Supplement of

An examination of changes in autumn Eurasian snow cover and its relationship with the winter Arctic Oscillation using 20th Century Reanalysis version 3

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Supplementary Material

Table S1. Details of the 133 meteorological stations from which daily snow depth data were used to define snow onset. Data availability is the proportion of years for which snow onset can be calculated.

WMO Number	Station Name	Latitude (°N)	Longitude (°E)	Elevation (m a.s.l.)	Data availability: 2003-2022 (%)	Data availability: 1966-2022 (%)
20674	Ostrov Dikson	73.50	80.40	42	100.0	100.0
20891	Hatanga	71.98	102.47	31	100.0	100.0
21946	Chokurdah	70.62	147.88	44	100.0	100.0
22113	Murmansk	68.97	33.05	57	100.0	100.0
22217	Kandalaksa	67.15	32.35	26	100.0	100.0
22550	Arkhangelsk	64.50	40.73	8	100.0	98.2
22583	Kojnas	64.75	47.65	63	100.0	100.0
22602	Reboly	63.83	30.82	180	100.0	100.0
22641	Onega	63.90	38.12	11	100.0	100.0
22802	Sortavala	61.72	30.72	17	100.0	98.2
22820	Petrozavodsk	61.82	34.27	112	100.0	100.0
22837	Vytegra	61.02	36.45	55	100.0	100.0
22887	Kotlas	61.27	46.72	55	100.0	100.0
23205	Nar'Jan-Mar	67.63	53.03	10	100.0	100.0
23405	Ust'-Cil'Ma	65.43	52.27	78	100.0	100.0
23418	Pechora	65.12	57.10	53	100.0	100.0
23472	Turuhansk	65.78	87.93	38	100.0	100.0
23527	Saran-Paul	64.28	60.88	28	100.0	96.5
23552	Tarko-Sale	64.92	77.82	26	100.0	98.2
23631	Berezovo	63.93	65.05	27	100.0	100.0
23678	Verhneimbatsk	63.15	87.95	46	100.0	100.0
23711	Troicko-Pechorskoe	62.70	56.20	134	95.0	98.2
23724	Njaksimvol'	62.43	60.87	50	100.0	100.0
23734	Oktjabr'Skoe	62.75	66.05	70	100.0	98.2
23804	Syktyvkar	61.68	50.78	116	100.0	100.0
23884	Bor	61.60	90.02	62	100.0	100.0
23891	Bajkit	61.67	96.37	256	100.0	100.0
23921	Ivdel	60.68	60.45	93	100.0	100.0
23933	Hanty-Mansijsk	61.02	69.03	44	100.0	100.0
23955	Aleksandrovskoe	60.43	77.87	47	100.0	100.0
23966	Vanzil'-Kynak	60.35	84.08	98	100.0	100.0
24125	Olenek	68.50	112.43	217	95.0	98.2
24266	Verhojansk	67.57	133.40	136	100.0	100.0
24343	Zhigansk	66.77	123.40	88	100.0	98.2
24507	Tura	64.27	100.23	205	100.0	100.0
24639	Njurba	63.28	118.33	117	100.0	98.2
24641	Viljujsk	63.78	121.62	111	100.0	100.0
24671	Tompo	63.95	135.87	399	100.0	93.0
24688	Ojmjakon	63.25	143.15	740	100.0	100.0
24738	Suntar	62.15	117.65	131	100.0	100.0
24768	Churapca	62.03	132.60	181	100.0	98.2
24817	Erbogacen	61.27	108.02	284	100.0	100.0
24908	Vanavara	60.33	102.27	259	100.0	100.0
24923	Lensk	60.72	114.88	241	100.0	98.2
24944	Olekminsk	60.40	120.42	225	100.0	100.0
24951	Isit	60.82	125.32	123	100.0	98.2
24959	Yakutsk	62.02	129.72	98	100.0	98.2
24966	Ust'-Maja	60.38	134.45	169	100.0	100.0
24982	Uyega	60.72	142.78	396	100.0	98.2
25551	Markovo	64.68	170.42	25	100.0	100.0
25563	Anadyr'	64.78	177.57	64	100.0	100.0
25703	Sejmchan	62.92	152.42	206	100.0	100.0
25913	Magadan	59.55	150.78	115	100.0	100.0
26063	St. Petersburg	59.97	30.30	3	95.0	98.2
26477	Velikie Luki	56.35	30.62	97	95.0	98.2
26781	Smolensk	54.75	32.07	236	100.0	100.0

