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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Present and future changes in winter climate indices relevant for access disruptions in Troms, northern Norway" *by* Anita Verpe Dyrrdal et al.

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General comments:

I highly welcome this study on future changes of winter climate indices relevant for snow avalanche release. I especially appreciate that this study focusses on Northern Norway, as this is the area I am also working in. There is certainly a lack of studies focusing on future snow avalanche activity in a warming climate. At a first glance, this is rather astounding given the potential geohazard implications.

However, there are mainly two things that prevent the majority of studies from being

made: 1) Avalanche release is very complex and not fully understood yet. A combination of snowpack and meteorological factors at different spatial and temporal scales lead to their release. 2) Knowledge of avalanche activity over time at regional scale is not available in many regions.

This manuscript focusses on triggering meteorological factors and studies how they change over time under a climate warming scenario. I think this is a great idea, however, this study falls short on a number of major things. I would like to point these shortcomings out to the authors and ask them to consider my suggestions:

1) Appropriate choice of winter climate indices: I do not think that all indices and/or their thresholds chosen in this study are relevant for snow avalanche release. The problem might be that the authors are not completely familiar with snow avalanche literature and the concepts of prescribing meteorological thresholds to avalanche release. You are mainly studying direct action avalanching and as a starting point, I would suggest looking into Hendrikx et al. 2005 in CRST, or Davis et al. 1999 in CRST, or Floyer and McClung, 2003 in CRST.

You will find both meteorological variables, their rates and time scales at which we need to forecast them. I do not think it makes any sense if you are for example neglecting thresholds cited from an NVE report and instead use a 4 times lower threshold only because it gives you more data to work with. If you do so, you would have to argue for it and explain the uncertainty associated. I also think you would for example gain from deriving a snowdrift factor instead of looking at precipitation and wind separately.

I would also like to suggest rewriting the introduction after studying the literature on statistical avalanche forecasting and by also considering climate change studies on avalanche activity. There are a few studies from Switzerland (e.g. Schmucki et al., 2014, Marty & Meister, 2012) or France (e.g. Eckert et al., 2013, Castebrunet et al., 2014).

2) Past winter climate indices: I am not quite sure why the past development of the

chosen winter climate indices is of interest. In its current form, what do we learn from this exercise? These results would certainly be of great interest if you could compare them to past avalanche activity. One could then calculate an avalanche activity index and look if meteorological values were different between avalanche / non avalanche days. There is a database of avalanche accidents from NGI, there are road closure databases from Statens Vegvesen and there are regobs.no observations from recent years to work with. Finally, there is NVE's skrednett database of avalanche observations that could be used. I would like to suggest rereading Jaedicke et al., 2008 for inspiration.

3) Mixing of terms and geohazard focus A lot of times you are talking about different types of slope processes or you talk about slides and avalanches, snow avalanches, slushflows and so on. There is a lot of intermixing of terms describing the same process. I would suggest you are clearly focusing on one slope processes – snow avalanches and for that matter, the closure of roads by snow avalanches.

4) Two communities Since there are large differences between coastal and inland regions, wouldn't it be more interesting to look at communities from these two different regions?

5) Aim of this study As I mentioned above, I find this study very interesting. However, I feel like your aim of this study is rather thin and very wage. What does it mean to 'go deeper' into selected indices? What do you mean by 'somehow' generating life interruptions and so on? I think you could present a clear research question or even better a hypothesis (maybe based on the literature you presented) and then go on and test it.

6) Discussion and conclusion In many studies, reports and fact sheets on the climate change – avalanche relationship, very general statements are given that in my opinion do not have much value. Simply because there is always a second or third alternative scenario that is probably as likely as the one proposed.

Let me give you two examples:

You start by stating that areas with heavy snowfall and large snow amounts saw a high potential of dry snow avalanches. This can be true (you could check by comparing with skrednett.no). However, there is a different scenario, like we see in Japan every winter, that very frequent snowfall produces a snowpack that is increasingly harder towards the bottom, preventing avalanches of noteworthy size from releasing. We rather see frequent, very small avalanches, called sluff. You then go on by stating that there might be a decrease in dry snow avalanching before 2040 due to a decrease in maximum snow amounts and heavy precipitation. An alternative scenario would be that we suddenly introduce more favorable conditions for weak layer development and get an increase in dry snow avalanche activity before it might decrease due to shorter winters and less/no snow at low elevations.

