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Elastic-lidar wavelength-dependent detectability of dense aerosol objects through clear and hazy atmospheres

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The laser radiation wavelength is one of the factors that may influence the strength of the elastic-lidar return signal from clear and hazy atmospheres, either in the presence or in the absence of specific dense aerosol objects, such as cirrus clouds, Saharan dust or volcanic ash layers, etc. At a stronger signal and, respectively, higher measurement signal-to-noise ratio (SNR), the images of characteristic features along the lidar line of sight (LOS), including dense aerosol objects, would be, in general, brighter and clearer and better detectable. To reveal purposely and systematically the role of the sensing laser wavelength, at equal other factors, in achieving good images by elastic lidar, we recently began developing an approach consisting in numerical and statistical modeling, comparison and analysis of single-scattering mean lidar and SNR profiles and the corresponding noisy profile estimates obtained at different sensing wavelengths. The signal and background fluctuations are generated as due to the prevailing Poisson shot noise.

The purpose of this work is to demonstrate the performance and efficiency of the above-mentioned investigatory approach by applying it to aerosol stratification models of clear and hazy atmospheres containing simultaneously structures resembling a Saharan-dust layer and a cirrus cloud. The sensing radiation wavelengths considered belong to the UV (337.1 nm), VIS (514.5 nm), and NIR (1060 nm) spectral ranges.

The results obtained show that, due to stronger backscattering and not so high extinction (attenuation), the aerosol stratification in a clear atmosphere is better imaged when using shorter (UV) wavelengths. In a hazy atmosphere, when the turbidity increases, the advantage of the shorter wavelength radiations decreases and even vanishes at some altitudes, because of the additional increase in the attenuation, which is higher as a rule. At the same time, the detectability (imaging quality) of relatively larger-particle aerosol objects (cirrus clouds and Saharan dust layers) is better when using longer-wavelength (NIR) sensing radiation. Then, because of the lower optical background, lower attenuation and backscattering outside of the object and the nearly wavelength-independent attenuation and backscattering inside the object, its image obtained using NIR radiation is the brightest, clearest and most contrasting. The SNR of detecting the object is then maximum and an acceptable image quality is achievable at a smaller statistical volume and not so severe smoothing along the LOS, thus ensuring better temporal and spatial sensing resolutions. Besides, multiple scattering could be considered negligible when NIR radiation is used and any corrections to the single-scattering lidar equation would not be necessary. The conclusions deduced here are in agreement with experimental results obtained formerly.

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