Point-by-point response

Response to anonymous referee #1:

The manuscript is revised according to the comments provided by the reviewer. We appreciate the reviewer for his/her comments and suggestions, which help us improve the original manuscript. Thank you.

Our detailed response to every points:

Major points:

1. There is a lack of discussion on the results of glacial meltwater with previous works. A number of studies on glacial meltwater hydrology and hydrochemistry has already been conducted in Bayelva River as well as other Svalbard glacier basins. For example, Hodson et al. (2002) suggested that ice marginal and proglacial environments are the most important zones of solute acquisition in melt water, thus, some part of the POC and DOC appeared to be derived from glacial forefield soils. It also implies that carbon flux in glacier-fed rivers is likely to differ between land-terminated glaciers (like Bayelva) and tidewater glaciers. Authors should discuss carefully that how the measurements of the meltwater chemistry are representative in glacier-fed rivers of Svalbard using previous works (please discuss carefully with the papers listed below at least).

Hodson, A., Tranter, M., Gurnell, A., Clark, M., & Hagen, J. O. (2002). The hydrochemistry of Bayelva, a high Arctic proglacial stream in Svalbard. Journal of Hydrology, 257(1), 91-114.

Hodson, A., Gurnell, A., Tranter, M., Bogen, J., Hagen, J. O., & Clark, M. (1998). Suspended sediment yield and transfer processes in a small Highâ˘AR˘ Arctic glacier basin, Svalbard. Hydrological Processes, 12(1), 73-86.

Wadham, J. L., Hodson, A. J., Tranter, M., & Dowdeswell, J. A. (1998). The hydrochemistry of meltwaters draining a polythermalâ˘AR˘ based, high Arctic glacier, south Svalbard: I. The ablation season. Hydrological Processes, 12(12), 1825-1849.

Yes, previously there are lots of hydrology and hydrochemistry work that has been done for both the Bayelva river glacier basin, and other glaciers in Svalbard. Though these work is mainly based on inorganic parameters (e.g., several selected negative and positive ions) and TSM, the findings are essential to the latter work, and especially important to our organic work.

In the revised version, we added discussion of our results with the previous hydrology and hydrochemistry findings, while sticking to the organic matter theme of the present study. The clear existence of D form amino acids in the meltwater suspended particles is far over the abiotic racemization contribution, indicating the presence of bacteria, and this is in agreement with findings from previous hydrology/hydrochemistry work (Hodson et al., 2002). The bacteria discussion/comparison is added into the revised manuscript in last paragraph in section 4.1.1.

Another interesting point is the organic carbon concentration decreased along the Bayelva river. The TSM decreased from 741 mg/L at the glacier terminus to 214 mg/L at NVE stn and correspondingly the POC decreased from around 100 µM at the glacier terminus to 56 µM at NVE stn (Table 1). The decrease trend along Bayelva river agrees well with the previous findings that the proglacial sandur can be a major net suspended sediment sink throughout most of the remaining melt season (Hodson et al., 1998). While the reviewer suggested that ice marginal and proglacial environments are the most important zones of solute acquisition in melt water (Hodson et al., 2002), we carefully went through the table1 in that literature (i.e., Hodson et al., 2002). To

facilitate discussion, we directly copy that table1 here (see below)

Table 1
Summary statistics of the major ion, pH and Si data from the principal sampling sites. Mean values are presented followed by the standard deviation (in parenthesis) and the number of observations. 'VB' denotes the Vestre Brøggerbreen sampling site and 'WAB' denotes the western Austre Brøggerbreen sampling site (see Fig. 1 for locations). For the hillslope sampling site, 'soil water' denotes samples collected by suction sampling, whilst 'soil Qs' denotes overland flow

Site	Ca^{2+} (μEq l^{-1})	Mg^{2+} (μEq l^{-1})	Na^{+} (μEq l^{-1})	K^{+} (μEq l^{-1})	Cl^{-} (μEq l^{-1})	NO_3^{-} (μEq l^{-1})	SO_4^{2-} (μEq l^{-1})	HCO_3^{-} (μEq l^{-1})	SiO_2 (mg l^{-1})	pH
Lower, 1991	520 (130) *51*	170 (54) *59*	98 (66) *61*	8.8 (2.2) *59*	120 (87) *64*	1.6 (2.2) *61*	60 (27) *68*	620 (67) *68*	0.26 (0.10) *67*	7.03 (0.19) *69*
Lower, 1992	400 (60) *47*	120 (22) *47*	83 (90) *47*	6.8 (1.2) *47*	110 (120) *49*	1.4 (2.4) *49*	42 (21) *49*	530 (92) *49*	0.21 (0.06) *41*	7.00 (0.17) *48*
Upper, 1991	240 (50) *29*	81 (30) *28*	110 (110) *28*	6.7 (1.9) *30*	130 (130) *32*	2.4 (3.6) *33*	42 (23) *32*	300 (70) *31*	0.14 (0.07) *29*	6.84 (0.20) *30*
Upper, 1992	170 (60) *43*	70 (42) *49*	100 (130) *44*	5.9 (14) *48*	140 (170) *50*	3.0 (4.8) *50*	38 (40) *49*	230 (40) *50*	0.12 (0.05) *42*	6.92 (0.22) *50*
Snow, 1992	25 (41) *49*	34 (53) *45*	90 (110) *49*	4.5 (4.9) *49*	110 (160) *47*	1.5 (2.3) *46*	18 (35) *47*	11 (18) *7*	0.0 (0.0) *5*	–
Supraglacial	38 (43) 9	18 (14) 9	29 (14) 9	1.5 (1.7) 9	35 (19) 9	0.72 (0.90) 9	10 (7.0) 9	68 (52) 9	0.038 (0.074) 8	6.37 (0.55) 9
Soil water	2700 (810) *8*	1700 (500) *9*	180 (20) *9*	31 (8.3) *8*	120 (22) *8*	19 (10) *9*	240 (16) *9*	4100 (1500) *6*	3.3 (1.1) *8*	7.38 (0.19) *6*
Soil Qs	550 (300) *8*	360 (180) *8*	190 (271) *8*	13 (2.4) *8*	88 (20) *8*	1.5 (1.7) *8*	59 (36) *8*	870 (490) *7*	0.63 (0.14) *6*	
VB	520 (31) *3*	130 (23) *3*	42 (26) *3*	5.3 (1.2) *3*	48 (35) *3*	0.56 (0.49) *3*	32 (7.2) *3*	630 (12) *3*	0.23 (0.06) *3*	7.2 (0.07) *3*
WAB	510 (83) *7*	130 (28) *7*	38 (16) *7*	8.1 (2.4) *7*	44 (17) *6*	0.79 (0.77) *6*	27 (9.3) *6*	660 (75) *7*	0.24 (0.10) *7*	7.13 (0.06) *7*

And yes, for many ions (e.g., Mg^{2+}, K^{+}, and silicate …), the lower site concentration is higher relative to the upper site, as shown in above table (i.e., table 1 in Hodson et al., 2002), indicating the solute acquisition in melt water between upper and lower sites (i.e., the ice marginal and proglacial environments) and we also observed some nutrients increased downstream. But there are a few exceptions, like the nitrate (I highlighted $NO3^{-}$ in above table). Our result is in excellent agreement with the previous work: nitrate decreased (from 5.4 to 3.2 μM) and silicate increased (from 6.21 to 6.88 μM) along the river, and also we found that conductivity of the meltwater increased from upstream to downstream (from 29.8 μS/cm @BC stn to 74.8 μS/cm @NVE stn), indicating the increase of ion concentration in meltwater. As in this manuscript we are focusing on organic, we further compared dissolved organic carbon and found that dissolved organic carbon decreased from 167 μM at the glacier terminus (BC stn) to 73 μM at NVE stn. It is possible that the acquisition of solute along the river increased the conductivity of the meltwater, which in turn influenced flocculation and other processes (e.g., desorption/adsorption), so that the organic part is negatively influenced (i.e., decrease downstream). A new paragraph was added to the beginning of section 4.2, in order to describe the above POC/TSM/DOC variation discussion and comparison with previous work.

In addition, we also added "*Unlike temperate glaciers (e.g., alpine glaciers), suspended sediment in high arctic glaciers becomes increasingly available to the fluvial system through the melt season (Hodson et al., 1998) and hence the particulate organic carbon (POC) output may maintain at an elevated level throughout the melt season.*" in the introduction part (second paragraph in section 1). and added "*The manners by which melt water drains through the glaciers vary in Svalbard (Hodgkins, 1997) and the manners impact the melt water chemistry (Hodson et al., 2002; Wadham et al., 1998). Whether the melt water flows through supra-, en- or sub-glacial channels would have great impact on the nutrients, TSM and organic matter content in the glacier melt waters. Also, the ice marginal and proglacial environments play an important role in further modifying the organic carbon and nutrients content in glacier melt waters before it enters the sea (Hodson et al., 2002).*" into the discussion part (see the beginning of last paragraph in section 4.2), and modified the last sentence of section 4.2 into "*Consequently, the organic carbon flux will need to be further updated when tidewater glaciers contribution become available.*".

2. The difference in area-weighted carbon fluxes among glaciers is unlikely due to carbon process on the glaciers, but likely to thermal regimes in internal ice body of glaciers, which affect production of meltwater (e.g. Irvine-Fynn et al., 2011). Since the greater part of area of

Greenland ice sheet is cold frozen ice, which doesn't contribute the fluxes of meltwater and carbon, thus it is obvious that area-weighted fluxes are greater for Svalbard than Greenland. Therefore, the simple comparison of the area-weighted carbon flux between Svalbard and Greenland is worthless. Discharge-weighted average of those carbons is more appropriate to discuss the difference between the two glacial systems.

Irvine-Fynn, T. D., Hodson, A. J., Moorman, B. J., Vatne, G., & Hubbard, A. L. (2011). Polythermal glacier hydrology: a review. Reviews of Geophysics, 49(4).

Yes, thanks for the constructive suggestion. We calculated the discharge-weighted flux and made a new table 5 accordingly. Svalbard glaciers meltwater was higher both in discharge-weighted and area-weighted DOC flux when compared to Greenland ice sheet meltwaters (Table 5), indicating Svalbard glaciers is more efficient in generating DOC. But when compared with Alaska gulf glaciers meltwaters, Svalbard glaciers meltwater was 2.8 times higher in discharge-weighted DOC flux, whereas the area-weighted DOC flux was only 42% of that in Gulf of Alaska (Table 5). This is explained by the much higher meltwater discharge per unit area that yielded by Alaska gulf glaciers (~ 61 °N), relative to that yielded by Svalbard glaciers (76 °N ~ 80 °N). In another word, Svalbard glaciers meltwater was high in DOC concentration but low in discharge per unit area, whereas Alaska gulf glaciers meltwater was low in DOC concentration but high in discharge per unit area. A quantitative calculation further proves our idea. Namely, the area-weighted runoff for the glaciers in the Gulf of Alaska is 0.0042 km/year (320 km^3/year/75300 km^2) (Hood et al., 2009), whereas the area-weighted runoff for the glaciers in Svalbard is only 0.00068 km/year (25 km^3/year/36600 km^2). Hence glaciers in Gulf of Alaska yield 6.2 times higher meltwater in discharge when compared to glaciers in Svalbard in per unit area (i.e., 0.0042 vs. 0.00068), and this 6.2 times multiple relationship is very close to the multiple relationship between the area-weighted DOC flux and discharge-weighted DOC flux between the two glaciers, which is 6.6 times (namely (0.86/0.31)*(1.3/0.55), table 5). In another word, glacier meltwater in Alaska is high-in-discharge and low-in-DOC-concentration, whereas glacier meltwater in Svalbard is in the opposite situation, namely low-in-discharge and high-in-DOC-concentration.

Table 5. Estimated organic carbon flux for Svalbard glaciers and a comparison with other glacier systems (for formal version see manuscript).

	POC flux	DOC flux	area-weighted POC flux	area-weighted DOC flux	discharge-weighted POC flux	discharge-weighted DOC flux
	10^6 t/yr	10^6 t/yr	t/km2/yr	t/km2/yr	mg/L	mg/L
Svalbard archipelago	0.056 ± 0.02	0.02 ± 0.01	1.5 ± 0.5	0.55 ± 0.3	2.2	0.86
Greenland ice sheet	0.9 – 0.94	0.08 – 0.15	0.7 – 0.8	0.07 – 0.12	3.7	0.32
Gulf of Alaska		0.10 ± 0.01		1.3 ± 0.11		0.31

Accordingly, we modified the original statement (e.g., removed the carbon process explanation part), calculated the discharge-weighted organic carbon flux, made a new table 5 in the revised manuscript, and the above corresponding findings/discussion for discharge-weighted flux was added in the revised version (see the last but two paragraph in section 4.2).

Minor points:

- P15657 L15 Please explain what the source of POC in glacial meltwater is….

The following description is added in the revised version, in second paragraph in section 1 (introduction).

"*The main sources of organic carbon in glacial meltwater include bed rock and paleosoil at the bottom of glaciers and subglacial microbial activity (Sharp et al., 1999), the proglacial/ice margin (e.g., soils) (Hodson et al., 1998), and the cryoconite and supraglacial microbial contribution (Anesio et al., 2010; Irvine-Fynn et al., 2012)*."

- P16657 L23-24 But, there is a number of papers published microbial process of glaciers in Svalbard

Thanks for reminding. Yes, previously lots of microbial work has been done in Svalbard glaciers. Also, some of those microbial work is closely related to the present organic carbon work. For example, Irvine-Fynn et al., (2012) calculated the total fluvial export of cells and further estimated the corresponding carbon flux. This literature is now cited in the revised version at the same location.

- P15670 L1 "glacier mass balance" is incorrect. "glacial meltwater production" would be more appropriate in this case.

We agree. The original sentence was removed in the revised manuscript. Instead, we wrote "*The vast central part of the Greenland Ice Sheet can hardly contribute to the runoff materials flux and hence the different thermal regimes may be the reason for the much lower area-weighted fluxes of the Greenland Ice Sheet, when compared to the other two Svalbard and Alaska glaciers (Table 5)*". See the last but three paragraph in section 4.2 in the revised manuscript.

- P15670 L10-12 This is not convinced due to too small number and short period of the measurements.

To convince the reader, we further cited other people's work to support this idea that DOC in the meltwater maintained at high level throughout the ablation season for Svalbard glacier meltwaters. Namely, previous investigations covered the whole melt season also showed that DOC concentration in the meltwater is high throughout the melt season (our [DOC]: 73 µM; previous work [DOC]: all >165 µM from June to September)(Tye and Heaton, 2007). So the reported DOC concentration and hence high discharge-weighted DOC flux in Svalbard in this work (relative to glaciers in Gulf of Alaska and Greenland ice sheet) can be considered as a conservative estimate, and if based on previous work (Tye and Heaton, 2007), the DOC concentration and flux would be even higher.

- P15670 L18-20 I disagree this conclusion. The difference is due to the area of meltwater production as mentioned above.

