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Interactive comment on "February 2017 extreme Saharan dust outbreak in the Iberian Peninsula: from lidar-derived optical properties to evaluation of forecast models" *by* Alfonso J. Fernández et al.

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Attached also in the pdf.

Firstly, the authors claim that this is an outstanding dust outbreak, but this is not really assessed from a quantitative point of view. The authors should use the long time series that have been gathered in the framework of EARLINET and AERONET to demonstrate this. Without this "climatological" perspective, the case discussed here is just another dust case. A proper justification is given in lines 91-99 Secondly, the origin and evolution of the dust outbreak should be better explained. The outstanding nature of the dust outbreak could very well hold in the peculiar meteorological situation

leading to it, so it is important that more discussion be dedicated to this aspect. What is the meteorological situation that led to this episode? This is important as one of the objectives of the paper is to assess the performance of a couple of operational dust forecast models: understanding the deïňĄciencies of the dust models in representing the dynamical processes responsible for the dust outbreak will be quite useful in this performance assessing study. The origin and evolution of the dust and a better documentation of the episode are now discussed in section 3.1. On one hand the back-trajectories during the period of study are presented, as suggested by a reviewer, and the related discussion introduced in the manuscript (lines 358-373). On the other hand and also as suggested by another review, Fig.1 was modified to include several plots that not only show the geopotential height at 850 hPa, but also the surface wind friction velocity, which is a good indicator of possible dust emissions from deserts. The related discussion is included in the manuscript (lines 294-322). As a non-native English speaker, I dislike saying this, but the English should really be improved. Also, the formatting of the references in the text is not standard... The English has been checked and also the references The paper needs major and mandatory modiïňĄcations before being acceptable for publication in ACP. Minor comments Abstract : - Unprecedented... meaning what ? Unprecedented means that we have not seen something similar before. Of course, Saharan dust outbreaks occur in the Iberian peninsular frequently but not with such high aerosol load and to such spatial extent. Please check the data referred in lines 91-99. You have not seen such an event over the IP before? How far back goes you series? No, we have not seen it before at such level in terms of aerosol load and at this spatial distribution. This idea is already presented in the text. The series asked by the reviewer are now included in the supplementary material. - Extreme what is your deïňĄnition of extreme? A definition of extreme is introduced in lines 92-94 Introduction - line 58-59: this sentence is unclear, please rephrase. Torrential rain leads to weathering and in turn alluvial deposits in more or less ephemeral river beds... then wind kicks in to lift the dust... We have removed "torrential rains in order to make it clear -line61: 5000m...This case occurred in winter: 5 km is the maximum altitude

reached by the top of the PBL over the Sahara... In the summer the PBL top can reach 7 km, see results from FENNEC over the Sahara. The referee is right, in summer the PBL top can reach 7 km, but as this event took place in winter, we firmly believe is more convenient to give references about this phenomenon for winter time. - line 83: “clear summer prevalence”: meaning there is no dust max in the summer ? Prevalence of clear air? How is this different from the central Med basin? Please clarify. Clear means evident, unambiguous. I have removed the adjective to not mislead conclusions - line 87: Sharav cyclones do appear in the winter (generally jan-fev), see Bou Karam et al. 2007 Sharav cyclone is now mentioned where we suggest it may be related - line 103-104: not true, there is a large amount of literature on the link with meningitis (chiapello, Martiny in Dijon) Although the precise role of dust on the meningitis development is still not well understood, the authorst ackowledge that there is a large amount of literature on the subject (Chiapello, Martiny in Dijon). However, the sentence in the manuscript referred to a broader context of several possible health issues related with poor air quality when dust amounts greatly increase in the air. A reference is now added in the sentence.

- line 123: how is the horizontal distribution obtained? Via the multi-site approach? Yes, lidar stations at different sites. - line 128: what is the AOD limit for active and passive retrievals not to be available ? There is a large extinction and consequently a poor radiative flux to be collected. Retrievals can not be performed properly under such conditions. - line 128-130: when were these events? In September, as stated . Was it the largest previously observed over the IP? Until our knowledge, yes. Why mention this apart from the fact that they took place in other seasons? As you mentioned before these events are the largest previously observed, so the authors deemed it interesting to mention as comparative information. When was the episode reported by Priessler et al., 2011? In April. I have included it in the text - line 139: why these 2 models only? Aren’t there other model forecasts available in the framework of the SWS-WAS programme at WMO. Because we are interested in the performance of these two models since people concerning this paper have worked developing them. - line 143-144: what

