

# Pakistan

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## General Climate

Pakistan's geography is very diverse and this contributes to the diversity in climatic conditions in different regions of the country. The far north of Pakistan reaches into the Himalayas, whilst the southern and western, and coastal regions are lowland plains of the River Indus. Two smaller mountain ranges (the Safed Koh and Sulaiman ranges) run along the eastern border of Pakistan.

Average temperatures are strongly dependent on this topography, with coolest annual temperatures below zero in the far North (the Himalayan region), and higher average temperatures in the lower-lying south-east. In the warmest months (May to September) average temperatures in the north do not exceed 15°C, whilst in the south they can reach up to 35°. In the coolest months (November to February) are well below zero in the highest altitudes, and 20-25°C in the low-lying south.

Most of the country receives very little rainfall throughout the year (20-30mm per month), but the Northern regions, on the southern side of the Himalayan mountains, receive rainfall of up to 200mm per month as a result of with the summer monsoon through July to September.

## Recent Climate Trends

### Temperature

- Mean annual temperature has increased by 0.35°C since 1960, an average rate of 0.08°C per decade.
- The rate of increase is most rapid in OND, at 0.19°C per decade, whilst there is no evidence of a warming trend in the warmest season, JAS.
- The frequency of hot days<sup>1</sup> and hot nights has increased significantly, annually, since 1960.
  - The average number of 'hot' days per year in Pakistan has increased by 20 (an additional 5.5% of days<sup>2</sup>) between 1960 and 2003. The rate of increase is seen most

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<sup>1</sup> '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.

strongly in SON when the average number of hot SON days has increased by 2.4 days per month (an additional 7.6% of SON days) over this period.

- The average number of 'hot' nights per year increased by 23 (an additional 6.4% of nights) between 1960 and 2003. The rate of increase is seen most strongly in MAM when the average number of hot MAM nights has increased by 2.3 nights per month (an additional 7.6% of MAM nights) over this period.
- The frequency of cold days<sup>3</sup> and nights, annually, has decreased significantly since 1960.
  - The average number of 'cold' days per year has decreased by 9.7 (2.7% of days) between 1960 and 2003.
  - The average number of 'cold' nights per year has decreased by 13 (3.6% of days). This rate of decrease is most rapid in DJF when the average number of cold DJF nights has decreased by 2.1 nights per month (6.9% of DJF nights) over this period.

### Precipitation

- Mean annual rainfall over Pakistan has not changed with any discernible trend since 1960.
- There is no consistent trend in the extremes indices for observed daily rainfall.

## GCM Projections of Future Climate

### Temperature

- The mean annual temperature is projected to increase by 1.4 to 3.7°C by the 2060s, and 1.9 to 6.0°C by the 2090s. The range of projections by the 2090s under any one emissions scenario is 1.5- 2°C.
- The projected rate of warming is most rapid in the most northern regions of Pakistan.
- All projections indicate substantial increases in the frequency of days and nights that are considered 'hot' in current climate.
  - Annually, projections indicate that 'hot' days will occur on 16-25% of days by the 2060s, and 18-38% of days by the 2090s. Days considered 'hot' by current climate standards for their season are projected to increase most rapidly in JAS, occurring on 27-74% of days of the season by the 2090s.
  - Nights that are considered 'hot' for the annual climate of 1970-99 are projected to occur on 18-30% of nights by the 2060s and 20-42% 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 32-81% of nights in every season by the 2090s.
  - Projected increases in hot days and nights in JAS are more rapid in the southern, coastal regions of the country than the north.

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<sup>2</sup> 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.

<sup>3</sup> '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.

- All projections indicate decreases in the frequency of days and nights that are considered 'cold' in current climate, and in much of the country, do not occur at all by the 2090s.

## Precipitation

- Projections of mean annual rainfall averaged over Pakistan, from different models in the ensemble, project a wide range of both positive and negative changes in precipitation. Projected changes range from -9 to +20mm per month (-20 to +41%) by the 2090s, with ensemble means close to zero.
- Whilst the range of projections across the model ensemble is large, the model ensembles tend to project decreases in rainfall in JFM and AMJ, and increases in JAS.
- Whilst there is very little agreement between models as to changes in mean rainfall amount, there is greater consistency for the rainfall extremes.
  - The proportion of total rainfall that falls in heavy<sup>4</sup> events shows mixed positive and negative changes in projections from different models. These changes do, however, tend towards increases over the annual average and particularly in JAS.
  - Maximum 1- and 5-day rainfalls also tend to increase in projections (particularly in JAS), although some models do project decreases. Changes range from -3 to +24 mm in 1-day maxima, and -8 to +36mm in 5-day maxima.

## Additional Regional Climate Change Information

- Complex topography in this part of the world means that local variations in response to global warming, particularly precipitation, are likely to be large and many areas may vary from the regional trend (Christensen *et al.*, 2007).
- A lack of consistency between models in representing monsoon processes contributes to uncertainty in estimates of future precipitation in this region (Christensen *et al.*, 2007).
- For further information on Climate Change projections for Asia, see Christensen *et al.* (2007) IPCC Working Group I Report: '*The Physical Science Basis*', Chapter 11 (*Regional Climate projections*): Section 11.4 (*Asia*).

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<sup>4</sup> 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	21.3	0.08*	A2	0.9	1.6	2.1	2.1	3.0	3.7	4.0	5.1	6.0
			A1B	1.0	1.8	2.4	1.8	3.1	3.6	3.0	3.9	5.2
			B1	0.8	1.3	1.8	1.4	2.2	2.6	1.9	2.8	3.6
JFM	14.5	0.08	A2	0.8	1.7	2.4	1.8	3.2	4.6	3.7	5.1	6.8
			A1B	1.1	1.9	2.8	2.0	3.3	4.1	2.9	4.1	5.4
			B1	0.7	1.4	2.0	1.1	2.2	3.1	1.9	2.8	4.1
AMJ	26.2	0.12	A2	0.9	1.6	2.3	2.1	3.1	4.4	3.8	4.9	6.6
			A1B	1.2	1.9	2.9	1.5	3.1	3.6	3.1	4.1	5.3
			B1	0.4	1.3	2.3	1.6	2.0	2.9	1.5	2.7	3.6
JAS	26.3	-0.04	A2	1.0	1.6	2.1	1.5	3.0	3.7	3.5	4.7	5.9
			A1B	0.7	1.4	2.4	1.8	2.9	3.8	2.4	3.7	5.2
			B1	0.4	1.2	1.8	1.2	2.2	2.8	1.7	2.6	3.4
OND	17.3	0.19*	A2	0.4	1.5	2.3	2.2	3.1	4.2	3.6	5.0	6.3
			A1B	0.7	1.8	2.6	2.0	3.1	4.7	2.8	4.4	5.1
			B1	0.9	1.3	2.2	0.8	2.2	3.0	1.9	2.9	3.7
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	25.5	-0.5	A2	-5	0	8	-7	1	15	-9	0	20
			A1B	-5	0	9	-5	0	9	-6	0	9
			B1	-2	0	5	-2	0	7	-4	0	5
JFM	29.2	-0.4	A2	-9	0	11	-12	-2	11	-14	-1	8
			A1B	-7	-2	3	-7	-3	7	-10	-1	14
			B1	-8	-1	9	-6	-2	5	-8	-2	4
AMJ	20.1	0.1	A2	-4	0	16	-5	0	17	-7	-3	18
			A1B	-6	-1	10	-5	-1	10	-8	-3	11
			B1	-5	0	7	-5	-2	8	-5	-1	11
JAS	42.7	-1.6	A2	-9	0	17	-18	3	42	-23	2	52
			A1B	-11	1	21	-12	3	20	-19	1	28
			B1	-3	1	9	-9	2	16	-11	1	19
OND	10.0	0.5	A2	-5	0	8	-5	0	6	-2	1	13
			A1B	-5	0	6	-5	0	7	-4	0	10
			B1	-3	0	5	-2	0	9	-8	0	5
Precipitation (%)												
	(mm per month)	(change in % per decade)		% Change			% Change			% Change		
Annual	25.5	-1.8	A2	-18	2	17	-23	4	30	-28	0	41
			A1B	-18	-2	18	-16	0	18	-22	4	22
			B1	-9	-1	23	-11	-2	17	-20	0	11
JFM	29.2	-1.4	A2	-34	-3	33	-43	-7	40	-49	-10	24
			A1B	-26	-6	13	-33	-11	21	-35	-4	42
			B1	-29	-7	36	-24	-10	16	-29	-12	32
AMJ	20.1	0.4	A2	-21	1	43	-23	0	47	-30	-16	49
			A1B	-29	-4	27	-28	-5	28	-36	-8	31
			B1	-25	1	31	-23	-9	22	-27	-4	31
JAS	42.7	-3.7	A2	-19	4	38	-38	15	172	-50	12	227
			A1B	-24	8	53	-27	14	68	-42	1	292
			B1	-16	3	37	-22	10	93	-34	4	78
OND	10.0	4.6	A2	-21	-2	39	-22	-4	23	-10	4	44
			A1B	-27	-3	22	-29	-1	26	-18	3	34
			B1	-18	3	21	-12	0	42	-34	-1	16

	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			Future % frequency			
Frequency of Hot Days (TX90p)												
Annual	10.6	1.27*	A2	****	****	****	18	21	23	26	29	38
			A1B	****	****	****	18	21	25	20	27	36
			B1	****	****	****	16	19	21	18	21	26
JFM (DJF)	10.7	(1.49*)	A2	****	****	****	19	23	32	30	39	46
			A1B	****	****	****	19	22	31	25	32	41
			B1	****	****	****	16	17	21	17	23	28
AMJ (MAM)	10.0	(1.40)	A2	****	****	****	22	26	31	36	43	55
			A1B	****	****	****	21	28	37	30	38	54
			B1	****	****	****	17	23	24	20	25	36
JAS (JJA)	10.9	(0.62)	A2	****	****	****	23	36	45	39	54	74
			A1B	****	****	****	27	32	47	28	47	64
			B1	****	****	****	22	26	36	27	33	52
OND (SON)	10.9	(1.77*)	A2	****	****	****	16	20	25	25	30	37
			A1B	****	****	****	15	19	24	20	27	33
			B1	****	****	****	14	19	22	17	21	25
Frequency of Hot Nights (TN90p)												
Annual	10.6	1.48*	A2	****	****	****	23	25	28	31	36	42
			A1B	****	****	****	21	26	30	27	32	40
			B1	****	****	****	18	22	26	20	24	29
JFM (DJF)	11.1	(1.73*)	A2	****	****	****	19	25	30	30	40	49
			A1B	****	****	****	18	26	31	23	34	45
			B1	****	****	****	14	19	21	16	24	30
AMJ (MAM)	10.1	(1.76*)	A2	****	****	****	28	32	38	40	51	62
			A1B	****	****	****	26	32	42	37	46	58
			B1	****	****	****	21	25	31	23	27	38
JAS (JJA)	10.2	(0.70)	A2	****	****	****	42	45	57	64	70	81
			A1B	****	****	****	36	46	57	54	59	76
			B1	****	****	****	29	36	46	32	42	58
OND (SON)	10.4	(1.30*)	A2	****	****	****	22	23	35	32	37	52
			A1B	****	****	****	20	23	37	28	31	49
			B1	****	****	****	17	21	29	19	23	32
Frequency of Cold Days (TX10p)												
Annual	9.9	-0.62*	A2	****	****	****	1	3	6	0	1	3
			A1B	****	****	****	2	3	4	0	2	4
			B1	****	****	****	4	4	7	2	3	5
JFM (DJF)	9.8	(-0.97)	A2	****	****	****	0	2	5	0	1	4
			A1B	****	****	****	1	2	5	0	1	3
			B1	****	****	****	3	4	7	1	3	4
AMJ (MAM)	9.8	(-0.86)	A2	****	****	****	1	3	6	0	1	2
			A1B	****	****	****	0	3	5	0	1	2
			B1	****	****	****	3	5	6	2	3	7
JAS (JJA)	10.0	(-0.2)	A2	****	****	****	1	3	4	0	1	4
			A1B	****	****	****	1	3	5	0	2	6
			B1	****	****	****	2	4	5	1	3	5
OND (SON)	9.6	(-0.65)	A2	****	****	****	0	3	5	0	1	2
			A1B	****	****	****	1	2	4	0	1	3
			B1	****	****	****	3	5	7	1	3	4
Frequency of Cold Nights (TN10p)												
Annual	9.0	-0.83*	A2	****	****	****	1	3	4	0	0	3
			A1B	****	****	****	2	3	4	0	2	3
			B1	****	****	****	3	5	6	2	3	5
JFM (DJF)	8.9	(-1.60*)	A2	****	****	****	0	1	4	0	0	3
			A1B	****	****	****	1	2	5	0	1	3
			B1	****	****	****	2	5	6	0	3	4
AMJ (MAM)	9.6	(-0.68)	A2	****	****	****	1	2	4	0	0	1
			A1B	****	****	****	1	3	4	0	1	2
			B1	****	****	****	3	4	5	1	3	6
JAS (JJA)	10.1	(0.50)	A2	****	****	****	0	1	2	0	0	1
			A1B	****	****	****	0	1	2	0	1	1
			B1	****	****	****	1	2	5	0	2	3
OND (SON)	8.7	(-1.28*)	A2	****	****	****	1	2	4	0	0	1
			A1B	****	****	****	1	2	3	0	1	3
			B1	****	****	****	3	4	6	1	3	4

