Atmos. Chem. Phys. Discuss., 11, C2189–C2194, 2011
www.atmos-chem-phys-discuss.net/11/C2189/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Role of sea surface temperature responses in simulation of the climatic effect of mineral dust aerosol" *by* X. Yue et al.

Anonymous Referee #2

Received and published: 22 April 2011

General comments:

The paper aims to systematically study the specific role of sea surface temperature (SST) changes within the interactions of dust aerosol cycle, radiative forcing, and climate on a global scale using experiments with a general circulation model of the atmosphere (AGCM), in which an interactive soil dust cycle model is embedded. Physical relationships are being explored by performing experiments with the fully coupled system, which are compared to experiments for which either the dust cycle passively depends on the model climate (the control experiment), or the dust aerosol forcing drives the climate state without the climate state feeding back into the dust cycle. This

is done both for a prescribed fixed SST and for a calculated SST of a mixed layer ocean coupled to the AGCM. Since the emphasis in the study is on qualitative physical relationships, the used model appears to be adequate for it.

The conclusion from the study is that there can be significant differences between the climate response to dust radiative forcing depending on whether the SST is prescribed or calculated, not just with respect to the magnitude, but even with respect to the sign of the climate response. For instance, the experiments show a general warming of the atmosphere for prescribed SST, but a cooling for calculated SST as response to dust radiative forcing. There is the caveat that the conclusions can't be generalized for the real climate, since horizontal heat transport in the oceans hasn't been taken into account. Thus, we don't know how the climate response and feedbacks would be modified, if this was taken into consideration. This objection has been addressed in the discussion section by the authors. Despite the caveat, the paper provides evidence that using a prescribed SST is not an adequate approach to study the climate response to dust radiative forcing and the feedbacks. Perhaps this point should be emphasized in the conclusion part. The study could be a valuable contribution, a step to understanding the climate effect of dust aerosols on a global scale.

However, I have a few comments and concerns. Some of them are about the methodology and should be clarified before the conclusions in the study could be considered as sufficiently supported. Others address some additions, which would improve the study, but can be considered as rather minor.

Major concerns:

1. The authors designed a separate control simulation for the experiments with fixed SST and the calculated SST. The model climates for fixed and calculated SST and therefore the dust cycles in the two simulations won't be exactly the same. They even could be statistically significantly different, particularly regionally. For

instance, even the globally averaged dust emission and dust burden are about $4.5\ \%$ and $4.9\ \%$ lower, respectively, in the calculated SST control compared to the fixed SST control. That is, when comparing the fixed dust experiments or the interactive dust experiments between the fixed and calculated SST set, everything else is not the same besides the different SSTs. How do the authors ensure that the changes going from fixed SST to calculated SST are only due to the different SSTs, but not also at least partly due to differences in the dust cycle or differences in the geographical distributions of the dust aerosols in the various seasons? Even if it is very well conceivable, that the conclusions will be robust in the end, to be methodically sound, the authors should provide evidence that the differences between the control climates, the dust cycles, and the radiative forcings of the fixed SST and the calculated SST experiments can be neglected when the changes are being attributed to the differences of the SSTs in the later part of the study.

2. The authors examine only annual averages of the climate response to dust aerosols and the feedbacks in their study. However, on one hand, the soil dust cycle exhibits a strong seasonal cycle due to seasonal variations of dust emission from the various source regions and transport of dust to remote regions. On the other hand, the Hadley-Walker circulation cells display an annual cycle as well. The climate response, particularly changes in the hydrological cycle, specific humidity, cloud cover, and atmospheric circulation to dust radiative forcing could be sensitive to the proximity between the regions with significant dust aerosol forcing and the convective regions (*Perlwitz and Miller*, 2010). Thus, there may be significant differences between the results comparing winter and summer, which are blurred for the annual average. How do the results vary when each season is examined separately?

3. **Section 4.2.3, pg 1134, line 5 and following, and Figures 6 and 8:** The authors discuss the feedback links. Have they examined the responses of the general cir-

culation and their role within the feedbacks? The cloud cover decrease in a band from the North Atlantic to East Asia in Figure 6b indicates the possibility of large-scale changes in the Hadley-Walker circulations system, similar to the response found by *Perlwitz and Miller* (2010), particularly since the maximum cloud cover changes are displayed adjacent to the region with maximum dust aerosol depths. Changes in dust radiative forcing in the sources regions and cloud cover and precipitation changes in remote regions and in the source regions could be linked through circulation changes (*Rodwell and Jung*, 2008).

