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# ANALYSIS OF AERONET EXTENDED WAVELENGTH RETRIEVALS OF AEROSOL ABSORPTION PARAMETERS INCLUDING 380 NM AND 500 NM FOR DETECTION OF BROWN CARBON IN BIOMASS BURNING AND IRON OXIDES IN DESERT DUST

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## ABSTRACT

To investigate near UV aerosol absorbers, such as iron in mineral dust and brown carbon from biomass burning, AERONET spectral imaginary refractive index and size distributions retrievals were performed with the input of additional wavelength data. This includes adding both measured spectral AOD and sky radiances at 380 nm and 500 nm to the four channels (440, 675, 870 and 1020 nm) that are used in the standard retrieval data product. The vector radiative transfer code in the AERONET Version 3 retrievals enabled more accurate computations in the ultraviolet region (380 nm). Calibration of the 380 nm channel radiances was done by the vicarious method since the integrating sphere radiance source that is used for all other wavelengths does not produce sufficient energy at 380 nm. Spectral single scattering albedo, imaginary refractive indices and aerosol size distributions from these six wavelength retrievals are compared to the standard four wavelength retrieval values.

***Index Terms***— Aerosol, absorption, biomass burning, desert dust

## 1. INTRODUCTION

For various biomass burning regions in the mid-latitudes and tropics the retrievals of fine mode dominated aerosol show enhanced absorption at 380 nm and 440 nm relative to 500 nm, consistent with expected brown carbon absorption in these wavelengths from organic particles. The inclusion of the 500 nm input data and inversion results are important as this allows for better quantification of enhanced brown carbon absorption (plus iron oxides for desert dust) in the short wavelength visible and UV-A region, while black carbon alone dominates the absorption from the mid-visible through the near-infrared wavelengths. Some comparisons to other retrieved aerosol spectral SSA from tropical biomass burning regions are shown. The size distribution retrievals for fine mode dominated cases show minimal differences between the standard four wavelength and the new six wavelength retrievals. For coarse mode dominated observations of desert dust aerosol, the 6 channel retrievals show enhanced absorption by iron oxides at 380 nm. Dynamics of the dust spectral absorption are examined, as a function of AOD levels, day of year (seasonal) and for some selected cases variation in source regions inferred by back trajectories. Comparisons to recently published spectral SSA of desert dust in various regions are discussed.

## 2. SMOKE TRANSPORT CASE

We investigated and compared aerosol properties from long-distance transported smoke from the California-Oregon mega-fires from September 8-11, 2020 to the GSFC Maryland site on Sep 15. The California smoke transported to GSFC on Sep 15, ’20 had significantly larger peak radius particles and narrower fine mode distributions (see Figure 1 below) than the major transport event of Quebec forest fire smoke to GSFC on July 8, 2002 and both events with significant peat burning (Bonanza Creek, Alaska in 2004 and Palangkaraya, Indonesia in 2015). The extreme smoke size distribution at GSFC from this event is

likely due to both of the aerosol aging processes of coagulation and condensation. Only the smoke transported to GSFC from the California/Oregon fires exhibited an AOD spectra with decreasing AOD for $\lambda$<500 nm as wavelength decreased (see Figure 2; this is a very rare AOD spectral feature). The AOD data for the GSFC is highly accurate (~0.005 or less, most wavelengths) since this instrument was calibrated by Langley technique at the Mauna Loa Observatory. Mie calculations of AOD spectral variations for various size distributions and complex refractive indices were performed. These showed a minimal influence of absorption (imaginary refractive index) on AOD spectra while the real part of the refractive index had a significant influence. Size distribution variations caused the largest changes in spectral AOD, as expected, with both increases in fine mode radius and narrowing of the width of the fine mode resulting in enhanced decreases in AOD with decreasing wavelength within the visible and UV wavelength range. Simulation of a case with volume median radius of 0.48 micron and the same width as the GSFC case (in Figure 1), resulted in maximum AOD at 675 nm which would result in a blue colored sun, similar to that observed in Scotland in 1950 from transported Canadian smoke and reported by Wilson in [2].

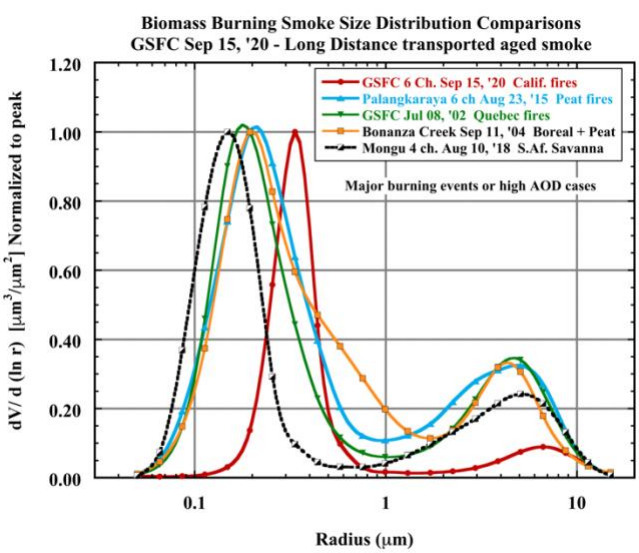


Figure 1. Smoke size distribution comparisons for various high optical depth events. Note the significantly larger fine mode particle radius in the GSFC case as compared to all other cases shown. The fine mode volume distribution width is also narrower than all other size distribution retrievals from other AERONET sites.

