UNDP Climate Change Country Profiles

Morocco (excluding Western Sahara)

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

Morocco is located in north-east Africa, on the Atlantic and Mediterranean coast, at latitudes of 27 to 35˚N. The Atlas mountain range runs through the centre of the country, forming a dividing line between the two main climatic zones, the Mediterranean northern coastal regions, and the southern, interior regions which lie on the edge of the hot Sahara desert.

Temperatures in the coastal regions range between 22-25˚C in the summer (JAS) and 10-12˚C in the winter. Temperatures throughout the year are considerably lower than this range at the higher altitudes of the Atlas Mountains. The wet season lasts between November and March, affecting only the north of Morocco, with an average of 50 to 100mm per month.

The interior border of Morocco experiences string seasonal temperature variations, with average temperatures of 25 to 30˚C in the summer (JAS) dropping considerably in winter to less than 15˚C in the winter (JFM). This region is very dry throughout the year.

Recent Climate Trends
Temperature

- Mean annual temperature has increased by 0.9˚C since 1960, an average rate of 0.20˚C per decade. This increasing trend varies with season, and is only statistically significant in AMJ and SON. The rate of increase is most rapid in the hot, dry season, AMJ, at 0.34˚C per decade.

- The frequency of days that are classed as 'hot'[1] has increased significantly since 1960 in all seasons except SON. The frequency of nights that are classed as 'hot', however, has increased significantly in all seasons.

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[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.

- o The average number of 'hot' days per year in Morocco has increased by 21.5 (an additional 5.9% of days[2]) between 1960 and 2003. The rate of increase is seen most strongly in JJA when the average number of hot JJA days has increased by 3.8 days per month (an additional 12.4% of JJA days) over this period.
  - o The average number of 'hot' nights per year increased by 40 (an additional 10.8% of nights) between 1960 and 2003. The rate of increase is seen most strongly in SON when the average number of hot SON nights has increased by 6.3 days per month (an additional 20.2% of SON nights) over this period.
- The frequency of 'cold'[3] days and nights has decreased significantly in all seasons.
  - o The average number of 'cold 'days per year has decreased by 21 (5.8% of days) between 1960 and 2003. This rate of decrease is most rapid in summer (JJA) when the average number of cold summer days has decreased by 2.2 days per month (7.2% of summer days) over this period.
  - o The average number of 'cold' nights per year has decreased by 29 (7.9% of days). This rate of decrease is most rapid in summer (JJA) when the average number of cold summer nights has decreased by 2.9 nights per month (9.4% of JJA nights) over this period.

Precipitation

- Mean annual rainfall over Morocco has not changed with any consistent trend since 1960.

- There are insufficient daily rainfall observations available from which to determine changes in the extremes indices of daily rainfall.

GCM Projections of Future Climate
Temperature

- The mean annual temperature is projected to increase by 1.1 to 3.5˚C by the 2060s, and 1.4 to 5.6˚C by the 2090s. The range of projections by the 2090s under any one emissions scenario is 1.5- 3.0˚C.
- The projected rate of warming is faster in the interior regions of Morocco than in those areas closer to the coast.

- All projections indicate increases in the frequency of days and nights that are considered 'hot' in current climate.
  - o Annually, projections indicate that 'hot' days will occur on 15-28% of days by the 2060s, and 16-39% of days by the 2090s. Days considered 'hot' by current climate

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[2] The increase in frequency over the 43-year period between 1960 and 2003 is estimated based on the decadal trend quoted in the summary table.

[3] '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.

standards for their season are may increase most rapidly in JAS, but the range between model projections is large, occurring on 28-83% of days of the season by the 2090s.

- o   Nights that are considered 'hot' for the annual climate of 1970-99 are projected to occur on 16-30% of nights by the 2060s and 19-41% of nights by the 2090s. Nights that are considered hot for each season by 1970-99 standards are projected to increase most rapidly in JAS, occurring on 31-92% of nights in every season by the 2090s.

- • All projections indicate decreases in the frequency of days and nights that are considered 'cold' in current climate. Cold days occur on less than 5% of days by the 2090s, and cold nights less than 4% of nights.

Precipitation

- • The models in the ensemble are consistent in projecting decreases in annual rainfall in Morocco. The ensemble projections range from very small increases of up to 10%, to a maximum decrease of 52%. The ensemble median change is -15 to -29%.

- • The changes proportion of total rainfall that falls in heavy[4] events tend towards decreases, ranging from -14% to +3%

- • Changes in 1- and 5-day rainfall maxima tend towards decreases. The changes in projections from the model ensemble range between -6mm to +3mm in 1-day annual maxima, and -11mm to +4mm in annual 5-day maxima.

Other Regional Climate Change Information

- • For further information on climate projections for Africa, see Christensen *et al.* (2007) IPCC Working Group I Report: '*The Physical Science Basis*', Chapter 11 *(Regional Climate projections)*: Section 11.2 *(Africa)*.

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[4] 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.

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	
Annual	17.6	0.20*	A2	0.9	**1.3**	2.1	1.8	**2.8**	3.5	2.9	**4.7**	5.6
			A1B	0.7	**1.5**	2.1	1.2	**2.8**	3.2	2.1	**3.7**	4.4
			B1	0.4	**1.2**	1.5	1.1	**1.8**	2.3	1.4	**2.2**	3.0
JFM	11.8	0.05	A2	0.7	**1.2**	2.2	1.5	**2.0**	3.3	2.5	**3.6**	4.7
			A1B	0.6	**1.4**	1.9	1.0	**2.2**	2.7	2.0	**3.0**	3.6
			B1	0.2	**0.9**	1.4	0.7	**1.4**	1.9	1.4	**1.8**	2.8
AMJ	19.1	0.34*	A2	0.8	**1.5**	2.5	1.7	**3.0**	3.8	3.4	**4.9**	6.0
			A1B	0.5	**1.7**	2.5	1.2	**2.9**	3.8	2.1	**4.0**	4.7
			B1	0.7	**1.3**	1.8	1.3	**2.0**	2.9	1.5	**2.2**	3.0
JAS	25.3	0.14	A2	0.8	**1.5**	2.5	2.2	**3.1**	4.2	3.2	**5.2**	6.7
			A1B	1.0	**1.7**	2.5	1.8	**3.4**	4.5	2.2	**4.2**	5.8
			B1	0.5	**1.3**	1.9	1.4	**2.3**	2.8	1.5	**2.6**	4.0
OND	14.4	0.26*	A2	0.6	**1.3**	2.0	1.6	**2.6**	3.2	2.7	**4.2**	5.3
			A1B	0.1	**1.3**	2.1	0.9	**2.6**	3.2	2.0	**3.3**	4.5
			B1	0.1	**1.0**	1.6	0.9	**1.8**	2.2	1.0	**2.3**	2.7
Precipitation												
	(mm per month)	(change in mm per decade)			Change in mm per month			Change in mm per month			Change in mm per month	
Annual	23.6	-1.1	A2	-3	**-1**	0	-7	**-2**	0	-10	**-4**	0
			A1B	-4	**-2**	0	-7	**-4**	0	-8	**-4**	0
			B1	-3	**-1**	0	-6	**-2**	0	-4	**-2**	0
JFM	36.3	-2.4	A2	-7	**-2**	3	-10	**-4**	3	-14	**-6**	2
			A1B	-10	**-3**	3	-11	**-5**	2	-12	**-5**	6
			B1	-6	**0**	6	-10	**-5**	1	-8	**-2**	4
AMJ	18.5	-1.7*	A2	-4	**-1**	0	-5	**-1**	2	-9	**-3**	0
			A1B	-4	**-2**	1	-6	**-2**	0	-6	**-3**	0
			B1	-3	**0**	0	-5	**-2**	1	-5	**-1**	1
JAS	6.2	0.3	A2	-5	**0**	6	-9	**-1**	1	-12	**-1**	3
			A1B	-6	**0**	3	-8	**-2**	0	-11	**-1**	1
			B1	-6	**0**	5	-5	**-1**	4	-7	**-1**	3
OND	33.2	-0.3	A2	-10	**-4**	1	-14	**-4**	0	-12	**-8**	0
			A1B	-8	**-2**	1	-11	**-6**	-2	-11	**-8**	0
			B1	-6	**-1**	1	-9	**-3**	1	-10	**-3**	0
Precipitation (%)												
	(mm per month)	(change in % per decade)			% Change			% Change			% Change	
Annual	23.6	-4.5	A2	-25	**-15**	5	-43	**-21**	-7	-52	**-29**	-1
			A1B	-24	**-18**	0	-40	**-28**	-5	-51	**-27**	10
			B1	-25	**-5**	5	-32	**-15**	-8	-29	**-15**	12
JFM	36.3	-6.7	A2	-44	**-10**	49	-43	**-21**	43	-54	**-40**	38
			A1B	-35	**-18**	50	-50	**-25**	29	-59	**-25**	87
			B1	-28	**-5**	26	-48	**-31**	13	-44	**-14**	62
AMJ	18.5	-9.4*	A2	-31	**-11**	2	-56	**-25**	11	-58	**-34**	9
			A1B	-41	**-13**	7	-55	**-24**	-5	-50	**-32**	-5
			B1	-32	**-8**	5	-37	**-15**	21	-37	**-13**	17
JAS	6.2	4.3	A2	-40	**5**	37	-54	**-16**	11	-85	**-28**	17
			A1B	-29	**-11**	34	-49	**-19**	-7	-68	**-20**	16
			B1	-33	**-5**	26	-35	**-16**	33	-42	**-15**	24
OND	33.2	-1.1	A2	-32	**-21**	14	-66	**-30**	-3	-61	**-35**	2
			A1B	-45	**-13**	7	-46	**-29**	-17	-52	**-36**	10
			B1	-36	**-7**	21	-38	**-18**	21	-42	**-18**	0

