Intensity and spatio-temporal variability of chemical denudation in an arctic-oceanic periglacial drainage basin in northernmost Swedish Lapland

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Abstract The intensity and spatio-temporal variability of chemical denudation was analyzed in the Latnjavagge drainage basin (9 km^2; 950–1440 m a.s.l.; 68°20′N, 18°30′E), an arctic–oceanic periglacial environment in northernmost Swedish Lapland. Data on daily runoff and solute concentrations at different test sites within the selected representative drainage basin were collected during the entire arctic summer seasons of 2000, 2001, 2002 and 2003. The mean annual chemical denudation net rate for the Latnjavagge drainage basin is 5.4 t/km^2 yr. Most of the annual runoff occurs when the ground is still frozen. The rate in Latnjavagge is much lower than chemical denudation rates reported for Kärkevagge (Swedish Lapland) situated close to Latnjavagge, but at a similar level to a number of other subarctic, arctic and alpine environments. Chemical denudation shows a spatio-temporal variability within the drainage basin, which is mainly caused by a spatio-temporal variability of snow cover and ground frost and a spatial variability of regolith thicknesses within Latnjavagge.

Keywords Chemical denudation; ground frost; periglacial environment; regolith thickness; runoff; spatio-temporal variability

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Introduction

Quantitative data on fluvial solute fluxes and chemical denudation rates in periglacial environments are still rare (Clark 1988; Beylich 1999; Beylich *et al.* 2003, 2004a, 2004b, in press). For many years chemical weathering and chemical denudation were believed to be of only minor importance in periglacial environments (see Campbell *et al.* 2001). Lozinski (1909, 1912) postulated a dominance of mechanical weathering and denudation and Peltier (1950) proposed limited chemical weathering in cold environments. In contrast to this, Rapp (1960) concluded in his study of denudation and slope development in Kärkevagge, northern Swedish Lapland, that chemical denudation was by far the most important denudative geomorphological process type. Also the following research in different periglacial environments has shown that chemical weathering and chemical denudation are significant processes in cold areas (Thorn 1975; Caine 1979, 1995; Caine and Thurman 1990; Dixon *et al.* 1984, 1995; Beylich 1999, 2000, 2002; Darmody *et al.* 2000, 2001; Thorn *et al.* 2001; Campbell *et al.* 2001, 2002). Nevertheless, the nature and intensity of chemical denudation in subarctic, arctic, and alpine environments are still little studied (see Thorn *et al.* 2001).

Study area

This investigation of the intensity and spatio-temporal variability of chemical denudation was conducted in the Latnjavagge drainage basin (950–1440 m a.s.l.; 68°20′N, 18°30′E) in northernmost Swedish Lapland (Fig. 1). The mountains of northern Swedish Lapland are situated close to the North Atlantic in a prevailing westerly wind regime. The northerly position of the area is partly counteracted by the favourable influence of the Gulf Stream. The arctic–oceanic climate in Latnjavagge (at Latnjajaure Field Station, LFS) is characterized by an annual mean temperature of −2.3°C (1993–2001) and a mean annual

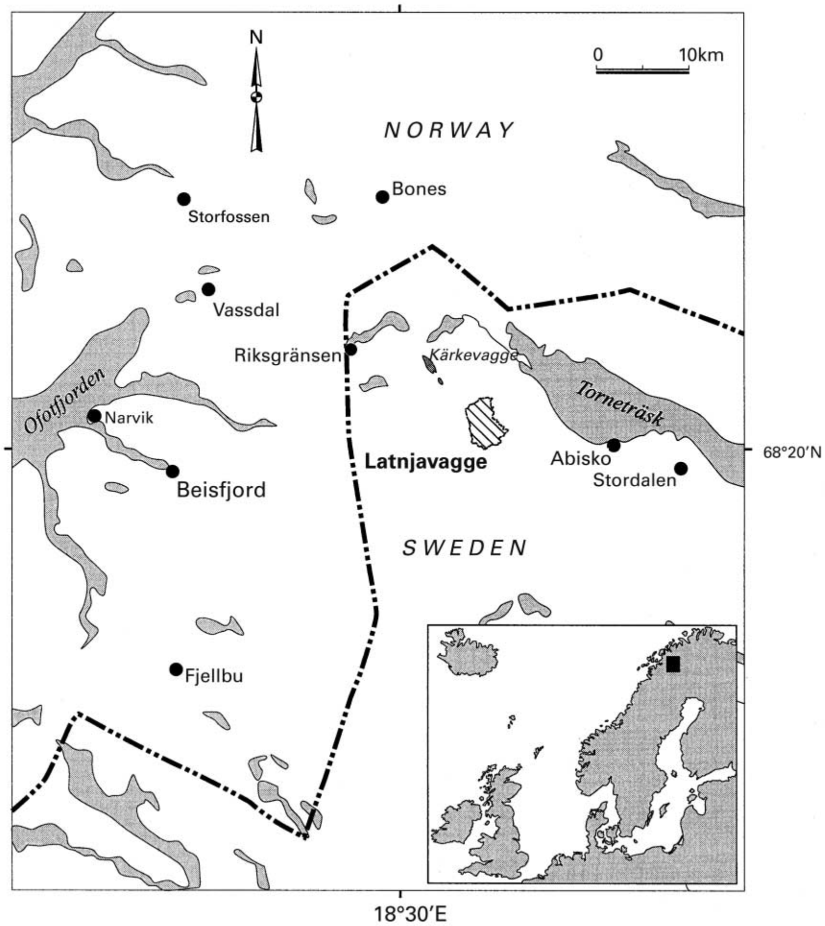

Figure 1 Location map of Latnjavagge, Swedish Lapland

precipitation of 818 mm (1990–2001). July is the warmest month of the year (8.0°C). The coldest month is February (− 10.1°C). About 66% of the annual precipitation is temporarily stored as snow during the winter. Regarding the summer months of June–August, August shows the highest mean precipitation amount (78 mm) and also the highest frequency of extreme rainfall events. Altogether, precipitation from June to August accounts for 24% of the mean annual precipitation (Beylich 2003).

