Anonymous Referee #2

This is an interesting paper on lake hydrochemistry of two contrasting sites in the Republic of Sakha. Authors examine drivers of lake inorganic and organic chemistry by considering landscape and climate characteristics. The idea is clear; the research is scientifically sound and data rich. Lakes are discussed from different perspectives, but at the same time, in a quite complex way. Here are several suggestions on how to improve the quality of the manuscript.

Authors are advised to improve M&M, Results, and Discussion in a way that the narrative better connects RQ stated, Results obtained, and the Discussion of these results.

This can be done by 1) better explaining reasons for assigning thermokarst development stage to lowland lakes and the choice of lakes for sampling; 2) better explaining the rationale of choosing the parameters involved (buffer zones, LC dataset, and climatic variables; 3) better explaining the reason of MPA.

Further, although the laboratory analytics and data post-processing and Methods seem very convincing, the Discussion of the obtained Results is a little speculative.

Abstract requires some numbers and clearer statements about drivers: higher/lower seams non-informative; hydrochemical analysis clearly distinguished mountain lakes from lowland lakes: mountain lake hydrochemistry is determined by the climate and topography; lowland thermokarst lakes are diverse: this is explained by the lake development stage, these groups show different ranges of hydrochemical characteristics: DOC, pH etc.

Reply: We thank the referee for the detailed assessment of our analyses and discussion, interesting questions, checking our data and several suggestions.

[Referees' comments in bold and our reply in blue with *new text in the manuscript in Italic***]**

We edited a major part of the abstract accordingly:

Our hydrochemical analysis reveals a clear distinction between the low-mineralised mountain lakes and the highly variable hydrochemistry of the lowland thermokarst lakes. The mountain lake hydrochemistry is determined by the climate and topography, the environmental drivers of the hydrochemistry in the lowland thermokarst lakes are more diverse. The lake developmental stage within the thermokarst lake sequence seems to be a key driver of anorganic, isotopic and organic lake hydrochemistry for the lakes of the Central Yakutian lowland. For our sampled lowland lakes we could define three successional thermokarst lake stages: recently forming thermokarst lakes, in the following 'new thermokarst lakes'; Alaas lakes within alaas systems without in and outflow, in the following 'old alaas lakes' and the connected thermokarst lake type with in and outlets in highly degraded alaas systems, in the following called 'connected alaas lakes'. Specifically, the thermokarst lake's developmental stage is reflected by dissolved organic carbon (DOC), pH, its stable isotopic composition, and the hydrochemical facies of alkali and earth alkali elements. New thermokarst lakes have a depleted stable isotopic composition, possibly due to contributions from meltwater of adjacent permafrost ground-ice. These new thermokarst lakes are typically located within forest and characterised by high DOC. In contrast, connected lakes that *are typically located in large alaas systems despite their location close to settlements and managed land use show low DOC and low mineralisation. High discharge, even only temporary such as the regular snowmelt, enables dilution. In contrast to the more diluted connected alas lakes, the old alaas lakes without in and outlet show an enriched oxygen isotope composition and mineral content due to evaporation in summer, highlighting their vulnerability to future warming. However, low chloride despite high salinities and an enriched isotopic composition characterise several of the sampled high-salinity lakes showing elevated fluoride. As these sampled lakes are far from settlements and managed land use the human influence cannot cause the high fluoride levels. This points to an additional process beyond the current evaporation for these specific lakes, such as fluoride leakage from lacustrine sediments or salt deposits. Our results provide a detailed examination of lake systems in modern conditions within highly climate-sensitive lowland and mountain permafrost landscapes.*

We enriched the discussion, also we used the suggested literature from referee 2, please see our replies, specifically related to the last two comments of referee 2.

i) We explained the reasons for assigning the thermokarst development stage to lowland lakes and discussed the differences to the Western Siberian peatland thermokarst lake sequence (e.g., Manasypov et al. 2014) in depth and great detail in Results and Discussion. We added information on the choice of lakes for sampling in the chapter 2 Data and Methods, 2.1 Field work.

ii) we explain in our reply the choice of the buffer zone, the chosen land cover data set and the climatic variables, and added details in the text

iii) by making the text more clear in introduction, some sections of Data and Methods and specifically the Discussion we hope that the details are now better described and more in order and clear.

Replies in detail:

Please explain how sampling sites were chosen: sample sizes for each type are inequal (15-15-8-28).

Reply: As it was not possible to clarify the lake development stage of the lakes before the expedition and due to logistic constraints with the dependance on the road network it was not possible to sample an equal size for each lake type. We preselected the lakes according to different terraces, land cover and lake sizes and shapes and according to recommendations from Sakha scholars. We thank the reviewer for this question and added the details in the text:

New text: *During a joint German-Russian expedition conducted in 2021 from 6th August to 2nd September (Fig. 1) lakes could be sampled along the roads. For the lowland region, we preselected lakes according to different terraces, land cover and lake sizes and shapes and according to recommendations from Sakha scholars. For the mountain region we preselected the lakes according to different land cover, elevation and lake sizes.*

….These 51 lowland lakes are all thermokarst lakes in various stages of development, however in the preselection of sample lakes it was not possible to determine the thermokarst lake stage, therefore we did

not aim to sample an even distribution of the thermokarst lake stage but to capture a large variety of lakes in different land cover settings across climate gradients.

