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A Spatially Distributed Conceptual Model for Estimating Suspended Sediment Yield in Alpine catchments

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Suspended sediment is associated with nutrient and contaminant transport in water courses. Estimating suspended sediment load is relevant for water-quality assessment, recreational activities, reservoir sedimentation issues, and ecological habitat assessment. Suspended sediment concentration (SSC) along channels is usually reproduced by suspended sediment rating curves, which relate SSC to discharge with a power law equation. Large uncertainty characterizes rating curves based only on discharge, because sediment supply is not explicitly accounted for.

The aim of this work is to develop a source-oriented formulation of suspended sediment dynamics and to estimate suspended sediment yield at the outlet of a large Alpine catchment (upper Rhône basin, Switzerland). We propose a novel modelling approach for suspended sediment which accounts for sediment supply by taking into account the variety of sediment sources in an Alpine environment, i.e. the spatial location of sediment sources (e.g. distance from the outlet and lithology) and the different processes of sediment production and transport (e.g. by rainfall, overland flow, snowmelt). Four main sediment sources, typical of Alpine environments, are included in our model: glacial erosion, hillslope erosion, channel erosion and erosion by mass wasting processes.

The predictive model is based on gridded datasets of precipitation and air temperature which drive spatially distributed degree-day models to simulate snowmelt and ice-melt, and determine erosive rainfall. A mass balance at the grid scale determines daily runoff. Each cell belongs to a different sediment source (e.g. hillslope, channel, glacier cell). The amount of sediment entrained and transported in suspension is simulated through non-linear functions of runoff, specific for sediment production and transport processes occurring at the grid scale (e.g. rainfall erosion, snowmelt-driven overland flow). Erodibility factors identify different lithological units, while the distance from the outlet is accounted for by including sediment wave velocities. The model is calibrated and validated on the basis of continuous turbidity data measured at the outlet of the basin. In addition, SSC data measured twice per week since 1964 are used to evaluate the performance of the model over longer time scales.

Our predictive model is shown to reproduce SSC dynamics of the upper Rhône basin satisfactorily. The model accounts for the spatial distribution of sediment sources (location and processes of erosion and transport) and their activation/deactivation throughout the hydrological year. Therefore, it can reproduce the effects of changes in climate on sediment fluxes. In particular, we show that observed changes in SSC in the upper Rhône basin during the last 40 years are likely a consequence of increased air temperatures in this period and the consequent acceleration of glacial erosion.