

Comment on egusphere-2022-137

Anonymous Referee #1

Referee comment on "Environmental Controls on Observed Spatial Variability of Soil Pore Water Geochemistry in Small Headwater Catchments Underlain with Permafrost" by Nathan Alec Conroy et al., EGUsphere, <https://doi.org/10.5194/egusphere-2022-137-RC1>, 2022

Does the paper address relevant scientific questions within the scope of TC?

Yes

Does the paper present novel concepts, ideas, tools, or data?

Yes.

Are substantial conclusions reached?

Yes

Are the scientific methods and assumptions valid and clearly outlined?

Yes

Are the results sufficient to support the interpretations and conclusions?

The authors link water quality to vegetation, however I fell this link is rather qualitative. They have compiled vegetation data from the NGEE Arctic project. This section needs either more description or references to papers and reports on the methods used. Additionally it would greatly strengthen the paper to be more quantitative and descriptive with the vegetation. Are there photos of the sites that can be shown in supplementary material etc.

We agree that the description of vegetation at these sites needs to be strengthened. We have taken the reviewer's recommendations into consideration and done the following:

- Added plot photos for plant functional types to the Supplementary Materials.
- Provided percent cover data for dominant plant functional types for each plot in Table 1 and Table 2.
- Added the following text to Section 2.2:
"Vegetation data were collected at the peak of the growing season in mid to late July 2016 and 2017 at the NGEE Arctic Kougarok and Teller field sites, respectively. The distribution of plant communities in the Arctic is primarily controlled by landscape, topography, soil chemistry, soil moisture, and the plants that historically colonized an area (Raynolds et al., 2019). Soil available rooting depth, which can be limited by shallow depths to bedrock, permafrost, or the water table, can also restrict plant growth and survival of certain species by reducing access to water and nutrients. We surveyed the dominant plant communities along each hillslope, which varied in their shrub abundance, canopy height, and structure, to characterize the vegetation composition at

the sites following the recommended protocol of Walker et al. (2016). Extensive field site details and vegetation sampling methods are more thoroughly described in previous studies (Salmon et al., 2019; Langford et al., 2019; Yang et al., 2020; Sulman et al., 2021; Yang et al. 2021).

For this study, we provide summary statistics for vegetation plots associated with intensive stations. Vegetation composition plots within each intensive station were chosen subjectively in areas of homogeneous and representative vegetation varying in size from 1 to 25 m² depending on canopy structure and height. The surveyed plot area was 1 × 1 m for all plant communities except for the taller stature willow-birch tundra, mesic willow shrubland (2.5 × 2.5 m), and alder shrubland (5 × 5 m). For each plot, all plant species (vascular plants, lichens, and bryophytes) were recorded along with visual estimates of their percent cover. For plots with multiple canopies, field cover estimates were recorded as absolute cover, meaning that the total cover per plot can be >100%. We calculated relative cover values (adding to 100%) from the field data and use these for all subsequent analyses.

Plant species were further aggregated into nine plant functional types (PFTs), groupings of plant species that share similar growth forms and roles in ecosystem function (Wullschleger et al., 2014), based on growth patterns and plant traits. PFTs in this study include: (1) nonvascular mosses and lichens, (2) deciduous and evergreen shrubs of various height classes, including an alder PFT, (3) graminoids, and (4) forbs. Canopy height was estimated within each plot for each PFT as the average of 4 measurements, including a maximum canopy height. Active layer depth was measured at the end of the growing season for all plots in September 2018 using a frost probe. A temperature probe was used to determine if the resistive layer was permafrost (≤ 0 °C) or rock (>2 °C). Thaw depth is an average of 4 measurements from the vegetation plot corners.”

Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

Overall, yes, however they should provide a data table of their water chemistry dataset in a supplementary material table.

