Supplement of The Cryosphere, 15, 1343–1382, 2021
https://doi.org/10.5194/tc-15-1343-2021-supplement

The Cryosphere
Open Access

Supplement of

Observed snow depth trends in the European Alps: 1971 to 2019

Michael Matiu et al.

Correspondence to: Michael Matiu (michael.matiu@eurac.edu)

Figures

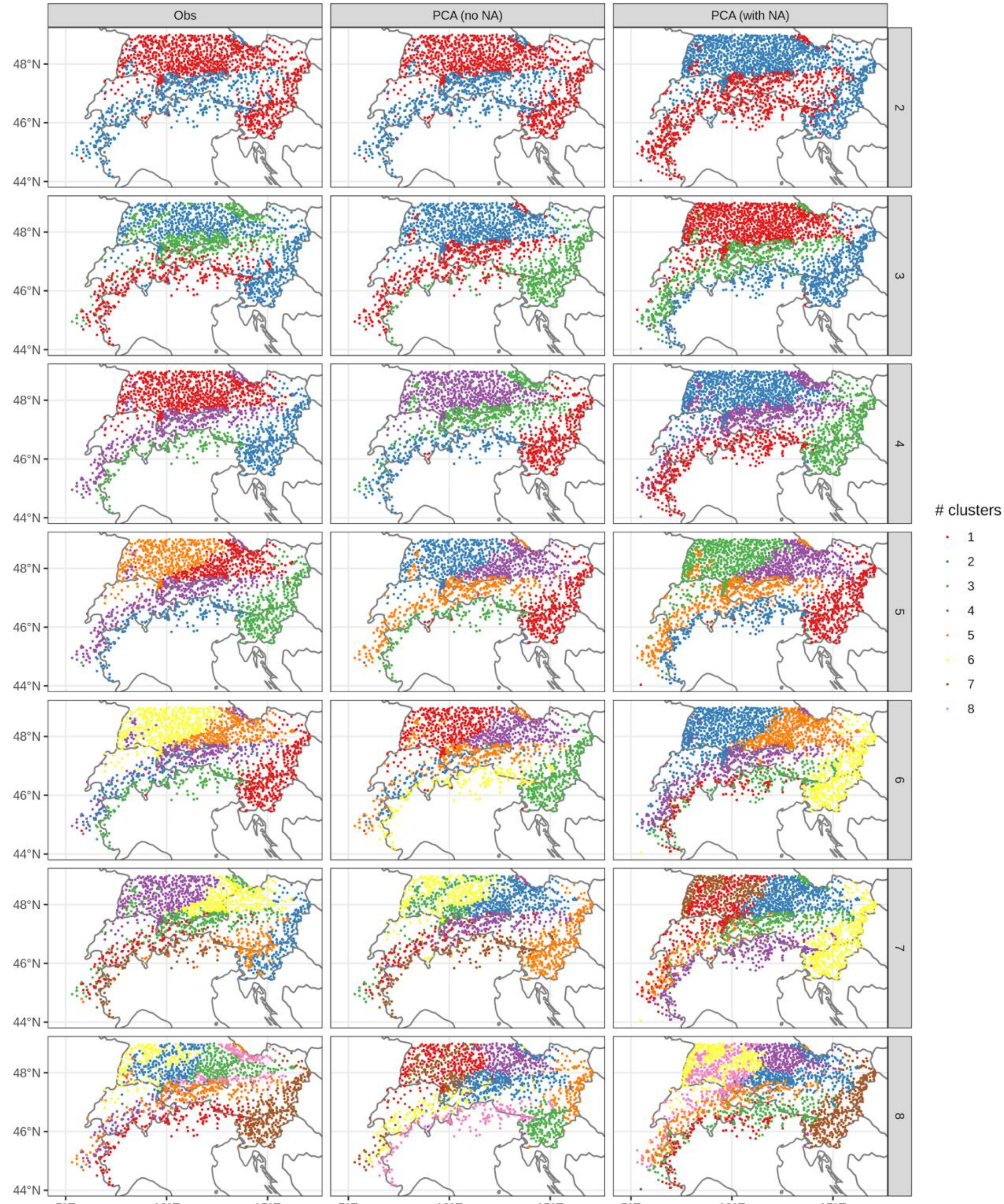

Figure S1: Results of k-means clustering. Rows show the number of clusters (order is arbitrary, so colors might not match within a row). Columns identify the input matrix for the clustering algorithm: For Obs scaled daily observations of snow depth were used and for PCA the PCA matrix. The two PCA columns stand for the standard PCA that does not allow

missing values (no NA), which corresponds to the same station set as in Obs, and the second PCA column is for the modified PCA algorithm that allows missing values (with NA) and has a higher station coverage.

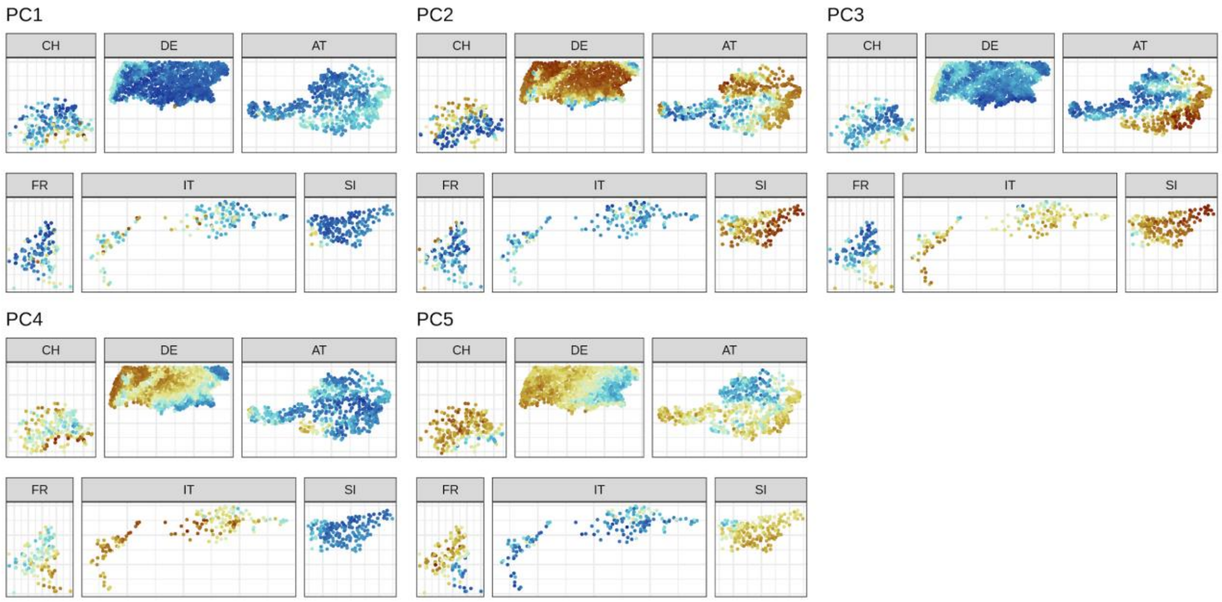

Figure S2: PC loadings from Fig. 3 divided by country showing clearer that gradients are not driven by national borders.

