Aerosol-type classification based on AERONET version 3 inversion products

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Motivation

The availability of accurate measurements of aerosol-specific lidar parameters for the main aerosol species together with advancements in the analysis of passive remote-sensing measurements with sun photometers allows for adapting methodologies that have been developed for the analysis of lidar data to the application to data from new sources. Specifically, the particle lidar ratio (S) and the particle linear depolarization ratio (δ) as provided in the AERONET version 3 level 2.0 aerosol inversion product can be used for (i) obtaining reference values of pure aerosol types in regions where a long-term deployment of lidar instruments is not feasible (*Shin et al.*, 2018), (ii) inferring AOD and AAOD of the dust and non-dust components in dust-containing mixed aerosol plumes (Shin et al., 2019a), and (iii) a refined aerosol-type classification that is capable of accurately separating between spherical and non-spherical particles as well as between absorbing and non-absorbing particles (*Shin et al.*, 2019b).

dust contribution to backscatter coefficient

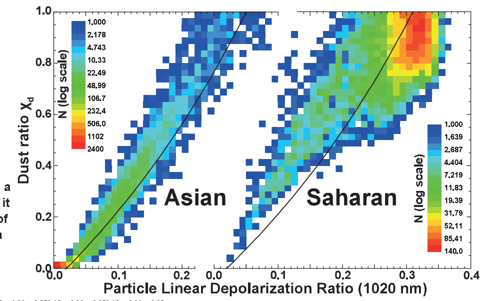
$$R_d = \frac{(\delta-\delta_{nd})(1+\delta_d)}{(\delta_d-\delta_{nd})(1+\delta)}$$

needs to be transformed for application to AOD

$$X_d = \frac{AOD_d}{AOD} = R_d\frac{S_d}{S}$$

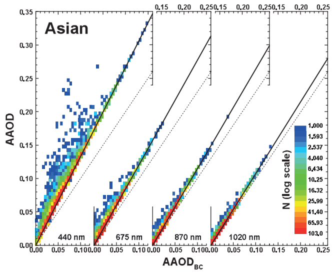
Single-scattering albedo (ω) is split into the contributions of dust (d) and non-dust (nd) aerosols to get non-dust and BC-related AAOD

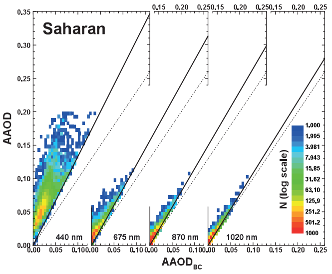
$$\omega = X_d\omega_d + X_{nd}\omega_{nd};\quad AAOD_{nd} = (1-\omega_{nd})AOD_{nd};\quad AAOD_{BC} = (1-\omega_{BC})AOD_{nd}$$

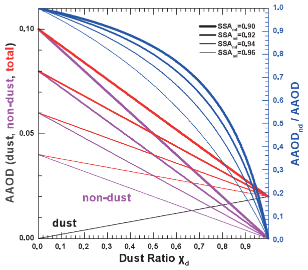


AAOD components

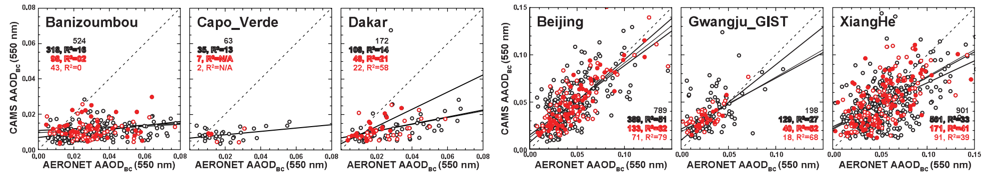
Absorption aerosol optical depth (AAOD) as from AERONET measurements provides a measure of the light-absorbing properties of the columnar aerosol loading. However, it is not an unambiguous aerosol-type-specific parameter, particularly if several types of absorbing aerosols, for instance black carbon (BC) and mineral dust, are present in a mixed aerosol plume. The lidar-based technique for the separation of dust and non-dust aerosol types of *Tesche et al.* (2009) has been refined for the use with AERONET direct sun and inversion products.







