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Interactive Comment

Interactive comment on "Aerosol seasonal variability over the Mediterranean region and relativeimpact of maritime, continental and Saharan dust particles over the basinfrom MODIS data in the year 2001" *by* F. Barnaba and G. P. Gobbi

F. Barnaba and G. P. Gobbi

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1) On page 4290 in section 2 (near line 21) it would be appropriate to inform the readers. . .

This information was already provided in the manuscript (page 4290, line 10, "The AOT is provided over both land and ocean merging the two different retrievals developed for the two different surfaces"). To further stress this point, in Section 2 (page 4290, line 1) we also modified the following sentence: "Aerosol retrievals from MODIS data are performed over both land and ocean surfaces by means of procedures thoroughly

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described in Kaufman and Tanré (1998)" into "Aerosol retrievals from MODIS data are performed over land and ocean surfaces by means of two separate algorithms thoroughly described in Kaufman and Tanré (1998)".

2) In Section 2.1 (the Aerosol Mask), I strongly suggest the authors to add a paragraph. . .

Based on the Reviewer's suggestion we decided to extend the discussion on the assumed aerosol mask thresholds in Section 2.1 and to provide further references.

3) In regard to the Figures in which wind fields are presented, I can not see the wind arrows. . .

On the basis of the Reviewer's remark, we are providing a new version of Figures 2, 3, 4, 5. In particular, we tried to improve the readability of panels c) by increasing the dimension of the plots. In addition, for homogeneity, the same scale is now employed for the three wind plots in each Figure. We hope this can actually improve the Figures readability. The choice of the final dimension of the Figures is up to the Editorial office, however.

In addition, the explanation on page 4293 (beginning on line 14) was partially modified.

4) It is also confusing that on page 4294, line 2 the visible SeaWifs image does not show. . .

As opposite to desert dust transport (mostly associated to high AOTs), pollution-related plumes are often associated to low aerosol optical thicknesses (see for example Figure 11 and relevant comments in the text). In such conditions, the limited optical impact of such particles does not allow their identification in the RGB composite images.

The case presented in Figure 3 is an example of that, with low AOT (< 0.09) and high FF (> 0.8) associated to the narrow continental aerosol plume detected out of the Sardinian coasts by the aerosol mask. In this case, the fine fraction parameter plays a major role in the aerosol type classification.

However, the reviewer comment highlighted that this aspect was not sufficiently explained in the text. We added the following sentence at the beginning of Section 2.2: "Wind fields are found to be particularly useful in evaluating the transport of continental aerosols. In fact, as opposite to desert dust transport (mostly associated to high AOTs), pollution-related plumes are often associated to low aerosol optical thicknesses. In such conditions, the limited aerosol load in the atmospheric column does not allow its identification in the true-color images. This also means that, in these cases, the fine fraction parameter plays a major role in the aerosol type classification".

5) It is disturbing to read on page 4297 line 15, that ground level and satellite seasonal trends..

Generally speaking, the amount of aerosols in the atmospheric column (to which the satellite measurement refer) is not directly related to the amount of particles at the surface. In fact, as evident from lidar measurements, different vertical distributions of aerosols along the atmospheric profile can be registered. For example, the seasonal analysis of the aerosol vertical distribution over Rome (Italy) (Gobbi et al., 2004) showed that in winter about 80% of the total (i.e., columnar) aerosol optical thickness resides below 2 km, but this percentage goes down to 50% in summer. Therefore, a difference in the aerosol seasonal trend obtained from surface-level and atmospheric columnar measurements is not surprising.

With respect to the MODIS vertical averaging kernel, we don't believe this plays a major role in such differences. In fact, in cloud-free conditions, at visible wavelengths and for slightly absorbing aerosols, the impact of the aerosol vertical distribution on the top-of-the-atmosphere radiance is almost negligible (note that absorption contribution to the AOT is limited even for Saharan dust, i.e., about 5% (Dubovik et al., 2002). Therefore, as opposite to the UV region, the aerosol optical properties derived from satellite in the visible would not differ much depending on the aerosol layer altitude.

