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Improving the use of laser scanning intensity data in complex 3D mapping of the cave environment: Case study of the Gouffre Georges Cave, France

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Terrestrial laser scanning (TLS) is frequently used for contactless acquiring of highly detailed and accurate three-dimensional (3D) representation of natural landscapes and man-made objects. The advantage of TLS has been exploited in mapping the underground landscapes such as caves formed in various geological settings with variable dimensions extending from narrow passage to grand domes. Highly detailed cave surveying with TLS generates millions of 3D coordinates of cave surface by which mapping of features difficult to be reached and studied directly is possible, e.g. speleothems, ceiling channels, structural rock properties and rock type alongside with the tectonic features influencing overburden stability. Besides the 3D coordinates, intensity of the backscattered laser pulse is recorded in the form of an additional attribute, influenced by various factors including spectral properties of the surface material. The studies published on the use of laser intensity have been mainly focused on the correction of intensity recorded by TLS for objects in the above-ground environment, where atmospheric attenuation, specifically humidity or dust content in the air, is negligible or it is considered constant during scanning. However, caves are specific due to their complex morphology and aerosol in their atmosphere. The presented case study focuses on these aspects in correcting the recorded intensity with a long range TLS Riegl VZ-1000 in the Gouffre Georges cave which formed on the contact of marble and lherzolite in the French Pyrenees. We present complex workflow for elimination of the influencing factors associated with the scanning geometry, including range and incidence angle, taking into account the character and contours of the cave wall surface as a set of facets and effect of atmospheric attenuation. The resulting corrected intensity value depends mostly on the spectral surface properties. Derived reflectance values revealed different lithological layers allowing to analyse their lithological and structural properties. Corrected intensity can be also used in biospeleological studies for mapping and quantification of cave fauna, in speleology for observing structures with higher occurrence of wet areas where active karst processes occur and even in archaeological studies for identification of cave paintings.