6.1	6.7	7.0	7.2	7.3	7.3	7.4	7.4	7.5	7.5
72 HOURS	5.5	6.2	6.5	6.6	6.7	6.8	6.8	6.9	6.9	6.9
96 HOURS	5.1	5.7	6.0	6.2	6.3	6.3	6.4	6.4	6.4	6.5
120 HOURS	4.8	5.4	5.7	5.8	5.9	6.0	6.0	6.0	6.1	6.1

Table 1-26: Projected annual mean temperature changes for Southland. See Section 1.1.1 for details.

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual temperature changes	+1.0	+1.8	+1.2	+2.8	+1.3	+3.4

Here, we work through an example for Bluff applying the three steps outlined above. In this case, we calculate the projected rainfall depth by 2090 under SSP4.5, for a 20-year ARI, 12-hour rainfall event:

1. For a rainfall event of 12 hours duration, with an ARI of 20 years, the rainfall depth at Bluff is 61 mm.
2. The projected temperature increase by 2090 under SSP2-4.5 is 1.8°C. The projected percentage change factor (per degree of warming) for our event

ARI/duration combination is 9.7%. Therefore, our percentage change factor is $9.7 \times 1.8 = 17.5\%$

3. The percentage change factor (17.5) multiplied by the historic rainfall depth (61 mm) gives the projected rainfall depth of **71.7 mm**.

1.2.9 Dry days

Modelled historic and projected changes to future annual dry days are illustrated in Figure 1-56 and Figure 1-57. Regional average projected changes are summarised in Table 1-27, while location-specific projected changes are shown in Table 1-28. FMU average projected changes at annual and seasonal time scale are summarised in Appendix A.

Table 1-27: Projected changes in dry day (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	-0.3	-0.4	-0.2	+2.5	-0.4	+2.0

Table 1-28: Projected changes to number of dry days (days).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	-1.7	-2.5	-0.9	1.8	-0.5	1.2
Riverton	-2.3	-1.5	-0.8	2.0	-0.3	2.3
Mataura	-2.2	-1.4	-0.9	3.0	-1.2	2.4
Gore	-0.8	-1.6	-0.6	3.2	-0.4	1.9
Winton	0.0	-0.8	0.6	2.6	1.0	2.1
Lumsden	0.8	-0.2	0.3	3.1	2.1	4.1
Te Anau	1.8	1.3	0.6	3.6	1.9	2.3
Otautau	-2.1	-1.8	-1.6	2.1	0.0	1.7
Tuatapere	-1.6	-1.1	-1.6	2.0	-1.1	2.0
Oban	0.3	-0.3	1.0	3.9	0.1	4.5
Riversdale	-0.4	-1.6	-0.8	2.5	-0.1	2.3
Waikaka	0.6	0.0	0.2	2.9	-0.2	2.4
Milford Sound	0.4	-2.0	1.2	-0.8	-0.3	-2.0
Garston	1.6	2.1	0.6	6.0	0.5	5.3
Mossburn	0.2	-0.2	-0.2	3.8	0.5	3.9
Bluff	-2.3	-2.7	-1.0	1.3	-1.1	1.1

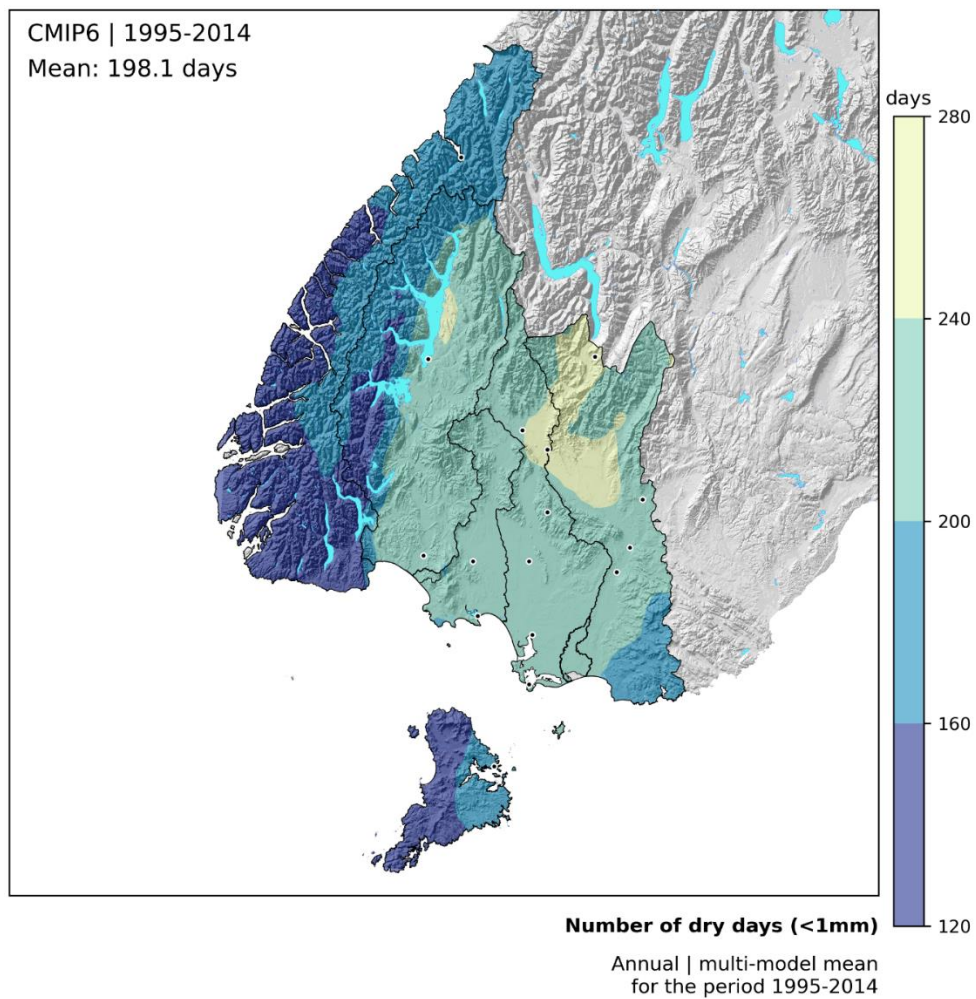


Figure 1-56: Modelled historic average annual number of dry days.

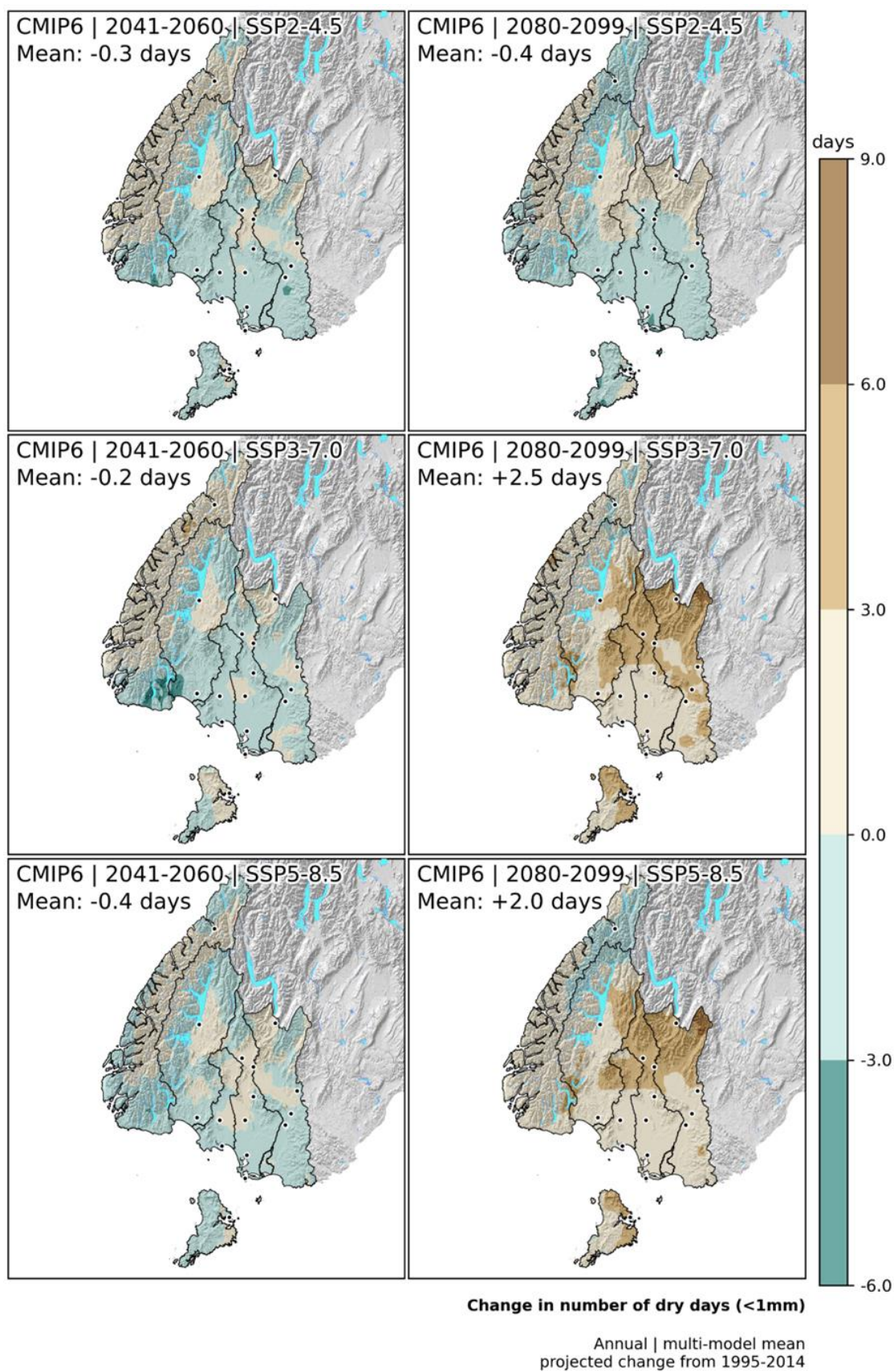


Figure 1-57: Projected annual dry day changes.

1.3 Relative humidity

Modelled historic and projected changes to future annual and seasonal relative humidity are illustrated in Figure 1-58 to Figure 1-64. Regional average projected changes are summarised in Table 1-29 at annual, seasonal and monthly time scale.

Table 1-29: Projected relative humidity changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	-0.1	-0.2	-0.2	-0.5	-0.3	-0.7
Summer	-0.1	-0.2	-0.4	-0.6	-0.3	-0.8
Autumn	0	0	-0.2	-0.3	-0.2	-0.5
Winter	-0.1	-0.2	-0.2	-0.5	-0.3	-0.6
Spring	-0.1	-0.2	-0.2	-0.5	-0.3	-0.7
January	-0.2	-0.4	-0.4	-0.6	-0.4	-0.9
February	-0.1	-0.2	-0.3	-0.5	-0.2	-0.7
March	0	0	-0.2	-0.2	-0.3	-0.5
April	0	-0.1	0	-0.2	-0.1	-0.4
May	-0.1	-0.1	-0.4	-0.4	-0.3	-0.5
June	-0.1	-0.3	-0.2	-0.5	-0.3	-0.6
July	-0.1	-0.3	-0.2	-0.6	-0.3	-0.7
August	-0.2	-0.2	-0.2	-0.5	-0.3	-0.7
September	-0.1	-0.3	-0.2	-0.5	-0.3	-0.7
October	-0.1	-0.3	-0.3	-0.4	-0.3	-0.7
November	+0.1	-0.1	-0.2	-0.5	-0.3	-0.7
December	-0.1	-0.2	-0.4	-0.8	-0.4	-0.9

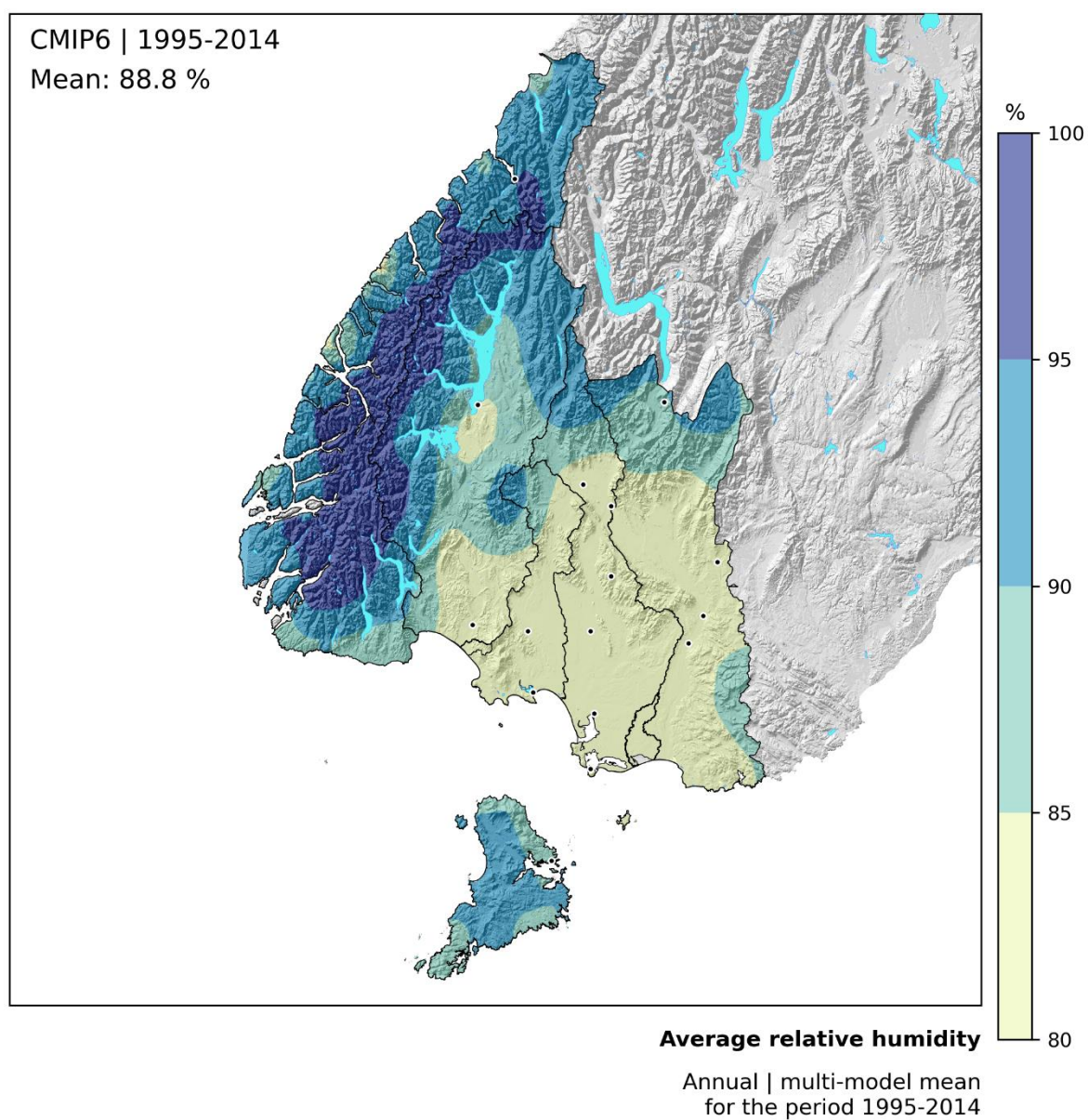


Figure 1-58: Modelled historic annual average relative humidity.

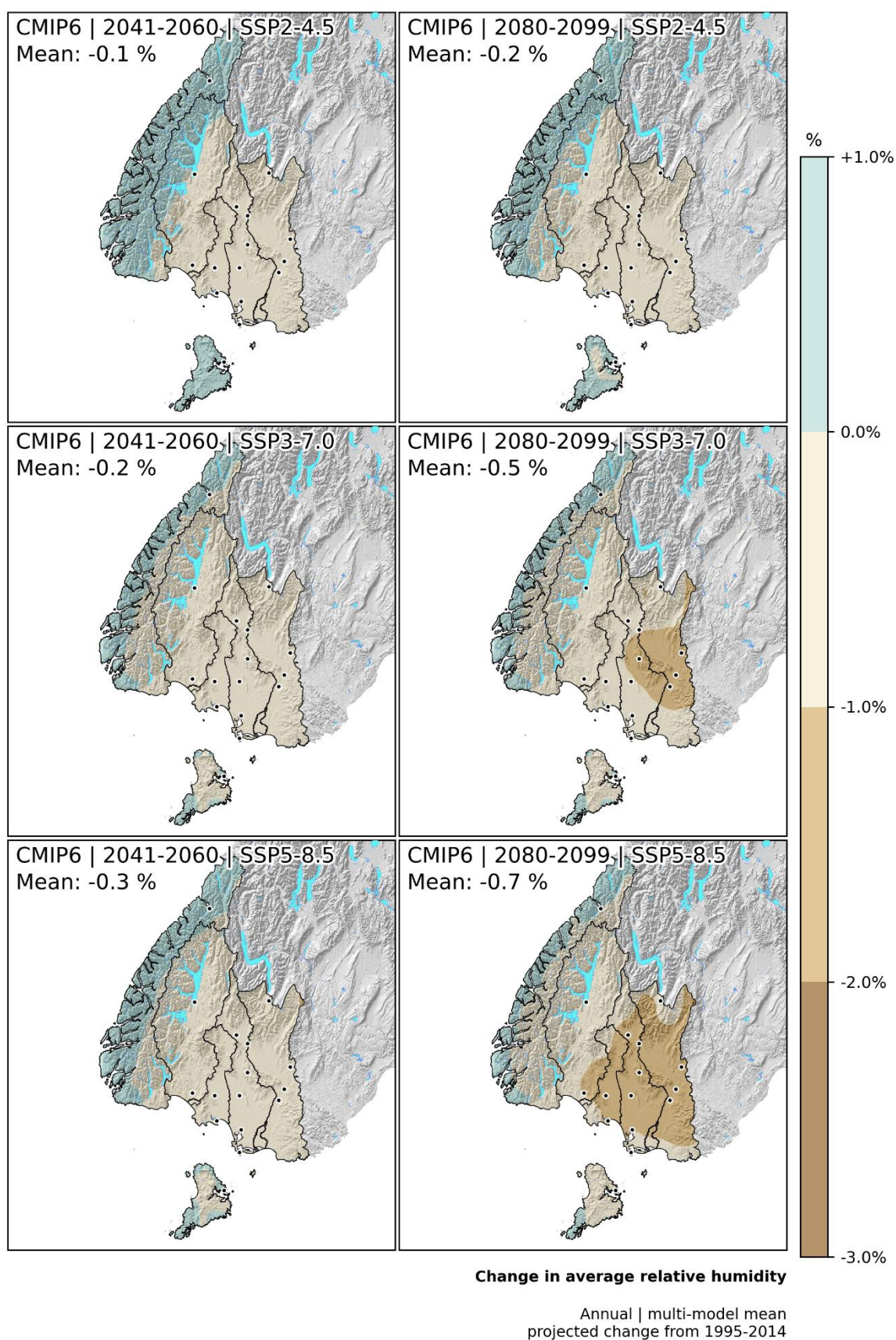
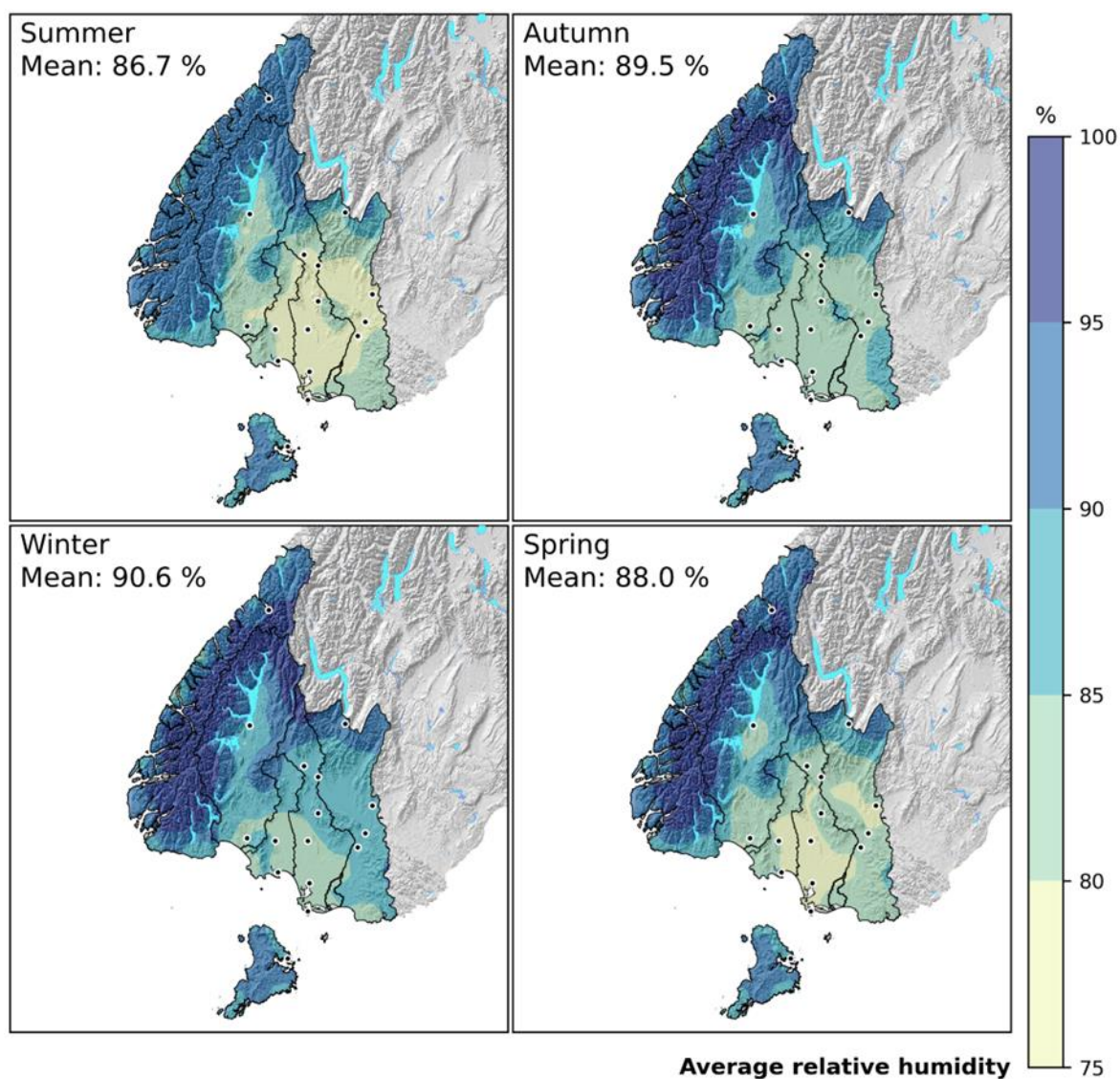


Figure 1-59: Projected annual average relative humidity changes.



multi-model mean | for the period 1995-2014

Figure 1-60: Modelled historic seasonal average relative humidity.

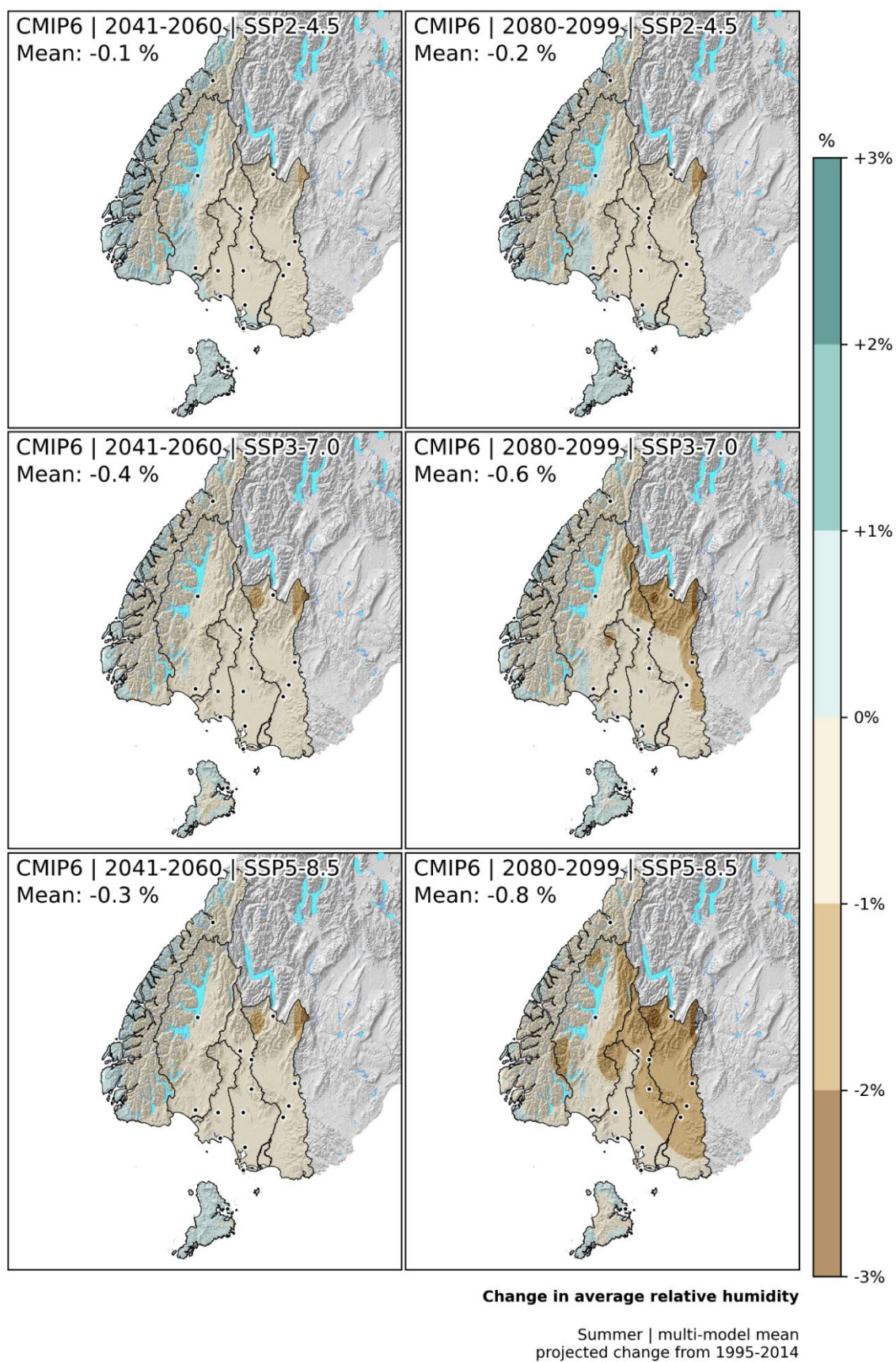


Figure 1-61: Projected summer average relative humidity changes.

