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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Modeling a typical winter-time dust event over the Arabian Peninsula and the Red Sea" *by* S. Kalenderski et al.

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Responses to the general comments

Q: The authors claim that their event is a "typical winter time dust event", however no proofs are shown for this. Are there multi-annual data from an AERONET station available to prove this claim? How often do such dust events occur annually in winter? What is the average AOD and dust emission of such winter time dust events?

A: There are not so many AERONET stations along the Arabian Red Sea coast. The only Aeronet station, established by our group in the middle part of the Red Sea, KAUST-campus, starts operating since the beginning of 2012. Satellite observations show that in winter time dust outbreaks affecting the Read Sea most frequently happen in Arabia, that is why this event is typical for winter-time. Dust events are well correlated with strong surface winds. Jiang et al. (2009) reported that: "wintertime westward-blowing wind-jet bands along the northwestern Saudi Arabian coast, which occur every 10–20 days and can last for several days when occurring". In summer, dust transport from Africa is more frequent. Our reasoning is to discuss both winter-time and summer-time (now in preparation) and then present climatology using available satellite data to make balanced estimates. We agree that it is important to know more about inter-annual variability of AOD and frequency of such events over the modeled domain but this is beyond the scope of this case-study. The text is corrected accordingly.

Responses to specific comments

Q: p.26615, l.13-14: To put the number of 18.3 Tg into context and to understand whether this is a large or low amount of dust emission, it would be interesting to compare this value with typical emission values for Saharan dust.

A: The dust emission is area dependent and it is known that Sahara produces more dust than Arabia. But this does not diminish the regional dust effect of Arabian dust considered in this study. A comparable quantity would be not total emission but emission fluxes reported in Fig. 2. and discussed in session 4.1.1. As to the global impact of this dust outbreak event, it is interesting to compare it with the Pinatubo eruption of 1991. Pinatubo injected into the atmosphere about 17 Tg of SO2 (about the same mass as the discussed dust outbreak) that being converted to sulfate aerosols and affected the Earth's climate globally and decreased the global surface air temperature by 0.5 K. So one outbreak produces almost Pinatubo-size effect (in magnitude of emissions). Text is corrected.

Q: p. 26616: The particle size distribution is critical for the simulation of dust radiative effects, but so far the authors rely only on model assumptions. I am aware that insitu measurements of dust size distributions for the Arabian Peninsula are rare, but a number of airborne measurements are available in the literature for the Saharan dust such



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as Ryder et al. (2012) or Weinzierl et al. (2009; 2011). These data should be used for intercomparison with the model size distributions.

A: In this modeling study we adjusted model settings to make simulated aerosol optical depth consistent with the AERONET and satellite observations. In the model, dust particles are emitted in accumulation and coarse modes. Both modes are distributed log-normally. The width of the distributions for the accumulation and coarse modes are 2.2 and 1.73, respectively, and were chosen following Osborne et al. (2008) observations during the DABEX aircraft measurements of Saharan dust. The text is improved, some comparison with the SAMUM observations is added.

Q: p. 26619, l. 25: typo: “wave-dependent” –> change to “wavelength-dependent”

A: done

Q: p. 26619. l.26ff: “(. . .) imaginary part of the dust refractive index (. . .) set to 0.006 (. . .), which gives comparable results with some other studies (. . .)” –> Please indicate the studies which show comparable results of the imaginary part of the refractive index. In contrast, literature values for Saharan dust show lower refractive indices.

A: We meant to say that the results are comparable in terms of the dust radiative forcing at the TOA. The text is clarified. The references are given in section 4.3.1. We also conducted simulations for the imaginary part of the refractive index of 0.003 (moderate absorbing dust) to study the sensitivity of dust radiative effect to the dust absorption. The results are discussed in section 4.3.1.

Q: p. 26623, l. 20 ff: The authors only talk about an overall decrease in T2, but if I understand Fig. 9 correctly, an increase in T2 of about 0.1 K is observed over the Red Sea. Please clarify.

A: The simulations in this study are conducted using WRF-Chem. WRF-Chem is an atmospheric model not coupled with ocean, so simulations were conducted with the



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prescribed observed SST. Therefore air temperature change over the Red Sea is not fully responding to the dust radiative impact. The slight warming could be caused by the thermal fluxes from the lower troposphere heated by absorption of solar radiation by dust particles. This warming is not completely realistic that is why we did not emphasize it. The text is corrected.

Q: Section 4.4. Dust deposition: Please add a figure showing the change in size distribution due to deposition of large mineral dust particles as the dust crosses the Red Sea. What is the largest particle size present in the air after depositing the dust into the Red Sea?

A: We have calculated the aerosol effective diameter in the cross section along the path of the plume over the Red Sea. Despite the Red Sea is relatively narrow, the plot clearly shows the deposition effect on the size distribution. The following figure is added to the text.

Fig.1

Aerosol effective diameter [$\mu$m] in the lowest model layer along the cross section (ii) in Fig.4 over the Red Sea averaged over the simulation period. The dust plume moves from East to West and the effective diameter decreases because of the predominant deposition of large particles.

Q: Section 4.5 is quite speculative. If this section is kept, more detail should be given, and the discussion should be put into context with already existing literature. The title implies that the dust impact on the Red Sea is investigated therefore one would expect to see numbers for example for the change in sea surface temperature or the nutrient transport into the Red Sea. Instead the authors only discuss the radiative forcing and state "This should have a profound effect on the energy balance at the sea surface." Please give references for this statement.