Our water chemistry dataset is very large and (despite our best efforts) was not conducive to a printed format. Therefore, we have provided it in an open-access electronic format which can be downloaded:

Nathan Conroy, Jeff Heikoop, Brent Newman, Cathy Wilson, Carli Arendt, George Perkins, Stan Wullschleger. 2021. Soil Water Chemistry and Water and Nitrogen Isotopes, Teller Road Site and Kougarok Hillslope, Seward Peninsula, Alaska, 2016 - 2019. Next Generation Ecosystem Experiments Arctic Data Collection, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, USA. <https://doi.org/10.5440/1735757>.

This data product is referenced in the Data Availability Statement (Section 7).

Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Yes, the authors give proper credit to prior work and outline their contribution.

Does the title clearly reflect the contents of the paper?

Yes.

Does the abstract provide a concise and complete summary?

Yes

Is the overall presentation well structured and clear?

Areas of the paper should be restructured, see detailed comments.

Is the language fluent and precise?

Yes.

Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Yes.

Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

I have specific questions about parts of the discussion, see specific comments.

Are the number and quality of references appropriate?

Yes.

Is the amount and quality of supplementary material appropriate?

Yes.

Overall Comments

The paper “Environmental Controls 1 on Observed Spatial Variability of Soil Pore Water Geochemistry in Small Headwater Catchments Underlain with Permafrost” presents an evaluation of water chemistry data collected from two catchments underlain by permafrost terrain. Overall, the paper presents interesting data on a topic which is important given the changing environment in permafrost terrain caused by anthropogenic warming. While the paper is well written I think there are some significant changes needed prior to publication. I think the suggested changes are needed to be able to strengthen the conclusions of the paper and will result in a significantly better paper.

Two general areas for improvement are here and detailed comments are below.

The information on the vegetation could be more quantitative, or at least include some photos etc. A significant portion of the discussion rests on the information provided in Table 1. The authors need to provide more information on how the vegetation assessment was done, and more information on the results of that, I have made a few more detailed comments on this below.

Please see above response plant functional type photos added to the Supplementary Materials, inclusion of dominant plant functional type cover to Table 1 and Table 2, as well as additional text added to Section 2.2:

"Vegetation data were collected at the peak of the growing season in mid to late July 2016 and 2017 at the NGEE Arctic Kougarok and Teller field sites, respectively. The distribution of plant communities in the Arctic is primarily controlled by landscape, topography, soil chemistry, soil moisture, and the plants that historically colonized an area (Raynolds et al., 2019). Soil available rooting depth, which can be limited by shallow depths to bedrock, permafrost, or the water table, can also restrict plant growth and survival of certain species by reducing access to water and nutrients. We surveyed the dominant plant communities along each hillslope, which varied in their shrub abundance, canopy height, and structure, to characterize the vegetation composition at the sites following the recommended protocol of Walker et al. (2016). Extensive field site details and vegetation sampling methods are more thoroughly described in previous studies (Salmon et al., 2019; Langford et al., 2019; Yang et al., 2020; Sulman et al., 2021; Yang et al. 2021).

For this study, we provide summary statistics for vegetation plots associated with intensive stations. Vegetation composition plots within each intensive station were chosen subjectively in areas of homogeneous and representative vegetation varying in size from 1 to 25 m² depending on canopy structure and height. The surveyed plot area was 1 × 1 m for all plant communities except for the taller stature willow-birch tundra, mesic willow shrubland (2.5 × 2.5 m), and alder shrubland (5 × 5 m). For each plot, all plant species (vascular plants, lichens, and bryophytes) were recorded along with visual estimates of their percent cover. For plots with multiple canopies, field cover estimates were recorded as absolute cover, meaning that the total cover per plot can be >100%. We calculated relative cover values (adding to 100%) from the field data and use these for all subsequent analyses.

Plant species were further aggregated into nine plant functional types (PFTs), groupings of plant species that share similar growth forms and roles in ecosystem function (Wullschleger et al., 2014), based on growth patterns and plant traits. PFTs in this study include: (1) nonvascular mosses and lichens, (2) deciduous and evergreen shrubs of various height classes, including an alder PFT, (3) graminoids, and (4) forbs. Canopy height was estimated within each plot for each PFT as the average of 4 measurements, including a maximum canopy height. Active layer depth was measured at the end of the growing season for all plots in September 2018 using a frost probe. A temperature probe was used to determine if the resistive layer was permafrost (≤ 0 °C) or rock (>2 °C). Thaw depth is an average of 4 measurements from the vegetation plot corners."

