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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Aerosol optical properties at Lampedusa (Central Mediterranean) – 1.Influence of transport and identification of different aerosol types" *by* G. Pace et al.

G. Pace et al.

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COMMENT: General Comments 1. To identify the origin of the airmasses the authors 1) employ 5-days back trajectories, 2) define three specific geographic sectors and 3) impose an "entrainment condition" (or alternatively a "permanence condition") using the information on the "mixed layer" provided by the back-trajectory model. Since the resulting classification of airmass origin over Lampedusa is one main achievement of this study, I would have expected some "sensitivity study" on these aspects. In particular: - How much the final results change if, for example, 3 or 7-days back trajectories are used instead? - What happens to the final statistics if a different choice of the A, B and C sectors is made (for example why including Spain and Western France in the

B sector?). The authors themselves recognize that "A degree of arbitrariness in the definition of the sectors exist.." and that "..a different identification of the sectors is thus possible" (page 4940, lines 4-5). But the sentence "We have verified however that this simple scheme is satisfactory for the identification of broad classes of aerosol optical properties as will be shown below" cannot be considered exhaustive since the reader does not know how they have verified that. - The source of the observed aerosol is defined according to the condition (zair-zmxl) $<$ 500 m (entrainment condition). A region of about 170 x 135 km2 (1.5°lat. x 1.5° long) around Lampedusa is excluded from the search (Page 4940, lines 3-5). What happens reducing the no-search area? Could this lead to enhance the occurrences of "local" (i.e., marine) aerosol source? (B sector). At the moment, the "unclassified" air masses are as frequent as the B-sector ones (See also the following comment).

ANSWER: Following the reviewer's comment, we added a better description of the procedure used to assess the reliability of the defined criteria. Moreover, the sensitivity study was expanded by addressing the questions raised by the reviewer. We would like to stress that, although commonly used, the combined use of column aerosol characteristics and air mass trajectories imply intrinsic uncertainties, difficult to be quantified. Critical assumptions are: - to consider the columnar aerosol load as composed by a single aerosol type. - to associate to a single geographic source the columnar aerosol load . - to associate a single aerosol type to a broad geographic region. Moreover, uncertainties are associated to the backtrajectories (e.g. those related to the geographical amplitude of the meteo grid and to the description of orography). The sensitivity study was carried out by: a) considering different length of the trajectories, b) modifying the boundary between sectors B and C, and, c) varying the dimensions of the no search area around Lampedusa. These different aspects will be discussed separately below. a) trajectory length The choice of 5-day trajectories is based on the expected spatial extent of the region influencing the aerosol distribution at Lampedusa. At a velocity of 10 m/s an airmass covers more than 4000 km in 5 days; the whole European continent, the whole Sahara desert, and a large fraction of the North At-

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lantic (including Iceland) are within a radius of 4300 km from Lampedusa. Thus, all the relevant sources that on a regional scale plausibly influence the aerosol properties at Lampedusa are potentially represented in the 5-day trajectories. Using longer trajectories implies extending the region of potential influence; moreover, the trajectory reliability decreases with its length. On the other hand, reducing the trajectory length may lead to miss significant phenomena. For example, in summer desert dust arrives at Lampedusa often following an anticyclonic circulation, leaving the African continent 2-3 days before the arrival at Lampedusa. However, the dust is loaded over the desert, and considering air mass paths shorter than 3 days would lead to non reliable results. Similar considerations apply to summertime smokes generated by European fires. The influence of the trajectory length was examined by classifying all the airmasses using 3-day and 7-day trajectories, as suggested by the reviewer. The results, express as percent change from those derived with 5-day trajectories, are reported in the table below. Note that the table includes also results obtained modifying the sector boundaries, as will be discussed below. The differences associated with the mean values of aerosol optical depth, t, and Ångström exponent, a, for the various sectors, are well below the uncertainties associated with the mean values presented in the paper and reported in parentheses in the first column of Table 2 (see text). Using 3-day instead of 5-day backtrajectories leads to a decrease in the number of African events (-5%), and an increase in the number of events included in sector C (+6%). This is due to the loss of some cases of “entrainment” in the African sector, and to the increase in the cases of “permanence” in sector C. The use of 7-day trajectories instead of 5 produces a somewhat larger effect on the results. Consistently with the previous results, there is an increase in the number of trajectories classified as African (+9.3%), and a notable decrease in the number of trajectories of sector C (-25.8%). The Atlantic-Western Europe, and the Undetermined cases increase by 5.6% and 11.2%, respectively. The use of 3-day or 7-day trajectories does not significantly modify the average optical properties of each class. The smallest number of cases classified as undetermined occur for 5-day trajectories. b) sector definition The choice of the 3 geographical sectors is

