Supplement of Biogeosciences, 13, 1877–1900, 2016
http://www.biogeosciences.net/13/1877/2016/
doi:10.5194/bg-13-1877-2016-supplement

Supplement of

Trace element transport in western Siberian rivers across a permafrost gradient

Oleg S. Pokrovsky et al.

Correspondence to: Oleg S. Pokrovsky (oleg@get.obs-mip.fr)

SUPPLEMENT

Tables of correlation coefficients, PCA results and latitudinal plots of TE

Table S1. 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**						
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**							
Pb	0.37								0.45	
Th	**0.80**		**0.86**		**0.83**		**0.86**	**0.73**	**0.88**	
U		-0.33								

Table S1. 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**	

Table S2. Correlation matrix of major and TE with percentage coverage of the watershed by lakes, bogs and forest. Bold shaded values are significant at $p < 0.05$. S.C. stands for Specific Conductivity.

Spring	Latitude	Bogs	Forest	Lakes	Area
S.C.	**-0.73**	**-0.36**	0.13	-0.16	-0.04
pH	**-0.78**	**-0.40**	0.24	**-0.38**	0.09
DIC	**-0.71**	**-0.44**	0.16	-0.12	-0.02
DOC	**-0.72**	-0.14	0.05	-0.26	-0.03
B	-0.04	-0.09	0.03	-0.02	-0.02
Na	**-0.31**	0.00	-0.01	-0.12	-0.05
Mg	**-0.72**	**-0.40**	0.14	-0.16	0.01
Al	-0.15	0.03	0.16	-0.24	-0.03
Si	**-0.38**	**-0.34**	**0.43**	**-0.38**	0.03
K	**-0.78**	**-0.45**	0.23	-0.25	0.00
Ca	**-0.77**	**-0.42**	0.17	-0.15	-0.04
Ti	**-0.37**	-0.17	0.12	-0.22	0.06
V	**-0.70**	-0.16	0.01	-0.24	0.00
Cr	**-0.72**	0.05	-0.07	-0.16	-0.19
Mn	**0.56**	-0.08	**0.38**	-0.21	**0.39**
Fe	0.05	0.21	-0.15	0.12	-0.04
Co	**0.40**	-0.13	**0.31**	-0.17	0.20
Ni	**-0.73**	**-0.37**	0.28	**-0.42**	0.14
Cu	**-0.62**	-0.22	0.15	**-0.34**	0.13
Zn	**0.55**	0.10	-0.06	0.12	0.00
Ga	-0.02	-0.05	0.17	-0.18	0.12
As	**-0.72**	-0.27	0.06	-0.29	0.02
Rb	**-0.74**	-0.10	0.03	**-0.33**	-0.02
Sr	**-0.69**	**-0.31**	0.12	-0.16	-0.05
Zr	**-0.56**	-0.06	0.12	-0.25	0.04
Mo	**-0.58**	**-0.40**	0.06	-0.25	0.01
Cd	-0.06	0.21	-0.02	-0.11	-0.01
Sb	**-0.76**	-0.17	0.02	-0.25	0.02
Cs	-0.23	0.13	-0.10	0.01	-0.09
Ba	**0.38**	0.06	-0.03	0.11	0.07
La	-0.12	0.04	0.09	-0.21	0.15
Ce	-0.02	0.09	0.07	-0.15	0.15
Nd	-0.10	0.05	0.09	-0.19	0.14
Gd	-0.14	0.07	0.09	-0.22	0.16
Yb	-0.15	0.04	0.11	-0.22	0.12
Pb	-0.23	0.04	-0.28	0.18	-0.21
Th	**-0.34**	0.04	0.15	**-0.32**	0.10
U	**-0.47**	-0.28	0.09	-0.20	0.04

Table S2. Continued.

Summer	Latitude	Bogs	Forest	Lakes	Area
S.C.	**-0.64**	0.11	0.01	**-0.37**	0.12
pH	**-0.35**	-0.07	0.15	**-0.54**	0.08
DIC	**-0.69**	0.16	-0.02	**-0.34**	0.12
DOC	0.11	0.09	-0.10	0.15	**0.41**
B	**-0.44**	-0.05	0.09	**-0.36**	0.07
Na	**-0.31**	-0.16	0.14	**-0.38**	0.03
Mg	**-0.61**	0.09	0.01	**-0.37**	0.14
Al	0.14	0.11	-0.28	**0.57**	-0.17
Si	**-0.45**	-0.08	0.29	**-0.66**	-0.18
K	-0.18	-0.24	0.13	**-0.34**	0.11
Ca	**-0.72**	0.21	-0.07	-0.30	0.12
Ti	-0.01	-0.14	0.19	-0.19	-0.18
V	0.11	-0.27	0.18	-0.15	**0.32**
Cr	0.07	0.05	-0.06	0.09	-0.19
Mn	-0.17	-0.16	0.27	**-0.37**	**-0.38**
Fe	0.00	0.15	-0.10	-0.01	-0.20
Co	0.04	**-0.35**	**0.37**	**-0.30**	**-0.36**
Ni	0.29	-0.27	0.14	0.00	0.11
Cu	0.26	-0.05	-0.15	**0.42**	0.04
Zn	0.16	-0.16	0.06	0.23	-0.04
Ga	0.01	-0.15	0.10	0.06	-0.27
As	-0.23	0.04	0.01	-0.20	0.05
Rb	**-0.42**	0.07	-0.03	-0.27	0.23
Sr	**-0.71**	0.22	-0.06	-0.30	0.07
Zr	0.05	-0.07	0.06	0.01	-0.11
Mo	-0.26	-0.03	0.02	-0.14	0.24
Cd	0.23	0.01	-0.23	**0.48**	-0.05
Sb	-0.05	0.21	**-0.32**	**0.31**	0.05
Cs	0.01	0.15	-0.26	**0.37**	-0.11
Ba	**-0.66**	0.27	-0.11	-0.22	0.01
La	**0.44**	-0.04	-0.20	**0.47**	0.13
Ce	**0.39**	0.02	-0.23	**0.50**	0.05
Nd	**0.39**	-0.05	-0.09	0.22	0.12
Gd	**0.33**	-0.05	-0.03	0.11	0.11
Yb	0.20	0.00	-0.02	0.03	-0.06
Pb	0.22	0.00	-0.18	**0.48**	-0.02
Th	0.17	-0.03	-0.04	0.19	-0.09
U	**-0.59**	0.15	-0.05	-0.22	0.16

Table S2. Continued.

Winter	Latitude	Bogs	Forest	Lakes	Area
S.C.	**-0.82**	**-0.31**	0.20	-0.28	0.18
pH	**-0.79**	**-0.33**	0.27	**-0.38**	0.18
DIC	**-0.82**	**-0.34**	0.27	-0.28	0.15
DOC	-0.22	0.26	-0.28	0.08	**0.44**
B	-0.23	0.11	-0.13	0.05	0.03
Na	**-0.35**	0.14	-0.07	-0.20	0.20
Mg	**-0.81**	**-0.38**	0.26	-0.28	0.19
Al	**0.31**	**0.32**	**-0.46**	**0.49**	-0.16
Si	-0.05	-0.06	**0.36**	**-0.36**	0.18
K	**-0.64**	-0.12	0.07	-0.25	0.19
Ca	**-0.85**	**-0.38**	0.25	-0.28	0.17
Ti	**0.43**	**0.42**	**-0.47**	**0.47**	-0.16
V	0.29	0.29	**-0.38**	**0.40**	-0.11
Cr	**0.40**	**0.39**	**-0.41**	**0.44**	-0.16
Mn	-0.09	-0.08	0.09	-0.16	0.12
Fe	0.22	0.25	**-0.40**	**0.32**	-0.12
Co	0.24	-0.16	0.19	-0.01	0.11
Ni	0.15	-0.04	-0.02	0.19	0.02
Cu	-0.15	0.14	-0.11	0.00	-0.01
Zn	0.12	0.28	-0.24	0.17	-0.07
Ga	**0.30**	0.29	-0.30	**0.32**	0.05
As	-0.14	0.01	-0.23	0.09	-0.03
Rb	**-0.42**	0.11	-0.20	-0.01	0.23
Sr	**-0.74**	-0.26	0.17	-0.27	0.19
Zr	**0.31**	**0.39**	**-0.52**	**0.56**	-0.07
Mo	-0.29	-0.16	0.10	-0.17	0.16
Cd	-0.03	-0.06	0.12	-0.02	0.20
Sb	-0.40	0.19	-0.28	0.03	0.16
Cs	-0.23	0.17	-0.08	-0.01	**0.35**
Ba	**-0.36**	0.09	-0.04	-0.09	0.06
La	**0.34**	0.24	**-0.34**	**0.42**	-0.10
Ce	**0.36**	0.26	**-0.36**	**0.44**	-0.11
Nd	**0.38**	0.25	**-0.35**	**0.44**	-0.11
Gd	**0.37**	0.27	**-0.35**	**0.42**	-0.06
Yb	**0.41**	0.29	**-0.34**	**0.42**	-0.02
Pb	0.12	**0.43**	**-0.36**	**0.34**	0.10
Th	**0.33**	**0.38**	**-0.49**	**0.51**	-0.04
U	**-0.64**	-0.29	0.09	-0.17	0.25

