

Interactive comment on “Modelling the direct effect of aerosols in the solar near-infrared on a planetary scale” by N. Hatzianastassiou et al.

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I. General Comments

The paper has been revised taking into account the comments of the Referee. In particular, the results have been explained more thoroughly and accurately, following his specific comments.

II. Specific Comments

1. In the Abstract, more emphasis was given to the global mean DRE values rather than to maximum values, as suggested by the Referee. Thus, the maximum values were removed from the text. Nevertheless, in Section 7 (Conclusions) and in the body of the text, the computed regional values are still discussed since it is not only the global mean aerosol radiative effect that is relevant to the climate of the Earth-atmosphere

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Discussion Paper

system, but also regional values affecting features of regional climates. However, even in the Conclusions (Section 7), priority was given to the global mean DRE values.

2. We accept that it might have been some confusion concerning the nature of aerosol DRE at TOA, especially by the colours used in the aerosol DRE figures. We would like to clarify that our DRE values strictly correspond to Eq. 11 (page 6, line 25) for every DRE component (TOA, atmosphere, surface) without making any assumption about sign relative to downward or upward direction of radiation, as mentioned by the Referee. Although we could easily adopt such an assumption, we prefer to work in this paper in the same way as in the papers by Hatzianastassiou et al. (2004a,b, Tellus-B, UV-visible aerosol DRE). Nevertheless, to avoid possible confusion by the colours used in (Figs. 4-6), the colorbar scales were changed in the way that aerosol cooling corresponds now to blue colours whereas warming is associated with reddish colours.

3. Yes, that was exactly the intended meaning. This is now stated more clearly in the Introduction, page 2, 2nd paragraph, lines 1-3.

4. A brief description for the treatment of solar radiation reflection from the Earth's surface is given in Section 2, page 6, lines 6-21. Also, more information is given for GADS aerosol properties (Section 3.1, page 8, lines 2-12) and for the re-computation of GADS aerosol properties depending on actual relative humidity (Section 3.1, page 8, lines 23-27). More information can be found in the references provided.

5. We would like to clarify that we only performed interpolation, and not extrapolation. Reference to extrapolation is now deleted from the text in section 3.1, page 8, line 33. Concerning interpolation, we would like to note that for each spectral interval in the solar near-IR, we use a nominal value for each GADS aerosol property, i.e. aerosol optical thickness, single scattering albedo and asymmetry parameter. This value corresponds to the center wavelength of the interval, and it is computed through interpolation of the adjacent values. Unfortunately, it is not possible to quantify errors caused by interpolating such properties, since this would require more detailed spectrally resolved aerosol

properties. These properties would constitute the truth, to which the interpolated quantities would have to be compared with. Unfortunately, such aerosol properties are not available. In addition, note that the spectral resolution of GADS aerosol properties is high, since these are provided at 29 wavelengths from 0.85 to 10 microns (see Section 3.1, page 8, lines 29-30).

6. In Section 3.1, page 9, lines 19-28, it has been explained how the water soluble, water insoluble and soot aerosol components are defined in GADS, and how they differ from sea-salt and sulphate aerosol components in terms of their chemical and optical properties. Also, the last sentence of Section 3.1 (starting with "In spite of ..." in the previous version) was re-written more clearly.

7. It is quite difficult to attempt such a comparison between GADS-derived optical depth and corresponding satellite retrievals. The GADS dataset was created to represent a comprehensive aerosol climatology by compiling aerosol data globally from different measurements and models. Nevertheless, it is well possible that the conditions at a specific location and time, as those represented by direct satellite measurements, can differ significantly from the GADS data. In addition, such a comparison is not possible because there are no available globally distributed satellite-based aerosol optical depth data at near-IR wavelengths that overlap with the time period covered by our study (i.e. 1984-1995). Such data (e.g. MODIS) are only available from 2000 onwards. However, to reply to the Referee's comment, we have attempted a comparison between our GADS-derived aerosol optical depth data with available TOMS measurements at the visible wavelength of 0.5 microns. The comparison was performed on a pixel-level (1deg x 1deg latitude-longitude) and monthly mean basis, for the years 1984-1995. Nevertheless, it should be noted that (as explained in the paper, Section 3.1, page 8, lines 12-19) the original GADS aerosol optical properties have been up-scaled to 1deg x 1deg latitude-longitude resolution. The results of our comparison show that apart from rare cases, the absolute differences between GADS and TOMS aerosol optical thickness (AOT) are mostly within 0.25, whereas the relative percentage differences

are mostly smaller than 75 percent and even 20 percent over extended areas. GADS mainly underestimates AOT, but there are also some areas (parts of Sahara desert in January) where GADS overestimates AOT. Overall, the scatterplot comparison between TOMS and GADS, with a total of 555000 matched pairs, indicates a correlation coefficient of about 40 percent, with a standard deviation of differences of 0.06 and a bias equal to 0.19 (GADS underestimation). These results are not too bad if one takes into account the very different philosophy and nature of the two datasets, and also the fact that the TOMS data have their own problems so that they cannot be considered as a totally reliable reference. In conclusion, we believe that GADS is not really adequate for a month to month and year by year assessment of aerosol radiative effects, but for climatological means. This is why GADS data are extensively used in GCMs and also for aerosol sensitivity studies (e.g. Kinne et al. 2003; Textor et al. 2006, apart from the references already cited in the paper, Section 3.1, page 7, lines 26-27).