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	42.5	1.26	A2	****	****	****	-8	2	7	-7	4	11
			A1B	****	****	****	-2	1	8	-6	4	8
			B1	****	****	****	-2	2	5	-6	2	8
JFM (DJF)	****	****	A2	****	****	****	-23	-1	11	-23	-7	16
			A1B	****	****	****	-13	-5	8	-23	-3	19
			B1	****	****	****	-12	-4	7	-10	-3	8
AMJ (MAM)	****	****	A2	****	****	****	-18	0	22	-25	0	14
			A1B	****	****	****	-16	-2	12	-15	0	13
			B1	****	****	****	-12	-2	18	-16	0	19
JAS (JJA)	****	****	A2	****	****	****	-20	4	10	-13	5	18
			A1B	****	****	****	-5	4	9	-15	5	21
			B1	****	****	****	-5	0	12	-13	1	12
OND (SON)	****	****	A2	****	****	****	-15	3	12	-6	2	10
			A1B	****	****	****	-4	1	6	-7	2	8
			B1	****	****	****	-12	3	12	-14	0	11
Maximum 1-day rainfall (RX1day)												
	mm	Change in mm per decade				Change in mm			Change in mm			
Annual	71.2	10.90*	A2	****	****	****	-3	3	9	-2	3	24
			A1B	****	****	****	-2	2	8	-1	4	10
			B1	****	****	****	0	2	7	-3	1	7
JFM (DJF)	10.9	(-0.05)	A2	****	****	****	-5	0	7	-4	-1	8
			A1B	****	****	****	-3	0	4	-2	0	11
			B1	****	****	****	-2	0	3	-1	0	4
AMJ (MAM)	12.7	(0.06)	A2	****	****	****	-2	1	5	-2	0	9
			A1B	****	****	****	-2	0	4	-3	0	5
			B1	****	****	****	-2	0	4	-3	0	5
JAS (JJA)	29.9	(0.26)	A2	****	****	****	-4	1	9	-3	2	20
			A1B	****	****	****	-1	0	7	-3	2	9
			B1	****	****	****	-2	0	6	-1	0	5
OND (SON)	10.3	(0.05)	A2	****	****	****	-2	0	4	-1	2	10
			A1B	****	****	****	-2	1	2	-4	1	5
			B1	****	****	****	-2	1	7	-4	0	5
Maximum 5-day Rainfall (RX5day)												
	mm	Change in mm per decade				Change in mm			Change in mm			
Annual	100	-1.30	A2	****	****	****	-9	3	19	-7	8	36
			A1B	****	****	****	-4	4	14	-5	7	15
			B1	****	****	****	-1	3	11	-8	0	12
JFM (DJF)	16.1	(-0.19)	A2	****	****	****	-9	0	12	-8	-2	14
			A1B	****	****	****	-5	-1	9	-4	0	17
			B1	****	****	****	-4	0	4	-3	0	5
AMJ (MAM)	20.3	(0.17)	A2	****	****	****	-4	1	13	-5	0	15
			A1B	****	****	****	-4	0	14	-6	0	13
			B1	****	****	****	-5	0	10	-6	0	15
JAS (JJA)	45.6	(-0.26)	A2	****	****	****	-11	4	20	-13	4	26
			A1B	****	****	****	-7	2	16	-10	4	17
			B1	****	****	****	-7	1	13	-9	0	13
OND (SON)	16.3	(-0.03)	A2	****	****	****	-3	0	11	-4	3	17
			A1B	****	****	****	-4	2	5	-7	2	10
			B1	****	****	****	-5	3	11	-12	0	7

\* 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.

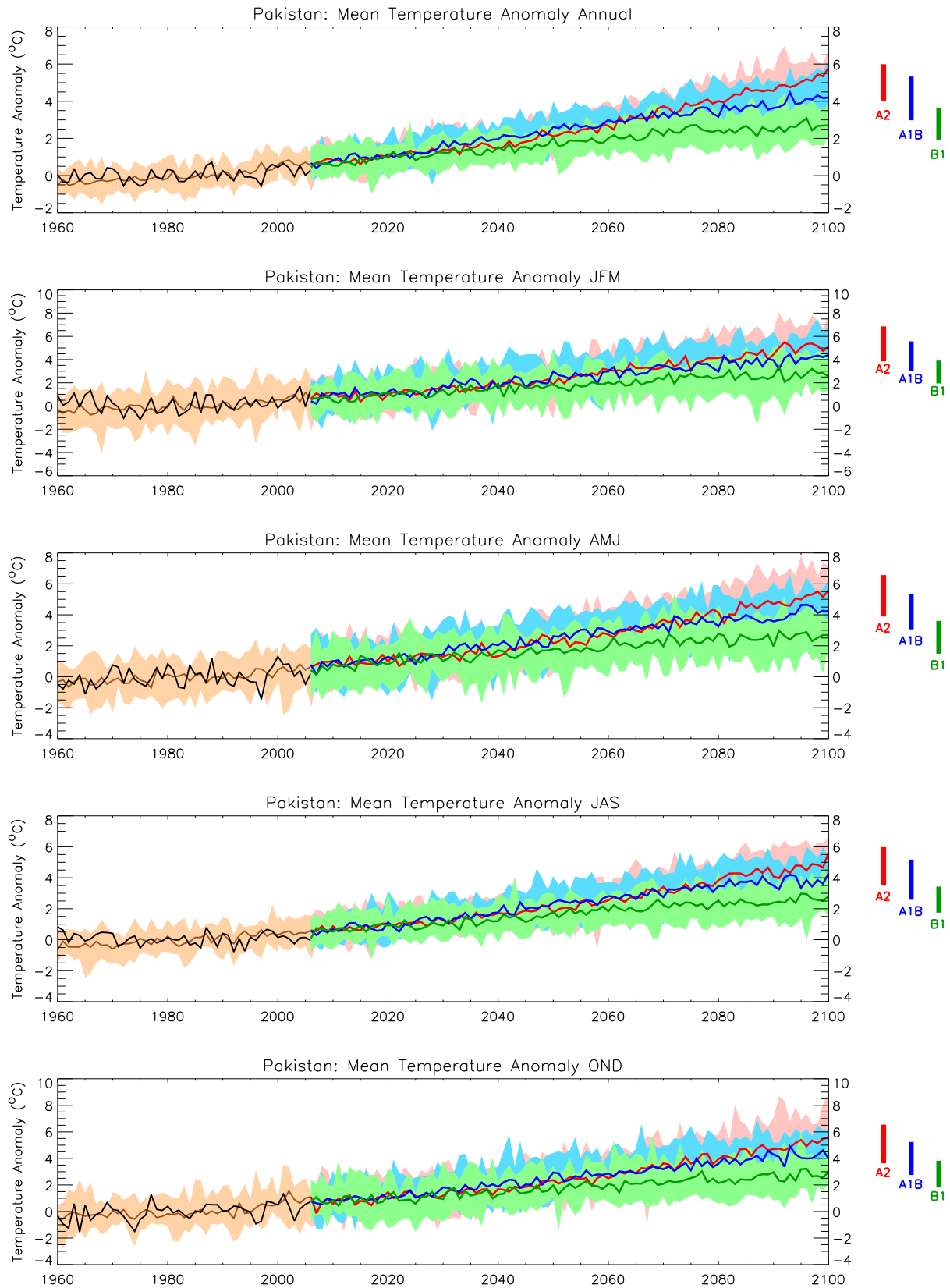


Figure 1: Trends in annual and seasonal mean temperature for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. Black curves show the mean of observed data from 1960 to 2006, Brown curves show the median (solid line) and range (shading) of model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

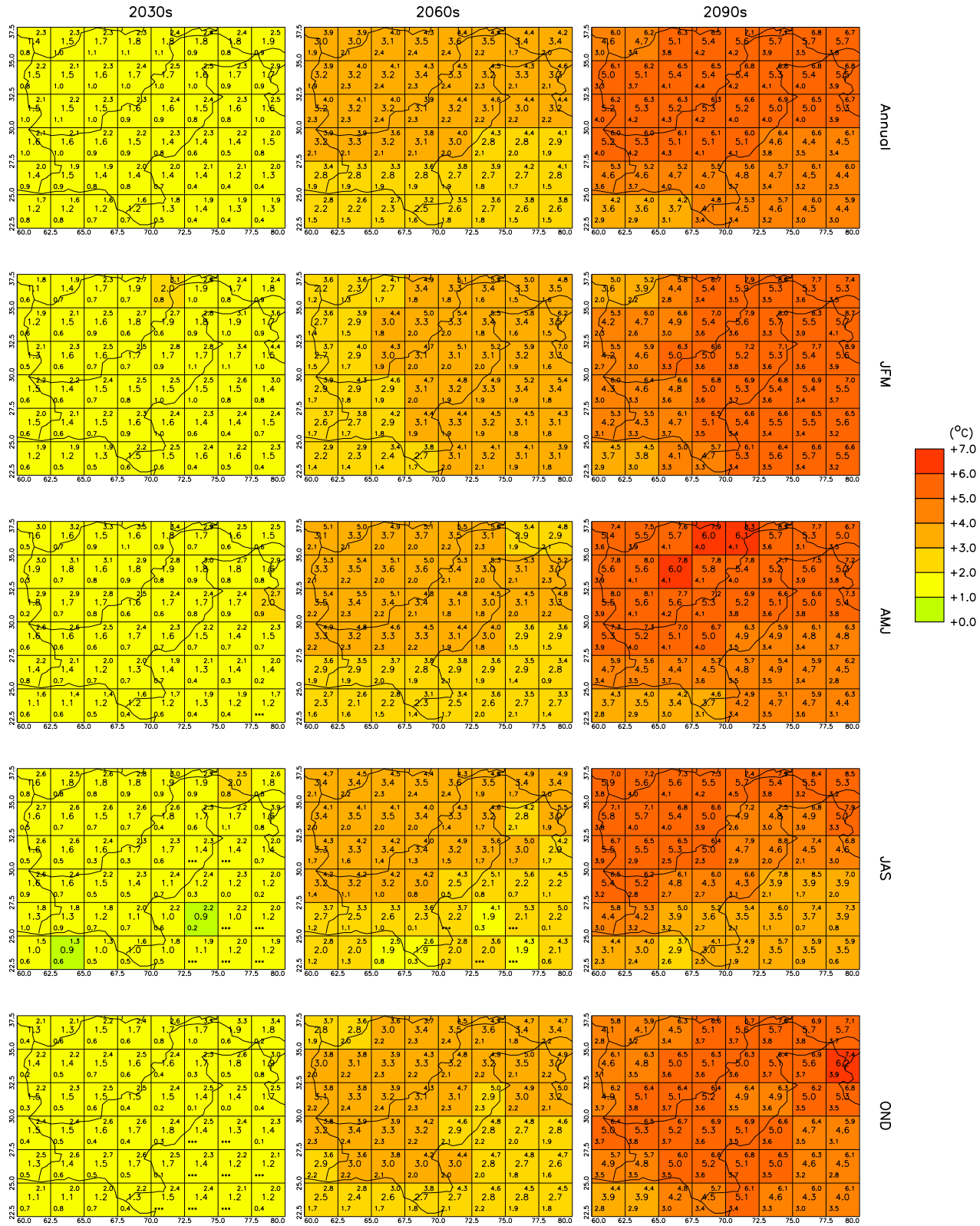


Figure 2: Spatial patterns of projected change in mean annual and seasonal temperature for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. In each grid box, the central value gives the ensemble median and the values in the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