Did Authors consider environmental drivers (LULC, climate) while choosing sampling sites?

Reply: We preselected the lakes according to different terraces, land cover and lake sizes and shapes and according to recommendations from Sakha scholars. We thank the reviewer for this question and added the details in the text:

See the new text in the reply above

How did Authors account for geomorphology? Through lake shore elevation?

Reply: We added in the methods chapter 2.4 on 'lake classification' details on how we used the geomorphological information

New text in 2.4 'lake classification': *Distinct geomorphological features for the assignment as new thermokarst lake are steep and freshly looking lake shore morphologies and often a steep lake slope, visible in the field as well as in bathymetric data when available. In some cases new thermokarst lakes occur with a considerable large lake surface area as on the sandy lithology of the first Lena River terrace. The distinction between the 'old alaas lake' type and the 'new thermokarst lake' type could be well made due to the very distinct alaas geomorphology in which the old alaas lake type is located. For the classification of lakes into the 'connected alaas lake' type we used local expert knowledge, field knowledge and UAV and satellite imagery. As several of the 'connected alaas lakes' are not connected during the drier summer months in contrast to the higher water levels during snowmelt. The 'connected alaas lakes' are frequently of a very irregular lake shape, therefore the derivation of the factor C of the lake shape may be less reliable for this lake type, in contrast to the other lake type*

L30-32 – this sentence is purely formulated: Do you intend to understand environmental drivers of lake hydrochemistry by land cover, plant diversity, land use, and climate? Or what? It must be rephrased.

Reply: We changed the sentence structure.

To understand their characteristics and environmental drivers of sixty-six lakes across the Central Yakutian lowland permafrost landscape and the Verkhoyansk Oymyakon high mountain plateau, we analyse the hydrochemistry, sedimentary DNA (sedDNA)-derived aquatic plant diversity, geomorphology, and adjacent land cover.

L46-50 – this part must be introduced into the main narrative (L35-45) about environmental drivers. Otherwise, it stays aside of the main results.

Reply: Thank you for your suggestion. We moved this text paragraph on the results of Sedimentary DNA derived macrophyte composition higher up in the abstract text.

Since the impact of lake type is among the main findings of a paper, the characteristic features of each type (lowland thermokarst lakes) must clearly be specified. How did Authors differentiate visually between tympy lake and mature alaas lake, that are of different stages of development? Do we connect these types to ages?

Reply: We thank the referee for this comment and added in the methods chapter 2.4 on 'lake classification' more details

New text in 2.4 'lake classification': *In our lake collection we did not sample the first development stage 'byllar'. New thermokarst lakes are represented by the 'dyede' and the 'tyympy' lake stage, however we could not robustly separate these two lake development stages and therefore decided to aggregate them in the lake development stage that we refer to as 'new thermokarst lake'. Distinct geomorphological features for the assignment as new thermokarst lake are steep and freshly looking lake shore morphologies and often a steep lake slope, visible in the field as well as in bathymetric data when available. In some cases new thermokarst lakes occur with a considerable large lake surface area as on the sandy lithology of the first Lena River terrace. The distinction between the 'old alaas lake' type and the 'new thermokarst lake' type could be well made due to the very distinct alaas geomorphology in which the old alaas lake type is located. For the classification of lakes into the 'connected alaas lake' type we used local expert knowledge, field knowledge and UAV and satellite imagery. As several of the 'connected alaas lakes' are not connected during the drier summer months in contrast to the higher water levels during snowmelt. The 'connected alaas lakes' are frequently of a very irregular lake shape, therefore the derivation of the factor C of the lake shape may be less reliable for this lake type, in contrast to the other lake types.*

L96 Alaas lakes, alaas landscapes, lake systems – all are very misleading terminologies.

Reply: Thank you for this comment. We clarified the text accordingly by changing the paragraph structure. As well we corrected typos of 'tympy' should be tyympy.

L99 - CAL – these might be connected during one season and "disconnected" during another. More robust explanation of CAL is required.

Reply: We thank the referee for this comment: We already had described this characteristic of the 'connected alaas lake' type in the introduction Lxx ' In strongly degraded and interconnected alaas systems, lakes can become hydrologically connected, eventually only during high discharge events when water levels are high, such as during the annually occurring snow melt. These lakes are generally larger in area and often more elongated and deeper (up to 10 m) (Ulrich et al., 2017a; Hughes-Allen et al., 2023) and are named in this study 'connected alaas lakes'.

new text in chapter 2 data and methods

For the classification of lakes into the 'connected alaas lake' type we used local expert knowledge, field knowledge and UAV and satellite imagery. As several of the 'connected alaas lakes' are not connected during the drier summer months in contrast to the higher water levels during snowmelt. The 'connected alaas lakes' are frequently of a very irregular lake shape, therefore the derivation of the factor C of the lake shape may be less reliable for this lake type, in contrast to the other lake types.

<u>L128</u> – thermokarst/alaas development stage?

Reply: Thank you for the suggestion. We need in this context to refer to the lake development stage as it is in the original text that we also had introduced before in the introduction.

