

Replies to reviewers point-by-point and changes made

Reviewer 1

Dear Dr Tripanera,
thanks for the very useful suggestions, which have been all taken into account in the new version of the manuscript. The point-by-point replies to all suggestions are listed below.

Replies point-by-point:

The manuscript is overall well-written and data support the discussion. In general, it would be better if the paper is more focused on scientific outcomes than on the Structure From Motion Technique itself (the details about the processing set up can be moved in the supplementary material if the authors want to keep them).

Reply – We shortened this description, but according also to the other reviewers, we would prefer to maintain the description of the Structure from Motion technics in the main text, because it is an important piece of work of the methods used in this paper.

Minor comments

line 20: maybe "injectionS"?

Reply - Corrected

line 29: this conclusion is quite obvious nowadays. The SfM is quite well established. Maybe the authors should tell us here, the meaning of their data in the context of the volcano-tectonic structure of the volcano.

Reply – The conclusion about the efficacy of the SfM has been substituted by a conclusion about the meaning of our structural data in the volcano-tectonic context.

line 37: It could be useful to cite more paper about drone applications to structural geology in the introduction.

Reply – Some references have been added at lines 62-64.

lines 84-86: this can be deleted or integrated below within lines 87 to 94.

Reply – Done

Figure 1a: I suggest explaining in the caption that this map shows the geodynamic context where Etna Volcano locates.

Reply – Done

line 115-117: Is there any paper to cite here?

Reply – The reference (Tibaldi and Groppelli, 2002) has been added.

line 121: middle, upper and lower is not really intuitive in Fig. 2.

Reply – In reality we are referring to the central part of the rift and its northeastern part, so we corrected the text.

line 123: since you use elevation references, I suggest to show them in the related figure. This will help to identify better the locations on the map.

Reply – Our previous version of the text was not clear since we were not referring to elevations. We thus corrected the text according to reference to the central and northeastern parts of the rift.

Lines 186-189: Are you talking about Fig. 1c. If yes, please cite it.

Reply – Done

Line 203: see my comments about Fig. 2

Reply – We changed the text as explained above.

Lines 234-242: these lines are not needed.

Reply: deleted.

Did you use a terrain-following technique? How did you manage to keep the drone at the same altitude from the ground in this steep morphology?

Reply - We did not use a terrain-following technique. We have carefully planned every mission to avoid any possible collision and to follow the topography by direct piloting the drone, in order to obtain a ground resolution of about 2-3 cm.

Lines 263-264: not needed.

Reply – We deleted them accordingly.

Lines 267-269 and lines 273-284: I don't think this is relevant info for the paper's scope.

Reply – We deleted lines 267-269, and lines 273-284 were severely reduced down to a couple of lines.

Table 301: Maybe it is useful to specify that the time is hh:mm:ss.

Reply – Done

Line 332 - 333: do you mean 54 craters or merged vents or line segments in GIS? Please clarify this point. I do not see 54 eruptive fissure in Fig. 5.

Reply – We mean 54 line segments in GIS; we have checked and in Fig. 5 we have actually 54 yellow lines. Some of them are very close to each other, and in the figure they seem like a single one.

Line 337: Could be useful to indicate the name on the map.

Reply – Done

Line 339: the faults segments dipping NW are much shorter than the others. Is this just a local topography or not? From Fig. 5a these seem local structures.

Reply – We agree with the reviewer's comment and added the following sentence here: "Both structures are quite short and developed only locally".

Line 407 - 409: This has been seen commonly even elsewhere (e.g. Mount Laki in Iceland for the graben, or along the Harrat Lunayyir fault for a single fault). You may also cite some papers here.

Reply – References have been added at lines 419-420.

Line 442 -423: Using drone images, it is possible to look at tiny structures also. The risk could be that minor structures may result "more prominent" than bigger ones, just because they are more in number. Did you take into account the dimensions (or "importance") of the structures? How?

It could be useful to see if any correlation exists between the kinematic and the dimension (or "importance") of faults/fractures.

Reply – In the new version of the paper we added a new section presenting data on: length distribution of fissures and faults, relationships length-offset for both structure types, relation

fracture strike-offset, and relation fracture strike-length, adding also three new graphs. The various correlations have been discussed.

Line 479: You could also cite Trippanera et al., 2019 as an example of a drone survey over a linear longer fault in Harrat Lunayyir.