| WMO Number	Station Name	Latitude (°N)	Longitude (°E)	Elevation (m a.s.l.)	Data availability: 2003-2022 (%)	Data availability: 1966-2022 (%)
27037	Vologda	59.32	39.92	125	100.0	100.0
27333	Kostroma	57.77	40.85	125	100.0	98.2
28064	Leusi	59.62	65.72	70	100.0	100.0
28138	Biser	58.52	58.85	463	100.0	100.0
28144	Verhotur'E	58.87	60.78	124	100.0	98.2
28240	Nizhny Tagil	57.88	60.07	262	100.0	96.5
28255	Turinsk	58.05	63.68	101	90.0	94.7
28275	Tobol'sk	58.15	68.25	45	100.0	100.0
28367	Tyumen	57.12	65.43	101	100.0	98.2
28411	Izhevsk	56.83	53.45	155	100.0	100.0
28434	Krasnoufimsk	56.65	57.78	205	100.0	100.0
28440	Ekaterinburg	56.83	60.63	280	100.0	100.0
28493	Tara	56.90	74.38	73	100.0	100.0
28661	Kurgan	55.47	65.40	73	100.0	98.2
28698	Omsk	55.00	73.40	121	100.0	98.2
28722	Ufa	54.72	55.83	104	100.0	100.0
28900	Samara	53.25	50.22	136	100.0	100.0
28952	Kostanay	53.21	63.61	170	100.0	100.0
29023	Napas	59.85	81.95	77	100.0	98.2
29111	Sredny Vasyugan	59.20	78.20	68	100.0	100.0
29231	Kolpasevo	58.30	82.95	73	100.0	100.0
29263	Jenisseisk	58.45	92.10	77	100.0	100.0
29282	Bogucany	58.38	97.45	131	100.0	100.0
29313	Pudino	57.57	79.43	96	100.0	100.0
29328	Bakchar	57.00	82.07	109	100.0	100.0
29430	Tomsk	56.50	84.92	141	100.0	100.0
29612	Barabinsk	55.33	78.37	119	100.0	100.0
29698	Nizne-Udinsk	54.88	99.03	410	100.0	100.0
29807	Irtyshsk	53.35	75.45	94	100.0	100.0
29838	Barnaul	53.40	83.50	183	100.0	100.0
29866	Minusinsk	53.70	91.70	254	100.0	100.0
30028	Ika	59.28	106.17	350	100.0	100.0
30054	Vitim	59.45	112.58	186	100.0	100.0
30230	Kirensk	57.77	108.07	257	100.0	100.0
30372	Chara	56.90	118.27	709	95.0	98.2
30393	Cul'Man	56.83	124.87	855	100.0	100.0
30521	Zhigalovo	54.80	105.17	417	100.0	100.0
30555	Troickij Priisk	54.60	113.10	1315	90.0	91.2
30636	Barguzin	53.60	109.60	488	100.0	98.2
30673	Mogocha	53.75	119.73	624	100.0	100.0
30692	Skovorodino	54.00	123.97	397	90.0	93.0
30710	Irkutsk	52.27	104.35	467	100.0	100.0
30758	Chita	52.08	113.48	671	100.0	93.0
30777	Sretensk	52.23	117.70	528	100.0	100.0
30823	Ulan-Ude	51.83	107.60	514	100.0	100.0
30925	Kjahta	50.37	106.45	791	95.0	98.2
30965	Borzya	50.40	116.52	675	95.0	98.2
31004	Aldan	58.62	125.03	678	100.0	98.2
31088	Ohotsk	59.37	143.20	5	100.0	98.2
31168	Ayan	56.45	138.15	6	100.0	100.0
31253	Bomnak	54.72	128.87	365	100.0	98.2
31329	Ekimchan	53.08	132.98	540	100.0	100.0
31369	Nikolaevsk-Na-Amure	53.13	140.70	67	100.0	96.5
31388	Norsk	52.40	129.90	207	100.0	100.0
31416	Im Poliny Osipenko	52.42	136.50	69	100.0	100.0
31510	Blagovescetnsk	50.25	127.50	130	100.0	100.0
31532	Cekunda	50.80	132.20	271	100.0	100.0
32061	Aleksandrovsk-Sahalinskij	50.90	142.17	30	100.0	100.0
32389	Kljuchi	56.32	160.83	28	100.0	98.2
33345	Kyiv	50.40	30.57	167	95.0	94.7

