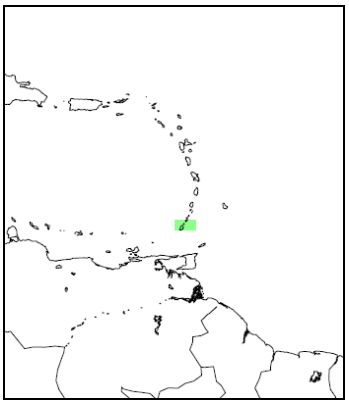
UNDP Climate Change Country Profiles

Grenada

C. McSweeney[1], M. New[1,2] and G. Lizcano[1]

1. School of Geography and Environment, University of Oxford.
2. Tyndall Centre for Climate Change Research

http://country-profiles.geog.ox.ac.uk



General Climate

Grenada and the southern Grenadine Islands are amongst the southernmost Caribbean Islands. Located at 12˚N the islands experience the year-round warm and humid conditions associated with the Tropics. Mean temperature is around 27˚C, dropping by only a degree or so in the cooler months of December to February. The wet season occurs through May to October, during which the island receives around 150-200mm per month.

Inter-annual variability in the Southern Caribbean climate is influenced strongly by the El Nino Southern Oscillation (ENSO) due through its influence on sea surface temperatures in the Atlantic and Caribbean. El Niño episodes bring warmer and drier than average conditions during the late wet-season, and La Niña episodes bring colder and wetter conditions at this time. Grenada lies on the southern edge of the Atlantic hurricane belt and is very rarely, but occasionally, affected by hurricanes which occur throughout August, September and October.

Recent Climate Trends

Temperature

- Mean annual temperature in Grenada has increased by around 0.6˚C since 1960, at an average rate of 0.14˚C per decade.
- There is insufficient daily observational data to identify trends in daily temperature extremes.

Precipitation

- Mean rainfall over Grenada has increased in SON, by 12.0 per month (6.3%) per decade since 1960, but this increase is not statistically significant. This increase is offset partially by decreases of around 4.5mm per month (2.5%) per decade in JJA.
- There is insufficient daily observational data to identify trends in daily rainfall extremes.

GCM Projections of Future Climate

Temperature

- The mean annual temperature is projected to increase by 0.7 to 2.6˚C by the 2060s, and 1.1 to 4.3 degrees by the 2090s. The range of projections by the 2090s under any one emissions scenario is around 1-2˚C. The projected rate of warming is similar throughout the year.

- All projections indicate substantial increases in the frequency of days and nights that are considered 'hot'[1] in current climate.
    - Annually, projections indicate that 'hot' days will occur on 33-66% of days by the 2060s, and 41-89% of days by the 2090s. Days considered 'hot' by current climate standards for their season are projected to increase most rapidly in DJF and SON, occurring on 52-99% of days of the season by the 2090s.
    - Nights that are considered 'hot' for the annual climate of 1970-99 are projected to increase in frequency more rapidly than hot days, occurring on 33-83% of nights by the 2060s and 41-99% of nights by the 2090s. Nights that are hot for each season are projected to increase most rapidly in DJF and SON, occurring on 67-100% of nights in every season by the 2090s.
- All projections indicate decreases in the frequency of days and nights that are considered 'cold'[2] in current climate. These events do not occur at all by the 2060s in projections from most of the models.

Precipitation

- Projections of mean annual rainfall from different models in the ensemble are broadly consistent in indicating decreases in rainfall for Grenada. Ensemble median changes for all seasons are negative. Annual projections vary between -61 and +23% by the 2090s, with ensemble median changes -13 to -21%.

- The proportion of total rainfall that falls in heavy[3] events decreases in most model projections, changing by -20% to +7% by the 2090s.
- Maximum 5-day rainfalls tend to decrease in model projections, but the ensemble range covers both increases and decreases at -29 to +20mm by the 2090s.

[1] 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.
[2] 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.
[3] A 'Heavy' event is defined as a daily rainfall total which exceeds the threshold that is exceeded on 5% of rainy days in current the climate of that region and season.

Additional Regional Climate Change Information

- Model simulations show wide disagreements in projected changes in the amplitude of future El Niño events, contributing to uncertainty in future climate variability in projections for this region.
- The Caribbean islands are vulnerable to sea-level rise. Sea-level in this region is projected by climate models to rise by the following levels[4] by the 2090s, relative to 1980-1999 sea-level:
    - 0.13 to 0.43m under SRES B1
    - 0.16 to 0.53m under SRES A1B
    - 0.18 to 0.56m under SRES A2

- For further information see Christensen *et al.* (2007) IPCC Working Group I Report: '*The Physical Science Basis'*, Chapter 11 *(Regional Climate projections*): Sections 11.6 *(South and Central America*), and 11.9 (*Small Islands*).

[4] Taken from the IPCC Working group I (*The Physical Science Basis*): Chapter 10 (Global Climate Projections) (Meehl *et al*., 2007). Regional sea-level projections are estimated by applying regional adjustments (Fig 10.32, p813) to projected global mean sea-level rise from 14 AR4 models.

Data Summary

	Observed Mean 1970-99	Observed Trend 1960-2006		Projected changes by the 2030s			Projected changes by the 2060s			Projected changes by the 2090s		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
Temperature												
	(˚C)	*(change in ˚C per decade)*		*Change in ˚C*			*Change in ˚C*			*Change in ˚C*		
			A2	0.8	**1.0**	1.4	1.6	**1.8**	2.6	2.5	**3.0**	4.3
Annual	26.7	0.14*	*A1B*	0.5	**1.0**	1.6	1.0	**1.8**	2.5	1.6	**2.4**	3.2
			B1	0.3	**0.9**	1.2	0.7	**1.4**	1.7	1.1	**1.6**	2.1
			A2	0.7	**1.0**	1.3	1.5	**1.8**	2.7	2.4	**3.0**	4.4
DJF	25.7	0.12*	*A1B*	0.5	**0.9**	1.7	1.0	**1.9**	2.6	1.5	**2.5**	3.4
			B1	0.3	**0.8**	1.2	0.7	**1.3**	1.7	1.0	**1.6**	2.1
			A2	0.6	**0.9**	1.2	1.3	**1.8**	2.4	2.4	**2.7**	4.1
MAM	26.6	0.13*	*A1B*	0.5	**0.9**	1.5	0.9	**1.7**	2.3	1.4	**2.4**	3.0
			B1	0.2	**0.8**	1.2	0.5	**1.3**	1.7	1.0	**1.6**	2.0
			A2	0.8	**1.0**	1.3	1.5	**2.0**	2.5	2.6	**3.1**	4.1
JJA	27.3	0.16*	*A1B*	0.5	**1.1**	1.5	1.1	**1.9**	2.5	1.7	**2.3**	3.4
			B1	0.3	**0.8**	1.2	0.7	**1.4**	1.6	1.1	**1.7**	2.2
			A2	0.8	**1.0**	1.5	1.6	**1.9**	2.8	2.6	**3.0**	4.5
SON	27.3	0.15*	*A1B*	0.7	**1.0**	1.8	1.2	**1.9**	2.7	1.7	**2.4**	3.5
			B1	0.5	**0.9**	1.3	0.8	**1.4**	1.7	1.2	**1.7**	2.0
Precipitation												
	(mm per month)	*(change in mm per decade)*		*Change in mm per month*			*Change in mm per month*			*Change in mm per month*		
			A2	-16	**-6**	7	-29	**-9**	1	-46	**-9**	-2
Annual	126	1.5	*A1B*	-14	**-2**	6	-31	**-8**	1	-44	**-10**	10
			B1	-17	**-2**	7	-28	**-5**	3	-36	**-6**	13
			A2	-8	**-2**	2	-8	**-3**	2	-15	**-4**	3
DJF	77.7	-0.5	*A1B*	-7	**-2**	12	-10	**-2**	0	-12	**-4**	2
			B1	-4	**-1**	9	-12	**-2**	2	-12	**-3**	5
			A2	-9	**-1**	8	-14	**-2**	11	-23	**-3**	12
MAM	56.9	-0.3	*A1B*	-14	**0**	4	-23	**-1**	2	-26	**0**	3
			B1	-9	**0**	10	-16	**-2**	1	-14	**-2**	9
			A2	-48	**-12**	7	-75	**-19**	14	-100	**-26**	2
JJA	179.5	-4.5	*A1B*	-42	**-7**	16	-77	**-19**	17	-99	**-25**	16
			B1	-45	**-7**	13	-77	**-10**	15	-86	**-13**	31
			A2	-21	**-4**	13	-34	**-10**	12	-72	**-13**	4
SON	189.3	12.0	*A1B*	-25	**-1**	18	-40	**-8**	10	-69	**-11**	20
			B1	-19	**-3**	11	-31	**-3**	3	-55	**-11**	15
Precipitation (%)												
	(mm per month)	*(change in % per decade)*		*% Change*			*% Change*			*% Change*		
			A2	-25	**-11**	6	-39	**-19**	0	-61	**-21**	-3
Annual	126	1.20	*A1B*	-20	**-7**	10	-41	**-15**	1	-60	**-16**	17
			B1	-23	**-4**	12	-37	**-10**	6	-49	**-13**	23
			A2	-18	**-9**	11	-34	**-12**	9	-60	**-16**	14
DJF	77.7	-0.6	*A1B*	-23	**-7**	51	-24	**-11**	2	-52	**-14**	11
			B1	-19	**-3**	36	-25	**-9**	2	-34	**-12**	15
			A2	-36	**-5**	13	-42	**-14**	14	-65	**-14**	21
MAM	56.9	-0.5	*A1B*	-48	**-3**	30	-64	**-9**	19	-71	**0**	15
			B1	-17	**-1**	34	-56	**-7**	12	-37	**-7**	65
			A2	-38	**-14**	3	-61	**-17**	5	-81	**-25**	2
JJA	179.5	-2.5	*A1B*	-34	**-13**	14	-62	**-23**	6	-79	**-25**	14
			B1	-36	**-4**	12	-62	**-14**	13	-69	**-16**	28
			A2	-29	**-9**	12	-40	**-17**	9	-60	**-22**	3
SON	189.3	6.3	*A1B*	-26	**-4**	21	-49	**-16**	4	-54	**-23**	22
			B1	-20	**-7**	7	-29	**-3**	6	-52	**-15**	17

