Interactive comment on “3-D visualisation of palaeoseismic trench stratigraphy and trench logging using terrestrial remote sensing and GPR – combining techniques towards an objective multiparametric interpretation”

Thanks to the Anonymous Referee #1 (16 October 2015) for her/his effort and thorough review. The main criticism of the reviewer was focused on which is the added value of our analysis (e.g. where the improvements and advantages from our presented analysis are). In order to reply to these concerns, we added another section in the conclusion part of the manuscript tending to the innovative use of t-LiDAR in palaeoseismology, the combination with GPR for pseudo-3D views into the hanging wall architecture, and its justified value as input for seismic hazard assessment. To support the understanding of the applied workflow and to strengthen the link to palaeoseismology we updated the figures in accordance to the reviewers’ comments.

Comments in the supplementary material

1) **References:** 3-D visualization of palaeoseismic trench stratigraphy and trench logging using terrestrial remote sensing and GPR – combining techniques towards an objective multiparametric interpretation
   (1) Comment: Title is confusing. You may delete “…towards…” or rephrase.

   (2) RE: done

   (3) Changes: 3D visualization of palaeoseismic trench stratigraphy and trench logging using terrestrial remote sensing and GPR – An objective multiparametric interpretation

2) **References:** Two normal faults on the Island of Crete and mainland Greece were studied to create and test and innovative workflow to make palaeoseismic trench logging more objective, visualize the sedimentary architecture within the trench wall in 3-D.
   (1) Comment: delete “create and”; delete “to make” and set “with the goal to obtain”; delete “visualise” and set “to obtain a 3-D view of”; “walls”; delete “in 3-D”

   (2) RE: done

   (3) Changes: Two normal faults on the Island of Crete and mainland Greece were studied to test an innovative workflow with the goal of obtaining a more objective palaeoseismic trench log, and a 3-D view of the sedimentary architecture within the trench walls. Sedimentary feature geometries in palaeoseismic trenches are related to palaeoearthquake magnitudes which are used in seismic hazard assessments. If the geometry of these sedimentary features can be more representatively measured, seismic hazard assessments can be improved. In this study more representative measurements of sedimentary features are achieved by combining classical palaeoseismic trenching techniques with multispectral approaches.

3) **References:** Passive data collection disadvatages (e.g. illumination) were addressed by complementing the dataset with active near-infrared backscatter signal image from t-LiDAR measurements.

(1) Comment: what you mean with “passive data”

(2) RE: The term passive data refers to data obtained by passive acquisition, which means that electromagnetic waves (e.g. from sunlight) are used instead of artificially generated (e.g. near-infrared laser beam from LiDAR systems)

(3) Changes: Photomosaic acquisition disadvantages (e.g. illumination) were addressed by complementing the dataset with active near-infrared backscatter signal image from t-LiDAR measurements.

4) **References:** Based on the trench log, a 3-D-interpretation of GPR data collected on the vertical trench wall was then possible.
(1) Comment: of “2-D acquisition?” GPR

(2) RE: Yes. Attached 2-D profiles were processed for a pseudo-3-D cube.

(3) Changes: Based on the trench log, a 3D-interpretation of attached 2-D GPR profiles collected on the vertical trench wall was then possible.

5) **References:** Sedimentary feature geometries related to earthquake magnitude can be used to improve the accuracy of seismic hazard assessment
(1) Comment: delete

(2) RE: Seismic hazard assessment is based on seismicity and geology. Reiss et al. (2003) showed a correlation of colluvial wedge height and earthquakes magnitude. Therefore, to measure colluvial wedges means to estimate palaeomagnitudes. In the past, several publications have shown the importance of measurements on coseismic feature on the earths’ surface and in the shallow subsurface (e.g. McCalpin, 2009; Papanikolaou et al., 2013; Grützner et al., 2016). We think, although we don’t address seismic hazard assessment directly, it is worth it mentioning the impact on it.

(3) Changes: none

6) **References:** (ii) how a multispectral digital analysis can offer additional advantages and a higher objectivity in the interpretation of palaeoseismic and stratigraphic information
(1) Comment: delete “and a higher objectivity in the interpretation of” set “to interpret”; delete “information” set “data”

(2) RE: ok, done

(3) Changes: this manuscript combines multiparametric approaches and shows: (i) how a 3D visualization of palaeoseismic trench stratigraphy and logging can be accomplished by combining t-LiDAR and GPR techniques, and (ii) how a multispectral digital analysis can offer additional advantages to interpret palaeoseismic and stratigraphy data.

7) **References**: As a result, the sample from the statistical elaboration of the historical and instrumental data is incomplete and a large number of faults would have not ruptured during the period where the historical record is considered complete (Grützner et al., 2013; Papanikolaou et al., 2015)

   (1) Comment: Substitute these references. There are many papers of fault studies showing incompleteness of catalogues relative to fault recurrence length in Spain, Italy, Greece, … is much more appropriate to use some of them as examples to refer

   (2) RE: done. This is true, however, Papanikolaou et al. 2015 presents a table with the completeness period of the historical records for tens of countries worldwide that in the majority of the cases are not mentioned in the seismic hazard studies. Data regarding the completeness is hard to find in the literature. When researchers refer to the historical record, in most cases they refer to its duration, but not to its completeness (this is the same with most readers). Therefore, this table is surprising since it shows how short the completeness period is, particularly compared to the recurrence interval of individual faults and this occurs worldwide so it is of higher value as a reference compared to a single or two countries. Greece is a great such example since the catalogue goes back up to 550 BC, but it is complete for M>6.5 only since 1845 – less than 200 years!

   (3) Changes: As a result, the sample from the statistical elaboration of the historical and instrumental data is incomplete and a large number of faults would have not ruptured during the period where the historical record is considered complete (Makropoulos and Burton, 1981; Stucchi et al., 2004; Woessner and Wiemer, 2005; Guidoboni and Ebel, 2009; Grützner et al., 2013; Stucchi et al., 2013; Papanikolaou et al., 2015).

8) **References:** (ii) how a multispectral digital analysis can offer additional advantages and a higher objectivity in the interpretation.

   (1) Comment: delete “and a higher objectivity”

   (2) RE: to increase the degree of objectivity on trench data interpretation is one of the major goals of this manuscript. Benefits from remote sensing data acquisition and multispectral analysis produce a higher objectivity in defining individual stratigraphies.

   (3) Changes: This manuscript adds on such approaches and shows: (i) how a 3D visualization of palaeoseismic trench stratigraphy and logging can be accomplished by combining t-LiDAR and GPR techniques, and (ii) how a multispectral digital analysis can offer additional advantages and a higher objectivity in trench data interpretation.

