Data Paper

Wataru Shigeyama, Fumio Nakazawa, Kumiko Goto-Azuma, Tomoyuki Homma, Naoko Nagatsuka, Ramona V. Mateiu, Morimasa Takata, Nobuhiko Azuma and Dorthe Dahl-Jensen. Microparticles in a deep ice core drilled at NEEM, Greenland: cryogenic scanning electron microscopic observations of location, size, shape, and constituent elements. Polar Data Journal. 2021, 5, p. 99–124. https://doi.org/10.20575/00000031.

(Received 3/31/2021; Accepted 8/26/2021)

1st submission

Editor Start Date: 3/31/2021

Editor Stop Date: 5/11/2021

Reviewer #1 (4/8/2021–5/11/2021)

Reviewer #2 (4/12/2021–4/16/2021)

Editor comments to the Author: Ryu Uemura

(1) Following the guideline of PDJ (a minimum of necessary figures), Figure 1 is recommended to move to supplementary or to delete it.

(2) Figure 2: The upper and lower figures are rotated 90 degrees? Is the direction of the core top in the lower figure different from the one in the upper figure? Please fix it.

Reviewer #1: Anonymous

Lines 58–59

"NaCl is one of the most common impurities in polar ice cores, it is not possible to detect NaCl whose Raman scattering wavelength is close to that of ice."

This is not correct. NaCl (anhydrous salt) is Raman inactive (no Raman lines). In the ice matrix, sodium chloride is present as hydrate (NaCl_2H2O). Its crystal water is Raman active (Raman lines around 3500 cm-1). Although the Raman lines of the crystal water are close to those of ice (approximately 3000-3700 cm-1), they are easily distinguishable because the former has much narrower band width. The reason why it is difficult to detect sodium-chloride particles in polar ice with Raman spectroscopy is simply due to their inherently weak Raman signal.

Lines 73–74

"With additional OM analysis conducted prior to the cryogenic SEM/EDS analysis, it was possible to exclude particles formed during cryogenic SEM/EDS experiments."

I agree that it is the advantage (originality) of this work. However, the use of OM has also its disadvantage. In this work, the SEM/EDS analysis is limited to particles which are visible with an optical microscope. Namely isolated submicron particles are excluded from measurements. If so, the authors need to mention the limitation of the method in the paper.

Line 80

"air-inclusion (e.g., air bubble, hydrate, or plate-like inclusion (PLI))"

Usually, air inclusion means air bubbles and hydrates (e.g., Lipenkov, 2000, Physics of Ice Core Records, 327–358). Plate-like inclusions are secondary voids (Mae, 1968, Philos. Mag., 18, 101–114), though some air flow into PLI with time due to gas diffusion from air bubbles and hydrates.

Lines 117–118

"using an optical microscope (BX 51; Olympus Corporation, Tokyo, Japan)"

Information about an objective lens is also needed.

Lines 125–126, Figure 3c

"it is possible to observe particles both on the surface and inside the ice, as a result of the wide focusing range of optical microscopy (Fig. 3(c))"

How long is the focusing range?

Figure 3d

How thick is the sublimated ice?

Lines 127–129

"To investigate the particles inside the ice, each specimen was sublimed by increasing the temperature of the cold stage from..."

Sublimation often gives rise to considerable roughness of ice surfaces that severely disturbs SEM observations. It is nice if the authors could show some tips how to prevent development of the roughness (e.g. pressure control).

Lines 131–132

"the pressure in the SEM chamber was regulated to 10, 50, or 120 Pa"

It is a pressure range for low-vacuum SEM. Under such pressures, backscattered electron images are often used rather than secondary electron images, because secondary electrons are diffused (signals are weakened) by atmospheric gases. I would like to know why the authors chose secondary electron images (how to obtain secondary electron images under low-vacuum).

Lines 153–155, Figure 4

"To define the outline of each particle, binary image processing was applied to all of the secondary electron images using the image analysis software, Image J (Image J v1.52a or Fiji v1.52p) or Python-OpenCV (Python v3.8.1 or v2.7.15; OpenCV v4.1.2 or v3.4.3)."

