Clim. Past Discuss.,
https://doi.org/10.5194/cp-2018-21-AC2, 2018

Climate of the Past Discussions

Interactive comment on "Wet avalanches: long-term evolution in the Western Alps under climate and human forcing" *by* Laurent Fouinat et al.

Laurent Fouinat et al.

laurent.fouinat@gmail.com

Received and published: 25 July 2018

We thank the referee for his review and suggestions to improvements. Generally, we agree with all his suggestions and think they will help to clarify the manuscript. The next section presents referee comment (C) and answers to those comments (A).

C1/The title could also be: Wet snow avalanches and floods: long-term evolution in the Western Alps under climate and human forcing.

A1/ Please refer to answer of comment 12. My co authors and I aren't absolutely sure about forcing mechanisms related to the flood record. We would like to have the title

unchanged.

C2/ P2, Line 4 ; Complex climatological conditions over a period of days to several weeks. . .I suggest meteorological conditions oe weather conditions rather than climatological, which refers to a different spatio-temporal scale.

A2/ We agree with the comment. We changed the text to "Complex meteorological conditions", referring to a shorter spatio-temporal time scale more adapted to the context of the sentence.

C3/ P2, Line 8 ; . . .dense wet avalanches ; the mass of wet snow per unit volume, generally expresses as a percent water content (10-20% for wet snow) makes wet avalanches a type of dense flow.

A3/ We thank the referee for this comment on the type of flow generated by a wet avalanche. Most authors agree on the definition of wet snow taken from the International Classification of Seasonal Snow on the Ground (Fierz et al., 2009), which is defined by liquid water content between 3-15 Vol. %. When snow have this characteristic, the water drains slowly with the effect of gravity. In order for a glide avalanche to occur the water must be able to percolate down to the lowermost layers of the snow cover (Ancey and Bain, 2015). The presence of the water induces a significant drop in basal friction which can initiate a snow glide or wet snow avalanche. We changed the sentence to : "as dense flows characterized by wet snow which liquid water content is around 3-15 Vol.% (Fierz et al., 2009). Those glide on the substratum. . ."

C4/ P2, Line 25 ; The detection of avalanches deposits. . .with coarse grains in a fine matrix. The authors should give more details by comparison to debris-flow events for example, knowing that in many places debris flows are recorded in wet snow avalanche paths.

A4/ My coauthors and I agree with this comment. The main difference concerning debris flow deposits and avalanche deposits is the fining upward trend. As both can be

observed in the same paths it is important to describe difference between the resulting deposits. We added a complementary explanation and reference to this sentence as follow “as opposed to debris flow deposits, characterized by fining upward trend with a coarse grain base (Iverson, 1997; Sletten et al., 2003).”

C5/ P4, Line 25 ; . . .at various intervals within the continuous sedimentation. On which basis the locations of the 32 samples for pollen analysis were selected? Sedimentological facies distinction?

A5/ Yes we based our sampling on the facies distinction avoiding thick bed layers with fining upward trend or layers containing numerous gravels. The selected samples are thus considered to be taken within event free sedimentation. In fact, pollen may be present in those event layers, but could correspond to reworking of material present in the soils or the litter and transported to the lake by turbulent flow. In this case, the identification of pollen grains is more difficult because of grain alteration and may not be statistically representative. We changed the sentence to: “In total, 32 samples of 1 cm3 of sediment were taken along the sequence between 0.09 and 15.41 m at variable intervals within the event-free sedimentation for better grain preservation and more accurate statistical representation.”

C6/ P5, Line 1 ; . . .is based on short-lived radionucleide. Ok but can you give a little bit more details please ? What kind of radionucleide ? As I understand it is 210Pb but it will also be useful in a few short sentences to have more details.

A6/ The recent chronology based on short-lived radionuclides details and figure is presented in (Fouinat et al., 2017a). We wanted to avoid too much repetition in this manuscript and focus on the 14C, but we agree the reader needs a more precision on this recent chronology. The text has been changed to: ” The chronology of the Lake Lauvitel sediment sequence is based on short-lived radionuclide 226Ra, 210Pb, 241Am, and 137Cs (Fouinat et al., 2017a), with non-regular sampling following facies distinction avoiding thick beds. In complement, we selected 19 samples on terrestrial

plant macroremains for 14C measurements. Those. . . “

C7/ P5, Line 17 ; should be written sub-horizontal

A7/ Thank you for this comment, we changed the word in the manuscript from “sub horizontal” to: “sub-horizontal”

C8/ P7, Line 11 ; . . .vegetation action. What do you mean by vegetation action ? Fire, insect outbreak, or gradual changes induced by climate warming ?

A8/ This sentence in the manuscript has for objective to detail the processes leading to the presence of unconsolidated gravels or pebbles in the steep slopes in the western part of the watershed. Natural weathering by chemical or mechanical are part of those processes. Vegetation action refers to the vegetation roots that follow cracks in the bedrock and fracture rocks when growing. The sentence has been changed to “. . .entering lake sediment related to slope processes such as natural chemical or mechanical weathering induced by frost and vegetation roots (Fouinat et al., 2017a).“

C9/ P8, Line 4 ; Same as previously, please give more details about the sediment deposition chronology based on 210Pb.

