Supplementary materials

Characterizing the Long-Term (1981–2023) Temperature and Precipitation Dynamics in the Trans-Mountain Regions of Kazakhstan, Central Asia

Baktybek Duisebek[1, 2 *], Gabriel B. Senay[3, 4], Talgat Usmanov[1], Kudaibergen Kyrgyzbay[5], Janay Sagin[1], Yerbolat Mukanov[6], Kanat Samarkhanov [1, 6], Xuejia Wang[7], Sulitan Danierhan[8], and Xiaohui Pan[9]

1. School of Information Technology and Engineering, Kazakh-British Technical University, Almaty 050000, Kazakhstan b.duisebek17@gmail.com.
2. Department of Water Resources and Melioration, Kazakh National Agrarian Research University, Almaty 050010, Kazakhstan.
3. U.S. Geological Survey (USGS) Earth Resources Observation and Science Center, Fort Collins Science Center, Fort Collins, CO 80526, USA senay@usgs.gov
4. USGS North Central Climate Adaptation Science Center, Fort Collins, CO 80528, USA
5. Al-Farabi Kazakh National University, Faculty of Geography and Environmental Sciences, 71 al-Farabi, Almaty, Kazakhstan, 050040, kyrgyzbay.kudaibergen@gmail.com
6. Faculty of Natural Sciences, Department of Physical and Economic Geography, L.N. Gumilyov Eurasian National University, Astana 010000, Kazakhstan; mukanov_yen@enu.kz, samarkhanov_kb@enu.kz.
7. Key Laboratory of Western China's Environmental Systems (Ministry of Education), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730000, China
8. State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China
9. State Key Laboratory of Ecological Safety and Sustainable Development in Arid Lands, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China

Table S1. Summary of meteorological stations in the study area and associated data availability.

No	Station ID	Station name	Region	Latitude (°)	Longitude (°)	Annual precipitation (mm)	Annual temperature (°C)	Number of years analysed (missing years)	Elevation (m)
1	-	Anarkhay	I	43.7	74.8	206.6	11.1	39 (2020-2023)	976
2	38208	Karatau	I	43.2	70.4	234.8	11.6	30 (1992-2004)	539
3	38108	Khantau	I	44.2	73.8	212.7	11.9	43	566
4	38229	Korday	I	43.3	74.9	457.6	8.8	43	1145
5	38343	Kulan	I	42.9	72.7	338.0	10.5	43	701
6	38344	Mereke	I	42.9	73.2	408.5	10.8	43	695
7	38099	Moiynkum	I	44.3	72.9	197.1	10.4	43	352
8	38330	Nurlykent	I	42.7	70.8	467.1	8.1	40 (2001-2023)	966
9	36865	Otar	I	43.5	75.2	220.2	9.4	43	352
10	38202	Saudakent	I	43.7	69.9	214.6	11.1	43	339
11	38223	Shokpar	I	43.8	74.4	339.3	11.0	43	771
12	35997	Shyganak	I	45.1	74.0	127.8	8.9	43	352
13	38341	Taraz	I	42.9	71.3	343.1	11.3	42 (2018)	652
14	38222	Tole Bi	I	43.7	73.7	303.2	10.5	43	456
15	38094	Ulanbel	I	43.0	72.1	147.4	10.4	40 (2001-2023)	630
16	38203	Uyuk	I	43.8	71.0	169.7	10.9	43	376
17	36819	Aidarly	II	44.2	75.8	235.9	10.4	42 (2000)	501
18	36874	Aksengir	II	43.5	76.3	359.5	8.7	43	646
19	36870	Almaty	II	43.2	76.9	667.8	10.4	43	849
20	36875	Almaty Kam-Plato	II	43.2	77.0	889.7	9.3	43	1321
21	36744	Auyl-4	II	45.5	75.2	123.7	8.4	43	362
22	36821	Bakanas	II	44.8	76.3	189.0	9.4	43	400
23	36885	Esik	II	43.4	77.4	652.0	9.4	43	949
24	36837	Kapshagai	II	43.8	77.1	294.8	10.2	43	491
25	36891	Karashoky	II	43.8	77.9	247.6	11.5	42 (1989)	492
26	36907	Kegen	II	43.0	79.2	405.2	3.7	43	1852
27	35996	Kuigan	II	45.4	74.1	138.1	8.4	43	343
28	36905	Kyrgyzsay	II	43.3	79.5	431.4	8.8	43	1281
29	36889	Mynzhylky	II	43.1	77.1	871.8	-1.0	43	2981
30	36953	Narynkol	II	42.7	80.2	391.7	4.0	43	1838
31	36894	Shelek	II	43.6	78.3	256.7	10.9	43	607
32	36873	Shymbulak	II	43.1	77.1	969.1	4.5	23 (1981-2000)	2194
33	36879	Big Almaty Lake	II	43.1	77.0	848.3	2.0	43	2512
34	36877	Uzynagash	II	43.2	76.3	475.4	8.4	41 (1996-1997)	818
35	36899	Zhalanash	II	43.1	78.6	531.7	6.0	43	1703
36	36803	Alakol	III	46.0	81.6	213.9	8.2	43	372
37	36846	Kogaly	III	44.5	78.7	549.7	5.5	43	1408

