Dear Reviewers,

Thank you for taking the time to review this manuscript. We really appreciate the reviewers' comments, which have helped us to improve the paper quality substantially. We have addressed all the comments very carefully in our following point-by-point responses. Our responses start with "R:".

General comments

In this study, mineral dust particles from snowpack were analyzed by SEM. They classified the measured particles based on their compositions and discussed the effects on their optical properties. This study is generally well designed and the topic is interesting. However, I have a concern with the classification of the particles and the subsequent discussions based on the classification. I suggest having more description of the classification and providing SEM chemical and image data of the particles that they classified.

R: We sincerely appreciate the reviewer's constructive feedback. To address concerns about particle classification and enhance transparency, we added Figure S1, which shows the percentage of each elemental index (without C and O) and the corresponding SEM images of typical particles for the 12 categories of mineral particles (See Page 10, Line7-16).

"Figure S1 presents the percentage distribution of elemental indices (excluding C and O) for 12 categories of mineral particles. Specifically, hematite-like, quartz-like, rutile-like, apatite-like, and dolomite-like particles are predominantly characterized by Fe, Si, Ti, Ca, and Mg, respectively. Kaolinite-like particles are enriched in Al and Si, while clay mineral-like and Ca-rich silicate particles contain significant amounts of Al and Si, along with notable Ca content, with the latter exhibiting a higher Ca concentration. In contrast, illite-like, smectite-like, and chlorite-like particles, in addition to being enriched in Al and Si, also contain varying amounts of K, Mg, and Fe, respectively. Correspondingly, representative SEM images of particles are presented within each mineral category panel."

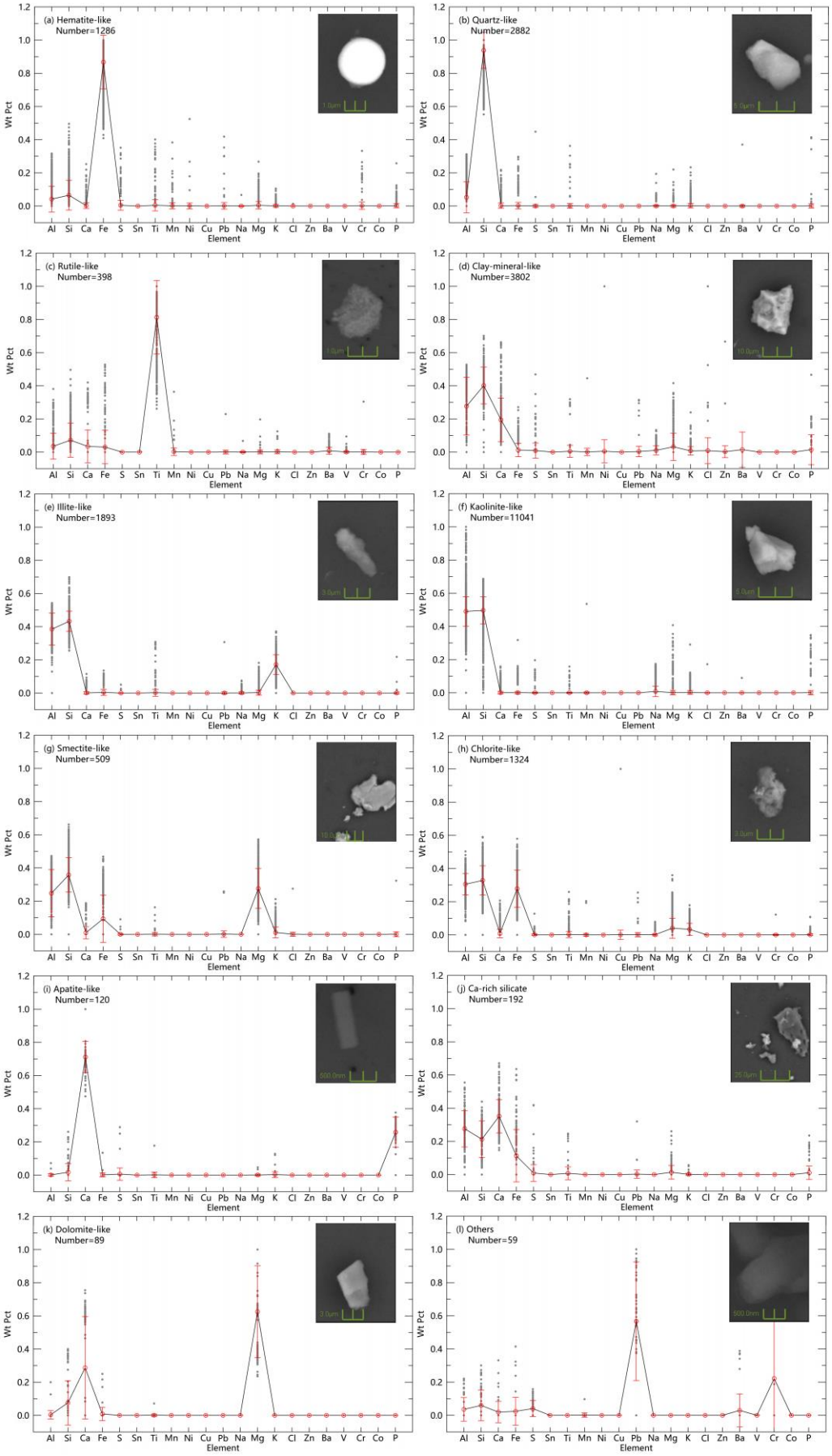
(a) Hematite-like
Number=1286
(b) Quartz-like
Number=2882
(c) Rutile-like
Number=398
(d) Clay-mineral-like
Number=3802
(e) Illite-like
Number=1893
(f) Kaolinite-like
Number=11041
(g) Smectite-like
Number=509
(h) Chlorite-like
Number=1324
(i) Apatite-like
Number=120
(j) Ca-rich silicate
Number=192
(k) Dolomite-like
Number=89
(l) Others
Number=59
Wt Pct
Element
Al Si Ca Fe S Sn Ti Mn Ni Cu Pb Na Mg K Cl Zn Ba V Cr Co P