The Latnjavagge basin drains to the south into the larger Kårsavagge. It has an area of approx. 9 km^2, a length of 4600 m and elevations ranging from 950 to 1440 m a.s.l. (Fig. 2). The bedrock of Latnjavagge is mainly composed of Cambro-Silurian mica-garnet schists and inclusions of marble (Kulling 1964; Kling 2004). Intrusions of acidic granites can be found in the northern part of the valley. Regional deglaciation occurred 8000–10 000 yr BP (André 1995). The Latnjavagge drainage basin is dominated by flat plateaux at 1300 m a.s.l., steep slopes which bound the glacially sculptured valley and the flat valley floor situated between 950 and 1200 m a.s.l. (Fig. 2). The plateaux are best described by bare bedrock and boulder fields. The transition to the slopes is generally abrupt and, on the very steep east-facing slope, covered by perennial snow and ice patches. The lower part of the valley floor is dominated by a lake, Latnjajaure (0.73 km^2) and a series of moraine ridges. The regolith thicknesses are generally small and exceed only a few metres in a few localities (Beylich *et al.* 2004b). The soils are mainly regosols and lithosols. The area belongs to the mid-alpine zone with

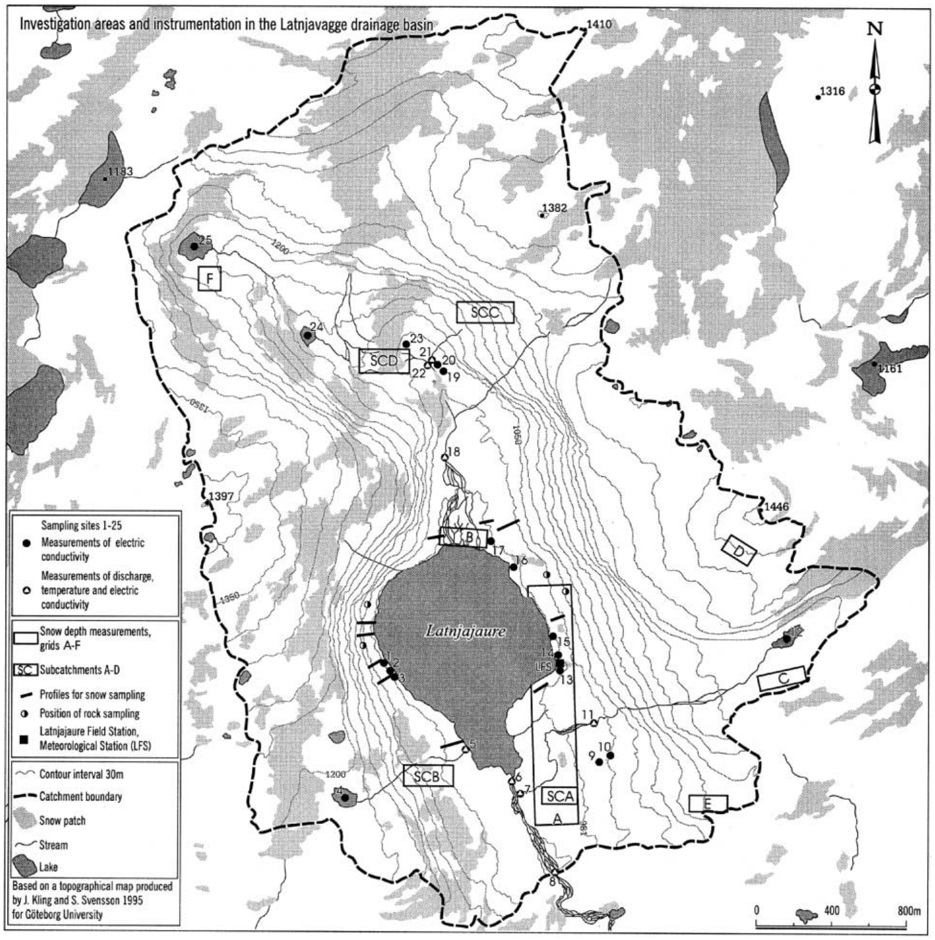

Figure 2 Investigation areas, sampling points and instrumentation in the Latnjavagge drainage basin

a continuous vegetation cover comprising dwarfshrub heaths and alpine meadows and bogs (Molau 2001, 2004; Molau *et al.* 2003). The distribution of permafrost is still not thoroughly investigated but drilling outside the drainage basin at 1200 m a.s.l. suggested at least sporadic permafrost down to 80 m below the surface (Kling 1996, 2004, see also Beylich *et al.* 2004b). The hydrological regime is nival, with runoff being limited to the period from middle/end of May until October/November (Beylich 2003). Direct anthropogenic impact on the natural system is presently small (Beylich *et al.* 2005).

Methods

The Latnjavagge drainage basin exhibits the major geological and geomorphological characteristics of the higher mountain area in northernmost Swedish Lapland and can be seen as a representative test site for this arctic–oceanic periglacial environment. Field work was conducted during the entire arctic summer field seasons (end of May until beginning of September) of 2000, 2001, 2002 and 2003. During these four field seasons discharge measurements and water samplings were carried out three times daily which provides a good database for analyzing intensity and spatio-temporal variability of chemical denudation in this environment. This paper focuses mainly on total chemical denudation rates of the entire drainage basin and of six different subcatchments within the Latnjavagge catchment, calculated with daily data on atmospheric solute inputs, runoff, solute concentrations and solute yields.

Selection of subcatchments, measuring sites and sampling sites

The Latnjavagge drainage basin is mainly composed of Cambro-Silurian mica-garnet schists and can be regarded as lithologically/geologically homogeneous. The very similar bedrock conditions in the entire catchment area make it possible to directly compare chemical denudation rates in selected subcatchments with different snow and ground frost conditions due to different altitudes a.s.l. and aspects, and with different regolith thicknesses. The selected subcatchments and sampling sites are shown in Fig. 2. Discharge measurements, water samplings, conductivity measurements and water temperature measurements were conducted at the outlets of the six chosen subcatchments (outlet lake Latnjajaure (site 6), inlet lake Latnjajaure (site 18), subcatchments A (site 7), B (site 5), C (site 21) and D (site 22) and the entire Latnjavagge drainage basin (site 8) (see the locations of all measuring and sampling sites in Fig. 2). Additional water samplings, conductivity measurements and water temperature measurements were carried out at 18 other sites within the basin (see all the measuring and sampling sites 1–25 in Fig. 2). Meteorological data and soil temperature data are from the Latnjajaure Field Station (LFS, 981 m a.s.l., see Fig. 2) (Molau 2001, 2004; Molau *et al.* 2003). The subcatchments and sampling sites were selected after an analysis of aerial photographs and after detailed field investigations.

