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Inferring sediment connectivity from high-resolution DEMs of Difference

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Topographic changes due to the erosion and deposition of bedrock, sediments and soil can be measured by differencing Digital Elevation Models (DEM) acquired at different points in time. So-called morphological sediment budgets can be computed from such DEMs of Difference (DoD) on an areal rather than a point basis. The advent of high-resolution and highly accurate surveying techniques (e.g. LiDAR, SfM), together with recent advances of survey platforms (e.g. UaVs) provides opportunities to improve the spatial and temporal scale (in terms of extent and resolution), the availability and quality of such measurements.

Many studies have used DoD to investigate and interpret the spatial pattern of positive and negative vertical differences in terms of erosion and deposition, or of horizontal movement. Vertical differences can be converted to volumes, and negative (erosion) and positive (deposition) volumetric changes aggregated for spatial units (e.g., landforms, hillslopes, river channels) have been used to compute net balances.

We argue that flow routing algorithms common in digital terrain analysis provide a means to enrich DoD-based investigations with some information about (potential) sediment pathways – something that has been widely neglected in previous studies. Where the DoD indicates a positive surface change, flow routing delineates the upslope area where the deposited sediment has potentially been derived from. In the downslope direction, flow routing indicates probable downslope pathways of material eroded/detached/entrained where the DoD shows negative surface change. This material has either been deposited along these pathways or been flushed out of the area of investigation. This is a question of sediment connectivity, a property of a system (i.e. a hillslope, a sub-/catchment) that describes its potential to move sediment through itself. The sediment pathways derived from the DEM are related to structural connectivity, while the spatial pattern of (net) erosion and deposition has emerged from sediment transfer between the two epochs of the DoD (i.e. functional connectivity).

In this study, we use multitemporal raster DEMs generated (i) from terrestrial LiDAR surveys and (ii) by a landscape evolution model to compute DoDs. Flow accumulation is used to compute, for the contributing area of each raster cell, (i) the net balance and (ii) the total sum of material eroded. The net balance represents the sediment yield of the contributing area. In the case of a study area delimited by a catchment boundary, it is either negative (more sediment eroded than deposited within the contributing area, i.e. net export) or zero (eroded material has been re-deposited within the contributing area). Finally, the ratio of sediment yield and gross erosion is called the sediment delivery ratio (SDR). This number has been used as a “performance factor” indicating the degree of sediment connectivity, as it describes the proportion of material eroded on the local scale that is being delivered to the outlet of the contributing area. The evaluation of a DoD to compute the SDR overcomes one major criticism of the SDR, namely that gross erosion is generally estimated (e.g. by empirical USLE-type equations) rather than measured.

Both our proposed approach and the concept of SDR are subject to a number of caveats, which we will discuss in our contribution. In any case, we advocate more detailed analyses of DoD using flow routing algorithms in order to include information on potential sediment pathways in morphological sediment budgets for hillslopes and catchments.