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The Cryosphere Discussions

Interactive comment on "Dust from the dark region in the western ablation zone of the Greenland ice sheet" *by* I. G. M. Wientjes et al.

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We thank anonymous reviewer 3 for his positive attitude and his valuable and constructive comments, which will help to improve the paper. Below we will discuss his comments.

major points:

Comment: 1. I would recommend to divide the section 3. Results and discussion into two sections of 3. Results and 4. Discussion. That would make clear what are analytical facts and what are interpretations and speculations.

Answer: Although we want to maintain the subdivision between grain composition (3.1), elemental composition (3.2) and microorganisms (3.3) we agree that another order within these paragraphs seems useful for a better understanding what are analytical facts and what are interpretations. We will make a new division in the revised version of the manuscript.

Comment: 2. There is a lack of analytical data in this paper. For example, XRD curves of each site sample should be shown in a figure, results of ICP-AES, MASS, TOC , N, and CN ratio data (concentrations of each elements for all samples) should be provided. Some of them were mentioned for only mean value in the text. Such raw data are valuable to those who want to compare in further studies.

Answer: We will add an appendix with the values for ICP-AES and ICP-MS for each sample location, for all elements used. We indeed only give mean values for each sample sites for TOC, N, and CN, but this is not uncommon in our opinion since we also indicate standard deviations to reveal the spread. We will also insert a figure with the XRD curves.

minor comments:

Comment: 1. P.2561 L.3-6 Authors have mentioned that wavy pattern in the dark region. Please describe relationship between the wavy pattern and sampling sites. How could the wavy pattern be visibly seen on the ice surface? Were the samples collected from a dark line? Authors may show the sampling sites on an ASTER image.

Answer: The wavy patterns are only visible on satellite images, due to the large distance to the earth. They have widths in the order of tens to hundreds of meters, whereas in the field, dark patches in the order of centimeters to decimeters covered the surface. As these patches are very irregular, it is hard to see if they are more or less in a certain area. It is also not visible in the field if outcropping ice contain more or les small dust particles, especially because single distributed particles might be not visible

detectable and if ice therefore has a higher or lower reflectance. We therefore do not know if we collected samples from a dark line. In addition one should realize that Aster works only on request, so there are not many images available for the sampling area. We studied the available images, but the only cloud free images for this area were from periods when the dark region was not (clearly) developed or covered with snow. For this reason, it makes no sense to show the sampling sites on an ASTER image.

Comment: 2. P.2561 the section of Samples: Authors should describe how the samples were transported from the field to the laboratory. Were the samples kept in frozen state? Transpotation and preservation methods can affect conditions of microbes observed with a microscopy.

Answer: Samples were not kept in frozen state, as we did not aspect them to reveal microorganisms under the microscope in the first place. However, samples were all the time kept in complete darkness, which makes growth of the photosynthesizing organisms unlikely. Unfortunately decay of the organisms is possible, but as all samples were all treated in the same way, decay should not have changed the relative abundance of organic matter between the various samples. Therefore our conclusion of higher OC values in the dark region compared to the reference can still be made. We do compare our TOC values to other sites that might have used different transport procedures. To check whether preservation significantly affected our results, we analyzed the cyanobacteria and algae from a small ice core that was taken at site 7 and has been in frozen state since it was taken. Optically, no significant differences were observed between the ice core organic matter and the samples we describe in the manuscript, which would be expected if significant organic matter decay occurred since sampling. Moreover, we state that our TOC values are rather high compared to literature values; an effect that would only be larger if some organic matter decay would have occurred. Collectively, we consider the effect of potential decay on our conclusions small and explain this in the revised MS.

Comment: 3. P.2563 L.25 Authors should quantitatively explain the coarseness of

mineral particles in the cryoconite. What are the size range, maximum and minimum sizes?

Answer: We did not measure the grain sizes of the mineral particles. We only qualitatively observed that the material from S4 was much coarser. Larger particles and even small stones could be detected by eye and the material was much harder to grind than the other samples.

Comment: 4. P.2565 L.5-13 This paragraph should be moved to Method section.

Answer: We will do this.

Comment: 5. P.2565 L.18 Please mention the reason why Sn and Al were used for this plot. There are many options (elements) shown in Fig. 7.

Answer: Figure 7 is an example for the differences between the two groups, as we could not show every possible combination. Both Al and Sn show very clearly the differences between samples from S4 and S5 on the one hand and S6 and S7 on the other hand. Al is a major element associated with input of terrigenous material, whereas Sn is a typical example of one of the minor elements that we found much more abundant in the dark region relative to the reference ice.

Comment: 6. P.2566 L.1 References are necessary to show that they are anthropogenic pollution.

Answer: Based on other comments, we will reconsider whether the dust is anthropogenic, if so, we will add a reference.

Comment: 7. P.2566 L.7 Please specify when the recent the deposition was. In several years or decadal years or more then 100 years?

Answer: We do not exactly know when the recent deposition was, as the dust can accumulate on the ice surface after deposition. However, we mean recent deposition in contrast to older deposition higher on the ice sheet in the accumulation zone, which

crops out after some time of traveling through the ice.

Comment: 8. P.2567 L.8-18 This is one of the very important finding of this study. But, please describe more carefully how the cryoconites are distinct between dark region and reference area on the microscopy basis. Fig. 9 shows only the cryoconite from dark region. Show the photographs of both cryoconites in dark region and reference area, and explain how they are different.

Answer: Figure 9 does not only show cryoconite from the dark region, 9c shows material from SHR, and from the reference ice. We will consider whether it is useful to add more photographs and will at least add at which locations the different cryoconites from figure 9 are.

Comment: 9. P.2568 L.9-21 Use a figure or table to compare the organic matter contents among glaciers.

Answer: We will add such a table.

Comment: 10. Table 1 Please show the coordinates of each sampling site.

Answer: We will add these coordinates.

Comment: 11. Fig.3 Why don't you use MODIS image of 2009, the year of your field work? Dark region is not clearly visible on this 2003 image.

Answer: We choose the MODIS images for figure 3 from a year with high melt rates and therefore a good development of the dark region. On the complete MODIS image (not shown in the paper) the dark region is better visible, but maybe due to zooming on the area where we collect the samples and due to the fact that we use a true color composite, the dark region might appear slightly less clear. However, we think that showing a true color composite is a good completion to figure 1, which shows only radiances for one single band.

Interactive comment on The Cryosphere Discuss., 4, 2557, 2010.