

## Reply from Authors on:

### Interactive comment on “Technical Note: Minerals in dust productive soils – impacts and global distribution” by S. Nickovic et al.

#### From “K. Kandler - Referee#2”

We thank to the Referee#2 for the review and suggestions for improving the quality of the paper. Below are our responses to the questions raised.

**Reviewer:** First, by common sense it can be seriously doubted that top soil measurements are available on a grid of 50 km across the desert regions. Particularly, the soil investigations available mainly rely on single samples taken from a vast area. Thus, many areas of this map must rely on averaging or interpolation. I suggest to add some comments to this point.

**Response:** We are aware that there is no dense network of soil sampling in desert regions and the gap in such measurements limits the accuracy of mineralogy databases. We however believe that by combining the existing data on minerals with other relevant data (soil types, land cover), and mapping the mineral fractions into a high-resolution grid a value is an added value to the existing geographical mineralogy distribution. We developed the database on 30sec (~1km) grid so to be compatible with other databases (topography, soil texture, land cover) frequently used in atmospheric modelling. The high-resolution structure of the database permits its use in both high-resolution regional models downscaled horizontally up to several kilometers, and in coarser global models as well.

To better clarify the requested Referee's comment, we made the following changes in the article text:

- At the end of Introduction we added the sentence: *Database is applicable for both global and regional scale atmospheric dust models.*
- Furthermore, at 26020,19 we added: *The database contains a mean global distribution of soil mineral composition appropriate for implementation in models for global and regional studies. Introducing information on dust mineral composition obtained from the database, in spite of large uncertainties originating from scarce soil sampling is expected to provide additional information for better understanding of the atmospheric dust processes.*

**Reviewer:** Second, for example Bristow et al. (2010, doi: 10.1029/2010GL043486) have shown that even on scales as small as 2 km (inside the Bodélé depression) there is a very high variation in soil composition. This is largely beyond that what the soil classification used here can resolve. So, a single value of soil composition has to represent an area of 50km x 50km, which can be either an average composition of the soils inside or the modal one or whatever. But it can be assumed that dust emission favors particular soil types, due to their texture, humidity, location, composition. So, this single value is not necessarily representative for the actual dust emission. Please comment on that (in the paper).

**Response:** We agree with the Reviewer that even the structure of our database named “high resolution” is far from representing real variability of minerals. The variability of this kind is however a common feature of other geospatial data as well, such as land cover, topography, soil types, etc. Although more detailed geospatial information is today available, such data could hardly resolve all real details of such fields. In practice, a mineral fraction is described with a single value in a database grid point. The same approach is used for all other surface geospatial parameters defining lower boundary conditions in the atmospheric models. In atmospheric dust models (having typically

coarser resolutions than a database), a single value is specified for a model grid box by interpolating or averaging the values of the database falling into a grid box.

### **Reply to specific comments:**

**Reviewer26017/26:** Where do we know that from?

**Response:** The question relates to why soil types presented in Fig. 1 are assumed as dust productive. The answer is given in the first paragraph of the 3.1 Section: dust productive soils are determined by overlapping FAO soils and selected land use categories related to arid soils.

**Reviewer26018/11-12:** Though the higher chemical reactivity due to surface roughness sounds plausible - is there any reference for that?

**Response:** We added the reference that confirms that: Norrish and Pickering (1983).

**Reviewer26018/15:** Actually, carbonates themselves are not exactly highly soluble, if we are speaking of water, but they are the most reactive ones of the common mineral dust in an acidic environment. Please correct this paragraph accordingly.

**Response:** We made a correction in the corresponding paragraph: "Carbonates were considered in Claquin et al. (1999) because of their important role in direct and indirect effects to the solar radiation. They have a low infrared absorption between 8 and 12  $\mu\text{m}$ . Carbonates are not highly soluble in water, but they are most reactive ones of common mineral dust in an acidic environment, making the carbonates-carrying aerosol favorable to influence the precipitation acidity, to act as cloud condensation nuclei and therefore to contribute to indirect radiation effects."

**Reviewer26018/23:** But the Bodélé depression is not particularly rich in gypsum, according to Fig. 4h.

**Response:** Referee's comment relates to : "*Gypsum originates mainly from (paleo-) lacustrine sources and has moderate absorption in the infrared spectrum.*" The importance of lacustrine sources for dust emission was emphasized by Tegen et al. (2002) and in their study lacustrine sources are introduced as a separate soil texture class. For example, the Bodélé depression, one of the largest worldwide dust source consists of fine lacustrine sediments deposited by paleo lake Chad in the Holocene. Tegen et al states that gypsum is mainly existing in lacustrine sediments typical for the Bodele depression, To avoid confusion we decided to remove the following sentence from the paper:

*"For example, the Bodélé depression, one of the largest worldwide dust source consists of fine lacustrine sediments deposited by paleo lake Chad in the Holocene."*

**Reviewer26018/27:** I do not think that this is a good idea, as hematite and goethite (or other iron oxide/hydroxide compounds, which are often not very well distinguished) do have different spectral behavior. If the information on iron speciation is available, I would suggest keeping it as long as possible.

