water

MDPI

Supplementary Materials

Effects of Climatic Drivers and Teleconnections on Late 20th Century Trends in Spring Freshet of Four Major Arctic-Draining Rivers

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Table S1. Characteristics of drainage sub-basins identified in Figure 2. Note: M = Mackenzie, O = Ob, L = Lena, Y = Yenisei, H_U = unregulated, H_R = Regulated and H_M = minimally regulated. Stations IDs in *italic* have data during t_2 (1980-2000) only.

Label	Basin	ID	Lat. (°N)	Long. (°E)	D.A. (km²)	% Infilled	Classification	Region
1	M	07AD002	53.42	-117.57	9765	0.0%	H_U	South
2	M	*07DA001*	56.78	-111.4	132585	0.0%	H_U	East
3	M	07GJ001	55.71	-117.62	50300	0.0%	H_U	South
4	M	07KC001	59.11	-112.43	293000	0.0%	H_R	East
5	M	07NB001	59.87	-111.58	606000	0.0%	H_M	East
6	M	*10BE001*	59.41	-126.1	104000	0.0%	H_U	West
7	M	*10CD001*	58.79	-122.66	20300	0.0%	H_U	West
8	M	*10ED002*	61.75	-121.22	275000	0.0%	H_U	West
9	M	*10JC003*	65.13	-123.55	146400	15.60%	H_U	North
10	M	*10FA002*	61.14	-119.84	9270	0.0%	H_U	East
11	M	*10FB005*	61.45	-121.24	1310	0.0%	H_U	West
12	M	*10GC003*	61.9	-121.61	2050	0.0%	H_U	North
13	M	*10KA001*	65.27	-126.84	1594500	11.80%	H_M	North
14	M	*07OB001*	60.74	-115.86	51700	0.0%	H_U	East
15	M	*07TA001*	63.11	-116.97	13900	0.0%	H_U	East
16	M	*07AA001*	52.86	-118.11	629	0.0%	H_U	South
17	M	*07AA002*	52.91	-118.06	3872	0.0%	H_U	South
18	M	07AF002	53.47	-116.63	2562	0.0%	H_U	South
19	M	07AG003	53.6	-116.27	826	0.0%	H_U	South
20	M	07BB002	53.6	-115	4402	0.0%	H_U	South
21	M	07BC002	54.45	-113.99	13014	0.0%	H_U	South
22	M	07BE001	54.72	-113.29	74602	0.0%	H_U	South
23	M	*07BF002*	55.45	-116.49	1152	0.0%	H_U	South
24	M	*07BJ001*	55.32	-115.42	1900	0.0%	H_U	South
25	M	*07BK007*	55.26	-114.23	2100	0.0%	H_U	East
26	M	07CD001	56.69	-111.26	30792	0.0%	H_U	East
27	M	*07EC002*	55.92	-124.57	5560	0.0%	H_U	South
28	M	*07EE007*	55.08	-122.9	4930	0.0%	H_U	South
29	M	07FB001	55.72	-121.21	12100	0.0%	H_U	South
30	M	*07FC001*	56.28	-120.7	15600	0.0%	H_U	South
31	M	*07FC003*	56.68	-121.22	1770	0.0%	H_U	South
32	M	*07FD001*	55.96	-120.56	3630	0.0%	H_U	South
33	M	*07FD007*	55.86	-120.03	2860	14.00%	H_U	South
34	M	07GE001	55.07	-118.8	11300	0.0%	H_U	South

