Responses to the comments of reviewer 3

The authors really appreciate the valuable comments and constructive suggestions from the reviewer. The suggestions and comments of reviewer are listed in black font, and responses are highlighted in blue. The changes made in the revised manuscript are marked in red font.

Comments from reviewer 3:

General Comments:
This study presents an original measurement of dust samples and therefore fulfils the criterion of novelty. As it additionally presents a combination of techniques that can be seen as a new method, it fits the scope of AMT. While the paper still needs some improvement, the methods are ultimately fine. There are some weaknesses as to the significance of the work and the conclusions that are drawn, but these can probably be targeted by clearly stating the limits and some more explanation. The language is mostly fluent and precise. However, there are a still lot of mistakes. These can be fixed easily. The manuscript would benefit from having a native speaker or professional English proofreader go over it in detail. If the comments can be addressed appropriately, I recommend publication.

Response:

Thanks a lot for reviewing our manuscript and all these constructive comments. We have responded your comments point by point and modified related descriptions in the revised manuscript. In addition, we have tried our best to correct languages mistakes by checking our manuscript repeatedly and inviting native speakers to review it. We hope that you will reconsider our manuscript.

- The complete analysis is based on one single sample. This is a major weakness of the study. Yet as this is unlikely to be corrected retroactively, I suggest to discuss this fact thoroughly and state the limitations of the study. How representative is this sample of the Chinese Loess Plateau? There must be local variations, and the fact that it was sampled from the middle (page 3, line 93) does not make it representative per se. The limitation of drawing and measuring just one single sample have to be stated clearly.

Response:

Thank you for the valuable comments.

As mentioned in manuscript, our original loess sample was collected from Luochuan Loess National Geological Park, which is the only national park for loess landform in China. So we think the sample represents Chinese loess to some extent, but it still cannot represent all loess distributed in China, even all loess in Chinese Loess Plateau.

In our another work (Liu et al., 2019), we investigated fine loess particles sampled from Luochuan and Yangling, which located at the southern edge of Chinese Loess Plateau. Results showed that discrepancies in their scattering matrices are also obvious and even larger than that for Luochuan samples with different sizes, which means the effect of local variations of loess on scattering matrices are also significant. When we tried to explain the discrepancies for loess sampled from different sites based on analyses of numerical simulations, we found it is hard to summarize which physical property (size distribution, micro structure, and refractive index) plays a major role, because there are no significant differences in these properties in our opinion. Because difference in size distributions have significant effects on scattering matrices for dust, and particles with different sizes are relatively easy to obtain compared to other properties. Therefore, we investigated scattering matrices for loess dust with large difference in their sizes distributions in this study to further explore explanations of discrepancies in scattering matrices based on analyses of numerical simulations, which is significant from the perspective of particle transportation.

In short, local variations of loess are also important and worthy of extended investigations, but this is slightly different from the motivation of this work. So we would like to conduct this extended research in our future work, representative samples from more regions of Chinese Loess Plateau (even China) with various size distributions will be investigated, and the average scattering matrix will be updated constantly.

We have modified related descriptions in Section 2 and added necessary discussions in Conclusions in the revised manuscript:

“Original loess dust sample was collected from Loess National Geological Park (35.76 °N, 109.42 °E) at Luochuan, which is lying on “loess zone” and also at the center of CLP. Since this park is the only national geological park in China which has typical loess geomorphology, it can be considered that the sample collected represents Chinese loess to a certain extent.”

“Fine loess dust sampled from Luochuan and Yangling, two regions of Chinese Loess Plateau, were investigated by Liu et al. (2019). Local variations of loess dust also have obvious effects on the measured scattering matrices. It should be noted that all these samples investigated may still cannot completely represent the loess in Chinese Loess Plateau and China, so one of the efforts in the future is to investigate more loess samples collected from more regions and with more size distributions, accordingly, the average scattering matrix for loess will be updated constantly.”

- The original sample is milled to produce smaller particles that may be transported further. Why is it milled to the given size, not larger and not smaller? The study shows significant change of dust properties with size, and the milled loess seems to be just an arbitrary size.

