Consiglio Nazionale delle Ricerche
Istituto di Ricerca per la Protezione Idrogeologica

Dr. Norman Kerle
University of Twente/ ITC, Earth Systems Analysis
Hengelosestraat 99, P.O. Box 6
7500 AA Enschede
Netherlands

Subj.: second resubmission of manuscript nhess-2018-177, entitled "*Brief communication: Application of remotely piloted aircraft systems for estimating road exposure to rockfall*".

Dear Dr. Kerle,

   This cover letter is to go with our second re-submission of the manuscript entitled "*Brief communication: Application of remotely piloted aircraft systems for estimating road exposure to rockfall*", by Michele Santangelo, Massimilano Alvioli, Marco Baldo, Mauro Cardinali, Daniele Giordan, Fausto Guzzetti, Ivan Marchesini, Paola Reichenbach.

   We have replied to the last comment of one referee, please see the response after this cover letter. We have also thoroughly checked typos, grammar and the general style.
   Together with this response letter, we will submit a new pdf without track changes. No changes were thought necessary to answer the reviewer comment, but few typos that were corrected throughout the text.

   We hope that that this manuscript can be now considered for a possible publication in Natural Hazards and Earth System Science.

        Sincerely,

                                                            Dr. Michele Santangelo

Dear Dr. Kerle,

this document contains the rebuttal to the comment of the reviewer. Reviewer comment is in italics, indented. Response is in plain text, not indented. Quotations from the manuscript are in italics between inverted commas, not indented.

ANSWER TO REVIEWER

In my opinion the raised points by the reviewers were mostly addressed in the new revised version. A further point to consider is that as mentioned in the text one of the purposes of this study was to set up protection measures (i.e., elastic barriers), however still the results of the analysis indicate that blocks can be deposited on pixels with <=1 trajectories from the run out results. In that sense, those pixels should also be taken into consideration for the installation of protection measures, and this includes almost the whole road. Given this, I think that the authors need to explain a bit further how their analysis helps in suggesting limited protection measures, as mentioned in the abstract.

We thank the reviewer for pointing out our effort in revising the paper. About this last comment, the issue was actually widely discussed throughout the paper. Namely, in the Results and Discussion section we state:

"*The portion of the SP18 closest to the source site S1 was not hit by the rockfalls during the seismic sequence. This is confirmed by the STONE simulations which reveal a total of 957 pixels affected by possible trajectories with a mode value of 1 within the road or downhill of it. The 957 pixels represent the 0.49% of the total number of the simulated trajectories and the 0.6% of the trajectories simulated from uphill this tract of the road (152,300). Such figures can be considered negligible. The plot in Figure 3C also confirms that in most of the simulations, the trajectories did not reach this tract of the SP18...Modelling results show that outside the most hazardous part of the SP18 (Fig. 3), only few locations are potentially affected by rockfalls. Here, the pixels that could potentially be reached by rockfalls along the road show count values of 1. It is worth noting that, over 100 trajectories simulations for each source pixel, a count value of 1 suggests a probability of occurrence that is equal to 1×10^{-2}. It actually corresponds to probability values much smaller since most frequently a single pixel can be crossed by trajectories starting from different (even not so close) locations. In the case of the tract of the road threatened by the site S1, the 957 trajectories that could reach the road represented the 0.6% of the total number of simulated trajectories (152,300)*".

In the Conclusions we affirm:

"*The numerical model allowed performing a semi-quantitative evaluation of the residual rockfall risk posed to the road SP18. It was observed that the tract of the road that had been hit by a rockfall during the seismic emergency was predicted as unsafe by the model, since the 29.2% of the total simulated trajectories from uphill the tract of the SP18 reached the road. The remaining portion of the studied tract of the SP18 was reached by the 0.6% of the modelled trajectories from uphill the tract of the SP18, and hence its exposure to rockfall was considered negligible. It is worth mentioning that results of this study were used to set up protection measures (i.e., elastic barriers) along the track of the road more exposed to rock fall impacts.*"

The areas where the count is at maximum equal to 1 are considered negligible since they represent the tail of the statistical distribution of the simulated rockfalls which, as stated in the paper, were conducted assuming precautionary conditions. As an example, the STONE simulation assigns random values of initial velocity which can reach up to 5 m/s, an unrealistic value for the seismic shaking of this area, where the highest recorded values of peak ground velocity never exceed 1 m/s. Therefore, the pixels that assume value of 1 can be considered outliers, that is why it was decided to consider such pixels as

safe. Moreover, the 0.6% probability concerns the entire length of the portion of the SP18 closest to the source site S1. It means that the average value of rockfall impact probability per unit of length of this tract of the road is even much lower and can not be used to request the installation of additional protection measures by the local road authorities. In addition, this portion of the road has already a protection system, which was built during the exploitation of the quarry in the 1950s, and that has also proved to be still working. In particular, in the Study Area section, we wrote: "*For a distance of 50 m uphill of the road, a system of scarps, counter scarps and rough and ruined embankments parallel to the SP18 was developed to protect the road during the quarry activities… The rocky material detaching from S1 did not reach the SP18, but stopped on the talus deposit and on the quarry protection system*"

Based on these points, we maintain that the manuscript already contains the text to support the decision of considering as safe the pixels showing values of 1 in the trajectory analysis. Therefore, we do not think necessary any additional text to the manuscript.