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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A climatology of dust emission events from northern Africa using long-term surface observations" *by* S. M. Cowie et al.

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This paper is valuable because it proposes a comprehensive analysis of existing data on dust events over a 29 yr time period by using the systematic observations performed in the meteorological stations. This clearly provides more temporal depth to our knowledge of the occurrence of dust events. For these reasons, this paper should be published. However, significant improvements are necessary before publication. Especially, because the SYNOP data are the key point of this paper a better description of the data set in terms of interannual, seasonal and daytime representativeness is really necessary. On various

points of the paper, a more rigorous statistical approach should be used; Lastly, in many parts of the paper, the authors use words like "suggest" (11 times!), "could", "we hypothesize" etc. . . which limit the interest of the paper while in some cases, additional examinations of the SYNOP data would have helped to conclude in a clearer way.

1) Introduction: the bibliography is too much oriented on modeling works especially on the part concerning dust emissions. This does not reflect completely the state on our knowledge on the occurrence of the dust events over North Africa over the last 50-yr period. For example, there is an insufficient use of previous works dealing with the temporal variability of dust events at different scales. Even if some of the publications which have addressed these items are quite old, they content interesting points that could be discussed in relation with the scope of the present paper (among others: N'Tchayi, G. M., Bertrand, J., Legrand, M., and Baudet, J.: Temporal and spatial variations of the atmospheric dust loading through West Africa over the last thirty years, Ann. Geophys., 12, 265–273, doi:10.1007/s00585-994-0265-3, 1994; N'Tchayi et al., The Diurnal and Seasonal Cycles of Wind-Borne Dust over Africa North of the Equator J. Applied Meteorol.,36, 868-882, 1997; Moulin and Chiapello, Impact of human-induced desertification on the intensification of Sahel, GRL, 33, L18808, doi:10.1029/2006GL025923, 2006; Marticorena B. et al.: Temporal variability of mineral dust concentrations over West Africa Atmos. Chem. Phys., 10, 8899–8915, 2010. etc. . ..)

Firstly, thank you for taking the time to provide these really useful comments.

These papers are indeed relevant and useful to this work, though perhaps the Moulin and Chiapello 2006 one less so as it is more concerned with trends of dust presence over the Atlantic from satellite. We have been unable to gain access the first paper on the list, but from reading the available abstract it would appear to use a similar methodology as the 1997 paper which focuses on the diurnal and seasonal aspects of

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dust presence. A couple more sentences have been added into the introduction:

"The seasonal and diurnal cycles of dust are explored in relation to visibility and rainfall in Mbourou et al., 1997 while Marticorena et al., 2010 discusses dust concentration and strong wind frequency. The time and spatial scales of these two studies are quite different with 53 stations and three four-year periods investigated in Mbourou et al., 1997, compared to three stations for a three year period in Marticorena et al., 2010. This paper intends to build on the information gathered by these studies by including a larger spatial area, a longer data record and new data analysis techniques which aim to clearly separate emission from transport events."

2) P7427 line 17: The original paper by Bagnold is 1941. Even if the authors have used a new reissue from 2005, it is preferable to use the original reference of this work (Bagnold, R. A. (1941), The Physics of Blown Sand and Desert Dunes, 265 pp., Methuen, London).

This will be amended.

3) Page 7429 line 29: The authors mentioned that they use observations which are reported at 3 and 6 h intervals. The fact that all the data have not the same recording time is not discussed while one can imagine that, if dust events are more frequent at a certain period of time during the day (for example in the middle of the afternoon) the absence (or not) of observations at this time (for example 15h) could affect the result. It could interesting for some stations for which the sampling time is 3h to evaluate if the frequency of occurrence is changed when only a value each 6h is considered.

We have added the following information to section 2.1.1

"In the Sahel region 6-hourly sampling is more common than 3-hourly sampling. Different sampling regimes tend to be confined to within countries. For example in Mauritania nearly all stations have no night-time observations, while in Mali and Niger sampling

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tends to be limited to 6-hourly. This is documented in detail in the supplementary material P1–18."

