UNDP Climate Change Country Profiles

Kenya

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

Kenya is located in east Africa, at latitudes of 6˚S to 6˚N. Its climate is tropical, but moderated by diverse topography in the west. Kenya's topography rises from the coastal plains to the eastern edge of the East African Plateau, and the Great Rift Valley. The central highland regions are substantially cooler than the coast, with the coolest (highest altitude) regions at 15˚C compared with 29˚C at the coast. Temperatures vary little throughout the year, but drop by around 2 degree in the coolest season, JJAS.

Seasonal rainfall in Kenya is driven mainly by the migration of the Inter-Tropical Convergence Zone (ITCZ), relatively narrow belt of very low pressure and heavy precipitation that forms near the earth's equator. The exact position of the ITCZ changes over the course of the year, migrating southwards through Kenya in October to December, and returning northwards in March, April and May. This causes the Kenya to experience two distinct wet periods – the 'short' rains in October to December and the 'long' rains in March to May. The amount of rainfall received in these seasons is generally 50-200mm per month but varies greatly, exceeding 300mm per month in some localities. The onset, duration and intensity of these rainfalls also vary considerably from year to year. The movements of the ITCZ are sensitive to variations in Indian Ocean sea-surface temperatures and vary from year to year. One of the most well documented ocean influences on rainfall in this region is the El Niño Southern Oscillation (ENSO). El Niño episodes usually cause greater than average rainfalls in the short rainfall season (OND), whilst cold phases (La Niña) bring a drier than average season.

Recent Climate Trends

Temperature

- Mean annual temperature has increased by 1.0˚C since 1960, an average rate of 0.21˚C per decade. This increase in temperature has been most rapid in MAM (0.29˚C per decade) and slowest in JJAS (0.19˚C per decade).

- Daily temperature observations show significantly increasing trends in the frequency of hot days[1], and much large increasing trends in the frequency of hot nights.
    - The average number of 'hot' days per year in Kenya has increased by 57 (an additional 15.6% of days[2]) between 1960 and 2003. The rate of increase is seen most strongly in MAM when the average number of hot MAM days has increased by 5.8 days per month (an additional 18.8% of MAM days) over this period.
    - The average number of 'hot' nights per year increased by 113 (an additional 31% 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 12 days per month (an additional 38.2% of SON nights) over this period.
- The frequency of cold[3] days has decreased significantly in annual and SON records. The frequency of cold nights has, however, decreased more rapidly and significantly in all seasons.
    - The average number of 'cold 'days per year has decreased by 16 (4.4% of days) between 1960 and 2003. This rate of decrease is most rapid in SON when the average number of cold SON days has decreased by 1.8 days per month (5.7% of SON days) over this period.
    - The average number of 'cold' nights per year has decreased by 42 (11.5% of days). This rate of decrease is most rapid in DJF when the average number of cold DJF nights has decreased by 3.5 nights per month (11.4% of DJF nights) over this period.

Precipitation

- Observations of rainfall over Kenya since 1960 do not show statistically significant trends.

- Trends in the extreme indices based on daily rainfall data are mixed. There is an increasing, but no statistically significant trend in the proportion of rainfall occurring in heavy[4] events. 1- and 5-day rainfall maxima show inconsistent trends.

[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] 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.

[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.

GCM Projections of Future Climate

Temperature

- The mean annual temperature is projected to increase by 1.0 to 2.8˚C by the 2060s, and 1.3 to 4.5˚C by the 2090s. The range of projections by the 2090s under any one emissions scenario is 1.5-2.0˚C.

- All projections indicate increases in the frequency of days and nights that are considered 'hot' in current climate.
    - Annually, projections indicate that 'hot' days will occur on 17-45% of days by the 2060s, and 23-75% of days by the 2090s.
    - Nights that are considered 'hot' for the annual climate of 1970-99 are projected to increase more quickly that hot days, occurring on 32-75% of nights by the 2060s and 40-95% of nights by the 2090s.
- All projections indicate decreases in the frequency of days and nights that are considered 'cold' in current climate. These events are expected to become exceedingly rare, and do not occur at all under the highest emissions scenarios (A2 and A1B) by the 2090s.

Precipitation

- Projections of mean rainfall are consistent in indicating increases in annual rainfall in Kenya. The ensemble range spans changes of -1 to +48% by the 2090s.
- Projected increases in total rainfall are largest in OND (-3 to +49mm per month), but the proportional changes are largest in JF (-7 to +89%).

- The models consistently project increases in the proportion of annual rainfall that falls in heavy events. The increases range from 1 to 13% in annual rainfall by the 2090s.
- The models consistently project increases in 1- and 5-day rainfall annual maxima by the 2090s of up to 25mm in 1-day events, and 3 to 32mm in 5-day events.

Other Regional Climate Change Information

- Model simulations show wide disagreements in projected changes in the amplitude of future El Niño events (Christensen *et al.*, 2007). East Africa's seasonal rainfall can be strongly influenced by ENSO, and this contributes to uncertainty in climate projections, particularly in the future inter-annual variability, for this region.

- 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*).

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	0.9	**1.2**	1.5	1.8	**2.4**	2.8	2.8	**3.7**	4.5
Annual	23.9	0.21*	*A1B*	0.8	**1.2**	1.5	1.6	**2.3**	2.7	2.3	**3.0**	4.0
			B1	0.5	**1.0**	1.2	1.0	**1.7**	2.0	1.3	**2.0**	2.6
			A2	0.7	**1.2**	1.6	1.4	**2.2**	3.1	2.4	**3.6**	4.6
JF	25.1	0.22*	*A1B*	0.6	**1.1**	1.6	1.7	**2.3**	2.8	2.1	**3.1**	4.1
			B1	0.4	**1.0**	1.3	1.0	**1.5**	2.2	1.1	**1.9**	2.6
			A2	1.0	**1.2**	1.8	1.8	**2.4**	2.7	2.9	**3.8**	4.5
MAM	24.6	0.29*	*A1B*	0.5	**1.3**	1.6	1.6	**2.3**	2.7	2.3	**3.0**	3.9
			B1	0.5	**1.0**	1.5	1.1	**1.6**	2.0	1.4	**2.1**	2.8
			A2	0.9	**1.2**	1.6	1.9	**2.5**	2.8	3.0	**3.9**	4.7
JJAS	22.7	0.17*	*A1B*	0.8	**1.3**	1.7	1.6	**2.4**	2.7	2.3	**3.2**	4.4
			B1	0.6	**1.1**	1.3	1.0	**1.7**	2.1	1.5	**2.1**	2.7
			A2	0.6	**1.1**	1.3	1.7	**2.2**	2.8	2.6	**3.4**	4.3
OND	23.9	0.19*	*A1B*	0.8	**1.1**	1.3	1.4	**2.1**	2.6	2.0	**2.7**	3.8
			B1	0.2	**0.9**	1.2	0.8	**1.5**	2.0	1.2	**1.8**	2.5
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	-1	**3**	11	0	**5**	20	3	**13**	27
Annual	57.3	-1.5	*A1B*	-3	**4**	12	0	**7**	16	1	**10**	21
			B1	-3	**2**	10	-4	**4**	10	-1	**5**	15
			A2	-8	**2**	11	0	**5**	23	0	**17**	30
JF	29.0	-1.0	*A1B*	-3	**6**	17	-2	**3**	25	-4	**10**	20
			B1	-11	**2**	17	-3	**6**	14	-3	**5**	19
			A2	-12	**3**	18	-12	**9**	31	-12	**15**	47
MAM	95.7	-3.7	*A1B*	-8	**7**	21	-7	**9**	29	-13	**12**	35
			B1	-13	**0**	19	-8	**2**	23	-7	**5**	23
			A2	-5	**0**	12	-5	**0**	12	-2	**3**	22
JJAS	34.6	-0.8	*A1B*	-8	**0**	6	-5	**1**	11	-3	**1**	13
			B1	-4	**0**	7	-8	**0**	8	-4	**2**	6
			A2	0	**11**	19	-3	**13**	33	5	**29**	49
OND	67.2	-0.6	*A1B*	-6	**8**	29	0	**9**	30	6	**21**	32
			B1	-5	**4**	22	-8	**12**	19	-3	**13**	37
Precipitation (%)												
	(mm per month)	*(change in % per decade)*		*% Change*			*% Change*			*% Change*		
			A2	-2	**5**	14	0	**8**	24	5	**20**	48
Annual	57.3	-2.6	*A1B*	-5	**6**	17	0	**8**	26	2	**15**	30
			B1	-3	**2**	12	-6	**6**	19	-1	**10**	19
			A2	-11	**6**	26	-3	**11**	49	0	**27**	89
JF	29.0	-3.5	*A1B*	-14	**11**	50	-6	**9**	60	-7	**20**	58
			B1	-16	**5**	21	-4	**12**	43	-5	**16**	29
			A2	-16	**3**	14	-27	**8**	40	-17	**19**	60
MAM	95.7	-3.9	*A1B*	-9	**5**	27	-7	**10**	37	-18	**10**	45
			B1	-17	**0**	26	-7	**3**	31	-5	**4**	37
			A2	-7	**-1**	26	-13	**0**	25	-4	**11**	46
JJAS	34.6	-2.4	*A1B*	-18	**1**	24	-7	**5**	28	-6	**3**	27
			B1	-9	**1**	15	-17	**2**	27	-8	**5**	17
			A2	0	**11**	16	-4	**13**	32	6	**27**	48
OND	67.2	-0.8	*A1B*	-4	**8**	20	0	**12**	29	7	**19**	36
			B1	-6	**4**	29	-9	**12**	18	-2	**14**	26

	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	****	****	****	18	**36**	45	33	**51**	75
Annual	13.7	3.62*	*A1B*	****	****	****	19	**33**	45	26	**44**	69
			B1	****	****	****	17	**28**	33	23	**32**	49
			A2	****	****	****	26	**45**	68	39	**60**	86
JF	13.6	(3.26*)	*A1B*	****	****	****	21	**47**	66	33	**59**	85
(DJF)			*B1*	****	****	****	24	**38**	48	27	**44**	71
			A2	****	****	****	25	**44**	59	35	**53**	80
MAM	14.9	4.38*	*A1B*	****	****	****	23	**40**	61	30	**50**	83
			B1	****	****	****	22	**35**	49	25	**45**	65
			A2	****	****	****	27	**49**	60	44	**71**	90
JJAS	14.1	(4.25*)	*A1B*	****	****	****	28	**50**	63	38	**65**	87
(JJA)			*B1*	****	****	****	23	**39**	46	31	**51**	66
			A2	****	****	****	22	**32**	58	34	**46**	79
OND	14.6	4.26*	*A1B*	****	****	****	23	**32**	55	30	**43**	72
			B1	****	****	****	19	**26**	40	26	**32**	58
Frequency of Hot Nights (TN90p)												
			A2	****	****	****	46	**53**	74	77	**86**	95
Annual	16.1	7.21*	*A1B*	****	****	****	45	**56**	75	64	**77**	93
			B1	****	****	****	32	**43**	59	40	**56**	73
			A2	****	****	****	53	**65**	88	84	**92**	99
JF	15.6	(6.36*)	*A1B*	****	****	****	51	**66**	86	70	**82**	97
(DJF)			*B1*	****	****	****	37	**49**	70	48	**61**	85
			A2	****	****	****	54	**66**	92	84	**92**	99
MAM	16.7	7.42*	*A1B*	****	****	****	47	**66**	94	73	**82**	98
			B1	****	****	****	38	**53**	69	45	**71**	89
			A2	****	****	****	55	**64**	84	85	**94**	98
JJAS	16.8	(7.05*)	*A1B*	****	****	****	55	**66**	89	77	**87**	96
(JJA)			*B1*	****	****	****	41	**47**	68	46	**68**	81
			A2	****	****	****	47	**65**	91	79	**92**	99
OND	17.4	8.89*	*A1B*	****	****	****	52	**65**	93	66	**83**	96
			B1	****	****	****	35	**52**	75	41	**67**	89
Frequency of Cold Days (TX10p)												
			A2	****	****	****	1	**2**	5	0	**0**	3
Annual	7.8	-1.03*	*A1B*	****	****	****	1	**2**	5	0	**1**	4
			B1	****	****	****	2	**4**	6	1	**3**	5
			A2	****	****	****	1	**5**	8	0	**1**	4
JF	8.0	(-1.03)	*A1B*	****	****	****	1	**3**	7	0	**2**	6
(DJF)			*B1*	****	****	****	2	**5**	7	1	**3**	6
			A2	****	****	****	1	**1**	7	0	**0**	4
MAM	8.1	-0.71	*A1B*	****	****	****	1	**2**	6	0	**1**	5
			B1	****	****	****	1	**3**	6	1	**2**	6
			A2	****	****	****	1	**2**	4	0	**0**	3
JJAS	7.9	(-0.71)	*A1B*	****	****	****	1	**2**	4	0	**1**	4
(JJA)			*B1*	****	****	****	2	**5**	6	1	**3**	4
			A2	****	****	****	0	**2**	4	0	**0**	2
OND	7.4	-1.33*	*A1B*	****	****	****	1	**2**	4	0	**1**	3
			B1	****	****	****	2	**4**	5	0	**2**	5
Frequency of Cold Nights (TN10p)												
			A2	****	****	****	0	**0**	0	0	**0**	0
Annual	6.7	-2.67*	*A1B*	****	****	****	0	**0**	1	0	**0**	0
			B1	****	****	****	0	**1**	2	0	**0**	1
			A2	****	****	****	0	**0**	1	0	**0**	0
JF	6.0	(-2.64*)	*A1B*	****	****	****	0	**0**	2	0	**0**	0
(DJF)			*B1*	****	****	****	0	**1**	2	0	**0**	3
			A2	****	****	****	0	**0**	1	0	**0**	0
MAM	6.8	-2.28*	*A1B*	****	****	****	0	**0**	1	0	**0**	0
			B1	****	****	****	0	**1**	2	0	**0**	1
			A2	****	****	****	0	**0**	0	0	**0**	0
JJAS	6.3	(-2.36*)	*A1B*	****	****	****	0	**0**	0	0	**0**	0
(JJA)			*B1*	****	****	****	0	**0**	1	0	**0**	0
			A2	****	****	****	0	**0**	1	0	**0**	0
OND	7.2	-2.36*	*A1B*	****	****	****	0	**0**	1	0	**0**	0
			B1	****	****	****	0	**1**	2	0	**0**	1