35	M	*07GG001*	54.75	-117.21	1040	0.0%	H_U	South
36	M	07GH002	55.46	-117.16	11100	0.0%	H_U	South
37	M	07HA001	56.24	-117.31	194374	0.0%	H_R	South
38	M	*07HA003*	56.06	-117.13	1968	0.0%	H_U	South
39	M	07HC001	56.92	-117.62	4679	0.0%	H_U	East
40	M	*07JD002*	57.87	-115.39	35800	0.0%	H_U	East
41	M	07LE002	59.15	-105.54	50700	4.80%	H_U	East
42	M	*07MB001*	58.97	-108.18	9120	0.0%	H_U	East
43	M	*07OC001*	58.6	-118.33	10370	1.30%	H_U	East
44	M	*10AB001*	60.47	-129.12	12800	0.0%	H_U	West
45	M	*10AC005*	59.12	-129.82	882	0.0%	H_U	West
46	M	*10BE004*	58.85	-125.38	2540	0.0%	H_U	West
47	M	*10BE007*	59.34	-125.94	1170	0.0%	H_U	West
48	M	*10CB001*	57.23	-122.69	2180	0.0%	H_U	South
49	M	*10EA003*	61.53	-125.41	8560	0.30%	H_U	West
50	M	*10EB001*	61.64	-125.8	14500	0.0%	H_U	West
51	M	*10ED001*	60.24	-123.48	222000	2.50%	H_U	West
52	M	*10GC001*	61.87	-121.36	127000	0.0%	H_M	East
53	M	*10LA002*	66.79	-133.09	18750	1.10%	H_U	North
54	M	*10LC014*	67.456	-133.75	1679100	2.00%	H_M	Outlet
55	M	*10MC002*	67.26	-134.89	70600	6.30%	H_U	North
56	M	*10ED003*	61.33	-122.09	542	0.0%	H_U	West
57	O	11801	66.63	66.6	2950000	2.60%	H_M	Outlet
58	O	11056	58.2	68.23	1500000	0.80%	H_M	West
59	O	11048	55.02	73.3	769000	0.0%	H_R	West
60	O	10031	61.07	68.9	2690000	5.60%	H_M	East
61	O	10021	58.3	82.88	486000	0.0%	H_M	South
62	O	10062	51.28	87.72	16600	9.90%	H_U	South
63	O	10126	51.02	84.32	3480	5.60%	H_U	South
64	O	10176	53.73	84.95	15900	5.10%	H_U	South
65	O	10219	55.32	84.1	15700	5.10%	H_U	South
66	O	10277	53.33	87.23	7080	5.10%	H_U	South
67	O	10317	55.38	91.62	14700	12.20%	H_U	South
68	O	10387	56.2	87.78	9820	5.10%	H_U	South
69	O	10407	56.18	86.4	3460	7.70%	H_U	South
70	O	10428	57.78	82.63	25000	5.10%	H_U	South
71	O	10444	56.85	83.07	2560	5.10%	H_U	South
72	O	10466	59.37	82.83	6500	5.10%	H_U	East
73	O	10478	59.22	78.22	31700	9.40%	H_U	East
74	O	10489	59.85	81.95	24500	5.10%	H_U	East
75	O	11309	55.45	78.32	12200	5.10%	H_U	West
76	O	11353	56.38	75.25	16400	0.0%	H_U	West
77	O	11496	57.13	69.22	2140	2.60%	H_U	West
78	O	11556	66.87	65.78	1240	0.60%	H_U	North
79	O	11558	66.03	68.73	15100	2.90%	H_U	North
80	O	11574	64.93	77.8	31400	0.20%	H_U	North
81	Y	9803	67.43	86.48	2440000	0.0%	H_M	Outlet
82	Y	9092	61.1	90.08	1760000	0.0%	H_M	North