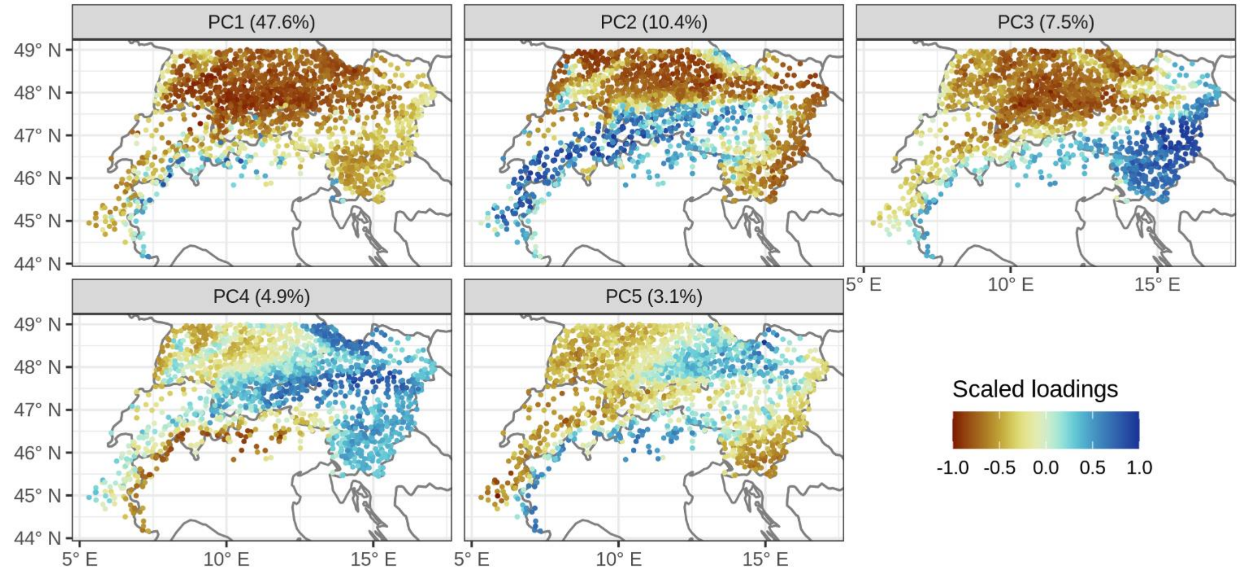

Figure S3: Same as Fig. 3 but using a standard principal component analysis (PCA) and only stations which had complete data. Main modes of variability in daily snow depth series. The plots show scaled loadings for the first five principal components (PCs). The title in each panel contains the amount of variance explained by the respective PC. The principal component analysis was applied on daily snow depth data from December to April for the hydrological years from 1981 to 2010, for stations that had no missing observations.

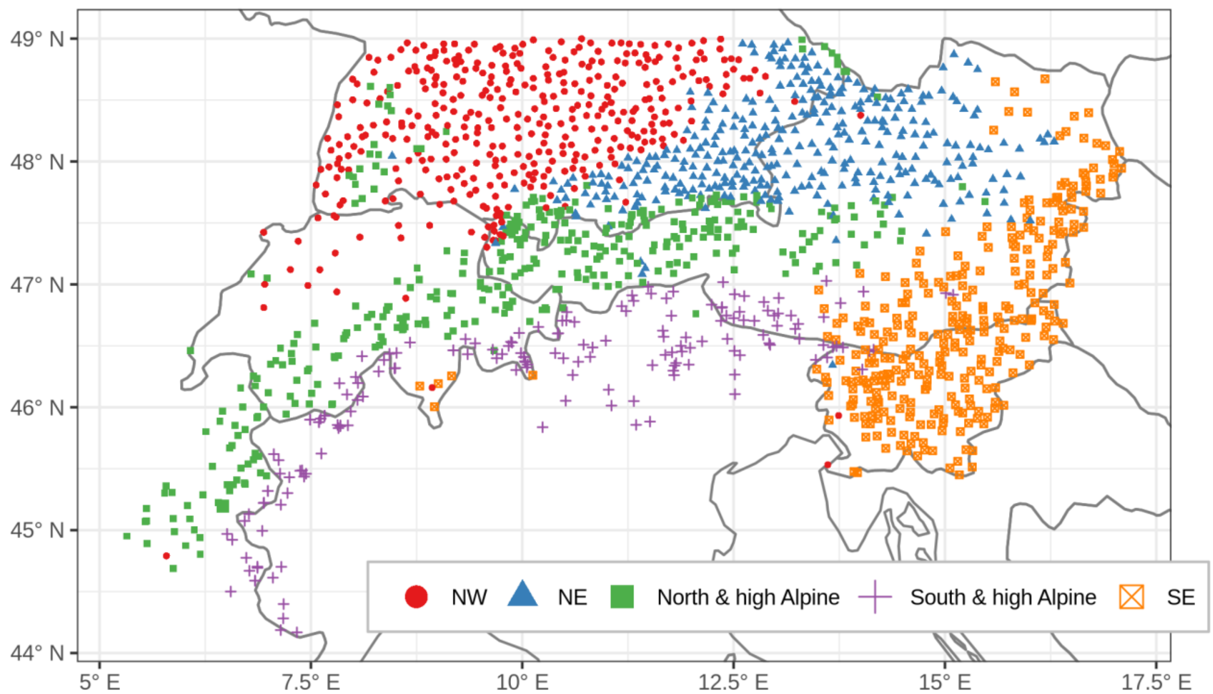

Figure S4: Same as Fig. 5, but based on the PCA from Fig. S3, which is for stations with no missing observations. Clustering of stations based on daily snow depth data. Map of regions from k-means clustering on the first five principal components.

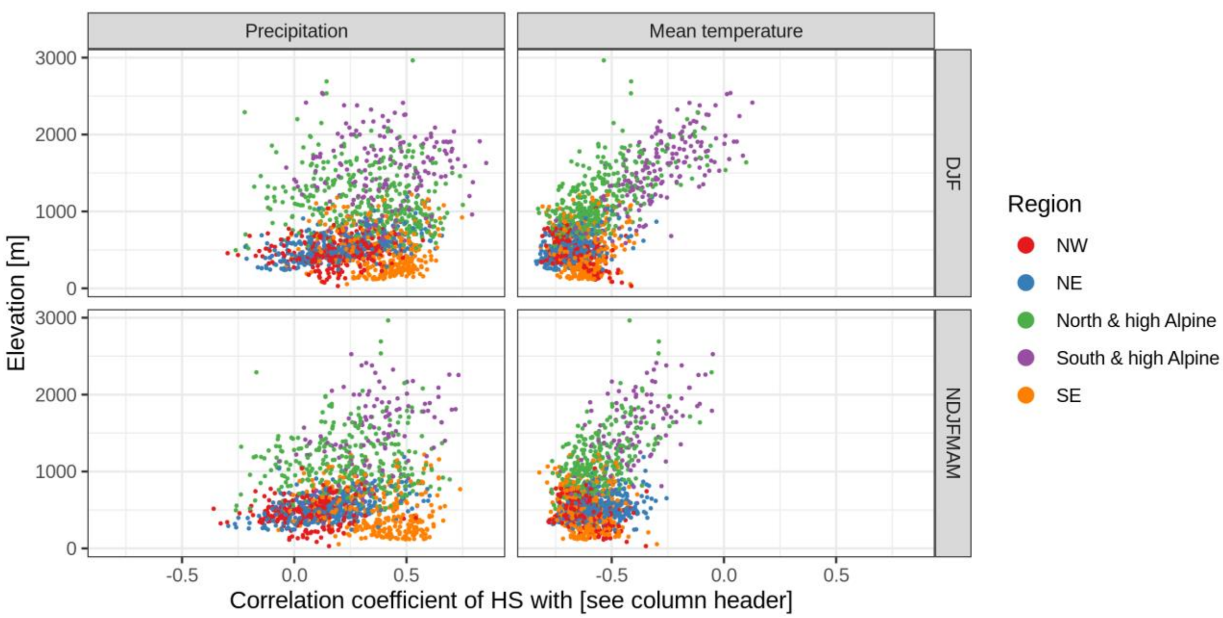

Figure S5: Correlation of station snow depth (HS) with precipitation and temperature extracted from gridded products. Each point shows the Pearson correlation coefficient of seasonal HS with the seasonal sum of precipitation (left column) and with the seasonal mean temperature (right column) for one station. The top row shows the season December to February (DJF), and the bottom row the season November to May (NDJFMAM). The temperature values used in the correlations are extracted from the reanalysis MESCAN-SURFEX.

