

Preliminary co-seismic displacements for the August 24, 2016 M_L6, Amatrice (central Italy) earthquake from the analysis of continuous GPS stations

INGV-CNT Working Group “GPS Geodesy (GPS data and data analysis center)”

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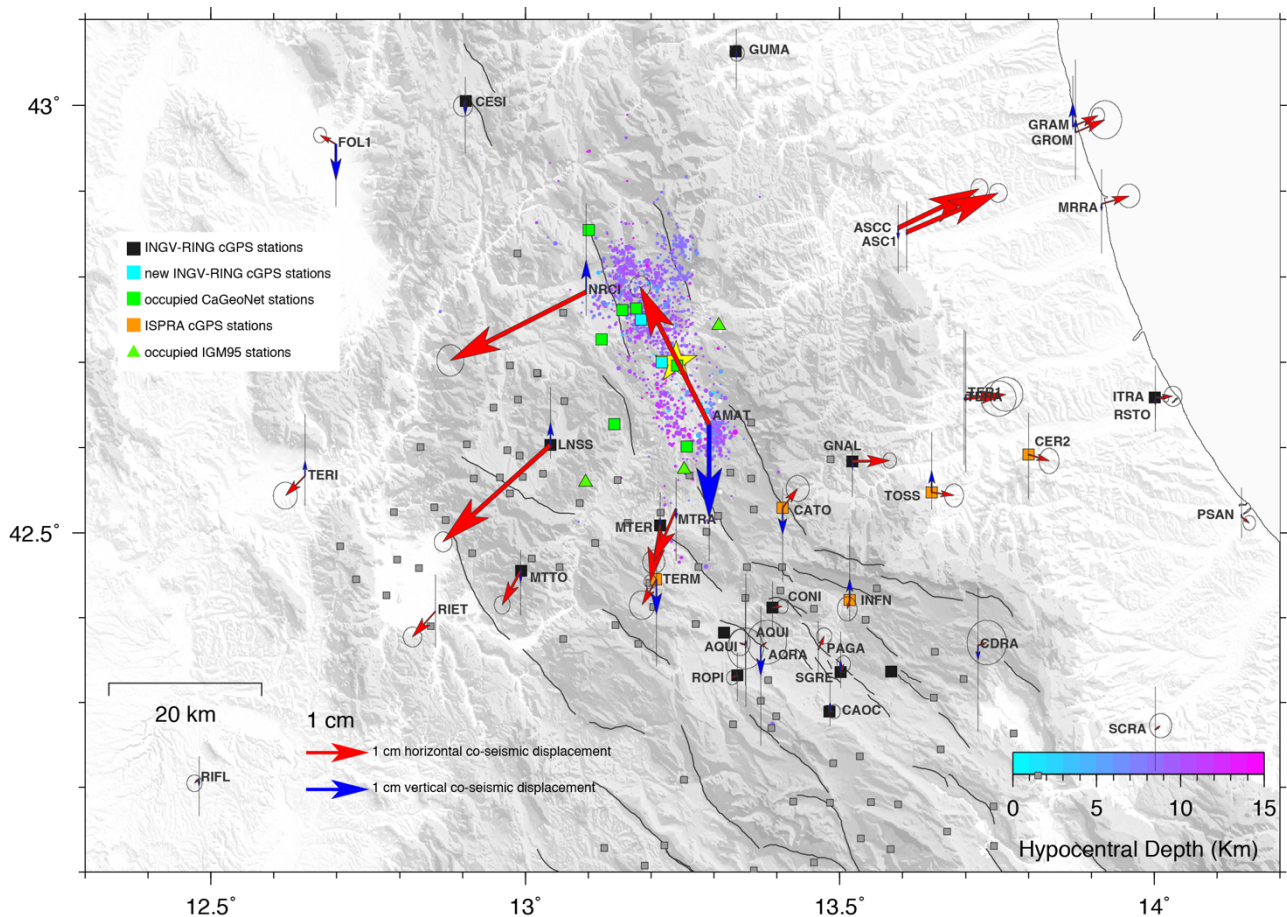
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On August 24, 2016, at 03:36 (local time) a ML 6.0 earthquake (M_w 6.0) struck the Central Apennines between the towns of Norcia and Amatrice. This earthquake occurred in a sector of the Apennines characterized by high geodetic strain-rates (e.g., D'Agostino 2014) and where several continuous GNSS networks are operating.