9) **References:** Typical features caused by recurrent seismic events include: (i) progressive displacements (Keller and Rockwell, 1984), (ii) colluvial wedges, (iii) Liquefaction, and (iv) fissure fills (Reicherter et al., 2003; Kokkalas et al., 2007; McCalpin, 2009).

   (1) Comment: delete “recurrent” set “the repetition of”

   (2) RE: earthquake “recurrence” is the predominant expression used in the literature

   (3) Changes: none

10) **References:** Typical features caused by recurrent seismic events include: (i) progressive displacements (Keller and Rockwell, 1984), (ii) colluvial wedges, (iii) Liquefaction, and (iv) fissure fills (Reicherter et al., 2003; Kokkalas et al., 2007; McCalpin, 2009).
    (1) Comment: delete "(i)"

    (2) RE: why not use itemization? We think it is ok.

    (3) Changes: none

11) **References:** Typical features caused by recurrent seismic events include: (i) progressive displacements (Keller and Rockwell, 1984), (ii) colluvial wedges, (iii) Liquefaction, and (iv) fissure fills (Reicherter et al., 2003; Kokkalas et al., 2007; McCalpin, 2009).
    (1) Comment: If you intend features that indicate repeated occurrence of more than one earthquake in the trench wall and along the fault, liquefaction is not!

    (2) RE: Liquefaction is indeed evidence for ground shaking events. The herein studied faults have to generate moderate earthquakes to produce liquefaction features close to the fault trace. Indeed, unless these features can get dated, it is not easy to correlate liquefaction to different events. However, first we are not dealing with interpretation of different events but with an innovative method to recognize those features and second liquefaction is only one feature in a conglomerate of possible evidence of palaeoearthquakes. In addition, there are cases in the stratigraphy where different liquefaction events can be traced.

    (3) Changes: none

12) **References:** Typical features caused by recurrent seismic events include: (i) progressive displacements (Keller and Rockwell, 1984), (ii) colluvial wedges, (iii) Liquefaction, and (iv) fissure fills (Reicherter et al., 2003; Kokkalas et al., 2007; McCalpin, 2009).
    (1) Comment: insert: (ii) ""faulted" colluvial wedges

    (2) RE: colluvial wedges might get faulted by younger surface rupturing events. However, colluvial wedges are accumulations of material coming from the top of a scarp more or less immediately after an event. Over time a new soil horizon develops on top of it. If a colluvial wedge is faulted within a trench exposure than a younger event happened and yield to progressive displacements (see (i)). The newest colluvial wedge (e.g. formed after the last event) by definition will not be faulted.

    (3) Changes: none

13) **References:** The geometry and stratigraphic position of these features allow the relative dating of recurrent surface rupturing events, whereas carbon rich material (usually within buried palaeosols) can be used to date prehistoric earthquakes and determine recurrence intervals.
    (1) Comment: Not clear what you mean. Rephrase.

    (2) RE: rephrased

(3) Changes: The geometry and stratigraphic position of these features allow retrodeformation of recurrent surface rupturing events, whereas carbon rich material can be used to date prehistoric earthquakes and determine recurrence intervals.

14) **References:** To access these potential archives of seismic information expensive trenches are excavated across deformation zones

    (1) Comment: not completely true. Generally the costs for digging trenches are very low compared to other techniques. It depends on the countries where you operate. Turkey, Italy, Greece etc..are very cheap. Germany is expensive.

    (2) RE: Trenches can be expensive in some cases and countries (e.g. paying the owners). In addition, they can bare higher costs if for example water pumping is needed, or time consuming for obtaining permits from owners, archaeology, local municipality. These direct or indirect costs can make trenching costly.

    (3) Changes: To access these potential archives of seismic information trenches, which are often expensive, are excavated across deformation zones.

15) **References:** The accuracy of the trench log is, however, dependent on the logger's experience and ability to define mappable units; discrete deposits that are composed of similar lithology need to be distinguished from adjacent deposits.

    (1) Comment: delete "mappable"

    (2) RE: Basically, distinct units are mapped based on their lithology and structure. This is similar to geological mapping. We think, overall it is mapping, not in the horizontal but in the vertical dimension

    (3) Changes: The accuracy of the trench log is dependent on the logger's experience and ability to define units of discrete deposits that have distinguishable lithological characteristics compared with adjacent deposits.

16) **References:** The excavated trench is then a 2-D representation of the fault zone stratigraphy.

    (1) Comment: insert: trench "wall"

    (2) RE: done

    (3) Changes: The excavated trench wall is then a 2D representation of the fault zone stratigraphy.

17) **References:** without widening the trench along strike, or excavating more trenches, we must assume that the 2-D trench log is representative for this location along the fault.

    (1) Comment: Not clear. How much is the extent along the strike you want to consider. Surely one trench is representative for the fault at that location and not necessarly at other sites along the fault strike. So how much you would need to widen your trench? However, you have two parallel walls to correlate obtaining a 3D reconstruction even if for few meters along the strike. The assumption is to consider the trench analysis valid for the entire fault extension. This is resolvable only trenching at different sites along the fault

(2) RE: clarified

(3) Changes: It is assumed that the 2-D geometry of the logged sedimentary features continues along strike either side of the trench; without widening the trench along strike, or excavating more trenches, we must assume that the 2-D trench log is representative for this location along the fault. Hence, an interpretation of a 2-D exposure of very local variations and/or accumulations of colluvial deposits yield results different from statistical significance which gets closer to the real world conditions.

18) **References:** Trenches target predominantly palaeosols on either side of the fault, and then according to empirical relationships (Wells and Coppersmith, 1994) palaeomagnitudes can be estimated based on these co-seismic displacements.
(1) Comment: change "palaeosols" to "units" or "deposits"

(2) RE: "Units" or "deposits" is too general. We need a distinct horizon that is thin and can be dated, so we target palaeosols.

(3) Changes: none

19) **References:** In this study we demonstrate how high-resolution t-LiDAR (terrestrial light detection and ranging) measurements and photomosaics can be used to assist in the interpretation of palaeoseismological exposures; we also show how GPR can be used to visualize sedimentary structures in 3-D within the trench wall.
(1) Comment: GPR acquisition was 2 dimensional or acquire 3D volume that is much effective?; please refer to some of the numerous papers on GPR survey to assist the fault imaging, among them Liner & Liner, 1997 The Leading Edge; Jewell & Bristow, 2006 Near Surface Geophys.; Vanneste et al., 2008 Geophyiscs; Pauselli et al., 2010 J. Appl. Geophys.; Ercoli et al 2013, J. Appl. Geophys.; Christie et al 2009 J., Appl. Geophys.

