

Interactive comment on “Clay mineralogy, strontium and neodymium isotope ratios in the sediments of two High Arctic catchments (Svalbard)” by Ruth S. Hindshaw et al.

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We sincerely thank both reviewers for providing valuable feedback on the original version of this manuscript. Page and line numbers in the response below refer to the ‘marked changes’ manuscript.

Reviewer 1

COMMENT: I think one of the main issues of the study is the sampling strategy. First, I do not understand why the authors decided to focus on such small catchment areas (a few km² at most) when the aim of the study is to better constrain the composition of

C1

river sediment inputs from Svalbard to the oceans (cf. page 2, lines 32-35 and page 3, lines 1-10). What is special about this area? REPLY: The catchments were selected for a number of reasons. First, the smaller the catchment, the easier it is to constrain the geology. Second, we wished to compare a glaciated and an unglaciated catchment with the same lithology, in order to assess the impact of glaciation on chemical fluxes of both the dissolved load and suspended sediments. Third, fieldwork in Svalbard is difficult and these catchments were logistically feasible (close to the nearest settlement). The aim of the study as previously written did not fully reflect the second factor and we have amended the text accordingly (P3 L6-7). (See also comments below regarding representativeness).

COMMENT: Are the lithologies exposed in these two catchment areas representative of what can be found elsewhere on Svalbard? REPLY: We have added a panel to Fig. 2 to show the extent of the Central Basin, highlighting that the formations present in the two studied catchments are representative of a large areal proportion (8%) of the archipelago (P3 L4).

COMMENT: I found that there was a general confusion on what is considered a sediment source, a sedimentary rock or a sediment all through the manuscript. After several readings, I think I finally understood that the authors had collected random pieces of sedimentary rocks (not in place) in the catchment areas together with river, and supraglacial sediments and that they were trying to determine the nature of the sedimentary formations randomly sampled, the sources of the river and supra-glacial sediments, and the sources of the sedimentary formations exposed in the catchment area. Again, if the aim is to constrain the composition of sediments exported from Svalbard to the Arctic ocean, I do not understand the sampling strategy of the authors. Why didn't they sample the drained formations in place to know the isotopic compositions of the sources? How did they choose the pieces of bulk rock to analyze? The information given in Table 1 and 2 are also not very clear: Which samples are assumed to be the sources and which ones are the sediments for which the sources are un-known? Why

C2

are the stream sediments from Fardalen and Dryadbreen (samples L and O) and the sediment collected at the surface of a glacier (sample D) grouped together with bulk rocks collected in the catchment areas? This needs to be clarified. I would suggest that the authors clearly divide their samples into two groups: river sediments and potential sources; or first-cycle sediments and second-cycle sediments; or sedimentary rocks (old consolidated sediments exposed in the catchment area) and sediments (modern river, stream, glacial sediments). REPLY: We are grateful to the reviewer for highlighting the inconsistencies in our use of 'sediment' and have corrected usage throughout the manuscript.

The aim of this study was to study the effect of glaciation on dissolved and suspended matter fluxes. In order to interpret the suspended sediment data, we took representative samples from the two catchments to constrain the rock sources supplying sediment to the streams.

We agree that it was not clear which samples were sampled from formations and which were modern sediments. We have re-organised the samples in Table 1 to clarify which samples are from a specific formation and which are modern sediments. In Table 2, we have added clarification as to which samples are sedimentary rocks and which are modern sediments. In addition, we compare our rock samples to the core samples analysed by Schlegel et al., 2013 on a Herron diagram to provide further confirmation linking the sedimentary rock samples to a specific Formation (Fig. 4). We have re-made Fig. 3 to only focus on the sedimentary rock samples and highlight where our samples plot in relation to the major element composition of the core samples reported in Schlegel et al. (2013). In Fardalen the Frysjaodden Formation is clearly exposed and we took two samples (R01 and G). In Dryadbreen the rocks could not be sampled in outcrop as the outcrops were inaccessible due to the glacier. Here we aimed to take a representative selection of samples. Thus for rock samples collected in Dryadbreen, we identify the Formation that the samples originated from by comparing our data (chemical composition and clay mineralogy) with that of Schlegel et al., 2013. (P6

C3

L15-25).