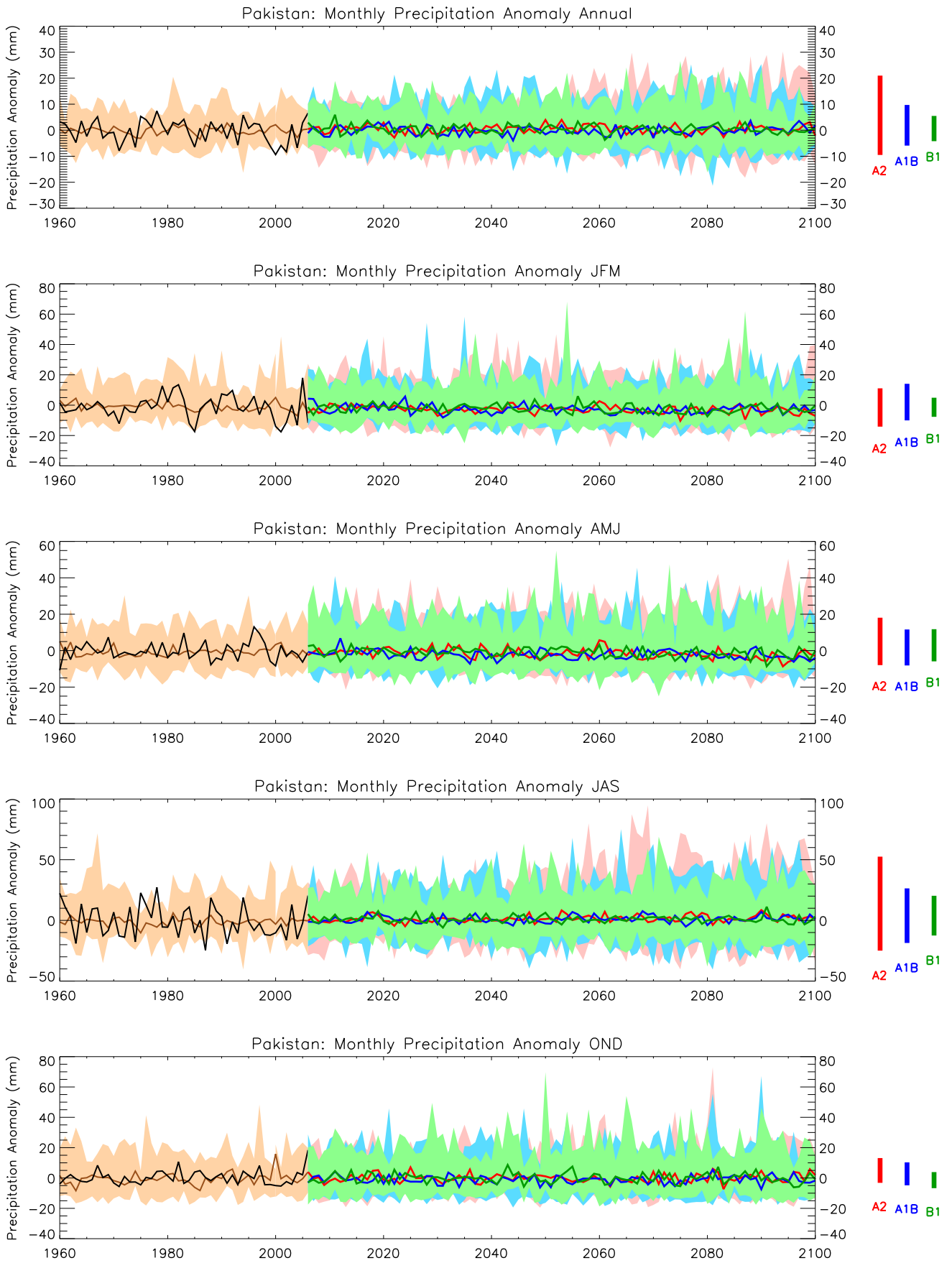


Figure 3: Trends in monthly precipitation for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

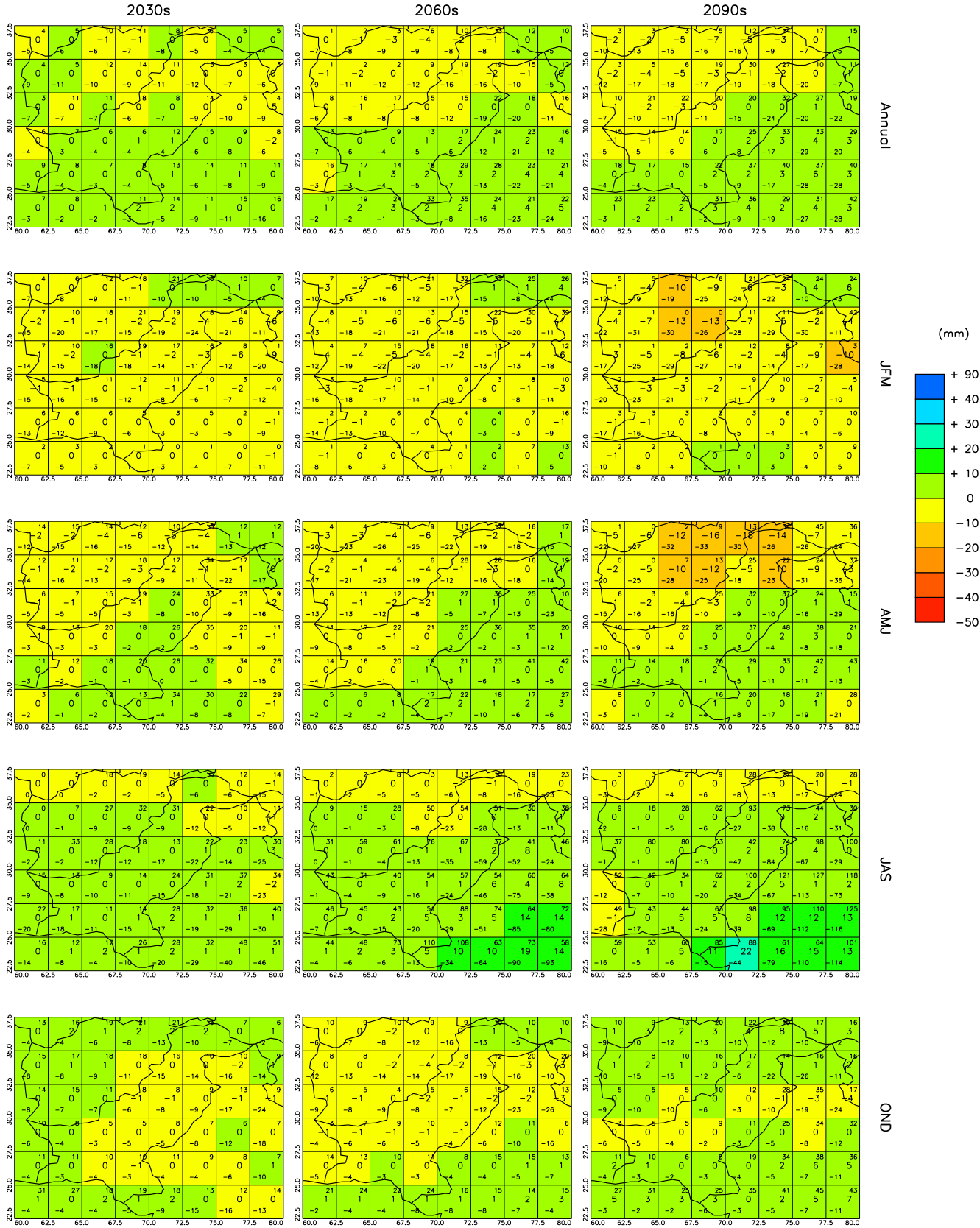


Figure 4: Spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.

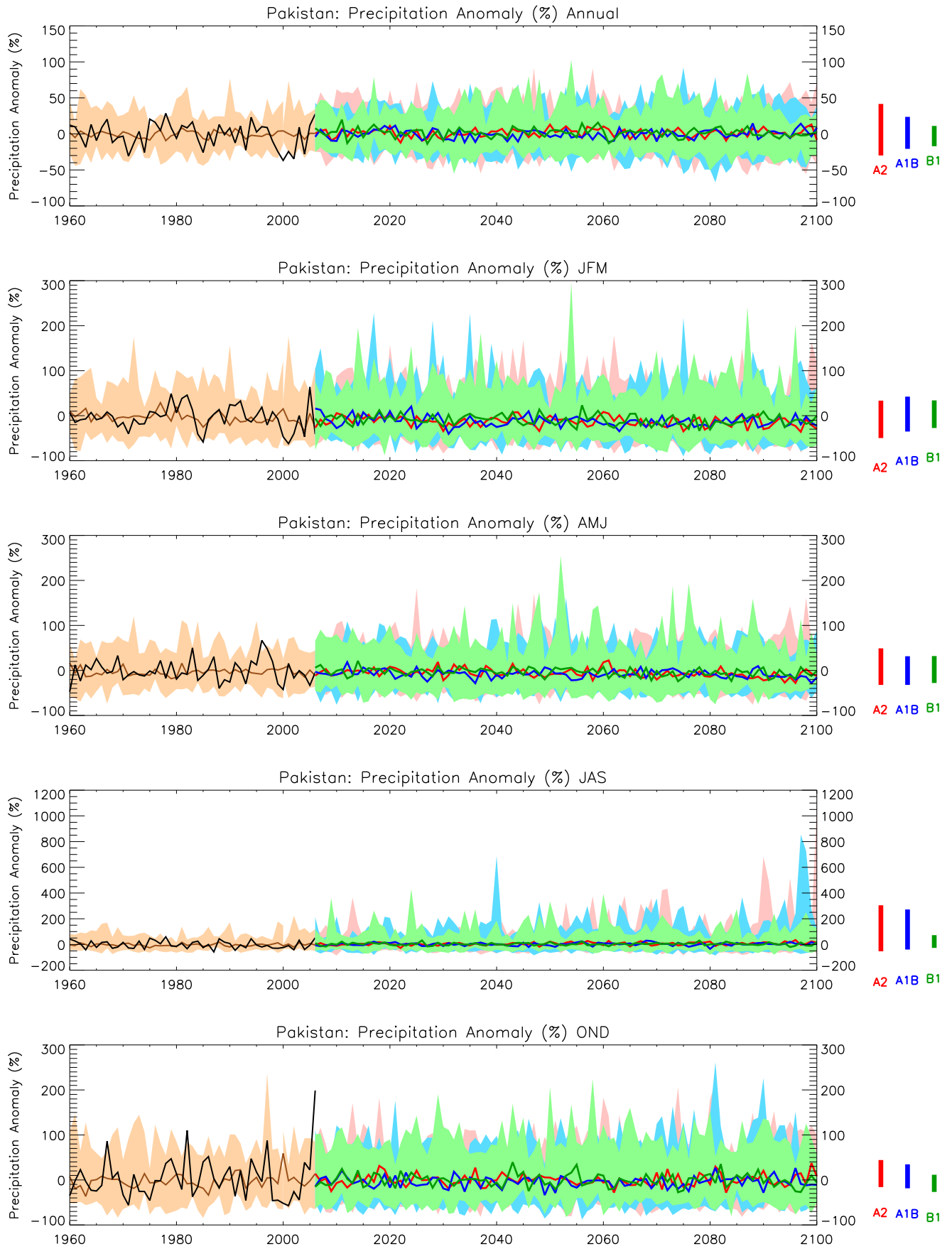


Figure 5: Trends in monthly precipitation for the recent past and projected future. All values shown are percentage anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