	Observed Mean 1970-99	Observed Trend 1960-2006		Projected changes by the 2030s			Projected changes by the 2060s			Projected changes by the 2090s		
	% Frequency	Change in frequency per decade		Min	Median	Max	Min	Median	Max	Min	Median	Max
							Future % frequency			Future % frequency		
Frequency of Hot Days (TX90p)												
Annual	11.0	1.37*	A2	****	****	****	18	**22**	28	25	**32**	39
			A1B	****	****	****	18	**23**	28	20	**29**	37
			B1	****	****	****	15	**18**	20	16	**20**	25
JFM (DJF)	11.3	(1.62*)	A2	****	****	****	16	**25**	38	27	**39**	61
			A1B	****	****	****	17	**23**	40	23	**33**	58
			B1	****	****	****	14	**17**	25	19	**22**	27
AMJ (MAM)	10.4	(1.41*)	A2	****	****	****	22	**25**	39	36	**43**	66
			A1B	****	****	****	22	**28**	40	24	**36**	59
			B1	****	****	****	15	**21**	30	19	**23**	35
JAS (JJA)	12.0	(2.88*)	A2	****	****	****	35	**40**	60	53	**65**	83
			A1B	****	****	****	31	**42**	59	37	**57**	81
			B1	****	****	****	20	**30**	36	28	**42**	50
OND (SON)	10.3	(0.54)	A2	****	****	****	21	**22**	31	26	**36**	48
			A1B	****	****	****	15	**23**	30	22	**30**	46
			B1	****	****	****	11	**16**	21	13	**21**	24
Frequency of Hot Nights (TN90p)												
Annual	12.0	2.52*	A2	****	****	****	21	**24**	29	29	**34**	41
			A1B	****	****	****	19	**24**	30	23	**30**	39
			B1	****	****	****	16	**19**	22	19	**24**	30
JFM (DJF)	11.5	(1.51*)	A2	****	****	****	20	**29**	41	31	**47**	69
			A1B	****	****	****	19	**28**	39	31	**37**	66
			B1	****	****	****	14	**17**	27	19	**28**	31
AMJ (MAM)	11.8	(2.44*)	A2	****	****	****	21	**28**	42	39	**45**	65
			A1B	****	****	****	23	**28**	42	26	**38**	60
			B1	****	****	****	13	**20**	30	18	**26**	38
JAS (JJA)	14.0	(4.71*)	A2	****	****	****	37	**49**	68	64	**80**	92
			A1B	****	****	****	34	**47**	66	46	**63**	89
			B1	****	****	****	23	**30**	44	31	**44**	62
OND (SON)	11.8	(2.55*)	A2	****	****	****	21	**27**	34	32	**41**	53
			A1B	****	****	****	16	**26**	33	25	**37**	50
			B1	****	****	****	14	**18**	23	15	**25**	29
Frequency of Cold Days (TX10p)												
Annual	9.4	-1.35*	A2	****	****	****	1	**3**	4	0	**1**	2
			A1B	****	****	****	1	**3**	5	0	**2**	3
			B1	****	****	****	3	**5**	8	2	**4**	5
JFM (DJF)	9.2	(-1.51*)	A2	****	****	****	1	**2**	4	0	**0**	2
			A1B	****	****	****	0	**2**	5	0	**1**	3
			B1	****	****	****	2	**4**	7	0	**3**	6
AMJ (MAM)	9.6	(-1.38*)	A2	****	****	****	1	**2**	4	0	**1**	1
			A1B	****	****	****	1	**3**	5	0	**1**	2
			B1	****	****	****	3	**4**	6	2	**4**	4
JAS (JJA)	8.9	(-1.68*)	A2	****	****	****	0	**2**	3	0	**0**	1
			A1B	****	****	****	0	**2**	3	0	**0**	2
			B1	****	****	****	2	**3**	7	0	**3**	4
OND (SON)	9.7	(-1.32*)	A2	****	****	****	0	**2**	3	0	**1**	1
			A1B	****	****	****	0	**2**	4	0	**1**	2
			B1	****	****	****	1	**3**	7	1	**2**	4
Frequency of Cold Nights (TN10p)												
Annual	8.7	-1.85*	A2	****	****	****	1	**3**	4	0	**1**	2
			A1B	****	****	****	1	**3**	6	0	**1**	3
			B1	****	****	****	3	**4**	7	2	**3**	4
JFM (DJF)	8.9	(-1.39*)	A2	****	****	****	0	**2**	3	0	**0**	1
			A1B	****	****	****	0	**1**	4	0	**1**	2
			B1	****	****	****	3	**4**	6	0	**2**	5
AMJ (MAM)	9.4	(-1.20*)	A2	****	****	****	0	**2**	3	0	**0**	1
			A1B	****	****	****	1	**2**	4	0	**1**	2
			B1	****	****	****	2	**4**	5	1	**2**	4
JAS (JJA)	7.5	(-2.18*)	A2	****	****	****	0	**1**	2	0	**0**	0
			A1B	****	****	****	0	**1**	2	0	**0**	1
			B1	****	****	****	1	**2**	3	0	**1**	3
OND (SON)	9	(-2.17*)	A2	****	****	****	1	**2**	4	0	**0**	1
			A1B	****	****	****	0	**3**	6	0	**1**	2
			B1	****	****	****	1	**3**	7	2	**2**	6

	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 %	
Annual	****	****	A2	****	****	****	-9	**-2**	3	-14	**-4**	1
			A1B	****	****	****	-9	**-4**	2	-10	**-2**	3
			B1	****	****	****	-5	**-1**	1	-3	**-1**	1
JFM	****	****	A2	****	****	****	-13	**-4**	10	-18	**-14**	2
(DJF)			A1B	****	****	****	-15	**-7**	3	-23	**-6**	11
			B1	****	****	****	-13	**-6**	8	-11	**-2**	12
AMJ	****	****	A2	****	****	****	-13	**-7**	0	-29	**-10**	-1
(MAM)			A1B	****	****	****	-15	**-8**	0	-37	**-7**	4
			B1	****	****	****	-14	**-4**	3	-15	**-3**	8
JAS	****	****	A2	****	****	****	-13	**-5**	3	-37	**-8**	4
(JJA)			A1B	****	****	****	-18	**-5**	0	-24	**-6**	9
			B1	****	****	****	-18	**-1**	10	-22	**-3**	2
OND	****	****	A2	****	****	****	-18	**-7**	10	-22	**-9**	4
(SON)			A1B	****	****	****	-13	**-7**	2	-21	**-8**	5
			B1	****	****	****	-13	**-1**	5	-12	**-4**	5
Maximum 1-day rainfall (RX1day)												
	mm	Change in mm per decade						Change in mm			Change in mm	
Annual	****	****	A2	****	****	****	-3	**-1**	1	-6	**-1**	2
			A1B	****	****	****	-3	**-1**	0	-6	**-1**	1
			B1	****	****	****	-2	**0**	3	-3	**0**	3
JFM	****	****	A2	****	****	****	-3	**0**	2	-4	**-1**	2
(DJF)			A1B	****	****	****	-3	**0**	1	-3	**-1**	2
			B1	****	****	****	-3	**-1**	2	-2	**0**	3
AMJ	****	****	A2	****	****	****	-2	**0**	0	-3	**-1**	0
(MAM)			A1B	****	****	****	-3	**-1**	0	-3	**-1**	0
			B1	****	****	****	-1	**0**	1	-1	**0**	0
JAS	****	****	A2	****	****	****	-2	**0**	0	-6	**0**	2
(JJA)			A1B	****	****	****	-2	**0**	0	-5	**0**	2
			B1	****	****	****	-2	**0**	3	-1	**0**	2
OND	****	****	A2	****	****	****	-3	**-1**	1	-6	**-1**	0
(SON)			A1B	****	****	****	-3	**-1**	0	-6	**-1**	0
			B1	****	****	****	-2	**0**	2	-2	**0**	0
Maximum 5-day Rainfall (RX5day)												
	mm	Change in mm per decade						Change in mm			Change in mm	
Annual	****	****	A2	****	****	****	-9	**-1**	2	-10	**-3**	2
			A1B	****	****	****	-10	**-4**	0	-11	**-2**	2
			B1	****	****	****	-5	**-1**	2	-7	**-1**	4
JFM	40.2	(-3.87*)	A2	****	****	****	-6	**-2**	4	-7	**-4**	2
(DJF)			A1B	****	****	****	-7	**-2**	1	-7	**-3**	4
			B1	****	****	****	-5	**-2**	4	-4	**0**	5
AMJ	****	****	A2	****	****	****	-5	**-2**	0	-5	**-2**	0
(MAM)			A1B	****	****	****	-5	**-2**	2	-5	**-2**	0
			B1	****	****	****	-3	**-1**	0	-3	**-1**	0
JAS	7.0	(-0.73)	A2	****	****	****	-5	**-2**	1	-12	**-1**	2
(JJA)			A1B	****	****	****	-6	**-1**	0	-9	**0**	3
			B1	****	****	****	-2	**0**	8	-5	**0**	3
OND	40.2	(-0.21)	A2	****	****	****	-8	**-3**	1	-10	**-4**	1
(SON)			A1B	****	****	****	-7	**-3**	1	-10	**-4**	1
			B1	****	****	****	-8	**-1**	2	-5	**-2**	1