	Observed Mean 1970-99	Observed Trend 1960-2006		Projected changes by the 2030s Min	Median	Max	Projected changes by the 2060s Min	Median	Max	Projected changes by the 2090s Min	Median	Max
% total rainfall falling in Heavy Events (R95pct)												
	%	*Change in % per decade*					*Change in %*			*Change in %*		
			A2	****	****	****	1	**5**	8	3	**8**	13
Annual	42.0	2.45	*A1B*	****	****	****	2	**4**	11	2	**6**	12
			B1	****	****	****	-1	**2**	5	1	**4**	10
			A2	****	****	****	-2	**5**	15	-5	**10**	20
JF	****	****	*A1B*	****	****	****	-6	**5**	13	-1	**7**	12
(DJF)			*B1*	****	****	****	-2	**4**	12	-4	**5**	16
			A2	****	****	****	-6	**5**	12	-2	**9**	15
MAM	****	****	*A1B*	****	****	****	-5	**4**	9	0	**5**	14
			B1	****	****	****	-3	**2**	9	0	**5**	15
			A2	****	****	****	-5	**1**	12	-7	**5**	16
JJAS	****	****	*A1B*	****	****	****	0	**3**	7	-3	**2**	9
(JJA)			*B1*	****	****	****	-6	**2**	8	-2	**3**	9
			A2	****	****	****	-3	**6**	11	-3	**11**	17
OND	****	****	*A1B*	****	****	****	0	**6**	14	-4	**6**	15
			B1	****	****	****	0	**4**	6	-1	**5**	11
Maximum 1-day rainfall (RX1day)												
	mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
			A2	****	****	****	0	**4**	15	1	**8**	25
Annual	****	****	*A1B*	****	****	****	0	**2**	15	0	**5**	17
			B1	****	****	****	0	**1**	9	0	**3**	7
			A2	****	****	****	0	**1**	6	-1	**3**	7
JF	26.3	(-2.39*)	*A1B*	****	****	****	-1	**1**	6	0	**2**	6
(DJF)			*B1*	****	****	****	0	**0**	1	-1	**1**	3
			A2	****	****	****	-1	**1**	12	0	**4**	15
MAM	39.4	0.4	*A1B*	****	****	****	-1	**1**	6	0	**2**	12
			B1	****	****	****	-1	**1**	5	0	**2**	4
			A2	****	****	****	-1	**0**	2	0	**1**	5
JJAS	22.1	(3.00*)	*A1B*	****	****	****	0	**1**	6	0	**1**	3
(JJA)			*B1*	****	****	****	-2	**0**	6	0	**1**	1
			A2	****	****	****	0	**2**	13	0	**5**	19
OND	29.5	1.55	*A1B*	****	****	****	0	**3**	14	-1	**4**	14
			B1	****	****	****	0	**1**	9	0	**2**	5
Maximum 5-day Rainfall (RX5day)												
	mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
			A2	****	****	****	0	**8**	23	3	**13**	32
Annual	145.6	-1.11	*A1B*	****	****	****	2	**5**	19	2	**10**	24
			B1	****	****	****	-1	**4**	11	3	**6**	13
			A2	****	****	****	-2	**3**	11	-3	**7**	16
JF	43.6	(1.41)	*A1B*	****	****	****	-1	**4**	8	-1	**5**	12
(DJF)			*B1*	****	****	****	-3	**0**	4	-3	**4**	6
			A2	****	****	****	-6	**5**	18	-2	**11**	18
MAM	77.9	0.39	*A1B*	****	****	****	-5	**5**	8	-1	**7**	19
			B1	****	****	****	-2	**0**	10	-1	**4**	12
			A2	****	****	****	-1	**1**	7	0	**2**	9
JJAS	34.4	(1.03)	*A1B*	****	****	****	-2	**2**	8	-1	**2**	4
(JJA)			*B1*	****	****	****	-6	**1**	10	-1	**1**	5
			A2	****	****	****	-1	**7**	24	-2	**12**	28
OND	49.2	0.51	*A1B*	****	****	****	0	**7**	22	-5	**9**	20
			B1	****	****	****	-2	**3**	13	-1	**6**	10

* 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.

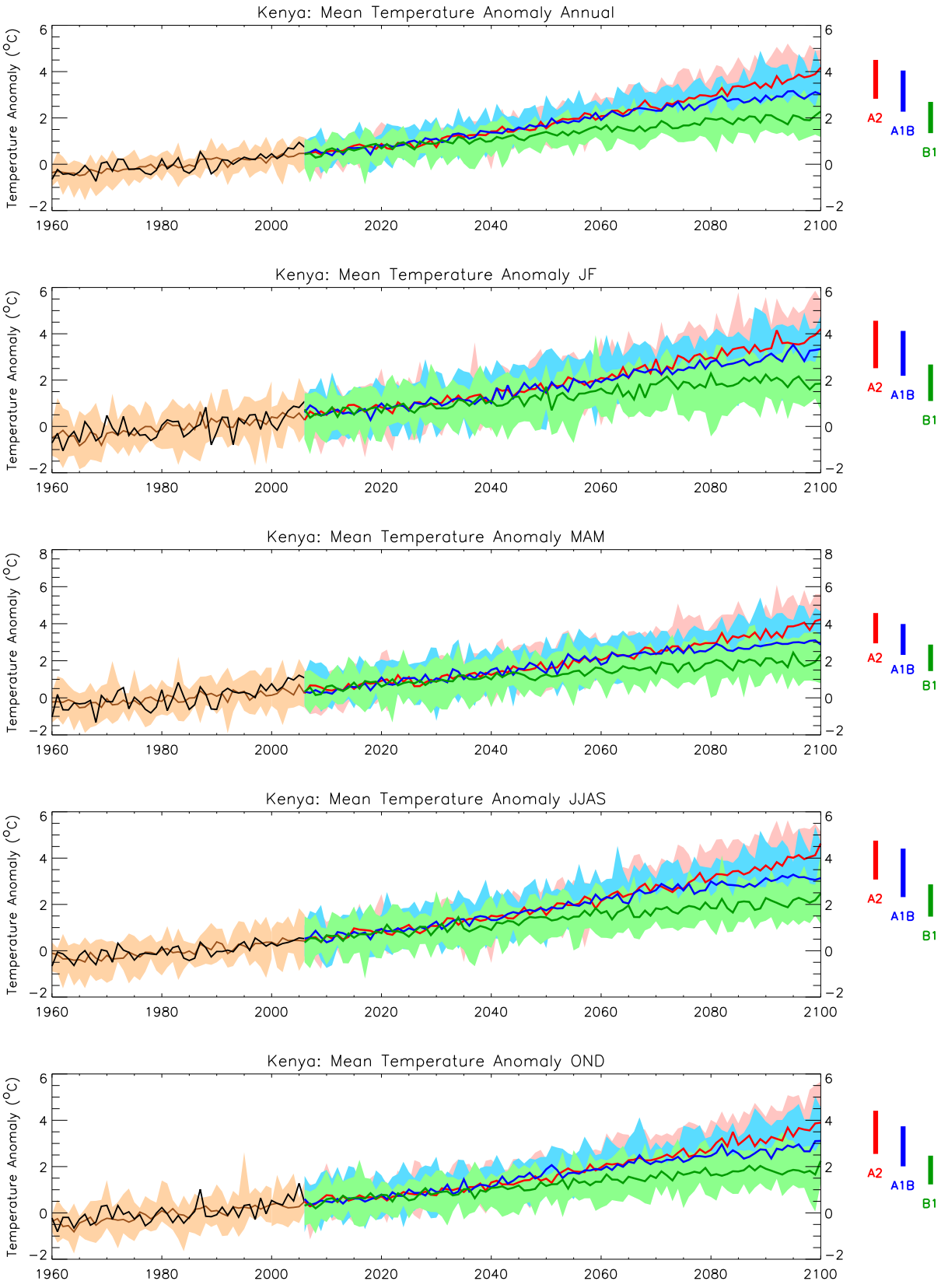

Figure 1: Trends in annual and seasonal mean temperature for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. Black curves show the mean of observed data from 1960 to 2006, Brown curves show the median (solid line) and range (shading) of model 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.

