An aternative method for deriving aerosol optical properties and aerosol type via an all-sky imager and machine learning

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Atmospheric particles, both natural and anthropogenic, affect the Earth's radiative balance by attenuating (absorbing and scattering) the incoming solar radiation (direct effect) and by acting as cloud condensation nuclei (indirect effect). Several remote sensing techniques, including ground-based measurements and satellite observations, exist for retrieving aerosol optical properties (AOP) on a global and regional scale. AERONET provides AOPs at the highest temporal resolution (5-15 min) with over 600 stations worldwide. Despite the dense number of active stations, they still lack global coverage and long-term measurements. In this work, an alternative and affordable methodology to retrieve AOPs, such as Aerosol Optical Depth (AOD), Ångström Exponent (AE) and Fine Mode Fraction (FMF), is presented, using the information contained in the images of the whole sky dome from an all-sky imager (ASI) in conjunction with machine learning (ML). The ASI was installed next to a CIMEL sun-photometer (AERONET station) at the National Observatory of Athens at Thissio, Greece, recording simultaneous measurements for almost a year (01−11/2021). Sky information (RGB channels) at different scattering angles from the ASI, the saturated area of the sun (the pixels of the image that are considered burnt), solar geometry (solar zenith angle – SZA), and water vapor are used to train a ML model (in this case, the light Gradient Boosting Machine) to retrieve AOD at three distinct wavelengths (440, 500, and 675 nm), AE between 440 and 675 nm and FMF at 500 nm. The retrieved AODs (AE) revealed good accuracy, with a dispersion error lower than 0.07 (0.15) against independent, cloud-screened, and quality-assured measurements provided by the co-located AERONET sun-photometer. Further, the retrieved AOPs were implemented to classify the prevailing aerosol type. The aerosol classification results indicated that the proposed retrieval methodology could correctly predict the dominant aerosol types with relatively high precision (>60 % in 4 out of the 6 aerosol clusters). The results of the proposed study revealed the potential of using an ASI to accurately retrieve AOP, and the retrieved AOP measurements can be used to perform aerosol type classification.

Keywords: aerosol optical properties, all-sky imager, machine learning, aerosol retrieval, AERONET