

Supplementary materials for "The imbricated foreshock
and aftershock activities of the Balsorano (Italy) M_w
4.4 normal fault earthquake and implications for
earthquake initiation"

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Additional Supporting Information

1. Seismic catalog for the seismic sequence associated to the 2019 (M_W 4.4) Balsorano
earthquake

Table S1: General information of the 2019 M_w 4.4 Balsorano earthquake. All this information is taken from the INGV's online catalog.

| Mainshock data | |
|--------------------------|----------------------|
| Magnitude | M_w 4.4 |
| Lat (°) / Lon (°) | 13.61 / 41.78 |
| Depth (km) | 14.0 |
| NP1: Strike / Dip / Rake | 299 / 58 / -120 |
| NP2: Strike / Dip / Rake | 166 / 42 / -51 |
| Reported activity | \approx 150 events |
| # Stations < 100 km | 6 |

Table S2: Receiver locations. The distances reported are measured with respect to the mainshock epicentral location (taken from the INGV).

| Receiver | Lon. (°) | Lat. (°) | Dist. (km) |
|----------|----------|----------|------------|
| CERT | 41.94903 | 12.98176 | 72.297 |
| GUAR | 41.79450 | 13.31229 | 33.093 |
| INTR | 42.01154 | 13.90460 | 41.820 |
| POFI | 41.71743 | 13.71202 | 13.112 |
| PTQR | 42.02193 | 13.40057 | 35.780 |
| VVLD | 41.86965 | 13.62324 | 10.411 |

Table S3: Velocity model used for the relocation process. A V_P/V_S ratio equal to 1.73 is assumed. Slightly modified version from the model proposed by [Bagh et al. \(2007\)](#)

| Depth of top of layer (km) | P-wave velocity (km/s) |
|----------------------------|------------------------|
| 0.0 | 5.360 |
| 3.0 | 5.360 |
| 6.0 | 5.800 |
| 14.0 | 6.650 |
| 25.0 | 6.900 |

Table S4: Reference templates and phase traveltimes at the six available stations (estimated from INGV data).

| # | Origin time | P _{tt} CERT | P _{tt} GUAR | P _{tt} INTR | P _{tt} POFI | P _{tt} PTQR | P _{tt} VVLD | S _{tt} CERT | S _{tt} GUAR | S _{tt} INTR | S _{tt} POFI | S _{tt} PTQR | S _{tt} VVLD |
|----|---------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| 1 | 11/07/2019 00:37:18 | 9.63 | 5.51 | 6.9 | 3.46 | 6.37 | 3.48 | 17.09 | 9.11 | 11.95 | 5.82 | 11.28 | 5.71 |
| 2 | 11/07/2019 03:21:00 | 9.72 | 5.38 | 6.92 | 3.57 | 6.62 | 3.57 | 17.15 | 9.4 | 12.12 | 5.87 | 11.36 | 5.82 |
| 3 | 11/07/2019 10:37:05 | 9.69 | 5.39 | 6.93 | 3.7 | 6.52 | 3.54 | 17.15 | 9.15 | 12.05 | 6.00 | 11.38 | 5.82 |
| 4 | 11/07/2019 17:35:21 | 9.7 | 5.38 | 7.01 | 3.54 | 6.48 | 3.59 | 17.22 | 9.02 | 12.12 | 5.89 | 11.52 | 5.92 |
| 5 | 11/07/2019 17:47:53 | 9.77 | 5.4 | 6.93 | 3.32 | 6.53 | 3.55 | 17.29 | 9.12 | 12.07 | 5.45 | 11.42 | 5.68 |
| 6 | 11/07/2019 18:04:55 | 9.74 | 5.35 | 6.9 | 3.39 | 6.54 | 3.49 | 17.21 | 9.12 | 11.86 | 5.68 | 11.45 | 5.72 |
| 7 | 11/07/2019 23:19:50 | 9.62 | 5.29 | 7.09 | 3.54 | 6.44 | 3.55 | 16.89 | 8.99 | 12.19 | 6.00 | 11.20 | 5.79 |
| 8 | 11/08/2019 03:08:06 | 9.06 | 5.14 | 7.06 | 3.56 | 6.45 | 3.42 | 16.85 | 8.76 | 12.21 | 5.85 | 11.08 | 5.58 |
| 9 | 11/08/2019 08:10:56 | 9.93 | 5.56 | 6.75 | 3.17 | 6.72 | 3.37 | 17.33 | 9.23 | 11.69 | 5.39 | 11.58 | 5.48 |
| 10 | 11/08/2019 08:16:10 | 9.84 | 5.44 | 6.88 | 3.44 | 6.51 | 3.54 | 17.40 | 9.49 | 12.00 | 5.76 | 11.53 | 5.71 |
| 11 | 11/08/2019 10:43:24 | 9.50 | 5.15 | 6.89 | 3.32 | 6.29 | 3.38 | 17.00 | 8.91 | 12.08 | 5.78 | 11.19 | 5.61 |
| 12 | 11/08/2019 12:00:43 | 9.75 | 5.44 | 7.04 | 3.34 | 6.61 | 3.55 | 17.29 | 9.13 | 12.44 | 5.70 | 11.35 | 5.77 |
| 13 | 11/08/2019 13:07:07 | 9.41 | 5.08 | 6.86 | 3.32 | 6.22 | 3.34 | 16.88 | 8.77 | 12.31 | 5.64 | 11.04 | 5.45 |
| 14 | 11/08/2019 14:22:12 | 9.52 | 5.14 | 6.92 | 3.39 | 6.48 | 3.38 | 16.99 | 8.79 | 12.39 | 5.69 | 11.19 | 5.56 |
| 15 | 11/09/2019 10:57:09 | 9.72 | 5.35 | 6.87 | 3.21 | 6.54 | 3.46 | 17.20 | 9.03 | 11.98 | 5.52 | 11.33 | 5.70 |
| 16 | 11/09/2019 22:14:15 | 9.59 | 5.27 | 6.66 | 3.24 | 6.43 | 3.14 | 17.07 | 9.04 | 11.61 | 5.33 | 10.91 | 5.04 |
| 17 | 11/09/2019 23:09:52 | 9.79 | 5.49 | 6.90 | 3.62 | 6.61 | 3.59 | 17.48 | 9.12 | 11.88 | 5.69 | 11.66 | 5.91 |
| 18 | 11/10/2019 03:31:36 | 9.55 | 5.15 | 6.58 | 3.51 | 6.37 | 3.42 | 16.82 | 8.68 | 12.21 | 5.79 | 11.07 | 5.55 |
| 19 | 11/10/2019 06:56:28 | 9.62 | 5.15 | 6.56 | 3.15 | 6.40 | 3.07 | 17.04 | 9.04 | 11.92 | 5.42 | 11.39 | 5.09 |
| 20 | 11/11/2019 01:43:21 | 9.59 | 5.31 | 6.90 | 3.44 | 6.42 | 3.53 | 18.00 | 9.27 | 12.05 | 5.25 | 11.44 | 5.76 |
| 21 | 11/11/2019 13:41:33 | 9.46 | 5.11 | 7.00 | 3.49 | 6.22 | 3.39 | 16.81 | 8.79 | 12.20 | 5.85 | 11.10 | 5.54 |
| 22 | 11/11/2019 16:04:53 | 9.39 | 5.05 | 6.95 | 3.43 | 6.25 | 3.34 | 17.07 | 8.70 | 12.27 | 5.75 | 11.08 | 5.52 |
| 23 | 11/11/2019 17:46:53 | 9.61 | 5.22 | 6.86 | 3.32 | 6.40 | 3.43 | 17.05 | 8.97 | 12.44 | 5.22 | 11.23 | 5.62 |