The original conclusion was removed in the revised version. And the explanation to the low area-weighted discharge of Greenland ice sheet is now changed to "*The singular Greenland Ice Sheet is considerably greater in both area and thickness (>2000 m) than small glaciers in Svalbard and Alaska (Hood et al., 2009), which comprise small, relatively thin glaciers. The vast central part of the Greenland Ice Sheet can hardly contribute to the runoff materials flux and hence the different thermal regimes may be the reason for the much lower area-weighted fluxes of the Greenland Ice Sheet, relative to other two Svalbard and Alaska glaciers*" in the revised version. See the last but three paragraph in section 4.2 in the revised manuscript.

- Table 1 Indicate the time of collection since the concentrations of meltwater solutes usually change diurnally.

The time is now added into table1.

- Table 2 Please indicate which sample were used for the data.

For Bayelva river, we used all the samples that collected in the river, namely from the glacier terminus to NVE station. The salinity of these samples were all 0.

For floating ices: we collected floating ices in the fjord and those samples were determined for nutrients.

For fjord waters (surface): all the surface samples (0 m) collected in the fjord were used, including the estuary samples. All samples were salinity >0.

For fjord waters (near-bottom): the deep water samples in the fjord. Samples were all from the bottom layer, with depth deeper than 170 m (max.: 320 m). they are usually 15 m above the seabed.

We added the above information into both revised table 1 and table 2 in the revised manuscript.

- Figure 1a It would be worth to show all glaciers in the map to recognize the importance of glaciers in the fjord

Schematic for glaciers are now showed in the revised manuscript, fig. 1a and fig. 2.

Response to anonymous referee #2:

The reviewer listed four points in the comments as major points, followed by some further minor points. We will answer them point by point. We appreciate the reviewer's help in improving the original manuscript.

Thank you.

Major points:

(1) DOC, POC and TSM concentrations are possibly related to river discharge, i.e., higher concentrations during greater river discharge period. Did the authors compare DOC, POC and TSM concentrations (Table 1) with daily (or hourly) river discharge data? If these concentrations are function of river discharge, the authors should include the function for their DOC/POC flux estimations. In addition, it was not able to follow how the authors estimate fluxes of POC and DOC, including associated errors. The authors should describe the estimation methods of the fluxes. Especially, the authors should clarify how the authors determined errors associated with estimation of the fluxes. Also, the discussion regarding with representative of the Bayelva River in Svalbard (comparison of TSM, POC, DOC concentrations in the Bayelva River with those in other rivers at Svalbard) is necessary for better understandings of TSM/POC/DOC fluxes from Svalbard to ocean.

In this major comment, the reviewer mentioned several points together, and we will answer/response to them one by one:

--- is the DOC, POC and TSM correlated with discharge?

A detailed response was uploaded by us in the form of 'the author reply' in the interactive discussion. Briefly, during our observation, DOC/POC/TSM was not correlated with daily nor hourly discharge. We added "*During our observation, TSM, POC and DOC concentrations at NVE stn (Table 1) showed no relation with water discharge at the sampling day nor at the sampling hour (data not shown)*" into the discussion part. See second paragraph in section 4.2. The statistical result (e.g., r, p) is as follows (Table R2):

Table R2. Statistical result for the correlation analysis for Bayelva river discharge and its chemical parameters*

	TSM			POC			DOC		
	r	p	n	r	p	n	r	p	n
hourly discharge	-0.209	0.736	5	-0.499	0.392	5	-0.831	0.081	5
daily discharge	-0.822	0.087	5	-0.759	0.137	5	-0.034	0.957	5

*Note that 'significant related' is defined as $p < 0.05$ or $p < 0.01$

--- how do you calculate the flux and error? And the discussion regarding with representativeness of the Bayelva river in Svalbard

Basically, the DOC flux is calculated as concentration (in mg/L) multiplied by discharge volume (in km3 or m3). For POC, the Bayelva river annual POC flux is calculated in a similar way, namely POC

concentration (in mg/L, derived from NVE stn) multiplied by annual discharge (in m3, calculated from our instrumental record). For whole Svalbard POC flux estimate, we use our own POC content (in %) multiplied by the whole Svalbard TSM flux (cited from literature, in tons). As in this work we have a continuous observation for chemical parameters at NVE station in August, so the POC and DOC data set gave standard deviation. And the flux error is basically estimated as half of the standard deviation multiplied by discharge. The area-weighted flux and discharge-weighted flux is the flux divided by glacier area (in km2) or glacier annual runoff (in km3), respectively. A more detailed explanation for flux and error calculation was presented before, in the author reply to referee comments, and it can be found on the Biogeosciences web: http://www.biogeosciences-discuss.net/12/C7949/2015/bgd-12-C7949-2015-print.pdf
In the revised manuscript, we added the flux and error explanation in the materials and methods section (see last paragraph in section 2.4).

Though Bayelva river alone can hardly represent the whole Svalbard in a 100% manner, we argue that it will give us a result probably not deviated from the true value too much. A much more detailed explanation for its representativeness can be found in our previous reply to referee comments (http://www.biogeosciences-discuss.net/12/C7949/2015/bgd-12-C7949-2015-print.pdf). Briefly, the POC and DOC concentration in Bayelva river is comparable to other Svalbard meltwater (Kuliński et al., 2014; Stibal et al., 2008; Tye and Heaton, 2007). Also, the whole Svalbard glacier coverage is 55% (Lang et al., 2015) to 60% (Nuth et al., 2010), while the glacier coverage in Bayelva river basin is almost the same, namely 55% (Bogen and Bønsnes, 2003). The whole Svalbard annual TSM flux was estimated via the sediment yield rate of 586 t/km2/year (Hasholt et al., 2006), which was obtained from the Bayelva river basin. Also, Bayelva river is the earliest river that started in the long-term monitoring program of water discharge and sediment transport (by Norwegian Water Resource and Energy Directorate), which started in 1989 (Bogen and Bønsnes, 2003). Accordingly, in section 4.2, we added a paragraph assessing the representativeness of Bayelva river, before the discussion to the whole Svalbard flux: (see 3rd paragraph in section 4.2)
"*There are many meltwater rivers/creeks on Svalbard, and a comprehensive study to their organic carbon concentrations is not available. However, previous meltwater organic carbon study reveals that DOC in the meltwater rivers ranged from 165 – 426 μM (Stibal et al., 2008; Tye and Heaton, 2007), while POC content in common meltwater rivers is about 0.5% (Kuliński et al., 2014). DOC concentration in our study (Table 1) is lower when compared to these values, but POC content is very comparable to previous values (i.e., 0.35% vs. 0.5%). Further, the glacier coverage in Bayelva river basin is 55% (Bogen and Bønsnes, 2003), the same as the whole Svalbard, whose glacier coverage is also 55% (Lang et al., 2015). So the Bayelva river alone can hardly represent the whole Svalbard meltwater rivers in a 100% manner, but at least it enables the assessment, and the estimated flux is likely lower than the true value, given that its DOC and POC concentrations are lower when compared to other rivers and previous work.*"

(2) In section 4.1, the authors determined bacterial contribution to POC/PN (I could not follow how the authors determined the contribution). In addition, the authors determined bacterial contribution to POC/PN using D-Ala concentrations. Why did the authors determine bacterial contribution to POC/PN by two different ways? I think the latter is reasonable, and thus, recommend using only the latter estimation.

We agree.

We now only use the latter estimation as is suggested and so in the revised manuscript, bacteria THPAA nitrogen contribution to PN is now only based on D-ala concentration calculations. In the original manuscript, D-ala-based calculations was in 4.1.2 and the discussion of bacterial contribution to POC/PN was in 4.1.1. In order to make the manuscript read more smoothly and logic, we exchanged the old order of section 4.1.1 and 4.1.2 in the revised manuscript.

Furthermore, in the next comment the reviewer suggests the importance of non-living detritus. We agree. In the revised version, we slightly modified the terms of three sources that contribute their THPAA nitrogen to bulk PN, in order to make it read clearer. Namely, 1) bacteria and any detritus/non-living matter that contains D-Ala (calculated via D-Ala and conversion factor), 2) phytoplankton and any other detritus that contains chlorophyll a (calculated via chlorophyll a and conversion factor) and 3) the rest organic nitrogen detritus that were free of D-Ala and Chla (calculated via the inconsistency of AA contribution to PN), which is probably mainly derived from zooplankton.

Accordingly, we further revised the original term “zooplankton” into “zooplankton detritus” in the revised version (see last paragraph in section 4.1.2). Visible zooplankton had been manually removed during filtration but its detritus can hardly be avoided. Zooplankton detritus is largely free of D-Ala and chlorophyll a, so this part of nitrogen contribution cannot be covered in bacterial and phytoplankton sources. This may be one of the key sources for the non-living detritus mentioned by the reviewer.

Now, the phytoplankton, bacteria, zooplankton detritus THPAA nitrogen contribution to PN is 14%, 36% and 28%, respectively.

All these above description is added into the revised version, and please see new section 4.4.2.

(3) The authors discussed zooplankton-derived amino acids to PN in the fjord from the inconsistency of AA contribution to PN derived from calculation (using phytoplankton and bacterial derived AA) and measurements (of THPAA and PN). I think non-living AA also contributed to PN. The authors calculated the degradation index (DI) from AA composition. I think DI will be useful for evaluating contribution of non-living AA to PN.

Yes, non-living AA is an important source and we think that in the original manuscript, the term of ‘zooplankton contribution to PN’ is not so strict. We agree with the reviewer and instead we should described it as zooplankton detritus contribution to PN. Please see previous reply for detail.

About the DI for evaluating contribution of non-living AA to PN, thanks for the suggestion. We tested that but it didn’t work. The samples that were used to estimate the respective (e.g., bacterial, phytoplankton, detritus) THPAA nitrogen contributions were all surface fjord samples, and their DI values ranged narrowly from 0.41 to 0.76. As degraded OM (e.g., old sedimentary highly degraded OM) has a negative DI (e.g., -1) and totally fresh (i.e., pure phytoplankton) OM has a DI value as high as +1.5, so the DI range of 0.41-0.76 indicates that these samples concerned were basically fresh. A further statistical analysis indicates that DI values have no relationship with detritus THPAA nitrogen contribution ($r = -0.477$, $p = 0.0702$, $n=15$). We think this may due to that DI value is not directly related to the amount of non-living AA, but instead it is related to the overall degradation status of that OM (Dauwe et al., 1999). In another word, non-living detritus can have very depleted

DI value (e.g., some terrestrial or sedimentary OM, or those POM in Bayelva river), but some others can also have very positive DI value. For example, zooplankton detritus in the surface waters is fresh OM (it is not degraded, or is just at the beginning of degradation), but in the meantime it is non-living. In this study, surface fjord samples in the west open region showed DI value as high as 0.75 (6 #stn), while in the meantime pigments data (degraded chlorophylls) indicates strong grazing pressure and hence presence of zooplankton. I also recorded notable swimmers during the in situ filtration. As a result, we didn't show DI part in the discussion of detritus contribution to PN (i.e., section 4.1.2).

(4) The authors measured many organic matter parameters (listed in Table 1) for Kongsfjorden waters in addition to the Bayelva River. I think a new table which summarize the organic matter parameters for the river and the fjord waters (like as Table 2) will lead readers' better understandings, and thus, I recommend to adding a new table.

OK. We revised the old table 1 and expanded it, adding further other endmember (e.g., surface and bottom fjord samples) into this table. Now the new table 1 looks like as follows:

Endmember*		TSM	POC		$\delta^{13}C$	PN	THPAA	D-AA**	DI	Chla	DOC
		mg/L	μM	%	‰	μM	μM	nM		ng/L	μM
NVE station	8th 20:20	159	49	0.37	-23.8	13	0.8	29	-0.38	223	75
	12th 10:07	115	46	0.48	-24.1	8.3	0.6	18	0.69	213	98
	13th 20:15	169	58	0.41	-24.3	6.9	1.1	50	-0.51	209	80
	16th 18:30	281	55	0.23	-23.5	16	1.2	54	-0.44	264	21
	19th 16:25	345	70	0.25	-23.8	12	1.3	58	-0.06	377	92
NVE station	average	214	56	0.35	-23.9	11	1.0	42	-0.14	257	73
Fjord waters	average	41	23	1.1	-24.6	2.4	1.0	16	0.46	448	90.8
(surface)	(min~max)	(7.3~178)	(2~203)	(0.1~2.5)	(-26.1~-22.8)	(0.67~11)	(0.33~2.9)	(2.4~61)	(-0.18~0.76)	(47~1250)	(20~204)
Fjord waters	average	10.5	5.7	0.62	-24.5	0.21	0.36	5.9	0.42	nd***	109
(near-bottom)	(min~max)	(5.9~18)	(2.2~12)	(0.45~0.79)	(-25.2~-23.8)	(0.19~0.27)	(0.15~1.1)	(2.7~15)	(0.20~0.74)	nd***	(72~152)

Please refer to the revised manuscript for a detailed view for this table.

Minor points:

Specific comments Page 15656, line 11: Please use POC or PN rather than POM.

The POM is now changed to POC.

Page 15656, line 12: "particulate nitrogen" should be "particulate nitrogen (PN)"

Revised accordingly.

Page 15656, line 15: "particulate nitrogen (PN)" should be "PN"

Revised accordingly.

Figure 1: The characters in Figure 1 are too small and can not read.

The characters are enlarged this time.

Page 15659, lines 24-25: It seemed that the authors collect water samples from surface to deep layers of the fjord. Please clarify sampling layers/depths.

We modified the original sentence and now it reads "*When on the R/V Tiesten, we obtained salinity, temperature, fluorescence, and turbidity profiles using a CTD (SD204, SAIV A/S, Norway) and discrete water samples were usually collected at two layers (i.e., surface and near-bottom layer 15-20 m above seabed) via Niskin samplers. For comparison, discrete water samples were also measured with a portable water quality meter. When on rubber boat, only surface waters were collected/measured.*". See first paragraph in section 2.2.

Page 15660, lines 15-16: "_M" should be "_m"

Revised accordingly.

Page 15660, line 16: "cleaned" should be "filtered"?

Yes thanks. This was a clerical error. It is revised accordingly.

Page 15661, lines 1-2: Tryptophan is easily degraded during acid hydrolysis. Thus, the authors should remove tryptophan data for estimation of AA concentrations and compositions.

Yes, acid-hydrolysis induces loss of tryptophan. This amino acid is now removed from the revised manuscript.

Page 15662 line 22 - page 15663 line 2: I could not understand how the authors determined DI values. Did the authors use factor score coefficients reported by Dauwe et al. (2009)? Or did the authors conduct PCA? If the latter case, how did the authors collect plankton/bacteria and highly degraded oxic sediments?

The factor score coefficients were cited from the literature, so that it makes sense to compare our DI with previous reported DI valuess. We revised the original sentence to make it clearer and now it reads "*Factor score coefficients were calculated using principal component analysis and were directly cited from the literature (Vandewiele et al., 2009).*".

Page 15666, lines 14-25: I could not understand this paragraph, especially, how the authors estimate contribution of phytoplankton and bacterial AA to POC/PN. Please rephrase this paragraph.

