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The Cryosphere Discussions

Interactive comment on "Discovery and characterization of submarine groundwater discharge in the Siberian Arctic seas: A case study in Buor-Khaya Gulf, Laptev Sea" *by* Alexander N. Charkin et al.

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We thank all three reviewers for their large effort and for providing valuable and very constructive comments, which have been useful in our revisions of the manuscript. Naturally, we are encouraged that all reviewers support our study of submarine groundwater discharge (SGD) in the Bhuor-Khaya Bay, SE Laptev Sea, and the conclusion that it provides a previously largely unexplored vector for transport from land to the East Siberian Arctic shelf, yet complicated by geocryological conditions such as permafrost. Below, each review comment is listed first, followed by our response and a description

of resulting edit. Author comments are marked below as AC.

General and specific comments by anonymous referee 3 (Reviewer 3).

RC: The manuscript Discovery and characterization of submarine groundwater discharge in the Siberian Arctic seas: A case study in Buor-Khaya Gulf, Laptev Sea coauthored by Charkin et al. presents the first evidences of the presence of SGD along the Eurasian Arctic margin. In my opinion the data provided in this manuscript is really interesting and will be the first step for other new studies. The paper is well written and the arguments are clear and well presented, although some parts of the text are difficult to follow. I recommend the publication of the manuscript after include some comments to the text. I have two major comments to the manuscript:

Why the study is so descriptive? The text describes the distribution of short-lived Ra isotopes and Rn but does not go deeply in the use of these radionuclides as a traces to estimate SGD fluxes or transit times.

AC: Thank you for the overall support and for this specific comment. We have now in the revised ms, incorporated a quantitative estimation of SGD discharge and transit times using short-lived Ra isotopes. Following the reviewers encouragement, we have now added an estimate of SGD discharge (1.7 x 10 6 m3 d-1) and transit times (3.2 – 1.5 days) around the SGD place, while stating clearly all assumptions. Discharge of the subpermafrost groundwater from Kharaulakh hydrogeological massif through the talik area were calculated on excess 224Ra activities using a Ra mass balance model (Moore 1996; Burnett and Dulaiova 2003; Null et. al., 2012, 2014). In order to calculate the growth of the water mass "radium ages," we used the equation proposed by Moore (2000). As a result, there will be two new chapters in the methods section and one in the discussion section. This results will be shown in our revised text.

RC: The second comment is for me the one that I can not understand. Where is the long-lived Ra data? I guess the authors have them and maybe they want to use in another manuscript. I feel that the long-lived Ra data will help to understand SGD

sources and discharge processes. For example, recently Rodellas et al (GCA, 2017) have published how the combination of short- and long-lived Ra isotopes can be used to distinguish sources of submarine groundwater discharge: fresh groundwater vs seawater recirculation through sediments that is the case of part of the study.

AC: We agree with this comment, but we still have not obtained the results of gamma spectrometry for the long-lived Ra isotopes for the wintertime (see our detailed response to a similar question by Rev. 1). However, in the final version of the manuscript we will include data on long-lived isotopes in the summertime: Regarding methods for Ra isotopes, this will be included in the revised ms. Briefly, in the shorebased/home laboratory, Ra was leached from the fibre with hot 6N HCl, coprecipitated as BaSO4 and counted with gamma spectroscopy for 226Ra and 228Ra (Moore, W.S., 1984. Radium isotope measurements using germanium detectors. Nuclear Instruments and Methods in Physics Research 223, 407-411).

RC: How you can discard that the short-lived Ra isotopes are not coming from recirculation or sediment resuspension?

AC: This is a very important comment and we have now included (in section 3.3) the long lived isotope data of the summertime cruise and an additional figure of radium isotopes versus salinity as supporting argument that the high activities of short lived Ra isotopes near station 1529 are due to SGD and not to resuspension (see the figure 1). Besides, according to our multi-year winter data, the resuspension effect is negligible during wintertime (see the details elsewhere: Charkin et al., BG, 2011)

Some other technical corrections are:

RC: Do you have any sample for Ra-isotopes and Rn that can be compared between winter and summer? o Line 35 pag 5. Do you need the two dots after Radiometer?

AC: Unfortunately, we do not have such data.

RC: Review the text because sometimes you write “kilometers” or “meters” and others

you write “km” and “m”.

AC: Yes, we apologize for not being consistent in use of these jnits. We will check the text carefully and streamline this

RC: I suggest rewriting the sentence of the Line 20 Pag 6 as: These TEM results agree well with data provided by Imaev et al (2004) for this region.

AC: Ok, will be done.

RC: Line 22 Page 6. Remove a space between 162, and 5 meters.

AC: Ok, will be done.

RC: 3.2 Features of the thermohaline water structure and SGD fate. In this chapter authors explained the features of the thermohaline water structure but there is not any comparison or relation with SGD. Is this a correct tittle?

AC: Yes, we agree: that is not correct. It will be changed to Features of the thermohaline water structure.