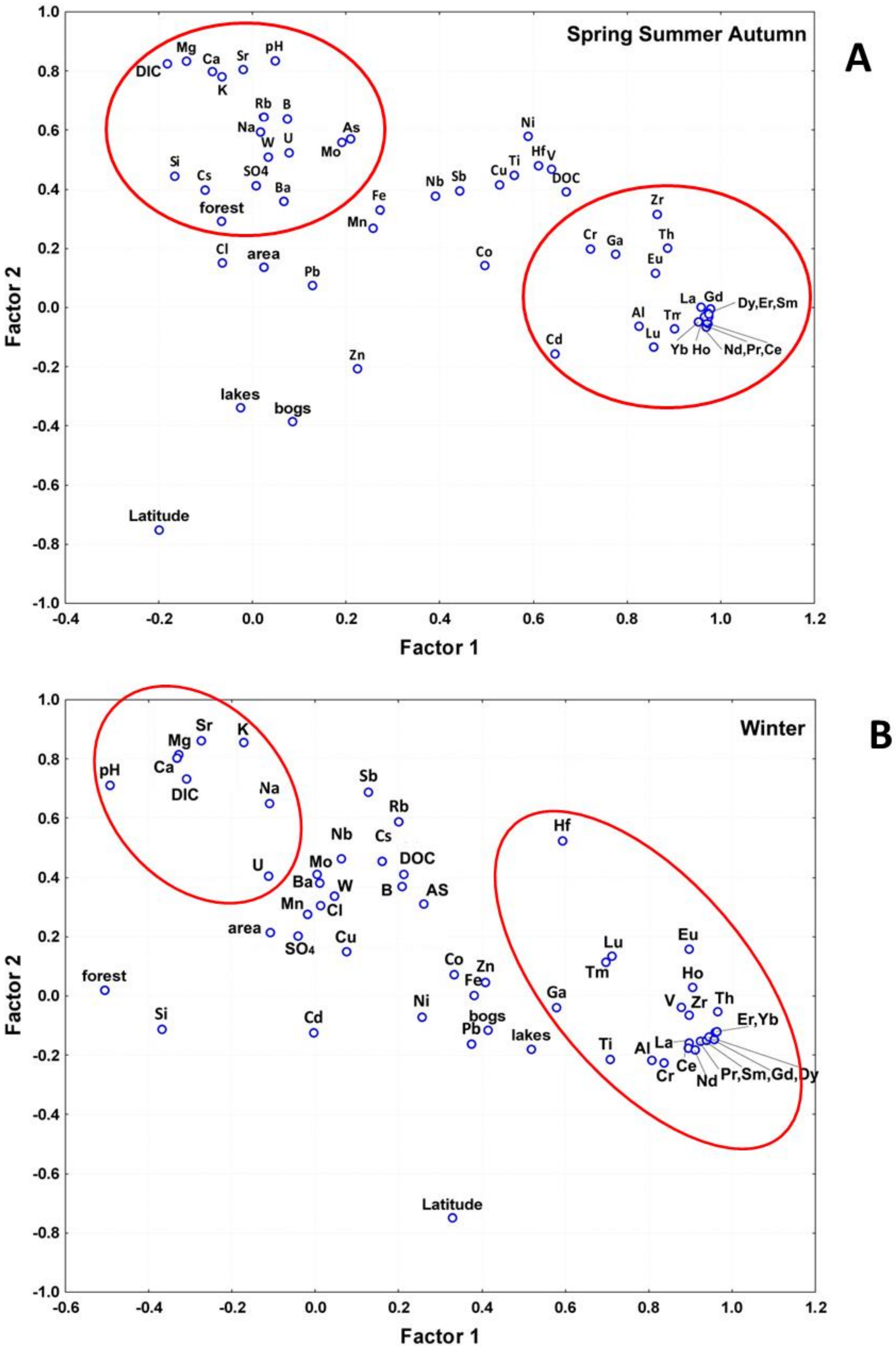


Fig. S1. PCA analysis of 55 variables in ~ 70 rivers sampled during open-water period (A) and in winter (B). The first factor (19% Var.) comprises DOC, Al, V, Cr and insoluble trivalent and tetravalent hydrolysates. The second factor (10% Var.) is latitude which is inversely correlated with soluble major and trace elements, alkali and alkaline earth metals, oxyanions and U whose concentration decreases with increasing latitude. During open water periods, the forest increase the mobile element export. The presence of bogs and lakes enhances the insoluble lithogneic element transport in winter. The impact of the latitude is strongly pronounced during all seasons..

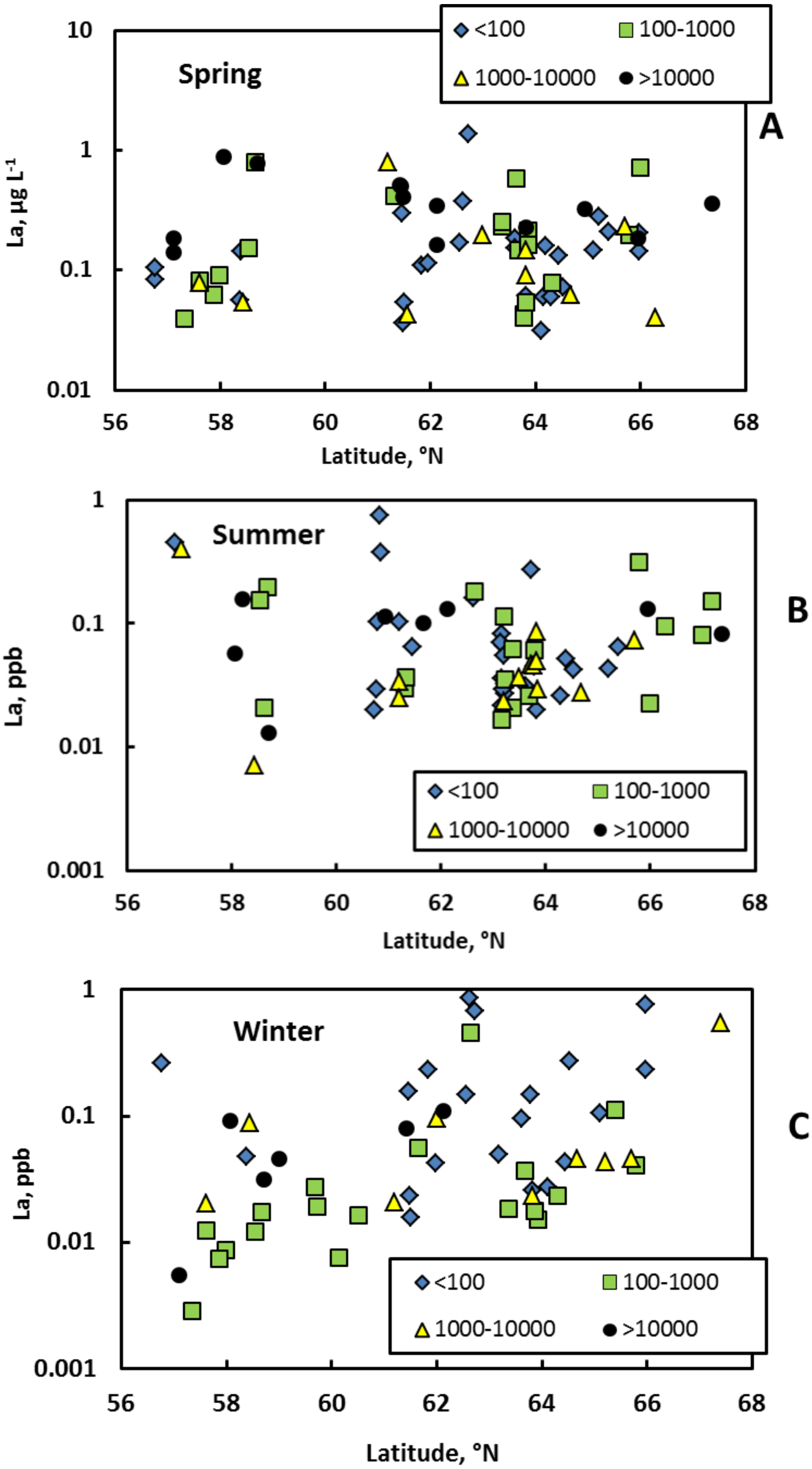
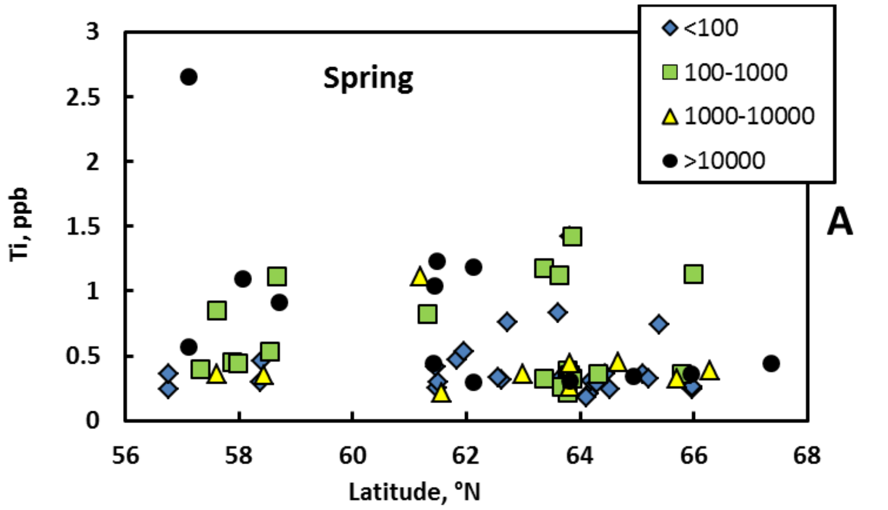
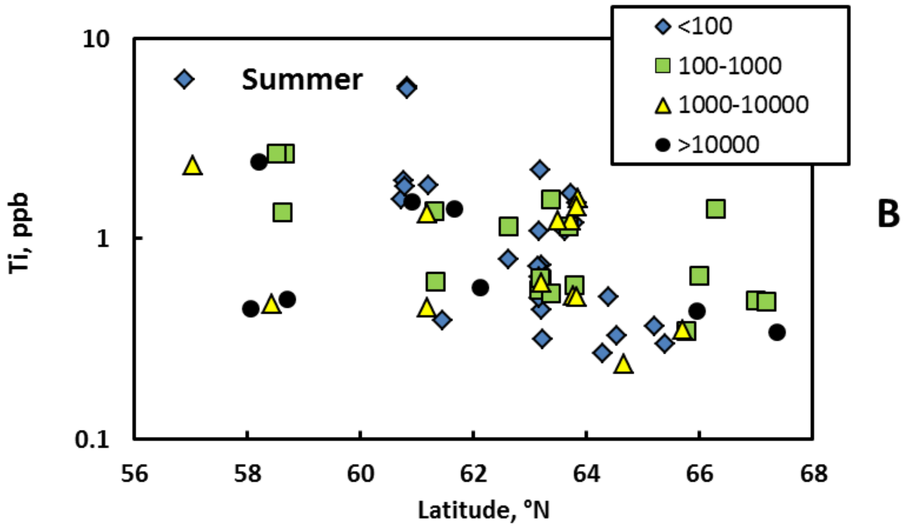


