Reply to referee #1

We thank referee #1 for her/his detailed and insightful comments on our manuscript nhess-2016-232. Below we try to give detailed replies to the annotations and briefly outline the changes we intend to make in the manuscript.

<u>2. Major point of criticism</u>

1) The use of the whole population to calculate mortality rates is (technically and methodologically) misleading and may lead to a strong underestimation of the mortality rate. Although it is used by many authors working on that topic I think using a better suited definition of the population would greatly enhance the value of the study. To put it in a different manner: imagine a building with three floors. In the third floor, which is hermetical separated from the other two floors, a laboratory is situated in which new and highly deadly poison is tested. If there is an accident the poison would only spread in the third floor. Calculating now the mortality rate based on the all the people in the building would underestimate the real risk because only those working on the third floor are at risk.

We acknowledge this point. But we do not really see an alternative solution. The difficulty is that dependent on the process, other parts of the population are at risk. Here, maybe a regular grid raster as proposed in comment # 2 could be a solution. In this approach only a part of the population (according to the grid cell) will be used to calculate the mortality rates.
However, when using a grid raster, we see the following general shortcoming: A rough estimation of our data shows that approximately 55% of all fatalities occurred close to or in the victim's place of residence or the victim's municipality (unpublished data, since the acquisition was difficult). In 30-35% of the cases the victims were killed in large distance from their home or the victims were from a foreign country (for 10-15 % of the fatalities their origin was unknown or unclear). This shows that it is very difficult to come up with an adequate mortality rate, especially when choosing a high resolution grid (let's say with a resolution of a mean extent of a municipality).
We suggest to try the approach using a regular grid raster (see also our responses in the detailed review section). However, if the results are not meaningful, we suspect that the only solution would be to omit presenting mortality rates in this contribution.

2. The artificial political borders to agglomerate the data are a point that is directly related to this criticism, in geostatistics also well-known as MAUP. To analyze the spatial distribution of fatalities and the mortality rate, the authors should find a better solution (such as e.g. a regular grid raster).

We agree with the criticism of referee # 1. We considered the solution of using a regular grid. This would be (according to Swiss Statistics BFS) available for the last approximately 1-5 years. Older gridded population data is not available. We would like to use the current data, at least as a proxy for raster population 1946-2015. But we see some problems such as (i) non-linear population growth; (ii) differences in population growth of different cantons; (iii) grid resolution (only roughly 55% of all fatalities occurred close to the place of residence, see our response to point (1) above).
We suggest to use a raster with population data of the year 2015 and to clearly state this shortcoming in our MS.

3. Detailed review

3.1 Introduction

Here it would be of added value if the authors could also include results from other Alpine countries, since a comparison with mortality rates of e.g. the US or some least-developed countries does not seem to be very targeted. For Switzerland, also the works of Schneebeli et al. (1997), Laternser and Schneebeli (2002) or Wilhelm (1997, see Table page 76 based on Laternser et al. 1995) should be acknowledged. For Austria, examples include those of Oberndorfer et al. (2007) or Luzian and Eller (2007), Luzian (2002) or Fuchs (2009).

We agree with the referee and will add results from other Alpine countries as far as available. We thank the referee for indicating appropriate studies in Switzerland and Austria..

3.1.1 Flood

Coastal floods where excluded from the analysis by Jonkman (2005) but the authors gave a reference to Chowdhury et al. how described a tidal surge caused by a cyclon which killed 67,000 people. Here I do not think that this reference is enough to give the statement enough confidence – there many other scientific reports about deaths caused by storm surges around that should be mentioned.

We see the referee's point and will add references to coastal floods or storm surges (e.g. Jonkman et al., 2009; Gerritsen, 2005; Kure et al., 2016) and tsunamis (e.g. Doocy et al., 2007; Inoue et al., 2007; Ando et al., 2013).

3.1.2 Landslides

[…] the authors summarize an article from Dowling and Santo from the year 2014 which is explicitly focusing on debris flows. With 213 debris flows causing 77,779 fatalities the authors yielding an average of 365 fatalities per fatal debris flow. This extraordinary high number is caused by two massive events which make up nearly 50 percent of all fatalities recorded by the two authors. The median number may therefore better reflect the number of fatalities with 11 per fatal debris flow but also this number may still be very high, compared to the European Alps. To give an example, in Fuchs and Zischg (2013) an average of around 1.5 fatalities due to torrential processes is recorded annually for the Austrian Alps.