	Observed Mean 1970-99	Observed Trend 1960-2006		Projected changes by the 2030s			Projected changes by the 2060s			Projected changes by the 2090s		
				Min	Median	Max	Min	Median	Max	Min	Median	Max
	% Frequency	Change in frequency per decade					Future % frequency			Future % frequency		
Frequency of Hot Days (TX90p)												
			A2	****	****	****	44	**55**	66	65	**86**	94
Annual	****	****	*A1B*	****	****	****	45	**58**	64	57	**77**	89
			B1	****	****	****	33	**42**	50	41	**50**	69
			A2	****	****	****	63	**79**	91	94	**98**	99
DJF	****	****	*A1B*	****	****	****	65	**82**	93	75	**97**	99
			B1	****	****	****	37	**62**	75	60	**79**	89
			A2	****	****	****	63	**73**	88	90	**95**	99
MAM	****	****	*A1B*	****	****	****	66	**77**	90	83	**90**	98
			B1	****	****	****	35	**57**	78	64	**76**	87
			A2	****	****	****	58	**75**	93	87	**93**	99
JJA	****	****	*A1B*	****	****	****	61	**77**	91	79	**92**	99
			B1	****	****	****	46	**55**	77	58	**75**	95
			A2	****	****	****	62	**83**	93	86	**98**	99
SON	****	****	*A1B*	****	****	****	66	**83**	96	76	**94**	99
			B1	****	****	****	33	**69**	89	52	**86**	97
Frequency of Hot Nights (TN90p)												
			A2	****	****	****	46	**64**	83	69	**91**	99
Annual	****	****	*A1B*	****	****	****	45	**66**	81	58	**85**	96
			B1	****	****	****	33	**53**	68	41	**58**	87
			A2	****	****	****	66	**80**	97	99	**99**	100
DJF	****	****	*A1B*	****	****	****	62	**86**	96	86	**98**	100
			B1	****	****	****	35	**60**	80	59	**85**	96
			A2	****	****	****	60	**79**	94	94	**99**	99
MAM	****	****	*A1B*	****	****	****	65	**81**	97	89	**97**	99
			B1	****	****	****	29	**65**	82	61	**84**	91
			A2	****	****	****	74	**89**	99	96	**99**	100
JJA	****	****	*A1B*	****	****	****	80	**88**	98	93	**98**	99
			B1	****	****	****	52	**77**	93	70	**87**	98
			A2	****	****	****	80	**93**	99	98	**99**	100
SON	****	****	*A1B*	****	****	****	83	**93**	99	96	**98**	100
			B1	****	****	****	57	**80**	96	67	**93**	99
Frequency of Cold Days (TX10p)												
			A2	****	****	****	0	**0**	0	0	**0**	0
Annual	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	1	0	**0**	0
			A2	****	****	****	0	**0**	0	0	**0**	0
DJF	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	0	0	**0**	1
			A2	****	****	****	0	**0**	4	0	**0**	0
MAM	****	****	*A1B*	****	****	****	0	**0**	2	0	**0**	1
			B1	****	****	****	0	**0**	3	0	**0**	3
			A2	****	****	****	0	**0**	0	0	**0**	0
JJA	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	3	0	**0**	1
			A2	****	****	****	0	**0**	0	0	**0**	0
SON	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	0	0	**0**	0
Frequency of Cold Nights (TN10p)												
			A2	****	****	****	0	**0**	0	0	**0**	0
Annual	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	1	0	**0**	0
			A2	****	****	****	0	**0**	0	0	**0**	0
DJF	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	0	0	**0**	0
			A2	****	****	****	0	**0**	0	0	**0**	0
MAM	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	0	0	**0**	0
			A2	****	****	****	0	**0**	0	0	**0**	0
JJA	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	4	0	**0**	2
			A2	****	****	****	0	**0**	0	0	**0**	0
SON	****	****	*A1B*	****	****	****	0	**0**	0	0	**0**	0
			B1	****	****	****	0	**0**	0	0	**0**	0

	Observed Mean 1970-99	Observed Trend 1960-2006		Projected changes by the 2030s			Projected changes by the 2060s			Projected changes by the 2090s		
				Min	Median	Max	Min	Median	Max	Min	Median	Max
% total rainfall falling in Heavy Events (R95pct)												
	%	Change in % per decade					Change in %			Change in %		
			A2	****	****	****	-10	**0**	5	-16	**-5**	2
Annual	****	****	A1B	****	****	****	-11	**-3**	8	-20	**-2**	7
			B1	****	****	****	-12	**0**	7	-14	**-1**	5
			A2	****	****	****	-12	**-3**	2	-19	**-3**	6
DJF	****	****	A1B	****	****	****	-11	**-1**	4	-24	**-4**	11
			B1	****	****	****	-13	**-1**	3	-13	**-3**	6
			A2	****	****	****	-7	**-4**	9	-30	**-5**	8
MAM	****	****	A1B	****	****	****	-10	**-2**	11	-24	**-2**	12
			B1	****	****	****	-14	**-2**	4	-13	**-2**	14
			A2	****	****	****	-13	**0**	4	-15	**-1**	3
JJA	****	****	A1B	****	****	****	-10	**-1**	7	-18	**0**	3
			B1	****	****	****	-13	**0**	7	-17	**-3**	5
			A2	****	****	****	-10	**-3**	7	-25	**-5**	6
SON	****	****	A1B	****	****	****	-12	**-3**	8	-23	**-4**	13
			B1	****	****	****	-13	**-4**	7	-23	**-3**	11
Maximum 1-day rainfall (RX1day)												
	mm	Change in mm per decade					Change in mm			Change in mm		
			A2	****	****	****	-9	**0**	2	-8	**0**	5
Annual	****	****	A1B	****	****	****	-9	**0**	5	-8	**0**	8
			B1	****	****	****	-4	**0**	5	-7	**0**	7
			A2	****	****	****	-2	**0**	0	-6	**0**	3
DJF	****	****	A1B	****	****	****	-2	**0**	1	-7	**-1**	1
			B1	****	****	****	-2	**0**	1	-1	**0**	1
			A2	****	****	****	-1	**0**	3	-3	**-1**	1
MAM	****	****	A1B	****	****	****	-2	**0**	6	-8	**0**	9
			B1	****	****	****	-4	**0**	3	-2	**0**	5
			A2	****	****	****	-8	**0**	1	-14	**-1**	5
JJA	****	****	A1B	****	****	****	-6	**0**	4	-16	**0**	3
			B1	****	****	****	-9	**0**	2	-11	**0**	2
			A2	****	****	****	-7	**0**	2	-7	**-1**	4
SON	****	****	A1B	****	****	****	-5	**0**	3	-5	**-1**	6
			B1	****	****	****	-5	**0**	4	-6	**-1**	8
Maximum 5-day Rainfall (RX5day)												
	mm	Change in mm per decade					Change in mm			Change in mm		
			A2	****	****	****	-17	**-1**	5	-28	**-4**	3
Annual	****	****	A1B	****	****	****	-17	**-2**	5	-29	**0**	20
			B1	****	****	****	-18	**1**	7	-24	**0**	8
			A2	****	****	****	-3	**-2**	0	-12	**-1**	7
DJF	****	****	A1B	****	****	****	-5	**-2**	3	-16	**-2**	1
			B1	****	****	****	-5	**-1**	1	-6	**-2**	4
			A2	****	****	****	-4	**0**	8	-16	**-1**	5
MAM	****	****	A1B	****	****	****	-4	**0**	12	-19	**0**	25
			B1	****	****	****	-13	**0**	1	-5	**-1**	11
			A2	****	****	****	-30	**-1**	4	-44	**-6**	4
JJA	****	****	A1B	****	****	****	-23	**0**	4	-45	**-3**	4
			B1	****	****	****	-30	**-2**	7	-34	**-2**	4
			A2	****	****	****	-17	**-1**	10	-22	**-6**	10
SON	****	****	A1B	****	****	****	-14	**-4**	8	-20	**-4**	13
			B1	****	****	****	-13	**-1**	7	-16	**-5**	12

* indicates trend is statistically significant at 95% confidence

**** indicates data are not available

Bracketed trend values for extremes indices indicate values for the closest seasons that data is available. See documentation.

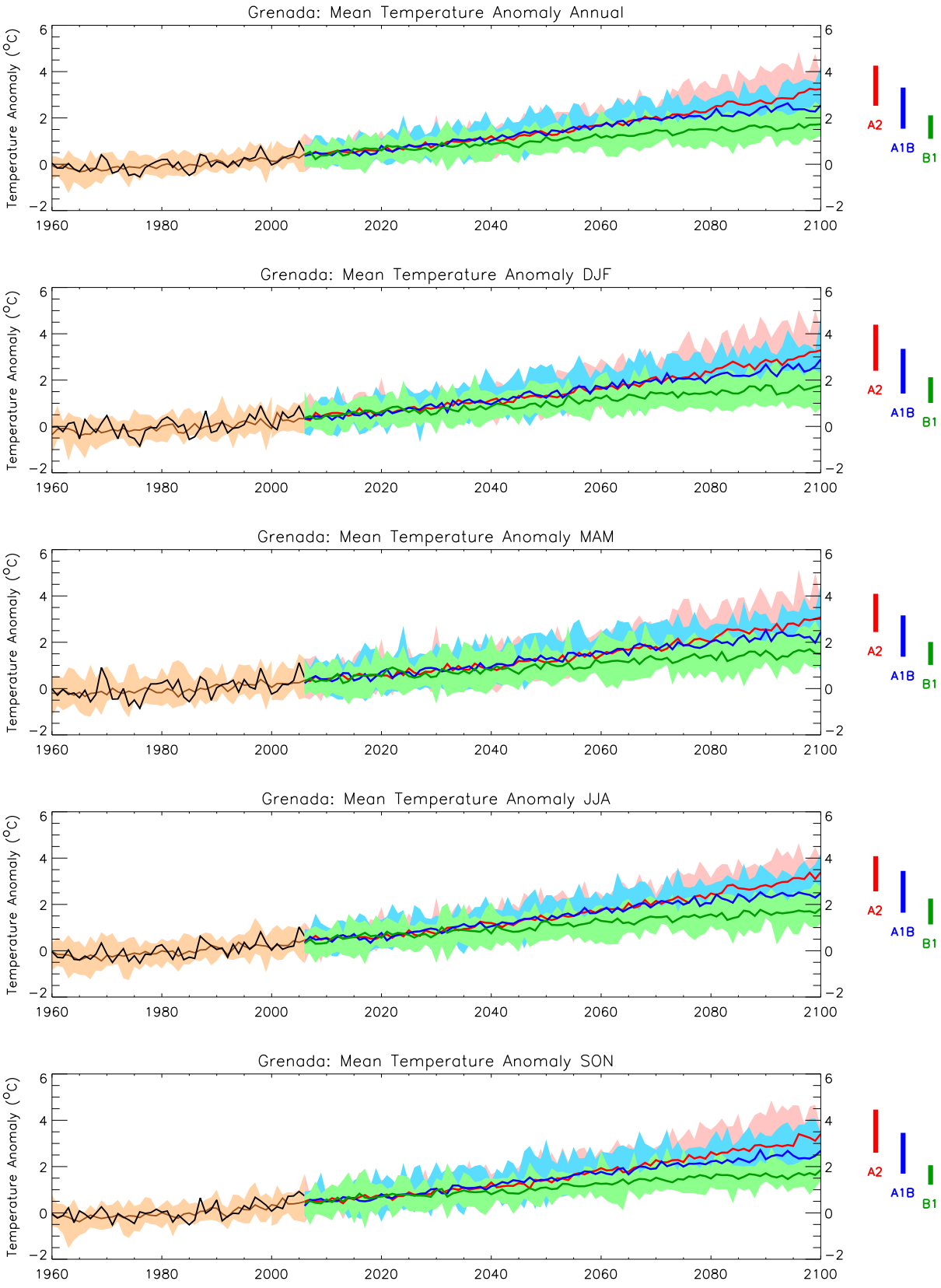


Figure 1: Trends in annual and seasonal mean temperature for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. Black curves show the mean of observed data from 1960 to 2006, Brown curves show the median (solid line) and range (shading) of model simulations of recent climate across an ensemble of 15 models. Coloured lines from 2006 onwards show the median (solid line) and range (shading) of the ensemble projections of climate under three emissions scenarios. Coloured bars on the right-hand side of the projections summarise the range of mean 2090-2100 climates simulated by the 15 models for each emissions scenario.