COMMENT: The notation F and D (Fardalen and Dryadbreen) is also unclear in Table 1 since D is the name of a sample. I would simply add an additional column to mention clearly the name of the catchment area from which the samples were taken in Table 1. REPLY: The description already states that sample D was collected from the surface of the glacier i.e. Dryadbreen. We do not have space to add another column but as this information is contained in Table 2 we have added a footnote to reference to this in Table 1.

COMMENT: There is a significant isotopic bias between samples from the Fardalen and Dryadbreen catchment areas (see specific comment below), how can the authors be sure that it is not a sampling bias? REPLY: Please see reply below.

Specific comments 1. What controls the isotopic variability of the samples (grey trend in Fig. 3)?

COMMENT: The question is why are the contributions so variable from one sediment/sedimentary rock to another? Page 9, it is explained that each sedimentary formation may have a distinct isotopic signature. Why not, but I don't think the arguments are convincing enough. Knowing the composition of a rock sampled in place from each formation would easily solve the problem but since this data is not available I think the authors should develop a little bit more this part of the discussion. Maybe they should add a figure to clearly compare the clay mineralogy and the major and trace element concentrations of each of the formations (published data) to the composition of their sedimentary rocks. REPLY: We have added a figure (Fig. 4) identifying the origin of the five sedimentary rock samples (two of which were collected directly from the Frysjaodden Formation) and re-made Fig. 3 to only focus on the sedimentary rock samples and clearly highlight the literature data for each formation. The discussion of the major element compositions of the rocks has been moved to the Results section (P6 L15-25).

COMMENT: A striking feature of the author's dataset is that the Dryadbreen and

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Fardalen suspended AND catchment rocks form two very distinct groups in the Nd-Sr isotopic space (see red and blue circles in Figure 3 in the attached pdf). This difference is discussed for the suspended sediments only (end of page 8 and page 9) but this actually also concerns ALL the other collected rocks. How do the authors explain this difference given that the same formations are present in the two catchment areas? Did they unexpectedly sample only one formation in each catchment area? Is it a sampling bias? I was wondering whether it could be related to the fact that one catchment is glaciated and not the other. Assuming each rock-type (shale, siltstone, sandstone), not each formation, has its own isotopic signature, would it be possible that sandstones, enriched in Archean erosion products, be more eroded by the glacier in Dryadreen than they are in the unglaciated catchment? Knowing the sampling locations of all the studied catchment rocks might help to understand this feature. Alternatively, assuming that the different formations exposed in the catchment area do have distinct Sr-Nd isotopic signatures, why would the presence of the glacier in Dryadreen favors the erosion of the upper part compared to Fardalen? Is it directly related to the steepness of the eroded area and the location of the glacier? I think more explanations are needed here. REPLY: By definition the formations contain different rock types: Frysjaodden primarily contains shale and Aspelintoppen primarily contains sandstone. Yes, the trends are related to rock-type but this is inextricably linked to the parent formations. The grouping of points referred to by the reviewer is a form of sampling bias: due to the effect of glacial erosion the Frysjaodden Formation has become covered in moraine material derived from the upper formations. The modern-day glacier is cold-based and is not contributing to erosion, but when it was active it would have transported sediment from the top of the catchment to the bottom depositing it in lateral and terminal moraines. Yes, in the end we sampled only the Frysjaodden Formation in the unglaciated catchment and primarily the upper (Battfjellet and Aspelintoppen) formations in the glaciated catchment. We have added text to clarify these points (P9 L2-6 and L15-25).