"Analysis of six hourly data was applied to stations which have stable three hourly sampling. The magnitude of annual FDE varied at a few stations, but overall the seasonal cycle remained similar at all but one station (supp material pp19 - 28). We suspect that this is due to natural inter-station variability in the diurnal distribution of dust emission mechanisms between SYNOP and inter-SYNOP hours"

"The approach we take in the paper is to highlight the main biases which might affect conclusions that apply to large areas and groups of stations, rather than focusing on the effect of individual station biases on their individual results. "

FDE is quite different if you cut down the stations with regular 3-hourly sampling to 6-hourly sampling. We have done this for the following stations which have a healthy record: Biskra (P19, supp. material), Touggourt (P19), ElOued (P20), Ghardaia (P20), Bechar (P21), HassiMessaoud (P21), TripoliAirport (P23), Sirte (P24), Cairo (P26), ElArish (P25), PortSaid (P25), ElGolea (P22), In Amenas (P22), In Salah (P23), Mersa Matruh (P24), Luxor (P26), Asswan (P27) and Kharga (P27).

While there is some variation in the magnitude of FDE (green and red combined), overall the seasonal cycle is similar with a peak in spring still occurring at most stations. At the stations where the annual FDE clearly increases (e.g. PortSaid, ElArish) or decreases (Asswan) when 6-hourly sampling is used it is probable that these stations have a dominant dust emitting mechanism, perhaps caused by a local wind regime, which mainly occurs at a particular SYNOP hour and is sensitive to the sampling time. At Kharga the main FDE season switches from spring to summer, though it is not clear why. It is perhaps not possible to explain a general effect of reducing 3-hourly sampling to 6-hourly sampling because – as shown in supp material, P19–28 – the impact of this will be variable on a station-to-station basis.

4) P 7431 lines 14 to 25. The main problem with these data is obviously the

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representativeness of their sampling and the fact that they can be compared one to another without bias. This implies that the sampling is sufficiently homogeneous in terms of year (because it could exist interannual variability that could induce bias if data are not sufficient for years with a low (high) number of dust events), in terms of season (because there is a seasonal cycle of dust emission in North Africa) or in terms of day (because there is a diurnal cycle of dust events). The information provided by the authors does not allow to have a clear idea on how these potential bias are accounted for. This should be explained with more details because these data are the key point of this paper. For example, it is mentioned that stations with less than 500 observations (of dust emission, I assume, is it correct?) per year for 5 years or less are marked A and those with less than 500 observations for more than 5 years are marked B. But it seems at least as much as interesting to know how much synop observations (not only dust emission) have been reported during the year and when these observations have been recorded? Only in wintr? Only during day time? All along the year? A better description of the available data is absolutely necessary to have a clear idea of what it can be concluded or not from these data.

The 500-observation criterion applies to all observations, not just those with dust emission. So the criterion does, to some extent, consider the point of how many SYNOP observations altogether there are. The number of dust emission reports is considerably less (see supp material P 29–99 for each of the 70 stations). These plots do not provide any evidence that variability in the number of observations in each year, or each season, have a considerable affect on the interannual variability of dust emissions.

A detailed description of the bias at each station is perhaps not possible within the scope of the paper, as there is a great deal of local variation. We have investigated all of these aspects of the record however, and highlighted in the paper the biases we think could impact the results – a daytime bias and a much shorter record. A more detailed description of the data in respect to seasonal reporting and time series (P 29–

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99), SYNOP hour (P 1–18) are now included in the supplementary material and the reader will be referred to these in the text.

The biases can only be very generally accounted for, as the variability in data sampling is huge between stations. We cannot really comment on the seasonality of dust sampling as it is impossible to know if dust is absent simply because surface winds and meteorological conditions were not right. We have looked at the seasonal time series of all observations and these are presented in P29–99 of supplementary materials. For example, where there is a significant lack of night-time data, such as in the Sahel, it is discussed in the paper how this could affect dust emission statistics as night-time dust emitting phenomena such as haboobs may be under-represented at biased stations. The variations in data sampling are so large (see supplementary material P1–18, 29–99) between the different stations that it is impossible to discuss and document the effect each one would have on the analysis.

