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Interactive Comment

Interactive comment on "Saharan dust transport and deposition towards the Tropical Northern Atlantic" *by* K. Schepanski et al.

K. Schepanski et al.

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The response to reviewers comments are indicated by italics.

General comment :
This paper describes and analyses the main characteristics of Saharan dust transport and deposition toward the Atlantic Ocean simulated by a regional model, for three months of 2006-2007 corresponding to contrasted transport pattern. The paper is well written and organized however the interest of the presented work is quite limited due to a lack of experimental constrains on the simulations. For example, the authors discuss the capability of the model to reproduce a general trend described in the literature: the change in the altitude of Saharan dust transport between winter/spring and summer.
However, no quantitative elements on the way the model describe the transport for

the specific studied period are given. The only comparison of the simulations with observations concerns a parameter that does not describe the vertical distribution: the aerosol optical thickness, i.e. the columnar integrated dust amount. A validation of the simulated profile is feasible, at least for the two months of 2007, since aerosol vertical profile are available from the CALIPSO instrument onboard the Aquatrain. Such data should be used to test not only the seasonal changes in the altitude of dust transport but also the changes that are simulated at 8220;sub-monthly8221; time scale (typically in January 2007). Similarly, the authors describe the simulated deposition pattern and contest the capability of satellite observation to be of any use to estimate dust deposition but they do not provide any evidence that the model reproduce correctly dust deposition over Africa. The comparison with AOT is made over the CapVerde Island only, while several other sunphotometers from the AERONET network were operational over Africa at the period of the simulation. These stations may be located closer from the dust sources responsible for the dust export over the Atlantic Ocean. The aerosol size distribution retrieved from the AERONET measurements can also be used to test simulated aerosols size distribution. Indeed, dust size distribution controls the transport and deposition fluxes and also the AOT, i.e. the main features discussed in this paper. Finally, the authors dedicated a significant part of the paper to discuss the result from a previous paper (Koren et al., 2006) on the estimation of the westward export of dust emitted from the Bodele depression. It is difficult to be convinced that the estimation provided in this work is really relevant for such a purpose since the way the dust emissions are simulated from the Bodele depression is not discussed and compared to any observations. In addition, the comparison of a two month estimation with an annual estimation is also questionable. In fact, a deeper analysis of the different source areas and of their relative contribution to this westward transport would be much more informative and original. Obviously, thi Bodele s would require a validation of the simulation of the different source activity, based for example on the IR satellite indexes the authors are familiar with (see Shepanski et al., 2007). The authors also contest the relevance of the empirical relationship used by the Koren et al. (2006),

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i.e. the ratio between the total mass and the AOT. Once again, to be convinced that the ratios found in the paper can perform better, a deeper quantitative validation of the simulations is needed. I would thus recommend the authors to improve the paper with additional comparison with observations and further analysis of the simulations in terms of (1) source location and contribution to the export over the Atlantic Ocean and (2) sensitivity of the simulated deposition pattern to the dust size distribution.

Additional comparisons with AERONET sun-photometer stations in the North African region are added (new Section 3.3). In the revised version, size distributions from AERONET inversions are compared with model results in addition to comparisons with AOT. See response to specific comments for details.

Specific comments :

Part 2 : In the description of the modelling system, the authors should indicate the initial dust size distribution used at the emission (and not only the size range of the different bins). The value of the extinction coefficient used to compute the AOT should also be given.

The values of the extinction coefficient for each size bin are now given. The initial size distribution at emission depends on the wind velocity and the soil type, which vary in time and space. It is parametrised following Tegen et al., 2002, Heinold et al., 2007

Part 3.1 It is not clear in the first part of the chapter, what elements are specific of Saharan dust transport and what elements are generally dynamical features (for example, the discussion on the evolution of the boundary layer, or the influence of the west African monsoon on the geostrophic winds). In addition to the simulated AOT, the simulated dust emissions should be displayed and compared with satellite observations.