* 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.
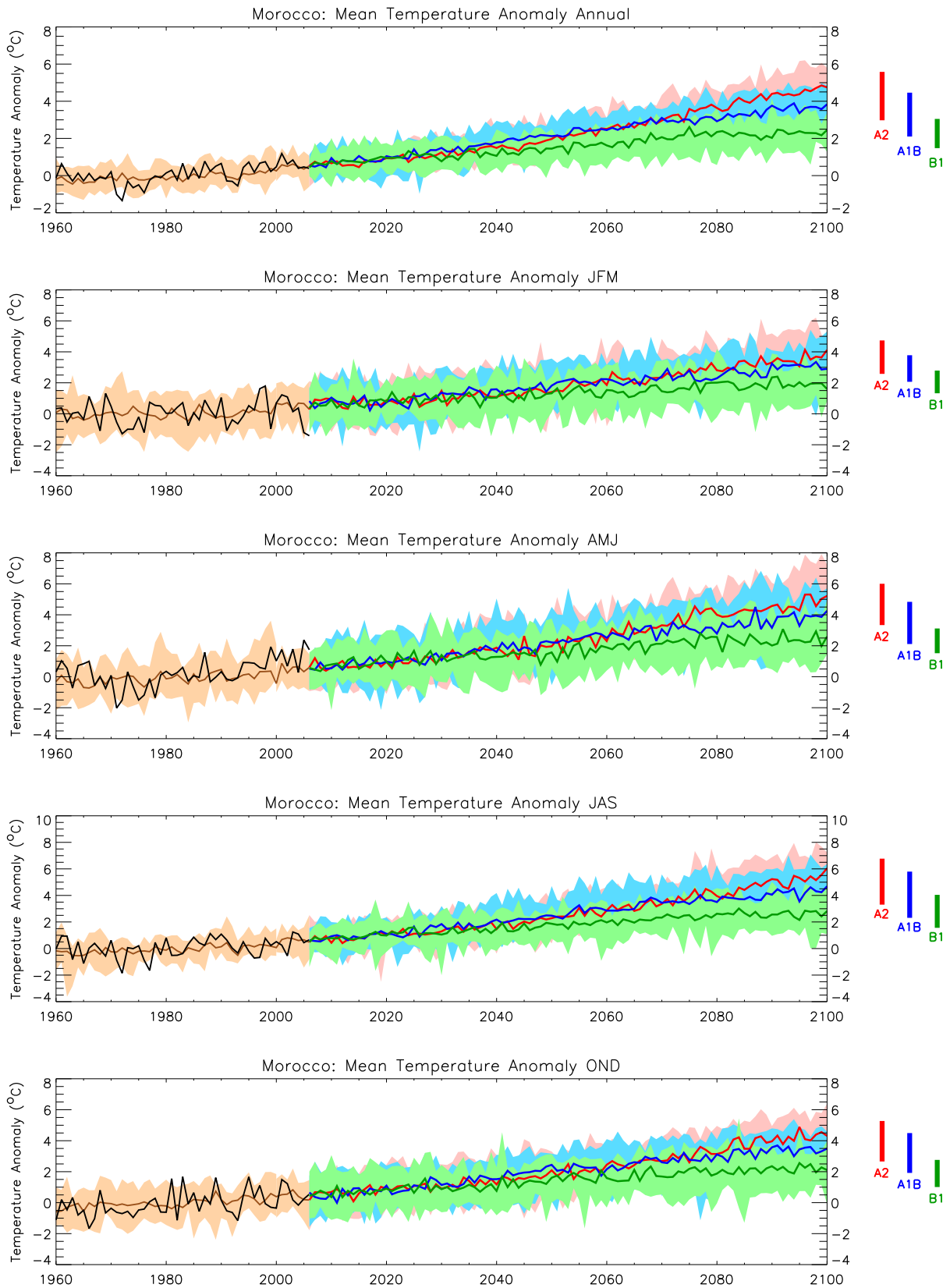
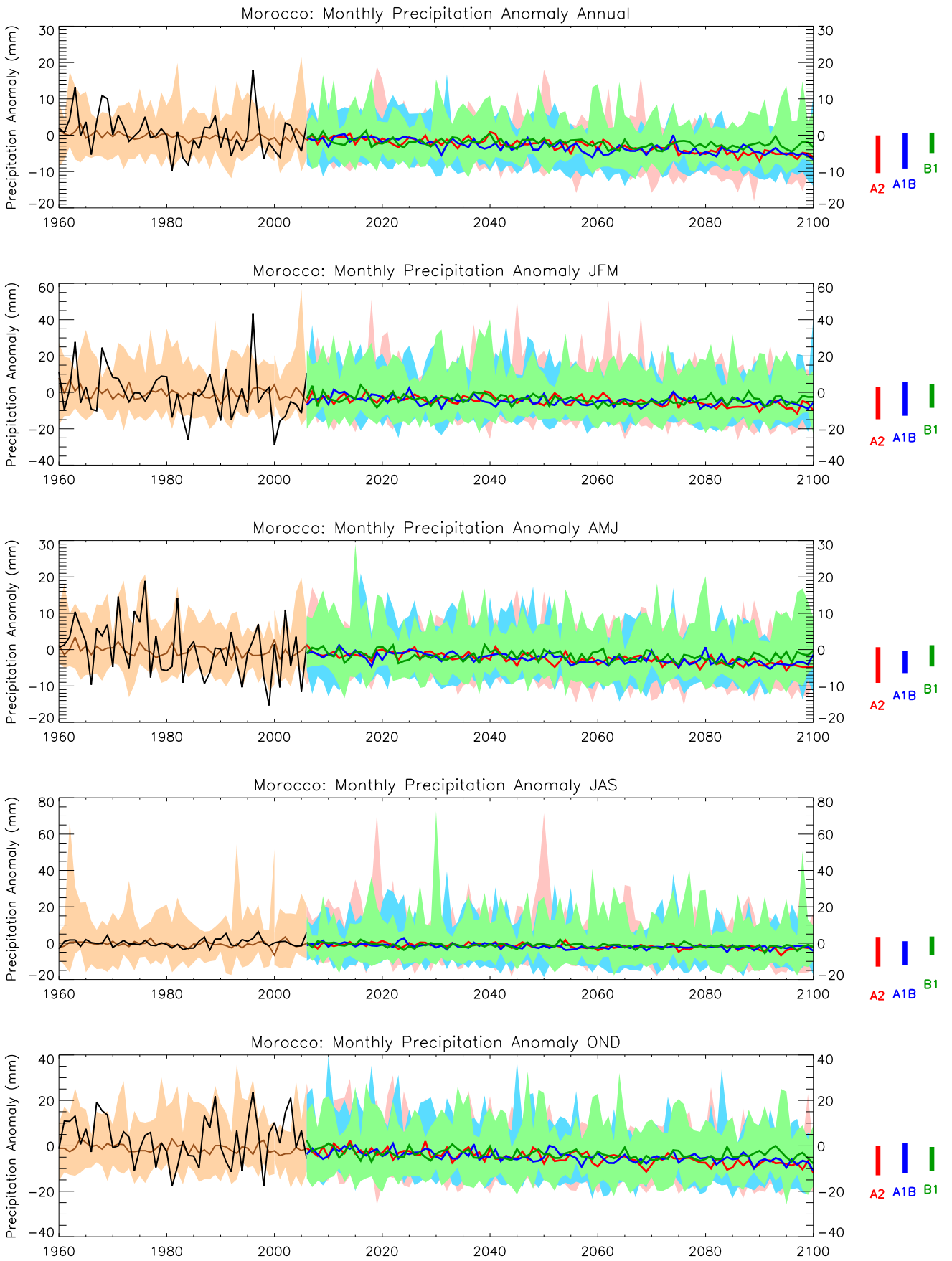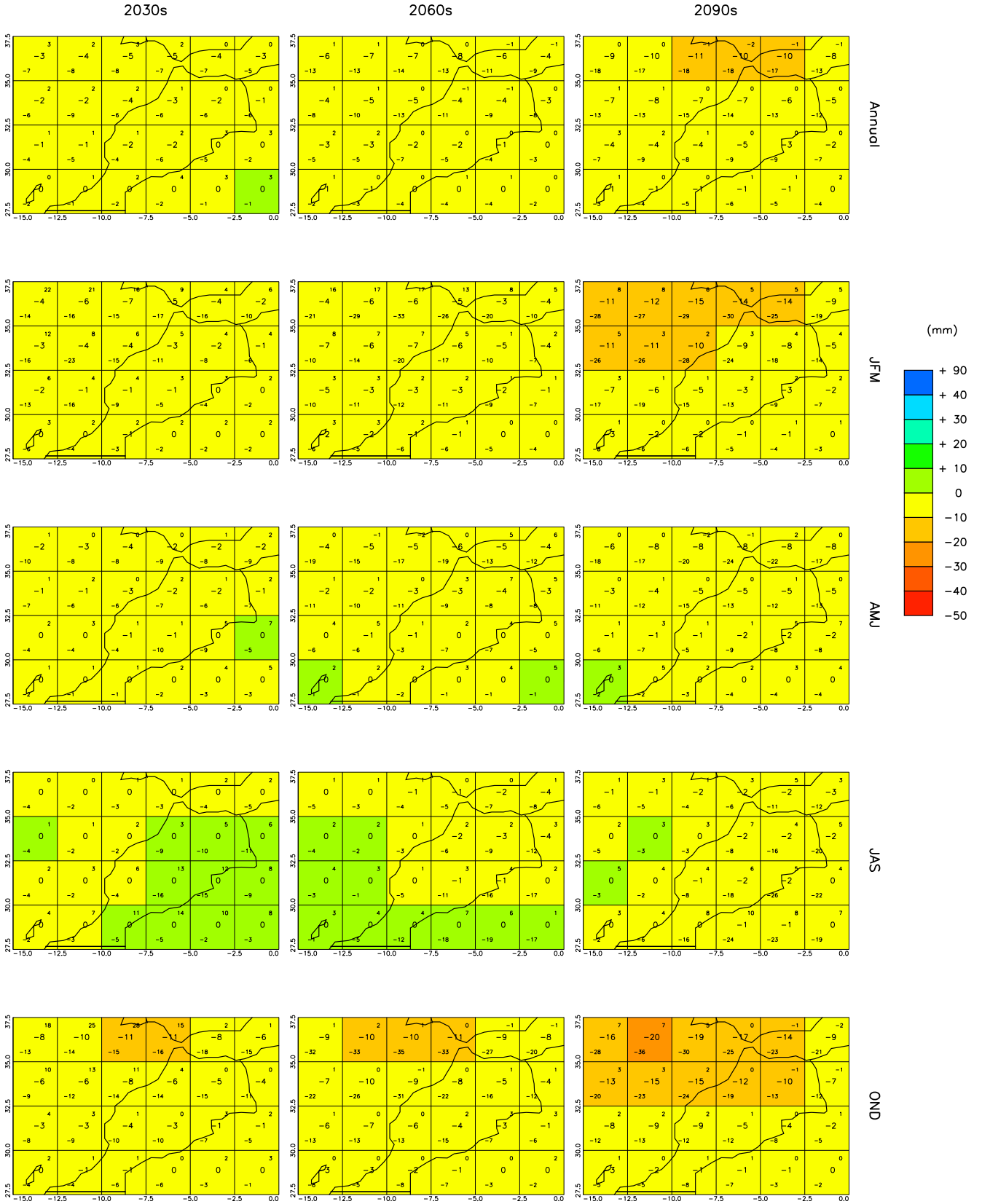Figure 1: Trends in annual and seasonal mean temperature for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. Black curves show the mean of observed data from 1960 to 2006, Brown curves show the median (solid line) and range (shading) of model 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.
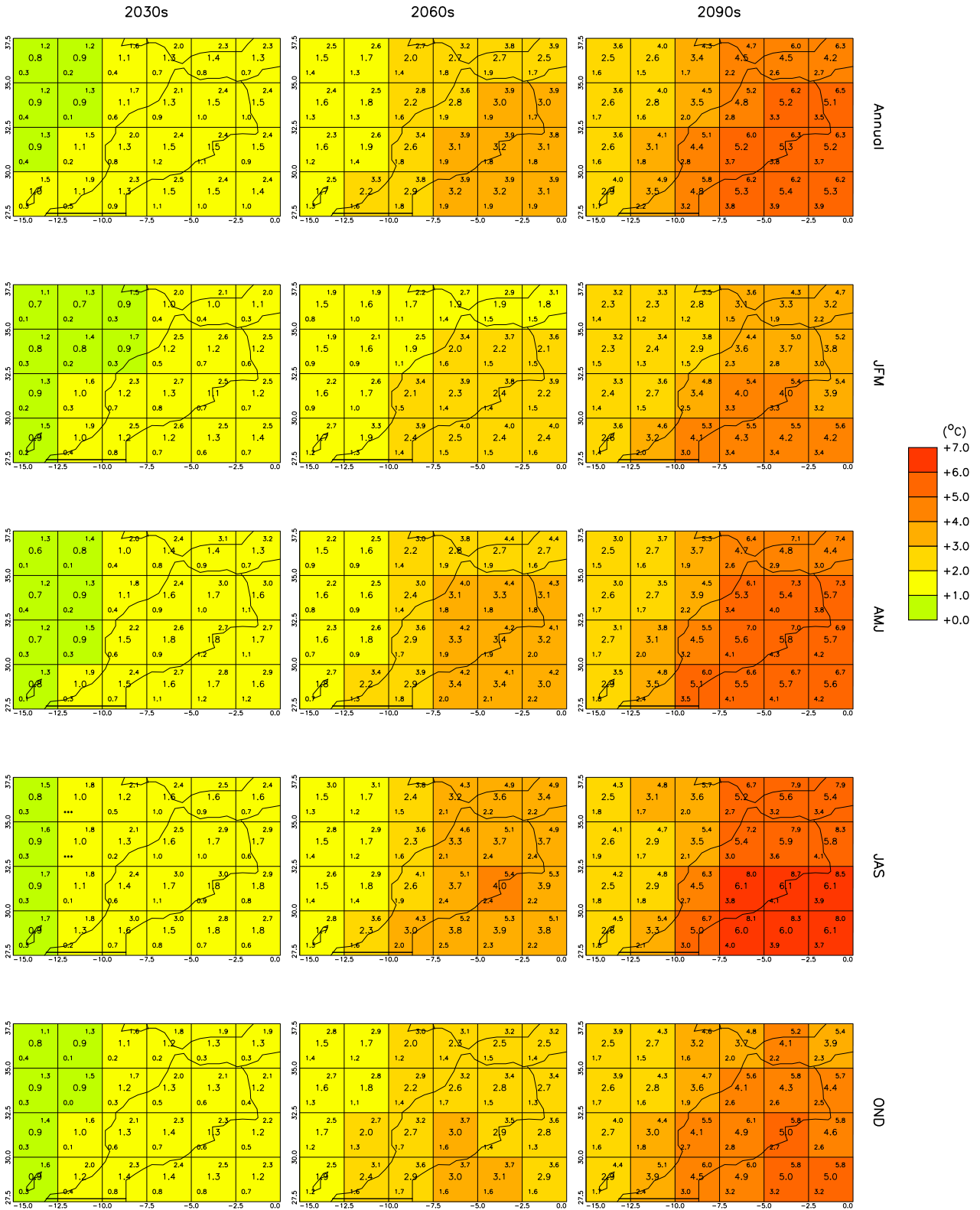