5) P7432: The choice of NDVI for tracing possible temporal changes in emission threshold can be really discussed. Beyond the comment addressed by N. Mahowald on the accuracy of the NDVI for low LAI as observed in semi-arid regions, and since dust emission is the main objective of the paper, information on rainfall at the station can also be really valuable (even if it is no a direct indicator of the soil moisture). In most of the case, Rainfall immediately stops wind erosion, even if high wind speed occurs and a knowledge of the rainfall at the station could limit the spread when linking wind speed and dust emission. Moreover, recent study by Pierre et al. (Impact of vegetation and soil moisture seasonal dynamics on dust emissions over the Sahel, J. Geophys. Res., 117, D06114, doi:10.1029/2011JD016950.) clearly shows that soil moisture is probably the main driver (more that vegetation) of the seasonal change in erosion threshold in the Sahel.

Thank you for the reading suggestion. After carefully comparing Figs. 6 and 7 in the Pierre et al. paper, we can see that in the parts of the Sahel where dust emission is

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not largely inhibited by vegetation, soil moisture is the dominating factor.

We had a closer look at the precipitation information contained in the MIDAS SYNOP dataset. Unfortunately, the majority of values are blank and there is no documentation to advise whether this is because there was no rainfall or there was no reading. If we ignore the blank values and only use those which have reported a number, between 1 – 5 % of rainfall values are greater than 0.00 (up to 17% at Elbayadh situated in the lee of the Atlas mountains). We found that out of 18387 observations of high winds with no emission from the 70 stations, 434 events (2.3%) experienced a documented rainfall event in the previous 24 hours. This provides evidence that some high wind events do not produce dust due to high soil moisture. However, the incompleteness of rainfall records is a major problem, so this effect cannot be quantified this way.

A respective comment has been added to the text:

"Out of 18387 observations of high winds with no emission from the 70 stations, 434 events (2.3%) experienced a documented rainfall event in the previous 24 hours. This provides evidence that some high wind events do not produce dust due to high soil moisture. However, as the majority of rainfall values are blank in the SYNOP records, and we cannot ascertain if this is because there was no rainfall or no reading, we are cautious of using SYNOP precipitation to investigate this any further."

6) P7434 line 2 : suppressed "all being close together" (considering the range of wind speed for erosion threshold, 7.5 and 9.25 m s-1 are not so close).

This sentence has been removed.

7) P7436 line 11: it is unclear what is called "the semi-arid transition zone between the Sahel and the Sahara". In fact, it is not completely what you are calling Sahel, Northern Sahel, etc. . . Please precise as much as possible the corresponding latitudes.

This sentence was referring to the earlier statement in the paragraph "All eleven sta-

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tions with FDE > 10% are located between 15 and 23 N (large circles, Fig. 4). ". For clarity we have included the latitudes again and added a reference to Klose et al., 2010:

"This pattern indicates that, although dust sources are found across the entire region, dust emission is generally more frequent in the semi-arid transition zone between the Sahel and Sahara (15–23°N). This is in agreement with the identification of a "Sahel dust zone" (Klose et al., 2010), though their study included transported events."

8) P7436 lines 17 and following: the explanation provides for the high dust emission frequency at least for the Tunisian station of Remada and the Algerian station of El Borma is not satisfying and probably wrong. The stations are far from the Chotts region and I do not understand what the authors want to suggest when indicating "this may have to do with their proximity to the Mediterranean Sea".

We decided to take this sentence out. See reply to reviewer 1.

9) P7437 lines 1-2: maybe it is only a problem of wording but the sentence "Overall this analysis demonstrates that emission events contribute significantly to all reported dust events in this region" is just an evidence.

This sentence has been reworded to the following to highlight the comparison between emission events and transported events.

"Overall, this section demonstrates that emission events contribute significantly to the frequency of all reported dust events, which includes transported dust, in this region"

10) P7437 lines 29-30: Why did not the authors test their assumption that the large difference in T50 and T75 in the Sahel is mainly due to an increase of the threshold in summer? More generally, the text contains a lot of "suggest" (11) or "could" while some additional treatments would have probably allowed to express a more clear conclusion.

The seasonal variability in thresholds is discussed for grouped regions in 3.2.2. In

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this section we discuss the role of precipitation events in the early growing season. Thresholds are highest when vegetation growth is at a maximum in autumn (P7438, Line 18. See point 14 where we insert a reference to Fensholt et al., 2012 here too).