A: There is not so much known about the Red Sea. E.g., the nutrient balance still has



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to be calculated. So some questions cannot be answered yet. But it is well known that the Red Sea experiences very little river discharge and it is very oligotrophic especially in the northern-central part we discuss in the paper. The satellite observations show that the chlorophyll concentration in this area is about an order of magnitude lower than in the southern part of the Red Sea connected with the Indian ocean (see references at the end of this section). Therefore the atmospheric deposition is a very important source of nutrients in this area. It is too early to ask for the detailed mineralogical and chemical composition of the deposited dust, but we added some information to the text. The simulations we presented here are conducted with the fixed SST so we did not calculate the SST response to aerosol forcing per se. But when incoming solar flux decreases by 25% it is legitimate to conclude that this will have a profound effect on the sea-surface energy balance and SST. We are currently working on coupling WRF with the ocean model, so in a little while we will be able to answer quantitatively to this question. At this time nobody can. The text is improved accordingly. Acker J, Leptoukh G, Shen S, Zhu T, Kempler S. (2008) Remotely-sensed chlorophyll a observations of the northern Red Sea indicate seasonal variability and influence of coastal reefs. J. Mar. Sys. 69: 191-204. Weikert H 1987. Plankton and the pelagic environment. In: Edwards AJ, Head SM (Eds.) Key Environments: Red Sea. Pergamon Press, Oxford, pp. 90–111.

Q: p. 26626, l. 9ff: "A complete understanding of the Red Sea's evolution and variability is impossible without a detailed quantification of the radiative effects of aerosols." I do not understand this statement. What do the authors mean with "the Red Sea's evolution and variability"?

A: The Red Sea has a long-term history of temperature variations. Recently, since the 1990s, an abrupt warming trend is observed. We meant to say that understanding and quantifying theses processes is impossible without accounting for the large and variable dust aerosol radiative forcing. Text is improved to reflect this point.

Q: p.26626, l.17: How much nutrients correspond to 0.65 Tg of dust? Is this a large or



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a small number compared to the nutrients present in the Red Sea?

A: There are no nutrients coming to this part of the Red Sea from the external world except from the atmospheric deposition. So it is important whatever it is. Please see our response to the previous section. We know too little about the mineralogy of the Arabian dust to say exactly how much iron it contains but we are working on this. The text is corrected.

p. 26626, l. 23: skip “most” Done

p. 26627, l. 8: add “satellite” between “temporal” and “coverage” Done

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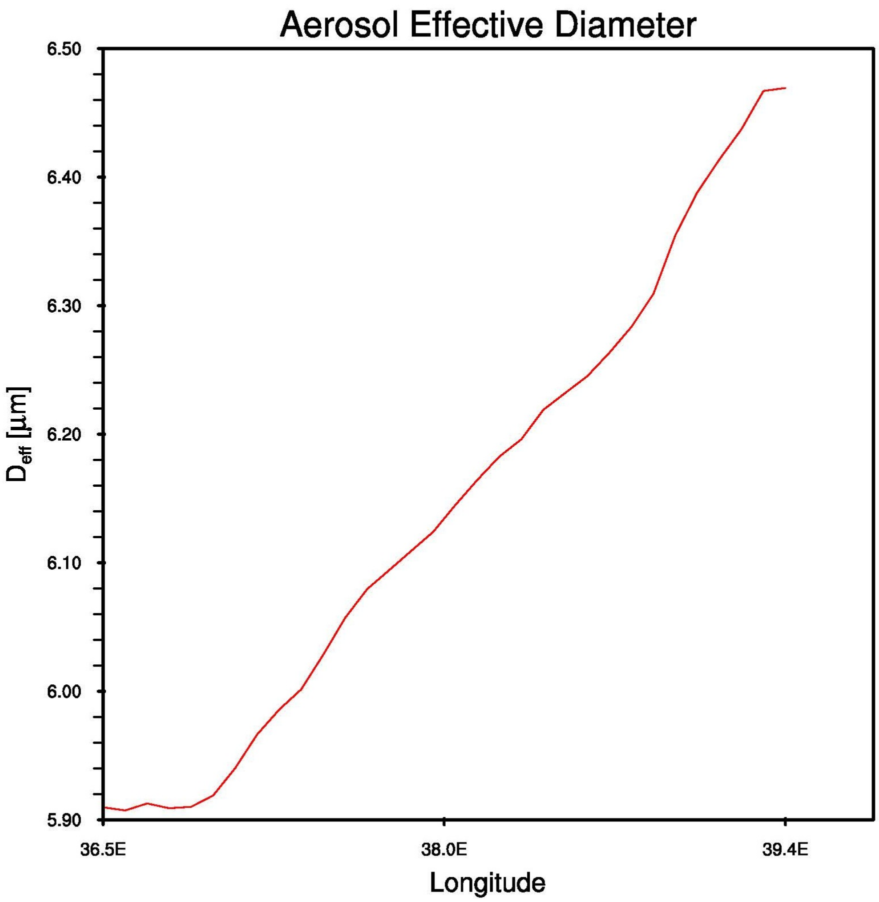


**Fig. 1.** Aerosol effective diameter [$\mu$m] in the lowest model layer along the cross section (ii) in Fig.4 over the Red Sea averaged over the simulation period.



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