INGV routinely collect and analyze the raw data using different software and approaches. In particular, GPS data are analyzed by the INGV National Earthquake Center (CNT) using the GIPSY-OASIS, GAMIT/GLOBK and BERNESE software (e.g., Avallone et al., 2010). Following the procedures described in Devoti (2012), and adopted for the 2012 Emilia (northern Italy) sequence (Serpelloni et al., 2012), here we provide the co-seismic displacements field obtained from the analysis of pre- and post- August, 24 main-shock positions obtained from the analysis of continuous GPS stations, using three days (up to day of year 2016/239) after the main-shock to estimate the co-seismic offsets.

The final co-seismic displacement field can be considered as a “consensus” measurement and is the result of a comparison and validation process with repeated feedback between the three different analysis centers. The comparison is done with the intention of comparing the different results and reducing sources of error associated with individual processing strategies, to allow the final combination of the different displacement fields into a single “consensus solution”. The process assesses the robustness of each single GPS result, thus minimizing erroneous interpretations of individual solutions.



The figure shows the horizontal (red arrows) and vertical (blue arrows) consensus co-seismic displacements (with 68% confidence errors), together with the August, 24 M6 mainshock (yellow star) and aftershocks (colored as a function of depth) from <http://iside.rm.ingv.it>. The black squares show the position of the ING V-RING stations (<http://ring.gm.ingv.it>). The grey squares show the position of the CaGeoNet network (Anzidei et al. 2008; Galvani et al., 2012) stations, where the green squares indicate benchmarks that have been re-occupied a few hours after the August, 24 main-shock. The green triangles indicate the position of IGM95 benchmarks (<http://www.igmi.org/geodetica/>) that have been occupied by ISPRA (www.isprambiente.gov.it) after the main-shock. The orange squares indicate continuous GPS stations managed by ISPRA and the Civil Protection Department (DPC).

Other continuous GPS data have been obtained from the Regione Abruzzo GNSS network (<http://gnssnet.regione.abruzzo.it>), the Regione Lazio GNSS network (<http://gnss-regionelazio.dyndns.org>), the ItalPos GNSS network (<http://it.smartnet-eu.com>), the NetGeo GNSS network (<http://www.netgeo.it>), the Regione Umbria GNSS network (<http://www.umbriageo.regione.umbria.it>), the ASI-Geodaf network (<http://geodaf.mt.asi.it>) and the Euref network (<http://www.epncb.oma.be>).

The table reports the co-seismic displacements (in mm) estimated for cGPS station around the epicentral area (up to 100 km of distance). The table can be download as ASCII file on the ING V-RING web page (<http://ring.gm.ingv.it>). The first column indicate the cGPS station name (site ID); lon. Is the longitude (°E), lat is the latitude (°N), Hei is the station height (in meters), East, sigE, North, sigN, Up, sigUp are the east, north and vertical co-seismic displacements and uncertainties, in mm. The last column indicates the GNSS/GPS network.