<u>L178-192</u> – do Authors present maximal lake depth, or depth of sampling? How did Authors use transparency (Secchi disk), and chromophoric DOM in the analysis? (these parameters are introduced)

Reply: We sampled water transparency and published the data in the data publication Baisheva et al. 2022. However, as we could not technically measure the transparency well in all lakes, e.g. limitations were in alaas lakes that they frequently were too shallow for a correct measurement, we did not integrate the water transparency in the statistical analyses and visualisation. We also measured cDOM, specifically to investigate the DOC/ cDOM relationship. However due to the very high concentrations in the lowland lakes we were cautious with the cDOM results and did not include the cDOM data in the Baisheva et al. PANGAEA data publications. We thank the referee for this comment and therefore removed all content that related to cDOM from the text in the chapter data and methods in the chapter 2.2. Field work.

<u>L276-279</u> - how did Authors use lake morphology in the analysis? (round, oval-elongated etc)

Reply: We added two sentences to clarify how we use the lake shapes in the analyses.

New text: *The connected alaas lakes and old alaas lakes are frequently of a very irregular lake shape, therefore the derivation of the factor C of the lake shape may be less reliable for these lake types, in contrast to the new thermokarst lakes. These shape irregularities are caused by high degradational processes with subsequent lake shore erosion, specifically due to strong water discharge events.*

In general, sub-Section 2.4 describes the UAV data processing and GIS analysis. A little is described regarding the lake type classification (lowland thermokarst lakes)

Reply: We thank the referee for this comment and added in the methods chapter 2.4 on 'lake classification' considerable details

New text in 2.4 'lake classification':

In our lake collection we did not sample the first development stage 'byllar'. New thermokarst lakes are represented by the 'dyede' and the 'tyympy' lake stage, however we could not robustly separate these two lake development stages and therefore decided to aggregate them in the lake development stage that we refer to as 'new thermokarst lake'.Distinct geomorphological features for the assignment as new thermokarst lake are steep and freshly looking lake shore morphologies and often a steep lake slope, visible in the field as well as in bathymetric data when available. In some cases new thermokarst lakes occur with a considerable large lake surface area as on the sandy lithology of the first Lena River terrace Bestyxxx. The distinction between the 'old alaas lake' type and the 'new thermokarst lake' type could be well made due to the very distinct alaas geomorphology in which the old alaas lake type is located. For the classification of lakes into the 'connected alaas lake' type we used local expert knowledge, field knowledge and UAV and satellite imagery. As several of the 'connected alaas lakes' are not connected *during the drier summer months in contrast to the higher water levels during snowmelt. The 'connected alaas lakes' are frequently of a very irregular lake shape, therefore the derivation of the factor C of the lake shape may be less reliable for this lake type, in contrast to the other lake types.*

F.e. Fig. 2D to my subjective understanding may be considered as NTL, CTL, and OTL (depending on the position in the alas)

Reply: We thank the referee for this comment. However, as we have assessed Lake EN21418 (= Fig. 2D) during field work it clearly represents a newly forming thermokarst lake (referred to as NTL), located at a higher position in the alaas system and characterized by steep slopes with up to 6 m height difference to the top of the Yedoma plateau. The outflow channel at the eastern flank represents a Yedoma degradation feature discharging some lake water to the lower levels of the alaas system.

We added the small detail in the figure caption Figure 2

New text: *Lake EN21418 is located at a higher position in the alaas system and characterized by steep slopes with up to 6 m height difference to the top of the Yedoma plateau* and EN21448 (A) showing the baydzharakh permafrost degradation features. (B,E) Two examples of old alaas lakes are EN21456 and EN21464 (green outlines). EN21456 (B) is one example with a nearly circular developed 'ice-hill' (pingo) of around 4 m height and 55 m diameter within an old alaas lake (in this case surface water not masked as white). (C) Lake EN21419 (blue outline) is of the connected alaas lake type showing a typical elongated shape.

Sub-Section 2.5. I do not understand why Authors have chosen to additionally utilize 10-m ESA WC land cover, if drone images are available?

Reply: UAV acquisitions are constrained by battery power during field work, therefore the UAV acquisitions covered the lake shores and ideally the lake itself, however we could not map the lake environment so extensively that we could use it for such a land cover analyses. Also in the case of large lakes, not all the lake shore could be covered due to restriction of battery power. Therefore we relied on a consistent continuous data set on land cover with high spatial resolution: the 10-m ESA World Cover land cover.

new text: *We used the 10 m resolution European Space Agency (ESA) World Cover 2021 land cover product (derived from Sentinel-1 and Sentinel-2; Zanaga et al., 2022) to extract the dominant land cover around the lakes as the UAV data coverage of the lake environments was not large enough, specifically around the large lakes.*

At the same time, important topographic catchment characteristics have not been included (i.e. from ArcticDEM).

Reply: Thank you for the comment, we investigated Arctic-DEM, specifically in relation to the delineation of the lake catchment, However this approach was technically not possible for the majority of our lowland lakes due to too low relief of the landscape. As we could not delineate the catchment, we also could not derive topographic characteristics linked to the catchment area.

We explained it in the original text in the subchapter on satellite-derived land cover: "Due to the very flat yet locally complex (e.g., braided rivers, ponds and other lakes close by) geomorphological relief in Central Yakutia, a robust lake catchment delineation for each of the lakes from Digital Elevation Model data could not be carried out. Instead, we created 50-m buffer zones extending landward from the shoreline around each lake for a consistent extraction of the surrounding land cover. We also created a wider buffer zone of 360 m according to the relevant source area of pollen areas in Central Yakutia as calculated in (Geng et al., 2022)."

