Reply to the RC3's comments on "Development and evolution of an anomalous Asian dust event across Europe in March 2020" by Tositti L. et al.

Manuscript Ref: acp-2021-429

We thank the reviewer for his/her useful comments. Below are the reviewers' comments in italic followed by our replies in blue text.

This paper provides a detailed investigation of a strong dust event over Italy during March 2020. The most interesting fact is that the origin of this dust event is located in central Asia, which is a rare source of dust for Europe. The synoptic conditions before and during the dust event are also discussed. The evolution of the event is monitored by in-situ measurements from optical particle counters (OPC) at three stations located in northern Italy. These measurements are complemented by back-trajectories analysis, air quality products from the Copernicus Atmosphere Monitoring Service (CAMS), AERONET AOD, and vertical profiles from a Lidar Ceilometer. Some information is also provided regarding the particles' chemical composition. The paper is generally well written, however there are some points that must be clarified or better explained.

We thank the reviewer for his/her overall judgement of our paper. Below we have answered to each specific point raised by the reviewer.

Line 25: "supported by AOD (Aerosol Optical Depth) maps" You are not showing AOD maps in the manuscript. However, I think that the paper would greatly benefit by including a map of satellite derived AOD (such as from MODIS) or reanalysis AOD data from MERRA-2.

We decided not to use AOD maps from MODIS satellite because the satellite signal was disturbed by the presence of clouds over Italy during the event, thus only in March 28 the satellite images detected an AOD signal from the dust transit. For this reason, we decided to use the CAMS reanalysis data instead of using satellite or reanalysis AOD data, as suggested by the reviewer. Accordingly, we have modified the text as suggested by the reviewer (Section 2.3).

Line 106 "aerosol vertical behavior" please rephrase to "vertical distribution"

We modified the term as suggested.

Sect. 2.4 Please provide more information about the two air quality stations of the ARPAE Regional Environmental Protection Agency in Bologna

We added more information in the revised version of the manuscript in Section 2.4.

AERONET: Please mention if you used "all-points" or "daily averages" data.

The information that we used "daily averages" data was added in the revised version of the manuscript.

Line 244: what do you mean by "ecologically active"?

We removed the sentence.

Lines: 251-252: "derived from satellite observations" You used data from CAMS product, which merges model and observation data. Please rephrase to "derived from CAMS".

We modified the term as suggested from the reviewer.

Lines 253-267: You discuss the synoptic conditions during 20-24 March without providing the respective maps. I suggest to include the Z500 maps for the aforementioned period in a supplement/appendix. Please include in the supplement/appendix the maps for Z850 during the episode days. Also, consider including in Figure 1 the Z500 and PM10 concentrations maps for the 29 March.

At the beginning, we decided to include only a few maps, in order to limit the number of figures. Since all reviewers raised this point, we deepened the discussion and we added several other maps. Specifically, the revised figures are now the following: new Figure 1 contains the Z850 maps and Figure 2 the PM10 and the surface horizontal wind. Moreover, in the Appendix there is a new figure (Figure A1) containing the Z500 maps. Regarding the dates, the most important period in which the dust transport is active is between 24-31 March, so we have produced and described the maps during this time period. For the previous days, we provided only a summary description in the first part of the analysis.

Line 270: "with a double curvature in correspondence of the Balkans" ? What do you mean by "double curvature"? Please rephrase.

On March 25th, the flow is directed towards SW on western Black Sea, then veers towards NW on Serbia and Bosnia, and the veers again towards SW on Adriatic sea and Italy, thus with an "S-shaped" path (double curvature). However, since this behavior is well visible on the maps (especially on those reporting surface winds – see the new Figure 2), we have eliminated the sub-sentence.

Lines 350-351: "besides the seasonal evolution pattern naturally leading to a decrease going towards the warmer season at this latitude" Please provide a reference.

We agree with the reviewer that this sentence was not clear in the original manuscript. We have modified it to “besides the typical seasonal pattern at this latitude characterized by a decrease in the warmer season” and we have added a citation to Perrino et al., 2014.

Fig. 4: What about the polar plot and the wind speed & direction time-series for CMN?