83	Y	9002	51.72	94.4	115000	0.0%	H_U	South
84	Y	8091	58.35	93.55	1040000	0.0%	H_R	South
85	Y	9079	58.45	92.15	1400000	0.0%	H_R	West
86	Y	7156	51.95	106.35	565	0.0%	H_U	East
87	Y	7172	51.53	104.07	959	0.0%	H_U	South
88	Y	7015	55.85	110.15	20600	0.0%	H_U	East
89	Y	7024	53.6	109.6	19800	0.0%	H_U	East
90	Y	7036	52.92	108.73	5050	0.0%	H_U	East
91	Y	7072	50.3	108.63	15600	0.0%	H_U	East
92	Y	7102	51.2	106.97	38300	0.0%	H_U	East
93	Y	9207	52.65	90.1	14400	0.0%	H_U	West
94	Y	9252	53.8	92.87	31800	0.0%	H_U	West
95	Y	9372	59.12	93.48	15100	0.0%	H_U	North
96	Y	9422	65.65	90.12	9100	0.0%	H_U	North
97	Y	9425	65.98	84.27	10100	5.10%	H_U	North
98	L	3821	70.68	127.39	2430000	0.0%	H_M	Outlet
99	L	3329	63.95	124.83	452000	2.00%	H_M	West
100	L	3156	60.98	115.5	32600	2.60%	H_U	West
101	L	3157	60.17	116.8	27600	0.30%	H_U	South
102	L	3277	60.68	135.03	24200	2.60%	H_U	East
103	L	3291	59.67	127.05	23900	2.60%	H_U	South
104	L	3202	60.9	120.8	16600	10.30%	H_U	West
105	L	3210	61.05	128.65	12200	10.30%	H_U	South
106	L	3219	58.97	126.27	49500	10.30%	H_U	South

