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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Climate anomalies associated to the occurrence of rockfalls at high-elevation in the Italian Alps" *by* R. Paranunzio et al.

Anonymous Referee #1

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General Comments:

Paranunzio and coauthors apply a statistical approach to identify temperature and precipitation anomalies associated with 41 recent slope failures in the Italian Alps. Such a systematic and robust approach is most welcome, as several previous studies in this field have tended to be rather inconsistent or less rigorous in how they have quantified weather and climate extremes. While this is an important step, I feel an opportunity has been missed in this study to improve our understanding of the underlying processes that link climate driving with slope failures. In this regard, the manuscript is largely speculative and offers little new insight. I believe the manuscript can make a far greater contribution if major revisions were undertaken either:

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Discussion paper

1) To significantly increase the sample size used in the analyses. As the authors indicate, an inventory of 41 events is comparable to those used in previous studies, so this means the current study faces the same statistical limitations as previous efforts, and all results need to be treated cautiously. This is unfortunate, because the analytical method developed by Paranunzio and coauthors offers great potential for applying over large datasets, which may then reveal robust patterns occurring over large regions. The authors mention that lack of consistent collection of climate data could prevent such an analyses of merged inventories, but I don't see this as being a limiting factor in the European Alps.

or

2) If the focus of the study is to remain only on the 41 events from the Italian Alps, then considerably more detail about these events should be tabulated and included in the manuscript, for example, geological conditions (joint density, factures, lithology etc), failure type, presence of ice/snow in the failure area etc. You should also provide estimated (extrapolated) temperatures at the elevation of your detachment zones. Yes there will be uncertainties with these extrapolations. However, you will then be much more confidently able to link melt or freezing related processes to these failures. Such information should not be difficult to compile for a listing of only 41 events, and would provide more evidence to support the currently speculated causes of the failures.

Specific Comments (P page, L line):

P 1, L 22: I don't really agree that your study points towards the possible role of climate change in triggering slope failures. In contrast, the fact that there is so little difference between warm and cold anomalies would rather suggest climate warming is less important than some other studies might suggest. You may simply delete the word "change" from this sentence.

P 2, L 14: I am a bit confused when you speak of "absence of evident rainfall". This suggests that you are already excluding some events that are clearly linked to precip-

itation triggering – why would you want to do this when the point of the analyses is to identify such climate triggers?

P 2, L 25: I missed some general overview of the geological and geomorphological setting of the study region which of course may have a significant control on the distribution of slope failures discussed later.

P 3, L 3-4: At what elevation are these temperature values from? Without such information the values are not of much use.

P 3, L 13-15: This clustering of events in 2004 is interesting and I expected to see it discussed again later in the context of your results. Were these events linked to a particular climate anomaly in 2004?

P 6, L 2: I find it very unlikely that "recent global warming" has had much (or any) influence on the distribution of permafrost relative to the mapping of Boeckli et al. Depends on what you mean by "recent", but certainly the distribution of permafrost unlikely to have moved beyond the 360 m uncertainty range.

P 6, L 25: This is where I begin to question if these results can be considered statistically significant, given we are dealing with only 41 events, and where application of your methodology to a larger combined inventory could lead to some truly interesting and robust findings.

P 8, L 35-36: Obviously this finding needs to be treated cautiously given the small sample size, but, nonetheless this warrants more discussion given that it would suggest the possible role of global warming is not at all clear. In fact, if this finding is robust, global warming could be expected to cause fewer events being triggered by cold anomalies, which would largely offset any expected increase in events caused by warm anomalies.

P 9, L 16-24: This attribution of the rockfalls to causal mechanisms is very speculative, and would need to be supported with more details about the specific conditions in the failure zones of these events (including extrapolated temperatures), and with cited

literature on these processes. I also don't find the logic regarding the different elevation of the western and eastern Alps particularly convincing. I could argue in contrast that marginal (around 0 degrees) and slowly degrading permafrost at depth is likely more prevalent in lower elevation zones, while at high elevation the permafrost is likely colder and less susceptible to recent warming.

P 9, L 30: As with previous comment, the logic that permafrost thawing would contribute only at highest elevations seems questionable, and is inconsistent with previous studies that highlight the importance of permafrost in elevation ranges where marginal conditions prevail (down to ca 2500 m on shaded slopes).

P 9, L 33-35: Short-term temperature anomalies will not lead directly to thawing of permafrost due to the slow response of temperatures at depth. Rather here you should highlight the link between short-term warm anomalies and active layer thickening, with references to appropriate literature (e.g., several papers by S. Gruber and co-authors).

P 9, L 36-37: But there is no reason that a ST warm anomaly causing precipitation to fall as rain rather than snow will on its own lead to a failure right? Such an event would also need to coincide with a large precipitation anomaly for there to be any influence on the underlying slope stability. Do you see in your results any such anomalies coinciding? Also, providing extrapolated temperatures to the elevation of the detachment zones would provide much more support for speculated processes such as these.

P 10, L 32-34: Merging and providing a combined analyses of these datasets (at least for the European Alps) would be very exciting, and I encourage the authors to consider this. In my view, this will provide the best opportunity for further advancement of understanding in this field.

P 11, L 3-6: Could gridded global scale datasets and reanalyses products be used to overcome the inconsistencies in ground based climate data?

P 11, L 14-17: Previously you describe only a "slight difference" in the role of warm

vs. cold temperature anomalies. So is this really a sufficient basis to support the hypothesis that global warming and cryosphere degradation is impacting on slope stability? Especially as your study does not specifically assess or quantify cryosphere degradation in or around your failure zones. In fact, some of the causal processes you speculate (rain vs. snow etc) are not linked at all with cryosphere degradation. Rather, I would suggest that the results of this study, and particularly the large amount of events associated with cold anomalies would indicate that the relationship between climate change and slope stability might not be so straight-forward.

Technical Comments (P page, L line):

P 1, L 1: “associated to” > “associated with”

P 1, L 11: “occurred at” > “occurring at” (numerous other instances also – please check)

P 1, L 16: I would add “SIGNIFICANT temperature anomalies in 83 % . . ..”.

P 1, L 35: Delete/move the Stocker et al. reference, as citing at the end of the sentence implies that Working Group I of IPCC made a link between cryosphere degradation and slope failures.

P 1, L 35: “change in” > “influence on”

P 2, L 11: “that can be deemed responsible” implies you are able to establish clear linkages. I would suggest “that may be responsible”

P 9, L 6: “prevail on” > “prevail with”

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