Replies to the comments from anonymous referee #2

First of all, we would like to thank the reviewer for their thorough revision of our manuscript. All the comments and insight are very much appreciated. We have copied their comments into this document; their comments are in Times New Roman blue font while our answers are in Calibri black font. Line numbers refer to the version of the manuscript with track changes.

The authors present a study describing the implementation of dust mineralogy in COSMO5.05-MUSCAT regional model. The results are compared with lidar, satellite, AERONET measurements and dust composition data from literature. This study is particularly relevant because there aren't many models that consider the dust mineralogy. I have a concern with respect to methodology and a few other points that should be addressed before publication:

1. In the abstract, introduction and conclusion, the authors wrote that this study is the first implementation of explicit representation of dust mineralogy in regional model. However, there is at least one older reference (Menut et al., 2020) dealing with this topic in regional model. Please add the reference.

   Thank you for the clarification. We have changed that and added another addition of mineralogy in a regional model: Solomos et al., 2023

   Solomos, S., Spyrou, C., Barreto, A., Rodríguez, S., González, Y., Neophytou, M. K. A., Mouzourides, P., Bartsotas, N. S., Kalogeri, C., Nickovic, S., Vukovic Vimic, A., Vujadinovic Mandic, M., Pejanovic, G., Cvetkovic, B., Amiridis, V., Sykioti, O., Gkikas, A., and Zerefos, C.: The Development of METAL-WRF Regional Model for the Description of Dust Mineralogy in the Atmosphere, Atmosphere, 14, 1615, https://doi.org/10.3390/atmos14111615, 2023.

2. Even if the simulations are compared with measurements and show relatively good results, how to know if the total amount of dust is conserved with mineralogy and with no mineralogy description? Is it possible to add a reference simulation with no mineralogy to estimate the potential benefit of this development?

   Fig.1 illustrates an example that showcases how the total amount of dust (black line) is closely related to the the sum of all the minerals (green line). We expect sometimes to have less mineral mass than total dust mass due to the lack of mineral information in some regions. Furthermore, we consider that the method itself shows how the mass

conservation of dust is ensured. Therefore, we do not consider it necessary to include a reference simulation with no mineralogy.

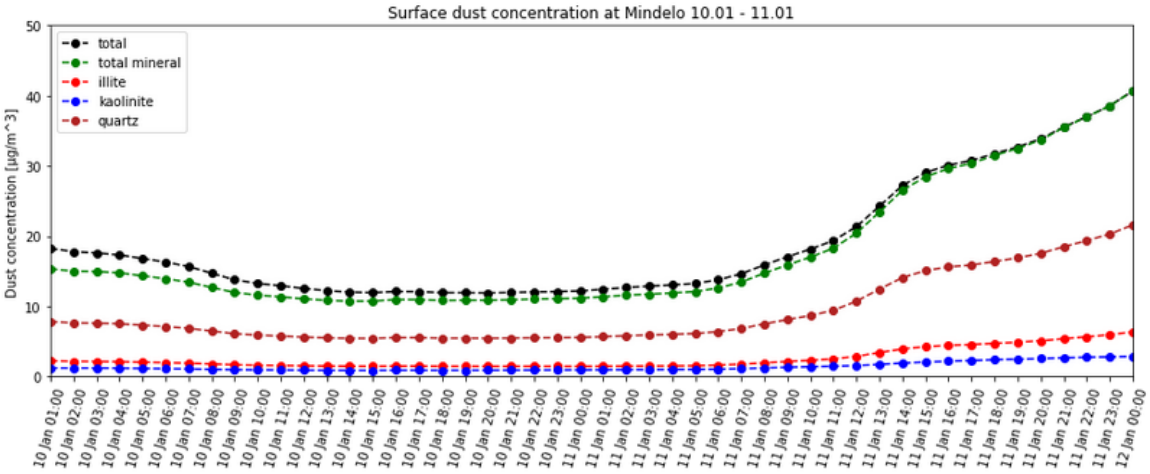

Figure 1. Surface dust mass concentration at Mindelo, Cabo Verde grid cell for 10 January 01:00 UTC – 12 January 00:00 UTC 2022. Black curve represents the total dust mass concentration, green curve represents the sum of each mineral mass concentration. The other curves show some examples of selected minerals mass concentrations where brick red curve represents the quartz mass concentration, red curve represents illite mass concentration and blue curve shows kaolinite mass concentration.

