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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Atmospheric dust modeling from meso to global scales with the online NMMB/BSC-Dust model – Part 1: Model description, annual simulations and evaluation" *by* C. Pérez et al.

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We thank referee 1 for the review and suggestions for improving the quality of the paper. Please find below an item-by-item response to the questions raised.

Reviewer: This paper presents the online implementation of dust emissions parameterization in the NCEP Non-Hydrostatic Multiscale Model, called NMMB/BSC-Dust model. The modules comprising/accompanying the dust emission scheme are described in detail and the evaluation section is presented in a rather clear way based

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on a previous work of Huneeus et al. (2011). The title of the manuscript reflects the contents of the paper and the abstract is sufficient. In terms of scientific quality and significance, the manuscript provides a detailed description of the modelling system used to simulate and forecast the dust production in regional and global scales. The evaluation that accompanies the model description reveals the model's strengths and weaknesses, which should be clearly presented in the conclusions of this paper. Modelling of desert dust in regional and global scales is a topic of continuous scientific interest because of the impacts of dust in the environment and the uncertainties that still arise from describing that procedure. This online coupled modelling system is an interesting development, mostly if the multi-scale option can benefit the process of modelling the dust intrusion in the atmosphere. The specific comments and questions that follow will help to clarify some issues that have arisen during the review process and strengthen the quality of the paper, before being accepted for publication in ACP.

Specific comments Reviewer: Section 2: One of the strengths of this work would be the ability to study the dust production and distribution in both regional and global scales in an interactive way. Although the authors imply such benefit in the introduction, it is not clear if such capability exists within the NMMB model. If this modelling system can work in an interactive way between the regional and global scales (e.g. nesting option) this must be clearly stated in section 2. If not, again it must be written explicitly.

Response: The version of the NMMB/BSC-Dust model presented in the paper can simulate weather and dust at global and regional scales. The model can supply lateral boundary conditions for the regional version of the model run on any regional domain using the rotated latitude-longitude coordinate. The latest version of the NMMB that is being developed at NCEP can run simultaneously with multiple stationary and moving nests, including several levels of nest telescoping on the latitude-longitude grid. The 2-way interaction between the nests and their driving regional and/or global model is under development. We will implement the latest version of the model with 2 way nesting capability as it becomes available. This issue has been clarified in Section 2.

Reviewer: Section 2: The implementation of RRTM to treat dust as an active substance is an advantage for this modelling system. A big question arises about why the authors did not include this option in the simulations for the regional and the global scale. This should be sufficiently explained in the text.

Response: We agree with the reviewer that the implementation of RRTM to treat dust as an active substance is potential advantage for the modeling system. The scheme was recently implemented. The reason why we used the GFDL scheme (which does not include aerosol treatment) is because it is currently the operational radiation scheme of the atmospheric model (the NMMB has become operational at NCEP in October this year). The scheme has been thoroughly refined for years at NCEP to properly work with the ETA, the WRF-NMM and now the NMMB model (the three generations of operational regional models). Besides being a research tool, the NMMB/BSC-Dust is intended to provide weather and dust forecasts at regional and global scales at the Barcelona Supercomputing Center, within the Sand and Dust Storm Warning and Assessment System of WMO. In a first step, the model will be routinely run with the GFDL scheme until the RRTM scheme is not thoroughly tested for operations in the atmospheric model. Research and future contributions using the dust radiative feedback within the model are planned but it is not the subject of this contribution. In this contribution we present the model and its evaluation using the schemes that will be operational over the next months. We introduced an explanation in the text with these considerations.

Section 3.1.2: Reviewer: I propose to replace the equations 4 with the ones actually used for the computation of the threshold friction velocity, plus the expression for the Reynolds number. The reference to the work of Iversen and White (1982) is sufficient for referring to the original equations.

Response: As suggested by the reviewer, we included the expression for the Reynolds number depending on D.

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Reviewer: In the discussion about the conversion of volumetric to gravimetric water content, the reference to Zender et al. (2003b) must be incorrect. It should be Zender et al. (2003a), referring to the DEAD model publication. If the authors used the same methodology as seen in that publication (equations 7-9 in Zender et al. 2003a) this should be clearly stated in the text (without the equations).

Response: Amended.

Section 3.1.3: Reviewer: The mass fraction mi used in equation 8 probably comes from Table 1 as the notation is different (1 to 4) compared to the m1, m2, m3 shown in equation 9 (from D'Almeida (1987)). You should consider renaming the different mass fractions and add references (to Table 1 and D'Almeida) to avoid any misunderstandings.

