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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 the anonymous reviewer for some useful suggestions. Below we will discuss his comments.

Comment: I find very little new information in this manuscript. And, a number of conclusions are drawn on solely speculative basis without testing the hypothesis behind the conclusion.

Answer: The conclusions are based on a number of microscopic and geochemical analyses. Our main point is to find out more about the processes causing a dark region in the melt zone of the Greenland ice sheet. We therefore analyzed surface dust

collected from the dark region as well as from the reference ice. Our main conclusions are:

- At least part of the investigated material is outcropping from the ice, based on the sharp-edged, triangular-faceted grains observed with transmitted light microscopy as well as electron microscopy, recent wind blown material would be much more rounded by erosion;

- The geochemical composition of material from the dark region is mostly the same as for the reference ice, based on XRD, EDX, ICP-AES and ICP-MS analyses;

- Abundant green algae and cyanobacteria were found in the dark region, based on microscopy and there are relative higher amounts of microorganisms in the dark region compared to the reference ice based on microscopy, TOC and N measurements;

- Because literature reported of high light absorbance of cyanobacteria, which we found abundant in the dark region, they likely contribute to the darkening of the surface, though quantification is not yet possible;

- The material in our samples has a similar composition as the earth upper continental crust, based on REE patterns measured with ICP-MS;

- We excluded Asian dust, as their geochemical composition reported by literature is different from our samples, based on XRD, EDX; we excluded meteorites based on electron microscopy as well as REE patterns and we excluded volcanic dust, based on REE patters measured with ICP-MS;

- Because other possible sources for Greenlandic dust reported by literature are excluded, and the geochemical composition of the material is everywhere the same, it seems most likely that the dust has a regional origin.

Therefore, we do not think that our conclusions are based on solely speculative basis, but on a lot of high quality measurements.

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Comment: A number of places I find results highligthed as new results, but in fact just being a repetition of older findings without a proper reference.

Answer: We were not aware that any of our results were not new. If the reviewer could point out other 'not new results', than the ones described below, we are very interested in these results.

Comment: The results are certainly not discussed in a proper way. For example Maurette et al found large qunatities of meteorites in the same region as this study. So, the lack of detection of meteorites in thi study does not indicate that they are not there.

Answer: Although we refer to the meteorites found be Maurette et al. (1987), we state that there seems to be no meteorites in our samples, and proof this explicitly. This is based first on the REE patterns of our samples that reveal a chemical composition similar to upper continental crust, which is highly different from most meteorites and second the appearance of grains from our samples by electron microscopy, which are clearly different from the micrometeorites found in Greenland (Olinger et al., 1990).

Comment: Such flaws also goes for the analysis of microorganisms. Stibal point out that the lack of observation of microbiobes is not necessarily evidence for them not being there.

Answer: We agree that we were too firm in our statement that no microorganisms are present at Site 4, just because we don't see them (p 2567, line 11). However, as the samples from this site contain less than 0.2 weight percent of Total Organic Carbon and less than 0.05 of Nitrogen, the volume of microbes at this site seems very low. As we try to explain the differences between the dark region and the brighter reference ice, our interest was mainly for the visible part of the spectrum. Microbes that are there but not visible are of less importance to the albedo. We will rephrase the statement about microbes accordingly.

Comment: A number of papers have been published or are in press, with much more

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detail on microbial processes, in the Annals of Glaciology (vol 51). I would recommend the author to carefully read the most relevant papers and refer to them in detail instead of inventing "new" results and from this drawing speculative conclusions. The most relevant papers are Hodson et al, Stibal et al and Langford et al.

Answer: Two of these three papers are published even after the posting of this review. Stibal et al. (2010) was only recently published. We did not refer to these three papers, because we were not aware that they were coming soon or were just available. Stibal et al. (2010) seems a highly interesting paper, describing TOC and N values and the origin of the microbes on a similar transect. They found the same trend of increasing TOC values with distance to the margin, but describe in more detail the origin of these microbes and the processes influencing the carbon cycling on the Greenland ice sheet. Therefore, the results of Stibal et al. (2010) seem to complete our findings, rather than to be exactly the same. In the revised version, we will discuss these results and properly refer to Stibal et al. (2010). The other two papers from Hodson et al. and Langford et al. were not published at the moment of submitting. However, we have got in the meantime confidential access to the manuscripts, both are interesting. Hodson et al. described the cryoconite ecosystem in the same area and Langford et al. the composition and structure of the cryoconite granules in this area. Although there seems to be some slight overlap between our and their results, they both do not look at differences between the dark region and the reference ice, which is the main focus of our paper. We therefore claim that our results are different from theirs.

Comment: Besides this the most recent paper by Uetake et al discuss the distribution of algae and cyanobacteria also in the same region.

Answer: This paper of Uetake et al., (2010) describe algae and cyanobacteria communities on two glaciers with different surface brightness and compares them with each other. Although one of these glaciers is located near our research area, they look at the differences between two glaciers, whereas we looked at differences between the dark and reference ice. Therefore, there seems to be no overlap with our results.

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This paper as well as the above called three papers deal with microorganisms and related processes, whereas our purpose is to unravel the composition and origin of the dust in this area to find out more about the dark region. Therefore, our paper discusses much more than only microorganisms and describes the microbes not in such details. However, we will add a description and refer to all these papers.

Comment: One major conclusion of the paper is that most dust is of local origin. Bøggild et al did reach the same conclusion but is only cited for clay in Pleistocene ice. So, local dust as a major source is also not a new result.

Answer: Bøggild et al. (2010) based his conclusion of a local source for the cryoconite from *northeast* Greenland on a similar mineralogical composition of the cryoconite and surrounding soil samples, as well as on the coarseness of the cryoconite. We investigated, additional to the mineralogical composition, the elemental composition of our dust samples. This is an important discriminative addition strengthening the deduction of a local source. So they conclude a local source based on a comparison of a similar mineralogical composition between nearby soil samples and cryoconite whereas we exclude other sources than the local source based on mineralogical and on elemental composition. Therefore, the findings of Bøggild et al. (2010) seems to supplement our conclusion rather then to be identical. However, Bøggild et al. (2010) found a fine mode (clay) in a brown band of *Pleistocene* ice, suggesting a non-local source for this fraction. This implies that local as well as non-local dust could cause dark areas in an ablation zone of the ice sheet. As *northeast* Greenland is quite a different area than *west* Greenland, Bøggild et al. (2010) findings did imply nothing for the dark region in *west* Greenland. So, we therefore think that local dust as major source for the dark region in *west* Greenland, which probably has a *Holocene* age is a new result. However, we will clarify the findings of Bøggild et al. (2010) in a better way in the revised version.

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