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Hydrology and Earth System Sciences Discussions

Interactive comment on "Reading the bed morphology of a mountain stream: a geomorphometric study on high-resolution topographic data" *by* S. Trevisani et al.

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The authors wish to thank the referee for his valuable comments.

General comments We agree with the observations of the referee about the difficulties in classifying the morphology of mountain channels. The uncertainties in achieving a univocal differentiation between step-pool and cascade reaches in the Rio Cordon, stressed by the referee, agrees well with the results of the geomorphometric analysis. Moreover, the reviewer comments that, at a reach scale, step pool and cascade are not different. This provides another explanation (non site-specific) for the lack of major differences between these morphologies, which arises from geomorphometric indexes. However, the geomorphometric “signature” of a step pool sequence (figure 10 b and figure 10 e) is really distinctive, at least when these structures are well developed. The advice of the reviewer about a cross-comparison of the proposed method with other algorithms/techniques opens an interesting prospect for next develpment of geomorphometric studies of mountain channels. More research on wavelets seems profitable, with particular focus on the shape of mother wavelets to be used to detect channel morphologies. This analysis could be first conducted on data from flume experiments or from numerical models. The use of “synthetic” streambed morphological data would ensure high quality of data (with a resolution permitting to work a the scale of individual particles) and a good control of external forcings. Moreover, it is worth testing this geomorphometric approach not only in channels featuring longer and well defined step pool sequences, but also in different fluvial morphological contexts, whenever high resolution topographical data are available.

In the followings lines we reply to reviewer’s specific comments.

“At p. 7289, second paragraph:. . ..”. We partially agree with the view of the referee. Actually our sentence could be misleading and needs to be revised. Geomorphic processes, such as debris flows and landslides are widespread and frequent in mountainous basins, and they often interact with the channels. These extrinsic episodic processes have a quite immediate effect locally on bed morphology. However, we agree that destabilization of beds in high gradient streams requires intense and infrequent floods and the downstream propagation of channel-bed disturbances requires more time than in lower gradient gravel bed rivers.

Laser attenuation and bathymetric LiDAR Using topographic LiDAR system emitting near-infrared laser pulses, the main issue when surveying water bodies is the absorption (non return of the signal) more than the attenuation. The a posteriori evaluation, i.e. not carried out during the LiDAR survey, of the proportion of stream bed affected by the absorption of laser beams can be conducted with rough approximation. In the studied channel the areas affected by absorption of LiDAR pulse are limited to the few pools presenting during the survey a water level deeper than about 20 cm. In regard to the benefit of the use of a bathymetric LiDAR system, also known as green LiDAR, there are many aspects that make it unsuitable in the studied channel and in similar conditions. First of all, because of the different technical requirements of bathymetric and topographic LiDAR systems, they acquire data at different spatial resolutions. Typically, topographic LiDAR system can collect data with a closer average point spacing than bathymetric systems. The limits of airborne topographic LiDAR for deep water channels, are less serious for small headwater channels and with shallow flow depth, and can be further reduced by means of some watchfulness in the survey, such as carrying out the survey in low flow condition. Moreover, due to the signal characteristic of bathymetric LiDAR, stream bed topographic recognition is difficult in very shallow waters (<2 m) (Allouis et al., in press).

DTM at higher resolution The possibility to analyze DTM of higher resolution could likely improve the results. LiDAR points are affected by errors, so there is the need of information redundancy to get accurate estimates of the mean pixel height (smaller the pixel, higher the detail to be described and higher the sampling density required to describe it). This means that deriving an accurate 0.25 m DTM requires a spatial point density which is difficult to achieve with airborne LiDAR system, especially in areas of dense vegetation. Surely, a smaller footprint and some improvements of point density could be achieved by planning surveys dedicated to the channel, with flight lines that follow the stream path at a low and an almost constant height. These improvements are more intended for improving the quality of a 0.5 m DTM than for deriving an higher resolution DTM.

Terrestrial LiDAR The use of terrestrial LiDAR could be very profitable for a geomorphometric study of small mountain channels. Conducting the surveys during low flow regimes and with and adequate scan angle makes it possible to derive high resolution DTMs. These spatial resolutions permit performing the geomorphometric study of

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channel beds at the spatial scale of granulometry (Heritage and Milan, 1999). The multiscale spatial structure of the channel bedforms could be adequately quantified and its temporal changes monitored. Moreover, the use of terrestrial LiDAR could improve the detection and analysis of large woody debris. However, terrestrial laser scanning in mountain streams has also some possible drawbacks: due to complex topography, multiple stations can be necessary for covering a whole channel reach, and difficulties may arise in selecting high scan angles.

As a concluding remark on the last two points arose by the referee, we agree that both aerial LiDAR surveys at low height focusing on the channel bed, and terrestrial laser scanning would permit refining the analysis presented in our paper. However, these surveys require ad hoc campaigns, which, in the case of terrestrial laser scanning, would be quite time consuming if carried out on stream reaches hundred of meters long (as in the case of the Rio Cordon). Aerial LiDAR data from surveys with flight and instrumental parameters similar to that of the Rio Cordon are increasingly available, even for large areas, without additional economic and time resources. Our study has explored the potential of exploiting these data for a detailed morphometric characterization of a complex channel bed.

Cited references:

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