Measurement of discharge

Discharge in channels was measured at the seven different sites (outlet Latnjavagge, outlet lake Latnjajaure, inlet lake Latnjajaure and outlets of the subcatchments A–D (see Fig. 2)) three times daily with an Ott-propeller C2 (Ott GmbH & Co.KG, Kempten) immediately prior to the sampling of water. The stream velocity was measured at well defined channel cross-sections in horizontal distances of 10 cm at each cross-section and in 60% depth of the total water depth at each measuring point. Velocity isolines over the entire channel cross-sections were calculated by interpolation. The discharges (m^3/s) were calculated by multiplying the velocity (m/s) by the corresponding cross-section area, and daily discharges (m^3/d) were estimated for the different channels by interpolating the three daily measurements. Daily specific runoff (mm/d) was then calculated by dividing the daily discharges by the contributing (sub-)catchment areas (see Beylich 1999). The installation of fixed gauge stations was not possible because of the characteristics of the channels (bedrock and/or blocks, shifting channels during snowmelt, slush flows) and the remote location of the measuring sites.

Field sampling

Surface water electric conductivity (μS/cm, reference 25°C) and water temperature were measured three times daily at the different sampling sites (Fig. 2) with a temperature-corrected portable conductivity meter (Cond 315i/SET, WTW, Weilheim). At sites 5, 6, 7, 8, 18, 21 and 22 the measurements were conducted directly after the discharge measurements. Daily mean values for all measuring sites were calculated by interpolating the three daily measurements (see Beylich 1999). Total dissolved solids (TDS (mg/l)) in surface water were estimated by multiplying electric conductivity by 0.7 (see Strömquist and Rehn 1981; Darmody *et al.* 2000). Precipitation samples were collected in a Hellmann totalizator (200 cm^2 surface area) with wind shelter and snow cores with the complete snow pack from the previous winter were taken along defined profiles (see Fig. 2) before the beginning of snowmelt in spring and melted in buckets at LFS (Beylich *et al.* in press). Surface water samples were taken with 1000 ml wide-necked polyethylene bottles. At all surface water sampling sites the turbulence of the water was high enough for a good mixing of the water. Water samples were filtered with a pressure filter and Munktell quantitative filter papers (OOH) and 205 of the samples were then tranferred into 200 ml polyethylene bottles for storage in a freezing box at LFS.

The 205 water samples taken in the field and stored at LFS were kept frozen until they were analyzed in the laboratory of FU Berlin, FB Earth Sciences, Institute of Geological Sciences, AB Hydrogeology (Beylich *et al.* 2004a, in press). In the laboratory Ca^{2+} was determined with an AAS Perkin-Elmer 5000 and SO_4^{2-} with an ion-chromatograph DX 100 Dionex.

Results

Runoff in Latnjavagge is closely correlated to the input of energy by radiation and heat fluxes to the catchment and rainfalls (Beylich *et al.* in press). Daily specific runoff, daily solute concentrations and daily solute gross yields for the entire Latnjavagge drainage basin, the subcatchment above the inlet of lake Latnjajaure and the subcatchments A and D (2000 and 2001 field seasons) are shown in Figs. 3 and 4. During snowmelt generated runoff peaks in the earlier season a significant diluting effect can be recognized at all sites. Nevertheless, days with high snowmelt generated discharges also show higher yields of dissolved solids.

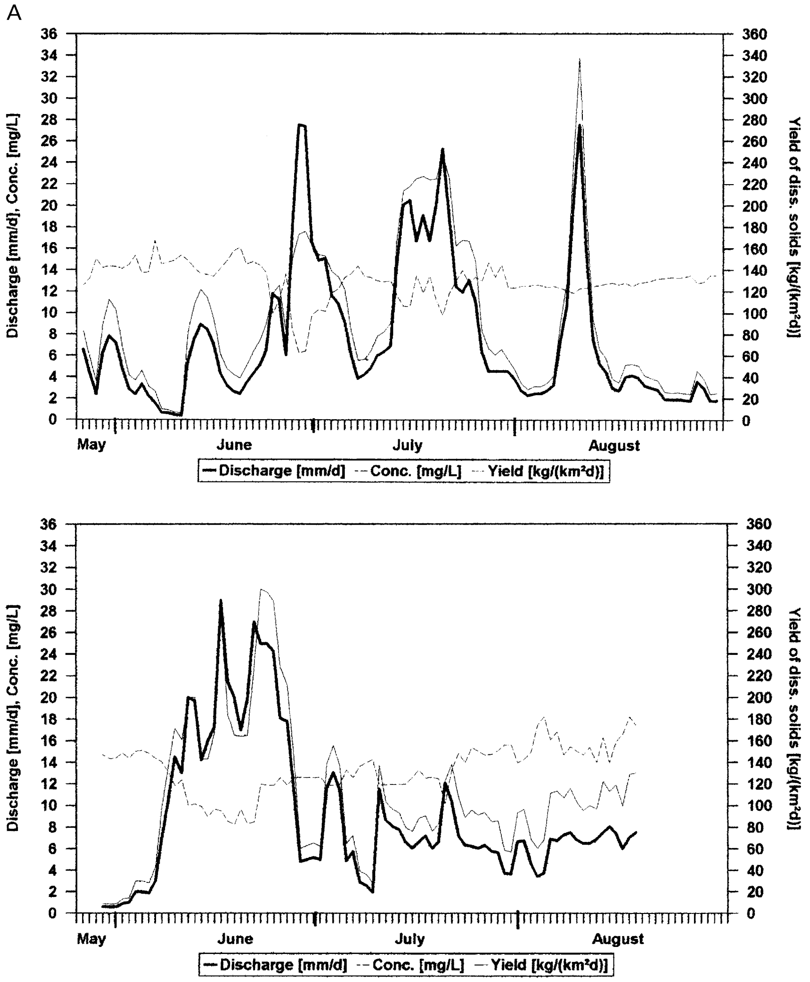

Figure 3 (a) Daily specific runoff, solute concentrations, and solute gross yields; outlet Latnjavagge (2000 and 2001 field seasons). (b) Daily specific runoff, solute concentrations, and solute gross yields; Latnjavagge, inlet lake Latnjajaure (2000 and 2001 field seasons)