SITE ID	lon °E	lat °N	Hei (m)	East (mm)	sigE (mm)	North (mm)	sigN (mm)	Up (mm)	sigUp (mm)	Network
ACQU	11.8648	42.7440	450.2	0.4890	1.2297	-0.9622	1.5464	3.7030	5.0753	LAZIO
ALRA	14.0344	41.7339	970.4	1.1850	3.0821	0.5892	3.8937	0.0185	13.1741	ABRUZZO
AMAT	13.2924	42.6265	1003.4	-11.0156	1.0904	21.9345	1.1709	-14.8495	4.4746	LAZIO
AQRA	13.3743	42.3659	747.8	0.9810	2.0726	0.7120	2.2975	-4.6170	7.3512	ABRUZZO
AQUI	13.3502	42.3683	713.5	-0.9295	1.1164	0.3170	1.3825	0.7924	4.8185	EUREF
ARCE	12.9494	43.5049	408.6	0.9250	1.7916	0.0390	2.0283	-2.8220	6.3585	ITALPOS
AREZ	11.8749	43.4637	328.8	-0.0282	1.4387	0.0993	1.8575	5.0929	6.2609	ITALPOS
ASC1	13.6061	42.8521	188.4	14.5814	0.9515	6.2451	0.9864	-0.6316	3.6641	NETGEO
ASCC	13.5930	42.8573	207.1	12.9191	0.8879	6.2370	1.0215	-1.8462	3.6052	ITALPOS
ATBU	12.5478	43.4760	1046.9	-1.8865	0.8355	-1.7721	1.0026	3.8501	3.6802	RING
ATFO	12.5671	43.3701	1021.0	0.9152	0.9508	-0.5591	1.1606	-1.9571	3.6420	RING
ATLO	12.4071	43.3151	653.0	1.3256	0.6950	1.1793	0.8914	1.6802	2.9401	RING
ATMI	12.2673	43.3339	573.6	-0.5443	0.7065	-0.3555	0.8975	5.6156	2.9438	RING
ATTE	12.3506	43.1998	993.1	-1.1729	0.5405	-1.2226	0.6298	3.9907	2.1791	RING
AVZZ	13.4456	42.0327	726.5	1.4210	1.9972	0.1490	2.2561	0.1070	7.3334	NETGEO
BLRA	13.5603	41.8104	420.0	-0.8811	3.6682	-0.3904	4.4576	0.8328	16.3871	ABRUZZO
CAFI	11.9662	43.3292	593.1	0.4196	1.4069	-1.8037	1.8555	-1.3756	7.1715	RING
CAM1	13.0708	43.1439	580.6	1.0020	0.8803	-0.2752	0.9159	-0.5665	3.4034	NETGEO
CAMU	11.9775	43.2589	313.8	-0.3986	0.7928	-1.2391	0.9989	-1.5089	3.5972	ITALPOS
CAOC	13.4844	42.2895	970.8	0.7080	0.6255	-0.0252	0.7382	1.4791	2.5668	RING
CATO	13.4091	42.5291	1386.0	2.3978	1.2143	3.0954	1.3590	-4.2582	4.9760	ISPRA
CDRA	13.7201	42.3675	1412.9	1.3820	2.0815	0.4440	2.3493	-2.3310	7.5864	ABRUZZO
CERT	12.9818	41.9491	765.9	0.6976	0.7927	-0.9382	0.8948	-0.5502	3.1772	RING
CESI	12.9046	43.0050	914.9	-0.3539	1.0091	-0.7539	1.0978	-2.2339	4.0177	RING
CIPV	12.0051	42.9522	566.6	-2.0977	1.3891	-2.1689	1.8349	-6.4210	7.2600	ITALPOS
CONI	13.3932	42.4117	1239.6	1.5292	0.6201	0.1836	0.7267	0.2581	2.5196	RING
CER2	13.8000	42.5917	618.2	3.2921	1.0528	-1.0159	1.3350	-0.1658	4.5167	DPC
CSSB	12.2454	43.2093	753.1	0.5250	0.8560	1.0928	1.0578	2.1284	3.4496	RING
CVTV	11.7973	42.0952	84.8	-0.8050	1.2221	-1.1672	1.5279	6.4947	5.0410	LAZIO
FIUM	12.2301	41.7714	65.4	0.4041	1.1816	0.1541	1.4920	0.6569	4.8209	LAZIO
FOL1	12.6988	42.9549	296.9	-2.5220	0.6748	1.4394	0.8070	-5.7198	2.8038	ITALPOS
FRES	14.6693	41.9735	405.2	-0.4572	0.8248	1.0826	1.0358	-4.0123	3.6132	RING
FRMO	13.7314	43.1684	260.5	2.1460	0.6263	2.1581	0.7512	-3.3793	2.6206	ITALPOS
FRRA	14.2922	42.4177	93.1	1.6532	1.1854	0.5040	1.2823	-0.8841	4.5674	ABRUZZO
GEOT	13.5111	43.5745	120.2	1.1550	2.3567	0.1830	2.7576	-4.7690	8.2847	NETGEO
GINE	13.3764	43.1206	385.7	2.0181	0.9591	3.4019	0.9997	-1.3762	3.6939	NETGEO
GNAL	13.5199	42.5837	1049.1	5.9601	0.7159	0.1391	0.8175	-1.2956	2.8290	RING
GRAM	13.8705	42.9755	64.9	4.0319	0.6820	1.7662	0.8060	3.7279	2.8190	ITALPOS
GROA	11.1093	42.7818	68.5	-0.8624	1.0247	-0.5536	1.3321	-0.7287	4.4535	ITALPOS
GROM	13.8749	42.9684	60.0	4.6880	1.7590	2.0160	2.0135	2.0240	6.3496	NETGEO
GUAR	13.3122	41.7944	719.3	0.3841	1.1085	0.6528	1.3344	7.4637	5.4356	RING
GUB2	12.5775	43.3510	545.2	2.5397	0.8893	0.5531	1.0290	-21.1909	3.9710	ITALPOS

