Reply to anonymous reviewers #1 and #2

We appreciate reviewers' valuable comments to improve this study. We hereby revised our manuscript as described below. Newly added description in the manuscript are colored in red.

Reply to Reviewer #1

General comments: The paper presents the exploitation of multi-source Earth Observation data (radar and optical) for a detailed analysis of the avalanche event triggered by the 7.8 Gorkha earthquake. Radar images are used to rapidly identify the affected area. Optical images are used to map the landslide area and to interpret the deposition sequence. Then, using pre- and post-event DSMs, the landslide volume is assessed. The paper well address a fundamental issue i.e., the need for a rapid assessment of landslide-affected area for urgent response in emergency situations. The paper is of broad interest and surely suited for the journal scopes and themes. The paper is interesting and relevant for this journal and within its topics. Description of methodology is informative and data analysis is flawless. In summary, the presented paper can represent, after some minor revisions (see below), a good addition to the literature.

Specific comments:

1) I appreciate the inclusion of the description of the avalanche event. I am sorry to notice that this description is poor and confusing. Please try to rephrase this part from general (description of the triggering event, including meteorological observation, and effects on wide area) to particular (description of the effects on the area of interest, dividing description of source area form accumulation zone);

> **Through the previous revision processes, the least statement of the event was left in the introduction, whereas detail description on the avalanche has been relocated to [2.2]. To avoid confusion, "as described in detail in [2.2] below" was added in the second paragraph of the introduction. Unfortunately, the reviewer's intending of "general" and "particular" could not be understood on this comment. A helpful suggestion from the editor would be welcomed.**

2) Names of villages and rivers cited in the text should appear in the images for easy location;

> **A new figure was added as Fig.1b.**

3) I suggest to include borders of zones A to J in Figure 7A;

> **They were added on Fig. 7a.**

4) Discussion paragraph is still weak. Your work is valuable and of practical use, please discuss which area the advantages, disadvantages, limits, opportunities of your application.

> **In terms of optical-sensor analysis, they were described at the end of [4.1].**

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Advantage:

"very-high-resolution imagery of WV-3 enables reconstruction of the deposition sequence by considering surface feature differences"

Disadvantage:

"this method, depending on visual interpretation, might contain small differences among individual interpreters, especially on the ambiguous border delineation"

Limit:

"remote-sensing techniques have difficulties observing the internal components of sediment"

Application:

"an in situ survey with a boring core and/or ground penetration radar is a possible way to provide some supporting findings. Realistic numerical simulation of avalanche collapse and analysis of heat balance related to the melting process would require consideration of multiple layers precisely mapped by our study"

In terms of SAR analysis, they were described at [4.2].

Advantage:

"The SAR-derived hazard scale is thus able to be known similarly to those from the optical sensors"

Disadvantage:

"splashed materials are difficult to recognize with the 3-m spatial resolution of PALSAR-2 imagery"

Limit:

"microwave reflection from/to PALSAR-2 was hindered by the very steep mountain hillslope", "we have recognized that the visual identification of an unknown hazard using only images is difficult", "The NCD calculation cannot be used for slightly but constitutively changing terrains, such as river banks and vegetation"

Application:

"the approximate scale of the collapse was successfully recognized and provided to the related authorities for emergency response"

In terms of DEM analysis, they were described at the end of [4.3].

The post-hazard WV-3 DSM in our analysis and the SPOT-derived DSM by Lacroix (2016) show the situation very soon after the hazard. This is valuable because following in situ surveys would measure the height after the internal ice/snow deposition started melting. These remote-sensing techniques enable repeat observations of the same accuracy at a lower cost than an in situ survey. Coupling of the regular surface-lowering measurements and assessment of thermal properties of the sediment would contribute to

understanding of the internal composition of ice/snow and rock materials, whether they have similar characteristics with those of a debris-covered glacier, for example. Fujita et al. (2016) demonstrated that image acquisition from unmanned aerial vehicles resulted in accurate DSM generation compared with in situ dGPS measurement. Such an in situ campaign would validate satellite-derived DSM accuracy.

Technical comments/Typing errors:

In general, in the reviewer's opinion, the paper is not well-written. Some parts in the results and discussion paragraph are difficult to read fluently. Some sentences seem to be incomplete and confusing. Editing of English language and style is required. The reviewer is not an English native speaker. I would suggest a professional correction service.

The new manuscript has been experienced English editing service after our revision.

The paper has been revised and improved following my suggestions. After the revision, some critical elements are still present in the manuscript. In the following some suggestions:

Page 2 line 1: the first part of the introduction is good, but in the second page the topic change sharply. I suggest introducing and describing better the use of remote sensing data for damage detection: I also believe that many papers that described the characterization of large landslides using remote sensing dataset have been published in last years, and I think that these manuscripts should be cited in this second part of the introduction.

Five related articles were added and the motivation of this study was slightly changed rather to assess a mountain hazard containing multiple hazard components.

[Paragraph-3] Damage detection through the synthetic aperture radar (SAR) technique has previously been applied for urban damaged areas (e.g., Kobayashi et al, 2011; Yonezawa and Takeuchi, 2001; Tamura and El-Gharbawi, 2015; Watanabe et al., 2016) and for landslide, rockslide, and avalanche mountain hazards (e.g., Wiesmann et al. 2001; Singhroy and Molch 2004; Metternicht et al. 2005; Riedel and Walther 2008; Joyce et al. 2009). However, almost no cases were studied for a large-scale mountain hazard containing multiple phenomena. Therefore, we applied SAR damage detection to this event and evaluated its effectiveness.

Page 2, chapter 2.2: some sentences are not very clear; I suggest a revision of the txt by an English native speaker.

The new manuscript has been experienced English editing service after our revision.

Page 7 discussion: the organization of this chapter should be reconsider because there are both results and comments From line 10 to line 27: these paragraph described some results obtained with SAR data, I believe that this part of the manuscript should be moved in the previous chapters.
From line 28 to (page 8) line 9: this second part is a real discussion.

All result values (areal values for methodological comparison) in this part (From line 10 to line 27) are once described in the result chapter. Here, they are discussed in quantitative comparison with another study. This part is needed to be here to develop the following paragraph (From line 28 to (page 8) line 9) without confusion.

Chapter 4.2 and 4.3: these paragraphs are a description of the validation and of the interpretation of the obtained results. I suggest authors to transfer these paragraphs in previous chapter. If authors disagree, I suggest that these paragraphs could remain inside chapter 4 but before the discussion of (page7) line 28 to (page 8) line 9. Chapter 4.3 represents reconstruction of sequence events and I think that it is one of the key point of the article. For this

reason, I suggest that this reconstruction should published immediately after the description of the results. After these changes, discussion and conclusion seem to be very short, I suggest to improve both.

Chap. 4.2 and 4.3. consists of our original evaluation and interpretation which should be separated from observed facts. Therefore they should be stayed in the discussion chapter. The description of chapter 4.3. was relocated in front of 4.1.