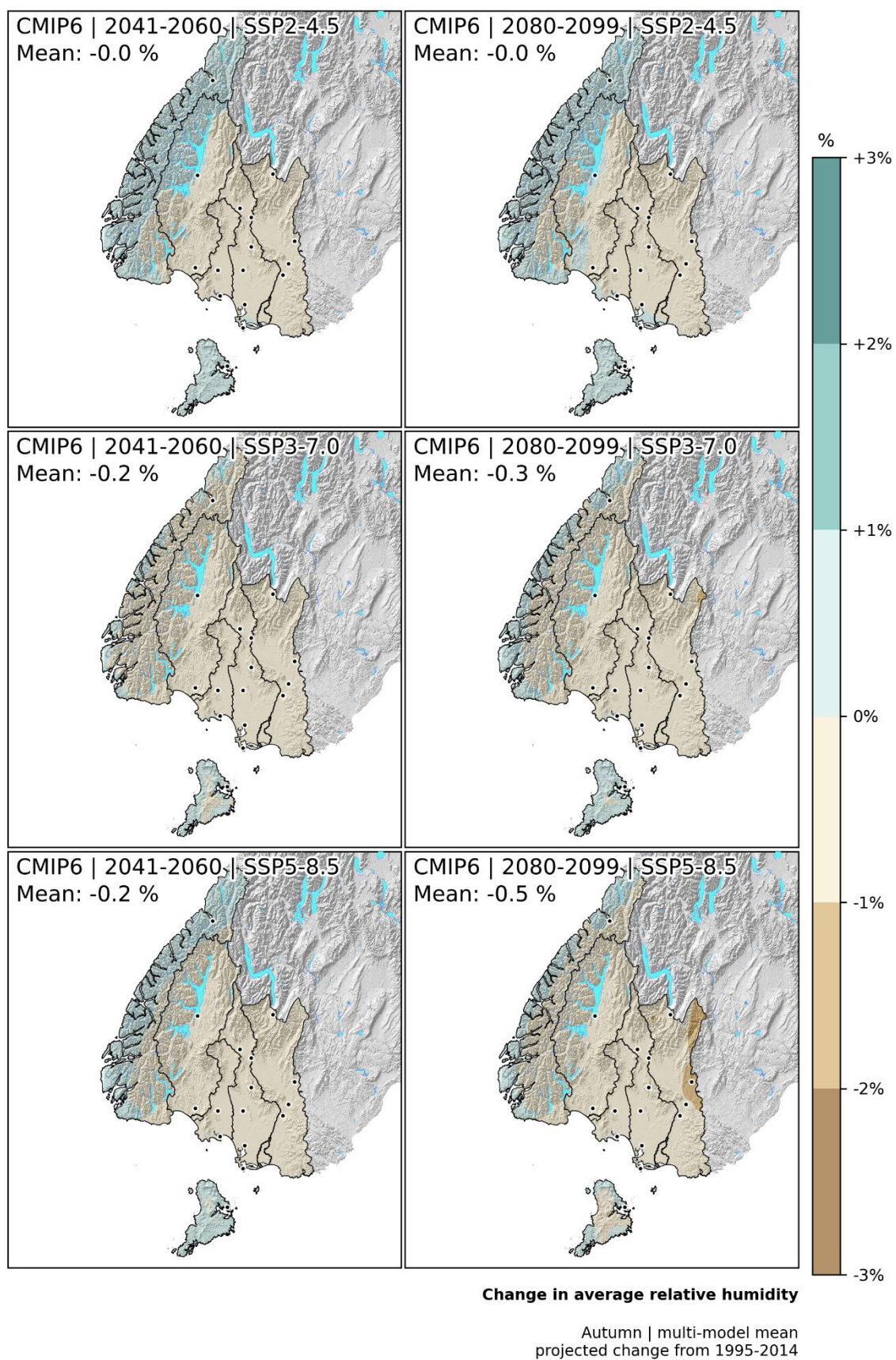


Figure 1-62: Projected autumn average relative humidity changes.

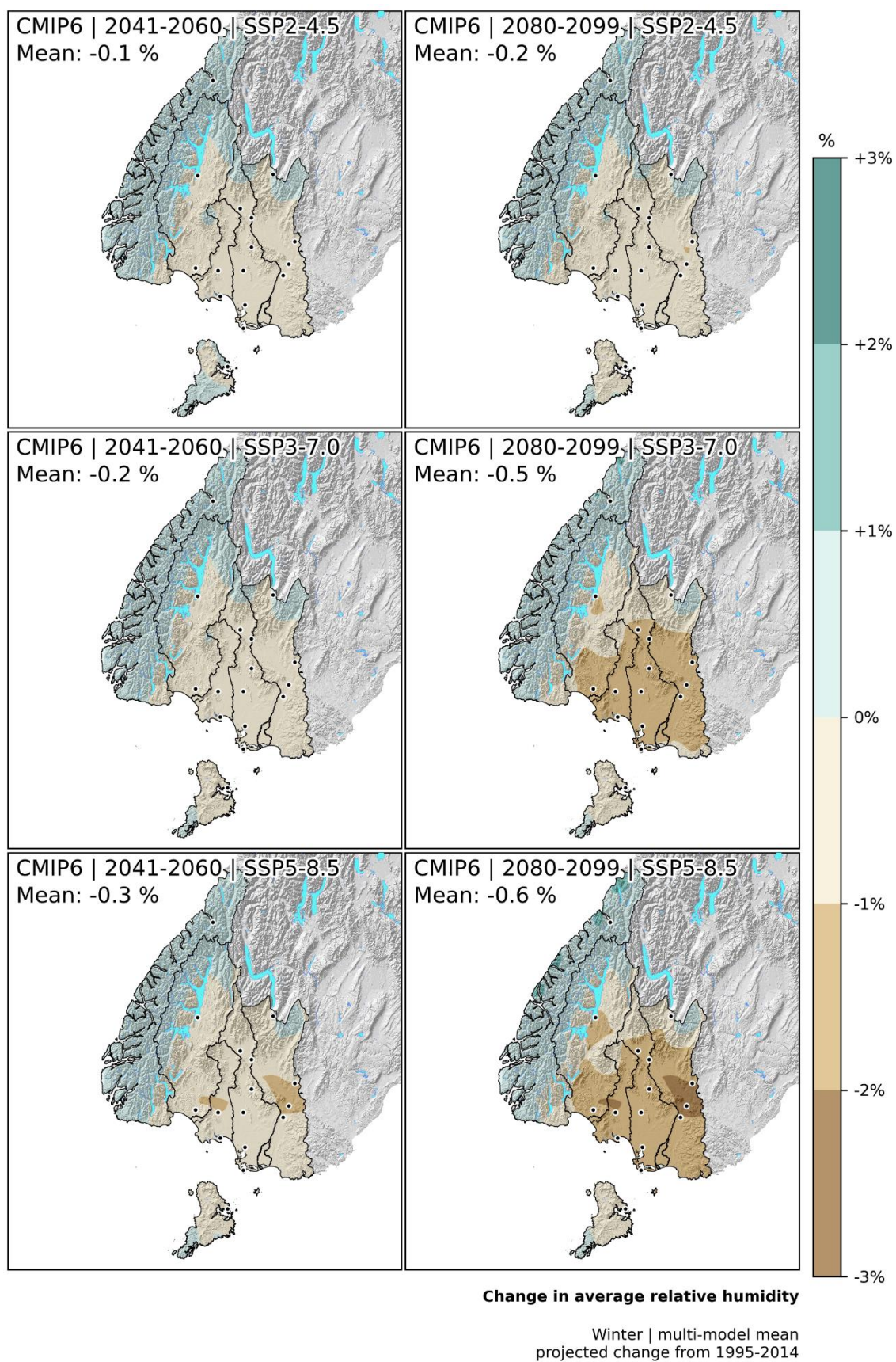
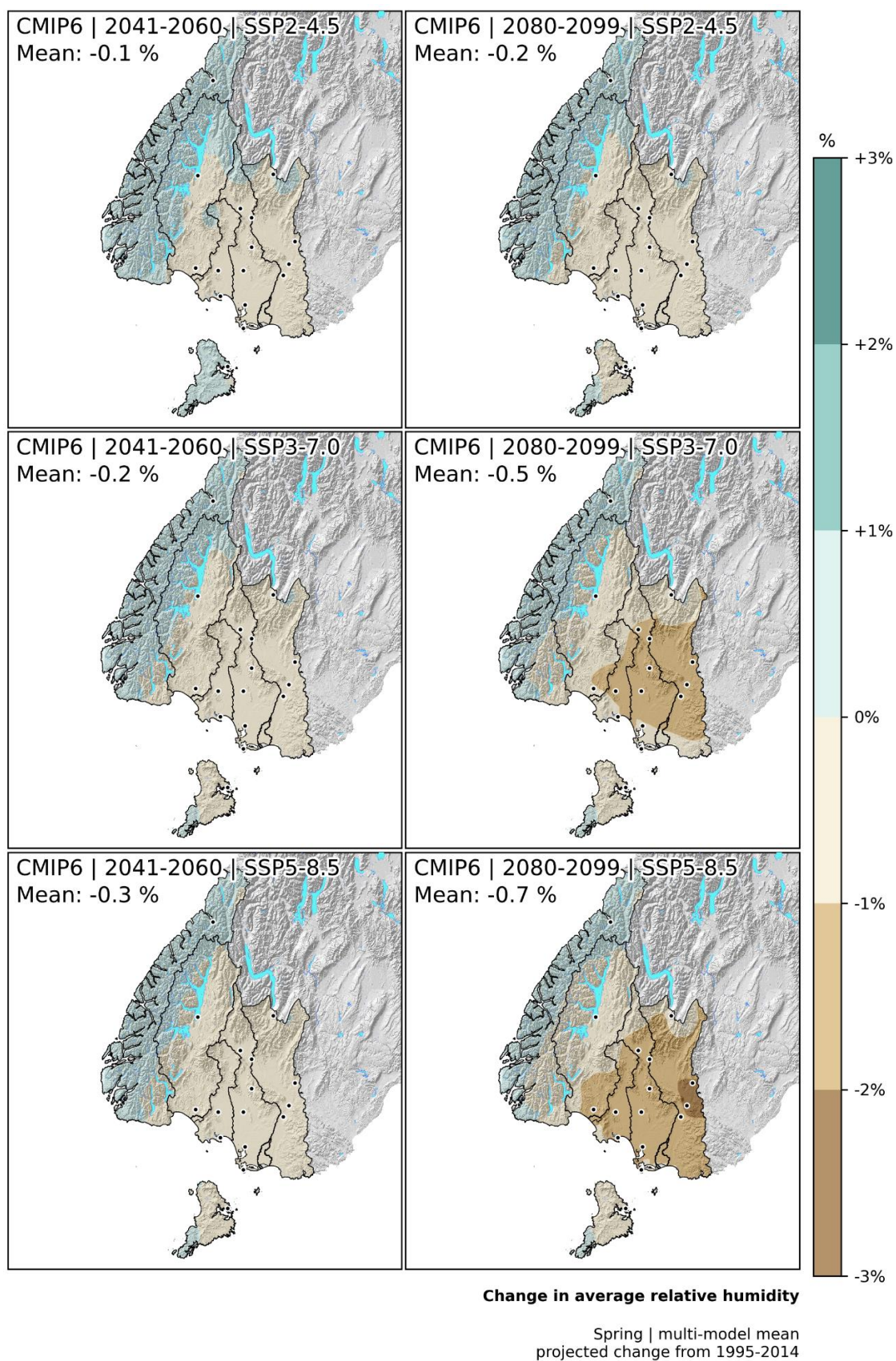


Figure 1-63: Projected winter average relative humidity changes.



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Figure 1-64: Projected spring average relative humidity changes.

1.4 Solar radiation

Modelled historic and projected changes to future solar radiation are illustrated in Figure 1-65 and Figure 1-66. Regional average projected changes are summarised in Table 1-30.

Table 1-30: Projected solar radiation changes (W m^{-2} , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	-0.8	-0.8	+0.3	+0.7	-0.2	+0.6
Summer	+0.8	+2.6	+2.9	+6.6	+2.6	+6.9
Autumn	-0.1	-0.6	+1.4	+1.6	+0.4	+2.1
Winter	-1.3	-2.4	-2.1	-3.0	-2.2	-4.0
Spring	-3.3	-3.1	-1.4	-2.6	-1.5	-2.4

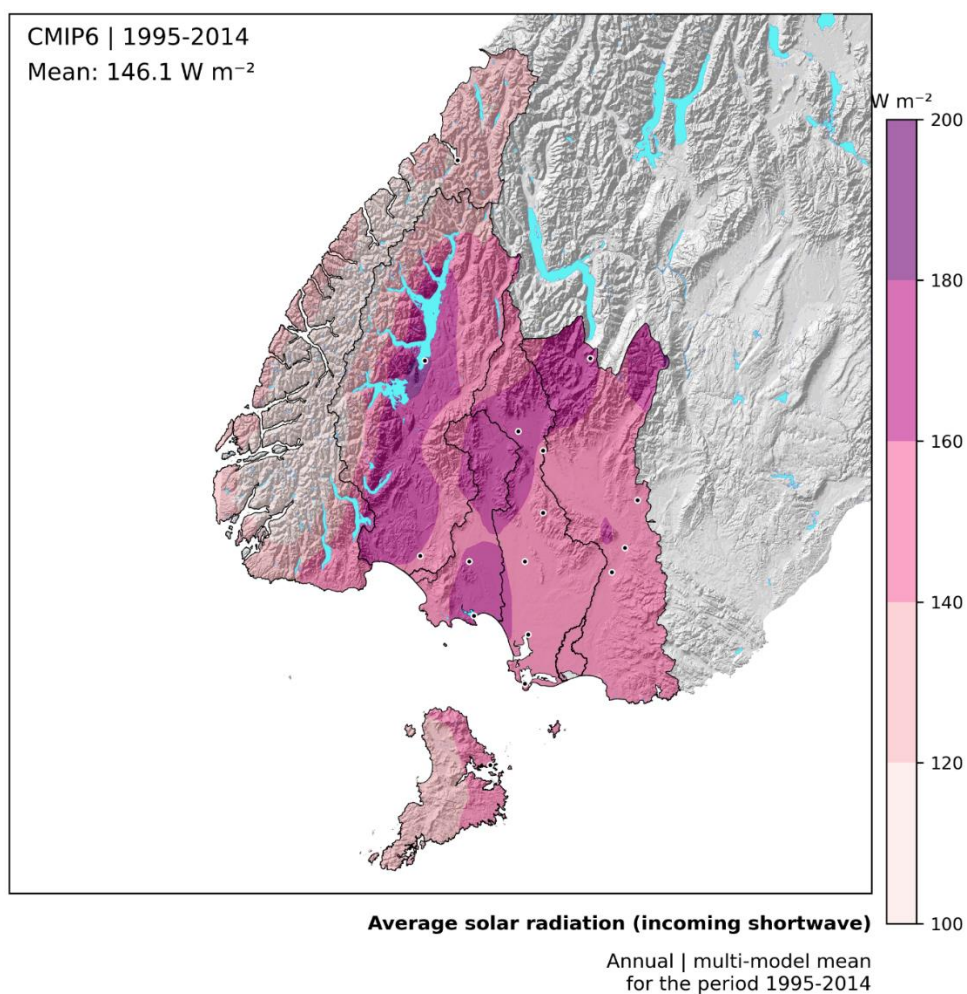


Figure 1-65: Modelled historic annual average solar radiation.

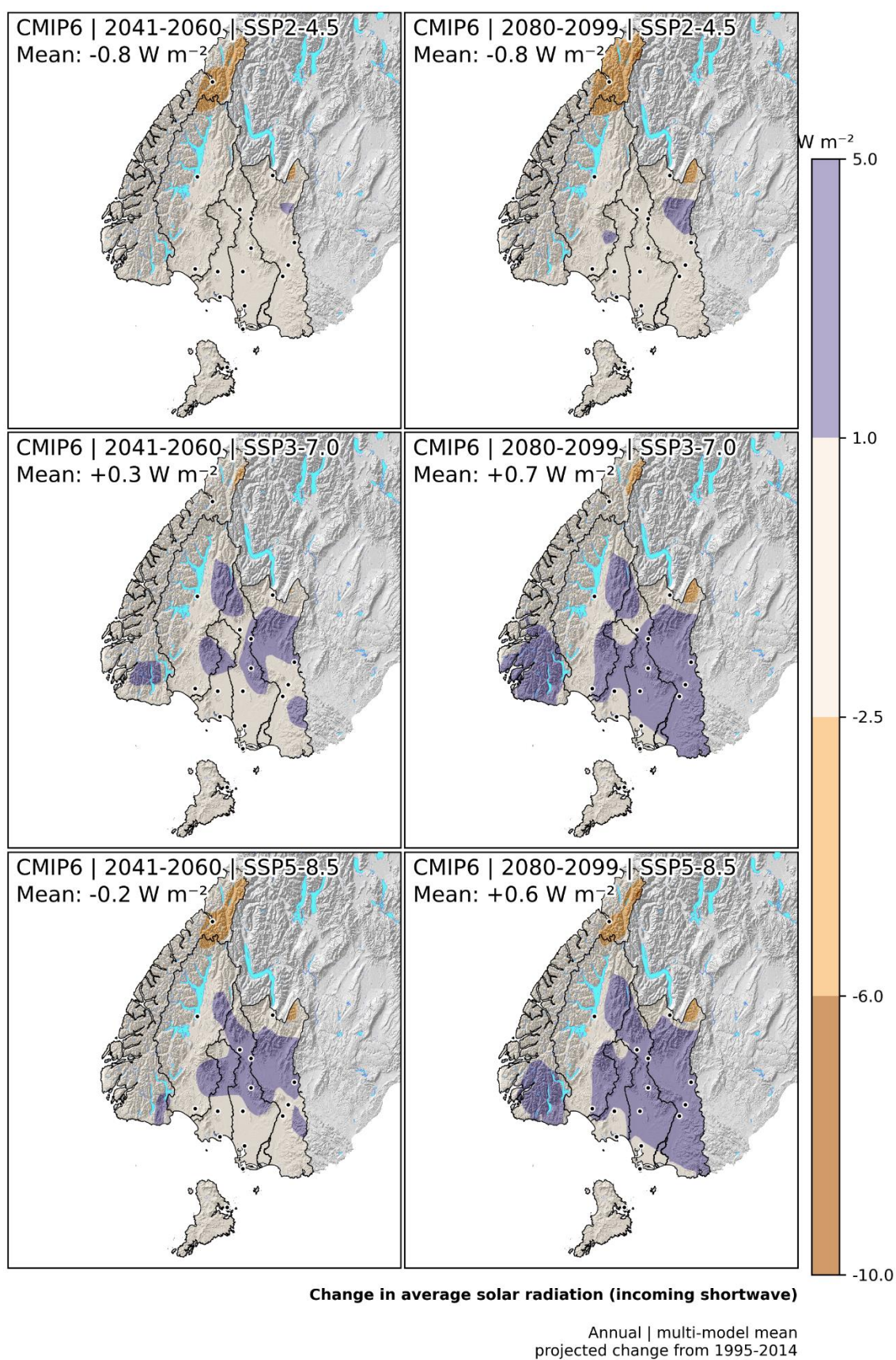


Figure 1-66: Projected annual average solar radiation changes.

1.5 Cloud cover

Modelled historic and projected changes to future cloud cover are illustrated in Figure 1-67 and Figure 1-68. Regional average projected changes are summarised Table 1-31 at annual and monthly time scale.

Table 1-31: Projected cloud cover changes %, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+0.1	-0.2	-0.6	-1.7	-0.4	-1.9
January	-0.2	-1.1	-1.2	-3.0	-0.1	-3.5
February	-0.2	-1.0	-0.5	-3.2	-1.8	-3.9
March	-0.3	-0.2	-1.6	-2.7	-0.6	-3.6
April	0.0	0.0	-1.1	-2.0	-0.8	-3.0
May	0.0	-0.9	-1.4	-1.8	-1.2	-2.3
June	-0.4	-0.1	0.1	-1.2	-1.1	-1.5
July	0.5	-0.4	0.5	-0.6	1.5	0.3
August	0.2	1.2	0.4	-0.2	0.4	-0.2
September	1.2	1.0	0.3	0.2	0.7	0.2
October	0.0	0.2	-0.2	-0.8	-0.2	-1.1
November	0.6	-0.2	-0.9	-2.3	-1.1	-2.2
December	0.1	-0.3	-1.1	-2.6	-0.8	-2.6

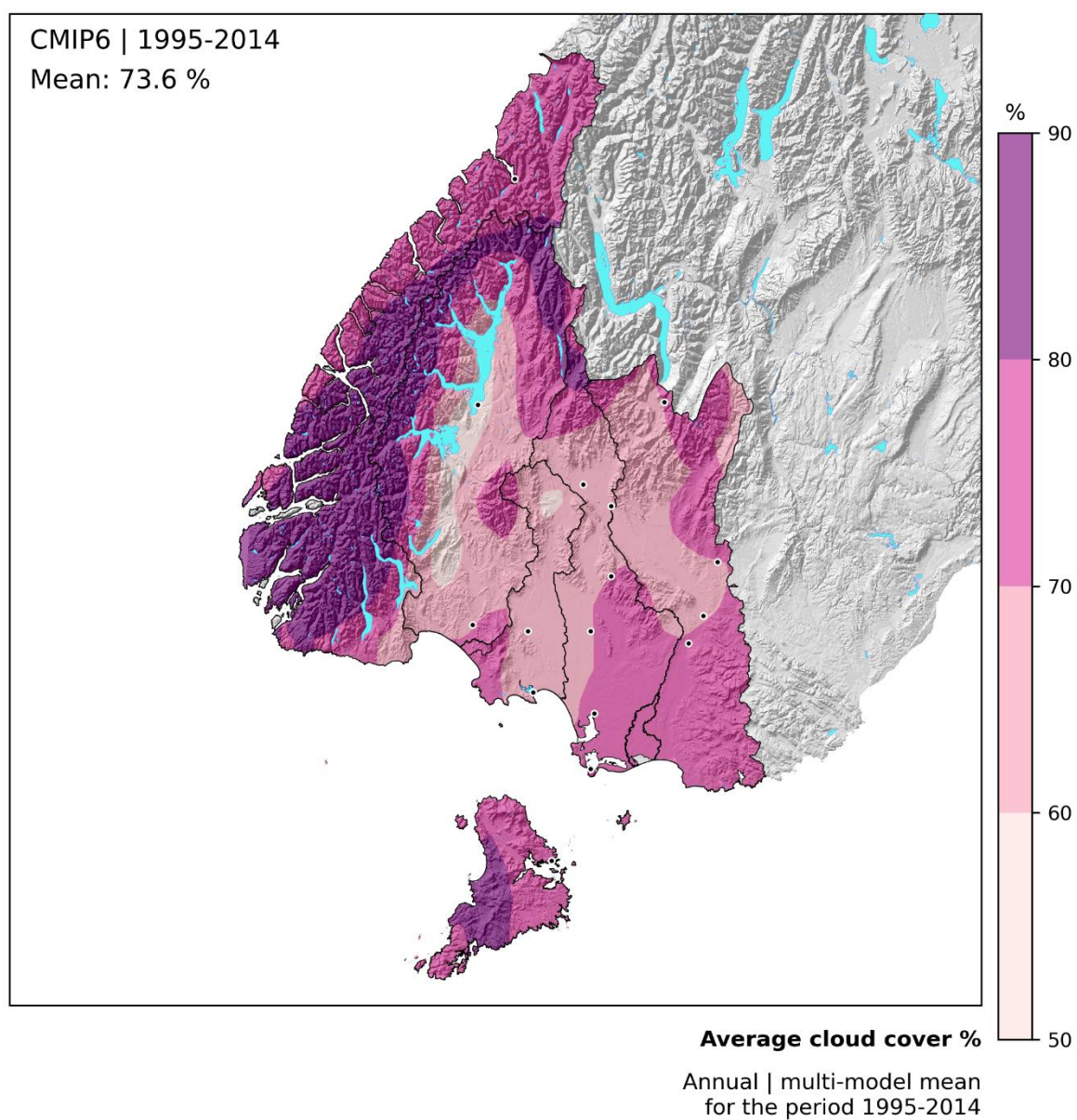


Figure 1-67: Modelled historic annual average cloud cover.

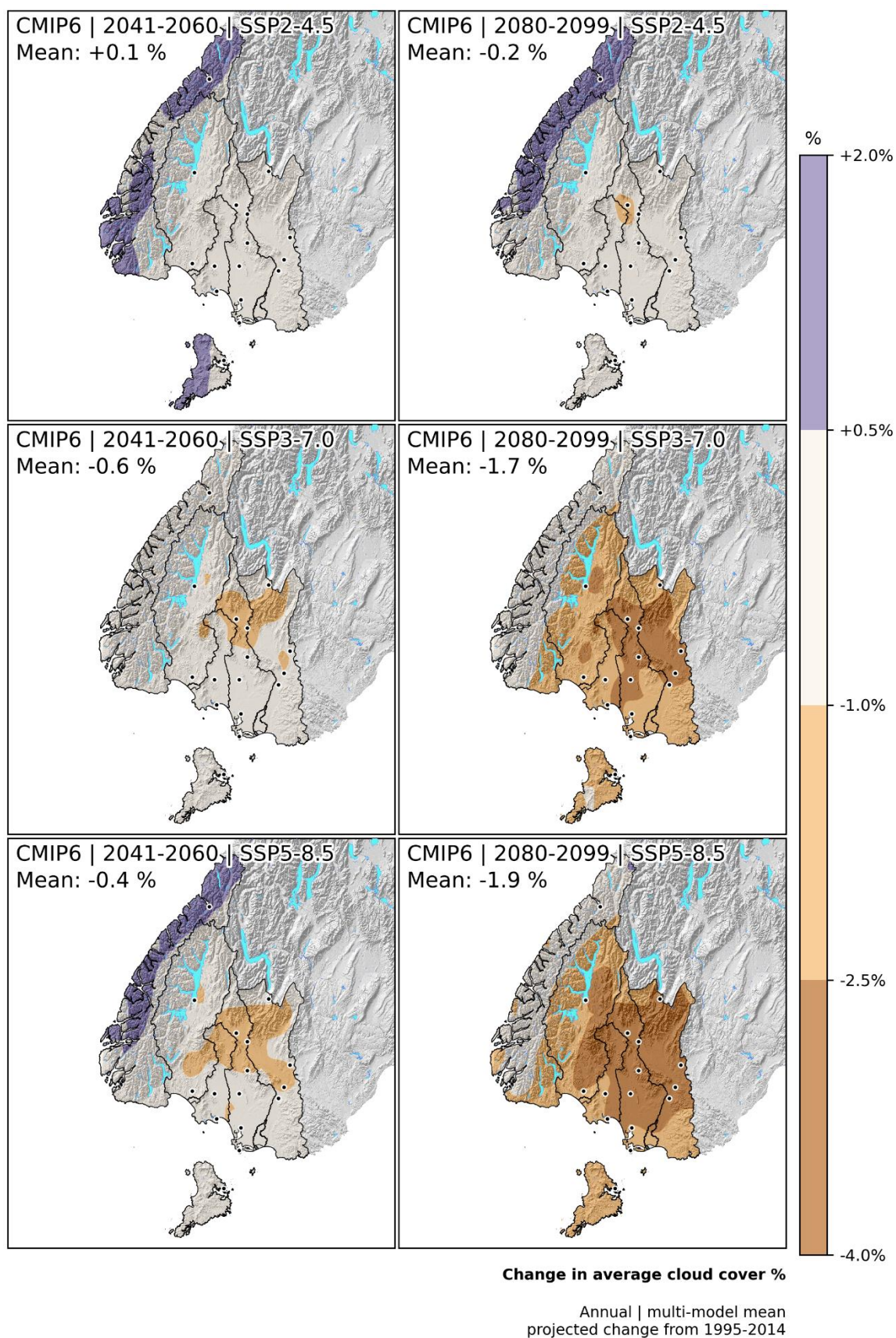


Figure 1-68: Projected annual average cloud cover changes.

