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Supplement of

Trace elements transport in western Siberia rivers across a permafrost gradient

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SUPPLEMENT

List of rivers, correlation coefficients and latitudinal plots of TE

Table S1. List of sampled rivers, their watershed area and annual runoff. The numbers in the first column represent the rivers in the map (Fig. 1).

River	N	E	watersheds, km^2	Annual runoff, mm/y
41. Vach-Yagun	61˚29'11.1"	74˚09'42.9"	1.79	192
40. Segut-Yagun	61˚29'46.6"	74˚15'30.3"	3.37	192
27. Medvedka	60°44'10,9"	77°22'55,9"	7	173
38. Kottym'egan	61˚27'17.3"	74˚40'23.3"	7.18	192
81. Tydylyakha	65˚06'48.8"	77˚47'58.8"	7.46	185
3. Chybyr'	56˚43'15.0"	83˚55'35.1"	8.14	44.8
35. Er-Yakh	61°12'19,5"	75°23'06,5"	9.35	173
42. Vachinguriyagun	61˚50'28.6"	70˚50'28.2"	9.52	192
47. Pertriyagun	62˚37'08.4"	74˚10'15.9"	9.65	192
60. Goensapur	63°12'43.38"	76°21'27.66"	11	194
82. Tydyotta	65˚12'17.6"	77˚43'49.8"	12.0	309
14. Istok	58˚24'38.0"	82˚08'46.0"	12.3	127
61. Denna	63°12'45.96"	76°24'1.32"	15	194
78. Seryareyakha	64˚32'07.9"	76˚54'21.3"	15.2	186
73. Apoku-Yakha	64˚09'06.4"	75˚22'18.1"	18.8	186
54. Ponto-Yakha	63°9'31.38"	75°3'2.58"	19	194
43. Lyukh-Yagun	61˚58'05.1"	73˚47'03.4"	21.6	192
49. Ai-Kirill-Vys'yagun	62˚43'09.9"	74˚13'45.9"	24.0	192
28. Saim	60°45'58,5"	77°26'12,6"	26	173
31. Kaima	60°50'43,6"	77°05'03,0"	31	173
6. Cherniy Klyuch	56°54'39,1"	82°33'33,3"	32	168
29. Mishkin Saim	60°47'29,3"	77°19'13,5"	32	173
67. Nyudya-Itu-Yakha	63°8'34.02"	74°54'29.1"	32	194
46. Pintyr'yagun	62˚33'39.8"	74˚00'29.5"	33.5	192
64. Khatytayakha	63˚36'48.2"	74˚35'28.6"	34.6	194
88. Tadym-Yakha	65˚59'05.7"	77˚40'52.6"	39.9	185
87. Yude-Yakha	65˚58'54"	77˚34'05"	42.4	185
57. Tlyatsayakha	63°13'25.2"	76°5'23.04"	43	194
30. Alenkin Egan	60°49'32,3"	77°13 46,3"	44	173
77. Kharv'-Yakha	64˚26'05.2"	76˚24'37.0"	46.4	186
76. Khaloku-Yakha	64°23'30,6"	76°19'50,1"	53	186
13. Tatarkin Istok	58˚23'16.8"	82˚11'39.0"	58.6	33.4
71. Ngarka-Tyde-Yakha	64˚12'08.4"	75˚24'28.4"	59.9	186
2. Prud	56˚46'19.5"	83˚57'35.7"	61.5	44.8
72. Ngarka-Varka-Yakha	64˚06'50.7"	75˚14'17.3"	67.1	186
74. Etu-Yakha	64˚17'31.9"	75˚44'33.4"	71.6	186
66. Khanupiyakha	63°49'58,0"	74°39'02,5"	74	194
83. Ponie-Yakha	65˚23'34.1"	77˚45'46.7"	78.9	185
53.Nyudya-Pidya-Yakha	63°10'4.68"	76°28'19.08"	79.5	194

50. Pyrya-Yakha	63°11'19,3"	74°36'25,5"	82	194
56. Yangayakha	63°13'12.06"	75°38'52.26"	88	194
52. Nekhtyn-Pryn	63°10'3.48"	74°45'16.32"	96	194
75. Varka-Yakha	64˚19'10.1"	76˚08'26.7"	105	186
86. Almayakha	65˚47'48.6"	78˚10'09.0"	106	185
69. Lymbyd’yakha	63˚47'04.5"	75˚37'06.8"	115	194
20. Vyalovka	58˚40'46.5"	84˚27'56.6"	117	127
58. Chukusamal	63°13'3.66"	76°15'24.6"	121	194
92. Malokha Yakha	66°59'20,9"	79°22'30,5"	157	208
55. Velykh-Pelykh-Yakha	63°9'39.84"	75°09'10.86"	170	194
63. Kamgayakha	63˚22'01.6"	74˚31'53.2"	175	194
10. Chemondaevka	57˚52'26.8"	83˚11'29.9"	177	63.4
85. Khiroyakha	65°46'34,5"	78°08'25,8"	183	185
22. Kornilovskaya	59˚41'01,6"	77˚44'33,9"	190	133
24. Koltogorka	60˚08'43"	77˚16'53"	220	155.4
51. Itu-Yakha	63°11'40.68"	74°38'16.92"	250	194
23. Levyi Il’yas	59˚44'09,2"	77˚26'06"	253	133
11. Sugotka	57˚58'45.7"	82˚58'32.2"	275	63.4
65. Pulpuyakha	63˚40'41.8"	74˚35'20.7"	281	194
8. Malyi Tatosh	57˚36'43.3"	83˚37'02.1"	302	63.4
5. Brovka	57˚19'20.7"	83˚55'53.8"	320	63.4
36. Ur’evskii Egan	61˚19'41.2"	75˚04'0.3"	359	272
17. Karza	58°32'05,8"	80°51'26,8"	473	148
18. Sochiga	58°37'29,9"	81°06'09,0"	510	148
90. Mal. Khadyr-Yakha	65˚59'14.7"	78˚32'25.2"	512	278
48. Kirill-Vys’yagun	63°38'23,4"	74°10'52"	598	225
93. Nuny-Yakha	67°10'54,8"	78°51'04,5"	656	312
16. Chigas	58˚33'03.1"	81˚48'44.3"	689	180
25. Sosninskii Yegan	60˚30'19"	76˚58'57"	732	199
67. Kharucheiyakha	63˚51'23.4"	75˚08'05.6"	820	292
9. Bolshoy Tatosh	57˚37'17.3"	83˚31'53.3"	1020	74.6
33. Mokhovaya	61˚34'27.4"	77˚46'35.4"	1260	192.3
70. Chuchi-Yakha	63°43'37,9"	75°59'04,1"	1396	292
44. Limpas	61˚59'39"	73˚47'39"	1648	320
91. Ngarka Khadyta-Yakha	66˚17'10.8"	79˚15'06.1"	1970	277
59. Vyngapur	63°46'22.92"	76°25'28.86"	1979	324
34. Vatinsky Egan	61˚11'52.7"	75˚25'20.2"	3190	287
7. Bakchar	57°02'23,75"	82°04'02,44"	3197	96.1
15. Shudelka	58˚26'06.9"	82˚05'43.6"	3460	211
84. Yamsovey	65˚41'51.1"	78˚01'05.0"	4030	309
79. Purpe	64˚40'14.0"	77˚05'27.2"	5110	309
95. Khadutte	67˚24'39"	76˚21'12"	5190	346
68. Pyakupur	63°49'54,2"	75°22'47,1"	9880	324
45. Tromyegan	62°07'50,0"	73°44'05,6"	10770	263
4. Shegarka	57˚06'39.2"	83˚54'41.1"	12000	58.3
19. Parabel	58˚42'34.5"	81˚22'22.0"	25500	131
80. Aivasedapur	64˚55'55.1"	77˚56'08.2 "	26100	309
12. Chaya	58˚04'20.8"	82˚49'19.7"	27200	96
37. Agan	61°26'13,6"	74°47'39,7"	27600	291

21. Vasyugan	58˚59'37"	80˚34'00"	63780	177
32. Vakh	60°55'41,0"	76°53'49,3"	75090	298
89. Pur	65˚57'05.5"	78˚18'59.1"	112000	298
94. Taz	67˚22'13.28"	79˚00'25,9"	150000	330
26. Ob’	60˚40'28.8"	77˚31'29.4"	773200	216
1. Ob’	56˚31'48"	84˚09'44"	423100	207

Table S2. Correlation matrix of major and TE with Fe, Al, DOC and DIC. Bold values are significant at $p < 0.05$.