Response:

Thanks a lot for your comments. We acknowledge that the milled fine sample actually has an arbitrary size distribution. Because it is almost impossible to obtain loess samples with preset sizes and size distributions by ball milling. Although particle size distributions of samples can be roughly changed by adjusting milling time, the particle sizes of finally obtained samples are still arbitrary in nature. Even through the size distribution of milled sample is kind of arbitrary, since this sample satisfies criterion for particle long range transportation, so the investigation of this sample still useful for developing optical models of fine loess dust.

- It is not clear enough what the conclusion of the study is. Scattering matrices are reported, but what do they ultimately tell us about the Chinese loess dust?

Response:

Thank you for the constructive comments.

In this study, we paid more attention to present the discrepancies in scattering matrices for Chinese loess dust with different size distribution and tried to find explanations for these discrepancies based on analyses of optical simulation results. The results and conclusions include the following three aspects: (1) there are obvious discrepancies in measured scattering matrices for Chinese loess dust with different size distributions, and these discrepancies are different from that for other kinds of mineral dust with various size distributions. (2) Qualitative analyses of numerical simulation results in literatures showed that the large difference in size distributions (effective radii differ by more than 20 times) plays a major role in leading to these discrepancies in scattering matrices. And Gaussian spheres may be promising models for simulating scattering matrix for Chinese loess dust, but more detailed quantitative verifications using measured size distributions and refractive indices are still needed. (3) The previously published average scattering matrix for loess dust was updated using measurements of new coarse loess sample, which is meaningful for validating existing models and developing more advanced models suitable for optical simulations of loess dust, and finally helps to retrieve dust aerosol properties with higher accuracy over both source and downwind areas.

We have modified and added related descriptions in Abstract and Conclusions in the revised manuscript to make the conclusions of our study more clear:

"Experimental results showed that there are obvious discrepancies in angular behaviours of matrix elements for "pristine loess" and "milled loess", and these discrepancies are different from that for other kinds of dust with distinct size distributions. Given that the effective radii of these two loess samples differ by more than 20 times, it is reasonable to conclude that the difference in size distributions plays a major role in leading to different matrices, while differences in refractive index and micro structure have relatively small contributions. Qualitative analyses of numerical simulation results of irregular particles also validate this conclusion. Gaussian spheres may be promising morphological models for simulating scattering matrix of loess but need further quantitative verification. At last, synthetic scattering matrices for both "pristine loess" and "milled loess" were constructed over 0 °-180 °, and the previous average scattering matrix for loess dust was updated. This study presents measurement results of Chinese loess dust and updated average scattering matrix for loess, which are useful for validating existing models and developing more advanced models for optical simulations of loess dust and finally help to improve retrieval accuracy of dust aerosol properties over both source and downwind areas."

"These discrepancies are unique and different from that for other kinds of dust with distinct size distributions published in literatures. Qualitative analyses of optical simulations of various morphological model showed that the large difference in size distributions (effective radii differ by more than 20 times) caused by milling process plays a major role in leading to discrepancies in scattering matrices for these two samples, while differences in factors such as refractive index and micro structure have relatively small and recessive contributions. And Gaussian sphere models may have good application prospect in optical modeling of loess dust, while more detailed quantitative verification using measured physical properties are still needed.”

“Synthetic scattering matrices for both “pristine loess” and “milled loess” were defined over 0°-180° scattering angle, and the previously presented average scattering matrix for loess was updated with new coarse “pristine loess” sample included. The phase function $F_{11}(\theta)$ in updated average matrix has larger forward scattering peaks and smaller values at side and backward scattering angles than that in previous average matrix. Compared to previous average matrix, updated average matrix has larger $-F_{12}(\theta)/F_{11}(\theta)$ at side scattering angles, has smaller $F_{33}(\theta)/F_{11}(\theta)$ and $F_{44}(\theta)/F_{11}(\theta)$ at backscattering angles. $F_{22}(\theta)/F_{11}(\theta)$ experiences the largest change before and after update, whose values are enlarged at almost all scattering angles.”

“In this study, scattering matrices for Chinese loess samples with large difference in their size distributions are investigated. Based on all the measurements, suitable shape distributions of spheroids can be obtained respectively, which are useful for the retrievals of airborne loess dust properties at both source and downwind areas in China or even East Asia. On the other hand, the updated average scattering matrix for loess are meaningful for the validation of exiting models and the development of more advanced morphological models suitable for loess dust, which are also useful to finally improve the retrieval accuracies of dust aerosol properties.”