1.6 Wind

1.6.1 Average wind speed

Modelled historic and projected changes to future annual and seasonal average wind speed are illustrated in Figure 1-69 to Figure 1-75. Regional average projected changes are summarised in Table 1-32. The surface wind speed climatology shown in the model compares very poorly with station measurements, with some of the strongest winds anywhere in New Zealand expected around the coastline of Fjordland and at high elevation. The reasons for this discrepancy remain under investigation but is likely related to the prescription of the surface roughness in the presence of vegetation. At this stage all results associated with wind speed in Southland should be considered unreliable.

Table 1-32: Projected average wind speed changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+1.4	+1.7	+1.2	+2.1	+2.6	+3.7
Summer	-1.3	-2.4	-1.9	-5.1	-0.9	-4.4
Autumn	-0.2	-0.9	-1.6	-2.6	+0.5	-1.7
Winter	+2.7	+5.0	+3.6	+8.8	+6.0	+11.6
Spring	+3.7	+4.4	+4.4	+6.6	+4.7	+8.4

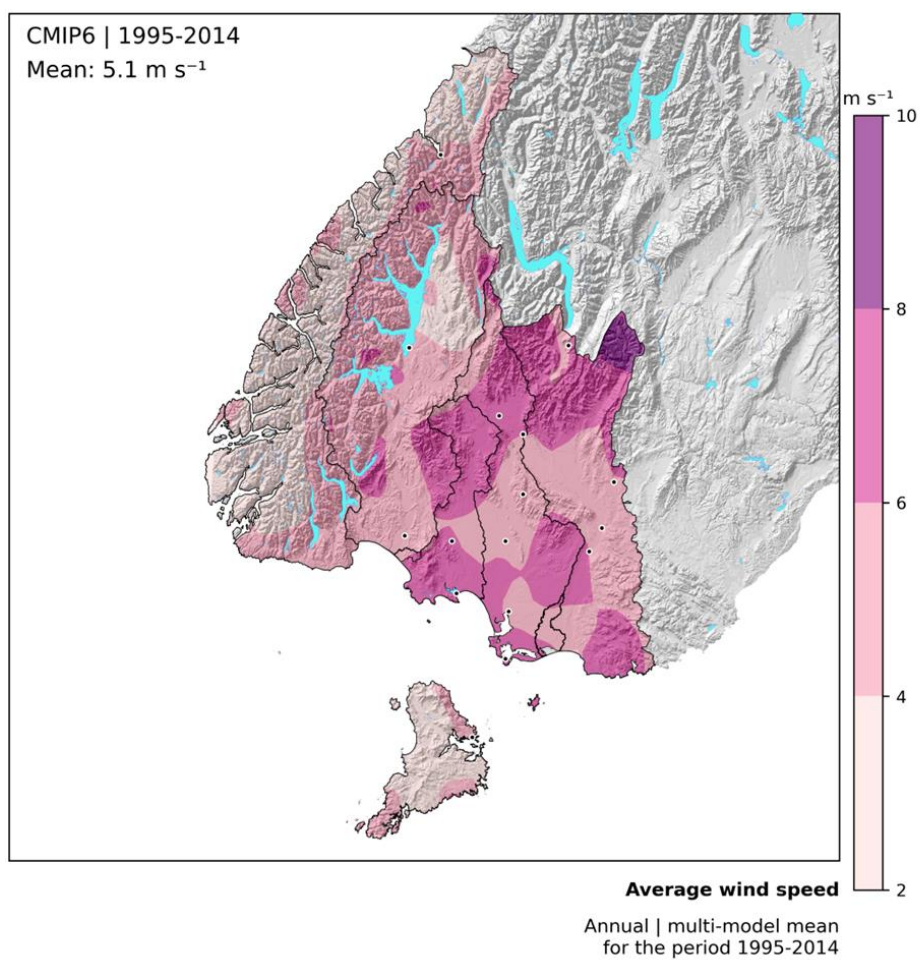


Figure 1-69: Modelled historic annual average wind speed.

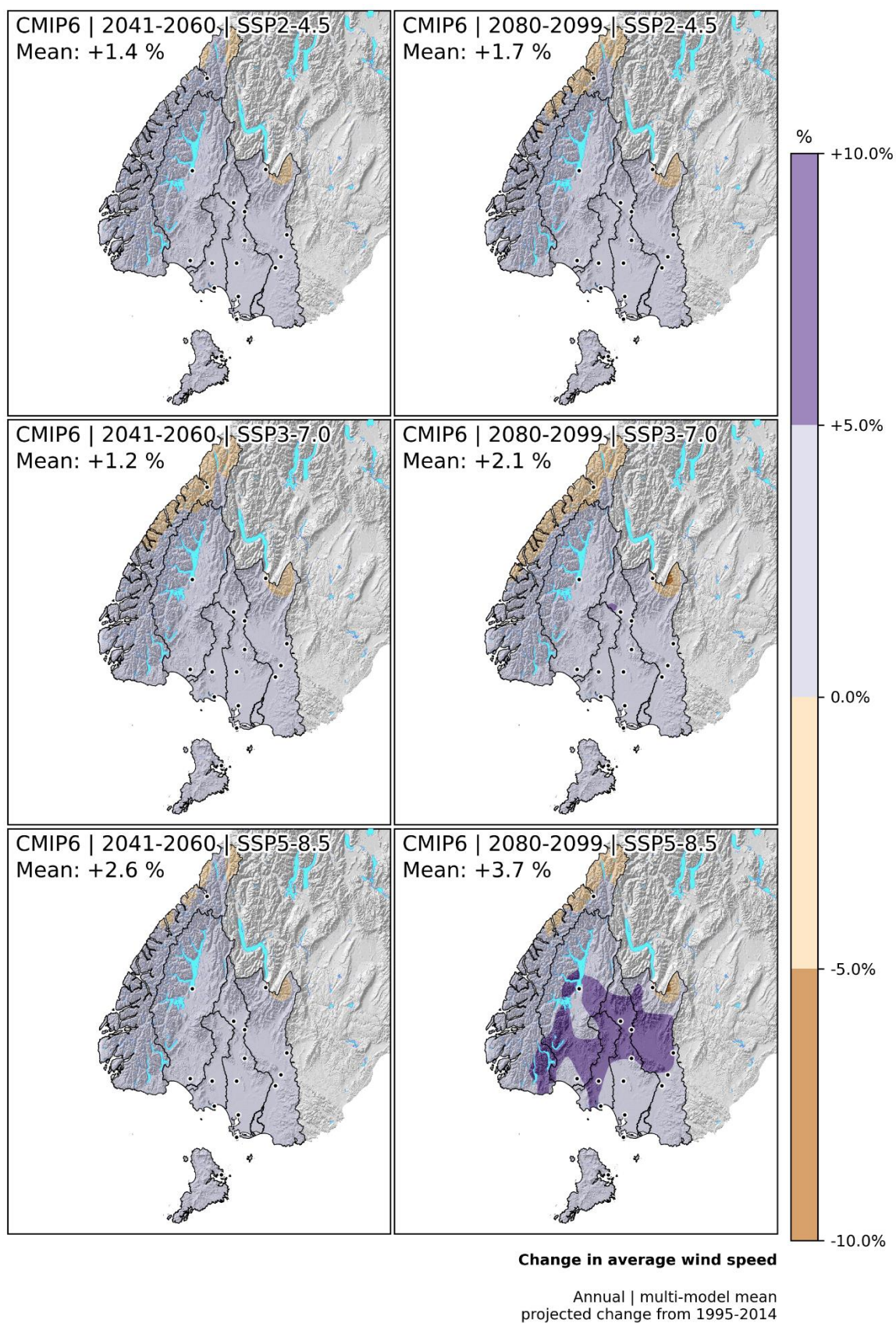
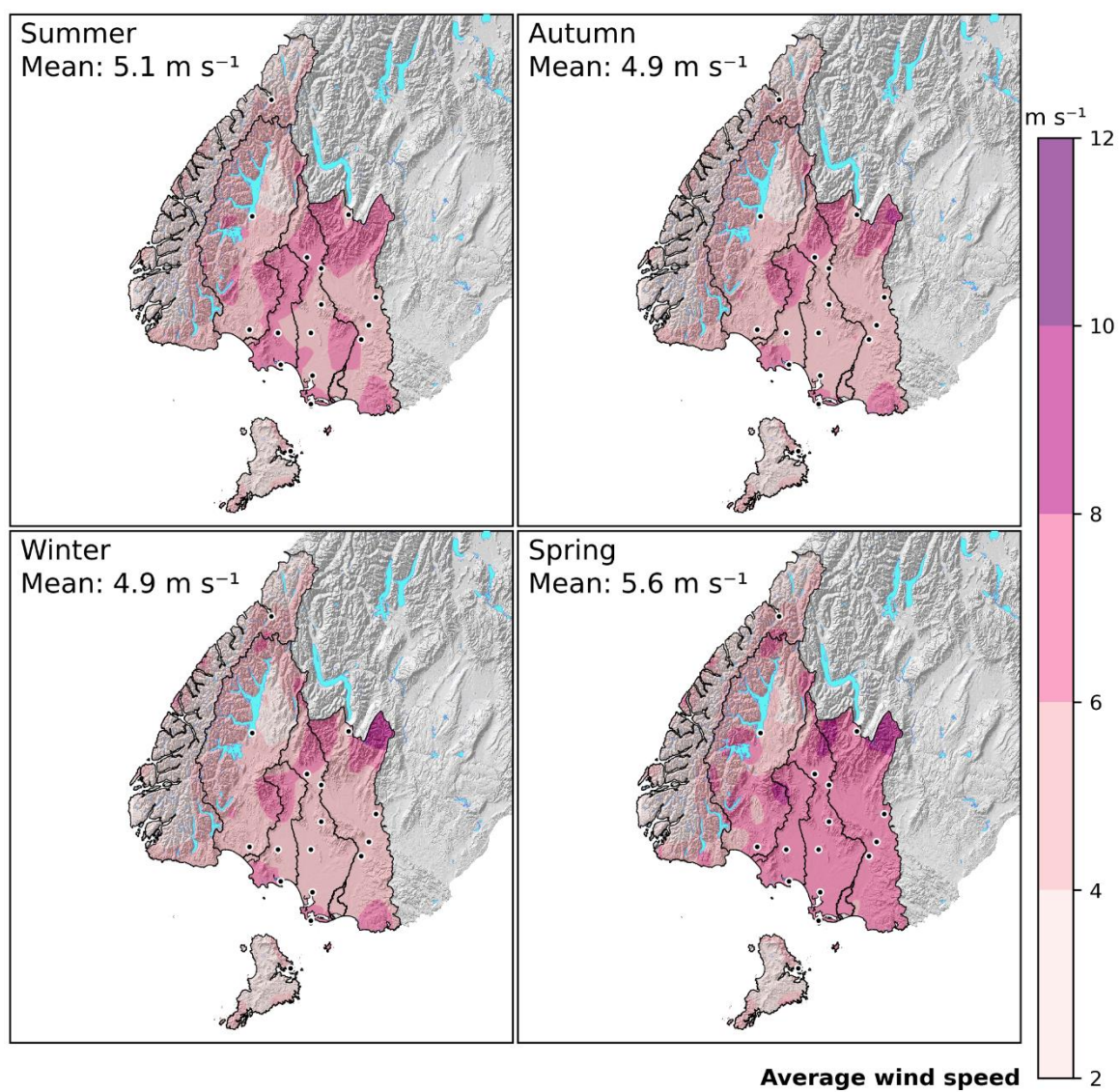


Figure 1-70: Projected annual average wind speed changes.



multi-model mean | for the period 1995-2014

Figure 1-71: Modelled historic seasonal average wind speed.

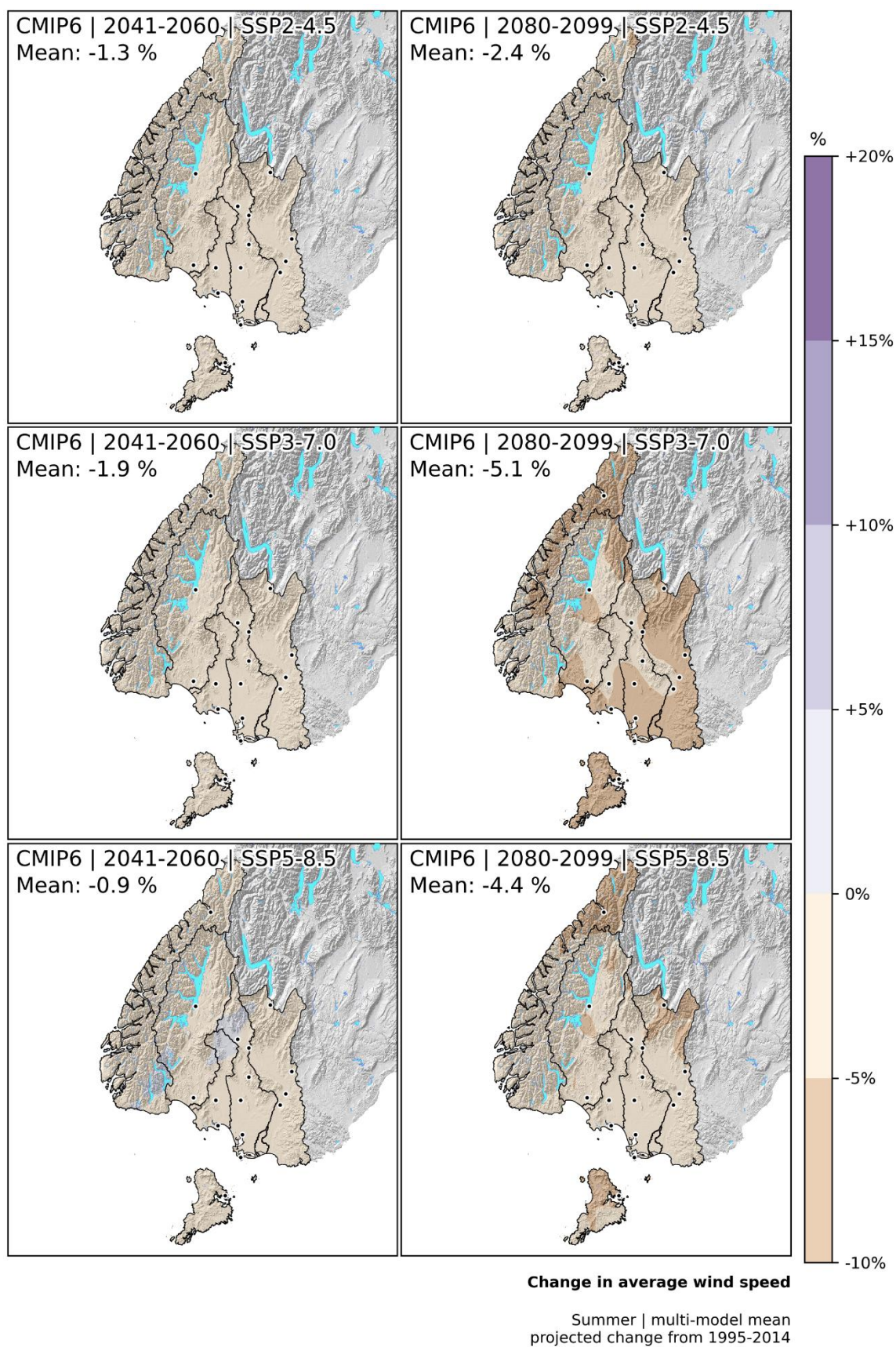


Figure 1-72: Projected summer average wind speed changes.

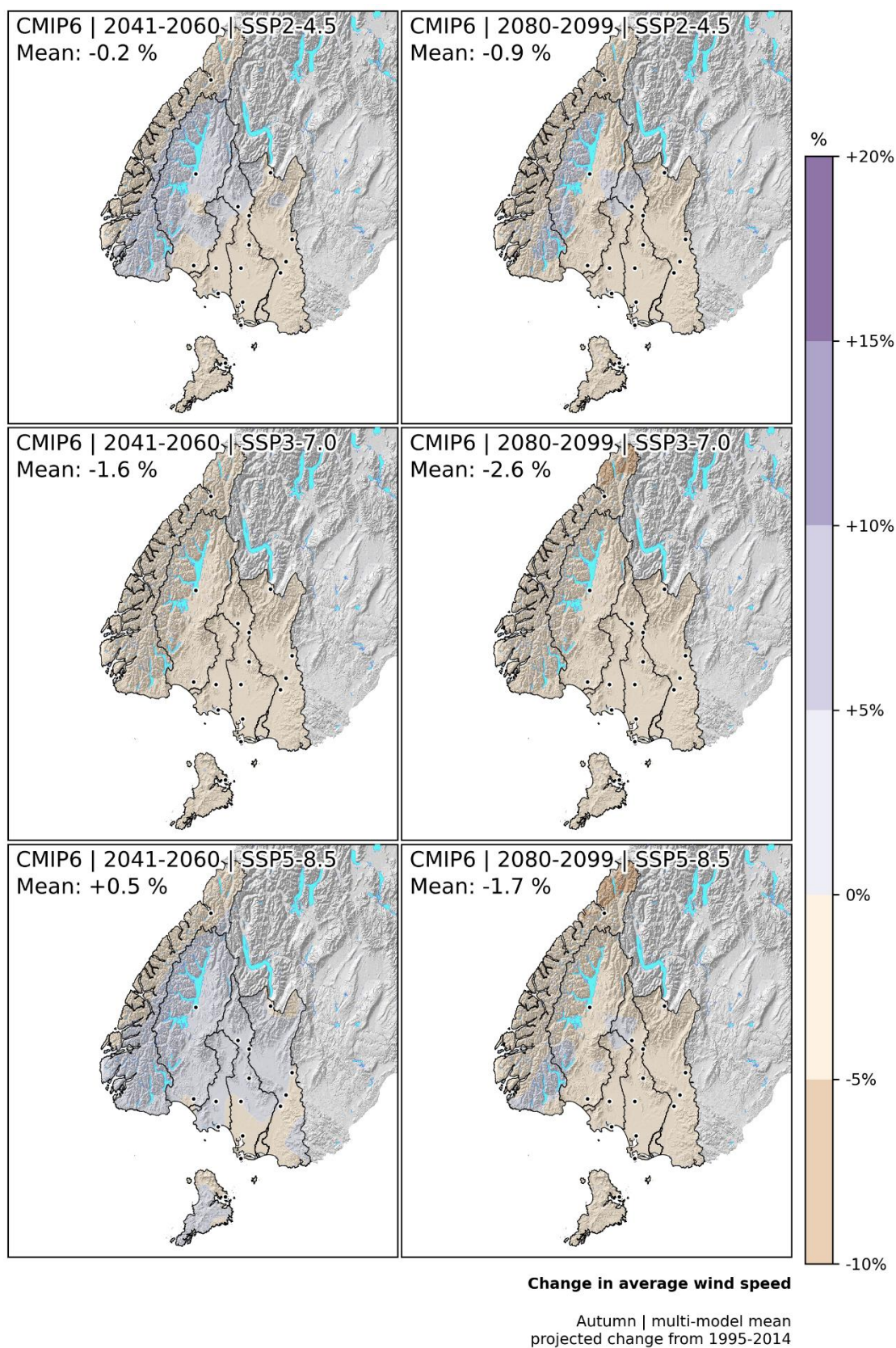


Figure 1-73: Projected autumn average wind speed changes.

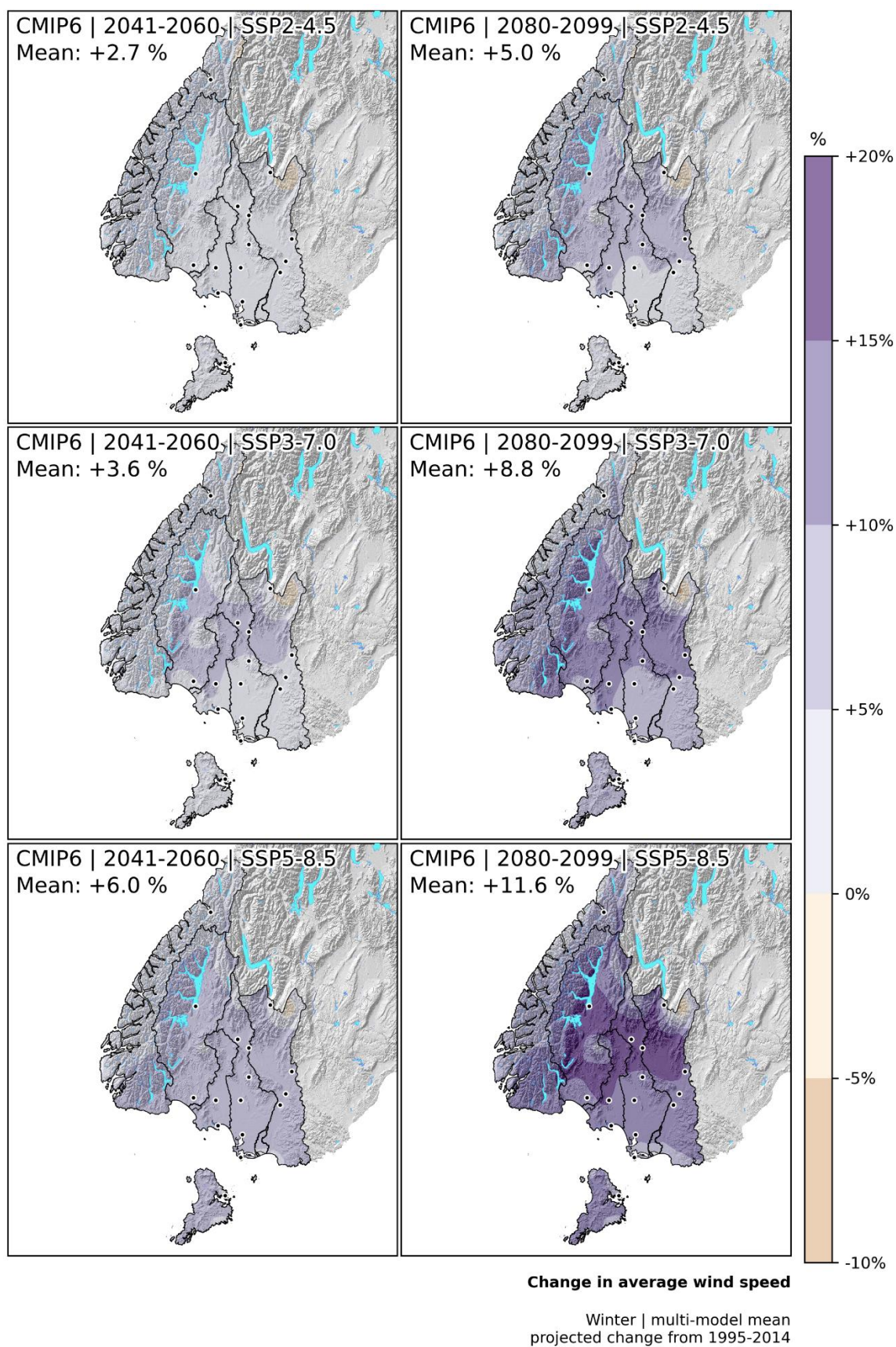


Figure 1-74: Projected winter average wind speed changes.

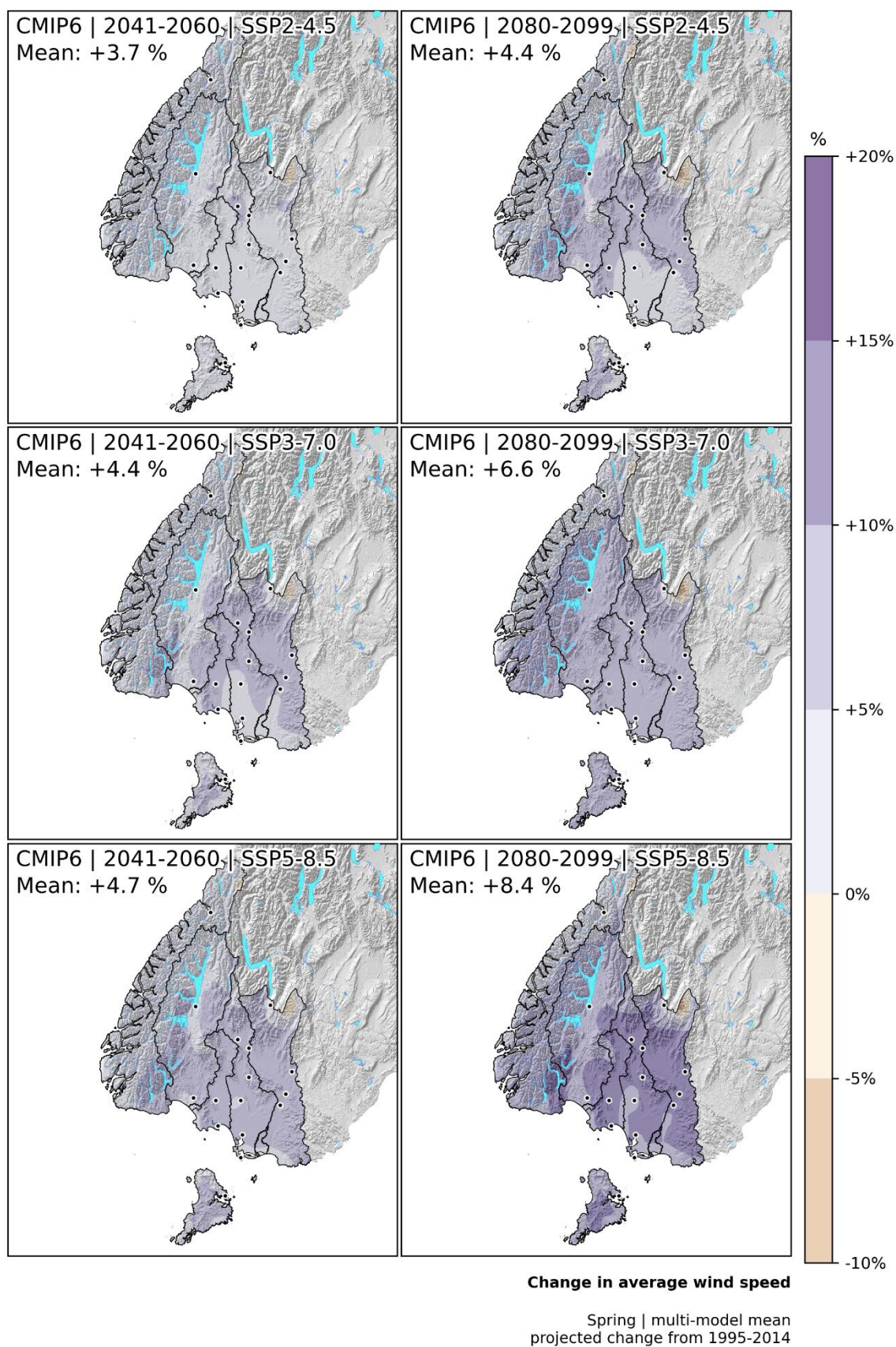
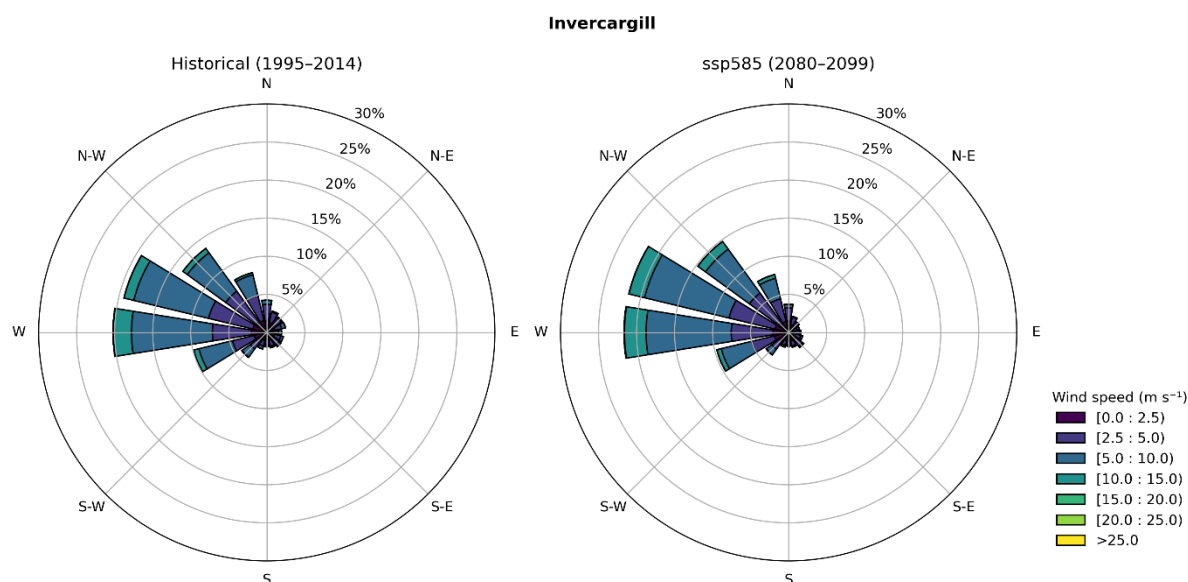
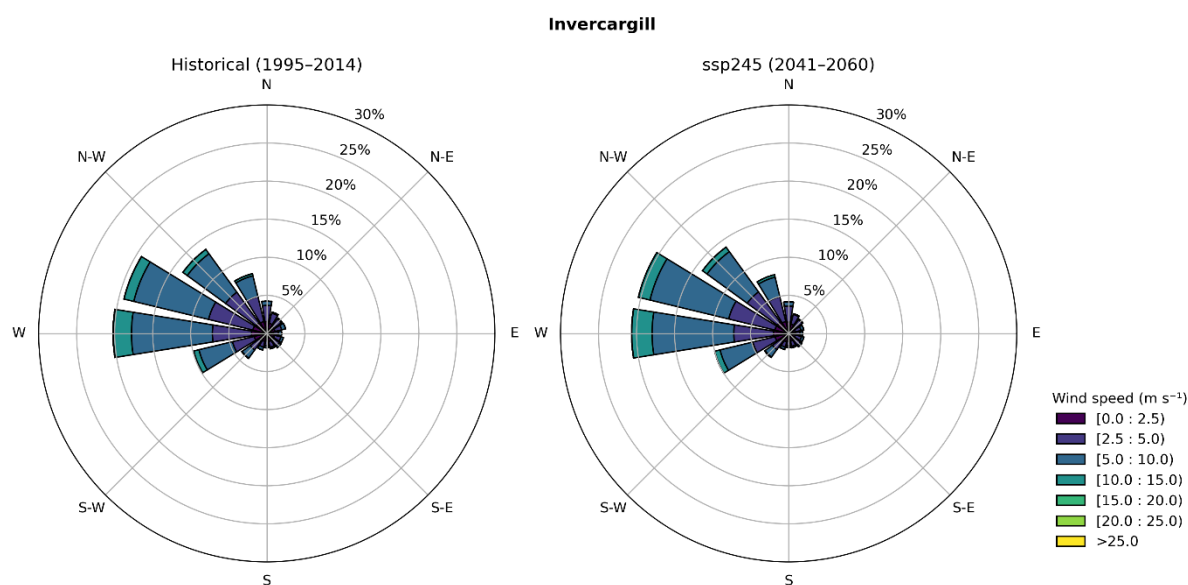


Figure 1-75: Projected spring average wind speed changes.