WMO Number	Station Name	Latitude (°N)	Longitude (°E)	Elevation (m a.s.l.)	Data availability: 2003-2022 (%)	Data availability: 1966-2022 (%)
34163	Oktyabrsky Gorodok	51.63	45.45	202	100.0	100.0
34391	Aleksandrov-Gaj	50.15	48.55	23	100.0	100.0
35078	Atbasar	51.82	68.37	304	100.0	100.0
35108	Uraisk	51.15	51.28	37	100.0	100.0
35121	Orenburg	51.68	55.10	115	100.0	100.0
35188	Astana	51.13	71.37	350	100.0	100.0
35229	Aktjubinsk	50.28	57.15	219	100.0	100.0
36034	Rubcovsk	51.58	81.22	216	100.0	100.0
36177	Semipalatinsk	50.42	80.30	196	100.0	100.0

Table S2. Proportion of 21-year running means that the 20CRv3 SC indices have positive and negative correlations with the 20CRv3 AO, and the proportion that are statistically significant based on a one-tailed test ($p < 0.10$). The significance of the proportion of decades with a significant SC-AO correlation is determined based on a probability distribution function derived from 10000 scrambled AO time-series using a one-tailed test for each sign of correlation: *** is $p < 0.01$, ** is $p < 0.05$, * is $p < 0.10$. The period covered is 1831-51 to 1995-2015.

Snow Cover Index	Positive (%)	Negative (%)	Pos. (significant) (%)	Neg. (significant) (%)
SCI_09	19.50	80.50	0.00**	37.74***
SCI_10	48.82	51.18	1.89	30.19**
SCI_11	57.23	42.77	14.47	8.18
SAI_OCT	69.18	30.82	12.58	5.66
SAI_NOV	48.43	51.57	1.89	0.63*

Table S3. Proportion of 21-year running means that various SC indices derived from 20CRv3 have positive and negative correlations with the 20CRv3 AO, and the proportion that are statistically significant based on a one-tailed test ($p < 0.10$). SCI_09 NE and SCI_11 SW developed in this study, the SAI_OCR_CJ index of Cohen and Jones (2011) and Nov_SNOWI defined in Han and Sun (2018). The significance of the proportion of decades with a significant SC-AO correlation is determined based on a probability distribution function derived from 10000 scrambled AO time-series using a one-tailed test for each sign of correlation: *** is $p < 0.01$, ** is $p < 0.05$, * is $p < 0.10$. The period covered is 1831-40 to 2006-2015.