We will consider adding this comparison (and large difference) between fatalities in torrential environments of developing and advanced (such as e.g. Austria, cf. Fuchs and Zischg, 2013) countries.

The reference to the study about landslides in South America (Sepuleva and Petley 2005) may be deleted or more information on reported findings should be given. It would also be more convenient to refer to this study before Guzetti (2000) because of its spatial scale […]

We will follow the advice of referee #1 and delete the reference to the study by Sepúlveda and Petley (2005) here. This will also help to keep the introduction section reasonably short and concise.

3.1.1 Meteorological

Focusing on meteorological hazards, the authors are reporting studies about tornados and hurricanes on a national level. Tornados are not very common in the study region of the authors. Referring to a report of the meteorological survey of Switzerland the frequency is one to five tornados per 10 years (0.1 to 0.5 per year) *which is large enough to cause serious damage. In this report four tornados are described in more detail (1890, 1934, 1926, 1971) where three of them caused fatalities.*

We thank the referee for this interesting information. The MeteoSwiss report states that of the four especially serious events two caused fatalities in Switzerland (one death in 1926 and three in 1934) and one event killed several people in France (1890). The one event that lies within our study period (1971) did only cause light injuries. We will add a sentence to the text stating that while hurricanes do not occur in Switzerland, tornadoes have occurred in the near past causing several fatalities.

3.1.4 Other

Because of the unimportance of hazards such as volcanic eruptions, earthquakes and tsunamis in Switzerland the author are not further considering geophysical hazards but mention an earthquake as an example of an extreme high death toll later in the discussion.

In connection with comment 3.8 of referee #1 (Discussion about the historical events in Switzerland), we are considering to considerably shorten our section 5.6 of the Discussion (Comparison of recent Swiss natural hazard fatality data with historic data) and to partly integrate it here, in the sixth paragraph of the Introduction.

3.2 Data

[…] Later in the discussion the authors were also talking about the drawbacks of the data collection. I would like to jump to that section (section 5.1 in the article) and express some of my concerns.

1. fatality not reported; 2. spatial bias because of the language of the newspaper; 3. wrong selection of keywords; 4. time spans with no newspaper available; 5. technical problems because of bad scans; 6. wrong hazard type

The authors then conclude, based on their validation strategy, that only a small fraction of 10% of all fatal hazard events were missed. At least three of the main reasons that impair the quality of the data are subject to the first 35 years of the time span analyzed. The validation was carried out for the years 1986 to 1995. If all newspaper of that period where already digitally available problem 5 could not occur. If there were no gaps also problem 4 would be underestimated. Finally problem 6 could also be of lesser importance than in the period before 1986. So maybe expanding the validation period could damp these concerns.

We agree that we could have chosen a different validation period (e.g. starting from 1972, which is the start of the Swiss Flood and Landslide damage database) or we could have opted for a longer validation period. Thereby trying to improve the quality of the search. However, we selected ten years of validation mainly to speed up the process and concentrate our efforts on the actual search. Also, we selected the years 1986-1995 because during this period more fatalities were recorded in the Swiss Flood and Landslide damage database than between 1972 and 1981 (27 vs. 20 victims). We stated in the manuscript that the overall data quality improved over time and is clearly better for the second 35 years of the study period (e.g. lines 466/7). This statement is based on two essential facts. (a) The main improvement that influences our data quality came in 1994 with the digital availability of all NZZ newspaper articles. (b) To complete the NZZ digital archive, newspaper issues older than 1994 were scanned and scans were processed using character recognition (problem no. 5 in section 5.1 of our manuscript). This effort was probably carried out by the Swiss Media Database in the last 10 to 20 years. Of course, older articles were more weathered at the time of scanning which resulted in qualitatively inferior scans. This, in turn, negatively affected character recognition.

Note that problem/point no. 6 in section 5.1 of the article should not affect the total number of fatalities detected in our search. For example, if a fatal channelized debris flow in the 1950ies was not identified as such, it was called something else by the newspaper (often e.g. “Schlammlawine” = mudflow or mud avalanche). However, it was still considered in our search, because we used all kinds of designations as keywords. Also note that we have not detected an increase in the occurrence of data gaps in our source of information (problem/point no. 4 in section 5.1).

In summary, we agree with referee #1 that the result of the methodological validation carried out for later years of the overall study period is probably not a good proxy for estimating the completeness of our database (or in other words the percentage of missed natural hazard deaths). By extending the validation period, this shortcoming could have been somewhat mitigated. However, we cannot expand the validation period at this point anymore. This would merely result in faintly different keywords combinations that would have to be run for all the newspaper issues again (months of work).

