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Natural Hazards and Earth System Sciences Discussions

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.

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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)

	Date	Time	Longitude	Latitude	EMS	Md
1	16/09/1980	0.104167	15.079	37.605	VI	2.9
2	26/11/1980	0.627778	15.118	37.723	VI	3.1
3	30/04/1981	0.522222	15.198	37.66	VI	3.5
4	13/09/1981	0.200694	15.161	37.647	VI-VII	3.3
5	06/07/1982	0.609028	15.104	37.698	VI-VII	3.8
6	20/07/1983	0.91875	15.096	37.603	VII	4.1
7	19/06/1984	0.638194	15.131	37.636	VII	3.4
8	19/10/1984	0.738194	15.103	37.694	VII	4.2
9	25/10/1984	0.049306	15.095	37.66	VIII	3.9

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.

	Fault 1 (FF)		Fault 2 (STF)	
X (m, center top)	509700	Fixed	512423	fixed
Y (m, center top)	4166660	fixed	4168595	fixed
Depth (m, top)	0	fixed	0	fixed
Azimuth (°)	140	fixed	142	fixed
Dip (°)	70 ± 0.0	70 - 89.9	70 ± 0.0	70 - 89.9
Semi-Length (m)	3500 ± 1200	2000 - 3500	2000 ± 0.0	2000 - 4000
Width (m)	3000 ± 0	1000 - 3000	2572 ± 1100	1000 - 3000
Strike-s (cm)	20.4 ± 1.6.	0 - 100 (dextral)	0.0 ± 0.0	0 - 100 (dextral)
Dip Slip (cm)	-12.7 ± 2.6	-100 - 0 (normal)	-10.4 ± 5.7	-100 - 0 (normal)

Minor points

1. line 44: better write "… along the Timpe Fault System" instead of "… along the Fiandaca fault". **Ok we have changed it**

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 al line 206?), enabling insights into Etna's eastern flank …

Yes, we have added a paragraph explaining the knowledge acquired about the fault parameters and adding relevant references.

3. The magnitude of the seismic events should be always stated when they are first mentioned.

Yes, we have added the magnitude to the cited seismic events.

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.

These comments are appropriates. 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 Etnean earthquakes:

Log(Mo) = (17.60 ± 0.37) + (1.12 ± 0.10)*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:

ML = 1.164 (±0.011) *MD – 0.337 (±0.020)

Finally we obtained that Mo cannot be greater than = $1.2 * 10^{23}$ **dyne-cm for the 25 October 1984 earthquake and** $2.4 * 10^{22}$ **dyne-cm for that on 19 June 1984.**

5. line 308: EMS VII is written here for the June '84 event while it is rated VIII at page 6.

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

- Azzaro, R., M.S. Barbano, B. Antichi and R. Rigano 2000. Macroseismic catalogue of Mt. Etna earthquakes from 1832 to 1998, Acta Vulcanologica, 12 (1-2), 3-36.
- Giampiccolo, E., S. D’Amico, D. Patanè, and S. Gresta, 2007, Attenuation and source parameters of shallow microearthquakes at Mt. Etna Volcano, Italy, Bull. Seismol. Soc. Am., 97, 184–197, doi:10.1785/0120050252.
- Tuvè T., D’Amico, S., Giampiccolo E. (2015). A new MD-ML relationship for Mt. Etna earthquakes (Italy). Annals of Geophysics, 58, 6, doi:10.4401/ag-6830S0657.

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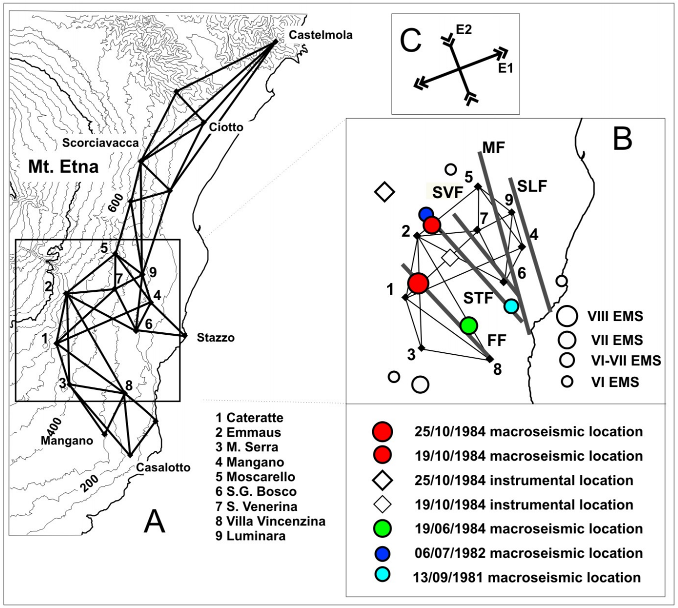
Castelmola
Ciotto
Scorciavacca
Mt. Etna
600
400
200
Stazzo
Mangano
Casalotto
A
1 Cateratte
2 Emmaus
3 M. Serra
4 Mangano
5 Moscarello
6 S.G. Bosco
7 S. Venerina
8 Villa Vincenzina
9 Luminara
C
E2
E1
B
MF
SLF
SVF
STF
FF
VIII EMS
VII EMS
VI-VII EMS
VI EMS
25/10/1984 macroseismic location
19/10/1984 macroseismic location
25/10/1984 instrumental location
19/10/1984 instrumental location
19/06/1984 macroseismic location
06/07/1982 macroseismic location
13/09/1981 macroseismic location

Fig. 1.

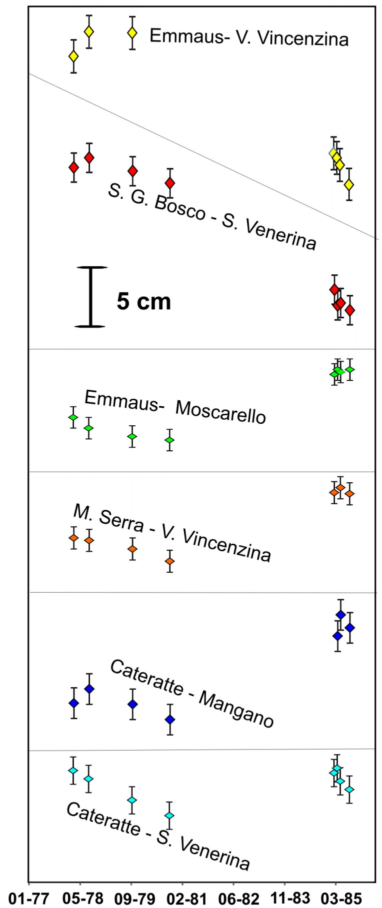

Fig. 2.

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