| Snow Cover Index	Positive (%)	Negative (%)	Pos. (significant) (%)	Neg. (significant) (%)
SCI_09_NE	6.92	93.08	0.00**	32.70**
SCI_11_SW	89.94	10.06	41.51***	0.00**
SAI_OCT_CJ	59.12	40.88	12.58	11.32
Nov_SNOWI	14.47	85.53	0.62*	42.13***
Nov_SNOWI (west)	86.16	13.84	41.51***	0.00**
Nov_SNOWI (east)	31.45	68.55	4.40	27.67**
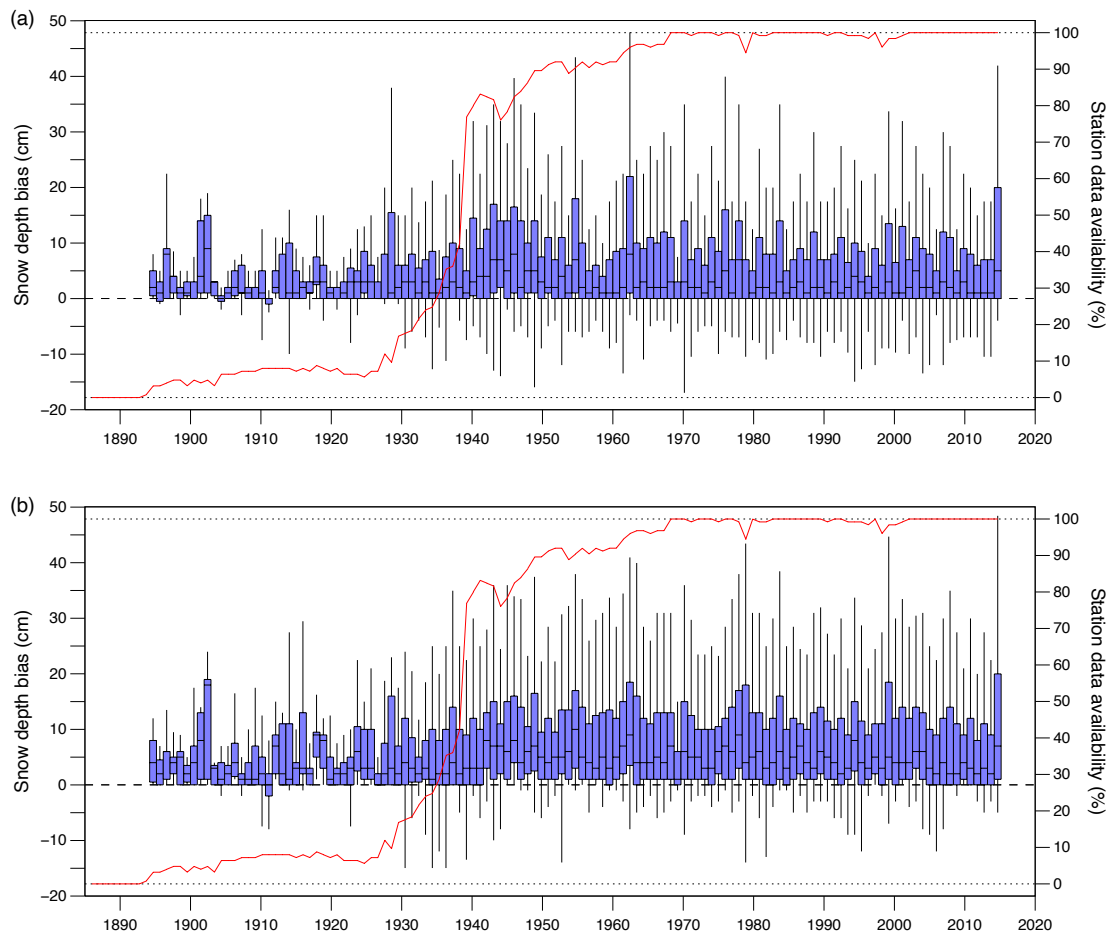
Figure S1. Bias of the median October-November snow depth in (a) 20CRv2c and (b) 20CRv3. The black horizontal line represents the median bias, the blue boxes show the interquartile range in the bias and the whiskers the larger (smaller) of either the upper (lower) quartile plus (minus) 1.5 times the interquartile range or maximum (minimum) value. The red line is the proportion of the 125 in situ station measurements available for comparison.
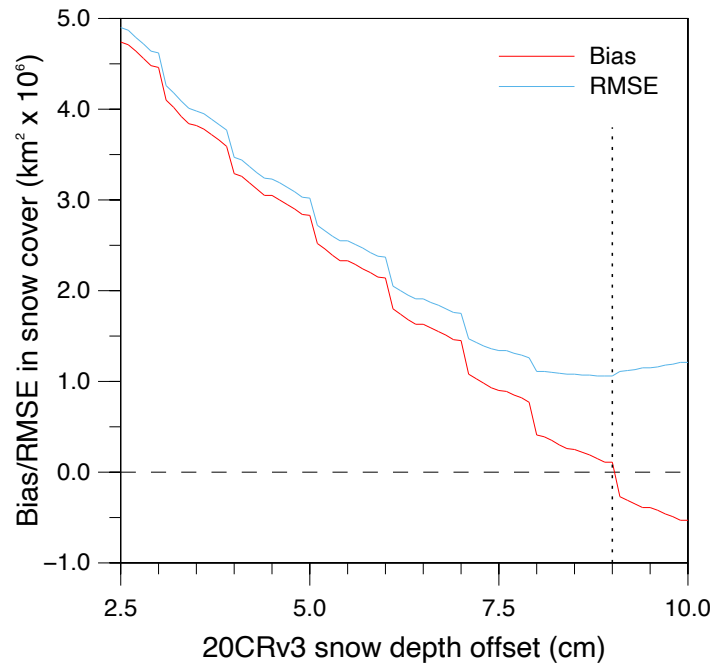
Figure S2. Relationship between the bias and RMSE in Eurasian SC in ERA5 (red) versus 20CRv3 (blue) for the calibration period (2003-2015). The vertical dotted line is where the bias is closest to zero and the RMSE is smallest (an offset of 9.0 cm).
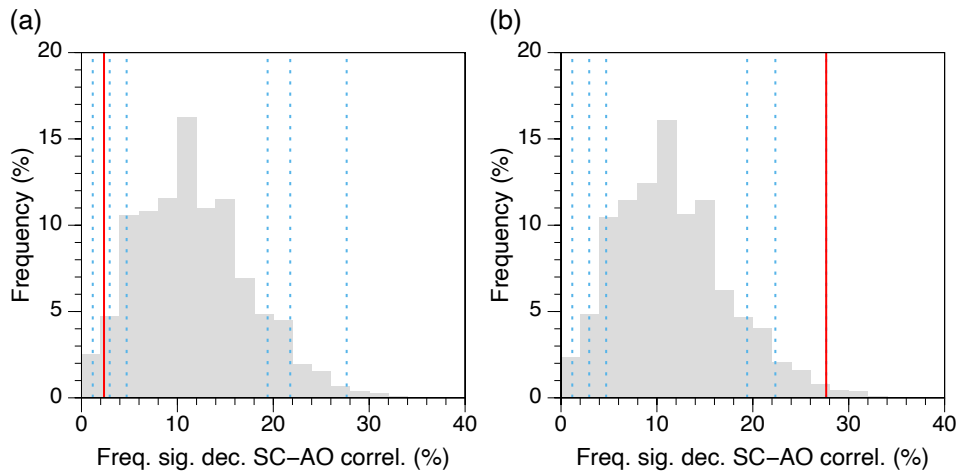