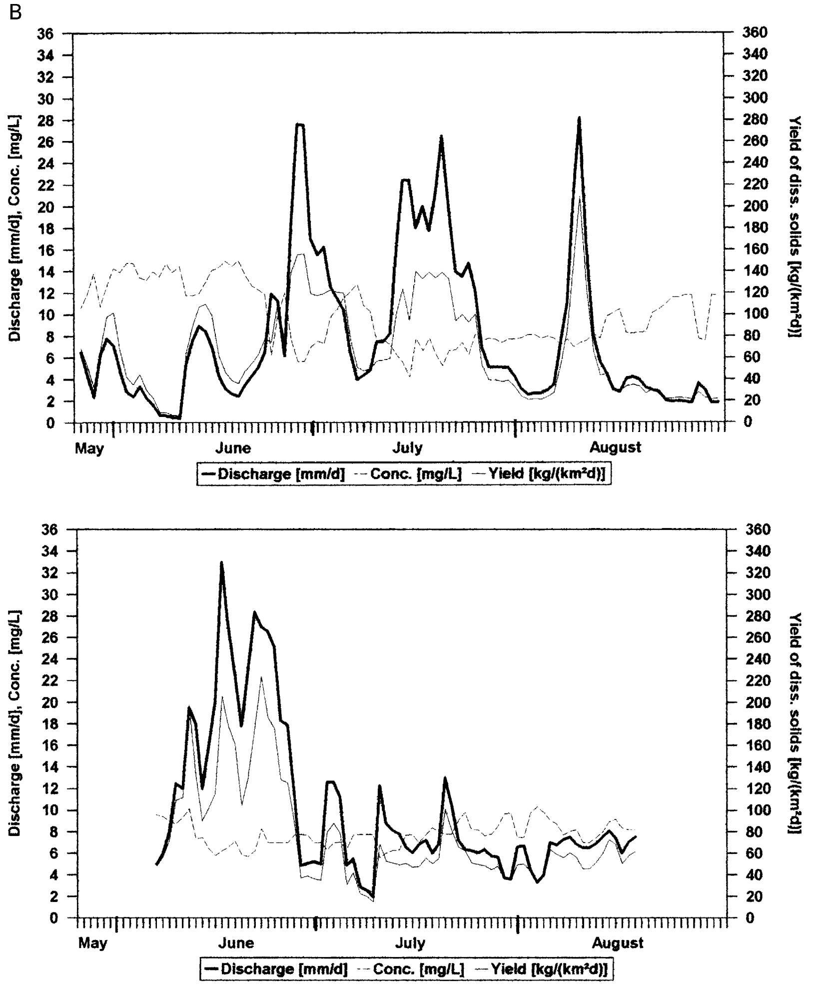

Figure 3 *Continued*

Thus, the lower concentrations of dissolved salts caused by diluting effects are more than compensated for by the increased runoffs (see Collins and Young 1981; Walling and Webb 1983; Barsch *et al.* 1994; Gude *et al.* 1996). The rainfall generated runoff peak in August 2000 is characterized by no concurrent diluting effect and, according to that, significantly higher yields of dissolved solids. The differences between the snowmelt generated discharge peaks in June and July 2000 and June 2001, on the one hand, and the rainfall generated peak in August 2000, on the other hand, are due to still persistent ground frost below the snow cover during the snowmelt generated peaks (Beylich *et al.* in press). The frozen ground prevents the infiltration of melt and rainwater into the regolith and a longer contact and reaction time between the ion-poor melt- and rainwater and the regolith. During the rainfall generated discharge peak in August 2000 the unfrozen regolith was water saturated and saturation overland flow and piping could be observed in larger areas of the valley. In addition to that, the rainfall of 8–9 August caused a high atmospheric solute input of 450 kg/km^2 (57.5 mm precipitation within two days) (Beylich *et al.* in press). A higher level of solute concentrations in the beginning of the main snowmelt period (ionic pulse), as reported by several authors from different periglacial environments (Johannessen and Henriksen 1978; Leser *et al.* 1992; Potschin and Leser 1994; Gude *et al.* 1996), could also be

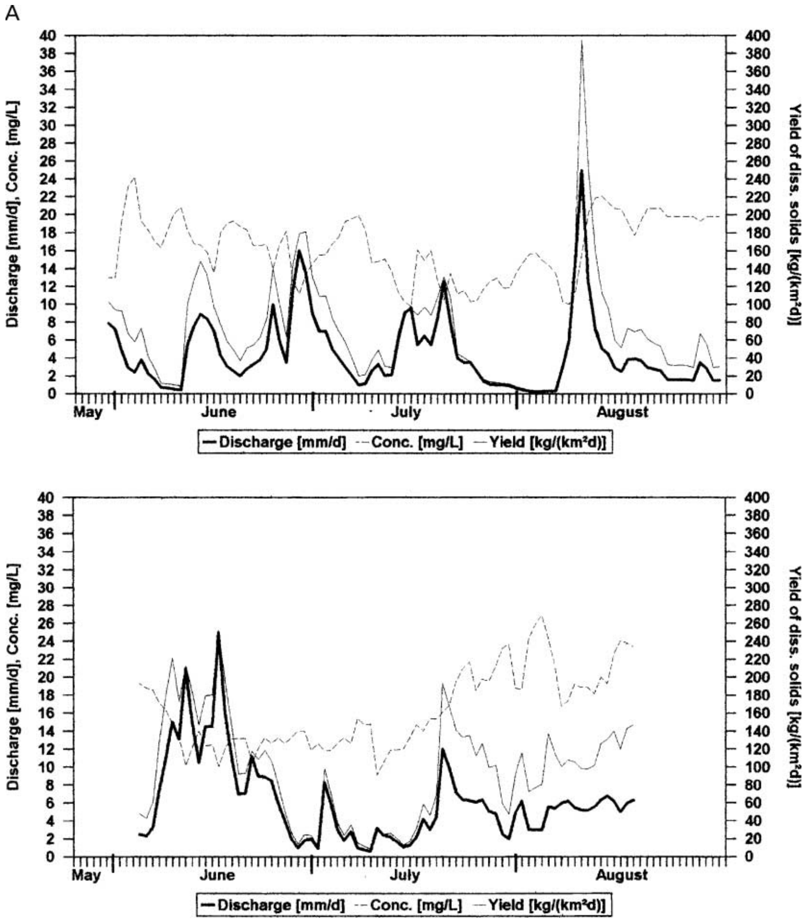

Figure 4 (a) Daily specific runoff, solute concentrations, and solute gross yields; Latnjavagge, Subcatchment A (2000 and 2001 field seasons). (b) Daily specific runoff, solute concentrations and solute gross yields; Latnjavagge, Subcatchment D (2000 and 2001 field seasons) (see over).

observed in Latnjavagge. Altogether, the ranges of temporal variation in solute concentration are comparatively small, which is common in periglacial fluvial systems (Clark 1988).