(2) RE: rephrased and now referring to Vanneste et al., 2008; Christie et al., 2009; Ercoli et al., 2013

(3) Changes: In this study we demonstrate how high-resolution t-LiDAR (terrestrial light detection and ranging) measurements and photomosaics can be used to assist in the interpretation of palaeoseismological exposures; we also show how an accurately arranged 2-D GPR survey can assist to visualise sedimentary structures in 3-D (e.g. Vanneste et al., 2008; Christie et al., 2009; Ercoli et al., 2013) within the trench wall.

20) **References:** Using these techniques we make experienced-based trench logging more objective.
(1) Comment: I do not think this is the right adjective, it would mean without bias! What is lacking in the paper is a clear description of the improvements respect with conventional

logging or better in which cases these techniques can be a valid substitute being the only applicable.

(2) RE: Rephrased and now pointing on the new dimension or the additional level for palaeoseismological interpretations

(3) Changes: Using these techniques we assist experienced-based trench logging and obtain 3-D spectral data to support the interpretation of palaeoseismological deposits.

21) **References:** GPR undertaken on top of the trench and on the vertical trench wall is used in combination with a high-resolution digital elevation model (DEM) from t-LiDAR scanning.
(1) Comment: Delete “GPR”

(2) RE: rephrased and referring to figure 2

(3) Changes: Two-dimensional GPR surveys, arranged for a pseudo-3-D cube reconstruction, undertaken on top of the trench and on the vertical trench wall (Fig. 2) are used in combination with a high-resolution digital elevation model (DEM) from t-LiDAR scanning.

22) **References:** We then applied this workflow on a professionally excavated trench in mainland Greece.
(1) Comment: “??” on “professionally”

(2) RE: a road cut is in our opinion not a professional trench excavated with for palaeoseismic investigations in mind.

(3) Changes: none

23) **References:** Ambraseys and Jackson (1990) estimate a maximum earthquake magnitude of M_s 7.0 could occur on these normal faults which coincides with fault lengths of 15-30 km as determined through empirical relationships (Wells and Coppersmith, 1994)
(1) Comment: insert: normal faults “using macroseismic and instrumental data”; Delete “as determined through empirical relationships (Wells and Coppersmith, 1994)”

(2) RE: done, but still referring to Wells and Coppersmith, 1994

(3) Changes: Ambraseys and Jackson (1990) estimate a maximum earthquake Magnitude of Ms 7.0 could occur on these normal faults using macroseismic and instrumental data, which coincides with fault segment lengths of 15 – 30 km (Wells and Coppersmith, 1994).

24) **References:** Ambraseys and Jackson (1990) estimate a maximum earthquake magnitude of M_s 7.0 could occur on these normal faults which coincides with fault lengths of 15-30 km as determined through empirical relationships (Wells and Coppersmith, 1994)
(1) Comment: referring to “30” – they say 20 km

(2) RE: Wells & Coppersmith (1994) Table 2A: log(SRL) = a + b * M with a = -2.01 (0.65) and b = 0.5 (0.10) gives SRL ≈ 30 km at M7

(3) Changes: none

25) **References:** This northwest dipping normal fault is easy to recognize as it offsets smooth mountain slopes, has a steeply dipping (ca. 70°) fault scarp up to 6 m in height, and has an onshore length of approximately 5 km (Fig. 1iv).
(1) Comment: you mean the fault scarp is clear because the slope is regular?

(2) RE: rephrased

(3) Changes: This northwest dipping normal fault is easy to recognise as a prominent fault scarp of up to 6 m. The scarp dips 70° towards the West and offsets smooth mountain slopes for approximately 5 km onshore (Figure 1 IV). Together with the opposing Lastros fault a 2 km wide graben structure is formed.

An outcrop in the form of a dirt road cut (located at 35° 7’58.97”N, 25°54’26.01”E) exhibits the fault zone as a contact between footwall Mesozoic carbonates and hanging-wall colluvium (Figure 1 V). The outcrop cuts the fault at an angle of approximately 75° from the fault strike.

26) **References:** The Kaparelli fault became well-known as it ruptured during the Corinthian Alkyonides earthquake sequence in spring 1981 (Jackson et al., 1982).
(1) Comment: insert the earthquake data

(2) RE: done

(3) Changes: The Kaparelli fault became well-known as it ruptured during the 1981 Corinthian Alkyonides earthquake sequence in February (24th, M_S6.7, depth: 10 km; 25th, M_S6.4, Depth: 8 km) and March (4th, M_S6.4, depth: 8 km) (Jackson et al., 1982).

27) **References:** The excavation from Kokkalas et al. (2007) are still open; therefore, the already logged and interpreted structures within trench Kap-1 (Fig. 1v) is a perfect site to test the workflow developed on the Sfaka fault road cut.
(1) Comment: you did not mentioned yet which work you develop on the Sfaka road cut

(2) RE: rephrased

(3) Changes: The excavations from Kokkalas et al. (2007) are still open; therefore, the already logged and interpreted structures within trench Kap-1 (Figure 1 V) represent a perfect site to test remote sensing data acquisition.

28) **References:** The herein presented workflow combines palaeoseismic trenching techniques with t-LiDAR measurements to improve the accuracy of palaeoseismic reconstruction.
(1) Comment: Please clarify the steps of your activities. Suggestion: i) combination of …ii) comparison of…iii) gpr survey….

(2) RE: done; also added a new figure 3 concerning this

(3) Changes: The herein presented workflow comprises (i) a combination of conventional trench logging and remote sensing measurements, (ii) a comparison of common photographs and near-infrared images, and (iii) a GPR survey. It combines palaeoseismic trenching techniques with t-LiDAR measurements to improve the accuracy of palaeoearthquake reconstruction.

29) **References:** Palaeoseismic trenching

(1) Comment: the following section are method, Suggestion for title: Trench logging and photomosaic

(2) RE: ok

(3) Changes: Conventional trench logging and photomosaic

30) **References:** A palaeoseismic trench is characterised by an often artificially produced subsurface exposure of sedimentological coseismic features.

(1) Comment: delete “an often artificially produced”; change “sedimentological coseismic features” to “fault zones and deformed stratigraphy”

(2) RE: done

(3) Changes: A palaeoseismic trench is characterised by the subsurface exposure of fault zones and deformed stratigraphy.

31) **References:** The trenches were conventionally logged in 1 : 10 scale in accordance with McCalpin (2009).