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based on the possibility to identify dominant sources of a determined aerosol type over broad geographical regions. Previous studies have shown that Central and Eastern Europe are characterized by large anthropic sources, while Africa is a well defined, spatially wide source of dust. Thus, the definition of sectors A and C is constrained by the available information on the distribution of sources. Regions excluded by sector A and C are grouped in sector B, although different solutions are possible. As indicated by the referee, the largest degree of arbitrariness is the choice of the borders between sectors B and C. In our study we adopted a conservative solution for the identification of anthropic aerosols, excluding Spain and Western France from sector C. Previous studies indicate that pure marine aerosols are rather difficult to be found in inland seas (see e.g. Smirnov et al., 2002). In the Mediterranean a continental influence is virtually always present. Smirnov et al. (2002) report mean values of t and a for "clean maritime" aerosol of 0.07 and 0.4-0.7, respectively. These values are measured at remote islands in the Pacific Ocean (Lanai, Nauru, Tahiti). They also show that even remote islands in the Atlantic Ocean (Ascention and Bermuda) are affected by the transport of different types of aerosol from the continents, and generally "mixed maritime" aerosol characteristics are found; in particular, these islands are characterized by higher mean values of t (˜0.13), and a higher variability of a. The choice to include in sector B the Mediterranean as well as Western France and the Iberian Peninsula is due to the fact that virtually all airmasses coming from the North Atlantic and expected to be representative of "clean maritime" aerosol, pass over the Iberian peninsula, where they may easily load continental aerosols. The sensitivity of the results to the choice of the boundaries between sector B and C have been tested by extending the C sector to include France and the Pyrenees, i.e. adding a region delimited by the three coordinates (50° N, -2° W), (42° N, -2° W), and (42° N, 10° E). The results are reported in the table. As expected, the number of cases of sector C increases (+4.3%), as well as that of undetermined origin (+14.1%), while the cases of sector B decrease. There are no changes in the African cases. The average aerosol optical properties of the different sectors show little variations. A more detailed identification of separate sources is not possible, due to the limited statistics and to the intrinsic limitations of the trajectories, which are based on 2.5° NCEP/NCAR reanalysis. In general, although airmasses coming from a specific sector are often primarily influenced by the dominant aerosol type of the sector, a different behaviour may emerge in specific cases. For example, summertime fires occurring near the north African coast determine cases of mixed aerosol (see page 4945, lines 12-21), or a limited passage over Africa may produce a dominant presence of dust. c) dimension of the no-search area We have verified that there are only 2 cases of "entrainment condition" occurring in the no search area surrounding Lampedusa. Air masses are in most cases attributed to sector B or C according to the "permanence condition" applied to the trajectory ending at 2000 m. All trajectories reaching the island have to cross and spend some time in the no-search area. Thus, a change of the dimensions of the no-search area would not alter the trajectory attribution. The inclusion of the no-search area in sector B appears questionable, since in most cases the continental influence appears dominant. Additional analyses aimed at isolating the contribution of marine aerosols were carried out, and are discussed in the answer to the next comment.

As a conclusion of the sensitivity study, we believe that the proposed classification is robust enough to allow the identification of main classes of aerosol properties. We have summarized the results of the sensitivity analysis in the revised paper.

COMMENT: 2. According to the author conclusions, one main achievement of the study is the aerosol type identification through both optical properties and back trajectories. A big lack of the study is that no attempt is made to identify the contribution of marine aerosol. To strengthen the manuscript (and make the chosen title - "..identification of different aerosol types" - more suited), I recommend to pay some effort at identifying the marine aerosol "signal" in the Lampedusa dataset (i.e., identify the marine aerosol contribution to the broad "mixed aerosol" (M) class). As suggestions, it would be interesting to: 1) separate the B sector into Atlantic and Mediterranean, 2) further investigate the bimodal behavior of the M-class in Figure 8.

ANSWER: As discussed above, the identification of “clean marine” aerosol in an inland sea like the Mediterranean is problematic. Obviously, there is no 5-day trajectory reaching Lampedusa that does not overpass continents. We believe that the continental influence is large in the Mediterranean, and the occurrence of pure marine aerosol is occasional (for example, it might be linked to episodes of airmass cleaning through wet removal of continental particles). We agree however that an effort aimed at identifying the marine cases (or, better, “marine dominated” cases) is needed. A new section describing the analysis carried out to identify the marine aerosol has been added to the paper. A summary of the results on the marine aerosol was added also to the abstract and in the conclusions. We feel that it is not possible to separate sector B into Atlantic and Mediterranean: this would imply neglecting some important interaction over continental regions that very likely largely affects the aerosol properties. Class M includes marine, as well all cases of mixed aerosols. The analysis on the marine aerosols shows that they are characterized by small optical depth, and a relatively wide range for the Ångström exponent. Its average value is however around 0.8, and probably corresponds to the peak at smallest values of Ångström exponent in the distribution. A comment on this aspect was added in the revised paper.