In this paragraph, we were transferring the observed Chla (in ng/L) into algal THPAA nitrogen (in μM). The idea is that, chla can be converted into algal-POC, based on conversion factor (i.e., 50)(Hop et al., 2002). And algal-POC can further be converted into algal-PN, based on Redfield ratio (i.e., C/N = 6.6). As 70% of algal-PN is THPAA or protein (Dortch et al., 1984), so the algal THPAA nitrogen can be calculated via Chla and a couple of conversion factors concerned.

In the original version, we further described that we also calculated the bacterial AA contribution to PN via several other conversion factors. As was suggested to use the D-ala approach only to calculate the bacterial contribution to PN, so the bacterial part in this paragraph is removed in the revised version.

Accordingly, we revised the original paragraph. And now it reads "*Although the proportion of proteins and AAs in total-cell nitrogen varies (due to algae physiological status and inter-group phytoplankton differences), proteins, together with AAs, constitute the primary form of phytoplankton nitrogen and on average account for 70% of total algal cellular nitrogen (Dortch et al., 1984). By employing an algal POC:Chla ratio of 50 (Hop et al., 2002) and a Redfield ratio of 6.6 (Redfield et al., 1963), it is possible to estimate the contribution of phytoplankton THPAA nitrogen to PN via observed Chla concentration. For Kongsfjorden, we estimate the phytoplankton contribution as 14%. As the calculation was based on Chla, so the term phytoplankton here includes both algae and any other detritus/matters that contains Chla.*".

Response to short comments (namely J. Ru):

Thanks for the interest in our work.

A full reply to J. Ru's comments was made during the open discussion period and can be found on the internet. During our revise of the manuscript, however, some suggestions from J. Ru are also considered, especially the comments on the method part that unclearly describing the flux calculation and POC proportion. Some further specific comments are also considered during revision, in order to improve the original manuscript.

Major comments:

- The estimation method of POC proportion.

In this work, we assume that the labile POC is composed of amino acids-represented POC and algal-POC.

Amino acids carbon is calculated as: every amino acid concentration (nM) multiplied by its carbon atom number (based on its chemical molecular formula) equals the amino acid carbon amount (nM), and by combining all the amino acids carbon amounts together then we have the total amino acids carbon amount (nM, namely POC_{AAs}). Similar calculation can be done for nitrogen (nM, namely PN_{AAs}). In the manuscript, the amino acids carbon and nitrogen amount was first normalized to bulk POC or PN (i.e., POC_{AAs}/POC and PN_{AAs}/PN) for discussion in section 4.1.2 (first paragraph), and then in section 4.2, the amino acids carbon and nitrogen amount was taken as part of labile POM. Note that in the revised manuscript, at section 4.1.2 where we were describing the POC_{AAs}/POC and PN_{AAs}/PN values at the river end (i.e., conductivity = 0, see figure 3), the POC_{AAs}/POC and PN_{AAs}/PN values are now revised to the average value, namely 7% for POC_{AAs}/POC and 11% for PN_{AAs}/PN, respectively, and the corresponding sentence in the revised manuscript now reads: "*For the turbid glacier meltwater, phytoplankton pigments are depleted (Table1) and on average AAs account for 7% of the riverine POC and 11% of the riverine PN (Fig. 3a).*". In the old version, the values were reported as 10% and 20% for POC_{AAs}/POC and 11% for PN_{AAs}/PN at the river end, respectively. The 10% and 20% were from a direct-figure3-based-reading, and was not based on the original data. In order to make it more accurate, the proportions are now revised to 7% and 11%, respectively, which is based on the data set, instead of based on figure3-reading.

For phytoplankton carbon, we use the reported algal-POC:Chla ratio of 50 (Hop et al., 2002), and so by multiplying the Chla concentration (in µg/L) with a factor of 50, we got the phytoplankton carbon amount (in µg/L).

For the glacier meltwater samples, by adding its amino acids carbon and phytoplankton carbon amount together, the result is taken as the labile POC proportion, which is ~10% of bulk POM (9.5% for POC, 11% for PN).

In the manuscript, we revised the corresponding part (in section 4.2), and now it reads "*Based on the particulate biomarker analysis, the phytoplankton carbon in the glacier meltwater can be calculated by multiplying the riverine Chla concentration with the algal-POC:Chla ratio of 50 (Hop et al., 2002). Further given the AA carbon and nitrogen amount (i.e., POC_{AAs} and PN_{AAs}), AA and phytoplankton carbon together accounted for 9.5% of the POC flux, and nitrogen accounted for 11% of the PN flux. Assuming that AA and phytoplankton carbon represent the labile POM pool, the labile proportion in the total POM flux will be ~10% of the total POM flux (i.e., for POC flux, 9.5%; for PN flux, 11%).*".

- Details of flux on Svalbard

The calculation details of flux is now explained and can be found in the reply to previous reviewer.

Also, in the manuscript, we revised the method section (section 2.4 data processing and flux estimate), and adding the description of how we do the flux estimate there.

- I see there was little variability in TSM. Does the POC sources and concentration change little before and after the freezing period? It is clear that your methods that you couple the POC concentration in a short period with discharge measurements to calculate flux is not reasonable as well as the comparison between these fluxes and others.

In order to present the POC flux for glacier meltwaters, the best solution would be continuously monitoring the POC concentration during the whole ablation season, and then multiplied the result with discharge. In our work, and other reported work so far, however, a continuously OC monitoring for glacier meltwater covering the whole ablation season is not available. Instead, we present a POC flux for Bayelva river by multiplying the POC concentration during our August observation with the annual water discharge in that year, and this flux is taken as estimate for readers. In the manuscript, we first described how we did the flux estimate in section 2.4 and then we further present a detailed description showing the TSM and discharge complexity (see section 4.2, namely "*The annual water discharge of the Bayelva River in 2012 (29 × 106 m3) was relatively low compared with levels recorded between 1990 and 2001 (~27 × 106 to more than 40 × 106 m3) (Bogen and Bønsnes, 2003). Seasonally, some studies of glacier meltwater flux reported no clear temporal variability in the concentration of suspended particles over the course of the melt season (Bhatia et al., 2013), but other study suggests that highest TSM concentrations often occur late in the melt season, and that rain floods, instead of snowmelt, can cause the high concentrations (Bogen and Bønsnes, 2003). Inter-annually, sediment flux in the Bayelva River showed large variation, ranging from 5126 to 22797 t/year (Bogen and Bønsnes, 2003) over a 12-year observation. All these previous studies indicate the complexity of TSM concentration variation in glacier meltwater.*"). After that, we present the Bayelva river POC flux and other TSM, DOC flux. So we think we are not misleading the readers, while our work can present some useful data for people's further study of glacier meltwater flux. Also, we think our Bayelva POC flux estimate is reasonable, as our estimated POC flux for the Bayelva River (20 ton) is very close to a previous estimate (22 ± 3 ton/yr) for the 2011 season (Kuliński et al., 2014).

In the following part, when the whole Svalbard flux was derived from Bayelva river result, as was also mentioned by another reviewer, the representative of Bayelva river is necessary. We added the discussion of the representativeness and a detailed reply and the revise in the manuscript can be found in the reply to reviewer 2# (reply to his/her first major point).

- You provide no detail on the effect of tide on the C fluxes in the Bayelva River

At the NVE station, river water is free of tide influence and the tide effect is not considered in the flux estimate. In order to make it clear to the readers, we add this sentence in the method 2.4 section.

Specific points:

- Page 15660 line 20 AA should be AAs

Yes, in the text, AA first appears here. We changed the AA enantiomers into amino acid (AA) enantiomers.

- Page 15661 line 18: how to use HCl to remove inorganic carbon.

We use HCl vapor. And in the method part, we revised the original sentence into "*Following the removal of inorganic carbon with HCl vapor (Wu et al., 2013), POC and PN were measured with an elemental analyzer (Vario EL III: Germany).*" this time. See first sentence in third paragraph in section 2.3.`

- Tabel 1 &2: round off the significant digits

The significant digits in table 1 and 2 were all controlled to no more than 3.

- I do not think there is a robust link between pigment and POC. Pigment POC (abstract) does not equal to phytoplankton carbon (Pages 15670 Line 23). How to transfer them?

This was a clerical error. We revised it now into *"Amino acids (AAs) and phytoplankton carbon accounted for ~10% of the bulk POC in the Bayelva River,"* in the abstract.

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List of Changes

Based on the comments and suggestions from the reviewers, and also in order to improve the original manuscript, we have made changes to the original manuscript. Here we list all the relevant changes.
Indeed, all the relevant changes are also mentioned in the previous point-by-point response.

Change 1, Discussion of our result and previous hydrochemical findings are added in the revised manuscript:
A statement of sediment source would maintain available during the whole ablation season was added into the introduction part;
In last paragraph of section 4.2, a statement that citing previous hydrochemical work is made and added.
The D-amino acid is compared with previous bacteria work in last paragraph in section 4.1.1;
A new paragraph was added to the beginning of section 4.2, in order to describe and compare our POC/TSM/DOC variation with previous hydrochemical work.

Change 2, modify the area-weighted flux discussion and further add the discharge-weighted flux:
We followed the reviewer 1's suggestion and revised the explanation of area-weighted flux. Also we added discharge-weighted flux and relevant discussion in the revised manuscript (made a new table 5, and revised the section 4.2).

Change 3, made it clear whether DOC, POC and TSM were correlated with discharge:
We made a statistical analysis between our DOC/POC/TSM and river daily/hourly discharge and found not relationships. This is now described in the section 4.2, telling the readers that DOC, POC and TSM were not correlated with discharge.

Change 4, flux and error description:
We revised method section 2.4, and added how we did the flux and error estimate into section 2.4.

Change 5, representativeness of Bayelva river when scale up the flux from Bayelva river to whole Svalbard:
We added a paragraph in section 4.2 to discuss the representativeness of Bayelva River and its importance in glacier meltwater flux estimate.

Change 6, bacterial THPAA nitrogen contribution to PN calculation:
We removed the original conversion-factor-based approach for the bacterial THPAA nitrogen contribution to bulk PN, and use the D-ala-based approach only now in the revised manuscript. Note that to faciliate the discussion, we exchanged the original order of section 4.1.1 and section 4.1.2 in the revised manuscript (i.e., the original 4.1.1 is 4.1.2 in the revised version and the original 4.1.2 is 4.1.1 in the revised version).

Change 7, the non-living detritus THPAA nitrogen contribution to bulk PN and check for DI usefulness:

We changed the original notion that zooplankton contributed to PN into that zooplankton detritus contributed to PN in the revised manuscript.
We checked the DI for evaluating the non-living detritus contribution to PN, but it didn't work and hence not showed in the revised manuscript.

Change 8, add a new table showing all key chemical parameters in the study:
We modified the original table 1, expanded it, added fjord surface and bottom endmembers into the table, so that the organic matter parameters in the table now covers from rivers to fjords.

Change 9, the amino acids carbon and nitrogen amount in bulk POC and PN, the labile proportion of POC:
We carefully went through the original data set and revised the original POC_{AAs}/POC and PN_{AAs}/PN from 10-20% into 7% and 11%, respectively. In the original manuscript, the 10-20% was derived directly from the figure (Fig. 3a), instead of raw-data based. We think this is not appropriate and revised it in the revised version.
Also, to make it clear how we calculate the labile proportion of POC, we revised the corresponding sentences (in section 4.2) and now it reads "*Based on the particulate biomarker analysis, the phytoplankton carbon in the glacier meltwater can be calculated by multiplying the riverine Chla concentration with the algal-POC:Chla ratio of 50 (Hop et al., 2002). Further given the AA carbon and nitrogen amount (i.e., POCAAs and PNAAs), AA and phytoplankton carbon together accounted for 9.5% of the POC flux, and nitrogen accounted for 11% of the PN flux. Assuming that AA and phytoplankton carbon represent the labile POM pool, the labile proportion in the total POM flux will be ~10% of the total POM flux (i.e., for POC flux, 9.5%; for PN flux, 11%).*".

Change 10, tidal influence is not considered and we made it clear in the revised version:
As NVE station at the lower end of Bayelva river is free of tidal influence, we didn't consider tital influence in the flux discussion. So in the method section 2.4, we added one more sentence saying that the tidal influence is not considered.

Chang 11, all the rest response to the minor points and clerical error:
Small changes were also made in the revised manuscript, in order to response to the comments/suggestions on minor points and clerical error.

The marked-up manuscript was sent to editor by a separate email attachment, as I failed to combine the marked-up manuscript with the above point-by-point response and list of changes. I am sorry for the inconvenience.

Particulate organic matter composition and organic carbon flux in Arctic valley glaciers: Examples from the Bayelva River and adjacent Kongsfjorden

Zhuo-Yi Zhu[1], Ying Wu[1], Su-Mei Liu[2], Fred Wenger[3], Jun Hu[1], Jing Zhang[1], Rui-Feng Zhang[1]

[1] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai, China

[2] Key Laboratory of Marine Chemistry Theory and Technology Ministry of Education, Ocean University of China, Qingdao, Shandong, China

[3] Norwegian Water resources and Energy Directorate, Oslo, Norway

Correspondence to: Z. Y. Zhu (zyzhu@sklec.ecnu.edu.cn)

Abstract

In the face of ongoing global warming and glacier retreat, the composition and flux of organic matter in glacier-fjord systems are key variables for updating the carbon cycle and budget, whereas the role of Arctic valley glaciers seems unimportant when compared with the huge Greenland Ice Sheet. Our field observations of the glacier-fed Bayelva River, Svalbard, and the adjacent Kongsfjorden allowed us to determine the compositions of particulate organic matter from glacier to fjord and also to estimate the flux of organic carbon, both for the river and for Svalbard in general.

Particulate organic carbon (POC) and dissolved organic carbon (DOC) in the Bayelva River averaged 56 μM and 73 μM, respectively, in August, 2012. Amino acids (AAs) and phytoplankton ~~pigments~~carbon accounted for ~10% of the ~~particulate organic matter (POM)~~bulk POC in the Bayelva River, while AAs represented >90% of particulate nitrogen (PN) in fjord surface water, suggesting the strong in situ assimilation of organic matter. Bacteria account~~s~~ed for 13% and 19% of the POC in the Bayelva River and the Kongsfjorden, respectively, while values for PN ~~are~~were

much higher (i.e., 36% in Kongsfjorden).

The total discharge from the Bayelva River in 2012 was 29 × 10^6 m^3. Furthermore, we calculated the annual POC, DOC, and PN fluxes for the river as 20 ± 1.6 tons, 25 ± 5.6 tons, and 4.7 ± 0.75 tons, respectively. Using the POC content and DOC concentration data, we then estimated the annual POC and DOC fluxes for Svalbard glaciers. Although the estimated POC (0.056 ± 0.02 × 10^6 t/yr) and DOC (0.02 ± 0.01 × 10^6 t/yr) fluxes of Svalbard glaciers are small in amount ~~compared with those of the Greenland Ice Sheet~~, ~~the area-weighted and discharge-weighted POC~~POC flux of ~~Svalbard glacier meltwaters~~ ~~is comparable, or higher~~is ~~when compared to other pan-arctic glacier systems~~twice ~~that of the Greenland Ice Sheet, while the flux of DOC can be 4 to 7 times higher and Svalbard glacier meltwater is especially high in~~its discharge-weighted ~~DOC~~ flux of DOC was over twice higher than other pan-arctic glacier systems, suggesting its important role as an terrestrial DOC source~~. Therefore, we propose that valley glaciers are efficient high-latitude sources of organic carbon~~.

