Response from the authors to the comments by anonymous referee.

GENERAL COMMENTS

The manuscript provides continuous data about precipitation, air and groundwater temperature, snow depth, pore-water pressure, monitored on a site in Western Norway that in November 2013 was involved in a weather-induced debris flow after a storm that caused about 142 landslides and 7 snow avalanches in the same region. The reported data allow, in particular, to compare the weather and piezometric conditions responsible of the debris flow with those occurred in the past not able to induce any failure. The paper is well written and contains very accurate figures.

We are glad you think the paper is well written and has accurate figures. We appreciate all your suggestions that will improve our paper. Below we comment on each of these.

The availability of information exactly during the landslide event represents undoubtedly a valuable aspect not to be overlooked. However, as also correctly recognized in the text by the Authors, two evident limitations exist: i) the pore-water pressure data are measured only by one piezometer (located upslope); ii) information about the properties of the involved soils are absent. Of course, the first aspect, that prevents to model the piezometric regime along the slope, can not be solved. On the contrary, I hope that some data about the physical, hydraulic and mechanical soil properties should be added because a full comprehension of the landslide is very hard without them. In particular, the absence of information regarding the shear strength parameters makes impossible analyzing the slope stability conditions. Some specific suggestions, aimed to improve the quality of the manuscript, are reported in the following section.

About the properties of the involved soils:

Ideally, it would be very nice to present the properties of the soils on the slope in a table. However, we do not have such data, such data are not available from other studies of the area, and the material on the slope varies a lot, both laterally and with depth, that makes it difficult. In the paper we present the information we have about the properties of the slope deposits that allow the reader to have some understanding of the slope and the soil. Below is line 85-90 in the method chapter:

> *"The lower part of the slope is covered by slide deposits and till and the average slope angle is 25 °– 26 °. The sediment-covered slope tapers off upwards into steeper and exposed bedrock and cliffs (Fig. 5A). From the outcrops of the slide scar of the 2007 slide event (Fig. 4B), we found that the thickness of the deposits on the slope varies, probably between 2 and 5 m.*
>
> *We drilled through boulders and relatively firm deposits down to 2.4 m below the surface using a hammer drill powered by compressed air (Fig. 5B).*

In the caption to Fig. 5B (line 143-146) we say:

> *"Average steepness of the sediment-covered slope is 25 °–26 °. The stippled line indicates where we believe the boundary between till and bedrock is located, based on observations from the 2007 slide scar (Fig. 4B). B. The mini-diver (sensor) is suspended from a wire in the piezometer*

and anchored 1.64 m below the surface. The top 60 cm of deposits consists of organic soil and weathered till, with firm till below that. We drilled through boulders at depths of ca. 1 m and 1.5 m."

And, in the discussion chapter we say (line 224-226):

"*The slope is covered by till and colluvium, deposits that vary widely in composition and grain size. Thus, observations from one borehole may not be representative of other areas on the same slope."*

In order to provide accurate data about the soil properties, especially data for cohesion and friction angle (the shear strength parameters), and data of the hydraulic conductivity etc., we would need to do a new study of the slope. Because of the heterogeneity of the soil, we would need information from several locations along the slope and also from different depths. On an ideal slope with homogeneous soils such data would be very useful, and possible also available. In addition, in this paper, we do not perform any calculations or simulations of stability or of the slide movement. We believe that the information given is sufficient for the reader to get the information of the soils on the slope to understand the work and data we present about the groundwater fluctuations during the debris flow event.

SPECIFIC COMMENTS

Line 30. The availability of real-time water level data during rapid landslides are effectively rare, but, on the contrary, many papers provide the pore pressure in slopes involved in active slow landslides, cyclically reactivated by seasonal weather events. Therefore, the sentence "rare because it is difficult to predict which slope will fail" should be replaced by "rarely provided during rapid landslide events".

We agree, thanks for this suggestion, we will replace as you indicate here.

Lines 39-40.

Snow avalanches are not landslides. Therefore, the sentence "Most of the slides were debris slides and flows (114), but rockfalls (28) and snow avalanches (7) also occurred" should be replaced by "Most of them were debris slides and flows (114), but rockfalls (28) also occurred. Some snow avalanches (7) were observed too".

We agree. We will change "slides" with "mass movements". The sentence will then be changed to:

"Most of the ~~slides~~ mass movements were debris slides and flows (114), but rockfalls (28) and snow avalanches (7) also occurred (Fig. 1).

Figure 1. The term "slides" in the legend can not be used to indicate at the same time the three types of phenomena. It should be replaced by a term like "Events". Moreover, I suggest to indicate them according to the following order: i) Debris flow and slide; ii) Rockfall; iii) Snow avalanche.

Yes, we agree and will change it as you suggested here.

Caption Figure 2.

I suggest to simplify it, inserting in a table (to be cited in the text) all the provided information regarding the three shown landslides: date and hour of the occurring events, landslide length, upslope and downslope altitudes, mean slope inclination, range of thickness, etc.

It seems as a good idea. We will provide such a table and simplify the caption to Fig. 2.

Section 2.