A9/ We added precision to the short-lived radionuclides chronology by detailing the way we calculated the 210Pbex on which we base our chronology for reader understanding. The complementary details and figure can be found in (Fouinat et al., 2017a). We changed the sentence to: “The recent sediment deposition study by Fouinat et al., (2017a) was based on short-lived radionuclides of which 210Pb excess was calculated as the difference between total 210Pb and 226Ra activities.”

C10/ P8, Line 26 ; Could it be drop stones like for avalanches ?

A10/ We thank the reviewer for this comment. In fact, this observation of gravels within some flood deposits could originate from different processes. It is however difficult for us to distinguish which ones because of several reasons. 1/ If the pebbles are located within a flood deposit and originated from drop stones, this would imply a flood deposit

occurring at the precise moment of the ice thaw in spring. As this latter phenomenon is quite fast, lasting several days at most, a heavy rainfall would have to occur while the watershed is still partly covered of snow. Those watershed conditions are not favorable to the formation of a turbulent liquid flow originating from the stream. However, this may be possible, but would be quite rare and doesn't agree with the high number of pebbles contained in flood layers (2536 individuals p.7, line 6). 2/ On the one hand, the presence of those pebbles in the clay cap of flood deposits (F3) could be explained by the CT Scan imagery resolution or sediment coring which would let us interpret a pebbles integration by the top in the flood deposit. 3/ A heavy rain fall in spring could create a combined flood deposit + a wet avalanche related to soaked snow cover thus integrating pebbles within the flood deposit. However, those hypotheses are difficult to verify and distinguish clearly from one another. For stronger interpretations of our record we decided to exclude those deposits from the avalanche chronicle.

C11/ P9, Line 10 ; debris flows are not necessarily subaqueous. Make you statement more clear. Are you talking about submarine landslides, for example, or subaerial sedimentwater flows?

A11/ We agree with this comment. Debris flows are created in sub-aerial environment, but in our case, we observe deposits in a lacustrine environment. Previous studies (Sletten et al., 2003; Irmler et al., 2006) have observed lacustrine deposits related to debris flows initiated in sub-aerial context then entering the lake water to be deposited in the subaqueous environment. In this case, a gradation or an erosive base is identified as specific characteristic to those deposits. In our wet-avalanche induced deposits this gradation has not been observed making it a notable difference. The probable reason would be the density of the matrix transporting the pebbles into the lake. In the case of debris flows, the matrix is composed of a mix of liquid water and sediment denser than the water of the lake, which create a subaqueous flow leading to a gradation of the deposit and/or and erosive base. In the case of wet snow avalanches, the matrix transporting the sediment is less dense than the lake water, which in the end

can't form a similar subaqueous flow. We changed the sentence to get the statement clearer: "Moreover, based on the grain size measurements we didn't identify evidence of gradation or erosive base characterizing debris flow in lacustrine environment, thus excluding a dense subaqueous sediment transport (Sletten et al., 2003; Irmler et al., 2006)."

C12/ P10; Line 12; It is particularly interesting to look at the increase of wet snow avalanche activity after 760 yrs cal. BP. What about flood frequency? Farther in the sane paragraph you present the main period of flooding, but are you able to calculate as you did for wet avalanche the frequency at century scale?

A12/ Figure 9 exhibits the flood deposits occurrence and frequency for the past 3300 yrs. Cal. BP, we were thus able to establish a flood chronicle for Lake Lauvitel sediment record. However, the date 780 yrs cal. BP. doesn't correspond to a significant increase of the flooding record. The main difference is that avalanches originate from the steep slopes in the western part of the watershed. A decrease in the forest cover from this part of the watershed seems to enhance quite significantly the occurrence of avalanches. However, the main stream of Lake Lauvitel is originating from the southern part of the watershed. This area presents few advantages concerning cattle farming, of which the gradual slopes, the larger space and an easier access to the lake water. Moreover, historical documents confirmed farming practices were principally occurring in the southern part of the watershed. Based only on the pollen diagram, anthropic taxa (plantago, Rumex) were found episodically before 780 yrs cal. BP. In this case we cannot confirm for sure the flood chronicle is entirely controlled by climate parameter making it difficult to compare with regional climate records. Moreover, an ongoing study (not published) found some micro charcoal in this southern part of the watershed, suggesting anthropic influence on the vegetation. Knowing this feature, my co-authors and I decided to present only the results on flood occurrence (Fig. 9), avoiding unverified interpretations of climatic or anthropic origin of the flood chronicle. Following those results, we hope they could be valuable in the near future to compare with the micro

charcoal data.

C13/ P12, Line 23; 299 events? . . .which represents 153 and 166 events = 319 events

A13/ Indeed we made a typing mistake, indeed it should be written a total of 153+166=319 events in the conclusion. We confirm the total number of 153 flood deposits and 166 avalanche deposits were identified in the sediment sequence.

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2018-21, 2018.