Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2020-55-AC3, 2020

Interactive comment on "A semi-automatic procedure to support the detection of rapid-moving landslides using spaceborne SAR imagery" *by* Giuseppe Esposito et al.

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Received and published: 3 July 2020

General comments:

This research is interested in by readers doing landslides inventory mapping, where SAR intensity images are employed in a large area. This method can overcome the shortage of optical images in case of cloud. The rational and procedure are introduced reasonably. However, some quantitative description of the parameters and the results need be considered carefully. Besides, the current title is somehow inaccurate. The main contribution of the research is the detection of failed landslides (event inventory mapping) rather than rapid moving landslides detection before occurrence. Therefore, I suggest to revise the title.

Author response: We agree with this comment. The title has been modified accordingly, by deleting the term “rapid-moving” as indicated below:

“A spaceborne SAR-based procedure to support the detection of landslides”

Specific comments:

(1) Lines 95-96: “Satellites Sentinel-1A and 1B acquire images characterized by a spatial resolution up to 5x5 m, . . .”. The statement is not correct, the spatial resolutions of Sentinel-1 images are about 5 x 20 m.

Author response: This point has been clarified in the text as indicated below:

“Satellites Sentinel-1A and 1B acquire images characterized by pixels with sizes ranging from 5 (range) $\times$ 20 (azimuth) m in the default acquisition mode for land observations (Interferometric Wide Swath mode - IW), up to 5x5 m in the Strip Map mode”.

(2) Lines 135-136: “. . ., the resulting stacked images are filtered for speckling reduction using the adaptive Frost filter (Frost et al., 1982), . . .”. There are many methods to filter speckle noise in SAR images, please give some explanation to use Frost filter in this study.

Author response: We agree with the Reviewer. We chose the Frost filter following the results of some previous studies. In particular, according to Schellenberger et al. (2012), it is one of the best choices in mountainous environments, it can account for the local properties of the terrain backscatter (and landslides are local objects in this context), and it was already used successfully in previous studies dealing with landslides (Mondini, 2017). We acknowledge that using different filters we might have obtained slightly different results, and this is now discussed.

(3) Lines 146 and 128, the meaning of $\beta 0$ should be unified.

Author response: We agree with this comment. Appropriate corrections have been done accordingly throughout the text.

(4) Due to the side-looking imaging geometry of SAR satellites, geometric distortions including layover, shadow and foreshortening are inevitable in mountainous regions, which will cause some blind areas and seriously decrease the capability of landslide detection. In this study, how did the authors deal with geometric distortions during the calculation of SAR amplitude changes?

Author response: Pixels in layover and shadows were obtained using the "SAR simulation Terrain Correction" tool available in SNAP, exploiting the SRTM 1Sec DEM, and then masked before running the statistical analysis. Foreshortening was partially mitigated by means of the reprojection procedure. We verified that the amount of the study area affected by such distortions is less than 1%.

(5) Line 583: "Flowchart of the automatic steps of the processing chain described in the text." The authors used the terminology "semi-automatic" in title, however, in here used "automatic". Please unify them. And the manual interaction section should be highlighted.

Author response: Considering this comment, we probably have improperly termed the proposed procedure as "semi-automatic". In fact, the operations described in the flowchart run in an automatic way but they need a one-time calibration phase to define both values of the parameters required for the segmentation and some statistics. Therefore, we preferred to delete "semi-automatic" from the title and within the revised version of the manuscript. Moreover, it is worth noting that information on how we automatized the described procedure is provided in the paragraph 2.5, that we have renamed as follows: "Automatic implementation of the processing chain".

(6) Figure 2: Please add the coverage of Sentinel-1 SAR images.

Author response: We accept this comment. A new version of Figure 2, including the spatial coverage of the used Sentinel-1 SAR images, has been prepared and shown in the attached pdf file.

(7) Figure 4: (1) Please add a color bar in Figure 4(b) and (c).