scale are we talking about, and what phenomena do we know are not well represented in models over Africa? Uplifts associated with cold-pools from mesoscale convective systems? A comment is introduced - Given the long record of the AERONET stations used in the paper, it would be interesting to show the reader how this episode stands out from the climatology. This would invigorate the interest the dust aerosol community. This has been included in the supplementary section - line 199-200: what is “a great radiation extinction”? Large values of extinction coefïňĄcient? Yes - line 207-209: on what occasions were you able to determine ïAËŻaËŻ and ïAËŻ′c independently and hence the LR? If a lidar ratio profile is given is because extinction and backscatter coefficient were obtained independently. Only at night conditions were able to perform backscatter and extinction coefficients independently. When lidar ratio is predefined is constant in altitude On what occasion are you using a predeïňĄned LR. -line209: In general at day time, and also when extinction was too noisy to perform independent retrieval. It is already specified through the text. what is an“intensive”parameter? Here for LR, but later also for the Angstrom coefïňĄcient (line 211) The one which does not depend on the aerosol burden. An intensive parameter is LR and Angstrom coefficient, and extensive parameter is AOD for instance. Section 2.3 modeling - You are looking at forecasts from 19 to 22 February while the episode under scrutiny is 20-23 February... meaning you are not going back in time long enough to look at the origin of the dust event... - How many levels do the models have in the ïňĄrst 1 km? Vertical resolution may also be an issue for uplift mechanisms. - line 257: would not it make more sense to compare the model with lidar data in the [t-30 min, t+30 min] interval? The authors have revised this point and made the following clarification in the text. Depending on data availability at each site, the profiles considered are actually averages over durations of 30 or 60 min. 30- (60-) min. duration lidar profiles have been compared to model profiles at time if their starting time was included in the interval ( ). In case two consecutive measurements fulfil this criterion, the measurement which was running at time is selected. Section 3 - 3.1 Synoptic situation: more charts are need here to explain the situation, especially 10-m winds (for emissions) and mid-tropospheric winds (for trans-

port) through the event, like what is done with Meteosat images. One MSLP chart from ECMWF is not enough for the reader to understand the origin and fate of the dust lifted over Africa this is transported of the IP. From the Meteosat RSB images it looks like a low pressure system is involved in the evolution of the situation. Could this be a Sharav cyclone? More charts have been added in order to better describe the evolution of the meteorological situation. We opted to show the geopotential height at 850 hPa and the wind friction velocity. The geopotential height is good to document the evolution of the weather systems and to show the circulation of the low/mid-troposphere, as the wind is roughly geostrophic at this level. The friction velocity is a good proxy for the emission of dust over deserts, as it is generally assumed that the dust flux from the surface involves a power law of the wind friction velocity (u*) and includes a threshold wind friction velocity, that depends on the source specificity. With these new charts the discussion of the meteorological situation was enlarged and enriched. A comment about the Sharav cyclone is also included (lines 295-296).

3.2 columnar properties: I have doubts about the quality of the AAE retrievals in Barcelona as they show a bell-shaped diurnal evolution that could indicate that the solar angle corrections are not properly done. Is this related to the nature of the dominant aerosol in the column? Also it is the only station with higher AAE on 22 February, while all the other stations show very low AAE. The Ångström exponent calculated with the AOD at 440 and 870 nm, AE, in Barcelona on 22 Feb. is different from the other stations because, Barcelona being northeast of the Iberian Peninsula and given the synoptic conditions, it is not hit completely by the event on 22 Feb. As can be seen in the Fig. 2c, 2d, 2e (revised manuscript) Barcelona is hit by a filament-type dust plume which sweeps anticlockwise between 21 and 22 Feb. The AOD diurnal variation on 22 Feb. that can be seen in the figure below with several peaks during the day, at 08, 10 UT and towards the evening, are related to the crossing of these filament-type dust plumes. A direct consequence is the drop of the AE at these periods, resulting in a bell-shaped diurnal evolution on the compact figure 3 of the paper. To reliably discard an erroneous correction of the solar angle in the raw AERONET data, we also plot below

the diurnal evolution of the AOD and the AE in Barcelona on a clean, cloud-free day earlier in Feb. 2017, on the 9th Feb. The increase of the AOD starting at 12UT is linked to the accumulation of anthropic pollutants and is highly correlated with the PM10 daily evolution (see Fig. 7 of Pérez et al., 2008). The formation and accumulation of PM10 along the day makes the AE practically monotonically decreasing (see figure below) where no artefacts are visible for slant solar angles neither in the morning, nor in the evening. This lets us think that the solar angle corrections in the Barcelona data are properly done. Note that on the afternoon of 23 Feb. one AE inversion is available in Barcelona (barely visible on Fig. 3 of the revised manuscript) and it is -0.024, in the same range of values that the other stations in the presence of dust.