(1) Comment: delete “conventionally” and “in accordance with McCalpin (2009)”

(2) RE: done

(3) Changes: The trenches were logged in 1:10 scale.

32) **References:** In Kaparelli in the eastern trench wall (see Fig. 1ii and iii) was investigated because it preserved the best stratigraphy and exhibits faulting events with clear marker horizon displacements (Kokkalas et al., 2007).

(1) Comment: change “faulting events with clear marker horizon displacements” to “clear horizons of multiple faulting events”; Comment: insert Kaparelli “trench” and Sfaka “road cut”

(2) RE: done

(3) Changes: The Sfaka road cut faces north (see Figure 1 IV and V) and is surrounded by steep slopes. Since footwall and hanging-wall deformation structures are exposed the outcrop is a suitable palaeoseimological trench after manual levelling and deepening of most interesting parts. In Kaparelli the eastern trench wall (see Figure 1 II and III) was investigated because it preserved the best stratigraphy and exhibits clear horizons of multiple faulting events (Kokkalas et al., 2007). To avoid most of the differing luminous exposures, the photographs were either taken in the morning when the angle of sunlight was shallow and did not shine directly onto the investigated wall (Kaparelli trench) or in the afternoon when the sun disappeared behind the surrounding hills (Sfaka road cut).

33) **References:** The photomosaic of true colour images (RGB; red, green, blue) was converted into a grey-level image to eliminate hue and saturation information while retaining the luminance (0-255) using the rbg2gray function in MATLAB®.
(1) Comment: delete “red, green, blue”, say “RGB method”

(2) RE: done

(3) Changes: The photomosaic of true colour images (RGB method) was converted into a grey-level image to eliminate hue and saturation information while retaining the luminance (0-255) using the rgb2gray function in MATLAB®.

34) **References:** t-LiDAR (terrestrial Light Detection and Ranging) is a remote sensing technique with high spatial and temporal resolution and is very effective instrument for reconstructing morphological and geological settings and monitoring approaches.
(1) Comment: ??? you mean is a tool for monitoring movements? Explain. Add some references as examples of t-LiDAR use for the mentioned purposes.

(2) RE: added reference. Further, added applications in seismic hazard assessment

(3) Changes: t-LiDAR (terrestrial Light Detection and Ranging) is a remote sensing technique with high spatial and temporal resolution and is a very effective instrument for reconstructing morphology (Brodu and Lague, 2012, Wilkinson et al., 2014; Wiatr et al., 2015), geological settings and monitoring movements (Jones, 2006; Hu et al., 2012). In seismic hazard assessment, this technology assists fault mapping (e.g. Arrowsmith and Zielke, 2009; Begg and Mouslopoulou, 2010) as well as providing a tool to trace palaeoevents based on changes in reflectivity and roughness on fault scarps (Wiatr et al., 2015).

35) **References:** The scans were carried out almost perpendicular to the trench wall and less than 10 m from the exposure.
(1) Comment: you mean 10 m from the road cut and 10 m from the trench wall but from outside the excavation? Specify, the two cases of studies are different.

(2) RE: agree, done

(3) Changes: The scans were carried out almost perpendicular to the trench wall. Since the Kaparelli trench is too narrow for scans from inside, the data was collected from outside of the excavation. At the Sfaka fault road cut, scans were undertaken at 5 m distance.

36) **References:** The authors conclude that imaging spectroscopy can be successfully applied to assist in the description and interpretation of palaeoseismic exposures because: (i) subtle or invisible features are displayed, (ii) quantitative analysis and comparisons of units using reflectance spectra can be undertaken, and (iii) unbiased data are stored for future access and analysis.
(1) Comment: unbiased data -> sure about this? After you mention at limitations and assumption (variation across exposure, other error source,…) affecting the data.

(2) RE: The data is unbiased since it represents measured values in physical units. Even variety in humidity along exposure is captured and recorded. Of course, the data quality is not very high when error sources are not avoided by the operator. However, when obey requirements to collect high quality data (scan position, dry exposure, etc…) the reflectance spectra at each pixel of the images provide unbiased compositional information (Ragona et al., 2006). Bad quality for interpretation does not mean biased data.

(3) Changes: none

37) **References:** The limitations of multispectral approaches are, by their very nature, closely connected to the application of photomosaics and t-LiDAR measurements.
(1) Comment: delete “very”

(2) RE: done

(3) Changes: The limitations of multispectral approaches are, by their nature, closely connected to the application of photomosaics and t-LiDAR measurements.

38) **References:** To reduce errors we assume that the moisture content was similar throughout the exposure and water absorptions should not affect the correlations because the spectral change is similar along the trench wall.
(1) Comment: delete “To reduce errors”

(2) RE: done

(3) Changes: We assume that the moisture content was similar throughout the exposure and water absorptions should not affect the correlations because the spectral change is similar along the trench wall.

39) **References:** Moreover, resampling down to 0.02 m cells enhances visibility and allows a more general interpretation and comparison to the conventional log. This is because average gridding and sketching inaccuracy is around 2% (McCalpin, 2009).
(1) Comment: not clear what you mean, general interpretation?

(2) RE: Resampling a raster reduces scattered signal and smoothens the dataset. Rephrased

(3) Changes: Moreover, resampling down to 0.02 m cells enhances visibility and allows a more general interpretation and comparison to the conventional log. This is because the scattered signal gets reduced so there is less influence by local variations. The threshold is chosen because average gridding and sketching inaccuracy is around 2 % (McCalpin, 2009).

40) **References:** GPR was carried out on the vertical trench wall and on the slope surface above the trench (see Fig. 2).
(1) Comment: how many profiles you performed. In figure 2 there are 4 arrows. Describe better the array.; You mean on top of the trench wall? And what about the road cut wall?

(2) RE: agree; done. More detailed information is added. However, Figure 2 shows the GPR arrays on the vertical wall and on top of the hanging wall.

(3) Changes: GPR was carried out on the vertical trench wall and on the slope surface above the trench (see Figure 2). At the Sfaka fault road cut three horizontal profiles were collected on the vertical exposure with 0.3 m spacing between profiles. 15 profiles were undertaken on top of the trench in a grid array to obtain a high resolution pseudo-3-D cube. At the Kaparelli trench 20 profiles were collected on the vertical trench wall, and 14 on top of the hanging-wall.

41) **References:** Furthermore, a 400 MHz antenna together with a SIR-3000 control unit from Geophysical Survey Systems Inc. (GSSI, Salem, NH, USA) was used to obtain desired resolution and noise levels.
(1) Comment: delete “furthermore”

(2) RE: Done

(3) Changes: A 400 MHz antenna together with a SIR-3000 control unit from Geophysical Survey Systems Inc. (GSSI, Salem, NH, USA) was used to obtain desired resolution and noise levels.