This section should contain a table reporting the available information (eventually deriving them by other papers) about the mean values of physical, hydraulic and mechanical properties of the involved soils: grain size, in-situ porosity and degree of saturation, unit weight, hydraulic conductivity, strength parameters. Such values are very important to allow a full understanding of the infiltration and seepage processes and, as a consequence, of the induced landslide mechanism.

See comment above under the heading “About the properties of the involved soils.”

Line 90.

Indicate at which altitude and distance from the toe of the landslide the piezometer has been installed.

OK!

Line 125.

Indicate the total length of the debris flow.

OK!

Figure 5A. Clarify which “Distance” is reported in the X-axis. Is it the distance from the toe of the landslide ?

No, it is not, it is the distance from the road on the flat valley bottom and upslope to the borehole, at 90° to the slope. We will indicate the location of the profile on the aerial photo in Fig. 4B, that will clarify the location of the profile.

Figure 6. According to the results, the influence of the snow cover melting on the water level is particularly important. Therefore, I suggest to insert in this figure the data about the snow depth (shown only by the supplementary Figure S9) and about the air temperature (partially shown in Figure 8).

In an earlier version of the paper we had included the graph of the snow cover (now in Fig. S9) in Fig. 6. We will go back to this earlier version now and move the snow cover figure from the supplements to Fig. 6. We will also consider to move the air temperature graph from the supplements to the main paper.

Caption Figure 7. Indicate at which depth and altitude the piezometer of the weather station has been installed.

Yes, we will provide that information.

Figure 8. Due to the important role of the snow melting, I suggest to insert in this figure the data about the snow depth (shown by the supplementary Figure S9).

Melting of snow has an important role, but we are uncertain that the measurements from the snow pillow at the day the slide happened, with low values, can be fully trusted. The snow pillow show 0.020 m of water equivalent before the event, and during the event rises to 0.024 m. This value is a combination of snow that was on the ground before the event, new snow during the first phase of the event and a change to rain. We want to look more carefully at the snow data and will strongly consider to present a graph of the data from the snow pillow in Figure 8.

Line 222.

The second important weak point of the manuscript regards the absolute absence of information about the soil properties. As already suggested, I hope that you are able to provide them. For instance, some information about the strength parameters could help (at least) estimating the slope stability conditions.

Again, see comment above under the heading “Information about the properties of the involved soils”

Lines 265-266.

Differently from what observed in November 2013, the piezometric peaks monitored in April and May 2013 were caused only by rainwater infiltration (and not by snow melting). Why do you consider such evidence so relevant to not induce sliding ? The corresponding measured peaks of 33 cm (measured in April) and 28 cm (measured in May) below the ground surface are very close to the critical estimated value of 30 cm in November 2013 (such value was extrapolated from the groundwater level curve measured from 19:00 and 23:00, as clarified in Lines 237-238). As a consequence, being the local shear strength approximatively the same at the onset of the three attained maximum water levels, the corresponding local slope stability conditions should be essentially the same too. Unfortunately, the availability of only one piezometer does not allow to make a reliable evaluation of the general slope stability conditions, therefore your consideration seems rather rash. Please make some comments.

We agree; the very high peaks in May and April is essential the same values as the critical peak in November 2013, but we now think, thanks to this review comment that encouraged more thinking about this, that the soil on the slope might have been partly frozen in April and May, especially the slope downslope of the borehole, that could have prevented effective drainage of groundwater downslope. The thawing of the frozen soil, melting of snow on the ground and the rain episodes caused the high piezometric peaks. In spite of the high pore pressures in the borehole, the slope was maybe not unstable, because part of the soil on the slope was maybe still frozen, and a frozen pore space would give higher shear strength. The air temperatures in April and May was low, most of the

nights were below freezing until May 5, that would prevent the thawing of the ground and refreezing of the surface water during nights.

We will rewrite this paragraph to enlighten this possibility of frozen soils in April and May.

Lines 276-279.

The emphasis of provided considerations is rather strange. It's well known that the initial conditions are crucial to determine the weather-induced effects. Once given an initial monitored piezometric value, the main challenge should be, of course, associating a landslide hazard to a forecasted weather event. At the same time, associating a very low landslide hazard to severe weather event if the initial measured groundwater level is located below a "safe" value should be also very useful for the implementation of an early warning system. I encourage the Authors to make some comments about this topic.

We will rephrase this paragraph; it also seems to us to be somewhat immature. This is a nice example of an event that would not bring the early warning system to an alarm despite the extreme infiltration rate. Thanks for pointing this out for us, we will try to rephrase this.

TECHNICAL CORRECTIONS

Title. Is the hyphen "-", between "Norway" and "triggered", necessary ?

It is not necessary for us to use "–", a comma instead would also work. However, using "–" (em dashes) to replace commas makes the reader focus a bit more on this information that is set inside the em dashes "–".

Caption Figure 1. "114 debris flows, slides" should be replaced by "114 debris flows and slides"

Yes, we agree.

Line 109.

The word "from" at the end of the line should be replaced by "carried out".

? We are not sure if we understand this comment …."carried out"…

Line 163.

The sentence "has also been" should be replaced by "already".

OK