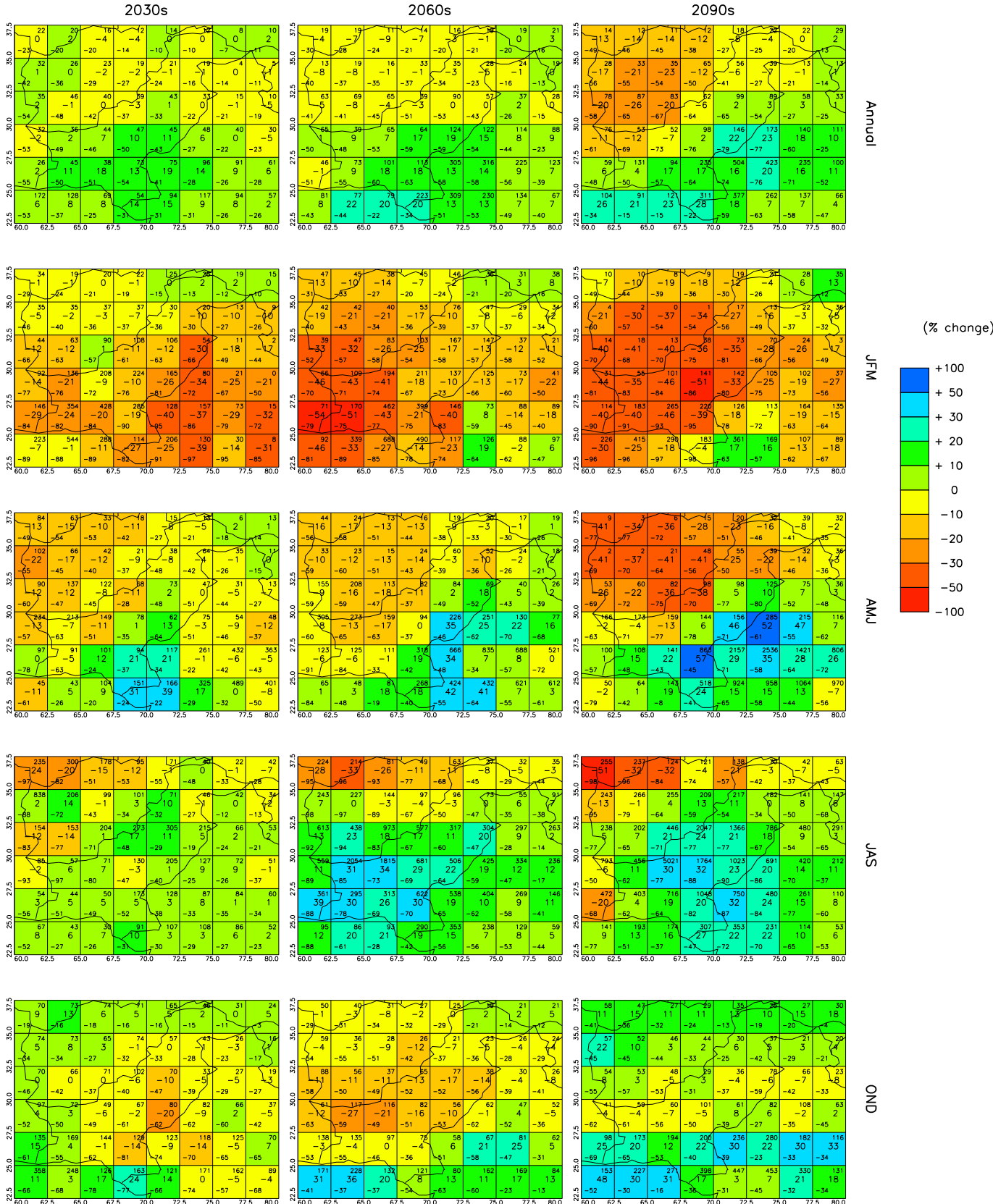


Figure 6: Spatial patterns of projected change in monthly precipitation for 10-year periods in the future under the SRES A2 scenario. All values are percentage anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.

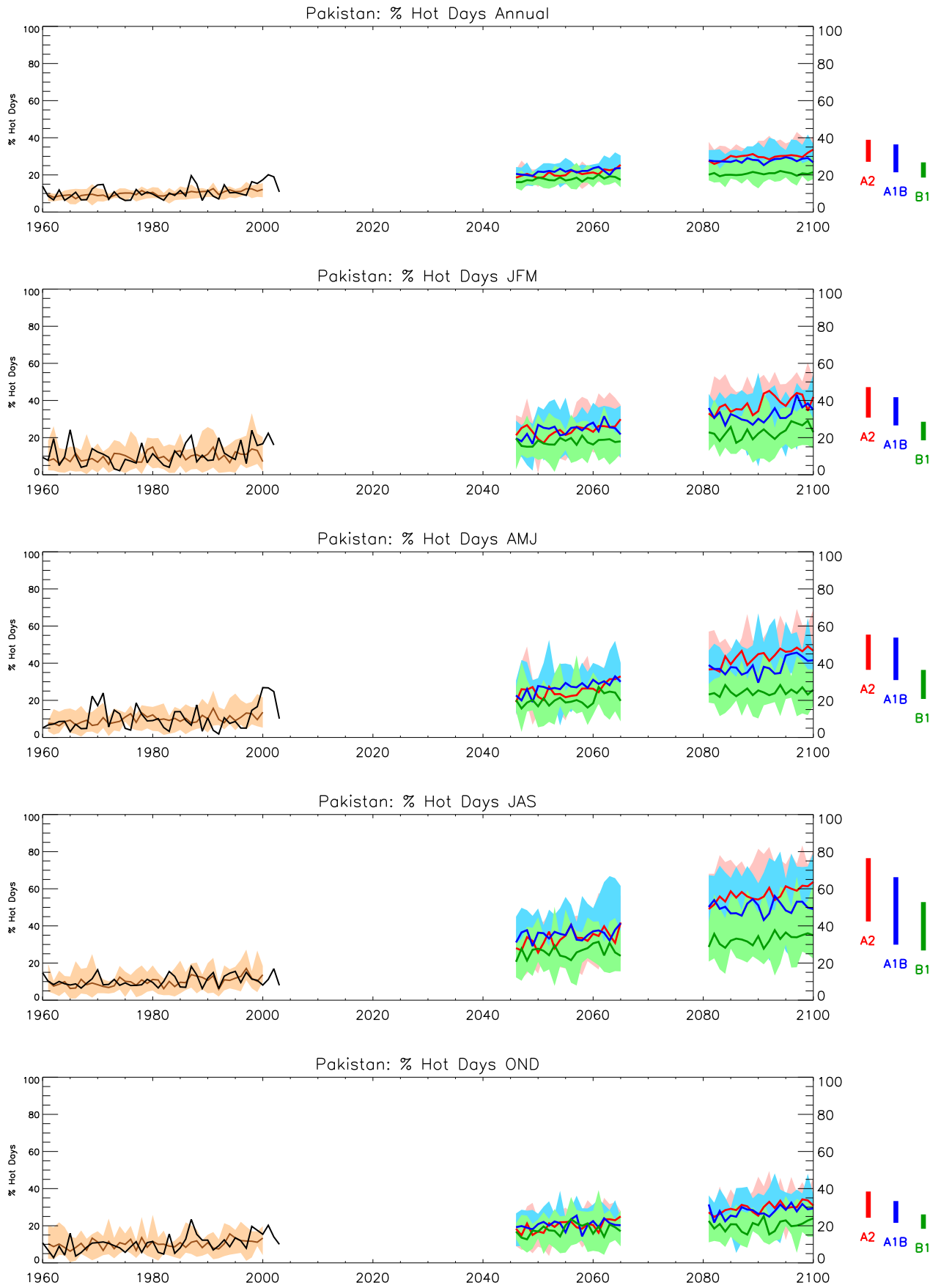


Figure 7: Trends in Hot-day frequency for the recent past and projected future. See Figure 1 for details.

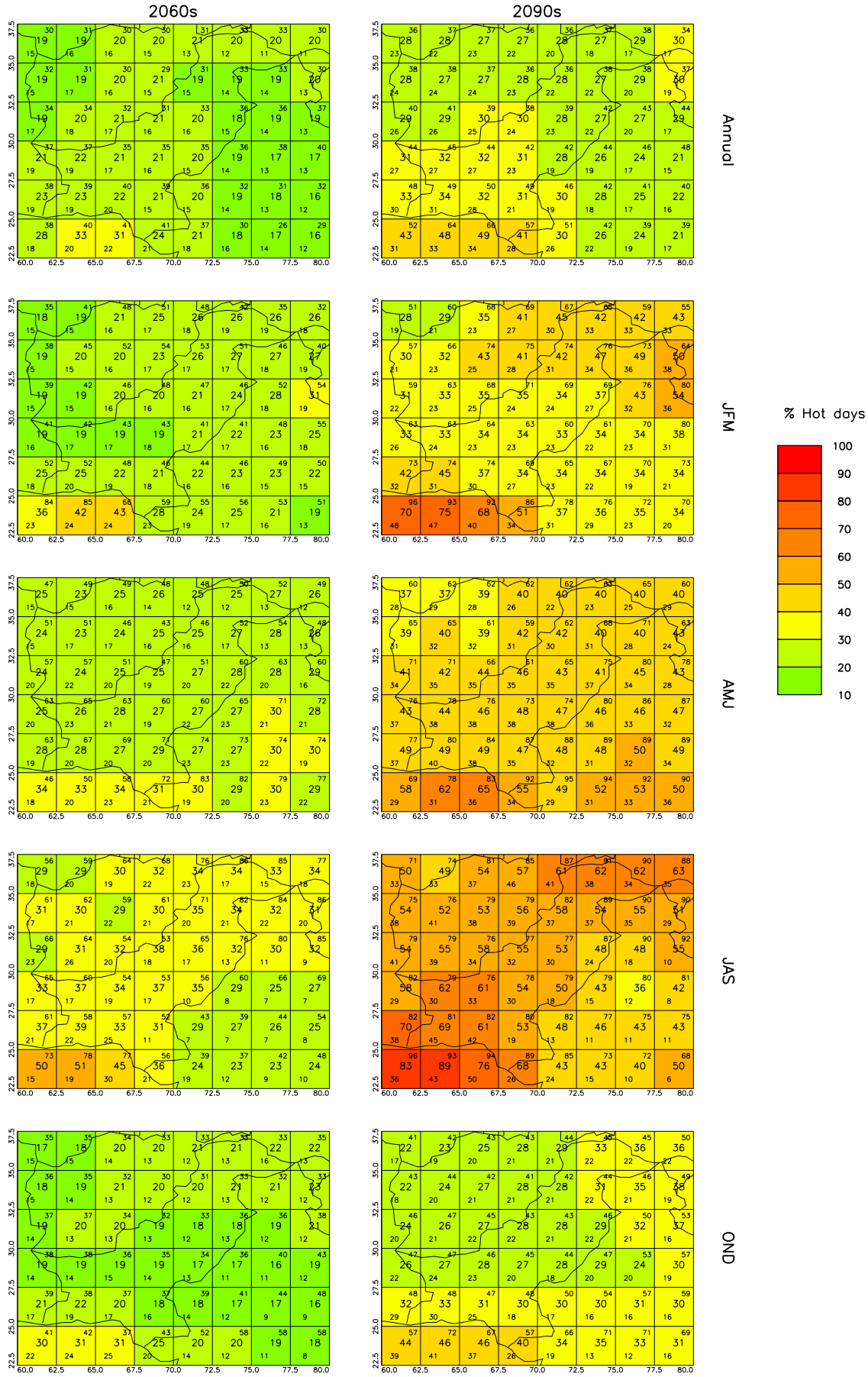


Figure 8: Spatial patterns of projected change in Hot-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