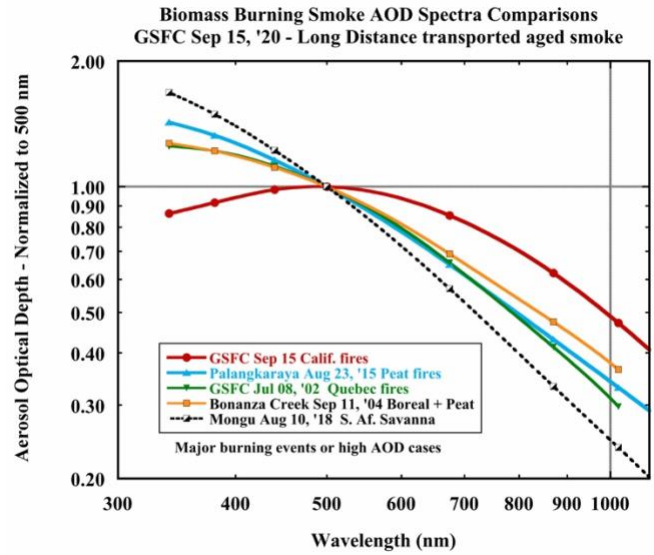


Figure 2. AOD spectrum comparisons, smoke cases.

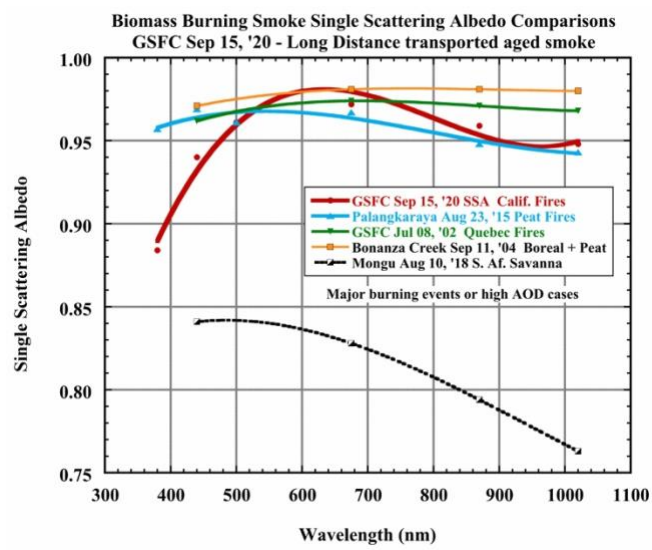


Figure 3. Smoke cases: comparison of spectral SSA.

The size distribution retrieval from the six wavelength inversion at GSFC on Sep 15. '20 along with associated refractive indices results in computed AOD from Mie calculations (spherical particles) that agree with measured AOD to within 0.001 at all channels from 380 to 1020 nm (The Dubovik retrieval requires a nearly perfect fit to all channels of measured AOD).

The spectra of the retrieved single scattering albedo (SSA) from 675 nm to 380 nm for the GSFC

case on Sep 15, '20 (see Figure 3) suggests greater brown carbon absorption in this transported CA smoke versus the two peat fire cases (Alaska & Indonesia) and also the smoke advected from Quebec forest fires to GSFC. Only the GSFC and Palangkaraya retrievals utilized the 380 nm sky radiance measurements so SSA at 380 nm was only inferred for those two sites/cases.

## 3. DESERT DUST ABSORPTION

Comparison of spectral SSA from AERONET dust retrievals (Angstrom Exponent: AE<0.4) from various dust sources and/or regions are shown in Figure 4. The most weakly-absorbing dust at 380 nm is from Ilorin with a trajectory from the Bodele Depression, and also a case from Mongolia. The strongest absorption is from Australia (red soils with high iron oxides). Similar SSA was observed at all sites for $\lambda$>650 nm.

