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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Analysis of the vertical structure and size distribution of dust aerosols over the semi-arid region of the Loess Plateau in China" *by* B. Zhou et al.

B. Zhou et al.

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Reply to: the interactive comments on "Analysis of the vertical structure and size distribution of dust aerosols over the semi-arid region of the Loess Plateau in China" by B. Zhou et al. Anonymous Referee #2

General comments: Comment 1: The important information on the used data, the data evaluation, and the accuracy is missing.

Reply: The lidar system (L2S-SM II) accords with the measurement standard of the NIES Lidar Network. The temporal resolution of the dual-wavelength polarisation lidar (L2S-SM II) is 15-min with running for 5-min and then stopping working during the next

10-min. The acquired data accuracy of the lidar is 12 bits. The concentration accuracy of the particle sizer (APS-3321) is $\pm$10% of reading plus variation from counting statistics. To ensure the measurement quality, the zero and span calibrations of the nephelometer (M9003) are carried out periodically, and the total scattering accuracy is about 5%.

Comment 2: I strongly recommend to add an in-depth discussion of all findings/statements/ conclusions of the paper.

Reply: We greatly appreciate the referee's comment. The paper's findings/statements/ conclusions will be modified in the revised version.

Comment 3: The linear depolarization ratio (at 532 nm) of the particles and the color ratio (and lidar ratios); all with error bars.

Reply: Figure 6 with error bars will be provided in the revised manuscript as shown in the following.

Comment 4: Add another piece of information to global aerosol climatology.

Reply: The information of global dust aerosol climatology will be added in the revised manuscript. The Saharan and Taklimakan (including Gobi) deserts are the major dust sources in the world. Generally, the dust optical depth over the Atlantic is higher than that over Pacific, and the size distribution of Asian dust is dual-modal while that of Saharan dust is uni-modal (Su and Toon, 2011). The single scattering albedo (SSA) of Saharan mineral dusts is 0.92-0.99 (Johnson and Osborne, 2008) while that of Asian dust ranges from 0.76-0.86 (Ge et al., 2010). Southwest Asia is being the world's third largest dust source region, and the United Arab Emirates Unified Aerosol Experiment (UAE2) was carried in August through September 2004. Here the aerosol concentration in background conditions ranges from 100 to 300μg/m3 while that in dust event is over 1.5 mg/m3, and smoke and pollution distribute at levels between 1.5 and 5 km (Reid et al., 2008).

Specific comments: Comment 1: Page 6114, line 14. “The number concentration decreases…increase”. It would help to explain what the reference with respect to “decrease” and “increase” is. Standard conditions at the site?

Reply: The reference is dust-free conditions at SACOL. “The number concentration decreases while those of particles in the moderate (2.5 μm<r$\leq$10.0 μm) and coarse (10.0 μm<r$\leq$20.0 μm) modes increase.” is replaced by “The number concentration decreases while those of particles in the moderate (2.5 μm<r$\leq$10.0 μm) and coarse (10.0 μm<r$\leq$20.0 μm) modes increase respect to the dust-free conditions.”

Comment 2: Page 6114, line 23. 20.95%,… two decimal places are certainly unrealistic! Throughout the paper!

Reply: The referee's comment is quite right. In the revised version, all two decimal places will be modified.

Comment 3: Page 6117, line 7. More details of the lidar system are required: e.g., overlap region, SNR. What is the SNR of signals from 24 km, can they be used? What is the reason for the low temporal resolution? Detail on the accuracy, the resolution, etc. of the particle sizer would help as well.

Reply: The field of view for the lidar (L2S-SM II) is 1 mrad, so the overlap region of lidar is very low at about 0.5 km, and the complete overlap is 0.06 km. In this paper, the backscattering signal from this lidar system has been made overlap and background noise corrections, and the SNR below 6.0 km is quite low, especial the clear sky. The retrieval optical parameters of the lidar from 0.1 to 6.0 km are analyzed, and that above 6.0 km is no use. The temporal resolution of the lidar is relation with the pulse repetition frequency, and shots are controlled by laser. Here the pulse repetition frequency of 10Hz satisfies aerosol measurement. To improve the SNR we should enhance the temporal resolution, but the higher temporal resolution, the more charge. The concentration accuracy of the particle sizer (APS-3321) is $\pm$10% of reading plus variation from counting statistics with 5-min temporal resolution.