Relationships between daily specific runoff and daily gross yields of dissolved solids (2000 and 2001 field seasons) for the different measuring sites are presented in Fig. 5. The double logarithmic relationships show the diluting effect occuring during snowmelt generated peaks at all test sites. Most of the annual runoff occurs at a time when the ground is still frozen, which is one explanation for the very low solute concentrations in the surface water.

The clearly highest solute concentrations were measured in subcatchment A. The concentrations in subcatchment A increase significantly in the later summer (see Fig. 4(a)), which is due to the continuous down melting of ground frost and a deeper infiltration of water into the thicker regolith (Beylich *et al.* 2004a, b). Compared to that the solute concentrations at the outlet of subcatchment D, which is characterized by only thin regolith and significantly longer lasting snow cover and ground frost, remain low over the entire summer season (Fig. 4(b)). The mean seasonal TDS values range from only 6.31 mg/l (sampling site 21, outlet subcatchment C, 2001 field season) to 55.10 mg/l (sampling site 15, creek below snow patch, 2003 field season). The mean TDS value at the outlet of Latnjavagge (sampling site 8) over

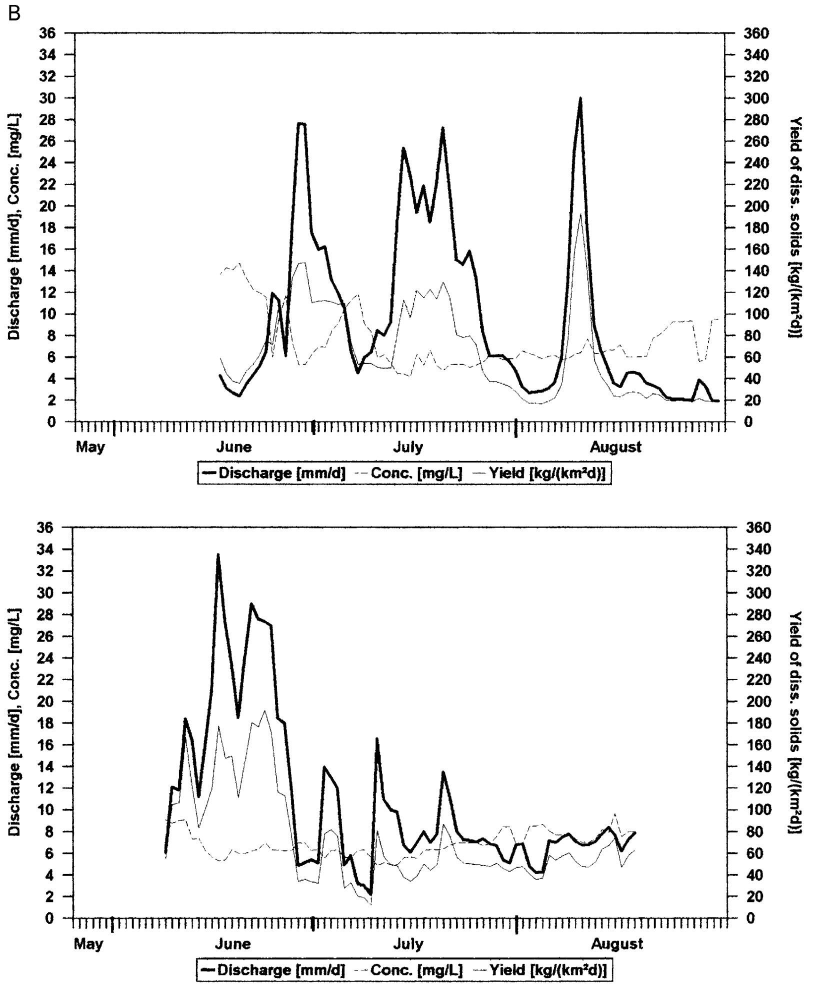

Figure 4 *Continued*

the four years 2000–2003 is 12.06 mg/l, at the outlet of lake Latnjajaure (sampling site 6) 10.94 mg/l, at the inlet of lake Latnjajaure (sampling site 18) 7.88 mg/l, at the outlet of subcatchment A (sampling site 7) 15.46 mg/l, at the outlet of subcatchment B (sampling site 5) 10.29 mg/l, at the outlet of subcatchment C (sampling site 21) 6.58 mg/l and at the outlet of subcatchment D (sampling site 22) 6.66 mg/l (Table 1). The radiation exposed and gentle W-facing slope and subcatchment A are the main source areas for dissolved solids whereas in particular the areas above the inlet of lake Latnjajaure show very low concentration values (see Table 1). The higher values at the W-facing slope and in subcatchment A are mainly due to the earlier thawing of ground frost (1–1.5 months earlier snowmelt, starting already in the middle of May) and larger regolith thicknesses for this radiation exposed slope and in subcatchment A (Beylich *et al.* 2004a, b, in press) which is also documented by higher mean water temperatures (Table 1).

