Reply to reviews (revised manuscript)

RC = Referee Comment

AR = Author Reply

General remarks to the editor and both referees

Please see the revised manuscript with tracked changes and with one new reference. One of the anonymous referees has indicated in the review report that she/he is willing to become acknowledged by her/his name. We are grateful to both anonymous referees whose comments have been most valuable and have greatly improved our manuscript. This new sentence we suggest being added in the acknowledgements of our manuscript, and the acknowledgements to be then completed by the editorial office with the correct name(s) if the manuscript gets accepted.

Referee 1

RC1.1

"**Anonymous during peer-review: Yes** No

Anonymous in acknowledgements of published article: Yes **No**

Recommendation to the editor

1) Scientific significance Does the manuscript represent a substantial contribution to scientific progress within the scope of this journal (substantial new concepts, ideas, methods, or data)?	Outstanding **E**
2) Scientific quality Are the scientific approach and applied methods valid? Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)?	Outstanding **E**
3) Presentation quality Are the scientific results and conclusions presented in a clear, concise, and well structured way (number and quality of figures/tables, appropriate use of English language)?	Outstanding **E**

For final publication, the manuscript should be

accepted as is

accepted subject to technical corrections

accepted subject to minor revisions

reconsidered after major revisions

rejected

Were a revised manuscript to be sent for another round of reviews:

I would be willing to review the revised manuscript.

I would not be willing to review the revised manuscript.”

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final pu

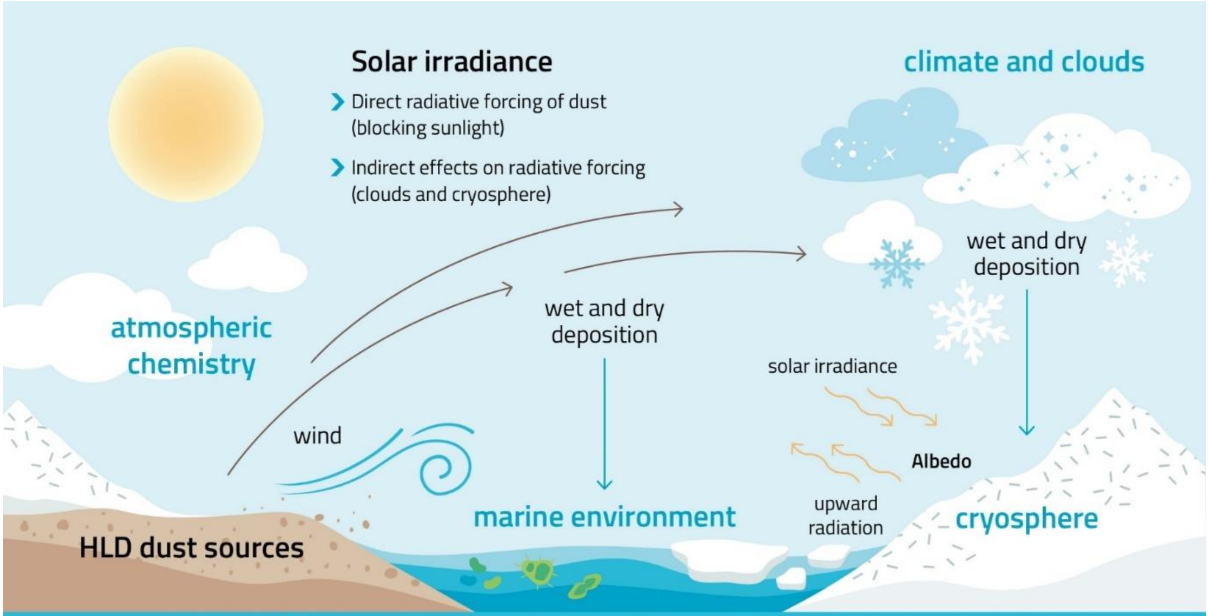
RC1.2: ”The Authors have addressed all my comments satisfactorily. The paper is clearer and well structurec the new SILAM modelling emission/deposition patterns, and related data analysis, is insightful and I feel was defi effort. I recommend publication in ACP.”

RC1.3: ”Note that some new Figures and Tables have the holder 'X' instead of the new number, which will ne publication. The first column of new table "Emission and deposition of global dust..." is defined as emission, but e data is presented in the rows; therefore, maybe alter header to be "flux" or similar.”

AR1.1: We thank Referee1 for the positive feedback. We are grateful to Referee1 whose comments have been most valuable and have greatly improved our manuscript. We are happy to acknowledge Referee1 by name in the acknowledgements of our manuscript if it gets accepted.