Comment 4: Page 6117, line 17. Images of the instruments are not necessary. Anyway, they are too small for useful information.

Reply: In the revised manuscript images of the instruments will be omitted. Figure 2 is modified as follows:

Comment 5: Page 6118, line 1. The brackets in “d(z')“ can be omitted; same in Eq. (2).

Reply: The brackets will be omitted in the revised version.

Comment 6: Page 6118, line 6. Maybe it is better to replace “aerosol” by “particles” (throughout the paper)

Reply: The referee's comment is quite well, and the “aerosol” will be replaced by “particles” in the revised version.

Comment 7: Page 6118, line 9. It should be mentioned that S_2 is known.

Reply: “The ratio of atmospheric molecules S2 is known with the value of 8π/3.” will be added in the relevant place of section 2.2.

Comment 8: 6118/13: Why is the reference height lower in case of dust storms? One would expect that in case of a dust storm the troposphere is (entirely) filled with dust; so that below 10 km no aerosol-free altitude range can be found. Or is it a problem of the SNR? I don't believe that a Rayleigh calibration is possible under these conditions.

Reply: In dust conditions, the SNR almost reduce respect to the clean sky, and the valid detecting height of lidar can hardly reach 10 km, so the reference height is lower in case of dust storm. In the referring case that the troposphere is full of dust the reference height should not be found using this method. Yes, the SNR is a problem. Under these conditions, the return signals from 20 to 24 km can not be believed, and the Rayleigh calibration is replaced by that of clean sky.

Comment 9: Page 6118, line 15. The lidar ratio is not related to the aerosol concentration!

Reply: The referee's comment is instructive. The lidar ratio is mainly related to the shape and composition of aerosol. "aerosol concentration" will be omitted in revised manuscript.

Comment 10: Page 6118, line 18. A lidar ratio of 20 sr is very low. Can this number be discussed in more detail? Maybe it would help to translate the main conclusion of Zhou et al. (in Chinese language).

Reply: In our study, we set S1 to 50 sr for dust conditions and to 20 sr for dust-free conditions (Zhou et al., 2011). Over SACOL, the lidar ratios have been examined using sun-photometers (CE-318 and L-97), and the value of 20 sr causes minimal errors in dust-fee conditions. It is considered that the low ratio is likely relation with the soot existing near surface. Over SACOL the soot layer can be always seen with people's eyes.

Comment 11: Page 6118, line 20. What is the "depolarization ratio"? Linear...? Volume or particle linear depolarization ratio? The definition given in the paper seems to be related to the volume linear depolarization ratio. However, the calibration constant has been forgotten; just the ratio of the two channels will not give the correct number (different sensitivity of the channels). The authors should add a paragraph how the polarimetric measurements of the lidar were calibrated! This governs the accuracy of the retrieved linear depolarization ratios.

Reply: In this manuscript, the definition of depolarization ratio is related to volume linear depolarization ratio. The calibration constant can be calculated as follows:

Where and stand for perpendicular and the parallel channels backscattering return signal at 532 nm, and and are the signals after the 90° rotation of detector system. In this paper the polarimetric data has been made sensitivity calibrated, and the accuracy of linear depolarization ratios is below 10%.

Comment 12: Page 6119, line 4. How is the mass of the particles determined?

Reply: The mass of the particles is determined as follows:

Here and are the density of particles and cell respectively, v is the volume of particles at one channel, l and u are respectively the low and upper boundary of the channel number, and are respectively the geometric and aerodynamic diameter, and n is the number of particles at one channel.

Comment 13: Page 6119, line 13. The authors mention 20 days of measurements during dust conditions. What is the reason for only selecting the three days 16-18 March 2010? At least a short summary how the other days compare to the selected days would be nice.

Reply: Add "There are two reasons for selecting the three days. The first is that the tree days are under a typical dust event whereas the other dust events are very short-lived no longer than 24 hours, and the second is that the sky condition of these days are almost no-cloud, then the retrievals are not impacted by cloud." in revised version.

Comment 14: Page 6120, line 2. Typo after "10 m s".

Reply: "10 m s" will be replaced by "10 m/s" in revised version.

Comment 15: Page 6120, line 6. Please specify the "depolarization ratio" (throughout the paper).