Response: Amended

Reviewer: Indicate the values used for the mass median diameter and geometric standard deviation in equation 10. They should be the same as in Zender et al. (2003a) but nevertheless the values must be stated in the text.

Response: Done

Reviewer: What value have you used for the global tuning factor C? Was it the same for the regional and the global configuration? Did you choose the value of C to match the available observations for concentration and AOD?

Response: We have used a factor of 2 for the global simulation of year 2000 and 0.66 for the regional simulation of year 2006. This factor was chosen to minimize the overall error with respect to the observations used. The different tuning factor in both simulations is mainly due to the following factors: differences in winds over sources due to the resolution of the model, the use of a different set of observations for the optimization (type, number, distribution and temporal resolution), the global versus the regional domain, and the different year for each simulation. A sentence has been

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added to the text.

Reviewer: There is an inconsistency in the calculation of the vertical flux, concerning the soil size distribution. You have used the up-to-date STATSGO-FAO database for the calculation of the horizontal flux H and the sandblasting efficiency α, but for the vertical flux F you have used the fixed background source modes from D'Almeida. Why didn't you use only STATSGO-FAO and calculate the mass overlap Mi,k using the data available on the 4 soil sizes (mass median diameter and geometric standard deviation)? In that way the emission scheme would be coherent and you would avoid this inconsistency.

Response: We acknowledge the suggestion of the reviewer. It would certainly be a possible way of specifying the size distribution of the emitted dust that may be explored in the future.

In our model we decided to constrain the emitted size distribution with the background modes of D'Almeida, which is another possible way of prescribing the size distribution of the emitted flux. As discussed in Bergametti et al. (2007) and Laurent et al. (2009), dust models usually classify soils according to the "well-known textural triangle" defined by the three size components: sand (2000 to 80 or 63 μm), silt (80 or 63 to 4 or 2 μm) and clay (<4 or 2 μm) (Chatenet et al., 1996; Ding et al., 1999). However, this classification is based on measurements performed by using wet sedimentation techniques, which break the soil aggregates (Chatenet et al., 1996; Ding et al., 1999). This classification leads to relatively high amounts of loose clay particles that are generally not encountered in the natural soils as loose particles. In natural soils, these particles generally form aggregates of larger size (>50-100 μm). An alternative approach is to determine the soil size distribution using dry techniques that minimize, as much as possible, the breakage of the aggregates. However such measurements are limited and global estimates are not available. In our framework, we assume that the horizontal flux is rather well approximated since saltation mainly applies to large silt and fine-medium sand. However, given the current uncertainties in the small particle range over soils we preferred to prescribe the size distribution of the emitted flux with the suggested background modes of D'Almeida. We cannot agree with the reviewer that this formulation is inconsistent. We just consider it another way of approximating the size distribution of the emission.

Reviewer: Sections 4.1.1 and 4.2.1: The output from the model is calculated every 1h? Is it an average or instantaneous value? This is important for assessing the comparison with the observations.

Response: The outputs of the model for concentration and optical depths for these simulations were instantaneous and 3-hourly. The deposition outputs are 3-hour accumulations. Results were then aggregated into daily, monthly and annual values.

Reviewer: Section 4.1.1: Usually the initial and boundary conditions for dust in regional modelling applications is set to zero, providing that there is no alternative solution. With the advantage of using regional and global setups within the same model it would be interesting to consider including boundary and initial conditions from the global simulation.

Response: Initial dust conditions in the regional domain should preferably come from the previous day regional model forecast. There wouldn't be any advantage of using the lower resolution global model forecast as initial condition. Ideally the initialization may be complemented by data assimilation if available and boundary conditions from the global model. The need for global model boundary conditions will depend to a large extent on the application and the location of the regional domain. Boundary conditions from the global model for 2006 are not used in this contribution. Since the sources affecting the region are mostly contained in the simulation domain, the use of global boundary dust conditions would only slightly affect the evaluation presented. Nesting from global to regional domains with the NMMB/BSC-Dust are planned for future operational application.

Section 4.2.3: Reviewer: a) page 17584: The 2nd paragraph starting "The model also successfully..” should be moved to page 17585 before the paragraph “Figure 11...” to improve the consistency of the text.