Please explain the rationale of choosing 50- and 360-m buffers for extracting LC fractions. Why not 100 or 200 m?

Reply: Thank you, we clarified the rationale based on a previous study where the aeolian pollen input area for Central Yakutian sites has been calculated by Rongwey Geng in Geng et al (2022).

We explained it in the original text in the subchapter on satellite-derived land cover: "We also created a wider buffer zone of 360 m according to the relevant source area of pollen areas in Central Yakutia in Geng et al. (2022)." To make it more clear we added that it was calculated *as calculated* in Geng et al. (2022).

<u>L312-313, L315-316</u> What is the rationale of merging grasslands with croplands from WC for Central Yakutia, if Authors intend to analyze the impact of the land use? Same with Built-Up class

Reply: Thank you for your comment. The classification at the level of these classes was not reliable enough; the classes merged into each other and were often incorrectly assigned, but only at the aggregated level the land cover classes come out reliably. We added new sentences in the text.

new text:

The class built up seemed to irregularly occur, e.g., being confused with bare /sparse vegetation. Therefore, built-up and bare/sparse classes were subsequently merged into a single 'barren' class while the moss/lichen class was renamed to 'tundra' for descriptive purposes. The Central Yakutian lakes included up to nine land-cover classes (tree cover, shrubland, grassland, cropland, built-up, bare/sparse vegetation, permanent water bodies, wetland, moss/lichen). For the lowland, there was even more confusion for the land cover classes 'built up' and 'barren/ sparse vegetation', similarly, regrettably also the land cover classes indicating the land use were not consistently correctly mapped according to our field knowledge and local knowledge. ThereforeHere, the classes 'grassland' and 'cropland' needed to be were merged into the single class 'grassland'. As 'moss/lichen' does not occur as the true land cover in the lowlands but represents sparsely vegetated areas in settlement and on agricultural land we further merged this class 'tundra' into the 'barren' class (i.e., built-up and bare/spare vegetation) for the lowland region. As a result, we could not use the specific land cover classes 'built up' and 'cropland' to statistically assign the area linked to human land use.

L330-337 Why not to choose data from nearest meteorological stations? What about permafrost relevant parameters: ground temperature, ALT?

Reply: We needed a data set that is available as a continuous variable in which all lakes are set, the meteorological stations are only local and close to few of the lakes and represent the local climate.

L369-370 This is a repetition

Reply: Thank you for your indication that we mention two times that 15 lakes are in the mountain region and 51 lakes in the lowland, however we use this information in a different context: in chapter 2.2 Fieldwork we for the first time introduce the sampling of the lakes with a lot more detail: original text: "Of these sampled 174 lakes, 15 (EN21401 to EN21415) are located within the Verkhoyansk mountain range at elevations ranging from 789 m to 175 1310 m, primarily on the Oymyakon high mountain plateau (Fig. 1B,C; Table A1); and 51 lakes are located in Central Yakutia at elevations between 115 m and 307 m (Fig. 1B,D; Table A1). These 51 lakes are thermokarst lakes in various stages of development.

In chapter 3.1 Summary of the morphological, physico-chemical and isotopic lake characteristics, we use this information in the original L369-370 as a short introduction to this paragraph and overview without the details introduced before. original text: "Our collection of lake data forms a large dataset across a wide (> 700 km) west to east gradient encompassing two contrasting 370 groups of lakes: thermokarst lowland lakes (n = 51) and mountain lakes (n = 15)."

L384 – ML TBS is 49 mg per L, but Table 1 shows the value of 61. Similar to OAL.

Reply: Thank you for pointing out this typo! We corrected the value in the table.

L414-419 Authors write that in 60 lakes, alkaline earths exceed alkalis, but at the same time, an opposite effect is observed in 9 lakes. How could that be?

Reply: We thank the referee very much for detecting this error in the manuscript text. n = 60 lakes should only refer to the results of the anion triangle that weak acids exceed the strong acids (CO3-+HCO3-)>(SO42-+Cl-) for 60 lakes corresponding to the bicarbonate type in the anion triangle. n = 60 lakes does not refer to the cation triangle, therefore we removed the subsentence 'alkaline earths exceed alkalis (Ca2++Mg2+)>(Na++K+)'.

We also corrected the sentence related to the results in the cation triangle, as for brackish Central Yakutian lakes, alkalis often exceed alkaline earths (Na++K+)>(Ca2++Mg2+) in the case of 25 lakes.

Corrections in the text

Weak acids exceed the strong acids $(CO_3^-+HCO_3^-)>(SO_4^{2-}+Cl^-)$, ~~*and alkaline earths exceed alkalis*~~ ~~$(Ca^{2+}+Mg^{2+})>(Na^++K^+)$~~ *for a large majority of the lakes (n = 60), corresponding to the bicarbonate type in the anion triangle….*

….For brackish Central Yakutian lakes, alkalis often exceed alkaline earths (Na++K+)>(Ca2++Mg2+) (n = 9 25, EN21420, 425, 426, 428, 431, 436, 437, 438, 440, 441, 442, 443, 444, 447, 449, 450, 453, 454, 455, 456, 457, 458, 464, 465, 466)

What is the idea of the lake clustering? How this answers the RQs stated at the beginning? (Intro)

Reply: Thank you for the comment. The clustering method helps to unveil RQ1 by identifying natural hydrochemical groups. We implemented the comment accordingly.

