Interactive comment on “Modeling ground deformation associated with the destructive earthquakes occurring on Mt. Etna’s southeastern flank in 1984” by Flavio Cannavò et al.

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Replies to Comments from Maurizio Bonafede – Department of Physics and Astronomy, University of Bologna, Italy

1) Several earthquakes struck the E flank of Mt Etna between 1980 and October 1984 (only one is mentioned in June 19th, 1984 but it is not accounted for); these may add transient components unresolved in the geodetic data between 1980 and 1984). Furthermore, as said already, deformation in a volcanic environment cannot be assumed as a steady state process, being related to episodic inflation/deflation episodes. For this reason, the straight dashed lines shown in figure 4 are meaningless.

R: In order to answer the raised comment, we have added the following table that reports the parameters of 1980-1984 recorded earthquakes. Their locations have been also reported in the new figure 2B; the colored circles report the events close to the FF and STF and represent the most energetic events of the 1980-1984 periods.

Table 1. List of earthquakes recorded between May 1980 and October 1984 occurred in the investigated area (from Azzaro et al., 2000)

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Longitude</th>
<th>Latitude</th>
<th>EMS</th>
<th>Md</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/09/1980</td>
<td>0.104167</td>
<td>15.079</td>
<td>37.605</td>
<td>VI</td>
<td>2.9</td>
</tr>
<tr>
<td>26/11/1980</td>
<td>0.627778</td>
<td>15.118</td>
<td>37.723</td>
<td>VI</td>
<td>3.1</td>
</tr>
<tr>
<td>30/04/1981</td>
<td>0.522222</td>
<td>15.198</td>
<td>37.66</td>
<td>VI-VII</td>
<td>3.5</td>
</tr>
<tr>
<td>13/09/1981</td>
<td>0.20694</td>
<td>15.161</td>
<td>37.647</td>
<td>VI-VII</td>
<td>3.3</td>
</tr>
<tr>
<td>06/07/1982</td>
<td>0.609028</td>
<td>15.104</td>
<td>37.698</td>
<td>VI-VII</td>
<td>3.8</td>
</tr>
<tr>
<td>20/07/1983</td>
<td>0.91875</td>
<td>15.096</td>
<td>37.603</td>
<td>VII</td>
<td>4.1</td>
</tr>
<tr>
<td>19/06/1984</td>
<td>0.638194</td>
<td>15.131</td>
<td>37.636</td>
<td>VII</td>
<td>3.4</td>
</tr>
<tr>
<td>19/10/1984</td>
<td>0.738194</td>
<td>15.103</td>
<td>37.694</td>
<td>VII</td>
<td>4.2</td>
</tr>
<tr>
<td>25/10/1984</td>
<td>0.049306</td>
<td>15.095</td>
<td>37.66</td>
<td>VIII</td>
<td>3.9</td>
</tr>
</tbody>
</table>

We also agree with the reviewer comment about the assumption of linear trend and we have redrawn figure 4 removing the unrealistic dashed lines; moreover we have re-inverted the data without consider the trends, as required by the reviewer in a following comment.

2) The formula at line 192 is wrong (hopefully it is only a misprint, otherwise the inversion procedure should be re-executed): the last term should read e_12 sin2d (not e_12 sin^2 d).

R: We thank the reviewer for noticing this typo. We have corrected the formula

3) It must be stated clearly that the deformation computed in this way is the “equivalent”
uniform deformation (as reported in figure 2. C) providing the same distance variations as the real non-uniform deformation, concentrated on the faults R: This comment is appropriate; we have included the suggested clarification in the 4.1 EDM Data paragraph. 4) Why are data at benchmarks 4 and 9 not taken into account? The number of free parameters (10) is so close to the number of independent data (13) that it is difficult to assess the reliability of the inversion.