Fig. S2. Variation of La concentration on the latitude during spring (A) and summer (B) and an increase of La concentration northward in winter (C). The latitudinal trend in winter is significant at $p < 0.05$. Considering all seasons together, the differences between different watershed sizes are not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





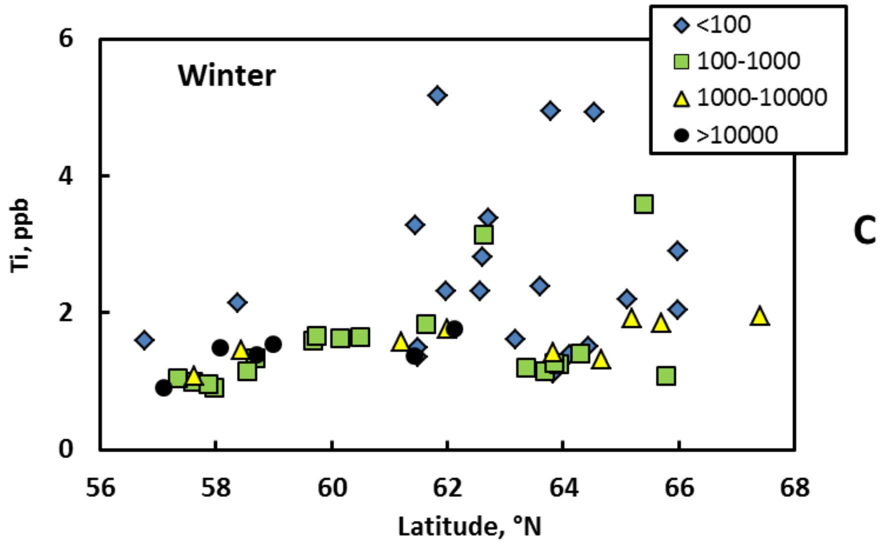


Fig. S3. Variation of Ti concentration on the latitude during spring (A), summer (B) and winter (C). The latitudinal trend in summer is significant at $p < 0.05$. Considering all seasons together, the differences between different watershed sizes are not statistically significant ($p > 0.05$). The symbols are the same as in Fig. 2.

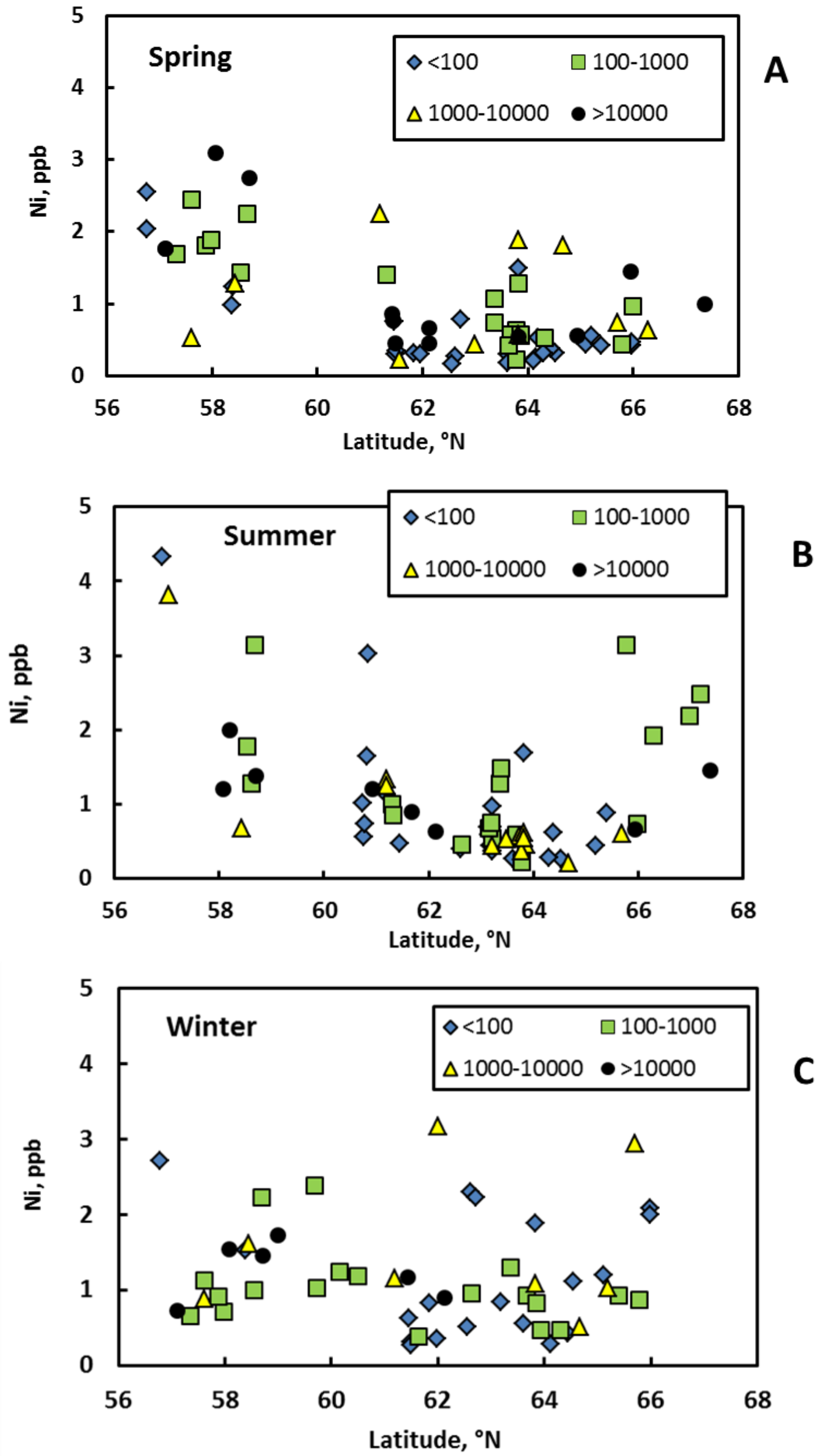


Fig. S4. The variation of Ni concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