There are two main reasons why we think that the percentage of missed natural hazard fatalities in our overall study is not larger than 10 %. These are: (1) Approximately 37% of all fatalities in the data set presented here were caused by snow avalanches. Now, the destructive avalanche database is considered complete for fatality data and no additional search was carried out. This means that only less than two thirds of our data is subject to underestimation. (2) Grave events that cause several deaths are normally not just mentioned once in a newspaper. Often such events are described in numerous articles that span over a couple of days or even a few weeks. Some events are also mentioned in subsequent years for commemoration or retrospection. It is thus very unlikely that by reason of a data gap in the digital library, we did not register a single article on a multi-fatality event. Note that about 36% of all victims died in a multi-fatality event with at least three deaths (50% of all victims in an event with at least two deaths).

3.3 Results temporal analysis (section 4.2 in the article)

First general statistics about the data are given. These mostly basic statistics are then used to describe the importance of multi-fatality events. The short sentences about the number of events per year may be enforced by adding the number of events to figure 2 (see also comments on figure 2 in section 4.2 of this review).

This is a good point. And as outlined below in the section titled “Comments on figures”, we will add the number of events per year in Figure 2 to strengthen our statement made in the first paragraph of section 4.2.1.

The determination of a trend in the data is done in two ways: with the nonparametric Mann-Kendall test and by checking the significance of the slope of a linear regression. The choice of the non-parametric test is a good one but the linear regression performed on the normal scale of the data is not appropriate for count data and I suggest to use a Poisson regression or a regression on the natural log scale if the authors still want to use the slope as an indicator of the trend.

We agree with the referee and will drop the linear regression performed on the normal scale of the data. Instead we will either use a Poisson regression and test the significance of the slope as an indicator or we will carry out a non-parametric Theil-Sen slope test (we still need to decide what suits the requirements better).

The fatality rate is used wrongly in line 283 (and in other places) since according to my understanding the authors are referring to a mortality rate. Because it is not age-adjusted the term crude death rate would be in better accordance with epidemiological terms.

In a previous version of the manuscript we used the term mortality rate instead of fatality rate (according to the remarks of the referee). During language check right before submission, we were encouraged to use fatality rate. We will discuss this with our consultant and plan to use the terms mortality rate (due to natural hazard processes) or crude mortality rate throughout the manuscript.

3.4 Results monthly distribution (section 4.2.2 in the article)

The key findings are the two peaked distribution of fatal natural hazards in Switzerland. The winter season dominated by avalanches and the summer season by lightning. The authors mentioned earlier that they see declining and rising trends in the annual temporal distribution and it may contribute to the monthly results if the authors would check for trends in seasonality also displaying figure 6 as a - maybe paneled – seasonal plot or adding some words to the text.

Natural hazards fatality numbers in winter (DJF) as well as in the months of March and April are dominated by avalanches (>62% for each of these months). The summer peak is definitely strongly influenced by lightning fatalities, a proportion of 50% is, however, only reached for the month of July.
We like the suggestion of the referee to check for trends in seasonal fatality numbers over the study period. We will establish a few graphs and assess if they would fit in the article. Because the process types snow avalanches and lightning are the ones that show a clear decrease in the temporal distribution of fatalities, we expect that winter (DJF) and summer (JJA) fatalities have a strong decreasing trend over the study period. Spring (MAM) fatalities might also decrease due to the importance of avalanche accidents in these months. Autumn victims will probably not show a trend.

3.5 Results spatial distribution (section 4.3 in the article)

The authors explained in a clear manner the spatial distribution of the fatalities caused by the different hazard types. They also refer to the geomorphological region which makes their introduction at the former chapter plausible. A suggestion would be to use different maps for every hazard type and to count the number of fatalities divided by the number of events in a predefined raster or other geometrical grid. The authors may ask why my criticism is again aiming at the graphical representation this is because of the explorative nature of the topic. Paneling the hazard types would go perfectly with the excellent structured text of that chapter.

We will try to create a new figure with six panels (maps) for the different hazard types. In these maps we plan to show the fatality data in a raster, as proposed by the referee. We are still considering which resolution of the grids to choose (e.g. 5 km or 10 km). Additionally to panelling the hazard types, we will probably keep our current Figure 8(a) as an overview for section 4.3.

