Reply to Reviewer Comments 2

In this study, the performance of the new NMMB/BSC-Dust model is evaluated using data from the Saharan Mineral Dust Experiment (SAMUM) and the Bodélé Dust Experiment (BoDEx). The paper is well-written and the results of this model evaluation study provide important insight into the performance of the NMMB/BSC-Dust model.

After the following revisions are considered, I recommend this manuscript for publication in ACP.

The authors would like to thank the reviewer for the constructive and very helpful comments. Several important questions have been asked. We have revised the manuscript according to these suggestions. Below we provide a point-by-point response addressing each comment in detail.

General comments

The intercomparison between the model and the data is made rather qualitative. I would prefer to see a more quantitative intercomparison (for example by showing maps of the differences between the AOD modelled with NMMB and the AOD retrieved from the satellites, by showing scatter plots of modelled and measured dust parameters, and by specifying how much the model under-/overpredicts the measurements).

We highly appreciate the comment of the reviewer. However, the current strong uncertainties in quantitative satellite retrievals over deserts preclude a meaningful quantitative comparison for two specific episodes as selected and presented in this paper. The differences among different satellite retrievals are often as large as the differences between the model and any satellite retrieval. Instead, we have decided to provide a detailed qualitative description of the comparison, which at the same time analyses the broad differences among the different retrievals.

Concerning the quantitative comparison, the first part of this contribution, Perez et al. 2011 (Atmospheric dust modeling from meso to global scales with the online NMMB/BSC-Dust model – Part 1: Model description, annual simulations and evaluation), provides a detailed statistical evaluation on a daily basis for a yearly cycle with AERONET data around the region including correlation coefficients, root mean square error (rmse) and bias.

Specific comments

Abstract

p. 30275, l. 20: Please insert „of dust“ after „(…) vertical distribution“.

Amended

Model description

p. 30278, l. 20: Insert „NCEP-NMMB“ between „the“ and „model“.

p. 30279, l. 26: What is the STATSGO-FAO database, and the NESDIS climatology? Could you give a little more detail?

References are now provided in the manuscript

p. 30280, l. 24: What is a dust spin-up? Could you give a little more background?

It describes the warm-up phase of the model which starts with zero or no dust initially. The spin-up time is the time for the dust concentration to reach equilibrium between emissions and removal processes. We use 7 days of spin-up time, which is far enough given the life time of the dust particles and the limited area domain.

p. 30281, l. 18: Please insert the altitude of Ouarzazate: 1150 m a.s.l.

Amended

Observational data

p. 30282, l. 12: "without the presence of clouds" outside of clouds
p. 30284, l. 14-15: repitition of p. 30283, l. 24/25

Both revised or amended, respectively

p. 30284, l. 23: "Angstroem exponent" please indicate which Angstroem exponent (of extinction, of scattering, of absorption?) you are referring to.

We always use data from CIMEL sun photometers (AERONET, SAMUM-1, BoDEx), see Holben et al. 1998 (AERONET - A federated instrument network and data archive for aerosol characterization - an overview.). They use direct sun extinction measurements at 8 nominal wavelengths for the retrieval of AOD and alpha. It is therefore the extinction Angstrom exponent.

p. 30284, l. 25-27: If the authors talk about background aerosols, are they referring to the vertical layering of the aerosols?

Background aerosols in this case refer to other aerosols (biomass burning, anthropogenic aerosols and other natural particles) with low concentrations that might influence the measurements. Typically background conditions are those found in unpolluted continental rural areas.

p. 30285, l. 5.: Insert "aerosol" between "vertical" and "profiles"

Amended

Results and discussion

I suggest to shorten this section (especially 4.1.2 and 4.1.2) in order to make the manuscript easier to read.

We assume you are referring to section 4.1.1 and 4.1.2? We agree that section 4.1.1 is quite lengthy. We thought about taking out one or two of the six days (16-21 May 2006) presented. However, since we see noteworthy developments at each particular day, we decided to maintain them all. We also think that this helps the reader to see what is going on during the time of the AERONET and EARLINET comparison. In fact, day 22 May 2006 has already been taken out since dust emissions over sources took place at a comparably moderate rate only. We have revised section 4.1.1 such that is more consistent.

Furthermore, it is quite difficult to see the differences between the model, MODIS Deep Blue, OMI. Please provide additional plots showing the differences between the model and the various satellite products. This would it make much easier to see where the model performs well and where deficiencies are present.

In line with the response to the general comment above, the discussion provided in the paper already highlights for every day analysed the larger discrepancies between both retrievals, which can be clearly identified from the maps. It is beyond the scope of the paper to provide a detailed quantitative comparison of both retrievals for a specific episode.

p. 30286, l. 24: Why is the deviation between MODIS Deep Blue and OMI AOD so large over the Arabian Peninsula? Which product is more trustable in this case and why?