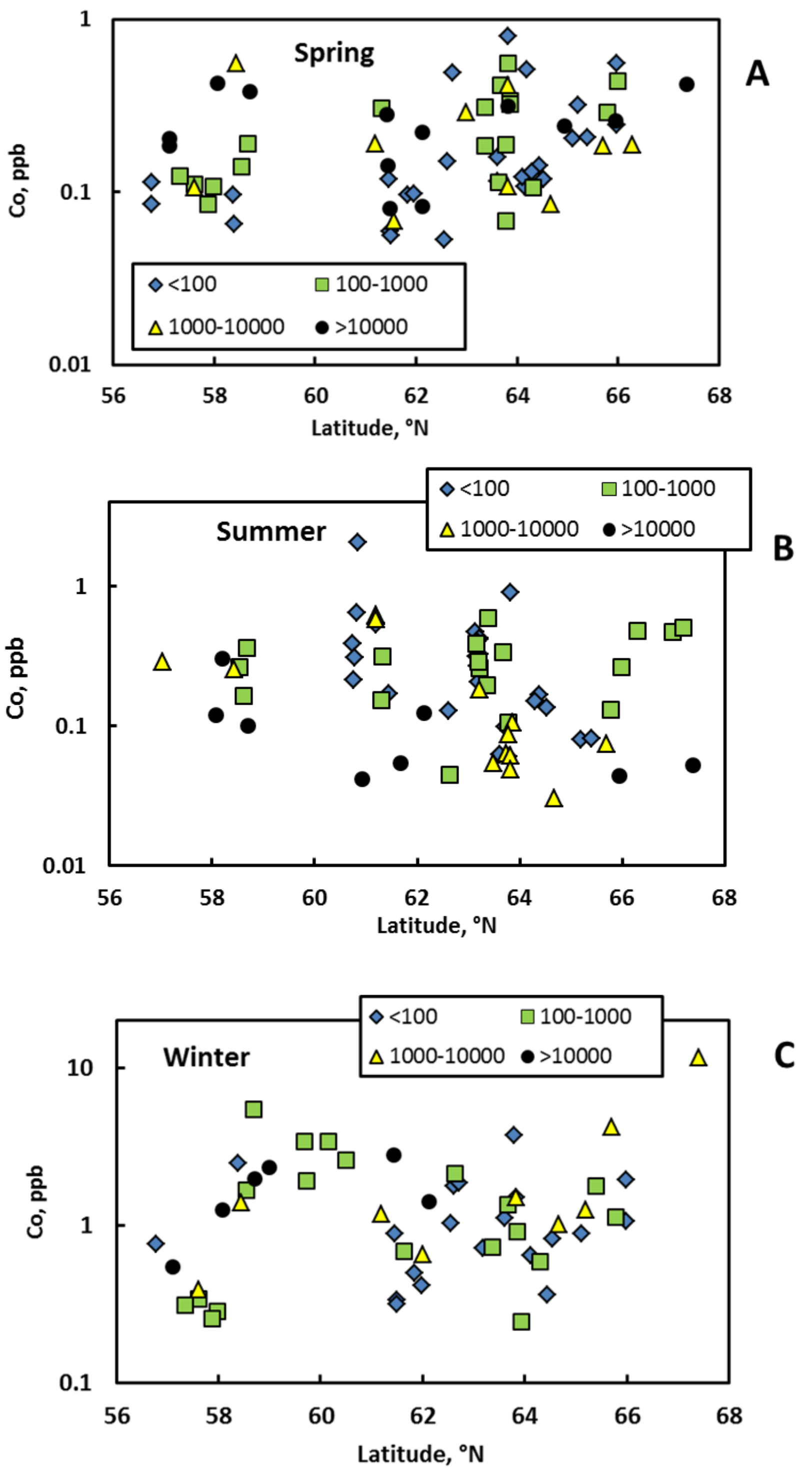


Fig. S5. The variation of Co concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2. Note a factor of 10 higher Co concentrations in winter compared to spring and summer, presumably linked to coupled to Mn reduction, Co mobilization from Mn (III, IV) hydroxides in anoxic waters.

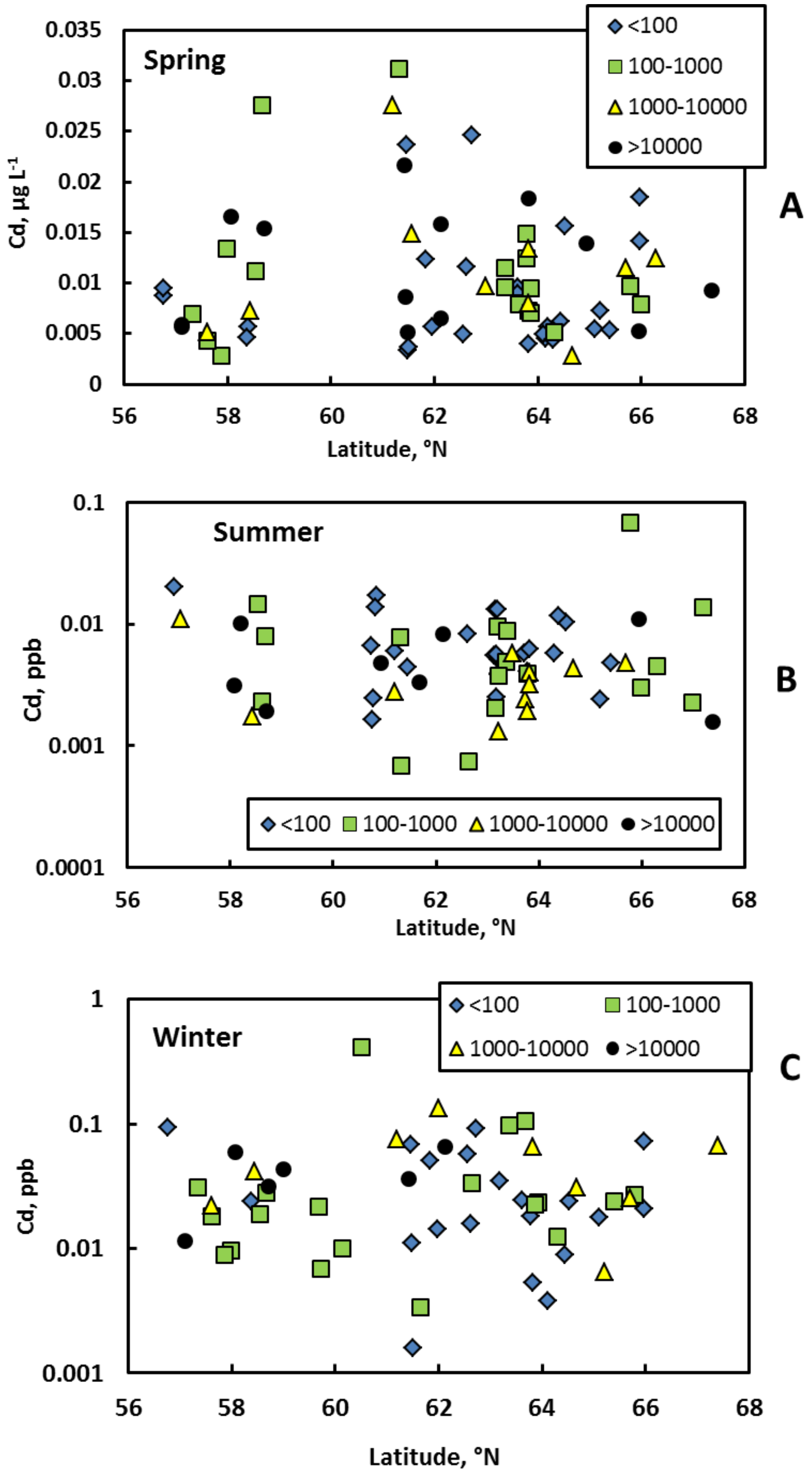


Fig. S6. The variation of Cd concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

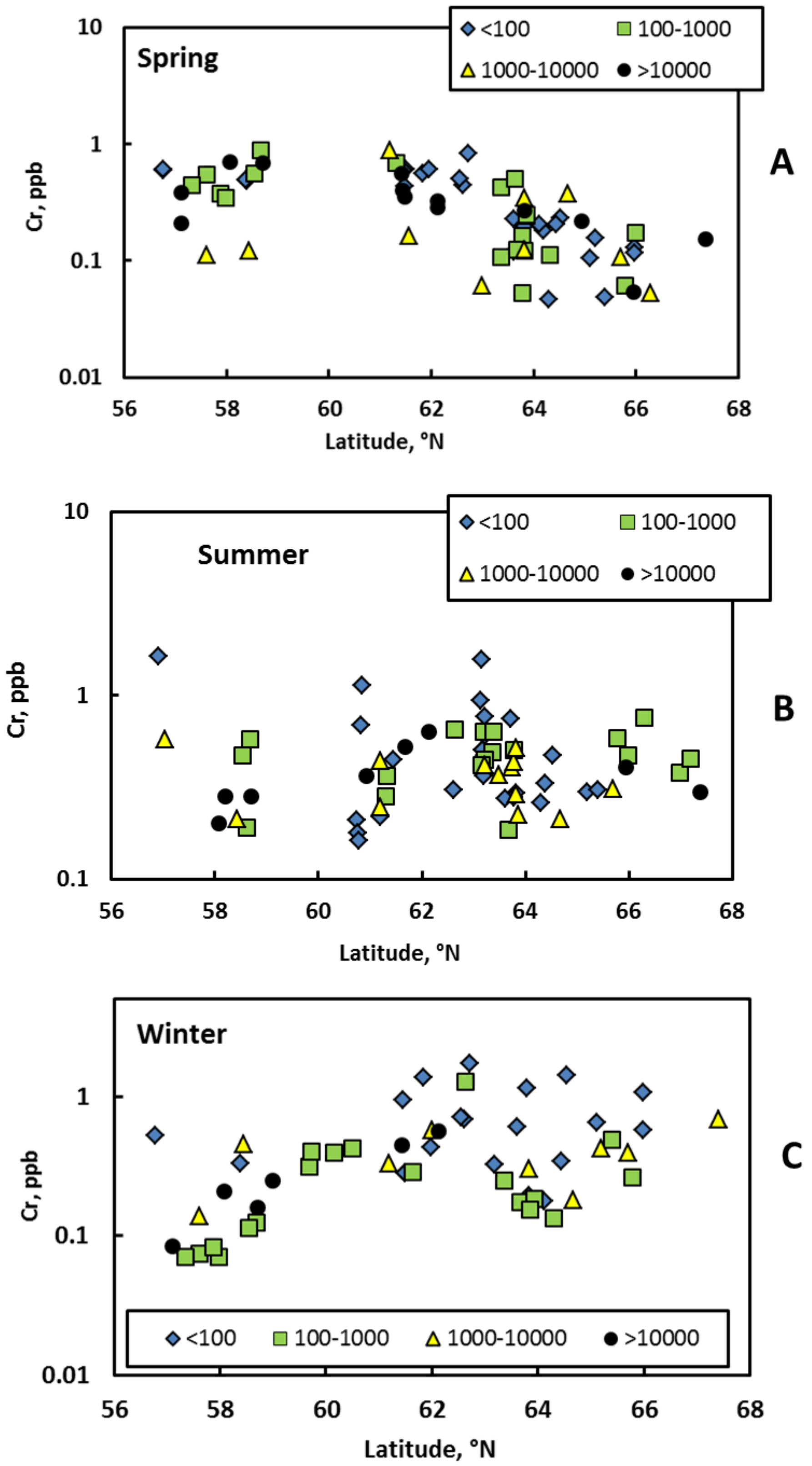


Fig. S7. The variation of Cr concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