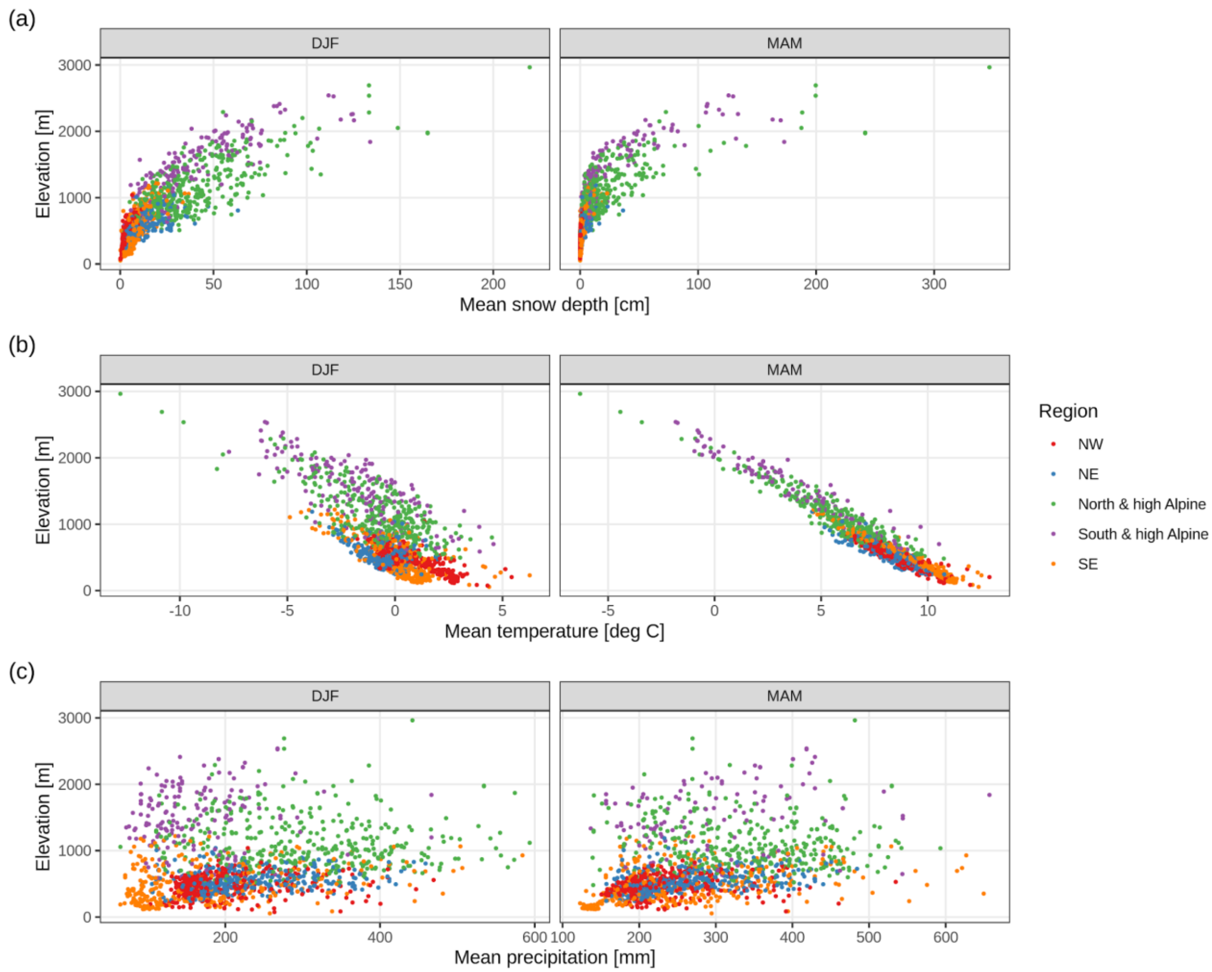

Figure S6: Same as Fig. 6 but using observation based spatial analysis data for temperature and precipitation and the period 1981–2008. Instead of MESCAN-SURFEX reanalysis, here the temperature and precipitation values were extracted from E-OBS and EURO4M-APGD, and the period slightly shortened form 1981–2010 to 1981–2008, because of the shorter availability of EURO4M-APGD.

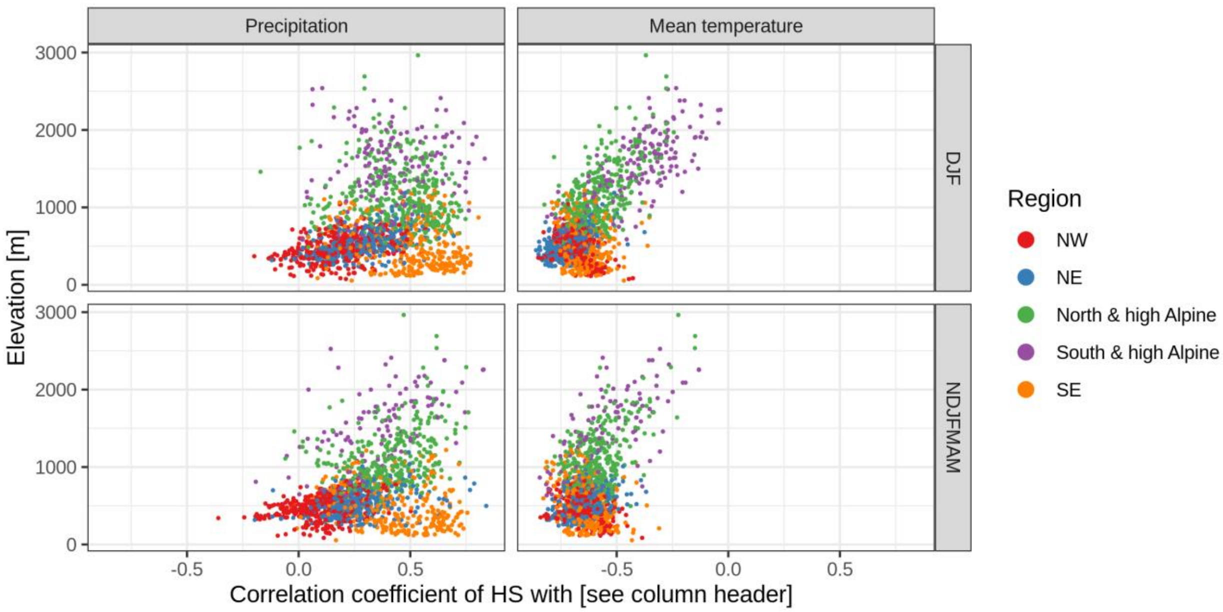

Figure S7: Same as Fig. S5 but using observation based spatial analysis data for temperature and precipitation and the period 1981–2008. Instead of MESCAN-SURFEX reanalysis, here the temperature and precipitation values were extracted from E-OBS and EURO4M-APGD

Tables

Table S1: Climatology of snow depth (HS), air temperature and precipitation for the period 1981–2010 for winter (December to February). The temperature and precipitation values were extracted from MESCAN–SURFEX reanalysis, while the snow depths are based on station data. See also Fig. 6.

Elevation	Region	HS [cm]	Temperature [deg C]	Precipitation [mm]	Number
(0,250]	NW	1.0	2.7	202	27
	NE	3.3	-0.2	135	5
	SE	3.5	0.8	145	73
(250,500]	NW	2.6	0.5	175	165
	NE	5.7	-0.3	184	148
	North & high Alpine	4.3	1.5	249	2
	SE	6.0	0.3	166	111
(500,750]	NW	4.8	0.0	189	123
	NE	11.9	-0.7	220	142
	North & high Alpine	20.8	0.3	284	48
	South & high Alpine	14.9	0.6	188	12
	SE	9.1	-0.2	207	69
(750,1000]	NW	8.0	-0.5	199	9
	NE	19.9	-1.6	229	31
	North & high Alpine	26.7	-0.4	288	108
	South & high Alpine	22.5	-0.5	215	16
	SE	14.3	-1.5	208	44
(1000,1250]	NW	7.4	0.1	194	1
	NE	21.3	-1.9	169	3
	North & high Alpine	35.4	-0.9	309	84
	South & high Alpine	22.5	-1.4	176	21
	SE	20.1	-3.4	189	16
(1250,1500]	North & high Alpine	48.9	-2.4	284	66
	South & high Alpine	34.6	-2.3	168	36
(1500,1750]	North & high Alpine	56.8	-3.9	287	35
	South & high Alpine	47.0	-3.3	177	34
(1750,2000]	North & high Alpine	81.1	-5.5	279	21
	South & high Alpine	65.5	-4.2	191	33
(2000,2250]	North & high Alpine	103.6	-6.7	290	5
	South & high Alpine	77.2	-6.4	165	13
(2250,2500]	North & high Alpine	58.0	-9.3	270	1
	South & high Alpine	95.5	-7.0	235	8
(2500,2750]	North & high Alpine	133.8	-9.8	237	2
	South & high Alpine	117.5	-10.5	360	2
(2750,3000]	North & high Alpine	218.0	-13.0	343	1

Table S2: Same as Table S1 but for spring (March to May).