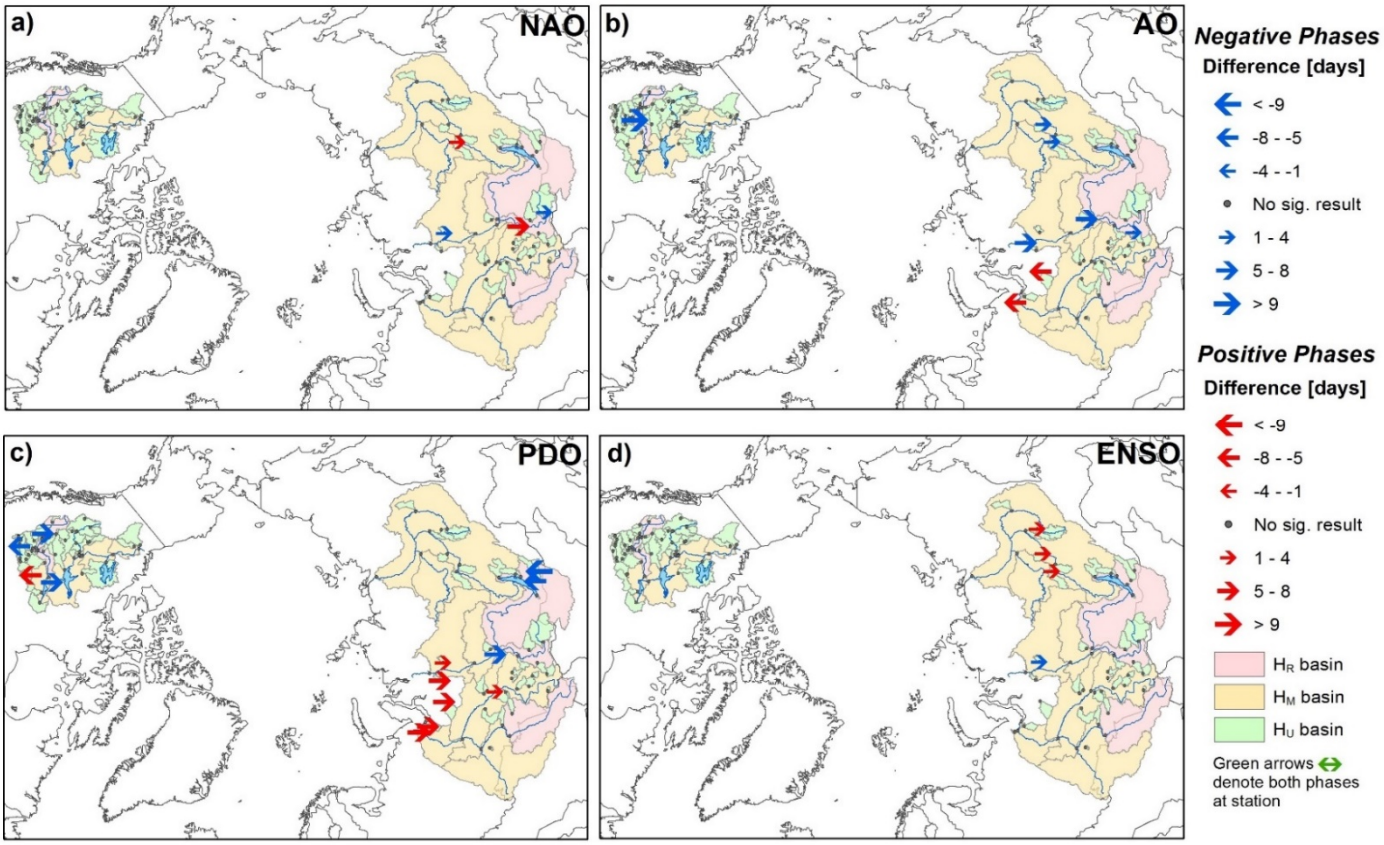

Figure S1. Teleconnection relationships between March through May (**a**) NAO (**b**) AO (**c**) PDO and (**d**) ENSO and freshet pulse dates F_P during the 1962–2000 period. Blue arrows indicate F_P is affected by the negative phase of a teleconnection index while red arrows indicates F_P is affected by the positive phase of the index at a 5% significance level. The direction of the arrows indicate whether F_P is delayed (pointing right) or advancing (pointing left) while the size of the arrow represents the magnitude.

During t1, NAO and ENSO show little influence in any of the basins during either phase, although some stations exhibited later pulse dates during the negative phase of each oscillation. The negative phase of AO (associated with cooler SAT anomalies) was shown to relate to later pulse dates in some Eurasian and Mackenzie stations while the positive phase was related to earlier pulse dates in two northern Ob basin stations. Positive phase of PDO was correlated with delayed pulse dates in the northern Ob and Yenisei regions. In the Mackenzie basin, negative PDO associated with lower SAT anomalies was correlated with later pulse dates in two stations while positive PDO was correlated with an earlier occurrence of pulse dates in one station.