It is however true that the sentence reported in the submitted manuscript was probably

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too general and, therefore, non fully correct.

In Section 3, we slightly changed that sentence ("It is also worth mentioning that surface aerosol mass measurements (PM2.5 and PM10) performed all over Europe (Van Dingenen et al., 2004; Putaud et al., 2004) show an opposite trend, i.e., summer minimum and winter maximum aerosol mass") into "It is also worth mentioning that surface aerosol mass measurements (PM2.5 and PM10) performed all over Europe (Van Dingenen et al., 2004; Putaud et al., 2004) generally show a different trend with maxima during the cold seasons, particularly at the polluted sites").

6) On page 4306, line 1, what are the IPCC variability ranges of α_{cont} and α_{mar}?

To provide the requested information, the following sentence is now reported in Section 3.2: "For example, minimum and maximum values of α = 1.8 $\pm$ 0.5 m^2/g and α = 3.8 $\pm$ 1.0 m^2/g are there reported for maritime aerosols, corresponding to "Pacific marine - accumulation and coarse mode", and "Atlantic marine", respectively. For continental aerosols, minimum and maximum values of α = 1.00 $\pm$ 0.08 m^2/g and α = 3.5 $\pm$ 1.2 m^2/g are given, corresponding respectively to "background continental - accumulation and coarse mode" and "polluted continental"".

(In the first version of the manuscript it was "As examples, α = 3.5 $\pm$ 1.2 and α = 1.8 $\pm$ 0.5 are there given for "polluted continental" and "Pacific marine (accumulation and coarse mode)" aerosol, respectively").

7) On page 4306, lines near line 13, how do the MODIS estimates of . . .

We are not aware of published aerosol mass data directly comparable to the ones presented in this study, i.e., seasonal averages referred to the Mediterranean region and differentiated in terms of aerosol types. To answer the Reviewer request, recently published modeling studies by Kinne et al. (2003) and observation-based findings by Sciarra et al. (2004) have been compared to our aerosol mass estimates at the end of Section 3.2.

Furthermore, in Section 3.1, we added a discussion on the comparison of our results with the seasonal AOT averages by Moulin et al. (1998).

See below for details.

The relevant discussion added at the end of Section 3.2: "Some comparisons of our results with similar estimates obtained from both modeling studies and observations are given hereafter.

In the case of modeling, the aerosol mass load is obtained by combining source emissions and meteorological data with atmospheric processing (chemistry, transport, etc..). A comprehensive study focusing on aerosol modules of different models was performed by Kinne et al. (2003). In that study, models including at least five aerosol components (sulphate, organic and black carbon, sea salt and dust) were considered and yearly average values of aerosol mass were computed for different regions of the world, including Europe (more precisely North-Eastern Europe). Overall, the authors highlighted significant differences between the different models in terms of aerosol simulated properties in most of the regions addressed. In particular, simulated by seven models, the aerosol mass yearly average, Y_{aerm}, over Europe was found to range between 0.05 and 0.15 g/m^2, with four models providing $Y_{aerm} \leq$ 0.06 g/m^{2}and three models $Y_{aerm} \geq$ 0.09 g/m^2. For comparison, the yearly average of the continental aerosol mass over the whole Mediterranean basin derived from our analysis is 0.014 g/m^2,which becomes 0.023 g/m^{2}when the yearly average is restricted to sectors 1, 2, and 5, i.e., closer to the region investigated by Kinne et al. (2003). It is therefore evident that our value is much lower than the modeled one. However, it should be noted that, as performed over the Mediterranean basin, our estimates are more representative of the continental aerosol export from Europe rather than of the continental aerosol burden over Europe. Moreover, some overestimation of the emissions over Europe (and consequently of the aerosol mass) was also suspected by Kinne et al. (2003) in their study.