Response: Amended

Reviewer: b) page 17586: The model overestimates and not “underestimates” the February to April AOD in Cape Verde according to Fig.13, if the station at Cape Verde is number 24 as shown in Huneeus et al. (2010). This should be corrected in the text.

Response: Amended. The model overestimates from February to April when compared to the climatology and slightly underestimates when compared to year 2000 observations.

Section 5, Summary and Conclusions: Reviewer: In general, the model performs reasonably well, taking into account the data availability for the evaluation and the complexity of the parametrization. What is missing from the conclusions is a comparative assessment of the two applications. For stations used in both simulations (regional and global) there should be a comment on the model's performance concerning the consistency between the two simulations even if these refer to different years (e.g. the regional simulation for Cape Verde shows underestimation of the AOD and for the global simulation shows an overestimation for several months).

Response: As outlined by the reviewer, the two simulations are performed for different years. The two simulations are also tuned with a different set of observations and have different resolutions. However, the global and regional simulations are consistent in North Africa and the Middle East. For North Africa, in the end of spring and the beginning of summer the model overestimates the emission over the Bodele leading to too high optical depths in Southern Niger, Northern Nigeria and Burkina Faso and underestimates the AOD over Dakar and Cape Verde for years 2000 and 2006. On the other side, the global model overestimates in Dakar and Cape Verde between February and April when compared to the AOD climatology which is explained by the strong year-to-year AOD variability in this region and season. The year-to-year variability can

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be very strong over the region in February and March as it is very sensitive to the phase of the North Atlantic Oscillation (NAO). During positive NAO winters the Azores anticyclone intensifies and the stronger easterlies over West Africa increase the dust load over the Atlantic Ocean when compared with negative NAO winters. In Figures 1 and 2 below we show the daily evolution of the AOD at the Cape Verde AERONET site for years 2000 and 2006, respectively. In year 2000, the dust load was very high with NAO indexes for February and March of 4.37 and 0.54, respectively. In year 2006, the dust load was much lower with NAO indexes of -1.24 and -1.12. The strongly positive NAO in year 2000 explains the overestimation of the model when compared to the AOD observed climatology between 1996 and 2006.

We have introduced these considerations in the text.

Reviewer: The deposition fluxes are not described very well by the model, and that can be attributed to the absence of chemistry in the model. The dust particles cannot change from the insoluble to the soluble mode which influences the ability of the particle to be deposited by wet removal processes.

Response: We agree. Also the fact that the data is not from year 2000 affects the results of the evaluation as discussed in Huneeus et al. (2011). We added a sentence in the conclusions.

Reviewer: The paragraph “For the regional model in North Africa...” which presents a companion paper should not be included in the conclusions section. If the authors wish to keep their reference to that paper, they should place it somewhere else in the text.

Response: Amended.

Technical corrections Reviewer: Page 17559 Line 5: The word “..microphyisics. . .” should be corrected. Page 17559 Line 10: “As detailed in Sect. 3.4 we have additionally coupled. . .”.

Response: Amended

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Reviewer: Page 17559 Line 25: The reference to Zender et al. (2003b) must be Zender et al. (2003a) as this is the paper where the lognormal distribution is described. The same change must be done in page 17566, line 1.

Response: Amended

Reviewer: Page 17566, line 2: The diameters in equation 10 should be written in capital letter D, to be in accordance with the rest of the text.

Response: Amended. The diameters d represent the transport bins and D the source mode diameters.

Reviewer: Page 17573, line 12: The "DQtot" must be "ΔQtot" as in equation 25.

Response: Amended

Reviewer: Page 17574, line 21: "(2001) siggested. . ." must be "(2001) suggested...".

Response: Amended

Reviewer: Page 17580, line 18: In the sentence "from the Sahara, and, to a minor degree, from the Anatolian plateau, Saharan, Negev deserts ..." the second reference to Sahara (the one in italics) must be removed otherwise the meaning is not clear.

Response: Amended

Reviewer: Page 17583, line 1: The observation stations from the University of Miami network must be 19 and not 20. Please revise accordingly.

Response: The number of stations is correct and consistent with what is used in Huneeus et al. (2011). The supplement material of the article provides a list of stations used. As in that study, we use a total of 22 stations as illustrated in figure 9 from which 20 are managed by the University of Miami.

Reviewer: Caption in Fig.5 (page 17612): The last sentence has an error. It is the "..top right corner.." and not the "..top left corner..".