I think you are getting my point. The solution to this problem might be to first carefully compare the modelled winter indices to past avalanche activity (skrednett.no) in order to quantify which meteorological triggering factors release which type of avalanches. Then one could pick two/three interesting cases (e.g. dry snow avalanches triggered by snow storms, wet snow avalanches triggered by rain on snow) and play through possible future scenarios.

7) Language and typos I am not an English native speaker, so I do not comment on language and typos. However, I found quite a lot typos in the text.

Specific comments: 1 Introduction Is the reference to Platt, 1991 relevant here? This reference is neither very recent, nor from Norway.

After I googled the reference to Jacobsen et al. (2016) I feel like that the first part of your introduction is uncomfortably close to the introduction written by Jacobsen et al. Could you consider change your introduction to make it more your own!

Your reference to PRA Hordaland is from 1995. Could you please find some newer

numbers that certainly exist?!

What is a ‘debris avalanche’ that you are mentioning here?

The paper by Hestnes & Jaedicke (2018) is not a study really, but much more a discussion paper. They do not present any data that supports their claims, but rather discuss different scenarios of what is likely to happen.

2 Study region Being entirely above the Arctic circle, I would say that the entire county of Troms lies in the Arctic.

Please consider to be a little bit more accurate with the term ‘avalanches’. You are using different terms describing the same process as well as the same term to describe different processes.

The fatality statistics by Walberg and Devoli, 2014 is from 5 years ago. You could look at NVE’s varsom.no site for updated numbers. Especially since there were quite some fatalities in recent years.

Is it two or three municipalities you are studying? You are presenting confusing numbers.

The link to the avalanche hazard map is not working. It is called ‘susceptibility map’.

What is the difference between a ‘slide’ and an ‘avalanche’?

When you talk about numerous stretches of roads having steep slopes on their sides, I feel like this statement is not really supported. How many roads, on either sides or just one side, how steep, steep enough for avalanches to occur or maybe too steep?

You are presenting data from two weather stations; however, the place names are not known to other readers. Could you mark them in Figure 1 for example?

Figure 2 The color bars make it difficult to understand in detail which temperature and precipitation certain parts of the region experienced. In particular as the tick marks with

the numbers are not aligned with the borders of each color. Could this be changed so one can not only understand the overall spatial trend, but get a little bit more detailed picture of what is going on?

You are defining winter as the period October – April. Is this an officially used definition of the period or is it arbitrary chosen by you? If the second is true, could you argue for it?

Figure 3 I wonder if the graphs would be more readable if you would stretch them out horizontally across the entire page? Maybe also changing to a bar chart would help understanding the trends that are going on. Right now, the graphs appear very cluttered and are difficult to read.

3.1 Gridded observation-based data To make sure, you are talking about daily average temperature (T) and daily amount of precipitation (P).

3.2 Future projections (you number it falsely 3.1) What does HBV model stand for?

Gridded wind data is used from the past, but no projections are made? Why use it then? And what about a wind drift factor?

Table 1 I am not a climate modeler, so this table does not make much sense to me. What are all the acronyms stand for? Why are there ten combinations of these things and what does that mean? Could you try and explain the table better?

3.3 Weather indices You could shorten the first paragraph to two sentences since you are explaining both the literature search and potential triggering factors twice.

The transition from dry to wet snow is decisive of the release of wet snow avalanches.

The statement by Lied & Kristensen (2003) is certainly true, however, I believe not really relevant for your study.

Your last paragraph citing the study by Eckerstorfer et al. (2018) reads like study area description. Please consider moving it there.

4 Results Figures Could you underly these maps with a hillshade so high and low-lying areas are better visible for interpretation?

Isn’t it counterintuitive to color negative change in warm colors and vice versa?

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