We thank very much the anonymous referee #1 for taking the time to review our manuscript and giving helpful suggestions and comments. We here respond to the referee #1's comments:

[General comments from referee #1]

In this manuscript Nagatsuka and colleagues analyze the mineral content of dust particles in a shallow ice core from central Greenland, and estimate the potential source contribution through backtrack trajectory modeling. They compare their results with a similar core drilled further west and published previously.

The main contribution of this manuscript are the detailed mineralogical analyses of this new shallow core since 1910. Although the results are new, they are rather incremental and it is not clear how these new data are improving our knowledge of Central Greenland dust advection or source contribution. That dust in central Greenland mostly originates from distant sources (mostly in East Asia) and not local ones was already known from other cores. This study mostly repeats this result at higher resolution. In addition, the authors imply links between their results with recent warming in Greenland, which is poorly supported since any kind of analyses including Atlantic and Pacific oscillations are missing. Finally, the discussion of volcanic particles is mostly a literature review without any contribution from this manuscript.

For these reasons I suggest to reject this manuscript as it does not include sufficient scientific advances for Climate of the Past. Instead, I suggest to publish these results in a more specialized journal.

[Author response]

We agree with your suggestions that we should discuss the link between mineral composition records and Atlantic and Pacific oscillations in much more details and that we should compare the results not only with a northwest Greenland ice core (SIGMA-D), but also with other central, east, and southeast Greenland. However, we would like to argue that this study demonstrates the following three important results for the first time that improve our knowledge of global climate and environment changes including Greenland.

1. We have known that mineral dust on the inland Greenland ice sheet primarily originates from distant sources, as suggested by referee #1. However, previous studies mainly investigated ice core dust sources from glacial periods using mainly the Sr-Nd-Pb (Hf) isotopes (e.g., Biscaye et al., 1997; Svensson et al., 2000; Lupker et al., 2010; Újvári et al., 2022). Little is known about the dust composition and sources from interglacial periods, especially in the modern times, when the dust concentrations are significantly lower than the glacial periods,

mainly due to the large sample amounts required for Sr-Nd-Pb (Hf) analyses. Furthermore, recent studies have revealed that the ability of ice nucleating particles (INP), which alter the cloud microphysics and lifetime in the Arctic, differs depending on the mineral types (e.g., Koop and Mahowald., 2013; Tobo et al., 2019). Thus, it is crucial to identify the variations in the composition and morphology of mineral dust in recent years.

This study is the first to demonstrate a high-temporal resolution record of the composition and morphology of mineral dust on inland ice sheet, which are not only important to understand modern INP variations but also reveals sources in a central Greenland (EGRIP) ice core over the past 100 years when global warming is remarkably progressing. Although our conclusion that one of the major sources of the EGRIP ice core dust is distant deserts may not sound new, it is very new and valuable information that there are no significant differences in dust sources between glacial and present periods since only a few study has confirmed it. This result is different from the results obtained from Antarctic ice cores, which show different source contributions between interglacial and glacial periods. However, we didn't stress this enough in the manuscript and gave the impression that our result is not new. When we revise our manuscript, we will stress this point.

Some studies have also revealed temporal variations of the Greenland ice core dust sources in modern days. For example, Amino et al (2021) and Kjær et al (2022) showed records of dust concentrations and fluxes from southeast and central Greenland ice cores respectively, and revealed a recent increase in dust sources from local ice-free areas. However, their records go back only to 1960s. Furthermore, they did not discuss contributions of dust from other source areas. Bory et al (2003) analyzed the Sr-Nd isotopes, and Drab et al., (2002) and Donarummo et al. (2003) carried out the SEM-EDS analysis of dust from Greenland snow and ice cores. The authors revealed dust source records in the 1900s, but they cover just for a few years. Thus, we give the first results showing temporal variations in ice core dust composition and sources from multiple regions covering such a long period (100 years).

2. The source of mineral dust on inland ice sheets has been generally thought to be primarily distant deserts. However, we demonstrate a possibility of a recent increase in local dust contribution to the inland ice sheet based on our high-temporal resolution records of ice core mineral size and composition and snow cover fraction anomaly. The possibility of local dust increase has also been suggested by Kjær et al (2022). Our result is considered valuable since there is still very little knowledge of local dust contribution to inland ice sheets.

However, our study has missed a discussion related to Atlantic and Pacific oscillations, as suggested by the referee #1. We will carry out analyses related to them and discuss in our revised manuscript about both possibilities of local dust increase and the oscillations as causes for our mineral composition records. If the oscillations turn out to be more likely cause, it also supports the importance of our study because we can find such a result only because of our high-temporal resolution analysis.

3. This study is the first to demonstrate the regional variation in Greenland dust sources over the 100 years by comparing inland and coastal ice cores. It is essential to identify spatial variations in the Greenland ice core dust source records, which would be a key to understand differences in climate and environment conditions within Greenland and atmospheric circulation patterns.