1. Introduction

The composition and flux of organic carbon are two key factors in the study of global climate change and material cycling. Current retreat of Arctic glaciers, as a consequence of global warming, not only contributes to sea-level rise but also serves to increase the input of terrigenous material to the ocean. This in turn impacts the composition of oceanic organic carbon and modifies the carbon flux, with potential ramifications for global climate variability and material cycles.

Terrigenous dissolved organic matter (DOM) in the Arctic Ocean exhibits a considerably shorter lifespan than that in the Pacific and Atlantic oceans (Opsahl et al.,

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1999). Furthermore, despite the ~~relative~~ depleted nature of ^{14}C values of glacial DOM, which results in old apparent ^{14}C ages, significant proteinaceous signals (Dubnick et al., 2010) and a high labile proportion (23% − 66%; Hood et al., 2009) were identified in the glacier meltwater DOM. This decoupling of age and stability in glacial DOM is probably due to the contribution of subglacial microbial communities (Sharp et al., 1999). The main sources of organic carbon in glacial meltwater include bed rock and paleosoil at the bottom of glaciers and subglacial microbial activity (Sharp et al., 1999), the proglacial/ice margin (e.g., soils) (Hodson et al., 1998), and the cryoconite and supraglacial microbial contribution (Anesio et al., 2010; Irvine-Fynn et al., 2012). ~~In contrast, the flux of~~ Unlike temperate glaciers (e.g., alpine glaciers), suspended sediment in high arctic glaciers becomes increasingly available to the fluvial system through the melt season (Hodson et al., 1998) and hence the particulate organic carbon (POC) ~~in~~output may maintain at an elevated level throughout the melt season. Indeed, the flux of POC in high arctic glacial meltwater is typically higher than that of DOC (e.g., Bhatia et al., 2013), while the labile proportion is relatively low (9%) (Lawson et al., 2014). As terrestrial DOC travels much farther away than POC does (Dittmar and Kattner, 2003), the DOC and POC impact of glacier meltwater to the ocean is different. By means of DOC, though both the total flux amount and refractory proportion are lower, glacier meltwater can exert great impact to the entire arctic ocean, whereas by means of POC, the ~~glacer~~glacier meltwater enhances the role of adjacent regional fjords and makes the fjords more important in the carbon cycle and budget. ~~Owing to the efficiency of erosion and transport within Arctic drainage basins and the high productivity of adjacent sea water, Arctic fjords contribute 11% of the global burial of marine organic carbon, yet comprise less than 0.1% of the global ocean surface~~ (Smith et al., 2015)~~. Therefore, particulate organic matter (POM) in~~

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~~Arctic glacial meltwater and adjacent fjords is an important component of the global carbon cycle and budget~~.

To date, most studies of organic matter in Arctic glacial meltwater have focused on the Greenland Ice Sheet (e.g., Bhatia et al., 2013; Lawson et al., 2014), with little attention paid to smaller valley glaciers, such as those on Svalbard (Irvine-Fynn et al., 2012; Kuliński et al., 2014; Tye and Heaton, 2007). However, a comparison of Alaskan glaciers (Hood et al., 2009) and the Greenland Ice Sheet (Bhatia et al., 2013) reveals that valley glaciers exhibit higher area-weighted fluxes of organic carbon. Although regional fluxes of POC have been estimated for glaciers on Svalbard (Kuliński et al., 2014), the area-weighted and discharge-weighted fluxes of organic carbon for the entire archipelago has yet to be determined. Furthermore, to our knowledge, little or no information exists on potential labile proportions in Svalbard glacial meltwater POM, or on the POM composition of glacier meltwater that enters adjacent fjords.

We carried out field observations of the Bayelva River and Kongsfjorden in summer of 2012. Using amino acid enantiomers and phytoplankton pigments as biomarkers, we first focused on variations in POM composition between glacial meltwater and the fjord. Subsequently, we employed 2012 discharge data for the Bayelva River to estimate the riverine flux of organic matter, and up-scaled this flux to cover the whole of Svalbard with representativeness discussion. Finally, we compared the organic carbon flux in Svalbard with that of other Arctic glaciers, including the Greenland Ice Sheet.

2. Materials and Methods

The Bayelva River in Ny-Ålesund, Svalbard, is the principal meltwater channel

draining the Austre Brøggerbreen valley glacier into Kongsfjorden (also known as Kings Bay). Downstream of the glacier terminus, a hydrologic station collects river discharge data during the freshet. The physical and biological characteristics of Kongsfjorden have been summarized by Hop et al. (2006). Nitrogen limitation of primary production occurs during summer months (Rokkan Iversen and Seuthe, 2011), when stratification of the water column and input of nutrient-depleted glacial meltwater results in oligotrophic surface water in the inner fjord (e.g., increase proportion of cyanobacteria and cryptophytes in surface phytoplankton communities; Hop et al., 2002). Moreover, where turbid meltwater has yet to mix with clear sea water, phytoplankton growth is limited by reduced illumination (Svendsen et al., 2002). In the outer fjord, the high abundance of zooplankton exerts considerable grazing pressure on algae, resulting in a relatively low standing stock in surface water (Hop et al., 2002).

The study area is shown in Figure 1a. The Bayelva River is ~4 km long and occupies a basin underlain by Permian and Carboniferous lithologies (Hjelle, 1993). In normal years, river flow begins in early–mid June, while the riverbed and banks are still frozen, and for approximately 10 days the water flows clear. Subsequently, the river flow becomes turbid and remains so until the river refreezes in autumn (usually in September/October). In Kongsfjorden, which lacks a sill at its mouth, the exchange of intermediate and deep fjord water with Arctic Water and Atlantic Water is facilitated by a prominent trench that decreases in depth towards the shallow continental shelf (Svendsen et al., 2002).

2.1 Monitoring discharge of the Bayelva River

Approximately 700 m upstream from where the river enters the fjord, a monitoring

station (NVE; Fig. 1b) is operated by the Norwegian Water Resources and Energy Directorate, and includes an artificial concrete flume with a so-called crump weir. Water level is measured using a system comprising a float, counterweight, and encoder, and the data are stored in a logger. Ultimately, water discharge is determined using a rating curve. In 2012, discharge data were collected between 15 June and 1 October. For the remainder of the year, data collection was not possible due to freezing.

2.2 Field observations and biogeochemical sampling

We conducted our field investigation between 6 and 19 August 2012. The area sampled covers both the Bayelva River basin and Kongsfjorden (Fig. 1b). For the terrestrial stations, we carried out our investigation on foot, collecting samples with a pre-cleaned bucket. Using a portable water quality meter (WTW®, multi 350i, Germany), which was calibrated daily, we measured salinity/conductivity, temperature, pH, and dissolved oxygen. For the marine/estuarine stations, sampling was carried out from the R/V *Tiesten* or a rubber boat~~, and samples were collected using Niskin samplers~~. When on the R/V *Tiesten*, we obtained salinity, temperature, fluorescence, and turbidity profiles using a CTD (SD204, SAIV A/S, Norway) and ~~discrete~~discrete water samples were usually collected at two layers (i.e., surface and near-bottom layer 15-20 m above seabed) via Niskin samplers.~~.~~ For comparison, discrete water samples were also measured with the~~a~~ portable water quality meter. When on rubber boat, only surface waters were collected/measured. Both terrestrial and marine samples were returned immediately to the marine laboratory for processing. Additionally, clean floating ice, without visible soil or sediment, was collected from the fjord for analysis of dissolved nutrients.

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In the laboratory, suspended particles were concentrated onto pre-combusted glass fiber membranes (Whatman®, GF/F, pore size 0.7 µM) under a mild vacuum, before being analyzed for total hydrolysable particulate amino acids (THPAA), particulate nitrogen (PN), phytoplankton pigments, and particulate organic carbon and its stable isotopes (POC and $\delta^{13}C$). Filtration volume ranged from 0.09 to 5.4 L, depending on the concentration of suspended particles. During filtration, visible swimmers (Calanoida and other zooplankton) were observed in fjord samples, especially those from open western areas. Whenever possible, all swimmers were removed from the membrane prior to storage, using clean tweezers. Water samples for dissolved nutrients were filtered through acid-cleaned acetate cellulose filters (pore size 0.45 µm~~M~~), whereas samples for DOC were ~~cleaned~~ filtered using nylon filters (pore size 0.45 µm~~M~~) and a syringe. Nutrient samples were poisoned with $HgCl_2$ and stored at 4°C in the dark. All other samples were kept frozen (−20°C) until laboratory analysis.

2.3 Instrumental measurements

Our measurement of amino acid (AA) enantiomers followed the protocol of Fitznar et al. (1999), a detailed description of which is provided by Zhu et al. (2014). Briefly, GF/F filters were first freeze-dried and then hydrolyzed with HCl at 110 °C for 24 hours. Following pre-column derivatization with *o*-Phthaldialdehyde and *N*-Isobutyryl-L/D cysteine (IBLC/IBDC), AA enantiomers were measured in hydrolyzates using a High Performance Liquid Chromatography (HPLC) system (1200 series, Agilent, USA). Asx and Glx were used for aspartic acid + asparagine and for glutamic acid + glutamine, respectively, due to the corresponding acids being formed through deamination during hydrolysis. In addition to Asx and Glx, we measured alanine (Ala), arginine (Arg), isoleucine (Ile), leucine (Leu), lysine (Lys),

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methionine (Met), phenylalanine (Phe), serine (Ser), threonine (Thr), ~~tryptophan (Try),~~ tyrosine (Tyr), and valine (Val). The non-chiral AAs, γ–aminobutyric acid (GABA) and glycine (Gly), were also measured. The D forms of AAs (D-AAs) generated by acid hydrolysis were calibrated according to Kaiser and Benner (2005). ~~The degradation index (DI) was derived from the AA data set using the calculations of Dauwe and Middelburg with minor modifications.~~

Phytoplankton pigments were extracted with N,N-dimethylformamide and analyzed using an HPLC system (1100 series: Agilent, USA), following a modified version of the method of Mantoura and Llewellyn, (1983) and Van Heukelem and Thomas (2001). Solvent A was methanol and 1 mol/L ammonium acetate (80:20, v/v), and solvent B was pure methanol. A detailed description of the gradient elution procedure is given by Huang et al. (2010). We identified pigments by their retention times and absorption spectra, using a set of 21 pigment standards (chlorophyll c3, chorophyllide a, chlorophyll c1+c2, peridinin, 19'-butanoyloxyfucoxanthin, fucoxanthin, neoxanthin, prasinoxanthin, 19'-hexanoyloxyfucoxanthin, violaxanthin, diadinoxanthin, alloxanthin, diatoxanthin, zeaxanthin, lutein, chlorophyll b, chlorophyll a, β,ε-carotene, β,β-carotene, pheophorbide a, and pheophytine a) obtained from DHI (Denmark).

Following the removal of inorganic carbon with HCl vapor (Wu et al., 2013), POC and PN were measured with an elemental analyzer (Vario EL *III*: Germany). The detection limits for carbon and nitrogen were 7.5 and 8.0 µg, respectively, with a precision better than 6%. We measured $\delta^{13}C$ samples using an isotope-ratio mass spectrometer (Deltaplus XP: Thermo Finnigan, USA) connected to a Flash EA 1112 analyzer. The $^{13}C/^{12}C$ is expressed in per mil relative to the V-PDB standard using the conventional δ notation. DOC samples were measured with a TOC analyzer

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(TOC-L_{CPH}: Shimadzu, Japan), whereas ammonium was measured manually using the sodium hypobromite oxidation method, with an analytical precision of 0.04 μM. The other four nutrients were measured using an auto-analyzer (AA3: SEAL Analytical, USA), with the precisions of nitrate, nitrite, dissolved inorganic phosphorus (DIP, PO_4^{3-}), and silicate (~~H_4SiO_4~~)SiO_3^{2-}) being 0.01, 0.003, 0.005, and 0.02 μM, respectively. The concentration of total suspended matter (TSM) was determined from POC samples (i.e., GF/F filters).

2.4 ~~CHEMTAX and DI calibration~~Data processing and flux estimate

We applied CHEMTAX to the phytoplankton pigment data set to estimate the structure of phytoplankton communities (Mackey et al., 1996). To avoid apparent changes in diagnostic pigment ratios, we avoided riverine samples and focused solely on samples from the fjord surface (Mackey et al., 1997). Based on our observations and those of previous workers (Not et al., 2005; Piquet et al., 2014; Schulz et al., 2013), the phytoplankton groups analyzed in this study include diatoms, cryptophytes, prasinophytes, dinoflagellates, haptophytes (e.g., *Emiliania* Hay and Mohler, *Phaeocystis* Lagerheim), chlorophytes, cyanobacteria (e.g., *Synechococcus*), and chrysophytes. Initial ratios are similar to the values reported by Not et al. (2005) for a neighboring study area. Finally, we present ratio data from a single CHEMTAX run, as our attempt at ratio-iteration (Latasa, 2007) produced anomalous results.

We note that the taxonomic terms are operationally defined based on the composition of the diagnostic pigments. Therefore, “chlorophytes” includes both chlorophytes and prasinophytes lacking prasinoxanthin. Similarly, “diatoms” may include both diatoms and some haptophytes and chrysophytes with a similar pigment composition. “Haptophytes” refers to the specific type of algae with both

19'hexanoyloxyfucoxanthin and fucoxanthin; e.g., *Emiliania* and *Phaeocystis*, which have been found in previous studies of Kongsfjorden (Piquet et al., 2014).

The degradation index (DI) was derived from the ~~DI was calculated using the~~ THPAA data set developed by Dauwe et al. (1998) and later modified by Vandewiele et al. (2009):

$$DI = \sum_{i} \left(\frac{var_i - AVG\ var_i}{STD\ var_i} \times fac.coef._i \right)$$

where var_i, AVG var_i, STD var_i, and $fac.coef._i$ are the mol%, mean, standard deviation, and factor score coefficient of amino acid i, respectively. Factor score coefficients were calculated using principal component analysis and were directly cited from the literature (Vandewiele et al., 2009). The index ranges from +1 for phytoplankton/bacteria to −1.5 for highly degraded oxic sediments.

For Bayelva River materials flux estimate, it is calculated as materials concentration during our observation at NVE station (in mg/L) multiplied by the 2012 annual river discharge ~~volumn~~volume (in m^3). At the NVE station, river water is free of tide influence and the tide effect is not considered in the flux ~~estimate~~discussion. For whole Svalbard POC flux estimate, we use our own POC content (at NVE station, in %) multiplied by the whole Svalbard TSM flux (cited from literature, in tons). For whole ~~svalbard~~Svalbard DOC flux estimate, we use DOC concentration in our study (at NVE station, in mg/L) multiplied by annual runoff of the whole Svalbard (cited from ~~lilterature~~literature, in km^3). The error for flux estimate is calculated as ~~as~~ half of the standard deviation of DOC (or POC) multiplied by discharge. The area-weighted flux and discharge-weighted flux is the flux divided by glacier area~~–~~ (in km^2) and annual runoff (in km^3), respectively.