	Al, all year	Fe, all year	Al, Spring	Fe, Spring	Al, Summer	Fe, Summer	Al, Fall	Fe, Fall	Al, Winter	Fe, Winter
DIC	-0.28				**-0.75**				-0.45	
DOC	**0.60**		**0.66**		**0.80**					0.40
UV_{280}	**0.71**	0.19	**0.67**		**0.75**				**0.61**	**0.64**
Cl				**0.75**						
SO_4										
Si										
Li				0.48						
Be	0.45	0.44	**0.75**		**0.83**		**0.75**			
B				**0.69**						
Na				**0.74**						
Mg	-0.27								**-0.51**	
Si	-0.45								-0.48	
K								**-0.78**	-0.46	
Ca									-0.47	
Ti	0.47		**0.71**		**0.98**		**0.87**	**0.78**	**0.76**	**0.68**
V	0.28		0.45						**0.77**	**0.53**
Cr	0.46	0.34	**0.60**		**0.91**		**0.86**		**0.80**	**0.54**
Mn	-0.28	0.34								**0.50**
Co		0.29			**0.84**		**0.73**			
Ni	0.45		0.46							
Cu	0.34	-0.31			**0.73**					
Zn										
Ga			**0.55**		**0.84**		**0.90**	**0.71**		**0.69**
As		0.36				**0.79**				**0.86**
Rb										
Sr				**0.51**					-0.44	
Zr	**0.59**		**0.75**		**0.83**		**0.75**		**0.86**	**0.62**
Nb	**0.79**		**0.88**							
Mo		-0.29						**-0.95**		
Cd	**0.71**		**0.74**		**0.92**		**0.95**			
Sb	**0.52**	-0.28	0.40							0.40
Cs				**0.56**						
Ba				0.48						
La	**0.77**		**0.72**		**0.88**		**0.86**		**0.79**	
Ce	**0.78**		**0.73**		**0.96**		**0.82**		**0.80**	
Pr	**0.72**		**0.74**		**0.91**		**0.89**		**0.80**	
Nd	**0.72**		**0.75**		**0.92**		**0.88**		**0.80**	
Sm	**0.70**		**0.74**		**0.92**		**0.90**		**0.80**	
Eu	**0.58**		**0.60**		**0.90**		**0.91**		**0.60**	
Gd	**0.66**		**0.68**		**0.92**		**0.85**		**0.78**	

Dy	**0.67**		**0.71**		**0.95**		**0.84**		**0.76**	
Ho	**0.64**		**0.67**		**0.91**		**0.89**		**0.51**	
Er	**0.65**		**0.69**		**0.94**		**0.82**		**0.71**	
Tm	**0.66**		**0.72**		**0.76**		**0.83**			
Yb	**0.61**		**0.68**		**0.97**		**0.83**		**0.70**	
Lu	**0.59**		**0.67**				**0.85**			
Hf	**0.69**		**0.72**							
W			0.47							
Pb	0.37								0.45	
Th	**0.80**		**0.86**		**0.83**		**0.86**	**0.73**	**0.88**	
U		-0.33								

Table S2. Continued

	DIC, all year	DOC, all year	DIC, Spring	DOC, Spring	DIC, Summer	DOC, Summer	DIC, Fall	DOC, Fall	DIC, Winter	DOC, Winter
DOC			**0.60**				**-0.77**			
UV_{280}		**0.90**	**0.53**	**0.99**		**0.98**	**-0.92**	**0.92**		**0.51**
Cl							**0.72**	**-0.87**		**0.64**
SO4							**0.71**			
Si	0.20						**0.73**	**-0.88**		
Li			**0.59**	**0.73**	0.28					
Be	-0.20	**0.63**				**0.80**	**-0.84**			
B	0.33				**0.56**		**0.89**	**-0.75**		
Na	0.34				0.32		**0.84**			**0.66**
Mg	**0.98**		**0.96**	**0.71**	**0.97**		**0.98**		**0.99**	
Al	-0.31	**0.59**		**0.66**		**0.72**			-0.46	
Si	0.40		**0.65**	0.42	0.32	-0.31	**0.74**	**-0.83**		
K	**0.59**	0.34	**0.94**	**0.55**	**0.71**				**0.77**	**0.44**
Ca	**0.91**		**0.99**	**0.71**	**0.91**		**1.00**	**-0.74**	**1.00**	
Ti		**0.52**	0.46	**0.56**		**0.70**			-0.46	0.47
V		**0.59**	**0.73**	**0.82**	0.34	**0.71**			-0.42	
Cr	-0.33	**0.54**	**0.55**	**0.87**	-0.34	**0.63**	**-0.90**		**-0.57**	
Mn	0.37					**0.58**		**-0.84**		
Fe		0.22				0.43				0.48
Co						**0.72**				
Ni		**0.62**	**0.80**	**0.88**		**0.71**	**-0.82**	**0.89**		
Cu		0.37	**0.77**	**0.66**		0.35				
Zn			**-0.57**	**-0.56**						
Ga		0.20	0.41	0.41		**0.66**				
As	0.28	0.42	**0.76**	**0.85**	0.37	0.47	**0.85**			**0.59**
Rb	**0.51**	0.25	0.46	**0.59**	**0.64**					**0.53**
Sr	**0.58**	0.19	**0.50**	**0.56**	0.49		**0.99**	**-0.71**	**0.82**	0.42
Zr		**0.62**	**0.59**	**0.85**		**0.86**			-0.42	
Nb	0.28	0.25	0.48	**0.76**		**0.53**				
Mo	0.21	**0.52**	0.40	**0.50**	0.33	**0.56**				
Cd				**0.54**						
Sb		0.45	**0.75**	**0.74**		0.45				
Cs	0.25									
Ba	0.29		-0.46	-0.46	0.33					**0.59**
La	-0.23	0.42		**0.62**		**0.70**			-0.44	
Ce	-0.24	0.34		**0.56**		**0.78**			-0.44	
Pr	-0.22	0.37		**0.62**		**0.74**			-0.44	
Nd	-0.26	0.44		**0.63**		**0.74**			-0.45	
Sm	-0.23	0.46		**0.65**		**0.75**			-0.46	

Eu		0.32				**0.65**				
Gd	-0.22	0.48		**0.65**		**0.79**			-0.45	
Dy	-0.23	0.47		**0.65**		**0.77**			-0.47	
Ho		0.21		**0.66**		**0.71**				
Er	-0.20	0.43		**0.65**		**0.77**			-0.47	
Tm				**0.68**		**0.53**				
Yb	-0.20	0.37		**0.66**		**0.69**			-0.48	
Lu				**0.61**	-0.31	0.39				
Hf	0.30	0.45	**0.62**	**0.85**		**0.80**				
W	0.35		**0.53**	**0.56**	0.29					
Pb										
Th		**0.53**		**0.79**		**0.88**			-0.45	
U	**0.60**	0.29	**0.79**	**0.57**	**0.54**	0.41	**0.76**		**0.80**	

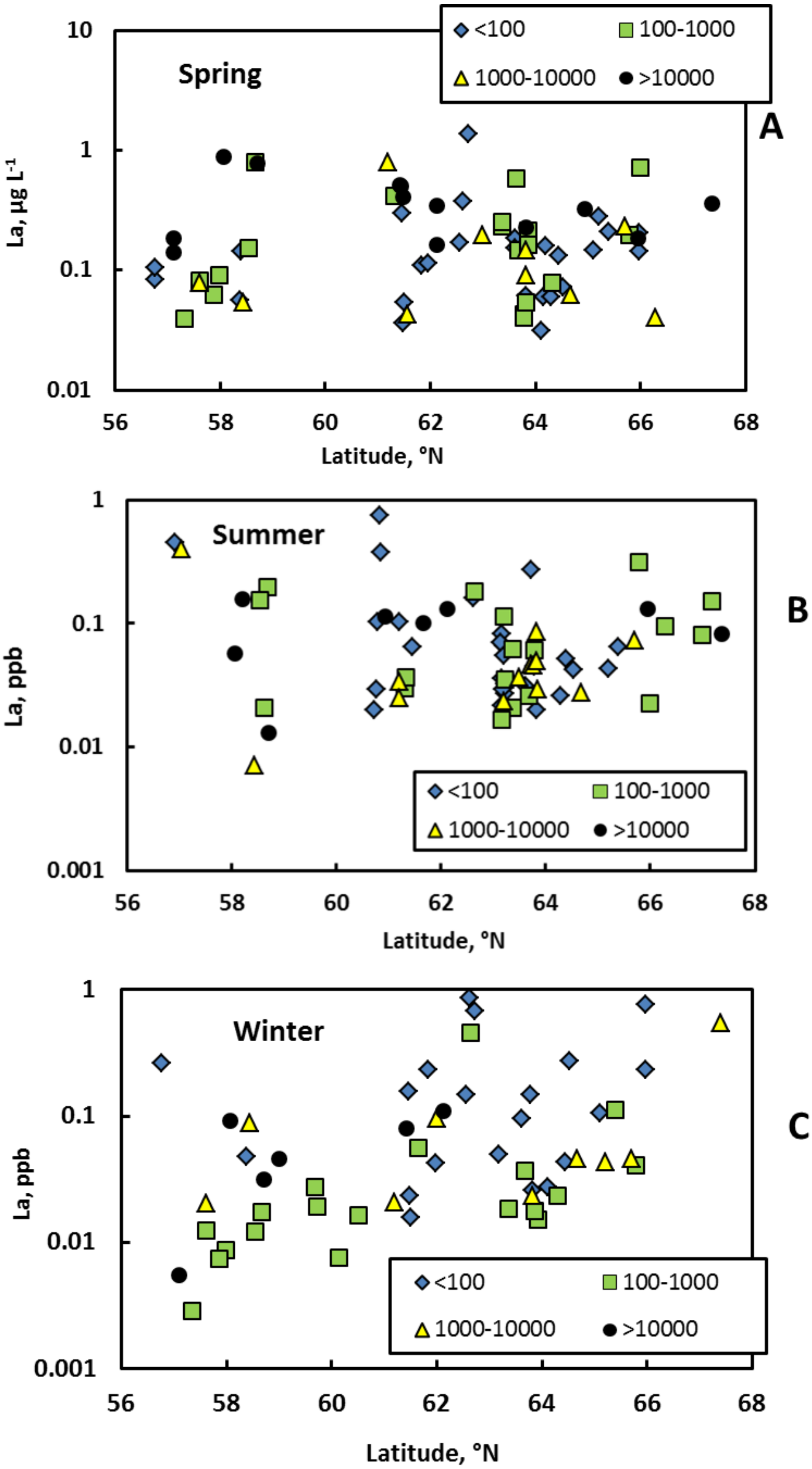

Fig. S1. Variation of La concentration on the latitude during spring (A) and summer (B) and an increase of La concentration northward in winter (C). The latitudinal trend in winter is significant at $p < 0.05$. Considering all seasons together, the differences between different watershed sizes are not statistically significant ($p > 0.05$). The symbols are the same as in Fig. 2.