Elevation	Region	HS [cm]	Temperature [deg C]	Precipitation [mm]	Number
(0,250]	NW	0.1	10.3	251	25
	NE	0.4	9.3	177	5
	SE	0.4	10.5	203	72
(250,500]	NW	0.4	8.7	214	156
	NE	1.1	8.8	226	147
	North & high Alpine	0.4	9.6	251	2
	SE	1.1	9.7	253	111
(500,750]	NW	1.0	7.8	241	117
	NE	3.4	7.9	276	143
	North & high Alpine	6.8	8.0	342	49
	South & high Alpine	3.9	8.8	329	8
	SE	2.2	8.3	302	71
(750,1000]	NW	2.1	6.5	260	10
	NE	7.4	6.7	292	30
	North & high Alpine	11.2	6.9	339	101
	South & high Alpine	9.6	7.1	371	13
	SE	4.9	6.9	320	44
(1000,1250]	NW	1.7	7.1	239	1
	NE	8.0	5.7	289	3
	North & high Alpine	16.8	5.9	385	81
	South & high Alpine	5.7	6.0	321	16
	SE	8.1	5.3	338	18
(1250,1500]	North & high Alpine	32.0	4.5	343	57
	South & high Alpine	14.5	4.7	340	26
(1500,1750]	North & high Alpine	38.6	2.8	333	26
	South & high Alpine	27.9	3.3	315	18
(1750,2000]	North & high Alpine	93.7	1.5	335	13
	South & high Alpine	60.6	2.5	372	24
(2000,2250]	North & high Alpine	118.1	-0.1	318	3
	South & high Alpine	94.0	0.6	392	9
(2250,2500]	North & high Alpine	73.1	-1.3	376	1
	South & high Alpine	119.8	-0.2	459	7
(2500,2750]	North & high Alpine	198.7	-3.5	295	2
	South & high Alpine	131.9	-3.6	336	2
(2750,3000]	North & high Alpine	345.8	-6.4	407	1

Table S3: Same as Table S1 but using observation based spatial analysis data for temperature and precipitation and the period 1981–2008. Instead of MESCAN-SURFEX reanalysis, here the temperature and precipitation values were extracted from E-OBS and EURO4M-APGD, and the period slightly shortened form 1981–2010 to 1981–2008, because of the shorter availability of EURO4M-APGD.

Elevation	Region	HS [cm]	Temperature [deg C]	Precipitation [mm]	Number
(0,250]	NW	1.0	2.8	194	37
	NE	3.1	0.4	152	5
	SE	3.5	1.2	139	73
(250,500]	NW	2.5	0.8	189	192
	NE	5.6	-0.2	208	153
	North & high Alpine	4.3	2.8	196	2
	SE	5.9	0.5	169	109
(500,750]	NW	4.8	-0.1	204	157
	NE	11.8	-0.5	246	149
	North & high Alpine	21.0	0.6	311	50
	South & high Alpine	14.7	1.7	189	11
	SE	8.9	0.0	212	69
(750,1000]	NW	7.6	-1.0	208	10
	NE	19.4	-1.2	268	34
	North & high Alpine	26.3	-0.1	313	116
	South & high Alpine	20.0	0.6	193	15
	SE	13.9	-1.4	218	44
(1000,1250]	NW	6.4	1.4	229	1
	NE	21.1	-1.2	141	3
	North & high Alpine	35.0	-0.3	315	84
	South & high Alpine	20.2	-0.6	145	21
	SE	19.6	-2.8	187	16
(1250,1500]	North & high Alpine	47.6	-1.1	296	64
	South & high Alpine	31.6	-0.9	146	37
(1500,1750]	North & high Alpine	56.3	-2.2	242	34
	South & high Alpine	43.5	-1.8	159	32
(1750,2000]	North & high Alpine	80.7	-3.9	311	21
	South & high Alpine	62.1	-2.8	177	31
(2000,2250]	North & high Alpine	103.4	-5.3	276	5
	South & high Alpine	72.6	-5.1	159	13
(2250,2500]	North & high Alpine	94.3	-5.5	286	2
	South & high Alpine	96.4	-5.6	195	7
(2500,2750]	North & high Alpine	133.4	-10.3	276	2
	South & high Alpine	113.0	-6.0	268	2
(2750,3000]	North & high Alpine	219.5	-12.8	442	1

Table S4: Same as Table S3 but for spring (March to May).

Elevation	Region	HS [cm]	Temperature [deg C]	Precipitation [mm]	Number
(0,250]	NW	0.1	10.7	236	32
	NE	0.4	10.2	186	5
	SE	0.4	11.0	198	72
(250,500]	NW	0.4	9.1	223	176
	NE	1.1	9.1	236	153
	North & high Alpine	0.4	10.1	194	2
	SE	1.1	9.9	252	110
(500,750]	NW	1.0	7.9	246	149
	NE	3.3	8.0	292	150
	North & high Alpine	6.7	8.2	343	49
	South & high Alpine	4.1	8.8	325	8
	SE	2.3	8.4	298	70
(750,1000]	NW	2.1	6.7	263	10
	NE	6.9	6.7	318	33
	North & high Alpine	10.6	6.9	345	107
	South & high Alpine	8.9	7.7	326	12
	SE	5.1	6.8	311	43
(1000,1250]	NE	7.9	5.9	217	3
	North & high Alpine	16.8	5.9	349	79
	South & high Alpine	5.5	6.1	239	14
	SE	9.0	5.3	290	15
(1250,1500]	North & high Alpine	31.8	4.5	330	57
	South & high Alpine	13.8	4.7	254	27
(1500,1750]	North & high Alpine	38.7	3.0	276	25
	South & high Alpine	30.0	3.1	302	18
(1750,2000]	North & high Alpine	94.2	1.5	339	13
	South & high Alpine	59.2	2.1	324	21
(2000,2250]	North & high Alpine	118.4	0.0	308	3
	South & high Alpine	90.1	-0.2	319	9
(2250,2500]	North & high Alpine	130.5	-1.2	359	2
	South & high Alpine	114.5	-0.7	389	7
(2500,2750]	North & high Alpine	199.6	-3.9	270	2
	South & high Alpine	127.7	-1.8	418	2
(2750,3000]	North & high Alpine	346.9	-6.3	482	1

Table S5: Same as Table 2, but with 500 m elevation bands.

Month	Region	Elevation: (0,500] m				Elevation: (500,1000] m				Elevation: (1000,1500] m				Elevation: (1500,2000] m				Elevation: (2000,2500] m				Elevation: (2500,3000] m			
		#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+
Nov	NW	2	-0.01	50.0%																					
	NE	27	-0.29	44.4%		7	-0.43	28.6%																	
	N&hA					4	-0.93	50.0%		8	-0.34			1	-0.06										
	S&hA					7	-1.02	71.4%		5	-0.55			18	-0.13			11	2.47			1	5.03		
	SE	133	-0.41	62.4%		85	-0.64	36.5%		8	-1.21	50.0%													
Dec	NW	2	-0.01																						
	NE	19	-0.66	26.3%		5	-0.76	40.0%																	
	N&hA	1	0.02			2	-2.59	50.0%		38	-1.56			29	-2.35	3.4%		1	-2.02						
	S&hA					17	-1.34	5.9%		26	-1.24	3.8%		41	-0.67		2.4%	16	3.64			1	9.35		
	SE	135	-0.46	17.8%		86	-1.26	36.0%		9	-2.38	44.4%													
Jan	NW	47	-0.38	14.9%		34	-0.69	8.8%																	
	NE	9	-0.59	11.1%		23	-0.53			2	0.23														
	N&hA	1	-0.65			82	-1.60	3.7%		115	-1.65	6.1%		39	-1.41			1	-0.21			3	-2.62		
	S&hA					19	-4.91	73.7%		33	-4.17	36.4%		43	-3.76	9.3%		16	-0.03			1	9.06		
	SE	151	-1.03	19.9%		92	-2.52	45.7%		10	-4.32	70.0%													
Feb	NW	48	-0.19	18.8%		30	0.06																		
	NE	1	-0.11			23	0.79			1	2.44														
	N&hA	1	-0.97	100.0%		83	-1.37	3.6%		114	-2.17	8.8%		39	-2.47	2.6%		1	-5.41			3	-2.94		
	S&hA					19	-4.10	10.5%		34	-3.96	14.7%		44	-5.96	15.9%		16	-2.50	6.2%		1	7.47		
	SE	136	-0.27	1.5%		92	-1.16	8.7%		12	-2.50														
Mar	NW	41	-0.15	4.9%		24	-0.64	4.2%																	
	NE	1	0.07			19	-0.99	10.5%		1	0.10														
	N&hA	1	-0.04			74	-3.14	31.1%		113	-4.05	25.7%		38	-3.62	10.5%		1	-4.48			3	-1.05		
	S&hA					18	-3.52	33.3%		31	-5.55	51.6%		42	-8.07	42.9%		16	-3.19	12.5%	6.2%	1	7.70		
	SE	128	-0.20	0.8%		84	-1.33	11.9%		12	-3.22	16.7%													
Apr	NW	11	-0.02	9.1%		23	-0.10	30.4%																	
	NE	2	-0.02			16	-0.37	43.8%		1	-0.73														
	N&hA					69	-1.48	68.1%		95	-4.65	68.4%		38	-8.33	57.9%		1	-9.53	100.0%		3	-6.25		
	S&hA					14	-0.92	50.0%		27	-3.04	44.4%		38	-9.19	65.8%		16	-9.24	43.8%		1	7.16		
	SE	59	-0.05	32.2%		77	-0.19	42.9%	1.3%	7	-1.42	14.3%													
May	NE					7	-0.01																		
	N&hA					36	-0.03	5.6%		86	-0.34	19.8%		28	-4.75	53.6%						3	-5.69		
	S&hA					9	-0.01	11.1%		15	-0.25	13.3%		26	-4.08	53.8%		14	-10.34	42.9%		1	2.88		
	SE	5	-0.03			47	-0.02		2.1%	7	-0.02														

Table S6: Same as Table C1, but with 500 m elevation bands.