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Response: Amended

Reviewer: Caption in Fig. 11 (page 27618): In the first line of the figure caption the reference to a bottom panel must be substituted by “right panel”.

Response: Amended

Reviewer: Figures 5-9, 11 and 12 must be larger to be easily readable in a print out version of the manuscript. It has been hard to distinguish the details as for example the station locations during the review process.

Response: We improved the quality of Figures 5 to 8. Concerning figures 9, 11, 12 they are similar (same resolution and size) to the ones already published in Huneeus et al. (2011). We will make sure, in coordination with the editor that in the final version of the manuscript all the figures are easily readable.

Reviewer: In Figure 13, it will be much better to align the plots as they are in Fig.9, the observations on the left and the model on the right. The consistent formats allow for comprehensible reading of the manuscript.

Response: Done

References:

Bergametti, G., B. Marticorena and B. Laurent, (2007) Key processes for dust emissions and their modeling, in Regional climate variability and its impacts in the Mediterranean area, A. Mellouki and A.R. Ravishankara (Eds.), Nato Science Series: IV: Earth and Environmental Sciences, 79, 326 pp.

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Ding, Z.L., Ren, J.Z., Yang, S.L., and Liu, T.S., 1999, Climate instability during the penultimate glaciation: evidence from two high resolution loess records, China, J. Geophys. Res. 104: 20,123-20,132.

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Laurent, B., Marticorena, B., Bergametti, G., Tegen, I., Schepanski, K., and Heinold, B. (2009): Modelling mineral dust emissions, IOP Conference Series: Earth and Environmental Science, 7, 012 006, http://stacks.iop.org/1755-1315/7/i=1/a=012006, 2009.

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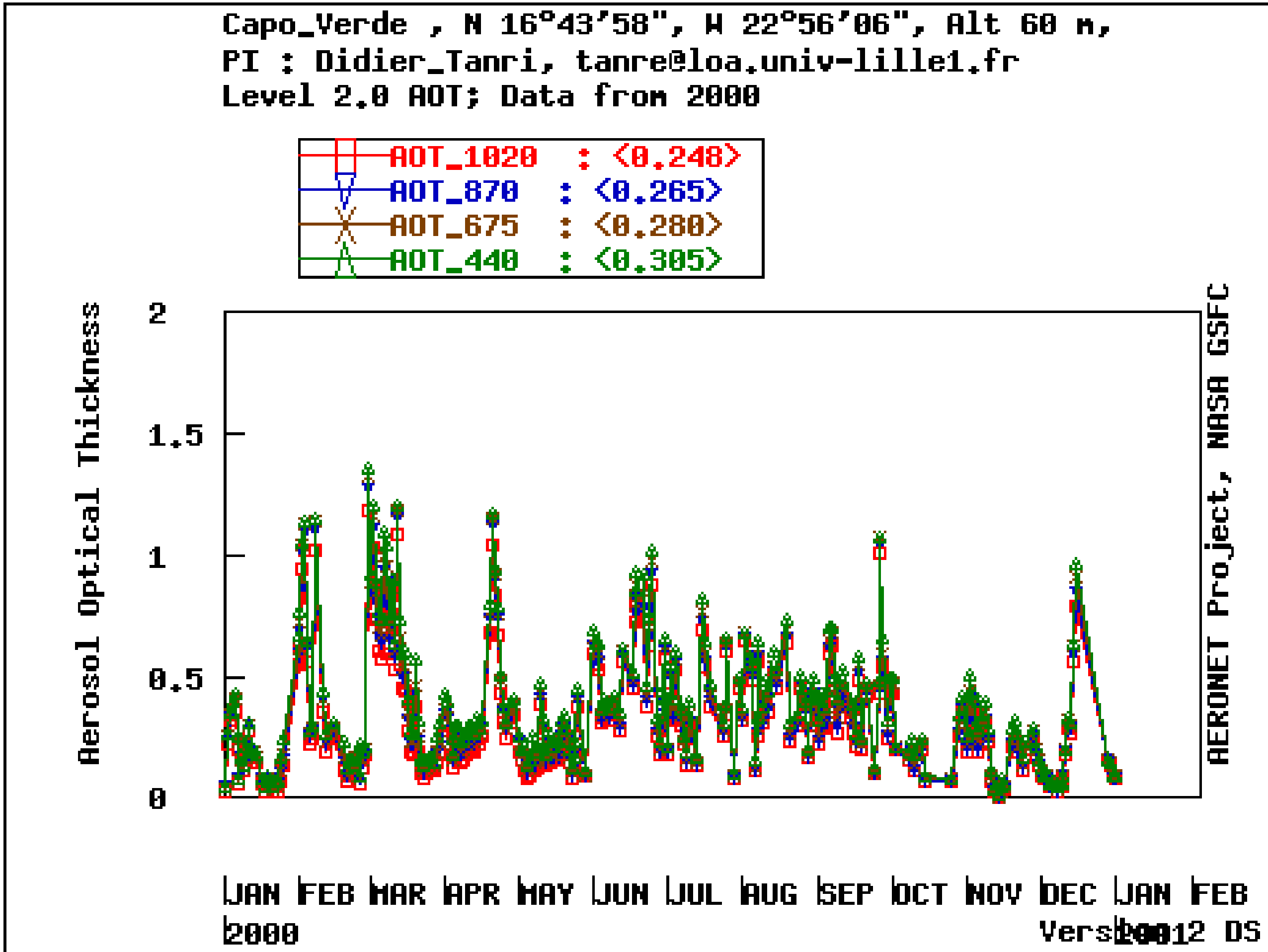

