

Interactive comment on “Sources, cycling and export of nitrogen on the Greenland Ice Sheet” by J. L. Wadham et al.

Anonymous Referee #2

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This paper presents an interesting dataset regarding nitrogen contents in meltwater and glacial ice within the Greenland Ice Sheet – more specifically the Leverett Glacier. The dataset is very interesting and while I don't have a problem with the authors' extrapolation of their results to the entire Greenland ice sheet I think many details need to be clarified in their paper. The dataset should be viewed in a far more quantitative way (the current manuscript is almost devoid of statistics) and the discussion of nitrogen cycling should be increased significantly. There is almost no mention of mechanisms behind the additional sources of nitrogen, the experiments they did are poorly reported (though could possibly provide interesting information). If the authors are interested in an observational paper that reports interesting concentrations and calculates nitrogen fluxes that could be acceptable but the title of the paper should then be changed to reflect the lack of discussion on processing.

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The extrapolation of results As stated – I don't have a problem with the extrapolation but I think that the reader needs to know more so that they can put it into context. For example – what percentage of the GIC drains to the Leverett Glacier? How do they determine this? This “watershed” calculation/determination is important because of the focus they put on comparing their results with that of the PARTNERS/GRO project on the Arctic rivers. The watershed area of the Lena, Ob, etc. is determined by topography how is the ice sheet drainage area determined? How good is this approximation? For example in the Arctic rivers they acknowledge that the watersheds as determined by topography may underestimate groundwater or permafrost sources given the terrain and unknown flow paths. Also – the authors state that it is ok to extrapolate because a large portion of the GIC is underlain by similar bedrock geology. Can the authors be more quantitative in this statement? What is the percentage?

Sources of N & discussion of processing The authors need to expand their discussion of N cycling in glacial environments. They continuously cite one study – however there is ample evidence of the processes that they are invoking from the alpine glacial community (e.g. Baron, Saros, Brooks & Williams, Clow in Rocky Mountain systems alone) or even more evidence within the snowpack studies.

In addition, there was significant explanation provided for the setup of the incubation experiments (though there should be further explanation to the choice of ice sampling location- presumably it was due to access?) and then the results of these experiments are barely mentioned and poorly presented. Figure 5 needs significant improvement. Simple things like making all the y axes the same scale would help the reader interpret your findings. They are still too busy though. What would be extremely helpful to is show changes in the various N species over time – maybe even with a bar chart (+ gain, - loss) that represents the net aerobic and net anaerobic processing for each species (NO₃⁻, DON, NH₄⁺ – I don't think TDN is needed). This would allow you to better track how the species are changing, quantify rate changes, do statistical tests on whether the “live” experiments were different than the water only ones. Overall this

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section needs significant improvement and then contextualization within the literature. What do these experimental fluxes represent? Is there any way to relate them to the N yields reported?

In terms of the discussion of source (relationship between moulin waters and bulk runoff – Figure 4), the authors also need to be more quantitative. The authors have enough solute data to do some sort of endmember analysis (or at the very least repeat the basic approach used in Figure 4 with other solutes that should also be unique to the meltwater). Figure 3 could be improved by using a ternary diagram instead to try and separate out sources visually. The authors show sulfate concentrations in Figure 6 but don't sufficiently use this information within the text. Sulfate is likely a weathering product UNLESS there is also high levels of sulfate in the glacial ice (which is possible given industrial emissions). A discussion regarding the possible sources of sulfate should be added.

The calculation of nitrogen and sediment fluxes – Why was a volume weighted average used instead of creating a relationship between discharge and concentration and then estimating the N concentrations for each daily Q value? It appears that there are discharge estimates ever 5 or 10 minutes and daily nitrogen values – surely that is enough data to figure out these relationships and therefore do a better job of quantifying (and discussing error) on the N fluxes.

Specific editorial notes: Abstract, line 9: remove “and” Pg 4, line 20-21: change to “in the last few thousand years” Pg 15, lines 24-25: typically these yields are referred to in “m a⁻¹” or “m yr⁻¹” (i.e. the units are “reduced”) Pg 16, line 7: change “to” to “than”

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