In comparison to that, the main part of the surface water analyzed on the very steep E-facing slope and in the areas above the inlet of Lake Latnjajaure comes directly from the plateau areas around 1300 m a.s.l. (see Fig. 2) with only very thin or completely lacking regolith cover. Because of the much longer lasting snow cover and ground frost in these areas (until July), there is only little contact and reaction time between the ion-poor melt- and

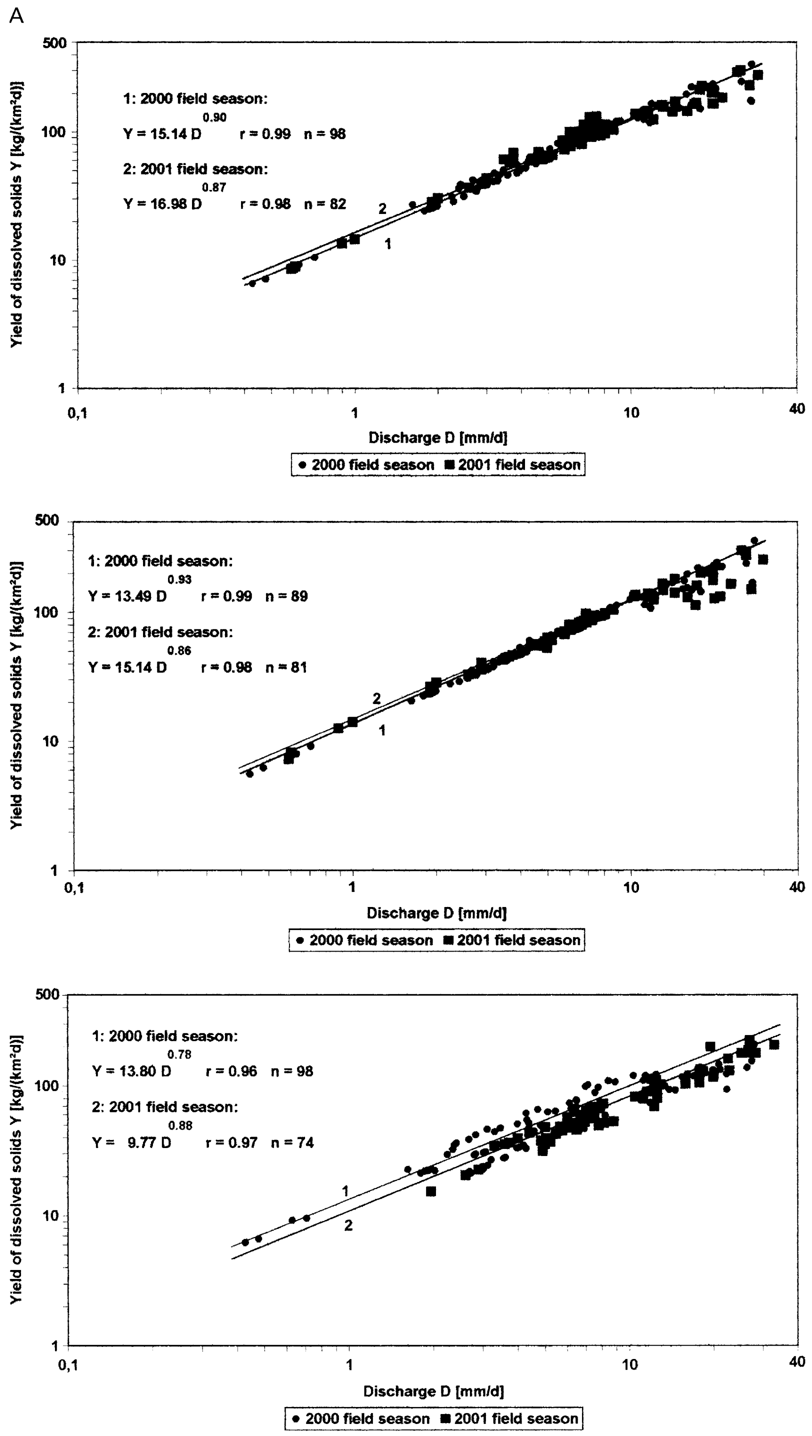

Figure 5 (a) Relationships between daily specific runoff and daily solute gross yields; outlet Latnjavagge, outlet lake Latnjajaure, and inlet Lake Latnjajaure (2000 and 2001 field seasons). (b) Relationships between daily specific runoff and daily solute gross yields; subcatchments A–D (2000 and 2001 field seasons)

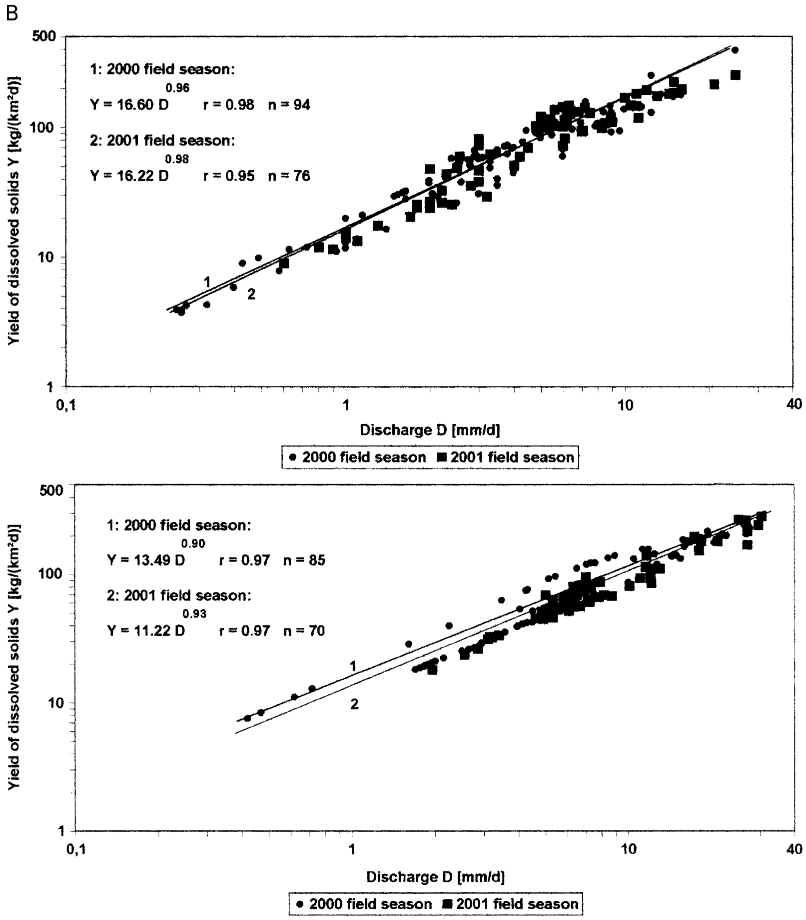

Figure 5 *Continued*

rainwater and the regolith during a longer part of the runoff season. The most important ion in the surface water samples from Latnjavagge is SO_4^{2-}, followed by Ca^{2+} (Table 1). A detailed analysis of the surface water chemistry within the Latnjavagge drainage basin is published in Beylich *et al.* (2004a).