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3. Results

Reflecting the considerable turbidity of the Bayelva River, we recorded TSM concentrations of up to 345 mg/L at the NVE station (Table 1) and as high as 740 mg/L at the BC station (Fig. 1b). Mean ~~R~~riverine POC at NVE station was 56 µM, while the POC content in TSM (i.e., POC%) averaged 0.35% (Table 1). Particulate AAs at the NVE station were low, with an average value of 1 µM (Table 1). Also at the NVE station, D-AAs averaged 42 nM (Table 1) and the proportion of D-AAs in THPAA was 4.0%. While trace amounts of several pigments were measured in the river, chlorophyll a (Chla) was the dominant pigment, with a mean concentration at NVE station of 0.2~~57~~6 ~~n~~µg/L (Table 1). In contrast, the principal diagnostic riverine pigment, fucoxanthin, gave a mean value at NVE station of 54 ng/L. Over the course of our observation, DOC concentrations at NVE station ranged from 20.8 to 97.8 µM, with a mean value of 73 µM (Table 1). In 2012, the annual water discharge of the Bayelva River was 29 × 10^6 m^3 according to the hourly-averaged instrumental record.

In Kongsfjorden, surface concentrations of TSM, POC, and THPAA generally decreased from the eastern end, where tidewater glaciers enter the sea, to the open western end. We identified an additional area of high concentration close to the Bayelva River mouth (Fig. 2a−c). The POC% of surface water averaged 1.3% in the marine sectors (i.e., S > 30) of the fjord, and POC% of all the surface fjord samples averaged 1.1% ~~of all the surface fjord samples~~ (i.e., S >0), but it fell to 0.62% in near-bottom water (Table 1). In comparison, the mean POC% of Bayelva River (e.g., at NVE station~~n~~) water was 0.35% (Table 1). $\Delta\delta^{13}C$ values of samples from the Bayelva River NVE ~~stationn~~station, the fjord surface, and near-bottom fjord water averaged −23.9~~4~~‰, −24.6‰, and −24.5‰, respectively (Table 1). The distribution of

PN was similar to that of POC, with the PN content in TSM (PN%) in near-bottom water and Bayelva River water being comparable. The mean PN% of samples from the fjord surface, near-bottom, and Bayelva River was 0.17%, 0.06%, and 0.07%, respectively. Not only was the DI of fjord surface water (~~0.54~~0.46) higher than that of river water (−0.1~~43~~) (Table 1), we also observed elevated DI values (e.g., 0.7~~56~~ at station 6#) in the western part of the fjord, where high concentrations of Chla and chlorophyllide a occurred (Fig. 2d&e). The DI value of near-bottom water was 0.42 (Table 1). D-AAs were higher in concentration in glacier meltwaters (i.e., Bayelva ~~river~~River) when compared to both fjord surface and near-bottom water (i.e., 42 nM vs. 16 nM and 5.9 nM; Table 1). The proportion of D-AAs in the fjord surface water (1.6%) was lower than that of the Bayelva River (4.7%) and of near-bottom water (1.8%), whereas levels of the non-protein AA, GABA, averaged 0.92 nM in fjord surface water and 2.6 nM in the Bayelva River. GABA was most depleted in the near-bottom water (mean value of 0.49 nM).

A clear difference ~~t~~~~exists~~existsed in the concentration of dissolved nutrients among respective regions/sources. For example, both the river water and floating glacier-derived ice were~~are~~ depleted in nutrients, whereas high concentrations of nutrients occurred in the near-bottom water of Kongsfjorden, beneath the pycnocline (Table 2). Despite this disparity in concentration, nitrate was~~is~~ the main form of dissolved inorganic nitrogen (DIN) in both the river water and the fjord near-bottom water (Table 2).

Cyanobacteria, chrysophytes, and dinoflagellates occurred only in trace amounts in the fjord surface water, where diatoms were~~are~~ the primary contributor to the total fjord phytoplankton biomass (i.e., Chla), followed by cryptophytes. On average, diatoms contributed half of the total phytoplankton biomass, with cryptophytes

contributing another 28% (Table 3). In western and middle parts of the fjord, diatoms ~~are~~were dominant, whereas in other regions there ~~i~~was a greater contribution from tiny cryptophytes. For example, at stations 14# and 15# (Fig. 1a), cryptophytes accounted for 40% and 48% of the total Chla, respectively.

4. Discussion

4.1 POM composition and implications

4.1.1 Bacterial influence on amino acid enantiomers and its contribution to POM

Bacteria plays an important role in organic matter composition (Rokkan Iversen and Seuthe, 2011). In a study at two other two marine sites (BATS and HOTS) at lower latitudes, Kaiser and Benner (2008) suggested that 12%–32% of the POC and 20%–64% of the PN were derived from bacteria. In Kongsfjorden, bacterial contributions to POC and PN can also be estimated. Here, we exploited the universal distribution of D-Ala in bacteria to calculate the amounts of bacterial organic carbon and nitrogen. Additionally, considering the potential differences between riverine and marine bacterial community structures, we estimated bacterial contributions for both riverine and marine samples (Table 4). For riverine samples (i.e., S = 0), we used only freshwater culture data from table 2 of Kaiser and Benner (2008) for the D-Ala converting factor, whereas for marine samples (i.e., S > 30) the D-Ala converting factor is based solely on marine bacteria (Kaiser and Benner, 2008). Note that ~~also that~~ the D-Ala-based estimates would also include contribution of any non-living detritus that contained D-Ala.

In Kongsfjorden, the bacterial contribution to POC (19%; Table 4) was well within the value reported by Rokkan Iversen and Seuthe (2011) based on the cell density and conversion factor approach, and it was similar to values reported for other marine

regions at lower latitudes (Kaiser and Benner, 2008). The bacterial contribution to POC was slightly lower (13%) in the Bayelva River. With respect to nitrogen, the bacterial contribution accounted for 36% of PN in fjord water (Table 4).

Given that D-Ala occurs widely in biopolymers, whereas D-Glx is present in relatively few bacterial compounds, the overall D-Ala/D-Glx ratio would become >1 (Kaiser and Benner, 2008 and ref. therein). Both the riverine ($r = 0.83$, $p = 0.006$, $n = 9$) and fjord ($r = 0.95$, $p < 0.001$, $n = 31$) D-Ala levels were strongly related to their respective D-Glx levels, exhibiting almost identical slopes (river: 1.26, fjord: 1.21; Fig. 4). The D-Ala/D-Glx slopes in both the river and the fjord (i.e., 1.26 and 1.21, respectively; Fig. 4) are comparable to the reported D-Ala/D-Glx value of 1.3 ± 0.4 (Kaiser and Benner, 2008), which was derived from a pure bacteria culture that included both marine/fresh and heterotrophic/autotrophic bacteria. Given that Glx has a higher abiotic racemization rate than Ala (Wehmiller et al., 2012), the slightly higher D-Ala/D-Glx slope for river samples relative to fjord samples (i.e., 1.26 vs. 1.21; Fig. 4) indicates that D-AAs in riverine suspended particles likely originate from a modern contribution (e.g., bacteria) rather than abiotic racemization in the river basin. The presence of bacteria and their modification of OM in both subglacial (Sharp et al., 1999) and supraglacial (Anesio et al., 2010) regions have been confirmed in previous study. As for the Bayelva River basin, previous hydrochemical data (e.g., NO_3^-/Cl^-) also indicated that there is nitrification process in the soils that contributes to riverine nutrients (Hodson et al., 2002), and hence the presence of bacteria.

4.1.~~1~~2 In situ POM assimilation in Kongsfjorden

The contribution of AAs to the total carbon and nitrogen budgets reflects the freshness of POM (Davis et al., 2009). Using our measurements of THPAA, we calculated AA carbon and nitrogen amounts, and normalized the results against bulk POC and PN,

respectively (i.e., POC_{AAs}/POC and PN_{AAs}/PN, in %). For the turbid glacier meltwater, phytoplankton pigments are depleted (Table1) and on average AAs account for ~~only~~ ~~10~~7% of the riverine POC and 11%~~–20%~~ of the riverine ~~POC and~~ PN (Fig. 3a). In contrast, the PN_{AAs}/PN of Kongsfjorden is as high as 90%, with an average of 78% (Fig. 3a). With the exception of one outlier, Chla/POC values rise gradually from glacier meltwater to the fjord surface water (Fig. 3a), suggesting an increasing contribution from in situ POM production.

In the case that other obvious sources of protein and AAs are negligible, we attribute the increasing PN_{AAs}/PN in the fjord (i.e., samples with S > 0) to the in situ assimilation of ambient nitrogen via autotrophs (e.g., phytoplankton) and further transfer within the food web (PN_{AAs}/PN vs. Chla: r = 0.49, p = 0.01, n = 25; Fig. 3b). As glacier meltwater is rich in TSM (Fig. 2a; Table 1), the observed distribution of POM composition suggests that light is a limiting factor for organic matter (OM) assimilation in the fjord surface water (i.e., PN_{AAs}/PN vs. TSM: r = −0.79, p < 0.001, n = 25; figure not shown). However, since the fjord is also characterized by a very low N/P ratio ~~(Bazzano et al., 2014)~~, as confirmed by our data (the mean N/P ratio in fjord surface water is 7.7), nitrogen could be another limiting factor for primary production (Rokkan Iversen and Seuthe, 2011). This effect is suggested by the distribution of POM composition when plotted against nitrate (PN_{AAs}/PN vs. nitrate: r = −0.72, p < 0.001, n = 25; Fig. 3b). However, PN_{AAs}/PN is not related to ammonium or nitrite (figure not shown).

Although ammonium is typically the preferred nitrogen nutrient for phytoplankton, we found nitrate, rather than ammonium, to be coupled with POM assimilation in Kongsfjorden (Fig. 3b). As glacier meltwater is depleted in nutrients relative to fjord water (Table 2), the seaward dilution effect on nitrate is expected to play a minor role

in the coupling between nitrate and POM assimilation (Fig. 3b). Instead, surface-water ammonium originates primarily from zooplankton, which exerts grazing pressure on phytoplankton and also leads to increased PN_{AAs}/PN (Fig. 3b). Also, as estimated by CHEMTAX (Table 3), diatoms are the principal phytoplankton group, particularly in open-fjord environments such as western Kongsfjorden. Previous work, using cultured diatoms preconditioned for nitrate, has shown that ammonium uptake in diatoms can be inhibited by nitrate (Dortch and Conway, 1984). In Kongsfjorden, inflowing Atlantic water masses are the main source of nutrients for phytoplankton (Hegseth and Tverberg, 2013). Therefore, since nitrate wa~~i~~s the main form of DIN in Atlantic water (Table 2), it is possible that the presence of diatoms in the fjord induce~~s~~d (or enhance~~s~~d) the nitrate limitation during OM assimilation (Fig. 3b).

Although the proportion of proteins and AAs in total-cell nitrogen ~~can vary~~varies (due to algae physiological status and inter-group phytoplankton differences), proteins, together with AAs, constitute the primary form of phytoplankton nitrogen and on average account for 70% of total algal cellular nitrogen (Dortch et al., 1984). ~~In bacteria cells, however, the ratio of bacterial carbon to protein/AA nitrogen has been calculated as 7.46 on the basis of bacteria protein:cell dry weight ratios, carbon:cell dry weight ratios, and AA compositions of bacterial proteins . Furthermore, b~~By employing an algal ~~phytoplankton~~ POC:Chla ratio of 50 (Hop et al., 2002) and a Redfield ratio of 6.6 (Redfield et al., 1963)~~, and considering that bacteria, on average, account for 20% of fjord POC ,~~, it is possible to estimate the contribution of phytoplankton ~~and bacteria~~ THPAA nitrogen to PN via observed Chla concentration. For Kongsfjorden, we estimate the ~~this~~ phytoplankton ~~total~~ contribution as ~~38~~14%. As~~Due to~~ the calculation was based on Chla, so the term phytoplankton here includes

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both algae and any other detritus/matters that contains Chla.

On average, THPAA nitrogen accounted for 78% of the fjord PN (Fig. 3a), given that bacteria ~~(and any other detritus/matters that contains D-Ala)~~ THPAA nitrogen contributed ~~another~~ 36% of the PN (Table 4) and phytoplankton contributed another 14%,~~;~~ so there is~~leaving~~ ~~40~~28%~~ ~~ of the THPAA nitrogen contribution unaccounted for ~~(i.e., 78 − 14 − 36 − 28)~~. We suggest that this inconsistency results from uncertainty and limitation in the above estimates and from the detritus that were free of both D-Ala and Chla~~, particularly concerning the bacteria~~. The samples with PN_{AAs}/PN > 70%, however, were all obtained from the open western end of the fjord, where zooplankton are abundant (Hop et al., 2006), and we also observed abundant zooplankton during filtration. Though zooplankton were ~~mannually~~manually removed during filtration, their detritus can hardly be avoided, which can be free of D-Ala and Chla. Due to their similar compositional distribution among different lives, amino acid composition can rarely be used to distinguish the respective contributions of phytoplankton, bacteria, and zooplankton (Cowie and Hedges, 1992). Degraded chlorophylls (e.g., chlorophyllide a), however, showed elevated concentrations at the western end of the fjord (Fig. 2e), suggesting the grazing pressure was heavier there (Hop et al., 2002). Therefore, for samples with extremely high (>70%) PN_{AAs}/PN value, it is likely that the detritus, probably derived from zooplankton, played an important role in modifying the composition of POM. In doing so, the zooplankton detritus contribution to PN is comparable to that of phytoplankton and bacteria (i.e., ~~40~~28% vs. ~~38~~14% and 36%).