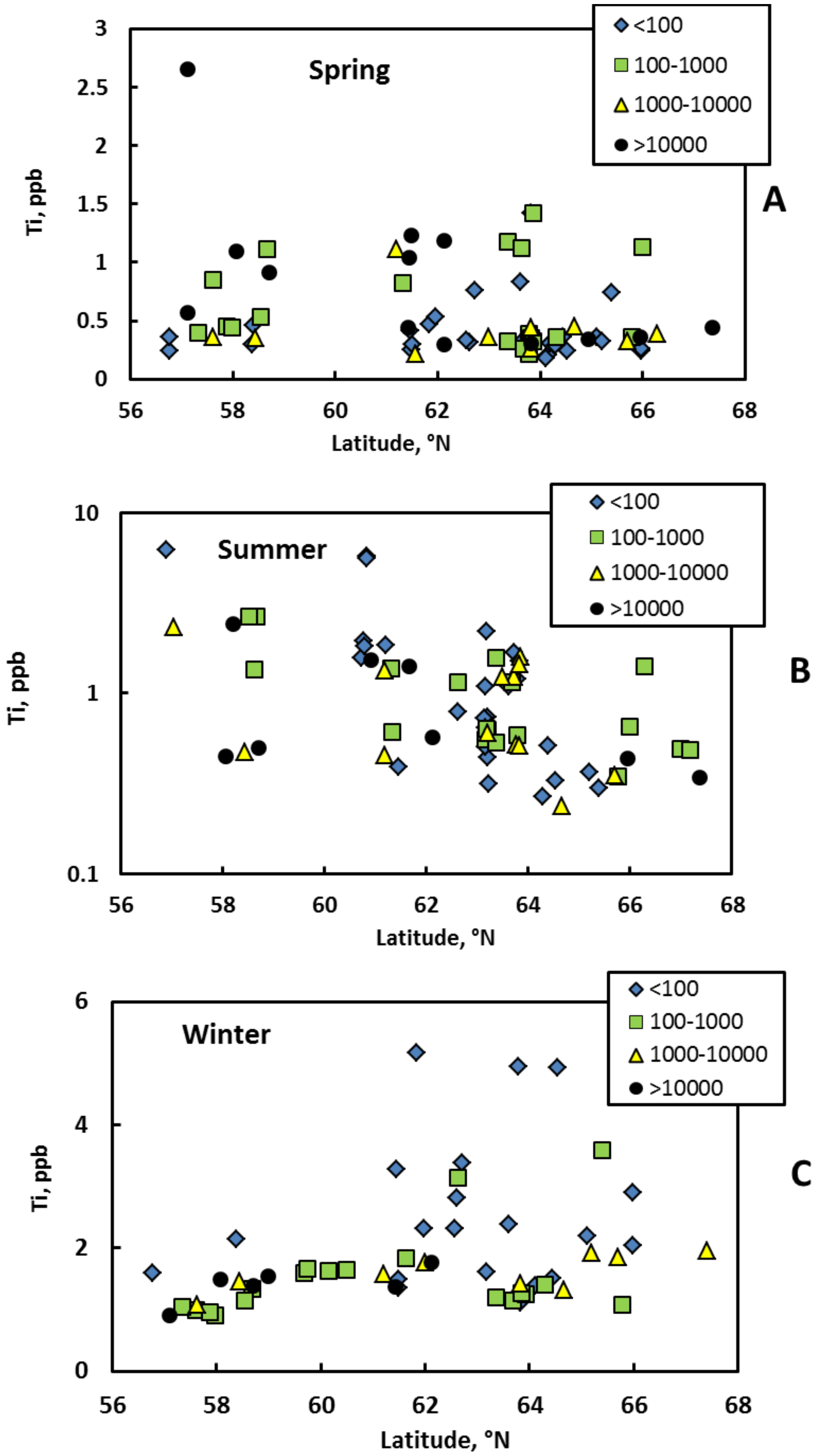

Fig. S2. Variation of Ti concentration on the latitude during spring (A), summer (B) and winter (C). The latitudinal trend in summer is significant at $p < 0.05$. Considering all seasons together, the differences between different watershed sizes are not statistically significant ($p > 0.05$). The symbols are the same as in Fig. 2.

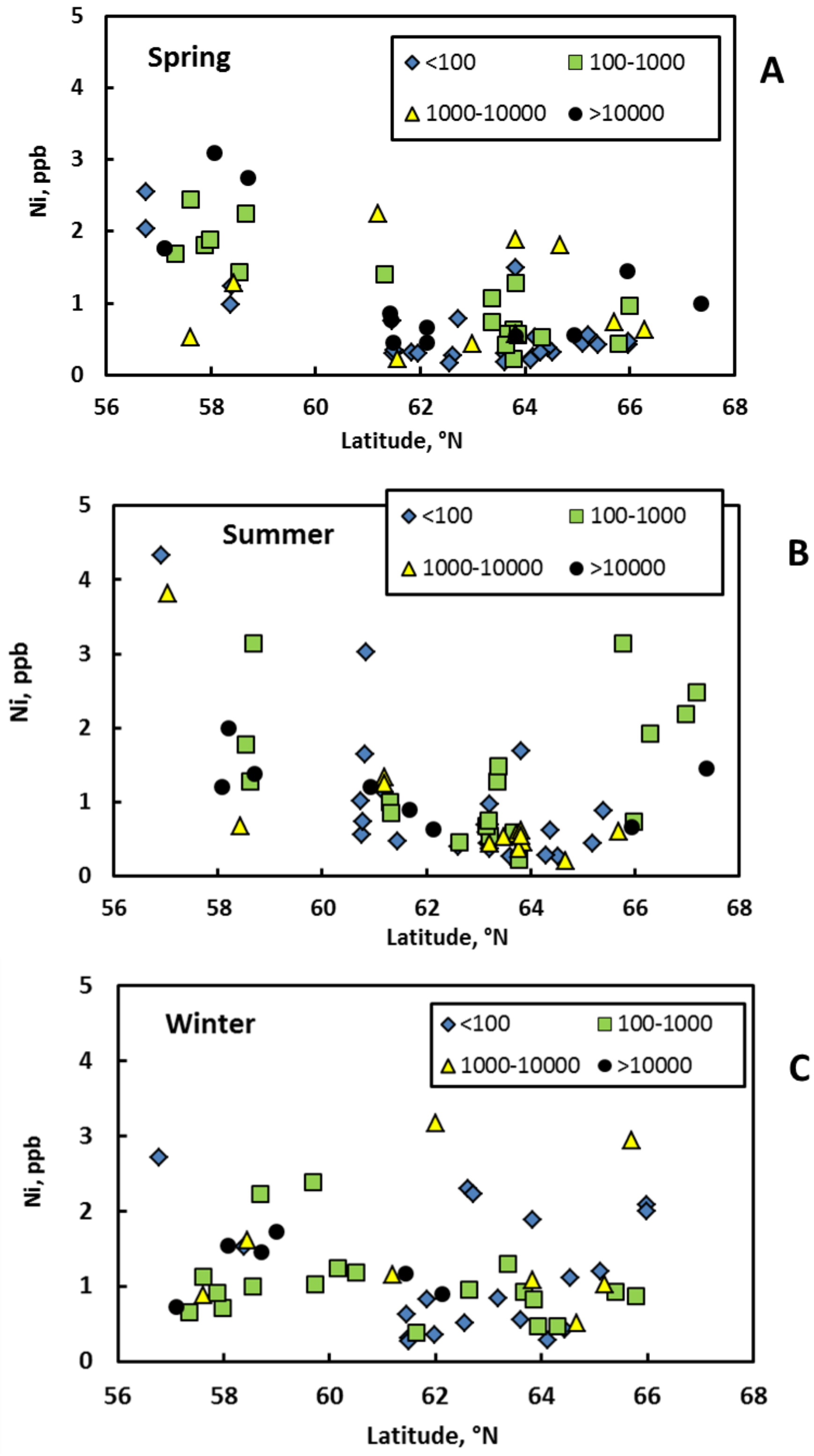

Fig. S3. The variation of Ni concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