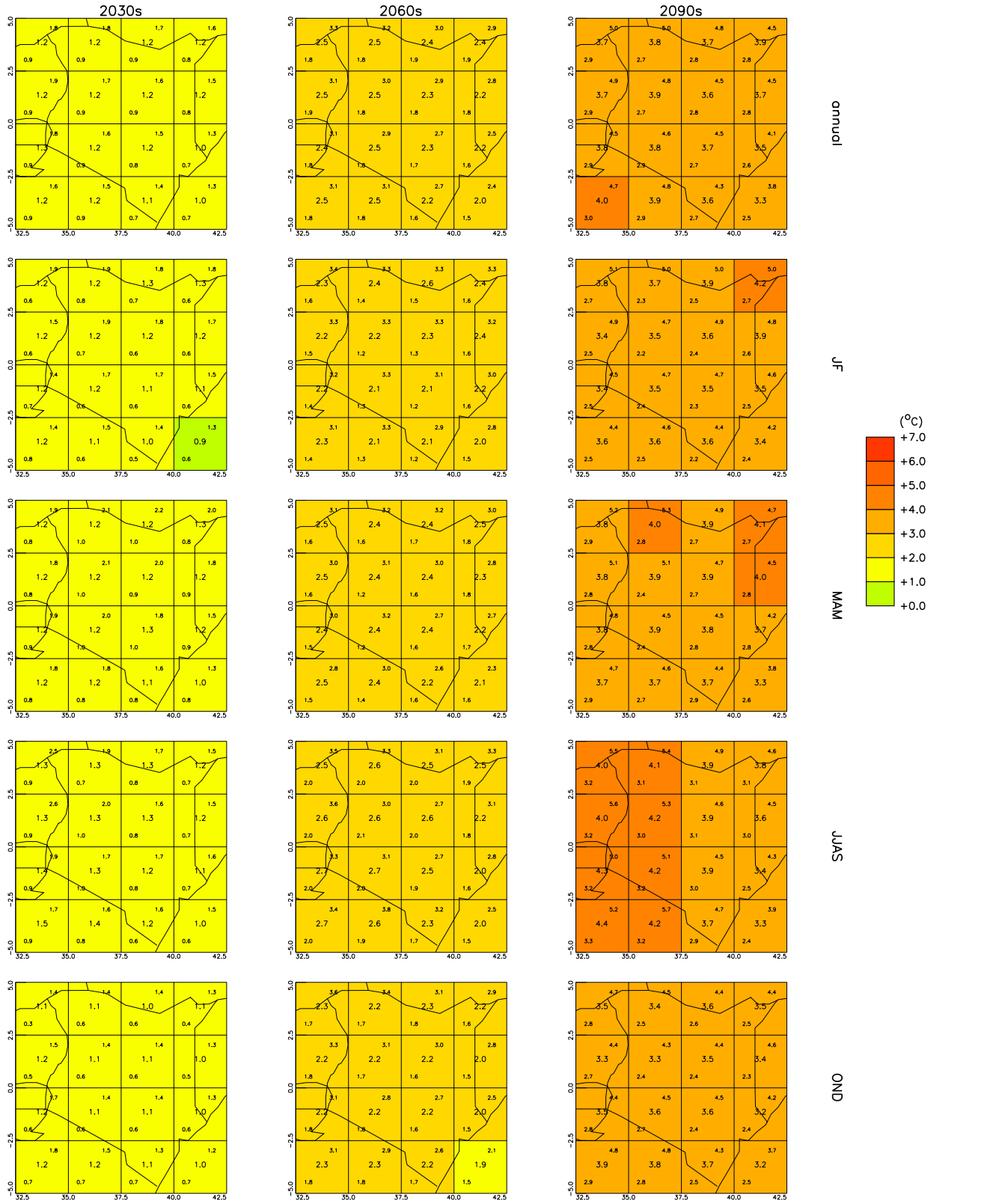

Figure 2: Spatial patterns of projected change in mean annual and seasonal temperature for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. In each grid box, the central value gives the ensemble median and the values in the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

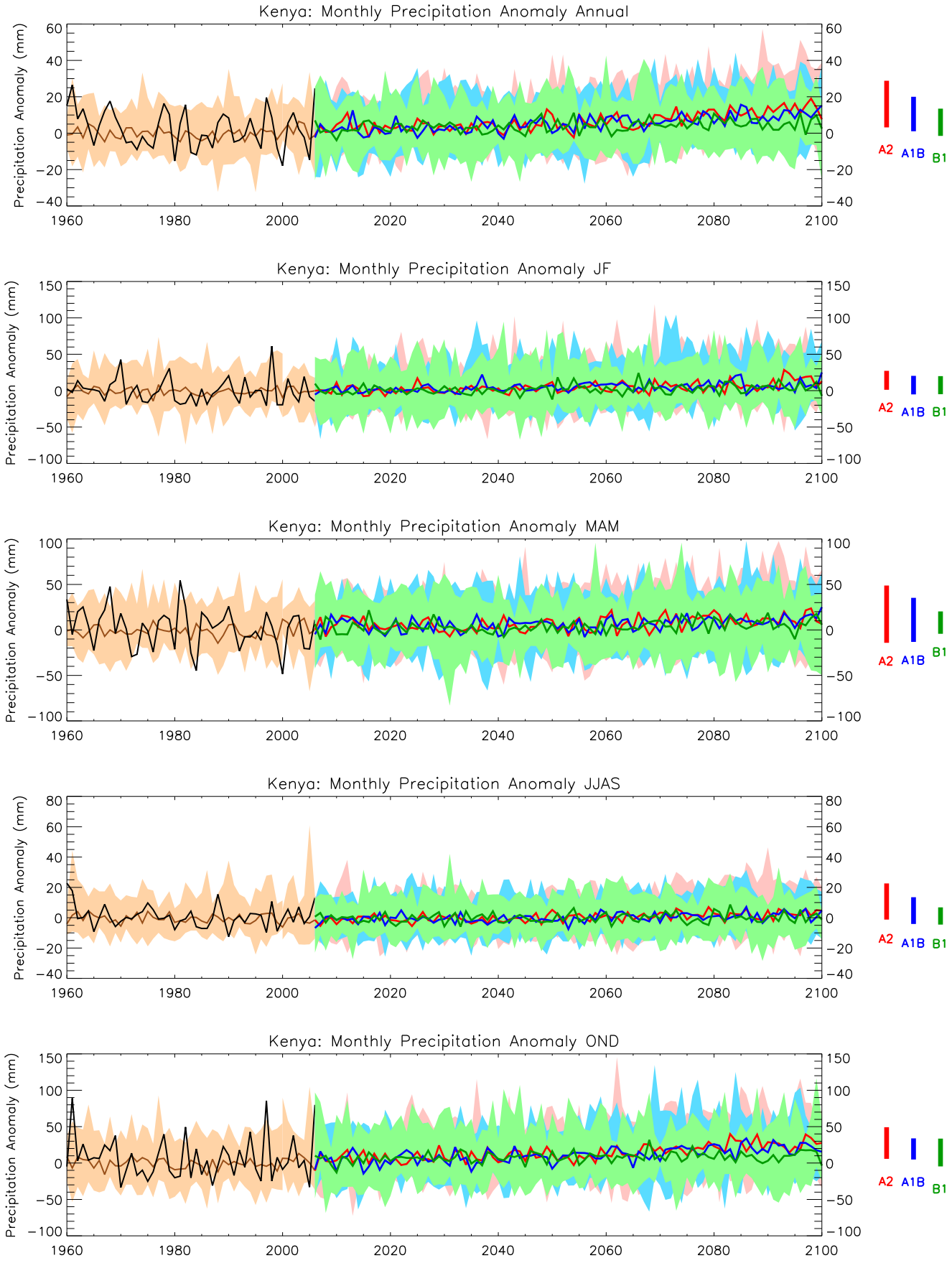

Figure 3: Trends in monthly precipitation for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

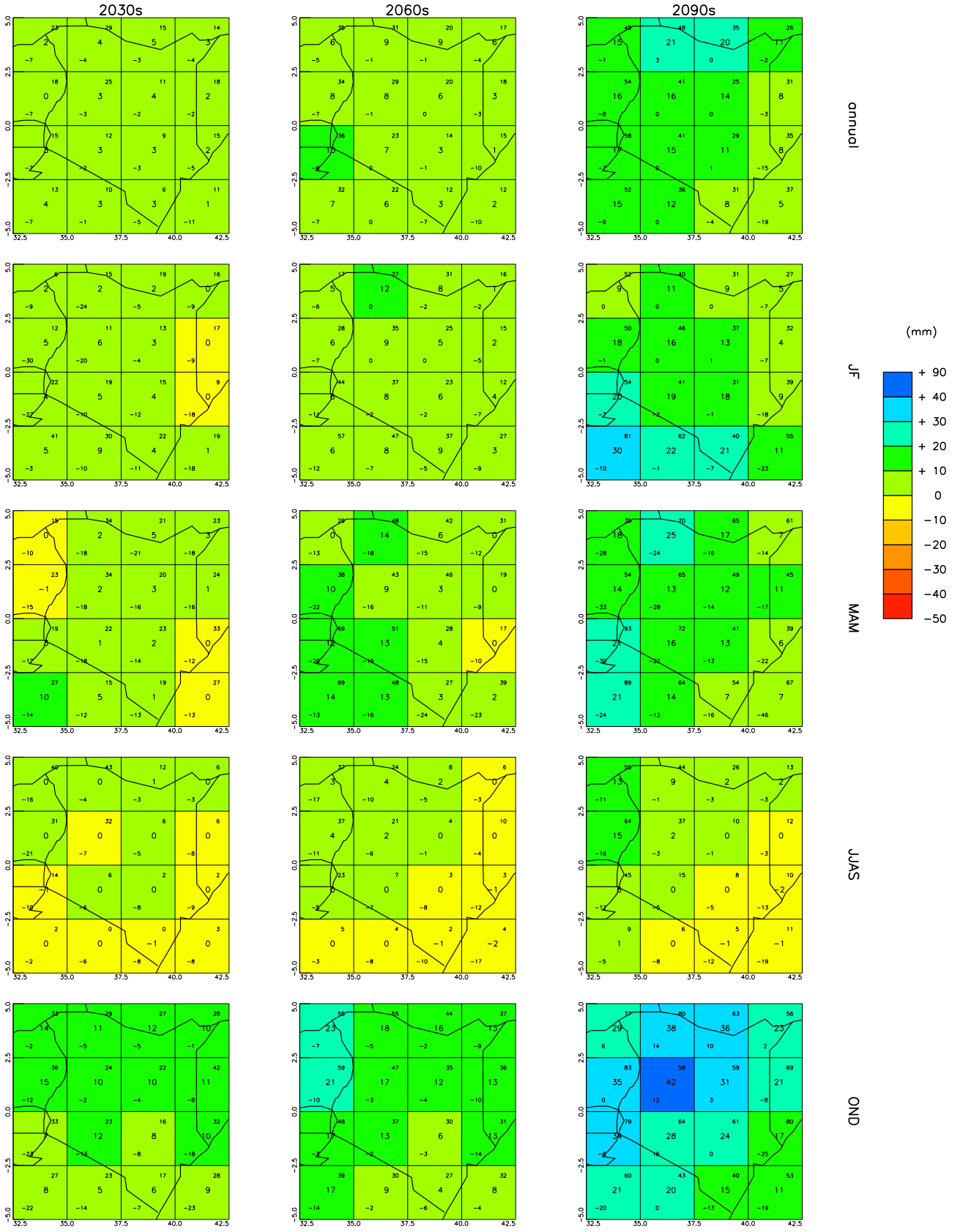

Figure 4: Spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999.See Figure 2 for details.