~~4.1.2 Bacterial influence on amino acid enantiomers and its contribution to POM~~

~~In a study at two other two marine sites (BATS and HOTS) at lower latitudes, Kaiser~~

~~and Benner (2008) suggested that 12%–32% of the POC and 20%–64% of the PN were derived from bacteria. In Kongsfjorden, bacterial contributions to POC and PN can also be estimated. Here, we exploited the universal distribution of D-Ala in bacteria to calculate the amounts of bacterial organic carbon and nitrogen. Additionally, considering the potential differences between riverine and marine bacterial community structures, we estimated bacterial contributions for both riverine and marine samples (Table 4). For riverine samples (i.e., $S = 0$), we used only freshwater culture data from table 2 of Kaiser and Benner (2008) for the D-Ala converting factor, whereas for marine samples (i.e., $S > 30$) the D-Ala converting factor is based solely on marine bacteria (Kaiser and Benner, 2008). Note that we did not estimate the contribution of bacteria in brackish water (i.e., $0 < S < 30$).~~

~~In Kongsfjorden, the bacterial contribution to POC (19%; Table 4) is well within the value reported by Rokkan Iversen and Seuthe (2011) based on the cell density and conversion factor approach, and is similar to values reported for other marine regions at lower latitudes (Kaiser and Benner, 2008). The bacterial contribution to POC was slightly lower (13%) in the Bayelva River. With respect to nitrogen, the bacterial contribution accounted for 36% of POC in fjord water (Table 4).~~

~~Given that D-Ala occurs widely in biopolymers, whereas D-Glx is present in relatively few bacterial compounds, the overall D-Ala/D-Glx ratio would become >1 (Kaiser and Benner, 2008 and ref. therein). Both the riverine ($r = 0.83$, $p = 0.006$, $n = 9$) and fjord ($r = 0.95$, $p < 0.001$, $n = 31$) D-Ala levels are strongly related to their respective D-Glx levels, exhibiting almost identical slopes (river: 1.26, fjord: 1.21; Fig. 4). The D-Ala/D-Glx slopes in both the river and the fjord (i.e., 1.26 and 1.21, respectively; Fig. 4) are comparable to the reported D-Ala/D-Glx value of 1.3 ± 0.4 (Kaiser and Benner, 2008), which was derived from a pure bacteria culture that~~

~~included both marine/fresh and heterotrophic/autotrophic bacteria. Also, riverine D-Ala and D-Glx levels are coupled in an almost identical manner to fjord samples (Fig. 4). Given that Glx has a higher abiotic racemization rate than Ala (Wehmiller et al., 2012), the slightly higher D-Ala/D-Glx slope for river samples relative to fjord samples (i.e., 1.26 vs. 1.21; Fig. 4) indicates that D-AAs in riverine suspended particles likely originate from a modern contribution (e.g., bacteria) rather than abiotic racemization in the river basin. The presence of bacteria and their modification of OM in the underlying rock/paleosols of glaciers has been confirmed in previous study (Sharp et al., 1999).~~

4.2 Organic matter~~carbon~~ flux estimate~~on Svalbard~~

~~(Hodson et al., 2002)~~Along the Bayelva ~~r~~River (i.e., from the glacier terminus BC station~~n~~ to NVE station, Fig. 1b), clear decrease of TSM and POC was~~can be~~ identified. The TSM decreased from 741 mg/L at the BC station to 214 mg/L at NVE station~~n~~ and correspondingly the POC decreased from around 102 µM to 56 µM. In the meantime, the DOC decreased from 167 µM at the BC station to 73 µM at NVE station. The ice marginal and proglacial environments are important zones of ion acquisition in melt water and increase trend of major ion concentration in meltwater can be found downstream along the river (Hodson et al., 2002). In this work, we found the conductivity of the meltwater increased from 29.8 µS/cm (BC station) to 74.8 µS/cm (NVE station), which also indicates the ion acquisition in the ice marginal/proglacial region. Given the increase of conductivity, the decrease of organic matter may due to flocculation process in the water column and also desorption/adsorption balance difference along the river. The decrease trend of suspended parameters along Bayelva ~~r~~River agreed well with the previous findings

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that the proglacial sandur is a major net suspended sediment sink throughout most time of the melt season (Hodson et al., 1998) and we further propose that it can also greatly impact DOC as a clear DOC decrease was observed.

~~(Hop et al., 2002)~~

The annual water discharge of the Bayelva River in 2012 (29×10^6 m^3) was relatively low compared with levels recorded between 1990 and 2001 (~27×10^6 to more than 40×10^6 m^3) (Bogen and Bønsnes, 2003). ~~Although~~Seasonally, some studies of glacier meltwater flux reported no clear temporal variability in the concentration of suspended particles over the course of the melt season (Bhatia et al., 2013)~~, sediment flux in the Bayelva River did show large inter-annual variation, ranging from 5126 to 22,797 t/year~~ , but other study suggests that highest TSM concentrations often occur late in the melt season, and that rain floods, instead of snowmelt, can cause the high concentrations (Bogen and Bønsnes, 2003). ~~Based~~Inter-annually, sediment flux in the Bayelva River showed large variation, ranging from 5126 to 22797 t/year (Bogen and Bønsnes, 2003) over a 12-year observation. All these previous studies indicate the complexity of TSM concentration variation in glacier meltwater. During our observation, TSM, POC and DOC concentrations at NVE station (Table 1) showed no relation with water discharge at the sampling day nor at the sampling hour (data not shown). As an estimate, we calculated the flux based on the discharge data and results from the NVE station (Table 1~~),~~). Bayelva River fluxes of TSM, POC, DOC, and PN in 2012 are estimated to be 6400 ± 1300, 20 ± 1.6, 25 ± 5.6, and 4.7 ± 0.75 ton, respectively. ~~Therefore,~~And our estimated POC flux for the Bayelva River is very close to a previous estimate (22 ± 3 ton/yr) for the 2011 ablation season (Kuliński et al., 2014).

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There are many meltwater rivers/creeks on Svalbard, and a comprehensive study to their organic carbon concentrations is not available. However, previous meltwater organic carbon study reveals that DOC in the meltwater rivers ranged from 165 – 426 µM (Stibal et al., 2008; Tye and Heaton, 2007), while POC content in common meltwater rivers is about 0.5% (Kuliński et al., 2014). DOC concentration in our study (Table 1) is lower when compared to these values, but POC content is very comparable to previous values (i.e., 0.35% vs. 0.5%). Further, the glacier coverage in Bayelva River basin is 55% (Bogen and Bønsnes, 2003), the same as the whole Svalbard, whose glacier coverage is also 55% (Lang et al., 2015). So the Bayelva ~~river~~River alone can hardly represent the ~~whold~~whole Svalbard glacier meltwater rivers in a 100% manner, but at least it enables the assessment, and the estimated flux is likely to be lower than the true value, given that its DOC and POC concentrations are lower when compared to other glacier meltwaters~~rivers and previous work~~.

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Given that the POC% in TSM is 0.35% (Table 1) and that the TSM flux for Svalbard is 16 × 10^6 t/yr (Hasholt et al., 2006), we estimate that the POC flux for all of Svalbard is 0.056 ± 0.02 × 10^6 t/yr (Table 5). Moreover, by incorporating the total surface runoff (25 km^3/yr) from Svalbard's glaciers due to melting of snow and ice ~~(25 km^3/yr;~~ (Hagen et al., 2003) and the DOC content of glacier meltwater (Table 1), we estimate the DOC flux for Svalbard to be 0.02 ± 0.01 × 10^6 t/yr (Table 5). The POC flux of Svalbard is equivalent to only 6% of that from the Greenland Ice Sheet (0.9–0.94 × 10^6 t/yr) (Bhatia et al., 2013; Lawson et al., 2014), and is significantly smaller than the POC flux of the Mackenzie River (1.8–2.1 × 10^6 t/yr) (Dittmar and Kattner, 2003). However, in terms of DOC flux, the value from Svalbard is 13%−25% that of the Greenland Ice Sheet (0.08–0.15 × 10^6 t/yr) (Bhatia et al., 2013; Lawson et al., 2014). In comparison, DOC fluxes from glaciers in the Gulf of Alaska and from

the small Arctic Yana River and the Mackenzie River are 0.13 × 10^6, 0.09 × 10^6, and 1.4 × 10^6 t/yr, respectively (Dittmar and Kattner, 2003; Holmes et al., 2012).

The glacier area on Svalbard is ~~~36,600~~36600 km^2 (Hagen et al., 2003) and the total surface runoff is 25 km^3/yr (Hagen et al., 2003), resulting in area-weighted fluxes of POC and DOC of 1.5 and 0.55 t/km^2/yr, respectively, and discharge-weighted fluxes of POC and DOC of 2.2 mg/L and 0.86 mg/L, respectively, (Table 5). The area-weighted fluxes of Svalbard is comparable to that~~. Therefore, the Svalbard DOC area-weighted flux~~ of glaciers in the Gulf of Alaska (Table 5)~~is ~40% that of glaciers in the Gulf of Alaska (1.3 t/km^2/yr)~~ and ~~is comparable to that of~~ the Mackenzie River (~~i.e.,~~ 0.82 t/km^2/yr) (Holmes et al., 2012)~~. It can be, however,~~ and it is ~~4 to 7 times~~much higher ~~higher~~ than that of the Greenland Ice Sheet, considering its area of 1,200,000 km^2 (Rignot and Kanagaratnam, 2006) (~~i.e.,~~e.g., for POC: ~~0.55 vs. 0.07 or 0.12~~1.5 t/km^2/yr vs. 0.7–0.8 t/km^2/yr; for DOC: 0.55 vs. 0.07–0.12 t/km^2/yr Table 5). ~~Similarly, POC flux from Svalbard is only 6% of that from the Greenland Ice Sheet, but the corresponding area-weighted flux is two times higher in Svalbard than in Greenland (Table 5).~~ The singular Greenland Ice Sheet is considerably greater in both area and thickness (>2000 m) than small glaciers in Svalbard and Alaska (Hood et al., 2009), which comprise small, relatively thin glaciers. The vast central part of the Greenland Ice Sheet can hardly contribute to the runoff materials flux and hence the different ~~bulk~~ thermal regimes may be the reason for the much lower area-weighted fluxes of the Greenland Ice Sheet, when compared to the other two Svalbard and Alaska glaciers (Table 5).

With respect to the DOC flux, ~~compared~~the Svalbard glaciers becomes important among the pan-arctic glaciers especially when the discharge-weighted flux is considered (Table 5). The discharge-weighted flux of DOC of Svalbard is over twice

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higher than that of the Greenland Ice Sheet and glaciers in the Gulf of Alaska. As reported by Bhatia et al. (2013), DOC from Greenland Ice Sheet showed temporal variability throughout the melt season, yet DOC concentration in glacier meltwater typically remains depleted (~27 μM) during the peak melt season. In the turbid Bayelva River, however, although DOC measured at the NVE station exhibited variability (Table 1), it was maintained at a much higher level compared with values from the Greenland Ice Sheets. DOC concentration was as much as 167 μM at the glacier terminus and remained elevated (73 μM) even as far as the NVE station (Table 1). Although we cannot assess monthly variability in DOC in this study, previous work in neighboring drainage basins suggests that DOC concentration in Svalbard glacial meltwater is maintained at high levels (250–426 μM in glaciated basins and 165–204 μM in non-glaciated basins) between ~~mid-June~~mid-June and early September (Tye and Heaton, 2007). Such high concentrations of DOC in Svalbard glacier meltwater are an important reason for the higher discharge-weighted DOC flux when compared to the other two glaciers (Table 5). And DOC flux would be even greater had we calculated via the previous monthly DOC concentration (Tye and Heaton, 2007). Compared with glaciers in Gulf of Alaska, glaciers in Svalbard was 2.8 times higher in discharge-weighted DOC flux, whereas the area-weighted DOC flux was only 42% of that in Gulf of Alaska (Table 5). This is explained by the much higher meltwater discharge per unit area that yielded by glaciers in Gulf of Alaska (~ 61 °N), relative to that yielded by glaciers in Svalbard (76 °N ~ 80 °N). Namely, the area-weighted annual runoff for the glaciers in the Gulf of Alaska is 0.0042 km/year (320 km^3/year divided by 75300 km^2) (Hood et al., 2009), whereas the area-weighted annual runoff for the glaciers in Svalbard is only 0.00068 km/year (25 km^3/year divided by 36600 km^2). Hence, in per unit area, glaciers in Gulf of Alaska yield 6.2

times higher meltwater in discharge when compared to glaciers in Svalbard (i.e., 0.0042 vs. 0.00068), and this 6.2 times multiple relationship is very close to the multiple relationship between the area-weighted DOC flux and discharge-weighted DOC flux difference between the two glaciers, which is 6.6 times (namely (0.86/0.31)*(1.3/0.55), (Table 5)). In other words, glacier meltwater in Alaska is high-in-discharge and low-in-DOC-concentration, whereas glacier meltwater in Svalbard is in the opposite situation, namely low-in-discharge and high-in-DOC-concentration. Higher discharge-weighted DOC flux suggests that Svalbard glaciers have a higher efficiency in generating DOC (or higher in DOC concentration) when compared to other pan-arctic glacier systems like the Greenland Ice Sheet and glaciers in Gulf of Alaska (Table 5).

Different from DOC flux, POC flux of Svalbard glaciers is not as important as other pan-arctic glaciers, and its discharge-weighted flux of POC is even smaller than that of the Greenland Ice Sheet (i.e., 2.2 mg/L vs. 3.7 mg/L; Table 5). Based on the particulate biomarker analysis, the phytoplankton carbon in the glacier meltwater can be calculated by multiplying the riverine Chla concentration with the algal-POC:Chla ratio of 50 (Hop et al., 2002). Further given the AA carbon and nitrogen amount (i.e., POC_{AAs} and PN_{AAs}), AA and phytoplankton carbon together accounted for 9.5% of the POC flux, and nitrogen accounted for 11% of the PN flux. Assuming that AA and phytoplankton carbon represent the labile POM pool, the labile proportion in the total POM flux will be ~10% of the total POM flux (i.e., for POC flux, 9.5%; for PN flux, 11%). This proportion is comparable to that of the Greenland Ice Sheet POM, in which the labile component is estimated at 9% using a carbohydrates approach (Lawson et al., 2014). Due to the rapid removal process in the estuarine and adjacent fjord, most glacier meltwater POC is expected to be buried within adjacent fjords

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(Dittmar and Kattner, 2003).

