Water extracts from thawing Siberian permafrost - from land to ocean

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Schirrmeister, L[1], Siegert, C.[1], Eulenburg, A.[1], Wetterich, S.[1,2], Overduin, P.[1], Schwamborn, G.[1,3], Fuchs, M.[4], Fritz, M.[1], Ogneva, O.[1], Strauss, J.[1], Grosse, G.[1,5]

[1] Permafrost Research Section, Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Potsdam, Germany
[2] Technische Universität Dresden, Institute of Geography, Germany
[3] Eurasia Institute of Earth Sciences, Istanbul Technical University, Turkey
[4] Institute of Arctic and Alpine Research, University of Colorado Boulder, USA
[5] Institute of Geosciences, University of Potsdam, Potsdam, Germany

contact details

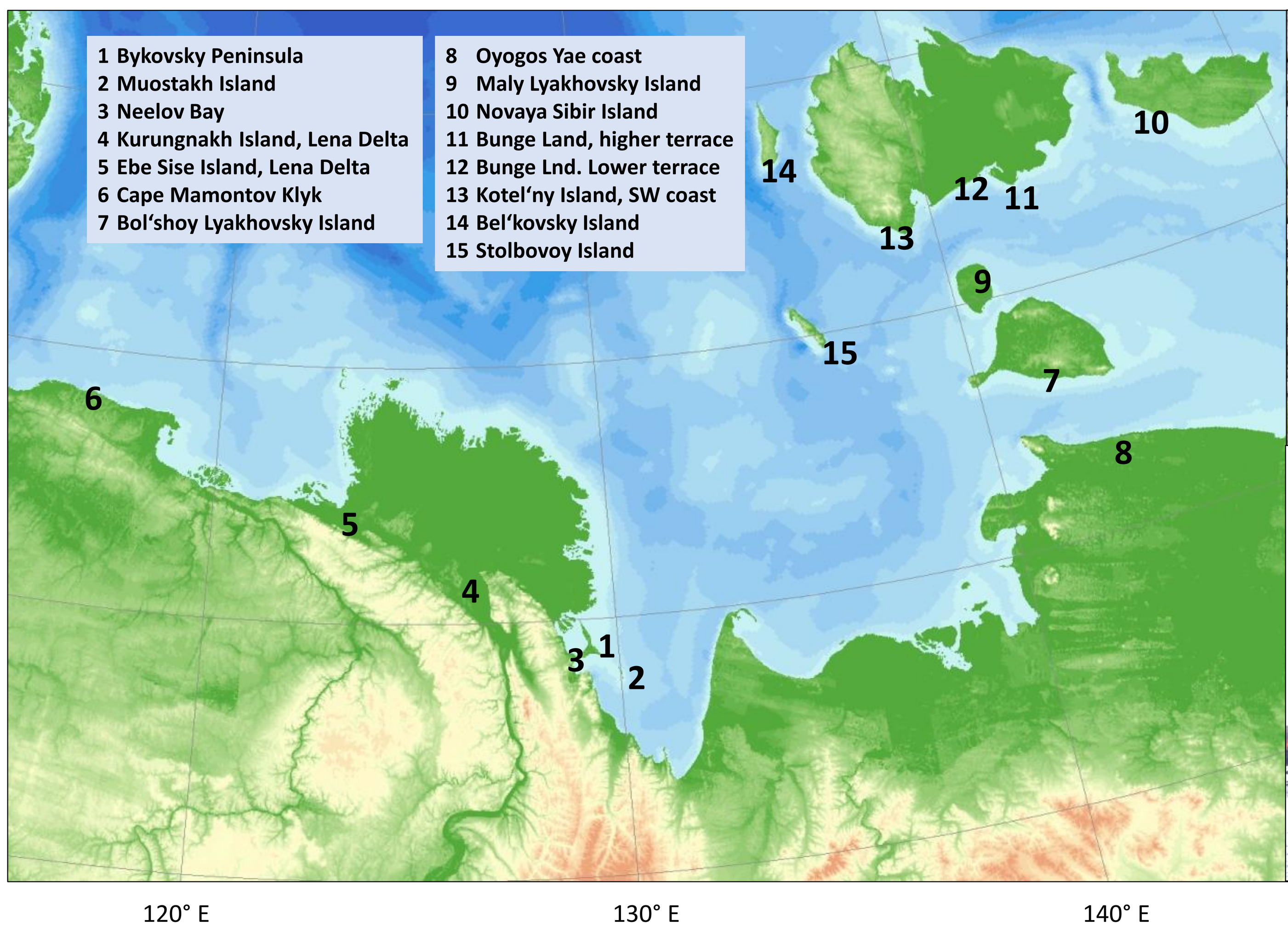


Fig. 1 Study sites in the Laptev Sea region

Fig. 2 Exposure photos from exemplary study sites

Background

