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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Radiative effects of desert dust on weather and regional climate" *by* C. Spyrou et al.

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Response to Sebastian Otto

Dear Authors! This is a nice paper which presents radiative effects of Saharan mineral dust over land and ocean surfaces. I recommend it for publication, however, I would like to comment the following points that should be discussed before:

[REPLY]The authors would like to thank Dr.Otto for the very constructive comments and the useful references he indicated. We include few of the most recent references in the revised manuscript. As follows, we discuss the comments step-by-step:

1) p 1329, 20-21: Do the cited papers discuss optical properties as a function of the particle shape?

[REPLY]Some of the cited papers discuss the importance of the particle shape on the optical properties of dust particles. We report for example the paper of Kalashnikova et al. (2005), which deals extensively on the subject. In the new text, we also included Otto et al. (2011) that also provides very useful information on this issue.

2) Section 3: Please give a brief overview of the settings of the model, particularly of the radiative transfer solver applied, e.g., how many streams are used or how the scattering phase function of the particles is considered or what spectral surface albedo is applied for the mean land and ocean surfaces.

[REPLY]The radiative transfer solver is described in Section 4 and the references reported therein. Also, please note that in Section 5 we provide detailed information on the handling of the radiative effects of particles in the model. A small paragraph has been added in order to give more of the model technical details related to radiative transfer scheme: “The UV/visible and Near-IR surface albedo are defined using the 30sec global land use database of the U.S. Geological Survey (Anderson et al., 1976). Absorption and emission from aerosols and clouds are included in the longwave, and the shortwave treatment includes extinction (absorption plus scattering) from aerosols, clouds and Rayleigh scattering. Aerosol radiative effects are treated in RRTMG through the specification of their optical properties within each spectral interval. For the dust particles the Henyey-Greenstein (1941) phase function is applied.”

3) p 1334, 18-23: The choice of a single scattering albedo (SSA) at 550 nm of 0.95 seems to be too large as it turned out during the last years (e.g. Otto et al., 2007, 2009, 2011; McConnell et al., 2008, 2010; Ryder et al., 2013). Close to source regions dust populations contain a big fraction of large particles (of diameters greater than about 3 microns) which decrease significantly the SSA of the dust in the solar spectral range. The paper of Kahn et al. (2009) suggests indeed a SSA value close to 1 for a scenario during the SAMUM campaign. However, these remote sensing results are in contrast to optical property calculations based on in-situ measurements for the same situation (Otto et al., 2009). That remote sensing techniques may lead to discrepancies and,

e.g., too high SSA values is discussed by other independent studies (Müller et al., 2010a,b, 2012).

[REPLY]We agree with the comment that different remote sensing techniques may lead to discrepancies in the SSA values. This proves to be an added difficulty to an already complex problem. A short text has been added where we discuss these difficulties with reference to the paper of Muller et al., 2012 suggested by Dr.Otto. As long as there is not a definitive answer to this we decided to adopt the value of Ralph Kahn. Also the SSA value close to 1 proved to give satisfactory simulations as discussed more extensively below.

Since the radiative forcing of dust is a complex function of, e.g., its size distribution (fraction of fine and coarse mode), spectral complex refractive index (chemical composition), the dust load, spectral surface albedo, surface temperature, it would help the reader to interpret the results, if the authors would present lower and upper bounds as well as means of these quantities as applied in the model simulations, graphically or tabulated. It would also be nice, if the spectral optical properties (SSA, asymmetry parameter, optical depth) would be displayed, for both the solar and thermal spectral range. For example, the optical properties both in the solar range and at the thermal window region (8-15 microns wavelength) are extremely influenced by the maximum particle size (Otto et al., 2011). In combination with surface albedo and temperature variabilities, different forcings can be obtained which makes unique interpretations impossible. So I suggest to additionally consider certain scaled spectral optical properties leading to a SSA value of 0.8 at 550 nm and to compare these results with those considering the lowly absorbing dust represented by 0.95.

[REPLY]A figure has been added showing the Single Scattering Albedo and Asymmetry Parameter values used in this study for the entire spectral range, as suggested by Dr.Otto. Unfortunately repeating the entire modeling experiment for the 6-year period for different optical properties is extremely time consuming and cannot be realized. In order to test the influence of SSA value on our results, we chose the test case described in Chapter 7 (a 3-day dust episode) and reproduced the simulations with the lowest value of SSA suggested (0.8 at 550nm). We are attaching the plot below. In the plot the red line is the simulation with the SSA value at 0.95 we used, the green line the 0.8 SSA suggested by the reviewer and the blue line is the actual incoming solar radiation values at Crete (see also Figure 2 of the manuscript). As can be noticed, by assuming a less absorbing dust the model simulations overpredict significantly the solar radiation at the day of interest (7th of April 2006). This seems to be due to the fact that the atmosphere does not absorb enough energy to create the cirrus cloud as described in Section 6 of the manuscript and thus leads to the reduction noticed in the station. However in the next day the modeled incoming solar radiation is closer to the measured one. This example also shows that the combination of the optical properties of dust and the changes in the surface albedo and temperature further complicates the problem, as Dr.Otto indicates. Note also that in this work, we attempt to quantify the dust feedback in a long-term period, so it seems more sensible not to use optical values derived from individual experiments, occurred at specific areas and periods.