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~~Based on the reported algal POC:Chla ratio of 50 , phytoplankton carbon concentration can be estimated by multiplying Chla concentration with factor of 50. Further given the AA carbon and nitrogen amount (i.e., POC_{AAs} and PN_{AAs}), The singular Greenland Ice Sheet is considerably greater in both area and thickness (>2000 m) than the glaciers on Svalbard, which comprise small, relatively thin alpine glaciers. Therefore, potential reasons for the offset in area weighted~~ Assuming that AA and phytoplankton carbon represent the labile POM pool, the labile proportion in the total POM flux will be ~10% of the total POM flux (i.e., for POC flux, 9.5%; for PN flux, 11%). This proportion is comparable to that of the Greenland Ice Sheet POM, in which the labile component is estimated at 9% using a carbohydrates approach ~~flux include differences in glacier mass balance, as well as various organic carbon processes and content at both the supraglacial and subglacial interfaces. Furthermore, the influence of different ocean currents means that most of the DOC exported from the Greenland Ice Sheet is expected to be transported southwards to the Atlantic, whereas DOC from Svalbard is expected to travel northward. Therefore, among the glaciers, Svalbard glaciers play a more important role than the Greenland Ice Sheet in terms of contributing terrestrial material to the Arctic.~~

~~As reported by Bhatia et al. (2013), DOC showed temporal variability throughout the melt season, yet DOC concentration in glacier meltwater typically remains depleted (~27 μM) during the peak melt season. In the turbid Bayelva River, however, although DOC measured at the NVE station exhibited variability (Table 1), it was maintained at a much higher level compared with values from the Greenland Ice Sheets. DOC concentration was as much as 167 μM at the glacier terminus and remained elevated (73 μM) even as far as the NVE station (Table 1). Although we~~

~~cannot assess monthly variability in DOC in this study, previous work in neighboring drainage basins suggests that DOC concentration in Svalbard glacial meltwater is maintained at high levels (250–426 μM in glaciated basins and 165–204 μM in non-glaciated basins) between mid June and early September (Tye and Heaton, 2007). Such high concentrations of organic matter in glacier meltwater are an important reason for the observed differences in area-weighted DOC flux between Svalbard and the Greenland Ice Sheet. And the area-weighted DOC flux would be even greater had we used the previous monthly DOC concentration (Tye and Heaton, 2007).~~

~~With respect to POM in the Bayelva River, AA and phytoplankton carbon together accounted for 9.5% of the POC flux, and nitrogen accounted for 11% of the PN flux. Assuming that AA and phytoplankton carbon represent the labile POM pool, the labile proportion in the total POM flux will be ~10% of the total POM flux (i.e., for POC flux, 9.5%; for PN flux, 11%). This proportion is comparable to that of the Greenland Ice Sheet POM, in which the labile component is estimated at 9% using a carbohydrates approach the both~~ As reported by Bhatia et al. , showed temporal variability throughout the melt season, yet DOC concentration in glacier meltwater typically remains depleted (~27 μM) during the peak melt season. In the turbid Bayelva River, however, although DOC measured at the NVE station exhibited variability (Table 1), it was maintained at a much higher level compared with values from the Greenland Ice Sheets. DOC concentration was as much as 167 μM at the glacier terminus and remained elevated (73 μM) even as far as the NVE station (Table 1). Although we cannot assess monthly variability in DOC in this study, previous work in neighboring drainage basins suggests that DOC concentration in Svalbard glacial meltwater is maintained at high levels (250–426 μM in glaciated basins and 165–204 μM in non-glaciated basins) between mid June and early September

~~(Lawson et al., 2014), and is considerably lower than the labile proportion of glacier meltwater DOM, which ranges from 23% to 66% (Hood et al., 2009). Considering the greater flux (Table 5) and lower labile proportion, POM in glacier meltwater plays a more significant role in glacier terrigenous carbon sequestration than DOM (Smith et al., 2015).~~

~~Svalbard glacial meltwater was higher both in discharge-weighted and area-weighted DOC flux when compared to Greenland ice sheet meltwaters (Table 5), indicating Svalbard glaciers is more efficient in generating DOC. wawa that yielded byannual divided by whereasannual divided by Hence, in per unit area, gbetween6.6 times (namely .)In another word, glacier meltwater in Alaska is high in discharge and low in DOC concentration, whereas glacier meltwater in Svalbard is in the opposite situation, namely low in discharge and high in DOC concentration.H~~The manners by which meltwater drains through the glaciers vary in Svalbard (Hodgkins, 1997) and ~~the manners~~it impacts the meltwater chemistry (Hodson et al., 2002; Wadham et al., 1998). Whether the meltwater flows through supra-, en- or sub-glacial channels would have great impact on the nutrients, TSM and further organic matter content in the glacier meltwater. Also, the ice marginal and proglacial environments play an important role in further modifying the organic carbon and nutrients content in glacier meltwater before it enters the sea (Hodson et al., 2002). The TSM in glacier meltwater is one of the few parameters that has been routinely monitored, and the Bayelva River shows a very large annual TSM flux variation over a 12-year time scale, with the maximum flux being over four times higher than the minimum flux (i.e., 22797 t/year vs. 5126 t/year; Bogen and Bønsnes, 2003), indicating ~~that there would also be a large variation in~~ the complexity in ~~total Svalbard~~ TSM concentration variation~~flux estimate~~ (Hasholt et al., 2006). Due to both the asymmetry of the organic carbon flux

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in a single glacier meltwater river and the heterogeneity among different meltwater drainages, we consider our provisional estimates of Svalbard POC and DOC to be tentative. ~~Moreover, the precision of these values is dependent on the~~Long time monitoring data for organic carbon ~~content~~in Svalbard is not reported so far, and ~~on approximations of TSM/runoff.~~little is known about Svalbard organic carbon flux. The values in Table 5 is a preliminary estimate and hence~~critically~~ it should be viewed with care and ~~Therefore,~~ more work is needed to improve ~~our~~the estimates for glaciers flux. Furthermore, the fluxes reported here are based solely on glacier meltwater runoff data and thus exclude iceberg calving, which accounts for one-sixth of the runoff flux in Svalbard (Hagen et al., 2003). Consequently, the organic carbon flux will need to be further updated when ~~further~~ tidewater glaciers contribution~~data~~ become available.

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5. Conclusions

Using AAs and phytoplankton pigments as biomarkers, we elucidated the POM composition in the glacier-fed Bayelva River and adjacent Kongsfjorden. In the glacier meltwater, AAs ~~and pigments~~ represent ~~~10~~7%~~–~~ and 11% of the bulk POC and PN~~M~~, respectively, whereas in the fjord, ~~PN_{AAs}/PN~~AAs nitrogen amount ~~can~~can exceed 90% of bulk PN, suggesting strong in situ assimilation. Furthermore, AAs ~~in POM~~ indicate that bacteria accounts for 13% and 19% of the POC in the Bayelva River and Kongsfjorden, respectively. This proportion is even greater for PN, with values of 36% being determined for the fjord.

The annual flux of terrigenous material in the Bayelva River is estimated at 6400 ± 1300 ton for TSM, 20 ± 1.6 ton for POC, 25 ± 5.6 ton for DOC, and 4.7 ± 0.75 ton for PN. Furthermore, annual POC and DOC fluxes for all of Svalbard are estimated to be

0.056×10^6 and 0.02×10^6 t/yr, respectively. Though lower in bulk value, the area-weighted and discharge-weighted organic carbon flux for Svalbard is comparable or even higher compared with other pan-arctic glacier systems (e.g., the Greenland ice sheet and glaciers in Gulf of Alaska). In particular, the discharge-weighted flux of DOC of Svalbard glaciers is over twice higher than other pan-arctic glacier systems and hence it is more efficient in DOC output,~~In particular,is much higher than that for the Greenland Ice Sheet is over twice higher than other pan-arctic glacier systems and hence Svalbard glaciers are~~ suggesting its important role as a terrestrial DOC source~~playing an important role in transporting terrestrial DOC among glacier meltwater DOC sources for the~~ . ~~Furthermore, gGiven the opposite terrigenous DOC transport direction between the Greenland Ice Sheet (to the Atlantic in the south) and Svalbard (to the Arctic Ocean in the north), which results from the respective surrounding ocean currents, we propose that the Svalbard glaciers are an important source of terrigenous material for the Arctic Ocean relative to the massive Greenland Ice Sheet~~. Further work is needed to improve our understanding of organic carbon fluxes of the whole Svalbard glacier meltwaters.

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Table 1. Basic parameters for the Bayelva River at NVE station and fjord waters in August, 2012. ~~(TSM: total suspended matter, POC: particulate organic carbon, PN: particulate nitrogen, THPAA: total hydrolysable particulate amino acids, D-AA: D-forms of amino acids, DI: degradation index, Chla: chlorophyll a, DOC: dissolved organic carbon)~~

~~*: all D-amino acids combined together~~

Endmember*		TSM	POC		$\delta^{13}C$	PN	THPAA	D-AA**	DI	Chla	DOC
		mg/L	µM	%	‰	µM	µM	nM		µg/L	µM
NVE station	8th 20:20	159	49	0.37	-23.8	13	0.8	29	-0.38	0.22	75
	12th 10:07	115	46	0.48	-24.1	8.3	0.6	18	0.69	0.21	98
	13th 20:15	169	58	0.41	-24.3	6.9	1.1	50	-0.51	0.21	80
	16th 18:30	281	55	0.23	-23.5	16	1.2	54	-0.44	0.26	21
	19th 16:25	345	70	0.25	-23.8	12	1.3	58	-0.06	0.38	92
NVE station	average	214	56	0.35	-23.9	11	1.0	42	-0.14	0.26	73
Fjord waters	average	41	23	1.1	-24.6	2.4	1.0	16	0.46	0.45	90.8
(surface)	(min.~max.)	(7.3~178)	(2~203)	(0.1~2.5)	(-26.1~-22.8)	(0.67~11)	(0.33~2.9)	(2.4~61)	(-0.18~0.76)	(0.047~1.25)	(20~204)
Fjord waters	average	10.5	5.7	0.62	-24.5	0.21	0.36	5.9	0.42	nd***	109
(near-bottom)	(min.~max.)	(5.9~18)	(2.2~12)	(0.45~0.79)	(-25.2~-23.8)	(0.19~0.27)	(0.15~1.1)	(2.7~15)	(0.20~0.74)	nd***	(72~152)

*: Bayelva River: river samples with salinity = 0; surface fjord samples were all collected at 0 m (S >0); near-bottom samples were fjord samples collected at the bottom layer (layer depth: 170 m to 320 m), usually 10 to 15 m above the seabed.

**: all D-amino acids combined together

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Table 2. Dissolved inorganic nutrients (mean (min – max)) in this study (unit: μM)

Endmember**unit: μM	NH_4^+	NO_2^-	NO_3^-	SiO_3^{2-}	PO_4^{3-}
Bayelva River	0.28	0.05	2.87	5.68	0.06
	(0.18 ~- 0.42)	(0.02 ~- 0.1)	(0.62 ~- 5.65)	(3.73 ~- 6.88)	(0.04 ~- 0.13)
Floating ices	0.33	0.003	0.20	0.08	0.02
	(0.23 ~- 0.44)	(bdl* ~- 0.01)	(0.03 ~- 0.43)	(bdl* ~- 0.13)	(0.01 ~- 0.03)
Fjord waters	0.76	0.059	0.6	1.74	0.05
(surface)	(0.18 ~- 2.2)	(bdl* ~- 0.17)	(0.01 ~- 2.32)	(0.56 ~- 6.07)	(0.01 ~- 0.26)
Fjord waters	1.65	0.3	7.88	3.85	0.66
(near-bottom)	(1.07 ~- 2.45)	(0.2 ~- 0.43)	(4.95 ~- 9.44)	(1.95 ~- 5.51)	(0.49 ~- 0.76)

*: below detection limit

**: floating ices: clean floating ices in the fjord, the rest endmembers are ~~is~~ the same as described in Table 1~~, Bayelva River: river samples with salinity = 0; floating ices: floating ices in the fjord; surface fjord samples were all collected at 0 m; near-bottom samples were fjord samples collected at the bottom layer (layer depth: 170 m to 320 m), usually 10 to15 m above the seabed.~~

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Table 3. Phytoplankton groups contributions to total Chla estimated via CHEMTAX.

(unit: %)

Group	Average	Min.	Max.
Diatoms	50	6.6	78
Cryptophytes	28	5.9	48
Prasinophytes	11	4.5	17
Chlorophytes	4.3	0	17
Haptophytes	3.8	0	9.5
Dinoflagellates	3.1	0	7.3
Chrysophytes	0.5	0	2
Cyanobacteria	0.2	0	2.2

Table 4. Bacteria-contributed POC and PN proportion relative to bulk POC and PN (in %) derived from D-Ala concentrations*. ~~(POC: particulate organic carbon, PN: particulate nitrogen)~~

Region **	bacterial POC%	bacterial PN%
Bayelva R.	13 ± 3.5	
Marine	19 ± 9.5	36 ± 18

* Terrestrial bacteria D-Ala content: 108 nmol/mg C, marine bacteria D-Ala content: 50.3 nmol/mg C, 215 nmol/mg N. The value is derived/cited from literature (Kaiser and Benner 2008)

** Bayelva River used all the samples with S = 0 and marine samples only used samples in the Kongsfjorden with S > 30~~.~~

Table 5. Estimated organic carbon flux from Svalbard and its comparison with ~~Greenland ice sheet~~other pan-arctic glacier systems.

	total POC flux	total DOC flux	area-weighted POC flux	area-weighted DOC flux	discharge-weighted POC flux	discharge-weighted DOC flux
	10^6 t/yr	10^6 t/yr	t/km^2/yr	t/km^2/yr	mg/L	mg/L
Svalbard archipelago	0.056 ± 0.02	0.02 ± 0.01	1.5 ± 0.5	0.55 ± 0.3	2.2	0.86
Greenland ice sheet*	0.9 – 0.94	0.08 – 0.15	0.7 – 0.8	0.07 – 0.12	3.7	0.32
Gulf of Alaska**		0.10 ± 0.01		1.3 ± 0.11		0.31

~~(POC: particulate organic carbon, DOC: dissolved organic carbon)~~

	~~POC flux~~	~~DOC flux~~	~~Area-weighted POC flux*~~	~~Area-weighted DOC flux*~~
	~~10^6 t/yr~~	~~10^6 t/yr~~	~~t/km^2/yr~~	~~t/km^2/yr~~
~~Svalbard archipelago~~	~~0.056 ± 0.02~~	~~0.02 ± 0.01~~	~~1.5 ± 0.5~~	~~0.55 ± 0.3~~
~~Greenland ice sheet~~	~~0.9** – 0.94***~~	~~0.08** – 0.15***~~	~~0.7 – 0.8~~	~~0.07 – 0.12~~
~~Gulf of Alaska~~[e]		~~0.10 ± 0.01****~~		~~1.3 ± 0.11****~~

~~* Organic flux divided by glacier area~~

~~*~~* Data ~~erived~~cited from Bhatia et al., (2013) and

~~*** Data cited from~~ Lawson et al., (2014)

~~*~~** Derived~~ata cited~~ from Hood et al., (2009)

