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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 Anonymous Referee #3

The paper constitutes an important contribution to the investigation of the role played by Saharan dust on dynamical processes and climate in the Mediterranean. The introduction of an accurate description of the radiation transfer processes into the SKIRON model, which already includes a detailed treatment of the dust mobilization, loading into the atmosphere, and transport, allows an improved investigation of the dust direct and indirect effects.

[REPLY]We would like to thank the reviewer for the very thorough and thoughtful comments he indicated. Our responses are provided below:

A couple of points need to be better discussed. One aspect is the way in which some dust optical properties are calculated. From the description in section 5 it seems that the dust optical properties are taken from OPAC, except at 550 nm, where a higher value of the single scattering albedo is adopted. I have the impression that by combining some properties derived from the Mie theory (i.e., by assuming a specific size distribution and refractive index) with some independently assumed properties, especially if in specific wavelength ranges, may produce inconsistencies. For example, the aerosol scattering coefficient is fixed once the extinction coefficient and the single scattering albedo are defined. It is dubious what may be the effect of changing only one of these properties.

[REPLY]We agree with the reviewer that the same source of data should be used for consistency purposes. It seems though rather difficult to obtain defined optical values from many sites around the area of interest. In order to reduce any possible inconsistency in our exercises, in the cases where we adopt another value for the 550nm window, all related parameters that derive from the wavelength are updated, such as the extinction efficiency per size bin, and wavelength, by applying the Mie theory. To this end we applied a value for the 550nm that was more appropriate and up-to-date (kalashnikova et al., 2005)

Another critical aspect is that the verification of the model results is given by comparison with Aeronet calculations of the surface irradiance. I believe that the caption of table 2 ("...between modeled and measured incoming solar flux...") is erroneous,since Aeronet is not giving direct measurements of downward irradiances. If I am not wrong, this is more an intercomparison among models (although the aerosol data from aeronet are direct observations); this should be stated clearly, and the significance of this exercise should be discussed.

[REPLY]We would like to point to the reviewer that AERONET indeed provides irradiances found at:http://solrad-net.gsfc.nasa.gov/cgi-bin/type_piece_of_map_flux?long1=-180& long2=180&lat1=-

90&lat2=90&multiplier=2&what_map=4&nachal=1&formatter=0&level=1& place_code=10&data_type=flux&shef_code=P There we can find data from pyranometers at specific locations. We compare this data from 3 different stations to two different model setups: One including the dust feedback on radiative transfer (WDE) and one where dust particles are inactive (NDE).

Regarding the correlation between SKIRON and aeronet, shown in table 2, we generally have a positive bias in all cases. The inclusion of the dust radiative effects appears to reduce a bit the bias, but not in all cases.

[REPLY]As discussed in the text (lines 16-27), the intercepts of the regression lines are indicative of the difference between simulated and observed values and the positive intercept values denote the model overestimation of the fluxes. This overestimation seems to decrease noticeably over the stations of Crete and Sede Boker that are close to dust sources and the radiative dust effects are of great importance. The decrease of the intercept is negligible at the northern station of Moldova, which is the most distant from dust sources station out of those studied here, and thus the radiative forcing due to the suspension of dust particles is expected to be significantly reduced.

Also the correlation does not seem to improve significantly. The correlation seems to be strongly site-dependent.

[REPLY]Please note that the correlation between our modeled fluxes and the measurements is strong, which is indicated by the high correlation coefficients and the close to unity slopes of the trend lines. As discussed previously, the correlation coefficient is lower for the more remote from dust sources station of Moldova as the dust amounts that reach the area are reduced and play a less significant role to the radiative effects.

Part of these results may be discussed in relation to the aerosol optical properties which have been adopted. For instance, what would be the impact of reducing the single scattering albedo with respect to what assumed?

[REPLY]As we responded to the first reviewer 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 a low value of SSA (0.8 at 550nm), as shown in the attached plot. The red line is the simulation with the SSA value of 0.95 we used, the green line the 0.8 SSA 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 shows the complexity of the problem and the difficulties that derive from this. Also note 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.

How the adopted values of the single scattering albedo compare with those measured by aeronet at the three sites?

[REPLY]Detailed information on the single scattering albedo was not available on AERONET (at least for the period that we worked on here). However in this work, we attempt to quantify the dust feedback in a long-term period, so it seems more appropriate not to use optical values derived from individual experiments, occurred at specific areas and periods.

The description of the April 2006 events may be improved. At least, figure 2 does not seem to be clear for the purpose of the presentation.

[REPLY]Figure 2 is produced basically for demonstration purposes, as it proves that by including dust effects in our calculations (WDE simulation) the model manages to capture the solar radiation reduction at the station in Crete. No more details are meant to be added at this point, the analysis is expanded in the following figures.

Firstly, cloudy periods should be labeled or removed, in order to avoid confusion.

[REPLY]The only cloudy period over the station is the 7th of April. We labeled the day for clarity.

I assume that the top graph of figure 2 displays the AOD derived from SKIRON, since also data during nighttime are displayed. May the authors clarify this aspect? How these data compare with aeronet data from Crete?

[REPLY]As correctly noted by the reviewer, the top graph of Figure 2 displays the AOD derived from SKIRON model. A small text has been added to the caption to clarify this. We added this plot in order to demonstrate the model efficiency to simulate the suspension of dust in the area. Unfortunately, AERONET network does not include data for that station on the day of interest, so we cannot provide a comparison with Crete measurements here.