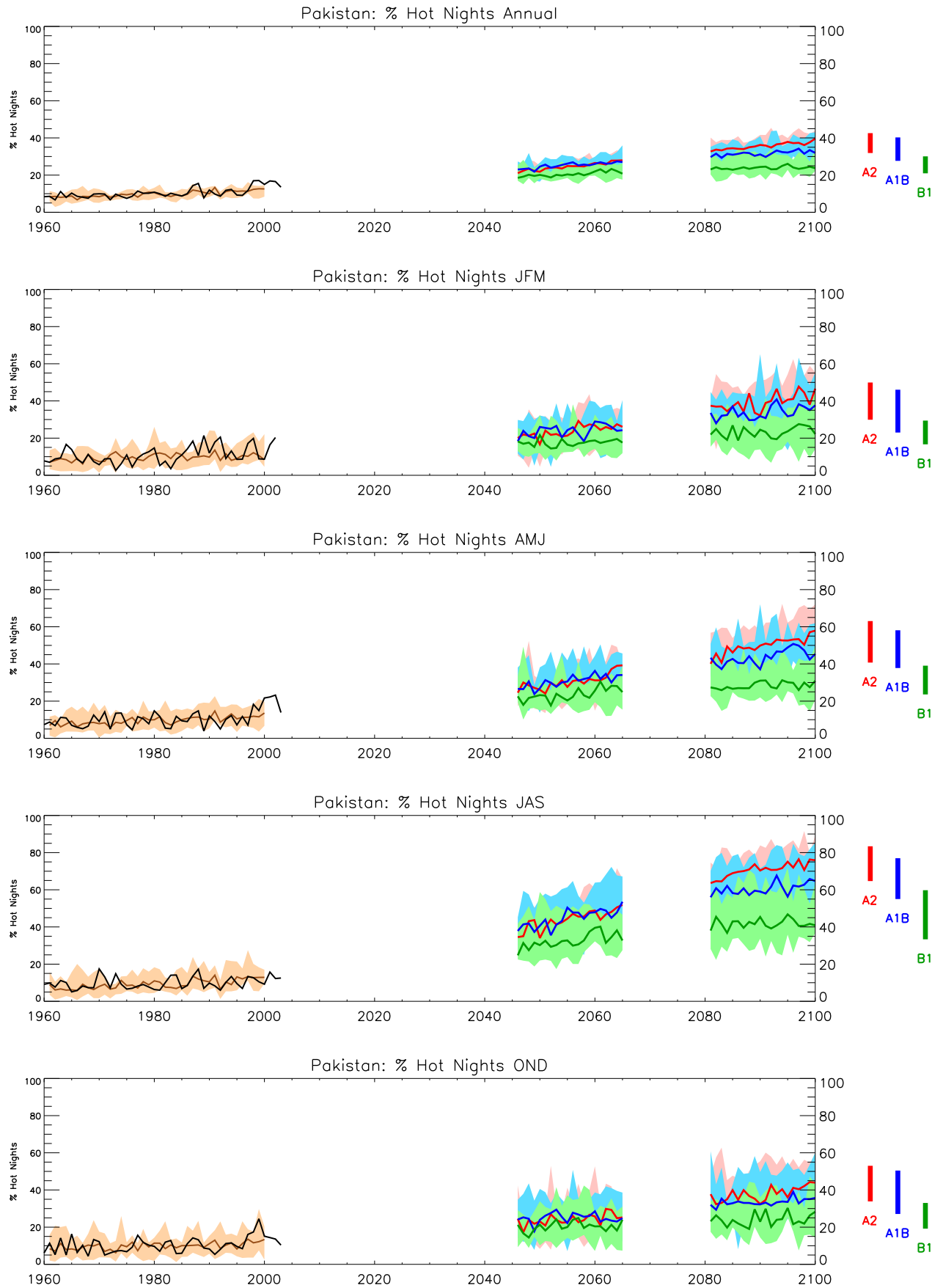


Figure 9: Trends in hot-night frequency for the recent past and projected future. See Figure 1 for details.



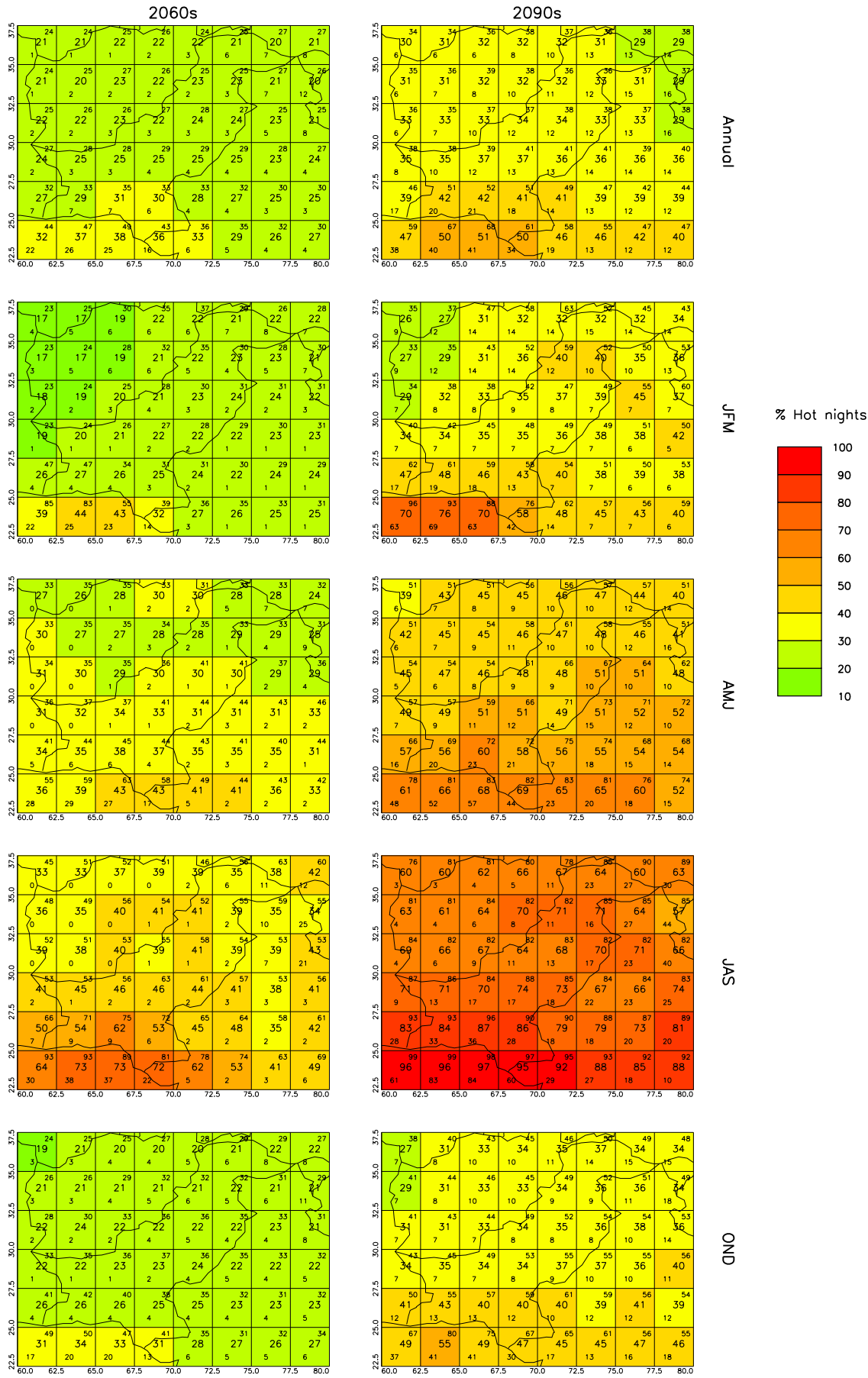


Figure 10: Spatial patterns of projected change in hot-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.



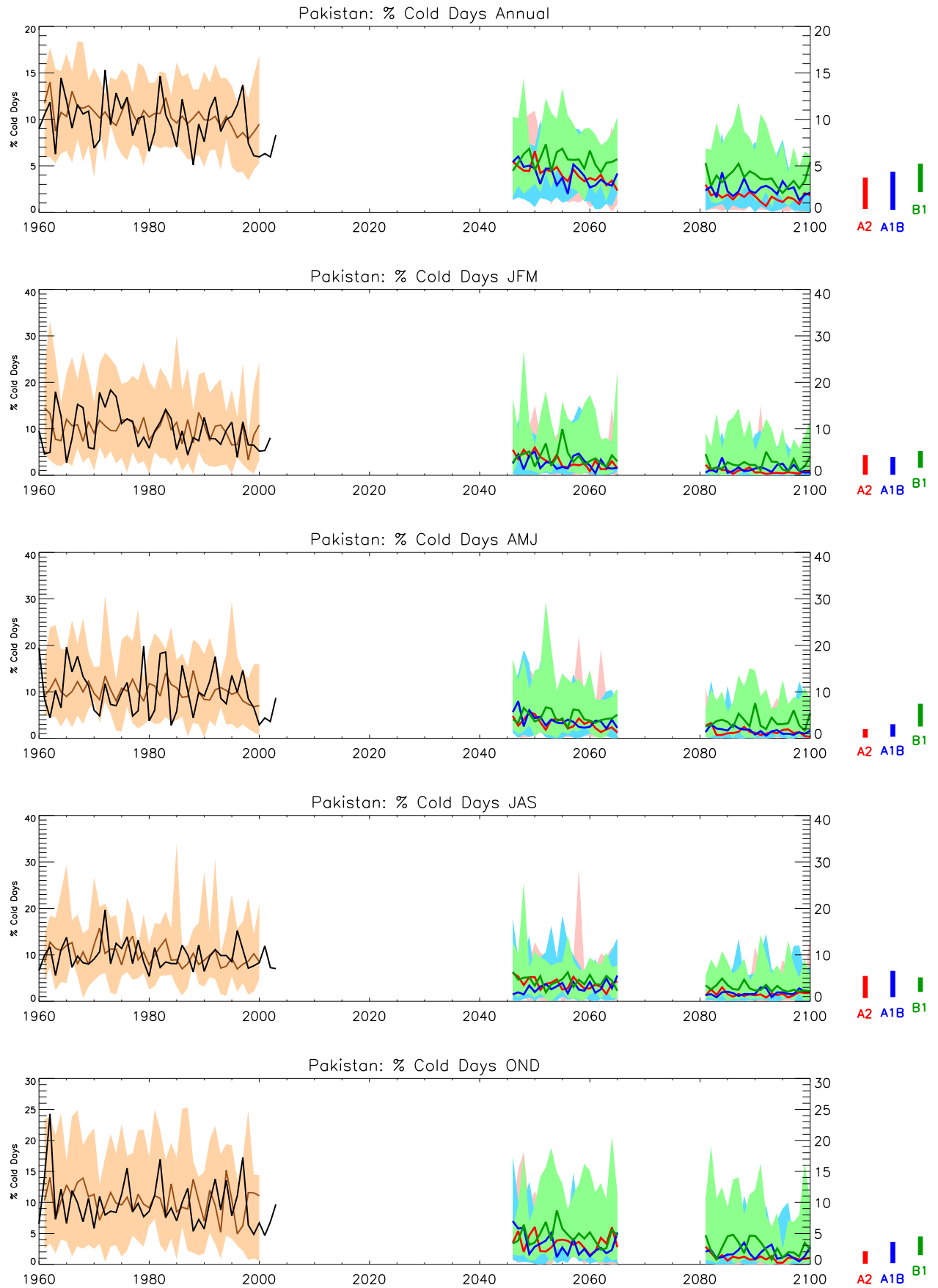


Figure 11: Trends in cold-day frequency for the recent past and projected future. See Figure 1 for details.