What is the criterion for selecting Image J (or Python-OpenCV). What is the difference between the measurements ALPHA and BETA??

Lines 167–168

"The location of a particle in the ice was expressed as the distance from an ice grain boundary and that from an air-inclusion (e.g., bubble, hydrate, or PLI)."

Locations (shapes) of grain boundary and an air inclusion exposed to the ice surface are altered with sublimation, though the position of micro-particles on ice remains unchanged. Under such a situation, how the authors measure the distances? Measurements were performed at the timing when particles appear at the ice surfaces??

Lines 189–191

"If the normalized weight ratio from a particle was more than twice as high as the maximum weight ratio in the 212 spectra (...), then it was assumed that the element was included in the particle."

It is nice if the authors could show why they can assume so. I guess that the assumption is based on some statistics (e.g. standard deviation of the normalized ratios from ice measurements).

Reviewer #2: Anonymous

Review comments on "Microparticles in a deep ice core drilled at NEEM, Greenland: cryogenic scanning electron microscopic observations of location, size, shape, and constituent elements" by S. Shigeyama *et al*.

This paper presents information on the location, size, shape, and constituent elements of particles preserved in the

NEEM ice core. The authors applied the unique and original analyses for the ice core samples and created valuable datasets, which provide important information to the ice core community. Overall, the paper is nicely written, and the datasets are appropriately prepared for PDJ.

I suggest that the authors provide individual images of each particle, including scales, so that data users can analyze the images and acquire the geometric information of particles by themselves, although the authors already show particle images in the catalog in PDF format. The current style is not useful to reuse particle images for users. I also have several minor comments and suggestions. I suggest publishing it once all comments have been taken into consideration.

Specific comments

L24

"it was possible to exclude microparticles formed during the cryogenic SEM/EDS experiments"

Unclear. Are particles formed during the experiments?

L36

ice-sheet ice. I think the last "ice" is not necessary.

L42 – 47

Most of the articles cited here deal with insoluble particles (mineral dust). A short review for soluble particles may be necessary before describing soluble particles (L47–48).

L45

Need reference(s).

L47–48

This sentence may mislead readers. Compositions of soluble particles in an ice sample cannot be measured once the ice is melted, but soluble particles themselves can be measured as ions. You should write more specifically (i.e., soluble particles of what is impossible to measure by melting ice samples).

L64–65

Need reference(s).

L65

"or while the ice…" "while" is not necessary.

L74

See above for the Line 24

L146

was -> were

L153–155

Please explain why two ways (Image J and Python-OpenCV) were applied to binarize images.

L157–158

The errors for diameters and aspect ratios should be provided.

L165

Please explain the importance and/or meaning of the distances from an ice grain boundary and air inclusions here or in section 1.

L168–170

It is unclear the distances from an ice grain boundary and air inclusions. For the distance from an ice grain boundary, did you measure the distance of the line orthogonal to the tangent of the grain boundary?

For the distance from air inclusions, it is unclear from which air inclusion and from which point you measured. For example, 226-C-I-1 on the first page of the catalog, there are several black marks in the upper left image. A blurred black mark in the upper right corner of the orange frame appears to be the closest air inclusion for me. Is it right? Another example, 226-C-III-1 in P.9, is also unclear. On 226-C-IV-1 in P.19, I see many black marks in the upper left image, but the authors state the distance from air inclusion is zero. Does it mean the particle is in the air inclusion? If so, perhaps you should describe it in the catalog. Also, air inclusions look quite large compared to particles. Did you measure the distance from the center of an air inclusion? Please explicitly define the distance.

I also suggest providing the errors of the distances.

L179–183

If Ar originates from an air hydrate, O and N also should originate not only from ice or the materials to fix the ice but also from the hydrate.

L189

Perhaps, "of C, N or Ar" is necessary between "If the normalized weight ratio" and "from a particle ……" .