42) **References:** Based on distinct layers in the trench log and taking into account the results of the multispectral analysis, GPR-data were then used to interpret the outcropping strata in 3-D.
(1) Comment: Change to “Based on the layers distinguished in the trench log…”

(2) RE: done

(3) Changes: Based on the layers distinguished in the trench log and taking into account the results of the multispectral analysis, GPR-data were then used to interpret the outcropping strata in 3-D.

43) **References**: 4.1.1 Trench log
(1) Comment: describe the stratigraphy in this section, and also describe a little bit more the log interpretation in terms of faults, fractures and deformations of deposits. You mention to details in this section but jump a macro-description of what you see in the log. I understand it is not the purpose of this paper, however at least mention to the number of events you found in this case, even because in the general description of the method you list the features used to recognized the event horizons as critical introduction….

(2) RE: added a description on stratigraphy and interpretation here

(3) Changes: The trench was logged and ten distinct layers were recognised. These vary in colour, matrix, and geometrical alignments. The trench exposes the limestone footwall at its eastern end between 0 and 1 m. The limestone is heavily weathered and degraded, both within and above the trench. Adjacent to the bedrock fault plane is fault gouge which is approximately 1 m in thickness. However, true thickness is calculated to around 0.8 m when correcting for the trench's 75° from fault strike. The western end of the gouge is the primary fault contact. Here, the clasts within the gouge are aligned vertically and there is an abrupt contact to the next units. These units are interpreted as fissures filled with palaeosols (Figure 5a). Palaeosol 1 comprises light brown to reddish brown very gravelly silty clay with occasional cobbles and containing roots and rootlets, and Palaeosol 2 comprises light brown to brown gravelly clay containing rare cobbles. Both these palaeosols have high clay contents and there is a sharp contact with the colluvial layers further to the west. The remaining sediments within the trench are colluvial deposits C1 to C6. C1 is cemented colluvium located at the western end of the trench. C2 to C6 are individual colluvial layers which can be traced from the cemented colluvium to the fissure fills. These colluvial layers are offset by a number of small displacement secondary faults. These minor faults are typical of extension in unconsolidated sediments.

The trench is not dominated by scarp derived colluvial wedges formed after rupturing events. Instead earthquake evidence comes in the form of fissure fills which have developed within the hanging-wall adjacent to the fault gouge (Figure 5b). These fissure fills are filled with palaeosols and are faulted against colluvial material which is partly scarp derived and partly hanging-wall derived. Due to the nature of the sloping hanging-wall and the location of both trenches, we believe that the main source of colluvial layers C2 to C6 is hanging-wall colluvium from the south at higher elevations. This is also evidenced by the alluvial/colluvial fan located 85 m to the west of the trench. Two displacement events can be inferred based on fissure fill and colluvial stratigraphy. Dip slip faulting causes the hanging-wall to be downthrown and tilted; due to a slightly concave fault plane below the trench site, a tectonic fissure then opens up between the fault gouge and colluvial layers, and tilting is taken up on the small displacement antithetic faults within the colluvial layers. The fissure was then filled with scarp derived and local hanging-wall material. The slope surface then stabilises allowing gravelly topsoil to accumulate. The second displacement event then occurs and the above described process is repeated.

44) References: In accordance with McCalpin (2009) the trench was logged and divided into ten distinct layers. These vary in colour, matrix specifications, geometrical alignments and soil formation.

(1) Comment: Say "The eastern trench wall was logged and ten distinct layers were recognized"

(2) RE: The facing is only true for the Kaparelli trench. Here, the term trench refers to both sites, Kaparelli trench and Sfaka road cut. To make it more clear, this is stated in 3.1 Conventional trench logging and photomosaic.

(3) Changes: none

45) **References:** In accordance with McCalpin (2009) the trench was logged and divided into ten distinct layers. These vary in colour, matrix specifications, geometrical alignments and soil formation.
(1) Comment: colour -> generally the difference in colour of deposits is not used as critical to discriminate and define distinct unit

(2) RE: This is why we referred to McCalpin (2009). This publication states at page 80, 2A.3.2.7 Identifying and Marking Contacts, "Lithologic units are differentiated as discrete sedimentary deposits characterized by a consistent texture, sorting, bedding, fabric, or color". Further, we do not promote colour to be a standalone soil property but say that it gives evidence for changing lithology.

(3) Changes: none

46) **References:** In accordance with McCalpin (2009) the trench was logged and divided into ten distinct layers. These vary in colour, matrix specifications, geometrical alignments and soil formation.
(1) Comment: delete "specifications"

(2) RE: done

(3) Changes: These vary in colour, matrix, and geometrical alignments.

47) **References:** In accordance with McCalpin (2009) the trench was logged and divided into ten distinct layers. These vary in colour, matrix specifications, geometrical alignments and soil formation.
(1) Comment: geometrical alignments -> you mean bedding?

(2) RE: No, geometrical alignments refers to the recognized layers which have a geometrical orientation or alignment.

(3) Changes: These vary in colour, matrix, and geometrical alignments.

48) **References:** In accordance with McCalpin (2009) the trench was logged and divided into ten distinct layers. These vary in colour, matrix specifications, geometrical alignments and soil formation.
(1) Comment: delete "and soil formation"; ??? layers that vary in soil formation? Non sense

(2) RE: deleted

(3) Changes: These vary in colour, matrix, and geometrical alignments.

49) **References:** 4.1.2 Imaging spectroscopy

(1) Comment: if you describe the stratigraphy and structure in the previous section, here you may focus only on the results from the spectroscopy and comparison…section is written in a confusing manner. Consider to change the title of this section is the same of section 3.3. Suggestion: imaging spectroscopy interpretation or analysis…

(2) RE: done

(3) Changes: Imaging Spectroscopy Analysis

50) **References:** The homogeneous silty layer contains only a view voids due to excavation works that influence reflectance value range.

(1) Comment: homogeneous silty layer -> which one is it, please refer to the unit in log figure 14a.; view voids -> ???

(2) RE: done

(3) Changes: The homogeneous silty layer (fault gouge) contains only a few voids due to excavation works that influence reflectance value range.

51) **References:** The structure follows a lineament of displacement within the colluvial strata

(1) Comment: "a lineament of displacement" -> a fault!