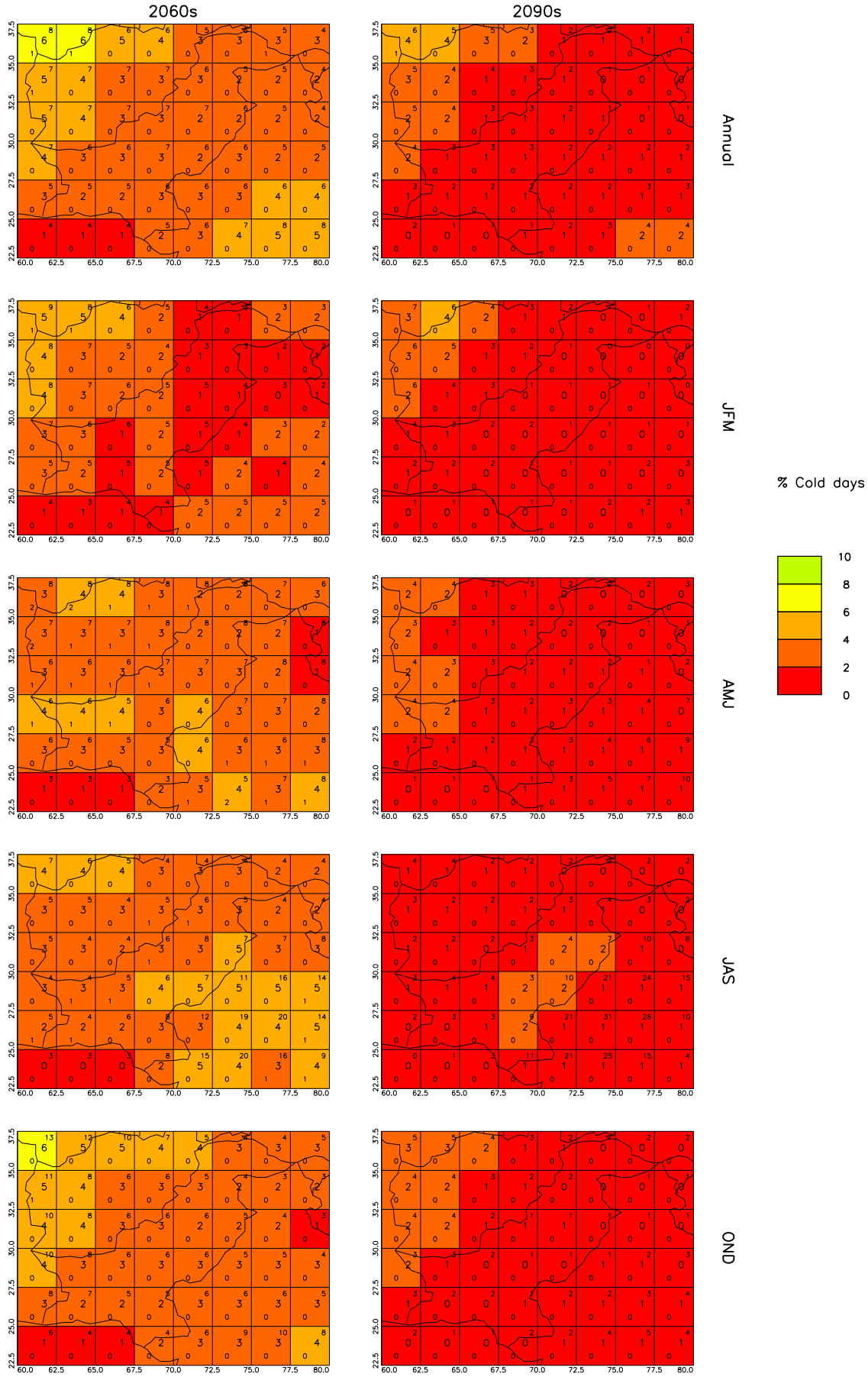


Figure 12: Spatial patterns of projected change in cold-day frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

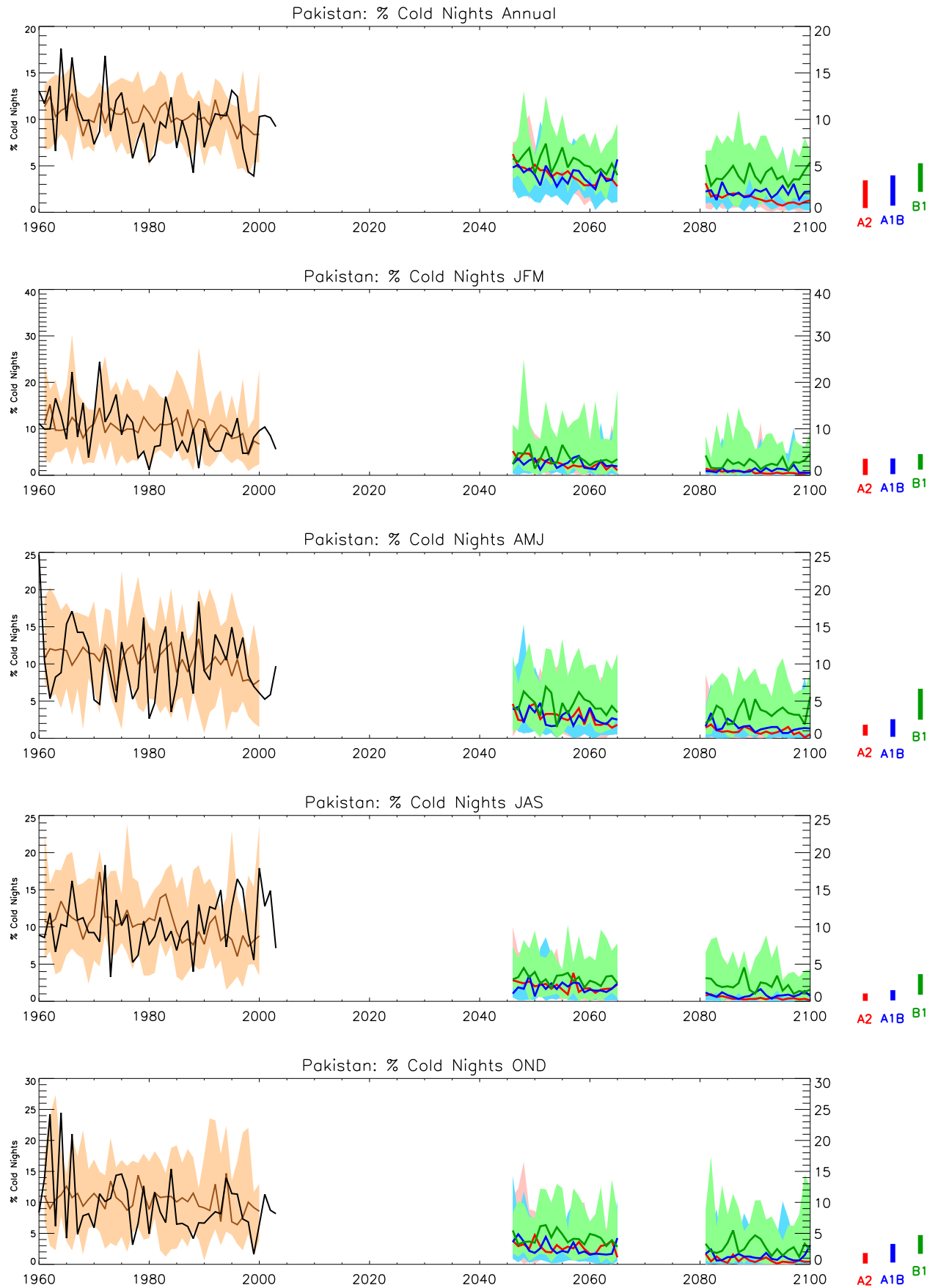


Figure 13: Trends in cold-night frequency for the recent past and projected future. See Figure 1 for details.

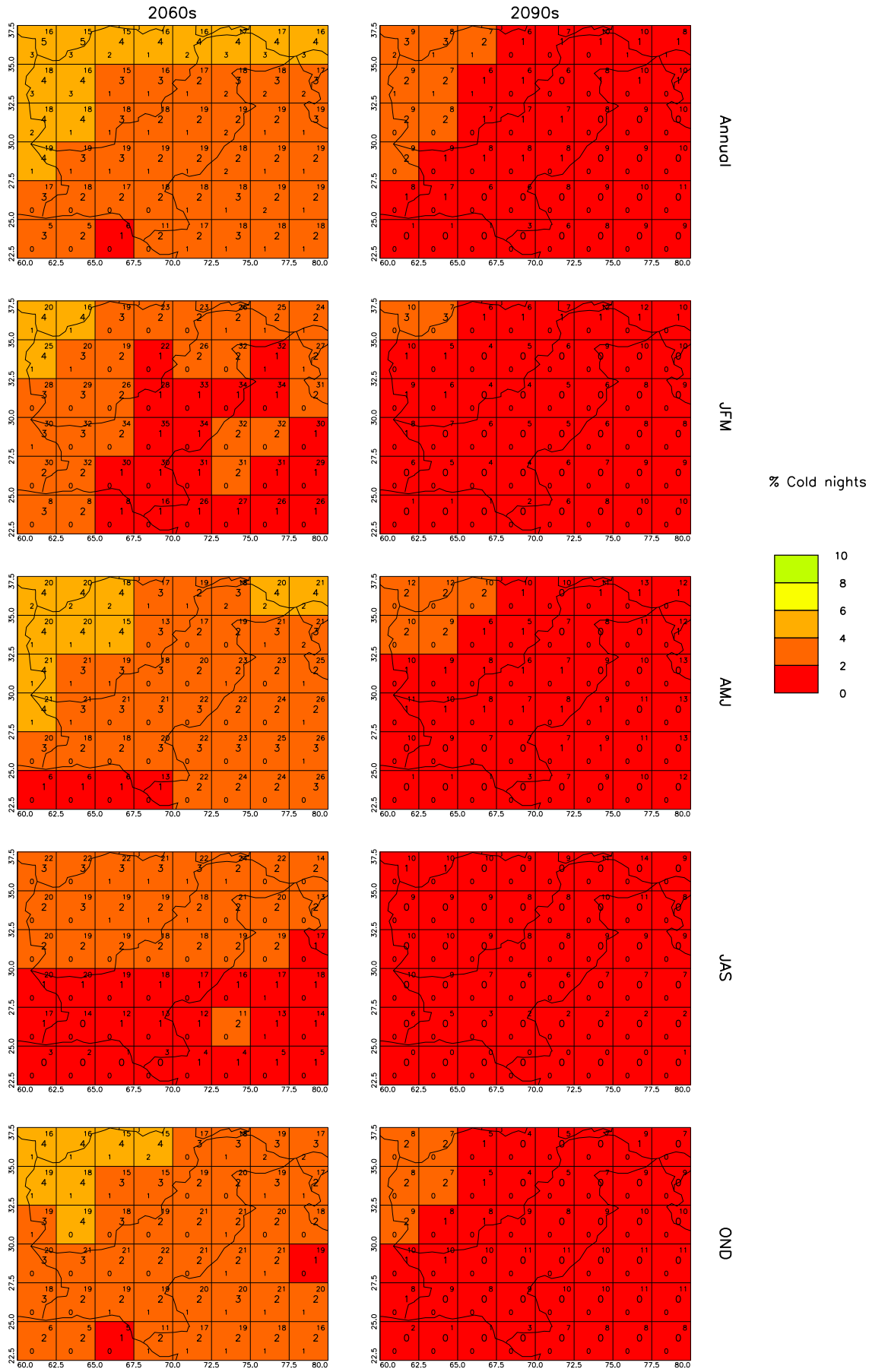


Figure 14: Spatial patterns of projected change in cold-night frequency for 10-year periods in the future under the SRES A2 scenario. See Figure 2 for details.