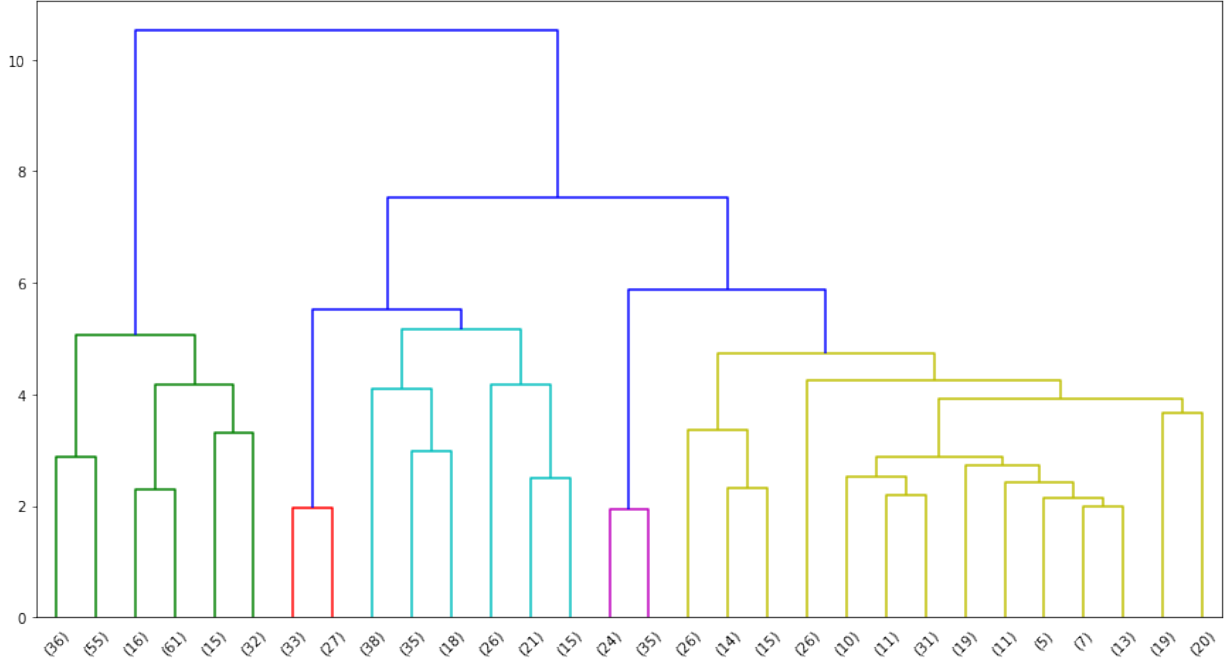


Figure S1: Dendrogram obtained from the waveform-based hierarchical clustering performed. The distance metric between two different waveforms (i and j) is estimated as $1-C_{ij}$. Ward's minimum variance linkage technique is used. The distance threshold to define the final number of cluster is set to 5.3 (the largest separation observed form dendrogram).