GUMA	13.3352	43.0628	652.3	0.1346	0.7703	-0.2309	0.8639	-1.2140	3.1364	RING
INFN	13.5158	42.4208	1044.5	-0.3874	1.0314	-1.3907	1.2716	3.4154	4.4424	DPC
INGR	12.5148	41.8281	105.0	0.2889	0.7104	-0.6953	0.8795	0.9390	2.9209	RING
ITRA	14.0018	42.6585	106.3	2.8082	0.9553	0.2028	1.0558	-0.1217	3.4673	NETGEO
LNSS	13.0403	42.6029	1151.4	-17.1031	0.9388	-15.3757	1.0555	3.5472	3.7793	RING
LPEL	14.1832	42.0469	817.0	-0.0114	4.9865	-0.0610	4.3080	-3.2576	23.7445	RING
MACE	13.4509	43.2941	307.6	1.1285	0.7384	1.4613	0.9253	-0.3551	3.0605	ITALPOS
MAGL	13.5879	43.1383	310.6	2.3362	0.7789	4.3955	0.8252	-1.5030	3.0479	ITALPOS
MAR1	11.8680	42.0364	80.9	-0.6675	1.6669	-0.7275	2.1354	0.2973	6.7418	NETGEO
MCIN	11.4890	43.0583	613.4	-0.6809	1.4777	-0.5419	1.7870	6.4558	7.4073	ITALPOS
MGAB	12.1114	42.9130	533.1	0.5551	1.1673	0.1834	1.2398	-0.3554	4.5830	RING
MOC1	11.6039	42.3536	95.6	0.3283	1.2575	-0.6220	1.6306	2.0685	5.3225	LAZIO
MOIE	13.1235	43.5032	175.4	1.0560	1.8226	0.5580	2.0993	0.8780	6.6632	NETGEO
MORO	12.6191	42.0525	202.1	-0.8215	0.6420	-1.1584	0.7382	2.7035	2.5780	ITALPOS
MRRA	13.9160	42.8853	62.4	4.3916	1.1595	1.2501	1.2391	-1.2156	4.4218	ABRUZZO
MTER	13.2144	42.5088	1143.3	-1.5630	0.6407	-8.9677	0.7256	1.3275	2.5464	RING
MTRA	13.2400	42.5279	996.4	-3.5790	1.1637	-8.4185	1.2404	-1.6215	4.3798	ABRUZZO
MTTO	12.9927	42.4555	1738.6	-2.9531	0.8314	-5.4478	0.9575	-1.9349	3.4604	RING
MUR1	12.5247	43.2632	883.6	0.8098	0.8784	0.7742	1.0729	-0.2639	3.4450	RING
MVAL	12.4066	43.3821	638.9	0.0821	0.7556	-0.9969	0.9683	-2.7132	3.2504	RING
NRCI	13.0971	42.7825	657.3	-21.6327	1.4209	-10.9122	1.6509	5.1067	5.9161	ITALPOS
OCRA	13.0390	42.0495	878.8	0.7043	1.8507	-1.3149	2.1184	4.8243	6.8492	ABRUZZO
OLGI	12.3551	42.0547	208.4	-0.2300	1.1620	-0.6896	1.4894	0.2790	5.0612	ITALPOS
PAGA	13.4656	42.3623	717.9	0.9595	0.8111	2.1924	0.8472	0.0505	3.0045	NETGEO
PAGL	14.4981	42.1644	288.1	0.8322	0.7168	0.1620	0.9160	2.6548	3.1131	ITALPOS
PET1	14.8605	42.0083	281.2	1.5138	2.0273	0.0100	2.6027	3.1208	8.9371	ITALPOS
PIBI	12.4531	43.1279	259.5	-0.2494	0.8823	0.2252	1.0852	2.0006	3.7235	ITALPOS
PIET	12.4019	43.4507	746.0	-0.1324	1.2297	-1.0458	1.5644	1.8260	5.3804	RING
PITI	11.6731	42.6339	392.5	-1.5572	0.7077	0.8467	0.8959	-1.9268	3.0361	ITALPOS
POFI	13.7119	41.7174	851.0	-2.9229	1.8302	0.6520	2.3250	-1.0706	8.0481	RING
PSAN	14.1390	42.5188	62.7	1.2305	0.6502	-0.9842	0.7690	0.6097	2.6478	ITALPOS
PSTE	11.1201	42.4280	72.9	-0.1430	1.2688	0.5506	1.5132	0.2250	5.3636	ITALPOS
RDPI	12.7103	41.7604	817.2	0.1663	1.3932	-0.3510	1.7838	0.2025	6.2473	RING
REPI	12.0024	42.9521	576.3	-1.4641	2.3106	-1.3158	2.9923	-1.6876	9.3227	UMBRIA
RIET	12.8571	42.4076	457.7	-3.6604	0.9734	-4.0847	1.0557	0.0045	3.8406	ITALPOS
RIFL	12.4811	42.2100	313.1	-0.7226	0.7968	-0.6845	0.8839	-1.1511	3.1517	LAZIO
RMPO	12.7032	41.8111	450.2	-0.1044	1.1536	-0.2902	1.3711	1.2203	5.1609	RING
ROAN	12.4196	41.9037	155.2	0.0948	2.0087	0.2643	2.5947	3.5248	8.7923	ITALPOS
ROPI	13.3372	42.3320	992.4	-0.8220	0.6246	-0.3804	0.7341	-0.2690	2.5578	RING
ROUN	12.4937	41.8932	120.8	0.3780	1.2088	-0.2754	1.5093	2.2686	4.9706	LAZIO
RSTO	14.0015	42.6584	103.1	1.6875	0.3230	-0.1062	0.3889	-1.3043	1.3257	RING
S1EN	11.3378	43.3149	387.3	0.4217	1.0100	0.1846	1.2947	2.1518	4.3431	ITALPOS
SACS	11.9097	42.8491	836.0	2.0362	1.4275	-0.7806	1.7907	-3.8033	6.5052	RING
SCRA	14.0021	42.2681	167.0	0.8153	1.1669	0.6389	1.2721	0.1164	4.4609	ABRUZZO