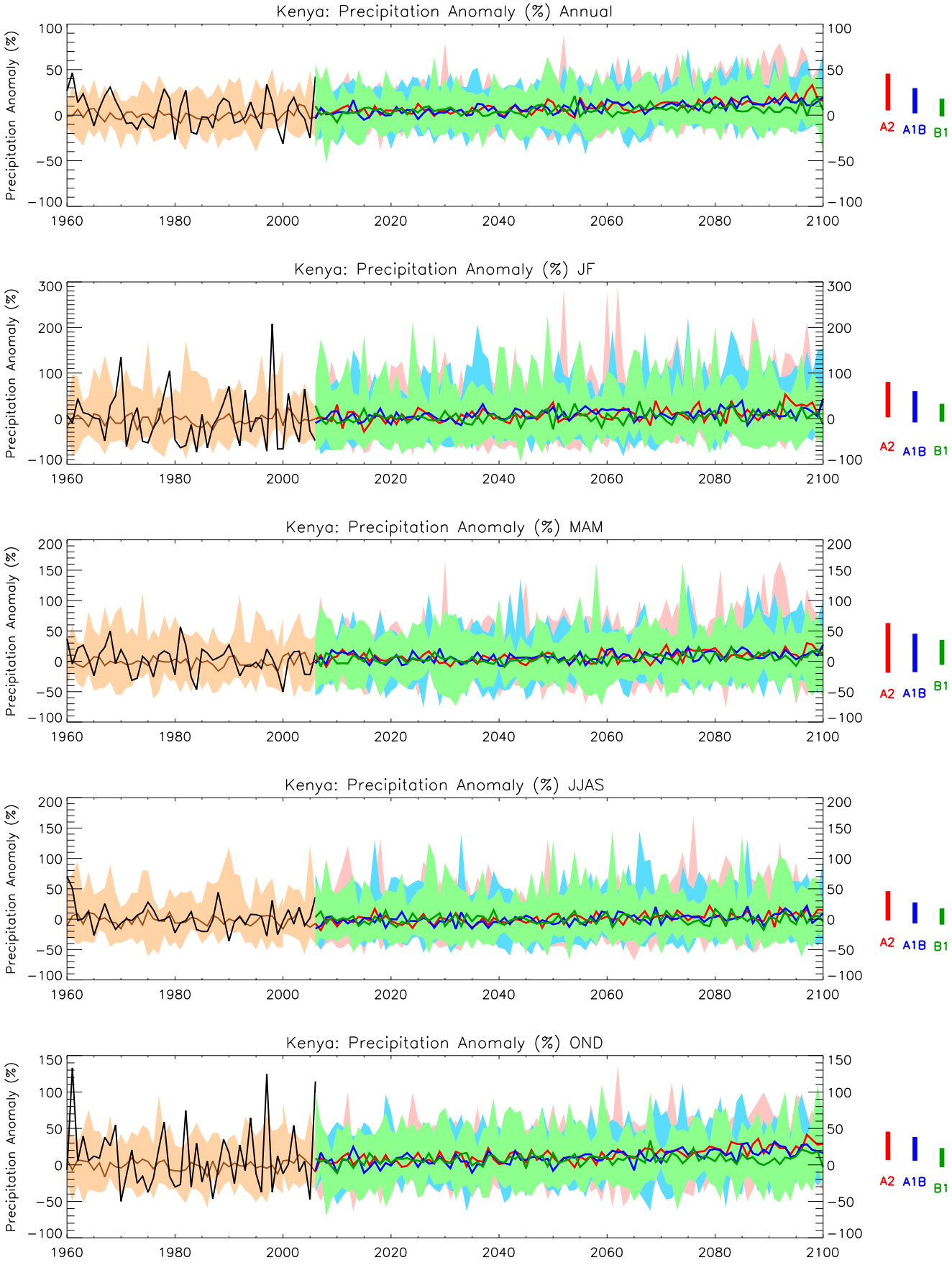

Figure 5: Trends in monthly precipitation for the recent past and projected future. All values shown are percentage anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

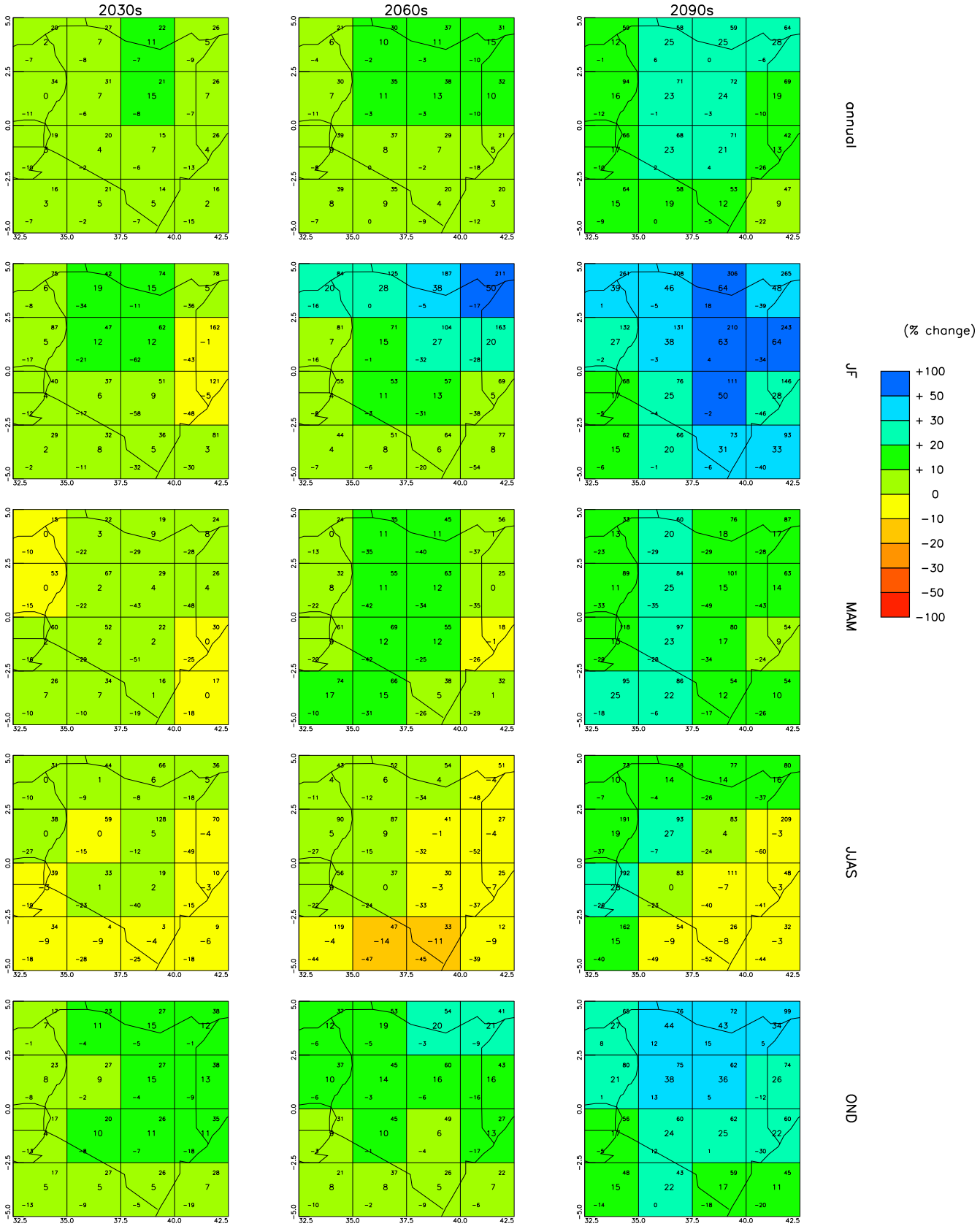

Figure 6: Spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 scenario. All values are percentage anomalies relative to the mean climate of 1970-1999.See Figure 2 for details.

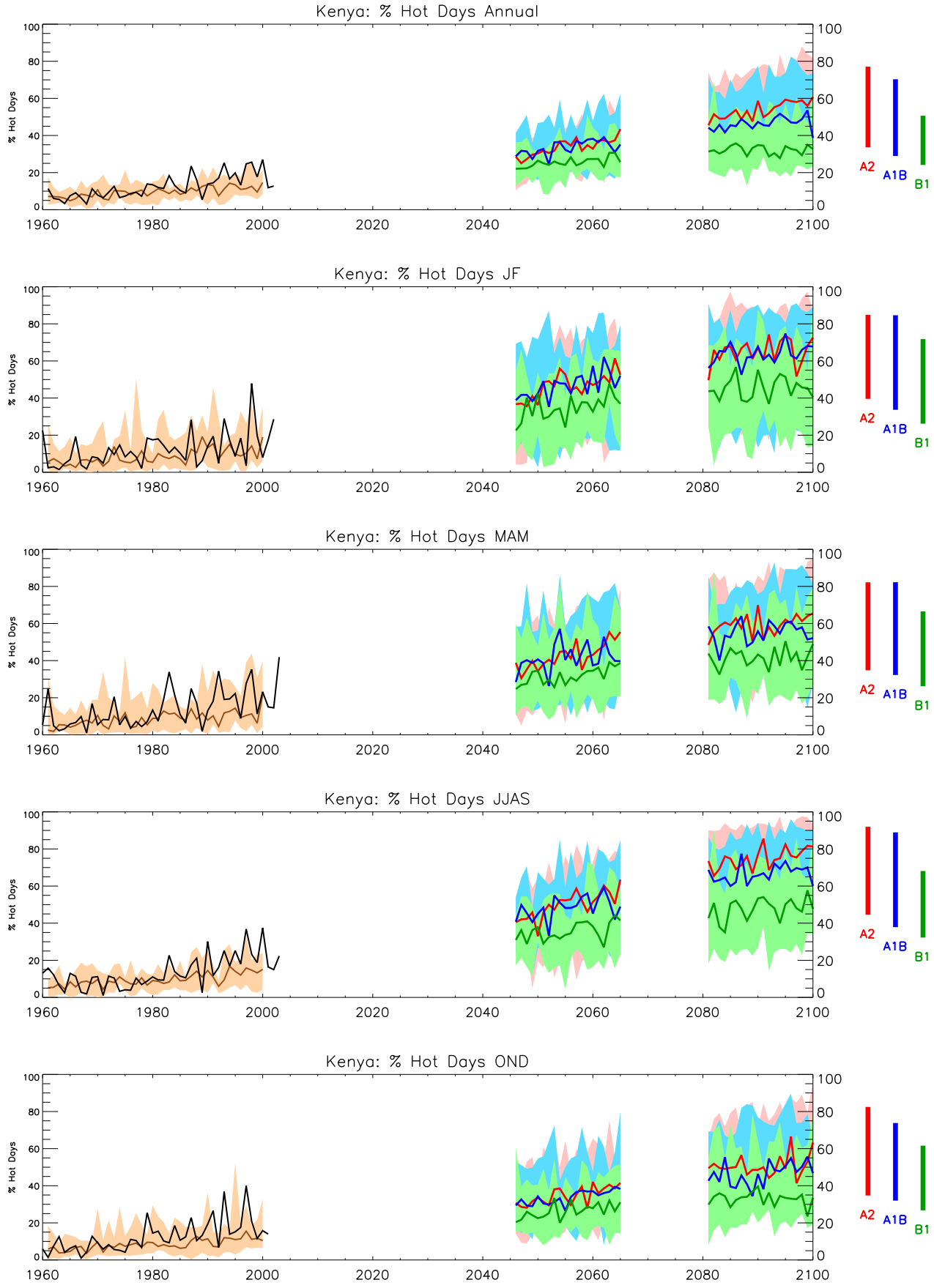

Figure 7: Trends in Hot-day frequency for the recent past and projected future. See Figure 1 for details.

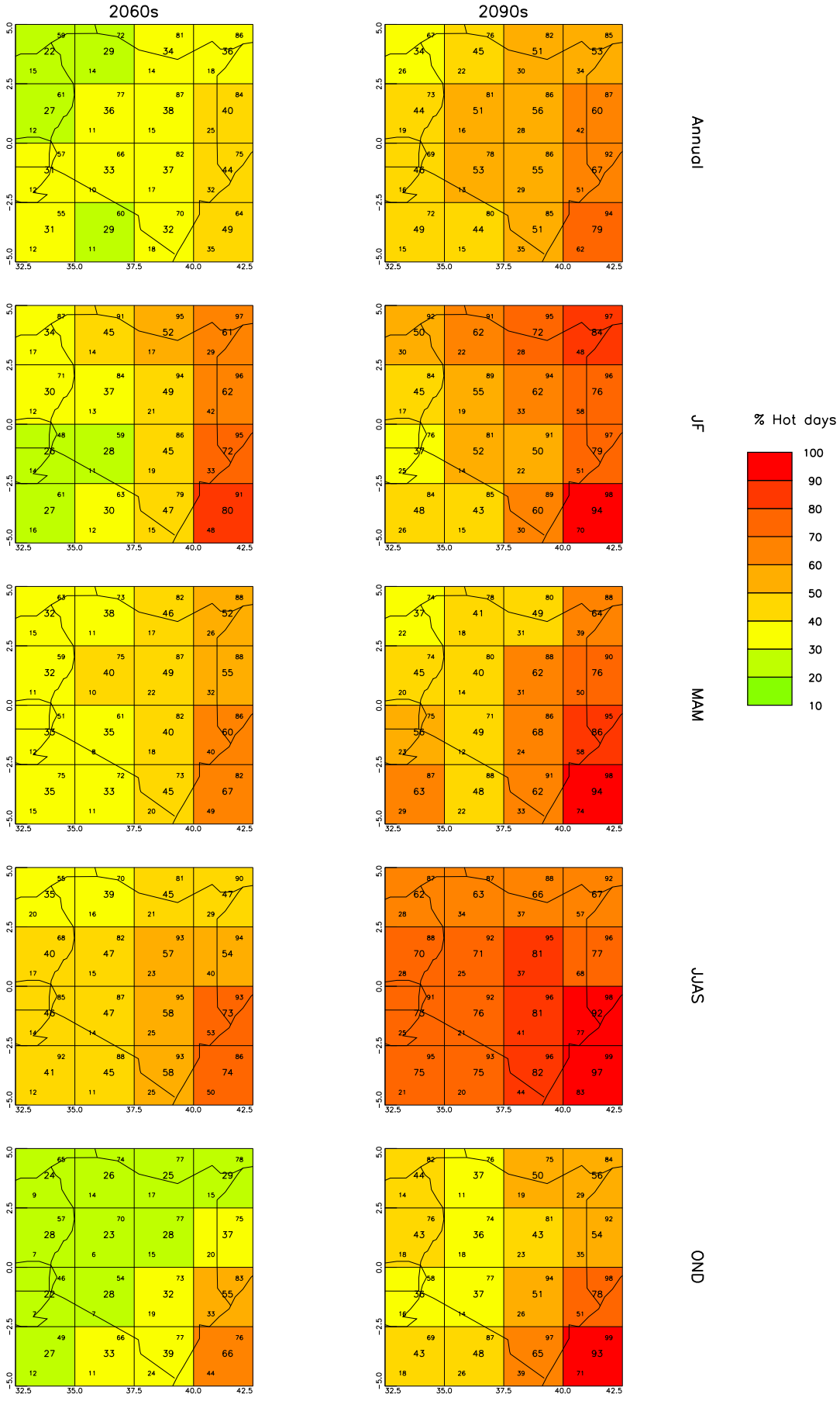

Figure 8: Spatial patterns of projected change in Hot-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