Reply: "depolarization ratio" is replaced by "volume linear depolarization ratio" throughout the paper.

Comment 16: Page 6120, line 9. A "depolarization ratio" of up to 0.2 should be explained. What sort of particles are associated to these values? Are additional linear depolarization ratios from dust free conditions available?

Reply: Generally, the volume linear depolarization ratio of the clean air is below 0.1, and that over SACOL is 0.15-0.20 which is caused by the little covered underlying surface and closed to dust source. Yes, the additional linear depolarization ratios from dust free conditions are available.

Comment 17: Page 6120, line 11. What do “higher” color ratios mean? “higher” is not a precise statement, it could be 100!

Reply: Higher color ratio means its value is more than 0.7. In dust condition, the value ranges from 0.8-1.0.

Comment 18: Page 6120, line 15. Figs. 4 and 3a should be very similar, as the only difference is the factor “lidar ratio”. However, they look quite different, in particular after 18:00 of the first day! What is the reason? Why is the signal almost totally attenuated above 1 km (Fig.3a), whereas there seem to be significant features in Fig. 3b and Fig. 3c at that time.

Reply: The detection height and SRN of lidar descends when dust storms are too strong. Here the differences between backscattering signals and aerosol extinction coefficients maybe are caused by the inapposite reference height in the dust storm. Sorry, we need consider more deeply the reasons for signal almost totally attenuated above 1 km.

Comment 19:

Page 6120, line 19. It should be clarified that the AOD is the optical depth at 532 nm. Furthermore, it should be explained how the AOD is calculated from the lidar: minimum height (extrapolation to ground), what is maximum height?

Reply: The AOD is the optical depth at 532 nm, and is integrated from 0.1 to 6.0 km.

Comment 20: Page 6120, line 21. I don’t see an AOD of 0.005 in Fig. 5! A discussion of the accuracy of the lidar derived AOD is missing (severe influence of the estimate of the lidar ratio!).

Reply: The AOD at 00:00 on 18 March is 0.005, and not before 17:00 on 16 March.

Comment 21: Page 6121, line 2. In Fig. 5a there a negative extinction coefficients

close to the surface. This seems to be an artifact due to the incomplete overlap. So, this height range should not be shown in the Figure.

Reply: The negative extinction coefficients close to the surface is caused by the complete overlap region (about 0.06 km) of the lidar system, not by incomplete overlap, and the negative extinction coefficients will be omitted in fig. 5a.

Comment 22: Page 6121, line 6. “The heights of the inflections. . .” I don’t understand this sentence.

Reply: “The heights of the inflections. . .” means that “The turning point of extinction coefficients with altitude”.

Comment 23: Page 6121, line 16: The “error of 10%”: how is this number derived? Is it just an estimate or from an elaborated error analysis?

Reply: Here the error is just an estimate from the references (Sugimoto et al., 2005, 2006; Huang, et al, 2010)

Comment 24: Page 6121, line 19. Typo: “Freudenthaler” is correct. A comparison with that study would clearly benefit from a precise error analysis provided by the authors. Thus, error bars should be included in Fig. 6.

Reply: “Freudenthaler” will be corrected in the revised version. Error bars include in Fig. 6b. The volume linear depolarization ratio of dust is 0.3 ± 0.02 in this paper while that of Sahara dust is 0.31 ± 0.03.

Comment 25: Page 6122, line 1. The time of the measurements shown in Fig. 7 should be given: is it a representative example? Is it the average over some time? What was the situation on different days/hours? Maybe, a larger set of size- and mass-distributions can be included to show the variability.

Reply: It is average over some time. For the dust condition the average time ranges from 17:00 on 16 March to 00:00 on 18 March while that for dust-free condition ranges from 08:00 to 17:00 on 16 March and from 00:00 to 08:00 on 18 March.

Comment 26: Page 6122, line 20. Please indicate the size range associated to the given number- and mass concentrations.

Reply: The size range of aerosol mass and number concentration is from 0.5 to 20.4 μm in Fig.8.

Comment 27: Page 6123, line 6. It is not clear, how the percentages (88.83%,. . .) are calculated. Are they averages of a subset of the columns in Fig. 9? Please explain! All similar statements in the following should be discussed in view of the accuracy of these numbers and whether differences are significant or not.