SGRE	13.5011	42.3362	808.9	0.4955	0.7174	1.2515	0.8807	1.9244	2.9575	RING
SMRA	13.9241	42.0479	474.7	0.4371	1.1741	2.4000	1.2749	-0.4898	4.5423	ABRUZZO
TARQ	11.7575	42.2539	186.1	-0.4369	0.7151	-0.1107	0.9063	3.3554	3.0810	ITALPOS
TER1	13.7004	42.6621	333.9	5.2000	1.8605	-0.6200	1.8605	-1.1500	7.3890	ABRUZZO
TERA	13.6981	42.6571	310.9	6.6400	1.7808	0.7300	1.7808	0.2600	7.0967	ITALPOS
TERI	12.6495	42.5669	210.3	-3.1185	1.2610	-3.1661	1.4159	2.4867	4.8268	ITALPOS
TERM	13.2084	42.4450	1096.6	-2.2859	1.3279	-4.0644	1.5053	-5.6111	5.4254	ISPRA
TOLF	11.9999	42.0640	363.3	-0.4901	0.7928	-0.4325	1.0118	2.3644	3.4466	RING
TOSS	13.6458	42.5472	480.1	3.5957	0.9985	-0.4689	1.2137	3.4299	4.0764	DPC
TRIV	14.5502	41.7666	599.9	0.1496	1.0917	-1.0498	1.3833	0.6011	4.7679	RING
UMBE	12.3286	43.3112	306.2	1.2384	1.0338	-0.9484	1.3091	6.9397	4.5902	RING
UNPG	12.3557	43.1194	351.6	2.7370	2.0150	-0.7890	2.2665	-1.6240	7.5124	EUREF
VALC	12.2849	43.2790	663.7	-0.2955	0.7123	-1.0745	0.8991	4.8774	2.9139	RING
VALM	12.9178	41.7756	350.4	0.0222	1.2872	-0.0181	1.5627	1.6657	5.7366	LAZIO
VIRB	12.1063	42.4199	394.3	-0.6795	0.7156	0.3041	0.7811	0.7288	2.8047	LAZIO
VIT1	12.1031	42.4264	406.1	-0.9424	0.6613	0.2428	0.8289	-0.1924	2.7766	ITALPOS
VIT2	12.1116	42.4194	419.6	-0.4294	0.7465	-0.3610	0.7955	0.4022	2.9143	NETGEO
VTRA	14.7079	42.1104	210.3	1.2090	2.9354	0.1144	3.7393	-0.4798	12.4734	ABRUZZO
VVLO	13.6232	41.8696	1046.3	1.4257	0.9926	1.9502	1.2003	-2.3024	4.1370	RING
ZAGA	12.7478	41.8624	199.3	0.1352	1.7588	-0.9584	2.2236	0.4330	7.5006	NETGEO

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