Specific comments:

- page 2, line 34-35: Please rephrase "It is common knowledge that ...". Literature that proves the statement is provided in the next paragraph, so there is no need to rely on "common knowledge".

Response:

Thank you for the suggestions. We have modified the related descriptions in the revised manuscript:

“Dust particles with different sizes can be transported over different distances, more specifically, dust particles with a size range of $r > 5$ μm exist in source areas only, while particles with a size range of $0.1 < r < 5$ μm can experience airborne transportation over long distances (like about 5000 km), even cross-continent from Asia to North America (Jaffe et al., 1999; Satheesh and Moorthy, 2005).”

- page 2, line 38 it should be "...CLP is expected to have important influence" instead of "...CLP will have important influence", as the statement is not proven.

Response:

Thanks for your comments. We have modified this description accordingly in the revised manuscript:

"Therefore, loess dust emitted from CLP is expected to have important influence on the radiation balance at both source areas and places far away from sources."

- page 2 and 3, literature values for scattering matrix: Please elaborate on what the scattering matrix tells us, which properties do Fij and their quotients describe? Explain either here or in section 3.1.

Response:

Thank you for the constructive comments. Scattering matrix elements describe the depolarization or transformation of incident light with several polarization states under the influences of particles. Accordingly, we have added descriptions of matrix elements in Introduction and Section 3.1 in the revised manuscript:

"Light scattering matrix $\boldsymbol{F}$, a 4×4 matrix containing 16 elements F_{ij} (i, j=1-4), is a fundamental optical property to characterize airborne dust particles, and describes the depolarization or transformation of incident light with several polarization states under the influences of particles (Quinby-Hurt et al., 2000; Volten et al., 2001)."

"Matrix elements describe the depolarization or transformation of incident light with several polarization state under the influence of particles (Quinby-Hurt et al., 2000). F_{11} describes transformation of incident light intensity; F_{12} describes depolarization of 0° and 90° linearly polarized light relative to scattering plane; F_{22} describes transformation of ±90° polarized incident light to ±90° polarized scattered light and it equals to F_{11} for spherical particles; F_{33} and F_{44} describe transformation of ±45° linearly (or circularly) polarized incident light to ±45° linearly (or circularly) polarized scattered light and these two elements are equal for spherical particles; F_{34} describes transformation of circularly polarized incident light to ±45° linearly polarized scattered light. Almost all these matrix elements are sensitive to physical properties of particles, including size distribution, particle shape, micro structure and refractive index."

- page 4, line 120: SEM "images", instead of "photographs", as this is an imaging technique detecting electrons, not photons.

Response:

Thank you for pointing this out. We have modified this description in the revised manuscript:

"Scanning electron microscope (SEM) images for "pristine loess" (left panel) and "milled loess" (right panel) are displayed in Figure 2."

- Table 2 and paragraph 1 on page 5: Are the differences in the sample composition significant? What are the errors on this analysis?

Response:

Thanks for your valuable comments. We added repeat measurements of chemical compositions of each loess sample. Then, the weight percentage of each composition was averaged from three measurements, and Table 2 has been updated using averaged values and measurement errors of components. Actually, the composition differences between these two loess samples are very small. We have modified related descriptions in the revised manuscript:

"As can be seen in Table 2, the largest change of content occurs for SiO_2, but this change is less than 2.5 % and even smaller than the errors between repeat measurements for "pristine loess" sample, and the change of ZrO_2 is only about 0.03 %. It can be concluded that the composition differences between these two samples are very small, and milling process has little effect on chemical compositions for loess samples."

"**Table 2.** Chemical components of "pristine loess" and "milled loess" measured by XRF-1800."

Components	Pristine loess (wt %)	Pristine loess error (wt %)	Milled loess (wt %)	Milled loess error (wt %)
SiO_2	63.8278	3.0237	66.2128	2.0900
Al_2O_3	12.3091	0.3772	11.6487	0.2018
CaO	9.2943	0.9455	7.8286	0.6450
Fe_2O_3	5.5260	0.8817	5.6390	0.7411
K_2O	3.3971	0.3004	3.3574	0.2358
MgO	2.7536	0.4522	2.4843	0.2665
Na_2O	1.2802	0.0243	1.3470	0.0214
TiO_2	0.8017	0.0595	0.7939	0.0579
P_2O_5	0.3340	0.0452	0.2549	0.0018
SO_3	0.2370	0.1056	0.1687	0.0721
MnO	0.1240	0.0294	0.1196	0.0120
ZrO_2	0.0583	0.0104	0.0846	0.0122
SrO	0.0348	0.0064	0.0299	0.0059
Rb_2O	0.0177	0.0041	0.0174	0.0040
Co_2O_3	NT*	-	0.0159	0.0049
Y_2O_3	NT*	-	0.0061	0.0025

- page 6, section 3.2: Add some more detail of how the analysis was done. How many measurement iterations were performed, how are the final results derived from these?