References Pérez, N., Castillo, S., Pey, J., Alastuey, A., Viana, M., and Querol, X., 2008. Interpretation of the variability of regional background aerosols in the Western Mediterranean, Sci. Total Environ., 407, 527–540.

22 Feb. 2017, Start of the dust intrusion 9 Feb. 2017, Clean, no clouds, no dust

- Based on Figure 3, I would say that the stations with AAE values higher than 0.6 are sensing other types of aerosols than just dust... Ths is conïňĄrmed by your analysis of SSA. What is it ? Anthropogenic pollution? If this is coming from northern EU, than this re-emphasizes the need for more ECMWF charts to apprehend the complex meteorological situation. - Between 20 and 12 February, the number of stations with higherAAE values is diminishing, consistently with the propagation of a dust front... Yes, AE=0.6 can be taken to distinguish roughly between pure dust (AE<0.6) and mixed dust or other types (AE>0.6). AE>0.6 is indicating that or the dust is not present yet, or that it is mixed with other aerosol types, or that it is present at a given height and other aerosols are present at another height (since the AE derived from AERONET is representative of the column). The origin of the aerosols outside the dust period is out of the scope of our paper, but it is very likely that AE>0.6 simply reflects anthropogenic pollution mixed or not with dust. Fig. 3 reflects very well the propagation of the dust front which chronologically hits: Granada, Évora, Cabo de Roca, Burjassot, Madrid

and Barcelona. Section 4: Evora - Figure 5: there is a sharp change in signal intensity at 1200 UTC on 21 February. What is this related to? Can this be trusted? Yes, it can be trusted. A proper explanation is given - Line 395-398: are you saying that the retrievals for the period should not be trusted because the dust load is too high for the lidar to handle?? Well, it does not mean that. It says that it may not be as accurate as it should given the circumstances. Madrid - Figure 8: same thing at 2330 UTC on 22 February in Madrid. And to a lesser extend at 0800 UTC on 23 February. - Cannot you use the Rayleigh signal from unaffected lidar proïňĄles of computed from radiosondes? Would not you expect Rayleigh extinction of backscatter to be relatively constant well above the dust layer? Still, there is a need to have a good quality reference lidar data for Rayleigh calculation at a clear atmosphere which is not possible given the aerosol burden.. It is not possible, there is no unaffected lidar profiles. Barcelona - Line 517-518: why is it difiňĄcult to ïňĄnd a clean atmospheric layer between 5 kml and the cirrus clouds above? Don't you have the same problem for the data in Marid where cirrus clouds are also observed? Why not use the P/T data from a sounding to retrieve the Rayleigh backscatter/extinction? Because the extinction is too large, then it is not possible to obtain a reliable lidar signal from this point. The P/T data is used, but still you need a lidar signal from the clear air!! In Madrid, it is possible to obtain reliable lidar signal from clear air before the cirrus. - Line 569-575: such an exercise has been conducted during the FENNEC and ChArMeX projets just to name a few... sometimes using operational models. Please refer to the relevant literature here... Literature already provided concerns such operational models.

- Figure 13: why are the lidar proïňĄles displayed not exactly the same for a given station when comparing to the 2 models? Because of the differences in model outputs temporal sequences? Right answer! Yes, DREAM has outputs every hour and NMMB every 3 hours, so that lidar measurements, in the periods indicated in the caption of Fig. 13, have been taken every hour for the comparison with DREAM and every 3 hours for the comparison with NMMB. - Line 623-624: how do you know that Evora is closer than Barcelona to the dust source. Would not you need back-trajectory analyses

to infer that? This sentence was rewritten. - Line 649: what does nervousness mean for a model?? - Line 682-685: what are the physical mechanisms at play in these tropospheric/stratospheric exchanges? To what meteorological phenomena is this related ? a cut-off low? Was such a feature observed during this event? There again there is too little details on the synoptic situation and its evolution to related any of this with the dust event. A further explanation concerning the meteorology has been introduced.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2018-370/acp-2018-370-AC2-supplement.pdf

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