

Interactive comment on “Impact of dust aerosols on the radiative budget, surface heat fluxes, heating rate profiles and convective activity over West Africa during March 2006” by M. Mallet et al.

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This article calculates the direct radiative effect of dust aerosols upon the energy balance at the top of atmosphere (TOA) and surface during a severe dust outbreak associated with the passage of a cold front over the Sahel during March 2006. The effect of dust is estimated by contrasting regional model simulations that either include or omit dust. The simulated dust effect is then compared to a number of observations taken during the African Monsoon Multidisciplinary Analyses or else previous experiments.

The authors have identified an interesting test case for regional models, where an intense dust outbreak provides a strong signal that was observed by a detailed network

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of instruments. I hope other regional modelers follow the authors' lead. In general, I enjoyed the article. I have listed a few fundamental comments about the article, along with a number of minor technical comments that I would like the authors to address prior to publication. If the authors have any questions about my review, they can contact me at rmiller@giss.nasa.gov.

1. The authors show the response of various energy fluxes to dust (what they describe as the dust 'effect' in section 5.1), but it would also be useful to know the forcing, even though this cannot be measured for comparison to model values. I believe the forcing would not be difficult to calculate. The authors would simply need to do an additional experiment where the radiative effect of the model dust distribution is calculated but not allowed to modify radiative fluxes that influence the dynamics. (The forcing then corresponds to the difference in the radiative fluxes calculated in the presence or absence of the model dust distribution.) Forcing is useful (even if as opposed to the 'effect', it can't be measured) as a method to compare the importance of different external variables such as changes in greenhouse gas concentrations and solar radiation, along with other aerosol species such as carbonaceous aerosols from biomass burning. Based on previous estimates of forcing, dust is considered to be an atmospheric constituent that is of central importance to Sahel climate. It would be helpful if the authors were able to provide the dust radiative forcing calculated by their model for this case of extremely high dust levels.

2. The authors overlook a few previous studies of the impact of dust radiative forcing on climate, particularly within the Sahel, which are cited below. In addition, a number of other articles have recently appeared, subsequent to the submission of this article, in a special section of the Journal of Geophysical Research devoted to the RADAGAST experiment. This experiment focused on a detailed set of measurements of energy fluxes at TOA by the SEVIRI instrument aboard Meteosat and at the surface near Niamey during 2006. I have provided specific citations below, and I ask that the authors look at these articles, because in many cases they provide observational values that

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can be compared to their model.

3. (p.11): The authors' model predicts that the downward longwave effect of dust at the surface is small and negative during the outbreak. This is contradicted by observations at Niamey presented by Slingo et al. (2006), who in their Figure 3d show that the effect of dust is positive (corresponding to increased downward radiation from the dust layer into the surface) and of the order of a few tens of W/m². The authors explain the reduction in downward longwave in their model due to the cooling of the lower troposphere by the reduction in surface SW. This mechanism is hard to understand, since the atmosphere is actually heated by SW (as shown in Table 1). To be sure, atmospheric longwave emission is reduced by the low temperature associated with the passage of the cold front and dust outbreak, but the observations presented by Slingo et al. 2006 indicate that the dust emissivity should overwhelm this effect and increase downward emission due to the large increase in the dust load. Given the good agreement with the observed downward SW at Djougou in Figure 6, the model probably has the correct amount of dust. Is it possible that the unrealistically negative downward LW is due to an unrealistically cold air temperature computed by the model? Is the dust emissivity unrealistically low? (Alternatively, was the net (downward minus upward) surface LW plotted by mistake?) Given the discrepancy of the magnitude and sign of the model flux compared to the observed values in Slingo et al (2006), the authors need to make more effort to understand and document the cause of their small and negative value, especially because this affects their calculation of the LW divergence in a subsequent section.

Minor technical comments (identified by page and line number):

p.2 line 3 of the Intro: to this list of references, the authors should add Tegen and Lacis (JGR 1996), who calculated radiative forcing by dust, along with Myhre and Stordahl (JGR 2001), who calculated the sensitivity of dust radiative forcing to various particle optical parameters.

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p.3 line 5: Prior to INDOEX, the change to West African (and global) rainfall by aerosols was calculated for the case of dust by Miller and Tegen (J. Climate 1998). See also Miller, Tegen, and Perlwitz (JGR 2004) and Yoshioka et al. (J. Climate 2007).

p.3 line 12: Woodward (2001) is a modeling study. The authors should also cite an observational study that supports the overwhelming importance of the Sahara to the global dust load: e.g. Prospero et al. Rev Geophys 2002.

p.4 lines 10-11: please add a citation to McFarlane, S. A., E. I. Kassianov, J. Barnard, C. Flynn, and T. P. Ackerman (2009), Surface shortwave aerosol radiative forcing during the Atmospheric Radiation Measurement Mobile Facility deployment in Niamey, Niger, J. Geophys. Res., 114, D00E06, doi:10.1029/2008JD010491, who show the large AOT at Niamey in early March 2006 (Fig. 1).

p.6 line 4: please explain 'turbulent stationarity' along with how it was verified using the observations.

p.7 line 12: The authors cite Dubovik et al. (2002) as evidence that models often assume unrealistically large absorption by dust. However, this citation is based on version 1 of the AERONET retrieval algorithm, and version 2 indicates that dust absorption is actually larger and closer to typical model values. This doesn't contradict the authors' point that the radiative effect of dust is very sensitive to the assumed absorption, which is highly uncertain. Nonetheless, the authors should use a more current reference that accounts for the revision to the AERONET retrievals: e.g. Sinyuk et al, Remote Sensing of Environment 107 (2007) 90-108.

p.7 third paragraph: What were the locations of the AERONET and PHOTONS radiometers used to infer the dust index of refraction? Also, the authors use a dust index of refraction taken from AERONET during the dust outbreak, and a dust size distribution calculated by their model. But AERONET also retrieves the size distribution. The authors should show a comparison of the calculated and retrieved size distribution. A comparison of calculated and observed AOT as a function of time at a radiometer site

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should also be included to assess the realism of the simulated dust load.