Rates of chemical denudation

Based on the daily runoff and solute concentration data, total gross yields of dissolved solids were calculated for the entire Latnjavagge drainage basin and the six different subcatchments within Latnjavagge (Fig. 2 and Table 2). The total gross yields for the entire Latnjavagge drainage basin (sampling site 8) are 8985 kg/km^2 for the 2000 field season, 9087 kg/km^2 for the 2001 field season, 7795 kg/km^2 for the 2002 field season and 8062 kg/km^2 for the 2003 field season. The total gross yields of the different subcatchments range from 4255 kg/km^2 in subcatchment C (sampling site 21, 2001 field season) to 8165 kg/km^2 at the outlet of Lake Latnjajaure (sampling site 6, 2000 field season). The spatial variability of the solute gross yields correlates well with the spatial variability of the solute concentrations described above but is also influenced by the different total runoffs from the different subareas. The differences between the measured seasonal runoffs are caused by uneven snow distribution at the beginning of the monitoring seasons, with more snow in the western and northern parts of the valley compared to the eastern and southern parts, and in particular little snow in subcatchment A (Beylich *et al.* in press).

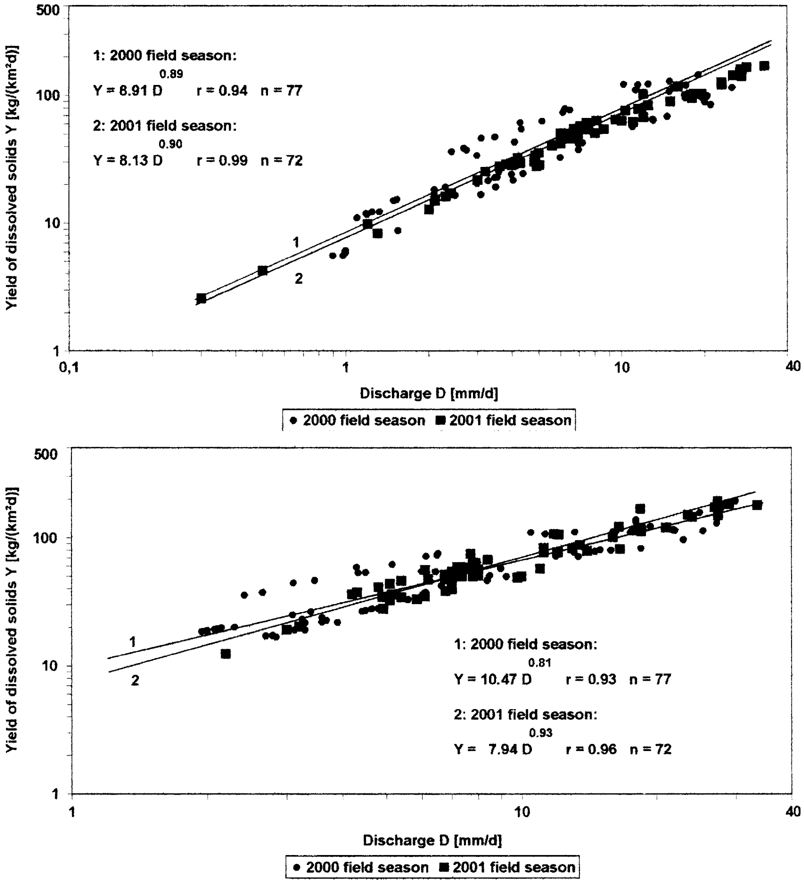

Figure 5 *Continued*

Defining the mean annual runoff at the inlet of Lake Latnjajaure (733 mm/yr) as representing the mean annual runoff for the entire Latnjavagge drainage basin (Beylich *et al.* in press), the mean annual gross yields can be calculated as 8840 kg/km^2 yr at the outlet of Latnjavagge, 8019 kg/km^2 yr at the outlet of Lake Latnjajaure, 5776 kg/km^2 yr at the inlet of Lake Latnjajaure, 11 332 kg/km^2 yr at the outlet of subcatchment A, 7542 kg/km^2 yr at the outlet of subcatchment B, 4823 kg/km^2 yr at the outlet of subcatchment C and 4882 kg/km^2 yr at the outlet of subcatchment D (Table 2).

Corrected by atmospheric solute inputs, the total annual gross yields provide information on the chemical denudation net rates within the Latnjavagge drainage basin. The mean annual atmospheric solute input in the area is 3436 kg/km^2 (Beylich *et al.* in press). According to that, the mean annual chemical denudation net rate of the entire Latnjavagge drainage basin is 5404 kg/km^2 yr. At the outlet of Lake Latnjajaure, the annual chemical denudation rate is 4583 kg/km^2 yr, at the inlet of Lake Latnjajaure 2340 kg/km^2 yr, in subcatchment A 7896 kg/km^2 yr, in subcatchment B 4106 kg/km^2 yr, in subcatchment C 1387 kg/km^2 yr and in subcatchment D 1446 kg/km^2 yr (Table 2). The annual chemical denudation net rates of the different subcatchments show a clear variation, with the lowest values in subcatchments C and D and the highest value in subcatchment A. The rates in Latnjavagge are much lower than the rates calculated by Rapp (1960) (26 000 kg/km^2 yr) and later by Darmody *et al.* (2000) (19 200 kg/km^2 yr) for Kärkevagge (see also Campbell *et al.* 2002), and also a bit lower than the denudation rate calculated by Beylich (1999, 2000) for the Austdalur drainage basin in East Iceland (8000 kg/km^2 yr; annual runoff 1130 mm/yr).