Figure 2: Spatial patterns of projected change in mean annual and seasonal temperature for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. In each grid box, the central value gives the ensemble median and the values in the 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.
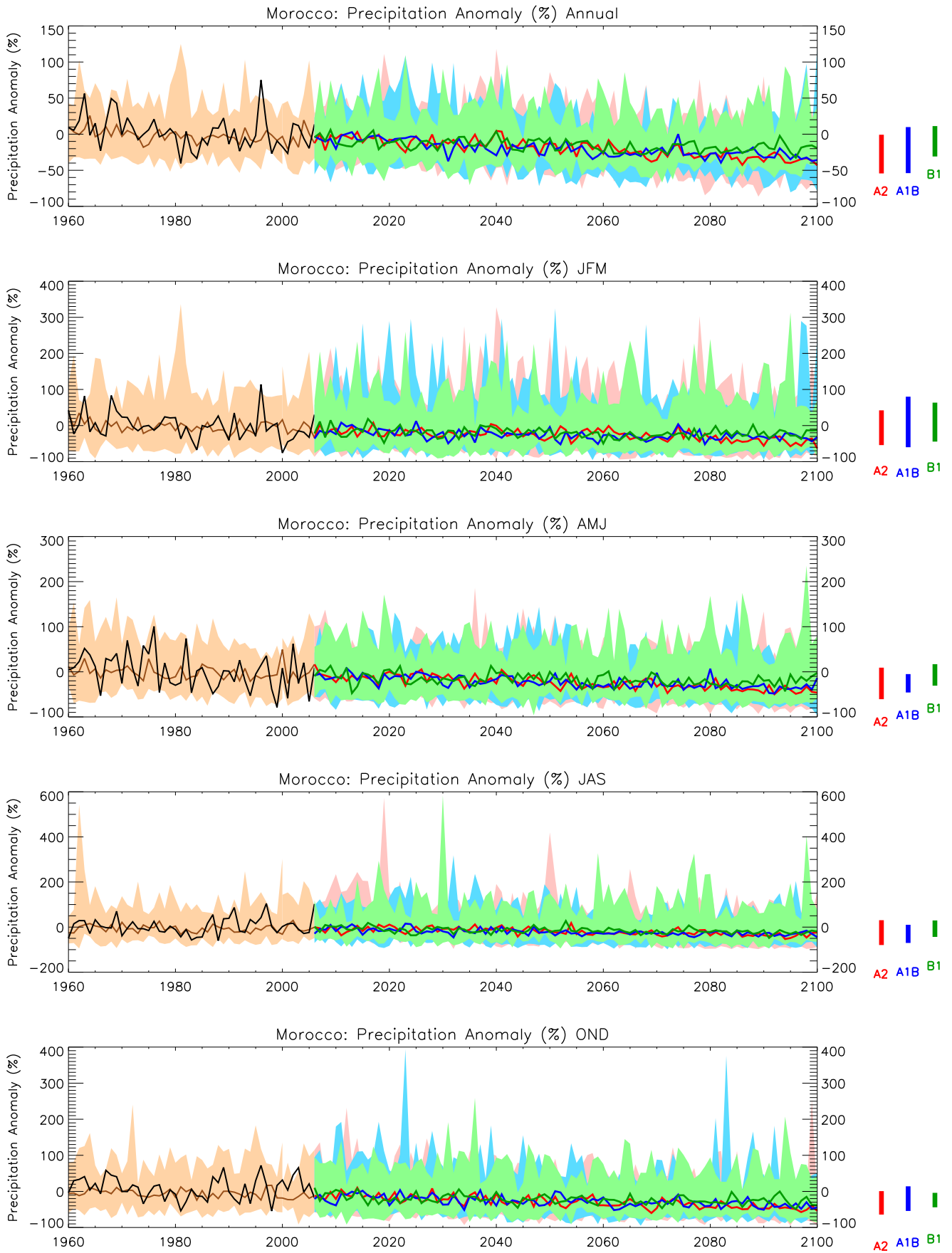
Figure 5: Trends in monthly precipitation for the recent past and projected future. All values shown are percentage anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.
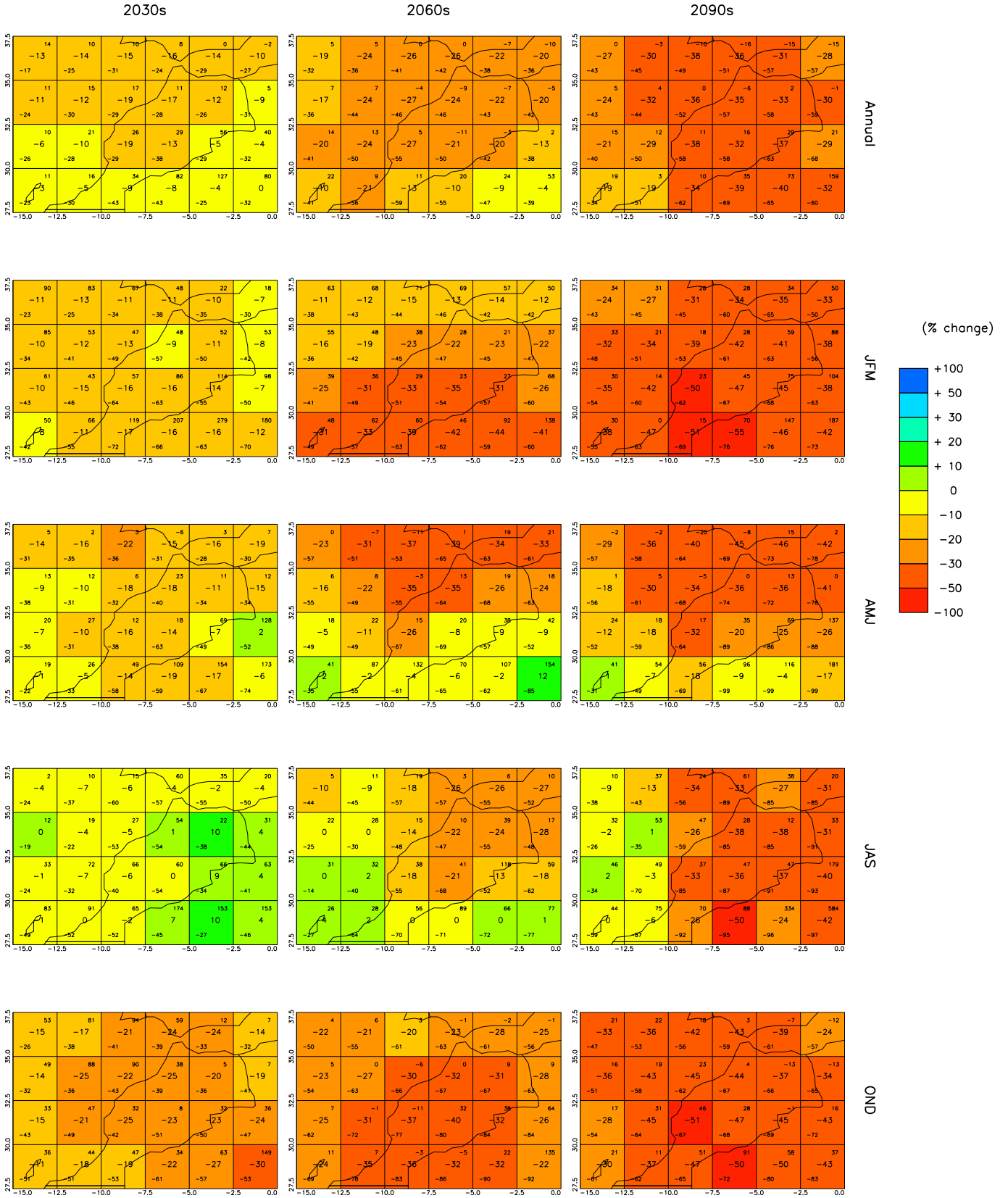
Figure 6: Spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 scenario. All values are percentage anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.
