Reviewer 1:

The manuscript presents the results of investigation of dissolved organic carbon and several major ions (sulphate, magnesium, calcium) concentrations, electrical conductivity measurements relationships with catchment discharge and seasonality using general additive models (GAMs) in the permafrost regions in Alaska. The authors tried to link the selected stream chemistry parameters with discharge and seasonality. I am not sure if the GAMs are applicable in this context. For me personally, It was difficult to understand the presented results (e.g. figure 5 and 6) that used the derived statistical modelling such as sDOY and CV ratios, thus it was accordingly difficult to follow the discussion.

Thank you for your feedback. Figure 6 has been edited where the colors now represent permafrost extent and topographical gradients. In addition, the caption along with the methods section have been expanded and clarified to aid in interpretation of the figures. GAMs are an emergent technique used to explore CQ relations, and we are furthering this new area of inquiry which we believe is quite fruitful.

The authors discuss the links of water chemistry with permafrost extent, topographic gradients, active layer. Perhaps, they can add catchment characteristics to their statistical model. As of now, the discussion reads more as a bare speculation. Significance of the work in terms of environmental implications must be more strongly highlighted. I provided some detailed suggestions on how to improve the work.

Although we have a limited number of sites, we have added further statistical tests to determine the influence of catchment characteristics on the seasonality and the average of solute concentrations. The tests are discussed in detail in the newly added sections 2.6 and section 3.3. Specifically, we use correlations between mean catchment slope vs sDOY range for all solutes. Since permafrost extent can only be estimated as a categorical variable, we opted to use ANOVA and Tukey tests to assess significant differences in sDOY range. Similarly, we use ANOVA and Tukey tests to assess significant differences in median concentrations of solutes amongst permafrost extents, and we use Pearson's correlation to assess the influence of mean catchment slope on average solute concentrations. The discussion now also incorporates these findings.

We cannot include catchment characteristics more broadly as a part of the model, as the focus of this paper is to assess the drivers of seasonality not total exports or avg concentrations. Additionally, the geology and climate are distinct among the catchments and it would be difficult to account for considering the data available. We have instead conducted statistical tests to assess the influence of permafrost extent and topography on

stream chemistry seasonality (model outputs) separately. Please see the first paragraph, or section 2.6 and 3.3 for additional details.

The introduction is very long, LL54-104 I would recommend to include in the discussion section or made more focused. The portion of text may better fit into methods (LL76-84).

We agree with this comment. There was some redundancy and irrelevant information in the introduction. Much of the introduction has largely been rewritten and clarified.

Section 2.1. Perhaps, it is better to combine the figures 1 and 2. Sections 2.1 and 2.2 are mostly land cover description, I would merge them.

Sections 2.1 and 2.2. have been combined. We explored alternation options yet feel that it is better to separate Figures 1 and 2, as the catchments are quite far apart, and two panels may make it difficult to read the maps.

Section 2.2. Table 1 seam more of land cover classification map, not catchment characteristics. I would move it to the supplement.

The table has been updated and improved. It now includes median specific discharge values, classifications for permafrost extent, and classification for topographical gradients. We believe it now plays a more integral role to the paper, especially for readers to cross reference site names with permafrost extent, and topographical gradients.

Section 2.3. for consistency LL203 replace sulphate with SO4 and elsewhere in the figures and text.

Thank you for noting this. We have made this change throughout the manuscript.

The main: You talk about discharge while presenting runoff data mm/day in the strict sense (see section 2.4). That's confusing. Discharge is flow data (m3/sec) though a catchment outlet, while runoff is calculated per catchment area? I think if you talk about specific discharge in mm/day (e.g. LL260 you state this explicitly) you need to describe this in methods (section 2.4). Given the high variability of contribution area to runoff in this region, use of specific discharge is maybe not appropriate.

We have replaced Runoff with specific discharge where appropriate, as runoff can at times be confused with overland flow. The decision to use specific discharge was primarily made to ease comparison among sites. The statistics i.e. sDOY range, log-log slopes, along with any interpretation of our results would be unaffected by the units of the measurement ($L^3 T^{-1}$ vs $L T^{-1}$).

LL259-260. Which figure or table do you refer to for median specific discharge numbers?

Table 1 now includes this information.

Fig. 7 and 8. I would recommend combining the figures, or better revising the figure to incorporate the topographical gradients and permafrost extent together, if possible.

Figure 7 and 8 (now figures 8 and 9), cannot be combined for this paper. Largely because topographical gradients and permafrost extent do not correlate across our study sites. For example, Km 71 has both high permafrost extent and strong topographical gradients.

Reviewer 2:

The authors present a unique dataset of seasonal stream chemistry of 10 catchments spanning a latitudinal and permafrost gradient in the Yukon. The objectives were to unravel the drivers behind the seasonality of major ion and DOC concentrations in catchments, while accounting for stream discharge variability. The manuscript is generally well written and organized, however, the presentation of the results makes it difficult to link the findings to the conclusions and conceptual models. Some additional analysis and figure adjustments may help to clarify this point. It is worth noting that multi-year datasets such as this are challenging to produce and are a rare occurrence in the North. This is a valuable contribution to the literature, but some improvements could be made as suggested below.