The next paragraph is dealing with the distribution of mortality rates per political region. My main concern about this result is the use of the political borders as an artificial subdivision of the space with no further connection to the underlying nature of the hazards. As an example the Canton of Bern has more than the half of its population in the five largest cities (Bern, Biel, Brugdorf, Interlaken, and Thun). Dividing the fatalities by the population incorporates a lot of people not even at risk to individual hazard types, and may therefore bias the shown results.

We will probably delete this paragraph in its actual form together with Figure 8b. We plan to explore the distribution of mortality rates per political region in an additional article for a Swiss journal (in German). Here, we will further discuss spatial distribution of fatalities by means of the new raster maps (if they prove successful) suggested by referee #1 in section 2 of the review (2. Major point of criticism).

3.6 Results regarding different social factors (section 4.4 in the article)

[…] This section boils down to the presentation of different n × n tables which are then described by words. Using tables in transporting information is mostly not a good choice (transporting data it is one of the best). To be sure that my critic is not just the normal table-bashing I got the data of table 2 and made a circos plot which I printed out and had it a the side while reading the text. In this fashion the text transports more information and is better understood than with the table.

So I strongly recommend to find prober graphical ways (mosaic, circos tec.) to present the categorical data from table 2 and 3 (see attached figure 3 to this review).

We thank the referee for suggesting this interesting way to display data. We promise to consider adequate solutions to present the information in the text (i.e. the data in Tables 2 and 3). We plan to keep Tables 2 and 3 in the supplementary material for readers that are interested in the exact numbers.

3.7 Discussion fatality numbers (section 5.3 in the article)

At line 529 the authors state that they assume that about half of all flood deaths can be ascribed to inappropriate behavior, for example when victims are carried away by floodwaters or surprised in their home by rapidly intruding surface water in contrast at line 585 being surprised is not considered inappropriate.

How could being surprised be an inappropriate behavior when the water is also rapidly intruding?

We understand why referee #1 raised this point and agree that the sentence at lines 529-531 should be rephrased. This misunderstanding is due to an inaccurate description of what we wanted to say.

Based on the descriptions given in the examined newspaper articles, we assume that a considerable number of fatalities caused during floods and inundations occur because of incautious behaviour. The first example pertains to people that are carried away by flood flows because they were standing too close to a channel. These victims approached swollen, dangerous rivers or streams because they wanted to cross them, to retrieve wood or other things, to save something or somebody, out of curiosity or for other unknown reasons. In many cases, circumspection would have saved these victims. The second example in our text (529-531) describes a situation that often occurs inside or around buildings. Like in the first example, regardless of a dangerous situation, victims take bad decisions and instead of taking refuge they expose themselves to a hazard. For example people try to save valuable belongings from the basement even though it is already inundated and the water level is rising quickly; or people try to drive their vehicles out of flooded underground car parks.

In contrast, the text at lines 585-586 applies to people killed by landslides. For both process types snow avalanches and landslide processes, about 50% of the fatalities occur in buildings. We assume that most of these people were aware of a critical situation (rainfall or avalanche hazard) and thought they were safe in a building. They had most probably not been asked by authorities to evacuate the building. Hence, we suppose they were surprised.

We will rephrase our sentence at lines 529-531 in order to better describe our point and will take care to avoid using the term *surprised*.

3.8 Discussion about the historical events in Switzerland

The events of the database are by far not the most devastating that occurred in Switzerland; three events are described in detail that caused 1500, 600 and 457 lives. Although this is an interesting information I do not see the direct connection to the article that is primarily concerned about trends and proportions in the fatality record. Maybe this section should be presented in a more condensed way in the introduction.

When preparing the article, the authors have discussed the importance of section 5.6 (Comparison of recent Swiss natural hazard fatality data with historic data) several times. Also, the original section was shortened before submission but not left out for the sake of completeness. We understand the referee's point of view and will delete this section from the discussion. Some of its content will briefly be presented in the introduction (sixth paragraph describing the significance of geophysical events in Switzerland).

4. Comments on figures

I liked how the authors stayed coherent with the use of colors and I can literally feel their agony in choosing the right figures that capture all the information they want to transport. The presentation of count data is difficult as is the analysis of count data. There are few standard techniques of handling count data graphically: the bar, cumulative, scatter or line chart. The authors decided to go with the bar chart which is in my opinion not the perfect solution although this might be a question of taste.