L191–194 and Figure 5 (b)

Does Au originate from the holder? If so, the authors need to explain which element(s) is (are) possible contamination from the holder in the text.

L247–251

This information should also be described in the catalog.

L283 and EDS_data.xlsx

Are the standard deviations one sigma?

Figure 6 caption

Please rephrase the 2nd sentence.

Authors Response:

Dear Editor and Reviewers,

On behalf of the co-authors, I would like to thank the editor and reviewers for their comments on our manuscript (PDJ-D-21-00003). The comments are important to convey the aim and details of our data to readers. Below, I wrote the comments from the editor and reviewers in black and our responses in red. We also wrote other modification at the end.

We submitted our revised manuscript ("Manuscript_Shigeyama_revised.doc", "Manuscript_Shigeyama_revised_marked.doc", "Table1_revised.docx", and "Table1_revised_marked.docx") and uploaded our data in the Arctic Data archive System (ADS). In "Manuscript_Shigeyama_revised_marked.doc" and "Table1_revised_marked.docx", modified words and sentences are shown in blue.

Yours sincerely,

Wataru Shigeyama

Response to Editor;

(1) Following the guideline of PDJ (a minimum of necessary figures), Figure 1 is recommended to move to supplementary or to delete it.

We moved Figure 1 to Supplemental figure 1.

(2) Figure 2: The upper and lower figures are rotated 90 degrees? Is the direction of the core top in the lower figure different from the one in the upper figure? Please fix it.

We modified Fig 2 (now it was changed to Fig. 1).

Response to Reviewer #1;

Lines 58–59

"NaCl is one of the most common impurities in polar ice cores, it is not possible to detect NaCl whose Raman scattering wavelength is close to that of ice."

This is not correct. NaCl (anhydrous salt) is Raman inactive (no Raman lines). In the ice matrix, sodium chloride is present as hydrate (NaCl_2H2O). Its crystal water is Raman active (Raman lines around 3500 cm-1). Although the Raman lines of the crystal water are close to those of ice (approximately 3000-3700 cm-1), they are easily distinguishable because the former has much narrower band width. The reason why it is difficult to detect sodium-chloride particles in polar ice with Raman spectroscopy is simply due to their inherently weak Raman signal.

We modified the sentence in the line 72.

Lines 73–74

"With additional OM analysis conducted prior to the cryogenic SEM/EDS analysis, it was possible to exclude particles formed during cryogenic SEM/EDS experiments."

I agree that it is the advantage (originality) of this work. However, the use of OM has also its disadvantage. In this work, the SEM/EDS analysis is limited to particles which are visible with an optical microscope. Namely isolated submicron particles are excluded from measurements. If so, the authors need to mention the limitation of the method in the paper.

We added the explanation in the lines 87–89.

Line 80

"air-inclusion (e.g., air bubble, hydrate, or plate-like inclusion (PLI))"

Usually, air inclusion means air bubbles and hydrates (e.g., Lipenkov, 2000, Physics of Ice Core Records, 327–358). Plate-like inclusions are secondary voids (Mae, 1968, Philos. Mag., 18, 101–114), though some air flow into PLI with time due to gas diffusion from air bubbles and hydrates.

We distinguished the air-inclusion and plate-like inclusion throughout the manuscript.

Lines 117–118

"using an optical microscope (BX 51; Olympus Corporation, Tokyo, Japan)"

Information about an objective lens is also needed.

We added the lens information to the lines 132–133.

Lines 125–126, Figure 3c

"it is possible to observe particles both on the surface and inside the ice, as a result of the wide focusing range of optical microscopy (Fig. 3(c))"

How long is the focusing range?

We added the information to the lines 142–144.

Figure 3d

How thick is the sublimated ice?

It was mostly several micrometers, but sometimes up to several tens of micrometers, depending on the sublimation time and temperatures. We described them in the caption of the Fig. 2 (the previous figure number was 3) and in the lines 146–148 in the text.

Lines 127–129

"To investigate the particles inside the ice, each specimen was sublimed by increasing the temperature of the cold stage from..."