Figure S1. The percentage of each elemental index (without C and O) for the 12 categories of mineral particles. Subplots (a)-(l) represent results for hematite-like, quartz-like, rutile-like, clay-mineral-like, illite-like, kaolinite-like, smectite-like, chlorite-like, apatite-like, Ca-rich silicates, domolite-like, and others, respectively. Correspondingly, representative SEM images of particles are presented within each mineral category panel. The red circle and whiskers denote the average value and mean deviation. The data for each particle is shown as gray solid dots.

Specific comments

Page 1, line 2: "industrial-polluted snowpack" Throughout the manuscript, there is not much discussion and results about the influence of industrial pollution. In an industrially polluted city, there should be many anthropogenic pollutants, but no results are provided. Please provide any results and discussion on anthropogenic pollutants.

R: The title has been revised to “Insights into microphysical and optical properties of typical mineral dust within urban snowpack via wet/dry deposition in Changchun, Northeastern China” to better reflect the focus on mineral dust rather than industrial pollutants. While the sampling site is in an industrial city, the study primarily analyzes dust components. Future work will explicitly address anthropogenic pollutants (e.g., heavy metals, black carbon). Additionally, we added more discussion about potential sources of dust (e.g., natural and anthropogenic sources), see Page 15, Line 5-10.

“Considering that industrial activities (e.g., coal combustion, urban construction, and road dust) emit quartz-rich particles, while long-range transport from arid regions (e.g., the Gobi Desert) contributes illite, which is consistent with the dust profile in Asia (Li et al., 2021). The anthropogenic contribution (e.g., hematite-like particles) aligns with the presence of nearby steel production facilities. Therefore, our results suggest that dust is likely a mixture of local and long-range sources.”

Page 2 lines 2-7: I do not think it is appropriate to include the name of commercial products in the first sentence of the abstract, although it is up to the author. The first sentence is long and needs to be checked for grammar.

R: The abstract has been rephrased:

"This study presents the first compositional analysis of dust in snowpack from a typical Chinese industrial city, utilizing computer-controlled scanning electron microscope combined with K-means cluster analysis and manual experience. The dust is predominantly composed of kaolinite-like (36%), chlorite-like (19%), quartz-like (15%), illite-like (14%), hematite-like (5%), and clay-minerals-like (4%), with minor contributions from other components."

The details of the IntelliSEM-EPAS™ software are provided in the Methods section.

Page 3, lines 7-10: This sentence is misleading and needs to be revised. Many aerosols are deposited on land and in the ocean.

R: The sentence has been revised as follows:

"Current research indicates that light-absorbing aerosols in the atmosphere (e.g. black carbon, brown carbon, and dust) are eventually deposited on various surfaces, including snow or glaciers through atmospheric diffusion, transport, and dry/wet deposition processes."

Page 4, lines 16-18: This sentence is awkward. Perhaps "while" is not needed.

