

## ***Interactive comment on “The mineral dust cycle in EMAC 2.40: sensitivity to the spectral resolution and the dust emission scheme” by G. Gläser et al.***

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We thank referee #4 for his/her helpful comments. Replies to his/her suggestions are embedded below.

General comments:

1. The major problem of the manuscript is the lack of quantitative comparison with observational data. There are many statements that one model setup leads to ‘more realistic’ results compared to a different setup, but this is not based on any sound evaluation with observations. In fact, for the only two stations for which the dust concentration simulated by the model is actually compared to measurements, only results for a single model setup are shown. For these cases the results from different model setups

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could be informative regarding the ability of the model to resolve dust processes.

2. Data that are suitable for comparisons of global dust model results include e.g. satellite retrievals (from MODIS, MISR, TOMS/OMI AI, ...), sunphotometer data from the Aeronet network, dust concentrations from the U. Miami surface network and others, see e.g. Huneus et al. 2011. Such data are mostly easily available and would help to evaluate the model results, supporting the decision on the use of the best model setup.

- 1., 2. We expand the evaluation of the different setups by quantitative comparison with dust deposition and surface dust concentration data sets (Ginoux et al. 2001, Tegen et al. 2002, Stier et al. 2005, and Mahowald et al. 2009), as well as with satellite retrievals from MODIS (mass concentration). The case studies are thought to be an additional evaluation of the most appropriate setup that was determined by the systematic evaluation of the time slice experiments. Hence, this analysis is not done for the remaining setups.

3. Such comparisons should also be extended to evaluate the seasonal cycle of dust distributions for the different regions of the world. The seasonal cycle is well known for the different dust source regions, and in particular the results for the different model setups would be of interest.

- Thank you for this valuable suggestion. We add a seasonal and regional analysis of the different setups.

Specific comments:

4. Section 2.1: The dust emission scheme by Balkanski et al. 2004 should be explained in more detail, particularly because the reference is a book chapter which is not generally accessible. Especially it would be of interest how the fields for threshold velocity and source strength factors were derived, since these factors appear to cause the unrealistically high emissions in the Thar desert. The discussion of the different

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dust emission schemes is not very useful if this information is not provided.

- We add some more details and the reference Kerkweg et al. 2006 (ONLEM) in the description of the BK emission scheme. This publication and citations therein give a detailed description of the scheme.

Section 3.1: 5. Stier et al 2006 already showed comparisons of the different dust schemes (TG and BK) in ECHAM5-HAM, it was already noted there that the BK scheme produces very high dust emissions in the Thar desert. Proper reference should be given to that publication.

- This is correct. Stier et al. 2005 mentioned the higher emissions in the Thar Desert (without discussing this issue in more detail). We add this information to our discussion on the Thar Desert.

6. The section contains a lot of qualitative and vague statements on the quality of the model results, which are not useful for the reader. Some examples:

+ “...dust emission in India ... in clear contradiction to published values” Please provide a reference to the mentioned published values.

- On page 27294, lines 25-26 we give reference to three studies that found the Sahara Desert to be the World’s largest dust source region. This justifies our statement but because there are no values given, we change the formulation to: “... in clear contradiction to the studies mentioned above.”

+ “unrealistic high dust loads in polar regions” – on which grounds is this unrealistic? The result is only compared to the mean result of Huneus et al., but global models can have a considerable range in the transport of trace substances to high latitude. If no measurements are available it should at least be noted if the simulated model value is within the range of Aerocom model results rather than compare to the mean value.

- Indeed, some of the AEROCOM models do also simulate high dust loads north of 60° N, e.g. GOCART, so the EMAC simulations with T42 and T63 are within the AEROCOM

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range in this region. However, in EMAC mainly the dust emitted in the Taklamakan Desert is responsible for the high dust load north of  $60^{\circ}$  N. Compared to the five-year mean of the MODIS mass concentration, the T42 and T63 simulations produce much too high dust column masses over this desert. This is a strong evidence for the overestimation of the dust load in the Arctic. We add this statement to the text.

+ “The global distributions ... look quite similar and appear reasonable” – a very crude assessment of the results. On what is this assessment based?

- This is based on the comparison of Figs. 2g, h and 3g, h. The distributions appear reasonable compared to the mean emissions of the AEROCOM models. We add this statement to the text.

+ “Hence we cannot decide which simulation is closer to reality” – If at least an attempt would be made to evaluate the model results with available observations from satellite remote sensing or network data (U. Miami surface concentration data, AERONET sun-photometer data) then at least some chance for a decision on the best model setup based on actual data might be possible.

- This is right. In the revised version we compare the EMAC simulations to the five datasets of dust deposition and surface dust concentration (see above) and calculate different skill scores. They indicate that the emission, the load, and the deposition are likely too high in T106TG.

+ “Because the dust load ... exceeds the range of the Aerocom models ....” What is that range? More reference to the results of the Huneus et al. paper should be given.

- We now give the values in the text: “Because the dust load of T106TG (31.55 Tg) exceeds the range of the AEROCOM models (6.8-29.5 Tg) ...”

7. The provided possible explanation for the decreasing dust life times with increasing model resolution is not obvious. Why would the dust particles need longer to reach a precipitating cloud at coarser resolution? Instead, does the precipitation distribu-

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tion change with model resolution? Are there different rain rates, which may explain different washout efficiencies?

- The total global precipitation increases by about 2 % from T42 to T106 which gave us this idea. We revised this analysis and found another important difference between the resolutions that we add in the revised version: Maximum near surface wind speed increases in finer resolutions. This causes the emission of larger particles that fall out quickly. This is confirmed by the ratio of “total deposition close to source regions” to “global total deposition” which increases with finer resolution.