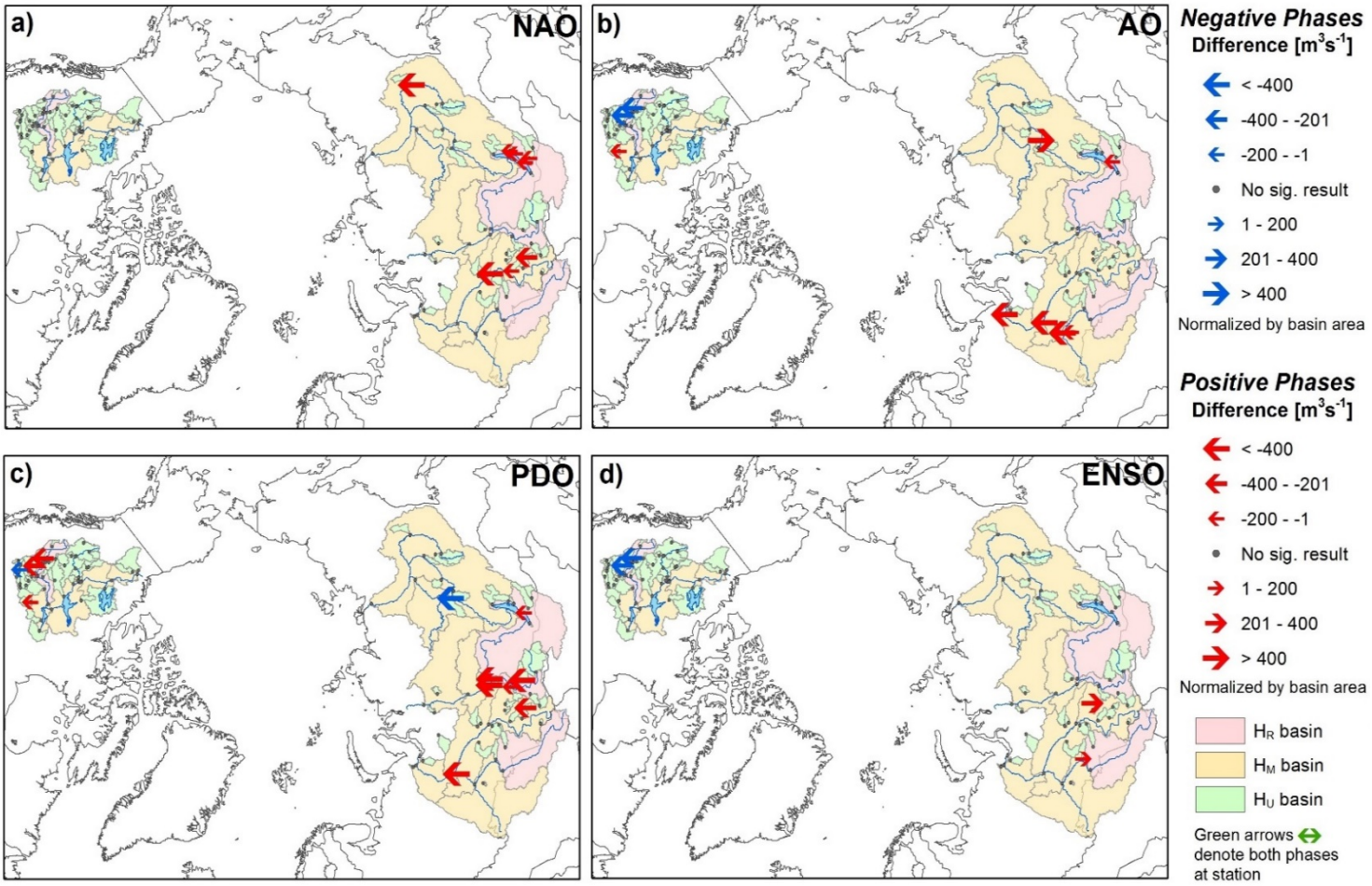

Figure S2. Teleconnection relationships between March through May (**a**) NAO (**b**) AO (**c**) PDO and (**d**) ENSO and peak freshet magnitude F_M during the 1962–2000 period. Blue arrows indicate F_M is affected by the negative phase of a teleconnection index while red arrows indicates F_M is affected by the positive phase of the index at a 5% significance level. The direction of the arrows indicate whether F_M is increasing (pointing right) or decreasing (pointing left) while the size of the arrow represents the magnitude.

During t_1, NAO and AO in their positive phases were associated with lower peak freshet magnitudes, particularly in Eurasian basins. NAO exhibited a strong influence in the eastern Ob and Yenisei regions while AO was mostly detectable in northern and western Ob. Similarly, PDO in its positive phase was associated with lower F_M except most results were located in high-relief regions of the southern Mackenzie and western Yenisei. These findings were consistent with positive SAT anomalies associated with the positive phases of these indices. They were also consistent with positive correlations of temperature with decreased F_M. Meanwhile, ENSO demonstrated little effect on F_M.