Region	Elevation: (0,500] m				Elevation: (500,1000] m				Elevation: (1000,1500] m				Elevation: (1500,2000] m				Elevation: (2000,2500] m				Elevation: (2500,3000] m			
	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+
meanHS_DJF																								
NW	46	-0.33	41.3%		32	-0.46	6.2%																	
NE	2	-0.75	50.0%		23	-0.22	4.3%		1	1.36														
N&hA	1	-0.47	100.0%		86	-1.65	14.0%		115	-1.99	8.7%		39	-2.41	5.1%		1	-2.92			3	-4.73		
S&hA					19	-3.57	42.1%		32	-3.23	25.0%		42	-3.81	11.9%		16	-0.60	6.2%		1	8.46		
SE	134	-0.56	15.7%		88	-1.55	31.8%		10	-2.94	50.0%													
meanHS_MAM																								
NW	39	-0.04	5.1%		23	-0.24	17.4%																	
NE	1	0.02			17	-0.47	11.8%																	
N&hA	1	-0.02			60	-1.58	48.3%		91	-3.12	44.0%		31	-5.58	38.7%						3	-4.45		
S&hA					16	-1.34	43.8%		22	-3.03	59.1%		30	-7.10	76.7%		15	-7.57	33.3%		1	5.85		
SE	131	-0.08	1.5%	0.8%	78	-0.53	16.7%		9	-1.82	33.3%													
meanHS_NDJFMAM																								
NW	39	-0.16	46.2%		26	-0.33	34.6%																	
NE	1	0.01			20	-0.33	10.0%																	
N&hA	1	-0.22	100.0%		75	-1.45	32.0%		100	-2.37	27.0%		33	-3.97	27.3%						3	-4.96		
S&hA					16	-2.15	56.2%		21	-3.19	52.4%		34	-5.11	50.0%		16	-3.51	25.0%		1	6.78		
SE	127	-0.34	17.3%		84	-1.00	41.7%		9	-2.13	55.6%													
maxHS_NDJFMAM																								
NW	39	-0.93	17.9%		26	-1.48	15.4%																	
NE	1	-0.42			20	-0.84	5.0%																	
N&hA	1	-1.74			75	-4.02	20.0%		100	-4.97	22.0%		33	-5.85	15.2%						3	-8.11		
S&hA					16	-8.87	75.0%		21	-9.37	57.1%		34	-10.93	55.9%		16	-9.85	43.8%		1	-1.65		
SE	127	-2.19	22.0%		84	-3.68	34.5%		9	-6.59	55.6%													

Table S7: Same as Table C2, but with 500 m elevation bands.

Region	Elevation: (0,500] m				Elevation: (500,1000] m				Elevation: (1000,1500] m				Elevation: (1500,2000] m				Elevation: (2000,2500] m				Elevation: (2500,3000] m			
	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+
SCD_NDJF																								
NW	48	-2.51	33.3%		31	-2.40	25.8%																	
NE	2	-1.91			23	-1.93	17.4%		1	4.96		100.0%												
N&hA	1	-3.33			84	-3.33	39.3%		110	-2.26	34.5%		34	-1.75	41.2%						3	0.09		
S&hA					16	-3.79	6.2%		26	-2.40	26.9%		37	-1.85	29.7%		16	-0.27		6.2%	1	1.06		
SE	130	-2.93	16.9%		86	-4.77	45.3%		9	-5.26	66.7%													
SCD_MAM																								
NW	39	-0.43	10.3%		23	-1.48	43.5%																	
NE	1	-0.00			17	-2.17	70.6%																	
N&hA	1	-0.38	100.0%		60	-2.60	58.3%		91	-3.17	65.9%		31	-2.59	67.7%									
S&hA					16	-3.06	75.0%		22	-3.84	68.2%		30	-4.39	86.7%		15	-0.64	20.0%	6.7%	1	-0.06		
SE	130	-0.44	5.4%		78	-1.91	46.2%		9	-3.58	66.7%													
SCD_NDJFMAM																								
NW	39	-2.89	41.0%		26	-3.99	38.5%																	
NE	1	-0.93			20	-4.01	35.0%																	
N&hA	1	-3.73			75	-5.60	58.7%		100	-5.54	73.0%		33	-4.48	75.8%						3	0.09		
S&hA					16	-6.66	50.0%		21	-6.87	66.7%		34	-6.54	88.2%		16	-1.11	18.8%		1	0.54		
SE	127	-3.40	16.5%		84	-6.65	61.9%		9	-8.84	88.9%													

Sensitivity of trend modelling: OLS instead of GLS

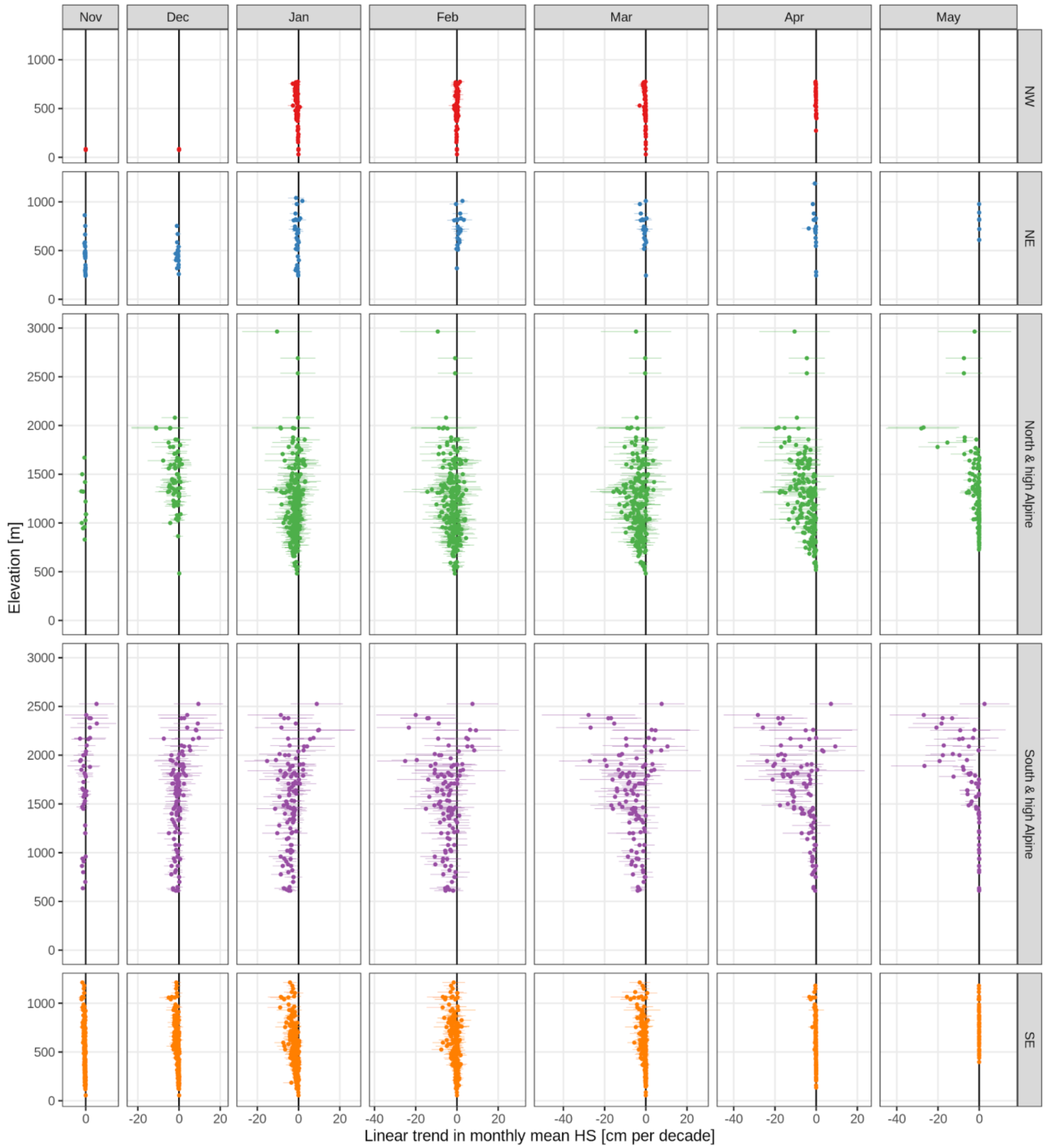

Figure S8: Same as Fig. 6, but using an OLS model instead of GLS.