8. In Section 4.1, page 12, lines 17-18, the reference of Ming et al. (2005) was added relevant to enhanced aerosol absorption over highly reflective surfaces.

9. The aerosol DRE at TOA is also determined by other aerosol optical properties such as τ_{aer} and $gaer$. The relevant text (Section 4.1, page 12, lines 21-23) was corrected accordingly.

10. Of course, the role of aerosol loading is very important to aerosol direct radiative effects (see also the paper by Hatzianastassiou et al., 2004b in Tellus-B). This role is discussed in the first paragraph of Section 4.1, before the sentence mentioned by the Referee. Nevertheless, apart from aerosol load, the role of cloud cover is also important, since the presence of clouds can overwhelm the aerosol effect (note that in general cloud optical depths are about one order of magnitude larger than those of aerosols). We performed sensitivity tests, as suggested by the Referee, showing that aerosol DREs under clear-sky conditions are larger than corresponding all-sky ones by more than 100% over extended oceanic regions (such as the storm-track zone of the southern hemisphere), but also by 20-90 percent over continental areas. However,

the structure of the sentence in its original form was really overemphasizing the role of cloud cover at the expense of aerosol load, which is now corrected in Section 4.1, page 12, lines 23-24.

11. Blanks in Fig. 4, but also in the rest of the figures, correspond to areas with missing data. This was explained in the text (Section 4.1, page 11, lines 30-31). The aerosol DRE appears noisy in July (Fig. 4b) because of the behaviour of surface albedo (R_g). It is well known from the literature that there is a "critical" value of surface albedo above which the aerosol cooling effect at TOA (positive values in Fig. 4) changes to a warming effect (negative values). The warming effect is due to particle absorption, which is increased through multiple reflections between the surface and the aerosols above. This is the case in Fig. 4b, because of quite large surface albedo values in July. In contrast, this occurs much less in January (Fig. 4a) because of smaller surface albedo values, below the "critical" point. To ensure this we have performed sensitivity tests with our model both with constant surface albedo values and with increasing/decreasing albedos. The results of the sensitivity analysis validate our statement, demonstrating that the sign of aerosol DRE at TOA is strongly dependent on surface albedo; the sign of DRE changes whenever the surface albedo values become larger or smaller than the critical value of R_g . These have been clarified in the text (Section 4.1, page 12, lines 30-34 through page 13 lines 1-4) while the sentence beginning with "For example ..." was re-written to be clearer.

12. The sentence beginning with "In contrast ..." was re-written to avoid confusion. What is supposed to say is that the smaller magnitude of aerosol DFTOA in July than in January along the storm-track zone of the Southern Hemisphere, is due to the increased surface albedo (0.3-0.35) because of increased Fresnel reflection (and solar zenith angle, see Hatzianastassiou et al., 2004a) under cloud-free conditions and the small amount of incoming solar radiation in that season. In fact, this is another indication of the role of surface albedo in determining the sign of DFTOA, which is of course more important under cloud-free conditions (under cloudy conditions, this role is domi-

nated by that of cloud albedo). These have been indicated in the text, and the sentence was re-written (see Section 4.1, page 13, lines 9-13) to be clearer.

13. The relevant sentence in Section 4.4, page 15, lines 3-6, was re-written so as to avoid reference to a cause-effect relationship, as indicated by the Referee.

14. It is true that comparing aerosol DRE as defined in our study (with a minus without aerosols) with the forcing of greenhouse gases (present minus pre-industrial concentration of gases) is not a like-to-like comparison. Therefore, the relevant sentence was re-written avoiding such a comparison (Section 4.4, page 15, lines 6-9). Moreover, the corresponding sentence in the Abstract has been removed.

15. By definition, the ratio $DFatmab(near-IR)/DFatmab(total-SW)$ becomes negative when . This is the case in the reported regions, i.e. western part of Antarctica, middle-to-polar oceanic regions of the northern hemisphere. The total SW effect $DFatmab(total-SW)$ is positive.

16. Yes, we mean that the two broad spectral intervals of the total solar spectrum (i.e. the UV-visible and the near-infrared) are affected by aerosols to a different extent. This was clarified in the text (Section 6, page 17, lines 28-30) and the relevant sentence was re-written.

III. Technical Corrections

a) The relevant text in the Abstract is now correct. b) The relevant text in the Abstract is correct. c) Although keeping the same colour scheme in panels within the same Figure could allow a better comparison between them, this would result in losing real (numerical) information about aerosol DREs when looking at each independent panel, which is probably more important to the reader. Therefore we prefer to keep the different colorbar scheme in the panels of each Figure.

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