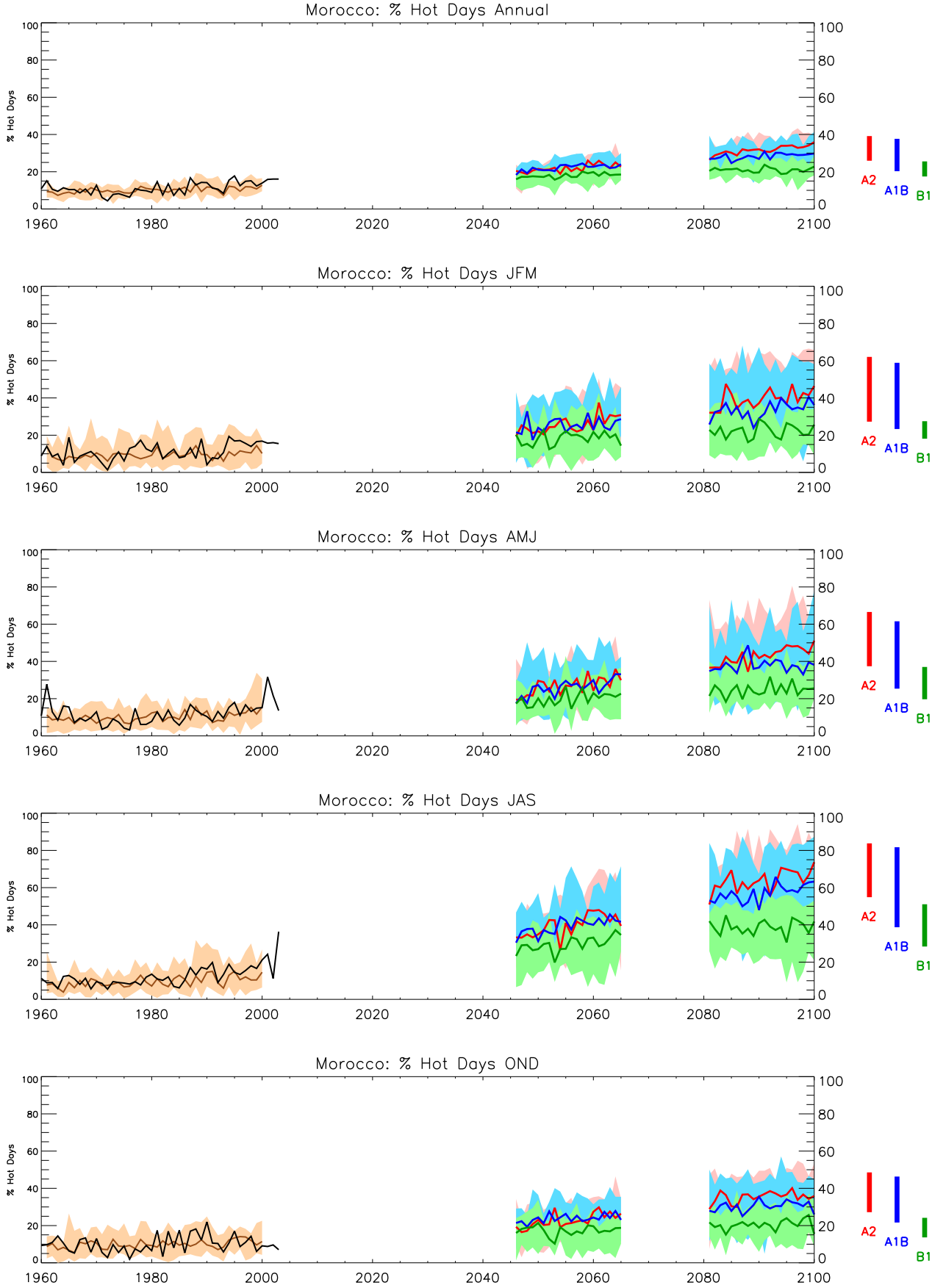
Figure 7: Trends in Hot-day frequency for the recent past and projected future. See Figure 1 for details.
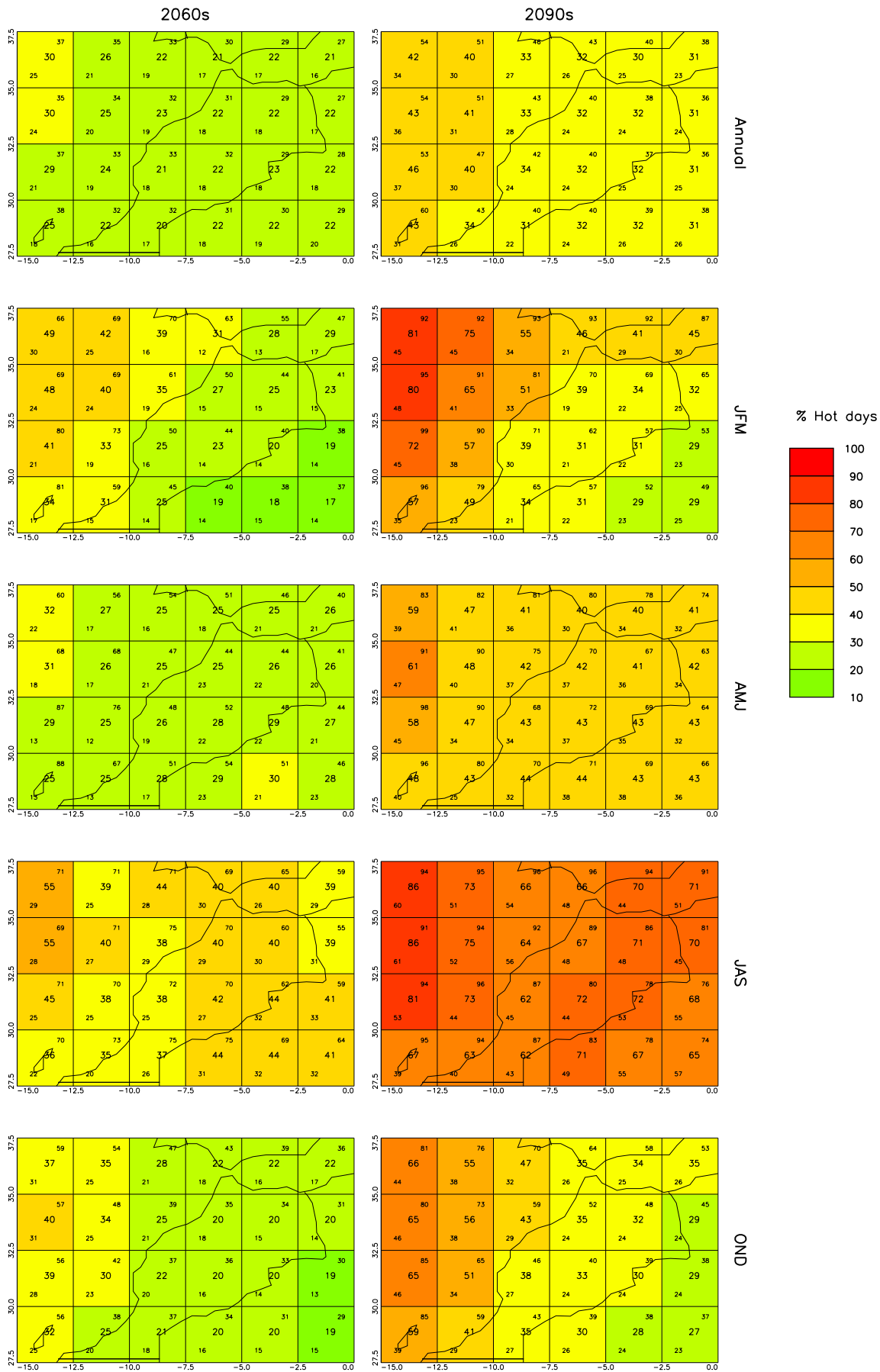
Figure 8: Spatial patterns of projected change in Hot-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.
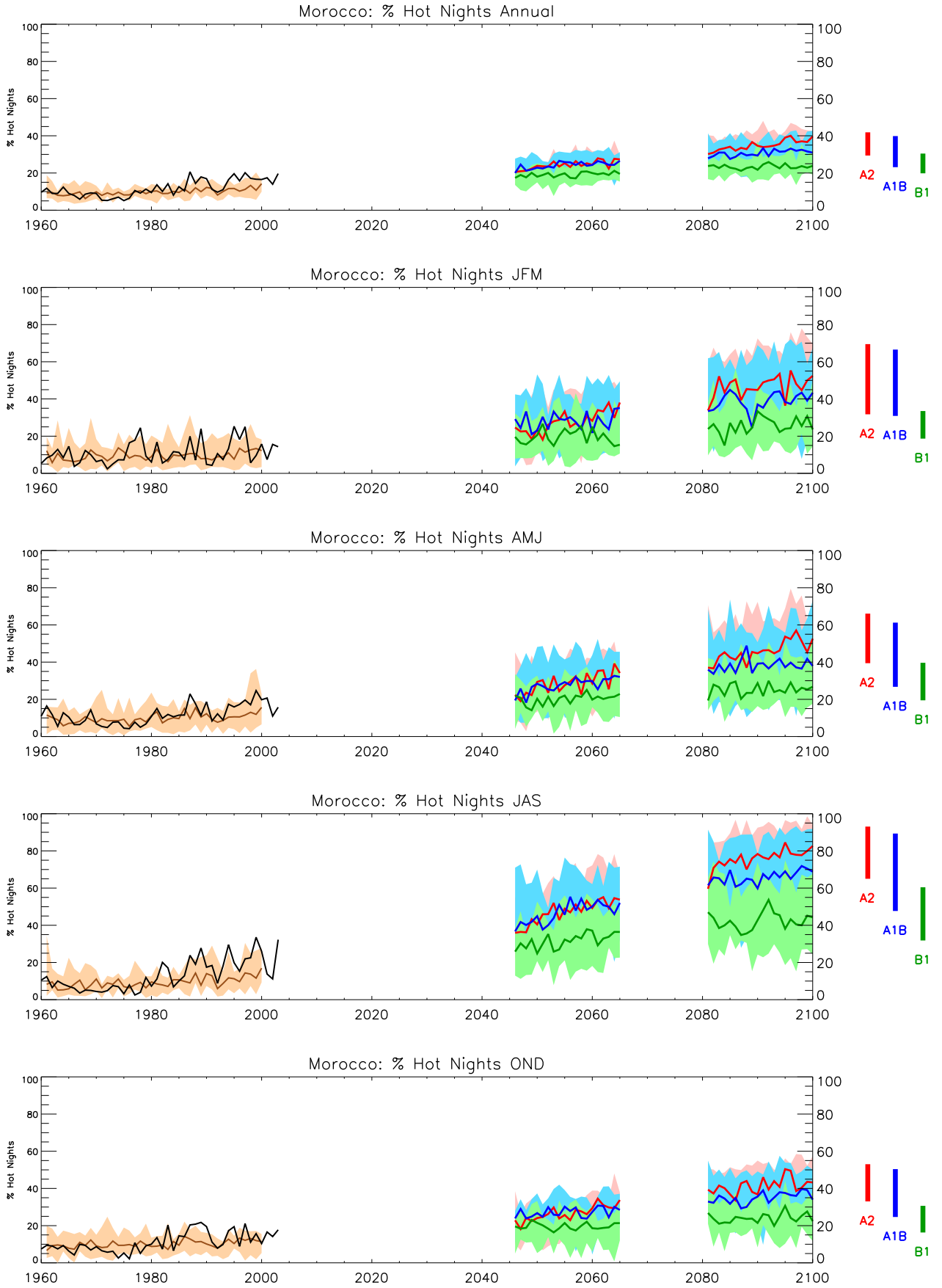
Figure 9: Trends in hot-night frequency for the recent past and projected future. See Figure 1 for details.
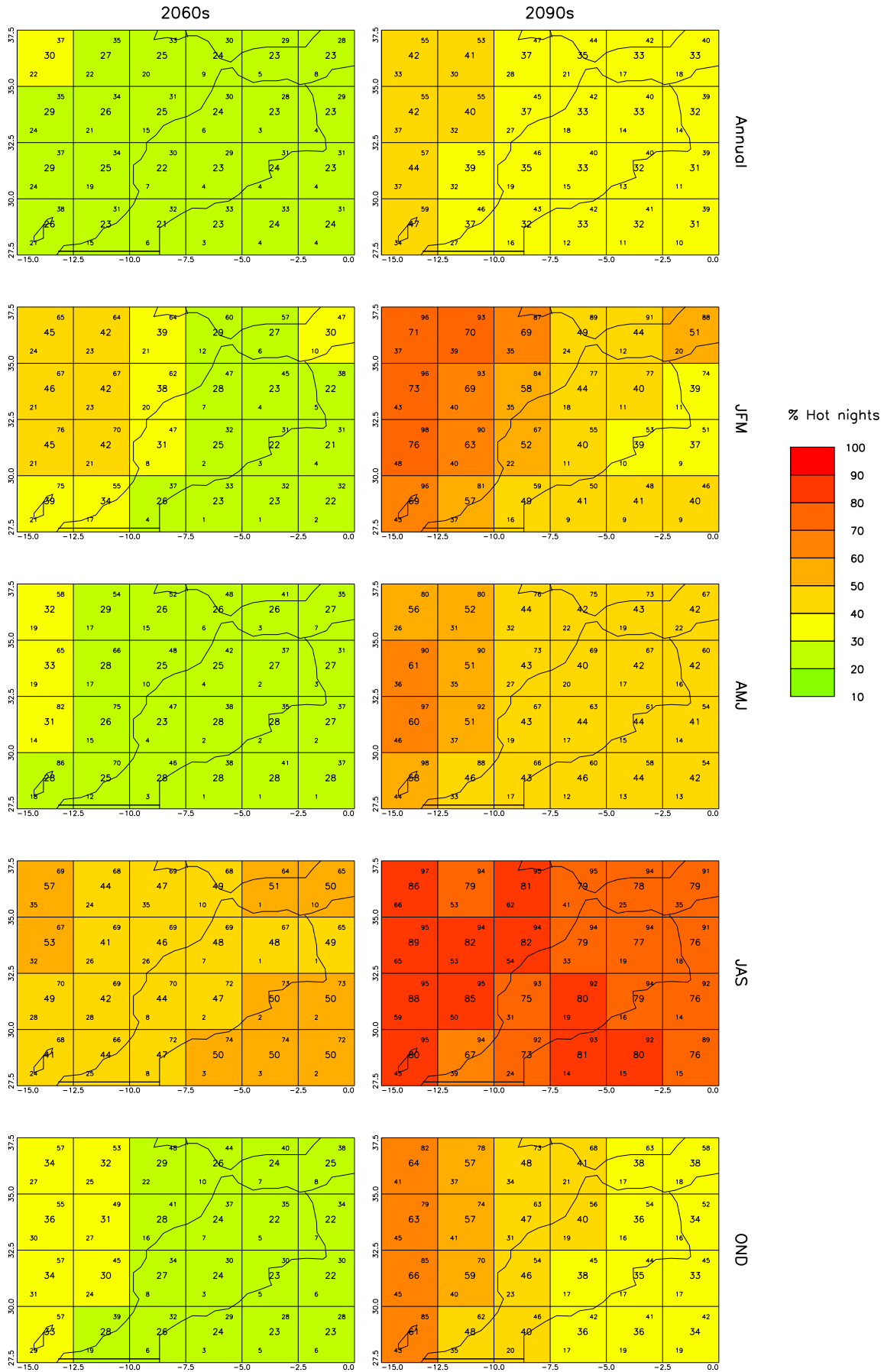
Figure 10: Spatial patterns of projected change in hot-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.