No	Station ID	Station name	Region	Latitude (°)	Longitude (°)	Annual precipitation (mm)	Annual temperature (°C)	Number of years analysed (missing years)	Elevation (m)
38	36796	Lepsy	III	45.5	80.6	703.3	2.8	43	1014
39	36772	Matay	III	45.9	78.7	249.4	8.2	42 (2021)	416
40	36786	Sarkand	III	45.4	79.9	496.4	8.3	43	759
41	36839	Saryozek	III	44.4	78.0	362.3	7.9	43	951
42	36770	Taldykorgan	III	45.0	78.4	414.6	9.0	43	596
43	36729	Usharal	III	46.2	80.9	312.5	7.9	43	387
44	36777	Ushtobe	III	45.3	78.0	283.3	8.4	43	429
45	36806	Zhalanashkol	III	45.6	82.2	97.9	8.6	42 (2001)	377
46	36859	Zharkent	III	44.2	80.0	198.6	10.6	43	634
47	36643	Aksuat	IV	47.8	82.8	207.4	3.9	43	537
48	36619	Aktogay	IV	47.0	79.7	192.4	7.0	43	368
49	36658	Akzhar	IV	47.6	83.7	232.6	4.0	40 (1993, 2000-2001)	655
50	36622	Ayagoz	IV	48.0	80.4	297.2	3.8	41 (1997-1998)	658
51	36736	Bakty	IV	46.7	82.7	300.3	7.1	43	447
52	36498	Barshatas	IV	48.2	78.7	208.0	4.5	43	651
53	36183	Dmitrievka	IV	50.8	80.8	332.1	3.6	41 (1994-1995)	357
54	36358	Kainar	IV	49.2	77.4	231.3	2.9	43	839
55	36501	Karauyl	IV	49.0	79.2	236.9	4.8	42 (1998)	616
56	36535	Kokpekty	IV	48.8	82.4	308.9	2.2	43	509
57	36152	Semijarka	IV	50.9	78.3	220.4	4.3	43	151
58	36177	Semipalatinsk	IV	50.4	80.3	291.4	4.5	43	196
59	36392	Shaliv	IV	49.7	81.5	335.1	4.4	43	350
60	36394	Shar	IV	49.6	81.1	289.2	3.9	43	340
61	36639	Urzhar	IV	47.1	81.7	441.8	5.8	43	498
62	36397	Zhalgyztobe	IV	49.2	81.2	299.0	4.5	43	456
63	36439	Katon-Karagay	V	49.2	85.6	440.7	2.5	42 (2003)	1063
64	36546	Kurshim	V	48.6	83.7	256.9	3.9	43	432
65	36208	Leninogorsk	V	50.3	83.6	631.3	2.9	43	786
66	36566	Markakol	V	48.8	86.0	576.9	-1.9	40 (1981-1982, 2000)	1471
67	36403	Oskemen	V	49.9	82.6	465.6	3.8	35 (2000-2007)	293
68	36418	Samarka	V	49.0	83.4	386.5	4.2	43	530
69	36415	Seleznevka	V	49.6	83.5	395.0	3.0	43	416
70	36186	Shemonaikha	V	50.6	81.9	467.0	3.6	43	312
71	36567	Terekty	V	48.4	85.7	377.8	5.2	43	600
72	36666	Tugyl	V	47.7	84.2	195.1	3.7	41 (1996, 2001)	393
73	36428	Ulken Naryn	V	49.2	84.5	388.7	2.7	43	408
74	36665	Zaisan	V	47.5	84.9	326.3	5.4	43	583