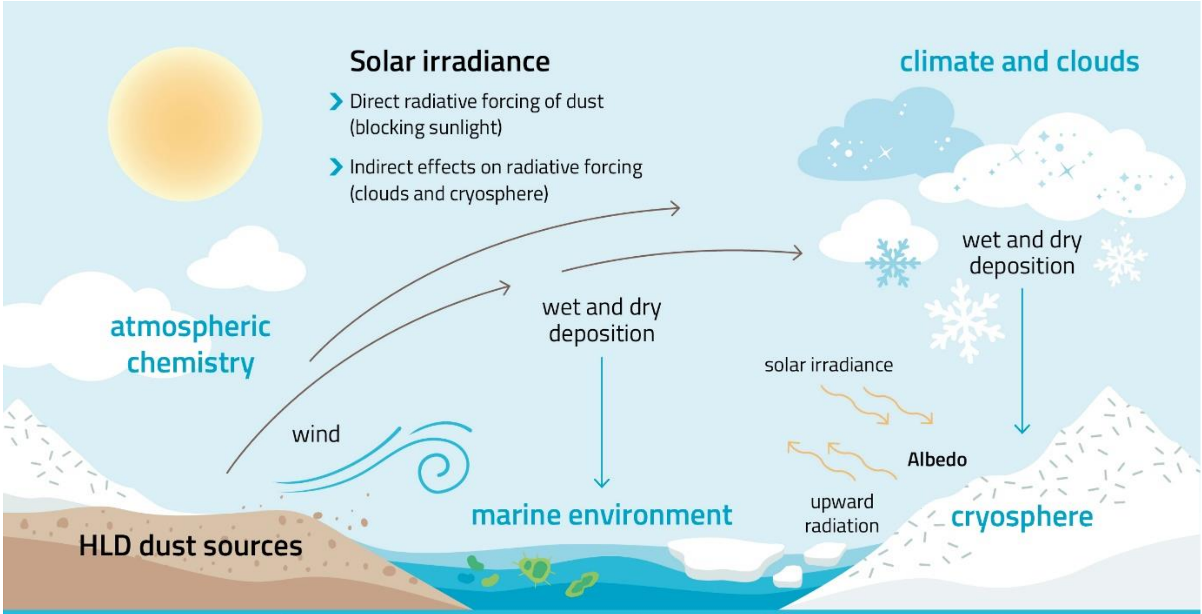
AR1.2: Thank you, we are happy to hear this.

AR1.3: We are grateful to Referee1 for checking the new numbers of the new Figures and Tables and have updated these. The header of the new table "Emission and deposition of global dust..." in the column of "emission" (below, surrounded with red color) has been altered to be Flux, as suggested by Referee1, since the rows represent emission and deposition data.



EMISSION (MEGATONNES)	GLOBAL DUST < 30 µm	GLOBAL DUST < 2.5 µm	ARCTIC DUST < 30 µm	ARCTIC DUST < 2.5 µm	ANTHROPOGENIC BLACK CARBON (CAMS global emissions v4.2)	WILDFIRE BLACK CARBON (5% of fire PM emissions)
Total emission	3000	160	30	1,6	4,6	1,9
Deposition on snow	32	5,2	4	0,21	0,18	0,029
Deposition on sea ice	5,5	0,59	3	0,17	0,009	0,008
Deposition on Arctic snow	7,6	1,1	4	0,19	0,027	0,013
Deposition on Arctic Sea ice	4,7	0,52	3	0,17	0,0055	0,0074
Deposition on sea surface	500	86	15	1,0	1,7	0,9
Deposition on Arctic Sea surface	21	2,4	12	0,68	0,035	0,063

New revised:



FLUX (MEGATONNES)	GLOBAL DUST < 30 µm	GLOBAL DUST < 2.5 µm	ARCTIC DUST < 30 µm	ARCTIC DUST < 2.5 µm	ANTHROPOGENIC BLACK CARBON (CAMS global emissions v4.2)	WILDFIRE BLACK CARBON (5% of fire PM emissions)
Total emission	3000	160	30	1,6	4,6	1,9
Deposition on snow	32	5,2	4	0,21	0,18	0,029
Deposition on sea ice	5,5	0,59	3	0,17	0,009	0,008
Deposition on Arctic snow	7,6	1,1	4	0,19	0,027	0,013
Deposition on Arctic Sea ice	4,7	0,52	3	0,17	0,0055	0,0074
Deposition on sea surface	500	86	15	1,0	1,7	0,9
Deposition on Arctic Sea surface	21	2,4	12	0,68	0,035	0,063

Referee 2

RC2.1:

