

Response to reviewers

“Spatial distribution of dust’s optical properties over the Sahara and Asia inferred from Moderate Resolution Imaging Spectroradiometer”

We would like to thank Dr. CL Ryder for the constructive comments. According to the comments, we modified the manuscript and we believe that the revised paper is improved. Our point-by-point responses and actions for the comments are listed as below. The comments from reviewers are *emphasized*, and *our responses and actions are shown in blue*. *Modified part in the revised manuscript is shown in red*. *English correction by several native speakers is shown in green*. *The original sentences removed in the revised manuscript are shown as orange*.

This paper presents some interesting results regarding spatial variability of dust optical properties over a long timescale (8 years) across northern Africa and Asia using MODIS data. Besides the relevant comments of reviewer 1, I would like to point out some comments to the authors:

First of all, thank you very much for your constructive comment. We add some discussions to the revised manuscript.

1) Regarding the correlation between single scattering albedo (SSA) and aerosol optical depth (AOD). If the authors are able to show that this relationship is physical, and not spurious (as suggested by reviewer 1), this presents a very interesting point. Recent work as part of the Fennec project over the Sahara [Ryder et al., 2013] has shown that particle size decreases with dust age during transport, connected to increases in SSA. Since larger particles contribute to a lower SSA, this would suggest an increase in SSA as dust ages, and AOD decreases, consistent with what the authors imply here. It would be interesting to expand on the physical mechanisms behind the SSA and AOD relationship a bit more.

Thank you very much for your constructive comment. As for the relationship between SSA and AOD, we give more discussion in Section 3.3 in the revised manuscript because of the response to the comment 16) of reviewer #1. It is not easy to validate the

spatial distribution of the aerosol optical properties and physical mechanisms at this stage because the number of validation site is very limited. We give discussion on the relationship between SSA and AOD according to your comment.

[P31127_L9] Section 3.3

The relationship between ω_0 and τ_a shown in Fig. 9 might be consistent with recent work by Ryder et al. (2013), who found that particle size decreased with dust during the transport. Since smaller particles contribute to a larger ω_0 , this would suggest an increase in ω_0 as τ_a decreases with dust age.

We add the reference below.

[Reference]

Ryder, C. L., et al. (2013), Optical properties of Saharan dust aerosol and contribution from the coarse mode as measured during the Fennec 2011 aircraft campaign, Atmos. Chem. Phys., 13, 303-325.

2) Page 31109/31110, lines 20 to 7 – it should be pointed out that in addition to the references for Saharan dust optical properties cited in this paragraph, there are several more recent (and lower) measurements that should be mentioned, such as by Otto et al. [2009] who found SSA values of 0.8 at 550nm during SAMUM1, Müller et al. [2010] who found SSA values of 0.82 at 550nm, and values measured during Fennec very close to fresh dust sources where 550nm SSA values from 0.7 to 0.97 were found [Ryder et al., 2013]. Several of the aircraft measurements cited by the authors in this paragraph did not include full measurement of the coarse mode of dust, which may have elevated the SSA measurements.

Thank you very much for your suggestion. We add more recent measurements as follows.

[P31110_L5] Section 1

More recently, ω_0 measured during Fennec very close to fresh dust sources where 550nm SSA values from 0.7 to 0.97 were found (Ryder et al., 2013).

3) I suggest the authors consider recent work comparing aircraft measurements to AERONET retrievals of SSA and size distribution which find that AERONET SSA values for Saharan dust may differ significantly [Johnson and Osborne, 2011; Müller et al., 2012; Müller et al., 2010], calling into question the ability of sunphotometers to provide SSA values and size distributions for dust, particularly where a substantial coarse mode of dust is present in remote desert locations, such as examined in this article. Since the authors use AERONET-derived size parameters, the uncertainties may be much larger than presented in Table 1.

Thank you very much for your suggestion. A discussion on the discrepancy between AERONET and aircraft measurement is given in the revised manuscript.

[P31123_the last line] Section 3.2.1

We should note that recent work found that AERONET retrievals of ω_0 are different from aircraft measurement (Johnson and Osborne, 2011; Müller et al., 2010; Müller et al., 2012). This might call into question the ability of AERONET to provide reliable ω_0 .