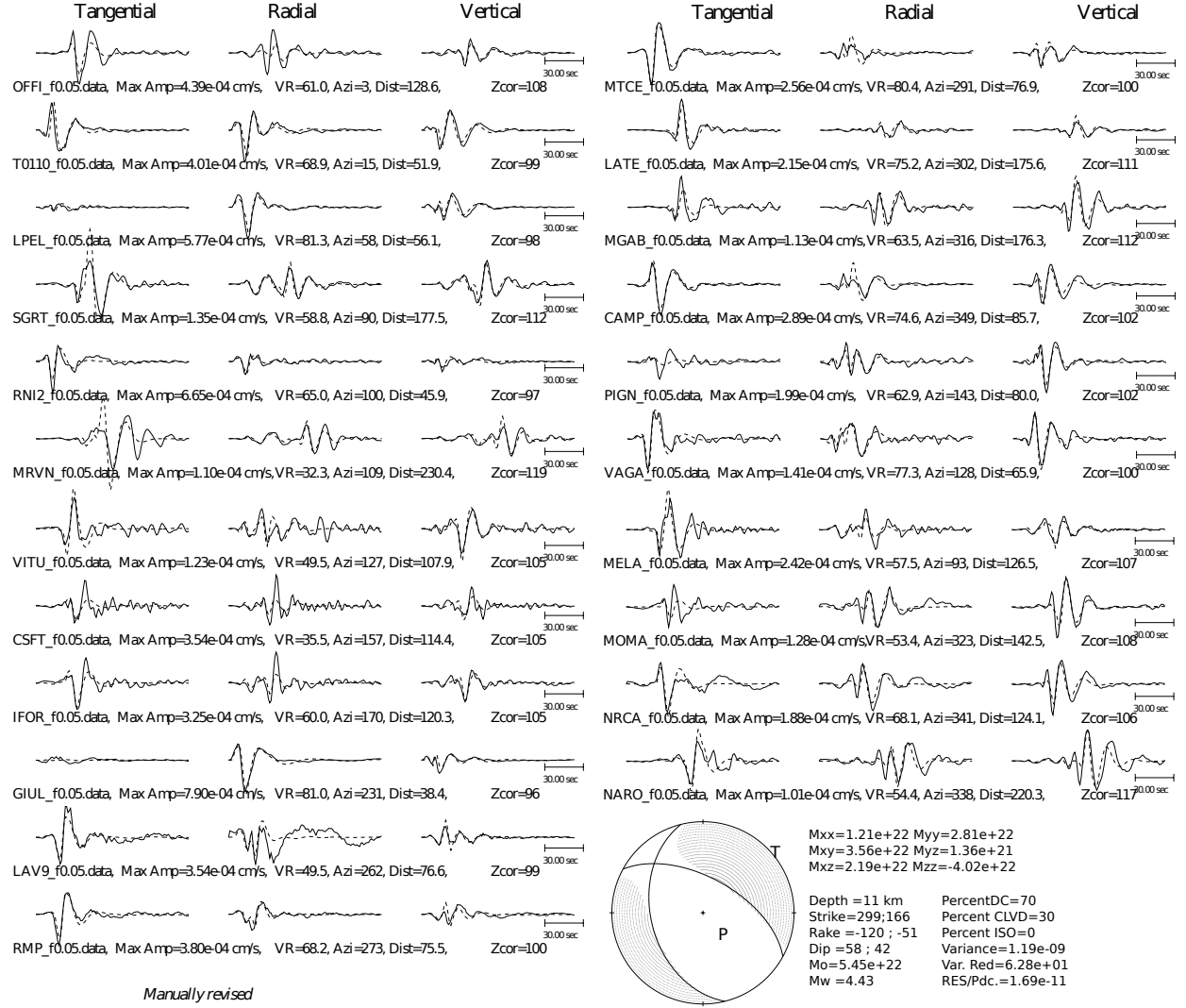


Figure S2: Estimated focal mechanism and comparison of observed (solid lines) and estimated synthetic seismograms (dashed lines) for the Mw 4.4 mainshock. The three components at 22 receiver locations are shown. This figure is a modified version from the original one provided by the INGV (http://webservices.ingv.it/webservices/ingv_ws_map/data/tdmt/15111/73711301_86_tdmt_reviewer_solution.pdf).

16 **References**

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