New text: *To identify natural hydrochemical groups, clustering analysis was undertaken using the package 'stats' (R Core Team, 2025) on the lake data of major ions, DOC, TDS, and isotopes.*

L512 Forest land cover fraction?

Reply: Thank you for the suggestion, we added 'fraction' for the forest land cover and the grassland land cover in the text.

Edited text: *The fraction* of forest land cover has a significant ….while *the fraction* of grassland *land cover* correlates …

L555 – what is the Elev variable? Ellipsoid elevation of the shoreline? Or mean catchment elevation?

Reply: Elev refers to the elevation of the lake, i.e. WGS84 ellipsoid elevation of the shoreline which was measured during the fieldwork from the boat in the center of the lake. We added "Lake" in the sentence and in table 2.

Edits in the text: *In contrast, precipitation of the wettest month (Pwet) and lake elevation (Elev) are linked to the distribution of the mountain lakes along the positive PC1 axis.*

L575-580 This is the repetition. I suggest removing this part.

Reply: Thank you, for your suggestion, we deleted this part.

L579 what is the "hydrochemical lake status"?

Reply: Thank you, we deleted this part.

L581-584 It is obvious that permafrost lakes receive an input from surface runoff, but Authors do not directly measure the hydrochemical parameters of the active layer or catchment streams.

L594-595 One could add stable water isotope values for ground ice and add these numbers to the Figure 5 with isotopic composition with relevant references.

Reply to both comments: We thank the reviewer and included N.V. Torgovki from the Melnikov Permafrost Institute as co author as he is the scientist with the regional knowledge on the geochemistry and isotopic composition of soils and lithostratigraphy (holocene and pleistocene Yedoma) in Central Yakutia with several publications that we now included in methods and results and in Figure 5.

New text in methods:

Local evaporation lines (LELs) were calculated by fitting a linear regression to the δ18O and δD values of the lake water samples for all lowland lakes as Yak21Lowland, and separately by lake types as for connected alaas lakes (Yak21CAL), old alaas lakes (Yak21OAL), new thermokarst lakes (Yak21NTL) and mountain lakes (Yak21ML). We further include additional stable isotopic analyses from Central Yakutia from Yedoma ground ice from ice wedges and aggregated ice (Pavlova et al. 2024 et al; Torgovkin et al. 2024; Pope et al. 2006; Windirsch et al., 2020; Ulrich et al., 2021).

New text in results:

The average isotopic composition of syngenetic ice wedges in the Yedoma shows a light composition (–31 ‰ to –24.3 ‰ for d18O and –239‰ for dD (Pavlova et al. 2024, Torgovkin et al. 2024). The isotopic composition of pore ice in Yedoma varies more widely: –31.7 ‰ to –21.9 ‰ for d18O; –247.5 to –162.6‰ for dD (Pavlova et al. 2024; Torgovkin et al. 2024; Ulrich et al. 2021; Windirsch et al. 2019) (see also Figure 5).

We also extended the content on the influence of ground ice isotopic signature in new thermokarst lakes in the discussion chapter 4,1 indicated by *cursive letters* in the original text

Edited text in Discussion: Several of the sampled new thermokarst lakes show a depleted isotopic composition that could indicate lateral input from meltwater of permafrost ground-ice *from ice wedges or pore ice that shows a much lighter composition (Pavlova et al. 2024, Torgovkin et al., Ulrich et al. 2021, Windirsch et al., 2019, Popp et al. 2006)*. The Pleistocene Yedoma sedimentary deposits in which the sampled new thermokarst lakes with depleted isotopic composition are *mainly* located, are characterised by significantly higher ice content, and therefore, high potential for permafrost degradation due to ground-ice melt. This is in contrast to the considerably reworked and ground-ice depleted Holocene alaas deposits (e.g., Windirsch et al., 2020, *Torgovkin et al. 2024* for Central Yakutia). As the old alaas lakes and connected alaas lakes are all located in subsided and thoroughly degraded topographic depressions, the major ground-ice thawing processes have occurred several centuries to millennia earlier. Therefore, we can assume that no major ground-ice contribution in the form of meltwater input is expected for these two types of alaas lakes, in contrast to the potential meltwater contribution from the ground-ice rich Yedoma sedimentary deposits in the new thermokarst lakes. *However new thermokarst lakes also show a wide value range in stable isotope composition, as some of the new thermokarst lakes also formed on the first sandy terrace and in an alaas within a settlement.*