2. Effect of grain-size/mineral sorting

C5

Page 9, lines 17-20: the authors argue that the isotopic difference observed between the clay fractions and the bulk rocks in Figure 3 (black and white triangles) could be explained by a process similar to the one that creates the general trend (grey lines, Fig.3) in Sr-Nd isotopic space. However, when you link the bulk rocks to their respective clay fractions (see the red arrows in Figure 3 in the attached pdf), the variations point towards different endmembers (much steeper slope than the general trend). To me, this indicates that the intra-sample variability (clay-bulk) cannot be explained with the same processes or the same sources than the inter-sample variability. Initially, I thought that the steeper trend was due to the ingrowth of radiogenic Nd since the formation of the Eocene sedimentary rocks but the difference of Sm/Nd ratios between the clay and the bulk fractions is too small to generate such a large variability in ϵ_{Nd} in 50 Ma (only 0.1 to 0.4 ϵ_{Nd} units according to a quick calculation). One would need to do a mass balance calculation for Nd and Sr but the low ϵ_{Nd} value of sample R03 (the only coarse-grained sediment, presumably enriched in REE-rich accessory minerals) suggest that another mineral phase controls the Nd isotopic composition of the sedimentary rocks, probably heavy minerals (monazite, apatite, allanite; see Garzanti et al, EPSL, 2010; 2011 and Garçon et al, Chemical Geology, 2014). This mineral phase would plot below the grey trend. Anyway, my point is that the intra-sample and inter-sample variability are not easily comparable. Trying to understand why bulk and clay are different may be interesting in the scope of the study. REPLY: The purpose of this section was to introduce grain-size variation as a known cause of variation in ϵ_{Nd} and we accept this was not clearly done. We completely agree that the clay-sized fraction – bulk pair for a particular sample on a different mixing line to the inter-sample array. We have rewritten this part, adding a separate section (Section 5.2.1) to discuss grain-size effects and briefly discuss the offset of the clay array to the bulk rock array (P10 L1-3). We do not dwell too much on the latter as the primary focus of the paper is to explain the large-scale inter-sample variations.

3. Effect of weathering/leaching COMMENT: At page 10, the authors speculate on the nature the leached mineral phases based on the REE element pattern of the bulk and

C6

residual fractions after leaching (Fig. 7b). My first point is that Sr and Nd are likely not hosted by the same mineral phases, so the authors should address the problem separately for Nd and Sr. Using REE patterns to investigate the carrier phases of leached Nd is OK but this is certainly not a good way for Sr. Secondly, the authors should take advantage of the major and trace element data (Table 1) they measured in the bulk and residual fractions. There, one can see that the residues contain much less CaO and Mn than the bulk phases. The loss of Ca could be linked to apatite or carbonate leaching but Mn is more difficult to explain, maybe more in favor of a leaching of Mn-oxides? REPLY: We agree that the mineral sources of Sr and Nd should be considered separately and have reworded this section (Section 5.2.2). We discuss the major element data and have added measured P concentrations to Table 1.

COMMENT: The leaching experiment and the weathering effects are closely related together. I would discuss these two things in the same part of the discussion for more clarity. The section discussing weathering effect at page 7 is not clear and needs to be re-written anyway so maybe it would be better to merge it with the leaching section to explain that weathering, in particular the formation of secondary minerals, is responsible for some isotopic variability but cannot account for the large range of isotopic compositions measured in this study. REPLY: We agree that the structure of the paper would be improved by combining the leaching discussion with the discussion on chemical weathering effects. We have rearranged the discussion section accordingly.

4. Seasonal variability I would be more careful with the effects of seasonality. There are only two samples taken at different times of the year and they do not show a significant variability. For Nd, 20120618F and 20120726F could be slightly different but the difference is barely resolvable if an uncertainty of $\pm 0.6 \epsilon\text{Nd}$ (2s) is considered, as suggested by the repeated measurements of JNdi and the shale SCo-1. For Sr, the effect of seasonality seems to be bigger though. REPLY: We have reworded this part of this section to be more clear which differences are resolvable given the analytical uncertainty. Propagating the 2SD error on 20120618F(0.2) and 20120726F (0.4) gives

C7

0.4 (P12 L10-11). The discussion draws on evidence from previous literature studies which have identified seasonal variations in larger rivers.

