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Interactive comment on "Soil erosion and organic carbon export by wet snow avalanches" *by* O. Korup and C. Rixen

Anonymous Referee #2

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1 General Comments

This is a well-written, original paper that adds data to the issue of the geomorphic activity of snow avalanches, based on a partially decent (n=28 avalanche deposits) and partially unprecedented (n=100 point samples of debris cover on each deposit) sample size. While the results appear to corroborate existing data, they represent a major contribution in the following aspects: First, a new sampling strategy has been chosen that appears to be well suited to cover the inhomogeneous sediment cover of avalanche snow deposits. Second, stochastic estimates of the range and distribution of debris transport by avalanches are given that are comparable with estimates for different geomorphic processes (Fig. 6). Third, debris and organic carbon are treated separately,

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reflecting the increased interest in carbon cycling. The measurement results highlight the large between-sites variability, and the simulation is employed to estimate the site-specific variability under the assumption that avalanches have a power-law magnitude-frequency relationship.
In my opinion, the methods are well described, reproducible, and appropriate.
To me, the generality of the findings appears a little overstated here and there (captions of Fig. 4/5 say it refers to estimates of sediment yields for the "eastern Swiss Alps" rather than the particular study area; the coupling situation of avalanche deposits and the channel network can be very different in other study areas where avalanches stop on straight slopes and/or are by far wider than the channel they interact with).
It would be nice if the authors could add a few comments on the factors that influence the geomorphic activity (sediment availability, landcover, avalanche size, timing of the event, etc), at best with relation to their findings; does (or could) the spatial distribution of measured/simulated sediment yield (Fig. 5) reflect any properties of the corresponding source/transit zones ?
All in all, I recommend accepting this very interesting contribution after minor revisions.

2 Specific Comments

- p3l23 is there a difference between impact ponds and plunge pools ? A standard reference for avalanche geomorphology is Luckman (1977, Geogr. Ann.). This one, however, does not cover impact landforms; for those, refer to Luckman, B., Matthews, J., Smith, D., McCarroll, D., and McCarthy, D.: Snow-Avalanche Impact Landforms: A Brief Discussion of Terminology, Arct. Alp. Res., 26, 128–129, 1994.
  or to Owen, G., Matthews, J., Shakesby, R. A., and He, X.: Snow-avalanche impact landforms, deposits and effects at Urdvatnet, Southern Norway:ÂăImplications for avalanche style and process, Geogr. Annaler. A, 88,

TCD
8, C61–C67, 2014

295–307, 2006.

- p3l19 suggestion: rates of sediment transfer and nutrient cycling
- p4l10ff: At first reading, snow bridges (the focus of this paper) appeared to me as a rather special case; it is definitely not the only mode of deposition. Whether a snow bridge forms depends on the association of avalanche activity with the hillslope channel network as well as the spatial configuration of slopes and the trunk stream. What is addressed here is lateral connectivity or hillslope-channel coupling. It would be interesting to know the relative proportion of the "snow bridge" situation in your study area compared to fan-/cone/tongue-like avalanche deposits without direct coupling to a channel (either tributary or trunk). Later it is explained that ALL sampled deposits were in fact snow bridges. Does that refer to all avalanche deposits in your study area, or only to the sampled ones, as the focus lies on snow bridge-type deposits as stated in p4l11 ?
- p426f: This requires the avalanche to be covered in a continuous manner; in many of the avalanches that I have seen, I could not have employed a ruler to measure the thickness of the sediment cover, because there was "here a piece of rock, there a clod of soil, there a piece of torn-out grass", i.e. a very patchy distribution of sediment cover rather than a "layer" the thickness of which would be straightforward to measure... Maybe you could mention that the appearance of the deposits made your field approach feasible, and discuss if there might be situations in which this is not the case, and plot sampling rather than point measurement would probably be needed.
- p5l1: I could not imagine the "blindfolded and at random" choice of measurement spots until I read how you chose the 1 square meter plots in line 7f; probably the procedure should be explained already when you first mention the sampling strategy/technique.

TCD
8, C61–C67, 2014

- p5l29: You describe how you introduce a 20 percent error for the area of the avalanche deposits. Did you also propagate the 20 percent error of the thickness measurements, or did you only rely on the variance of thicknesses measured (either site-specific or across all sites) ?