Minor points:

1. **page 1123, line 20 and following, and Table 1:** The authors refer to previous studies on the climate effect of dust aerosols. An additional study on the topic was published by *Perlwitz and Miller* (2010), using a general circulation model coupled to a mixed layer ocean model with deep diffusion and prescribed dust radiative forcing for various single scattering albedo of dust particles. The results from this study may be relevant for interpreting the response of the hydrological cycle, cloud cover, and general circulation to dust radiative forcing. A recent combined observational and ocean modeling study by *Avellaneda et al.* (2010) supports the hypothesis about the cooling effect of dust aerosols on SST.

2. **Section 3.1:** Although the representation of the dust cycle in the model was examined in a previous study (*Yue et al.*, 2009) in detail by comparing it to observations, the authors should add one or two paragraphs to this subsection, summarizing the strengths and weaknesses of the representation of the dust cycle. It makes it easier for the reader to put the results of the current study in the context of this performance.

3. **Section 3.1 and Table 2:** What are the standard deviations for the various dust cycle variables? Adding the standard deviation to the table provides information

on the variability of the dust cycle and the significance of the differences.

4. **Section 4:** The authors test the statistic significance of the changes for various variables, as I understand it, between the fixed dust simulation and the control simulation and the interactive dust simulation and the control simulation, respectively, of the same experimental set. However, when examining the differences between the fixed SST and calculated SST experiments, it would be helpful instead to know whether the differences of the responses are statistically significant. For some variables it seems to be clear enough from visual examination that they are. It is not clear, for instance, for the sensible heat flux, though, since the responses look very similar comparing fixed SST and calculated SST simulations. If the difference in the response of this variable is not statistically significant there is no point in trying to interpret this difference.

5. **Section 4.2.3, pg. 1133, line 2 to 6:**

   "Relative to MXLSST_CTRL, MXLSST_CD simulates a $2.4\ \%$ lower global dust emission, because the dust-induced warming over the dust source regions (Fig. 7e) increases evaporation and air moisture and consequently reduces dust mobilization based on the dust generation function in Yue et al. (2009)".

   Could the response of the dust cycle be a specific feature of the emission parameterization? I would expect that increased evaporation lowers soil moisture, particularly in dry regions where the water supply to soils is limited. It is conceivable, that emission parameterization schemes that are constrained by soil moisture exhibit an increased dust emission in this case instead. This question can't be answered within the scope of this study. However, it should be added to the discussion of the uncertainties in the conclusions part of the paper.

6. **Figure 2:** Please add the information to the figure caption that the column burden of dust is displayed for the control experiment with fixed SST.

Technical corrections:

1. The doi codes for many of the references in the bibliography list aren't correct. This seems to be the case particularly for publications in J. Geophys. Res. The authors will have to carefully go through the reference list and correct the erroneous doi codes.

2. The publication year of the paper by Yue et al. in Journal of Climate on mineral dust aerosol at the Last Glacial Maximum is 2011, not 2010.

References

Avellaneda, N. M., N. Serra, P. J. Minnett, , and D. Stammer (2010), Response of the eastern subtropical Atlantic SST to Saharan dust: A modeling and observational study, *J. Geophys. Res.*, *115*, C08015, doi:10.1029/2009JC005692.

Perlwitz, J., and R. L. Miller (2010), Cloud cover increase with increasing aerosol absorptivity: A counterexample to the conventional semidirect aerosol effect, *J. Geophys. Res.*, *115*, D08203, doi:10.1029/2009JD012637.

Rodwell, M. J., and T. Jung (2008), Understanding the local and global impacts of model physics changes: An aerosol example, *Q. J. R. Meteorol. Soc.*, *134*(635), 1479–1497, doi:10.1002/qj.298.

Yue, X., H. Wang, Z. Wang, and K. Fan (2009), Simulation of dust aerosol radiative feedback using the Global Transport Model of Dust: 1. Dust cycle and validation, *J. Geophys. Res.*, *114*, D10202, doi:10.1029/2008JD010995.