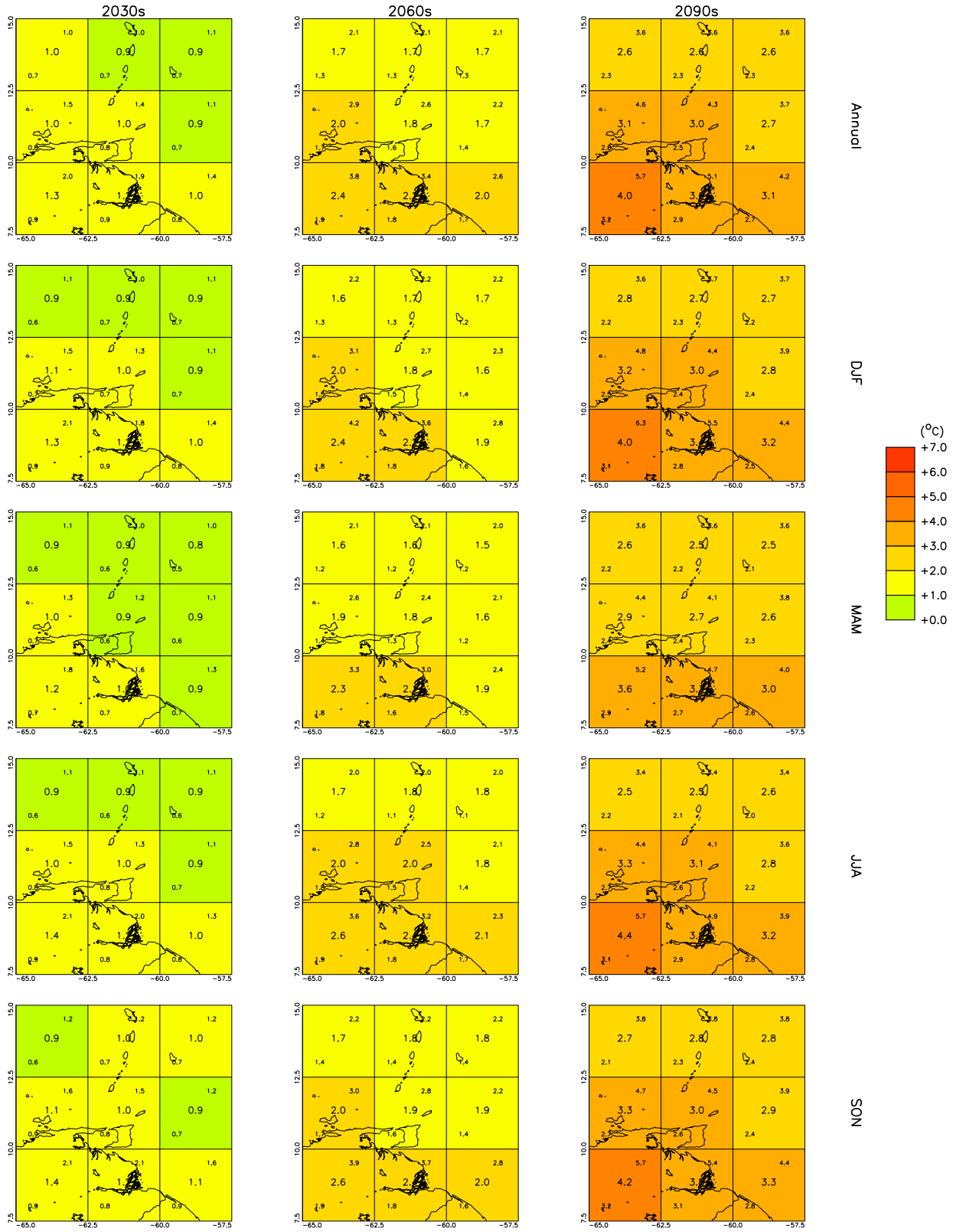


Figure 2: Spatial patterns of projected change in mean annual and seasonal temperature for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. In each grid box, the central value gives the ensemble median and the values in the upper and lower corners give the ensemble maximum and minimum.

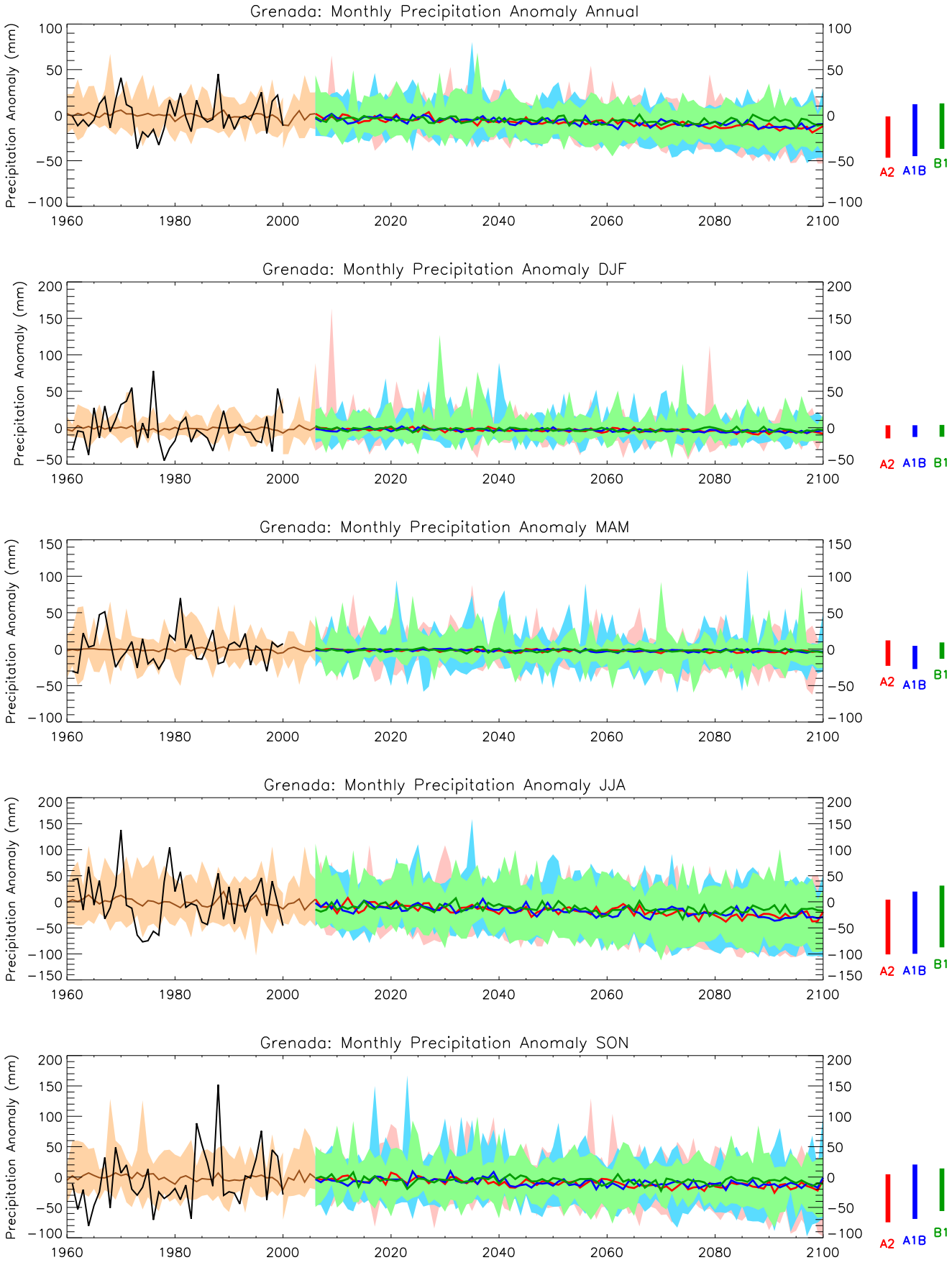


Figure 3: Trends in monthly precipitation for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

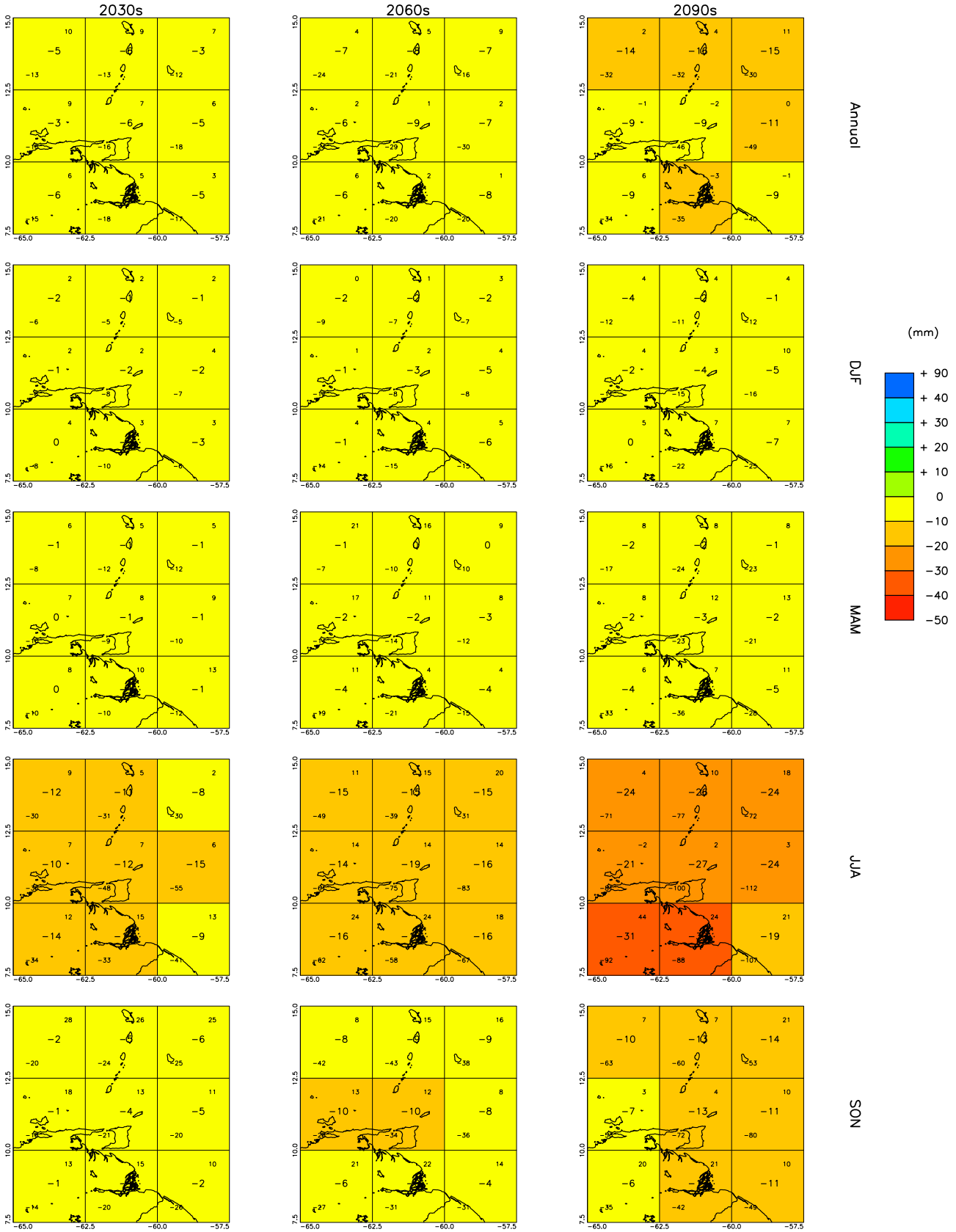


Figure 4: Spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999.See Figure 2 for details.

