Aerosol Studies with Spectrometric Fluorescence and Raman Lidar

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Aerosols are widely monitored with lidars, which are often sophisticated instruments such as multiwavelength Raman lidars. However, the focus of the observations is still mostly on the elastic-optical properties of the aerosols although it has been demonstrated that measurements of their inelastic optical properties (Raman scattering, fluorescence) offer additional useful information. Especially in the case of fluorescence, lidars that are equipped with spectrometers rather than only discrete detection channels allow investigations of aerosol type and cloud interaction never performed before.

RAMSES (Raman lidar for atmospheric moisture sensing), is the operational spectrometric fluorescence and water Raman lidar of the German Meteorological Service at its Lindenberg site, Germany. With its three spectrometers covering the ultraviolet-A and visible wavelength range, it is optimally equipped to study the inelastic properties of aerosols. During its routine operation in 2020 and 2021 RAMSES collected a vast data set of atmospheric aerosol measurements covering distinct events such as wild fires, volcanic eruptions, Saharan dust outbreaks and domestic biomass burning.

This contribution can only provide a small insight into this treasure trove of data because of the complexity of the matter. First, it describes in broad detail certain aspects of the data analysis, specifically, the absolute calibration of the measured fluorescence spectrum and the correction of the water-vapor measurement for fluorescence interference. Second, the efforts are outlined which are undertaken to determine the source regions of the aerosols measured with RAMSES. Finally, some measurement examples are presented. Here, emphasis is put on the aerosol-specific shape of the fluorescence spectrum and its relation to the elastic-optical aerosol properties and the atmospheric environment. However, interaction of aerosol and clouds is not discussed.

Although the studies are ongoing, some key results can already be summarized as follows. Fluorescence spectra of aerosols generated locally by biomass burning (boundary layer) or advected from wildfires afar (free troposphere) exhibit a pronounced maximum in the visible light range and high fluorescence capacity. The center wavelength of the fluorescence maximum shifts, depending on a number of factors of which source region, atmospheric residence time and trajectory history seem to be the most important. In contrast, fluorescence spectra of Saharan dust or volcanic debris show a steady decrease in backscattering with wavelength, with little fluorescence capacity and weak dependence on the atmospheric state.