Figure 3: The distinction between 'bottom' and 'down' in the caption is unclear.

p.8 lines 16-19: The comparison to AERONET over the Persian Gulf based upon Dubovik et al 2002 is out of date, given the subsequent change in AERONET retrieval algorithm. Revised values from Version 2 over the nearby Solar Village are given in the Sinyuk article cited above (Fig. 21).

p.9 last two lines and Figure 5: The model downward SW fluxes should be plotted in Figure 5 for comparison to the observations at Djougou. Also, the location of Djougou should be highlighted in one of the preceding figures, along with the location of the AERONET and PHOTONS radiometers.

Figure 6 caption: Why is the period of 10-12 of March referred to as 'pure clear-sky days' if there is so much dust in the air according to Figure 4?

p.11 line 1: One process capable of modifying the clouds was the cold front that accompanied the dust outbreak. (c.f. Slingo et al 2006)

p.11 line 3: The text should note that the regionally averaged SW effects in the figure correspond to noon.

p.11 lines 9-10: Please be explicit about how SRF_LW is defined. Is this the downward flux of LW from the atmosphere into the surface?

p.13 line 6 'reduction of total solar radiation' It should be noted that the forcing by dust also includes increased downward LW due to the increased emissivity contributed by dust. See Figure 8 of Miller et al 2009 (full citation below).

p.13 line 7 'few work have documented' see a recent article showing the effect of dust (and other atmospheric constituents) on the surface energy balance by Miller, R. L., A. Slingo, J. C. Barnard, and E. Kassianov (2009), Seasonal contrast in the surface energy balance of the Sahel, J. Geophys. Res., 114, D00E05,

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Figure 9: The authors should plot the model values at Djougou to accompany the observed time series. They could also plot the anomaly attributed by the model to dust.

p.13 last paragraph. The authors should compute the reduction in the daily averaged sensible heat flux simulated at Niamey, and compare this to the reductions inferred from observations at Niamey. Miller et al 2009 (Figure 11) calculate that the daily average sensible heat flux should drop by about 7 W/m² for a unit reduction in dust AOT, based on observations during March and April of 2006. Are the model values consistent?

p.15 line 13 (see also p.19 line 4) 'dust particles are always shown to cool' This is only true for the regional average. Figure 10 (and the text on page 14) shows that in the northern Sahel, the dust effect on upward SW at TOA is to increase the energy trapped within the earth-atmosphere column.

p.16-17 (section 5.4.2): The LW cooling simulated by the model should be compared to the value calculated at Niamey by Slingo, A., H. E. White, N. A. Bharmal, and G. J. Robinson (2009), Overview of observations from the RADAGAST experiment in Niamey, Niger: 2. Radiative fluxes and divergences, J. Geophys. Res., 114, D00E04, doi:10.1029/2008JD010497. The authors combined measurements of the surface fluxes by radiometers with OLR retrieved from radiances measured by the SEVIRI instrument. Figure 10c from the Slingo article shows that the divergence increases with aerosol extinction. In addition, the model LW divergence should be compared to the value from Figure 3f of Slingo et al 2006. (One can infer from Figure 3f of Slingo et al. 2006 that the effect of dust is to increase LW cooling by about 50 W/m²). The text should also note that the model LW cooling is influenced by the erroneous downward LW at the surface, and speculate about the value of the model LW divergence were the model downward LW similar to observed values.

p.16 'values ranging from -6 to -16 K (per) day'. It should be noted that these large

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values are found only at the surface, and that LW cooling decreases to nearly zero within a hundred meters or so above this level. Using a typical dust LW cooling of 50 W/m² over the entire column during this period as estimated from Figure 3f of Slingo et al 2006, I estimate a column-average cooling of 0.43 K per day, which smaller than the surface value cited by the authors.

Figure 13: The axis labels need to be made much larger in this figure. Also, a vertical line corresponding to zero radiative heating should be added so that negative and positive simulated values can be distinguished. (This same comment applies to Figure 12.)

p.17 lines 5-6 'logically cooled' It is true that there is less upward LW emitted by the surface during the dust outbreak (see Figures 8 and 11 of Miller et al 2009 for the daily averaged reduction). However, there is also increased solar heating of the dust layer due to absorption. Again, the reduction in air temperature is at least partly a result of the arrival of cold air associated with the front and dust outbreak.

p.17 line 10 'instantaneous surface cooling of 13C' Over what period of time does the cooling of 13C correspond to?

Figures: the color scale isn't consistent among the figures: yellow sometimes corresponds to positive values (Figures 8, 10, 11) and in other figures (Figures 4, 7) to negative values. A consistent scale should be applied to all these figures.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 2967, 2009.

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