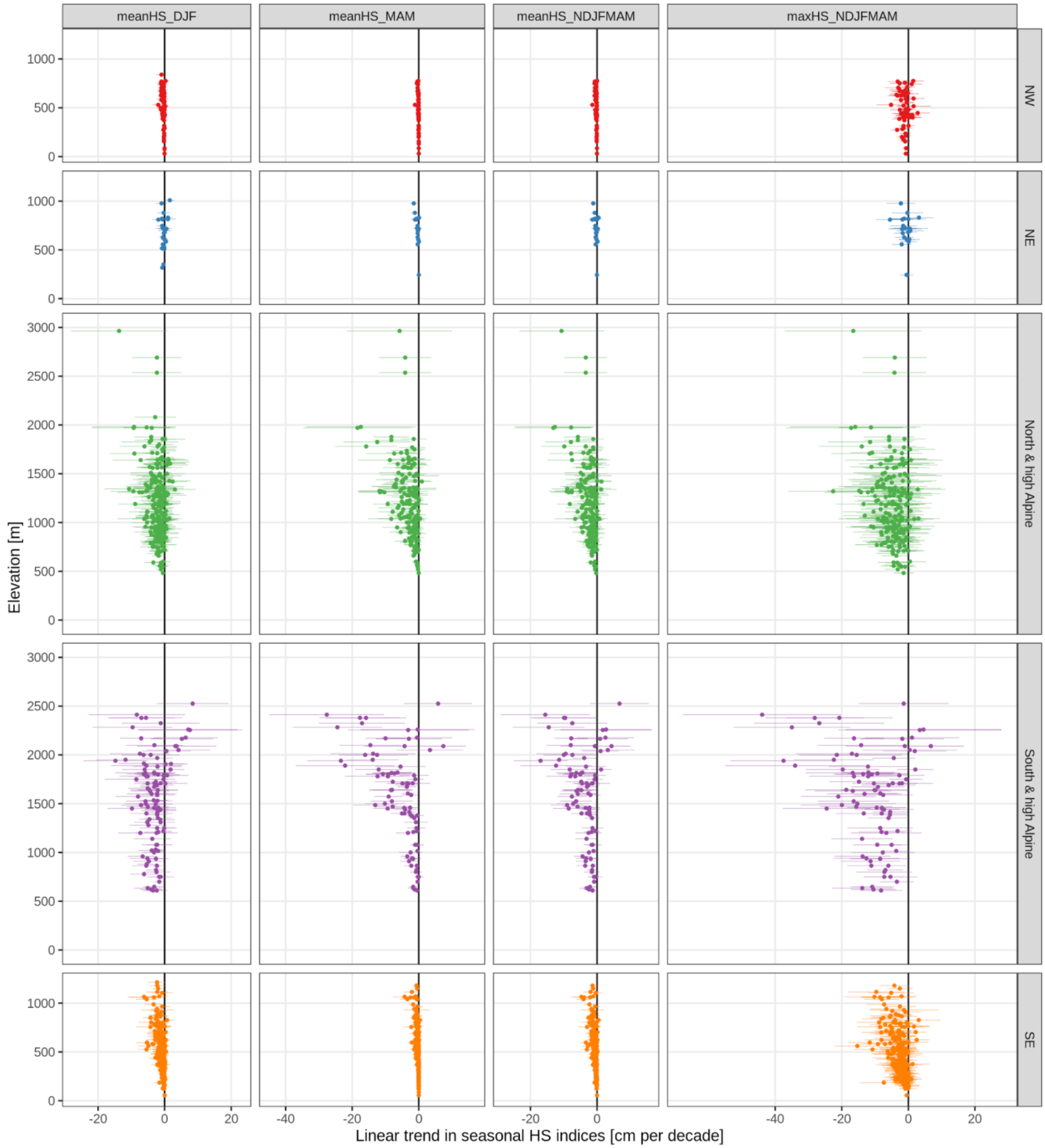

Figure S9: Same as Fig. C1, but using an OLS model instead of GLS.

Table S8: Same as Table 2, but using an OLS model instead of GLS.

Month	Region	Elevation: (0,1000] m				Elevation: (1000,2000] m				Elevation: (2000,3000] m			
		#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+
Nov	NW	2	-0.01	50.0%									
	NE	34	-0.25	8.8%									
	N&hA	4	-1.05	25.0%		9	-0.67	22.2%					
	S&hA	7	-1.03	57.1%		23	-0.80			12	1.52		
	SE	218	-0.45	11.9%		8	-1.34	50.0%					
Dec	NW	2	-0.00										
	NE	24	-0.62	8.3%									
	N&hA	3	-1.54	33.3%		67	-2.06	4.5%		1	-2.02		
	S&hA	17	-1.47	11.8%		67	-0.85	1.5%		17	4.21		
	SE	221	-0.61	7.7%		9	-2.27	22.2%					
Jan	NW	81	-0.72	27.2%									
	NE	32	-0.70			2	0.32						
	N&hA	83	-1.98	9.6%		154	-1.72	5.2%		4	-2.83		
	S&hA	19	-5.03	73.7%		76	-3.91	22.4%		17	0.08		
	SE	243	-1.66	32.1%		10	-4.58	70.0%					
Feb	NW	78	-0.07										
	NE	24	0.77		4.2%	1	2.67		100.0%				
	N&hA	84	-1.35	3.6%		153	-2.30	9.2%		4	-4.09		
	S&hA	19	-4.76	15.8%		78	-5.09	16.7%		17	-2.91	23.5%	
	SE	228	-0.66	4.8%		12	-2.73	8.3%					
Mar	NW	65	-0.30	1.5%									
	NE	20	-0.90			1	-0.01						
	N&hA	75	-2.82	21.3%		151	-3.94	21.2%		4	-2.44		
	S&hA	18	-3.68	38.9%		73	-6.90	41.1%		17	-5.55	29.4%	5.9%
	SE	212	-0.61	3.8%		12	-3.25	16.7%					
Apr	NW	34	-0.11	52.9%									
	NE	18	-0.61	66.7%		1	-0.64						
	N&hA	69	-2.02	85.5%		133	-5.93	61.7%		4	-7.22	25.0%	
	S&hA	14	-1.34	50.0%		65	-7.85	69.2%		17	-8.66	47.1%	
	SE	136	-0.15	10.3%		7	-1.39	14.3%					
May	NE	7	-0.02										
	N&hA	36	-0.09	11.1%		114	-1.81	43.9%		3	-5.70		
	S&hA	9	-0.04			41	-4.17	58.5%		15	-10.80	46.7%	
	SE	52	-0.06			7	-0.14	14.3%					

Table S9: Same as Table C1, but using an OLS model instead of GLS.