**Response:** Since we did not have additional data on hematite and goethite as separate fractions, we keep them together under the name of hematite, as was originally done by Claquin et al. (1999).

**Reviewer26019/29:** The phosphorus solubility is also depending on atmospheric processing (Nenes et al 2011, doi: 10.5194/acp-11-6265-2011) and in general the P cycle is not well

understood (Okin et al. 2011, doi: 10.1029/2010GB003858), so I would suggest not giving a number here would be more favorable.

**Response:** Accepted; we changed the corresponding sentence as: “Although only small part of phosphorus in mineral dust aerosol is bioavailable (Jickells and Spokes, 2001; Mahowald et al., 2005), it may play an important role in biological response of the marine ecosystem when dust is deposited into the ocean”.

**Reviewer26020/9-10:** I understand that there is not more data available, but I have serious doubts whether this is close to reality. Trace contributors to soils like P most probably depend on traces in the geological basement, but soils are a product of basement and climate, so at least a very large uncertainty with respect to the P content should be given as a caveat here.

**Response:** In the absence of more detailed sampling data for P, we followed the approach of Okin et al. (2004) to downscale spatial distribution of P over arid areas. We therefore changed sentence as: “In the absence of more detailed information, we assumed that all soil types that belong to the same group have the same phosphorus content. The obtained results are given in percentages equal for both clay and silt populations.”

**Reviewer26020/20:** Up to here the paper is on soil composition, but now this soil composition is set equal to an atmospheric dust composition. However, the transfer function from soil composition to dust composition is not unity (e. g., Eltayeb et al. 2001, doi: 10.1023/A:1012272208129). In a work like that, I would expect at least some comments on this to aid the user in identifying potential uncertainties.

**Response:** We have added a sentence to identify potential uncertainties as required by the Reviewer: “The quantification of minerals in aerosol samples is not easy, mainly because of the very small sample masses involved. Some authors have therefore assumed that the aerosol mineral content is the same as in source soils (Claquin et al., 1999). Furthermore, Caquineau et al. (1998) have shown that the relative proportions of clay minerals in the aerosol are close to those of the parent soils and are conservative during transport; the same argumentation was exploited by Lafon (2004)”.

The corresponded references added in the reference list are:

Caquineau, S., Gaudichet, A., Gomes, L., Magonthier, M.-C., Chatenet, B., 1998. Saharan dust: clay ratio as a relevant tracer to assess the origin of soil-derived aerosols. *Geophysical Research Letters* 25 (7), 983–986.

Lafon, S., J.L. Rajot, S.C. Alfaro, and A. Gaudichet, 2004, Quantification of iron oxides in desert aerosol. *Atmospheric Environment* 38, 1211–1218.

**Reviewer26030/Table 1:** Please distinguish carefully between “fractions of clay minerals” (i. e. relative amount of minerals in the clays group) and “clay fraction” (particles with sizes smaller than 2  $\mu\text{m}$ ). I suggest - to improve uniqueness - to print explicitly “clay size fraction”, if the particle size is referred. Same applies to “fraction of silt”.

**Response:** Accepted. Titles in Table 1 are changed to: “Table 1. Mineral content in clay and silt size fraction in selected soil types. Mineral content in clay size fraction normalized to 100% Mineral content in silt size fraction normalized to 100%”. As also suggested, we improved uniqueness in the paper by introducing “clay size fraction” and “silt size fraction” wherever appropriate in the text.

**Reviewer26030/**Table 1: Some of these compositions are very similar. I understand that these numbers represent an ideal composition of a particular soil or a composition that represents and average over several samples of that soil. But how variable can be the composition of a single soil type? This would be particularly interesting, when addressing iron and phosphorus contents, which have been most probably not of primary concern when these soil classes have been established.

**Response:** We are aware that there is large variability of mineral fractions given in Table1. Claquin et al. report that standard deviations of a mineral content range between 27 and 33% of the average observed value. A corresponding sentence is added in the article text.