And at Line 75:

"Indirect effects would include vegetation canopy impacts on soil moisture (through evapotranspiration and snow trapping). Direct effects of vegetation would include nutrient cycle changes resulting from the annual deposition of plant litter. Such a direct effect can be augmented at sites populated by alder shrubs due to this genus of

deciduous shrubs ability to form a symbiotic relationship with nitrogen-fixing Frankia that they host in underground root nodules. Nitrogen fixation associated with alders has been shown to accelerate local nitrogen cycling (Binkley et al., 1992; Clein and Schimel, 1995; Bühlmann et al., 2014)."

The authors conduct numerous geochemical calculations which is great, however were samples collected of the soil for mineralogical analysis? It would greatly support the paper if there were some XRD analysis of the soil, or other relevant information (other reports, papers discussion the soil mineralogy in the study areas). If you have this or can easily do it, it would greatly improve the paper. I think your geochemical discussion needs to better reflect that the water chemistry suggests these are the mineral phases present, however this you don't actually know this.

Unfortunately, we did not perform XRD nor are we aware of any studies that did. We were able to find some XRF performed at the Teller-27 site, which does not provide mineralogical information, but does confirm the presence of significant amounts of Al, Fe, Si, and Ba, agrees nicely with our thermodynamic models.

Added to Section 4.5:

"Although it does not provide mineralogical information, X-ray fluorescence (XRF) data reported by another study at Teller confirmed high concentrations of Al, Fe, Si, and Ba in the organic and mineral soil layers at that site (Graham et al., 2018). We are unaware of any similar studies at Kougarok, nor are we aware of any studies that provide would provide confirmatory mineralogical information, for example by X-ray diffraction (XRD)."

Specific Comments:

Line 29: NO3-

Resolved here and throughout the text.

Line 52: I have not reviewed this journals style guide, but is it correct to list Koch, Runkel, Striegl, and McKnight, 2013; most journals would be Koch et al. Please check.

Thank you for catching this. Resolved here and throughout the text.

Line 75 to 77: Much of your paper involves discussion about the role of alders and nitrogen fixing but rests on one reference, can you provide more. I think this is a well studied topic, it would be good to show its well established.

Thank you for pointing out this omission and we agree that the role alders play in modifying local nitrogen cycling has been well-studied. We therefore modified text at line 75 to include more references and read as follows:

"Indirect effects would include vegetation canopy impacts on soil moisture (through evapotranspiration and snow trapping). Direct effects of vegetation would include nutrient cycle changes resulting from the annual deposition of plant litter. Such a direct effect can be augmented at sites populated by alder shrubs due to this genus of deciduous shrubs ability to form a symbiotic relationship with nitrogen-fixing Frankia that they host in underground root nodules. Nitrogen fixation associated with alders has been shown to accelerate local nitrogen cycling (Binkley et al., 1992; Clein and Schimel, 1995; Bühlmann et al., 2014)."

Line 100 – 146: This section provides a good general background. I find it lacking in real information about the geology. Based on the locations in Figure 1, I think the two catchments are underlain by different geology. I looked at “Preliminary Bedrock Geologic Map of the Seward Peninsula, Alaska, and Accompanying Conodont Data, By Alison B. Till, Julie A. Dumoulin, Melanie B. Werdon, and Heather A. Bleick, <https://pubs.usgs.gov/of/2009/1254/>” However you can probably find larger scale maps with more detail. Referencing this would help your description of the site, and can also be made consistent with the geochemical discussion.

Thank you for your efforts in locating the USGS map by Till et al. The final version of the map you referenced is actually already referenced in Line 133:

“The upper shoulder of Kougarok is a well-drained rocky outcrop composed of metagranitic rock (Hopkins et al., 1955; Till, Dumoulin, Werdon, and Bleick, 2011).”