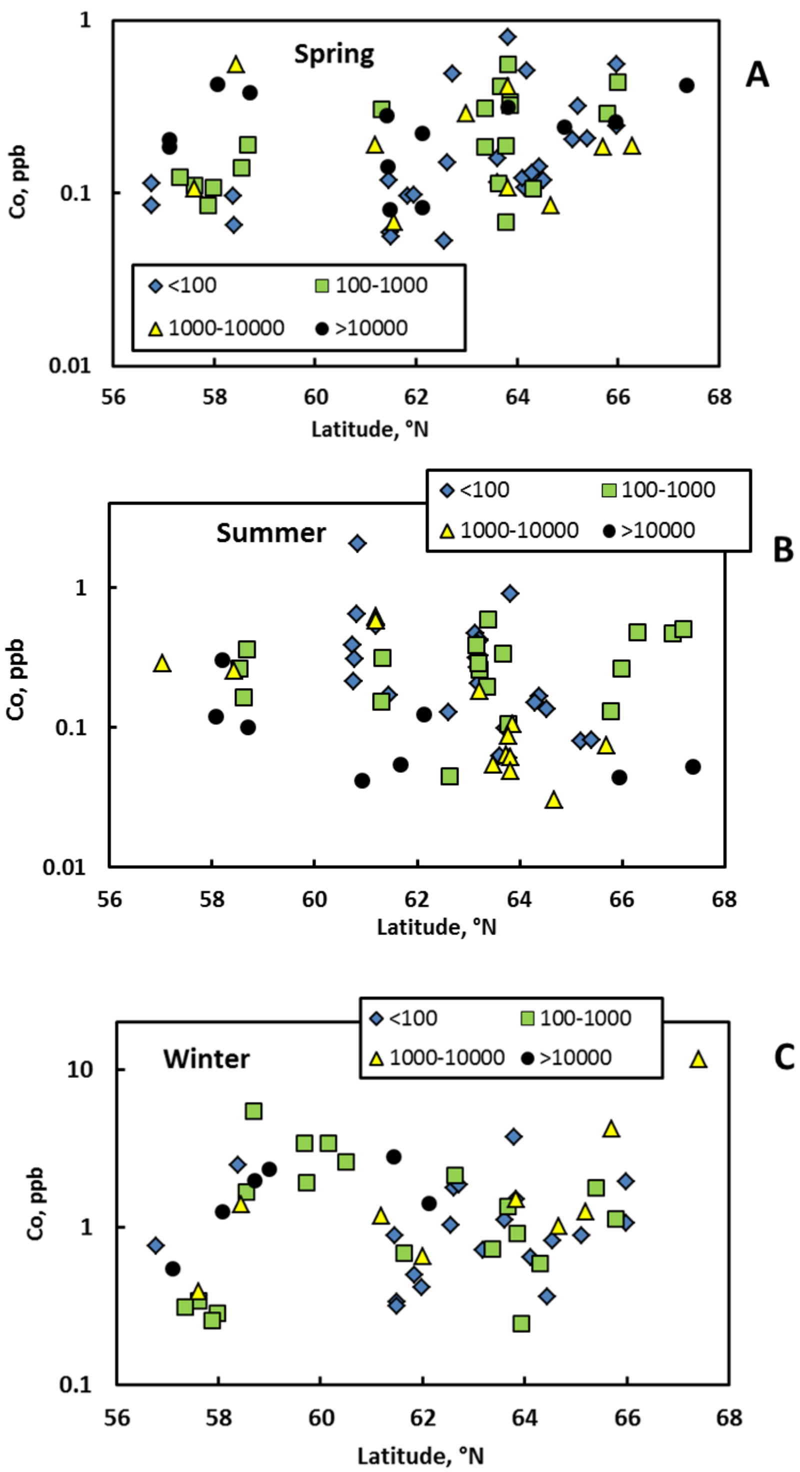

Fig. S4. The variation of Co concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2. Note a factor of 10 higher Co concentrations in winter compared to spring and summer, presumably linked to coupled to Mn reduction, Co mobilization from Mn (III, IV) hydroxides in anoxic waters.

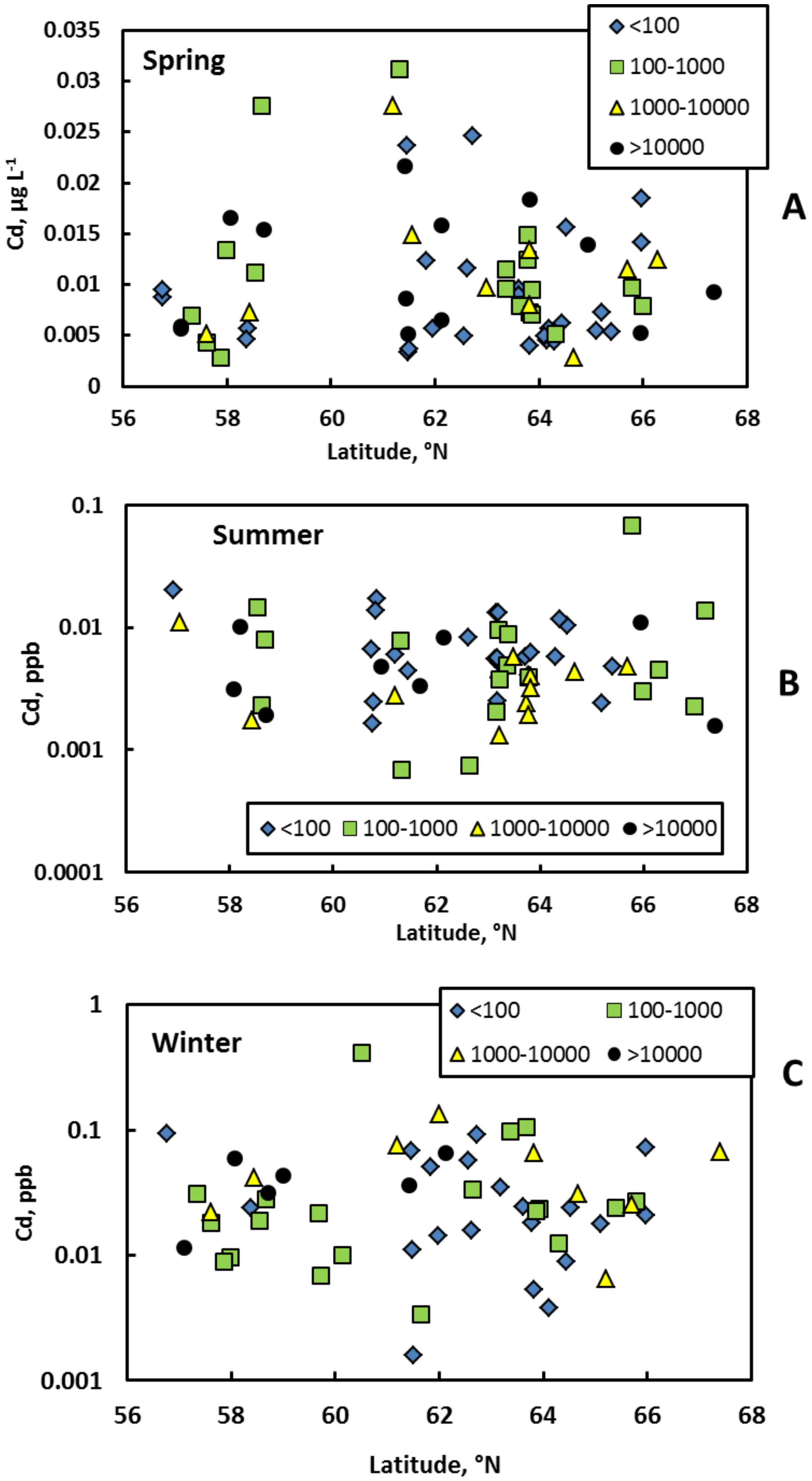

Fig. S5. The variation of Cd concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

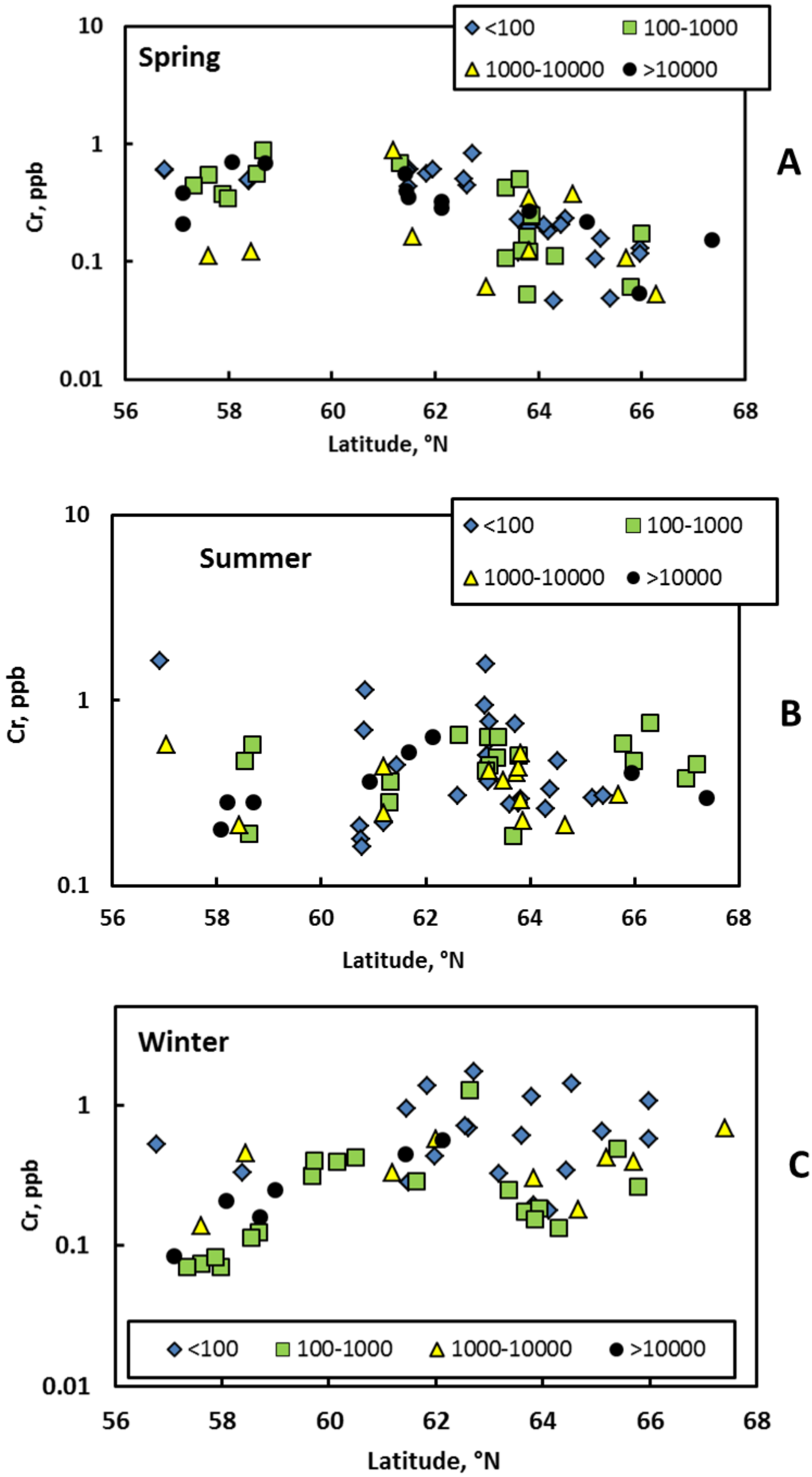

Fig. S6. The variation of Cr concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