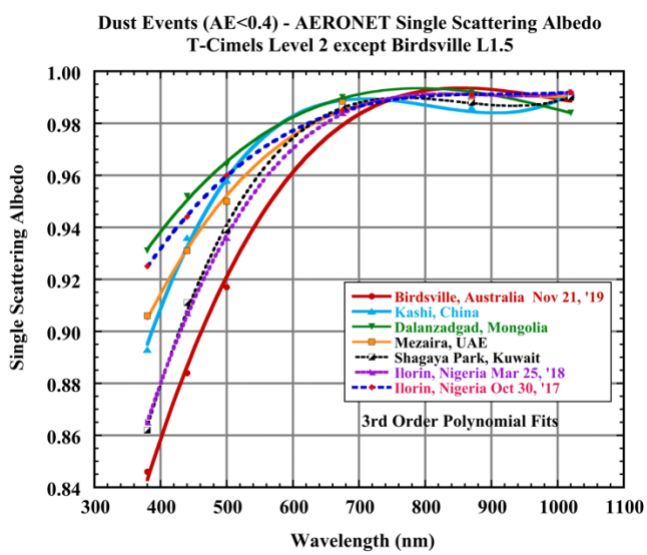


Figure 4. Desert dust SSA spectra compared for various source regions.

At the Ilorin, Nigeria site the SSA from Feb-May is lower at shorter wavelengths than from October – December (Figure 5), possibly due to more transport from the Bodele to Ilorin in the fall season. SSA also increases as AOD increases, possibly in part due to the Bodele Depression events having both very high AOD and very low SSA (weak absorption in diatomaceous sediment versus iron oxides in mineral dust). The data gap in January is likely due to lack of AE<0.4 due to biomass burning smoke mixing with dust

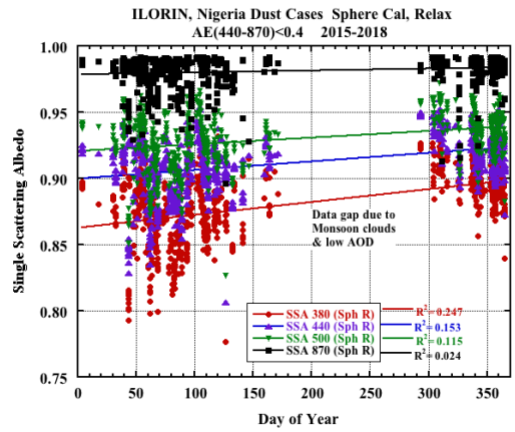


Figure 5. Spectral SSA as a function of the day of yaer at the Ilorin, Nigeria AERONET site.

## 4. SUMMARY AND CONCLUSIONS

### 4.1. Spectral Absorption of Dust

a. Desert dust absorption as retrieved by AERONET in general is very weak (SSA>0.98) at wavelengths >650 nm and show the most variability at the shortest wavelengths (380 nm is the minimum measured), dependent primarily on source regions likely due to relative iron oxide content.

b. In general the variability of regional desert dust absorption from AERONET retrievals at short wavelengths is in agreement with the laboratory measurements of soil dust absorption obtained by Di Biagio et al. and presented in [1]. Both find the strongest dust absorption from Australia and the weakest from the Bodele Depression in Africa. However, the magnitudes of the extremes are much greater from the lab measurements possibly due to dust types from different sources mixing the atmospheric dust clouds measured by AERONET.

c. AERONET monitoring at two sites show seasonal changes in dust absorption magnitude, however these results are preliminary and further investigation is needed. These two sites are (1) Ilorin, Nigeria which is downwind of various dust source regions to the north in the Sahel and Sahara and (2) Kanpur, India which is downwind of the Thar desert source region plus agricultural sources and potential interaction with high concentrations of absorbing pollution aerosols.

### 4.2. Extremely Aged Biomass Burning Case

a. Smoke from mega-fires in September 2020 in California and Oregon produced aerosol with varying optical properties which were transported large distances to the US east coast and beyond.

b. On September 15, 2020 some of this transported biomass-burning aerosol displayed very rare AOD spectral signature of maximum AOD at 500 nm and decreasing at the shorter measured wavelengths of 440, 380 and 340 nm. At the GSFC site a 2nd order polynomial fit in logarithmic coordinates fit these AOD spectra extremely well, to within ~0.01 or less for all AOD from 340 to 1020 nm (note AOD>1 for all $\lambda$ <700 nm).

c. These anomalous AOD spectra resulted from fine mode size distributions of these smoke cases that had very large modal radius (~0.32 μm) and narrow width (geometric standard deviation = 1.39). These large sized particles were very likely a result of the aging processes of coagulation and condensation occurring under very high aerosol concentrations. The coarse mode contribution was minimal in these cases with fine mode fraction of AOD of >0.99 in the visible and UV wavelengths.

d. The spectral absorption of this extremely aged aerosol including the 380 nm data in the AERONET retrieval at GSFC on Sep 15, 2020 showed decreases in single scattering albedo (SSA) at 440 and 380 nm relative to 500 nm thus suggesting significant brown carbon absorption. This contrasts with a retrieval made at Palangkaraya, Indonesia (that also included the 380 nm channel) during the major peat burning year of 2015 which showed relatively weak spectral signature of brown carbon absorption.

e. The absorption spectra including 380 and 500 nm data of fine mode aerosols is currently in the research phase at AERONET, therefore these spectral SSA results are preliminary.

## 5. REFERENCES

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