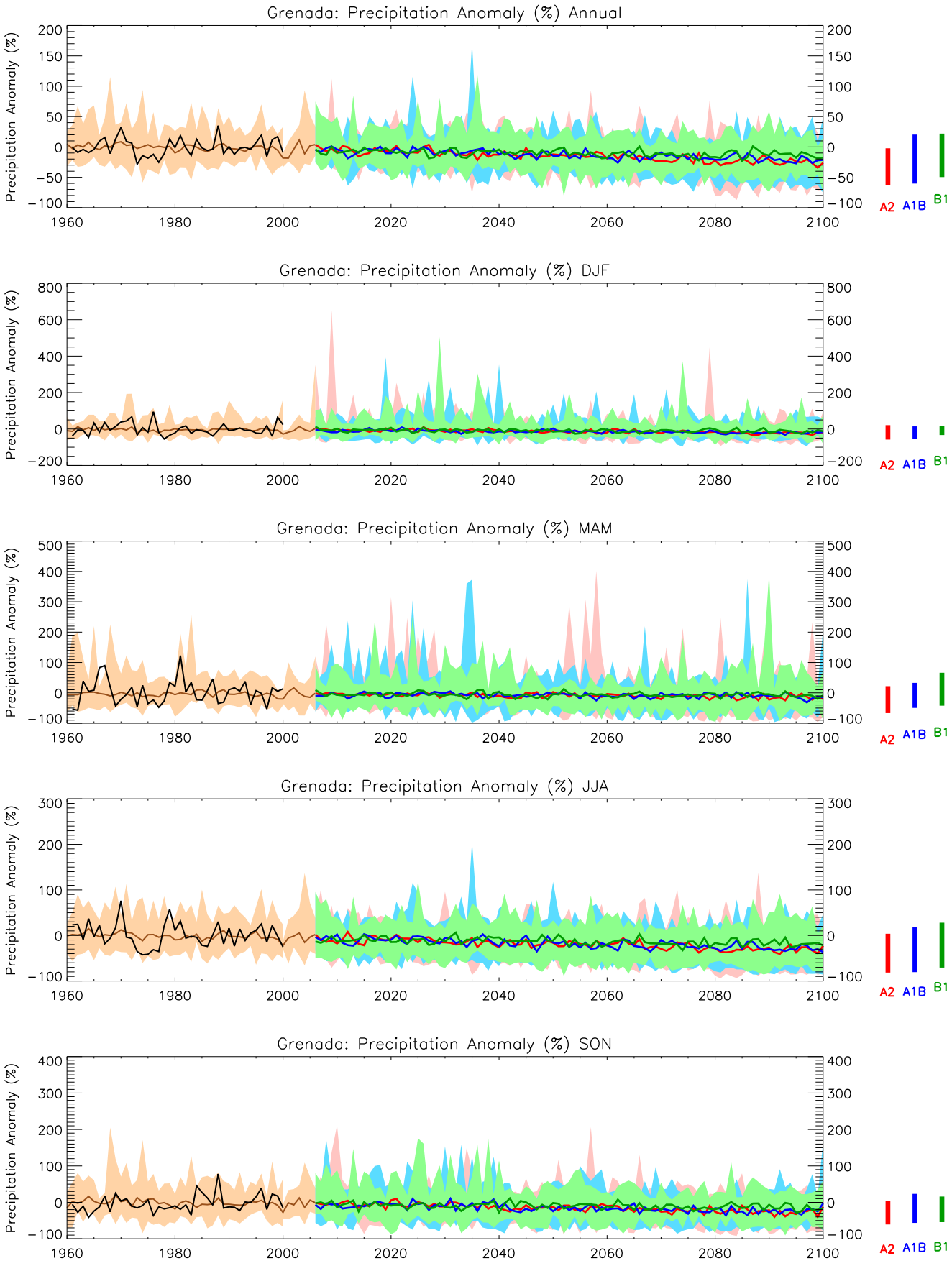


Figure 5: Trends in monthly precipitation for the recent past and projected future. All values shown are percentage anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

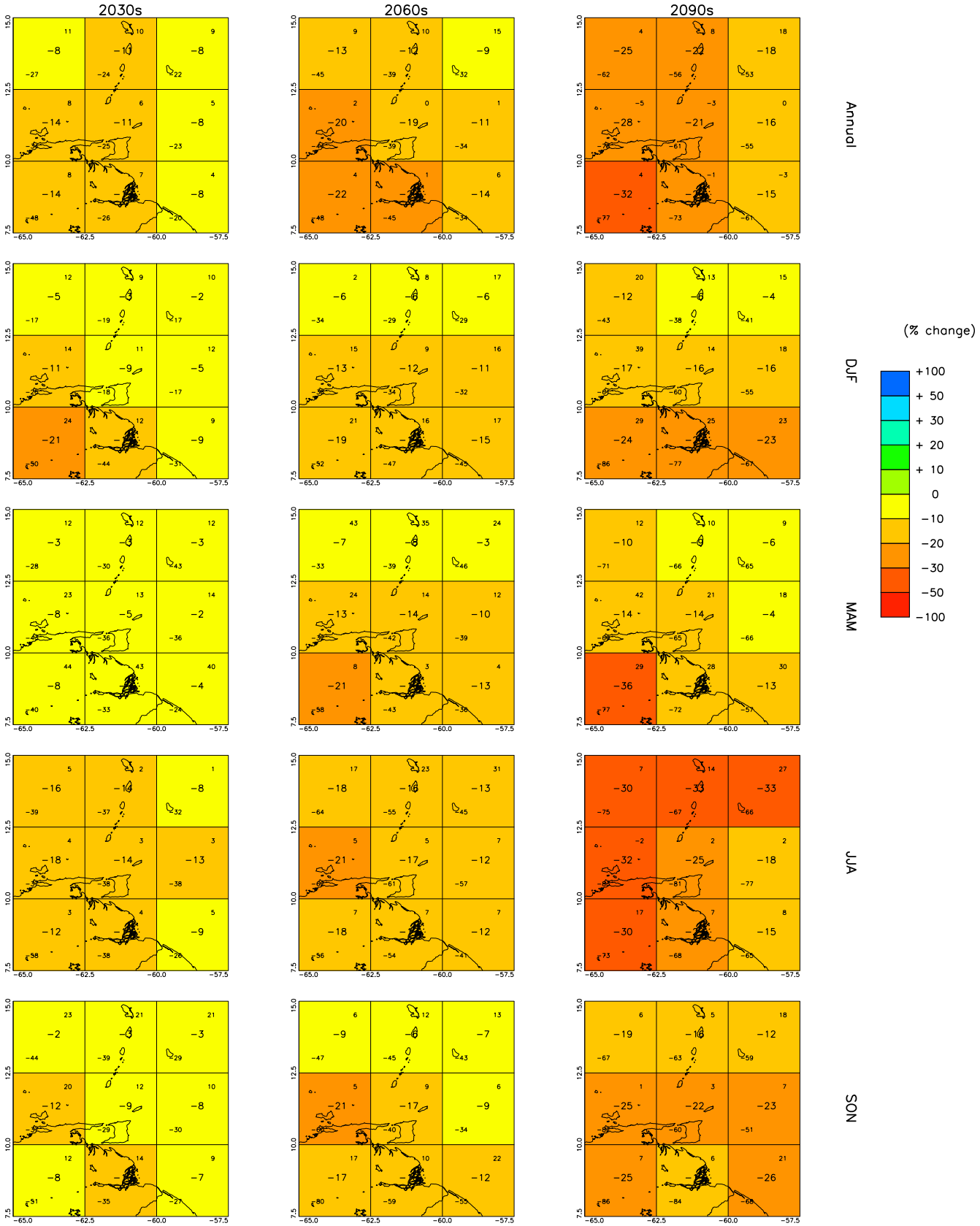


Figure 6: Spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 scenario. All values are percentage anomalies relative to the mean climate of 1970-1999.See Figure 2 for details.

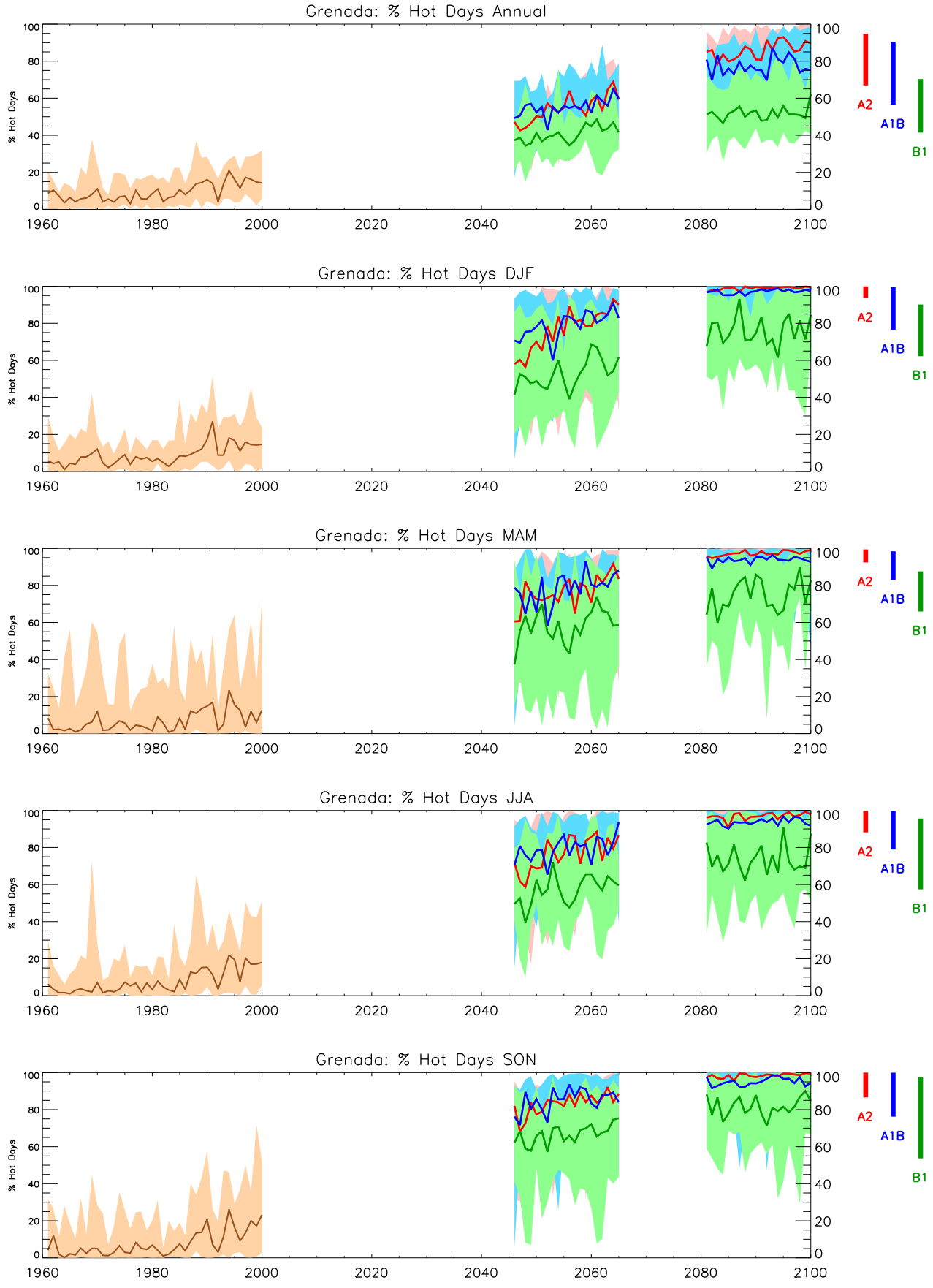


Figure 7: Trends in Hot-day frequency for the recent past and projected future. See Figure 1 for details.

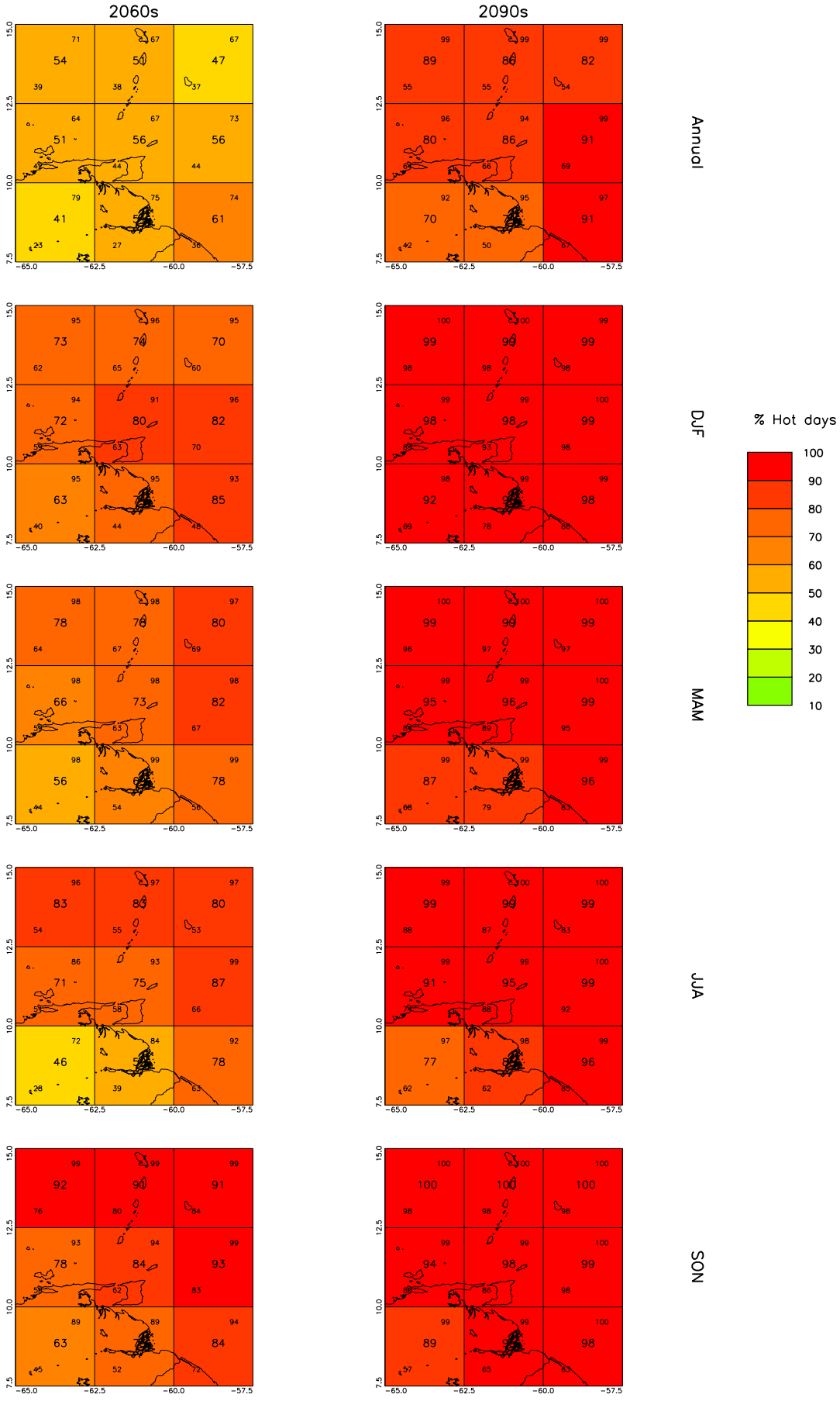


Figure 8: Spatial patterns of projected change in Hot-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