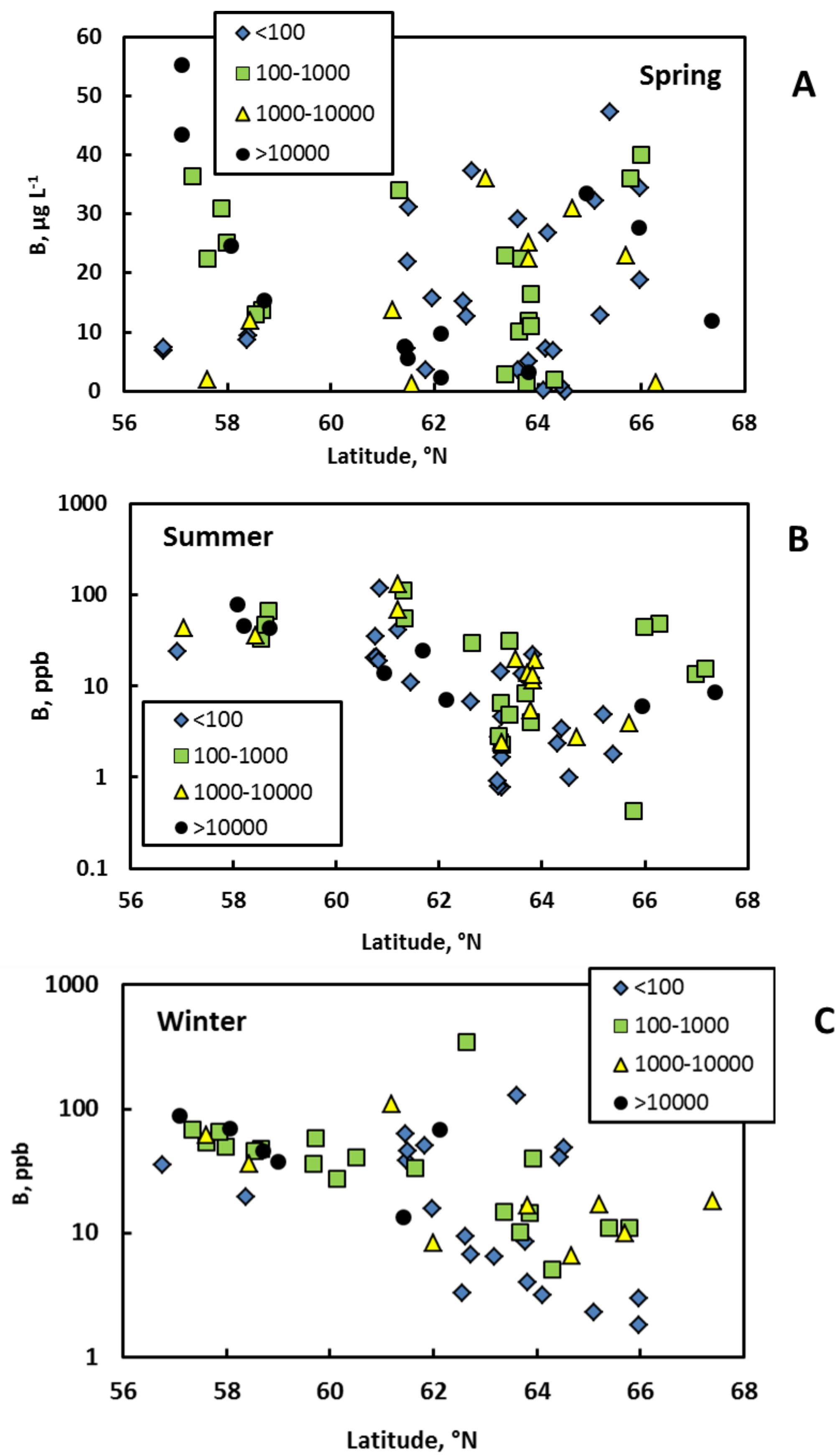


Fig. S8. The variation of B concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

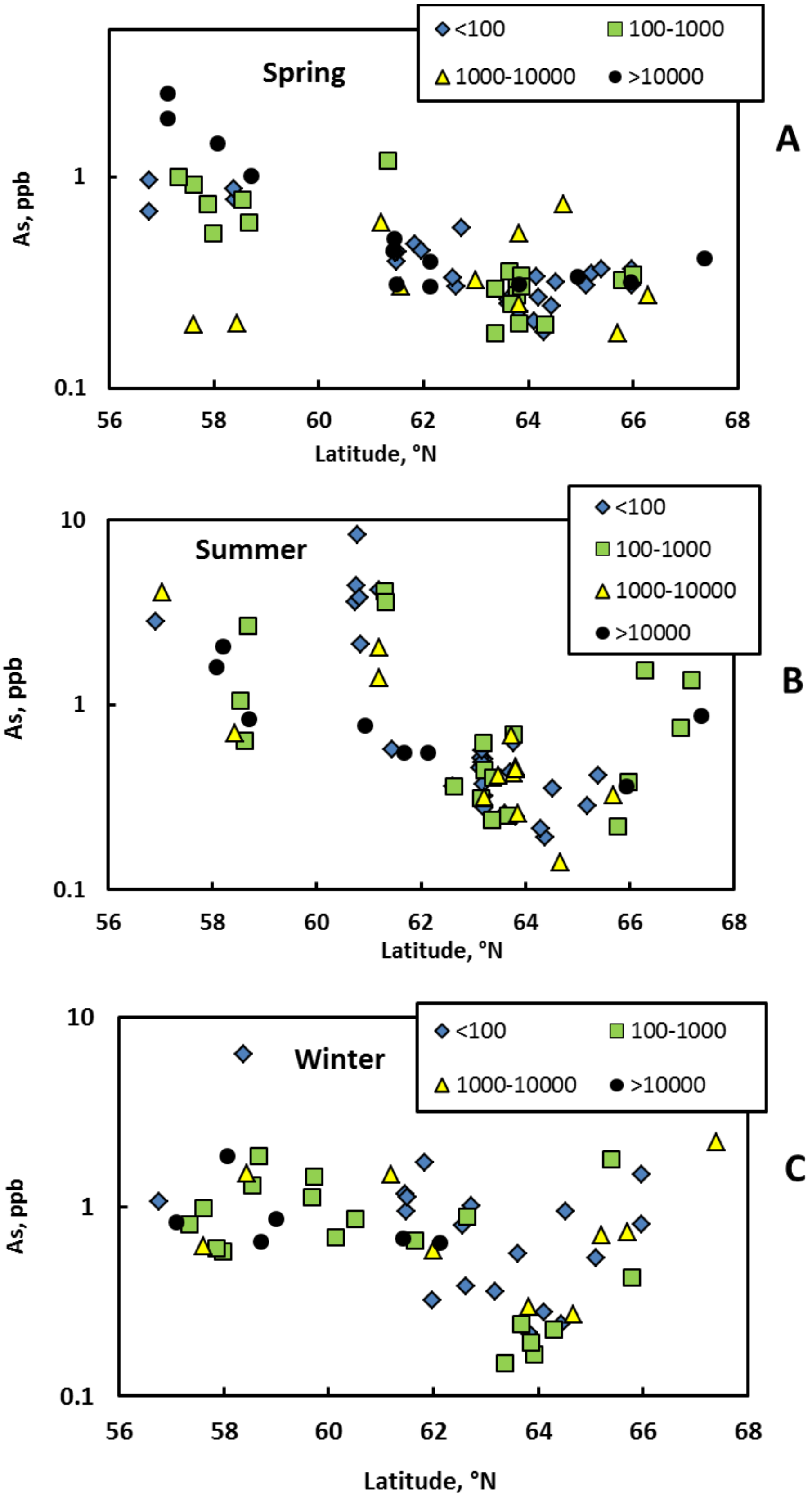


Fig. S9. The variation of As concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2. Clear groundwater effect consists in gradual decrease of concentration northwards, visible during all seasons.