8. As mentioned in the ‘General Comments’ there are many possibilities to evaluate the dust simulations with observations that are suited for global models, as e.g. done in the Huneeus et al. publication. Many of those data are freely available as the products from the NASA satellite instruments (MODIS, MISR, TOMS/OMI AI), the optical thickness data from the AERONET sunphotometer network and the surface concentration data from the University of Miami network.

- In the revised version we compare the simulations with the five datasets (Ginoux et al. 2001, Tegen et al. 2002, Stier et al. 2005, and Mahowald et al. 2009) and the MODIS mass concentration.

9. Section 3.2: A closer look at some emission regions is of some interest for the model evaluation. But what is the motivation of choosing to do this only for the Thar and Central Asian deserts? While the Asian deserts are mentioned, why is the model ability to capture the spring maximum not shown? Also, the authors could easily make a direct comparison with TOMS AI, which is mentioned but not shown. Because the comparisons with station data in the next section is for Saharan dust, it would also make sense to evaluate the modelled seasonal changes of dust emissions for the Sahara. In general, evaluation of the full seasonal cycle of the dust in the model would be of interest as this is usually well known for the different regions of the world. Here it would be of particular interest to evaluate the results from the different model resolutions.

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- In the revised version we investigate the seasonal cycle in the different model setups and compare it to seasonality of the MODIS mass concentration. We add also the discussion of the seasonal cycle of the Saharan dust.

Section 4: 10. Timmreck et al., 2004 (JGR, vol. 109, D13202) have compared the performance of the 'free' and the nudged version of the ECHAM model with respect to the effect on dust emission simulations. They found considerable differences, in particular lower wind speeds in the nudged model version lead to partly considerable reductions in dust concentrations compared to the non-nudged version. If this is also the case for this model version then the evaluation of the model performance from the nudged version is only of limited use for the evaluation of the full model.

- This is correct. We are aware of the fact that the wind speed is lower in nudged simulations. But one intention behind the case studies is to test the model's capability to produce single dust emission events. In the revised version we mention this in the beginning of Section 4.

11. The authors themselves question the usefulness of comparing results from a global model with local, short-term measurement from an individual station. While the model provides astonishingly good results in comparison with the observations, the representativeness of these results must be questioned, particularly for the near-source case in Morocco.

- For this reason we do not only compare the EMAC results with measurements at one station, but also with DREAM simulations and satellite images. With this we broaden the investigation to a large region over a few weeks during the campaign.

12. The evaluation of the individual episodes could be of some interest if the performance of the different model setup would be compared rather than just showing the results for the favoured setup.

- The main topic of this study is to investigate the dust cycle in EMAC in global climate

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simulations with different setups. Our decision on the most appropriate setup is based on the climatological results. With the analyses of the episodes we expand the investigation of the “most appropriate” setup to shorter scales. The evaluation of all eight setups is beyond the scope of this study.

13. What is the motivation of comparing to the DREAM results? In particular in Figure 7 it appears that the DREAM model predicts much higher dust loads compared to EMAC, and since it is argued that EMAC concentrations are somewhat too high for this event then the DREAM results must be way too high. So what is learned for the EMAC performance from this comparison?

- We completely revise the paragraph comparing to the DREAM results. In the revised version we leave out the panel showing the DREAM results in Fig. 7. A short qualitative comparison to DREAM is discussed in the text.

14. The comparison of the results with the MSG dust index (Figure 7) is not useful. The IR dust index can give an indication of the presence or absence of dust, but the strength of the signal is not necessarily related to the dust load present at a particular location. The IR signal strongly depends on temperatures, humidity and the vertical extension of the dust layer and should therefore not be used for quantitative or even qualitative comparisons of relative dust concentration and emission strengths..

- In the discussion of Figure 7 we use the MSG image to confirm high dust concentrations in Central Algeria. This composite of different IR channels shows airborne dust in magenta colours. We do not use this image for a quantitative comparison with the model results, but we think that the qualitative information from these images is highly useful to qualitatively validate the presence of dust layers transported out of the Sahara.

15. The dust episode from the SAMUM period is rather complex, and too much room is given to explain the episode itself, which has been done in detail by Knippertz et al 2009 (please note also the large number of publications on dust measurements during

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SAMUM published in the Tellus 2009 special issue – available are not only ground measurements but also aircraft data, sunphotometer and lidar measurements of dust distribution) Since different mechanisms are responsible for dust emission during this period it would be of some interest to test which of the processes can be resolved by the model at the different resolutions. But again, it is questionable if a global-scale model is suitable for such detailed comparisons. E.g. dust mobilization by density currents that occurred twice during the SAMUM period are problematic to simulate even with much higher-resolved mesoscale models (see Reinfried et al., 2009, JGR vol 114, D08127)

- We add the references of the Tellus 2009 Special Issue. For the comparison we have to recapitulate the different meteorological situations during the campaign. In our view, this is necessary for the comparison, especially for readers that are not familiar with the SAMUM campaign. We are aware of further measurements during SAMUM but the comparison with all available data would go beyond the scope of this article. As said in the comment to point 12, the decision on which setup is the most appropriate one to simulate the mineral dust cycle is made on the climatological results. The simulation of the episodes with all the eight setups would not lead to another decision for the “most appropriate” setup because we need a reasonable reproduction of the dust cycle on global scale.

16. Are LAGRANTO trajectory results computed with EMACS fields or are those results unrelated to the EMACS model? If the latter is the case those model results should be left out here, since they are not informative regarding the EMACS model performance.

- We expand the description of the trajectory calculation to clarify this. The trajectories are computed with the EMAC data.

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