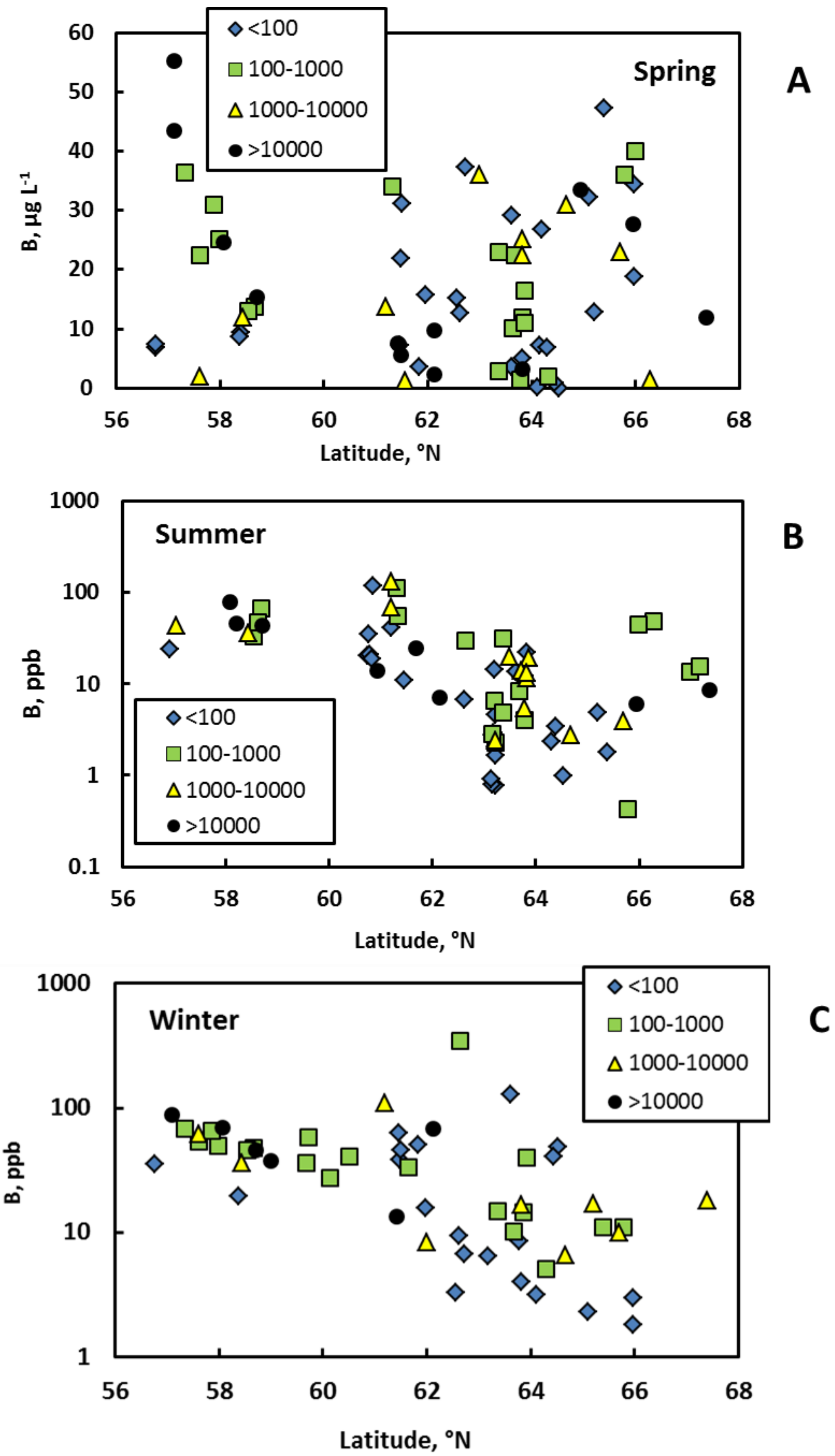

Fig. S7. The variation of B concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

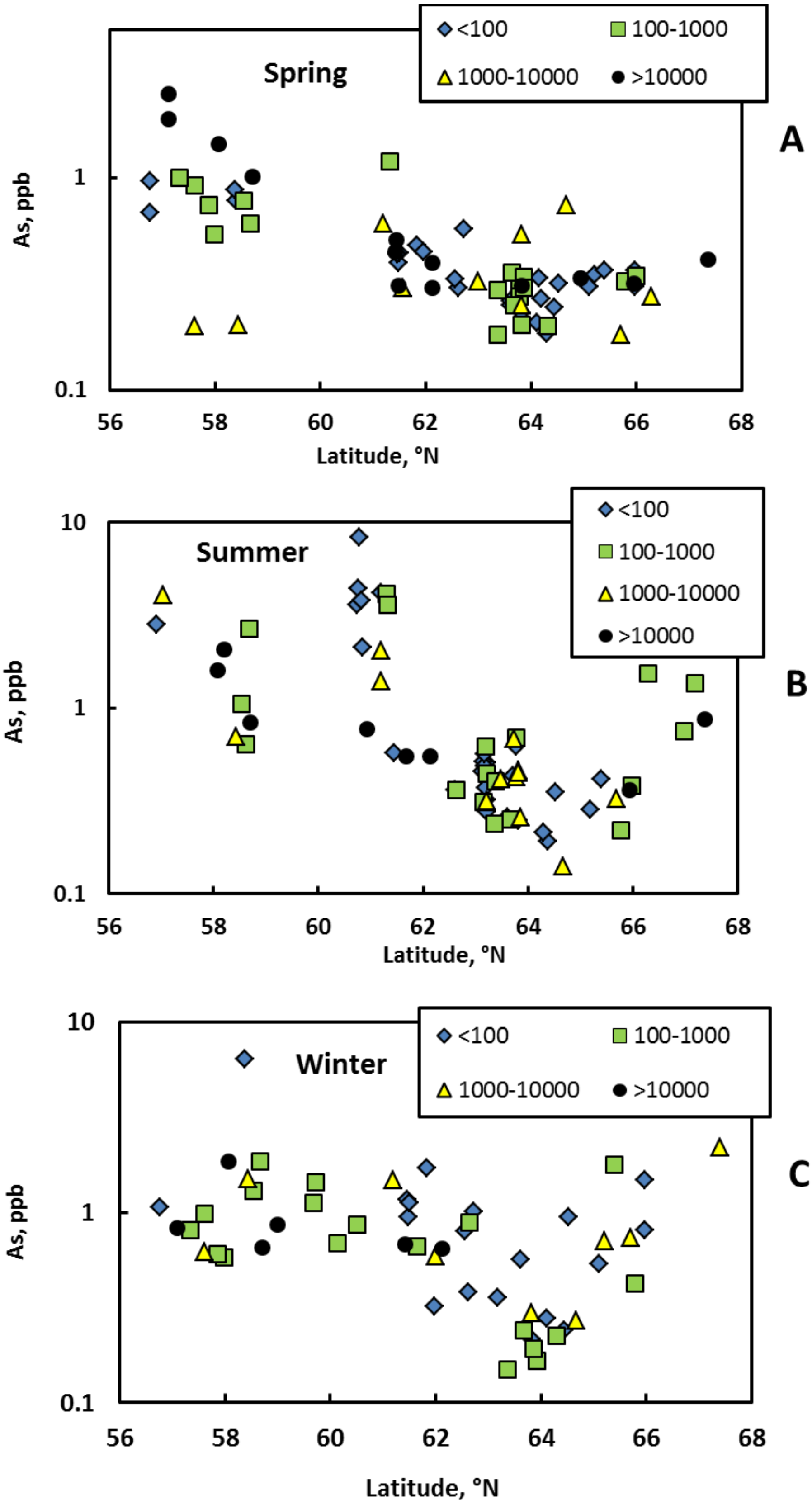

Fig. S8. The variation of As concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2. Clear groundwater effect consists in gradual decrease of concentration northwards, visible during all seasons.

