Atmos. Chem. Phys. Discuss., 9, C10746–C10751, 2010
www.atmos-chem-phys-discuss.net/9/C10746/2010/

Atmospheric
Chemistry
and Physics
Discussions

Interactive comment on "Using aircraft measurements to determine the refractive index of Saharan dust during the DODO experiments" *by* C. L. McConnell et al.

C. L. McConnell et al.

c.mcconnell@imperial.ac.uk

Received and published: 12 February 2010

The authors thank the referee for their useful comments and suggestions.

1a) We would like to clarify and stress that chemical composition results from DODO were indeed used in Section 2.3. The elemental composition of dust samples collected during DODO was obtained using X-ray fluorescence as described in Formenti et al. (2008). The iron oxide content was determined using the CDB extraction technique as described in Formenti et al. (2008) and Lafon et al. (2004). Using the Lafon et al. (2006) approximation, the proportions of relevant minerals were calculated based on the measured elemental concentrations and the iron oxide content. Therefore the

proportions of the different minerals varied depending on the proportions of different elements in the filter samples collected during DODO. The text in Section 2.3 has been modified to explain this more clearly.

1b) We used a simplified representation of dust where quartz, calcite and iron oxide-clay aggregates were externally mixed, while the iron -oxide clay aggregates represent clay particles with iron oxide particles aggregated to them.

Additionally SEM analyses of dust for both DODO and AMMA campaigns (McConnell et al., 2008; Chou et al., 2008; Lafon et al., 2006) have shown that there is no evidence of internal mixing between minerals - quartz, carbonates and clays are not internally mixed, while iron oxides can be either internally or externally mixed to clays, but internal mixing (as employed in this study) is more frequent. We have added a paragraph to Section 2.3 explaining this.

2a) We use two radiation streams to be consistent with climate models, which typically employ just a two stream radiation model, though we acknowledge that using four or more streams would be more accurate. We have run a simple test simulation using the SBDART model comparing the surface irradiances for an aerosol optical depth of 0.55 microns using different numbers of streams: 2, 4, 8, and 16. The changes in surface up and downwelling irradiances between the 2 and 16 stream simulations are small - under 1%. We therefore conclude that the uncertainty due to the two-stream approximation used in this study is small, and certainly smaller than the other uncertainties, such as surface albedo and changes due to different aerosol composition. We also note that our calculations are over land, where the surface is likely to be more isotropic, than for example, over ocean, where the use of more than two streams may be more significant.

2b) Surface Albedo

For the surface albedo we used a value of 0.44, which was calculated from up and downwelling pyranometer measurements at an altitude of 300m altitude. The value of 0.44 is therefore a broadband measurement representative of 0.3 to 3 micrometers, to coincide with the wavelengths measured by the pyranometers. This value therefore neglects spectral variation of surface albedo. This has be made clearer in the article text. We agree that the spectral variation in surface albedo could be important to the modelled radiation, particularly to the upwelling calculations, and thank the referee for pointing out the ASTER database resources. Using a set of four different spectrally varying surface albedos, obtained from the ASTER database and scaled so that the spectrally integrated albedo was 0.44 (as measured by the aircraft pyranometers), we have investigated the uncertainty in the model simulations due to the assumption of a spectrally constant surface albedo. The tests were carried out for the Mie refractive indices.

Firstly the sensitivity of the downwelling irradiance to the different surface albedos is very small - to within a maximum of around 2% at the lowest altitudes, and within less than 1% at the higher altitudes shown in Figure 9. However, the upwelling irradiances at the lower altitudes are very sensitive to the spectral surface albedo variations, and the uncertainties are of the same scale as the differences in upwelling irradiance due to the different refractive indices. The upwelling irradiances at the highest two altitudes, however, show changes of less than 5% due to the different spectral surface albedos - an uncertainty around the same as that of the pyranometers, and less than the differences resulting from the different chemical compositions tested. Therefore we conclude that the exact spectral variation in surface albedo is of critical importance to radiative transfer modelling over desert surfaces at low altitudes (pressures greater than 700mb in our study), and do not use these low altitude SWU measurements towards achieving radiative closure. However, the remaining measurements (i.e. all SWD calculations, and SWU calculations for pressures under 600mb) still point towards the Mie and GK tests giving the best closure.