5. Implications for Nd as a sediment source tracer (pages 11-12) I generally agree with this section and I think it is a great idea to discuss the potential consequences of the re-organization of glaciers in catchment areas on short-time (annual) scales. However, the authors need to keep in mind that their studied area is pretty small and the bigger is the drained area, the more homogenous will be the composition of the exported sediments. Therefore, the global river exports from Svalbard to the oceans could be much more homogenous in composition than what they analyzed in this study. Also, this part of the discussion is a bit short and should be more developed/ elaborated to strengthen the argument being made. Maybe the authors can try to model the worst-case scenario based on the Nd isotopic variability measured in this study, for example by quantifying by how much such a seasonal variability will change the relative source proportions in the study of Tuólkten et al. (2002)? REPLY: This section was intended to highlight the impact of changes on glacial-interglacial timescales rather than annual scales. Yes, larger drainage areas would be expected to have a more homogenous sediment composition, but as we highlighted in this paragraph, even large rivers (Madeira River, Amazon and Ganges tributaries) show resolvable seasonal variation in ϵNd . Over longer timescales, glaciers can significantly redistribute sediment within a basin and reorganize the hydrology, potentially altering the ϵNd export. We intended to just highlight these ideas and they would require further data to develop further and model. Modelling with the data available is outwith the scope of this study.

Technical comments COMMENT: I found that Figure 1 was not enough detailed. I think you should add more information to help the lecturers understand the context of the study. First, I would enlarge the small map of Svalbard to show the different areas you mention in the text on Svalbard but also around (Central basin, Spritsbergen, Ny Friesland, Longyearbyen, Greenland, Arctic ocean, Uralides, Siberia, etc.). I'm not a specialist of the Arctic region and Svalbard and had to download several maps to be able to follow

C8

your discussion on the sources and the seawater composition, so a general map at the beginning would definitely help. Then, you should show the sampling locations of ALL samples in Figure 1. As it is now, it's unclear to me which ones are shown and why. Since the suspended sediments were taken from rivers, maybe you can also show the rivers on the figure. REPLY: We agree that more background information should be provided. We have added a new figure highlighting the circum-Arctic region to show the Paleogene position of Svalbard relative to the proposed source areas (Fig. 1). We have added two panels to the catchment map figure to show Svalbard and the extent of the Central Basin and the stratigraphy of these formations. Further locations have been included in the catchment map (Fig. 2).

COMMENT: P1 L6: Are you talking about the consolidated sediments (drained sources) or modern river sediments here? Given the cited range of values, it looks like you included the drained sources, why? REPLY: We have changed the text and now only refer to the stream suspended sediments. (P1 L6)

COMMENT: P2 L5: Does this paper mention the Arctic region? REPLY: No it does not. We have changed the reference to a paper that does focus on the Arctic (Meinhardt et al., 2016). (P2 L3)

COMMENT: P2 L21: Fractionation of Sm from Nd during soil formation should not affect epsilon Nd values unless this soil was formed a few hundred million years ago. A lot of time is needed to see the effect of Sm-Nd fractionation on Nd isotopic compositions... REPLY: Agree, the soils in the Öhlander et al., 2000 study are formed from 1.9 Ga bedrock, long enough for inter-mineral variation to occur in eNd. We have amended the text for clarification. (P2 L20-21)

COMMENT: P3 L17: Why did you focus your study on such a small area? REPLY: Please see earlier reply to this question.

COMMENT: Do you think that river sediments from such a small area could be representative of the total river inputs of Svalbard into the Arctic ocean? There is a need for

C9

a bit more explanation here. REPLY: We did not intend to claim that these sediments were representative of the whole of Svalbard, only of the Central Basin. The Central Basin dominates the southern part of Spitsbergen and there have been no prior Sr-Nd measurements in this area. We have amended the text to clarify this point. (P3 L2-7)

COMMENT: P4 L16: Are these from rivers? If yes, then indicate which rivers in Table 1 and Figure 1. REPLY: Yes, we have amended the text throughout to refer to "Stream suspended sediments" and added a sentence in the method section to describe the sampling location (P4 L23-25). The locations were described in the footnote to Table 1 and locations were shown in Figure 1.

COMMENT: P5 L6: What is the blank level of this technique for Nd and Sr? REPLY: The procedural blank for the digestion procedure was less than 0.1% of the amount of Sr and Nd in the sample (P5 L19-20).