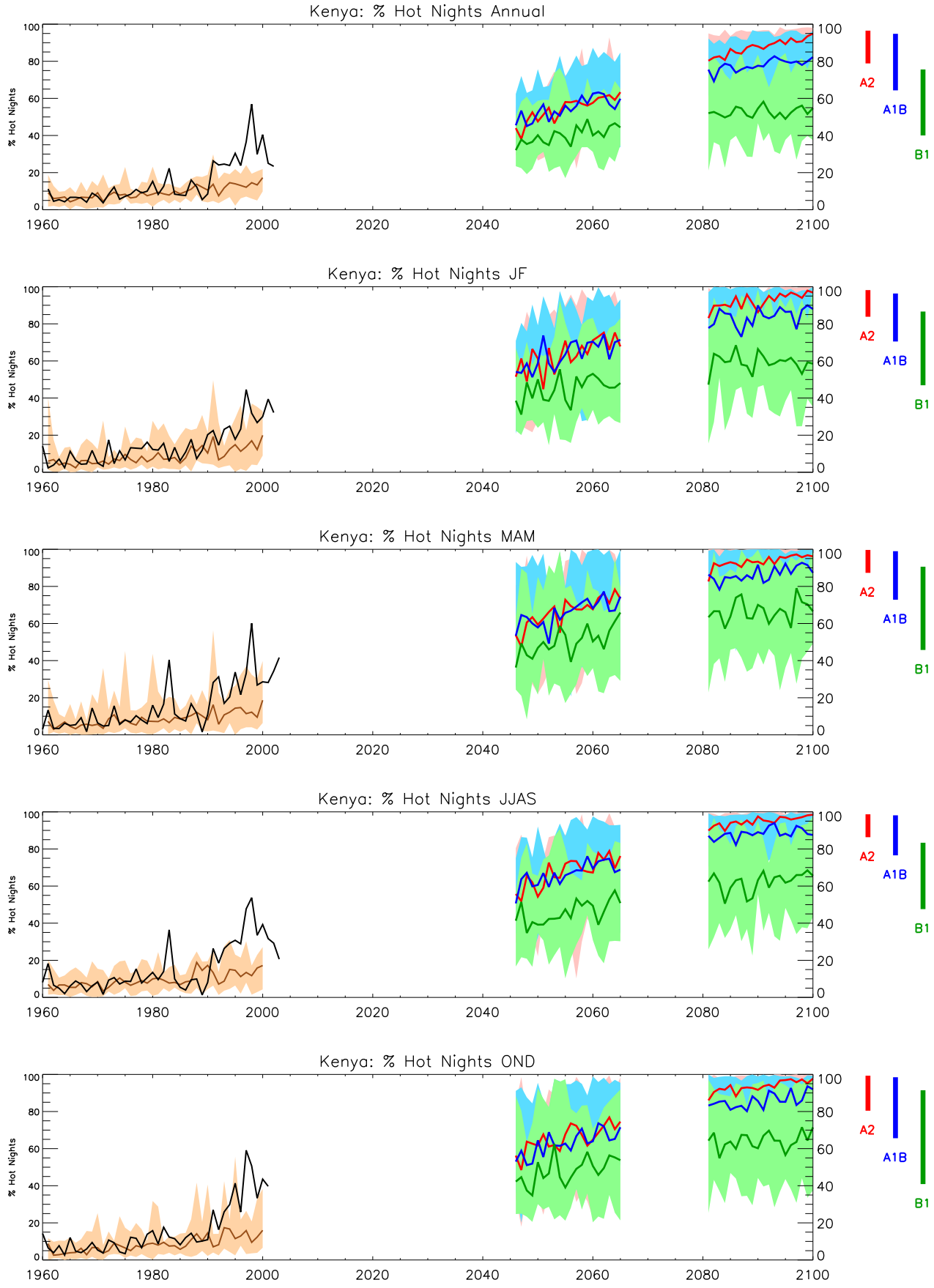

Figure 9: Trends in hot-night frequency for the recent past and projected future. See Figure 1 for details.

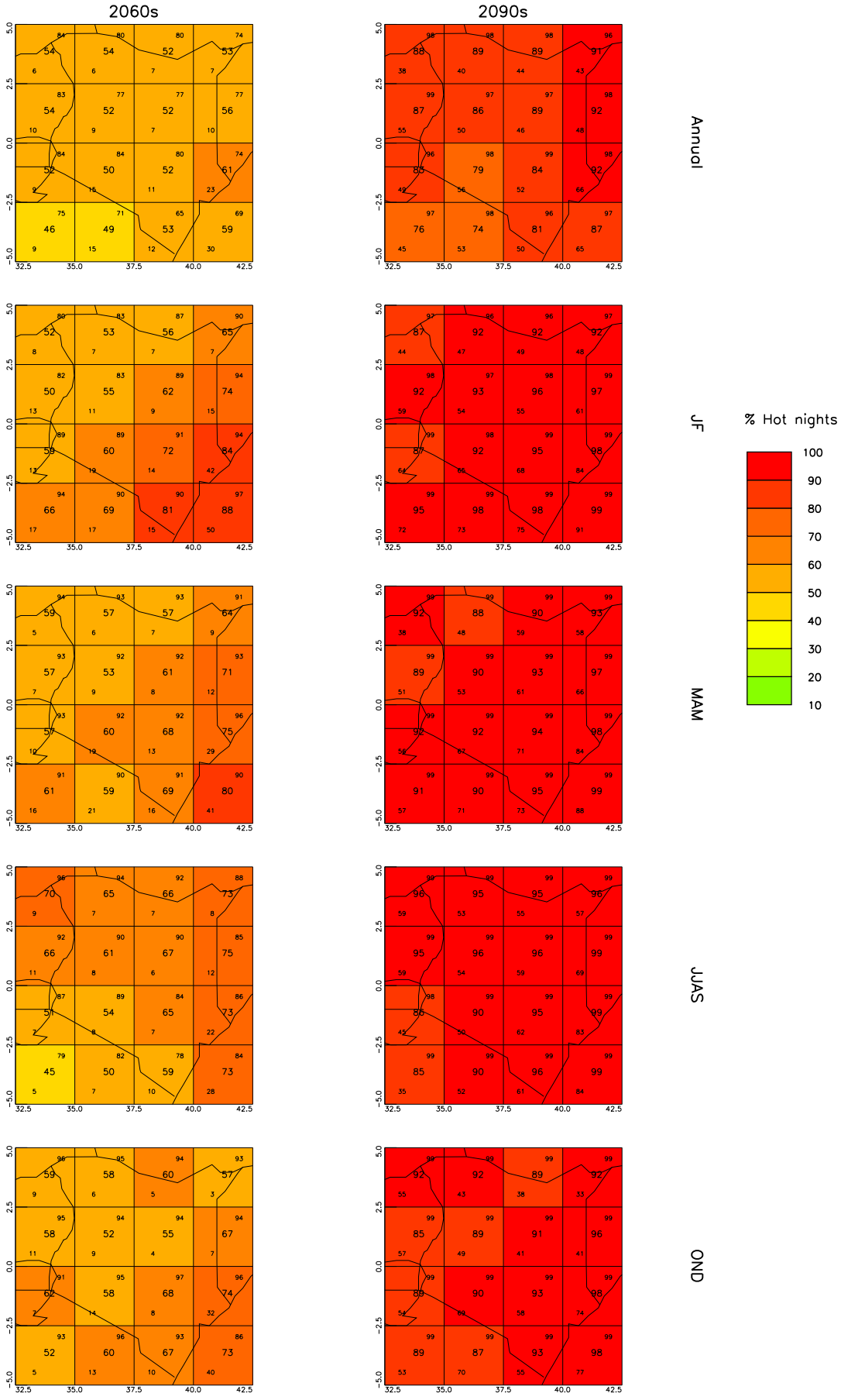

Figure 10: Spatial patterns of projected change in hot-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

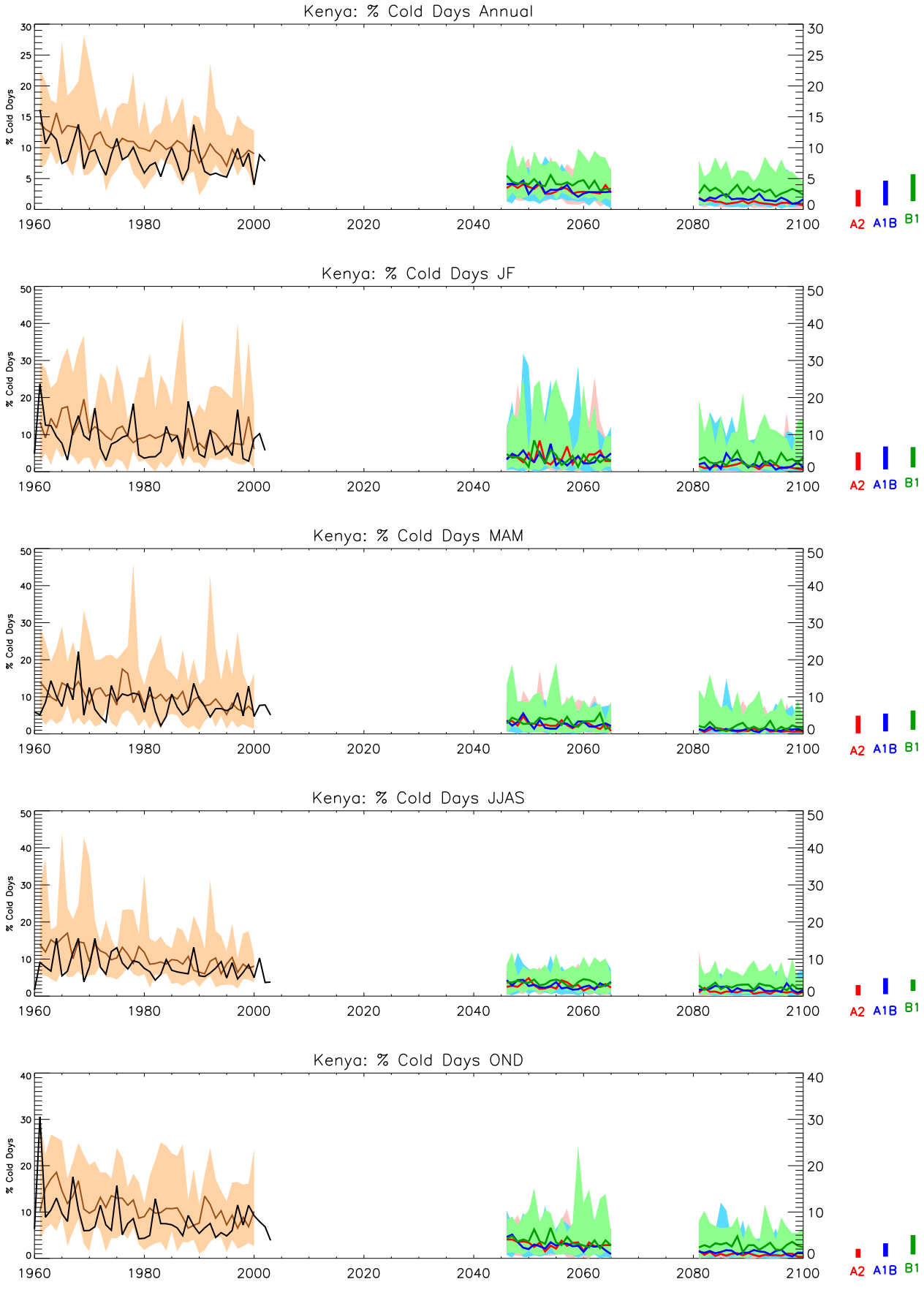

Figure 11: Trends in cold-day frequency for the recent past and projected future. See Figure 1 for details.