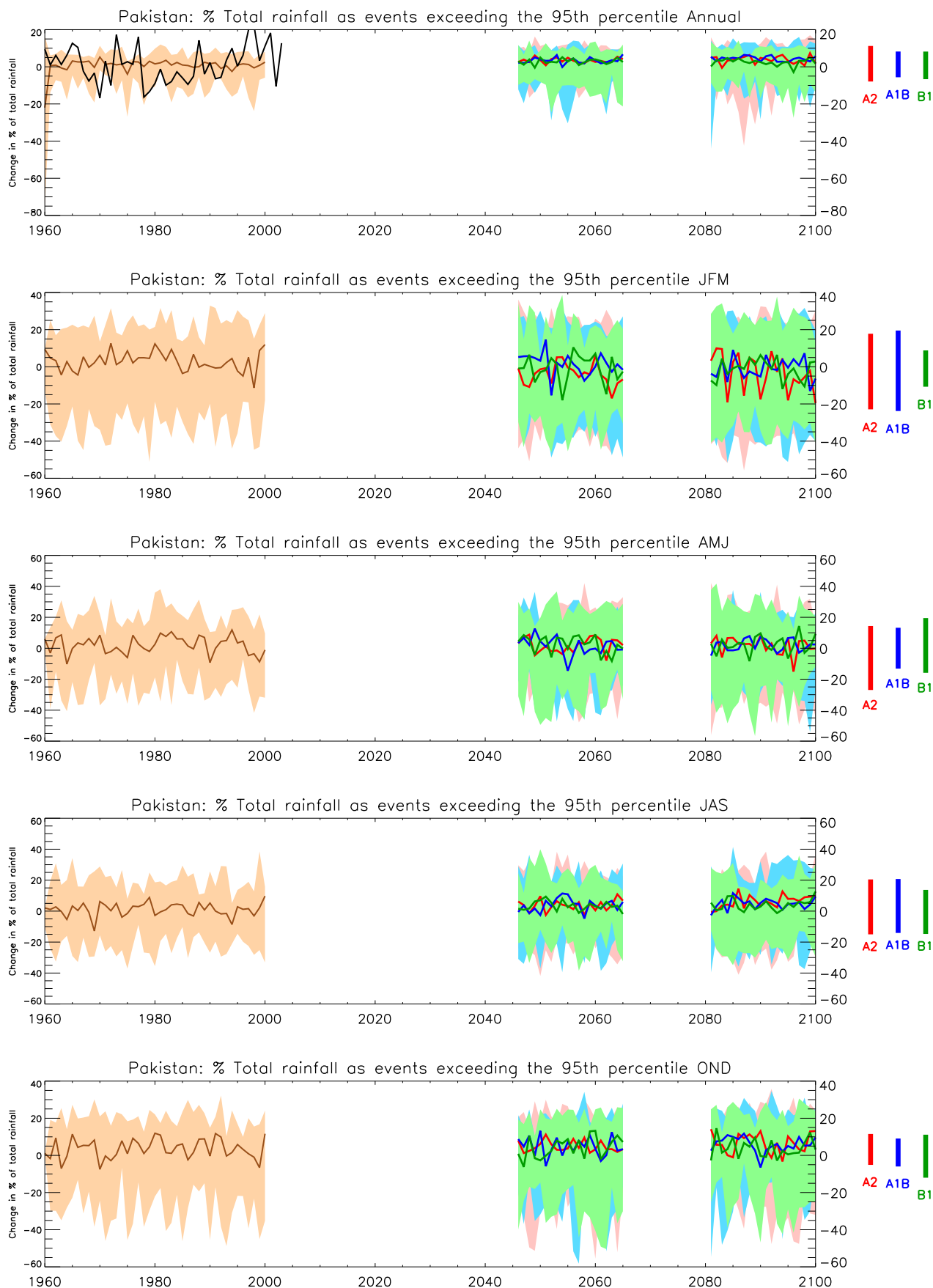


Figure 15: Trends in the proportion of precipitation falling in 'heavy' events for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

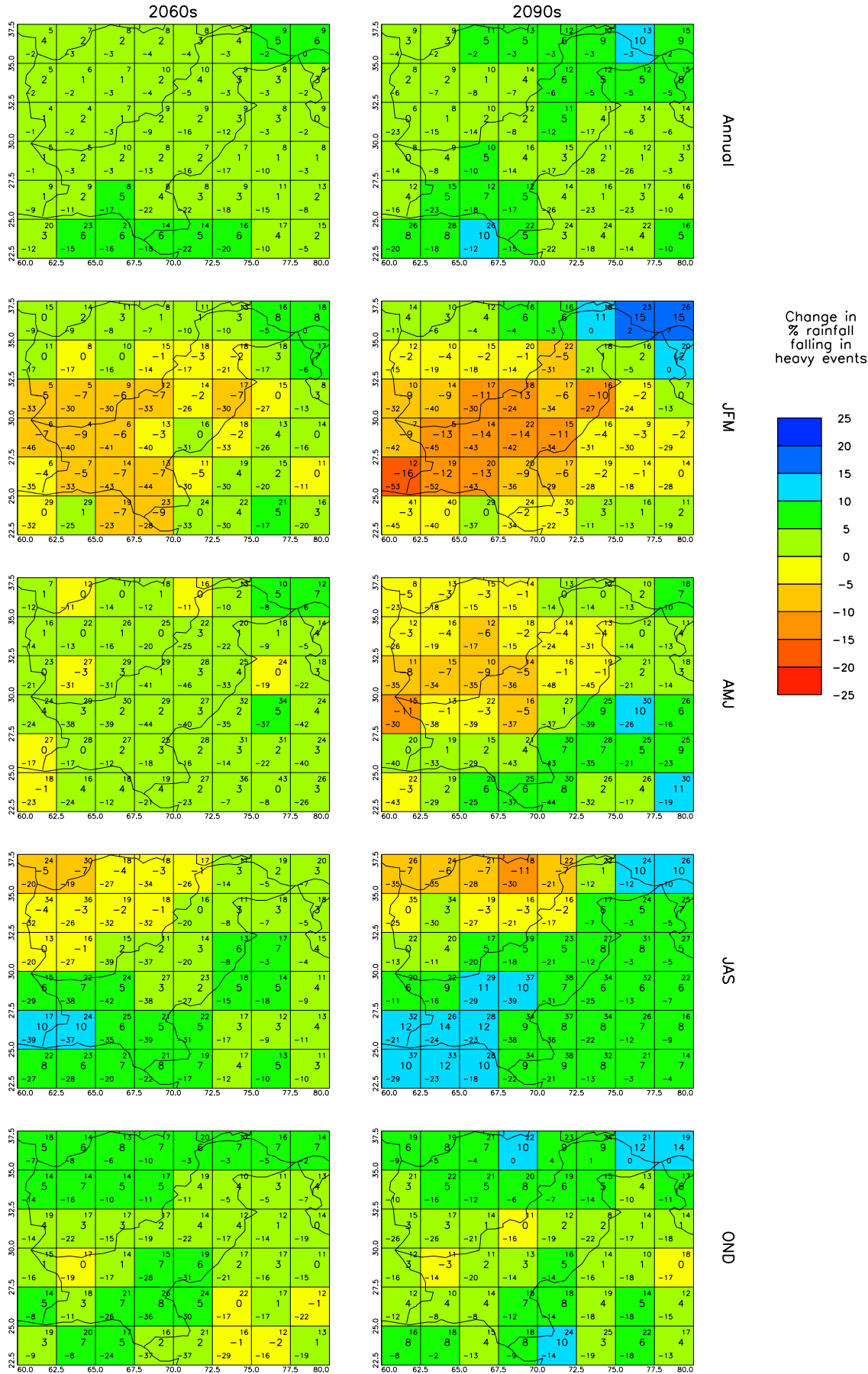


Figure 16: Spatial patterns of projected change in the proportion of precipitation falling in 'heavy' events for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.

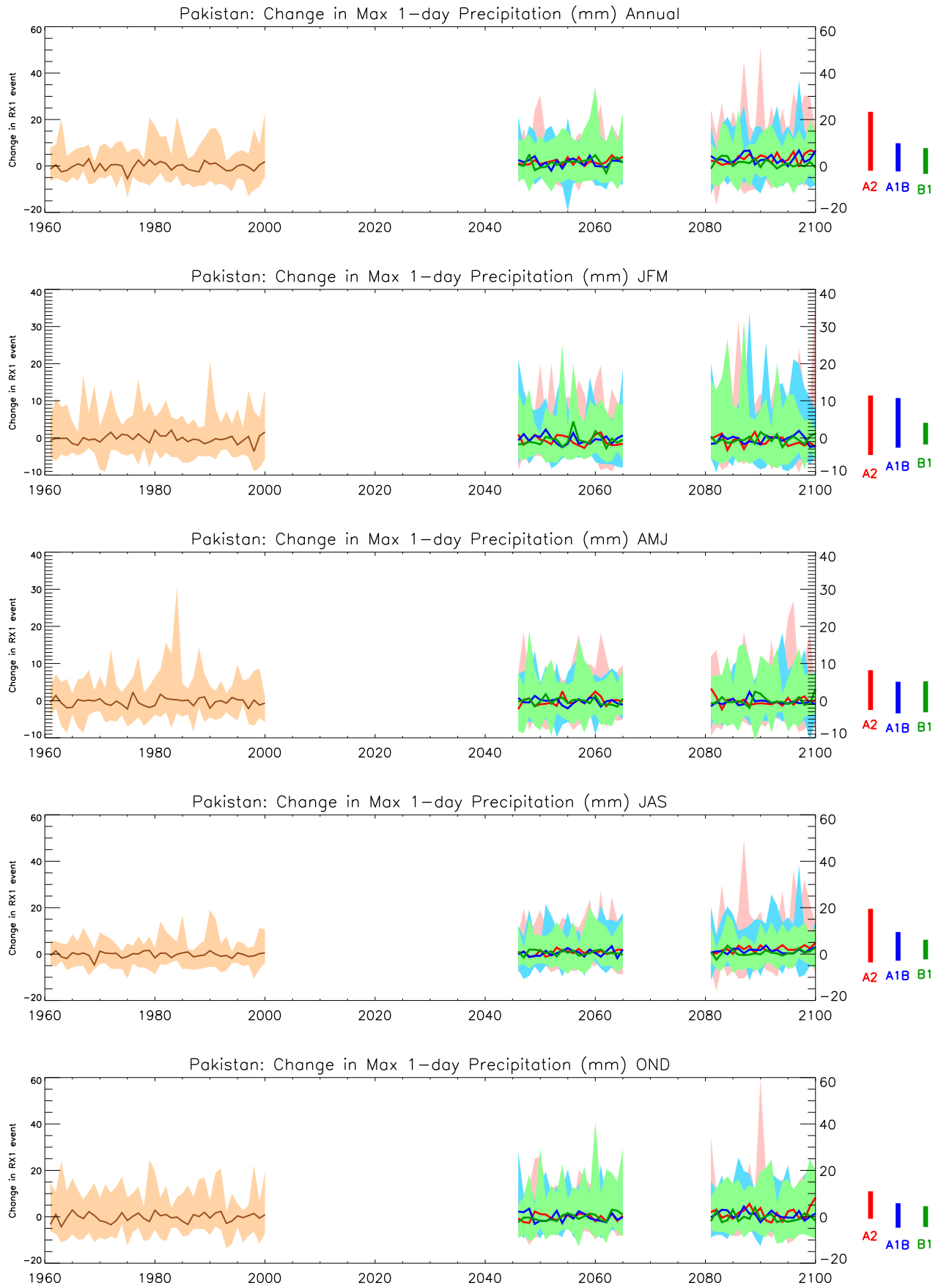


Figure 17: Trends in maximum 1-day rainfall for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