COMMENT: P5 L10: Please provide data obtained for reference materials analyzed together with the studied samples in a Supplementary File so that the lectors get an idea of the accuracy and precision of your measurements REPLY: We have added two appendix tables providing this information, one each for major and trace elements. (Tables A3 and A4)

COMMENT: P5 L18: Why? REPLY: Samples were run in triplicate in order to obtain replicate measurements under different tuning conditions of the instrument in order to properly assess the external reproducibility. Text not amended.

COMMENT: P5 L23: Not that minor! REPLY: Agree, we have removed the word 'minor'. (P5 L31)

P6 L15: Not necessarily. REPLY: We have clarified this sentence with reference to the proportion of clay minerals in the samples obtained from XRD measurements of the bulk. (P7 L1-3)

COMMENT: P7 L10: What about mineral sorting during sediment transport? It's likely

C10

more important than weathering. I would say "sedimentary processes" rather than "weathering" here. REPLY: Changed as suggested. (P8 L3)

COMMENT: P7 L16: Again here, this is NOT the fractionation of the Sm/Nd ratio during chemical weathering that generates epsilon Nd variations but the preferential release (or adsorption) of Nd from specific mineral phases (i.e. incongruent weathering). REPLY: Agree. Text amended. (P10 L16-17).

COMMENT: P7 L20: This part is unclear. You did not measure the composition of individual minerals so how can you be sure that they share the same Nd isotopic compositions? Your results actually suggest the opposite: the fact that you measured distinct Nd and Sr isotopic compositions for clay, bulk and leached residues suggest that Nd and Sr are hosted by different mineral phases with different isotopic compositions in the studied sediments/sedimentary rocks. So the trend could be generated by mineral sorting. REPLY: We have rewritten this section. We now discuss the effects of chemical weathering using the data from the suspended sediment leaching procedure to examine the effect of a labile phase with a distinct isotopic composition. (Section 5.2.2)

COMMENT: P8 L8: This is discussable since R03 is not on the main trend... REPLY: We have changed this to -23.3 which is the ϵ_{Nd} value of D (on the main trend). (P8 L19)

COMMENT: P8 L13: Maybe this can be refined a bit by using the median Sr and Nd concentrations of the two endmembers. Since the two endmembers represent very different lithologies (i.e. basalts vs. likely more felsic lithologies for the Archean terrane), you can at least define whether r is $<$ or $>$ 1 in Figure 6. REPLY: Using the median values of the same literature data used to define the isotopic composition of the endmembers we obtain an r value of 1.8. The basalt source is well defined (little scatter in the data), but the Sr/Nd ratio of individual rock samples from the western source varies from 0.5 to 167! We are not convinced that defining whether r is greater to or less than

C11

1 adds useful information to the discussion when the uncertainty in the felsic source is so great, and have therefore not discussed this further in the text.

COMMENT: P8 L24: Not sure I understand what you say here. Above, you show that the isotopic variability of the studied sediments is related to variable contributions of the two "proto-sources" but we still don't know how this variability was created: is it linked to the type of formation sampled/eroded (you do not provide the information on the origin of the sedimentary rocks so I can't tell)? Is it created by mineral sorting (fine-grained sediments with more basaltic erosion products and coarse-grained with more felsic products)? Is it linked to modern erosion (unglaciaded or glaciaded catchment)? There is a clear isotopic difference between the two catchments. For me, this suggests that something is going on at the catchment scale, maybe irrespective of the sedimentary formations eroded. REPLY: Schlegel et al. 2013 concluded that the geochemical variation between the Frysjaodden and Aspelintoppen Formation was caused by changes in chemical weathering. In Section 5.2.2, we rule out chemical weathering as an explanation for the range in radiogenic Sr and Nd values. This range must therefore be due to end-member mixing between distinct sources. In the re-writing of the discussion this paragraph no longer exists. How the variation might arise is discussed elsewhere in the discussion section.