Anonymous during peer-review: Yes No

Anonymous in acknowledgements of published article: Yes No

Recommendation to the editor

1) Scientific significance Does the manuscript represent a substantial contribution to scientific progress within the scope of this journal (substantial new concepts, ideas, methods, or data)?	Outstanding **Excellent** Good Fair Low
2) Scientific quality Are the scientific approach and applied methods valid? Are	Outstanding **Excellent** Good Fair Low

the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)?	
3) Presentation quality Are the scientific results and conclusions presented in a clear, concise, and well structured way (number and quality of figures/tables, appropriate use of English language)?	Outstanding Excellent **Good** Fair Low

For final publication, the manuscript should be

accepted as is

accepted subject to technical corrections

accepted subject to minor revisions

reconsidered after major revisions

rejected

Were a revised manuscript to be sent for another round of reviews:

I would be willing to review the revised manuscript.

I would not be willing to review the revised manuscript.

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

RC2.2: This revised manuscript is much improved. I have just a few minor comments.

For the introduction, there are a few redundancies that should be removed on lines 134-143 and lines 151-153

RC2.3: Lines 221-231 belong in the introduction of the paper

RC2.4: Dust sources #7 and #8 are outside of the authors self-defined latitudinal cut off for HLD.

RC2.5: For Figure 9, it would be helpful to include the EDX spectra with the SEM images.

AR2.1: We are thankful to Referee2 for the positive feedback. We thank Referee2 whose review has been most helpful and has greatly improved our manuscript. We are happy to acknowledge the valuable work of anonymous Referee2 in the acknowledgements.

AR2.2: Thank you, we are pleased to hear this. The redundances of the introduction on lines 134-143 and lines 151-153 have now been removed.

AR2.3: We agree and have moved the lines 221-231 in the introduction.

AR2.4: We thank Referee2 for pointing out that sources no. 7 and 8 are outside our self-defined latitudinal cut off for HLD. It is true that our collection contains two sources that are outside the latitudinal cut off for HLD, when we have followed the definition of Bullard et al. (2016) saying that HLD refers to ≥ 50°N and ≥ 40°S.

We are most grateful for Referee2 for bringing this up once more and making us to clarify the manuscript further. Namely, as an outcome of our own results, we say in the revised manuscript (lines 1001-1004):

"The results (Fig. 2) suggest two northern high-latitude dust belts. The first HLD belt would extend at 50–58°N in Eurasia and 50–55°N in Canada, and the second dust belt at >60°N in Eurasia and >58°N in Canada, with a "no dust" belt between the HLD and LLD dust belts (except for British Columbia)."

Hence, our results suggest a potential need for updating the definition for HLD. Therefore, we have now removed from the abstract the latitudinal cut off for HLD latitudes according to Bullard et al. (2016) as follows:

Abstract. Dust particles from high latitudes have a potentially large local, regional, and global significance to climate and the environment as short-lived climate forcers, air pollutants, and nutrient sources. Identifying the locations of local dust sources and their emission, transport, and deposition processes is important for understanding the multiple impacts of High Latitude Dust (HLD~~), ≥ 50°N and ≥ 40°S)~~ on the Earth's systems. Here, we identify, describe, and quantify the Source Intensity (SI) values, which show the potential of soil surfaces for dust emission scaled to values 0 to 1 concerning globally best productive sources, using the Global Sand and Dust Storms Source Base Map (G-SDS-SBM). This includes sixty-four HLD sources in our collection for the Northern (Alaska, Canada, Denmark, Greenland, Iceland, Svalbard, Sweden, and Russia) and Southern (Antarctica and Patagonia) high latitudes. Activity from most of these HLD dust sources shows seasonal character. It is estimated that high-latitude land areas with higher (SI≥0.5), very high (SI≥0.7), and the highest potential (SI≥0.9) for dust emission cover >1 670 000 km^2, >560 000 km^2, and >240 000 km^2, respectively. In the Arctic HLD region (≥ 60°N), land area with SI≥0.5 is 5.5% (1 035 059 km^2), area with SI≥0.7 is 2.3% (440 804 km^2), and with SI≥0.9 is 1.1% (208 701 km^2). Minimum SI values in the north HLD region are about three orders of magnitude smaller, indicating that the dust sources of this region greatly depend on weather conditions. Our spatial dust source distribution analysis modeling results showed evidence supporting a northern High Latitude Dust (HLD) belt, defined as the area north of 50°N, with a 'transitional HLD-source area' extending at latitudes 50–58°N in Eurasia and 50–55°N in Canada, and a 'cold HLD-source area' including areas north of 60°N in Eurasia and north of 58°N in Canada, with currently 'no dust source' area between the HLD and LLD dust belt, except for British Columbia. Using the global atmospheric transport model SILAM, we estimated that 1.0% of the global dust emission originated from the high-latitude regions. About 57% of the dust deposition in snow- and ice-covered Arctic regions was from HLD sources. In the south HLD region, soil surface conditions are favorable for dust emission during the whole year. Climate change can decrease snow cover duration, retrieval of glaciers, and increase drought, heatwave intensity, and frequency, leading to the increasing frequency of topsoil conditions favorable for dust emission, which increases the probability of dust storms. Our study provides a step forward to improve the representation of HLD in models and to monitor, quantify, and assess the environmental and climate significance of HLD going forward.