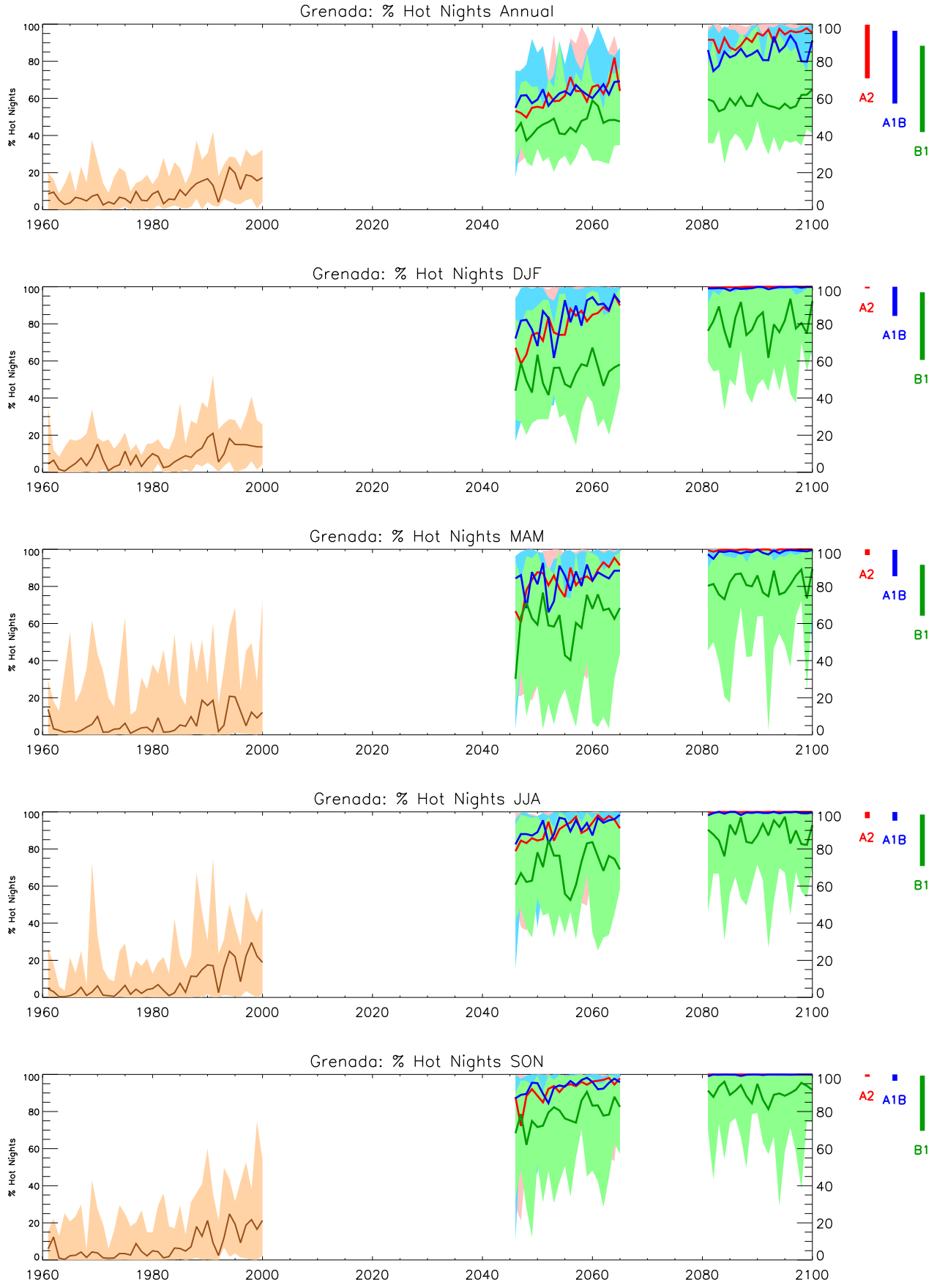


Figure 9: Trends in hot-night frequency for the recent past and projected future. See Figure 1 for details.

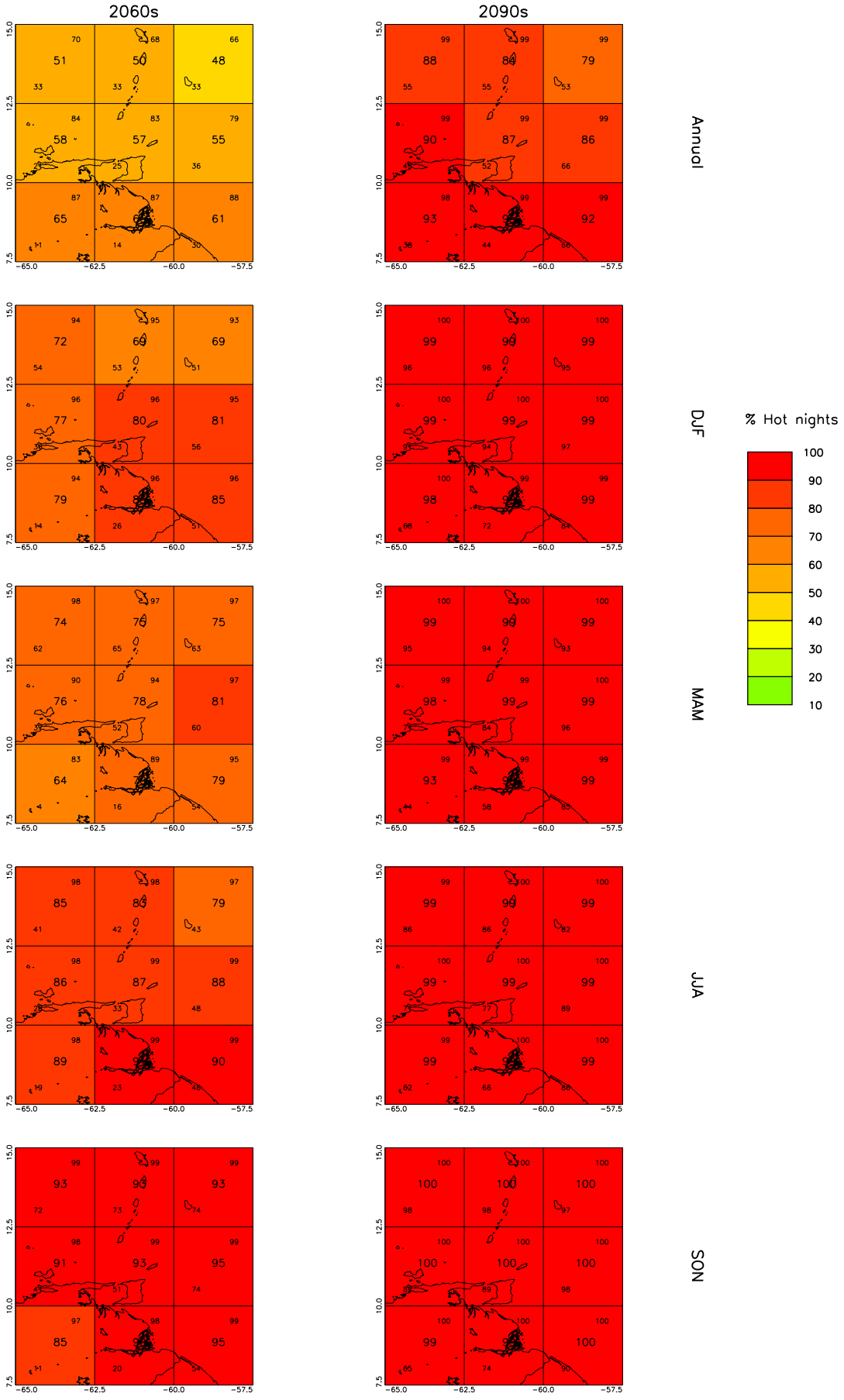


Figure 10: Spatial patterns of projected change in hot-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

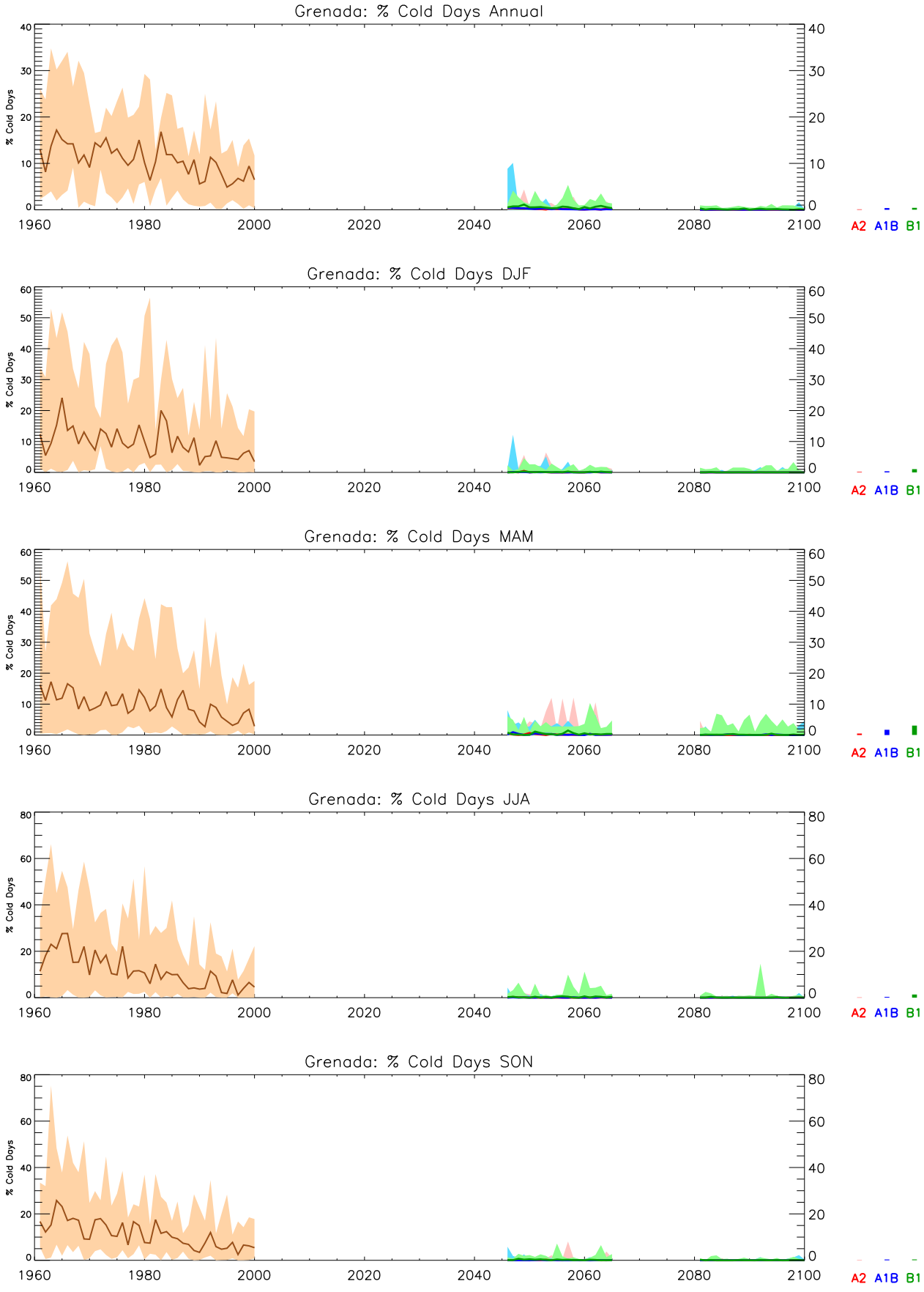


Figure 11: Trends in cold-day frequency for the recent past and projected future. See Figure 1 for details.