COMMENT: Specific Comments Section 1 - Page 4932, lines 5-6. There is some confusion here. Aerosol size distribution, composition, shape, vertical distribution should not be listed as “other factors” with respect to aerosol optical depth and single scattering albedo. In fact, the latters are rather a result of the formers. Aerosol physical/chemical and optical properties are not independent.

ANSWER: We changed the sentence accordingly.

COMMENT: Section 2 - Page 4933, lines 22-23. It is not clear how the averaging interval was changed during the addressed period. What’s the meaning of “...starting from 10 min in July 2001 to 1 min in 2003”? Should the value for 2002 be extrapolated?

ANSWER: The sentence was clarified.

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COMMENT: - Page 4934, line 3. What does it mean ".. a relatively large number.."? The number of averaged extraterrestrial constant was reported already in the paper (lines 7-8 of page 4934).

ANSWER: The sentence was rearranged to better clarify the concept.

COMMENT: - Page 4934, lines 27-28. Specify which "TOMS observation" is employed.

ANSWER: Information on the satellite and algorithm version was added.

COMMENT: - Page 4937, lines 23-24. The authors state that "Marine aerosol are expected to contribute significantly to the dataset as local background condition", but do not mention which are the typical background conditions encountered in Lampedusa (see also my General comment n.2).

ANSWER: The sentence was rearranged. The meaning of the sentence, evidently not well expressed, was that some contribution from marine aerosols is always present, and constitutes a background component. As discussed above, this component is difficult to be isolated. The additional analysis on the marine aerosol however defines the properties of the marine background.

COMMENT: Section 3 - The number of data actually employed in the analysis is essential to evaluate the statistical significance of the data provided. The information on "number of occurrences" given in Tables 1 and 2 clearly shows a non-uniform availability of data during the year (the sum of the autumn and winter data is only 11.5% in Table 1 and reduces down to 6% in Table 2). At the beginning of the Analysis Section, the authors should give some indication on the relative weight of data gaps sources (cloudy conditions, instrumental problems, etc..). I would suggest to move to Section 3 the sentence reported in this respect in Section 4 (page 4946, lines 27-29), further commenting the relative role played by cloudy conditions, instrumental problems, etc.. on data availability in the different seasons. - Page 4937, line 2. Specify that the 1616 cloud-free measurements refer to the 5 values of the solar-zenith angle.

ANSWER: We added more information on the data availability as a function of the season and the instrumental problems.

COMMENT: - Page 4938, line 17. It would be more correct to state "In this study, we assume that trajectories ending at 4000 m provide information on ą E", and (line 20) "We also assume that the trajectories ending at 2000 m..."

ANSWER: We changed the sentences as suggested.

COMMENT: - Page 4938, line 27. It seems to me (Figure 3c) that sector B includes not only the Western Mediterranean, but also a large part of the Central and Eastern Mediterranean.

ANSWER: The reviewer's comment is correct, and the text was changed accordingly.

COMMENT: - Page 4939, line 25 - Page 4949, line 2. In this part of the text, two different terms: "boundary layer" and "mixed layer", are used with no explanation of their meaning (these terms have different definitions in literature). The use of both terms is misleading and unnecessary, since these are used to indicate the same concept in the text. I would suggest to employ a single term (more appropriately, "mixed layer"), and possibly define it. ANSWER: We agree with the reviewer. The term "mixed layer" is used throughout the paper in the revised version, and its definitions was added.

COMMENT: - Page 4940, lines 1-3. The source of the observed aerosol is defined according to the condition (zair-zmxl) $<$ 500 m. What if the condition is met in more than one point along the trajectory?

ANSWER: This case is discussed on page 4940, lines 5-6 of the original manuscript.

COMMENT: - Page 4940, lines 3-4. Explain better how the no-search area is defined. Is it 1.5_ lat x 1.5_ long centered at Lampedusa?

ANSWER: The region is better defined in the revised paper.

COMMENT: - Page 4940, lines 9-11. I suppose the entrainment condition for the

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4000m-trajectories is only satisfied by African air masses because the mixed layer height is significantly higher over the Saharan region than over the European continent or over the Sea. This factor should be mentioned, otherwise the sentence results to be misleading. - Page 4940, lines 17-18. This sentence is not clear. Again: adding the information on the typical mixed layer height over the three regions (A, B, C) would help the reader understanding better the procedure.

ANSWER: We added the mean values of the mixed layer altitude over the three sectors as calculated along the trajectories.