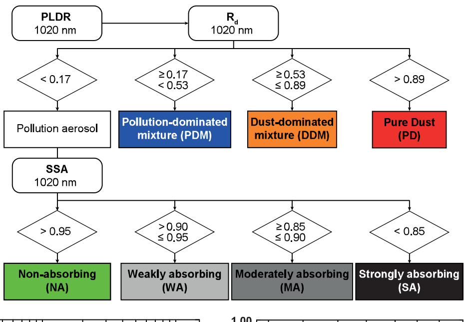
We extend the methodology to retrieve AAOD related to non-dust aerosol ($AAOD_{nd}$) and BC ($AAOD_{BC}$). We test the method at selected AERONET sites that are frequently affected by aerosol plumes that contain a mixture of Saharan or Asian mineral dust and biomass-burning smoke or anthropogenic pollution, respectively. We find that aerosol optical depth (AOD) related to mineral dust as obtained with our methodology is frequently smaller than coarse-mode AOD. This suggests that the latter is not an ideal proxy for estimating the contribution of mineral dust to mixed dust plumes. We present the results of the $AAOD_{BC}$ retrieval for the selected AERONET sites and compare them to coincident values provided in the Copernicus Atmosphere Monitoring System aerosol reanalysis. We find that modelled and AERONET $AAOD_{BC}$ are most consistent for Asian sites or at Saharan sites with strong local anthropogenic sources.

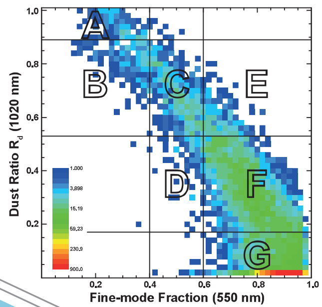


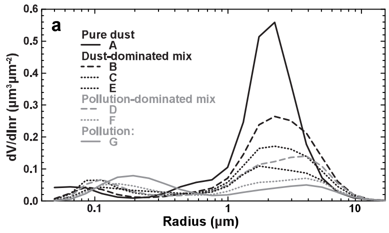
Aerosol-type classification based in inversion products

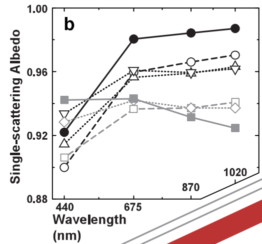
We propose an aerosol-type classification based on the particle linear depolarization ratio (PLDR) and single-scattering albedo (SSA) provided in the AERONET version 3 level 2.0 inversion product. Our new method allows for a refined classification of mineral dust that occurs as a mixture with other absorbing aerosols: pure dust (PD), dust-dominated mixed plume (DDM), and pollutant-dominated mixed plume (PDM). We test the aerosol classification at AERONET sites in East Asia that are frequently affected by mixtures of Asian dust and biomass-burning smoke or anthropogenic pollution.

We find that East Asia is strongly affected by pollution particles with high occurrence frequencies of 50% to 67%. The distribution and types of pollution particles vary with location and season. The frequency of pure dust and dusty aerosol mixture is slightly lower (34% to 49%) than pollution-dominated mixtures. Pure dust particles have been detected in only 1% of observations. This suggests that East Asian dust plumes generally exist in a mixture with pollution aerosols rather than in pure form.