Unfortunately, on the maps both sites are underlain with the same broadly-defined geology: “Surficial deposits, undivided (Quaternary)”. We made a significant effort to search for geological maps and old literature that described the region. To the best of our knowledge, we found what was available and have summarized it in Lines 100-146.

Line 101, 103: km2 should be superscript

Resolved here and throughout the text.

Line 108 -109: Reword sentence, it is confusing.

“Teller and Kougarok are not paired watersheds in the classical sense, differing in only one major characteristic, which provides the basis for comparison. Instead, Teller and Kougarok differ in many respects and are both representative of the broad range of hillslope conditions common on the Seward Peninsula.”

Changed to:

“It should be noted that Teller and Kougarok are not “paired watersheds” in the classical sense, differing in only one major characteristic, which provides the basis for comparison. Instead, Teller and Kougarok differ in many respects and are both representative of the broad range of hillslope conditions common on the Seward Peninsula.”

Line 129 / Figure 3: The figure shows a watershed boundary, however I think the authors are trying to show a boundary of the area studied, as this cannot be a watershed boundary. On the west side the boundary is shown along a contour line which water will continue to flow over.

Thank you for pointing this out, we really appreciate your attention to detail. The watershed boundaries were delineated in ArcGIS using the Hydrology Toolbox and using a 5m resolution IFSAR DEM to run the analysis. The ArcGIS Hydrology Toolbox determines the direction of flow by determining the direction of steepest descent from each cell. This mechanism worked very well at Teller-27, which has well-defined drainage divides and pour point, but did not work as well at Kougarok, which is more of a convex hillslope. The legend has been changed to “Hillslope Boundary” to reflect this.

Line 174-178: More information is needed on the methods used for the vegetation assessment. If this assessment is part of this study how was it determined that the dominant plant function type was “Deciduous low to tall shrub (willow)”. From the text its sounds like this was done part of another project “NGEE Arctic project”, if so the text should reference where we can get information on how this was done, however, even with a reference, a sentence or two is needed to explain roughly how it was done.

We appreciate the reviewer's attention to detail that these methods were missing from the manuscript. We added the text below to Section 2.2 – where noted by the reviewer.

“Vegetation data were collected at the peak of the growing season in mid to late July 2016 and 2017 at the NGEE Arctic Kougarok and Teller field sites, respectively. The distribution of plant communities in the Arctic is primarily controlled by landscape, topography, soil chemistry, soil moisture, and the plants that historically colonized an area (Raynolds et al., 2019). Soil available rooting depth, which can be limited by shallow depths to bedrock, permafrost, or the water table, can also restrict plant growth and survival of certain species by reducing access to water and nutrients. We surveyed the dominant plant communities along each hillslope, which varied in their shrub abundance, canopy height, and structure, to characterize the vegetation composition at the sites following the recommended protocol of Walker et al. (2016). Extensive field site details and vegetation sampling methods are more thoroughly described in previous studies (Salmon et al., 2019; Langford et al., 2019; Yang et al., 2020; Sulman et al., 2021; Yang et al. 2021).

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We also added this text to Tables 1 and 2 to clarify the dominant species in the deciduous shrub classes:

For Table 1 - Deciduous shrub PFT classes identify the dominant species in the plant community as either willow or willow and birch. There is no alder at the Teller site.

For Table 2 - Deciduous shrub PFT classes identify the dominant species in the community as either willow, alder, willow and birch, or alder, willow and birch.

Line 216: “Modelling exercises were performed at 25 °C utilizing the” why was this done at 25C when your studying water in permafrost terrain? Maybe necessary stability constants were only available at this temp. but you should comment on who it may differ with field temperatures.

The authors spent significant time deliberating what temperature to run the thermodynamic models but found that selecting a defensible temperature for the purposes of modeling was non-trivial. The temperatures on the Seward Peninsula span a remarkable range, with wintertime lows of – 30 C and summertime highs of 25 C. Meanwhile, freeze/thaw processes (and the accompanying charge exclusion, cryoturbation, ect...) are superimposed on these large temperature swings. Because the thermodynamic models were used as a tool understand what could be controlling soil pore water solute concentrations and were not intended to model the system or to predict future concentrations, it was decided that the “default” value was most suitable; using something other than the default required defensible justification. 25 C is the default temperature for PHREEQC (and for many geochemical thermodynamic modeling efforts). While there is some temperature dependence of mineral solubility, the differences in predicted solubility between 4 °C and 25 °C did not impact the interpretation of our results.