COMMENT: P9 L1: This suggests that you collected the rocks randomly (rocks not in place) in the catchment areas...is it the case? Why would you do that when you have the geological map to tell you where to go to sample each of the formations exposed in the catchment areas? REPLY: We have clarified the sampling strategy in the methods section (and please see reply to main comment 1). (Section 3)

COMMENT P9 L2: This is not very convincing. Maybe you can add a figure to show how your samples compare to these published data in terms of clay mineralogy and major elements. REPLY: We have rewritten this section and added a new figure (please see reply to main comment 1). (P6 L15-25, Figs. 3,4)

C12

COMMENT P9 L17: Ok but when you link the bulk to their respective clay fractions, the variations point towards different endmembers (see arrows on Figure 3 below). This indicates that the intra-sample variability (clay-bulk) cannot be explained with the same processes or the same sources than the inter-sample variability. This is something that should be discussed in more details. REPLY: We agree and have rewritten this section (please see reply to main comment 2). (Section 5.2.1)

COMMENT: P10 L13: Ok for Nd but carbonate are highly concentrated in Sr, so you probably leached out a lot of carbonate Sr. This is also what the CaO concentrations suggest in Table 1. Acid-treated sediments are 2 to 10 times less concentrated in CaO than the bulk sediments for both the two catchments. REPLY: Carbonate is leached out, but it is also possible that Sr derives from exchangeable sites on the clay minerals. We have added to text to discuss this (P10 L30 – P11 L3).

COMMENT: P10 L26: The Mn concentrations are divided by at least a factor of 2 between the residue and the bulk so you must have lost a Mn-rich phase. REPLY: Agree, and this could release adsorbed Sr. We have added to text to discuss this (P10 L30 – P11 L3).

COMMENT: P10 L26: I would say that you can rule out the leaching of clays since the bulk-clay pairs vary following a much steeper trend in the Nd-Sr isotopic space (see red arrows in Figure 3 below). REPLY: We agree that we can rule out leaching of bulk clay, but the leaching procedure employed could easily release Sr loosely bound in interlayer sites of I/S and this could well fall on a different trend to that defined by the bulk clay samples.

COMMENT: P10 L27: "younger" is not appropriate here. I understand what you want to say but it's better to use the term "more depleted". REPLY: This sentence no longer exists in the revised manuscript.

COMMENT: P11 L14: I doubt you can create a 12 epsilon Nd variability with diagenetic processes just by mixing seawater and detrital Nd. Your leaching is pretty strong and

C13

it's quite possible that you start to dissolve and/or leach out Nd from primary minerals with such a procedure. REPLY: Agree. We have rephrased this sentence to more clearly rule out this process as the primary factor causing variation. (P12 L4-7).

COMMENT: P11 L21: Almost not resolvable given the reported external precision (± 0.6 epsilon unit). REPLY: Please see reply to main comment 4.

COMMENT: P11 L30: You cannot say that when you analyzed only 2 samples AND the seasonal variability is barely resolvable (actually not resolvable for Dryabreen). REPLY: This sentence was intended to refer to the larger sample size of our data and previously published literature data. We added in the references for the other studies for clarification. (P12 L20).

COMMENT: P12 L15: It's rather unusual to cite a figure in the conclusion for the first time. REPLY: We have now added references to this figure in the main discussion section of the manuscript.

COMMENT: Fig. 3: When you link the pairs clay-bulk (red arrows), you see that the direction of Sr-Nd isotopic variability generated by grain-size sorting is not the same as the general trend you show in grey. REPLY: Please see reply to main comment 2.

COMMENT: Fig. 5b: Please explain what the black points are. REPLY: The black points are the other bulk samples, for which the isotopic composition of the clay-sized separate was not measured. This information is now included in the figure panel. (Fig. 7)

COMMENT: Table 1: Please report in-run errors (2SE) for Nd and Sr isotopic compositions. REPLY: We have included the 2SD of the 3 replicates. (Table 1)

COMMENT: Table A1: You do not discuss this data in the text. Maybe you can add a few lines in the text to indicate which one of the two dataset is the best and how do they compare. REPLY: The full sample suite was analysed by ICP-OES only and due to HF digestion we did not obtain Si concentrations. In order to assess whether Si con-

C14

centrations obtained by difference were accurate we compared ICP-OES data with four samples previously measured by XRF at an earlier data at a different institution. The table shows excellent agreement between the two techniques, giving us confidence that the Si concentrations obtained by difference are accurate. We have added text to refer to this table in the methods section. (P5 L16-20)