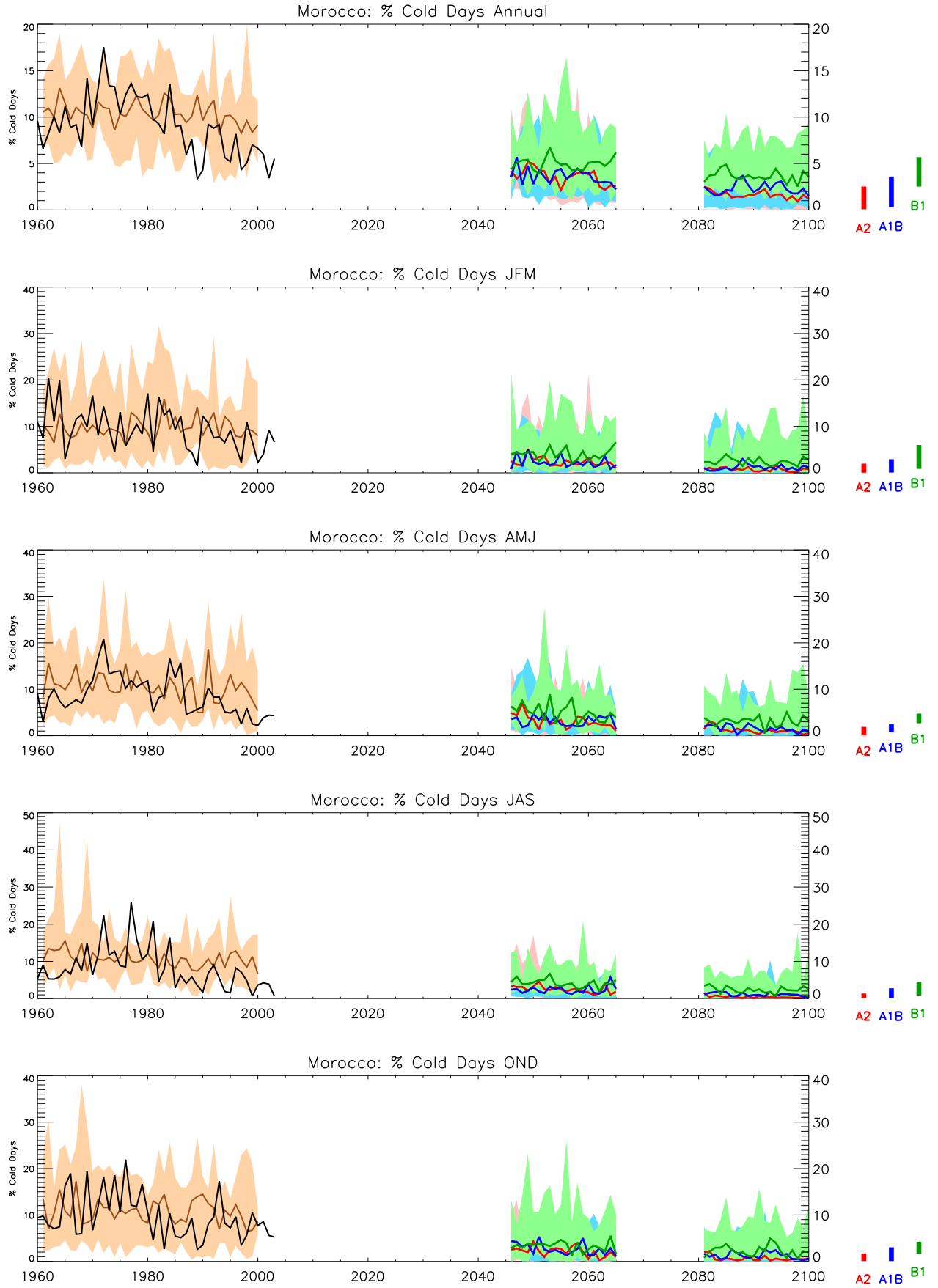
Figure 11: Trends in cold-day frequency for the recent past and projected future. See Figure 1 for details.
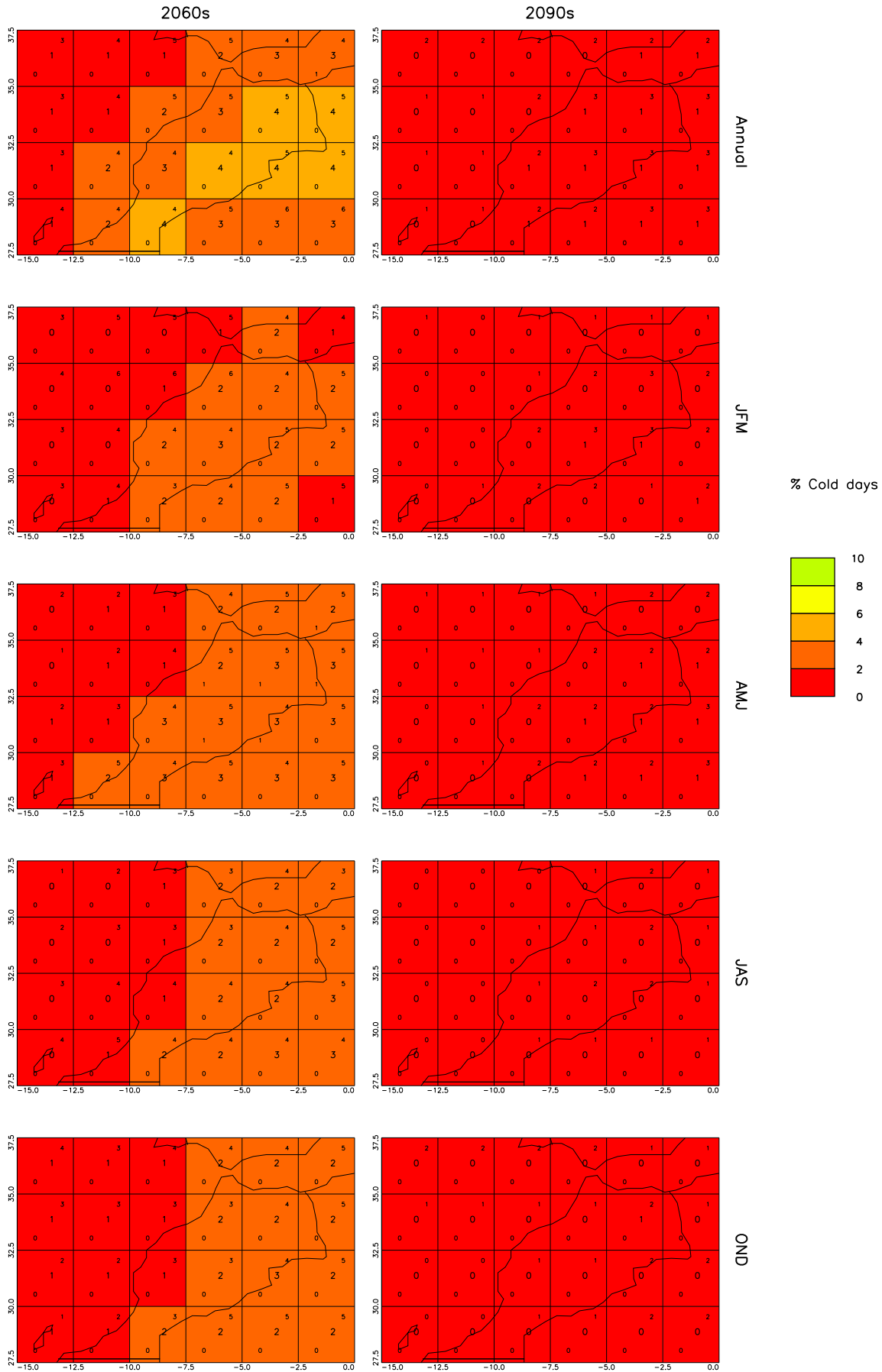
Figure 12: Spatial patterns of projected change in cold-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.
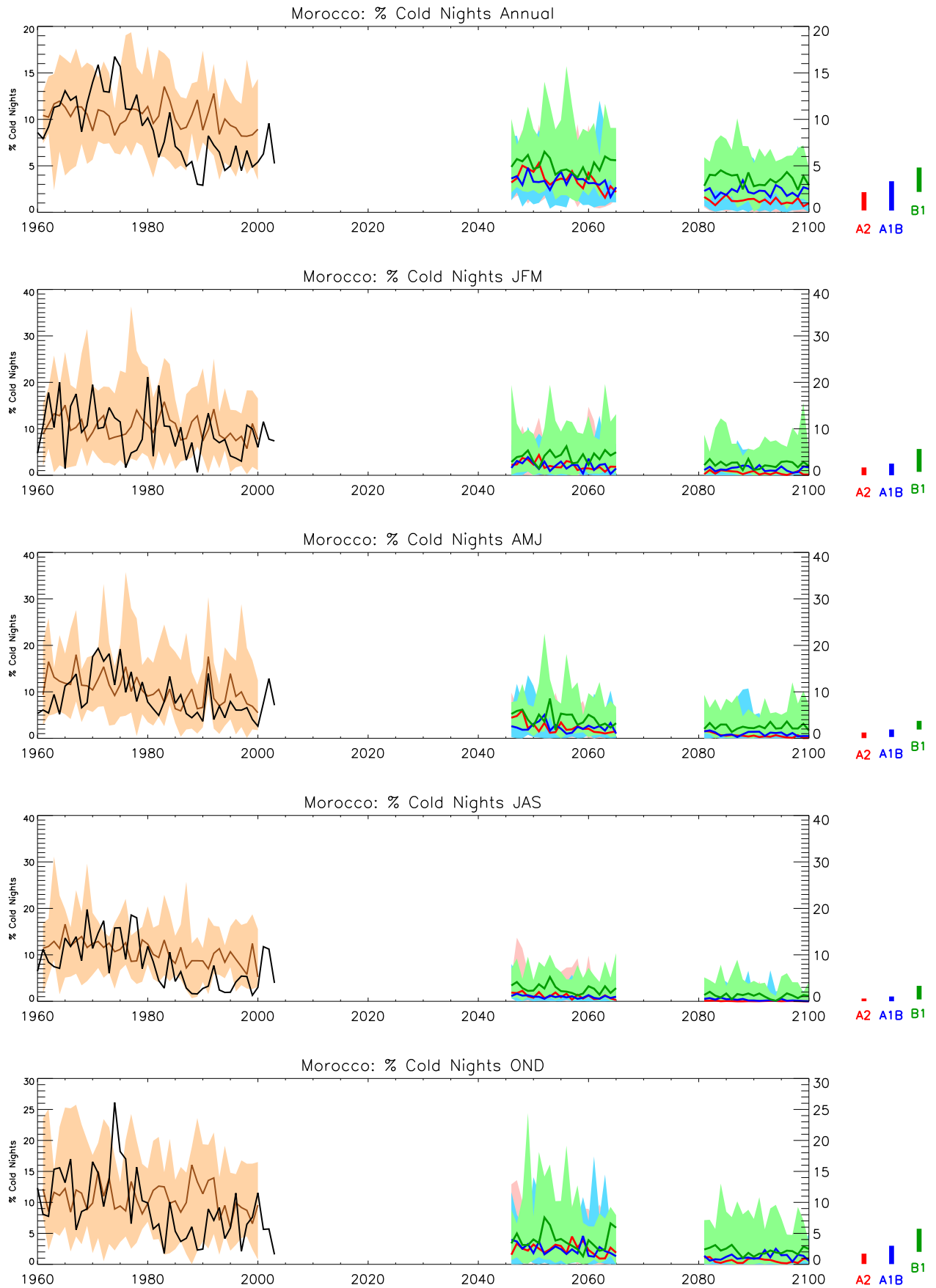
Figure 13: Trends in cold-night frequency for the recent past and projected future. See Figure 1 for details.
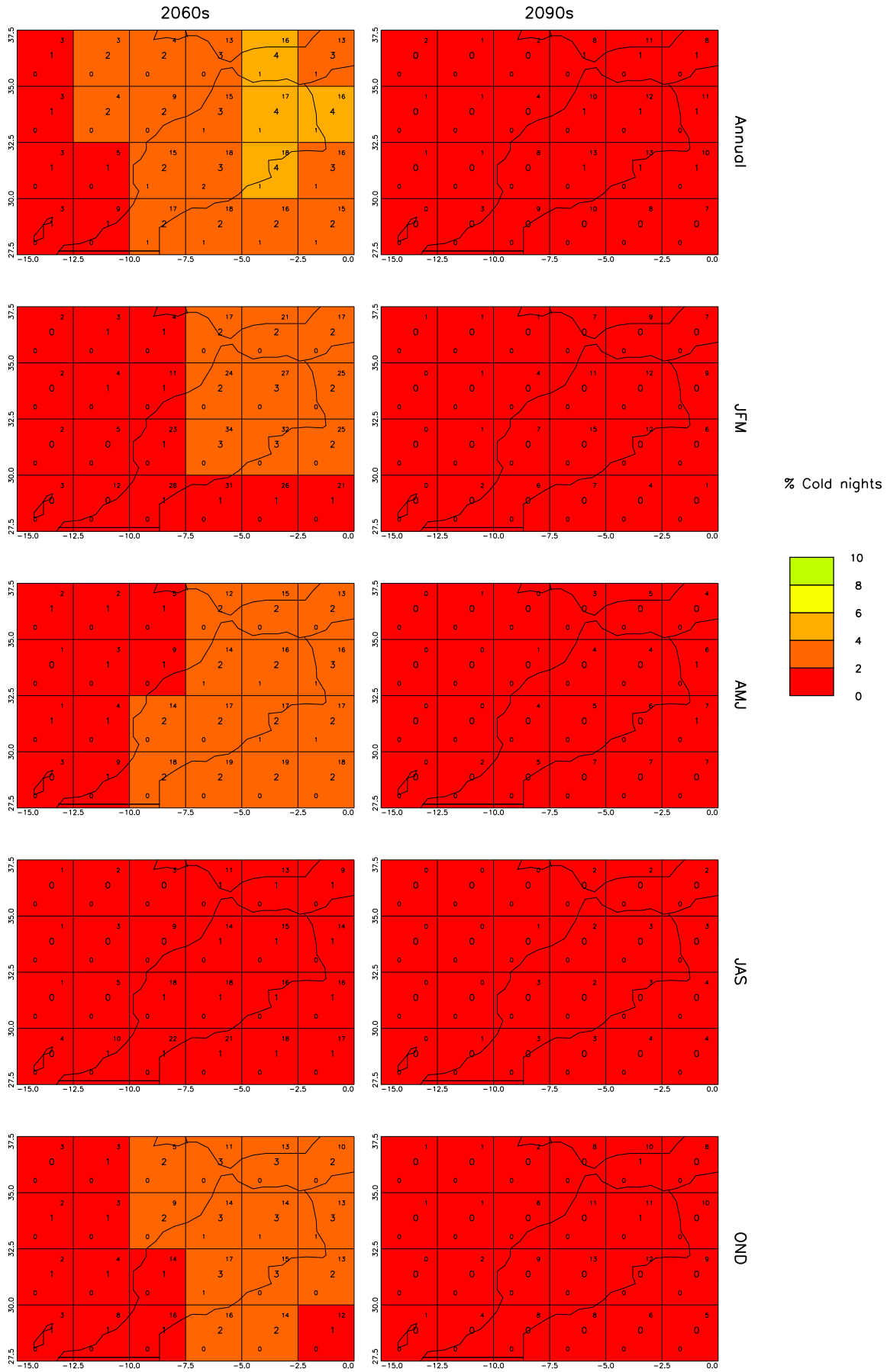
Figure 14: Spatial patterns of projected change in cold-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.