1.6.2 Wind direction

Southland's prevailing wind direction typically spans the westerly quarter, i.e., from northwest through to southwest. This is projected to remain the case in future. Figure 1-76 and Figure 1-77 present annual wind direction projections for Invercargill by 2050 under SSP2-4.5, and 2090 under SSP5-8.5, respectively. These illustrate little change in the distribution of wind direction in Invercargill; a pattern repeated across the remaining locations selected for this report. All wind roses generated in this project were supplied separately to Environment Southland.



1.6.3 Calm days

A calm day is defined here as a day when the mean wind speed is less than 1.5 m s^{-1} . Modelled historic and projected changes to future annual calm days are illustrated in Figure 1-78 and Figure 1-79. Regional average projected annual and monthly changes are summarised in Table 1-33 at annual and monthly time scales, while location-specific projected changes are shown in Table 1-34. As calm days are related to the model's simulation of wind speed these results should be considered unreliable.

Table 1-33: Projected calm day changes changes ($^{\circ}\text{C}$, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	-0.1	-0.2	-0.1	-0.1	-0.2	-0.2
January	0	0	0	+0.1	0	0
February	0	0	0	+0.1	0	+0.1
March	0	0	0	+0.1	0	+0.1
April	0	0	0	0	0	0
May	-0	0	0	0	0	0
June	0	0	0	0	0	-0.1
July	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
August	0	-0.1	-0.1	-0.1	-0.1	-0.1
September	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
October	0	0	0	0	0	0
November	0	0	0	0	0	0
December	0	0	0	0	0	0

Table 1-34: Projected changes to the number of annual calm days ($<1.5 \text{ m s}^{-1}$).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	0	0	0	0	0	0
Riverton	0	0	0	0	0	0
Mataura	0	0	0	0	0	0
Gore	0	0	0	0	0	0
Winton	0	0	0	0	0	0
Lumsden	0	0	0	0	0	0
Te Anau	-0.1	0	0	-0.1	0	-0.1
Otautau	0	0	0	-0.1	0	0
Tuatapere	0	0	0	0	0	0

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Oban	0	+0.1	+0.1	+0.2	-0.2	0
Riversdale	0	0	0	0	0	0
Waikaka	0	0	0	0	0	0
Milford Sound	-0.2	-0.3	-0.1	-0.2	-0.1	-0.2
Garston	0	0	0	0	0	0
Mossburn	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Bluff	0	0	0	0	0	0

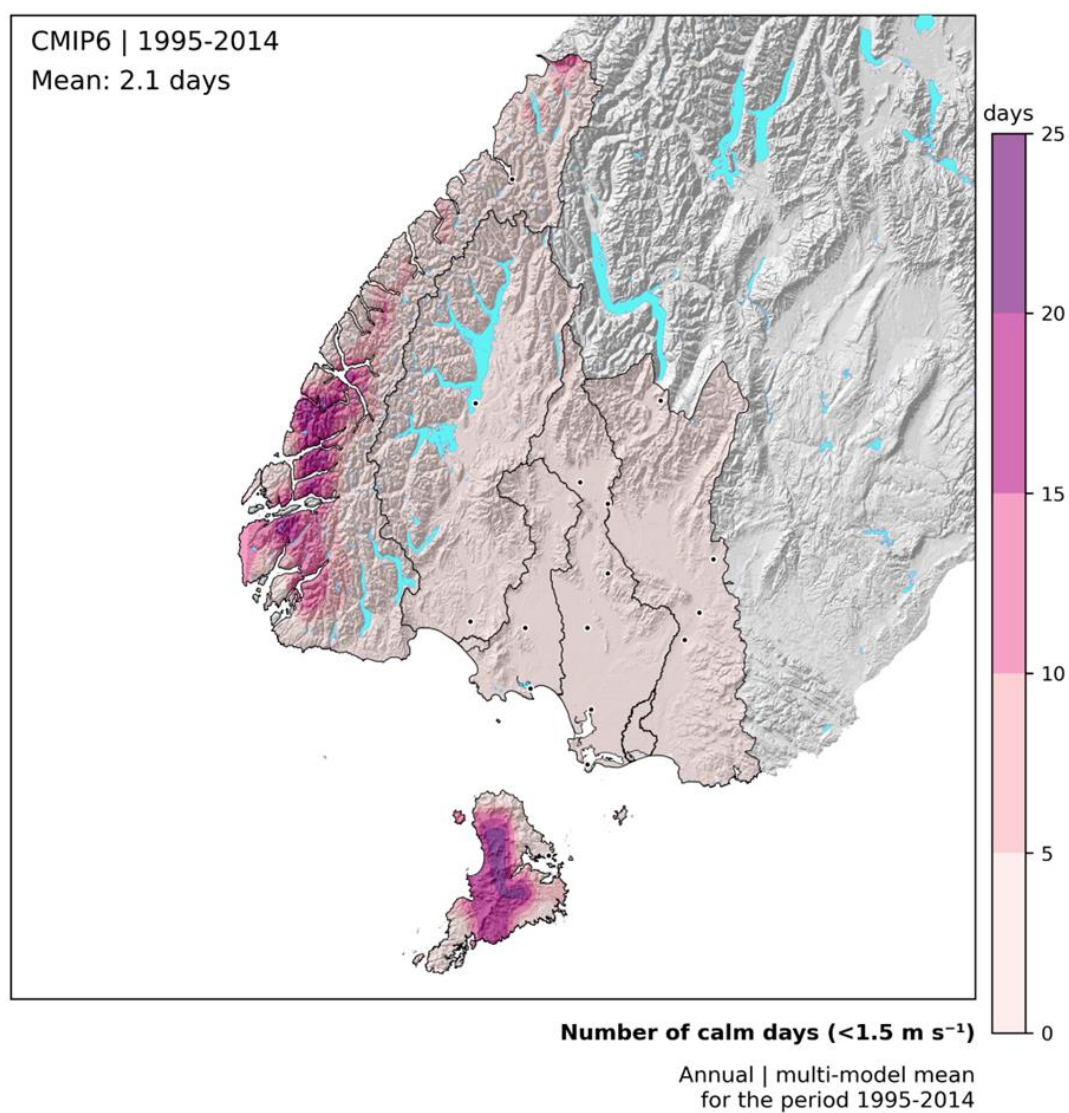


Figure 1-78: Modelled historic average annual number of calm days.

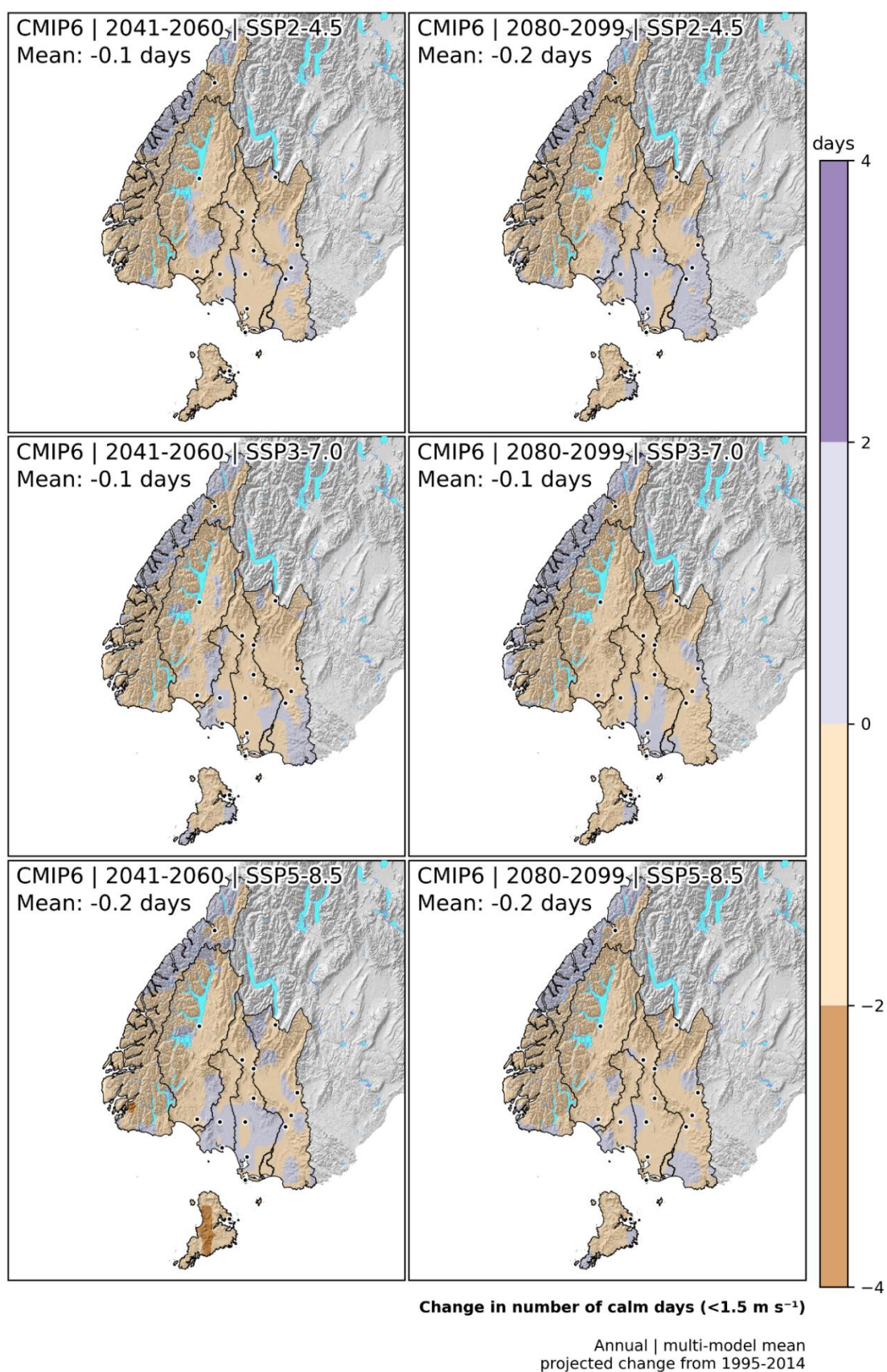


Figure 1-79: Projected annual average calm days changes.

1.6.4 Windy days

Modelled historic and projected changes to future annual windy days are illustrated in Figure 1-80 and Figure 1-81. Regional average projected annual and monthly changes are summarised in Table 1-35. As windy days are related to the model's simulation of wind speed these results should be considered unreliable.

Table 1-35: Projected windy day changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+3.6	+4.6	+3.3	+5.7	+6.4	+9.5
January	0	-0.3	-0.4	-0.9	+0.5	-0.8
February	-0.3	-0.5	-0.1	-1.0	-0.4	-1.4
March	-0.3	-0.3	-0.4	-0.8	+0.1	-0.9
April	+0.1	+0.1	-0.5	-0.7	-0.2	-0.1
May	+0.1	-0.1	+0.3	+0.5	+0.3	+0.4
June	+0.6	+1.2	+0.5	+1.4	+0.9	+1.9
July	+0.5	+0.7	+0.9	+1.8	+1.3	+2.2
August	+0.4	+0.7	+0.6	+1.4	+1.0	+2.5
September	+1.3	+1.3	+1.2	+2.2	+1.8	+2.7
October	+0.6	+1.3	+1.1	+1.5	+0.9	+1.7
November	+0.6	+0.4	+0.5	+0.6	+0.5	+1.0
December	+0.2	+0.1	-0.3	-0.3	-0.2	+0.3

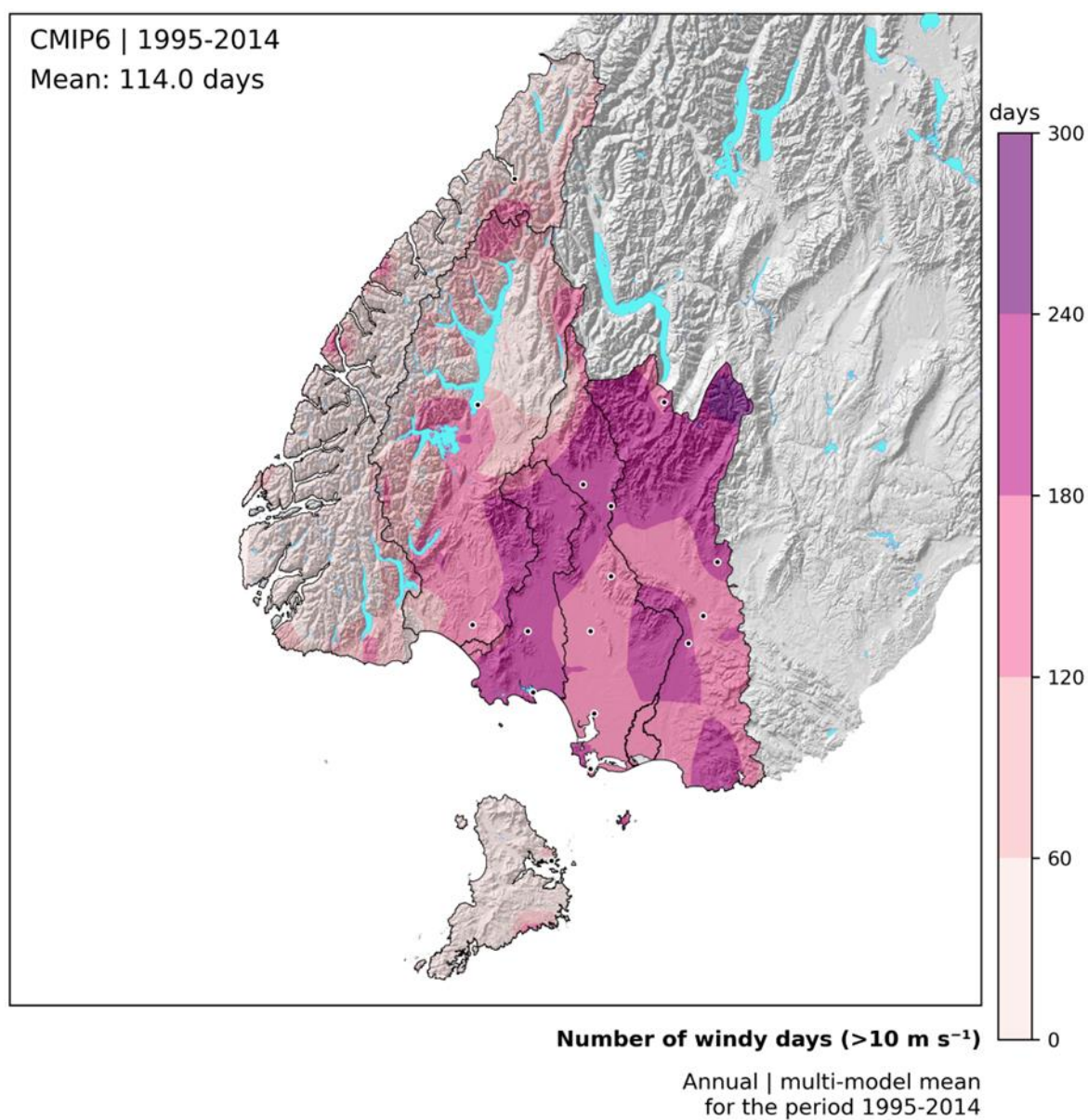


Figure 1-80: Modelled historic average annual number of windy days.

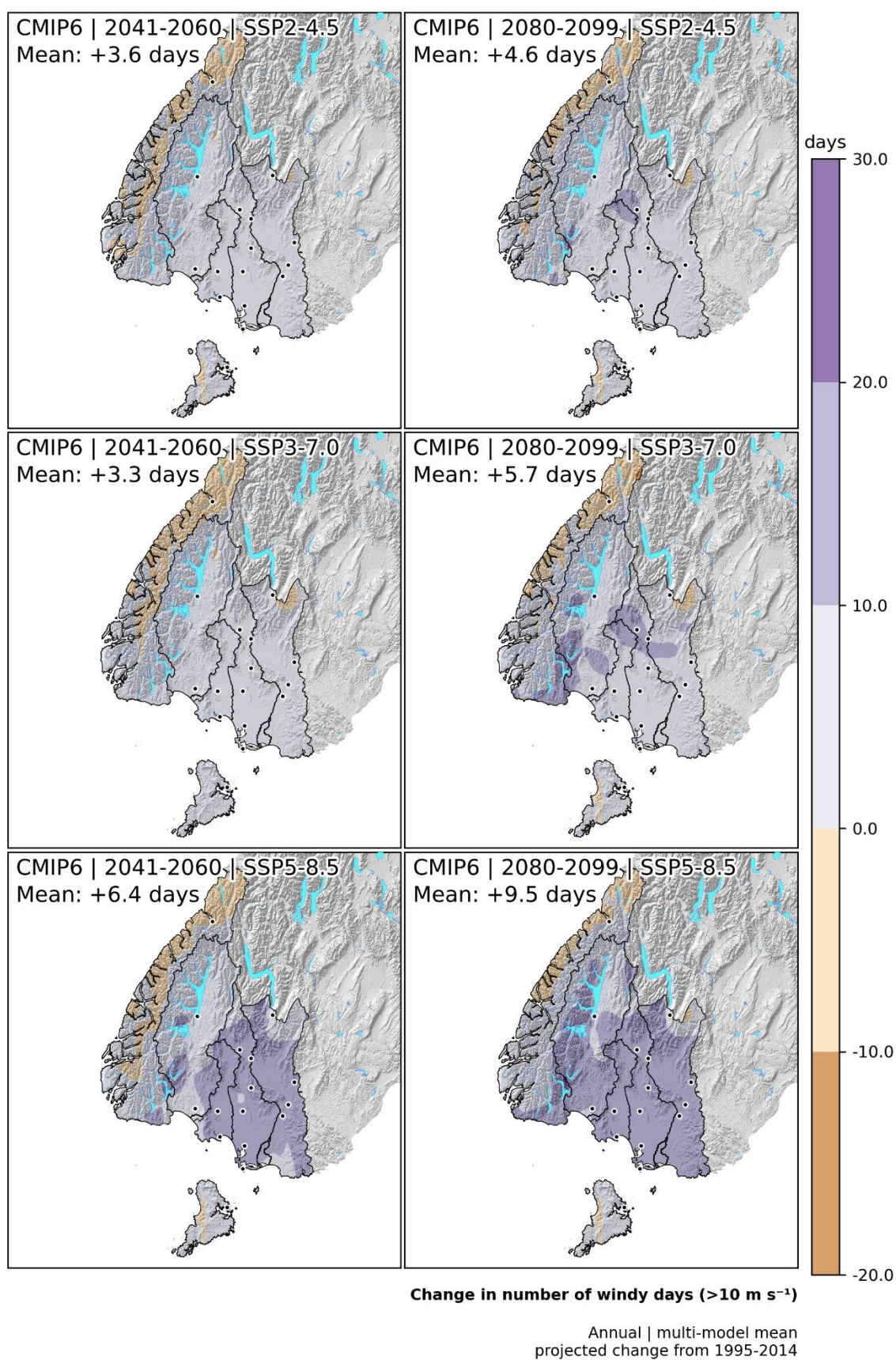


Figure 1-81: Projected annual average windy days changes.

1.6.5 Strong wind (99th percentile)

Modelled historic and projected changes to future annual strong wind (99th percentile) are illustrated in Figure 1-82 and Figure 1-83. Regional average projected annual and monthly changes are summarised in Table 1-36. As strong wind is related to the model's simulation of wind speed these results should be considered unreliable.

Table 1-36: Projected strong wind (99th percentile) changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	-0.2	+0.4	+0.2	+0.8	+0.5	+1.6
January	-0.7	-0.9	-1.2	-1.5	-0.5	-0.4
February	-3.5	-2.3	-1.5	-2.8	-1.5	-2.5
March	+0.1	+1.1	+0.3	-0.8	+1.1	+1.0
April	-0.4	-1.1	-1.7	-1.8	-1.6	-1.8
May	+1.4	+0.6	+1.0	+1.1	+1.8	+1.3
June	+1.2	+1.8	+3.5	+4.0	+2.3	+5.6
July	-0.7	+0.7	+1.0	+2.5	+0.8	+4.1
August	0	+1.8	+3.1	+2.8	+3.1	+4.0
September	+1.8	+2.3	+0.7	+3.0	+2.5	+2.9
October	-0.9	+1.4	-0.4	+1.5	+1.9	+2.3
November	+2.4	+1.2	+1.3	+3.4	-0.2	+2.7
December	-2.1	-0.3	-1.3	-1.2	-1.2	+1.5

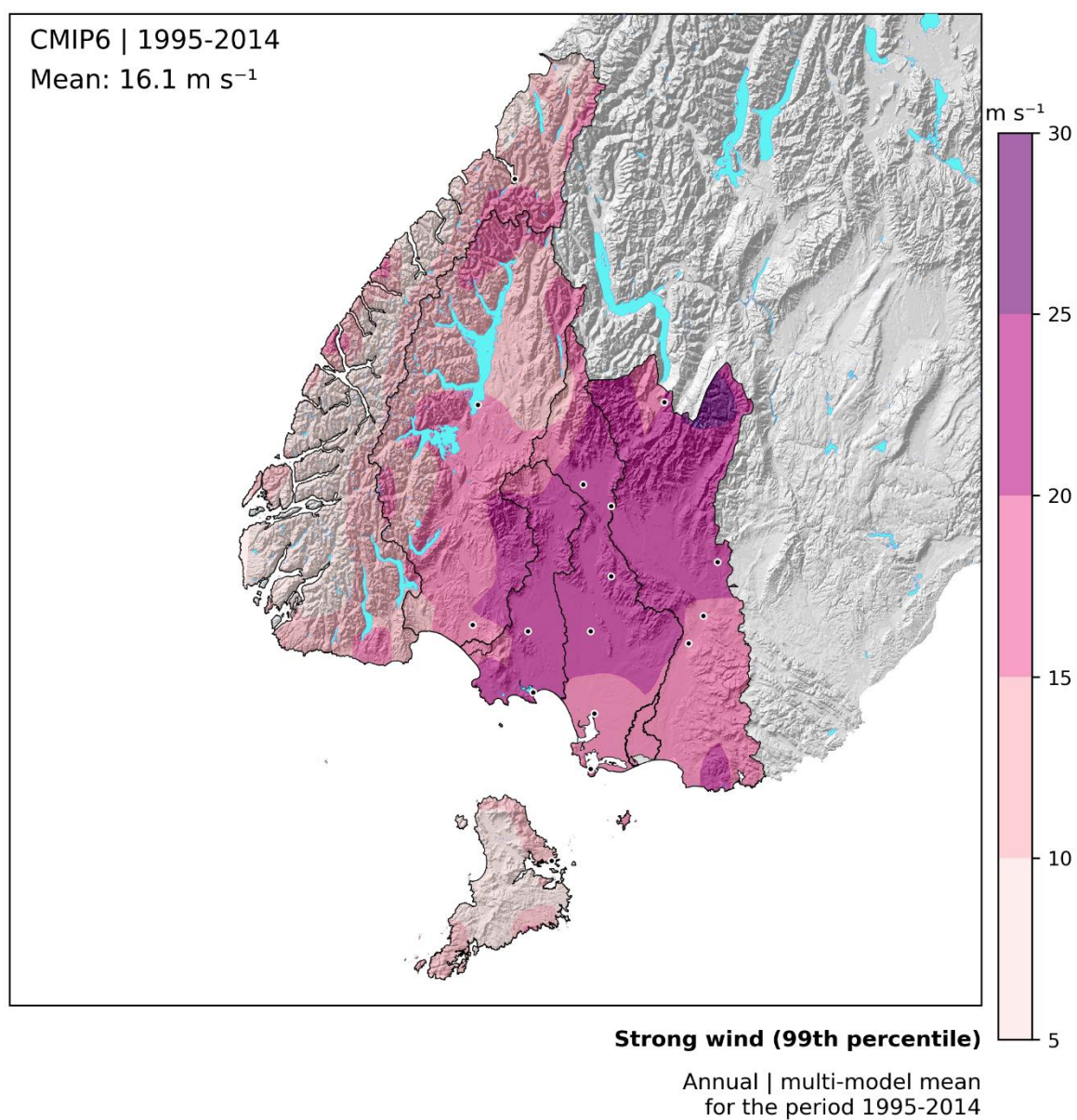


Figure 1-82: Modelled historic average annual strong wind speed.

