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Interactive comment on "Geo-climatic hazards in the eastern subtropical Andes: Distribution, Climate Drivers and Trends" *by* Iván Vergara et al.

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General Comments

This manuscript offers a clear and interesting analysis of the interaction of snowfall and rainfall on the triggering of landslides and snow avalanches in a section of the Argentinean central Andes, where they pose a significant hazard and risk in a very busy transport corridor. The hazards are divided in two zones with different climatic patterns, which allow statistical analysis to assess the effects of climate and global warming on the hydrometeorological hazards activity. The manuscript is well written, figures are fine and results are sound.

[Reply] Thank you for your general and specific comments. They have helped to improve the manuscript. We addressed all the observations and below are our point-by-point responses.

My main comments are on the line of providing some more detail in the statistical methods used for the analyses, rather than just giving a reference citation, and in particular to provide, if possible, or at least comment in the discussion, more detailed insights on the relationship of snowfall and rainfall patterns with landslide types.

[Reply] Thanks for raising this point. Where necessary we clarified the statistical methods (lines 191-193) and we expanded our discussion on the G-CH types and climate drivers (lines 299-301).

You have a database with landslides classified as debris flows, falls, rotational and translational slides and complex landslides, with nearly 80% of them debris flows. Is it possible to get relationships for those types as separate subsets of data? They may be not statistically significant, but it would be interesting to comment on this. Are the results biased for debris flows?, thus are they applicable for the other landslide types?

[Reply] In the new historical record of events, there is no a dominant type of G-CH: 31% are flows, 33% are falls, 20% are snow avalanches and 16% are undetermined (lines 156-162). Thus, while your suggestion is interesting we have refrained from getting specific relationships for each subset given the small number of events in those samples. The aggregated analysis, on the other hand, provides more statistical robustness. Due to the rather even distribution of G-CHs types we don't think that results are biased for debris flows. We have commented on this issue in lines 178-180.

A second issue is that for the analysis you separate the area into terrain units of ravine, talus and rock walls, which are very variable in size. Could you explain the criteria to define these terrain units, which are used for probability assessment? Is the size difference a problem? I presume they are linked to some preferent landslide type (e.g. rock wall for falls, ravine for flows), is then possible to analyse the data in subsets of landslide type and/or terrain unit?

[Reply] The definition of the terrain units is now described in section 2 (lines 128-129). All terrain units that intercept the route or the railway were drawn using hydrological tools of the SAGA software. The G-CHs were assigned to the different units either because the sources indicate the name of the activated ravine or the kilometre of the route or the railway that were cut. For the second case, the distances along the route and the railway were georeferenced to know which terrain units were activated. Sometimes talus cones and rock walls (not always automatically separable with the channel network) present activities in specific sectors of a terrain unit. In these cases, the terrain units were subdivided but having a minimum area limit of 0.2 km2, in order to not delimit a terrain unit in each place where a fall or a debris avalanche occurred. The different size of the terrain units was not a problem for the spatio-temporal probability assessment since we used the date of each G-CH and the along-route distance that was affected by the G-CH. We are aware that having the volume of each G-CH or a proxy of this could have resulted in a better probability assessment, but such volume is unknown for the vast majority of the cases.

Minor Points

L55-57. What can you say about g-CHs in the Chilean side? Are they absent, or there are no data?

[Reply] In the valley of the Aconcagua River (Chilean side of the international road) there are also many G-CHs (e.g., Sepúlveda and Moreiras, 2013; Sepúlveda et al., 2015) with negative impacts in infrastructure and transportation. In this work, however, we have focused on the Argentinean side give the long, high quality record developed for this sector. Note that the route and the railroad change the jurisdiction, and the databases of these organisms, which are the most important source, were not available for the Chilean side. We acknowledge this limitation in lines 55-57.

L67-79 In this paragraph you provide some details on debris flows characteristics and mechanics, but say nothing on the other landslide types or snow avalanches also included in the analysis, can you homogeneize the information?

[Reply] Thanks for the comment. We add information about the other landslide types and the snow avalanches in lines 75-77.

L144-147. could you mention the proportion of those landslides/avalanches triggered by earthquakes or other identified triggers in comparison with climatic or unknown trigger?

[Reply] 59 landslides triggered by earthquakes (9% of the total landslides and snow avalanches), 16 landslides by snowmelt (2% of the total) and 55 landslides without an established trigger (8% of the total) were counted. Information added in lines 52-54.

L173-174 could you please explain a bit these methods in the Methods chapter? Computing the probability is of the most significant aspects for hazard analysis.

[Reply] Thanks for the comment, information about the method to calculate the probability was added in lines 191-193.

L220-227. Please explain why you use surface temperature data only from the Chilean side? are they representative?

[Reply] These high-elevation station are located at 25-80 km from W zone where 87% of the snowfall-driven G-CHs take place. These distances are acceptable for the typical spatial variation of temperature. It is now indicated in the text because these stations were used and not those in Argentina (lines 248-250).

L465 please revise the sentence "Horizontal lines indicate the seasonal division used and vertical thick (thin) line."

[Reply] We have corrected this phrase (lines 509-510).

New References

Sepúlveda, S. A., and Moreiras, S. M.: Large volume Landslides in the Central Andes of Chile and Argentina (32°-34°S) and related hazards, Bulletin of Engineering Geology and the Environment, 6, 287-294, 2013.

Sepúlveda, S. A., Moreiras, S. M., Lara, M., and Alfaro, A.: Debris flows in the Andean ranges of central Chile and Argentina triggered by 2013 summer storms: characteristics and consequences, Landslides, 12(1), 115-133, 2015.

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