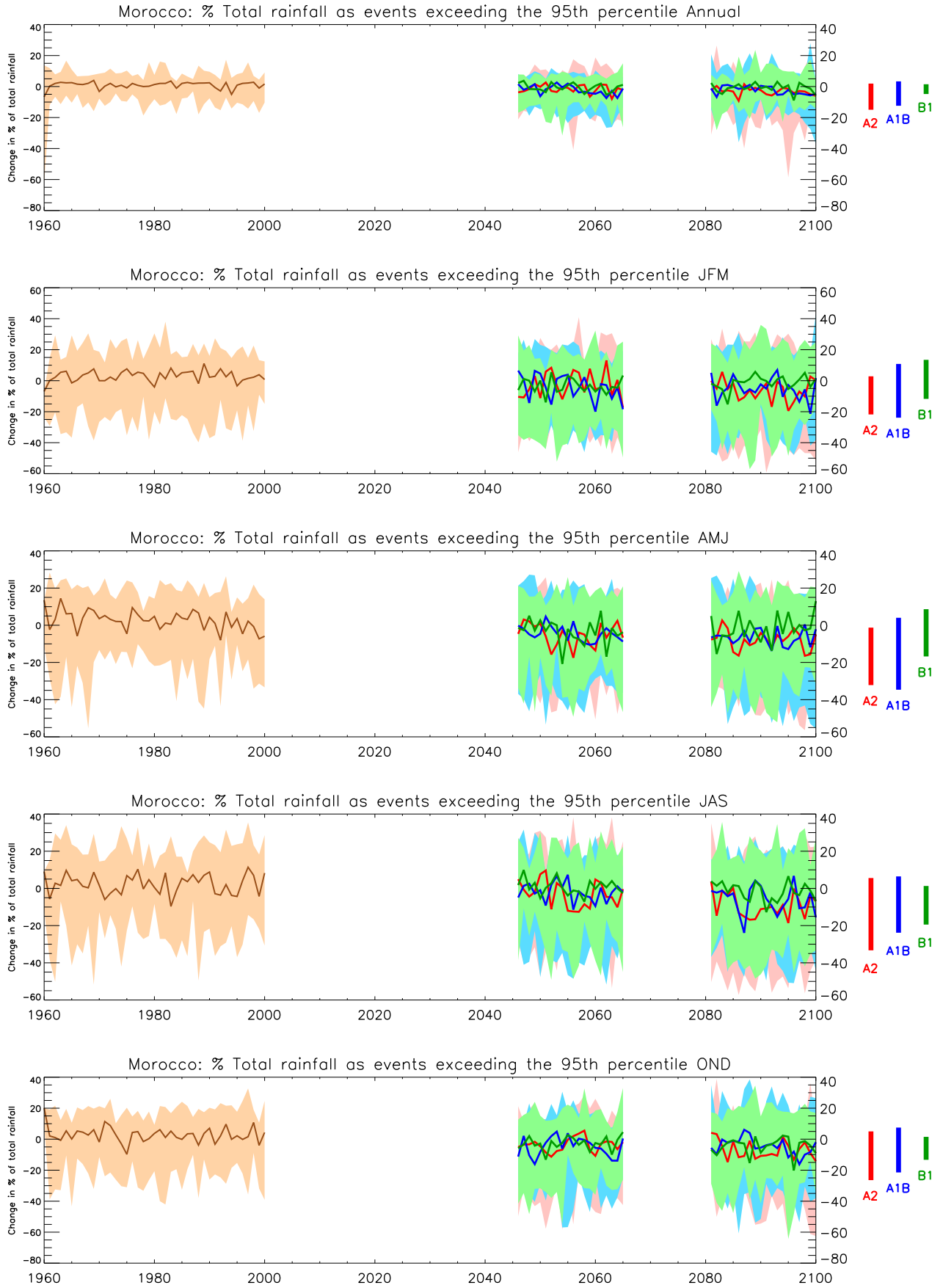
Figure 15: Trends in the proportion of precipitation falling in 'heavy' events for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.
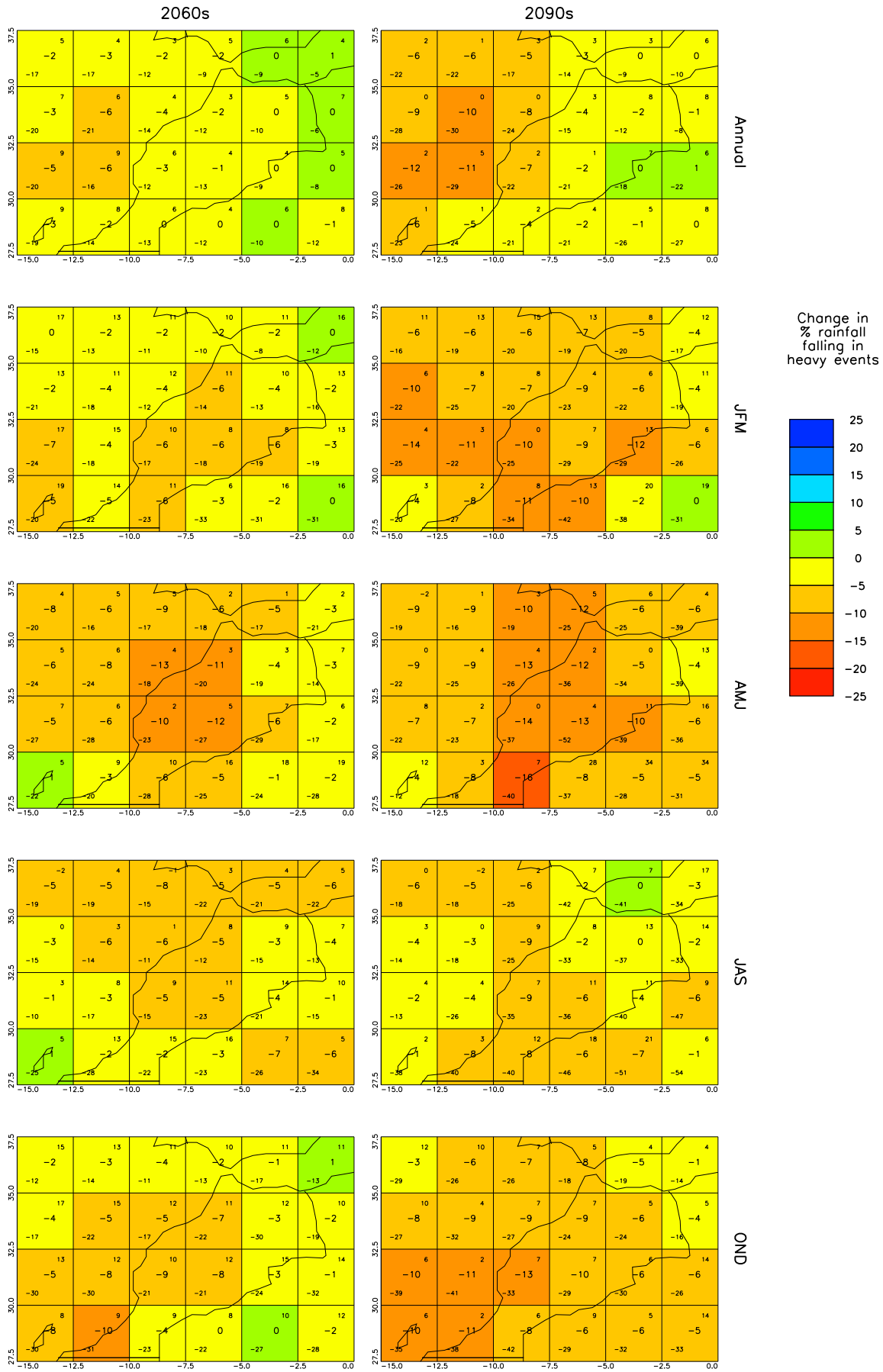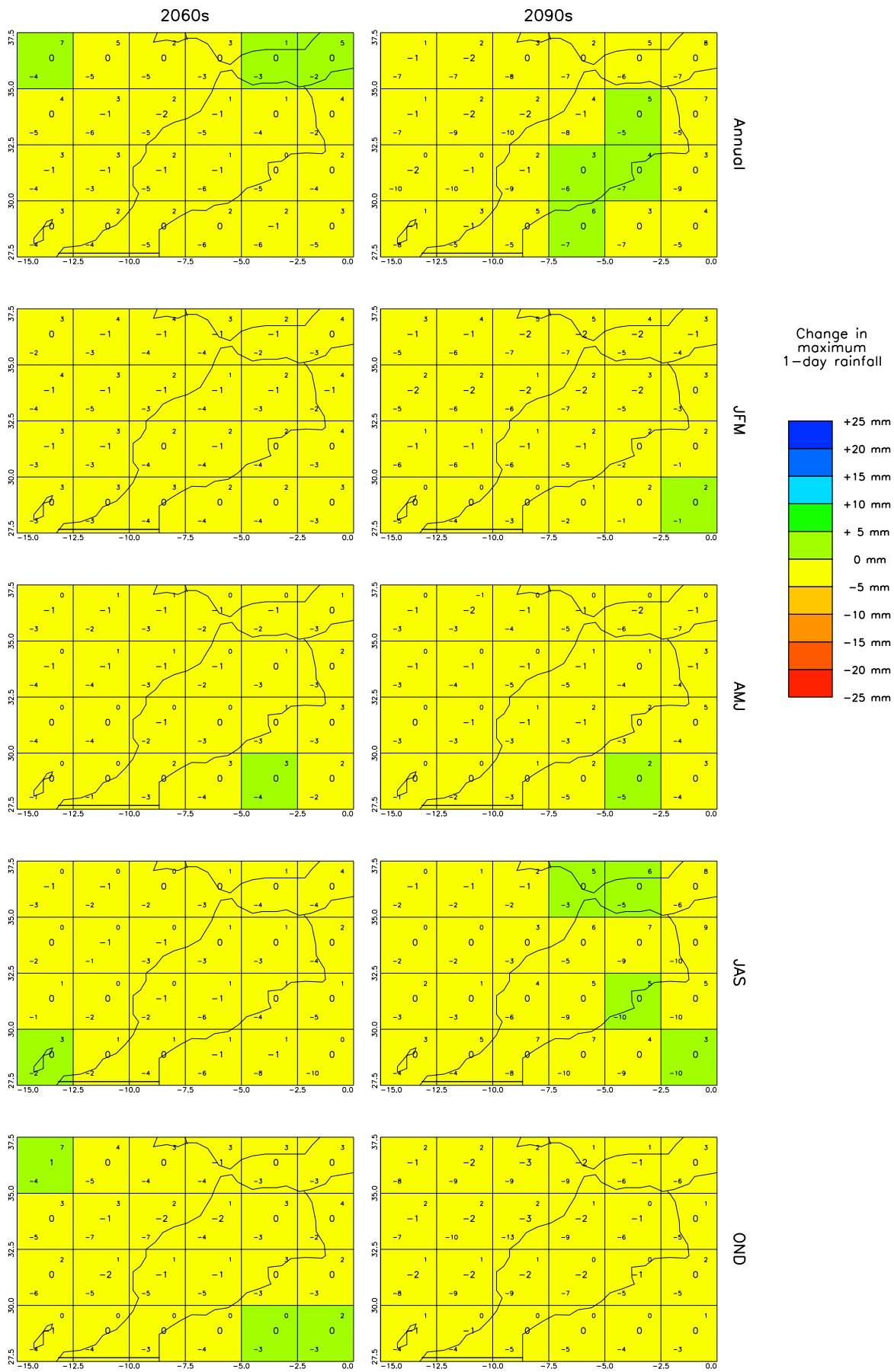
Figure 16: Spatial patterns of projected change in the proportion of precipitation falling in 'heavy' events for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.
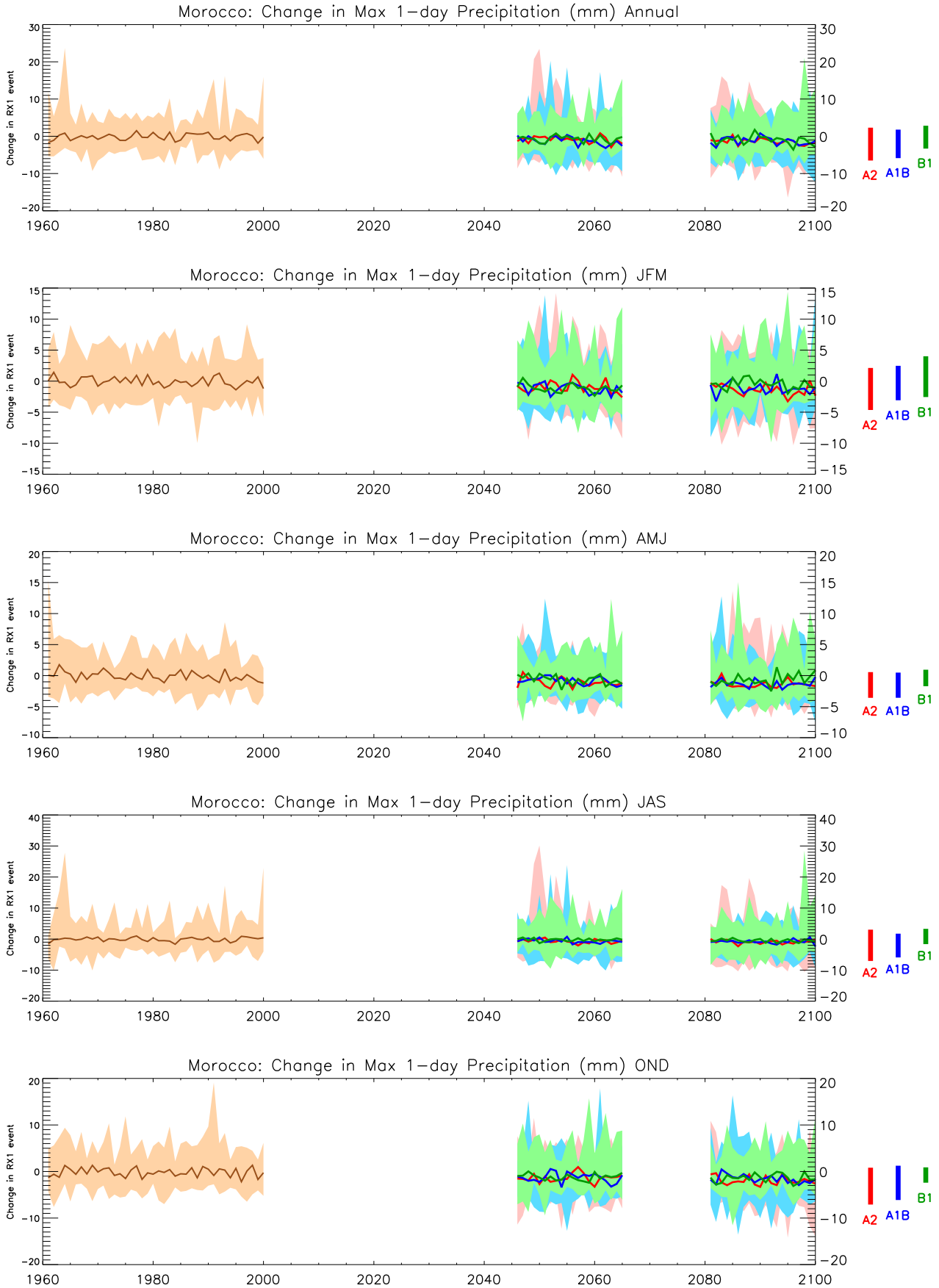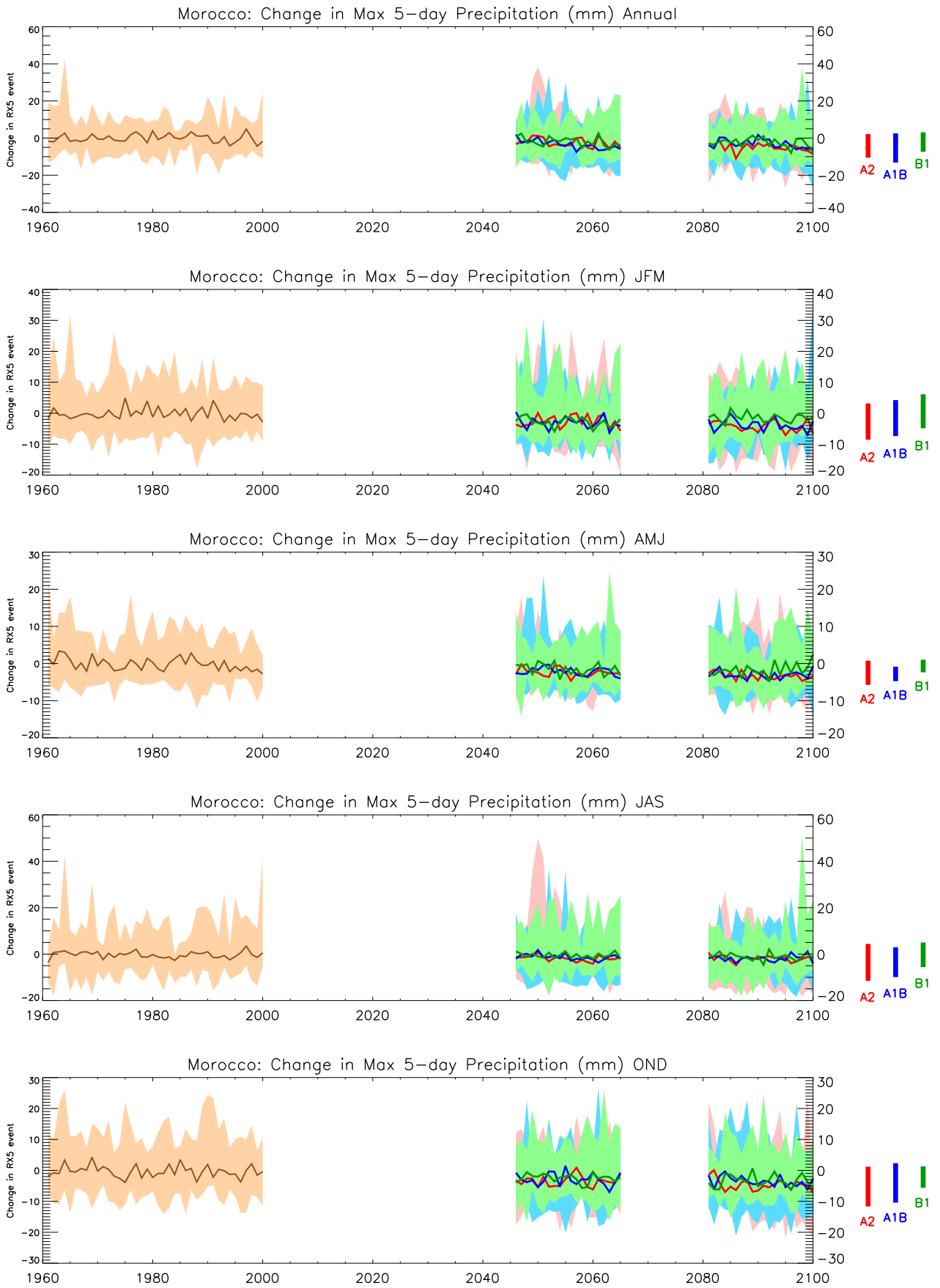
Figure 17: Trends in maximum 1-day rainfall for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