There are multiple reasons for such a behaviour (among others surface reflectance, influence of combustion aerosols (which indeed play an important role over the Arabian Peninsula,) cloud contamination treatment) and it depends on specific aspects of each satellite retrieval whose detailed analysis is beyond the scope of this contribution. See for example Knippertz and Todd, 2012 (Mineral dust aerosols over the Sahara: Meteorological controls on emission and transport and implications for modeling), who provide a review and brief discussion of all dust monitoring tools which are currently available. For the time being, definite conclusions and detailed analyses are hampered by the lack of in-situ data directly over sources. Section 4.1.1 of the manuscript has been revised with regard to these aspects such that our assessment becomes better contextualized.

Section 4.1.2

Please provide (in addition to Figure 8 and 9) scatter plots showing the measurements of the AOD for the different stations together with the modelled AOD to evaluate the model performance.

The detailed statistical results of the model compared to AERONET observations are available in the first part of this contribution (Perez et al, 2011). Annual scatter plots are available for the year 2006 for Banizoumbo, but again, it is beyond the scope of this paper.

p. 30288, l. 15: Please give more background, why (scattering?) Angstroem exponents with values larger than 0.6 indicate significant influence of fine anthropogenic aerosol.

We use the extinction Angstrom exponent. For dust model evaluation the Angstrom exponent is used to discriminate AOD measurements affected by fine anthropogenic particles. The Angstrom exponent follows the relationship between fine and coarse modes. Since coarse-mode particles is a feature that differentiates dust from fine-mode anthropogenic aerosols such as urban-industrial particles, an increase (decrease) in the Angstrom exponent involves an increase (decrease) of the ratio fine/coarse particles and in our case denotes the low (high) influence of the dust plume during an episode. As analyzed in Basart et al. 2009 (Aerosol characterization in Northern Africa, Northeastern Atlantic, Mediterranean Basin and Middle East from direct-sun AERONET observations.), a value of 0.6 represents an appropriate threshold value for use in dust-affected areas with influence of other aerosols. It is reformulated in the manuscript and two references are given as well.

p. 30288, l. 24: What is the reason for the overestimation of the AOD by up to a factor of 2 in Banizoumbou? Transport pathway of the dust plumes?

As shown in the companion paper Perez et al. 2011 (Atmospheric dust modeling from meso to global scales with the online NMMB/BSC-Dust model – Part 1: Model description, annual simulations and evaluation), the model has the tendency to overestimate the dust in the Sahel. It is due to its location downstream of the major sources, whose emissions are slightly overestimated. As can be seen in seasonal comparison of the model AOD with the satellite imagery (Fig. 4 in Perez et al. 2011), the

Bodele is overestimated in the model in spring and early summer. Hence dust from the Bodele is persistently transported to Banizoumbou (as it ought to be), leading to overestimation of AOD in a few cases in May, June, and July as can be seen in Fig. 5 in Perez et al. 2011. However, the remaining months and seasons show very good agreement at Banizoumbou. An additional remark has been introduced in the manuscript.

p. 30289, l. 24-26: Please reformulate to make clear that lidar and the radiosonde observations of the boundary layer height are consistent while the model underestimates the boundary layer height.

Reformulated

p. 30293, l. 6: "Very large particles (…)" What size range? Are the authors referring to the saltation mode?

We refer to particles larger than 10 um median diameter (which is yet below the saltation size range). It is clarified in the manuscript.

p. 30293, l. 16-17: "(…) particles larger than 20 µm in diameter are not taken into account (…)". I disagree with this statement. For example, measurements in the Cape Verde area showed dust particles larger than 20 µm in more than 30% of all measured cases (Weinzierl et al., 2011, SAMUM-2 special issue, Tellus 63B, 4). Other studies (e.g. Maring et al., 2003) even showed the presence of large super-micron particles in the Caribbean.

We have revised this part and included an earlier general reference from Middleton et al. 2001 (Long-range transport of 'giant' aeolian quartz grains: linkage with discrete sedimentary sources and implications for protective particle transfer) which discusses this aspect in depth. We agree that larger particles are observed and transported over long distances. However it is not accounted for in this model.

p. 30294 (and Fig. 15): Are the same averaging intervals used in the sun photometer data as used in the model?

Both AERONET and model AOD values are instantaneous.

p. 30297, l. 2: What is "alpha"?

Although previously explained, we changed to the explicit term here again

Conclusions

p. 30299, l. 20: Insert "investigated in this study" after "SAMUM-1 period"

Amended

p. 30299, l. 24: "Inefficient dust sources are identified". What is an inefficient dust source? Why is this dust source inefficient in the model? Please give more detail.

It refers to the activation of potential dust sources in the model once the threshold friction velocity is exceeded. Some sources are found to be less frequently activated compared to satellite observations. We reformulated the sentence such that it is hopefully clearer now.

Figures

Figure 1: Please note that the Falcon research aircraft did not fly into Algeria.
For people not familiar with the location of the different countries in Africa, please indicate the names of the different countries in this figure. This would make it easier to follow the discussion in Section 4.

Amended and revised with country names

Figure 12: Please use height above sea level on the y-axis. Otherwise, a misleading conclusion could be drawn, if the humidity/mixing ratio data are compared with the lidar data and the reader does not know the altitude of Ouarzazate (1150 m a.s.l.)

Fig. 12 revised such that it shows standard height above sea level as Fig. 10 and 11