RC: In the chapter 3.3 the units of Ra-223, Ra-224 and Rn are wrong. It is “dpmÂ ËŽu100L-1” or “dpm/100L”. Check the document and Figures.

AC: We are sorry, this is a typo. It should of course be dpm/100L or dpm 100L-1. It will be edited to dpm 100L-1.

RC: Line 25 Page 8. Add a space between the numbers and “m” as you do for “km” or other units.

AC: Ok, will be done.

RC: Line 10 to 13 Pag 8. Maybe the 228/226 AR provides information about the SGD fluxes.

AC: Yes, you are right. We included to the manuscript the summer data on long-lived isotopes which supporting argument that the high activities of short-lived Ra isotopes

near station 1529 are due to SGD.

RC: Line 10 page 9. Maybe this is a possible explanation, but what about the increase due to resuspension processes? Is it a possibility? Maybe the long-lived Ra isotopes can help you to understand the origin of this high 224/223 AR.

AC: Yes, you are right, this could be an explanation for summer time, but in under ice conditions at a relatively large depth and with a low winter Lena River discharge, resuspension is very unlikely. This is also indicated by the very low concentration of suspended particulate matter in the water for this time (Charkin et al. BG, 2011). Moreover, we included to the manuscript the summer data on long-lived isotopes which supporting argument that the high activities of short-lived Ra isotopes near station 1529 are due to SGD and not to resuspension (see the figure 1).

RC: Line 33 page 9. Correct the 100L-1.

AC: We will correct.

RC: Line 20 page 10. Can you explain why this water is saltier?

AC: This water is saltier because this water was formed as the result of multi-year freezing of rocks and the simultaneous concentration of salts (Pinneker, 1983; Romanovskii, 1983), resulting in elevated levels of total dissolved solids in the cryogenic groundwater.

RC: Line 38 page 10. Here you notice: The fact that the summertime and wintertime SGD springs were found on a line parallel to the fault once again points to the connection between the tectonogenic talik and the SGD. Here you talk about summertime and wintertime SGD springs. Why the seasonality is not shown in the text?

AC: The seasonality is not shown in the text, because the summer data is very limited for SGD place.

RC: Table 1. Add the uncertainties to the 224/223 AR and review the significant figures

of the Ra-223 and Ra-224.

AC: Ok, will be done.

RC: What is the meaning of the equation of the upper plot?

AC: We will redo this piece of the text by removing both the linear mixing lines (because short-lived isotopes can be highly modified by decay in addition to mixing) and the equation.

RC: I guess there is a mistake in the Figure referred to CSW in the plot and RFS in the caption.

AC: Yes, you are right. It is a typo. We will correct. Thank you.

Thank you for your valuable comments which help to improve our manuscript.

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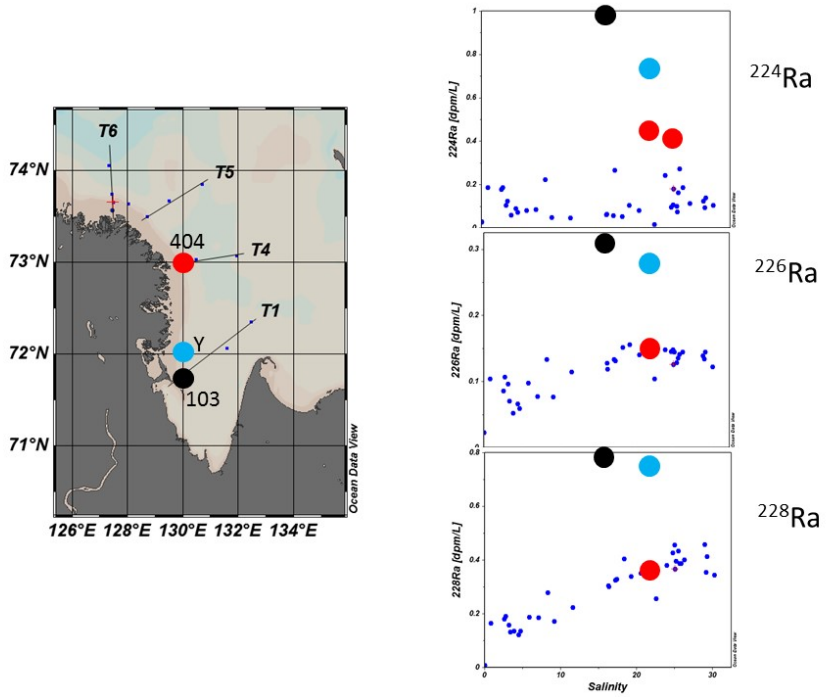
T6
T5
T4
T1
404
Y
103
74°N
73°N
72°N
71°N
126°E 128°E 130°E 132°E 134°E
Ocean Data View
224Ra (dpm/L)
226Ra (dpm/L)
228Ra (dpm/L)
Salinity
224Ra
226Ra
228Ra

Fig. 1.