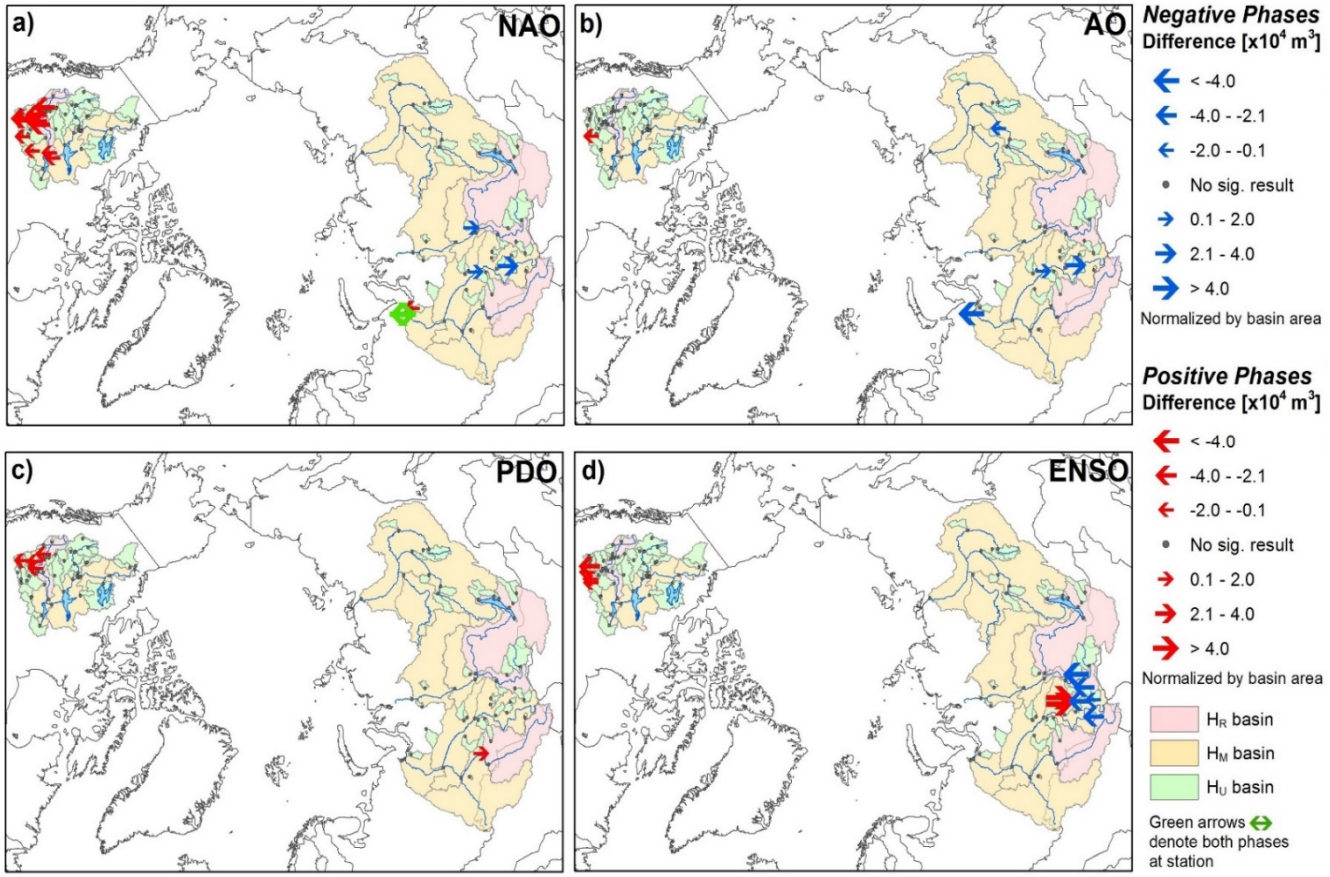

Figure S3. Teleconnection relationships between December through February (**a**) NAO (**b**) AO (**c**) PDO and (**d**) ENSO and freshet volume V_2 during the 1962–2000 period. Blue arrows indicate V_2 is affected by the negative phase of a teleconnection index while red arrows indicates V_2 is affected by the positive phase of the index at a 5% significance level. The direction of the arrows indicate whether V_2 is increasing (pointing right) or decreasing (pointing left) while the size of the arrow represents the magnitude.

Regional patterns were most pronounced during t_1, with strong influence of positive phases of PDO, AO, NAO and ENSO (El Niño) reflecting positive Central Pacific SST anomalies resulting in warmer, drier winter conditions for the southern Mackenzie basin and correspondingly decreased freshet volumes. In the Eurasian basins, negative NAO and AO were related to increased volumes in some southern Ob basins. This is likely due to regional variation in precipitation anomalies associated with these indices, where negative phases can lead to increased winter precipitation anomalies in southern portions of the Eurasian basins. PDO generally did not exhibit any significant relationships in Eurasian basins. ENSO, meanwhile, showed increased volume during El Niño (wetter winters, regionally) in two Ob sub-basins, while nearby in southern Ob and western Yenisei alpine regions, La Niña (drier winters, regionally) showed significant relationships with decreased freshet volumes.