The bottom part of figure 2 does not allow understanding clearly what the author are meant to display. The central part of the day for cloud-free periods may be selected for the purpose, or a different way to put in evidence the differences among the different curves.

[REPLY]In the bottom part of figure 2, three lines can be seen: the blue line shows the actual data from Crete, while the other two lines present the two different model setups, the purple line presents the model simulations by including dust feedback (WDE) and the green line the simulations without dust feedback (NDE). The only cloudy day is the 7th of April 2006. In this figure, we can see that by including the dust radiative effects the model simulations by including the dust feedback (purple line) is clearly closer to the measured values (blue line) and this example highlights the importance of including dust effects on radiative transfer. A small text has been added to the caption to make the discussion clearer.

Minor points that may be clarified are listed below.

p. 1329, l. 23: what is meant by "optical intensity of dust"?

[REPLY]By optical intensity we refer to how strongly dust particles interact with radiation. We changed the phrase to "…factors that influence the magnitude of the dust feedback…"

p. 1329, l. 28: "Several studies have focused on calculating the radiative feedback of dust on a global scale". I believe that the sentence refers to radiative effects (and not feedbacks)

[REPLY]We generally refer to the interaction of dust particles with radiation using both terms: feedbacks and effects

p. 1330. l- 7-16: an intense dust event producing radiative perturbations of similar amplitude, both in the shortwave and longwave spectral ranges, has been reported also in the Mediterranean basin (di Sarra et al., 2011).

[REPLY]We would like to thank the reviewer for this information. The additional text and reference have been added to the manuscript.

p. 1334, l.6: I would suggest "... scattering of light by a homogeneous spherical particle..."

We modified the text as suggested.

p. 1334, l.11: the sentence "The real part n expresses attenuation due to scattering (non-absorbing)" does not seems totally correct; while the absorption depends only on the imaginary part of the refractive index, the scattering coefficient depends on both (real and imaginary parts).

[REPLY]The definition of the refractive index is as expressed in the manuscript. The real part corresponds to scattering processes, while the scattering coefficient depends on both parts as the reviewer states.

p. 1334, l. 18-20: what is meant by: "For the 550nm spectral window, where the extinction of the incoming solar radiation is most intense..."?

[REPLY]The phrase was rewritten as: "For the 550nm spectral window a single scattering albedo. . ...”

p. 1335, l. 7: it may be useful to specify in which units the dust load is given (if I have derived it correctly, should be in ug/m2).

[REPLY]The dust load is given in Kg/m2. The missing units have also been added to the equation.

p. 1340, l. 25: expression 2 does not seem totally correct to me. The atmospheric absorption is generally given by the difference between the TOA and surface net irradiances; moreover, the definition of atmospheric absorption should apply only to the shortwave, and consequently should be positive (or zero for totally non absorbing particles). If only the TOA values are used, one gets an information on the behaviour of the whole armosphere + surface system (and in fact it is generally used to determine if the addition of a specific component heats or cools the whole system). This may be the reason for some details of ïňĄg. 11 (e.g., the radiative effect changing sign over the ocean, depending on the season). This aspect should be considered in the discussions of figure 11.

[REPLY]In this paragraph we define the atmospheric absorption as the difference between the incoming and outgoing radiation at the top of the atmosphere. Indeed the surface processes are included, but the effect of dust radiative feedback on them ranges from limited to negligible. So we can assume that the differences between incoming and outgoing radiation is what stays into the atmosphere. By repeating this for the two model setups we obtain the effects on atmospheric absorption. Expression 2 has been changed and simplified and a small text has been added to clarify this.

p. 1341, l. 1-2: the authors attribute negative values of F in Fig. 11 to an increase in

the atmospheric absorption due to dust feedback, and positive values to a decrease. I would expect that a reduction of the outgoing flux density at TOA (F > 0) is associated with an increase of the absorption, not the opposite.

[REPLY]See the comment above. After changing eq.2 the figures are easier to interpret.

p. 1341, l. 5-10: how is the sea surface temperature (SST) treated in the model? Changes of SST induced by dust are part of the indirect effect. Are they excluded from the NDE analysis? A 20 W/m2 perturbation due to trapping of emitted radiation from the sea surface by the aerosols appears large to me. How much of this may be due to surface effects (see the comment to the use of expression 2 above)?

[REPLY]The SST used in the model for all the cases described here is updated daily from the ECMWF analysis fields with a resolution of 0.5x0.5 degrees. However we do not consider dust effects on the SST for either simulation set (NDE and WDE). We agree that the value of 20 W/m2 is quite large, however it appears only at specific locations with high SST and for the conditions described in Section 7 of the manuscript.

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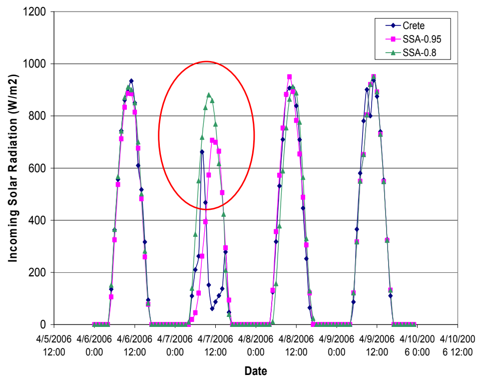

Fig. 1. Comparison of the Incoming Solar Radiation at the surface in W m-2 as measured from the station in Crete (blue line) and as simulated by the SKIRON/Dust system with two different SSA values