Response:

Thank you very much for the comments. As mentioned in the first paragraph of Section 4.1, three independent measurements were conducted for each loess sample, and averaged results and their errors are obtained and shown in figures. In addition, we have added more details about measurements and data processing in the revised manuscript:

“All the matrix elements of dust samples can be determined as functions of scattering angles with the help of various combinations of orientation angles of above optical elements as shown in Table 3, which is just the same as Muñoz et al. (2010).”

“**Table 3.** Combinations of orientation angles of optical axis of all the optical elements.”

Combination	γ_P	γ_{EOM}	γ_Q	γ_A	$DC(\theta)$	$S(\theta)$	$C(\theta)$
1	45 °	0 °	-	-	$F_{11}(\theta)$	$-F_{14}(\theta)$	$F_{13}(\theta)$
2	45 °	0 °	-	0 °	$F_{11}(\theta)+F_{21}(\theta)$	$-F_{14}(\theta)-F_{24}(\theta)$	$F_{13}(\theta)+F_{23}(\theta)$
3	45 °	0 °	-	45 °	$F_{11}(\theta)+F_{31}(\theta)$	$-F_{14}(\theta)-F_{34}(\theta)$	$F_{13}(\theta)+F_{33}(\theta)$
4	45 °	0 °	0 °	45 °	$F_{11}(\theta)+F_{41}(\theta)$	$-F_{14}(\theta)-F_{44}(\theta)$	$F_{13}(\theta)+F_{43}(\theta)$
5	90 °	-45 °	-	-	$F_{11}(\theta)$	$F_{14}(\theta)$	$-F_{12}(\theta)$
6	90 °	-45 °	-	0	$F_{11}(\theta)+F_{21}(\theta)$	$F_{14}(\theta)+F_{24}(\theta)$	$-F_{12}(\theta)-F_{22}(\theta)$
7	90 °	-45 °	-	45 °	$F_{11}(\theta)+F_{31}(\theta)$	$F_{14}(\theta)+F_{34}(\theta)$	$-F_{12}(\theta)-F_{32}(\theta)$
8	90 °	-45 °	0 °	45 °	$F_{11}(\theta)+F_{41}(\theta)$	$F_{14}(\theta)+F_{44}(\theta)$	$-F_{12}(\theta)-F_{42}(\theta)$

“Multiple groups of values of measurable quantities, that is the DC component $DC(\theta)$, first harmonics $S(\theta)$ and second harmonics $C(\theta)$ of voltage signal, are recorded at every scattering angle for each combination of optical elements. The first step of data processing is to average these recorded values and get their errors. The optical platform is surrounded by black curtains to avoid the effect of environmental stray light, and background signals need to be measured and subtracted. Fluctuations of dust aerosols can be eliminated by normalizing measurements of the “detector” using $DC(30°)$ measured by the “monitor”. Scattering matrix elements can be extracted from preprocessed $DC(\theta)$, $S(\theta)$ and $C(\theta)$ according to Table 3. Subsequently, $F_{11}(\theta)$ is normalized to 1 at 10 ° scattering angle, and the remaining matrix elements $F_{ij}(\theta)$ are normalized to $F_{11}(\theta)$ at the same angle. At last, whether measurement results of scattering matrix satisfy Cloude coherency matrix test should be examined (Hovenier and Van Der Mee, 1996). Three iterations of measurements are performed for each particle sample, the final results are average of three groups of experiments, and the errors are also calculated which contain errors during every measurement and errors for repeat measurements. Furthermore, the improved apparatus is validated using water droplets. Measured all six non-zero scattering matrix elements for water droplets can be well fitted using Mie calculation results, indicating that the measurement accuracy of apparatus are satisfactory. For more details about the measurement principle and validation method of the apparatus, it can be referred to Liu et al. (2018)."