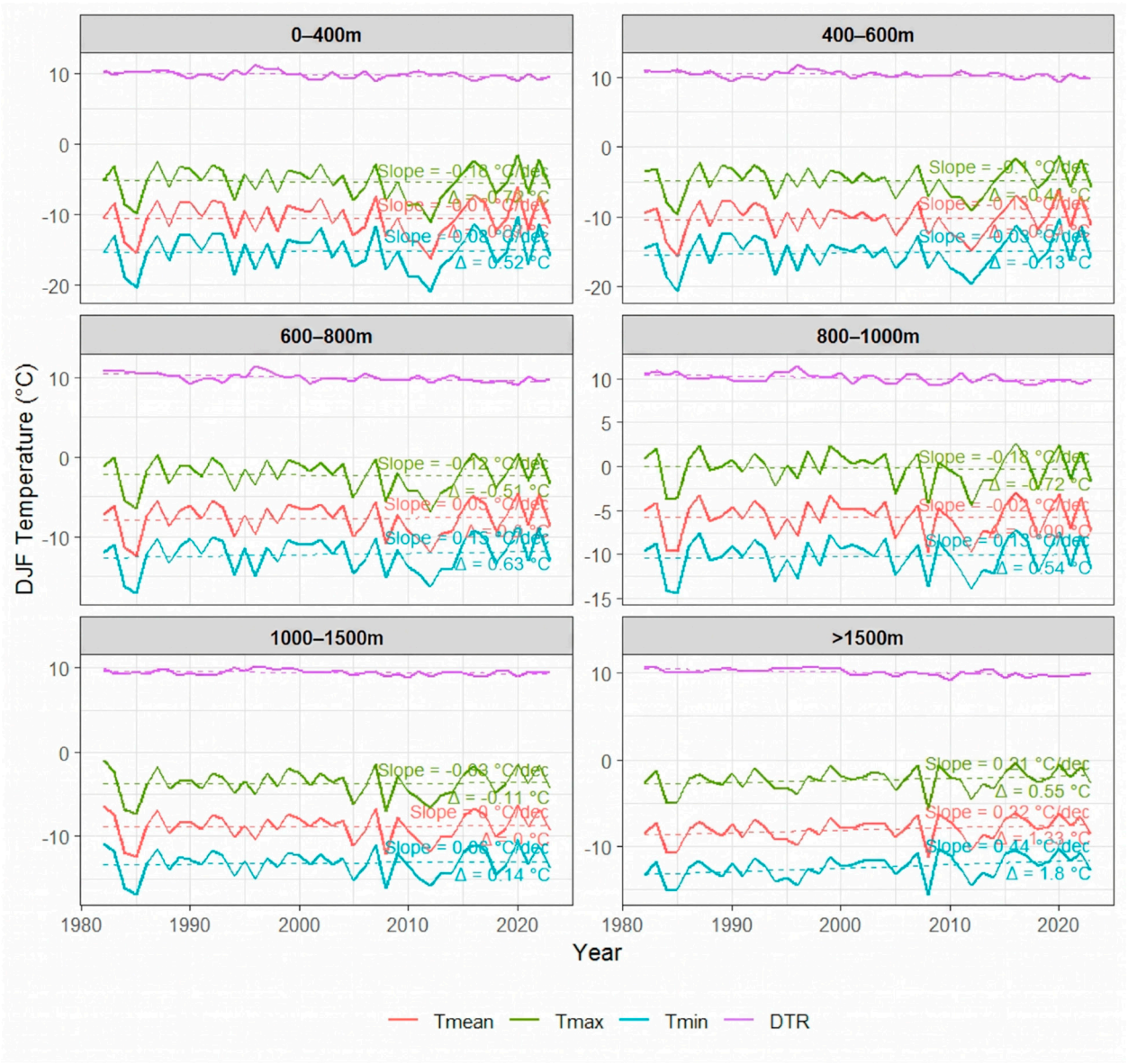


Figure S1. Elevation-dependent long-term (1981–2023) trends in DJF (December - February) mean (Tmean), maximum (Tmax), and minimum (Tmin) air temperature, as well as the diurnal temperature range (DTR), across six elevation bands. Trends are quantified using Sen's slope estimates (°C decade^{-1}), with corresponding absolute temperature changes (Δ, °C) over the study period shown for each elevation range.