4) p 1334-1335, 26-l2: Actually, the non-sphericity of the particles cannot be neglected. Size equivalence and particle shape have non-negligible optical impacts. However, to deal with non-spherical particles is too time-consuming to be considered here.

[REPLY]In this work, we adopted the commonly used assumption of spherical dust particles because it permits the implementation of Mie theory for the computation of radiative parameters required by the model radiative transfer solver, and also in such long-period (6-year) simulations it would be too time-consuming to deal with non-spherical particles, as mentioned by Dr.Otto.

5) p 1335, 22: What is meant here by heating/cooling rates? Does "heating rate" mean the solar and "cooling rate" the thermal spectral range or the sum of both?

[REPLY]We discuss the changes in heating and cooling rates as the total of the spectral range (both solar and thermal). A short text has been added to clarify this.

6) p 1337, 16-27: It would be interesting to see the impact on these findings, if a lower SSA would be chosen as suggested above (see 3)).

[REPLY]As discussed in 3, by assuming a lower scattering efficiency of the suspended dust particles the incoming solar radiation would be overpredicted by the model. The test case we used to investigate the effect of SSA on model results revealed that if the dust particles are considered to scatter less, the modeled solar radiation will be significantly higher than the measured one. Thus, by using a lower SSA value we would expect to obtain higher differences between simulated and observed values and as a consequence less effectiveness at reducing model overestimation of the radiation fluxes.

7) p 1340, 11: This value of 25 W m-2 over Morocco is quite similar to the values of about 22 W m-2 (spherical particles) and 24 W m-2 (spheroidal p.) as calculated for a dust scenario based on in-situ data measured in May 2006 in Morocco (Otto et al., 2011).

[REPLY]That is a particularly useful remark for this work. It has been added to the manuscript along with the related reference as it is a strong validation of our work. We would like to thank Dr.Otto for pointing this out.

8) p 1340-1341, 24-l2: As defined by the authors, negative values of F are obtained, if F_TOA_up for the dusty atmosphere (WDE) is larger the F_TOA_up in the case of a clear-sky atmosphere (NDE). This would mean that more radiation leaves the Earth to space, that is, we have a cooling by the dust compared to the clear-sky case. This seems to be the opposite to the statement that "negative values [...] denote an increase in the atmospheric absorption", if it is meant here that an increased amount of radiation stays in the atmosphere.

[REPLY]In this paragraph we define the atmospheric absorption as the difference between the incoming and outgoing radiation at the top of the atmosphere. So basically F_TOA_DOWN – F_TOA_UP denotes the energy that “remains” in the

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atmospheric column. This goes for both WDE and NDE cases. So expanding equation (2) we get that: F = F_TOA_DOWN_WDE – F_TOA_UP_WDE – F_TOA_DOWN_NDE + F_TOA_UP_NDE. By assuming that the amount of radiation reaching the TOA is not so much affected by the presence of aerosols the F_TOA_DOWN_WDE – F_TOA_DOWN_NDE results in zero. However the F_TOA_UP_WDE and F_TOA_UP_NDE terms that remain still refer to the atmospheric absorption and not just the outgoing radiation. As such negative values correspond to an increased amount of radiation that remains in the atmosphere. As it seems to be a bit confusing in the original text, we rewrote the paragraph in order to give more clarifications.

9) p 1341, l3-15: In principle, I would expect a cooling over ocean and a warming over land, that is, negative and positive values of F as defined in the paper. A cooling over land can also occur, if the fraction of fine and coarse mode particles is very high and hence SSA in the solar spectral range is close to 1 (Otto et al., 2011, Fig. 14 top) as assumed in the present paper. In this case, the variabilities in the solar and thermal forcings at the top of the atmosphere might be of the same order of magnitude such that the variabilities in the thermal forcing due to surface temperature changes might be larger than the solar forcing. However, a change in the thermal forcing of about 25 m-2 over two different ocean surfaces, which changes also the sign of the forcing from cooling to warming, seems to be more than interesting. On the other hand, as said above, the forcing is a complex function of a lot of parameters and ambiguous. That's why, as stated in 3), it would be nice to get quantitative information about the optical properties (graphically or tabulated) that were the basis for these results of the radiative transfer simulations, especially for the situations marked by circles in Fig. 11.

[REPLY]The optical properties used in this study have been added as suggested. Also in section 5 the discussion has been extended (as discussed in comment 3) so as to address the complexity of quantifying the radiative feedback of desert dust.

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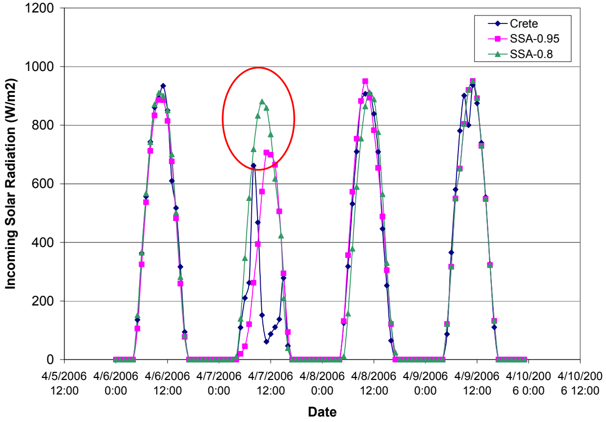

Fig. 1. Comparison of the Incoming Solar Radiation at the surface in W m-2 as measured from the station in Crete (blue line) and as simulated by the SKIRON/Dust system with the two model setups

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