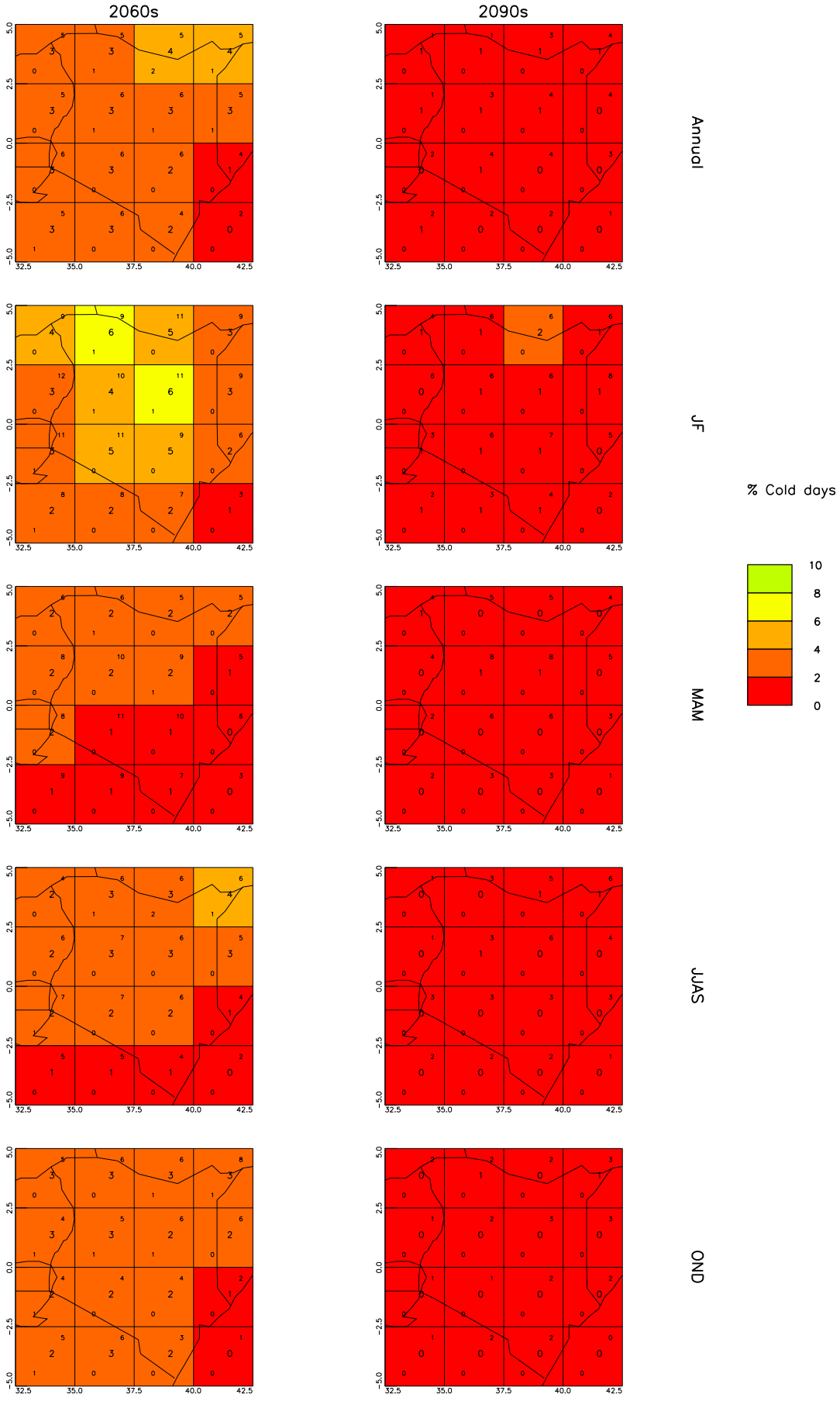

Figure 12: Spatial patterns of projected change in cold-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

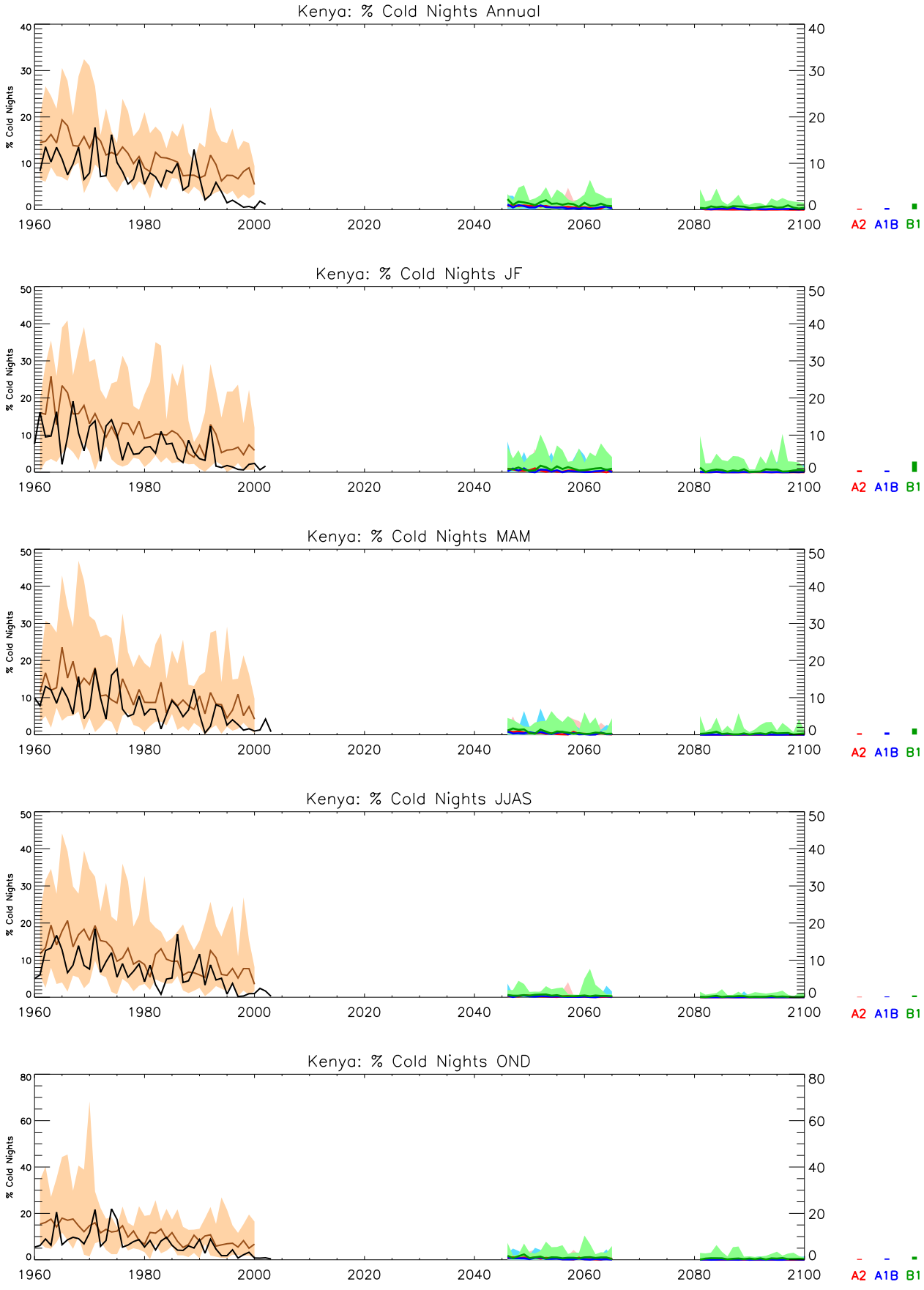

Figure 13: Trends in cold-night frequency for the recent past and projected future. See Figure 1 for details.

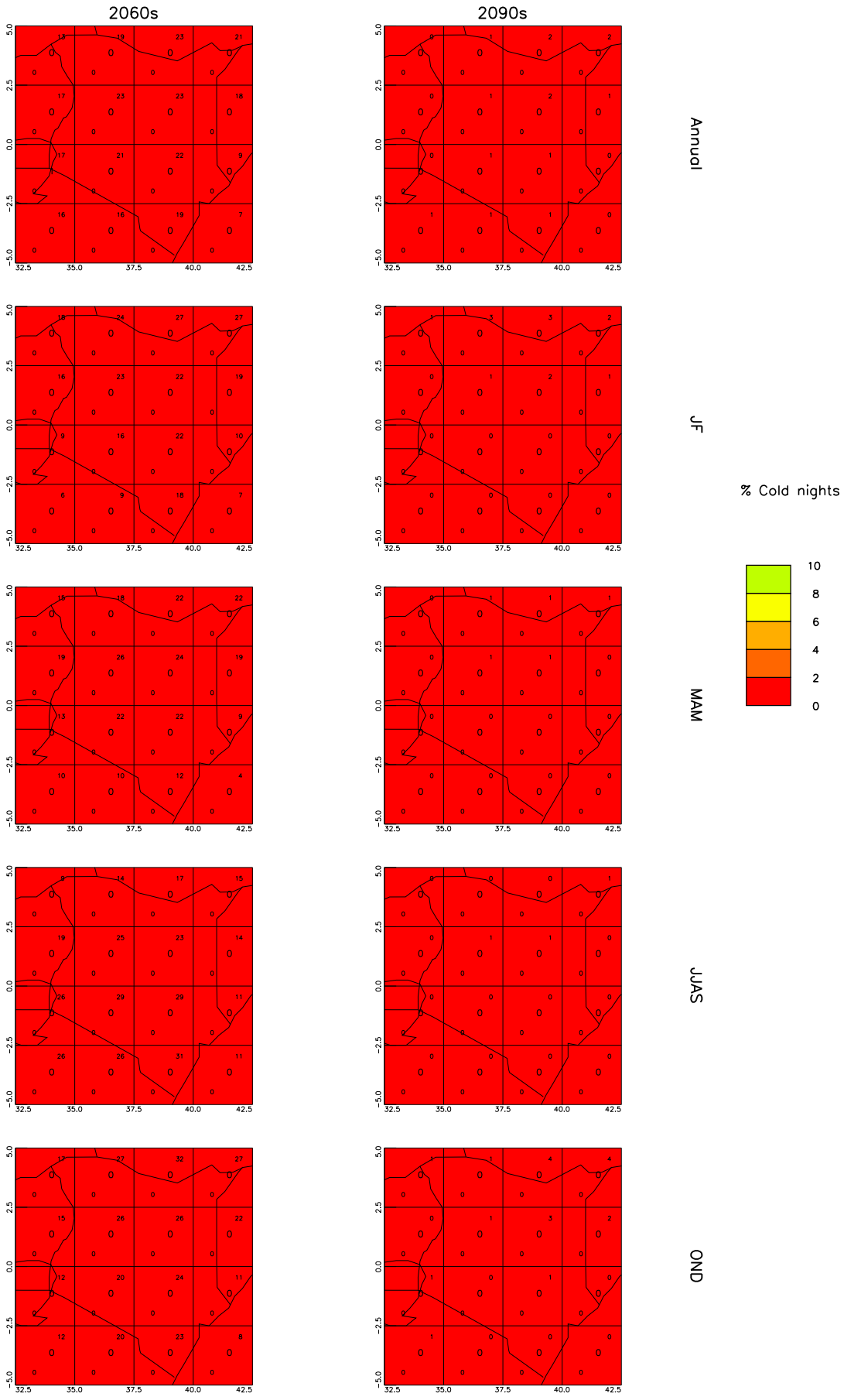

Figure 14: Spatial patterns of projected change in cold-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