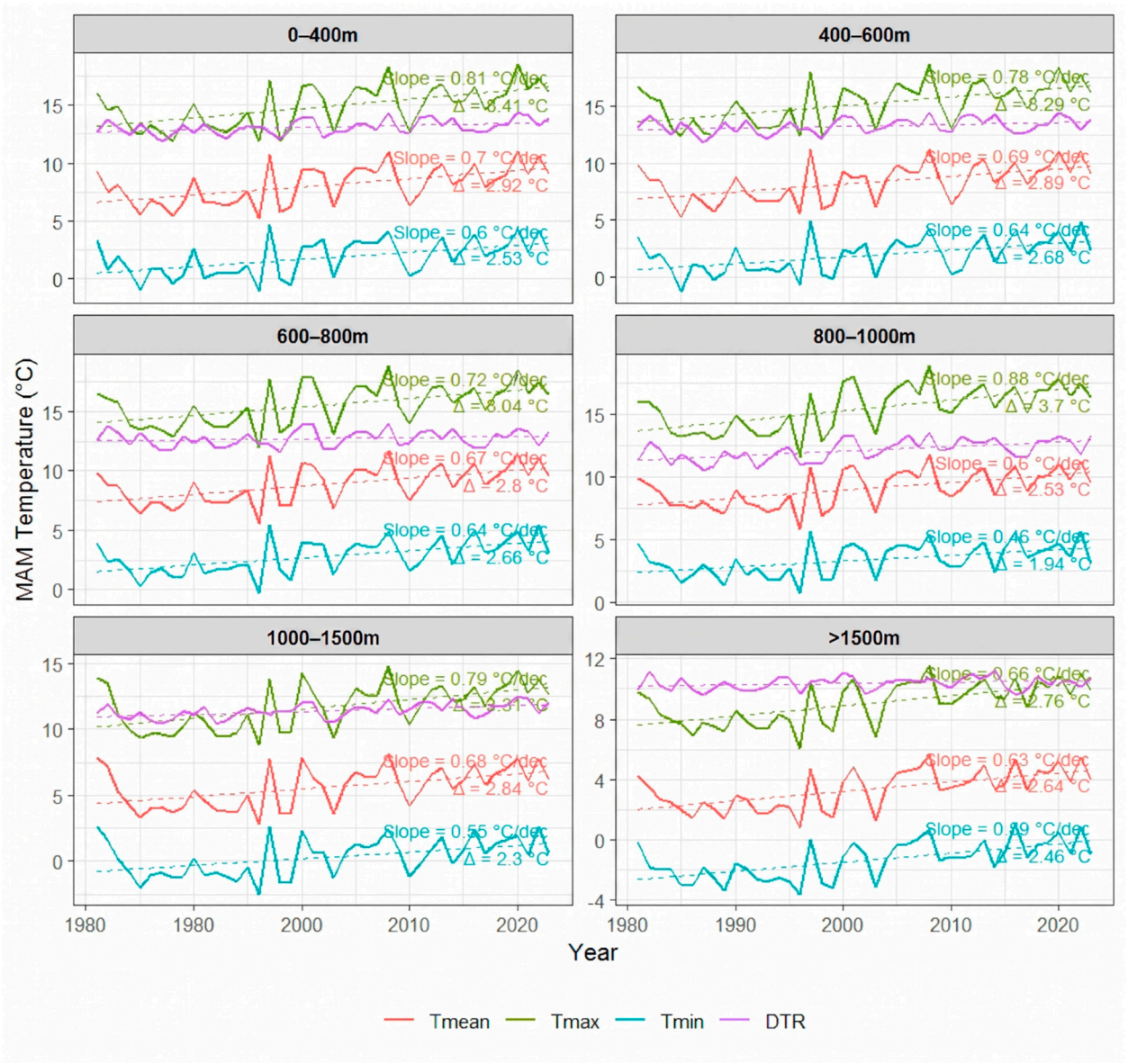


Figure S2. Elevation-dependent long-term (1981–2023) trends in MAM (March -May) mean (Tmean), maximum (Tmax), and minimum (Tmin) air temperature, as well as the diurnal temperature range (DTR), across six elevation bands. Trends are quantified using Sen's slope estimates (°C decade^{-1}), with corresponding absolute temperature changes (Δ, °C) over the study period shown for each elevation range.