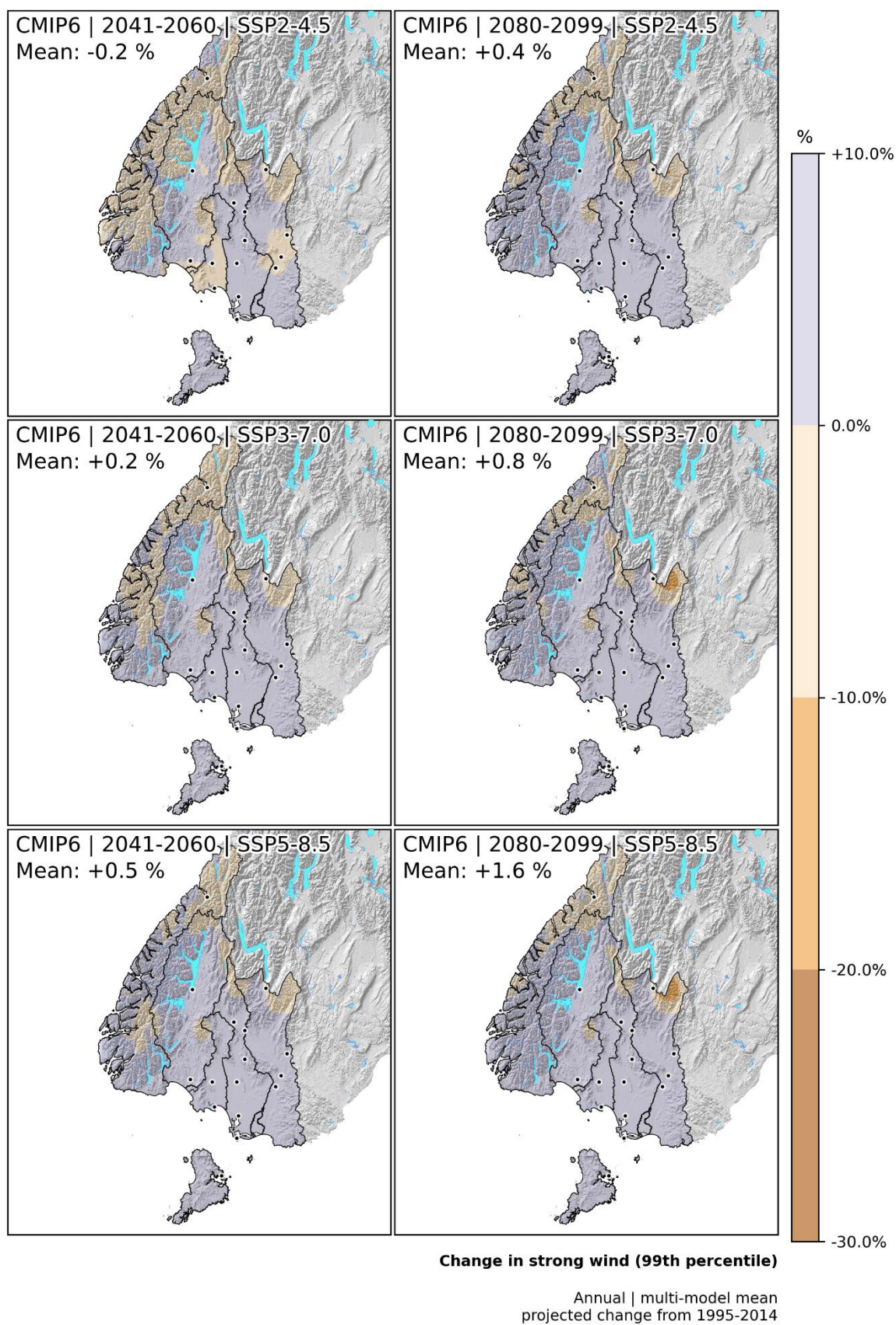


Figure 1-83: Projected annual average strong wind changes.

1.7 Potential Evapotranspiration Deficit (PED)

1.7.1 PED

Modelled historic and projected changes to future annual PED accumulation are illustrated in Figure 1-84 and Figure 1-85. Regional average projected changes are summarised in Table 1-37.

Table 1-37: Projected PED accumulation changes (mm, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+5	+7	+11	+21	+12	+23

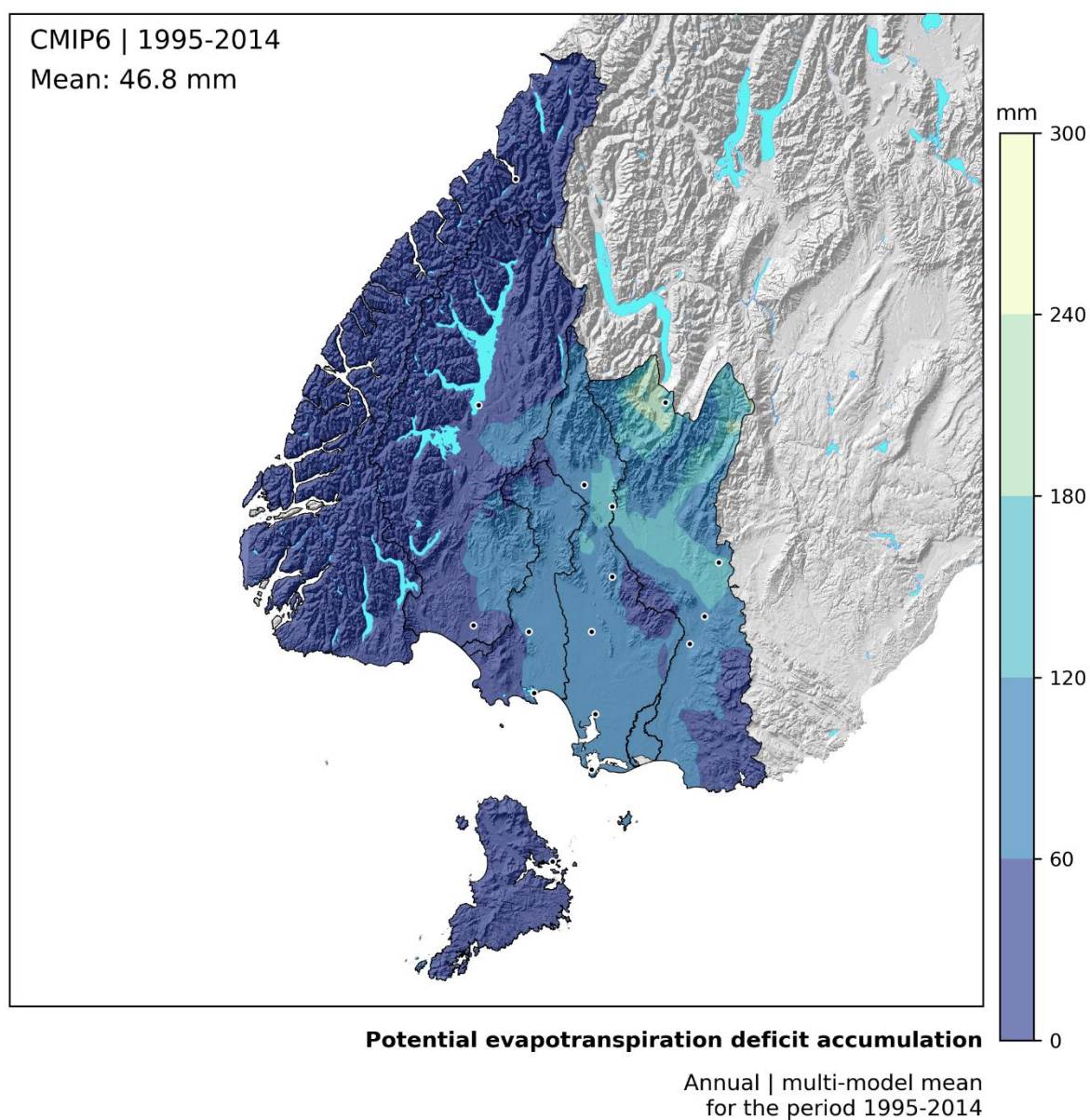


Figure 1-84: Modelled historic average annual potential evapotranspiration deficit accumulation.

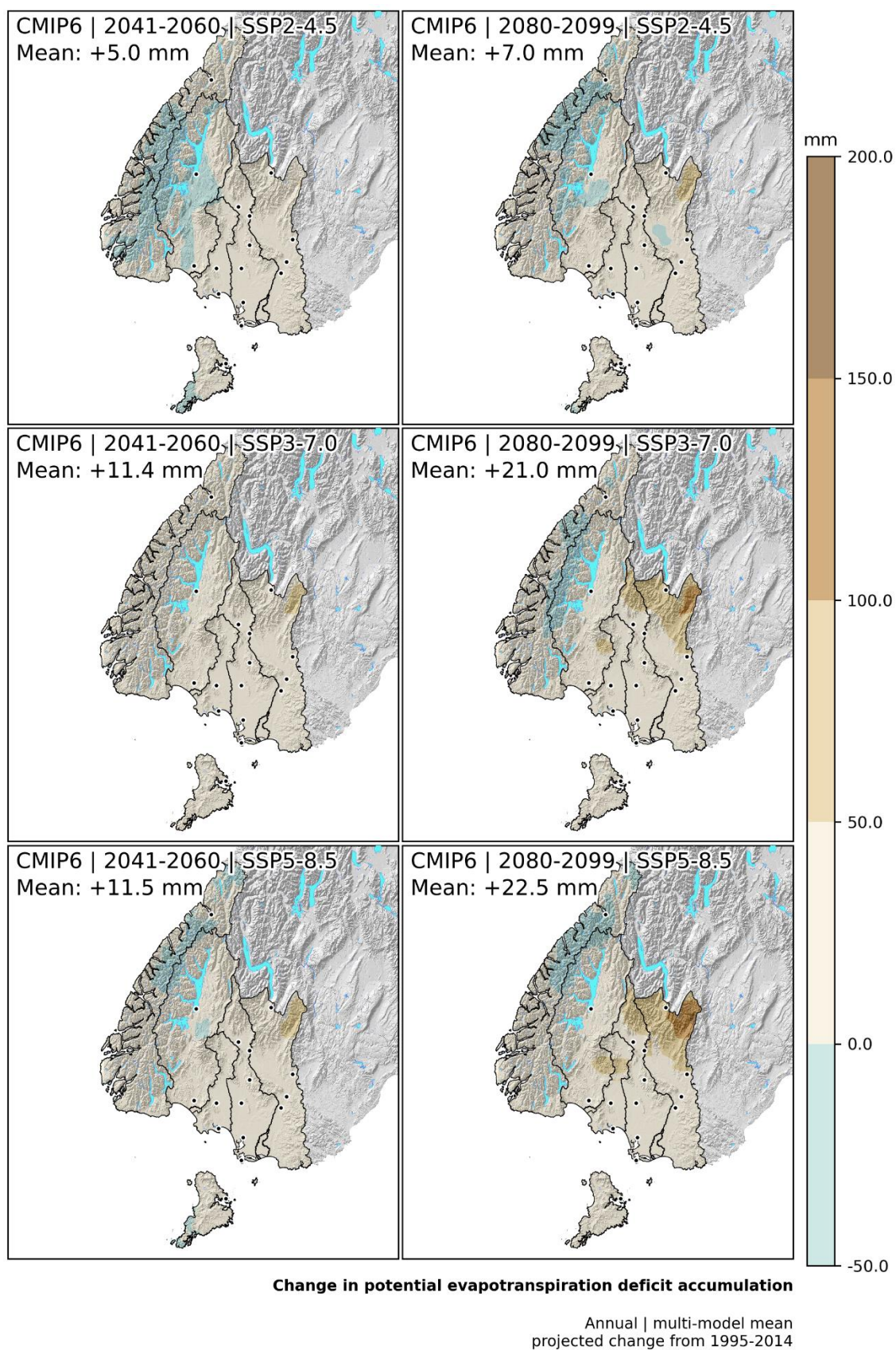


Figure 1-85: Projected annual potential evapotranspiration deficit accumulation changes.

1.7.2 Probability PED >200 mm

Modelled historic and projected changes to future annual probability of PED accumulation >200 mm is illustrated in Figure 1-86 and Figure 1-87. Regional average projected changes are summarised in Table 1-38.

Table 1-38: Projected probability of annual PED accumulation >200 mm changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	+1.1	+1.6	+2.3	+5.0	+2.5	+6.4

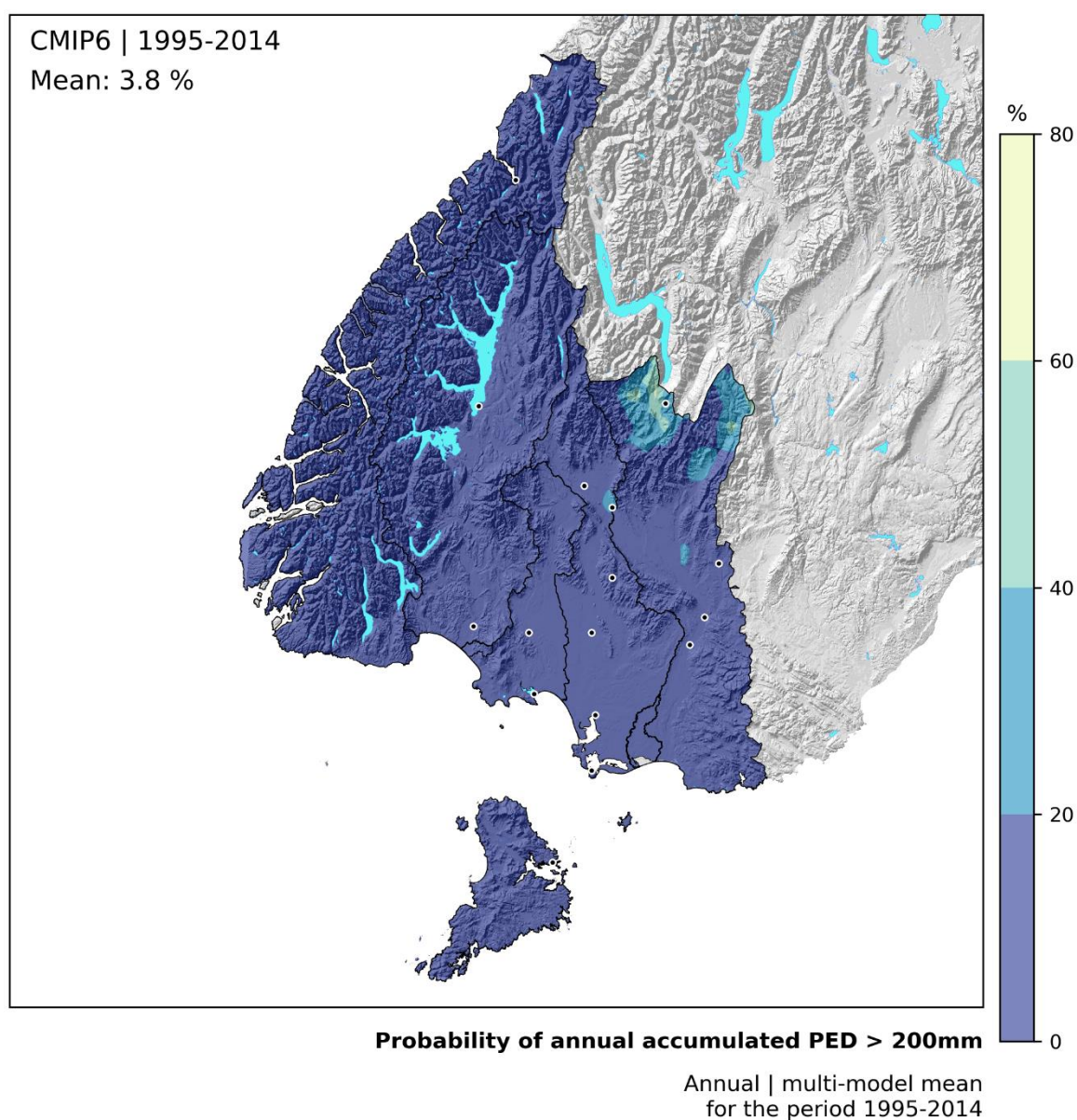


Figure 1-86: Modelled historic annual probability of PED accumulation >200 mm.

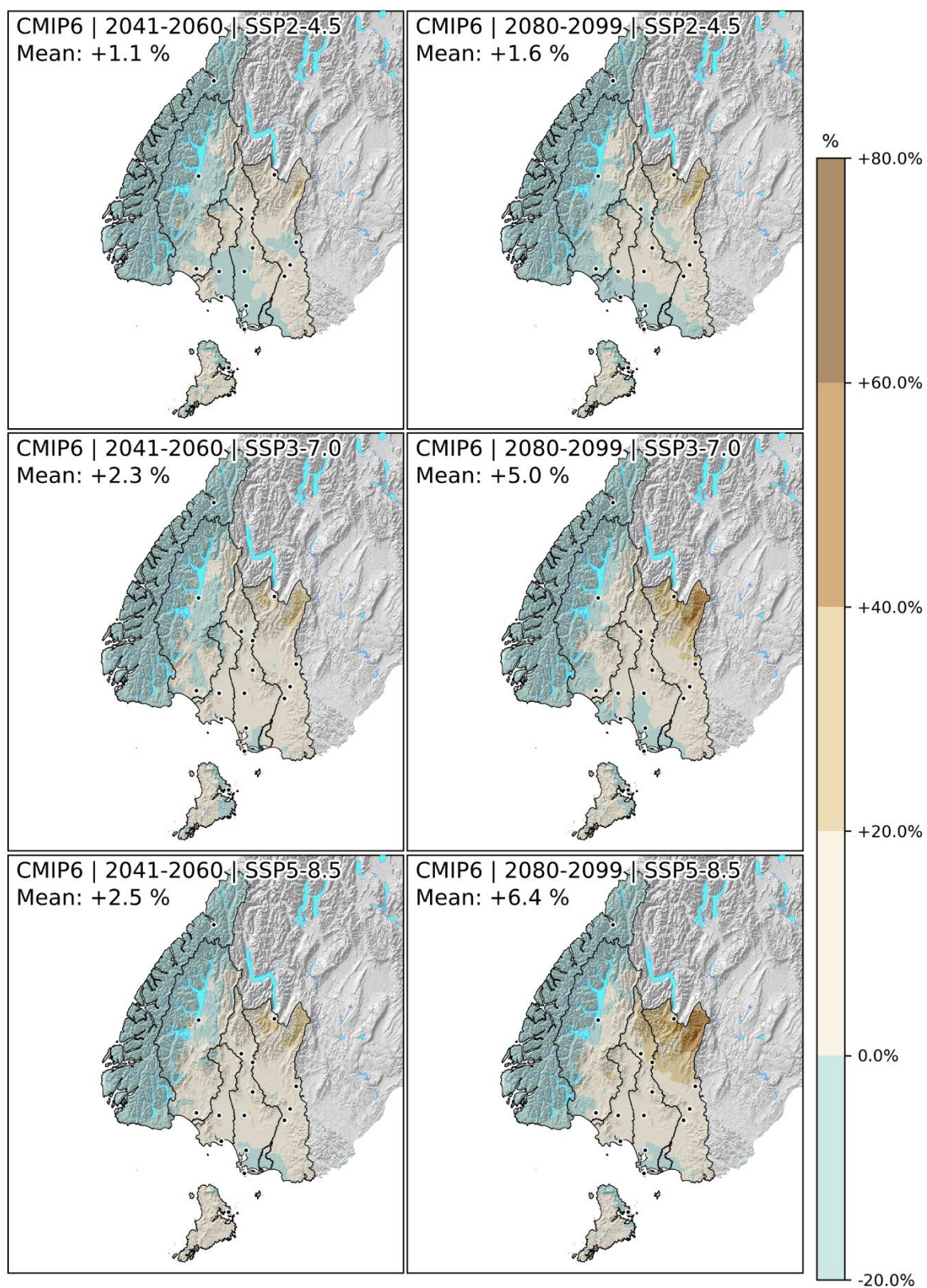


Figure 1-87: Projected change in probability of annual PED accumulation >200 mm.

1.8 Extreme events

1.8.1 Probable Maximum Precipitation

Modelled historic and projected changes to future PMP are generated for 12-24-48-72 hrs storm duration. Freshwater Management Unit (FMU) averaged projected changes in PMP rainfall depth for all storm event return periods are generated by the DSHG tool using nominal annual average temperature changes. The changes are not derived from the CMIP6 projections shown in this report but rely on alternative information incorporated within the DSHG tool. The change in PMP rainfall depth for different temperature changes and storm durations are summarised across Southland in Table 1-39 based on change in rainfall depth with warming for different event duration as provided by the DSHG tool. Location specific PMP rainfall depth and projected changes are shown in Table 1-40, with the location being moved to the outlet of the closest catchment represented in the DSHG tool. PMP estimations are not provided for Oban as this location is currently outside of the area currently covered by the DSHG tool. To enable the calculation of the flood magnitude associated with the PMP event (referred as the Probable Maximum Flood (PMF)) through the modelling chain, the timing of the maximum annual 1-day rainfall total is identified for each General Circulation Models (GCMs) over the period 1995-2014 (see Table 1-41).

It is noteworthy that projected change in PMP rainfall depth with temperature is uniform across the different event durations. This result is different from the strong dependence in the High Intensity Rainfall Design System (HIRDS) projected changes in rainfall depth for different duration (i.e., amplified changes with warming for shorter than 24hr duration event and reduced changes with warming for larger event duration). This result is also inconsistent with Earth Sciences NZ understanding of how climate change was intended to be implemented within the Dam Safety Hydrology Group (DSHG) PMP tool. As such extreme care should be taken when considering results other than for the 24hr index event.

Table 1-39: Projected change in PMP rainfall depth for 12-24-48 and 72 hrs storm duration (°C, relative to DSHG updated PMP rainfall depth under current warming level).

Annual Temperature change	12 hr	24hr	48hr	72hr
+1.0°C	+1.0	+1.8	+1.2	+2.8
+2.0°C	+1.1	+1.8	+1.4	+3.0
+3.0°C	+1.1	+1.8	+1.2	+2.8

Table 1-40: Historical PMP rainfall depth estimation for 12hr -24 hr- 48 hr and 72 hr storm event duration. PMP estimation generated using Tomlinson and Thompson (1992) original storm catalogue (Blue book) or DSHG updated storm catalogue (Updated, Bodeker et al. 2023).

FMU	Location	PMP	Storm duration			
		source	12hr	24hr	48hr	72hr
Aparima	Hamilton Burn at Mt Hamilton Road**	Blue Book	305	386	482	550
		Updated	351	515	750	887
	Pourakino Valley at Cascade Road **	Blue Book	256	335	431	501
		Updated	294	398	542	635
Mataura	Fairlight at Cainard Station	Blue Book	474	602	753	861
		Updated	357	523	793	968
	Glenlapa at Round Hill**		331	394	462	506
			293	417	611	736
	Mokoreta at Mt Alexander**	Blue Book	229	319	438	526
		Updated	279	361	465	541
	Waikaia River at Piano Flat	Blue Book	340	421	513	577
		Updated	362	536	852	1059
	Wendon Valley at Waikaka	Blue Book	296	348	402	436
		Updated	288	408	581	696
	Garston at Nevis Road**	Blue Book	323	398	484	543
		Updated	338	491	778	986
Oreti	Invercargill (Waihopai dam)	Blue Book	217	291	385	454
		Updated	278	357	459	524
	Woodlands at Garvie Road	Blue Book	223	296	386	453
		Updated	282	363	467	531
	McKellars Flat at Gorge Burn	Blue Book	473	614	783	906
		Updated	344	488	720	915
	Hokonui Hills at Lora Station**	Blue Book	265	320	381	421
		Updated	282	372	501	586
	Five Rivers at Five Rivers Station	Blue Book	409	517	642	731

FMU	Location	PMP	Storm duration			
		source	12hr	24hr	48hr	72hr
Waiau	Bluff*	Updated	352	522	798	969
		Blue Book	223	299	396	468
	Ohai at Wether Hill Station	Updated	286	367	472	536
		Blue Book	301	379	470	534
		Updated	325	473	691	840
	Waiau River at Clifden	Blue Book	333	447	591	697
		Updated	238	372	549	676
	Whitestone Aquifer at Lynwood	Blue Book	355	462	592	686
		Updated	302	421	578	684

with

- ** upstream catchment area is outside of the Blue Book range of the depth-area reduction factor (25-15,000 km²).
- * Bluff location is outside of the area currently covered by the DSHG tool.

Table 1-41: Timing of the historical maximum annual 1-day rainfall total over the period 1995-2014 for each CMIP6's GCMs. Timing of the maximum annual 1-day rainfall total is provided by its month for each GCM.

FMU	Location	ACCESS-CM2	AWI-CM-1-1-MR	CNRM-CM6-1	EC-Earth3	GFDL-ESM4	NorESM2-MM
Aparima	Hamilton Burn at Mt Hamilton Road**	January	October	January	October	April	January
	Pourakino Valley at Cascade Road **	March	November	December	November	December	January
Mataura	Fairlight at Cainard Station	March	November	February	June	March	February
	Glenlapa at Round Hill**	February	January	November	July	March	November

FMU	Location	ACCESS-CM2	AWI-CM-1-1-MR	CNRM-CM6-1	EC-Earth3	GFDL-ESM4	NorESM2-MM
Oreti	Mokoreta at Mt Alexander**	March	November	December	January	December	November
	Waikaia River at Piano Flat	December	November	November	January	March	March
	Wendon Valley at Waikaka	March	November	November	October	March	November
	Garston at Nevis Road**	December	November	November	January	March	November
	Invercargill (Waihopai dam)	March	May	December	February	December	February
	Woodlands at Garvie Road	March	May	December	February	December	January
	McKellars Flat at Gorge Burn	March	November	January	March	June	March
	Hokonui Hills at Lora Station**	January	December	December	January	December	November
Waiau	Five Rivers at Five Rivers Station	December	January	January	July	March	February
	Ohai at Wether Hill Station	March	February	January	February	January	February
	Waiau River at Clifden	January	May	January	February	April	February
	Whitestone Aquifer at Lynwood	October	January	February	January	December	April

Future projections taking into account global warming are available only for PMP estimation generated using the DSHG tool. Warming impact on PMP magnitude for different storm duration (assumed not to be impacted by climate warming) is provided in 1°C increments (see Table 1-42).

Table 1-42: PMP magnitude under 1.0°C, 2.0°C and 3.0°C warming for storm duration of 12 hr-24 hr-48 hr and 72 hr.