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From Kinne et al. (2003) it is also possible to derive an indirect estimate of the yearly average of Saharan dust mass reaching the Mediterranean ($Y_{aerm,Med}$). In fact, in that study model-derived values of both dust mass emissions from North Africa ($Y_{aerm,emiss}$) and dust mass outflow towards the Atlantic ($Y_{aerm,outfl}$) are given. As an approximation, we can therefore derive $Y_{aerm,Med}$= $Y_{aerm,emiss}$- $Y_{aerm,outfl}$. In this way, we obtain $Y_{aerm,Med}$in the range 0.02 – 0.55 g/m^2(with three models giving $Y_{aerm,Med} \leq$ 0.1 g/m^2, two models providing 0.1 $<$ $Y_{aerm,Med} <$ 0.2 g/m^{2}and two models with $Y_{aerm,Med} >$ 0.3 g/m^2).

For comparison, the yearly average of Saharan dust mass over the Mediterranean derived from our analysis is 0.05 g/m^2.

Recently, the desert dust load over the Mediterranean was also estimated by Sciarra et al. (2004) in the framework of the EU-ADIOS (Atmospheric Deposition and Impact of pollutants, key elements and nutrients on the Open Mediterranean Sea) project. In that case, the true color images from the SeaWIFS sensor were visually inspected to identify presence of desert dust and SeaWIFS AOT values (at 670 nm) were converted to dust mass with α = 0.77 m^2/g. Then, monthly averages of dust load were derived for the Western, Central and Eastern Mediterranean (note that the definition of such regions is slightly different from ours). Taking into account the relative weight of the three regions in the whole basin (R. Sciarra, personal communication), the yearly average dust mass over the whole Mediterranean can be computed. For the year 2001 this is 0.036 g/m^2, i.e. within 30% of our value (0.05 g/m^2). The corresponding seasonal values are: 0.024 g/m^{2}in DJF, 0.065 g/m^{2}in MAM, 0.030 g/m^{2}in JJA and 0.026 g/m^{2}in SON. Our analysis provides the following results: 0.017 g/m^{2}in DJF, 0.076 g/m^{2}in MAM, 0.055 g/m^{2}in JJA and 0.053 g/m^{2}in SON."

The sentence added to Section 3.1:

"In the case of desert dust, the results obtained for the year 2001 and reported in Table 2 can be compared to the 11-year climatology (from 1984 to 1994) obtained by

Moulin et al. (1998). In that study, seasonal averages of the optical thickness due to Saharan dust over the Western, Central and Eastern Mediterranean were computed on the basis of daily analysis of Meteosat images. To be compared to the Moulin et al. (1998) data, the dust contribution to the total AOT in the Western, Central and Eastern Mediterranean can be computed by averaging the AOT$^{*}_{S,SEC,dust}$values in Table 2 over the relevant sectors, weighted by the area of each sector (see Figure 10 caption). In this way, we find that 8 out of our 12 seasonal averages (four seasons times three regions) are within the variability ranges obtained by Moulin et al. (1998), whereas the variability range of 11 out of our 12 seasonal averages overlaps with the ones of Moulin et al. (1998). Our mean dust optical thickness is however generally lower (about -30%), with maximum and minimum relative differences registered in Winter (-50%) and Fall (-7%), respectively".

8) On page 4307, lines near line 5: what is the frequency of occurrence of cloud pixels. . .

In the submitted manuscript, we indicated the presence of clouds as a factor likely to produce an underestimation of the dust mass (sentence in Section 3.2: "The AOT data considered in this study are cloud-screened. In fact, dust transport over the Mediterranean is generally associated with meteorological fronts so that presence of dust is often associated to water clouds. Therefore, being that dust is inevitably undetected in cloudy pixels, dust occurrence frequency is expected to be underestimated, thus leading to an underestimation of its impact in terms of mean AOT* and mass").