We very much appreciate your feedback.

General:

1. I was surprised about the lack of time series data presented. I think it would be worth presenting it, at least in supplemental data. It was difficult to grasp exactly when samples were taken over which years for what catchments.

We have added a figure in the SI (Figure S1) which shows when samples were taken. We also reference this figure in text in section 3.1.

"Detailed time series information on when samples were collected, are represented in Figure S1."

2. I found it difficult to interpret the figures in results, even with the description in the results section. I think there is a missed opportunity to better link your results to your conceptual model. Can some of the key drivers you mention be included in these figures through colour, annotation, or organization? Some specific suggestions are below.

We have edited figure 6 so sites are color coded by permafrost extent and topographical gradients as well. In addition, we have made significant edits to the results and methods section to improve clarity on how to interpret results.

3. While the conceptual model intuitively makes sense, and the interpretation of the results seem valid, there is still a bit of a tenuous connection between the drivers of seasonality. 10 catchments is a relatively high number, so could there be some additional univariate or multivariate statistics be done to more firmly link the drivers to the results? As a very simple example, correlation between average catchment slope and DOC variability?

Although we have a limited number of sites, we have added further statistical tests to determine the influence of catchment characteristics on the seasonality and the average of solute concentrations. The tests are discussed in detail in the newly added sections 2.6 and section 3.3. Specifically, we use correlations between mean catchment slope vs sDOY range for all solutes. Since permafrost extent can only be estimated as a categorical variable, we opted to use ANOVA and Tukey tests to assess significant differences in sDOY range. Similarly, we use ANOVA and Tukey tests to assess significant differences in median concentrations of solutes amongst permafrost extents, and we use Pearson's correlation to assess the influence of mean catchment slope on average solute concentrations. The discussion now also incorporates these findings.

Section 2.2: This section could be removed and the information be combined with the previous section since there is already detailed descriptions of each of the catchments in 2.1.

Section 2.2 is now incorporated into section 2.1.

Line 188: Can you be more specific about timing of the sampling? Was this just once in May/June and a second July/August? How are you defining spring and summer?

Timing varied across sites. The definition of spring would also largely depend on the site in the context of this line. We have reworded to clarify that samples were generally taken whenever the streams were not ice covered. The line now reads:

"We collected grab samples for major ions and dissolved organic carbon (DOC) across flow states and open water seasons at all sites over multiple years."

Line 204: Was this measured in all catchments continuously throughout the entire study period? Was this data used in the analysis or did you just use the YSI data? If continuous data for this exists for each catchment, I think it would be worth presenting.

Although we have continuous SpC data at some sites for certain years. The data has too many gaps and is missing from some sites making it difficult to incorporate into the manuscript. SpC samples were taken from spot measurements from a handheld YSI probe.

The section referencing continuous SpC collection has now been omitted, as it was never referenced in text.

Figure 3: Can the data be colour coded to permafrost extent or other key catchment characteristic? It might help tease out if there are other relationships going on and support the conceptual model.

Yes. Two additional figures were included in the supplemental information. These figures are identical to figure 3 but the colors represent catchment permafrost extent and topographical gradients. The caption for figure 3 now reads:

"Figure 3. Solute concentrations plotted against flow for all sites. Winter samples were lumped in with spring. Analogous figures where samples are color coded by permafrost extent and topographical gradients instead of site names are available in the SI (Figure S2; Figure S3)."

Figure 4: Similarly, could you put these in order from lowest to highest permafrost coverage or catchment slope?

As permafrost extent cannot be represented as a percentage (due to high uncertainty in permafrost coverage products), we cannot order by permafrost coverage. However, we do refences in text that all TWO sites have greater than or equal to permafrost extent when compared to WCRB sites (with the exception of Km 44).

Figure 5: Can you include annotations or an additional example box that explains how to interpret these curves? Perhaps it could just be added to the caption as well.

We have changed the caption for additional clarity. We now clarify that the plots represent the sDOY value in reference to equation 1 and 2. We now clarify how the value of the term changes depending on the DOY. Initially the caption was:

"Figure 5. sDOY from GAMs for all solutes and sites where the sDOY was significant (p-value < 0.05) and 321 mean SE was less than 0.4."

Now the caption reads:

"Figure 5. Partial effect plot for sDOY term from GAMs for all solutes and sites where the sDOY was significant (p-value < 0.05) and mean SE was less than 0.15. The plots represent how the value of the sDOY term in equation 1 and 2 changes depending on the day of year a sample was taken. Larger sDOY shift over time represents greater relative change in solute concentrations driven by processes other than seasonal discharge. The sDOY value is

logged, thus a shift of 1 (i.e. Mg for Km 104) would result in a 10x increase or decrease of solute concentrations if discharge is constant."

464-467: Right now, your figures do not demonstrate this readily.

We believe that figures 6 and 7 (now updated), along with the addition of correlation and ANOVA tests support our claims.

Figures 7 and 8: Remove the description from the figure itself. This should just go into the figure caption.

The description from figures 7 and 8 (now 8 and 9) were moved from the figure to the caption itself.