We added a description of CMN polar plot and wind time-series at lines 469-480, with separate discussions relative to the different locations of Trieste, Bologna and Cimone, in which different behaviors correlated with the meteorological situation were founded.

You mention (line 375) that "the dust event was preceded and followed by weak winds, lower than 2 m/s" . However, the time series in Fig. 4 does not support this statement. For example, for Trieste, between 25-27 March we observe a persistent NE flow (ws>10m/s). During 28-29 March the wind speed decrease, while it increases again in 30 March. Over Bologna the wind speed is much lower compared to Trieste and does not exhibit clear patterns. Moreover in March 28 (day with high dust concentrations) the mean wind speed seems to be lower than before the event. Please elaborate more on the results presented in Figure 4, taking also into account the previous discussion of the synoptic conditions.

The results shown in Figure 4 are better and deeper discussed and presented in the revised version of the manuscript, in Section 3.2.1, with some hypotheses justifying the differences among the behaviors in different stations.

Line 406: please provide a short description of the algorithm and its possible shortcomings.

We added some details and a reference about the algorithm in Section 3.2.2.

Line 408: You state that there is "a negative bias" with respect to the experimental values recorded by the Regional Environmental Protection Agency in Bologna. However, according to Fig 6a the solid lines representing the concentration values recorded in Bologna ARPAE stations are slightly above the blue-dashed lines (OPC data in Bologna). Also, the red dashed line (Trieste) seems to fits better with the ARPAE line. Is there a chance that something went wrong in Fig6? Are you sure that colors represent the appropriate time-series? Please check.

“Negative bias” means that the OPC-calculated values of PM_{10} in Bologna (blue dashed line) are underestimated with respect to the ARPAE stations (solid lines), as correctly shown in Fig. 6a (now Fig. 7a). Indeed, the blue dashed line is always lower than the solid lines. However, we have checked the data from the ARPAE stations and found a mistake in the previous figure. The revised version of the manuscript contains the corrected data for PM_{10} and dust load.

Line 416-417: "while two relative maxima were detected on 27 March (36.4 μg m-3) and 22 March (35.0 μg m-3)" Please check the reported dates, they do not seem to be in agreement with the figure.

These values are referred to the blue dashed line of Figure 6a (now Fig. 7a), which, besides the maximum due to the event, show a peak in March 22 and another relative maximum (less visible on the graph) on March 27. We pointed out in the text that those values are referred to OPC data.

Line 421-423: According to Fig 6, the Trieste time-series are shorter (20/3 - 6/3) than those of Bologna, (1/3 - 18/4). From witch dates the mean PM10 values (before and after the dust event) in Trieste are calculated? Averaging data from different dates can lead to non-comparable results between Trieste and Bologna regarding the pre- and post-event mean PM10 concentrations.

The daily means averaged for such comparisons are only those of the common period 20 March – 6 April: we added some specifications about it in the text. The longer time series reported in Fig. 6 (now Fig. 7) are used only to show the "baseline" of PM10 and highlight the peak due to the Aralkum dust transport.

Fig. 6, caption: "Bologna at three air quality stations from the ARPAE network" possible typo: three-> two

The typo was corrected in the revised version of the manuscript.

Sect. 3.3.1, AERONET: Please elaborate more on the spectral variation of AOD. For example, on 28 March the decrease of AOD with wavelength is smaller. This probably is caused by a larger coarse particles fraction.

Further information of the spectral variation of the AOD, together with references, were added to the section in the revised version of the manuscript.

Line 484: "The change in dust optical properties". There is no change in dust optical properties. The aerosol optical properties changed due to the dust intrusion.

We corrected the sentence in the revised version of the manuscript.

Sect. 3.3.3, general comment: Please elaborate more on the findings regarding the chemical composition, pointing also to the differences between the analyzed dust event and typical Saharan dust events.

We thank the reviewer for his/her comment. We have added more information on the findings about chemical composition in the revised version of the manuscript.

conclusions: please write 2-3 sentences mentioning the synoptic conditions resulting in the dust event.

We have included a synthesis of the synoptic conditions in the revised conclusions.