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The comparison of dust emission with satellite data is implicitly included in the comparison of monthly mean AOT fields. A acceptably correct simulation of AOT in space and time requires a correct treatment of dust emission, transport and deposition as well. A qualitative study on each dust source using geostationary satellite observations like the MSG SEVIRI IR dust index (provided by EUMETSAT) is possible for the place of first occurrence but not for dust emission under dust plumes in progress. Furthermore, a comparison of qualitative information and model simulations only give information on the correct placement of the 8220;starting point8221; of the dust emission. No comparison of quantitative dust fluxes are possible using this way. Quantitative information of atmospheric dust content are not available on a time resolution accounting for the time-scale on which dust source activity has been observed.
Here, to account the aspect of correct simulation of dust source and flux, the temporal evolution of AOT values measured by sun-photometer in the frame of AERONET are now shown for several stations at different longitudes and latitudes around the Sahara to draw a most complete image of three dimensional dust plume evolution.

The influence of biomass burning aerosol on AOT is not mentioned despite the fact that it can significantly contribute to the AOT in winter.

This aspect is now included in the discussion on the comparison of AOT values.

For the March 2006 dust storm, the authors discussed AOT values of 0.3 to 0.6 over Algeria while AOT higher than 3 have been measured by the AERONET stations in Niger and Mali. How does the model perform in these stations ? Many AERONET stations can be used to test the relevance of the simulations.

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Interactive Discussion

Discussion Paper

This part of the present paper is overworked and available level-2 data for several AERONET stations are added (new Section 3.3).

MODIS AOT are monthly average for clear sky situations only. Are the cloudy days excluded for the computation of the simulated monthly AOT ?? This may explain part of the discrepancies between the model and MODIS AOT especially in July.

The monthly mean AOT is computed by taking missing values into account. For each pixel the available AOT values are summed and divided by the number of available values. This information is also added.

Part 3.2 This part is of limited interest since there is no way to test whether the distribution of wet and dry deposition is reasonably simulated. Deposition being largely controlled by the dust size distribution, some constrains could be given the AERONET retrieval of aerosol size distribution. It would also be interesting to discuss the change in the aerosol distribution from the source areas to the transport and deposition regions. It would also be interesting to compare the simulated precipitation fields controlling the wet deposition pattern to observations of precipitations.

A comparison of model size distribution and those given by AERONET is added (new Section 3.5). Discrepancies between modelled and observed precipitation is not able to explain these differences, a more detailed will be beyond the scope of the present manuscript and give space for further studies.

In the last sentence, it is not clear what the authors mean by 8220;unsettled weather character8221;.

8220;unsettled8221; is replaced by 8220;varying8221; .

Part 3.3 The discussion on the discrepancies between the simulated and observed AOT is not totally convincing. In particular there is no discussion on the capability of the model to reproduce the sources of the observed dust events. Part of the discrepancies in summer is attributed to wet deposition. As mentioned above, the authors can, at least, compare the precipitation used in the model with observations.

A comprehensive discussion on daily dust sources is beyond the scope of the present paper. To account for the reviewers argument to give more detailed validation of the model simulations, the discussion on monthly mean AOT fields is extended and a comparison of modelled AOT to DeepBlue AOT and OMI AI over land surfaces and MODIS visible AOT over the Atlantic is now included. The authors assume in their discussion, that a good reproduction of mean AOT fields implicitly require a correct reproduction of dust emission, transport and deposition. Furthermore, studies comparing with LM-MUSCAT simulated wind fields, a key-component for simulating dust emission, with observations have been performed in earlier studies. This references are added.

The different altitudes of transport are given in km in the discussion but in pressure on figure 5.

Figure 5 gives the altitude at both, pressure levels and height levels (km).