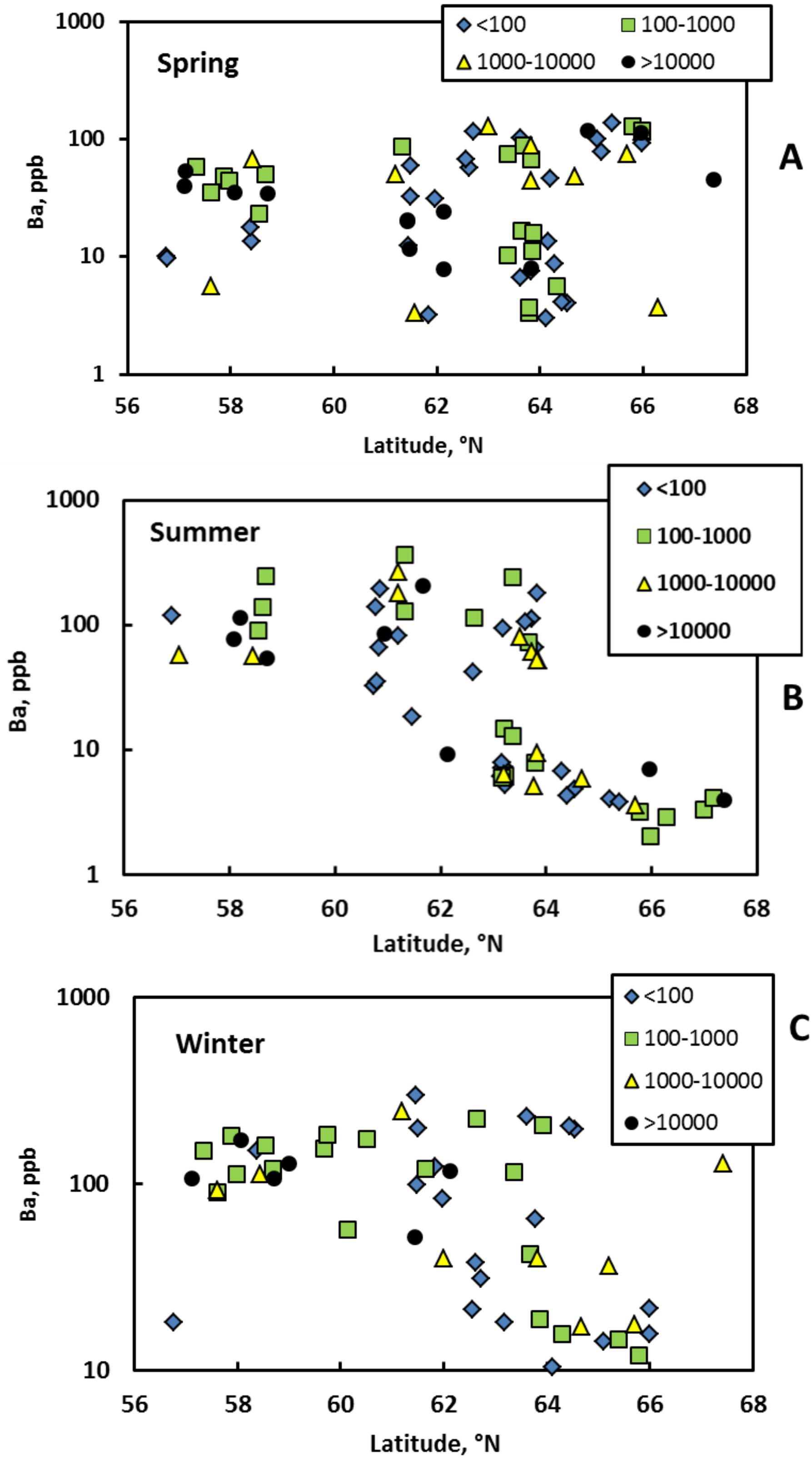


Fig. S10. The variation of Ba concentration with latitude during spring (A), summer (B) and winter (C) for watershed of different size. The symbols are the same as in Fig. 2.

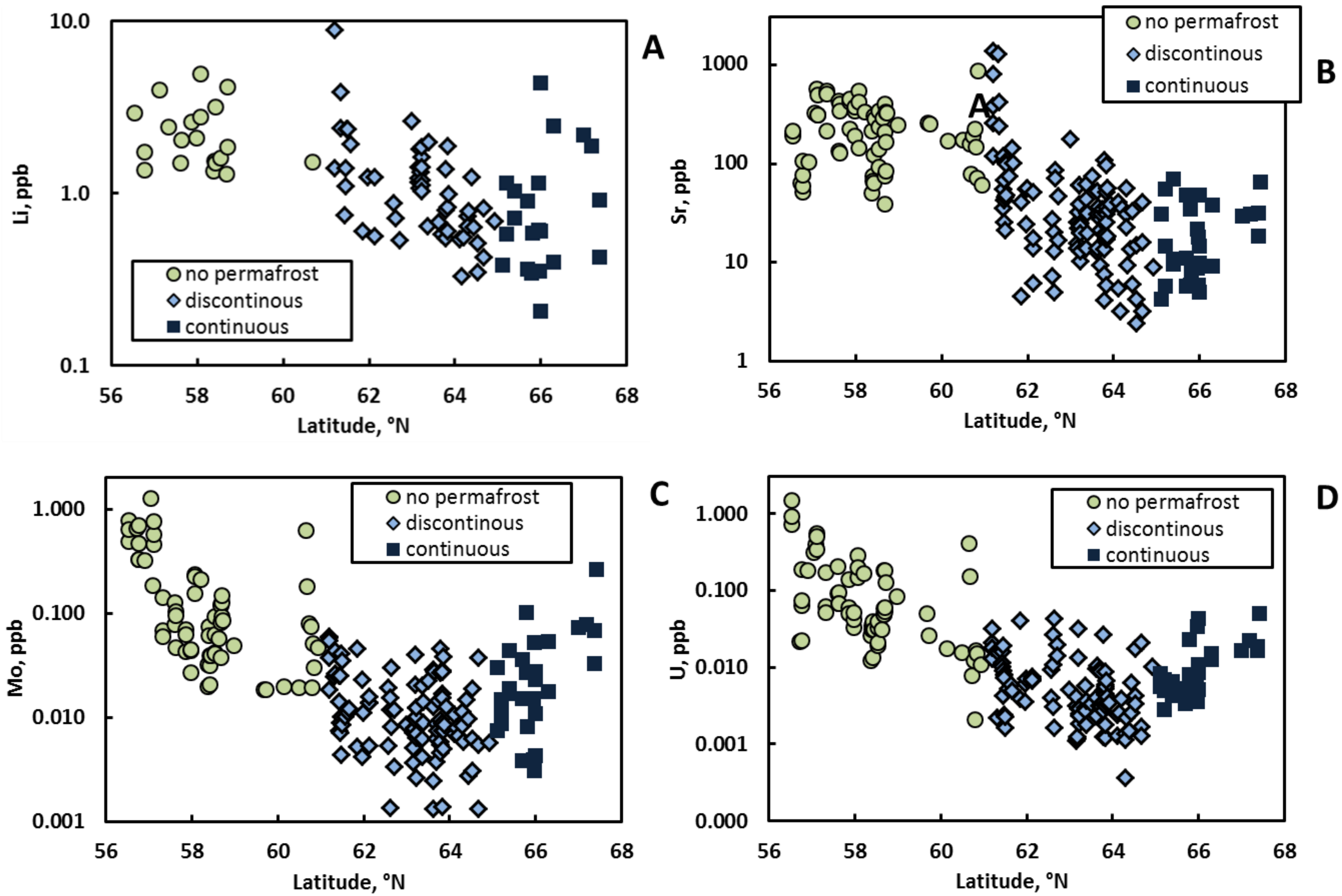


Fig. S11. Li (A), Sr (B), Mo (C) and U (D) concentration in rivers as a function of latitude representing all seasons and all river watersheds. The difference between three permafrost zone are significant at $p < 0.05$. Note log scale for concentration as a function of latitude.

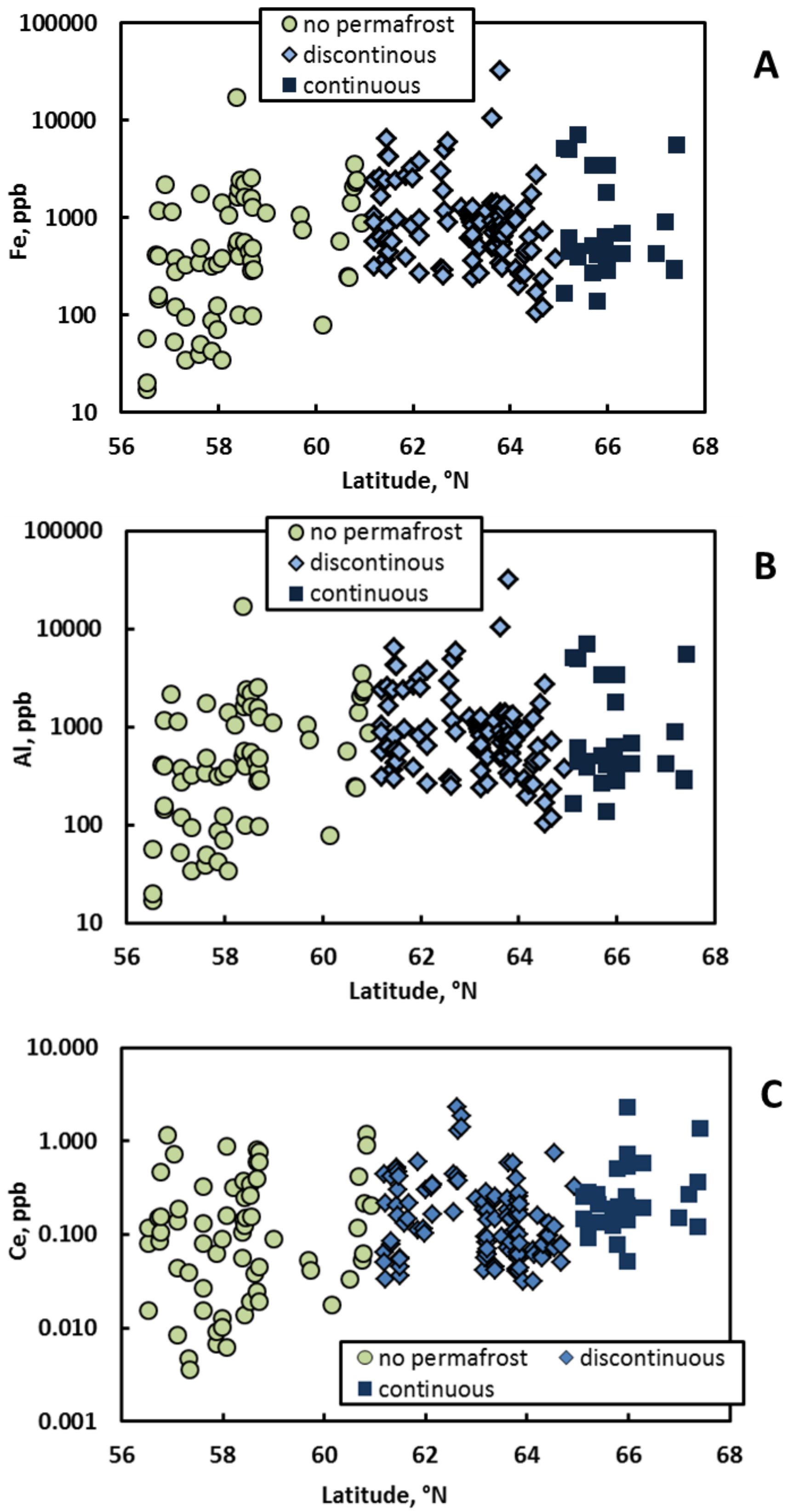


Fig. S12. Fe (A), Al (B) and Ce (C) concentration in rivers as a function of latitude representing all seasons and all river watersheds. The difference between three permafrost zone for Fe and Al are significant at $p < 0.05$. Note log scale for concentration.