Figure S3. Probability distribution functions of the frequency of statistically significant ($p < 0.10$) decadal SCI_09-AO correlations based on 10000 scrambled AO time-series for (a) positive and (b) negative relationships. The dashed blue lines represent the values of statistical significance ($p < 0.10$, $p < 0.05$, $p < 0.01$) for high and low values. The red line is the value derived from the 20CRv3 data.
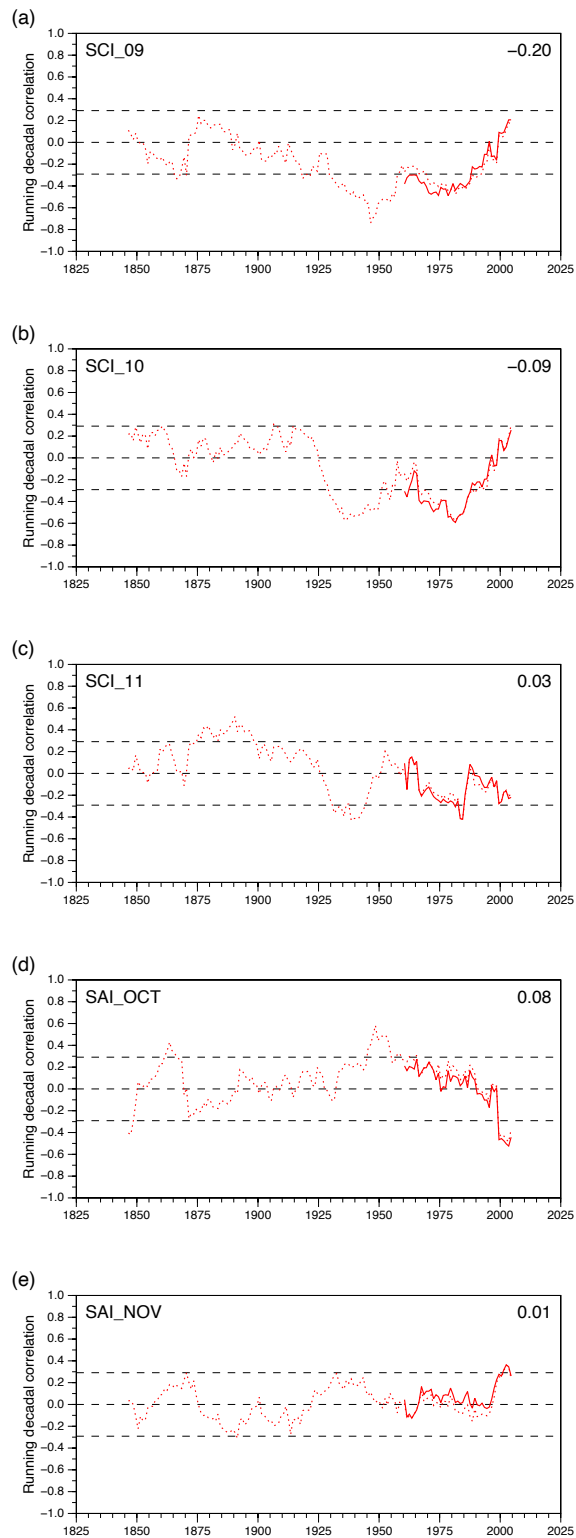
Figure S4. Running 21-year correlations between snow cover indices and winter AO: (a) SCI_09; (b) SCI_10; (c) SCI_11; (d) SAI_OCT; (e) SAI_NOV. Correlations with winter AO from the CPC and derived from 20CRV3 are shown as