Sublimation often gives rise to considerable roughness of ice surfaces that severely disturbs SEM observations. It is nice if the authors could show some tips how to prevent development of the roughness (e.g. pressure control).

We sublimed the ice once to several times in the SEM chamber at temperatures of -100 to -50°C and pressures of 10, 50, or 120 Pa). The ice surfaces were smooth enough so that it was possible to observe the particles. We added the explanation to the lines 146–148.

Lines 131–132

"the pressure in the SEM chamber was regulated to 10, 50, or 120 Pa"

It is a pressure range for low-vacuum SEM. Under such pressures, backscattered electron images are often used rather than secondary electron images, because secondary electrons are diffused (signals are weakened) by atmospheric gases. I would like to know why the authors chose secondary electron images (how to obtain secondary electron images under low-vacuum).

We added the explanation and detector information in the lines 151–157.

Lines 153–155, Figure 4

"To define the outline of each particle, binary image processing was applied to all of the secondary electron images

using the image analysis software, Image J (Image J v1.52a or Fiji v1.52p) or Python-OpenCV (Python v3.8.1 or v2.7.15; OpenCV v4.1.2 or v3.4.3)."

What is the criterion for selecting Image J (or Python-OpenCV). What is the difference between the measurements ALPHA and BETA??

We added the explanations to the lines 180–183.

Lines 167–168

"The location of a particle in the ice was expressed as the distance from an ice grain boundary and that from an air-inclusion (e.g., bubble, hydrate, or PLI)."

Locations (shapes) of grain boundary and an air inclusion exposed to the ice surface are altered with sublimation, though the position of micro-particles on ice remains unchanged. Under such a situation, how the authors measure the distances? Measurements were performed at the timing when particles appear at the ice surfaces??

We imaged the particles when they were inside ice with optical microscopy or when they were exposed to the ice surface with scanning electron microscopy. We added the information on the error to the lines 201–203.

Lines 189–191

"If the normalized weight ratio from a particle was more than twice as high as the maximum weight ratio in the 212 spectra (...), then it was assumed that the element was included in the particle."

It is nice if the authors could show why they can assume so. I guess that the assumption is based on some statistics (e.g. standard deviation of the normalized ratios from ice measurements).

The twice of the maximum normalized weight ratio was much higher than the mean value plus the standard deviation for each element. We modified the sentences in the lines 231–232.

Reponse to reviewer #2;

Review comments on "Microparticles in a deep ice core drilled at NEEM, Greenland: cryogenic scanning electron microscopic observations of location, size, shape, and constituent elements" by S. Shigeyama *et al*.

This paper presents information on the location, size, shape, and constituent elements of particles preserved in the NEEM ice core. The authors applied the unique and original analyses for the ice core samples and created valuable datasets, which provide important information to the ice core community. Overall, the paper is nicely written, and the datasets are appropriately prepared for PDJ.

I suggest that the authors provide individual images of each particle, including scales, so that data users can analyze the images and acquire the geometric information of particles by themselves, although the authors already show particle

images in the catalog in PDF format. The current style is not useful to reuse particle images for users. I also have several minor comments and suggestions. I suggest publishing it once all comments have been taken into consideration.

We also think that providing individual particle images is useful for those who want to analyze the images by themselves. However, the data size would be very large, which would make it difficult to reuse the data for a general reader unless we make a user-friendly search engine. But this is beyond the scope of our work. We rather chose to make the particles' characteristics easily-visible and decided to make the pdf-formatted catalog. We are pleased to provide individual images upon requests from readers.

Specific comments

L24

"it was possible to exclude microparticles formed during the cryogenic SEM/EDS experiments"

Unclear. Are particles formed during the experiments?

During sublimation in SEM, artifacts so-called "white spots" and "filaments" were formed (line 80). The word "particles" seems to be confusing so we changed it to the word "artifacts." We have done similar modifications throughout the manuscript.

L36

ice-sheet ice. I think the last "ice" is not necessary.

