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Interactive comment on "The direct radiative effect of biomass burning aerosols over southern Africa" *by* S. J. Abel et al.

S. J. Abel et al.

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We thank J. Feichter for his constructive comments.

General comments

1) Conclusions drawn from the paper need to be strengthened. In particular, it would be helpful, if uncertainties regarding modelling and observations could be ranked, in order to learn, where future efforts should focus on.

We agree with the reviewer that the conclusions could be strengthened by ranking the uncertainties in the order of importance. The following text has been added to the conclusions section. "Improving current model estimates of the direct radiative effect of biomass burning aerosols over southern Africa may be achieved by focusing future

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efforts on simulating the most important parameters revealed in the sensitivity study, which are prioritized as follows;

i) Horizontal distribution of aerosol optical depth. ii) Aerosol and cloud vertical structure, especially in the area of the Namibian cloud sheet. iii) Optical properties of the aerosol, particularly ω_0. iv) Well simulated cloud fields, including cloud optical properties and diurnal cycle. v) Spectral dependence of the land surface albedo."

2) The reasons for the large deviations between observed and model calculated optical depth should be discussed. Why is the optical depth over land under estimated even after 'corrections' were applied? (Simulated optical depth fields reproduce the observed maximum at the west-coast but fail to mirror the high optical depth levels observed over Zaire and Zambia).

The model data used in this study (Tegen et al., 1997) is shown to significantly underestimate the aerosol optical depth over southern Africa in the burning season when compared to observations. This may be the result of an underestimation in the source strength of the aerosol, a result that is a common feature in more recent models in areas influenced by biomass burning (Kinne et al., 2003). Furthermore, as the reviewer points out, the emission inventories used in the model are from the early 1980s. Emission strengths may certainly have increased in the years where the observation statistics were compiled (1995 - 2003). Deficiencies in how the model transports the aerosol may also contribute to the low model optical depths, although such assessments are not possible in this article.

The reviewer asks why the peak in aerosol optical depth observed in the MODIS data off the west coast is recreated after corrections are applied to the model data, whereas the peak over Zaire and Zambia is still underestimated. A single correction factor is applied to the model optical depth and was calculated from a linear fit between the model data and all of the AERONET station data in the climatology. However, because the uncorrected model data did not have a peak in optical depth over Zaire and Zambia, it is impossible to recreate this peak when applying a single correction factor to the whole of southern Africa. The peak off the west coast is present in the uncorrected data. This is because Tegen et al. (1997) calculate the aerosol optical depth (τ) from the model simulated aerosol columnar mass (M) with the formula $\tau = Mk_e$, where k_e is the aerosol specific extinction coefficient. For carbonaceous aerosol (assumed to be biomass smoke in this study), a highly simplified humidity dependence in k_e is used. No humidity dependence was assumed for black carbon aerosol, whereas organic carbon aerosol over land was assumed to have a lower k_e than over oceanic areas based on a higher average relative humidity over oceans (k_e = 6 m^2g^{-1} over land, 10 m^2g^{-1} over oceans). This results in the sharp increase in the model organic carbon τ off the west coast of southern Africa. Recent in-situ measurements from SAFARI 2000 show that biomass burning aerosol is only moderately affected by relative humidity (Magi and Hobbs, 2003), suggesting that the large increase in k_e and hence τ in the model data over oceans is unrealistic.