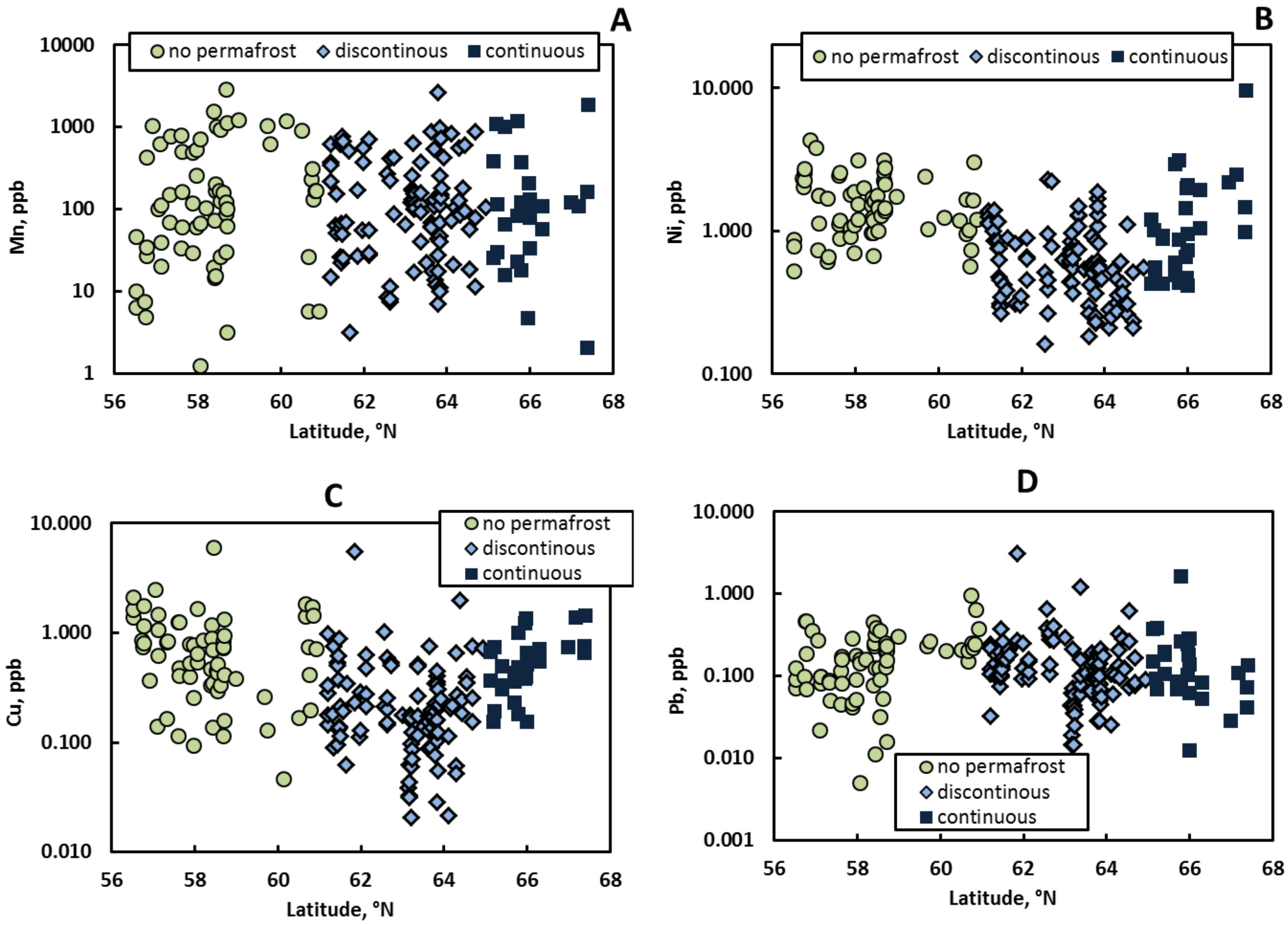


Fig. S13. Mn (A), Ni (B), Cu (C) and Pb (D) concentration in rivers as a function of latitude representing all seasons and all river watersheds. The difference between three permafrost zone for Fe and Al are significant at $p < 0.05$. Note log scale for concentration.

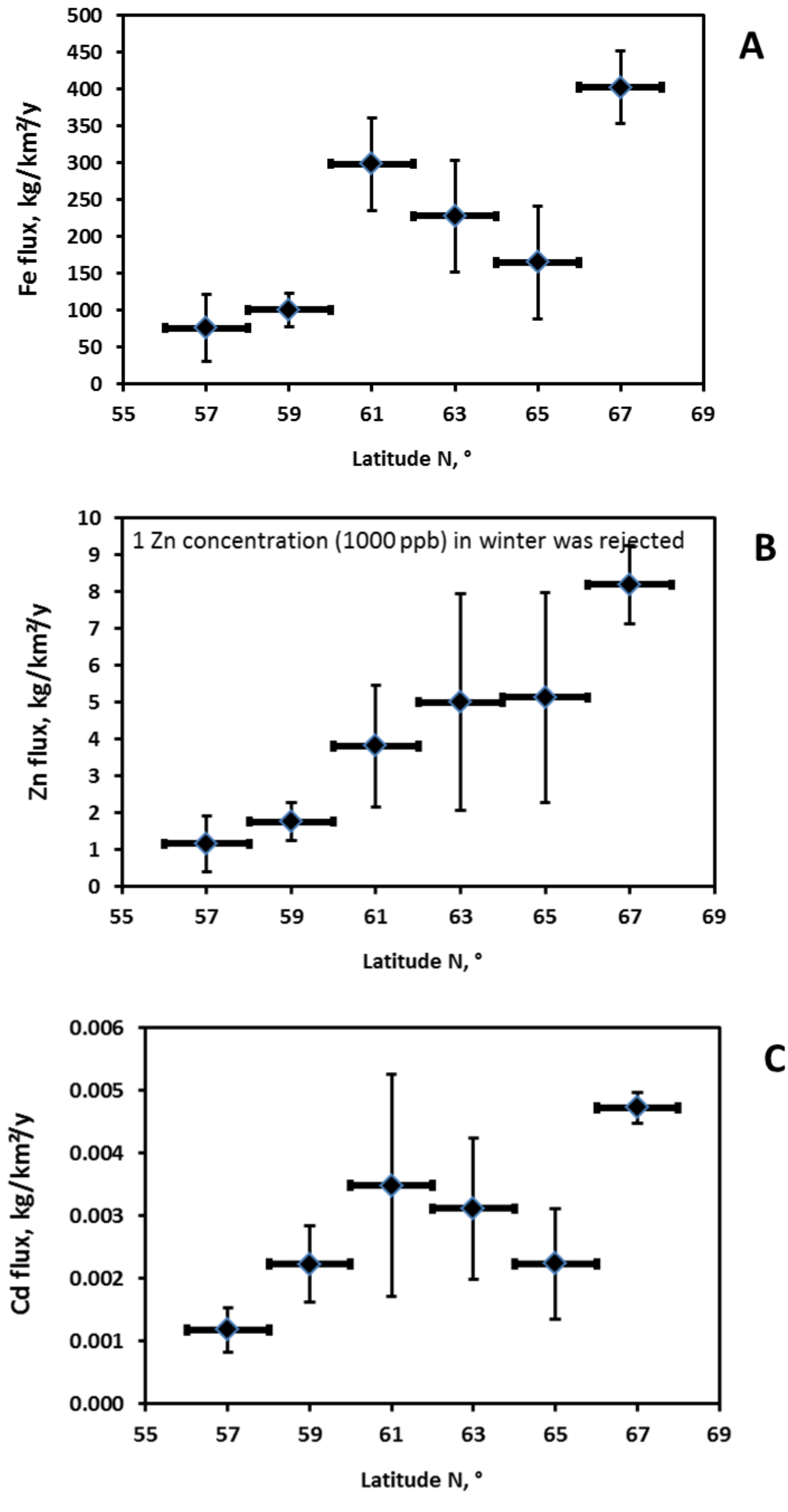


Fig. S14. Latitude range-averaged, all river-size averaged, annual fluxes of Fe (A), Zn (B) and Cd (C) in western Siberian rivers.