Author response: We added a color bar only in the Figure 4(b), since it was missing in the early version. Further comments aimed to clarify the contents reported in the Figure 4(c), as well as the source of optical images used in the Figures 4(a) and 4(d) are added into the caption. Please, see the attached pdf file.

(8) Line 290, what do you mean the multiply 196 m2 .5 (980 m2)?, Combined with the results shown in figure 6, what's the uncertainty and accuracy of the landslides detection? Moreover, what's the minimum area (size) can be detected with SAR intensity change method with high precision?

Author response: 980 m2 derives from the product of a single pixel area, roughly equal to 196 m2 (14x14 m2 considering that 14 m is the Log-Ratio pixel size calculated after the multi-looking process), times 5 that is the minimum number of pixels included within a segment. We decided to use 5 pixels after a general evaluation of the preliminary landslide-related images published on news websites and social networks, and considering that the detection of smaller segments in the test area was not significant at the scale of our analysis. Therefore, 980 m2 is a minimum area that we retained as potentially affected by a landslide. Moreover, our procedure is not aimed at landslide mapping but at a preliminary detection and rough localization of landslides, considering as minimum area affected by landslides the one selected according to the decided pixel threshold only.

(9) Figure 6: The obtained results look not good compared with the previous studies (Tessari et al., 2017; Konishi and Suga, 2018) of SAR amplitude images used for landslide detection. Such a result used directly in the detection of landslides will cause serious mis-interpretation. On the other hand, the authors should compare the landslide detection results with the ground truth to evaluate the accuracy and reliability of the method presented in this study, rather than just superimpose the SAR amplitude

changes on the ground truth. Here some quantitative assessments will be better for this method.

Author response: Thank you for this comment that gives us the opportunity to explain better a relevant point of our work. Both the cited studies were based on X-band SAR data acquired at high resolution and focused on areas smaller than the one analyzed in our study. This allowed both detection and mapping operations with a relatively high accuracy. In addition, both studies refer to geographic areas with different geological, geomorphological and land use properties with respect to the one analyzed in this work, which are also exposed to different landslide typologies. In the light of this, we believe that suitable comparisons should be possible if the same data were applied in the same area with similar techniques. Besides this, we would highlight that we present an attempt that use freely accessible C-band data, exploiting their constant availability with respect to other SAR products. The aim of the processing chain is in fact the early detection and localization of land cover changes induced by landslides over wide areas (i.e. thousands of square kilometers). The Figure 6 shows that the calculated segments concentrate mostly in the yellow polygons, where numerous landslides really occurred in the field. Considering this a first test, we retain the outcome satisfactory. Further detailed analyses, aimed at reducing some limitations of the used data, should be done for future improvements of the processing chain.

(10) Still in Figure 6, the shapes of yellow polygons do not look like landslide, especially the ones close to epicenter of M7.5. So I wonder the surface changes even in the yellow polygons are not landslides but earthquake damage. Can you verify the results?

Author response: The yellow polygons in Figure 6 (see legend) highlight the areas affected by landslides. The polygons were drawn independently from the segmentation, by means of a rough interpretation of optical data, with the aim of delimiting areas where landslides occurred in the field. In the test area, we did not perform a detailed mapping since we consider it out of the aims of the study. We used the yellow polygons to check whether the segments (red and blue pixels in Figure 6) obtained with our procedure were located in areas where the concentration of landslides was high and evident. We exclude earthquake damage into the yellow polygons, given that the study area is sparsely populated.

(11) In general, "rapid-moving landslides" represent the landslides which are deforming with large gradient without failures so far. Accurately, the landslides detected in this manuscript belong to the event-triggered landslides, i.e. landslides triggered by earthquakes. Please think more about it and make it express more precisely.

Author response: We agree with this comment. The title and the text have been modified accordingly.

Please also note the supplement to this comment:
https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2020-55/nhess-2020-55-AC3-supplement.pdf

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Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2020-55, 2020.