Part 3.4 This part is not clear and confusing. The fact that significant eastward transport is simulated, especially at 20W is very surprising. The authors argued that the high altitude transport eastward simulated in winter it is due to fact that the air flow in the upper troposphere is reversed compared to the lower layers. However, even if the possibility of such transport appears as realistic from a dynamical point of view, its intensity is quite surprising. The zonal flux being computed as the product between the mass concentration and the wind in the considered direction, this result suggests quite high concentrations in the upper troposphere that seems inconsistent with the vertical profiles displayed in figure 5. The result is even more surprising when looking at the zonal fluxes from Bodele region alone. From figure 7, it seems that in January the high altitude eastward flux is as intense as the westward flux figure suggesting that a significant part of the dust emitted from the Bodele depression in winter re-circulate over the Sahara at high altitude ?? If this is correct, this quite a new and original result; but in this case, it absolutely requires some experimental evidence. The eastward fluxes simulated close to the surface in summer is explained as being due to the monsoon flow however, once again, this meteorological feature explains the main flow direction but not its intensity. Does this mean that some of the dust transported in the Saharan Air layer deposit in the marine boundary layer and is backward transported in the monsoon flow ? The very high westward flux at 20W at the higher level of the model is also very surprising. Such a high flux is not simulated at 10W, suggesting the existence of active dust sources between 10 and 20W from which dust can be lifted at very high altitude in such a small distance. Once again, it does not look realistic.

This part is re-written considering the arguments of the reviewer and basing on the re-drawn Figure 7 and 9 (former Fig. 6 and 7) now showing the altitude as height-axis as suggested by the reviewer. Furthermore, the depth of each model layer is considered, which gives a more realistic impression on upper-level dust transport. As the model computations are done on terrain following sigma-p coordinates, level depth increases with height. The revised way of showing dust fluxes account for the increasing layer depths.

The vertical axis of figure 6 corresponds to 8220;levels8221; of the model ?? It should be changes in pressure or altitude.

The vertical axis of figure is changed to altitude. Thanks for this helpful advice! It helped to improve the discussion on dust export.

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Part 3.5 As suggested in the general comment, a discussion on the contribution of the different sources as a function of the season would be of greater interest than this focus on the contribution of the Bodele depression.

To account for the contribution of different source areas to atmospheric dust, a detailed study and discussion is required which is beyond the scope of the present paper.

Additional explanation on the positive high altitude fluxes in winter are absolutely needed. The discussion on the Bodele export compared to the Saharan dust export is really difficult to understand and must be revised. Obviously, the sign of the zonal budget can be different when looking at Bodele souce alone compared to the whole Sahara, but the fact the export from Bodele can be higher than the export from the whole Sahara appears as impossible. The argument that dust from Bodele can reach high tropospheric levels as 8220;illustrated on figure 78221; is not clear.

The discussion on the export of dust emitted over the Bodele region is re-written. Figure 9 (former Fig. 7) (and Figure 7 (former Fig. 6) as well) is re-plotted. The y-axis is changed to 8220;altitude8221; and the amount of dust export is set into relation of the depth of the corresponding layer. Now the dust flux is set into relation of the layer thickness. Before, high values at high model levels easily led to the impression of high fluxes. The new figures revise this impression. The same arguments are true for Figure 6 which is re-drawn as well.
To compare the net-export (total of the column) of North African dust and dust originating from the Bodele more clearly, Table 1 and 2 are replaced by figures.

Part 3.6 It is not clear how the ratio M/AOD is computed in the simulation. Is it an average over the whole simulation domain ? Is it computed as the total monthly

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mass divided by the total monthly AOD or as an average of individual ratio M/AOD ?? The authors argue that most of the difference with the ratio used by Kaufman could come from differences in the aerosols size distribution, however the distribution of this ration in the simulation is quite limited, suggesting a moderate change in size distribution. So instead of giving the size bin limit, the authors should give the modelled size distribution for example at the sources and at different points of the 20N transect. It is not clear whether the computation of the dust fluxes from case 1 to 3 concerns the three studied months or for selected periods.

The ratio M/AOD for the model simulation is the average of the distribution over a meridional transect, as given in the figure caption and now also added to the manuscript itself.
To make the discussion more clear, the relation of meridional changes of zonal dust fluxes and deposition rates is added.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 16061, 2008.

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