Response to reviews and comments on the NHESS-manuscript

Dear editor and reviewers,

We sincerely thank you for the supportive comments and reviews related to our manuscript "Monitoring and prediction in Early Warning Systems (EWS) for rapid mass movements" (nhess-2014-281).

We are pleased to respond to the different comments and suggestions brought up by the reviewers and have implemented the corresponding answers into the manuscript.

Response to anonymous referee 2:

Major point 1: **The structure and contents of some sections may be improved… Some of the Sections (e.g. 4.2 and 4.3) are really specific and might not be necessary in a review paper. In conclusion, the second part should be reorganized and partly rewritten.**

As mentioned above in response to referee 1, section 4 has been reorganized, and a clear link back to the shortcomings discussed in section 3 has been made. With the new structure of section 4 we now have a consistent outline: "shortcomings of current EWS" (section 3) -> "innovations to overcome these shortcomings" (section 4) -> "implementation of these innovations" (section 5) -> "outlook" (section 6)
However, we think that (former) sections 4.2 and 4.3 are important for this manuscript because they highlight potentially useful innovations for next-generation EWS. Thus we would prefer to keep these sections in the manuscript.

Major point 2a: **In the present version, the work is mostly focused on Switzerland and references to worldwide EWS and recent innovations outside of Switzerland are rarely included…**

Yes, the manuscript has a strong focus on Swiss EWS. But we clearly don't want to restrict the review to only Swiss EWS.

*-> **We followed option b) suggested by referee 2 and included additional examples of non-Swiss EWS in the text.** Please also note that the first part of the introduction includes already a number of overview papers of world-wide, US and European EWS.*

Major point 2b: **I strongly animate to summarise the existing EWS in a Table (including: type of RMM, type of EWS, location, institution in charge, parameters implemented, sensor/techniques used etc.). Such a Table would really help to have a complete overview of the present state of the art.**

This is a useful suggestion, but it is very difficult to implement. All EWS summarized in Figure 1 have been reported in the scientific literature, however, many of these publications are incomplete with regard to the above-mentioned information (institution in charge, sensors/techniques used). To research all these information in detail and compile them into a comprehensive table would be hardly feasible. … and, nevertheless, the table would still be incomplete. Also, the primary goal of our review paper is not provide a survey of existing EWS, but to discuss current limitations in EWS and to describe innovations which may be useful for the next-generation EWS.

-> ***We refrained from introducing such a Table.***

Major point 3: **The authors should define at the beginning of the ms the different types of RMM dealing with in this review…**

This point is similar to the first major point of referee 1.

-> ***We have added a definition of what RMM we deal with in this manuscript*** *– in the introduction of the paper, third last sentence.*

Specific comments:

i) **An alarm system is defined as one type of EWS. However, as written in the ms, an alarm system detects an ongoing hazard, which may contradict EARLY warning.**

No, this is not a contradiction. For example, in the case of Illgraben (a typical alarm system) we still have a few tens of minutes of lead time between debris flow detection in the upper part of the catchment and debris flow passage in the residential area. This may not be extremely "early", but still "early enough" for people to not cross or to leave the channel when a flow has been detected, which was one of the main goals of that system.

ii) **Sometimes there is a bit confusion about the meaning of the terms "alarm", "warning", "alert", "level of danger" or "hazard level".**

See answer to referee 1, Major point 3: -> we carefully checked that these terms have been used correctly.

iii)   **One of the limitations states that EWS focus on simple thresholds, but then no real "solution" is proposed in the following sections of the ms. Probabilistic approaches would be an elegant way to overcome this limitation.**

Good point! We addressed this comment in section 3 and refer to the paper of Berti et al. in J Geophy. Res, 2012.

iv)   **Before describing satellite derived precipitation products (P9L1), I would introduce the possibilities of rainfall radars.**

Section 4.1 is actually referring to ground-based rainfall radar products (and not to satellite derived products).

v)   **Uncertainty analysis (P9L21). Probabilistic approaches would reduce uncertainty. See comment above.**

We addressed this comment in our answer above (iii).

vi)   **Sections 4.2 and 4.3 describe very interesting research outcomes, but maybe these topics are too specific.**

We agree that implementing the technologies and models in EWS will be very challenging. Nevertheless, we propose that these innovations are promising new elements of future EWS; and therefore we definitely want to keep the content of (former) sections 4.2 and 4.3 in the manuscript.

vii)   **Section 4.4 maybe divided into 2 sections: first, the seismic monitoring and then the GB-SAR monitoring**

Because we have introduced a new structure to section 4, with each of the sub-sections linking back to one of the shortcomings discussed in section 3, we prefer to keep both parts (seismic monitoring and GB-SAR monitoring) in one and the same sub-section.

viii)   **P15L21: I'm not sure that we can call the current EWS "well-established", since there are still many limitations to overcome.**

We remove "well-established" as recommended.

ix)   **Sections 5 and 6 (first 4 paragraphs) may be merged and better connected with section 3, where the limitations are exposed.**

We refrained from merging sections 5 and 6. With the new structure of section 4 we now have a consistent outline: "shortcomings of current EWS" (section 3) -> "innovations to overcome these shortcomings" (section 4) -> "implementation of these innovations" (section 5) -> "outlook" (section 6).

The second part of section 6 describing a novel EWS for shallow slides maybe not necessary, due to the reason stated above: many shallow slides do not transform into RMM. In addition, the authors state that better soil information is a main challenge for future EWS (P16), while in the novel EWS presented (P18/19) exactly this information is strongly needed for a correct implementation.

We also modified the description on the design of a novel EWS and stated explicitly that its applicability depends on information on soil type and depth and that we expect that more information on these properties will be available in the future as for example deuced from remote sensing data.

x)   Table 1 must be improved.

See our comment above (Major point 2 b). We slightly reworked and complemented Table 1.

Technical corrections:

P4L11: *Here, in this publication the last name of Martina Sättele was actually misspelled … therefore we have to use "Saettele"*

P4L23: *ok; we change to "scientific and technical"*

We hope that the amendments proposed above are to your satisfaction and look forward to finalizing the manuscript for publication in NHESS.

Best wishes,

Manfred Stähli and co-authors