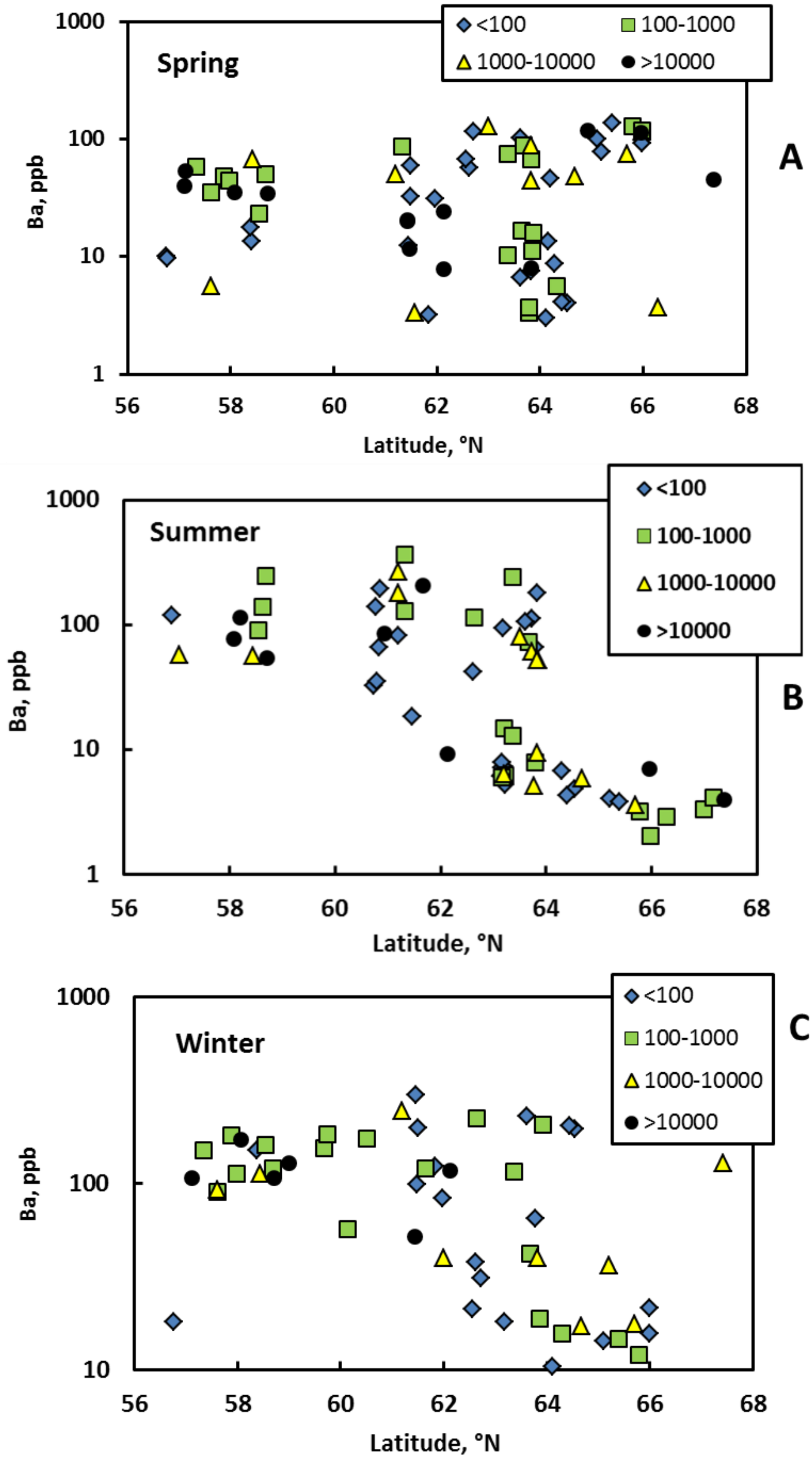

Fig. S9. The variation of Ba concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

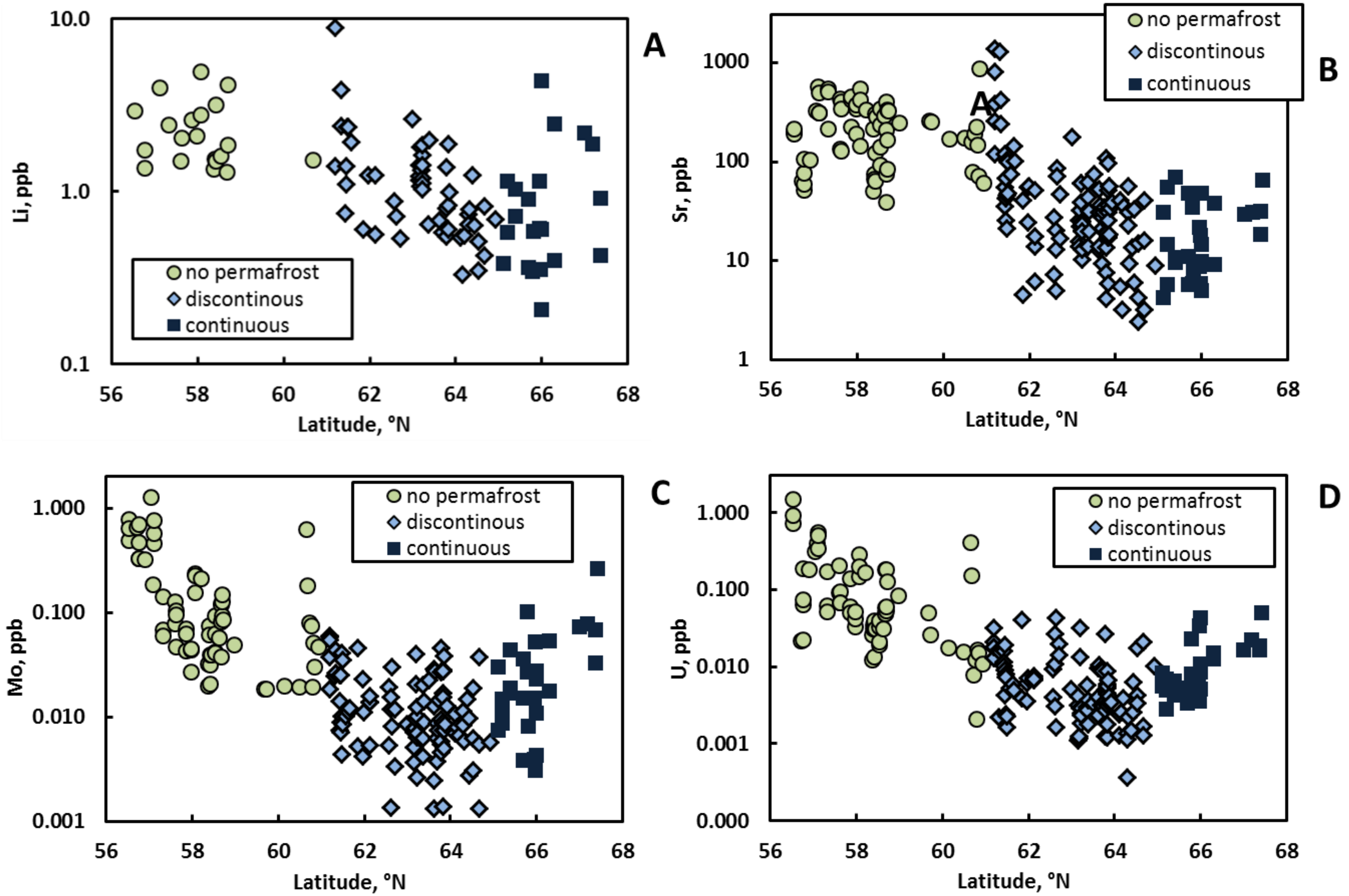

Fig. S10. Li (A), Sr (B), Mo (C) and U (D) concentration in rivers as a function of latitude representing all seasons and all river watersheds. The difference between three permafrost zone are significant at $p < 0.05$. Note log scale for concentration as a function of latitude.

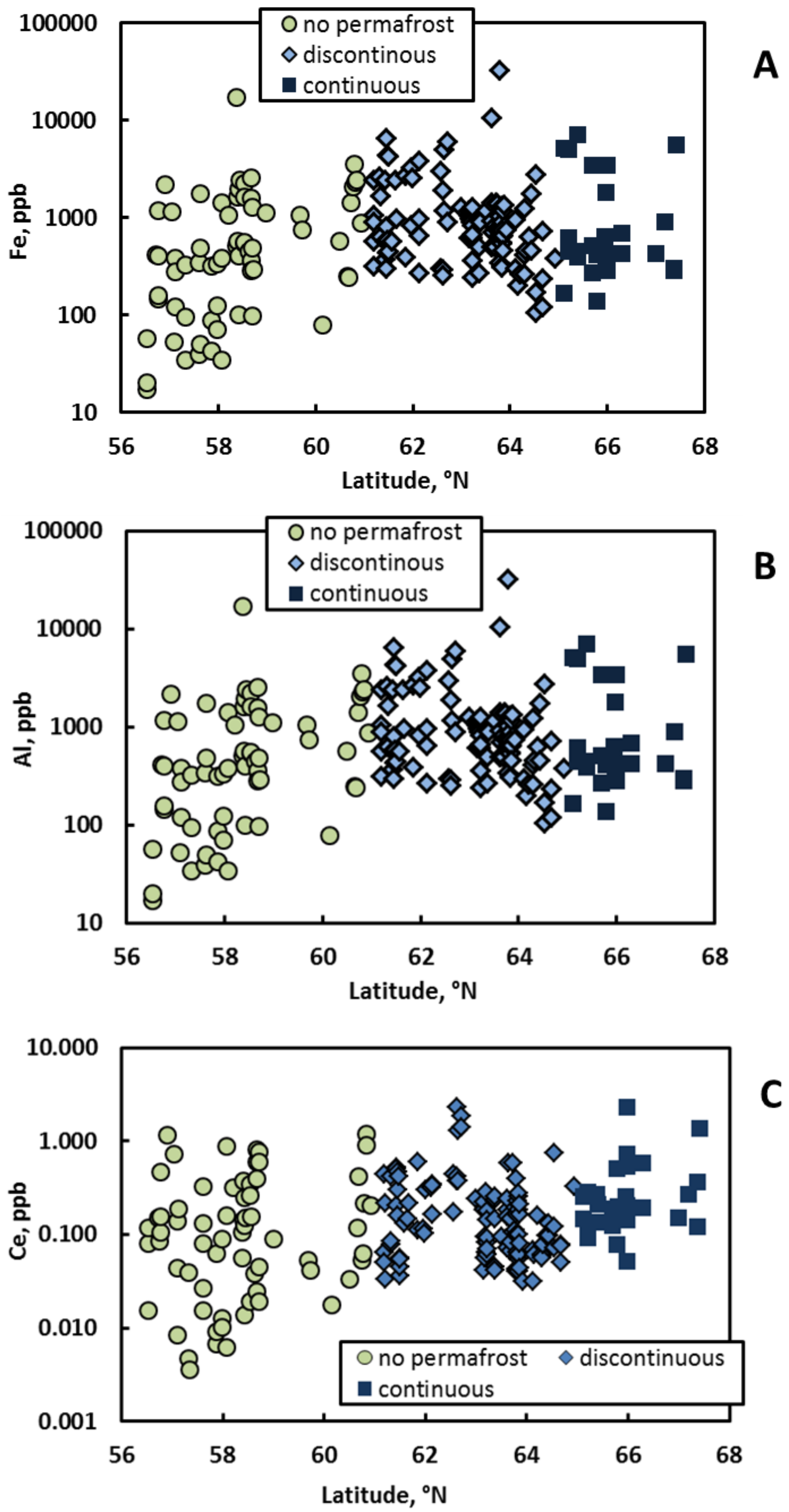

Fig. S11. Fe (A), Al (B) and Ce (C) concentration in rivers as a function of latitude representing all seasons and all river watersheds. The difference between three permafrost zone for Fe and Al are significant at $p < 0.05$. Note log scale for concentration.