Since the measurements taken during DODO do not enable us to determine the spectral variation of the surface albedo, we believe that the spectrally constant value is most appropriate for this study. Measurement of the spectral surface albedo will be the

subject of future work and field campaigns. Please also see response to Referee 2 regarding the uncertainty in the broadband surface albedo.

3a) Dubovik et al., (2002a) state that the AERONET algorithm represents particles where 0.1um < d < 30um. We note that the values shown in Table 1 for each method therefore represent different size ranges as follows, noting the possibility that none fully represent the full coarse mode, and have made this more explicit in the main text, caption for Table 1 and Conclusion.

i. Mie code refractive indices - accumulation mode only, from 0.1 < d < 3um

ii. Filter sample refractive indices - accumulation mode and part of the coarse mode (see section 2.3) with upper limit of around d=15um

iii. AERONET retrievals - representative of 0.1 < d < 30um

3b) The referee is right that dust composition might change with size, hence might do the optical properties. This was not investigated in detail in our study. Single-particle analysis was performed on a limited number of particles in the fine and the coarse fraction for one aircraft run from flight b238, and for one run in flight b237. We now mention this in more detail in Section 2.3. These results indicate that dust is mainly composed by aluminosilicates, carbonate and quartz in relatively equal proportions. Feldspaths were more abundant in the coarse fraction, whereas gypsum, iron and titanium oxides were found in the fine fraction only. For example, one run from flight B238 had the following proportions for the submicron and supermicron composition respectively: aluminosilicate (56%, 62%), Fine aggregates (7%, 20%), Ca-rich (3%, 8%), Si-rich (5%, 8%), NaCl (2%,0%), CaS (19%, 0%), K-S (3%, 0%), Ti-rich (2%, 2%), Fe-rich (3%, 0%). Because of the low significance of our analysis (i.e. a relatively small number of particles was sampled) we did not attempt to calculate refractive indices based on these results. This will be the subject of future research.

4) The accuracy of the CDP, which was used to measure the coarse mode size dis-

tribution, has been addressed in McConnell et al. (2008). To summarize, the CDP measured size distribution during DODO on the BAe146 extends to 20 microns radius. In this study, a lognormal size distribution has been fitted to this data, which is then allowed to extend to 60 microns radius. It is therefore assumed that the size distribution declines lognormally between radii of 20 and 60 microns. Unfortunately due to instrumentation problems with two FFSSPs during DODO, we have no other airborne coarse mode size distributions to compare the CDP data with. However, CDP measurements have been shown to be consistent (up to a radius of 20 microns) when compared to other measurements during previous flights (McConnell et al., 2008, and references therein).

The lognormal parameters shown in Table 2 are an average used to represent the optical properties of the full vertical profile from flight b238. In this particular dust event, the size distribution, and particularly the coarse fraction, dropped off sharply with altitude (represented by the vertical profile of the mass mixing ratio in Figure 8). This is one possible explanation for the difference of coarse mode radius with respect to the SAMUM measurements (Wienzierl et al., 2009), though it is possible that many factors could cause the difference (such as different sources, different uplift and transport conditions). We also note that from the lower altitude runs where the largest coarse mode was present, to the higher altitude runs where far less coarse mode was present, the radius of the coarse mode decreased by around a factor of two.

5) Please see response to point 2 above.

6) We have added an extra paragraph to Section 2.5 to define our calculations of the aerosol radiative effect (ARE). Following IPCC convention, positive values indicate a warming, and negative values indicate a cooling effect, due to the presence of aerosols. The ARE is therefore the difference in net irradiance at a particular level (e.g. surface or top of atmosphere) due to the presence of aerosol. Net irradiance is defined as downwards minus upwards.

7) The reviewer is correct, and although it would be interesting to investigate this further, we do not attempt to do this in the present study due to the limited number of particles sampled by SEM and TEM, as described in point 3, since the results would not be representative of the samples. Additionally TEM analysis (i.e. submicron composition) was not performed for flight b242 samples. The sentence under question will be modified to read, "The results from b238 and b242 seem to indicate that refractive index does not always change substantially with particle size. This issue will be addressed in future research."

References

Lafon, S., I. N. Sokolik, J. L. Rajot, S. Caquineau, and A. Gaudichet (2006), Characterization of iron oxides in mineral dust aerosols: Implications for light absorption, J. Geophys. Res., 111, D21207, doi:10.1029/2005JD007016

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 23505, 2009.