New Fig 5 in results

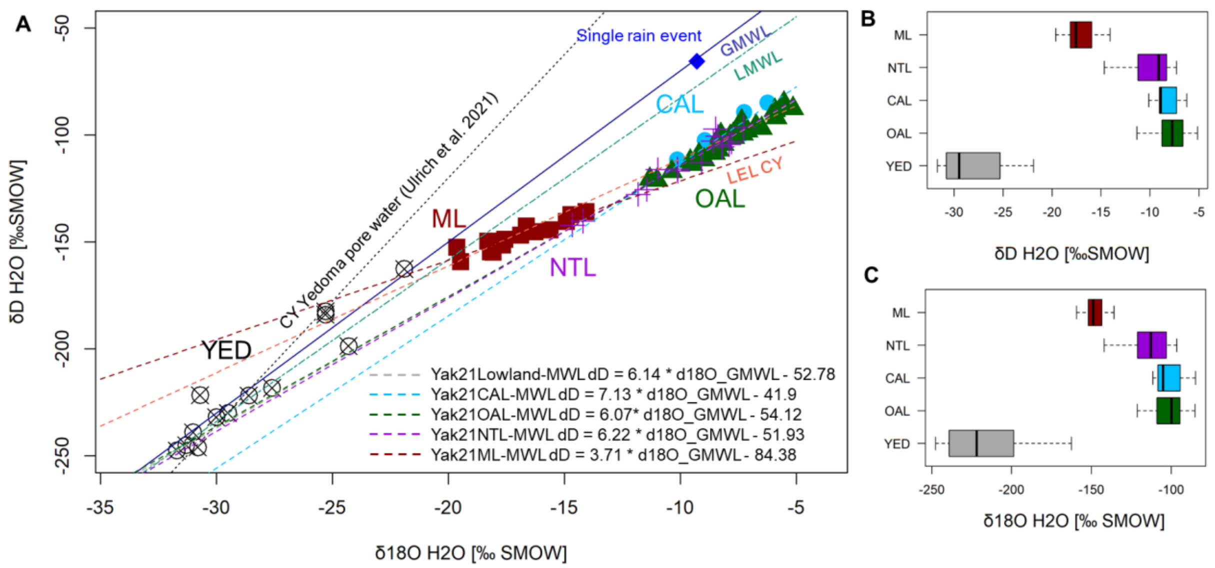

Figure 5: (A) Stable isotopes (δ18O and δD) from lake surface-water and from one summer precipitation sample (August 2021) along a700 km west to east transect from Central Yakutia (old alaas lakes (OAL), connected alaas lakes (CAL), new thermokarst lakes (NTL)) to the Oymyakon High mountain plateau in the east (mountain lakes (ML)). *YED values include ice wedges and segregated ice in Yedoma from Pavlova et al. (2024) et al; Torgovkin et al. (2024); Popp et al. (2006); Windirisch et al. (2019,2020); Ulrich et al. (2021).* Displayed are the Global Meteoric Water Line (in solid blue), GMWL: δD = 8*δ18O + 10 (Craig 1961), the Local Meteoric Water Line (in dashed green) LMWL: δD = 452 7.57*δ18O_GMWL – 6.86 (Kloss, 2008), and a local evaporation line from Central Yakutia (in dashed orange), LEL CY (lakes sampled in 2008): δD = 4.99*δ18O_GMWL – 61.41 (Wetterich et al. 2008), and our local evaporation lines based on the different lake types (Yak21Lowland(lowland lakes), Yak21CAL(connected alaas lakes), Yak21OAL(old alaas lakes), Yak21NTL(new thermokarst lakes), and Yak21ML(mountain lakes)).

Section 4.3 In the title, Authors declare “thermokarst lakes”, but it is obvious that these are of different origin

Reply: Thank you for your comment, we removed ‘thermokarst’ in the title

<u>L650</u> – it is not a glacial type, it is a glacial origin

Reply: Thank you for your comment, we corrected the wording and added new details in the text.

New text: *Mountain lakes are on one hand glacial lakes spanning from large deep lakes to small lakes representing bedrock-dammed and moraine-dammed glacial lakes. On the other hand, lakes in moraine settings and mountain river floodplains formed due to thermokarst*

L656-659 – this is a repetition as in 4.1

Reply: Thank you for this observation, we now kept the land cover information in the discussion chapter 4.1 Environmental drivers of physico-chemical lake characteristics.

Fig. 8 – orange and yellow colors can hardly be distinguished

Reply: Thank you for your comment, we changed the figure colors in Figure 8

4.5. Yakutian lakes as a resource – L731-751 (this is an irrelevant information). I suggest removing this part.

Reply: We kindly decline the suggestion. It is a relevant chapter to understand the local knowledge and the use of the Yakutian lakes as a resource, it is also a relevant chapter to understand the potential future pathways of the different lake types.

We added new text in the chapter 2 data and methods, 2.1 fieldwork and also highlighted the text on the future pathways as a separate new chapter 4.6 Future.

New text: *During the fieldwork, we also conversed with local Sakha people on lakes as a resource for the local population, and included excerpts of their knowledge in our study according to the recommendations of McCartney et al. (2022). We also included traditional indigenous knowledge from the author team, Izabella A. Baisheva, Evgenii S. Zakharov, Aital V. Egorov, Paraskovya V. Davydova, Lena A. Ushnitskaya, Sardana N. Levina, and Luidmila A. Pestryakova, who were born in the Republic of Sakha (Yakutia; Sakha Sire, Ksenofontov et al. 2025) and identify themselves as Sakha scholars.*

L1324 – forming

Reply: Thank you for your comment, we corrected the typo.

Regarding the speculations about sources of fluoride in samples considered: Authors are advised referring to a research paper by Pavlova & Fedorova 2022 "Fluoride distribution in sub-permafrost groundwater in Central Yakutia" published in Earth's Cryosphere.