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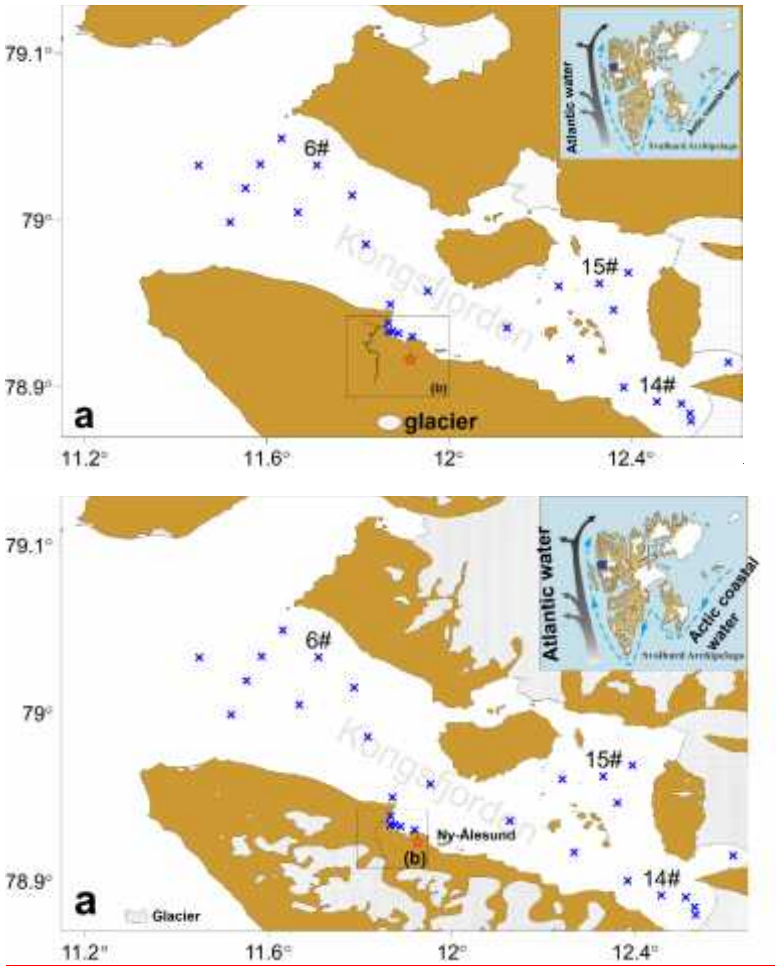
79.1°
79°
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6#
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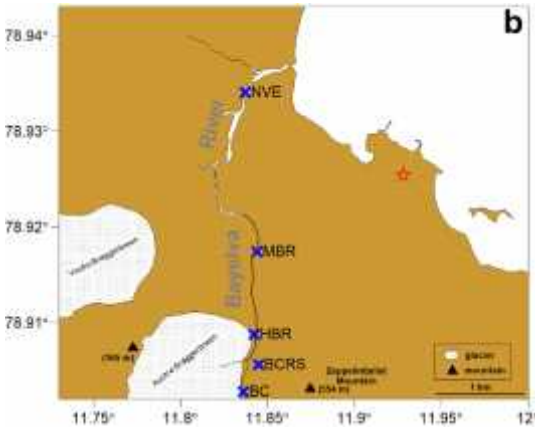
Kongsfjorden
(b)
a
glacier
Atlantic water
Arctic coastal water
Svalbard Archipelago
Ny-Ålesund
Glacier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11.8°
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11.9°
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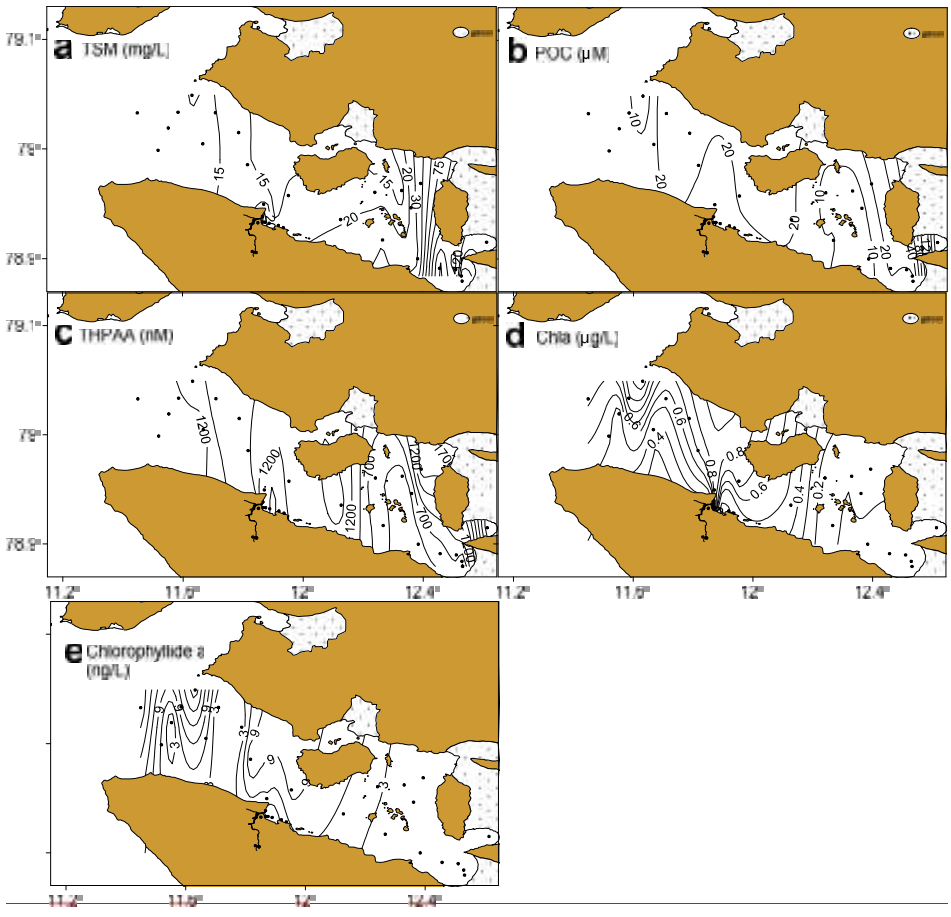
12°
NVE
MBR
HBR
BCRS
BC
River
Bayelva
glacier
mountain

Fig.1: Study area and sampling stations in (a) the Kongsfjorden ~~(a)~~ and (b) the Bayelva River ~~(b)~~ in Aug., 2012 (red star indicates the location of Ny-Ålesund; the schematic of ~~note that only tidewater~~ glaciers are also shown in plot a)



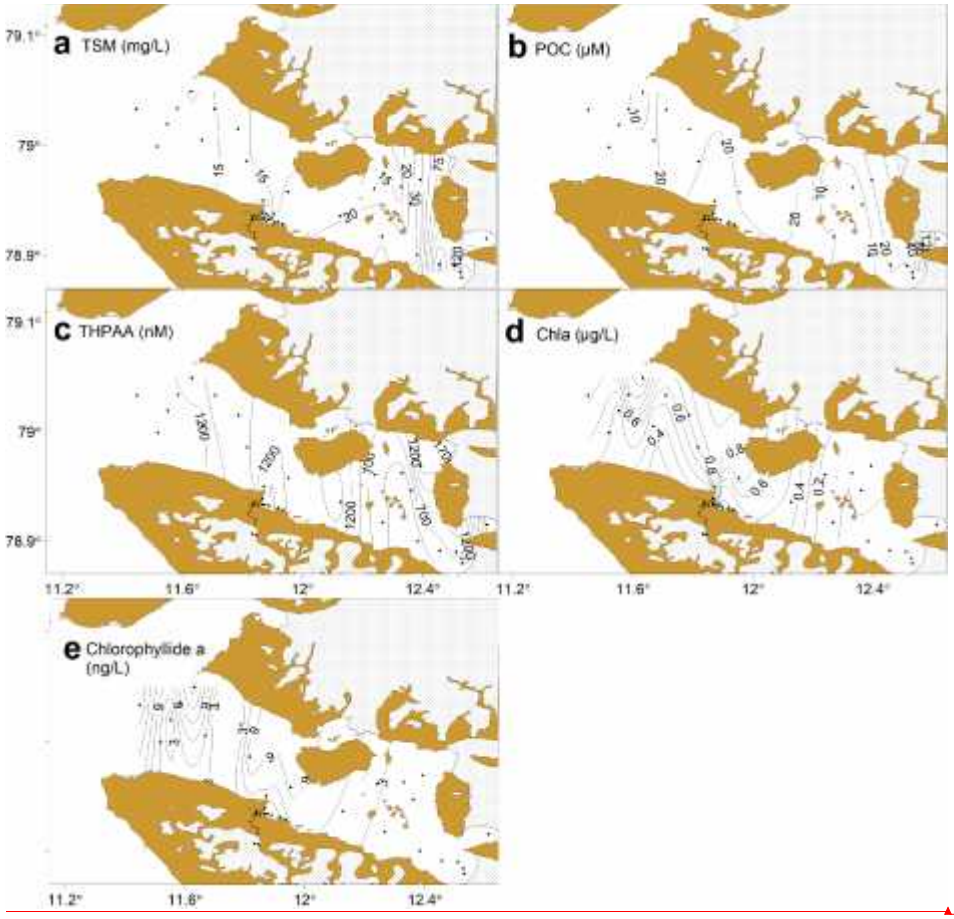


Fig. 2. Surface (a) total suspended matter (TSM), (b) particulate organic carbon (POC), (c) total hydrolysable particulate amino acids (THPAA), (d) chlorophyll a (Chla) and (e) chlorophyllide a distribution in the Kongsfjorden.

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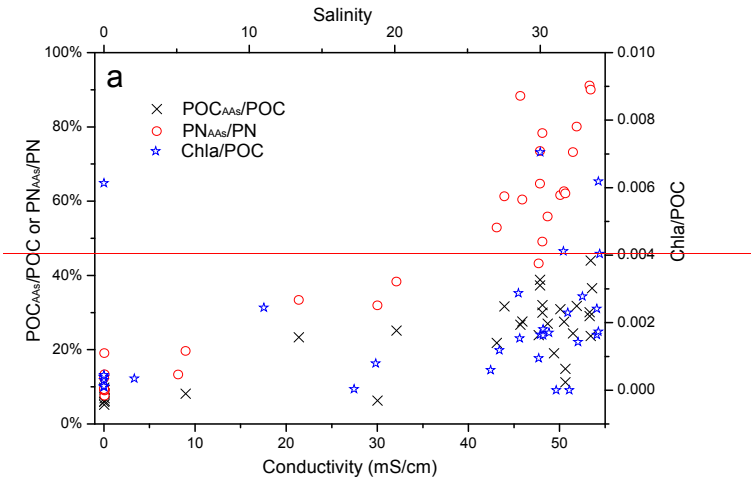
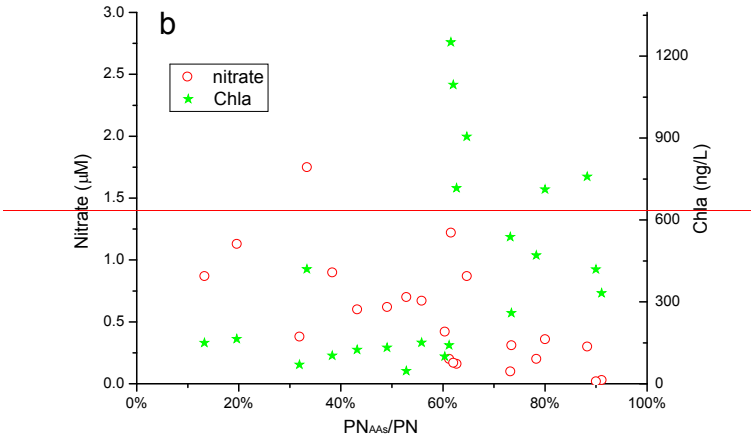
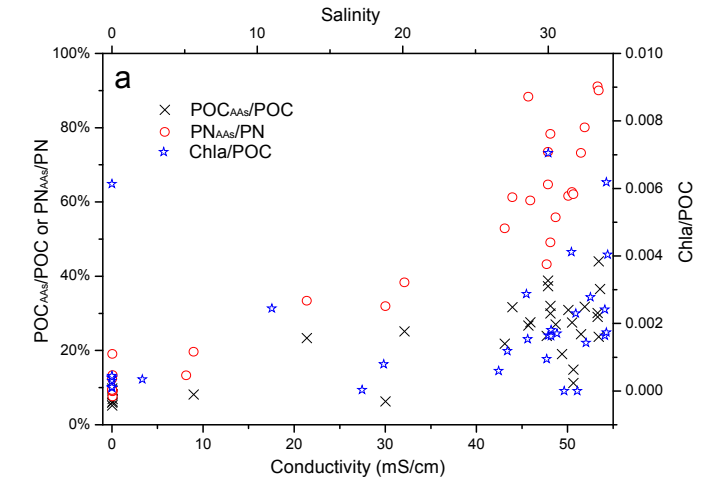

Salinity
a
POCAAs/POC
PNAAs/PN
Chla/POC
POCAAs/POC or PNAAs/PN
Chla/POC
Conductivity (mS/cm)

1
2


b
nitrate
Chla
Nitrate (μM)
Chla (ng/L)
PNAAs/PN

3



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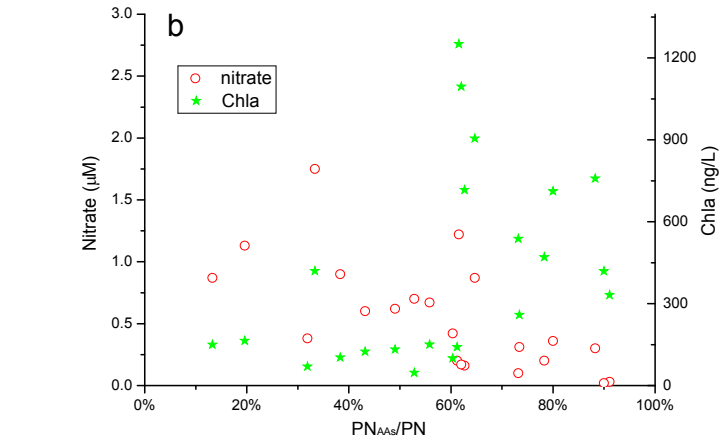

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Fig. 3. THPAA contribution to carbon and nitrogen: (a) along with salinity in the surface waters from glacier ~~melt water~~meltwater to the Kongsfjorden; (b) its relations with nitrate and Chla for fjord samples only (i.e., S > 0). ~~(THPAA: total hydrolysable particulate amino acids, Chla: chlorophyll a, PN: particulate nitrogen, POC_{AAs}/POC or PN_{AAs}/PN: amino acids carbon or nitrogen divided by POC or PN, respectively)~~

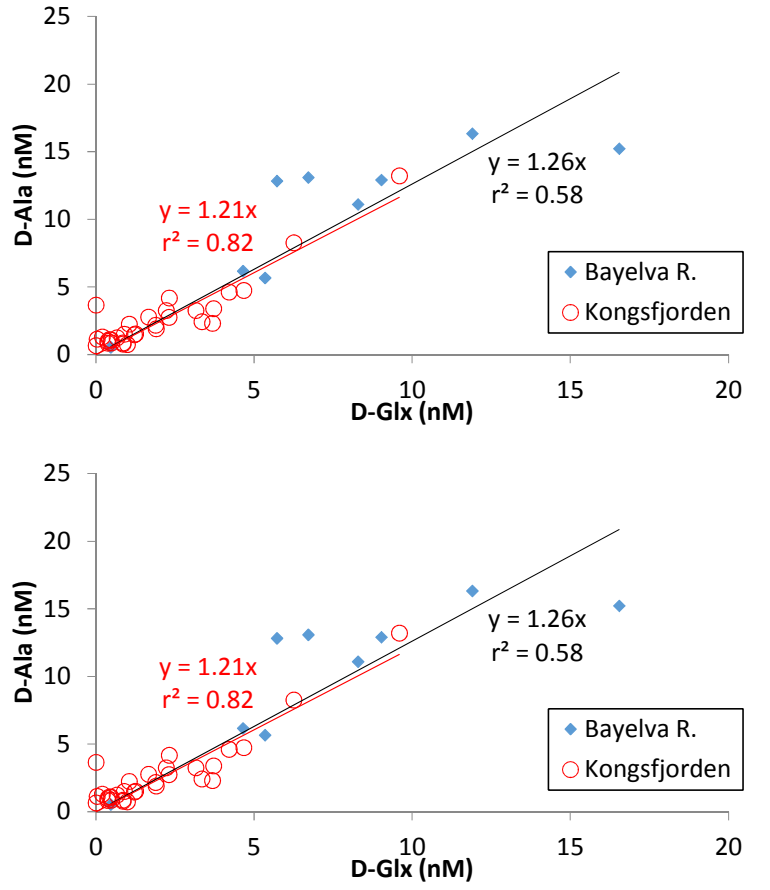

Fig. 4. D-Ala plotted against D-Glx for both river (S = 0) and fjord (S > 0) suspended particulate samples. ~~(D-Ala: D-form of alanine, D-Glx: D-forms of glutamic acid and glutamine)~~