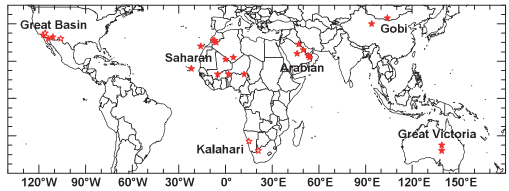




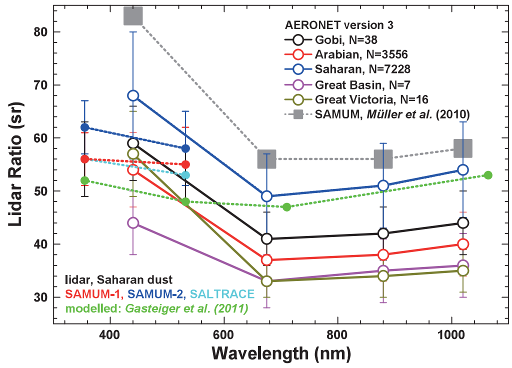
In the next stage of this work we intend to expand the aerosol-type classification and $AAOD_{BC}$ retrieval presened here to the entire AERONET data base. We will then use the information obtained in this way for aerosol-type specific optical and microphysical properties as input to radiative transfer calculations. This will allow us to compile a global data set of the direct radiative effect of individual aerosol types. Such a measurement-based data set can be used as an additional benchmark for the validation of satellite observations and the output of regional and climate models.

Dust properties

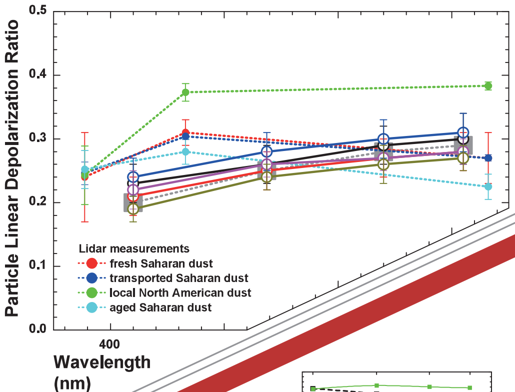
Knowledge of the particle lidar ratio (S) and the particle linear depolarization ratio (δ) for different aerosol types allows for aerosol typing and aerosol-type separation in lidar measurements. Reference values generally originate from dedicated lidar observations but might also be obtained from the inversion of AERONET data. *Shin et al.* (2018) have investigated the consistency of spectral S and δ provided in the AERONET version 3 inversion product for observations of undiluted mineral dust in the vicinity of deserts. Pure dust conditions are identified by an Ångström exponent < 0.4 and a fine-mode fraction < 0.1.



The values of spectral S are found to vary for the different source regions but generally show an increase with decreasing wavelength.The feature correlates to AERONET, retrieving an increase in the imaginary part of the refractive index with decreasing wavelength.The smallest values of S = 35-45 sr are found for mineral dust from the Great Basin desert, while the highest values of 50-70 sr have been inferred from AERONET observations of Saharan dust. Values of S at 675, 870, and 1020 nm seem to be in reasonable agreement with available lidar observations, while those at 440 nm are up to 10 sr higher than the lidar reference.

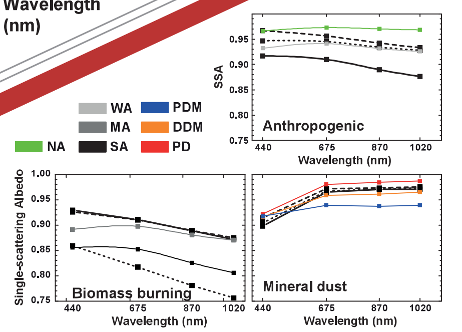


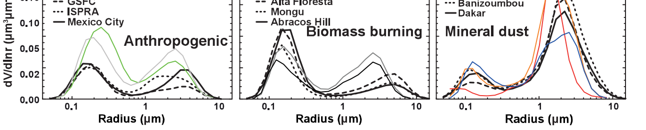
The spectrum of δ shows a maximum of 0.26-0.31 at 1020nm and decreasing values as wavelength decreases. AERONET-derived δ values at 870 and 1020 nm are in line with the lidar reference, while values of 0.19-0.24 at 440 nm are smaller than the independent lidar observations by a difference of 0.03 to 0.08. This general behaviour is consistent with earlier studies based on AERONET version 2 products.



Application

We have also considered data from selected AERONET sites that are representative of anthropogenic pollution (GSFC, ISPRA, and Mexico City), biomass-burning smoke (Alta Floresta, Mongu and Abracos Hill), and mineral dust (Cape Verde, Banizoumbou, and Dakar). We find that average aerosol properties obtained for aerosol types in our PLDR-SSA-based classification agree reasonably well with those obtained from AERONET measurements at sites that are considered to be representative for aerosol types of different origin.





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