We thank the reviewer for the constructive suggestions on how to better handle our data graphically. We will change several of our figures according to the referee's advice (see below) and will presumably only keep two bar chart graphs (current Figs. 6 and 7 showing the monthly distribution and distribution of fatalities by time of day, respectively).

4.1 Figure 1 of the article

The authors use this figure to set the spatial frame of the study introducing important categories like the cantons and the geomorphological classes of Switzerland. The hillshade was a good choice because it gives a good impression of the topography, only the use of the blue for the Swiss Plateau may be problematic because of the low distance in color space to the rivers and lakes.

We will slightly adapt the colour used for indicating the Swiss Plateau in order to better represent the streams and lakes on the map.

4.2 Figure 2 of the article

The authors want to introduce their database and the trends in the number of population and the number of fatalities. I like how they plotted the mean and median which enforces the understanding of their data and has a direct link to the text. Another important point about that plot is that the authors use it to show the declining trend in the number of fatalities as well that the first 35 years include 73% of all fatalities. To get this information clearly transported I would suggest the following: the use of a second axis to show the population growth does not contribute to the topic – to be honest I find it distracting. By erasing it, the figure would get clearer. The most prominent feature of the figure is given by the two extremes in the year 1951 and 1965 with the high number of deaths. These two years masking the trend the authors found and I would therefore use a transformation of the count. Typically the natural logarithm is chosen because of is direct connection to the link function of the Poisson regression model. Adding a running mean with the size of 10 years - to have a connection to Figure 3 - to the transformed data will enhance the trend apparent in the data.

Another point in the text is the fact that 73% of the total fatalities occurred in the first 35 year period of the database. This fact and the declining "fatality growth" will be better shown - in my opinion - using a cumulative chart of the fatalities. This chart also has the advantage that its behavior can be used to infer if a simple Poisson process is generating the fatalities – which would be a straight line. Maybe the number of events per year as a third panel below the yearly number of fatalities would help to transport the severe multi fatality arguments of the authors.

The suggestions of referee #1 for the improvement of Figure 2 are all very helpful. We are working on an extended version of the suggested graph (Fig. 1 of the review). It will probably include:

→ A top panel with the cumulative number of fatalities in Switzerland over the study period (x-axis, logarithmic scale);
→ A second panel with the fatality data per year (logarithmic scale; including information on mean, median, as well as a running mean);
→ A third panel showing the number of events per year (logarithmic scale);

4.3 Figure 3 of the article

The authors want to show the general decline in the number of fatalities over the years, especially the decline in the deaths caused by avalanches and lightning. I think that the information of that figure can be also transported with an enhanced version of figure 1 and a slightly changed version of figure 4.

With strongly adapted and enhanced versions of our Figures 2 and 4, we think that the current Figure 3 will not be necessary anymore in the revised manuscript. Thus, we plan to remove it from the article.

4.4 Figure 4 of the article

The authors want to describe how the number of fatalities is changing over time per hazard type or more general show the temporal behavior (also that there are no fatalities at all) and the differences between the hazard types. The x-axis is the same for all plots and therefore combining these without repeating the x-axis is recommended organizing the plot as a 3 by 3 panel. A problem may arise from the higher numbers of avalanche fatalities but this could be overcome by using a square root or logarithmic transformation of the x-axis and labeling the axis with the real number of fatalities. To better detect the temporal trend adding a running mean or other smoothing would help. Also it may be better suited to plot the cumulative number instead the number per year as a step function which would also indicate when there are no fatalities.

We like the idea of a 3 by 2 panel graph. We plan to use the count data with a logarithmic (or square root) transformation of the y-axis and to add a running mean as suggested by the referee. A square root transformation of the axis of ordinates would allow us to show years with no fatalities.
We are also exploring the possibility to display the cumulative fatality numbers for all different process types over the study period in an additional figure.

4.5 Figure 5 of the article

The key massage is the decline in crude mortality rate over the years. The same critiques as for figure 2 are true for figure 5. Because of the high spread of the rate the figure gets clumped and the distinction between the processes is hard. This is especially a problem when the figure is compared to the text from lines 286 to 288, since I am not able to see the distinct decline in mortality rate. Maybe transforming and paneling the data would help also in this case.

This is a good point and we will try to adapt this figure to make it more comprehensible (similarly to Fig. 2). In a first effort to improve Figure 5, we noticed that with a transformed y-axis, the graphs for mortality rate and fatality count (in Fig. 2) look very much alike. Hence, maybe Figure 5 is not that important for the manuscript.

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