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Quantifying suspended sediment sources during flood events in headwater catchments using diffuse reflectance spectroscopy

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Increasing the understanding of the hydro-sedimentary dynamics at the catchment scale requires data on the origin of suspended sediments in addition to the classical measurements of suspended sediment concentrations and discharge. In mountainous environments the extremely high spatial and temporal variability of suspended sediment fluxes suggests that the proportions of suspended sediment sources transiting at outlets may also exhibit strong variations during flood events. However, conventional fingerprinting techniques based on geochemical and radionuclide measurements are time-consuming and rather expensive. They constitute a major limitation to conduct routine characterisation of the source of suspended sediment transiting at outlets that would require the analysis of a large number of samples. We investigated how visible or infrared diffuse reflectance spectroscopy coupled with partial least squares chemometrics techniques could be used to predict the proportion of source material in suspended sediment samples and how it could help understanding the hydro-sedimentary processes occurring during floods.

The studied catchment is located in the southern French Alps, draining an area of 22-km^2. It is composed of black marls, limestones, molasses, undifferentiated deposits and gypsum. Forty-eight source material samples were collected in badlands areas and 328 suspended sediment samples were collected at the outlet during 23 flood events. Spectroscopic measurements were carried out on dried samples. Given that the erosion processes are particle size selective, five size fractions of source material were measured in order to assess the potential alteration of the signatures. As the biogeochemical processes occurring in the river such as iron oxidation could also affect the signatures, source materials that were immersed in the river for durations ranging from 1 day to 9 weeks were analysed. Finally, partial least-squares regression models were constructed on 81 artificial laboratory mixtures to predict the proportion of source material in suspended sediment samples.

Both measurement techniques in the visible and infrared wavelengths discriminated the primary source materials but not the quaternary deposits. As the gypsum was not conservative, only the black marls, molasses and limestones were used in the fingerprinting procedure. The construction of the partial least-squares regression models with artificial mixtures led to a median prediction error of 1.1%. This error increased to 4.8%, 5.4% and 14.7%, respectively, when the models were applied to source samples with different immersion duration in the river, with different particle size and with different origins than those used in the artificial mixtures. Given those uncertainties, we found a general good agreement between results obtained with both techniques. Half of the 23 flood events analysed exhibited high temporal variations in the source proportions measured at the catchment outlet. This emphasizes the need to characterize the suspended sediment source routinely on all samples collected during flood events using automatic sequential samplers. The simultaneous analysis of the data set produced with this non-conventional fingerprinting method with the discharge-concentration time series as well as with rainfall radar data should provide new insights to improve our understanding of hydrosedimentary processes occurring at the flood event scale in small mountainous catchments.