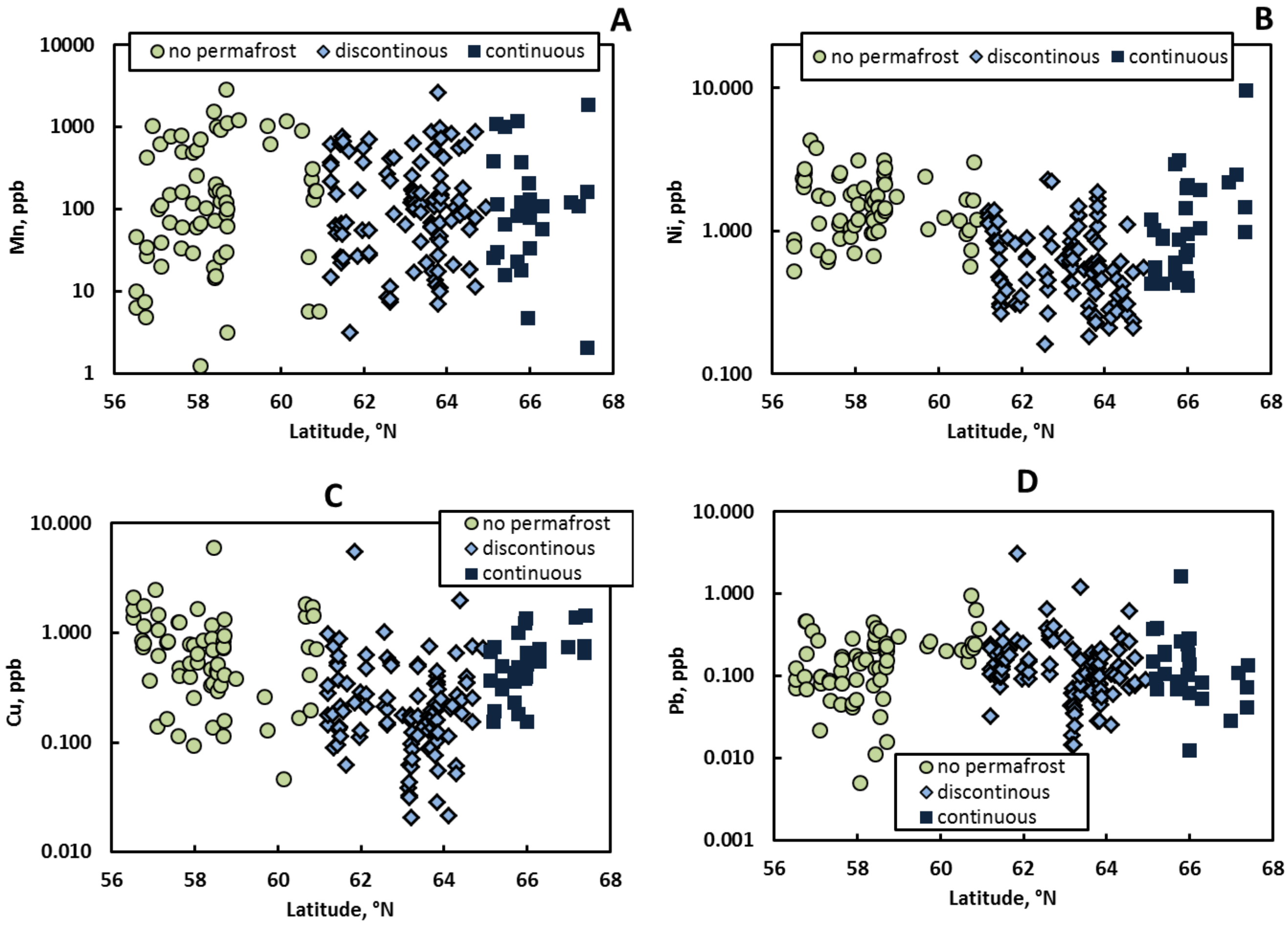

Fig. S12. Mn (A), Ni (B), Cu (C) and Pb (D) concentration in rivers as a function of latitude representing all seasons and all river watersheds. The difference between three permafrost zone for Fe and Al are significant at $p < 0.05$. Note log scale for concentration.

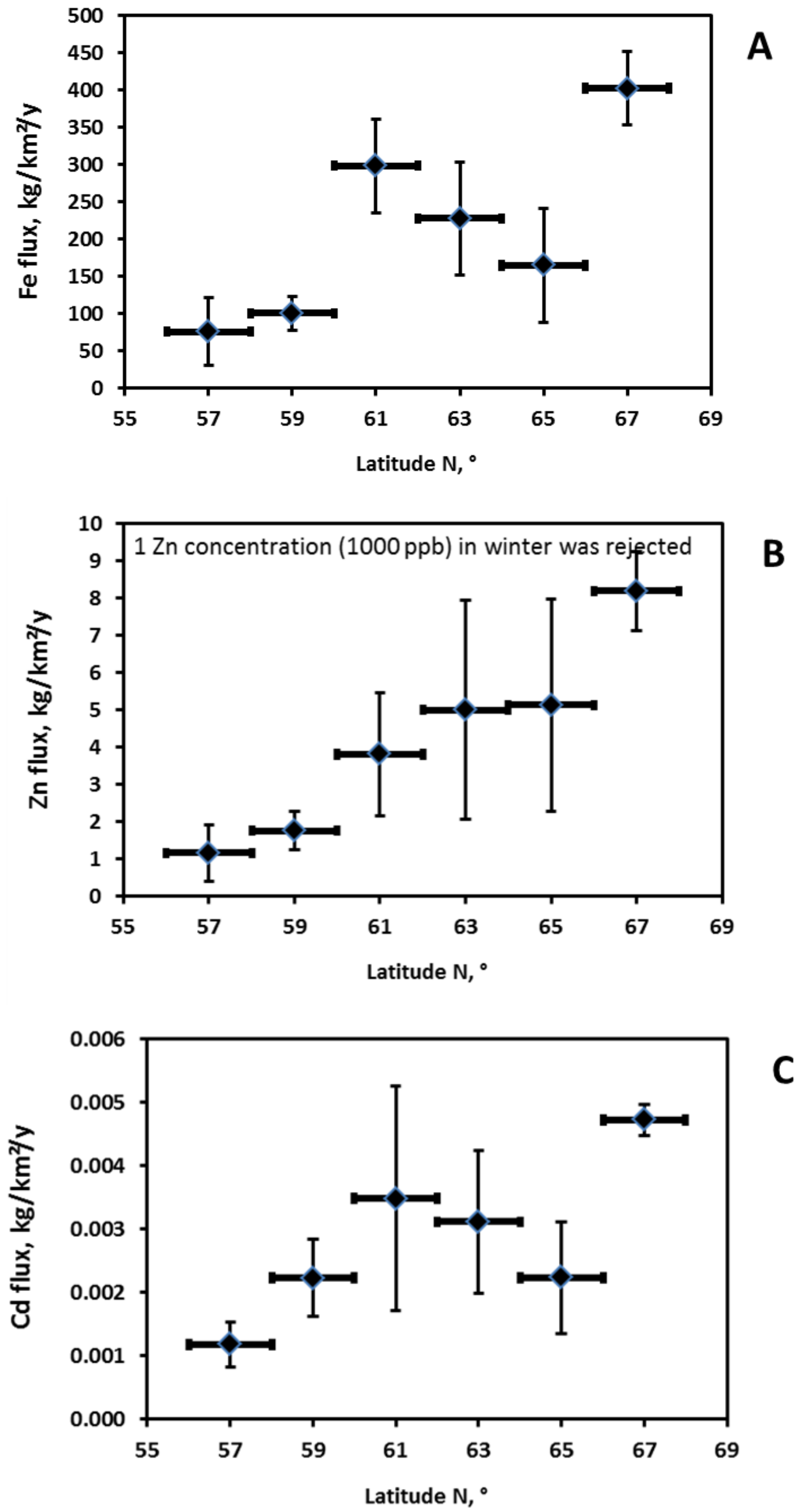

Fig. S13. Latitude range-averaged, all river-size averaged, annual fluxes of Fe (A), Zn (B) and Cd (C) in western Siberian rivers.