(2) RE: changed to "a secondary fault"

(3) Changes: An upward oriented structure of approximately 0.5 m thickness is obvious in the HRDBSM and false colour composition. The structure follows a secondary fault within the colluvial strata.

52) **References:** 4.1.3 GPR

(1) Comment: clarify the steps to reach the 3d interpretation. Again, change title, same as section 3.4. You may use GPR interpretation

(2) RE: done

(3) Changes: 4.1.3 GPR Data Interpretation

53) **References:** A significant contrast in all three datasets is traced by the abrupt transition from fault gouge and palaeosols I (see Figs. 4c and 6).

(1) Comment: which datasets?

(2) RE: rephrased

(3) Changes: A significant contrast in all GPR images is traced by the abrupt transition from fault gouge to palaeosol I (see Figure 5c and Figure 7).

54) **References**: However, value range given by standard deviation reach wider than the in previous section.
(1) Comment: rephrase

(2) RE: done

(3) Changes: However, the value range given by the standard deviation of each sample has a wider reach than in the previous section (Figure 7).

55) **References:** The hanging-wall and footwall of the Kaparelli fault are clearly separated by a 70-80° south dipping fault zone.
(1) Comment: figure?

(2) RE: now referring to Figure 1 II

(3) Changes: The hanging-wall and footwall of the Kaparelli fault are clearly separated by a 70-80° south dipping fault zone (Fig. 1 II).

56) **References:** The fissure thicknesses ranges from around 10 cm to over 80 cm and are filled with sub-angular to rounded gravel deposits in a silty matrix (Fig. 8a) (now Figure 9a).
(1) Comment: “thicknesses” -> you mean “opening”?

(2) RE: changed to “width”

(3) Changes: The fissure width ranges from around 10 cm to over 80 cm and are filled with sub-angular to rounded gravel deposits in a silty matrix (Figure 9a).

57) **References:** The manually sketched trench log, calibrated using the results from Kokkalas et al. (2007), correlates well wih the results from imaging spectroscopy (Fig. 8a) (now Figure 9a).
(1) Comment: delete “manually sketched”

(2) RE: done

(3) Changes: The trench log, calibrated using the results from Kokkalas et al. (2007), correlates well with the results from imaging spectroscopy (Figure 9a).

58) **References:** However, a distinct transition to a silty-sand unit, which prior to this stuy was described as the fault zone of the 1981 rupture event (Kokkalas et al., 2007), is obvious.
(1) Comment: change “obvious” to “very clear”

(2) RE: Done

(3) Changes: However, a distinct transition to a silty-sand unit, which prior to this study was described as the fault zone of the 1981 rupture event (Kokkalas et al., 2007), is very clear.

59) **References:** Major components of the trench wall are identified in individual GPR images.
(1) Comment: I do not see any GPR images from this trench site. And also the results are very poorly discussed. Expand the section of GPR at this site or do not mention to the use of this approach here.

(2) RE: expanded the section a bit and added GPR images to Figure 9b

(3) Changes: Major components of the trench wall are identified in individual GPR images. Their three-dimensional extension information is assembled by interpolating between multiple overlaying GPR images. Hence, information on continuation into depth as well as the varying thicknesses of individual layers is gathered. For instance, the colluvial wedge has only a minor variation in its thickness to 2 m penetration depth. The estimated average height for this unit is 0.6 m. This correlates to palaeoevent magnitudes of M6.5 (Reiss et al., 2003) which is comparable to previous ruptures (Kokkalas et al., 2007). Adjacent units that differ by huge grain size contrasts, like sand and silt next to gravel units, are easy to recognise. Coarse components produce chaotic reflections, while fine grained units of homogenous material appear with even and quasi-parallel reflections. Thus, the very fine grained silty clay parts produce fewer reflections than those of pure sand. The unit of debris-element association contains poorly sorted coarse-sized gravels that are expressed by wavy reflection pattern that do not appear in the hanging-wall in the South.

60) **References:** However, the outcome is highly dependent on the ability of the trench logger to define mappable units and the influence of sunlight
(1) Comment: Yes, but the logger has more than one day to see the wall in different light and humidity conditions…this is an advantage. However all the approaches and techniques applied are dependent to operators' quality and experience

(2) RE: but these operators do not have to be necessarily the same person. Now referring to visual appearance of components to derive individual layers

(3) Changes: However, the outcome is highly dependent on the ability of the trench logger to define mappable units and the influence of sunlight since only visual appearance is used to make decisions on individual layer distinction.

61) **References:** This process can be enhanced using the outcome of a numerically and a multispectral view of the palaeoseismic exposure, which allows quantitative information to be assigned to mapped units within the trench wall.
(1) Comment: specify which are the quantitative info you obtain (xxxx, xxx…)

(2) RE: done

(3) Changes: This process can be enhanced using the outcome of a numerically and a multispectral view of the palaeoseismic exposure, which allows quantitative information (reflectivity of electromagnetic waves at different spectra at certain materials) to be assigned to mapped units within the trench wall.

62) **References**: Colour, matrix specifications, geometrical alignments and soil formation features influence the t-LiDAR backscatter signal.
(1) Comment: delete “specifications”

(2) RE: done and rephrased

(3) Changes: Colour, matrix, surface roughness and orientation, and varying water content influence the t-LiDAR backscatter signal.

63) **References:** This method allows more accurate calculations of geometric layer thicknesses to be made, which are needed to correlate the amount of vertical offset caused by a specific rupturing event (e.g. Reiss et al., 2003)
(1) Comment: I do not understand. You mean: the method allows to go deeper in the wall and then to calculate vertical throw, geometries differently not visible.

(2) RE: basically. Rephrased

(3) Changes: This method allows more accurate calculations of mean geometric layer thicknesses to be made, which are needed to correlate the amount of vertical offset caused by a specific surface rupturing event. Information on the average height of a colluvial wedge can be estimated from the in-depth data and then be used to estimate palaeomagnitudes (e.g. Reiss et al., 2003).

64) **References:** The presented workflow has basic requirements concerning computing capacities; the collected high-resolution data from conventional photo cameras, t-LiDAR scanning and GPR measurements engage substantial disk space and random access memory.
(1) Comment: Consider the cases when you cannot proceed with a detailed conventional log because… among the other reason: short time opening, hazardous walls to let people work inside the trench for a long time…. I would say that can also be complementary approaches.

(2) RE: thanks! Agree, done

(3) Changes: The presented workflow has basic requirements concerning computing capacities; the collected high-resolution data from conventional photo cameras, t-LiDAR scanning and GPR measurements engage substantial disk space and random access memory.

