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Scanning reflectance spectroscopy (380-730 nm) on varved sediments of Lake Silvaplana, Swiss Alps: a novel method for high-resolution quantitative climate reconstructions

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We systematically explore the potential of scanning in-situ reflectance spectroscopy in the visible spectrum (380 – 730 nm) as a novel tool for quantitative, high-resolution (2 mm) climate reconstructions that are well-calibrated against and validated with local meteorological data. Varved Lake Silvaplana (south-eastern Switzerland) is chosen as a case study, because (i) the chronology (varve counting corroborated with documented flood layers back to AD 1177) is very accurate, (ii) the mineralogical and geochemical composition of the sediments are very well understood, (iii) long meteorological data series are available for calibration and verification and (iv) independent reconstructions are available for comparison. This allows us to assess the performance and skills of the novel method on instrumental and longer time scales.

First, we summarised the individual reflectance spectra with six spectral features (variables). According to principal components and redundancy analysis (PCA, RDA), the six variables reflect the mineralogical composition of the sediments (mainly biotite, illite and chlorite). Individual and combined variables (multiple linear regression) were calibrated against mean instrumental June to September (JJAS) temperature data (AD 1864 – 1950) and tested for their performance (root mean square error of prediction, RMSEP). The best calibration model was based on three variables (Trough590-730, Min690 and Min 480), explains ∼84% of the variance of the meteorological data (1864 – 1950) and has a Leave-One-Out RMSEP of 0.1°C).

The JJAS temperature reconstruction back to AD 1177 is in good agreement with two fully independent temperature reconstructions from documentary (back to AD 1500) and tree-ring width data confirming the high performance of the scanning reflectance-spectroscopy method and reconstruction. All the major tropical volcanic eruptions (negative forcing) appear as multi-annual negative summer temperature anomalies that were particularly pronounced if combined with solar minima.