Table 1 Solute concentrations and water temperatures at the different measuring sites in Latnjavagge (field seasons of 2000–2003): see Fig. 2

Period of investigation	Sample site	Description	GPS position	TDS (mg/l)	Ca^{2+} (mg/l)	SO$_4^{2-}$ (mg/l)	Temp. (°C)
2000–2003	1	Pipe	68°21.583N 18°28.714E 983 m a.s.l.	29.1	4.9	11.2	3.7
2000–2003	2	Overland flow	68°21.529N 18°28.810E 982 m a.s.l.	9.3	1.2	2.6	6.7
2000–2003	3	Temporary creek	68°21.515N 18°28.825E 982 m a.s.l.	15.0	2.4	6.1	3.5
2000–2003	5	Outlet subcatchment B	68°21.376N 18°29.197E 981 m a.s.l.	10.3	1.1	3.6	6.5
2000–2003	6	Outlet Latnjajaure (lake)	68°21.263N 18°29.558E 981 m a.s.l.	10.9	1.6	4.5	4.7
2000–2003	7	Outlet subcatchment A	68°21.094N 18°29.735E 972 m a.s.l.	15.5	2.0	5.2	6.1
2000–2003	8	Outlet Latnjavagge	68°20.973N 18°29.827E 956 m a.s.l.	12.1	1.7	4.5	5.2
2000–2003	9	Tributary	68°21.272N 18°30.078E 1005 m a.s.l.	20.5	2.9	4.2	7.1
2000–2003	10	Temporary creek	68°21.296N 18°30.164E 1020 m a.s.l.	37.9	0.4	5.5	8.3
2000–2003	11	Tributary	68°21.406N 18°30.271E 1010 m a.s.l.	7.5	1.1	3.4	6.6
2000–2003	13	Creek below snow patch	68°21.569N 18°29.999E 981 m a.s.l.	31.7	4.7	8.3	6.1
2000–2003	14	Temporary creek	68°21.631N 18°29.952E 981m a.s.l.	26.5	3.5	7.8	8.0
2000–2003	15	Creek below snow patch	68°21.667N 18°29.941E 983 m a.s.l.	54.4	7.3	23.6	7.5
2000–2003	16	Creek below snow patch	68°21.872N 18°29.775E 984 m a.s.l.	33.7	4.2	8.3	7.2
2000–2003	17	Temporary creek	68°21.944N 18°29.513E 983 m a.s.l.	19.4	2.8	4.1	6.8
2000–2003	18	Inlet Latnjajaure (lake)	68°22.231N 18°29.278E 1000 m a.s.l.	7.9	1.0	2.1	5.7
2000–2003	19	Pipe, overland flow	68°22.458N 18°29.250E	9.6	1.0	2.9	8.6

Table 1 – *continued*

Period of investigation	Sample site	Description	GPS position	TDS (mg/l)	Ca^{2+} (mg/l)	SO_4^{2-} (mg/l)	Temp. (°C)
			1031 m a.s.l.				
2000–2003	20	Pipe overland flow	68°22.472N 18°29.220E 1032 m a.s.l.	8.1	1.0	2.7	9.0
2000–2003	21	Outlet subcatchment C	68°22.473N 18°29.208E 1031 m a.s.l.	6.6	1.0	1.8	6.7
2000–2003	22	Outlet subcatchment D	68°22.473N 18°29.208E 1031 m a.s.l.	6.7	1.0	2.0	5.3
2000–2003	23	Creek below ice patch/field	68°22.497N 18°29.092E 1043 m a.s.l.	6.8	0.7	2.3	5.1

As discussed by Darmody *et al.* (2000) and Thorn *et al.* (2001), chemical weathering and denudation appear to be more intensive in Kärkevagge than in other arctic or alpine areas, which is mainly due to the special lithological conditions in Kärkevagge. The calculated annual chemical denudation net rate in Latnjavagge is at a similar level as in a number of other subarctic, arctic and alpine areas (see Table 4 in Darmody *et al.* 2000; Beylich 1999, 2000; Beylich *et al.* in press).

Conclusions

The mean annual chemical denudation net rate in the Latnjavagge drainage basin is 5.4 t/km^2 yr and is much lower than the rates reported for the Kärkevagge valley which is situated a few kilometres NW of Latnjavagge and shows special lithological conditions. Most of the annual runoff in Latnjavagge occurs when the ground is still frozen. Chemical denudation shows a spatio-temporal variability, which is mainly caused by the spatio-temporal variability of ground frost and the spatial variability of regolith thicknesses within Latnjavagge. The gentle, radiation exposed W-facing slope and subcatchment A are the main source areas for dissolved solids, according to the ca. 1–1.5 months earlier thawing of the snow cover and ground frost, and larger regolith thicknesses in these areas. Subcatchments C and D, being characterized by larger bedrock areas in the upper parts, only shallow regolith in the lower parts and a significantly longer lasting snow cover and ground frost, show very low solute concentrations and small chemical denudation rates. The results discussed in this paper underline the importance of ground frost and regolith thickness as controlling factors of chemical denudation in a lithologically homogeneous artic–oceanic periglacial environment.

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Table 2 Runoff, solute yields and net chemical denudation rates in the Latnjavagge drainage basin, Swedish Lapland (2000–2003 field seasons)

Field season	Catchment	Precipitation (mm)	Runoff (mm)	Gross yield of dissolved solids (kg/km^2)	Annual net chemical denudation rate (kg/km^2 yr)
26/05/2000 – 31/08/2000	Latnjavagge	226	754	8985	
	Outlet Lake		734	8165	
	Inlet Lake		790	6561	
	Subcatchm. A		422	6522	
	Subcatchm. B		735	7838	
	Subcatchm. C		629	4281	
	Subcatchm. D		747	4912	
29/05/2001 – 18/08/2001	Latnjavagge	264	748	9087	
	Outlet Lake		754	8046	
	Inlet Lake		757	5626	
	Subcatchm. A		472	7296	
	Subcatchm. B		675	6343	
	Subcatchm.C		674	4255	
	Subcatchm. D		784	5212	
28/05/2002 – 31/08/2002	Latnjavagge	158	648	7795	
	Outlet Lake		650	7086	
	Inlet Lake		654	5143	
28/05/2003 – 31/08/2003	Latnjavagge	175	663	8062	
	Outlet lake		670	7397	
	Inlet lake		676	5340	
Annual yields; deunudation rates	Latnjavagge		733	8840	5404
	Outlet Lake			8019	4583
	Inlet Lake			5776	2340
	Subcatchm. A			11332	7896
	Subcatchm. B			7542	4106
	Subcatchm. C			4823	1387
	Subcatchm. D			4882	1446

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