R: Revised as follows:

"Hao et al. (2023) projected a decrease in black carbon deposition on ice and snow under future emission scenarios, and anticipated that heightened dust emissions and deposition fluxes driven by climate change-induced land use changes…"

Page 6, line 21: Please describe the sampling location in more detail. Is it near a road or industrial facility?

R: Added as follows:

"The sampling site is located at the meteorological station of Lvyuan District (43°88'N, 125°25'E), with no apparent sources of air pollution emissions in the visual range."

Page 7, line 1: Aged surface snow should include both wet and dry deposition.

R: Revised as suggestion.

Page 7, lines 4-6: How much snow did you use for the measurements?

R: Fresh snowfall sample was filtered for about 20 ml, the remaining four samples were filtered for 1 ml. The measurements of the snow samples were added in Line 11, Page 7.

Page 7, line 12: Please provide information about the SEM (e.g., company).

R: Addition:

"…the scanning electron microscope (TESCAN Mira3)…"

Page 7, line 18: The selected elements are 29, not 24. Some elements (e.g. Rh) may be misclassified because they are very rare. Please check them from the original SEM data.

R: We sincerely apologize for this error. After carefully reviewing the original SEM data, we have confirmed the analysis of 24 elements (including C, O, Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Sn, Ba, Se, and Pb), which also revised in the manuscript accordingly.

Page 7 line 21: "thousands of particles per hour" How many seconds did you use for chemical analysis? In general, 1 or 2 seconds for EDS is not enough to qualify the elements.

R: The IntelliSEM-EPAS^{TM} utilizes two Bruker XFlash 6|60 energy dispersive spectroscopy (EDS) detectors to analyze the relative content of 24 chemical elements, enabling high analytical efficiency.

Page 8, line 5: "particle concentration level" Did you measure particle concentrations?

R: The particle concentration can be calculated based on the filtered meltwater volume, membrane area, and scanned area. This study does not report such results, our previous research has reported particle concentration levels (Wang et al., 2023).

Page 9, line 1: "K-means clustering algorithms and manual experience" Although I understand that it is difficult to classify particles based only on the K-means clustering technique, please describe the "manual experience". Also, I strongly suggest showing, for example, average compositions of the particle group (e.g., quartz-like, ...) and representative SEM images of the particles. In the current discussion, there is no such data, and I cannot judge whether the classification worked well or not. Thus, I question whether the particle size distributions are adequate or not, i.e., whether the distributions are similar for all particle types.

R: This study uses the k-means algorithm to classify particles with similar chemical compositions into 30 types. The classification is based on the elemental index of each element. Then, according to relevant research and manual classification principles of EDS spectra (Panta et al., 2023), the 30 types are grouped into 12 mineral phases. This is done by merging some similarly classified clusters. The particle categories are named after their most common chemical composition. These include hematite-like, quartz-like, rutile-like, clay-mineral-like, illite-like, kaolinite-like, smectite-like, chlorite-like, apatite-like, Ca-rich silicates, domolite-like, and others. Specifically, hematite-like, quartz-like, rutile-like, apatite-like, and dolomite-like particles are predominantly characterized by Fe, Si, Ti, Ca, and Mg, respectively. Kaolinite-like particles are enriched in Al and Si, while clay mineral-like and Ca-rich silicate particles contain significant amounts of Al and Si, along with notable Ca content, with the latter exhibiting a higher Ca concentration. In contrast, illite-like, smectite-like, and chlorite-like particles, in addition to being enriched in Al and Si, also contain varying amounts of K, Mg, and Fe, respectively.

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Page 11, lines 13-16: Similar to the comment above, please describe how you classify the mineral dust particles into these categories.

R: We have supplemented additional descriptions regarding mineral dust classification in Section 2.2, as detailed in our response to previous comment.

Page 23 lines 12-22: "It is worth noting that there is currently no strict set of criteria in the scientific community for classifying dust mineral components" These discussions are misleading. In mineralogy, there are strict definitions of each mineral phase based on composition and crystal structure. The problem with the mineral dust particles used in this study is that they are mixtures and not simple components, resulting in the difficulty of particle classification.

R: As suggested by the reviewers, we have revised the relevant statements to avoid being misleading, See Page 26, Line 4-8.

"it is worth noting that although mineralogy provides strict definitions for mineral phases based on composition and crystal structure, atmospheric dust particles typically consist of heterogeneous mixtures. Currently, the scientific community lacks standardized protocols for classifying the mineralogical components of such complex particulate assemblages…"

References:

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