Since presence of clouds is expected to affect detection of continental and maritime aerosols as well, the mentioned sentence implied that occurrence of clouds in presence of dust is higher than in continental or maritime conditions. However, due to insufficient evidence of such effect, we decided not to refer to this aspect in the revised version of the manuscript and removed the above mentioned sentence from Section 3.2.

In fact, it has been demonstrated that presence of desert dust in the atmosphere affects the cloud microphysical properties (e.g. Rosenfeld et al., 2001) but it is not clear yet if the presence of dust can produce/is associated to an actual increase in the mean cloudiness. For example, the long-term study by Mahowald and Kiehl (2003) suggested a positive correlation between low thin clouds and desert dust off the west coast of North Africa, though in that study definitive conclusion could not be reached as admitted by the authors themselves. This aspect would certainly merit further investigation. However, quantification of the dust impact on the mean cloudiness is beyond the scope of the presented study.

On the other hand, the reviewer's comment highlighted that some information on the cloud occurrence variability was missing in the submitted manuscript. We then added the following paragraph in Section 3: "In general, occurrence of cloudy pixels in the investigated region strongly depends on the season and latitude. During 2001, minimum incidence of clouds (mean cloud fraction $\leq$ 20%) was registered in Summer in the Eastern part of the Mediterranean basin (latitudes $<$ 40° N, longitudes $>$ 15° E) while maximum incidence of clouds (mean cloud fraction $\geq$ 70%) was registered in Winter above 44° N. We therefore believe that the seasonal averages presented provide reliable statistics even in the worst cases of highest cloud occurrence (i.e., about 30% of successful retrievals)."

To complete the answer to the Reviewer remark, also note that quantification of the dust mass underestimation produced by assuming a mean mass-to-extinction factor α_{dust} = 1.36 (rather then lower values as often employed in literature) is now given in Section 3.2 ("On the whole, this variability is expected to produce a maximum dust mass underestimation, dM/M, of the order of 50% close to the dust sources (dM/M = [(1/0.93 – 1/1.36)AOT]/(1/1.36)AOT) $\cong$ 0.47)").

Relevant References (not included in the manuscript):

- Mahowald, N., and Kiehl, L., "Mineral aerosol and cloud interactions", *Geophys. Res. Lett.*, 30, 9, 1475, doi: 10.129/2002GL016762, 2003.

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- Rosenfeld D., Rudich, Y., and Lahav, R., “Desert dust suppressing precipitation: A possible desertification feedback loop”, *Proc. Natl. Acad. Sci. U.S.A.*, 98, 5975 – 5980, 2001.

Minor comments

Page 4288, line 27

We changed “by such aerosol “fine fraction”” into “by the aerosol fine fraction”.

Page 4289, line 6

The sentence has been corrected into: “Moreover, we evaluate the contribution to the total AOT of continental and desert-dust aerosols over the Mediterranean basin (in addition to the maritime aerosol one)”. Therefore, “maritime aerosol one” indicates the “maritime aerosol contribution”.

Page 4289, line 13

Done

Page 4290, line 26

Done

Page 4291, line 6

Done

Page 4292, line 14

We changed the sentence into: “These assumptions would classify as “maritime aerosol” both dusty conditions with AOT < 0.3 and continentally-affected conditions with AOT < 0.3 and FF < 0.8”.

Page 4294 , line 26

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We changed the sentence into: "It is worth noticing that, in contrast to the pollution advection pattern occurring at the lower levels, the wind field in Fig. 4c . . . ."

Page 4296, line 19

Done

Page 4297, line 29

Done

Page 4298, line 4

Done

Page 4298, line 8

Done

Page 4298, line 18

Done

Page 4298, line 23

We changed "North-North Eastern" into "North and North-Eastern".

Page 4298, line 27

Done

Page 4299, line 26

We could not understand this suggestion since no reference to 2001 is made at that point.

Page 4306, line 1

The relevant sentence has been fully revised in this new version of the manuscript.

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Page 4310, line 10

Done

Page 4310, line 19

Done

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