R: We don’t take in account data at benchmarks 4 and 9 in order to exclude the MOF structure from inversion to reduce the number of free parameters. We are aware that the number of free parameters is close to the number of independent data, however we have now performed a goodness-of-fit test ($\chi^2$ test) that assesses the inversion reliability for the given data.

5) The more so, since data were arbitrarily (if I understand correctly, according to statement A above) corrected assuming a steady-state creep (dashed lines in figure 4) which is not supported by real data. Furthermore, some fault parameters (fault depth, length, dip) are fixed a priori. The data clearly show post-seismic creep and a major creep event is mentioned before the earthquakes (page 6). What would be the result of the inversion if the real data (1984 minus 1980) were considered?

R: In order to overcome the correct issue raised by the reviewer we inverted the real data (1984 minus 1980). New results are reported in the following table and although slightly different form the previous ones they lead to similar considerations reported in the old manuscript. However in light of the new results we have reshaped the manuscript and made the new calculations for moments comparison and sensitivity parameters.

<table>
<thead>
<tr>
<th>Minor points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. line 44: better write &quot;... along the Timpe Fault System&quot; instead of &quot;... along the Fiandaca fault&quot;. <strong>Ok we have changed it</strong></td>
</tr>
<tr>
<td>2. Lines 83-84: the previously unpublished data ... have been reviewed in the wake of new knowledge acquired in the last two decades (explain: what new knowledge? Is it the fault parameters mentioned at line 206?), enabling insights into Etna's eastern flank ...</td>
</tr>
<tr>
<td><strong>Yes, we have added a paragraph explaining the knowledge acquired about the fault parameters and adding relevant references.</strong></td>
</tr>
<tr>
<td>3. The magnitude of the seismic events should be always stated when they are first mentioned. <strong>Yes, we have added the magnitude to the cited seismic events.</strong></td>
</tr>
<tr>
<td>4. line 297: I do not get the mentioned Mo values employing the magnitudes $m=4.2$ and $m=3.9$ mentioned in the text. Furthermore, these are duration magnitudes, not Richter magnitudes ML. In any case, it is clear that most of the fault displacement is aseismic.</td>
</tr>
</tbody>
</table>
These comments are appropriate. We have revised calculations considering the local magnitude and we have rewritten the sentences as following:

An estimate of the seismic moment (Mo) release associated with the seismic events was obtained using the relation (Giampiccolo et al., 2007) for Etna earthquakes:

\[
\log(\text{Mo}) = (17.60 \pm 0.37) + (1.12 \pm 0.10)\times \text{ML}
\]

where ML is the local magnitude

Duration magnitude (MD) of 19 June and 25 October 1984 earthquakes were estimated in 3.4 and 3.9 (Table 1); we converted MD in local magnitude (obtaining 3.62 and 4.20 respectively) by using the Tuvè et al., (2015) relation:

\[
\text{ML} = 1.164 (\pm 0.011) \times \text{MD} - 0.337 (\pm 0.020)
\]

Finally we obtained that Mo cannot be greater than \(1.2 \times 10^{21}\) dyne-cm for the 25 October 1984 earthquake and \(2.1 \times 10^{22}\) dyne-cm for that on 19 June 1984.

We have corrected in VII at page 6.

6. explain acronym TDF at line 323; I cannot find it elsewhere; It’s a misprint.

We have changed it in STF

7. the acronym MF is employed for both the Messina-Fiumefreddo line and for Moscarello fault: consider revising.

We thank the reviewer for revealing this ambiguity. We have changed in MOF the acronym of Moscarello fault

8. Figure 2: consider reporting in the caption the acronyms of the faults. Eliminate topographic level lines from panel B. Write “instrumental epicenter” (instead of “analytic location”) and “macroseismic epicenter” otherwise (if I understand correctly).

We have modified figure 2 considering these suggestions.

9. Figure 3 is unnecessary: consider deleting, leaving the web link in the text.

We have removed figure 3

References


Fig. 1.

C7

Fig. 2.

C8