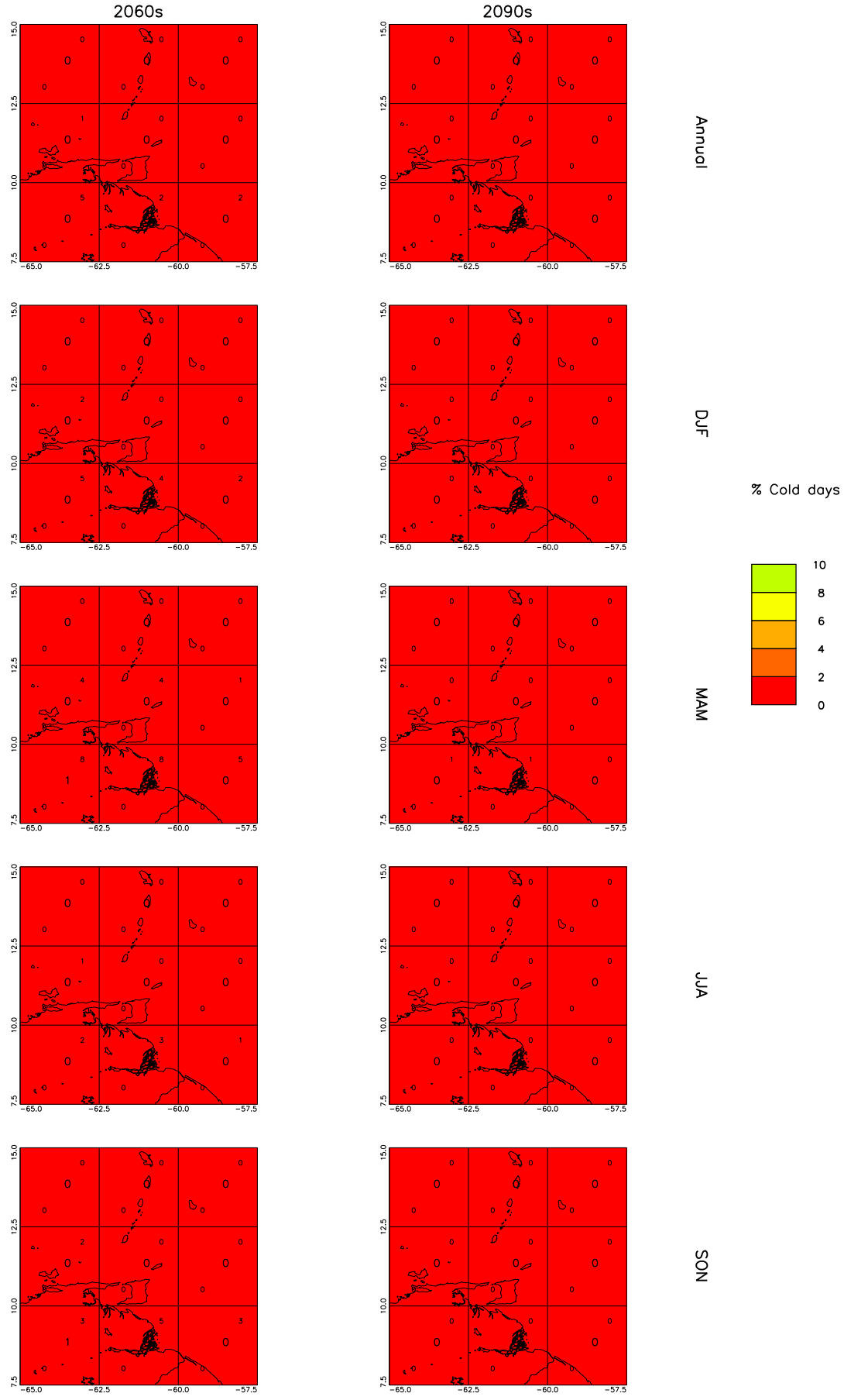


Figure 12: Spatial patterns of projected change in cold-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

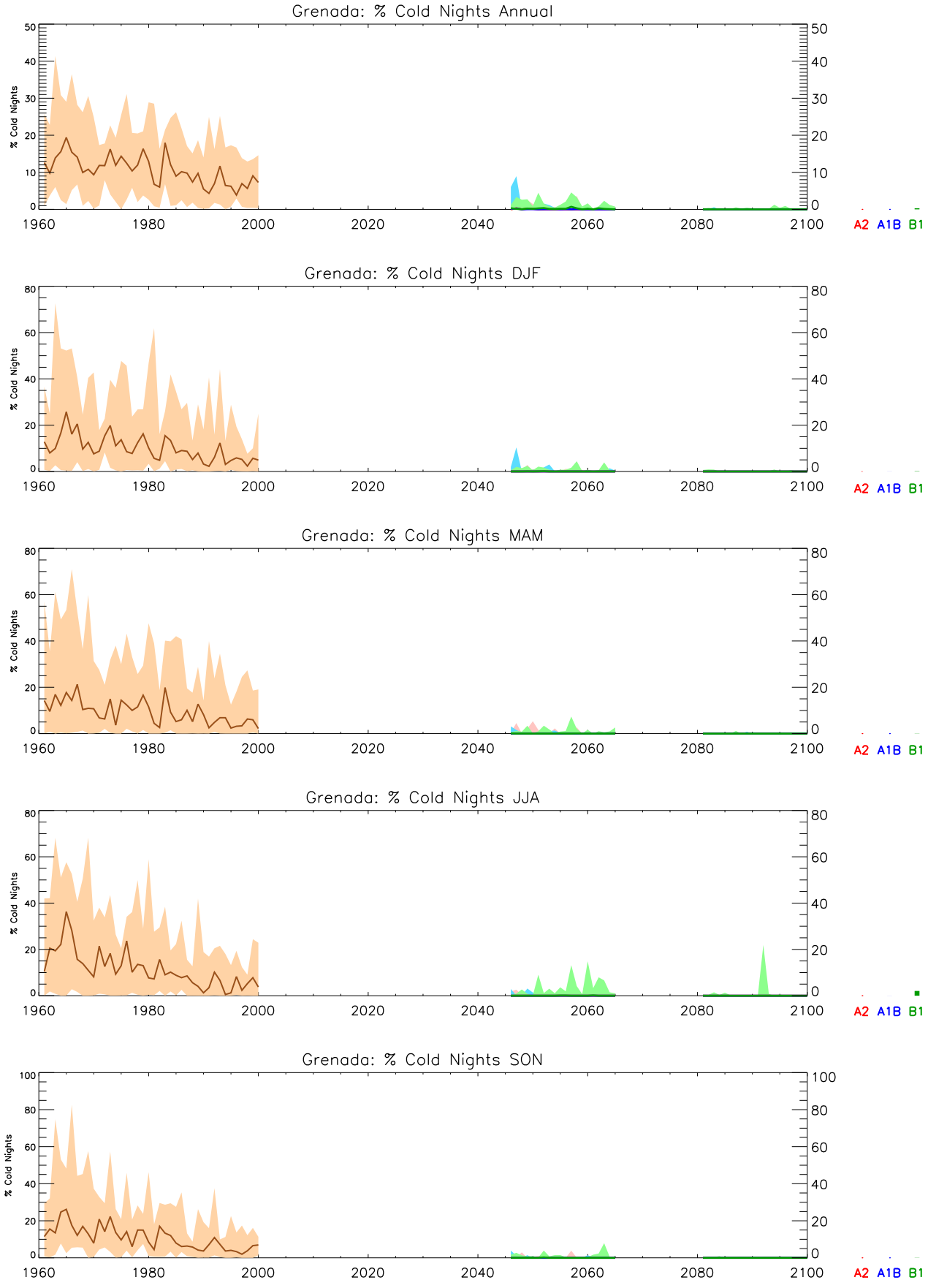


Figure 13: Trends in cold-night frequency for the recent past and projected future. See Figure 1 for details.

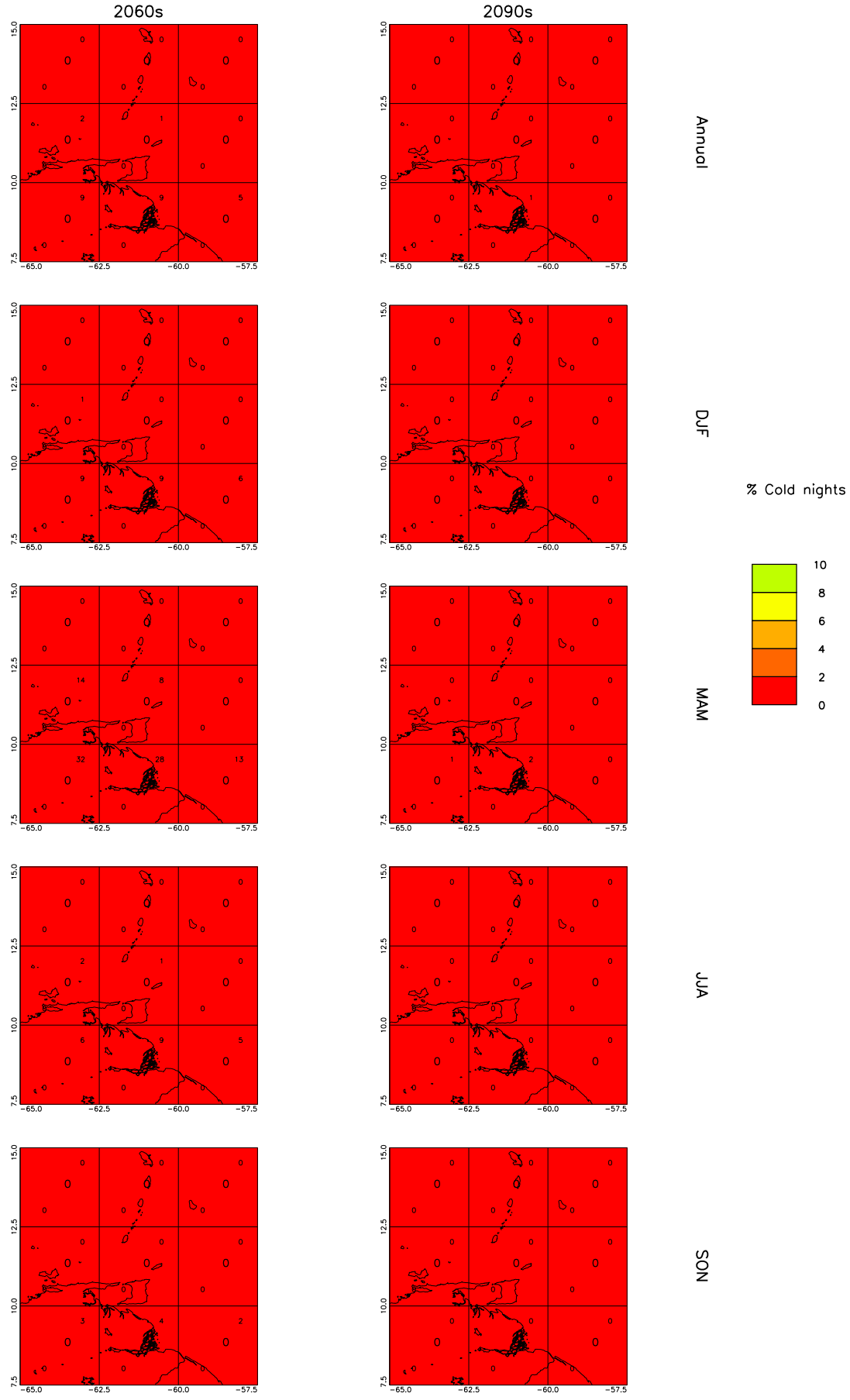


Figure 14: Spatial patterns of projected change in cold-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