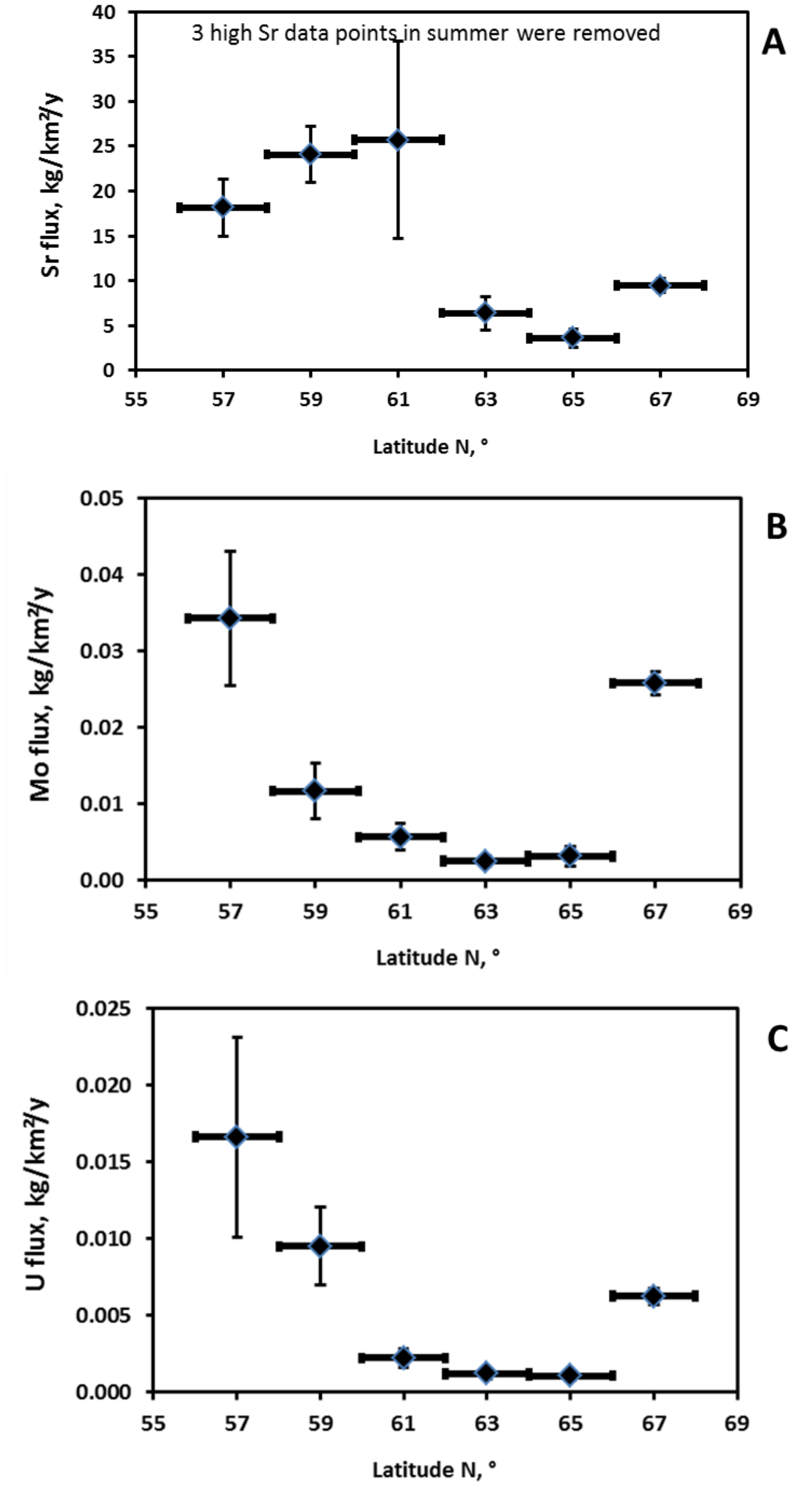

Fig. S14. Latitude range-averaged, all river-size averaged, annual fluxes of Sr (A), Mo (B) and U (C) in western Siberian rivers.

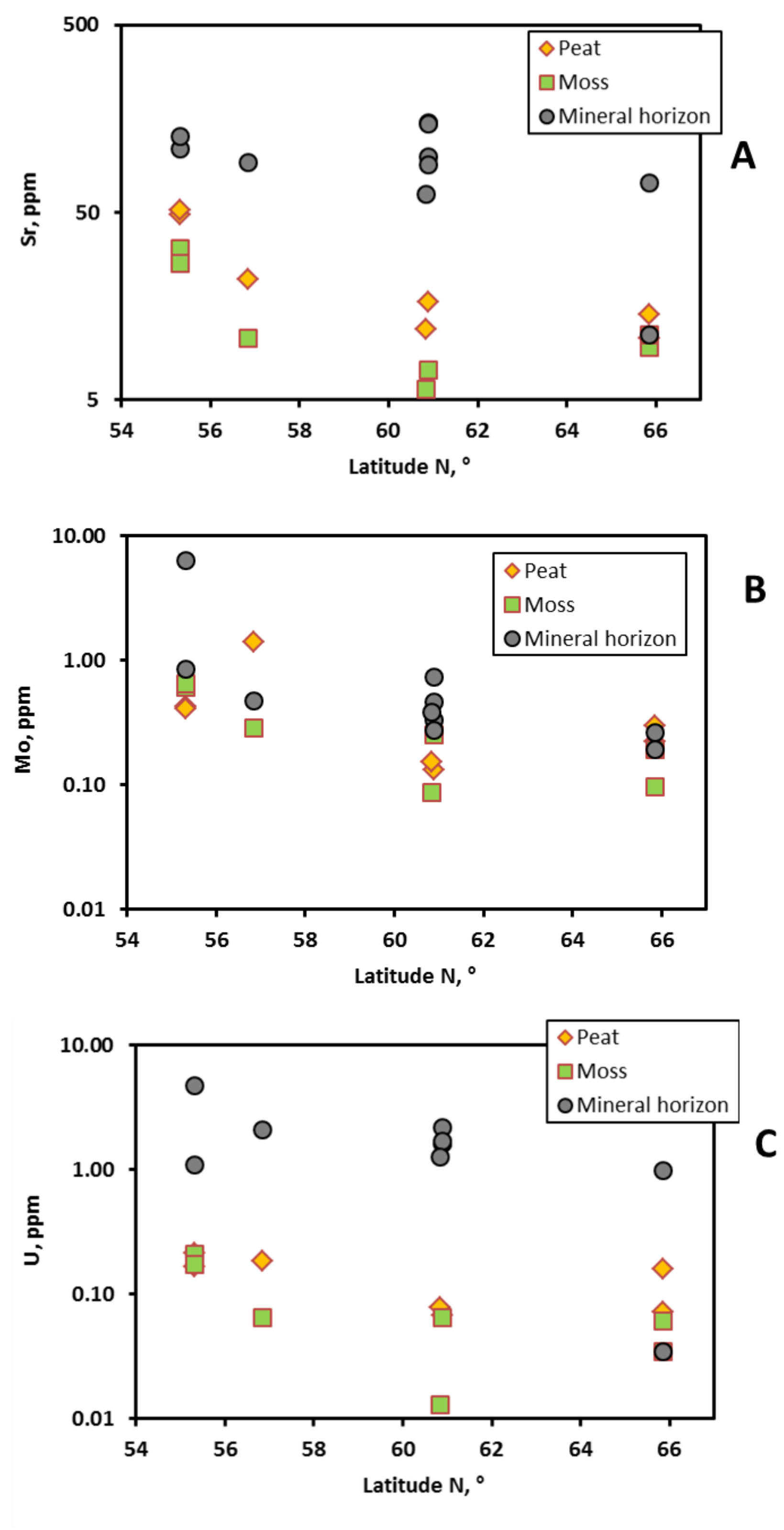

Figure S15. Average peat, moss, and mineral horizon concentration of Sr (A), Mo (B), and U (C) in western Siberia as a function of latitude. Data of Stepanova et al. (2014).

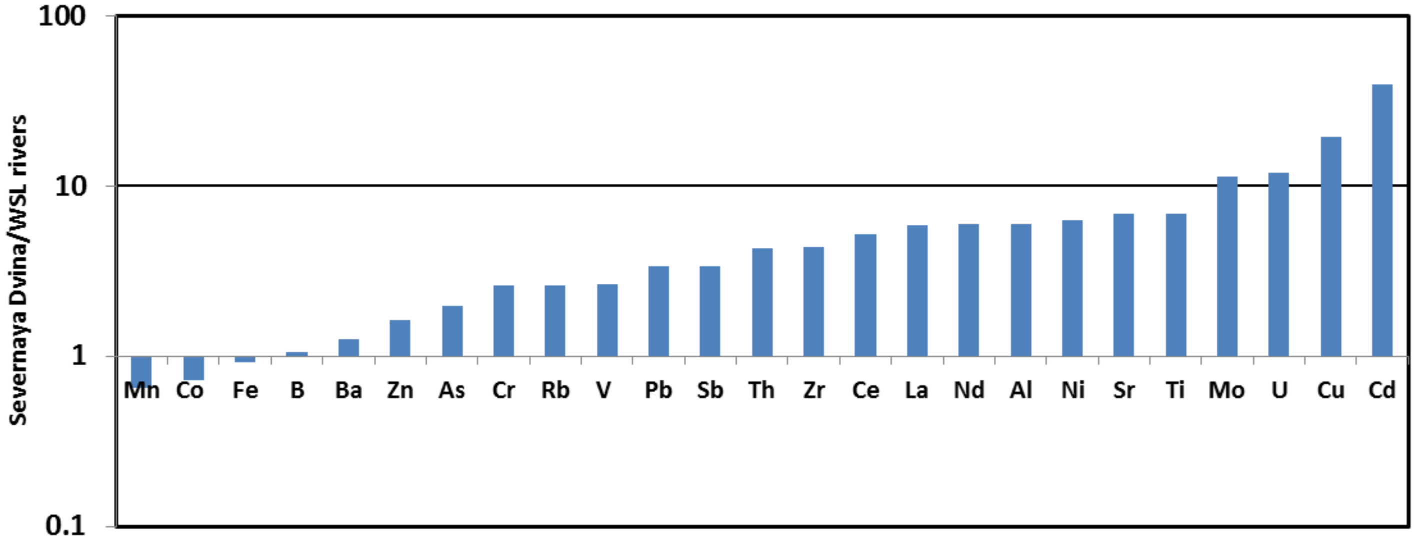

Figure S16. The ratio of annual element fluxes in the largest pristine European Arctic River (Severnaya Dvina) measured in 2007-2009 to mean fluxes of the WSL rivers. Given the intrinsic uncertainties on the fluxes of each region ranging between ±30 and ±50%, the agreement within a factor of 1.5 to 2 is within the uncertainty.