Reply: Thank you for your suggestions. We made the text more clear and changed to a more general title
new title*: 4.2 Saline lakes in Central Yakutia*

We added information from Pavlova & Fedorova 2022 "Fluoride distribution in sub-permafrost groundwater in Central Yakutia" in the Discussion chapters on 4.2 Saline lakes in Central Yakutia and 4.5. Yakutian lakes as a resource.

In chapter 4.2 Saline lakes in Central Yakutia we inform on the high fluoride groundwater content in Central Yakutia in sub-permafrost aquifers, i.e. below the permafrost and provide more details on the lithostratigraphy of Central Yakutia, however we are very cautious in describing mechanisms how to bring sub-permafrost ground water up to the surface.

In chapter 4.5 Yakutian lakes as a resource we added the information on the potential use of sub-permafrost water from wells to eliminate problems with the drinking water supply for the population.

New text in 4.2 Saline lakes: *Pavlova and Fedroova (2022) investigated the hydrochemistry in water sampled from wells below permafrost in Central Yakutia and identified high fluoride concentrations in the subpermafrost aquifers resulting from weathering of Jurassic source rocks. Over the Jurassic bedrocks, the Aldan Basin contains several hundred metres of sediment successions of Neogene to late Pleistocene age (e.g. Alekseev et al. 1990). These Cenozoic and Late Pleistocene sediments are covered by Quaternary sediments, comprising fluvial, glacial and loess-like deposits. (Soloviev, 1973). The permafrost table in the lowlands of Central Yakutia is 400 to 700 m thick, increasing in depth within the central Verkhoyansk Mountains up to 1000 m (Agriculture Atlas of the Republic Sakha (Yakutia), 1989). In locations of tectonical disturbances there might be pathways upwards for fluoride rich subpermafrost waters under pressure, however this is not described by Pavlova and Fedroova (2022).*

New text in 4.5 Yakutian lakes as a resource: *The exploration of drinking water extraction from ground water below the permafrost seems to be possible in areas, where aquifers are hydraulically connected with the Lena River through open taliks (Pavlova & Fedroova (2022). The authors identified distribution patterns of fluoride in subpermafrost aquifers that should be taken into account when planning to use subpermafrost water from wells to eliminate problems with the drinking water supply for the population*.

The impact of thermokarst development stage on lake hydrochemistry has already been discussed in Manasypov et al. 2014 ('Thermokarst lake waters across the permafrost zones of western Siberia')

Reply: Thank you for your suggestions. We made the text in the discussion more clear and added considerable more discussion in the text by contrasting the western Siberian thermokarst peatland lake chronosequence (Manasypov et al., 2014) and relationship with hydrochemistry versus our Central Yakutian lake chronosequence and relationship with hydrochemistry and are confident that this enriched our discussion. Manasypov et al 2014 and associated publications describe that a typical feature of the Western Siberian thermokarst peatland lakes, ponds and khasyreys that are all closed basins is a linear relationship between decreasing DOC concentration and specific electrical conductivity, respectively, versus the increasing lake surface area that is also a proxy for increasing lake age and lake development stage. In summary, Manasypov et al. (2014) describe how DOC together with the specific electrical conductivity decrease along the increasing lake size and lake age. This Western Siberian peatland lake chronosequence however is different compared to the Central Yakutian thermokarst lake chronosequence described in our study that does not represent a thermokarst peatland lake chronosequence. For the Central Yakutian thermokarst lakes we could not find this systematic relationship of lake area size inverse to DOC and specific electrical conductivity (new analyses visualised in new Fig A3A, A3B in appendix). We show these findings now new in results, also in the form of two new figures displaying the relationship of lake area size inverse to DOC and specific electrical conductivity. These graphs show the high scatter of the data, for example, new thermokarst lakes in Central Yakutia also occur as larger lakes, e.g. on terraces with sandy lithostratigraphy and may at the same time show high DOC despite the large lake size. On the other hand, old alaas lakes also show high scatter in the DOC and lake surface area relationship.

According to Masypov et al 2014 Figure 2 and Figure 3 we show the two new figures, Fig A3A and FigA3B in the form of linear-log graphs of specific electrical conductivity and DOC and lake area for Central Yakutian lowland lakes and added new text to the chapters methods, results 3.1 Summary of the morphological, physico-chemical and isotopic lake characteristics and discussion 4.3 Specificity of lakes and lake hydrochemistry.

New text in 2.5 Environmental data processing

…*To examine the lake area with DOC and EC we created a scatterplot, using the ggplot library*.

New text in 3.1 Summary of the morphological, physico-chemical and isotopic lake characteristics

…The analyses of the lowland lake area versus the mineral content expressed as electrical conductivity and the organic content expressed as DOC shows that their relationship is not strongly linked to the three different thermokarst lake types. The range of lake area size is wide for new thermokarst lakes linking high DOC also to larger lakes, whereas lower EC values also occur in smaller new thermokarst lakes (Fig appendix A3 on DOC and EC versus lake size).