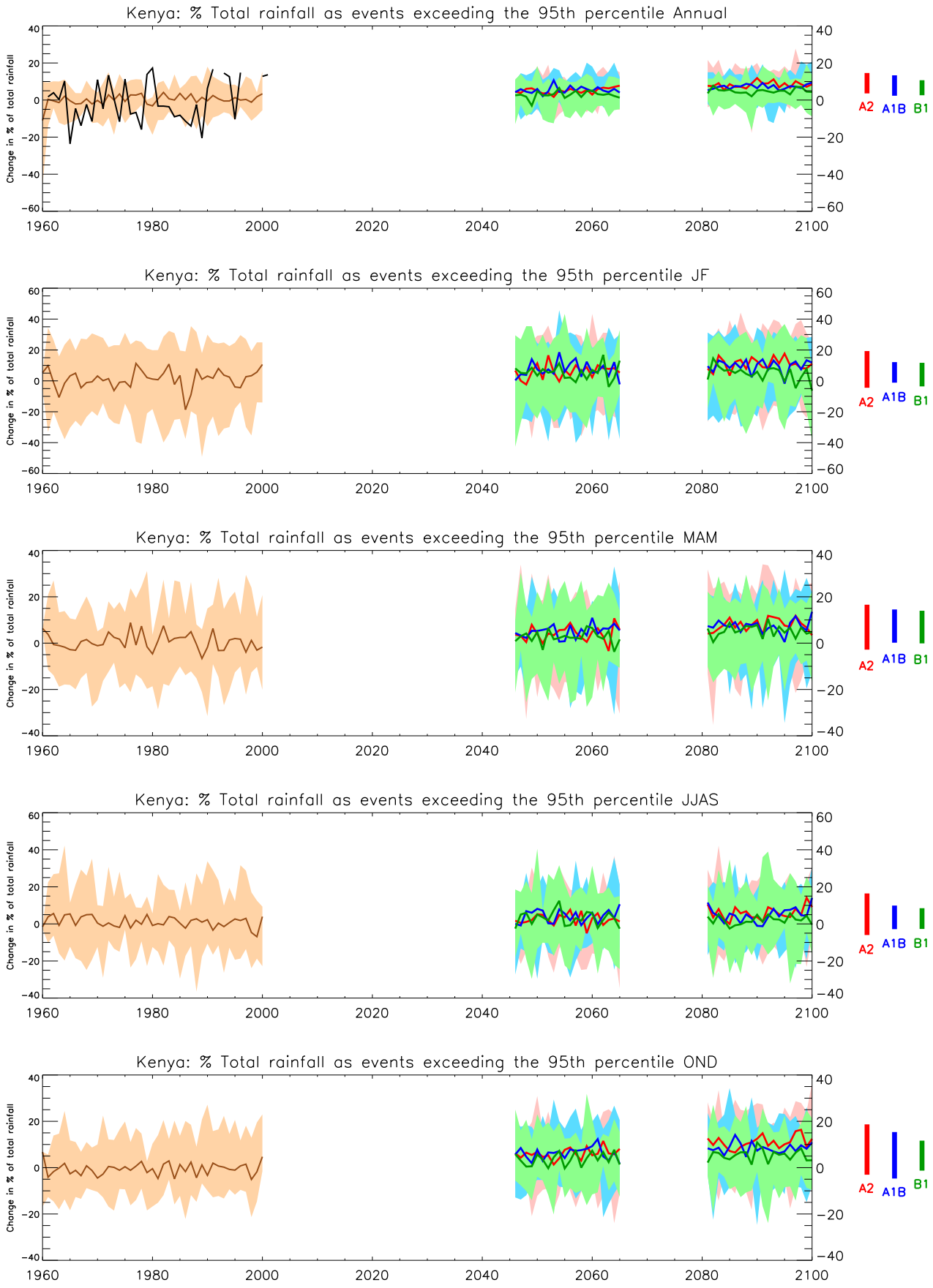

Figure 15: Trends in the proportion of precipitation falling in 'heavy' events for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

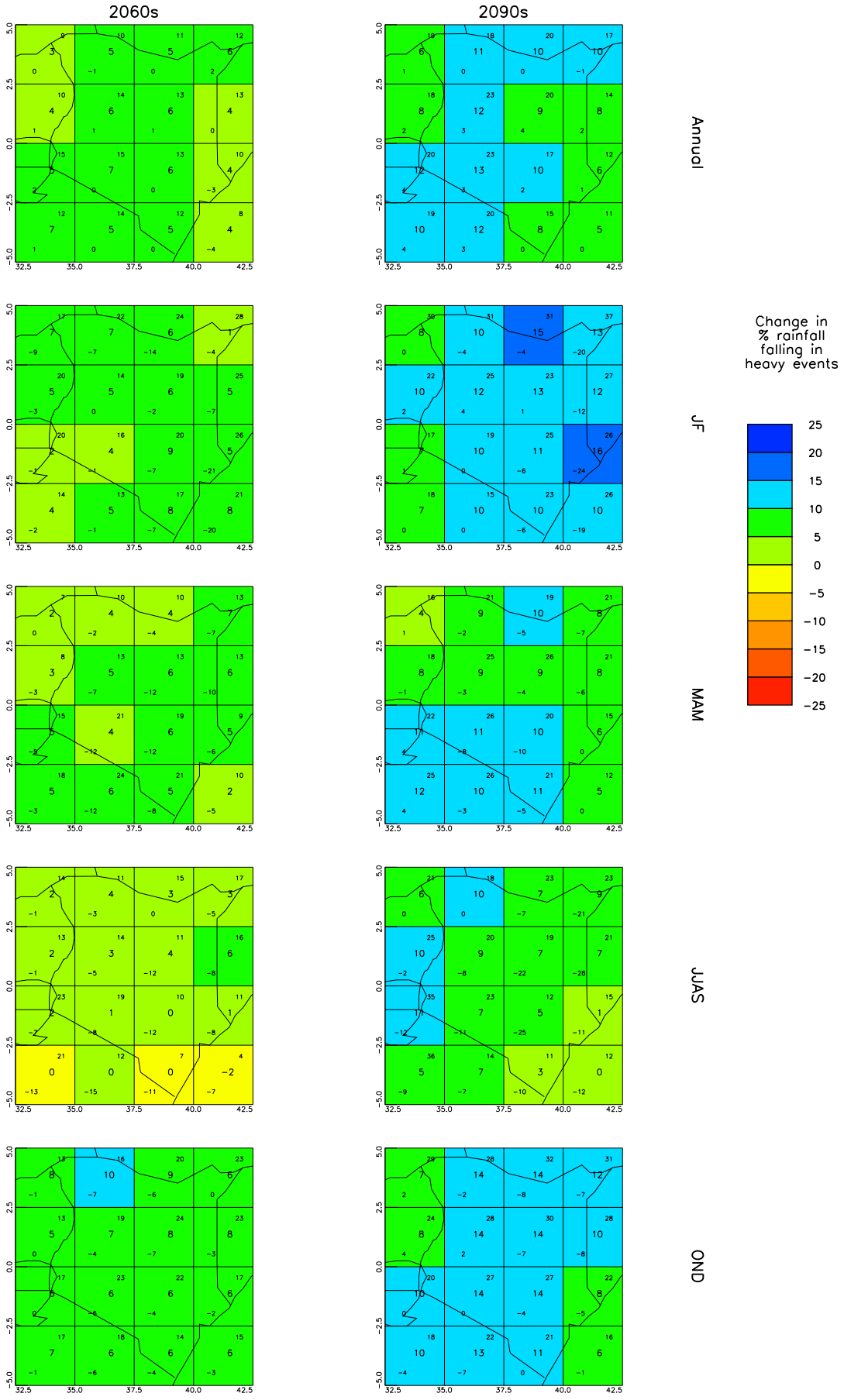

Figure 16: Spatial patterns of projected change in the proportion of precipitation falling in 'heavy' events for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.

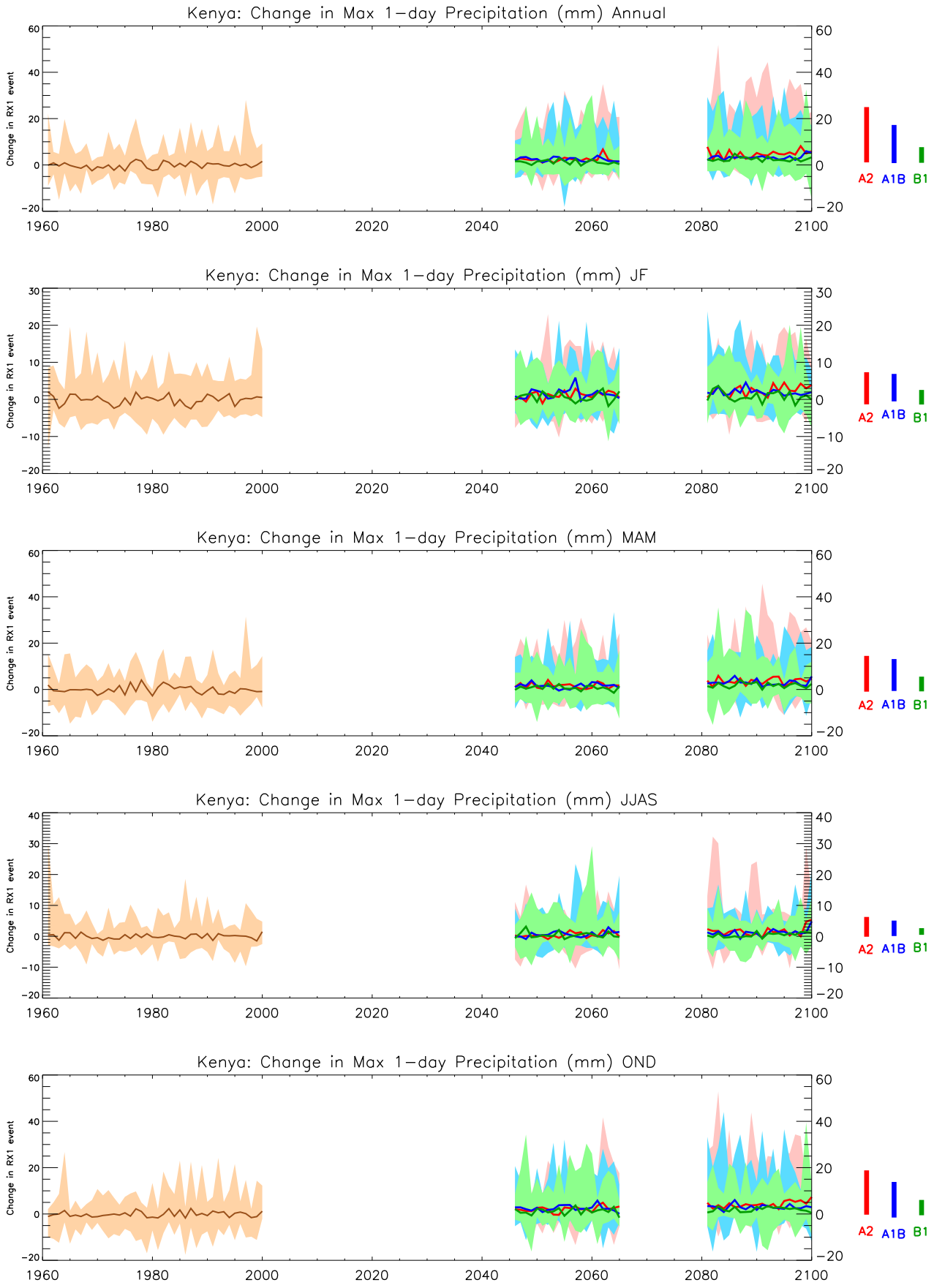

Figure 17: Trends in maximum 1-day rainfall for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