Reply: As the measurement of particle sizer (APS-3321) including 52 channels (0.5-20.4 μm), the mass and number of particles can be observed for each channel. Here we calculate the percentages of fine, moderate, and coarse modes in dust storm and dust-free condition from the averages of a subset of the columns in Fig. 9. The percentages of number concentration in dust and dust-free cases are significant differences.

Comment 28: Page 6123, line 10. "The decrease was particularly large for the moderate-mode. . . numerous coarse. . .". I don't understand this sentence.

Reply: "The increase was particularly large for the moderate-mode aerosols (Fig. 9), which indicated that numerous coarse particles were loaded into the atmosphere under dust conditions." is replaced by "The increase was particularly large for the moderate-mode aerosols (Fig. 9), which indicated that numerous large particles were loaded into the atmosphere under dust conditions".

Comment 29: Page 6123, line 20. The whole section 3.4 should be critically reviewed to make clear what the authors' message is.

Reply: We greatly appreciate the referee's instructive comment. The whole section 3.4 will be adjusted in revised manuscript.

Comment 30: Page 6124, line 3. "effective diameter" is not defined.

Reply: Effective diameter means aerodynamic equivalent diameter.

Comment 31: Page 6124, line 4. The data set resulting in the scatter plot must be explained: are those measurements conducted every hour; during which time period?

Reply: The data set resulting in the scatter plot (Fig. 11) is an average of a subset from March to April 2010.

Comment 32: Page 6124, line 4. Fig. 11a shows a large number of points clearly below the 1:1 line. What is the reason for this?

Reply: It could be related with the measurement error of nephelometer (M9300) and wavelength.

Comment 33: Page 6124, line 8. What is a "surface dust aerosol scattering coefficient"?

Reply: "Surface dust aerosol scattering coefficient" means "scattering coefficient of dust aerosol near surface"

Comment 34: Page 6124, line 11. That is the physical reason for the Gaussian shape of the curve?

Reply: The scattering efficiency and the size distribution of particles both cause the Gaussian distribution. For the fine-mode (rïijIJ2.5 μm), it is that the scattering efficiencies are very low while the number is large; the scattering efficiencies of moderate-mode particles (2.5ïijIJr≤10.0 μm) are very large and the number increases in dust storm while the scattering efficiencies of coarse-mode particles are also very lager but the number is so little.

Comment 35: Page 6124, line 16. 20.95% + 83.88% are more than 100%.

Reply: The percentage contributions of PM2.5 and PM10 to the scattering coefficient were 20.95% and 83.88% respectively during the dust storm. PM10 includes PM2.5.

Comment 36: Page 6125, line 1. The last section is quite similar to the abstract. The paper would benefit from a revision of the conclusions (inclusion of new ideas, an outlook, a broader discussion of the limitations and benefits,. . .)

Reply: The referee's comment is instructive. The outlook, a broader discussion of the limitations and benefits will be added in the second and third paragraphs of section 4.

References Huang, Z., Sugimoto, N., Huang, J., Hayasaka, Y., Nishizawa, T., Bi, J., and Matsui, I.: Comparison of depolarization ratio measurements with Micro-pulse Lidar and a linear polarization lidar in Lanzhou, China, Proc. of 25th ILRC, 1, 528-531, 2010. Johnson, B. T. and Osborne, S. R.: Physical and optical properties of mineral dust aerosol measured by aircraft during the GERBILS campaign, Q. J. R. Meteorol. Soc., 137, 1117-1130, 2011. Reid, J. S., Piketh, S. J., Walker, A. L., Burger, R. P., Ross, K. E., Westphal, D. L., Bruintjes, R. T., Holben, B. N., Hsu, C., Jensen, T. L., Kahn, R. A., Kuciauskas, A. P., Mandoos, A. A., Mangoosh, A. A., Miller, S. D., Porter, J. N., Reid, E. A., and Tsay, S. C.: An overview of UAE2 flight operations: Observations of summertime atmospheric thermodynamic and aerosol profiles of the southern Arabian Gulf, J. Geophys. Res., 113, D14213, doi:10.1029/2007JD009435, 2008. Su, L. and Toon, O. B.: Saharan and Asian dust: similarities and differences determined by CALIPSO, AERONET, and a coupled climate-aerosol microphysical model, Atmos. Chem. Phys., 11, 3263-3280, 2011.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 6113, 2012.