As for the uncertainty in the aerosol size distribution, we performed a sensitivity test using the maximum of volume median radius observed by SAMAM (Heintzenberg, 2009), and found that this uncertainty had no impact on the total uncertainty.

[P31121_L20] Section 3.1.1

Here, the uncertainties in aerosol model parameters are derived from the standard deviation of the AERONET retrievals as shown in Table 1. However, recent aircraft measurement found the wider range of aerosol size distributions. We performed the sensitivity test with coarse mode of volume median radius of 10 μm observed in Saharan Mineral Dust Experiment (SAMUM: Heintzenberg, 2009). The estimated uncertainty in ω_0 was 0.006 (band9) and 0.003(band1), and the uncertainty in τ_a was 0.06 (band9) and 0.06(band1). These uncertainties do not affect the total uncertainty so much.

We add the references below.

[Reference]

Müller, D., et al. (2012), Comparison of optical and microphysical properties of pure Saharan mineral dust observed with AERONET Sun photometer, Raman lidar, and in situ instruments during SAMUM 2006, J Geophys Res-Atmos, 117.

Müller, D., et al. (2010), Mineral dust observed with AERONET Sun photometer, Raman lidar, and in situ instruments during SAMUM 2006: Shape-independent particle properties, J Geophys Res-Atmos, 115.

Heintzenberg J. 2008. The SAMUM-1 experiment over southern Morocco: Overview and introduction. Tellus 61B: 2–11.

4) It would be interesting to comment briefly on whether dust events on smaller timescales show any variability in dust properties either spatially or over several days as the dust event ages?

Thank you very much for your suggestion. We took a look at our results of ω_0 on the same days as Ryder et al. 2013 (17th -26th June, 2011) and found the variability of ω_0 over the western region of Sahara. However, it was not easy for us to relate dust age and ω_0 because we do not have enough information on the dust age. We include the discussion on the relationship between the dust age and our results in the revised manuscript as follows.

[P31131_L22] Section 4

For instance, time evolution of aerosol optical properties might be investigated if combined with information on dust age (e.g., Ryder et al. 2013).

5) Figure 4 – the color bar appears to be missing?

Thank you very much for your suggestion. We modified the color bar in the revised manuscript.

6) Figure 7 – there appears to be an interesting contrast in the east-west SSA between western and eastern Africa between band 9 and band 1, with more spectral variation in west Africa than eastern Africa. Are the authors able to suggest a physical/chemical mechanism for this? Is this consistent with composition differences between eastern and western Africa?

Thank you very much for your good comment. As shown in Fig. 9, the spatial variation of SSA is consistent with that of the surface reflectance for both band 1 and 9. This is possibly because of the spatial feature of the surface mineral composition. We describe the feature of the contrast in the revised manuscript.

[P31126_L25] Section 3.3

As shown in Fig. 7 (a), the spectral variation in w_0 is larger in the western part of Sahara than in the eastern part. This is consistent with the feature of spectral variation in the surface reflectance shown in Fig. 7 (c).

7) Are any assumptions about the vertical distribution of dust made? This can vary substantially between dust events and change as dust ages, becoming more well-mixed throughout the Saharan Boundary Layer with age.

The assumption of vertical distribution of dust is described in P31121_L22 in the original manuscript. In our standard model, the aerosol layer is at an altitude of 4-8 km. We also performed sensitivity tests by changing the dust layer to lower (1-5km) and higher (7-11km) altitudes. In the revised manuscript, we add information on the recent observation. We also confirmed that the spatial distributions of ω_0 and τ_a as shown in Fig 7 and 8 using the lower (1-5km) altitude are not so much different from the figures in the original manuscript.

[P31121_L23] Section 3.1.1

Recent work found that the dust exists the altitude below 5-6 km (e.g., Johnson and Osborne; 2011, Ryder et al.; 2013). We perform the sensitivity test by changing the dust layer to lower (1-5 km) and higher (7-11 km) altitudes.