To address this we have added a temperature dependency figure to the Supplementary materials and added the following text to Section 2.4:

“Modelling exercises were performed at the default PHREEQC modelling temperature (25 °C), as the selection of an alternative defensible temperature was non-trivial; temperatures on the Seward Peninsula span a very wide range and it is unclear what temperature would be most suitable for mineral solubility limitation modelling. Ultimately, because the thermodynamic models were used as a tool understand what could be controlling soil pore water solute concentrations and were not intended to model the system or to predict future concentrations, the default temperature was decided to be the most suitable. While there is some temperature dependence of mineral solubility, the differences in predicted solubility between 4 °C and 25 °C did not impact the interpretation of our results (Supplementary Figure 8).”

Line 231, compounds measured as ions should be listed with their charge (eg SO42-, NO3-, however Sr and Ca are likely measured as total concentration (so don't list charge))

Resolved here and throughout the text.

Figure 4: I have had to zoom into 150% to be able to read this. Make it bigger, and you may also be able to use a crisper font.

The authors agree. We hope this will be a full-page figure for the final publication. We used a very high-resolution version of Figure 4, but the quality in the Cryosphere pdf print is less than ideal. We will work with The Cryosphere typesetters and editors to ensure this figure is published at an appropriate size and resolution. As a note: when printed from our Word Document, Figure 4 appears very crisp and clear, and is easy to read. This should be easily resolvable with the Cryosphere editorial team.

Line 282-283: “NO₃⁻ concentrations at both sites were generally low, with the exception of Kougarok Stations 3, 5, and 12, and Teller Station 7 (Figure 4). Kougarok Stations 3, 5, and 12 all have a significant alder presence.”

Can you back up this statement further? This is very qualitative? Do you have photos of the different sites that you could compare on contrast? Do other papers talk about vegetation density?

Thank you, this is a very good point. The percent coverage of the dominant plant functional types has been added to Table 1 and Table 2. Meanwhile, the text has been changed to make it more precise and quantitative:

“NO₃⁻ concentrations at both sites were generally low, with the exception of Kougarok Stations 3, 5, and 12, and Teller Station 7 (Figure 4). Kougarok Stations 3, 5, and 12 all have a significant alder presence.”

Changed to:

“NO₃⁻ concentrations at both sites were generally low, with the exception of Kougarok Stations 3, 5, and 12, and Teller Station 7 (Figure 4). Low to tall alder shrubs are the dominant vegetation type at Kougarok Stations 3 and 12. Meanwhile, alders are present at Kougarok Station 5 despite the dominant vegetation type being low willow and birch shrubs.”

Also, plant functional type photos have been added to Supplementary Materials.

Section 4.5 Mineral solubility Effects: Have you measured the presence of the mineral you discuss in soil samples? Perhaps you have done some XRD? If not, have other papers done soil analysis in the area? You can pull in reference to the local geological maps as well. I have had the experience myself where a given mineral is predicted by a geochemical software, but you don't actually have that mineral in your system and something more complicated is going on.

Unfortunately, we did not perform XRD nor are we aware of any studies that did. We were able to find some XRF performed at the Teller-27 site, which does not provide mineralogical information, but does confirm the presence of significant amounts of Al, Fe, Si, and Ba, agrees nicely with our thermodynamic models.

Added to Section 4.5:

“Although it does not provide mineralogical information, X-ray fluorescence (XRF) data reported by another study at Teller confirmed high concentrations of Al, Fe, Si, and Ba in the organic and mineral soil layers at that site (Graham et al., 2018). We are unaware of any similar studies at Kougarok, nor are we aware of any studies that provide would provide confirmatory mineralogical information, for example by X-ray diffraction (XRD).”