3. I do not understand why you could consider the same relative part of silt and clay from the soil to the aerosol. There is a lot of literature available to take into account the relative part of clay and silt from soil to aerosol (eg: Scanza et al., 2015 simplified in Menut et al., 2020, Gonçalves Ageitos et al., 2023…)

We have answered a similar concern on our reply to anonymous referee #1, please refer to our answer to the first comment. Furthermore, we have made changes in order to clarify and justify our decision throughout the "2.1 Mineralogy Implementation" section, where major changes can be read at L211-225.

4. In the Methodology you discuss model configuration and emissions, but you don't mention deposition processes? How are minerals deposited?

The deposition processes are mentioned in L120 – 123.

5. Finally, you used the same density for each mineral and you used a fixed composition to calculate $Q_{ext,\ 500nm}$ for each size class. How far is this fixed composition from the simulated one? Can you explain why do you choose to do that? It would seem relatively easy to run sensitivity tests taking into account the simulated composition range.

Thank you for your recommendation. We would like to consider the changes on the $Q_{ext,550nm}$ parameter due to changes in composition, and to implement such changes in the model's radiation scheme. We consider that such a study is not trivial since the mineral specific optical properties found in literature vary in significant ways (Go et al., 2022). Furthermore, such an addition to our study is outside the scope of this

manuscript, where we focus on the addition of the mineral soil map to the emission scheme. The impact of mineral dust compositional changes in the atmospheric radiation balance is definitely a project we are interested in pursuing.

Go, S., Lyapustin, A., Schuster, G. L., Choi, M., Ginoux, P., Chin, M., Kalashnikova, O., Dubovik, O., Kim, J., da Silva, A., Holben, B., and Reid, J. S.: Inferring iron-oxide species content in atmospheric mineral dust from DSCOVR EPIC observations, Atmos. Chem. Phys., 22, 1395–1423, https://doi.org/10.5194/acp-22-1395-2022, 2022.

6. For the validation, you used only 5 AERONET stations. In fact there are more in your simulation area. Why don't you use all available data? How do you choose your stations? Can you plot the Ångström coefficient to be sure they're mostly dust?

We chose the AERONET stations that are on the dust path towards the Atlantic Ocean and that were actively measuring and provided cloud-screened data (level 1.5 or 2.0) for the studied period (Jan-Feb 2022). We appreciate the suggestion of adding the Ångström Exponent and we have consequently added it.

7. The validation is almost complete (lidar, satellite, AERONET measurements and dust composition from literature). Only mass concentration at the ground is not use. It could be interesting to use INDAAF data (https://indaaf.obs-mip.fr/catalogue) to compare your simulation with the PM_{10}

Even though we appreciate the comment and the idea of validation with INDAAF data, we consider it at the moment, outside the scope of the study, since we would want to focus on the mineralogical validation. We consider that the confirmation of COSMO-MUSCAT's ability of representing dust atmospheric life cycle is well covered with the cases presented.

8. What is the cost in computation time of implementing this level of detail?

The implementation of minerals in MUSCAT creates 60 additional tracers from which emission and transport is calculated. This addition results in an increase of roughly 10 times of the computational time used for these two processes. In total, the mineral implementation translates into an increment of computational time for the whole model system, COSMO-MUSCAT, of 67%.

9. Can the mineralogy representation be used with activated chemistry? Are there any impacts of this representation on heterogeneous reaction?

COSMO-MUSCAT current state cannot consider mineral dust as a chemically active aerosol. We could hypothesize that if it was allowed to interact in heterogeneous reactions that this would impact its optical properties, nevertheless, this is not being considered as part of the project for the time being, even though the concept is really interesting and we will revisit it again for future works.