FMU	Location	Annual temperature changes	Storm duration			
			12hr	24hr	48hr	72hr
Aparima	Hamilton Burn at Mt Hamilton Road	+1.0°C	380	557	812	957
		+2.0°C	409	500	874	1030
		+3.0°C	438	643	937	1104
	Pourakino Valley at Cascade Road	+1.0°C	328	443	604	707
		+2.0°C	361	489	666	779
		+3.0°C	395	534	727	851
Mataura	Fairlight at Cainard Station	+1.0°C	387	566	858	1048
		+2.0°C	416	609	923	1127
		+3.0°C	446	652	989	1207
	Glenlapa at Round Hill	+1.0°C	317	452	661	797
		+2.0°C	341	486	712	857
		+3.0°C	365	521	762	918
	Mokoreta at Mt Alexander	+1.0°C	304	393	506	590
		+2.0°C	328	426	548	638
		+3.0°C	353	458	589	686
	Waikaia River at Piano Flat	+1.0°C	392	580	923	1147
		+2.0°C	422	625	994	1235
		+3.0°C	452	669	1064	1322
	Wendon Valley at Waikaka	+1.0°C	312	442	6299	754
		+2.0°C	336	475	676	811
		+3.0°C	359	509	724	869

FMU	Location	Annual temperature changes	Storm duration			
			12hr	24hr	48hr	72hr
Oreti	Garston at Nevis Road	+1.0°C	366	535	842	1067
		+2.0°C	394	572	906	1148
		+3.0°C	421	613	970	1230
	Invercargill (Waihopai dam)	+1.0°C	305	392	504	575
		+2.0°C	332	427	549	626
		+3.0°C	359	462	593	677
	Woodlands at Garvie Road	+1.0°C	308	397	511	580
		+2.0°C	335	431	554	629
		+3.0°C	361	464	597	678
	McKellars Flat at Gorge Burn	+1.0°C	375	532	785	996
		+2.0°C	405	575	849	1078
		+3.0°C	436	619	913	1159
	Hokonui Hills at Lora Station	+1.0°C	306	403	543	635
		+2.0°C	329	434	585	684
		+3.0°C	353	465	626	733
Waiau	Five Rivers at Five Rivers Station	+1.0°C	381	565	863	1049
		+2.0°C	410	608	929	1128
		+3.0°C	439	651	995	1208
	Ohai at Wether Hill Station	+1.0°C	352	512	748	909
		+2.0°C	379	551	805	978
		+3.0°C	405	590	862	1047
	Waiau River at Clifden	+1.0°C	259	405	597	736

FMU	Location	Annual temperature changes	Storm duration			
			12hr	24hr	48hr	72hr
		+2.0°C	280	438	646	796
		+3.0°C	301	471	694	855
	Whitestone Aquifer at Lynwood	+1.0°C	329	458	629	744
		+2.0°C	355	495	679	804
		+3.0°C	382	532	730	864

Analysis indicates:

- PMP rainfall depths estimated using the updated DSHG's storm catalogue are generally larger than PMP previously estimated by Tomlinson and Thompson (1992).
- Large difference (up to 50 percent) can be found between the original PMP and the DSHG PMP estimation.
- Difference in PMP estimation is increasing with the storm duration.
- Development of a linear regression model indicates that the change in PMP rainfall depth can be estimated to be 8.3 percent per degree change (slightly larger than Clausius-Clapeyron relationship) (Figure 1-88).
- While most of the maximum annual 1-day rainfall total events occur over the period October to February, two events (across the GCMs) occurred in at the start of the snow year and are potentially impacted by snowfall (Oreti FMU). Four winter events were identified across the Oreti and Mataura FMU. The impact of increase warming on those events may affect the phase of the precipitation and potentially amplified the hydrological response to those events.

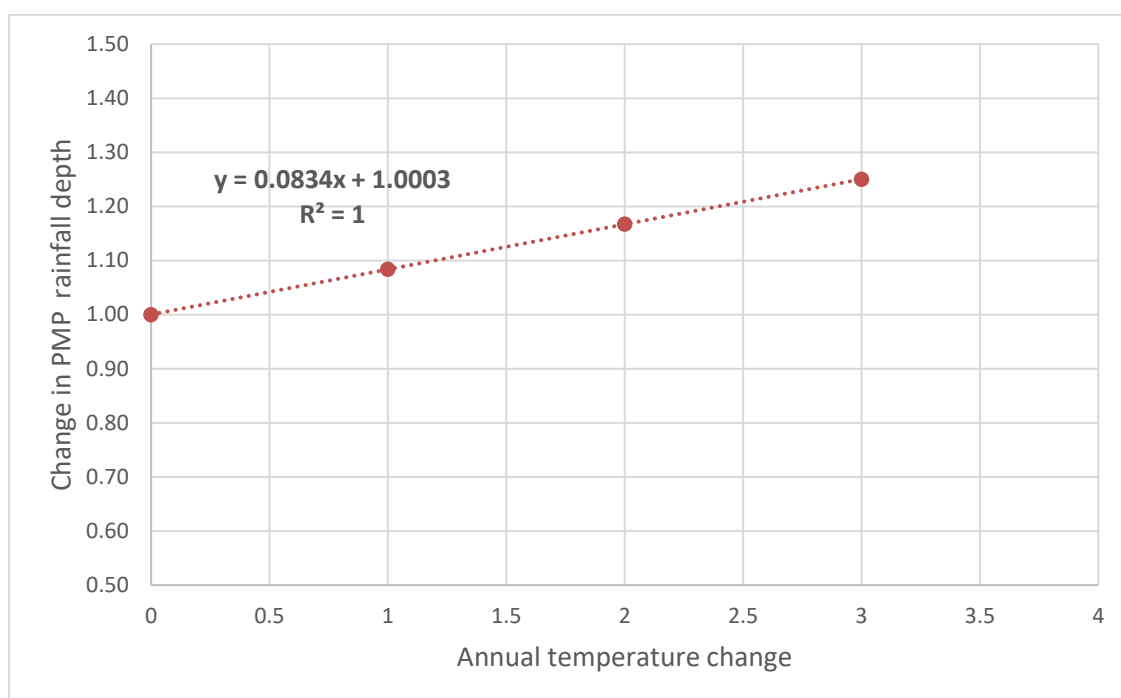


Figure 1-88: Change in PMP rainfall depth with air temperature. Change in PMP rainfall depth is expressed as a ratio to current DSHG PMP rainfall depth under current warming (1995-2014).

1.8.2 Meteorological drought frequency

Modelled historic and projected changes to future annual meteorological drought frequency is illustrated in Figure 1-89 and Figure 1-90. Regional average projected changes are summarised in Table 1-43, while location-specific projected changes are shown in Table 1-44.

Table 1-43: Projected meteorological drought frequency changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Annual	-12.7	-21.9	-11.1	-17.1	-11.3	-19.9

Table 1-44: Projected changes to annual meteorological drought frequency (days).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Invercargill	-15.5	-24.8	-12.7	-26.9	-7.4	-27.4
Riverton	-17.0	-23.6	-13.9	-24.8	-8.6	-26.1
Mataura	-22.3	-31.7	-17.5	-24.1	-14.4	-31.4
Gore	-18.5	-26.6	-9.9	-23.1	-13.2	-26.9
Winton	-19.0	-27.6	-16.2	-31.9	-16.7	-33.2
Lumsden	-21.6	-34.2	-22.1	-28.1	-12.2	-23.8

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Te Anau	-18.0	-29.7	-25.3	-29.4	-20.3	-30.2
Otautau	-13.4	-23.8	-16.2	-25.9	-11.2	-26.9
Tuatapere	-21.3	-31.4	-26.6	-32.2	-18.0	-31.7
Oban	-13.9	-26.1	-10.7	-15.0	-11.2	-24.6
Riversdale	-15.5	-26.6	-19.0	-25.3	-9.4	-27.1
Waikaka	-17.5	-27.1	-14.7	-24.6	-13.4	-27.4
Milford Sound	-11.9	-26.1	-7.4	-28.4	-20.8	-27.6
Garston	-1.0	-15.2	-7.6	-5.1	-6.1	-6.3
Mossburn	-20.3	-27.6	-24.1	-23.1	-13.9	-23.1
Bluff	-14.4	-22.8	-9.4	-26.4	-7.6	-26.6

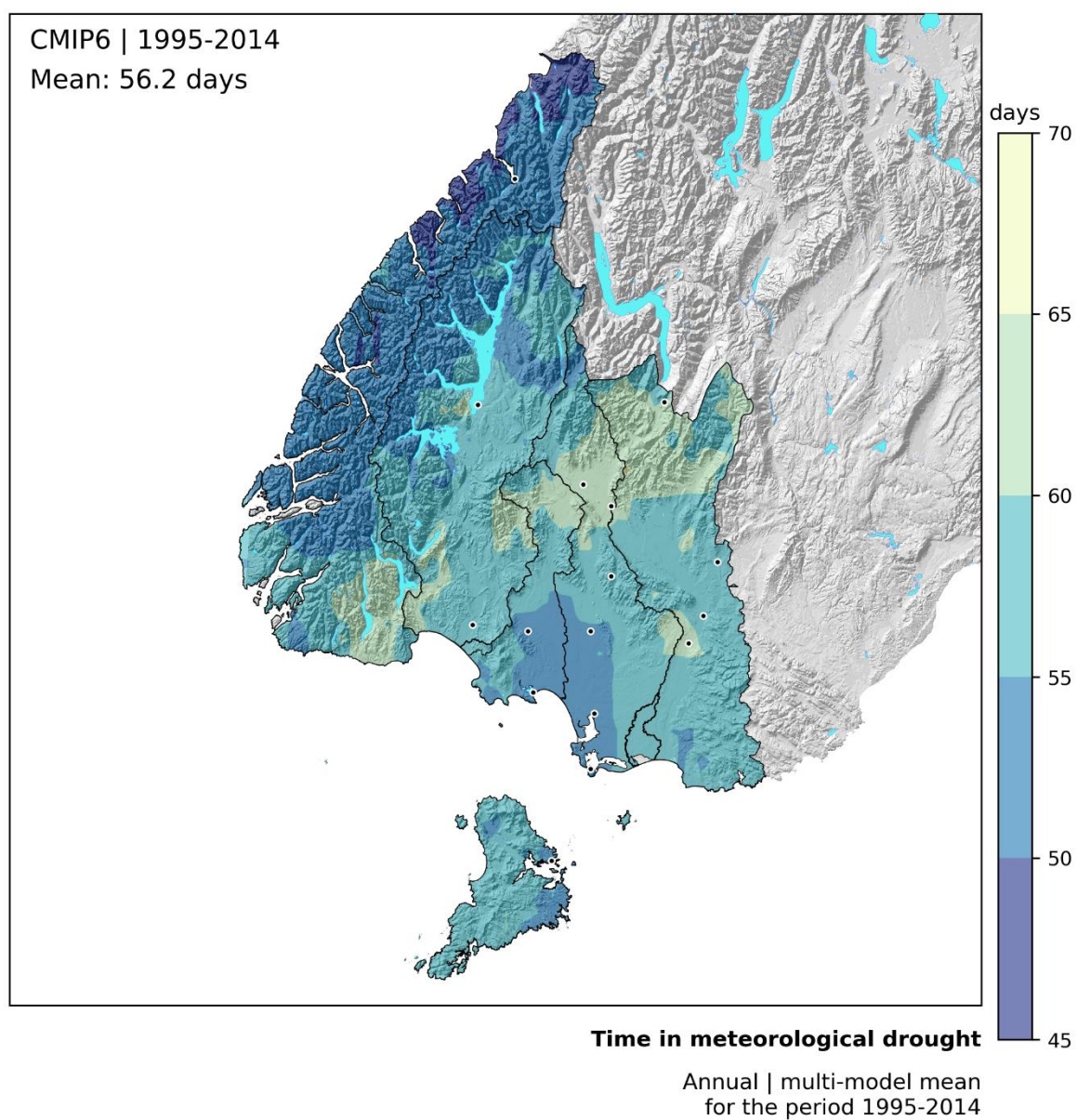


Figure 1-89: Modelled historic average annual meteorological drought frequency.

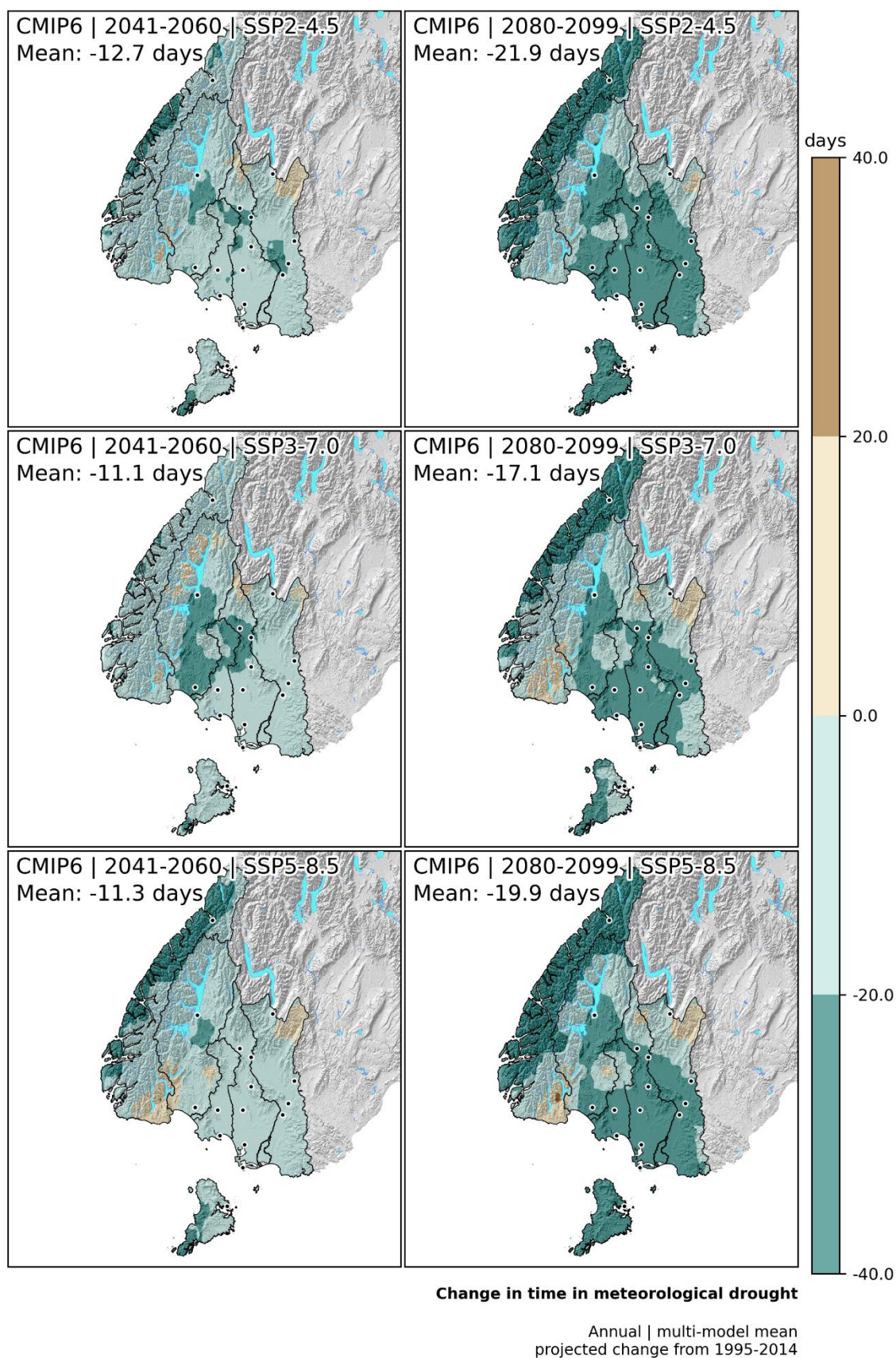


Figure 1-90: Projected annual meteorological drought frequency changes.

1.9 Discussion

1.9.1 Temperatures

Ongoing temperature increases are projected for Southland, with greater increases by the end of the century under high (SSP3-7.0) and very high (SSP5-8.5) greenhouse gas concentration scenarios. At the seasonal scale, greatest increases in mean temperature are projected for winter while the smallest increases in mean temperature are projected for spring.

Average daily maximum temperatures are projected to increase more than average daily minimum temperatures, with larger differences emerging by the end of the century during the summer and autumn seasons. Consequently, the average daily temperature range is projected to increase both annually and seasonally, but by no more than 0.6°C. Increasing daily maximum temperatures contribute to an increase in projected hot days (daily maximum temperature above 25°C) and a decrease in projected frost days (daily maximum temperature below 0°C). In effect, the projections result in an extension of the historic summer season, with summer-like temperatures occurring more regularly during spring and persisting deeper into autumn. Despite the greatest increase in mean temperature projected for winter, winter temperature is projected to remain in average below 10°C.

Heatwave frequency is projected to increase with up to 36 more days of heatwave by 2090 under SSP5-8.5. As noted by Harrington and Frame (2022), minimum overnight temperatures are also relevant when contextualising the overall risks associated with a heatwave. This is because humans need lower nighttime temperatures to recuperate so they can handle any extreme heat on the following day (Perkins 2015). Therefore, future investigations could consider humidity-based heat stress metrics as additional heatwave metrics (Harrington and Frame 2022).

Rising temperature across Southland, across seasons and warming lead to the increase in the number of days exceeding the base threshold of 10°C, increasing GDD totals with the largest increase (up to 100 days) occurring during summer. This increase will likely result in faster crop maturation across Southland, redevelopment of the primary sector (as the region may become more suitable for crops limited to warmer areas), and increased pest and disease activity due to more rapid reproduction cycle resulting in increasing pressure on crops.

All models project increases to mean temperature for each future period and SSP scenario, which provides a high degree of confidence that future warming will occur. There is uncertainty as to the precise amount of warming that will occur under each SSP, therefore the multi-model (ensemble) average values presented in Section 1.1 are the most appropriate estimate for projected changes across Southland.

1.9.2 Precipitation

Annual total rainfall is projected to increase across Southland mostly by less than 10% independently of time and warming scenario (except by end of century under SSP5-8.5). The increase in precipitation has a strong seasonal signal with the largest increase predicted for the winter and spring seasons (up to 24% by the end of century under SSP5-8.5), while autumn precipitation is projected to slightly decrease (by up to 1%) by mid-century under SSP3-7.0. The multi-model (ensemble) of average projected total rainfall changes obscures significant variations between the individual models run under each SSP. As a result, there could be little

agreement among all the models as to the direction of the projected rainfall changes (increase or decrease), with the exception for winter and spring season due to the magnitude of the predicted changes. The general lack of agreement between models, mainly during the summer and autumn seasons, means that uncertainty remains as to the direction of projected rainfall changes during those seasons. Greater confidence can be placed on projections under which the majority of the models (e.g., five of the six models) project the same direction of change.

The uncertainty as to the direction and amount of change under each SSP means the multi-model (ensemble) average values are the most appropriate estimate for projected rainfall changes across Southland. Nevertheless, the spread of model results under each SSP implies that these projections should be interpreted carefully. Emphasis should be placed on ongoing monitoring of rainfall throughout Southland to track observed changes in total rainfall. Additionally, improvements to GCM capabilities are likely, as well as refinements to downscaling and bias-correction procedures, and this may result in reduced uncertainty when future iterations of rainfall projections are generated.

A warmer atmosphere can hold more water – the Clausius-Clapeyron relationship predicts an increase in the moisture capacity of air of approximately 7% per degree Celsius (Held and Soden 2006). Indeed, a growing body of evidence demonstrates that observed extreme rainfall events have already been exacerbated by climate change (e.g., Vasconcelos Junior et al. 2024; Tradowsky et al. 2023; Otto et al. 2023). Two aspects were considered as part of the analysis:

- Changes to heavy rainfall frequency have been examined using the heavy rainfall threshold of 25 mm (very wet days) and 50 mm (heavy wet days). Using this metric, heavy rainfall frequency is projected to become slightly more frequent (by up to 5 days) with time and warming. Compared to other regions, the increase in number of heavy wet days is less than the increase in the number of very wet days, potentially indicating change in the distribution of wet days in Southland.
- Change in heavy rainfall magnitude have been examined using the maximum annual 1-day (99th percentile) and 5-day rainfall total. Using this metric, magnitude of the wettest day and wettest 5-day in the year is projected to increase with time and warming (up to 25% by the end of century under SSP5-8.5).

The projected change in frequency and magnitude of daily rainfall extremes is likely to result in increased risk of flooding and associated infrastructure damage.

Extreme rainfalls of sub-daily duration were not assessed directly in this report but are important to consider given their propensity to cause sudden and significant impacts. Carey-Smith et al. (2018) presented New Zealand's future changes to rainfall depths for event durations/average recurrence intervals (ARI) spanning 1-120 hours/2-100 years. Per degree of warming, the percentage change factors for rainfall depths ranged from 4.8% to 13.6%, with greater increases for shorter duration/higher ARI event combinations (Carey-Smith et al. 2018).

1.9.3 Relative humidity

Relative humidity is projected to slightly decrease with time and warming (by up to 1% under SSP5-8.5) across Southland. Spatially, changes are slightly larger for the eastern FMUs.

Little change in relative humidity may signal complex region-wide change in atmospheric dynamic such as increase in specific humidity (actual vapour content) as warmer air holds more

moisture, and larger contrast of humidity between land and ocean (Byrne and O’Gorman 2016). This could result in an increase of heat stress affecting human and animals across the Southland region, heavier rainfall events due to increased moisture capacity (Section 1.2), increase in wildfire risk depending on the interaction between temperature and wind (Willett 2020).

1.9.4 Solar radiation and cloud cover

Across Southland, changes in annual average solar radiation are projected to be minimal across time and warming. This masks significant changes occurring seasonally, with the largest increase in solar radiation projected for summer (by up to 7% by end of century under SSP5-8.5), and the largest decrease projected for winter (by up to 4% by end of century under SSP5-8.5). Conversely, cloud cover is projected to decrease by up to 4% during summer, with little to no change during winter.

The change in solar radiation which can be attributed to atmospheric changes such as change in cloud cover can have wide-ranging implications for the climate, agriculture and ecosystems across Southland. Increases in solar radiation during summer could result in intensification of heatwaves, boosted evaporation resulting in dryer soil and reduced water availability, and increases in photosynthesis and carbon sequestration if water and nutrient uptake are sufficient (Wild 2012). Decrease in solar radiation during winter and spring season, could slow down melting of snowpack and glaciers during the snow melt season (Wild 2012).

1.9.5 Wind

Across Southland, wind speed is projected to slightly increase with time and warming (up to 4% by end of century under SSP5-8.5). The relatively small increase in average annual wind speed is masking a strong seasonal shift in windspeed, with wind speed reducing up to 4.4% in summer while increasing up to 12% in winter. A decrease in summer winds could be explained by weaker temperature gradient across Southland associated with changes in jet stream positioning, thus potentially reducing irrigation demands. Increases in winter winds could be explained by stronger atmospheric pressure gradients resulting in increased storm activity and magnitude, resulting in potential increased damages to buildings, power lines and trees while providing higher wind generation potential across Southland (Purdie 2022). Because the modelled wind speeds do not appear to validate well against observations, projected changes in wind speeds should be treated with caution.

1.9.6 Potential Evapotranspiration Deficit

Atmospheric water demand, analysed as annual PED accumulation over 200 mm, is projected to increase across Southland with time and warming, with the probability of occurrence increasing by up to 6.4% by end of century under SSP5-8.5. The relatively small increase in probability of occurrence at the regional scale is masking a strong spatial signal independently of time and warming scenario, with the risk decreasing in western Southland and increasing everywhere else. Decreases in the probability of occurrence (up to 20%) are projected across Fiordland and western Waiau (i.e., area of the Waiau FMU discharging to the hydro-generation lakes) FMUs. In contrast, probability of occurrence is projected to increase for the remaining parts of Southland, with increases up to 20% for the eastern Waiau, Aparima, Waituna, lower and mid Maitara and most of the Oreti FMUs. Larger increases are projected for the upper

Mataura (up to 40%) and very large increases (up to 80%) are projected for the upper Waikaia catchment.

Increases in the probability of PED accumulation over 200 mm could be explained by a combination of factors. Among these are consistent rising temperature, shift in precipitation pattern (e.g., projected decrease for the Waikaia catchment), reduced snowpacks (extended dry seasons in snow affected catchments), and higher evapotranspiration (soils and vegetation lose water faster under heat stress) resulting in increased vulnerability for areas reliant on the seasonal water cycle (like Southland's eastern FMUs). This result points to increased future challenges for farming and water management in those areas. Decreased probability of occurrence of meteorological drought in the hydro-generation lakes catchment could benefit water availability for hydro-generation.

1.9.7 Meteorological drought

The number of days under meteorological drought conditions is projected to decrease with time and warming across most of Southland, with decreases by up to 19.9 days by end of century under SSP5-8.5. The relatively large decrease in probability of occurrence at Southland scale is masking strong spatial differences, with increase in number of days under meteorological drought conditions (up to 20 days) for the Waikaia catchment and eastern coastal Fiordland, while decreases are projected (up to 40 days) for the eastern Waiau, Aparima, Waituna, lower and mid Mataura and most of the Oreti FMUs.

Although initially counterintuitive, the projected decrease in the number of days under meteorological drought conditions is consistent with the projected increase in PED accumulation above 200 mm threshold under future warming scenarios. This result points to droughts being, under future warming scenarios, shorter (fewer dry days) but more severe (faster accumulation of deficit).