- page 7, section 4.1: Similar as in the introduction, it should be discussed what the physical meaning of the results are. This is partly attempted in line 199, but should be done more thoroughly.

Response:

Thanks for your comments. To our best knowledge, there are very limited direct implications of scattering matrix elements on particle properties, because optical simulation results showed that these matrix elements are sensitive to almost all physical properties of irregular particles, like micro structure, size distribution and refractive index (Liu et al., 2015; Muinonen et al., 2007; Zubko et al., 2007). Only $F_{22}(\theta)$ equals to 1 as well as $F_{33}(\theta)$ equals to $F_{44}(\theta)$ directly imply that particles are spherical.

- page 8, lines 216-217 Please add the units of the parameters.

Response:

Thank you very much for the comments. According to Equation (1) in the manuscript, the unit of effective radius r_{eff} is μm. Refractive index is expressed as $m=n+ki$, i is imaginary unit, n and k are real and imaginary part of refractive index respectively, and both of the two parameters are dimensionless. We have made necessary modifications in the revised manuscript:

"As shown in Table 1, effective radii for "pristine loess" and "milled loess" are 49.40 μm and 2.35 μm, respectively. The real part of refractive index for "pristine loess" is 1.65 and that for "milled loess" is 1.70."

- page 8, lines 235-240 The description is rather vague, please make it clear you're your actual finding is.

Response:

Thank you for your valuable comments. We have modified and re-organized the related descriptions in the revised manuscript:

"In summary, different factors have different or similar effects on a certain matrix elements. The discrepancies in scattering matrices for "milled loess" and "pristine loess" can be mainly interpreted from the perspective of difference of effective radii, while differences in other factors such as refractive index and micro structure have relatively small contributions, and Gaussian spheres may be promising models for simulating scattering matrix for loess dust.”

- page 10, line 302: As in page 2, line 38: Rather write "is expected to affect" or similar instead of "will affect".

Response:

Thank you for the suggestions. We have modified the description in the revised manuscript:

“Loess dust aerosols originated from CLP are expected to affect the radiation balance potentially at both source areas and downwind places far away from sources, because dust particles with different sizes can be transported over different distances.”

- page 11, paragraph 2: Please make it more clear what the scattering matrices tells us. This section is now more a summary than a conclusion.

Response:

Thanks a lot for your valuable comments. We have re-organized the related descriptions in the revised manuscript to make conclusions of this study more clear:

“Even through experimentally determined angular behaviors of scattering matrix elements for “pristine loess” and “milled loess” are similar, there are still obvious discrepancies in matrix elements. More specifically, for small “milled loess”, relative phase function $F_{11}(\theta)/\ F_{11}(10^\circ)$ as well as ratios $-F_{12}(\theta)/F_{11}(\theta)$ and $F_{22}(\theta)/F_{11}(\theta)$ are smaller than that for coarse “pristine loess”, while ratios $F_{33}(\theta)/F_{11}(\theta)$, $F_{34}(\theta)/F_{11}(\theta)$ and $F_{44}(\theta)/F_{11}(\theta)$ are larger than that for coarse “pristine loess”. These discrepancies are unique and different from that for other kinds of dust with distinct size distributions published in literatures. Qualitative analyses of optical simulations of various morphological model showed that the large difference in size distributions (effective radii differ by more than 20 times) caused by milling process plays a major role in leading to discrepancies in scattering matrices for these two samples, while differences in factors such as refractive index and micro structure have relatively small and recessive contributions. And Gaussian sphere models may have good application prospect in optical modeling of loess dust, while more detailed quantitative verification using measured physical properties are still needed.”

“Synthetic scattering matrices for both “pristine loess” and “milled loess” were defined over 0°-180° scattering angle, and the previously presented average scattering matrix for loess was updated with new coarse “pristine loess” sample included. The phase function $F_{11}(\theta)$ in updated average matrix has larger forward scattering peaks and smaller values at side and backward scattering angles than that in previous average matrix. Compared to previous average matrix, updated average matrix has larger -

$F_{12}(\theta)/F_{11}(\theta)$ at side scattering angles, has smaller $F_{33}(\theta)/F_{11}(\theta)$ and $F_{44}(\theta)/F_{11}(\theta)$ at backscattering angles. $F_{22}(\theta)/F_{11}(\theta)$ experiences the largest change before and after update, whose values are enlarged at almost all scattering angles."