Figure S3. Elevation-dependent long-term (1981–2023) trends in JJA (June - August) mean (Tmean), maximum (Tmax), and minimum (Tmin) air temperature, as well as the diurnal temperature range (DTR), across six elevation bands. Trends are quantified using Sen's slope estimates (°C decade^{-1}), with corresponding absolute temperature changes (Δ, °C) over the study period shown for each elevation range.

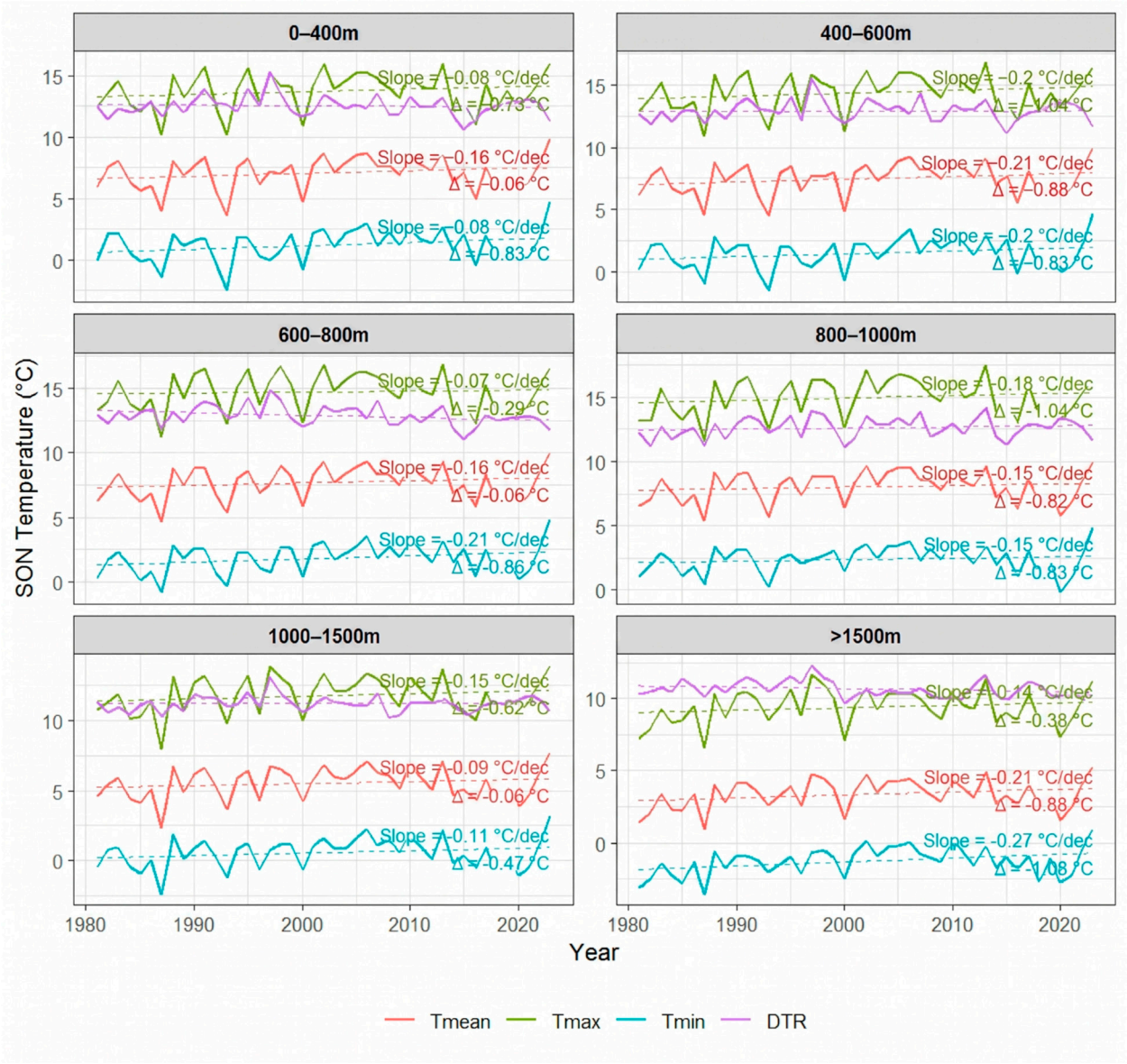


Figure S4. Elevation-dependent long-term (1981–2023) trends in SON (September - November) mean (Tmean), maximum (Tmax), and minimum (Tmin) air temperature, as well as the diurnal temperature range (DTR), across six elevation bands. Trends are quantified using Sen's slope estimates (°C decade^{-1}), with corresponding absolute temperature changes (Δ, °C) over the study period shown for each elevation range.