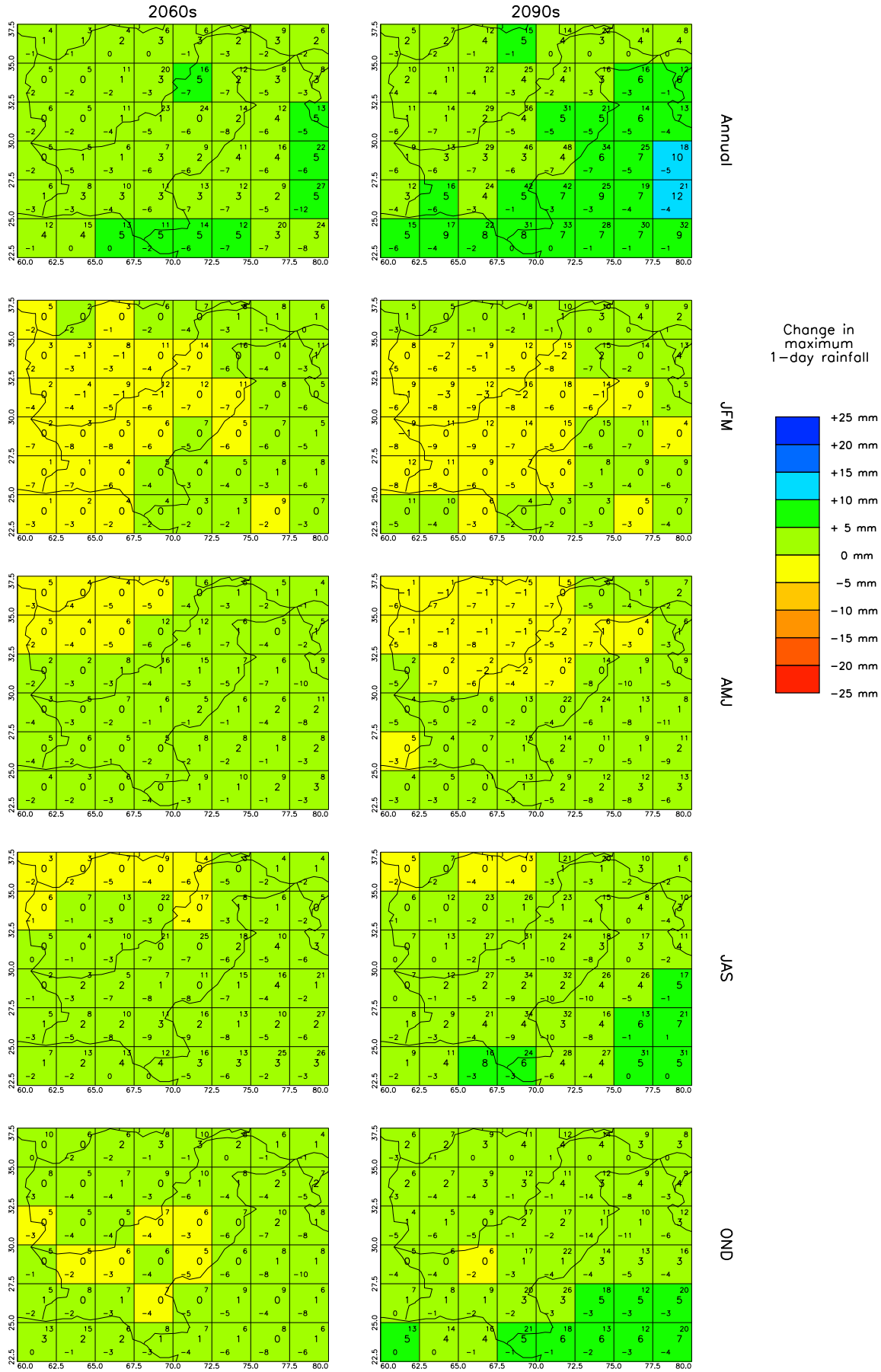


Figure 18: Spatial patterns of maximum 1-day rainfall for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.



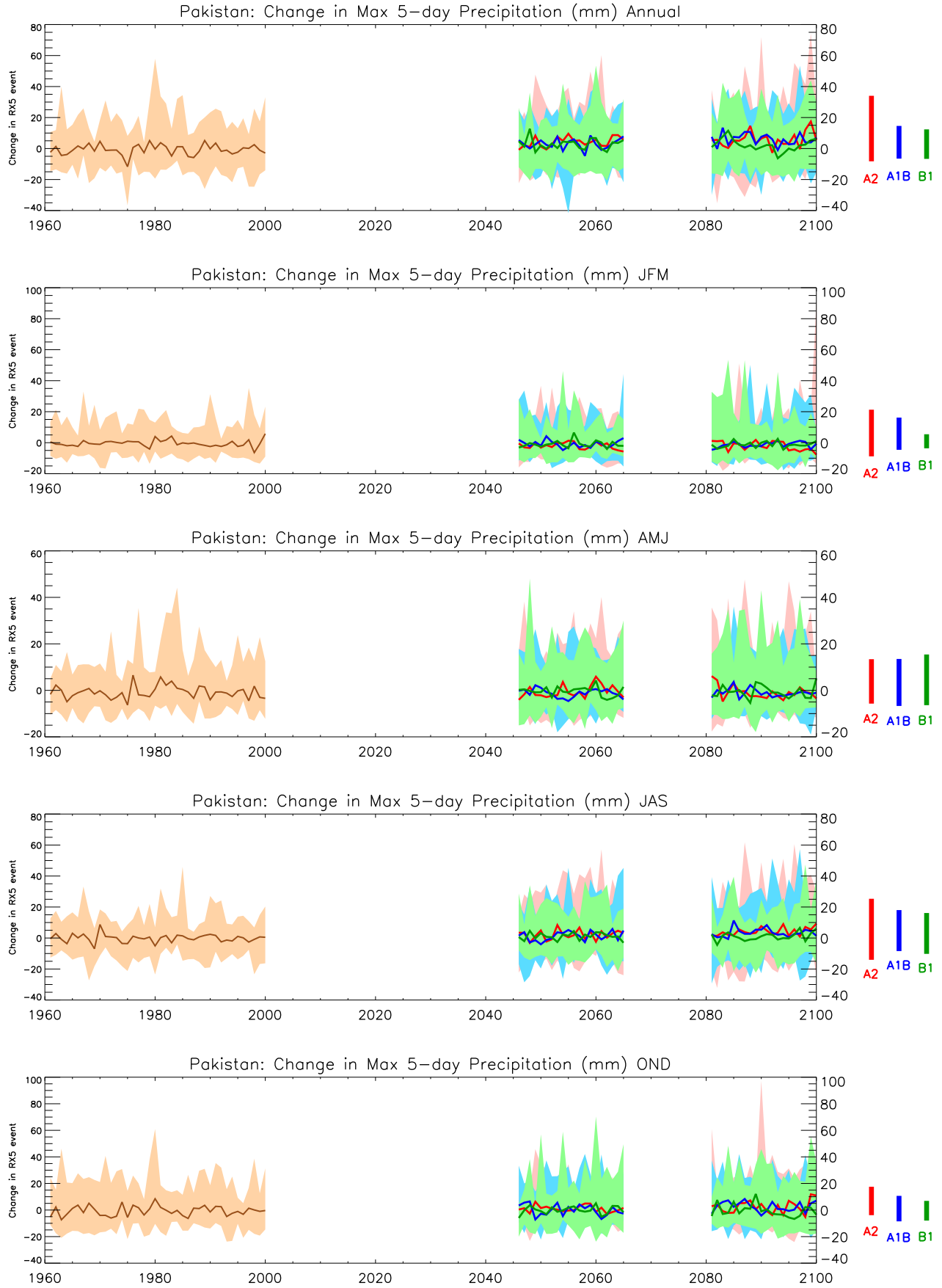


Figure 19: Trends in maximum 5-day rainfall for the recent past and projected future. All values shown are anomalies, relative to the 1970-1999 mean climate. See Figure 1 for details.

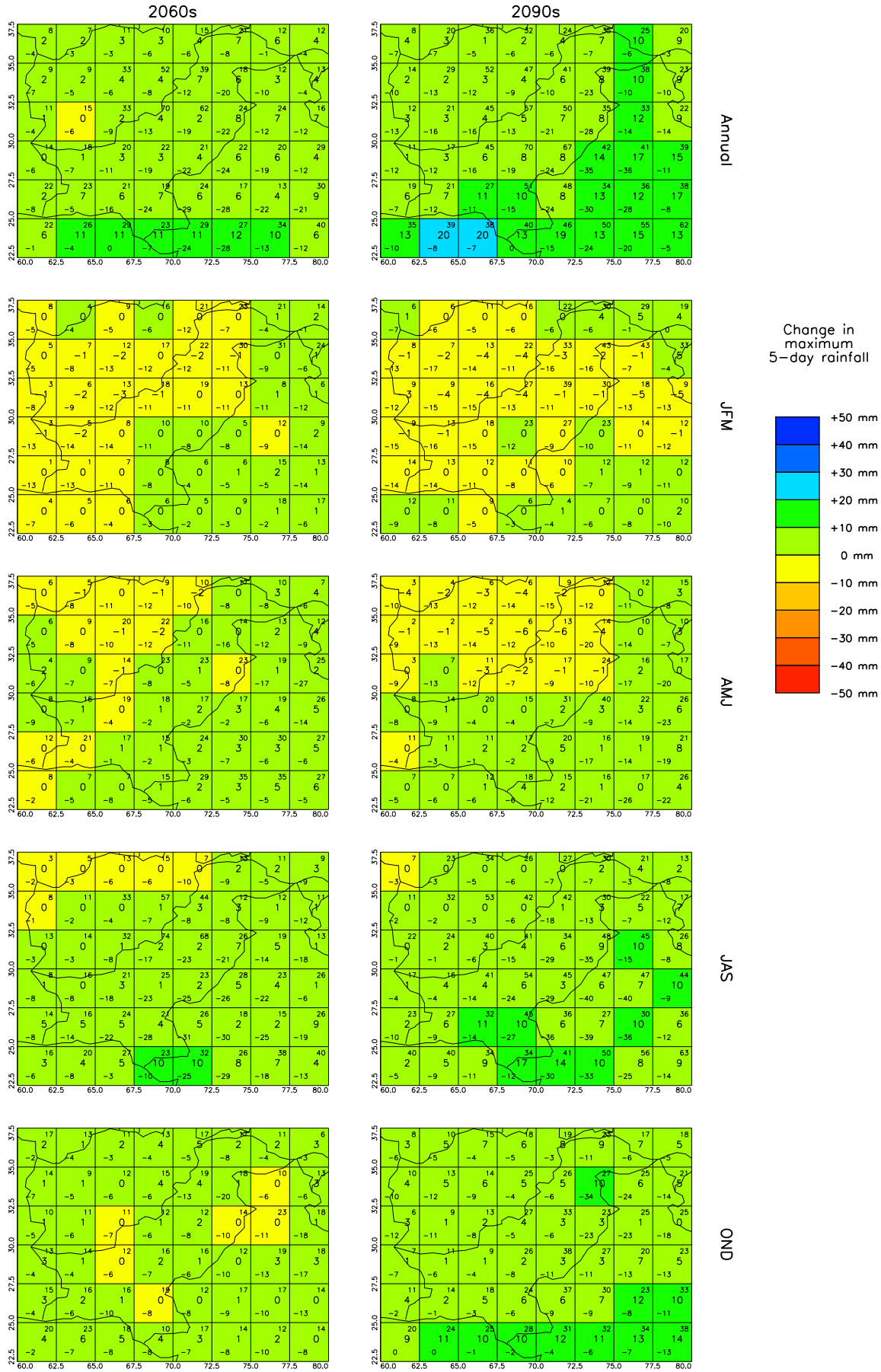


Figure 20: Spatial patterns of projected change in maximum 5-day rainfall for 10-year periods in the future under the SRES A2 scenario. All values are anomalies relative to the mean climate of 1970-1999. See Figure 2 for details.