11) P7460 Figure 4: It will be probably more clear for the reader to have two maps (instead of one), one for FDE, one for the ratio emission-transport with only black squares of different radius on each. Figure 7 is too small and most of the graphs cannot be read (especially the NDVI line).

We hope that the addition of the individual plots shown in Fig. 7 of the main paper, in the supplementary materials P100 -117, which the reader will be referred to, will be satisfactory.

12) 3.1.3 and 3.2.1: the method used to cluster of stations is not objective ("this was done subjectively by looking for similar characteristics. . .") while there are many statistical methods allowing to perform objective clustering. In the same way, the significance of the seasonality or its link with NDVI is not established on real statistical basis. In fact the authors assume a priori the reasons for which the stations should be grouped as they did: they used mainly considerations on meteorological pattern (circulation, precipitation,etc..) and then they can only concluded on the agreement with the starting hypothesis. Why did not the authors use such powerful statistical approaches allowing classification without a priori?

Due to the multidimensional nature of the problem we are investigating, our concern was that the time invested in working out how to use the statistical methods (we did consider a PCA analysis) would not be well spent, as the design of the metric would require many subjective decisions too. In some regions we wished to consider the quality flags we applied earlier, and information from the literature. Not all of the information which went into the decision making process is included in section 3.2.1., such as descriptive knowledge gained from literature, but what is there is deemed enough

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to justify the choice of grouped stations.

13) P7441 line 20: "We hypothesise that this is due to infrequent early season precipitation events. . .". This hypothesis can be verified with the SYNOP data.

As discussed in point 5, the precipitation fields are not complete enough for a reliable analysis.

14) 3.2.3 Seasonal cycle in dust emission. There is almost no references in this part while many works have attempted to discuss he seasonal variability of dust emissions in the Sahara and the Sahel. How are these results in agreement with previous studies that have used observations from satellites, photometers or local stations? This should discuss.

We don't presently compare to many other studies as we are specifically looking at the frequency of emission, which is quite different to visibility and concentration, which has been studied in the past. We are also cautious about the difference in spatial and time resolution of other studies too. We do refer to Klose et al., 2010 when discussing the Sahel "dust zone".

Some changes have been made to the manuscript regarding this comment:

P7438, Line 13 "Faya, the only station in Chad, shows high values of both FDE and DSF during the winter half year (Washington and Todd, 2005).." – Washington, R., and M. C. Todd (2005), Atmospheric controls on mineral dust emission from the Bode′le′ Depression, Chad: The role of the low level jet, Geophys. Res. Lett., 32, L17701, doi:10.1029/2005GL023597

P7438, Line 18

"in Autumn, following the summer rainfall maximum (Fensholt et al., 2012)" - Fensholt, Rasmus, et al. "Greenness in semi-arid areas across the globe 1981–2007âĂŤAn Earth Observing Satellite based analysis of trends and drivers." Remote Sensing of Environment 121 (2012): 144-158.

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P7443, Line 20 remove sentence “FDE is high during winter and spring and dips during the summer and autumn, when the monsoon influence reduces emission by changing the soil type and wind regime (Fig. 8d and e)”

and insert

“A similar effect on dust concentration was observed by Marticorena et al., 2010 for two stations located within the C and W Sahel regions.” Marticorena, B., et al. "Temporal variability of mineral dust concentrations over West Africa: analyses of a pluriannual monitoring from the AMMA Sahelian Dust Transect." Atmospheric Chemistry and Physics 10.18 (2010): 8899-8915.

P7444, Line 10 insert sentence

“Extremely intense, local emissions were found to be important to dust concentrations in Marticorena et al., 2010 in the Sahel summer months, associated with the passage of MCSs. However, with their short durations at the observation stations of less than 1 hour, these might not be properly represented by the 3 hrly SYNOP data used here”

P7444, Line 14 insert sentence after “..DSF. ”

“..DSF. This summer maximum is also identified in TOMS AI measurements (Englestaedter and Washington, 2007) ” - Engelstaedter, S., and R. Washington (2007), Atmospheric controls on the annual cycle of North African dust, J. Geophys. Res., 112, D03103, doi:10.1029/2006JD007195

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