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Hyperspectral imaging of alpine ice cores: application to light-absorbing impurities and ice structure

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The optical properties of snow have been studied since the ‘70s and early ‘80s. Radiative transfer models have been developed to describe and to predict the spectral behaviour of snow. Inversion schemes of these radiative transfer models have been also developed in order to estimate snow key variables (e.g. albedo, grain size, impurities etc.) from satellite multi- and hyper-spectral data. While snow optical properties have been extensively studied, the same cannot be said for glacier ice. In the last decade, different optical scanners have been developed for ice cores. These instruments were based on RGB cameras mounted on linear stages, and they were mainly used for ice core stratigraphy purposes.

In this context, we developed a novel system based on a hyperspectral imaging sensor (HeadWall Hyperspec® VNIR) to analyse the optical properties of ice cores in a non-destructive way. The system is composed of a high-precision linear stage which embeds a hyperspectral imaging sensor and a halogen light source. It was designed to collect high resolution hyperspectral images of ice cores in the visible and near-infrared wavelengths (spectral range: 380-1000nm) with spectral resolution of 2-3 nm (calculated at Full Width at Half Maximum), and spatial resolution from 1mm to 20μm. The system has been tested on new ice cores extracted from the Adamello glacier (Eastern Alps) and the Rutor glacier (Western Alps). Different narrow-band and broad-band indices were computed to analyse the optical properties of ice and impurities enclosed in ice layers. Empirical regressions were investigated to relate the reflectance and density of ice. A novel method for estimating the fractal dimension of ice crystals from spectral reflectance was also developed. This system can be coupled with traditional techniques applied to ice cores, and predictive models can be developed to estimate key variables in ice cores at an unprecedent spatial and spectral resolution. We believe that hyperspectral digital imaging offers great potential for improving the analysis of ice cores in the next years, and guarantying the preservation of ice core records over time.