Index	Region	Elevation: (0,1000] m				Elevation: (1000,2000] m				Elevation: (2000,3000] m			
		#	mean	sig-	sig+	#	mean	sig-	sig+	#	mean	sig-	sig+
meanHS_DJF	NW	78	-0.39	21.8%									
	NE	25	-0.27	8.0%		1	1.55						
	N&hA	87	-1.77	14.9%		154	-2.23	7.8%		4	-5.30		
	S&hA	19	-3.65	36.8%		74	-3.53	17.6%		17	-0.19	5.9%	
	SE	222	-0.97	19.4%		10	-3.18	50.0%					
meanHS_MAM	NW	62	-0.12	6.5%									
	NE	18	-0.46	5.6%									
	N&hA	61	-1.53	44.3%		122	-3.82	45.1%		3	-4.64		
	S&hA	16	-1.42	37.5%		52	-6.27	69.2%		16	-8.48	50.0%	6.2%
	SE	209	-0.23	4.3%		9	-1.80	22.2%					
meanHS_NDJFMAM	NW	65	-0.23	32.3%									
	NE	21	-0.33	9.5%									
	N&hA	76	-1.49	32.9%		133	-2.87	29.3%		3	-5.80		
	S&hA	16	-2.15	50.0%		55	-4.55	54.5%		17	-3.49	29.4%	
	SE	211	-0.59	21.3%		9	-2.29	44.4%					
maxHS_NDJFMAM	NW	65	-1.05	13.8%									
	NE	21	-0.79	4.8%									
	N&hA	76	-4.02	15.8%		133	-5.33	23.3%		3	-8.27		
	S&hA	16	-9.03	68.8%		55	-11.56	65.5%		17	-11.07	41.2%	
	SE	211	-2.70	20.4%		9	-6.24	44.4%					

Sensitivity to gap filling

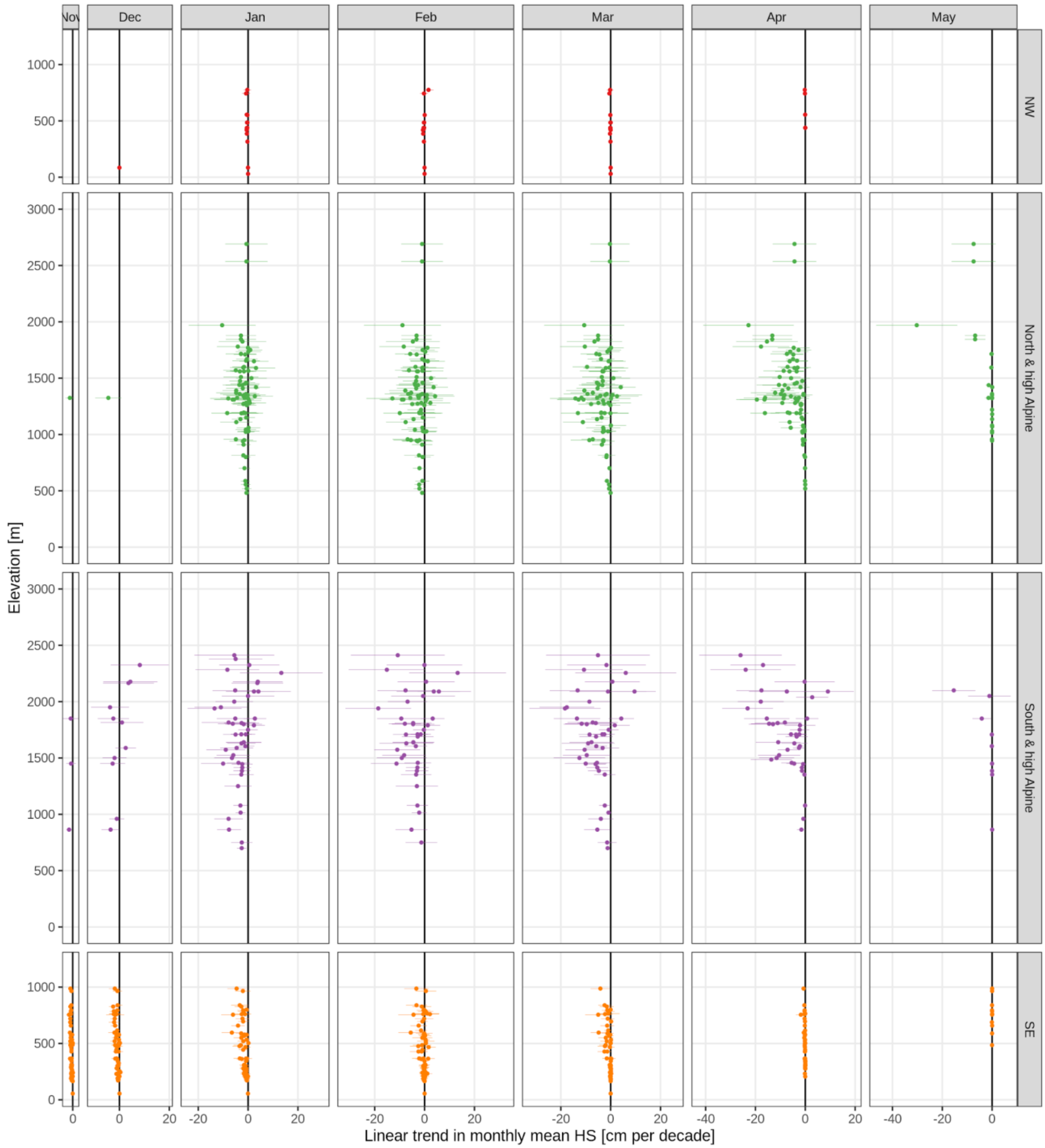

Figure S10: Same as Fig. 5 (monthly trends), but without gap filling.

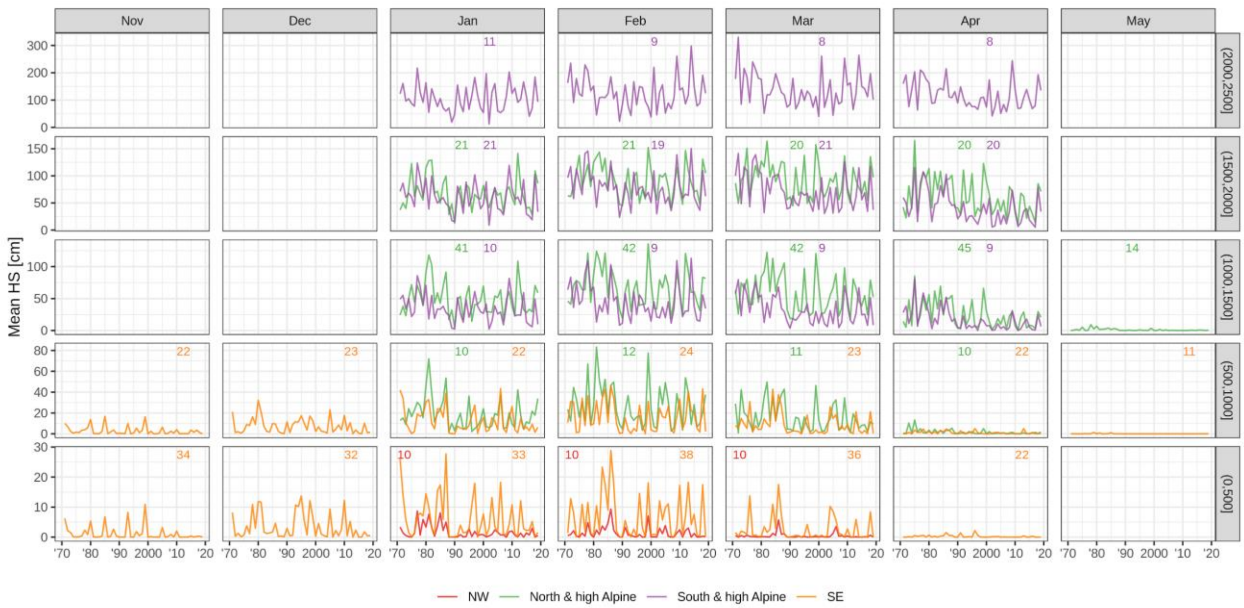

Figure S11: Same as Fig. 7 (monthly time series), but without gap filling.

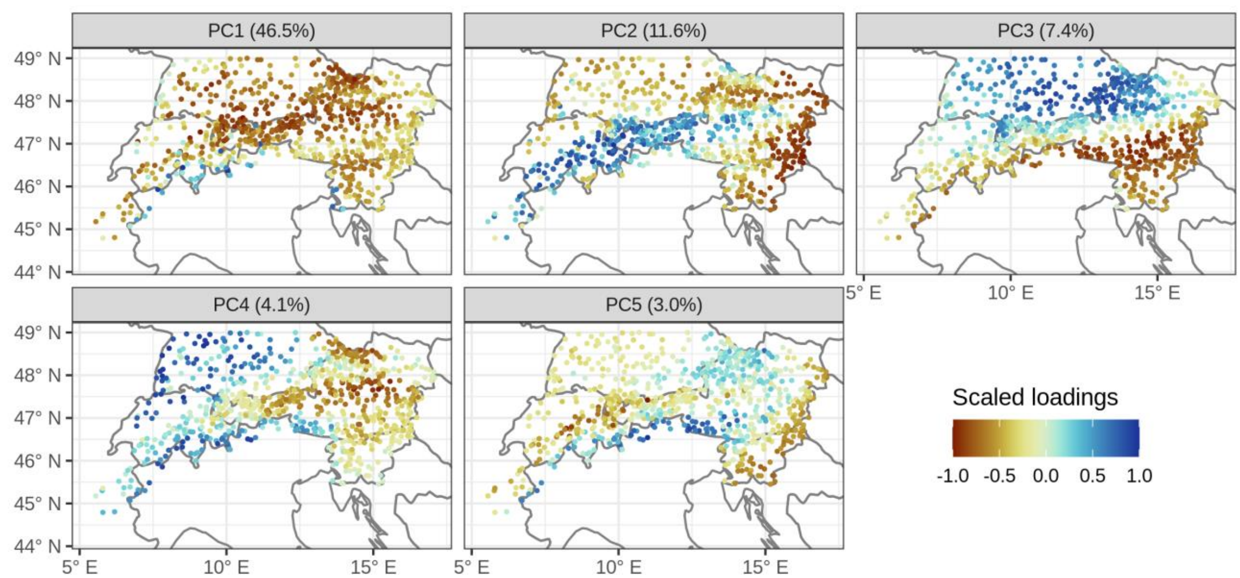

Figure S12: Same as Fig. S3 (PCA without NA), but without gap filling.