Similarly, we have checked the consistency of using HLD definition throughout the manuscript, keeping in mind that our results suggest a need to update the definition for HLD. For example, in "3 Results and discussion":

3 Results and discussion

3.1 Locations of the HLD sources

> Sixty-four HLD sources at northern and southern high latitudes (Fig. 1) were identified. In the north HLD region are 49 locations (47 locations ≥50°N and two >47°N) in A
> Sweden, and Russia, of 35 are in the Arctic HLD subregion (≥60°N). In the south HLD region (≥40°S), 15 sources were identified in Antarctica and Patagonia, South A

and in "3.6.1 Source intensity values", where we also found a typo in the latitude for sources no. 8 and no. 48; now corrected, as follows:

> Forty-nine locations were in the north HLD region (47 according to HLD definition by Bullard et al. (2016), (except for two: no. 8 and

When checking and discussing these latitudinal definitions among the co-authors, we found that we would need carefully consider the sources no. 7, 8 and 48. In the appendix, we have the coordinates for these sources as follows:

7	51.3	88.5	0.0	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.4
8	47.3	66.7	0.5	0.0	0.5	0.0	0.6	0.3	0.7	0.4	1.0
48	47.6	-111.25	0.5	0.1	0.8	0.1	0.8	0.7	1.0	0.7	1.0

Hence, no. 7 is inside the defined HLD according to Bullard et al. (2016), but no. 8 and no. 48 are not. In the revised manuscript (lines 600-610), we described sources no. 7 and no. 8 as follows:

"Some Russian sources included in our collection (e.g., no. 7 and 8 of Fig. 1) could be identified as dust sources on the periphery of HLD and low-latitude source regions. Source no. 7 of Fig. 1 is the Altai Mountains. Some parts of these territories are covered by permafrost, where winter lasts for 5–6 months. From October, in lower mountains (less than 1000 m a.s.l.), and from September, in higher mountains (more than 1500 m a.s.l.), a stable snow cover persists. The mean daily air temperature during winter within the lower, middle, and higher mountains is –21°C, –29°C, and below –30°C, respectively. Source no. 8 is in Central Kazakhstan. From late December to early March, a stable snow cover from 5 cm to 30 cm occurs within plains and up to 50 cm within hollows. Periods of snow cover and thaw correspond to transitions of the mean daily temperature of air through 0°C, which, on average, are the 7 November and 23 March plus/minus 10–12 days. From early January to late February, the air's mean daily temperature can be as low as –20°C. Soil Atlas of the Northern Circumpolar Region (https://esdac.jrc.ec.europa.eu/content/soilatlas-northern-circumpolar-region) covers all land surfaces in Eurasia and North America above the latitude of 50°N. Thus, these territories are considered high-latitude."

Keeping in mind that our results suggest a need to update the definition for HLD, we would like to suggest that including #8 and #48 in our collection is reasonable, when referring to the new self-defined high latitude dust belt of our manuscript and suggesting to add one **new sentence** and **one new reference in the Conclusions** to clarify further by saying that:

"Our results suggest that future HLD studies should include and update sources within the here defined high latitude dust belt, i.e., at 50–58°N in Eurasia and 50–55°N in Canada, and at >60°N in Eurasia and >58°N in Canada, as well as sources in the periphery of these regions, especially if sources are highly elevated (Wang et al. 2016)."

<u>*New reference:*</u>

Wang, Q., Fan, X. & Wang, M. Evidence of high-elevation amplification versus Arctic amplification, Sci Rep, 6, 19219, https://doi.org/10.1038/srep19219, 2016.

AR2.5: Thank you. We agree that it could be helpful to include EDX spectra with the SEM images. Legend for Figure 9 (Figure 13 in the revised version) is created based on the EDX spectra statistical analyses. We performed such analyses just after sampling in 2015-2016. Unfortunately, however, we did not withdraw all EDX spectra from the software data set stored on the EDX machine. Now this instrument does not operate anymore, and unfortunately, we cannot fully address this comment.