New text in 4.3 Specificity of lakes and lake hydrochemistry:

…For the Western Siberian permafrost peatland, Kirpotin et al., (2007, 2009) and Pokrovsky et al., (2011, 2014) developed a cyclic chronosequence for peatland thermokarst lakes, using lake diameter as a proxy for the lake age. Shirokova et al., (2009), and Manasypov et al. (2014) describe that a typical feature of western Siberian thermokarst peatland lakes, ponds and khasyreys that are all closed basins is a linear relationship between DOC concentration and specific electrical conductivity, respectively versus the lake surface area. The authors describe how DOC together with the specific electrical conductivity decrease along increasing lake size and lake age. High DOC and mineralisation characterise the youngest and smallest water bodies due to leaching and thawing of surface soil ice. In contrast, the large water bodies are characterised by low DOC and specific electrical conductivity, predominantly due to much long residence times and strong mineralisation of DOC. This Western Siberian peatland lake chronosequence however is different compared to the Central Yakutian thermokarst lake chronosequence described in this study. For the Central Yakutian thermokarst lakes we could not find a systematic relationship of lake area size inverse to DOC and specific electrical conductivity. For example, new thermokarst lakes also occur as larger lakes, e.g. on terraces with sandy lithostratigraphy and may at the same time show high DOC despite the large lake size due to leaching from forest soil and plant litter. On the other hand, old alaas lakes also show high scatter in the DOC and lake surface area relationship.

New figure A3A, A3B in appendix

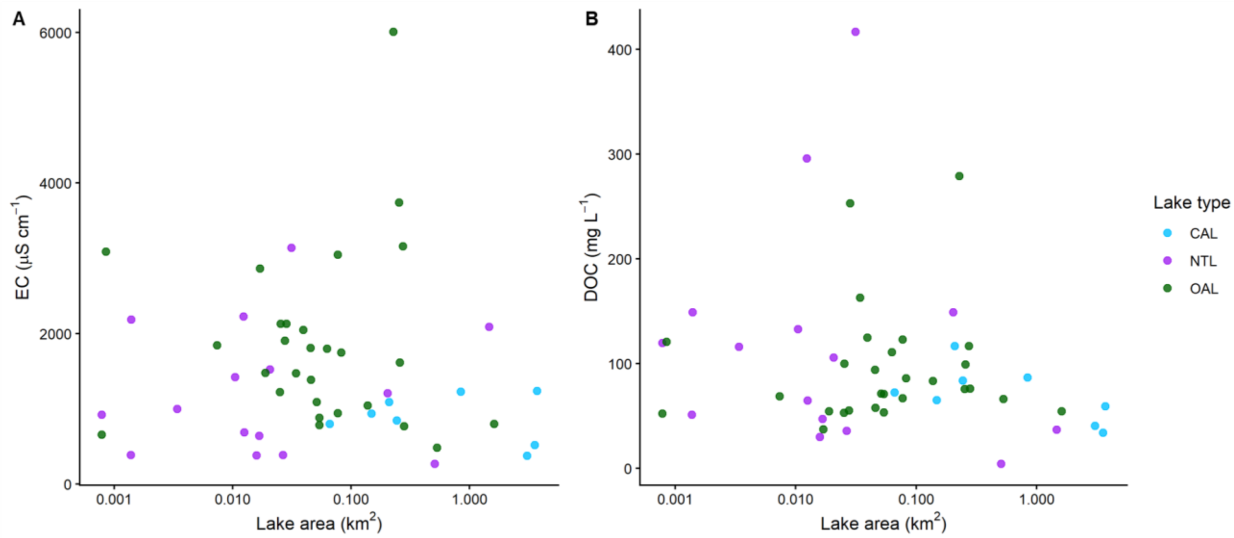

Figure A3A,B. Linear-log graph of (A) specific electrical conductivity (EC) and (B) dissolved organic carbon (DOC) concentration and lake area for Central Yakutian lowland lakes. Points are colored according to lake type: old alaas lakes (OAL, green), connected alaas lakes (CAL, blue), and new thermokarst lakes (NTL, purple). Lake area (km2) is shown on a logarithmic scale.

Overall, the Discussion is the weakest part of the manuscript, that must largely be improved by replacing the irrelevant parts with truly important findings of other researchers.

Reply: Thank you for your comments. We made the text in the discussion more clear. In addition, we also included N.V. Torgovki from the Melnikov Permafrost Institute as co author as he is the scientist with the regional knowledge on the geochemistry and isotopic composition of soils and lithostratigraphy (holocene and pleistocene Yedoma) in Central Yakutia with several publications that we now included in methods and results and in Figure 5.

We know the relevant findings from i) Pavlova & Fedorova 2022 related to fluoride in subpermafrost groundwater in Central Yakutia and ii) Manasypov et al 2014 and other related publications on the Western Siberian peatland lakes in the continuous and discontinuous permafrost zones and related hydrochemistry. We consider them as great findings and very important publications, however as relevant as they are, i) and ii) are not directly linked to our research objects and cannot directly explain i) the high fluoride concentrations in Central Yakutian lakes because Pavlova & Fedorova 2022 discuss high fluoride in subpermafrost groundwater in aquifers below the permafrost and do not link it to surface water hydrochemistry; ii) for the lake chronosequence Kirpotin et al., (2007, 2009), Pokrovsky et al., (2011, 2014) Shirokova et al., (2009), Manasypov et al. (2014) show the lake chronosequence of peatland thermokarst lakes that is different to the Central Yakutian lake chronosequence, mainly developing in Yedoma and on fluvial terraces, and therefore also not showing the same hydrochemical characteristics as described for the Western Siberian peatland lakes in Manasypov et al. (2014), please see the detailed reply and the enriched discussion on it above.

We would like to thank you for your detailed review.

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