Ground ice is melting more and more in permafrost regions with increasing climate warming. This leads to increased erosion on coasts and river banks and to the deepening of the active layer. As a result, permafrost that has been frozen for millennia and unaffected by change is being exposed more quickly.

To better understand and quantify fluxes of dissolved elements upon permafrost thaw, water-soluble elements from about 400 Siberian permafrost samples of 15 sites (Figs. 1, 2) covering a wide geographic range were determined.

Methods

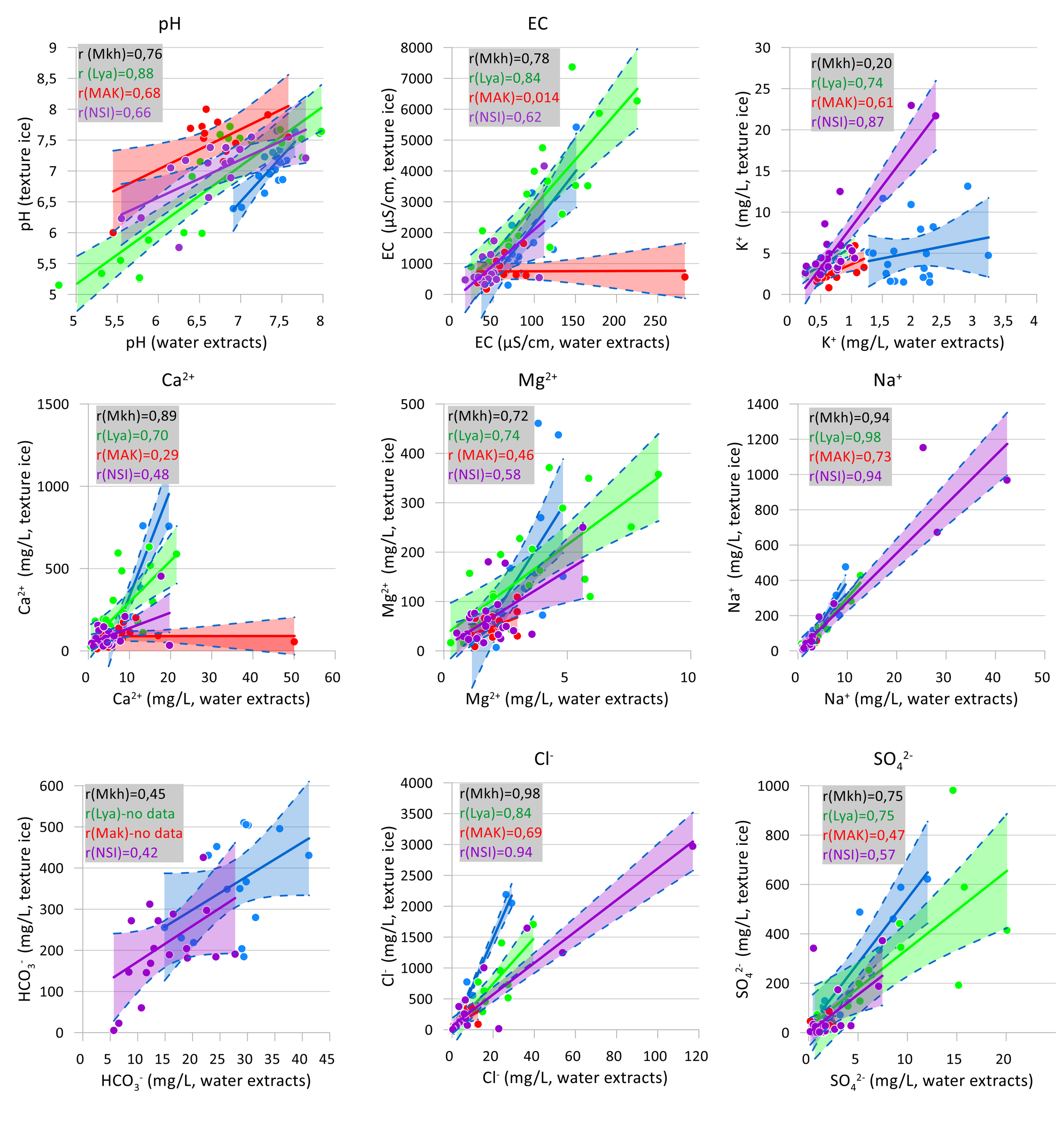
To determine water-soluble ion concentrations from dry samples, approximately 1 g of a freeze-dried sample was shaken for approximately 90 min in 50 ml centrifuge tubes with ultrapure water at a soil:water ratio of 1:25 using an overhead shaker. Then, the suspension was centrifuged at 4000 rpm for 15 min. The decanted extraction was filtered through a 0.45 µm cellulose acetate filter.