2 Glossary of abbreviations and terms

Anthropogenic	Originating in human activity
ARI	Average recurrence interval. The average time interval (averaged over a very long time period and many "events") that is expected to elapse between recurrences of an infrequent event.
Bias-corrected	The process of using observations (e.g., data from existing climate stations, or streamflow stations) to calibrate climate model or climate-hydro modelling chain simulations. This ensures climate model or hydrological output resemble a given location's climate and weather/ hydrological characteristics appropriately.
CCAM	Conformal Cubic Atmospheric Model, which uses dynamical downscaling to simulate climate and weather at finer resolutions than GCMs. Developed by CSIRO in Australia.
Climate variable	An element of the climate that is liable to vary or change, e.g., temperature, rainfall.
CMIP5	Fifth Coupled Model Intercomparison Project. This project involved a number of experiments with coupled atmosphere-ocean global climate models, most of which were reported on in the IPCC Fifth Assessment Report, Working Group I
CMIP6	Sixth Coupled Model Intercomparison Project. This project involved a number of experiments with coupled atmosphere-ocean global climate models, most of which were reported on in the IPCC Sixth Assessment Report, Working Group I
Downscaling	Deriving local climate information from larger-scale model or observational data. Two main methods exist – statistical and dynamical. Statistical methods develop statistical relationships between large-scale atmospheric variables (e.g., circulation and moisture variations) and local climate variables (e.g., rainfall variations). Dynamical methods use the output of a regional climate/weather model driven by a larger-scale global model
Ensemble	Referring here to the collection of six GCMs that were selected for downscaling and bias-correction in New Zealand
GCMs	Global Climate Models
IPCC	Intergovernmental Panel on Climate Change. This body was established in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) to objectively assess scientific, technical and socioeconomic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation. One of its major outputs is regular assessments of the climate system and our knowledge of climate change, known as Assessment Reports

Radiative forcing	The difference between the energy entering our atmosphere and the energy leaving it. If the number is greater than zero, our atmospheric temperature can increase.
RCPs	Representative Concentration Pathways. These comprise scenarios used in CMIP5 modelling. They describe four possible climate futures represented by the concentration of greenhouse gases in the atmosphere, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W m ² , respectively)
Seven-station series	This refers to seven long-term temperature records used to assess New Zealand's warming on the century time-scale. The sites are located in Auckland, Wellington, Masterton, Nelson, Hokitika, Lincoln, and Dunedin.
SSPs	Shared Socioeconomic Pathways. These comprise scenarios of projected socioeconomic global changes up to 2100, used in CMIP6 modelling
SST	Sea-surface temperature. The temperature of the uppermost layer of the ocean

Appendix A FMU change summary

Mean temperature

Table A-1: FMU projected mean temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.8	1.3	2.8	1.3	3.5
Fiordland and Islands	0.9	1.7	1.2	2.7	1.2	3.3
Mataura	1.0	1.8	1.3	2.9	1.4	3.6
Oreti	1.0	1.8	1.3	2.8	1.3	3.5
Waiau	1.0	1.8	1.3	2.8	1.3	3.5
Waituna	1.0	1.7	1.2	2.7	1.3	3.4

Table A-2: FMU projected winter mean temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.9	1.3	2.9	1.4	3.7
Fiordland and Islands	0.9	1.8	1.2	2.7	1.3	3.5
Mataura	1.0	1.9	1.2	2.9	1.4	3.8
Oreti	1.0	1.9	1.3	2.9	1.4	3.7
Waiau	1.0	1.9	1.2	2.9	1.4	3.7
Waituna	1.0	1.8	1.2	2.8	1.4	3.6

Table A-3: FMU projected spring mean temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.9	1.7	1.2	2.6	1.2	3.3
Fiordland and Islands	0.8	1.5	1.1	2.4	1.1	3.0
Mataura	0.9	1.7	1.2	2.6	1.3	3.3
Oreti	0.9	1.7	1.2	2.6	1.3	3.3
Waiau	0.9	1.6	1.1	2.5	1.2	3.1
Waituna	0.9	1.6	1.2	2.5	1.2	3.2

Table A-4: FMU projected mean summer temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.8	1.3	3.0	1.3	3.5
Fiordland and Islands	1.0	1.8	1.3	3.0	1.2	3.4

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	1.1	1.9	1.4	3.1	1.3	3.6
Oreti	1.1	1.8	1.4	3.0	1.3	3.5
Waiau	1.1	1.9	1.4	3.1	1.3	3.6
Waituna	1.0	1.7	1.3	2.8	1.2	3.3

Table A-5: FMU projected autumn mean temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.1	1.8	1.2	2.8	1.4	3.5
Fiordland and Islands	1.0	1.8	1.2	2.7	1.3	3.4
Mataura	1.1	1.9	1.3	2.9	1.4	3.6
Oreti	1.1	1.9	1.2	2.8	1.4	3.5
Waiau	1.1	1.9	1.2	2.8	1.3	3.5
Waituna	1.0	1.8	1.2	2.7	1.3	3.4

Minimum temperature

Table A-6: FMU projected minimum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.7	1.2	2.7	1.3	3.3
Fiordland and Islands	0.9	1.7	1.1	2.6	1.2	3.2
Mataura	1.0	1.7	1.2	2.7	1.3	3.3
Oreti	1.0	1.7	1.2	2.7	1.3	3.3
Waiau	1.0	1.7	1.2	2.7	1.2	3.3
Waituna	0.9	1.7	1.1	2.6	1.2	3.2

Table A-7: FMU projected winter minimum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.9	1.3	2.9	1.5	3.7
Fiordland and Islands	0.9	1.8	1.2	2.7	1.3	3.4
Mataura	1.0	1.8	1.2	2.8	1.4	3.6
Oreti	1.0	1.9	1.2	2.8	1.4	3.7
Waiau	1.0	1.8	1.2	2.8	1.4	3.6
Waituna	1.0	1.8	1.2	2.8	1.4	3.6

Table A-8: FMU projected spring minimum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.9	1.7	1.2	2.5	1.2	3.2
Fiordland and Islands	0.9	1.6	1.1	2.4	1.1	3.0
Mataura	0.9	1.6	1.2	2.5	1.2	3.1
Oreti	0.9	1.6	1.2	2.5	1.2	3.1
Waiau	0.9	1.6	1.1	2.4	1.2	3.0
Waituna	0.9	1.6	1.1	2.4	1.2	3.1

Table A-9: FMU projected summer minimum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.9	1.6	1.2	2.7	1.1	3.1
Fiordland and Islands	0.9	1.7	1.2	2.7	1.1	3.1
Mataura	1.0	1.7	1.3	2.8	1.2	3.2

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Oreti	1.0	1.7	1.2	2.7	1.1	3.1
Waiau	1.0	1.7	1.3	2.8	1.2	3.2
Waituna	0.9	1.6	1.1	2.5	1.0	2.9

Table A-10: FMU projected autumn minimum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.8	1.1	2.6	1.3	3.2
Fiordland and Islands	1.0	1.8	1.1	2.6	1.2	3.2
Mataura	1.0	1.8	1.1	2.6	1.3	3.3
Oreti	1.0	1.8	1.1	2.6	1.3	3.3
Waiau	1.0	1.8	1.1	2.7	1.3	3.3
Waituna	1.0	1.7	1.1	2.6	1.2	3.2

Maximum temperature

Table A-11: FMU projected maximum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.8	1.3	3.0	1.4	3.7
Fiordland and Islands	1.0	1.7	1.3	2.8	1.3	3.4
Mataura	1.1	1.9	1.4	3.1	1.5	3.8
Oreti	1.1	1.9	1.4	3.0	1.4	3.7
Waiau	1.0	1.9	1.3	3.0	1.4	3.6
Waituna	1.0	1.8	1.3	2.9	1.3	3.6

Table A-12: FMU projected winter maximum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	1.9	1.3	2.9	1.4	3.7
Fiordland and Islands	1.0	1.8	1.2	2.7	1.3	3.5
Mataura	1.1	1.9	1.3	3.0	1.5	3.9
Oreti	1.0	1.9	1.3	3.0	1.4	3.8
Waiau	1.0	1.9	1.3	3.0	1.4	3.8
Waituna	1.0	1.8	1.2	2.8	1.3	3.6

Table A-13: FMU projected spring maximum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.9	1.7	1.2	2.6	1.3	3.4
Fiordland and Islands	0.8	1.5	1.1	2.4	1.1	3.0
Mataura	1.0	1.8	1.3	2.8	1.4	3.5
Oreti	0.9	1.7	1.3	2.7	1.3	3.4
Waiau	0.8	1.6	1.2	2.5	1.2	3.2
Waituna	0.9	1.6	1.2	2.6	1.2	3.3

Table A-14: FMU projected summer maximum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.2	2.0	1.5	3.3	1.4	3.9
Fiordland and Islands	1.1	1.9	1.5	3.2	1.3	3.7
Mataura	1.2	2.1	1.6	3.5	1.5	4.0

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Oreti	1.2	2.0	1.6	3.4	1.5	3.9
Waiau	1.2	2.0	1.5	3.4	1.4	3.9
Waituna	1.1	1.9	1.4	3.2	1.4	3.7

Table A-15: FMU projected autumn maximum temperature changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.1	1.9	1.3	3.0	1.5	3.7
Fiordland and Islands	1.0	1.8	1.3	2.9	1.3	3.6
Mataura	1.2	2.0	1.4	3.1	1.5	3.8
Oreti	1.1	1.9	1.4	3.0	1.5	3.8
Waiau	1.1	1.9	1.4	3.0	1.4	3.7
Waituna	1.1	1.9	1.3	2.9	1.4	3.6

Hot days

Table A-16: FMU projected changes to annual number of hot days (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	6.4	11.4	8.7	24.4	7.8	31.3
Fiordland and Islands	0.5	1.1	0.6	3.3	0.5	4.9
Mataura	6.0	11.0	8.4	23.1	7.4	29.6
Oreti	6.4	11.6	8.9	24.6	7.8	31.5
Waiau	2.6	4.9	3.7	11.9	3.1	16.0
Waituna	5.0	10.2	7.3	22.1	6.2	28.0

Table A-17: FMU projected changes to number of winter hot days (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.0	0.0	0.0	0.0	0.0	0.0
Fiordland and Islands	0.0	0.0	0.0	0.0	0.0	0.0
Mataura	0.0	0.0	0.0	0.0	0.0	0.0
Oreti	0.0	0.0	0.0	0.0	0.0	0.0
Waiau	0.0	0.0	0.0	0.0	0.0	0.0
Waituna	0.0	0.0	0.0	0.0	0.0	0.0

Table A-18: FMU projected changes to number of spring hot days days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.3	0.5	0.3	1.3	0.4	2.2
Fiordland and Islands	0.0	0.0	0.0	0.1	0.0	0.2
Mataura	0.2	0.5	0.3	1.3	0.4	2.2
Oreti	0.2	0.5	0.3	1.3	0.4	2.2
Waiau	0.1	0.2	0.1	0.4	0.1	0.7
Waituna	0.2	0.4	0.2	1.2	0.3	2.1

Table A-19: FMU projected changes to number of summer hot days (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	5.4	9.2	7.2	19.1	6.2	23.0
Fiordland and Islands	0.4	1.0	0.6	3.0	0.4	4.3
Mataura	5.1	9.0	6.9	18.4	6.0	22.2

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Oreti	5.4	9.4	7.3	19.3	6.2	23.1
Waiau	2.4	4.3	3.2	10.2	2.7	13.3
Waituna	4.3	8.0	6.0	17.2	4.8	19.9

Table A-20: FMU projected changes to number of autumn hot days (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.7	1.7	1.1	3.9	1.1	6.0
Fiordland and Islands	0.0	0.1	0.0	0.2	0.0	0.5
Mataura	0.6	1.5	1.0	3.3	0.9	5.3
Oreti	0.7	1.8	1.1	3.9	1.1	6.0
Waiau	0.2	0.4	0.3	1.2	0.2	2.0
Waituna	0.5	1.7	1.1	3.6	0.9	6.0

Heatwave

Table A-21: FMU projected changes to annual time spent in heatwave (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	6.3	11.9	8.7	27.0	7.9	33.9
Fiordland and Islands	6.2	12.3	9.2	27.5	7.4	35.6
Mataura	6.8	12.4	9.0	27.4	7.9	34.7
Oreti	6.3	11.6	8.5	26.2	7.6	33.1
Waiau	6.8	13.2	9.4	29.9	8.2	38.6
Waituna	4.3	7.3	5.6	16.5	4.6	20.8

Cold nights

Table A-22: FMU projected changes in number of annual cold nights (-, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-17.0	-28.9	-20.4	-39.1	-22.6	-45.4
Fiordland and Islands	-12.5	-22.1	-15.4	-29.5	-16.7	-34.5
Mataura	-14.7	-25.8	-17.7	-35.6	-19.8	-42.8
Oreti	-15.1	-26.3	-18.2	-35.8	-20.3	-42.3
Waiau	-19.9	-35.3	-23.8	-48.5	-26.3	-58.5
Waituna	-7.3	-12.2	-8.9	-15.0	-9.8	-16.3

Table A-23: FMU projected changes in number of winter cold nights (-, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-9.8	-17.4	-12.2	-24.1	-13.8	-28.3
Fiordland and Islands	-7.0	-12.8	-8.8	-17.6	-9.7	-20.8
Mataura	-8.0	-14.6	-10.1	-20.8	-11.4	-25.5
Oreti	-8.6	-15.7	-10.8	-21.9	-12.3	-26.3
Waiau	-9.5	-17.9	-11.7	-25.7	-13.5	-31.9
Waituna	-5.9	-10.0	-7.4	-12.4	-8.1	-13.6

Table A-24: FMU projected changes in number of spring cold nights (-, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-3.5	-5.7	-4.1	-7.2	-4.2	-8.3
Fiordland and Islands	-3.3	-5.5	-3.9	-7.1	-4.0	-8.3
Mataura	-3.4	-5.5	-3.9	-7.1	-4.1	-8.4
Oreti	-3.3	-5.1	-3.6	-6.5	-3.8	-7.6
Waiau	-5.1	-8.7	-6.0	-11.6	-6.3	-13.8
Waituna	-0.7	-0.9	-0.7	-1.0	-0.7	-1.0

Table A-25: FMU projected changes in number of summer cold nights (-, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.4	-0.6	-0.5	-0.8	-0.5	-0.8
Fiordland and Islands	-0.3	-0.5	-0.4	-0.5	-0.3	-0.6

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	-0.4	-0.6	-0.4	-0.8	-0.5	-0.9
Oreti	-0.3	-0.6	-0.4	-0.7	-0.4	-0.8
Waiau	-0.8	-1.3	-1.0	-1.6	-1.0	-1.7
Waituna	0.0	0.0	0.0	0.0	0.0	0.0

Table A-26: FMU projected changes in number of autumn cold nights (-, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-3.2	-5.2	-3.7	-7.1	-4.1	-8.0
Fiordland and Islands	-2.0	-3.3	-2.4	-4.3	-2.6	-4.9
Mataura	-2.9	-5.0	-3.3	-6.8	-3.7	-8.0
Oreti	-2.9	-4.9	-3.4	-6.6	-3.7	-7.6
Waiau	-4.4	-7.3	-5.0	-9.6	-5.6	-11.1
Waituna	-0.7	-1.3	-0.8	-1.6	-1.0	-1.7

GDD

Table A-27: FMU projected changes in number growing degree day (base 10°C) (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	183	335	235	577	239	735
Fiordland and Islands	136	256	178	454	171	575
Mataura	185	335	237	575	240	726
Oreti	189	345	242	592	246	751
Waiau	140	256	180	450	178	565
Waituna	215	395	272	669	278	854

Total rainfall

Table A-28: FMU projected total annual rainfall changes (% relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	3.6	7.5	3.8	6.7	3.0	10.1
Oreti	5.0	9.9	5.3	10.0	4.6	14.2
Aparima	5.7	9.9	6.0	9.7	4.7	13.8
Waituna	6.2	11.2	6.0	13.2	5.7	17.5
Waiau	3.7	7.3	4.2	7.4	4.5	12.1
Fiordland and Islands	4.1	7.6	3.7	8.3	5.5	12.6

Table A-29: FMU projected winter total annual rainfall changes (% relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	4.7	9.6	7.7	10.5	6.4	19.9
Oreti	6.2	12.2	9.4	14.3	7.6	24.9
Aparima	7.5	12.2	10.8	13.4	8.2	23.7
Waituna	9.5	15.2	12.7	18.9	8.3	29.5
Waiau	6.1	10.4	7.9	14.0	9.4	24.4
Fiordland and Islands	7.2	11.4	8.8	18.4	11.3	26.4

Table A-30: FMU projected spring total rainfall changes (% relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	6.4	9.5	6.5	10.1	6.0	12.5
Oreti	7.3	11.6	7.7	13.3	7.5	16.3
Aparima	7.5	11.7	8.8	13.0	7.7	15.1
Waituna	9.5	14.6	10.4	19.8	10.7	25.4
Waiau	6.1	10.4	7.9	14.0	9.4	24.4
Fiordland and Islands	7.4	10.8	6.4	14.6	7.4	18.2

Table A-31: FMU projected summer total rainfall changes (% relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	2.1	4.5	3.3	4.7	0.9	7.9
Oreti	3.5	6.9	6.0	8.5	2.8	13.0
Aparima	4.1	6.4	6.9	8.9	2.9	13.9

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Waituna	0.4	6.1	2.7	8.3	2.1	10.9
Waiau	1.9	3.9	5.1	4.0	2.5	9.6
Fiordland and Islands	0.7	4.1	2.2	1.1	2.4	4.7

Table A-32: FMU projected autumn total rainfall changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	2.2	7.3	0.1	2.2	0.2	1.5
Oreti	3.9	10.3	0.6	5.0	1.8	4.5
Aparima	4.7	10.4	0.2	4.5	1.2	3.9
Waituna	6.3	9.8	0.7	7.7	2.6	6.4
Waiau	1.1	5.9	1.4	0.1	0.4	0.8
Fiordland and Islands	1.3	4.4	1.7	0.3	1.9	2.2

Wet days

Table A-33: FMU projected annual wet day changes (days relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.0	0.6	1.0	-2.8	0.2	-2.7
Fiordland and Islands	-0.3	0.6	-0.5	-1.8	0.4	-0.9
Mataura	0.6	0.2	0.4	-3.6	0.4	-3.3
Oreti	1.0	0.9	0.5	-2.8	0.2	-2.6
Waiau	0.1	0.0	0.3	-2.2	0.2	-1.8
Waituna	2.0	2.4	0.3	-1.8	0.6	-1.5

Table A-34: FMU projected changes in winter wet day (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.1	0.4	0.4	-0.1	-0.3	1.0
Fiordland and Islands	-1.0	0.4	-0.9	0.8	-0.7	1.9
Mataura	0.1	0.3	0.2	0.1	-0.2	1.0
Oreti	0.2	0.6	0.3	0.3	-0.2	1.3
Waiau	-0.6	0.0	-0.5	0.0	-1.0	1.3
Waituna	0.6	1.5	0.5	1.4	0.4	2.1

Table A-35: FMU projected changes in spring wet days (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.8	0.3	0.8	0.3	0.6	-0.1
Fiordland and Islands	0.0	0.5	0.3	0.5	-0.2	0.4
Mataura	0.4	0.2	0.6	0.0	0.5	-0.4
Oreti	0.6	0.4	0.6	0.3	0.5	-0.1
Waiau	0.1	0.1	0.4	0.3	0.1	-0.1
Waituna	1.0	1.4	0.9	1.1	0.8	1.6

Table A-36: FMU projected summer wet day changes (°C, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.2	-0.2	0.5	-1.5	0.3	-1.9
Fiordland and Islands	0.4	-0.5	0.8	-1.6	1.0	-2.0

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	0.2	-0.2	0.5	-2.0	0.5	-2.1
Oreti	0.2	-0.1	0.4	-1.8	0.3	-2.1
Waiau	0.5	-0.4	1.0	-1.3	0.9	-1.7
Waituna	-0.2	-0.5	-0.4	-2.6	-0.4	-3.0

Table A-37: FMU projected changes in autumn wet days (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.0	0.2	-0.6	-1.5	-0.3	-1.7
Fiordland and Islands	0.3	0.1	-0.6	-1.6	0.5	-1.3
Mataura	0.0	-0.1	-0.7	-1.7	-0.4	-1.9
Oreti	0.1	0.1	-0.7	-1.6	-0.3	-1.8
Waiau	0.2	0.4	-0.4	-1.4	0.2	-1.3
Waituna	0.6	0.0	-0.6	-1.8	-0.1	-2.2

Rain threshold

Table A-38: FMU projected changes in number of rain days above 10 mm (day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	2.2	3.8	2.1	3.8	1.5	5.5
Fiordland and Islands	2.7	4.1	1.4	2.5	2.9	4.4
Mataura	1.6	3.0	1.6	2.7	1.1	4.4
Oreti	2.0	3.8	2.1	4.0	1.7	5.8
Waiau	1.7	2.8	1.3	2.2	1.6	3.7
Waituna	3.5	5.4	3.1	6.6	2.6	8.8

Table A-39: FMU projected changes in number of rain days above 25mm (day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.2	2.2	1.5	2.6	1.2	3.4
Fiordland and Islands	2.5	4.3	2.0	4.8	3.3	6.7
Mataura	0.6	1.4	0.8	1.8	0.6	2.3
Oreti	0.7	1.8	1.1	2.3	0.9	3.0
Waiau	1.4	2.6	1.5	3.1	1.9	4.7
Waituna	0.7	1.7	1.2	2.6	1.1	3.3

Table A-40: FMU projected changes in number of rain days above 50 mm (day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.2	0.5	0.3	0.5	0.3	0.8
Fiordland and Islands	1.3	2.7	1.5	3.6	2.0	5.2
Mataura	0.1	0.3	0.2	0.4	0.2	0.5
Oreti	0.2	0.4	0.2	0.5	0.3	0.7
Waiau	0.7	1.4	0.9	1.8	1.2	2.9
Waituna	0.0	0.3	0.1	0.4	0.2	0.5

Table A-41: FMU projected changes in maximum annual 1-day rainfall total changes (mm/day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	5.1	9.7	5.9	10.5	6.7	15.0
Fiordland and Islands	6.9	15.9	10.7	20.1	15.6	30.0
Mataura	5.0	9.4	5.5	11.1	6.1	12.9
Oreti	4.8	9.9	5.7	12.1	6.6	14.6
Waiau	7.9	16.3	10.4	18.1	13.0	27.6
Waituna	1.0	6.8	4.3	9.6	5.6	12.5

Table A-42: FMU projected changes in maximum annual 5-day rainfall total changes (mm/day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	8.8	11.6	8.3	15.0	8.7	19.6
Fiordland and Islands	13.2	15.9	10.5	20.9	15.8	35.0
Mataura	7.5	9.1	6.7	13.2	5.5	14.5
Oreti	7.6	10.6	7.0	16.2	7.4	18.8
Waiau	10.3	12.3	8.7	17.8	12.0	29.0
Waituna	5.1	9.3	6.1	13.3	5.8	17.5

Dry days

Table A-43: FMU projected annual dry day changes (day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-1.0	-0.6	-1.0	2.8	-0.2	2.7
Fiordland and Islands	0.3	-0.6	0.5	1.	-0.4	0.9
Mataura	-0.6	-0.2	-0.4	3.6	-0.4	3.3
Oreti	-1.0	-0.9	-0.5	2.8	-0.2	2.6
Waiau	-0.1	0.0	-0.3	2.2	-0.2	1.8
Waituna	-2.0	-2.4	-0.3	1.8	-0.6	1.5

Table A-44: FMU projected winter dry day changes (day, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.1	-0.4	-0.4	0.1	0.3	-1.0
Fiordland and Islands	1.0	-0.4	0.9	-0.8	0.7	-1.9
Mataura	-0.1	-0.3	-0.2	-0.1	0.2	-1.0
Oreti	-0.2	-0.6	-0.3	-0.3	0.2	-1.3
Waiau	0.6	0.0	0.5	0.0	1.0	-1.3
Waituna	-0.6	-1.5	-0.5	-1.4	-0.4	-2.1

Table A-45: FMU projected spring dry day changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.8	-0.3	-0.8	-0.3	-0.6	0.1
Fiordland and Islands	0.0	-0.5	-0.3	-0.5	0.2	-0.4
Mataura	-0.4	-0.2	-0.6	0.0	-0.5	0.4
Oreti	-0.6	-0.4	-0.6	-0.3	-0.5	0.1
Waiau	-0.1	-0.1	-0.4	-0.3	-0.1	0.1
Waituna	-1.0	-1.4	-0.9	-1.1	-0.8	-1.6

Table A-46: FMU projected summer dry day changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.2	0.2	-0.5	1.5	-0.3	1.9
Fiordland and Islands	-0.4	0.5	-0.8	1.6	-1.0	2.0

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Mataura	-0.2	0.2	-0.5	2.0	-0.5	2.1
Oreti	-0.2	0.1	-0.4	1.8	-0.3	2.1
Waiau	-0.5	0.4	-1.0	1.3	-0.9	1.7
Waituna	0.2	0.5	0.4	2.6	0.4	3.0

Table A-47: FMU projected autumn dry day changes (days, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.0	-0.2	0.6	1.5	0.3	1.7
Fiordland and Islands	-0.3	-0.1	0.6	1.6	-0.5	1.3
Mataura	0.0	0.1	0.7	1.7	0.4	1.9
Oreti	-0.1	-0.1	0.7	1.6	0.3	1.8
Waiau	-0.2	-0.4	0.4	1.4	-0.2	1.3
Waituna	-0.6	0.0	0.6	1.8	0.1	2.2

PED

Table A-48: FMU projected PED accumulation changes (mm, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	4	9	12	26	18	30
Fiordland and Islands	0	1	3	3	1	3
Mataura	15	18	26	50	27	53
Oreti	7	8	17	32	19	33
Waiau	2	4	6	13	7	14
Waituna	6	5	18	20	9	16

Table A-49: FMU projected winter PED accumulation changes (mm, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	0.0	0.0	0.0	0.0	0.0	0.0
Fiordland and Islands	0.0	0.0	0.0	0.0	0.0	0.0
Mataura	0.0	0.0	0.0	0.0	0.0	0.1
Oreti	0.0	0.0	0.0	0.0	0.0	0.0
Waiau	0.0	0.0	0.0	0.0	0.0	0.0
Waituna	0.0	0.0	0.0	0.0	0.0	0.0

Table A-50: FMU projected spring PED accumulation changes (mm, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-1	1	0	3	1	3
Fiordland and Islands	0	0	0	0	0	0
Mataura	1	3	2	7	3	8
Oreti	0	1	1	4	2	4
Waiau	0	0	0	1	1	1
Waituna	0	2	1	2	1	1

Table A-51: FMU projected summer PED accumulation changes (mm, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	4	7	11	23	14	24
Fiordland and Islands	0	1	3	2	1	2
Mataura	10	13	20	39	19	38

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Oreti	5	6	14	27	14	25
Waiau	2	4	6	12	5	11
Waituna	3	3	15	16	6	10

Table A-52: FMU projected autumn PED accumulation changes (mm, relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1	1	0	0	2	3
Fiordland and Islands	0	0	0	0	0	1
Mataura	3	3	4	4	5	8
Oreti	2	0	1	1	3	4
Waiau	0	0	0	0	0	2
Waituna	3	0	2	1	2	4

Relative humidity

Table A-53: FMU projected relative humidity changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.2	-0.4	-0.4	-0.8	-0.5	-1.1
Fiordland and Islands	0.1	0.1	0.0	0.0	0.1	-0.1
Mataura	-0.3	-0.4	-0.5	-0.9	-0.6	-1.3
Oreti	-0.2	-0.4	-0.4	-0.9	-0.6	-1.2
Waiau	0.0	-0.1	-0.2	-0.4	-0.2	-0.6
Waituna	-0.2	-0.3	-0.3	-0.7	-0.4	-0.9

Table A-54: FMU projected winter relative humidity changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.4	-0.7	-0.5	-1.3	-0.8	-1.5
Fiordland and Islands	0.2	0.2	0.1	0.2	0.2	0.2
Mataura	-0.3	-0.5	-0.4	-1.0	-0.6	-1.3
Oreti	-0.3	-0.7	-0.5	-1.2	-0.7	-1.5
Waiau	-0.1	-0.2	-0.1	-0.4	-0.2	-0.5
Waituna	-0.3	-0.6	-0.5	-1.2	-0.6	-1.4

Table A-55: FMU projected spring relative humidity changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.2	-0.5	-0.5	-1.0	-0.6	-1.3
Fiordland and Islands	0.2	0.1	0.1	0.1	0.1	0.0
Mataura	-0.3	-0.5	-0.5	-1.1	-0.6	-1.5
Oreti	-0.3	-0.5	-0.5	-1.0	-0.6	-1.4
Waiau	0.0	-0.1	-0.1	-0.3	-0.2	-0.5
Waituna	-0.2	-0.5	-0.5	-0.9	-0.6	-1.3

Table A-56: FMU projected summer relative humidity changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.1	-0.2	-0.3	-0.5	-0.4	-0.8
Fiordland and Islands	0.0	-0.1	-0.1	-0.3	-0.1	-0.4
Mataura	-0.3	-0.5	-0.7	-1.1	-0.7	-1.4

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Oreti	-0.2	-0.3	-0.5	-0.8	-0.5	-1.1
Waiau	-0.1	-0.2	-0.3	-0.6	-0.3	-0.8
Waituna	-0.1	-0.1	-0.3	-0.3	-0.2	-0.6

Table A-57: FMU projected autumn relative humidity changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.1	-0.1	-0.3	-0.4	-0.4	-0.7
Fiordland and Islands	0.1	0.1	-0.1	0.0	0.0	-0.1
Mataura	-0.2	-0.2	-0.4	-0.5	-0.5	-0.9
Oreti	-0.1	-0.1	-0.3	-0.4	-0.4	-0.7
Waiau	0.0	0.0	-0.2	-0.3	-0.2	-0.4
Waituna	-0.1	-0.1	-0.2	-0.3	-0.3	-0.5

Wind speed

Table A-58: FMU projected wind speed changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	1.8	2.3	1.9	3.3	3.5	5.2
Fiordland and Islands	1.0	1.0	0.7	1.1	1.7	2.3
Mataura	1.3	1.5	1.2	2.1	2.8	3.9
Oreti	1.6	2.0	1.6	2.8	3.2	4.7
Waiau	1.8	2.2	1.6	2.8	3.0	4.4
Waituna	1.0	1.2	0.9	1.7	2.4	3.4

Table A-59: FMU projected winter wind speed changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	3.7	6.2	5.0	11.3	7.7	14.4
Fiordland and Islands	1.9	3.8	2.5	6.6	4.4	9.0
Mataura	2.7	4.7	3.6	8.9	6.2	11.8
Oreti	3.1	5.5	4.2	10.0	6.8	13.1
Waiau	3.2	6.0	4.1	10.1	6.7	13.2
Waituna	2.2	3.8	3.1	7.6	5.2	9.7

Table A-60: FMU projected spring wind speed changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	4.3	5.4	5.3	8.1	5.6	10.4
Fiordland and Islands	3.1	3.6	3.4	5.1	3.6	6.4
Mataura	3.8	4.5	4.8	7.2	5.2	9.3
Oreti	4.2	5.1	5.2	7.9	5.5	10.2
Waiau	4.0	4.9	4.5	7.0	4.9	8.7
Waituna	3.6	4.7	4.7	7.3	5.1	9.8

Table A-61: FMU projected summer wind speed changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-1.2	-2.0	-1.6	-4.6	-0.3	-3.7
Fiordland and Islands	-1.3	-2.8	-2.0	-5.4	-1.5	-4.8
Mataura	-1.5	-2.5	-2.1	-5.6	-0.7	-4.6

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Oreti	-1.3	-2.2	-1.8	-5.0	-0.5	-4.0
Waiau	-1.0	-2.1	-1.5	-4.6	-0.7	-4.1
Waituna	-1.8	-2.8	-2.6	-6.0	-0.8	-4.7

Table A-62: FMU projected autumn wind speed changes (% , relative to 1995-2014).

