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Climate of the Past
Discussions

Interactive comment on "Sensitivity simulations with direct radiative forcing by aeolian dust during glacial cycles" *by* E. Bauer and A. Ganopolski

Anonymous Referee #1

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The manuscript by Bauer and Ganopolski investigates the dust shortwave direct radiative forcing over the last four glacial-interglacial cycles using the intermediate complexity Earth system model CLIMBER-2. This is a follow up from a paper by the same authors (Bauer and Ganopolski, 2010), that described an offline version of the dust model coupled to CLIMBER-2 (including simulation of emission, transport and deposition) validated against observational data.

The new work incorporates the use of a radiative transfer model and simulates dust radiative effects and climate feedbacks under six different scenarios resulting from the combination of different assumptions in terms of mass balance of the dust cycle and optical properties of dust, allowing to evaluate the sensitivity of the climate to dust. The rationale of the study is grounded in the necessity of improving the understanding of

aerosol climate interactions, as also stated by IPCC AR5. The incorporation of the dust cycle in intermediate complexity Earth system models is an important addition to the set of tools relevant for dust-climate research and paleoclimate research.

The manuscript is well written and the figures and tables are clear and provide adequate support to the main text. The work is clearly described and presented results are discussed in a consistent way. It is indeed an interesting work, but I have one major point of concern that I think the authors should properly address before the manuscript can be accepted for publication.

The assumption that dust aerosols transported over long distances have sizes falling mainly within the accumulation mode lacks an acceptable justification and is in contrast with observations. Most important, it is likely to significantly affect the results discussed in the manuscript. The details of my analysis are provided below.

Major remark

The assumption that dust aerosols transported over long distances have sizes falling mainly within the accumulation mode described in the introduction is justified based on Sow et al. (2009). The mass vs diameter distributions in that study does not support this claim: Figure 11 in Sow et al. (2009) shows that only a significant but relatively small fraction of the dust mass falls in the sub-micron range typical of the accumulation mode, compared to the super-micron fraction. In addition a variety of observations far from the source areas (hence relevant for long-range transport) from the surface (e.g. Maring et al., 2003; Ruth et al., 2003) confirm this fact. Even vertical profiles (Reid et al., 2003b) and column-integrated estimates of size distributions (Reid et al., 2003a), which may be the more relevant parameters for the specific purpose of this study, do not support the authors' claim.

The possible relevance of the assumption that the airborne dust mass can be approximated to the accumulation mode is related to a couple of aspects, which relate to the mechanism described by the authors (162.24-29).

First, the modeled dust mass balance was tuned (Bauer and Ganopolski, 2010) by a global scale factor in order to match the DIRTMAP2 dataset, which is reasonable for a bulk dust model that does not simulate the dust size. In the new manuscript though, considering that all that dust has sub-micron size is equivalent to artificially shifting all the mass from the coarse to the accumulation mode.

Second, the consequence is that the dust (which is already largely overestimated for the accumulation mode) is biased towards small particles that are going to be more effective scatterers in the model because of the Mie theory (e.g. Tegen and Lacis, 1996).

In view of those considerations, it is likely that the assumption has significant impacts on the results. In the conclusion of the manuscript the authors indicate that inclusion of a coarse dust mode in their model will be the object of future work. I would be eager to consider the assumption acceptable for the work in these terms, provided it did not involve unrealistic justifications, but instead if its implications and limitations for the model and interpretations were thoroughly discussed, ideally with an additional sensitivity test or at least by a strong discussion and some reasonable estimates compared to the other sensitivity tests on the refractive index and dust load.

Minor observations

Title and text: since the model just includes SW-dust interactions, I think this should be made explicit, e.g. by changing throughout the manuscript “DRF” with “SW DRF”, including in the title.

152.20: Wind gustiness has also been indicated as a possible driver for dust emission changes on orbital time scales (e.g. McGee et al., 2010).

154.12: “presumably”? Please check

155.21: When mentioning dust size, please indicate explicitly if you refer to radius or diameter.

157.20: “The dust deposition of snow is prescribed” seems in contradiction with the description of the simulation of dust removal by dry and wet deposition. Please clarify this aspect.

161.7-10: Motivate “implies a long-range transport mainly from South America”

163.27: Define the “critical surface albedo”

165.24: “varies IN TIME”

166.13-14: What is the relation between AOT and the choice of the refractive index? How is the AOT calculated in the model?

168.13-14: This is an interesting point, I think it deserves more discussion. What are the possible causes? Just the bias induced by the size assumptions? A too slow response because of the attribution of glacial times sources in this model mostly to low/mid latitude desert sources rather than glaciogenic sources?

170.17-20: This statement should be reconsidered once the possible bias induced by the size assumptions made for this work has been addressed.

Figures 4 and 9: Several labels are missing.

Table 4: Please add either the reference value or the anomaly to that for each case.

Naming conventions: it may be helpful to add a coding also for the three refractive indices options, similar to the L1/L2 convention so that each of the six cases has a unique synthetic identifier to be used in the text e.g. as all the L1* cases or all the *R0015 cases, or something equivalent.

Reference list

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Tegen, I., and Lacis, A. A.: Modeling of particle size distribution and its influence on the radiative properties of mineral dust aerosol, J. Geophys. Res. 101, 19237-19244, 1996.

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