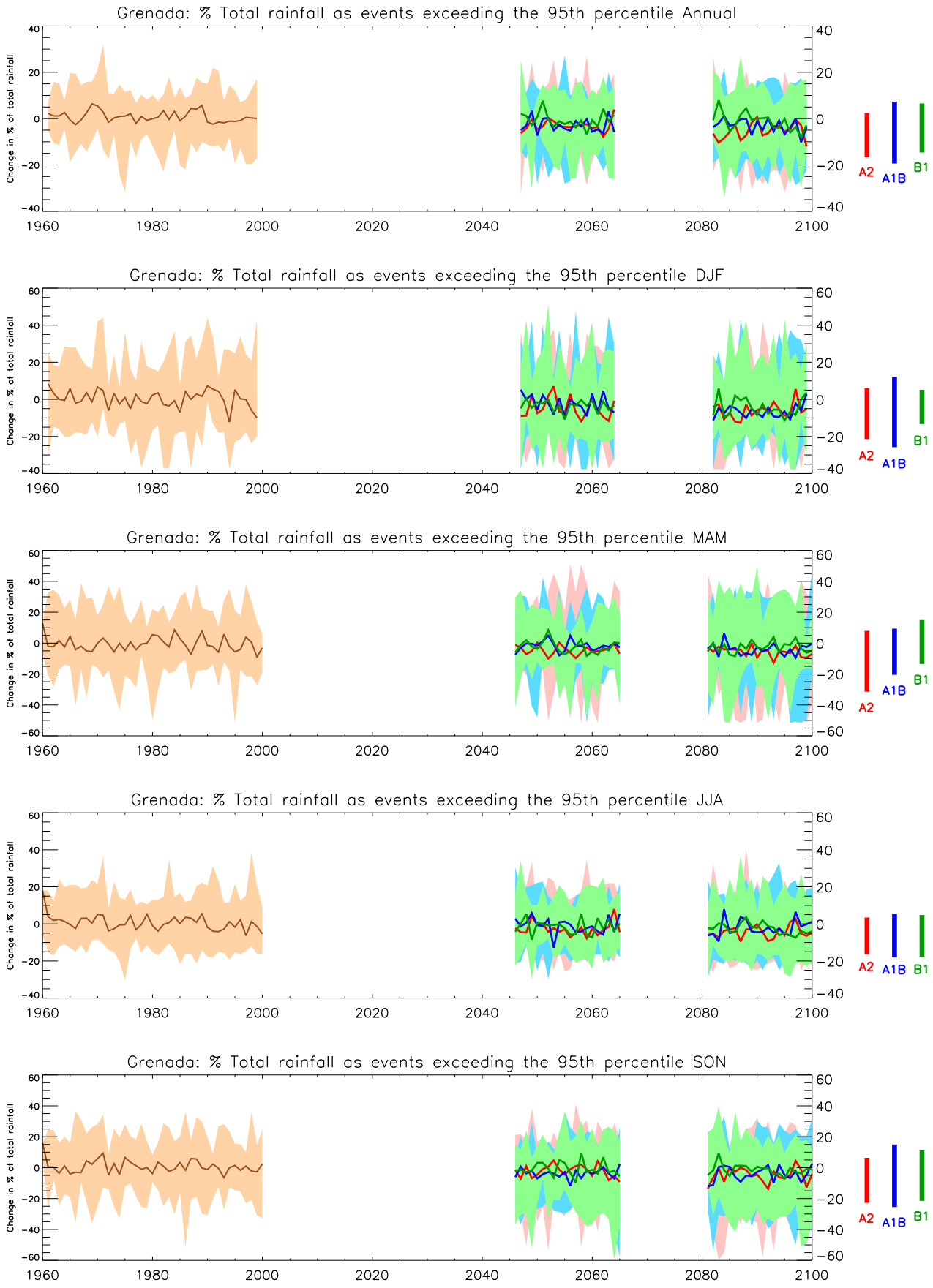


Figure 15: Trends in the proportion of precipitation falling in 'heavy' events for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

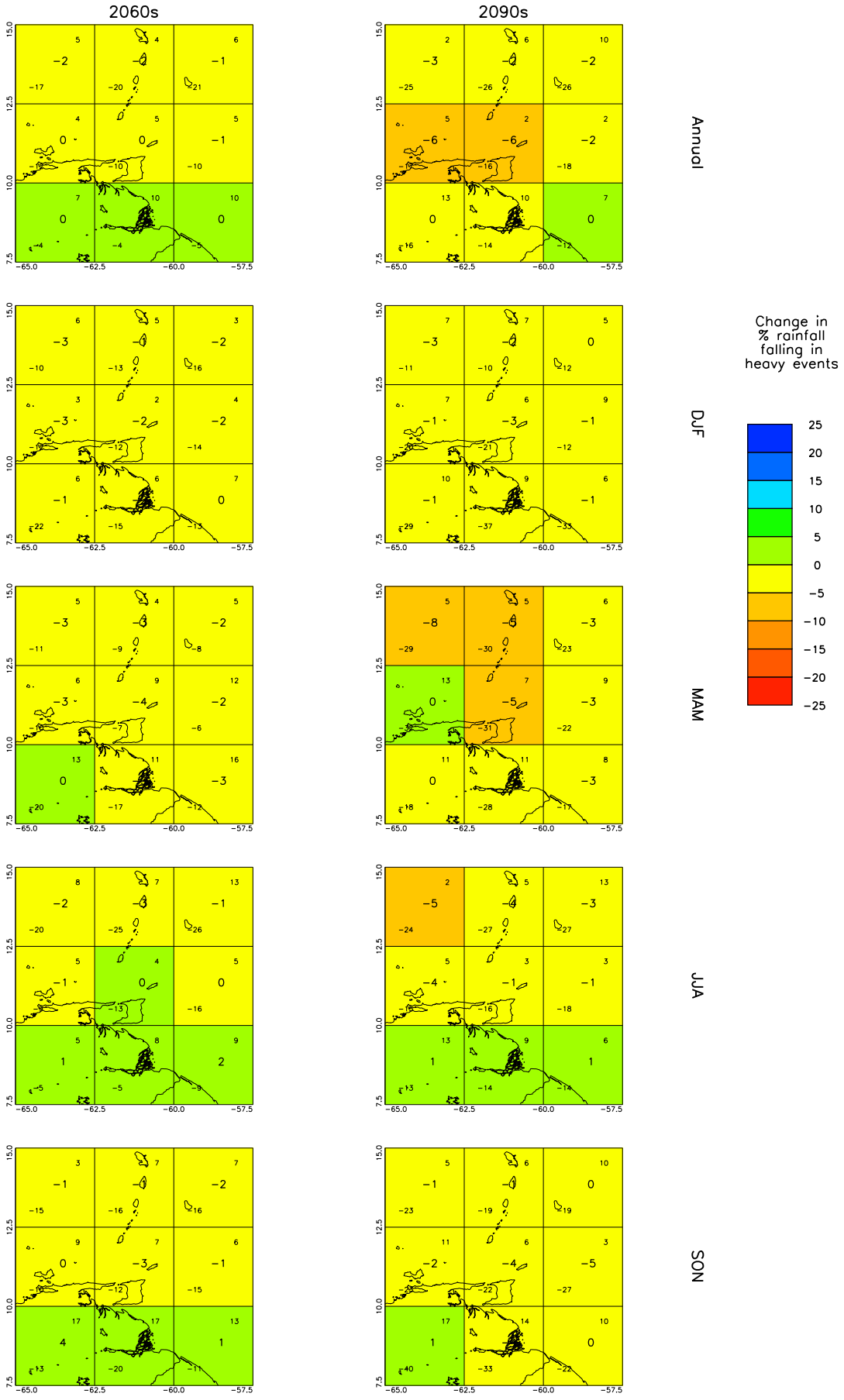


Figure 16: Spatial patterns of projected change in the proportion of precipitation falling in 'heavy' events for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.

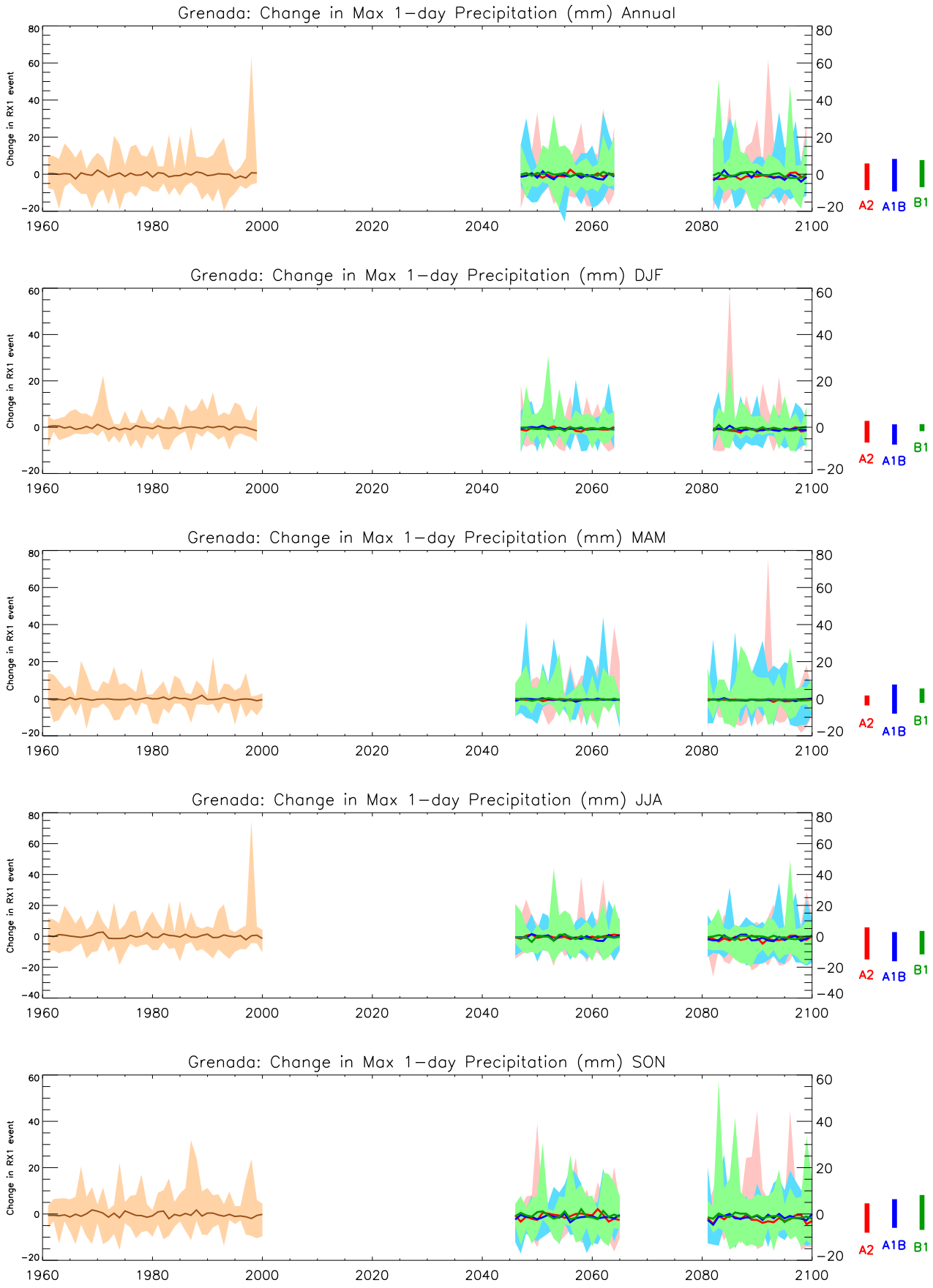


Figure 17: Trends in maximum 1-day rainfall for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