One major benefit from this workflow is the storage and future use of the raw data. The majority of paleoseismic trenches are designed to be closed after field investigations are completed. This means that not only is there no future access to these exposures, but the sedimentological environment of the excavated site is also destroyed. If a trench is left open after field investigations, the trench walls will get degraded and altered by weathering effects. t-LiDAR and GPR measurements provide and store information on the visual appearance of the trench and the reflection properties of different electromagnetic wavebands. The reflectance spectrum at each pixel of an image provides unbiased

compositional information. This saved data can always be used for future (re-)analyses. Another benefit is the ability to record trench data in hazardous exposures without extensive, time consuming and costly safety precautions. Also, as trenches are often only open for limited durations, the logger might not have enough time to accurately sketch and measure components, or he may rush to finish. In these cases, capturing and recording the outcrop in a multidimensional manner (x,y,z coordinates of each data point plus reflectance values of visual and near-infrared light and pseudo-3-D information within the hanging-wall) enables efficient productivity and forms a complementary approach.
(2) RE: Added section in conclusions concerning more benefits from this work.

(3) Changes: To extract such fault specific information is not only crucial for identification and mapping active faults but also depicts complementary input for seismic hazard assessment by extracting more accurate magnitudes of palaeoearthquakes (Papanikolaou et al., 2015). The use of t-LiDAR became a major tool to obtain such data. So far, this modern technology was used for fault mapping at regional to very scale coverage with up to millimetre resolution (e.g. Arrowsmith and Zielke, 2009; Begg and Mouslopoulou, 2010; Wilkinson et al., 2010; Bubeck et al., 2014; Wilkinson et al., 2014). Further, the visualisation of bare-earth topography in regional scale (Cunningham et al., 2006; Wiatr et al., 2013) as well as detection of roughness changes along fault scarps (Wiatr et al., 2015) are scopes of application. Here another approach of the use of t-LiDAR in palaeoseismology is presented. Recording and measuring the backscattered signal in the near-infrared band enables the visualisation of usually non-visible electromagnetic waves. The spectral response represents material specific properties and gives evidence for differing lithology along the exposure. For seismic hazard assessments, accurate and justified decisions on the interpretation of such data are needed. To further assist, high resolution GPR profiling visualises the associated sedimentary architecture within the hanging-wall and quantifies and qualifies event horizons to estimate palaeomagnitudes and slip rates on active normal faults (Reiss et al., 2003).

The presented workflow does not form an alternative to conventional trench logging since this approach only records complementary data. Information on detailed grain-size distribution along the exposure or the orientation of certain components is not addressed by the workflow. Even photomosaic methods cannot offer required pixel resolution. However, if logistics are difficult and/or trench wall are hazardous, a t-LiDAR scan and photographs can be applied from outside of the exposure and be used to quickly provide high resolution data. This forms an alternative data collection method when the opening time is short or when operators cannot stay safely in the trench. The provided data visualises features that are usually not visible, allows decisions on interpreting the seismic history of the fault to be justified, and the spectrum reflectance data provides unbiased measurements that can be (re-)processed any time after the trench has been backfilled.

65) **References:** This saved data can always be used for future (re-)analyses.
(1) Comment: this is true also for drawn log

(2) RE: the drawn log includes subjective perception of the logger

(3) Changes: none

66) **References:** Hence, (minor) differences in lithological description from expert to expert are expected, especially if one logger has access to no more than a photomosaic.

(1) Comment: Delete brackets

(2) RE: done

(3) Changes: Hence, minor differences in lithological description from expert to expert are expected, especially if one logger has access to no more than a photomosaic.

67) **References**: Hence, (minor) differences in lithological description from expert to expert are expected, especially if one logger has access to no more than a photomosaic.

(1) Comment: However, the major goal for a palaeoseismologists logging a trench is not only the lithology and its precise description of the tectonic relation between units, of the displacement events and horizon.

(2) RE: agree! But first horizons have to be identified before they can be correlated to each other. Identification and on physical data founded interpretation is the aim of this manuscript

(3) Changes: none

68) References: Reconstructing the paleoseismic history of both trench exposures is not an integral part of this paper, but this research has shown that recognizing individual event layers can be improved using multispectral viewing and 3-D visualization on GPR images.

(1) Comment: Change “shown that recognising” to “the target to show how”; “individual event layers” -> what are they: individual event layers? Individual event horizons?

(2) RE: rephrased.

(3) Changes: Reconstructing the paleoseismological history of both trench exposures is not an integral part of this paper. However, the objective of improving individual event horizon recognition using multispectral viewing and 3-D visualisation of GPR images was successfully undertaken. This method can therefore contribute to the accuracy of seismic hazard assessment.

69) **References:** This method can therefore contribute to the accuracy of seismic hazard assessment

(1) Comment: delete sentence; too far from the hazard evaluation

(2) RE: Seismic hazard assessment need justified input data such as palaeomagnitudes estimated from coseismic offset.

(3) Changes: none

70) **References**: Bull, W. B.: Tectonic Geomorphology of Mountains: a New Approach to Paleoseismology, Blackwell Pub., Malden, MA, 316 pp., 2007.

(1) Comment: not cited in text

(2) RE: deleted

71) **References:** Carcaillet, J., Manighetti, I., Chauvel, C., Schlagenhauf, A., and Nicole, J.-M.: Identifying past earthquakes on an active normal fault (Magnola, Italy) from the chemical analysis of its exhumed carbonate fault plane, Earth Planet. Sc. Lett., 271, 145–158, 2008.

(1) Comment: not cited in text

(2) RE: deleted

72) **References:** Sabins, F. F.: Remote Sensing: Principles and Interpretation, 3rd edn., edited by: Freeman, W. H. and Co., W. H. Freeman Electronic Publishing Center/Andrew Kudlacik, New York, USA, 494 pp., 1997.

(1) Comment: in text year is 1996

(2) RE: changed in text

(3) Changes: These features are valuable clues for recognising and distinguishing certain materials (Sabins, 1997).

73) **References**: Table 1 caption: The composition is the result of allocation of both, photomosaic and HRDBSM in equal parts, to visualize certainties and their variation within given zones.

(1) Comment: delete “both”

(2) RE: done

(3) Changes: Median greyscale values of photomosaic, high-resolution digital backscatter model (HRDBSM) and 2-component composition per stratigraphic unit from the trench log. The composition is the result of allocation of photomosaic and HRDBSM in equal parts, to visualise certainties and their variation within given zones. Error is given by single standard deviation.