- p6l4f: how was the maximum contributing area delineated ? As the catchment area of the uppermost cell(s) of the deposit on a DEM ? More importantly, is this assumption justified for all avalanches ? I could imagine that small hillslope facets or hollows effectively limit the size of the generated avalanches, but what about a situation in which the avalanche deposit is situated in/near a channel that drains a whole cirque, for example ? In this case I doubt that the ratio of catchment area and avalanche area will be close to 1:1. In my opinion, the maximum avalanche is limited by "hillslope facet" area rather than the total area of its hydrological catchment... Is there any theoretical or empirical justification for this, or has the limit been set arbitrarily without a theoretical background ? Again, this is not supposed to make your approach useless, but it should be briefly commented. The division of total yield by the catchment area in order to estimate specific yield is common practice and o.k., although for the specific avalanche the actual contributing area might be much smaller than the hydrological catchment, making the SSY a minimum estimate of the actual denudation...

- p6l10: n=1000 refers to 1000 simulated debris volumes in total (500 site-specific, 500 from pooled distribution) or 1000 simulations each ? I think this is of minor importance given the sample size, but should be 100 percent reproducible

- p7l2: the fractions are not displayed in Fig. 3b, this is the histogram of cover thickness. Did you mean 3A?

- p7l24ff I would say that your approach is rather new, as the studies I know of mostly employed plot-based sampling, stratified by pre-selected areas of homogeneous sediment cover

TCD
8, C61–C67, 2014

- p8l12: unprecedented ? Well, Andre sampled 88 avalanches (Andre, M.-F.: Geomorphic Impact of Spring Avalanches in Northwest Spitsbergen (79° N), Permafrost Periglac. Process., 1, 97–110, 1990, table 3 p. 108), Heckmann et al. (2005, ZfG) quantified 113 deposits, Rapp (1960, Geogr.Ann.) had 75 (table 18, p. 133)... However, I do acknowledge the novelty in your paper that lies in the large number of random samples (100 thickness measurements per avalanche might indeed be unprecedented), in the stochastic approach, and in the particular regard of organic material)

- p8p16: Pls explain a bit further. You did not find any systematic variation of avalanche sediment yield across the study area that could be related to some property of the avalanche tracks or the avalanche catchment area ?

- p8l26ff What density was used for bedrock ? If you compare your specific sediment yield, translated into denudation in mm/a, to Moore et al., you imply that in both cases sediment was in fact eroded from bedrock - in reality, much of the sediment in your study area is supposed to be entrained/mobilised by avalanches, having been mobilised by weathering and/or transferred to the avalanche path by some other process, right ? This has been stressed by many previous workers, e.g. by Luckman (1977). So your results are not really comparable to "bedrock erosion rates".

- p9l10: what about shallow landslides ?

- p9l11ff: I tend to disagree that MOST of the material is expected to be delivered the channel network (in my opinion, Fig 1D clearly shows that a large proportion of sediment is going to be deposited on an "open slope" and not in or near a channel when the snow bridge has melted away). Even if this was valid for your study area, it cannot be generalised. In my own work, for example, the vast majority of avalanches did not develop snow bridges and was not coupled to the

TCD
8, C61–C67, 2014

channel network in more than a point-based manner (to use the coupling typology of Korup, 2005, ESPL).

- Fig. 3A: Add that the avalanche samples on the x axis are sorted by total surface concentration. The "filled area" graph type is maybe better for continuous variables on the x axis, I'd like to suggest using stacked bars instead to stress that there are 28 separate deposits that you have sampled and analysed; the proportions of the grain size fractions are barely visible for the sparsely covered avalanches anyway.
  The explanation in the figure caption of Fig. 3 is not consistent with what I understood from the methods section. Why does Fig. 3B represent 2006 point measurements instead of 28*100=2800 ? Why is the debris-cover thickness measured in 1 square meter sample squares ? I understood that the thickness of the sediment cover was measured on a point basis (at 100 points) with a ruler, and that the there was only one square meter sample per avalanche deposit... In the stochastic approach, cover thickness drawn from the empirical data is attributed to 0.01 square meters (p6l6). Please check if these statements are all correct.

- Fig. 4: Generality appears a little overstated here: I think that your results may well be valid for your study area, but not for the "eastern Swiss Alps" as it reads in the caption. (Same for caption of Fig. 5)
  Is the position of "Field" between the PDFs drawn with 10 and 100 sqm minimum areas a hint that a realistic value for the minimum area parameter ranges between 10 and 100 ? Moreover, a minimum size of 1 sqm does not seem to be a reasonable minimum size... Avalanches on that scale are not supposed to exist, let alone to do geomorphic work, aren't they ? Perhaps the PDF with 1 sqm minimum can be left out.
  The "field" PDF appears to be bimodal for sediment yield - are there maybe two groups in the data ? Any idea why ?
  The log scale in both figures refers to log10 ?

TCD
8, C61–C67, 2014

3 Technical Corrections

- p3l27: disturbance...HAS been shown to increase...
- p4l18: deposits OF snow avalanches ?
- Figure caption Fig. 5: "...follow method outline*d* in text, assuming..."

Interactive comment on The Cryosphere Discuss., 8, 1, 2014.