Reply – Done

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Reviewer 2

Dear Dr Rizzo,

thanks for the very useful suggestions, which have been all taken into account in the new version of the manuscript. The point-by-point replies to all suggestions are listed below.

Replies point-by-point:

General Comments:

The manuscript is well-written, and all inferences made by the authors are very well supported by data. In the manuscript, most of the “Methods” section is devoted to a detailed description of acquisition, processing and interpretation of drone images, as well as the authors have dedicated a separate discussion section to drone imagery. At the same time, the authors have only swiftly mentioned the “Lissage”, and “ATMO-STRESS” software used to calculate the stress/strain field in the studied area, in turn fundamental for the general tectonics’ interpretations made by the authors.

Reply: we have expanded the description of this method.

As it is written now, it is unclear to me if the authors’ goal is an original research paper, or rather methodological paper.

Reply: we now detailed in the Introduction that the paper has a double focus: on one side it describes new data useful for the scientific interpretation of the activity of the NE Rift, and on the other side it wants to present a methodology useful for similar studies.

I have also found that the paper falls a bit short in making use of all the dataset collected: for example, the collected data of fault/fracture sizes (i.e., length) and vertical offset collected for this work could have combined to further study fault development and growth in the Mount Etna area.

Reply: In the new version of the paper we added a new section presenting data on: length distribution of fissures and faults, relationships length-offset for both structure types, relation fracture strike-offset, and relation fracture strike-length, adding also three new graphs. The various correlations have been discussed.

I would suggest reducing the section dedicated to UAV acquisition and SfM processing, while expanding on the scientific results obtained using these data acquisition methods (please see the 'specific comments' for more detailed indications).

Reply: Done.

Specific comments:

Line 53: I don't want to impose any style; however, I think that "huge" has a colloquial connotation. I would suggest changing it with "... large amount..."

Reply: Done.

Lines 65 – 68: This sentence is a bit hard to read. Can you please clarify the statement? At line 66, please consider deleting "so high"; as for my previous comment, this is a colloquial expression.

Reply: We rephrased it and eliminated "high".

Line 89: As for my first comment, please consider using a different term instead of "huge". In addition, "grows" should be in the past tense.

Reply: Done.

Line 91: As you are describing a general process, please consider deleting "one of these" for the sentence in this line.

Reply: Done.

Line 92: Please consider substituting "focused" with mostly.

Reply: Done.

Figure 1. On the map in figure 1C it is hard to see the acronym, PF, for the Piano Provenzana fault.

Reply: we moved the acronym PF in a better position.

Line 115: Can you please add in the text a definition for “dry fracture”? if this term refers to simple dilatant fractures please be consistent with the terminology.

Reply: Done.

Lines 116 - 117: This sentence is not very clear to me. Can you please further explain the statement where you’re claiming that “part of ...” the fault and fractures in the central portion of NE rift indicates “pure extension or both right-lateral and left-lateral transtension”?

Reply: we rewritten this phrase.

Line 125: Please consider changing “Actually” with “Both”.

Reply: Done.

Lines 129 - 130: Only referencing to Guardo et al., 2020 does not fully explain the correspondence between the described structures in this paper and the “upper slip surface”. Please consider adding a concise description of “upper slip surface” by Guardo et al., 2020.

Reply: a phrase has been added on this issue.

Line 201: Can you please consider integrating this sentence with the section in Lines 186 to 189?

Reply: we now specified at line 201 that: “since both have an arcuate shape and seismicity recalls the bow shape of the faults and fracture distribution.”

Line 205: For brevity, can you please consider modifying the current “the position of which” with “whose position”?

Reply: Done.

Line 209: Please delete “here” before ‘identified as a cluster’.

Reply: Done.

Line 211: is $M > 2$ supposed to be ML as in Line 212?

Reply: yes, thanks, we corrected it.

Lines 234 – 242: I found this information not necessary in main body of the paper, and I would suggest moving this to an appendix section.

Reply: part of this section has been deleted, but details on the methodology to maintain a correct fixed distance between the drone flight and topography has been requested by another reviewer.

Lines 253 – 254: The expression “plenty of time” is rather colloquial, and I would suggest to either delete this sentence or expanding it giving more information regarding the amount of time saved using the described method and also, how the suggested method helps in reducing processing time.

