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Hydrology and Earth System Sciences Discussions

Interactive comment on "Estimation of soil redistribution rates due to snow cover related processes in a mountainous area (Valle d'Aosta, NW Italy)" *by* E. Ceaglio et al.

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1 General Comments

The present study deals with the contribution of "winter processes" to the sediment dynamics of a high-mountain study area. Due to difficult accessibility caused by snow cover and avalanche hazard, this kind of processes is often ignored or underrepresented in geomorphological studies on sediment transport or the sediment budget, especially if these studies rely on direct field measurements and observations of geomorphic processes. The authors have chosen an avalanche path in a study area with well-documented snow avalanche activity and snow gliding processes. The twofold methodology to estimate erosion and deposition rates by a) direct measurement of sediment loads of full-depth snow avalanches and b) calculating medium-term erosion/deposition rates by the 137Cs method is an interesting approach to quantitatively look at the ratio of a) snow related erosion/deposition and b) erosion/deposition effected by all geomorphic processes active on the investigated hillslope. The authors argue that it is possible to assess the relative importance of winter processes from these results. Moreover, the spatial distribution of sampling points allows for checking if the spatial pattern of erosion and deposition is consistent.

In the introduction section, the authors clearly state why research on "winter processes" is needed, and they comprehensibly outline why they expect their approach to contribute to a better understanding of the relative importance of these processes. Following a description of the study area, the methods are outlined, reaching from field sampling (avalanche snow and debris, 137Cs soil samples) to laboratory work and evaluation (estimating soil loss/gain via the 137Cs profile distribution model). The results comprise an assessment of soil erosion and deposition by a) two full-depth snow avalanches and b) results of the 137Cs method, including a spatial pattern of erosion and deposition which is consistent with the processes supposed to be active in different units of the avalanche track. The main conclusion from the results is that snow processes, above all full-depth avalanching, represents the main agent of soil redistribution in the study area.

Although I have some questions, mainly concerning the "conventional" results in comparison to the medium-term 137Cs data, I consider the paper interesting, well-written and worth publishing if these minor revisions are dealt with. Despite caveats relating to the upscaling of very site-specific results to larger areas, it can be expected that the conclusions of this work hold similarly for high-mountain areas with conditions favourable for snow-gliding and avalanching.

2 Specific Comments

In addition to the comments given by the previous reviewers, I would like to ask the following questions:

- p8536 l15: Does that imply multiple events during one season ? Or does "frequent" mean that a full-depth avalanche (which removes per definitionem all of the snow in the release area) occurs almost in every year ?
- p8539 l8: It should be explained how snow depth (and its spatial distribution) was measured/estimated. The accuracy of this assessment is important because it directly influences the calculation of sediment mass deposited by the avalanche. I can imagine, however, that the area which is sufficiently accurately determined by GPS and/or georeferenced (aerial ?) photos should be much more important as the lion's share of the sediments is located on the surface of the snow deposits (see Fig. 2). Could the authors also comment on why this might be the case ?)
- p8539 l20(Fig.2: I have the impression that the small size of the sampling mask is problematic and has to be dealt with in an error estimation of the avalanche sediment yield. Looking at Fig.2, it can be clearly seen that the sediment cover on the avalanche snow is not at all homogeneous at that scale, at least not as much as it would look within a 50x50 cm or 100x100cm mask (sizes which have been used in previous studies on avalanche sediment transport). If one had taken the samples 20 cm away, it looks like one could have sampled only half of the material, or much more, e.g. with the single rock particle left of the sampling mask. This rock particle led me to another question: Did the authors only sample "soil", i.e. without larger rock particles (the procedure outlined in 2.2.2 suggests that) ? If so, is this due to the comparison with 137Cs derived erosion rates ? If not, is there at least an estimate of the proportion of coarse sediment in the bulk sediment ?

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- p8540 l5: Do the samples include inorganic sediment only ? If the samples contain a large amount of organic debris, it would lead to an overestimation of sediment volume. In my own work, the proportion of organic particles could sometimes reach >40° of the total mass... Moreover, error estimation is important here (methods: which errors were assessed and how) and in the results section (result +/- error estimation)(c.f. comments by Peter Molnar) ? In Table 1, only the sediment concentration data are given with an error estimation, and it is not clear if the latter comes from the determination of snow volume or from the scatter of the samples.

- p8544 l7: I would like to join Bernhard Kohl in his plea for (a little) more reference data here.

- p8544 l10: In my opionion, this is a major point of concern: The authors state that in previous years, full-depth avalanches had not occurred once a year ("only few events") with the exception of the last four winter seasons (2007/2008-2010/11). I have my doubts that under these circumstances data from two events can be taken 1:1 as yearly accretion rates, a) because of the large natural variability of event sediment loads (previous work has shown that the sediment load of avalanches is only loosely related to factors like avalanche size or substrate) and b) because of the temporal variability of avalanche occurrence. In the present study, the obviously well-documented record of avalanche activity (back to 1986 or even further ?) should make it possible to make at least an "educated guess" on the yearly transport rates on the basis of a) the measured data of two events and b) the frequency of potentially sediment-transporting avalanches as documented in the official record. This is important because it might affect the conclusion concerning the ratio of directly measured and 137Cs-inferred accretion rates, p8548 l10ff.

- p8544 l18: see comment in l7 and, again, Bernhard Kohl's reviewer comments.

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However, a comparison of erosion rates in the existing literature is difficult because different authors use very different reference surfaces (contributing area of the snow deposit or a subunit of it, total area of the avalanche, only release and track areas etc...).

- p8546 l20: This suggests that snow-gliding is a selective transport process which entrains fine material while leaving coarser fractions behind. From my personal understanding of the process "snow gliding" (more or less homogeneous movement of the whole snow cover over smooth surfaces, tearing out clods of soil e.g. where vegetation or other roughness elements were frozen in the snowcover, and/or "bulldozing" effects), I cannot fully follow here. I can however imagine that slope wash (or even rill erosion) may occur on areas stripped of vegetation/topsoil by snow gliding, and the transport of this material then occurs selectively leading to the observed sorting of the deposits. Hence, snow gliding not only directly causes removal and redistribution of soil but also conditions other soil erosion processes. Here is a possible reference: Stocker, E. (1985): Zur Morphodynamik von Plaiken, Erscheinungsformen beschleunigter Hangabtragung in den Alpen, anhand von Messungsergebnissen aus der Kreuzeckgruppe, Kärnten. In: Mitteilungen der Österreichischen Geographischen Gesellschaft 127: S. 44–70
- p8548 l12ff: In my opinion, it could also be due to a) extreme (spatio-)temporal variability of avalanche sediment dynamics (as documented in the literature) and also of b) avalanche activity itself (c.f. comment p8544 l10). This issue should be discussed in the results and discussion section and briefly included here.
- Fig8: Is it possible to include all sampling areas in their topological order in this diagram to identify the consistent pattern of erosion and deposition derived from your samples ?
- Peter Molnar has made an interesting suggestion concerning the interpretation of the results with a catchment perspective. In this respect, it would be interesting

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to see not only the number, but the areal proportion of terrain units favourable for "winter processes", e.g. steep alpine meadows or hillslopes with a low roughness.

3 Technical Corrections

- p8534 l11: by the 137Cs method
- p8534 l14: are comparable
- p8536 l3ff: Soil redistribution by winter processes is conventionally assessed by...
- p8538 l16: was affected
- p8539 l7: were mapped in a GIS
- p8545 l5: on the basis of OR based on
- caption Fig.9: ...all the points belonging to TA1 and TA2... Add explanation of empty circles

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