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How can fluorescence lidar improve the detection and characterization of aerosol particles? - Implementation and first results at Leipzig, Germany.

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Climate change is increasing the number and intensity of wildfires and therefore the amounts of biomass-burning aerosol released into the atmosphere [1]. Those aerosol particles can not only be spread in the troposphere but even reach the stratosphere, influencing Earth's radiation budget and cloud cover for long periods and large areas [2]. To fully understand and quantify aerosol effects on climate, an accurate aerosol typing is crucial. In this sense multiwavelength polarization lidars are very powerful tools to detect and classify aerosol based on intensive quantities such as the lidar ratio, depolarization ratio and Ångström exponent [3, 4, 5]. However, important limitations remain, namely, it is particularly hard to distinguish between stratospheric smoke, that was transported into the stratosphere via slow self-lofting pathway, from volcanic sulfate aerosol, or to separate between tropospheric smoke and urban pollution.

Recent studies showed that the fluorescence lidar technique has great potential to improve aerosol classification by providing an additional intensive aerosol optical property, the so-called fluorescence capacity (ratio of fluorescence-backscattering to elastic-backscattering coefficients) [6, 7]. Motivated by these results, the Multiwavelength Atmospheric Raman Lidar for Temperature, Humidity, and Aerosol Profiling (MARTHA) at TROPOS, Leipzig, was updated by adding two detection channels. One for the near-range (20 cm telescope diameter) and one for the far-range (80 cm telescope diameter), allowing measurements of fluorescence backscatter in the spectral range from 444 – 488 nm, and by following [6], the fluorescence backscattering coefficient and fluorescence capacity was derived from our lidar observations carried out from June to October 2022.

By means of the new product, we were able to identify smoke layers in the troposphere, attributable to the summertime fires in Europe but also from North America. One interesting case was the 21 September, in which the far-range fluorescence channel detected thin smoke layers in the upper troposphere and lower stratosphere that were barely detectable from background noise in all three elastic channels but were clearly visible in the fluorescence channel. Enlighted by our preliminary results, the fluorescence capacity proved itself to be an indicator of the fraction of fluorescent particles inside an aerosol layer improving the analysis of smoke-containing aerosol mixtures.

Keywords: fluorescence lidar, aerosol, wildfire smoke, retrieval algorithm, aerosol, clouds

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