Reviewer 2

COMMENT: It is not clear in the current manuscript how representative these data are of the whole Svalbard area. Indeed, the total area of these two catchments corresponds to 0.01% of the total Svalbard surface (61 022 km²), which is very small. In what extent the data from these two catchments can be considered as representative or not of the Svalbard source region for paleo-erosion source-mixing reconstruction? REPLY: We consider the two studied catchments representative of the Central Basin, and calculate that the Central Basin covers approximately 4800 km², corresponding to 8% of the total Svalbard area. The 'effective' proportion contributing sediment may be even larger as this region is relatively unglaciated compared to other parts of Svalbard e.g. Nordaustlandet. We have added text to clarify this point (P3 L2-7).

COMMENT: In the absence of any information about fluxes, it is difficult to conclude about the integrated contribution of these two catchments and hence whether there is indeed a significant difference between the contribution of glacial and non-glacial areas in Svalbard (as claimed by the authors in lines 30 to 33). REPLY: The two catchments have different suspended sediment isotopic compositions. As the reviewer correctly states, in the absence of flux measurements we cannot determine the modern contribution of fluxes from the glaciated versus the non-glaciated catchment. However, that there is a difference, implies that for a given point in space, glacial-interglacial cycles can redistribute sediment on land resulting in a non-constant isotopic composition of the suspended sediment flux. We have clarified these sentences (P12 L30).

COMMENT: The authors show that the clay mineral fractions have higher ϵ_{Nd} and

C15

lower $^{87}Sr/^{86}Sr$ compared to bulk sediments. The implication of this result, which is not discussed in the paper, is that the Sr-Nd isotope composition of detrital sediments is a function of grain-size. This grain-size control is important to take into account for interpretation of Arctic ocean marine sediments paleo-record. REPLY: We agree that grain-size control is vital to take into account in interpreting the paleo-record from ocean marine sediments. The impacts will depend on distance of the sediment core from source areas and this is currently a topic of active investigation.

COMMENT: Characterization of the leachable phase of Arctic river sediments: the authors do not give any justification for why they have conducted leaching experiment on these sediments (in section 5.3). REPLY: The leaching experiment provided valuable information of the isotopic composition of labile phases that could be released during modern weathering processes. We have added text (P10 L28) to provide the justification.

COMMENT: Does the presence of an acid-leach labile phase isotopically distinct from the bulk silicate sediments have any implication for studies looking at the isotope composition of the marine authigenic phase (carbonate and oxides fractions recording the marine isotope composition) of marine sediments? In other words, is it possible that part of the signal extracted by leaching methods (the classical Hydroxylamine Hydrochlorid (HH) in Acetic Acid solution extraction) is inherited rather than authigenic (marine)? REPLY: Yes, we think that an isotopically distinct leachable phase does have implications for the interpretation of Nd isotopes in the traditional HH sediment leach. It would seem to be possible that sediment containing an authigenic phase deposited in e.g. Paleocene could be re-mobilised and deposited in the modern ocean, potentially affecting the extracted ϵ_{Nd} value. The impact of inherited phases is not currently well understood but initial work has been conducted e.g. Bayon et al., 2004 EP SL, 224, 477-492 and Charbonnier et al., 2012, 99, 39-56. As this paper focuses on the solid phases we have not amended the manuscript text, but are working on a companion manuscript that addresses this point.

C16

COMMENT: The authors should provide more information about the samples other than just “samples were collected at different times during the melt season” in the main text in section 3. How many times during the melt season? How much different was the runoff between the different sampling dates? What are the suspended sediment concentration? Is there any available information about the fluxes (water and sediments) for these two catchments? REPLY: Additional information on the collection of the stream suspended sediment samples is now provide in the Methods section (P4 L21-29). Due to difficulties setting up a gauging station during spring when there was still significant snow cover, discharge data is only available for a 9 day period in the summer. With such a limited data set we are unfortunately not able to extrapolate to seasonal fluxes.

Please also note the supplement to this comment:

<https://www.earth-surf-dynam-discuss.net/esurf-2017-55/esurf-2017-55-AC1-supplement.pdf>

Interactive comment on Earth Surf. Dynam. Discuss., <https://doi.org/10.5194/esurf-2017-55>, 2017.