"In this study, scattering matrices for Chinese loess samples with large difference in their size distributions are investigated. Based on all the measurements, suitable shape distributions of spheroids can be obtained respectively, which are useful for the retrievals of airborne loess dust properties at both source and downwind areas in China or even East Asia. On the other hand, the updated average scattering matrix for loess are meaningful for the validation of exiting models and the development of more advanced morphological models suitable for loess dust, which are also useful to finally improve the retrieval accuracies of dust aerosol properties."

- page 11, line 323: Data availability: You uploaded the data, which is great, this should be linked here.

Response:

Thank you for this suggestion. During the revision of the manuscript, we re-measured scattering matrices for the two loess samples over angles from 5° to 175° using an improved apparatus (the previous apparatus can only cover 5-160°). Newly measured scattering matrices were in good agreement with measurement results using the previous apparatus in the range of 5-160°. The extension of scattering angles made the polynomial extrapolation of matrix elements $F_{11}(\theta)/F_{11}(10°)$ and $F_{22}(\theta)/F_{11}(\theta)$ at backscattering angles more rigorous when constructing synthetic matrix, and calculated backscattering depolarization ratios were also more reliable. Accordingly, we re-uploaded measured results to a new dataset. We have attached the link of new dataset in the revised manuscript:

"All the data involved in this study are available online at: https://github.com/liujia93/Scattering-matrix-for-loess-dust."

- Table 1: Add units.

Response:

Thank you for the comments. As mentioned above, the unit of effective radius r_{eff} is µm, real part n and imaginary part k of refractive index are dimensionless. According to Equation (2), the effective standard deviation σ_{eff} is dimensionless. In addition, since the effective size parameter x_{eff} is defined as $x_{eff}=2\pi r_{eff}/\lambda$, this parameter is also dimensionless and has no units.

- Abstract and Conclusions: Please add: What do the results of that study actually tell us about light scattering by Chinese loess in one sentence?

Response:

Thanks a lot for your valuable comments. As can be seen from the Response to the last General Comments, we summarized three major results and conclusions of our study. It is hard to describe the conclusions using just one sentences, but we have modified related descriptions in Abstract and Conclusions in the revised manuscript.

"Experimental results showed that there are obvious discrepancies in angular behaviours of matrix elements for "pristine loess" and "milled loess", and these discrepancies are different from that for other kinds of dust with distinct size distributions. Given that the effective radii of these two loess samples differ by more than 20 times, it is reasonable to conclude that the difference in size distributions plays a major role in leading to different matrices, while differences in refractive index and micro structure have relatively small contributions. Qualitative analyses of numerical simulation results of irregular particles also validate this conclusion. Gaussian spheres may be promising morphological models for simulating scattering matrix of loess but need further quantitative verification."

"This study presents measurement results of Chinese loess dust and updated average scattering matrix for loess, which are useful for validating existing models and developing more advanced models for optical simulations of loess dust and finally help to improve retrieval accuracy of dust aerosol properties over both source and downwind areas."

"Even through experimentally determined angular behaviors of scattering matrix elements for "pristine loess" and "milled loess" are similar, there are still obvious discrepancies in matrix elements. More specifically, for small "milled loess", relative phase function $F_{11}(\theta)/F_{11}(10°)$ as well as ratios $-F_{12}(\theta)/F_{11}(\theta)$ and $F_{22}(\theta)/F_{11}(\theta)$ are smaller than that for coarse "pristine loess", while ratios $F_{33}(\theta)/F_{11}(\theta)$, $F_{34}(\theta)/F_{11}(\theta)$ and $F_{44}(\theta)/F_{11}(\theta)$ are larger than that for coarse "pristine loess". These discrepancies are unique and different from that for other kinds of dust with distinct size distributions published in literatures. Qualitative analyses of optical simulations of various morphological model showed that the large difference in size distributions (effective radii differ by more than 20 times) caused by milling process plays a major role in leading to discrepancies in scattering matrices for these two samples, while differences in factors such as refractive index and micro structure have relatively small and recessive contributions. And Gaussian sphere models may have good application prospect in optical modeling of loess dust, while more detailed quantitative verification using measured physical properties are still needed."

References

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