Fig. 1. Daily AOD at several wavelengths for year 2000 in Cape Verde.

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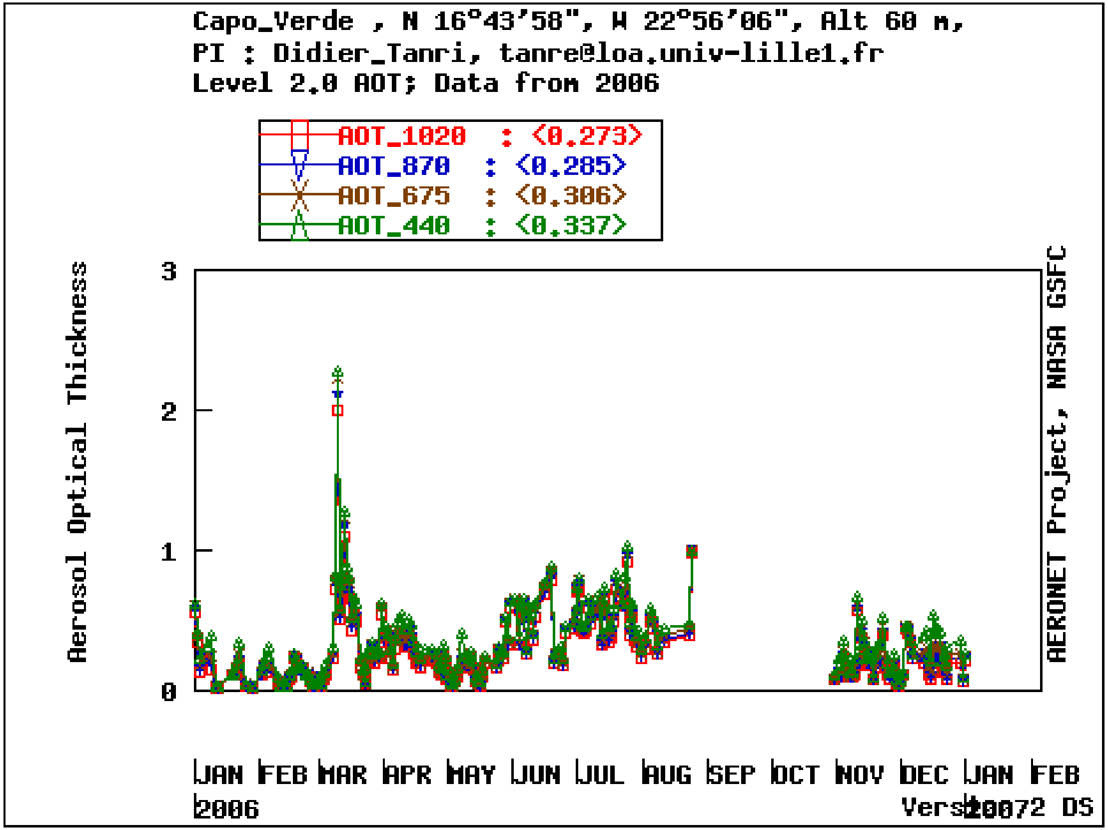

Fig. 2. Daily AOD at several wavelengths for year 2006 in Cape Verde.

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