full and dashed lines, respectively. The black dashed horizontal lines indicate significance levels at *p* < 0.10 based on a one-tailed test for each sign of correlation for each period considered independently. The figure in the top right corner is the mean correlation coefficient across all 21-year periods.
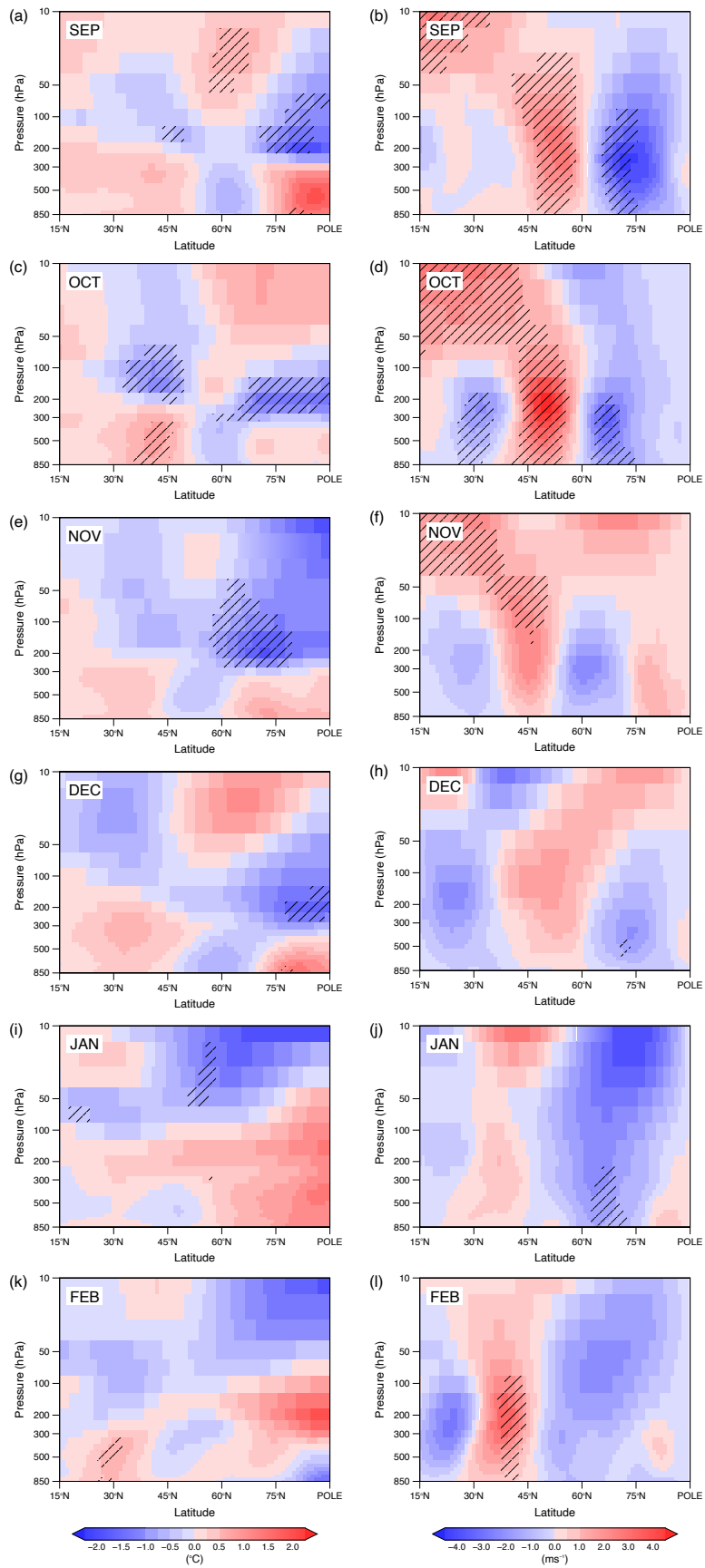
Figure S5. Difference in zonal mean temperature (left) and zonal mean zonal wind (right), between years with marked positive and negative values of the normalised SCI_09 NE index (above 1.0 and below-1.0, respectively). Data for 1966-2014 derived from 20CRv3. Hatched shading denotes a significant relationship at $p < 0.10$.