COMMENT: - Page 4941, lines 11-14. Why should the number of small particles increase in summer? Please provide at least some hypothesis for that (e.g., lower relative humidity with respect to winter?)

ANSWER: Possible explanations (i.e. the increased residence time of the aerosols, mostly affecting the accumulation mode, and the increased efficiency of small size aerosol sources, like fires and photochemical smog) were added.

COMMENT: Section 4 - Page 4945, line 24. Correct “known” into “typical”.

ANSWER: The text was changed as suggested.

COMMENT: - Page 4946, line 12. It would be more correct to state “We assume that cases dominated by DD are those..”

ANSWER: The text was changed as suggested.

COMMENT: - Page 4947, lines 6-7. Results obtained with the first and the second average type are quite similar. In fact, the difference between the two values is only due to 2 months of data (July 2001 and September 2003). Is the number of data points recorded in those two months high enough to justify such double average computation?
ANSWER: The number of measurements of the 2 months corresponds to about 7% of the 304 days used in this analysis. As a consequence the mean value of t and a are very similar. Although similar, we prefer to report both results in order to distinguish

between averages made over annual cycles, and over measurement periods, often found in the literature.

COMMENT: - Page 4948, line 3. A “reduced precipitation” and a “longer permanence of particles in the atmosphere” are not independent, so should not be listed as different causes of the summer AOD increase.

ANSWER: The text was changed as suggested.

COMMENT: - Page 4949, lines 26-29. As indicated in the text, the Moulin et al. (1998) seasonal averages of dust OD are computed for the whole Central Mediterranean. Apart from Meteosat-based retrieval problems, higher values at Lampedusa (Southern part of the Central Mediterranean, i.e., close to the Sahara region) is not unexpected (see for example the South-to-North gradient of the seasonal mean dust AOD in Barnaba and Gobbi, ACP, 4, 2367-2391, 2004). This gradient should be mentioned to explain the differences found.

ANSWER: We agree with the reviewer’s comment, and modified the text accordingly.

COMMENT: Section 5 - Point 6. It would be better to provide a more quantitative information here. Due to its position, the important role of desert dust over Lampedusa is rather obvious. A quantification of this role in comparison with the other Mediterranean sites mentioned would represent a more appropriate conclusive point of the manuscript.

ANSWER: We agree that the conclusion is rather obvious. Due to the lack of long-lasting measurements at different Mediterranean sites, a comparison can be made with one or two sites, and would be would be very partial. Thus, we removed this sentence from the conclusions.

COMMENT: Technical corrections -Page 4933, lines 2-3. Correct into “...and to determine their mean optical properties”.

ANSWER: The text was changed as suggested.

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COMMENT: -Page 4933, line 19. It would be better to list here the mentioned six, 10-nm wide channels.

ANSWER: The text was changed as suggested.

COMMENT: -Page 4934, line 18. Correct into "...on the constant $<$ 0.02 (di Sarra et al., 2002)."

ANSWER: The text was changed as suggested.

COMMENT: -Page 4934, line 26. Correct into "...routinely measured...".

ANSWER: The text was changed as suggested.

COMMENT: -Page 4936, line 21. Figure 2 is not a temporal evolution plot, therefore is not possible to evaluate gaps in the record looking at it. I would correct the relevant sentence into "It is worth mentioning that there are some gaps in the measurement record due to ... "

ANSWER: The text was changed as suggested.

COMMENT: -Page 4937, lines 3-4. Correct into "..optical depth vs. Angstrom exponent.."

ANSWER: The text was changed as suggested.

COMMENT: -Page 4946, line 17. Correct "belongs to" into "originates from".

ANSWER: The text was changed as suggested.

COMMENT: -Page 4946, line 18. Correct "class D" into "sector D" COMMENT: -Page 4946, line 20. Correct "class D" into "sector D"

ANSWER: We use the term sector to indicate a link with a geographical region. We define D as "class" because it includes the airmasses which do not satisfy the adopted criteria, and can not be associated with a specific geographical region. Thus, we prefer to maintain the used notation.

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COMMENT: -Page 4947, line 1. Correct into “...number, frequency of occurrence, mean, and standard deviation ...”

ANSWER: The text was changed as suggested.

COMMENT: -Table 1 caption. Correct into “...number of occurrences (frequency)...”

ANSWER: The text was changed as suggested.

COMMENT: -Figure 3. It would be better to have the plot indicating the three sectors first (i.e., Figure 3c to become Figure 3a).

ANSWER: The figure was changed as suggested.

COMMENT: -Figure 6. It would be better to have also the date format as day/month on the x axis.

ANSWER: The figure was changed as suggested.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 4929, 2005.