For these reasons, we believe that our study provides new perspectives on reconstruction of the past climate/environment and fluctuations of the Greenland ice sheet, thus contributing to scientific advances for Climate of the Past and earth sciences. However, the current version of the manuscript does not clearly show the significance of our study. We would like to revise it and emphasize these points.

[Major comments from referee #1]

The authors mostly compare their results with an ice core from northeast Greenland (sigma-d) for which similar data are available. However, the comparison to central Greenland, east Greenland (Renland) and southeast Greenland (Dye-3) should be included in the discussion. In particular, the comparison with NGRIP should be made, as the claim that EGRIP represents Eastern Greenland and NGRIP central Greenland is a bit shaky, considering both sites are at similar altitudes and quite close to each other.

The authors group Europe and NorthEast Asia, as well as Africa and SouthEast Asia into single potential source areas in their analysis. Considering the long debate about Asian, European and African dust sources for Greenland, these should probably be split into four, unless the authors can justify their choice.

The authors talk about trends in the data in various sections of the manuscript, in particular comparing the last 20 years with the mid-section of the core. In particular, the authors imply that the recent warming has been responsible for various changes in dust mineralogy and concentrations. But looking at the complete record, these look more like multidecadal oscillations to me and should not be described as trends. Although recent warming in Greenland may have been responsible for some of the observed changes, such a hypothesis has to be put in context with the complete oscillations shown in the records. The authors briefly mention NAO at some point, but the link between their record and various Atlantic and Pacific oscillations should be discussed in much more details.

[Author response]

We will compare our results with those obtained from other Greenland ice cores as suggested by referee #1. However, most of the previous studies have analyzed the dust from the last glacial period. Furthermore, there are no continuous records of size, composition, and source data of ice core minerals for the past 100 years. Thus, the results may not be directly comparable.

We recalculated the back-trajectories as follows. Potential dust source (land) areas are divided into eight regions following referee #1's suggestion; the Greenland Ice Sheet (GrIS), the Greenland coast (GrC), North America (NA), Europe (EU), Russia (RUS), Central Asia (CA), Southeast Asia (SA), Middle East (ME), and Africa (AF) (Fig. Rep1). Considering the dust sources, the ocean and GrIS were excluded from the calculation.
Revised version of figs 2 and 7 are shown in Figs. Reply 1 and 2, respectively. We will replace them in our revised manuscript.

We will carry out analyses related to Atlantic and Pacific oscillations as described above.

[Minor Comments from referee #1]

Line 18: Abstract could benefit from a more general introductory phrase at the beginning.

Line 33-34: Since Greenland is an island, all air masses must come from a coast. Be more precise.

Line 38: 100,000 years seems a bit short for the geological timescale, although I am not a geologist and may be wrong. Maybe Milankovitch timescale?

Line 42: "ice-core dust shows…". Also this is only shown for Central Greenland, not the whole of Greenland.

Line 44-45: This is not at all the message of Svensson et al., 2000. Generally, I very much doubt that the seasonal variability in dust advection to Greenland is due to climate change…

Line 46: Not "predict". "estimate" maybe.

Line 47: "partly responsible". Grain size and partial melt is very important as well for albedo.

Line 53-58: The message of these phrases is unclear. Are you suggesting to collect dust from outcropped ice in the ablation zone to measure old dust? Or just dust in fresh snow on the surface? Then why talk about the movement of ice and dust through the ice sheet?

Line 60: Ujvari et al. used Hf not Pb.

Line 75: Can you give some references to support that hypothesis?

Line 117: Is the Beckman CC located in a normal laboratory or a clean room or a laminar flow bench? What kind of aperture tube was used?

Line 145, Table 1: Why is South America included as a possible source for Type A particles? I'm not saying it's wrong (although I do doubt it), but I wonder why it was included in the list.

Lines 171-174: Snow cover fractions vary substantially from one model to another. Please provide and uncertainty estimate due to the choice of the model.

Lines 209-216: What do the numerical ranges indicate? 1-sigma range? If so how were the mean and standard deviations calculated?

[Author response]
All the minor comments and suggestions raised by the referee will be respected in our revised manuscript.

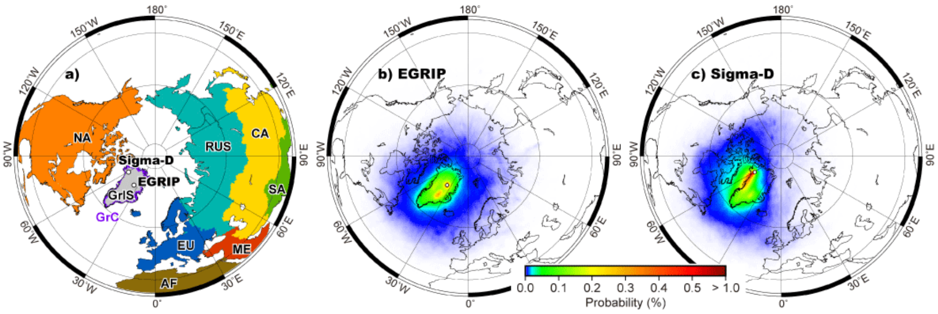

Figure reply1 (revised from fig. 2): Map showing (a) location of EGRIP and SIGMA-D ice core sites in Greenland and five regions used for calculating regional contribution (GrIS: Greenland Ice Sheet, grey; GrC: Greenland coast, purple; NA: North America, orange; EU: Europe, blue; RUS: Russia, light blue; CA: Central Asia, yellow; SA: Southeast Asia, green; ME: Middle East, red; and AF: Africa, brown) and probability distribution for air mass at (b) EGRIP and (c) SIGMA-D sites from 7-day three-dimensional back trajectory analysis from 1958 to 2014.