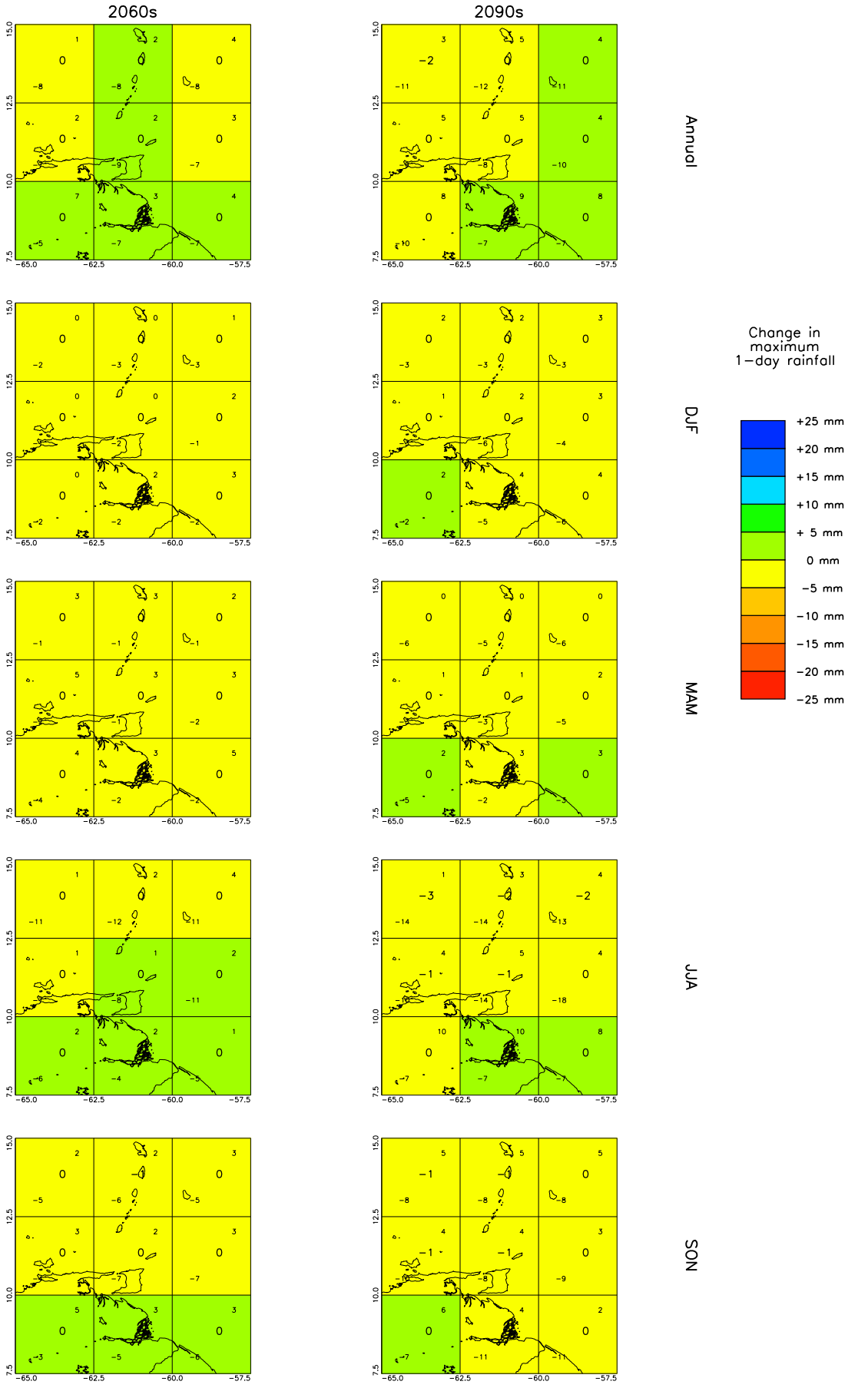


Figure 18: Spatial patterns of maximum 1-day rainfall for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.

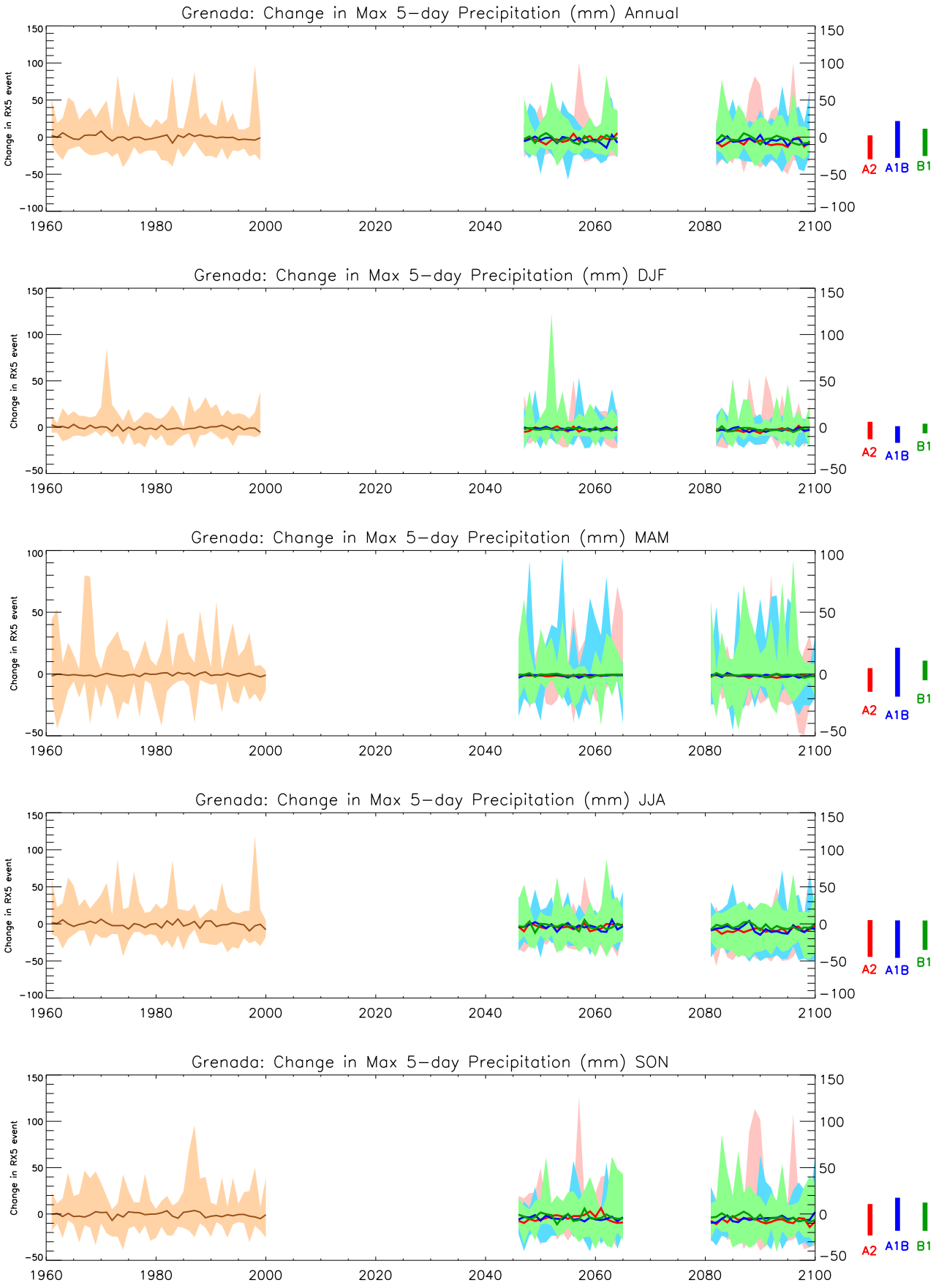


Figure 19: Trends in maximum 5-day rainfall for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

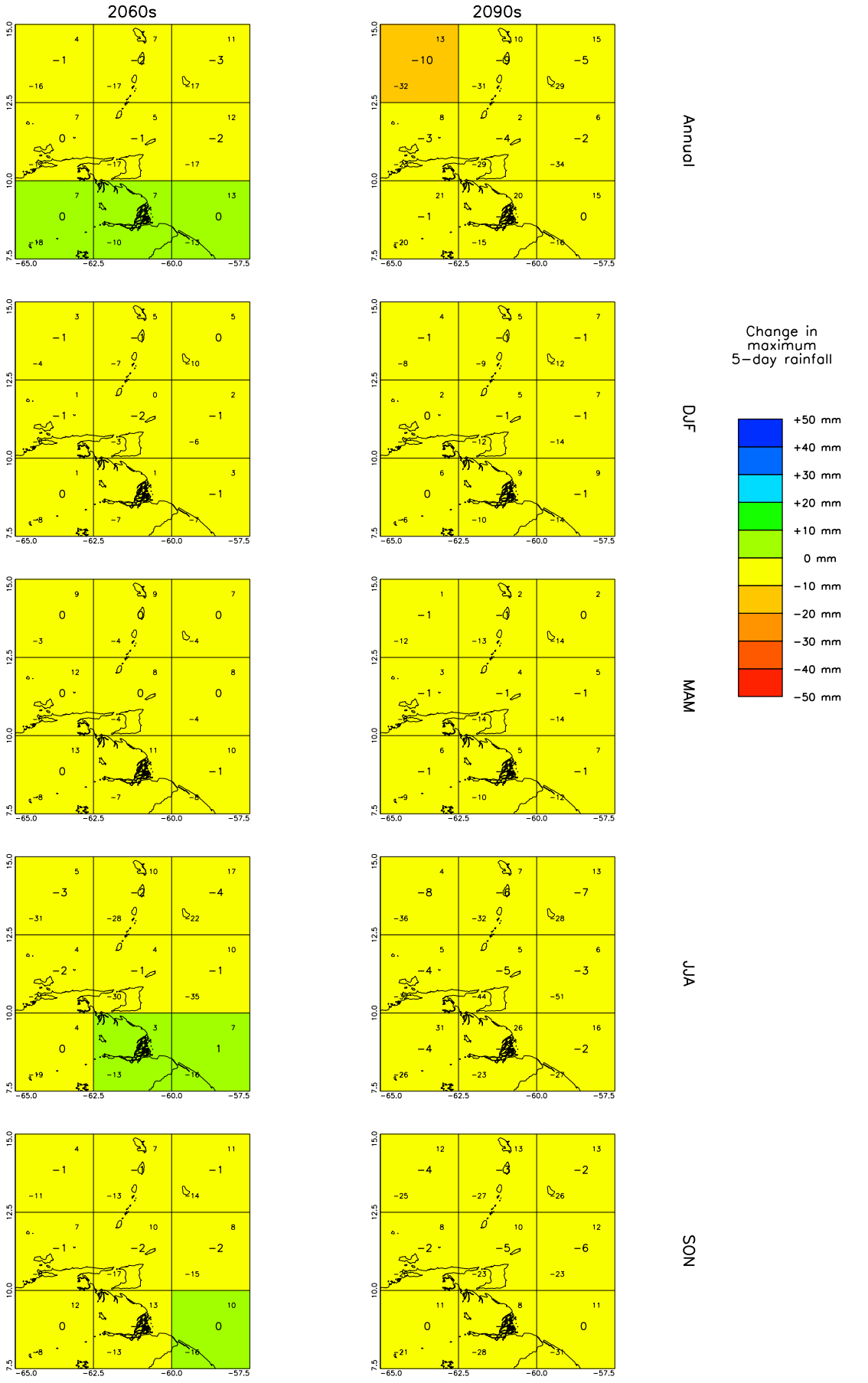


Figure 20: Spatial patterns of projected change in maximum 5-day rainfall for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.