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## Comment on nhess-2021-18

Sigrid Roessner (Referee)

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Referee comment on "Timely prediction potential of landslide early warning systems with multispectral remote sensing: a conceptual approach tested in the Sattelkar, Austria" by Doris Hermle et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2021-18-RC2>, 2021

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The paper represents an interesting contribution to process oriented remote sensing based monitoring of complex landslides with the aim of making a conceptual contribution to early warning. The paper is well written in language and structure and the figures are of good quality. Despite the overall good scientific relevance and presentation quality, in the current form the paper lacks a coherent scientific goal justifying the used approach. This problem already becomes apparent in L40 where the authors state that the study presents a new concept to systematically evaluate remote sensing techniques to optimize lead time for landslide early warning'. Although the presented work is very interesting, it does not fit the stated goal for the following reasons:

- Concept of lead time and need for best possible reduction is not new.
- Remote sensing techniques themselves are not the bottleneck for shortening the lead time.
- In remote sensing based approaches lead time mostly depends on the available imaging constellation and data distribution to the end user and in case of optical data on the atmospheric conditions (clouds). Both factors are only to a very limited extent in control of the authors - only in case of the UAV data acquisitions.
- The used data sources (planet and UAV) do not allow optimization of lead time in the context of early warning because of the scarcity of their availability which is reflected in the small number of only three multitemporal data takes between July and September analyzed in this study (Table 3)

The missing sound conceptual approach is also reflected in the introduction in form of a lengthy summary of in principle available remote sensing methods and data showing no clear line of arguments (L20-100). Moreover, the new conceptual approach presented in Fig. 1 is very general and not specific to landslide and does not qualify as a novelty in the current form.

L140: General applicability to optical data: This subheading does not fit the content of this

section comprising a compilation of rather basic and general steps of remote sensing data processing.

The study site (starting at L175) represents a very complex landslide case leading to rather erratic mass movements in form of debris flows initiated by changing slope water conditions related to increased atmospheric precipitation. This situation is another obstacle for an early warning approach which is solely based on optical remote sensing data and thus making it impossible to make full use of the in principle daily temporal resolution of the planet data. Taking into account these natural conditions and the constraints introduced by the used imaging constellations, leaves no room for true optimization of lead time in the sense as stated in the overall scientific goal of this paper.

Any sensible early warning approach for slope movements requires a continuous and reliable high temporal resolution input of observation data related to parameters which are relevant for triggering the potential mass movements. Such information are mostly provided by ground based measurements. In this context, it is surprising that no relevant ground based monitoring information seem to be available to this study despite the long-term history of scientific work at this study site. The mentioned temperature loggers need to be explained in their function for early warning. The GPS measurements seem to only support the remote sensing based analysis. The described setting does not seem to be suitable for identification of precursory signs of ‚slope preparation‘ related to the triggering of potential mass movements at this site in a way which would be required in the context of early warning.

L210: The complete dismissal of radar data is not justifiable in the current form since the authors only take into account InSAR based deformation analysis and neglect that the technique of pixel offset tracking can be also be applied to the intensity component of radar data. For the mainly rainfall driven processes at the study site, the integration of radar data seems to be mandatory into any sensible remote sensing based early warning approach, since a combination of optical and radar data is required to establish an as continuous as possible time series of remote sensing observations.

Moreover, taking into account the goal of lead time optimization, I consider it crucial to also include ground-based live-streamed time-lapse imagery in the proposed remote sensing based early warning approach (for an example see the Khan et al. (2021) paper ‚Low-Cost Automatic Slope Monitoring Using Vector Tracking Analyses on Live-Streamed Time-Lapse Imagery‘ published in Remote Sensing).

The materials and methods section (4.) as well as the result section (5) are sound and well written. Since reviewer 1 has already focused on this part of the paper as well as the accuracy assessment and made detailed suggestions for improving these parts, I only have a few comments left to make on these aspects of the paper.

L355: The authors state that core areas of the landslide are surrounded by wide fringes with no data. In this context the meaning of the term ‚no data‘ is not clear to me . Please, explain, what do you mean by ‚no data‘ – either missing results or zero deformation.

L370: Fig 6. The obtained deformation results show a very different degree of detail throughout the landslide. For better evaluation of the reasons for these differences the inclusion of an RGB UAV image of the same area would be helpful in order to be able to include surface texture properties in the evaluation of the obtained differences in the deformation patterns.

Conclusions related to the results presented until L370: The presented specific deformation results obtained from the analyzed planet and UAV data, represent a valuable contribution towards an improved area-wide process understanding of so far

unprecedented detail for this study site. Conceptually, such investigations mainly contribute to the preparedness phase within the disaster management cycle. Continuation of monitoring of the study site using the described approach would represent a very valuable prerequisite for developing and setting up a true early warning system for this site combining ground based and remote sensing observations. However, the results presented in this paper do not allow optimization of lead times within an early warning approach being stated being as the goal of this paper.

L375: 5.3 Time required for collection, processing and evaluation. The presented analysis is rather meaningless, since the scarcity of the available time steps does not allow the detection of critical process stages. Taking into account the big temporal gaps between the data acquisitions, the time needed for handling the planet and UAV imagery is not really relevant for lead time optimization. The obtained times only allow a relative comparison between planet and UAV based data acquisition within the narrow limits of the chosen approach. However, true early warning would require setting up a semi-automated processing chain including automated download and screening of available remote sensing data as well as semi-automated subsequent deformation analysis reducing data handling time to a minimum. Under such conditions, primary remote sensing data availability becomes the crucial decisive factor determined by the data distribution procedures of the satellite data providers and the atmospheric conditions in case of optical imagery. In conclusion, it needs to be stated that the used parameter of time to warning is only applicable under the condition of a near real time continuous data stream of input information which is not available within the presented study.

L390: In the current form of the paper the points raised in the discussion (6.) are only relevant in the frame of a process-oriented study and not for early warning purposes since the latter one requires the identification of precursors for critical process stages – tipping points – which are likely to trigger substantial complex mass movements later turning into potentially catastrophic debris flows.

L490: Estimating time to warning (6.3). This part of the discussion also suffers from the conceptual limitations which have already been pointed out earlier in this review. A comparison of lead times between the different example landslides would only be meaningful in case of continuous high resolution temporal information on deformation allowing the identification of precursory events which is usually only possible using ground based observations. The presented comparison between potential repeat rates of remote sensing data acquisitions and retrospectively derived lead times is too simplistic (Fig. 8), since the main remaining question is, whether the relevant deformation (cracks etc.) can be first, resolved by the used imagery and second, distinguished from other surface disturbances by the used analysis methods.

Overall recommendation:

The presented results comprise a very interesting process-oriented study evaluating the use of planet and UAV imagery for the derivation of spatiotemporally differentiated deformation information for a rather large and topographically pronounced terrain affected by complex mass wasting processes. I consider these findings well worth being published in this journal. However, the publication of these specific results requires a major conceptual reframing of the work which is targeted at the real potential usability of these results which cannot be early warning because of the reasons already stated in this review.

However, the work presented in this study has the potential to form an important basis for the development of a true early warning concept / approach in the future combining

remote sensing and ground based observations targeting at the same parameters allowing a multi-scale assessment of surface deformation related to triggering potential catastrophic mass movements at the study site.