74) **References**: Figure 1

(1) Comment: a) make the figure more readable. Black crosses are confusing with lines, try different symbology (white square?). b) zoom to fault area. You may cut part of the image south and north. Leave Gulf partially visible. Change the cross with different symbol. C) with arrows indicate the scarp, and position of the faults and structures on the trench wall. D) Useless sketch for the target of the paper, you do not deal with active tectonic interpretation, relation with main fault plane… however the sketch leads to an error, it seems that no primary scarps typically form within quaternary sediments…. F) I cannot believe you do not have a better picture. With arrows indicate fault plane and more. Is your interpretation that feature on the wall is a secondary fault?

(2) RE: done. Changed picture in f). We think figure d) is not useless for this paper since it represents the general features and their appearance that palaeoseimologists search for within trenches. Solid Earth Journal does not deal with palaeoseismology and seismic hazard assessment exclusively. For this reason, we think the reader should be informed about coseismic features such as colluvial wedges, where they appear and how they are formed. The estimate of an average height of those is one of the major benefits in this paper.

(3) Changes: Guide to the study area. I) Map of Greece showing simplified large-scale tectonic structures (CG, Corinthian Gulf; CF, Cephalonia fault; NAF, North Anatolian fault; NAT, North Anatolian Trough; black lines with barbs show active thrusts; black lines with marks show active faults) (after Kokkalas and Koukouvelas, 2005; Papanikolaou and Royden, 2007). White boxes highlight study areas. II) Satellite image (Landsat 8, 2015) of the easternmost Gulf of Corinth. The Kaparelli fault is shown in red and the white box marks the position of the paleoseismological trench of Kokkalas et al. (2007). (III) View of the Kaparelli trench. IV) Satellite image (Landsat 8, 2015) of the study area at the Sfaka fault (red) in northeastern Crete; the white box shows the position of the road cut along strike. V) View of the Sfaka road cut. VI) Sketch of a typical postglacial normal fault showing bedrock juxtaposed against Quaternary sediments which contain structures caused by recurrent earthquakes (modified after Reicherter et al., 2003). Colluvial wedges form at the base of the fault scarp from eroded material originating at the top of the scarp.

75) **References:** figure 1 caption: The Kaparelli fault is shown in red and the cross marks the position of the palaeoseismological trench of Kokkalas et al. (2007).
(1) Comment: delete “palaeoseismological”

(2) RE: the trench was excavated for palaeoseismological reasons located at a fault

(3) Changes: none

76) **References:** figure 2
(1) Comment: is this model referred to the work done at the site of Sfaka? Specify.

(2) RE: clarified

(3) Changes: A simplified model of investigated parts on footwall, scarp, hanging-wall and trench at both exposures of this study; visualisation shows the conditions at the Sfaka road cut. Dashed lines show the different workspaces: I) red, Overall workspace for a long-mid range t-LiDAR scan to retrieve the geometric relation of investigated components; II) blue, area of operations (log, photo, t-LiDAR, GPR) on the trench wall; III) green, workspace for GPR measurements (black arrows) on top of the colluvium.

77) **References:** Figure 4; now Figure 5
(1) Comment: a) mark with different lines fractures and faults traces respect to lines for stratigraphic contacts. Insert legend for units. B) log with thinner lines would help to see better the photomosaic in the background. Same for c) D) E)

(2) RE: done

78) **References:** Figure 4 (now Figure 5) caption: (a) trench log produced in the field and corrected with (b) photomosaic in the office.
(1) Comment: insert “at the Sfaka fault site”

(2) RE: done

(3) Changes: Compilation of analytical input and outcome at the Sfaka fault road cut.

79) **References:** Figure 4 (now Figure 5) caption: (a) trench log produced in the field and corrected with (b) photomosaic in the office.
(1) Comment: “corrected” -> ?? what did you have to correct from the original field log, show in figure the improvements in the contacts if any.

(2) RE: Usually minor corrections also for the associated retrodeformation are done in the office after fieldwork and after couple of discussions.

(3) Changes: none

80) **References:** Figure 6 (now Figure 7) caption: The error bar is given by the standard deviation of each sample
(1) Comment: ”bar” -> ??

(2) RE: changed to “range”

(3) Changes: The error range is given by the standard deviation of each sample.

81) **References:** Figure 8 (now Figure 9)
(1) Comment: Mark with different lines fractures and faults traces respect to lines for stratigraphic contacts

(2) RE: done

82) **References:** Figure 8 (now Figure 9) caption: Results from the trenching site of Kokkalas et al. (2007)
(1) Comment: rephrase to: Results from the Kaparelli fault trench site from Kokkalas et al. (2007)

(2) RE: done

(3) Changes: Results from the Kaparelli fault trench site from Kokkalas et al. (2007).

Thanks to the Anonymous Referee #2 (18 December 2015) for her/his contribution and improving suggestions. A very good suggestion was to add a flowchart in the methodological section to introduce the reader quickly to the implemented procedure and the main sough parameters. This is realised by the newly added Figure 3. Another suggestion was to emphasis the scope of applicability of the employed methodology. Therefore, we added a section in the conclusions that should indicate the benefits for seismic hazard assessment but also on practicable advantages on sites with difficult circumstances (hazardous, opening times).

We think the methodological section should come after a brief introduction on the sites mentioned in this paper. First, due to the high seismic activity Greece is an attractive country to study palaeoseismology in all its facets. As we emphasised, developments of new innovative techniques should be calibrated in regions which are well known to a broad community. The high seismic activity in Greece allures palaeoseimsologists from all over the world to study sites like the Lastros-Sfaka-Graben on Crete or the recently ruptured Kaparelli fault in mainland Greece. A brief description on the sites (here Sfaka and Kaparelli) enables researcher to locate this study in their well-known environment. Second, parameters such as Azimuth and Dip of a fault and hanging-wall exposure are important notes for the presented technique, since for example the illumination changes with the position of the sun.

Another critique of the reviewer is the structure of the introduction. Since Solid Earth Journal does not address palaeoseismology exclusively, we think it is worth giving a thorough explanation on seismic hazard assessment, its lack of strength which is stemmed by the discipline of palaeoseismology, and conventionally used techniques. Therefore, we point at parameters used for seismic hazard assessment such as recurrence intervals that easily exceed the period of completeness of catalogues. Then we explain palaeoseismological archives and the ongoing development of precise techniques to access them. This is needed to extend the period of completeness and this is the motivation for ongoing developments. T-LiDAR and GPR have been used in palaeoseismological approaches and we present another way to use them. The updated version of the manuscript emphasizes this matter in the conclusions. However, in order to better communicate the benefits of our technique we refer to the flowchart (Figure 3) in the introduction, now.