**Reviewer26030/**Table 1: This table implies that clay minerals like kaolinite, illite are never present in grain sizes larger than 2  $\mu\text{m}$ , and that feldspar and gypsum are never present in sub 2  $\mu\text{m}$  particles. This is certainly not true (e. g., Leinen et al. 1994, doi: 10.1029/94JD01735; Reid et al. 2003, 10.1029/2002JD002935; Kandler et al. 2007, 10.1016/j.atmosenv.2007.06.047), but relies on the definition of “clay mineral size fraction” as an a priori assumption. However, for the representation of the true composition, this might introduce a significant error, and should be addressed here. At least, it should be mentioned that this clearcut composition change is artificial.

**Response:** Following the Reviewer’s suggestion, we have added in the text (26017/5) a sentence: “However, the value of 2  $\mu\text{m}$  which delineates sizes between clay and silt minerals is arbitrary and used here as a first order approximation. “

**Reviewer26034:** This map is in my opinion quite misleading. Looking at the map, I would assume that most of the dust consists of quartz and feldspars. Though this is probably true for the soils, the question of applicability to airborne dust arises again, as that contains considerable amounts of clay minerals. Instead, I would suggest displaying the maps separately for the silt size fraction and the clay size fraction.

**Response:** In dust modelling applications, effective percentage of a mineral for a given soil population (clay or silt) is calculated by multiplying fractions of a mineral and a soil population. The mineralogical database actually contains fractions of minerals separately for clay and silt populations, permitting so users to use their own data on clay and silt. To reduce the number of shown maps in the article, we showed the effective percentages of minerals calculated using the hybrid STATSGO-FAO silt/clay fractions. Following the referee suggestion, we will try to provide as well the maps separately for the silt size fraction and the clay size fraction, as a supplementary material following journal rules for supplementary material submission, or we will provide this figures on download web page of database.

**Reviewer:** Also, there are very large phosphorus deposits in NW Africa (Morocco), which are even mined. But the map doesn’t show anything of it, so the relevance of the phosphorus concentrations estimated by that database should be addressed critically.

**Response:** Like in the approach we used for generating other components of the database, in case of P we have also calculated its fractions using the published evidence on P spatial distribution (Okin et al, 2004) combined with the gridded data on soil types and land cover. Although our approach has limitations resulting from the lack of enough sampling data, we still believe that information on P has a value for modelling research.

**Referee also made following corrections:**

**Reviewer26010/5:** are represented?

**Response:** Changed

**Reviewer26010/6:** determined?

**Response:** Changed.

**Reviewer26012/19:** It should be mentioned that “clay and silt” refer to particle size here, not to composition.

**Response:** changed

**Reviewer26014/6:** “In the ice nucleation process”

**Response** Changed.

**Reviewer26014/12:** “of dust”?

**Response:** Changed.

**Reviewer26015/1:** Though I like the expression “global warming”, it should be “warming”

**Response:** Changed.

**Reviewer26015/4:** cruise

**Response:** Changed.

**Reviewer26017/4:** Isn't the process of lifting a little bit more complex? Though it is not scope of this paper, the reader might be misled by this notion.

**Response:** To avoid misleading we have replaced “Soil fractions that contain fine particles (silt and clay with particle size less than 0.002mm and between 0.002 and 0.05 mm, respectively, according to USDA Soil Texture Classification system) are easily lifted from the Earth surface...”, with “...are lifted from the Earth surface in the complex process of the wind erosion (e.g. Tegen et al., 2002) ...”

**Reviewer26018/1:** Please refer correctly, that this list contains a mixture of mineral names (calcite, gypsum) and mineral group names (feldspars, smectite)

**Response:** Following the suggestion, we removed from the sentence “eight minerals”, and changed the sentence to: Following Claquin et al. (1999), we selected quartz, feldspars, illite, kaolinite, smectite, calcite, gypsum and hematite, for which fractions will be specified for different soil types.

**Reviewer26019/26:** food production → nutrient supply

**Response:** Changed.

**Reviewer26021/16:** “Not all of the area covered by . . . is necessarily dust-productive”

**Response:** Sentence changed to: Not all of the area covered by GMINER30 and in Figs. 3 and 4 is necessarily dust productive.

**Reviewer26030/heading** “slit” → “silt”, “gypsium” → “gypsum”

**Response:** Changed.

**Reviewer26033:** The Xerosols can't really be identified in the map due to their black color. Please use another color

**Response:** Color is changed in lighter blue to keep the consistency within Fig. 1.

**Reviewer:** Lastly, I'm not a native speaker myself, but it feels like a lot of “the”sare missing from the text. I suggest having the manuscript screened for style by a native speaker.

**Response:** We made several corrections following the Referee proposal to improve the language.