Reviewer comments and author responses

Reviewer comment (RC1)

The study provides a conceptual workflow for the integration of geophysical imaging in local landslide early warning systems (LoLEWS). Increased spatio-temporal resolution of geophysical data in combination with corresponding laboratory-based transformations can contribute to reducing uncertainties commonly associated with geological conditions on local scales and improve landslide forecasting. The authors are also encouraged to revise the paper and address the following comments:

RC1-1 Please clarify if the conceptual framework for LoLEWS is limited to landslides triggered by changes in groundwater conditions.

AC1-1 We have clarified this point in the introduction when introducing Fig. 1 (l.19 and l. 41) and also in the figure caption for Fig. 1

RC1-2 Quantitative analyses of slope failures and landslide forecasting with physical-based landslide prediction models often require knowledge on shear strength of soil. The relationship between geophysical data and shear strength properties of soil is not clear. Will the shear strenght properties be derived from classical tests (e.g., direct shear and triaxial tests) and enriched with geophysical data or directly from geophysical data? In Figure 3, the slope-scale shear streght model is derived from laboratory resistivity/suction/stress relationships and laboratory derived Waxman-Smith model. Please clarify if the laboratory tests also include shear strenght tests and if they are sufficient to describe shear strenght properties of soil.

AC1-2 We have clarified the different means of estimating shear-strength (between l.169 and l.175) specifically with the re-wording and expansion of the following sentence: "*Alternatively, shear-strength and shear-wave velocity can be measured in the laboratory (e.g., using direct simple shear testing and bender element measurements) or in the field (e.g., using shear vanes and field seismic measurements) to derive a relationship between the two properties (e.g., Trafford and Long, 2020).*"

RC1-3 Although geophysical data can contribute to reducing uncertinties in in geological conditions, it is unlikely that uncertainties in geological properties will be completely eliminated. In addition to the uncertainties due to heterogeneous geological conditions, uncertainties will arise in, among others, the process of transforming geophysical data to geological parameters and landslide forecasting. The conceptual framework in Figure 1 and the roadmap in Figure 3 do not explicitly include steps or methodologies for dealing with uncertainties. Please clarify if a strategy for dealing with uncertainties is envisioned in the conceptual workflow.

AC1-4 We have updated Fig.1 to reflect the major sources of uncertainty when considering geophysical imaging for LoLEWS, and have coded these uncertainties against their activity in the Fig.1 framework fro clarity.

We have also acknowledged the role of uncertainty when introducing Fig.1 in the text (l.47 – l.49), and have discussed this in the conclusions (l.235 – 237). We also include a summary of the new information in Fig.1 at the end of Section 2 (l.79 – l.90): "*The framework also highlights the major sources of potential uncertainty that require consideration, including: i) laboratory testing of samples (e.g., quality of samples and how well samples reflect the heterogeneity of a geological formation) and issues scaling laboratory measurements to the slope-scale, ii) geophysical surveys, including the design of the survey (e.g., equipment used, data coverage and data resolution), the survey conditions (e.g., signal-to-noise ratio impacting measurement quality), uncertainties surrounding the inversion process (e.g., model sensitivity, fitting of geophysical models to measured data, or the sensitivity of the inversion to regularisation constraints), and the presence of unfavourable conditions for geophysical surveying (e.g., buried low-velocity or high conductivity zones inhibiting accurate seismic and geoelectrical measurements respectively), iii) the accuracy, precision and representativeness of non-geophysical point sensors used to supplement geophysical monitoring systems, and issues surrounding scaling localised point-sensor measurements to the slope-scale, iv) the identification of geophysical thresholds at which critical slope conditions are reached, v) the limitations, particularly in the ranges of co-sensitivity, of petrophysical relationships, and vi) the confidence of end-users to incorporate sources of geophysical data in to decision making processes surrounding slope-scale early warning.*"

RC1-4 Is the technology necessary for collecting geophysical data suitable for being installed in very steep and remote areas, without access to power or internet and subjected to harsh weather conditions, which are typically encountered in deployments of landslide monitoring systems?

AC1-4 It is not possible within the scope of the Brief Communication to list all of the examples given in the public discussion stage of the review of this manuscript, however, we have summarised those points in the following sentence (l.144 – l.149): "*The low-cost modular and robust construction of monitoring systems such as PRIME, combined with their low-power consumption and optimised acquisition and data telemetry schedules make them adaptable for installing in harsh environments and difficult terrain, for example, where access may only be possible on foot (see Holmes et al., 2020; Whiteley et al., 2019 and references therein).*"

Reviewer comment (RC2)

The submission is a brief conceptual paper that can be seen as a "case" for the use of time-lapse geophysical surveys in local early warning systems (LoLEWS) for weather-induced landslides. The arguments, clearly expressed and well framed in the context of reference literature, are centered around three well-designed and self-explanatory figures, highlighting the role that geophysical field measurements have in the workflow of activities needed for landslide early warning. The paper is almost ready for being published as is, yet the following minor revisions are suggested.

RC2-1 Some issues that are worth being considered in this discussion are the costs and robustness of the geophysical deployments, and the effectiveness of geophysical surveys in relation to different types of soils and landslides.

AC2-1 We have added a sentence summarising the points raised in the public discussion stage of the review of this manuscript, which addresses these points (l.146 – l.149): "*The low-cost modular and robust construction of monitoring systems such as PRIME, combined with their low-power consumption and optimised acquisition and data telemetry schedules make them adaptable for installing in harsh environments and difficult terrain, for example, where access may only be possible on foot (see Holmes et al., 2020; Whiteley et al., 2019 and references therein).*"

RC2-2 Always introduce the meaning of acronyms when they are first used (HHLO, DAS).

AC2-2 The first instances of these acronyms in the manuscript have now been correctly identified and expanded (HHLO, l.213; DAS, l.140)

RC2-3 The first paragraph of conclusions does not derive from previous comments in the article. Thus, it is more appropriate to move it at the end of the conclusions.

AC2-3 Some of the information related to identifying collaborative partners, maintaining observatories for research and maintaining an inter-disciplinary approach have been moved to the preceding section 3 (The future of geophysics for LoLEWS). We have then re-organised the remaining text in to a more logical order that better represents the flow of the manuscript.