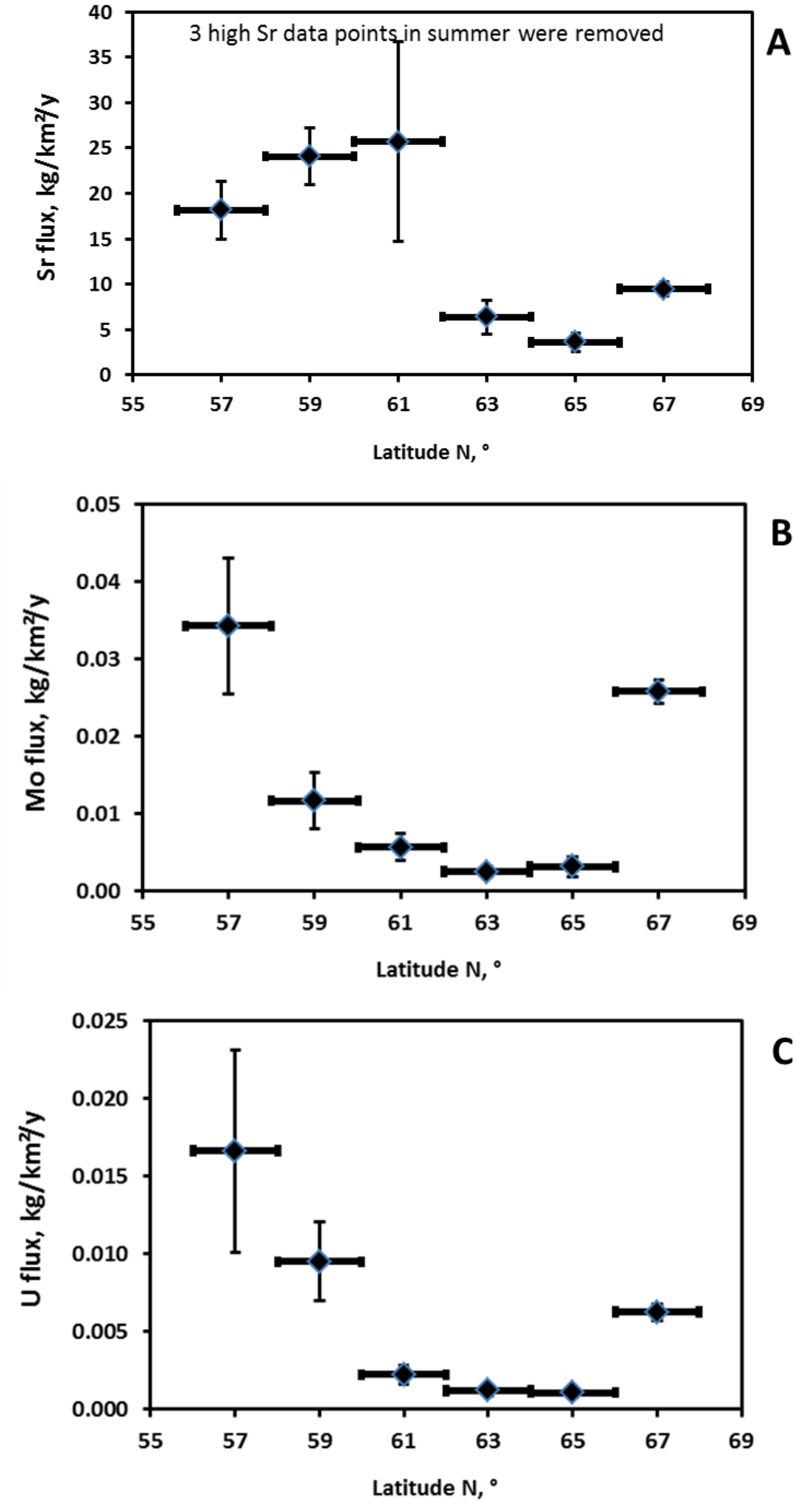


Fig. S15. Latitude range-averaged, all river-size averaged, annual fluxes of Sr (A), Mo (B) and U (C) in western Siberian rivers.

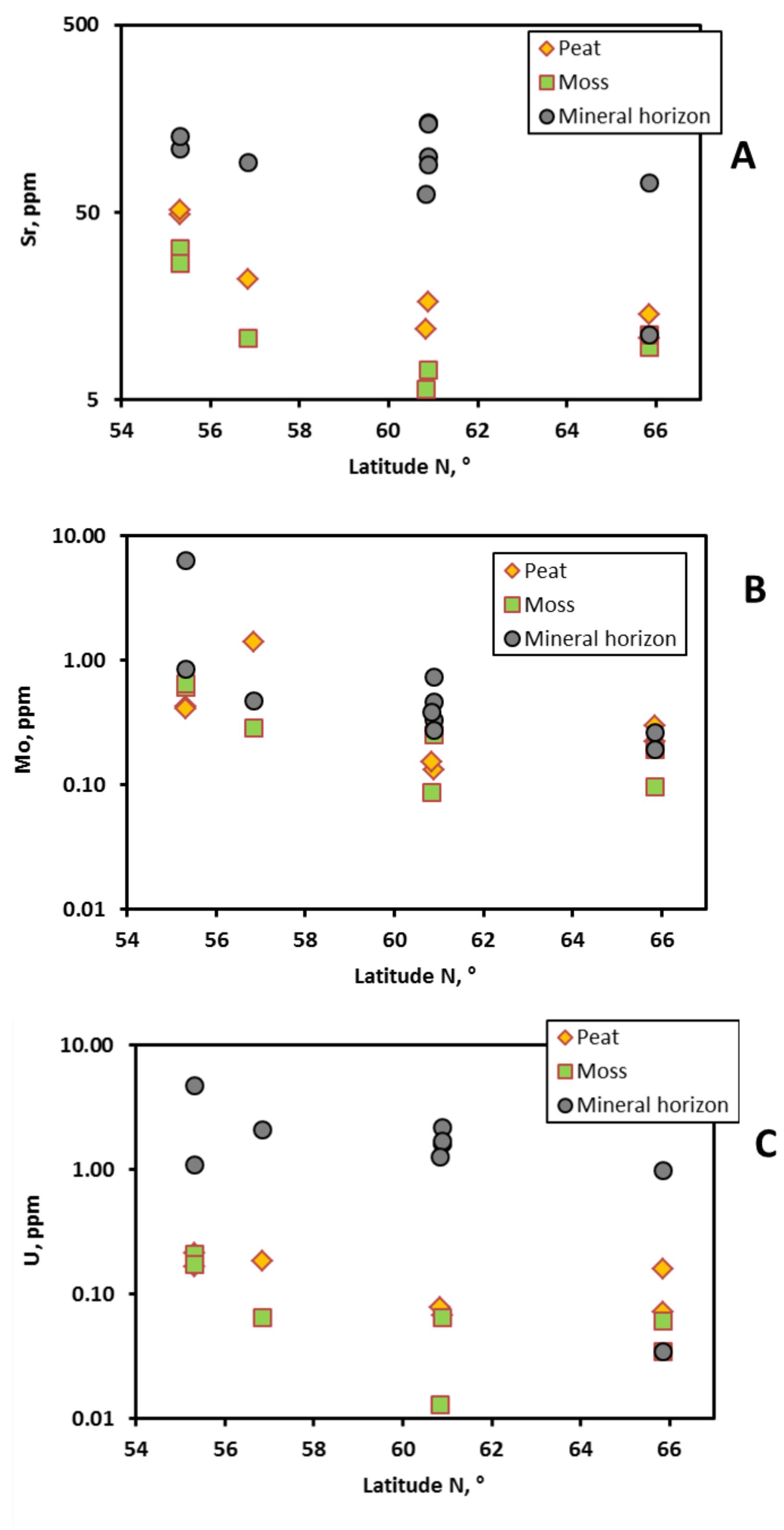


Figure S16. Average peat, moss, and mineral horizon concentration of Sr (A), Mo (B), and U (C) in western Siberia as a function of latitude. Data of Stepanova et al. (2014).

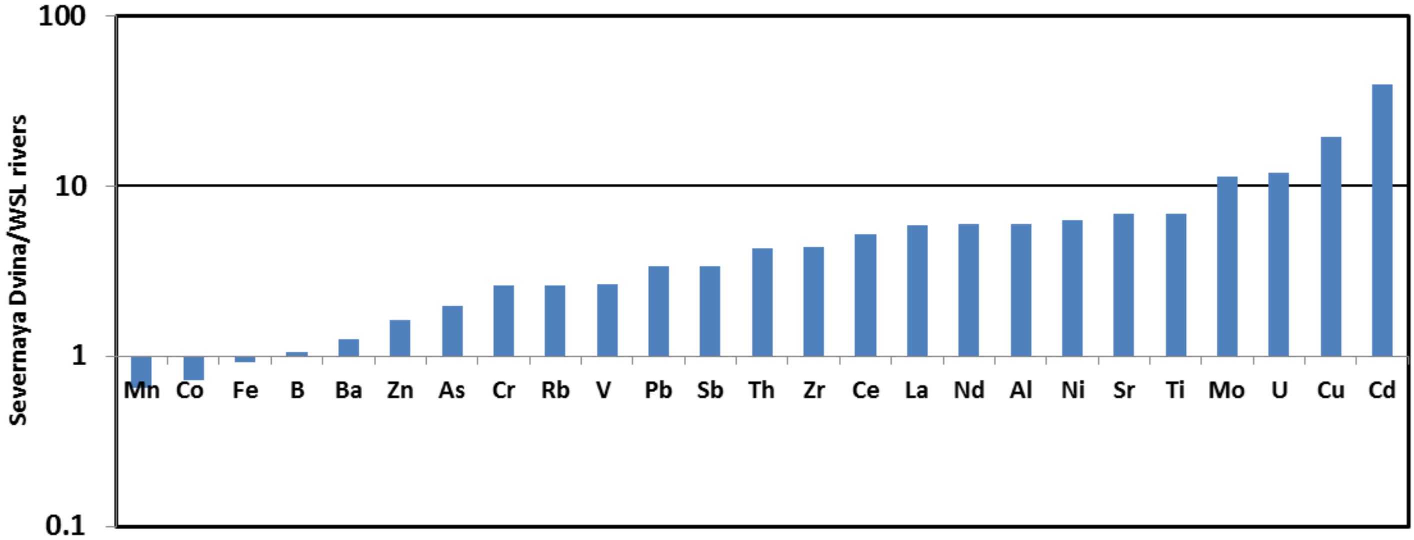


Figure S17. The ratio of annual element fluxes in the largest pristine European Arctic River (Severnaya Dvina) measured in 2007-2009 to mean fluxes of the WSL rivers. Given the intrinsic uncertainties on the fluxes of each region ranging between ±30 and ±50%, the agreement within a factor of 1.5 to 2 is within the uncertainty.