We tried to remove "ice" from "ice-sheet ice" but "the physical properties of ice sheet" might be misleading. We changed the words to "physical properties of ice in polar ice sheets."

L42–47

Most of the articles cited here deal with insoluble particles (mineral dust). A short review for soluble particles may be necessary before describing soluble particles (L47–48).

We described the soluble particles briefly in the lines 47–53.

L45

Need reference(s).

We added the references.

L47–48

This sentence may mislead readers. Compositions of soluble particles in an ice sample cannot be measured once the

ice is melted, but soluble particles themselves can be measured as ions. You should write more specifically (i.e., soluble particles of what is impossible to measure by melting ice samples).

We changed the sentence in the lines 50–53.

L64–65

Need reference(s).

We added a reference in the line 77.

L65

"or while the ice…" "while" is not necessary.

We think “while” is necessary here. The sentence was proofread by an English-language editor.

L74

See above for the Line 24

We modified the manuscript as we wrote above.

L146

was -> were

We changed the word.

L153–155

Please explain why two ways (Image J and Python-OpenCV) were applied to binarize images.

We had to use three computers to analyze the images. Two computers had Python-OpenCV while the other had only Image J. We described it briefly in the lines 180–181.

L157–158

The errors for diameters and aspect ratios should be provided.

The error arises mainly from the ambiguity of the determination of particle outlines and the evaluation is difficult. When the outline could be determined with the binary image processing, the difference in the particle size measured by Image J and Python-OpenCV was 1%, and no difference in the aspect ratio. Repeated measurements by manual outline drawing gave differences in diameter of about 7%, and 0.1 in the aspect ratio. We also described those differences in the lines 189–190.

L165

Please explain the importance and/or meaning of the distances from an ice grain boundary and air inclusions here or in section 1.

We added the explanation in the lines 55–60.

L168–170

It is unclear the distances from an ice grain boundary and air inclusions. For the distance from an ice grain boundary, did you measure the distance of the line orthogonal to the tangent of thegrain boundary?

We measured the distance from a particle to the nearest grain boundary. We added the explanation in the lines 197–199.

For the distance from air inclusions, it is unclear from which air inclusion and from which point you measured. For example, 226-C-I-1 on the first page of the catalog, there are several black marks in the upper left image. A blurred black mark in the upper right corner of the orange frame appears to be the closest air inclusion for me. Is it right? Another example, 226-C-III-1 in P.9, is also unclear. On 226-C-IV-1 in P.19, I see many black marks in the upper left image, but the authors state the distance from air inclusion is zero. Does it mean the particle is in the air inclusion? If so, perhaps you should describe it in the catalog. Also, air inclusions look quite large compared to particles. Did you measure the distance from the center of an air inclusion? Please explicitly define the distance. I also suggest providing the errors of the distances.

We identified a bubble, a hydrate, and a plate-like inclusion when its boundary to the ice was clear enough to recognize in optical microscope images. In case of 226-C-I (page 1 in the catalog), we measured the distances from particles P1 and P2 and to the bubble existing close to the lower-right corner of Area 1. Similarly, in case of 226-C-III-1 we measured the distance from particles P6-8 to the bubble existing at lower left of the ice sample (an image at upper left on page 9 in the catalog). On the images of the catalog, we indicated the bubbles, hydrates, and plate-like inclusions which were used for distance measurements.

In case of 226-C-IV-1 (page 19 in the catalog), particles P9-12 existed just above the bubble. We added the description to the catalog. Similarly, we added an explanation if the location of the particle relative to a bubble, a hydrate or a plate-like inclusion was not clearly observed from the OM/SEM image.

We measured the shortest distance between a particle and the outline of an air-inclusion or PLI. We added the explanation to the line 199–200.

We also mentioned the error in the line 201–203.

L179–183

If Ar originates from an air hydrate, O and N also should originate not only from ice or the materials to fix the ice but

also from the hydrate.