To address the above comment paragraph 2 on p. 1173 has been rewritten and now reads "The under estimation of the aerosol optical depth in the uncorrected GCM data is evident, with values over southern Africa being significantly lower than in the MODIS satellite retrieval. This may be the result of an underestimation in the source strength of the biomass burning aerosol, a result that is a common feature in many global aerosol models (Kinne et al., 2003). Furthermore, the emission inventories used in the model are from the early 1980s. Emission strengths may certainly have increased in the years where the satellite data is taken (2000 - 2003). Deficiencies in how the model transports the aerosol may also contribute to the low optical depths, although such assessments are beyond the scope of this article. Correcting the GCM data with the factor derived from the AERONET climatology brings the spatial pattern into much better agreement with the MODIS distribution. However, whereas there is a single peak off the western coast of southern Africa in the model data, the MODIS data has a secondary peak inland. Over oceanic regions the corrected GCM distribution tends to produce higher values of aerosol optical depth than the remotely sensed data, especially off the eastern coast of Africa. The higher values are likely to result from the unrealistic humidity dependence in the OC component of the aerosol in the model data. In calculating the $\tau_{\lambda=0.55\,\mu\mathrm{m}}$ from the model generated columnar mass, Tegen et al. (1997) use a specific extinction coefficient of OC aerosol that is a factor of 1.7 higher over oceanic regions than over land to account for hygroscopic growth of the aerosol. Recent in-situ measurements from SAFARI 2000 show that biomass burning aerosol is only moderately affected by relative humidity (Magi and Hobbs, 2003), suggesting that the large increase in $\tau_{\lambda=0.55\,\mu\mathrm{m}}$ in the model data over oceans is unrealistic. The sensitivity of the direct radiative effect of the biomass burning aerosol over southern Africa to the two spatial distributions of smoke (Figs. 3b and d) is examined in Sect. 3.1."

Specific comments

1) The calculated aerosol distribution (from a publication in 1996) may not have been the best available [these distributions could be compared with more recent estimates available through AeroCom efforts]. The emission inventory based from the early 1980s (due to decadal trends in domestic and agricultural fires) may not relate well to observations taken in the late 1990s and early 2000s.

The model data of Tegen et al. (1997) was used in this study as it is freely available at http://gacp.giss.nasa.gov/transport/. We feel that a comparison with model data from the AeroCom project is beyond the scope of this study, but feel that a statement referring to the AeroCom project should be in the conclusions section. As such, the following statement has been added to paragraph 2 on p.1188. "Through future multi-model and observational comparisons, improving the quality and thus reducing uncertainty in GCM aerosol simulations should be achieved and is a key objective of the AeroCom project (http://nansen.ipsl.jussieu.fr/AEROCOM/)."

2) p. 1170: The authors point out that the model initiates the biomass burning season too early in May and June. They are correct with respect to Southern Africa (e.g.

Mozambique or southern Zambia). On the other hand, Barbosa et al. (GBC 1999) show - based on burned area maps from 1981-1991 - that at least towards central and western Africa (e.g. Zaire, Angola) an initiation in May or June would be correct.

It is agreed that the location of the AERONET sites used in this study for assessing the model data may be biased to areas that are subject to fires occurring later on in the burning season (July onwards). Therefore, the northwest to southeast trend evident in the burned area maps is difficult to detect. AERONET data does not currently exist in central Africa and so this could not be included in this study. To address this point, the statement on p. 1170 now reads "The model also appears to initiate the biomass burning season in May to June, whereas the observations suggest it occurs closer to July. Satellite derived burned area maps also suggest that July is more appropriate for the areas where the continental based AERONET stations used in this study are located, although areas to the north and west of the AERONET sites are subject to burning from May onwards (Barbosa et al., 1999)."

3) p. 1184: The area impacted by fresh aerosol properties depends on the 'characteristic' aging time of smoke. The finding that radiative forcing simulations assuming only aged aerosol give similar results as the standard case, indicates that, if the simulation is correct, the aging time would be very short. Is this supported by observations?

An important result from this study is that the aged aerosol only case gives similar results to the base case (fresh and aged aerosol), indicating that measurements of aerosol optical properties taken near source regions are of limited use when assessing the large scale impacts of the smoke. The reviewer asks a pertinent question relating to the partitioning of fresh and aged aerosol in the model, whereby fresh aerosol is only included in grid boxes that contain a set number of satellite fire counts. The assumption made is that the aging time of smoke is small enough so that by the time the aerosol is transported outside of the grid box, the optical properties of aged smoke are more appropriate. This is supported by aircraft observations downwind of a biomass burning fire in southern Africa that show that rapid changes occur to the aerosol optical properties within the first few hours subsequent to emission (Abel et al., 2003). This is stated in section 2.3.

4) Table 1: It would be more informative to indicate the number of months by location in a Figure. This would give a better idea of regional coverage.

Figure 1 has been modified to indicate the number of months by location. Table 1 is unchanged.

5) Figures 5, 6, 10, and 11: It will be made sure that the text in the legends in the final version is readable.

6) p. 1174 line 24: The text should read -18N.

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