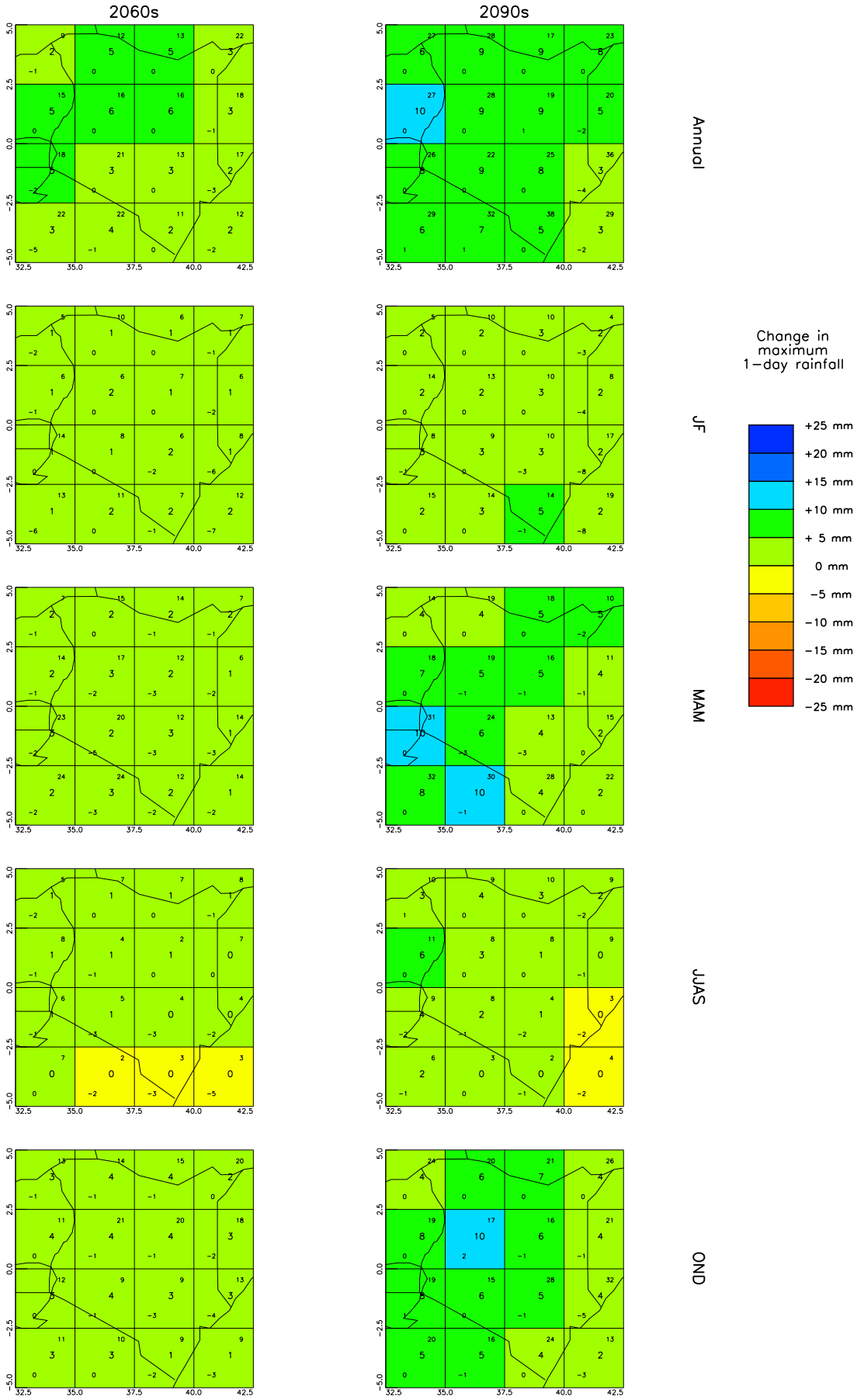

Figure 18: Spatial patterns of maximum 1-day rainfall for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.

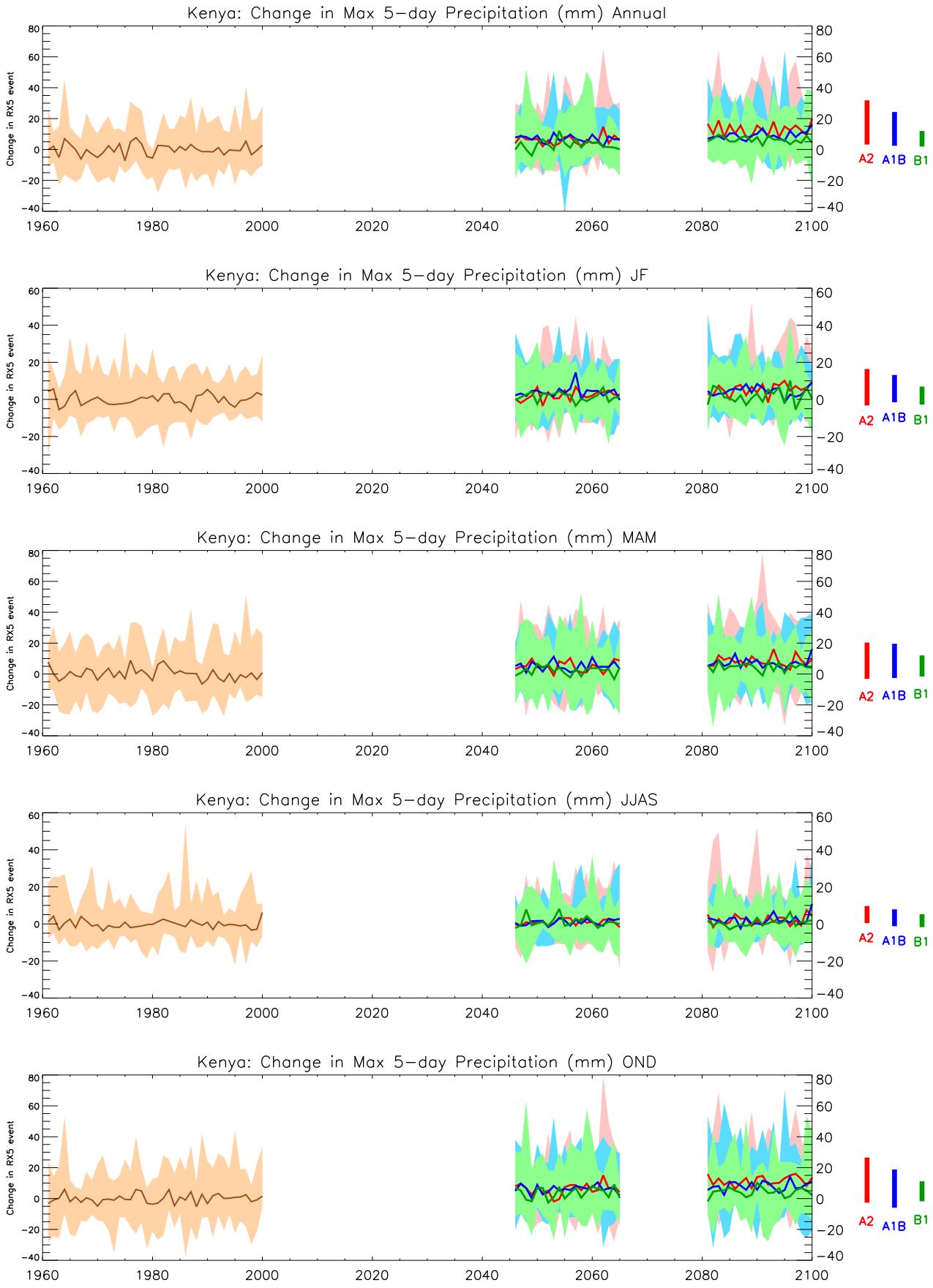

Figure 19: Trends in maximum 5-day rainfall for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

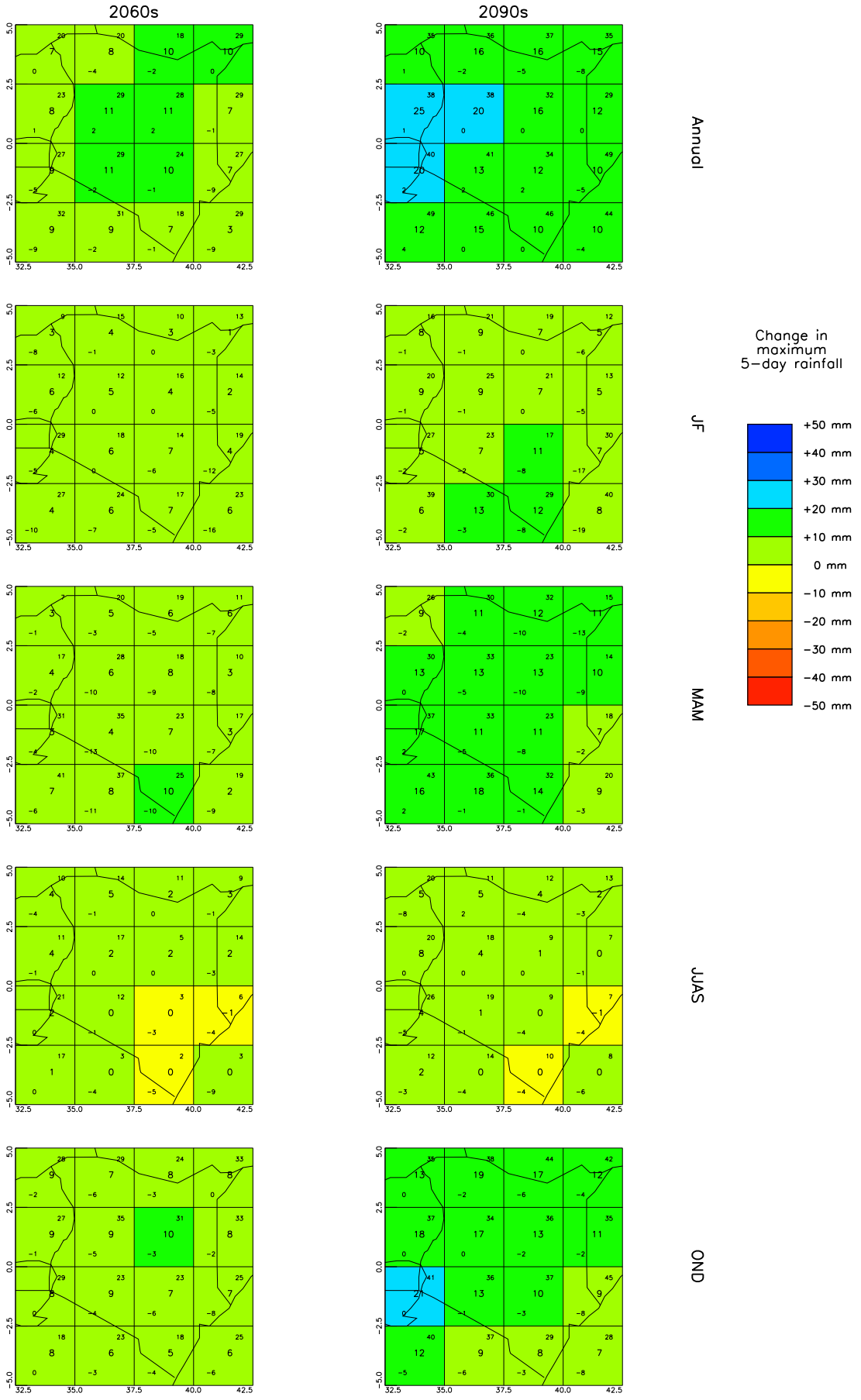

Figure 20: Spatial patterns of projected change in maximum 5-day rainfall for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.