Yes. The EDS spectra from hydrates showed peaks corresponding Ar, O, C, and N. We changed the sentence (line 220) not to mislead the readers.

L189

Perhaps, "of C, N or Ar" is necessary between "If the normalized weight ratio" and "from a particle ……" .

We added the words in the line 228.

L191–194 and Figure 5 (b)

Does Au originate from the holder? If so, the authors need to explain which element(s) is (are) possible contamination from the holder in the text.

Yes. We added a short description of the results of the EDS analyses of the sample holders in lines 211–214. We also noted it on the caption of Fig. 4 (previous figure number was 5).

L247–251

This information should also be described in the catalog.

We made a title page of the catalog and described the information together with other abbreviations.

L283 and EDS_data.xlsx

Are the standard deviations one sigma?

Yes, they are.

Figure 6 caption

Please rephrase the 2nd sentence.

We changed the sentence.

Other modifications in the manuscript

We added an example in L267–268.

2nd submission

Editor Start Date: 7/8/2021

Editor Stop Date: 8/3/2021

Reviewer #1 (7/12/2021–8/2/2021)

Reviewer #2 (7/12/2021–7/15/2021)

Editor Comments to the Author: Ryu Uemura

Thank you for submitting your work to PDJ. According to the comments of two reviewers, minor revision is needed before formal acceptance. During previous revision, reviewer#2 asked to provide individual particle images. But you refused to do so because of data size and user-friendliness. For data size, there is no problem on the ADS system (e.g., data size is 50GB or more). I think it is possible to upload photo data as follows:

(1) create folder "Particle_photo"

(2) under that create a subdirectory like, P1.jpg, P2.jpg, ...

(3) then put the photo into each subdirectory

I guess it will not take much effort. But if it's hard/difficult (due to some technical reasons), it's NOT compulsory at all.

Sincerely,

Ryu Uemura

Reviewer #1: Anonymous

For the most part the authors properly correct manuscript, following the comments. Thus, I recommend this work for publication in the Polar Dara Journal. Minor comments are as follows.

Lines 89

"sizes as small as…"

Sizes mean diameters??

Figure 2c

It is better to add specific values for the focusing range (6.1 to 70 μm) in the figure (or caption).

Lines 146–148

From the reply, I suppose the authors used low-vacuum/environmental SEM instead of normal high-vacuum SEM, to obtain relatively smooth ice surfaces (to prevent roughness of ice surfaces).

If so, specify the advantage of ice sublimation under the low-vacuum environment in the text.

Lines 180–183

"depending on the computers we used…"

Still it is not clear why the authors used the different image analysis programs.

Do the two programs provide essentially the same results??

Lines 230–232

"The mean normalized weight ratios were…Ar, respectively."

I suppose these are normalized weight ratios estimated from ice measurements.

If so, specify in the text that "The mean normalized weight ratios for ice were…".

Reviewer #2: Anonymous

Review comments on "Microparticles in a deep ice core drilled at NEEM, Greenland: cryogenic scanning electron microscopic observations of location, size, shape, and constituent elements" by S. Shigeyama *et al*.

The revised manuscript is improved well. I suggest that this manuscript can be published in Polar Data Journal after some corrections. Specific points are listed as follows.

I still suggest providing particle images, but if you do not provide them, please mention in the text that you provide individual images upon requests from readers.

L48

CaSO4, not Ca2SO4

L48–50

The last phrase, "and chemical reactions between them" is not correct. CaCO3 and NaCl react with sulfuric acid to produce CaSO4 and Na2SO4, but CaCO3, NaCl, CaSO4 and Na2SO4 do not react with each other.

L197–203

The distance between a particle, a grain boundary, an air-inclusion, and a PLI is still unclear. There is no description of how you determined (found) the distance. Did you measure it automatically or manually? If you measured manually, then how did you measure the shortest distance?

You write that the error is estimated to be mostly several micrometers. If so, you should describe the distance from which point of the particles (center or edge) because the diameter of most particles in this study is comparable to the estimated error.