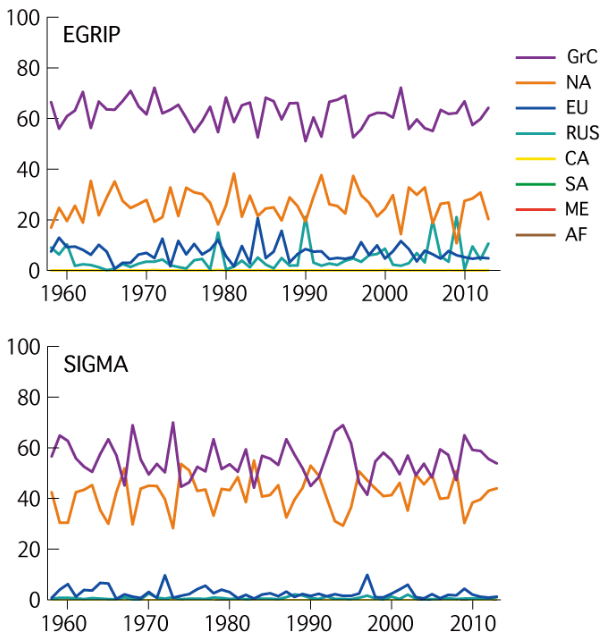

Figure reply 2 (revised from fig. 7): Annual variations in regional contribution of air mass to (a) EGRIP and (b) SIGMA-D sites excluding ice sheet and ocean areas. GrC, NA, EU, RUS, CA, SA, ME and AF denote the ice-free Greenland coastal region (Fig. 1), North America, Europe, Russia, Central Asia, Southeast Asia, Middle East, amd Africa, respectively (Fig. 2a).

References:

Amino, T., Iizuka, Y., Matoba, S., Shimada, R., Oshima, N., Suzuki, T., Ando, T., Aoki, T., and Fujita, K. (2021) Increasing dust emission from ice free terrain in southeastern Greenland since 2000, Polar Sci., 27, 100599.

Biscaye, P. E., Grousset, F. E., Revel, M., Van der Gaast, S., Zielinski, G. A., Vaars, A., and Kukla, G. (1997) Asian provenance of glacial dust (stage 2) in the Greenland Ice Sheet Project 2 ice core, Summit, Greenland, J. Geophys. Res., 102, 26765–26781.

Bory, A. J.-M., Biscaye, P. E., and Grousset, F. E. (2003) Two distinct seasonal Asian source regions for mineral dust deposited in Greenland (NorthGRIP), Geophys. Res. Lett., 30, 1167.

Donarummo, J., Ram, M., and Stoermer, E. F. (2003) Possible deposit of soil dust from the 1930's U.S. dust bowl identified in Greenland ice, Geophys. Res. Lett., 30, 1269.

Drab, E., Gaudichet, A., and Jaffrezo, J. L. (2002) Mineral particles content in recent snow at Summit (Greenland). Atmospheric Environment., 36, 5365–5367.

Kjær, H. A., Zens, P., Black, S., Lund, K. H., Svensson, A., and Vallelonga, P. (2022) Canadian forest fires, Icelandic volcanoes and increased local dust observed in six shallow Greenland firn cores, Clim. Past, 18, 2211–2230.

Koop, T., and Mahowald, N. (2013) The seeds of ice in clouds. *Nature* **498**, 302–303.

Lupker, M., Aciego, S. M., Bourdon, B., Schwander, J., and Stocker, T. F. (2010) Isotopic tracing (Sr, Nd, U and Hf) of continental and marine aerosols in an 18th century section of the Dye-3 ice core (Greenland), Earth Planet. Sci. Lett., 295, 277–286.

Svensson, A., Biscaye, P. E., and Grousset, F. E. (2000) Characterization of late glacial continental dust in the greenland ice core project ice core, J. Geophys. Res., 105, 4637–4656.

Újvári, G., Klötzli, U., Stevens, T., Svensson, A., Ludwig, P., Vennemann, T., Gier, S., Horschinegg, M., Palcsu, L., Hippler, D. Kovács, J., Di Biagio, C. and Formenti, P. (2022) Greenland ice core record of last glacial dust sources and atmospheric circulation. J. Geophys. Res. Atmo.s, 127, e2022JD036597.