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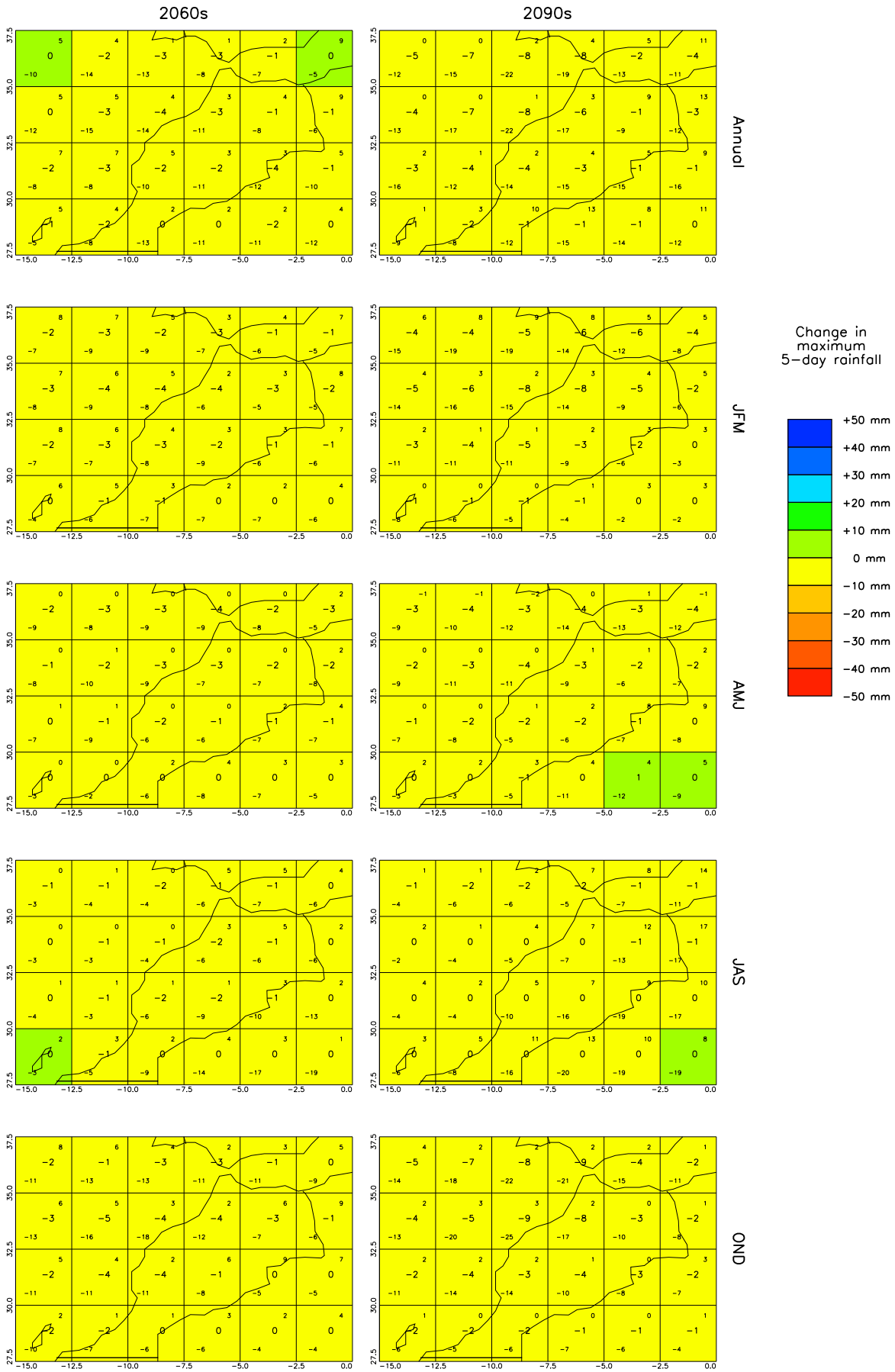
Figure 20: Spatial patterns of projected change in maximum 5-day rainfall for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.