REPLY - The use of natural targets allows us to speed up the GCPs collection significantly. This method allowed us to avoid the recovery of the targets after the survey enabling us to halve the overall surveying time. In this specific case, considering the extension of the monitored area (2.2 km²), the numbers of GCPs collected (34), and the terrain’s roughness, we saved one day (6/8 hours) of fieldwork. We modified the sentence in the text as follows: “We targeted 34 natural targets, as already successfully performed by Bonali et al. (2020), to speed up the GCPs collection avoiding the deployment and recovery of artificial targets. This method allowed us to save one day of fieldwork.”

Lines 263 – 264: I would suggest deleting the part of the sentence after the reference to the SfM processing software.

Reply: Done.

Lines 267 – 269: I feel that this information can be moved to an appendix section.

Reply: We deleted it.

Lines 308 – 311: Can you please give more information regarding the choice of the 20 cm threshold for classifying features as either normal fault or extension fractures?

Reply: Such threshold value is based on our field experience and plenty of observation focused on studying extension fractures and normal faults worldwide, from South America to Iceland.

Line 316: Please consider using a more specific terminology, instead of a generic and colloquial term as “plenty”. In addition, can you please report here how many structural data have you collected?

Reply: we substituted the word “plenty” with the exact number of data collected at faults and those collected at fractures.

Line 332 – 333: Can you please double check that the reported number of 54 fissure is correct? As, from the map in Figure 5, I could not count 54 fissures.

Reply: we have checked and in Fig. 5 we have actually 54 yellow lines. Some of them are very close to each other, and in the figure they seem like a single one.

Lines 339 – 341: Can you please make any further inferences about the differences between NW dipping segments the other segments? Why are the NW dipping segments short compared to others?

Reply: we added a section on this in the chapter “5.1. Rift geometry, structuring and kinematics”.

Lines 342 – 343: Since data quality and quality collected for this work, have you considered looking at the statistical distribution of fracture/fault length in the area to find a possible underlying statistical distribution able to describe the general behaviour of faulting in the area? In addition, it would be very interesting how this attribute (i.e., length) scales with vertical offset (throw). This type of analysis could potentially add further information on the kinematics of faulting in the studied area: please see Ranalli, 1977 and/or Gudmundsson et al., 2013 (both on Tectonophysics) for more details on length-throw relationships. Particularly relevant is the work of Gudmundsson et al., 2013 as they show data from Mt. Etna.

Reply – In the new version of the paper we added a new section presenting data on: length distribution of fissures and faults, relationships length-offset for both structure types, relation fracture strike-offset, and relation fracture strike-length, adding also three new graphs. The various correlations have been discussed. For the length/displacement ratios values, we compared our values with those by Gudmundsson et al. (2013) in the Discussion section.

Similarly, have you considered mapping fault/fracture density distribution? This can help in visualising where most of the ground deformation has accumulated.

REPLY – We have considered this kind of representation, but we prefer to make this kind of analyses afterwards, when the entire NE rift will be surveyed with drones in order to work on a complete, homogeneous and larger dataset of fractures.

Line 364: Please consider inverting the position of “We” and “thus” so to read “Thus, we...”

Reply: Done.

Line 372: Please consider substituting “represent the” with ‘show’.

Reply: Done.

Line 397: For brevity and readability, please consider modifying “... characterized by the dominance of...” with “dominated by”.

Reply: Done.

Lines 424 – 425: Can you please briefly describe the Lissage and ATMO-Stress softwares?

Reply: done, by adding the following text: Lissage is a C-based software designed to reconstruct paleostress trajectories in a given area (Lee and Angelier, 1994), using as input data multiple local stress determinations, including P and T axes derived from seismological data, the direction of principal stress axes from stress inversion and any other data that describe the azimuth of $\sigma_{HMax/Min}$. Such software can be used to reconstruct stress trajectories both using local field data and regional paleostress database (e.g. Hu et al., 1996; Munoz-Martín et al., 1998; Maestro et al., 2007; Bonali et al., 2019). ATMO-Stress software is the online version of such software.

Line 447: Please consider modifying “much more data”, with “wider dataset”.

Reply: Done.

Lines 467 – 468: Please consider modifying “for massive high”, with “to increase”.

Reply: Done.

Line: 478: Please consider modifying the sentence in point ii as: “the proposed approach reduces work-time compared to...”. The second part of the sentence at point ii (after the comma) is not clear, can you please rephrase it?

Reply: Done.