Authors Response:

Dear Editor and Reviewers,

On behalf of the co-authors, I would like to thank the editor and reviewers for their comments on our revised manuscript (PDJ-D-21-00003R1). The comments are useful to describe our data and to make our data reused. Below, I wrote the comments from the reviewers in black and our responses in red. We submitted our revised manuscript ("Manuscript_Shigeyama_revised-2.doc" and "Manuscript_Shigeyama_revised-2_marked.doc").

In "Manuscript_Shigeyama_revised-2_marked.doc", modified words and sentences are shown in blue.

Yours sincerely,

Wataru Shigeyama

Response to Reviewer #1;

For the most part the authors properly correct manuscript, following the comments. Thus, I recommend this work for publication in the Polar Dara Journal. Minor comments are as follows.

Lines 89

"sizes as small as…" Sizes mean diameters??

Yes. We mean diameters. We changed the word on the line 89.

Figure 2c

It is better to add specific values for the focusing range (6.1 to 70 μm) in the figure (or caption).

We added the values of focusing range in the caption of Figure 2.

Lines 146–148

From the reply, I suppose the authors used low-vacuum/environmental SEM instead of normal highvacuum SEM, to obtain relatively smooth ice surfaces (to prevent roughness of ice surfaces). If so, specify the advantage of ice sublimation under the low-vacuum environment in the text.

Following the suggestion from Reviewer#1, we modified the sentence here.

Lines 180–183

"depending on the computers we used…" Still it is not clear why the authors used the different image analysis programs. Do the two programs provide essentially the same results??

We had to use three computers to analyze the images. Two computers had Python-OpenCV while the other had Image

J. The two programs provided essentially the same results, which is described in the lines 191–193. Therefore, we thought the difference between the two pieces of software did not affect the measurements.

Lines 230–232

"The mean normalized weight ratios were…Ar, respectively." I suppose these are normalized weight ratios estimated from ice measurements. If so, specify in the text that "The mean normalized weight ratios for ice were…".

We added the words “for ice” in the line 233.

Response to Reviewer #2;

Review comments on "Microparticles in a deep ice core drilled at NEEM, Greenland: cryogenic scanning electron microscopic observations of location, size, shape, and constituent elements" by S. Shigeyama *et al*.

The revised manuscript is improved well. I suggest that this manuscript can be published in Polar Data Journal after some corrections. Specific points are listed as follows.

I still suggest providing particle images, but if you do not provide them, please mention in the text that you provide individual images upon requests from readers.

We are going to upload the individual particle images on ADS when they are ready. But it will take a long time and we are not able to provide them immediately. We will provide the individual images upon requests until individual particle images become ready on ADS. We mentioned it in the line 252–254.

L48

CaSO4, not Ca2SO4

We corrected the error.

L48–50

The last phrase, "and chemical reactions between them" is not correct. CaCO3 and NaCl react with sulfuric acid to produce CaSO4 and Na2SO4, but CaCO3, NaCl, CaSO4 and Na2SO4 do not react with each other.

We changed the sentence.

L197–203

The distance between a particle, a grain boundary, an air-inclusion, and a PLI is still unclear. There is no description of how you determined (found) the distance. Did you measure it automatically or manually? If you measured manually, then how did you measure the shortest distance?

You write that the error is estimated to be mostly several micrometers. If so, you should describe the distance from which point of the particles (center or edge) because the diameter of most particles in this study is comparable to the estimated error.

We revised the description to explain the measurement of the distances in detail in the lines 196–206.

3rd submission

Editor Start Date: 8/17/2021

Editor Stop Date: 8/26/2021

Editor-in-Chief comments to the Author: Akira Kadokura

Editor's decision is "Accept" for the current revised manuscript and data.

So, you do not need to register any additional data (each paticle image data) to ADS afterward.

In other words, please do not register any additional data to ADS after the manuscript and data have been accepted.

Editorial Office’s note

Calculate checksum date: 8/26/2021

Algorithm:SHA256

Hash link: http://id.nii.ac.jp/1434/00000031 > hash list