Comparison of trend models (OLS, GLS, Theil-Sen, NB)

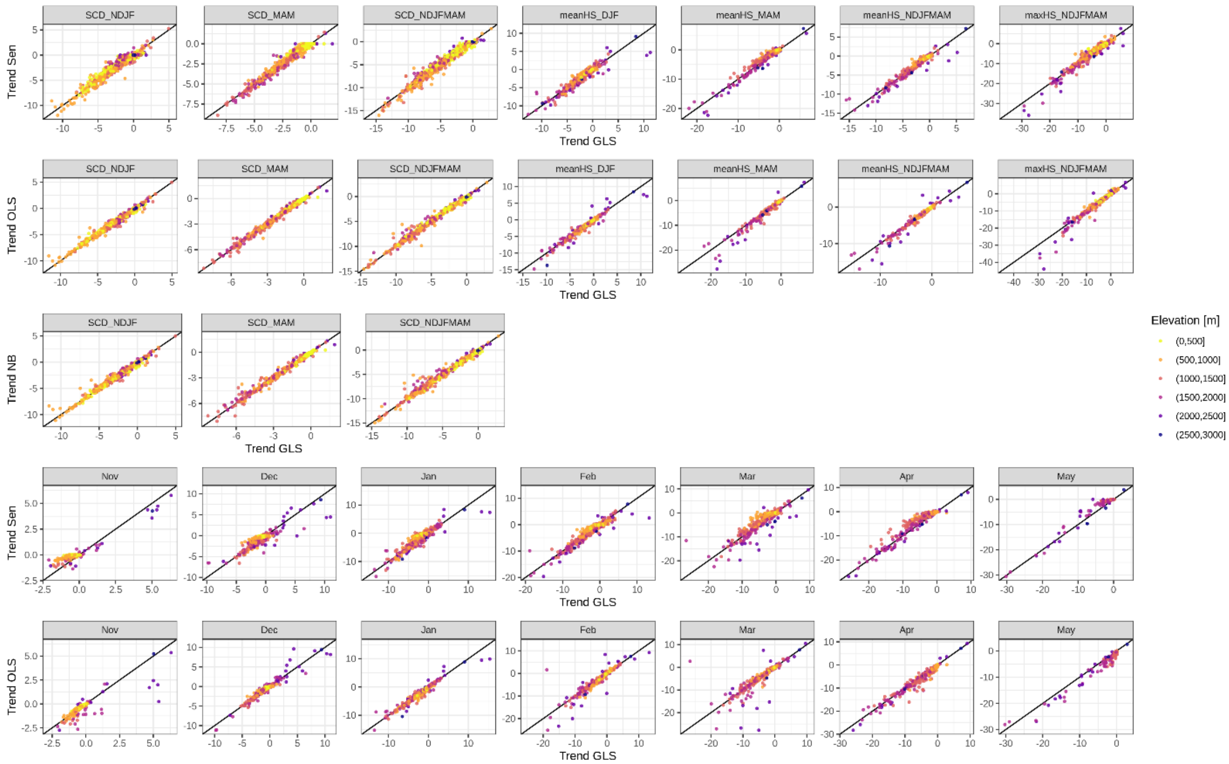

Figure S13: Scatterplots of trend estimates from various trend models for all seasonal (first 3 rows) and all monthly (last 2 rows) snow indices. The x-axes always show estimates of the GLS (generalized least squares) model, which includes a time coefficient for the residual variance. The y-axes show estimates from the Theil-Sen (Sen) trend estimator (robust non-parametric method), ordinary least squares (OLS; constant residual variance), and only for SCD indices a negative binomial model (NB; model for count data with overdispersion).

Table S10: Summary metrics for trend model comparison. For model abbreviations see Figure S13. Bias is the average difference of decadal trends between models (M1 minus M2). MAE is the mean absolute error of decadal trends between M1 and M2. Correlation is the Pearson correlation coefficient of M1 and M2. The last 4 columns denote the agreement between significance estimates of M1 and M2, where significance was assumed if p<0.05. Thus column "M1_sig_M2_sig" shows percentages where M1 and M2 both indicate significant trends, column "M1_sig_M2_ns" shows the percentage when M1 indicates a significant trend and M2 a non-significant one, etc. For the Theil-Sen trend estimator, the Mann-Kendall test was used to assess significance.

Model 1 (M1)	Model 2 (M2)	Variable	Bias	MAE	Corr	M1_sig_M2_sig	M1_sig_M2_ns	M1_ns_M2_sig	M1_ns_M2_ns
Sen	GLS	SCD_NDJF	0.11	0.46	0.96	21%	2%	10%	68%
Sen	GLS	SCD_MAM	0.08	0.27	0.98	38%	7%	6%	49%
Sen	GLS	SCD_NDJFMAM	0.04	0.50	0.98	46%	3%	5%	46%
Sen	GLS	meanHS_DJF	0.09	0.43	0.95	12%	3%	5%	79%
Sen	GLS	meanHS_MAM	0.25	0.44	0.98	22%	14%	6%	58%
Sen	GLS	meanHS_NDJFMAM	0.06	0.30	0.97	24%	5%	7%	63%
Sen	GLS	maxHS_NDJFMAM	0.10	0.79	0.97	22%	2%	6%	70%
OLS	GLS	SCD_NDJF	0.03	0.23	0.99	27%	2%	3%	68%
OLS	GLS	SCD_MAM	0.01	0.12	0.99	42%	1%	2%	55%
OLS	GLS	SCD_NDJFMAM	0.06	0.25	0.99	48%	1%	3%	48%
OLS	GLS	meanHS_DJF	-0.06	0.23	0.97	15%	2%	3%	80%
OLS	GLS	meanHS_MAM	-0.14	0.29	0.98	24%	2%	4%	70%
OLS	GLS	meanHS_NDJFMAM	-0.06	0.19	0.98	27%	2%	5%	66%
OLS	GLS	maxHS_NDJFMAM	-0.15	0.51	0.97	23%	2%	4%	70%
NB	GLS	SCD_NDJF	-0.03	0.22	0.99	27%	2%	3%	68%
NB	GLS	SCD_MAM	-0.01	0.14	0.99	42%	1%	2%	55%
NB	GLS	SCD_NDJFMAM	-0.00	0.27	0.99	48%	1%	3%	48%
Sen	GLS	Nov	0.36	0.43	0.94	15%	9%	29%	46%
Sen	GLS	Dec	0.12	0.59	0.87	7%	5%	10%	79%
Sen	GLS	Jan	0.39	0.73	0.93	10%	2%	8%	80%
Sen	GLS	Feb	0.01	0.66	0.94	4%	2%	3%	91%
Sen	GLS	Mar	0.45	0.96	0.91	13%	9%	5%	73%
Sen	GLS	Apr	0.64	0.83	0.97	41%	16%	10%	33%
Sen	GLS	May	0.32	0.41	0.98	15%	15%	5%	65%
OLS	GLS	Nov	-0.06	0.20	0.82	12%	1%	32%	55%
OLS	GLS	Dec	0.07	0.30	0.96	6%	1%	11%	83%
OLS	GLS	Jan	-0.14	0.31	0.97	17%	5%	1%	77%
OLS	GLS	Feb	-0.07	0.39	0.93	5%	2%	2%	91%
OLS	GLS	Mar	-0.03	0.56	0.87	14%	2%	4%	80%
OLS	GLS	Apr	-0.34	0.56	0.98	40%	10%	11%	39%
OLS	GLS	May	-0.46	0.52	0.98	18%	12%	2%	67%