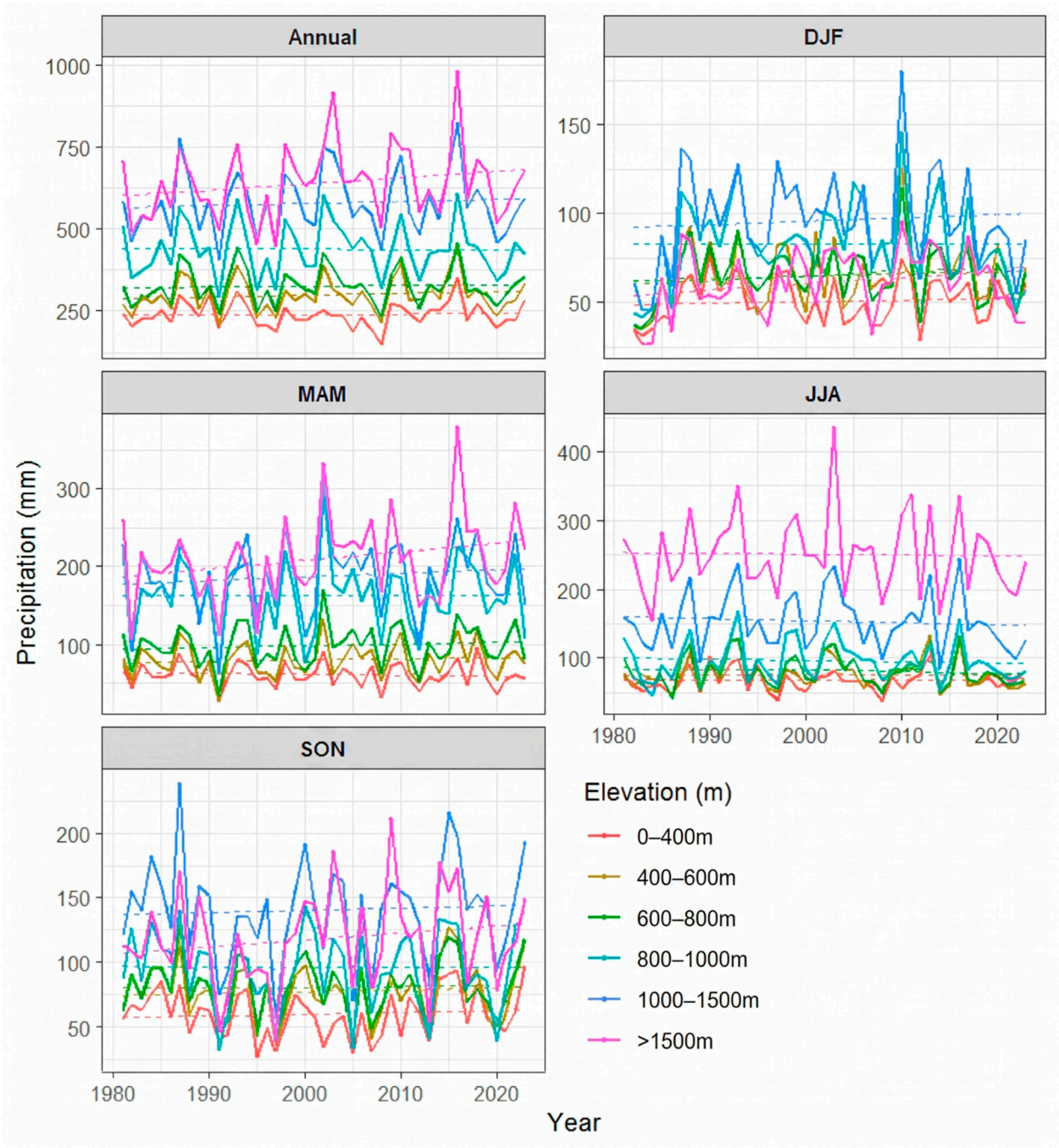


Figure S5. Elevation-dependent long-term (1981–2023) trends in annual and seasonal precipitation including DJF (December–February), MAM (March–May), JJA (June–August), and SON (September–November) across six elevation bands. Trends are quantified using Sen's slope estimates (mm decade^{-1}).

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