	SSP2-4.5		SSP3-7.0		SSP5-8.5	
	2050	2090	2050	2090	2050	2090
Aparima	-0.2	-0.9	-1.5	-2.2	0.8	-1.1
Fiordland and Islands	-0.2	-1.1	-1.7	-2.8	0.1	-2.2
Mataura	-0.5	-1.5	-2.1	-3.1	0.3	-2.2
Oreti	-0.3	-1.1	-1.7	-2.5	0.6	-1.5
Waiau	0.3	-0.2	-1.2	-1.9	1.1	-1.0
Waituna	-0.7	-1.9	-2.2	-3.3	-0.3	-2.4

Appendix B Historic rainfall depths

Historic rainfall depths for a given event duration/ARI combination were obtained from HIRDSv4 (Carey-Smith et al. 2018). We provide these data for 30 Southland locations, listed in alphabetical order, in Table B-1 to Table B-30 below.

Table B-1: Bluff historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.8	15	25.2	34.8	47.3	63.3	74.3	82.9	89.9
5 YR	14.6	20	33	44.8	60.2	79.5	92.6	103	111
10 YR	17.7	24.1	39.1	52.6	70.1	91.7	106	117	126
20 YR	21.1	28.5	45.7	61	80.6	105	121	133	143
30 YR	23.4	31.3	49.8	66.3	87	112	129	142	152
40 YR	25	33.5	52.9	70.2	91.8	118	136	149	159
50 YR	26.4	35.2	55.4	73.3	95.6	123	141	154	165
60 YR	27.5	36.6	57.5	75.9	98.8	127	145	159	170
80 YR	29.4	39	60.9	80.1	104	133	152	166	177
100 HR	31	40.9	63.7	83.5	108	138	157	171	183

Table B-2: Fairlight at Cainard Station historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.3	16.8	29.9	41.4	55.1	70.5	79.8	86.3	91.1
5 YR	15.6	23	39.8	54.2	70.9	89.3	100	107	113
10 YR	19.3	28	47.8	64.2	83.2	104	115	123	129
20 YR	23.5	33.8	56.6	75.3	96.5	119	131	140	146
30 YR	26.3	37.5	62.2	82.3	105	128	141	150	156
40 YR	28.4	40.3	66.5	87.5	111	135	149	157	164
50 YR	30.1	42.6	69.9	91.7	116	141	154	163	170
60 YR	31.6	44.6	72.8	95.2	120	145	159	168	175
80 YR	34	47.8	77.5	101	127	153	167	176	183
100 HR	36	50.4	81.4	106	132	159	173	182	189

Table B-3: Fiver Rivers at Five Rivers Station historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	12.6	18.1	30.8	41.6	54.5	68.8	77.4	83.5	88
5 YR	17.5	24.7	40.9	54.3	69.9	86.8	96.8	104	109
10 YR	21.5	30.1	49	64.4	81.9	101	111	119	124
20 YR	26.2	36.2	58	75.3	94.8	115	127	134	140
30 YR	29.2	40.2	63.7	82.3	103	124	136	144	150
40 YR	31.6	43.2	68	87.5	109	131	143	151	157
50 YR	33.5	45.7	71.5	91.6	114	136	149	157	163
60 YR	35.1	47.8	74.5	95.1	118	141	153	162	167
80 YR	37.8	51.2	79.3	101	124	148	161	169	175
100 HR	40	54.1	83.2	106	130	154	167	175	181

Table B-4: Garston historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.2	14.8	25.8	35.9	48.8	64.3	74.4	81.8	87.6
5 YR	14.3	20.2	34.5	47.2	63.2	82	94	103	109
10 YR	17.6	24.7	41.5	56.2	74.4	95.5	109	118	126
20 YR	21.5	29.8	49.1	66	86.4	110	124	135	143
30 YR	24	33.1	54.1	72.1	93.9	119	134	145	153
40 YR	25.9	35.6	57.7	76.7	99.5	125	141	152	160
50 YR	27.4	37.6	60.7	80.4	104	130	147	158	166
60 YR	28.7	39.3	63.2	83.5	108	135	151	163	171
80 YR	30.9	42.1	67.3	88.6	114	142	159	171	179
100 HR	32.7	44.4	70.7	92.7	119	147	165	177	186

Table B-5: Glenlapa at Round Hill historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	13.9	18.7	29.9	39.8	51.9	65.9	74.6	80.9	85.6
5 YR	19.5	25.8	40	52.2	66.8	83.2	93.1	100	105
10 YR	24.2	31.7	48.2	62	78.4	96.4	107	115	120
20 YR	29.8	38.4	57.3	72.9	90.9	110	122	130	135
30 YR	33.4	42.8	63.2	79.7	98.8	119	131	139	145
40 YR	36.2	46.1	67.6	84.9	105	126	138	146	152
50 YR	38.5	48.9	71.2	89.1	109	131	143	151	157
60 YR	40.5	51.2	74.2	92.6	113	135	147	156	162
80 YR	43.7	55.1	79.2	98.3	120	142	155	163	169
100 HR	46.4	58.3	83.3	103	125	148	160	169	174

Table B-6: Gore historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.9	14.4	22.1	28.7	37.3	48.1	55.7	61.7	66.8
5 YR	15.2	19.7	29.5	37.8	48.2	61.1	70	77.1	83
10 YR	18.8	24.2	35.4	44.9	56.6	70.9	80.8	88.6	95
20 YR	23	29.1	42	52.6	65.6	81.4	92.1	100	107
30 YR	25.6	32.3	46.2	57.5	71.2	87.8	99	108	115
40 YR	27.7	34.7	49.3	61.1	75.3	92.5	104	113	120
50 YR	29.4	36.7	51.8	64	78.7	96.3	108	117	125
60 YR	30.8	38.4	53.9	66.4	81.4	99.4	111	121	128
80 YR	33.1	41.1	57.4	70.4	85.9	104	117	126	134
100 HR	35.1	43.4	60.2	73.6	89.5	108	121	131	139

Table B-7: Hamilton Burn at Mt Hamilton Road historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	12.9	19.3	35.4	50.4	69.6	92.8	108	118	127
5 YR	17.7	26	46.6	65.4	89.1	117	135	147	157
10 YR	21.6	31.5	55.6	77.2	104	135	155	169	179
20 YR	26	37.6	65.4	90.1	120	155	176	191	203
30 YR	28.9	41.5	71.6	98.1	130	167	189	205	217
40 YR	31.1	44.5	76.3	104	138	176	199	215	227
50 YR	32.9	46.9	80.1	109	144	183	207	223	235
60 YR	34.4	49	83.3	113	149	189	213	230	242
80 YR	36.9	52.4	88.5	120	157	199	224	241	253
100 HR	39	55.1	92.7	125	164	206	232	249	262

Table B-8: Hokonui Hills at Lora Station historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.5	16.5	28.2	38.7	52.1	68.7	80	88.8	96
5 YR	16	22.6	37.7	50.8	67.2	87.2	101	111	119
10 YR	19.7	27.6	45.2	60.3	78.9	101	116	127	136
20 YR	24	33.2	53.6	70.7	91.6	116	133	145	155
30 YR	26.8	36.9	58.9	77.3	99.6	126	143	155	166
40 YR	29	39.7	63	82.3	105	133	150	163	174
50 YR	30.7	41.9	66.2	86.2	110	138	156	169	180
60 YR	32.2	43.9	69	89.6	114	143	161	175	185
80 YR	34.7	47.1	73.5	95	121	150	169	183	194
100 HR	36.7	49.6	77.1	99.4	126	156	175	189	201

Table B-9: Invercargill historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.8	14.7	23.6	31.9	42.8	57.5	68.2	77	84.6
5 YR	14.8	19.8	31	41	54.2	71.4	83.9	94	103
10 YR	18.2	23.9	36.8	48.1	62.8	81.9	95.5	106	116
20 YR	21.9	28.5	43.1	55.8	72	92.8	108	119	129
30 YR	24.4	31.5	47.1	60.6	77.8	99.6	115	127	138
40 YR	26.2	33.8	50.1	64.2	82	105	120	133	144
50 YR	27.8	35.6	52.6	67.1	85.4	108	125	137	148
60 YR	29.1	37.2	54.6	69.5	88.2	112	128	141	152
80 YR	31.2	39.7	58	73.4	92.7	117	134	147	158
100 HR	33	41.8	60.7	76.6	96.4	121	138	152	163

Table B-10: Lumsden historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.4	16.4	28.6	39.4	52.1	65.4	72.4	76.7	79.5
5 YR	15.9	22.6	38.5	52.2	68	84	92.3	97.2	100
10 YR	19.7	27.6	46.3	62.2	80.3	98.3	107	113	116
20 YR	23.9	33.2	54.9	73.1	93.5	113	123	129	132
30 YR	26.7	36.8	60.4	80	102	123	133	139	142
40 YR	28.7	39.6	64.5	85.1	108	129	140	146	149
50 YR	30.4	41.8	67.8	89.1	113	135	146	151	154
60 YR	31.9	43.7	70.6	92.6	117	139	150	156	159
80 YR	34.3	46.7	75.1	98.1	123	147	158	164	167
100 HR	36.2	49.2	78.7	103	128	152	164	169	173

Table B-11: Mataura historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.3	14.1	22.9	31	41.6	55.4	65.1	72.9	79.5
5 YR	14.4	19.3	30.6	40.7	53.7	70.2	81.8	91	98.6
10 YR	17.8	23.6	36.8	48.3	63	81.5	94.3	104	113
20 YR	21.7	28.5	43.5	56.5	73	93.4	107	118	127
30 YR	24.3	31.6	47.8	61.7	79.2	101	115	127	136
40 YR	26.2	34	51	65.6	83.8	106	121	133	143
50 YR	27.8	35.9	53.6	68.7	87.4	110	126	138	148
60 YR	29.1	37.5	55.8	71.3	90.5	114	130	142	152
80 YR	31.3	40.2	59.4	75.5	95.4	120	136	148	159
100 HR	33.1	42.4	62.3	78.9	99.4	124	141	153	164

Table B-12: McKellars Flat at Gorge Burn historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.5	16	30	43.3	60.3	80.2	92.6	101	108
5 YR	14.2	21.3	39.3	56.1	77.1	101	116	126	134
10 YR	17.3	25.7	46.7	66	89.9	117	134	145	153
20 YR	20.7	30.4	54.7	76.7	104	134	152	164	173
30 YR	22.8	33.5	59.8	83.4	112	145	164	176	186
40 YR	24.5	35.8	63.5	88.4	119	152	172	185	195
50 YR	25.8	37.6	66.6	92.3	124	158	178	192	202
60 YR	26.9	39.2	69.1	95.7	128	163	184	198	208
80 YR	28.8	41.8	73.3	101	135	172	193	207	217
100 HR	30.3	43.9	76.6	105	140	178	200	214	225

Table B-13: Milford Sound historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	30.2	48.5	99.1	149	213	285	328	356	375
5 YR	39.4	62.8	127	189	268	358	410	443	466
10 YR	46.4	73.7	148	219	310	412	470	507	532
20 YR	54	85.3	170	251	353	467	531	572	600
30 YR	58.6	92.4	183	270	379	500	568	612	641
40 YR	62.1	97.7	193	284	398	524	595	640	670
50 YR	64.8	102	201	295	413	543	616	662	693
60 YR	67.1	105	207	304	425	559	633	681	712
80 YR	70.8	111	218	319	445	584	661	710	742
100 HR	73.7	115	226	331	461	603	682	732	766

Table B-14: Mokoreta at Mt Alexander historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.4	16.1	27.6	38.2	52	68.7	79.6	87.6	93.9
5 YR	15.9	22	36.7	49.9	66.6	86.5	99.2	108	115
10 YR	19.6	26.8	43.9	59.1	78	100	114	124	131
20 YR	23.9	32.3	51.9	69.1	90.1	114	129	140	148
30 YR	26.7	35.8	57.1	75.4	97.7	123	139	150	158
40 YR	28.8	38.5	60.9	80.1	103	130	146	157	165
50 YR	30.6	40.7	64	83.9	108	135	151	162	171
60 YR	32.1	42.6	66.6	87.1	112	139	156	167	176
80 YR	34.5	45.7	70.9	92.3	118	146	163	175	183
100 HR	36.6	48.2	74.4	96.5	123	151	169	181	189

Table B-15: Mossburn historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.8	16.9	28.9	39.5	52.3	66.7	75.3	81.2	85.6
5 YR	16.4	23	38.4	51.7	67.3	84.5	94.5	101	106
10 YR	20.1	28	46	61.2	79	98.1	109	116	122
20 YR	24.4	33.6	54.4	71.7	91.5	113	124	132	138
30 YR	27.2	37.3	59.8	78.2	99.3	121	134	142	148
40 YR	29.4	40.1	63.8	83.2	105	128	141	149	155
50 YR	31.1	42.3	67	87.1	110	133	146	155	160
60 YR	32.6	44.2	69.8	90.4	114	138	151	159	165
80 YR	35.1	47.3	74.2	95.9	120	145	158	167	173
100 HR	37.1	49.9	77.9	100	125	150	164	173	179

Table B-16: Mossburn historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.5	16.2	27.8	38.9	53.7	72.9	86.2	96.6	105
5 YR	15.4	21.5	36.5	50.6	69.3	93.3	110	123	133
10 YR	18.5	25.6	43.2	59.6	81.3	109	128	143	155
20 YR	21.9	30.2	50.4	69.3	94.1	125	147	163	177
30 YR	24	33	55	75.4	102	136	159	176	191
40 YR	25.6	35.2	58.4	79.8	108	143	167	186	201
50 YR	26.9	36.9	61.1	83.4	113	149	174	193	209
60 YR	28	38.3	63.4	86.4	116	154	180	199	215
80 YR	29.8	40.7	67.1	91.3	123	162	189	209	226
100 HR	31.2	42.6	70	95.2	128	169	196	217	234

Table B-17: Ohai at Wether Hill Station historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	12.7	18	30.8	41.9	54.9	68.4	75.6	80	82.9
5 YR	17.4	24.3	40.7	54.7	70.9	87.2	95.7	101	104
10 YR	21.2	29.4	48.6	64.8	83.2	102	111	116	120
20 YR	25.5	35.1	57.3	75.8	96.5	117	127	133	136
30 YR	28.3	38.7	62.8	82.7	105	126	137	143	146
40 YR	30.4	41.5	66.9	87.8	111	133	144	150	154
50 YR	32.1	43.7	70.2	91.9	116	139	150	156	160
60 YR	33.5	45.6	73	95.4	120	143	155	161	165
80 YR	35.9	48.7	77.6	101	127	151	162	169	172
100 HR	37.9	51.2	81.2	106	132	157	169	175	179

Table B-18: Otautau historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.8	15.2	25.3	34.4	46.2	61.3	72	80.5	87.6
5 YR	14.8	20.5	33.4	44.9	59.5	78	90.9	101	110
10 YR	18	24.8	39.9	53.1	69.8	90.8	105	117	126
20 YR	21.7	29.5	47	62	80.9	104	120	133	143
30 YR	24.1	32.6	51.5	67.7	87.9	113	130	143	154
40 YR	25.9	34.9	54.9	71.9	93	119	137	150	162
50 YR	27.3	36.8	57.6	75.2	97.1	124	142	156	168
60 YR	28.6	38.4	59.9	78.1	101	128	147	161	173
80 YR	30.6	41	63.6	82.7	106	135	154	169	181
100 HR	32.3	43.1	66.6	86.4	111	140	160	175	188

Table B-19: Pourakino Valley at Cascade Road historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	13.9	19.9	34.4	47.9	66.1	90.3	108	122	134
5 YR	18.8	26.6	45	61.9	84.3	114	135	151	166
10 YR	22.9	32.1	53.5	72.9	98.3	131	155	174	190
20 YR	27.5	38.2	62.8	84.8	113	150	176	197	214
30 YR	30.5	42.1	68.7	92.3	123	162	189	211	229
40 YR	32.7	45	73.1	98	130	171	199	222	241
50 YR	34.6	47.4	76.7	102	136	177	207	230	249
60 YR	36.1	49.5	79.7	106	140	183	213	237	257
80 YR	38.7	52.8	84.6	112	148	192	224	248	269
100 HR	40.8	55.5	88.6	117	154	200	232	257	278

Table B-20: Riversdale historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10	13.8	22.7	30.6	40.3	51.5	58.4	63.4	67.2
5 YR	14	19	30.3	40.1	51.8	65.1	73.1	78.8	83
10 YR	17.4	23.2	36.4	47.6	60.8	75.4	84.2	90.2	94.7
20 YR	21.2	28	43.2	55.8	70.5	86.5	95.8	102	107
30 YR	23.7	31.1	47.5	60.9	76.5	93.3	103	110	114
40 YR	25.7	33.5	50.7	64.8	81	98.3	108	115	120
50 YR	27.2	35.5	53.4	67.9	84.6	102	112	119	124
60 YR	28.6	37.1	55.6	70.6	87.6	106	116	123	128
80 YR	30.8	39.8	59.3	74.9	92.6	111	122	129	133
100 HR	32.7	42	62.2	78.3	96.5	115	126	133	138

Table B-21: Riverton historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.3	15.4	24.6	32.5	42.5	54.8	63.3	69.9	75.3
5 YR	15.3	20.6	32.4	42.3	54.6	69.6	79.8	87.6	94.1
10 YR	18.6	24.9	38.5	50	64	80.9	92.3	101	108
20 YR	22.3	29.6	45.3	58.3	74	92.9	105	115	123
30 YR	24.7	32.6	49.6	63.5	80.3	100	114	124	132
40 YR	26.5	34.9	52.8	67.3	84.9	106	119	130	139
50 YR	27.9	36.8	55.3	70.4	88.6	110	124	135	144
60 YR	29.2	38.3	57.5	73.1	91.7	114	128	139	148
80 YR	31.2	40.9	61	77.3	96.7	120	134	146	155
100 HR	32.9	42.9	63.8	80.7	101	124	140	151	161

Table B-22: Te Anau historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	12.2	17.4	29.5	40.3	53.9	70.4	81.3	89.5	96.1
5 YR	16.5	23.3	39	52.7	69.8	90.1	103	113	121
10 YR	20	28	46.4	62.3	81.9	105	120	131	140
20 YR	23.8	33.2	54.5	72.7	94.9	121	138	150	160
30 YR	26.3	36.5	59.6	79.2	103	131	149	162	172
40 YR	28.2	39	63.3	83.9	109	138	157	170	181
50 YR	29.7	41	66.3	87.8	114	144	163	177	188
60 YR	30.9	42.7	68.9	91	118	148	168	183	194
80 YR	33	45.4	73	96.1	124	156	176	191	203
100 HR	34.7	47.6	76.3	100	129	162	183	198	211

Table B-23: Tuatapere historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.8	16.4	26.1	33.5	41.6	49.9	54.7	57.9	60.2
5 YR	15.9	22	34.4	43.8	53.8	63.9	69.5	73.2	76
10 YR	19.4	26.6	41.1	51.8	63.3	74.6	80.9	85	88
20 YR	23.2	31.6	48.4	60.7	73.5	86.2	93	97.5	101
30 YR	25.7	34.9	53	66.2	80	93.4	101	105	109
40 YR	27.5	37.3	56.5	70.4	84.8	98.7	106	111	114
50 YR	29.1	39.3	59.3	73.8	88.7	103	111	116	119
60 YR	30.4	41	61.7	76.6	91.9	107	114	119	123
80 YR	32.5	43.8	65.6	81.2	97.2	112	121	126	129
100 HR	34.2	46	68.8	84.9	101	117	125	131	134

Table B-24: Waiau River at Clifden historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.3	16.3	28.1	38.4	51.3	66.3	75.8	82.8	88.2
5 YR	15.3	21.8	36.8	49.8	65.6	83.8	95.2	103	110
10 YR	18.6	26.2	43.8	58.7	76.7	97.2	110	119	126
20 YR	22.3	31.2	51.4	68.5	88.8	112	126	135	143
30 YR	24.7	34.4	56.3	74.6	96.3	121	135	146	154
40 YR	26.5	36.8	59.9	79.2	102	127	142	153	161
50 YR	28	38.8	62.9	82.9	106	132	148	159	167
60 YR	29.2	40.5	65.4	86	110	137	153	164	173
80 YR	31.3	43.2	69.5	91.1	116	144	161	172	181
100 HR	33	45.4	72.8	95.2	121	150	167	179	188

Table B-25: Waikaia River at Piano Flat historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	11.4	15.7	25.1	32.9	42.1	52.7	59.4	64.2	68.1
5 YR	16.1	21.8	33.9	43.5	54.7	67.1	74.7	80.2	84.5
10 YR	20.2	26.9	40.9	51.9	64.5	78.1	86.3	92.2	96.7
20 YR	24.9	32.7	48.8	61.2	75	89.7	98.5	105	109
30 YR	27.9	36.5	53.9	67	81.6	96.9	106	112	117
40 YR	30.3	39.4	57.7	71.4	86.4	102	111	118	122
50 YR	32.2	41.8	60.7	74.9	90.4	106	116	122	127
60 YR	33.9	43.8	63.3	77.9	93.6	110	119	126	131
80 YR	36.6	47.1	67.6	82.7	98.9	116	125	132	136
100 HR	38.9	49.8	71	86.6	103	120	130	136	141

Table B-26: Waikaka historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10	13.7	22.1	29.3	38.3	49.3	56.6	62.1	66.6
5 YR	14.1	18.9	29.6	38.6	49.7	62.7	71.3	77.7	82.8
10 YR	17.5	23.3	35.7	46	58.5	73	82.3	89.3	94.9
20 YR	21.5	28.2	42.4	54.1	68	83.9	94	101	107
30 YR	24.1	31.3	46.8	59.2	73.9	90.6	101	109	115
40 YR	26	33.8	50	63.1	78.3	95.6	106	114	121
50 YR	27.7	35.7	52.6	66.1	81.8	99.5	111	119	125
60 YR	29.1	37.4	54.8	68.7	84.8	103	114	122	129
80 YR	31.3	40.2	58.5	72.9	89.6	108	120	128	135
100 HR	33.2	42.5	61.4	76.3	93.5	112	124	133	139

Table B-27: Wendon Valley at Waikaka historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.4	14.2	22.9	30.5	39.8	51.2	58.6	64.3	68.8
5 YR	14.6	19.6	30.8	40.1	51.6	65	73.7	80.2	85.4
10 YR	18.1	24.1	37.1	47.8	60.7	75.6	85.1	92.2	97.8
20 YR	22.2	29.2	44.1	56.2	70.5	86.9	97.1	105	111
30 YR	24.9	32.5	48.6	61.5	76.7	93.8	105	112	118
40 YR	27	35	52	65.5	81.3	99	110	118	124
50 YR	28.7	37.1	54.7	68.7	84.9	103	114	122	129
60 YR	30.1	38.9	57	71.4	88	106	118	126	132
80 YR	32.5	41.7	60.8	75.8	93	112	124	132	138
100 HR	34.5	44.1	63.9	79.4	97	116	128	137	143

Table B-28: Whitestone Aquifer at Lynwood historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.1	14.9	26.9	37.8	50.9	64.8	72.5	77.3	80.4
5 YR	13.7	19.9	35.2	48.8	64.9	81.7	90.6	96.1	99.6
10 YR	16.6	23.9	41.8	57.4	75.7	94.5	104	110	114
20 YR	19.9	28.4	48.9	66.7	87.2	108	119	125	129
30 YR	22	31.2	53.4	72.5	94.4	116	128	134	138
40 YR	23.5	33.4	56.8	76.8	99.7	122	134	141	145
50 YR	24.8	35.1	59.5	80.3	104	127	139	146	150
60 YR	25.9	36.6	61.8	83.2	107	131	143	150	154
80 YR	27.7	39	65.5	88	113	138	150	157	161
100 HR	29.2	40.9	68.5	91.8	118	143	156	163	167

Table B-29: Winton historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.7	14.9	24.4	32.6	42.6	54.5	62.2	68	72.5
5 YR	14.8	20.2	32.3	42.5	54.7	68.8	77.8	84.4	89.6
10 YR	18.1	24.6	38.6	50.2	63.9	79.6	89.5	96.7	102
20 YR	22	29.4	45.5	58.6	73.9	91.1	102	109	116
30 YR	24.4	32.6	49.9	63.9	80.1	98.2	109	117	124
40 YR	26.3	35	53.2	67.8	84.7	103	115	123	129
50 YR	27.9	36.9	55.9	71	88.4	108	119	128	134
60 YR	29.2	38.5	58.1	73.6	91.4	111	123	131	138
80 YR	31.4	41.2	61.8	78	96.4	117	129	137	144
100 HR	33.1	43.4	64.8	81.5	100	121	133	142	149

Table B-30: Woodlands at Garvie Road historic rainfall depths across various event ARI/duration combinations.

ARI/DURATION	1 hr	2 hrs	6 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
2 YR	10.3	14.4	24.3	33.3	44.9	59.4	69.1	76.4	82.4
5 YR	14.2	19.5	31.9	43	56.9	73.9	85	93.4	100
10 YR	17.4	23.6	38	50.5	66.2	84.8	96.9	106	113
20 YR	21.1	28.3	44.7	58.7	76	96.3	109	119	126
30 YR	23.5	31.3	48.9	63.9	82.1	103	117	127	134
40 YR	25.4	33.6	52.1	67.7	86.6	109	122	132	140
50 YR	26.9	35.5	54.7	70.8	90.3	113	127	137	145
60 YR	28.1	37.1	56.8	73.4	93.3	116	130	141	149
80 YR	30.3	39.7	60.4	77.6	98.2	122	136	147	155
100 HR	32	41.8	63.2	81	102	126	141	151	160