We measured the total dissolved cation (Ca^{2+}, K^+, Mg^{2+}, Na^+) and anion (Cl^-, SO_4^{2-}, and HCO_3^-) concentrations in the extracts. The cation concentrations were analyzed using inductively coupled plasma-optical emission spectrometry (ICP-OES, Perkin-Elmer Optima 8300DV), while the anion concentrations were determined by ion chromatography (IC, Thermo ICS2100). Hydrogen carbonate concentrations were measured by potentiometric pH value titration with 0.01 M HCl using an automatic titrator (Metrohm 794 Basic Titrino). Water EC and pH values were measured using a WTW MultiLab 540 multi-parameter device.

Results

Water extracts

Fig. 3 Boxplots from all permafrost study sites and some sea and river areas with sample numbers, pH, electrical conductivity (EC) values, major cation, and anion contents (min-max and mean values). Please note the different scaling of the x-axes between water extracts of permafrost deposits and water data.



Number of samples: Mkh 19, Lya 24, MAK 15, NSI 24

Fig. 4 Comparison of water extracts and seggregated ice from similar samples of Bykovsky Peninsula (1, Mkh), Bol'shoy Lyakhovsky Island (7, Lya), Cape Mamontov Klyk (6, MAK), and from the New Siberian Archipelago and two additional site (14, 12, 9, 13, 2, 10, 8, 15, NSI)

Tab. 1 Hydrochemical parameter comparison between water extracts and sea and river water data

Parameter	Water extracts		Sea and river water	
	Mean	Max. value	Mean	Max.
pH	5.6 – 7.1	8.2	7.6 – 7.8	8.0
EC (µS/cm)	17.3 – 364	756	161 -22,760	46,500
Ca^{2+} (mg/L)	0.5 – 10.6	50.0	17.8 – 171.6	360.2
Na^+ (mg/L)	1.3 – 60.6	95.1	7.6 – 4319.3	9,526
Mg^{2+} (mg/L)	0,4 – 3.5	21.6	4.9 – 538.3	1162
K^+ (mg/L)	0.4 – 3.2	7.0	0.5 -167.2	382.4
HCO_3^- (mg/L)	6.0 – 27.8	111.0	no data	no data
Cl^- (mg/L)	0.5 – 116.4	272.6	10.2 – 7619.6	17,144
SO_4^{2-} (mg/L)	0.6 – 8.7	28.4	13.1 - 1034	2337

Results of the comparison in a nutshell

- Water extract ion contents are one or two order of magnitudes lower than in segregated ice
- Many data correlate quite well, but there are local differences, especially for Cape Mamontov Klyk (MAK)

Conclusions

- Mobilization of previously freeze-locked material: Terrestrial input from thawing permafrost, including ground ice, is expected to increase as coastal and river shore erosion and other permafrost degradation processes accelerate under Arctic warming
- Increasing influx of dissolved elements influences transport and deposition processes in aquatic environments, nutrient supply, food chains and life cycles with largely understudied consequences for Arctic aquatic and coastal ecosystems
- Long-term erosion rates (last about 40 years) -2.2± 0.1 m/a; short-term erosion rates (last 1-4 years) -5.3±1.3 m/a → calculation of inputs to the aquatic environment are necessary in the future