remote sensing

MDPI

SUPPLEMENTARY MATERIAL

Geodetic study of the 2006-2010 ground deformation in La Palma (Canary Islands): observational results.

Joaquín Escayo [1], José Fernández [1,*], Juan F. Prieto [2], Antonio G. Camacho [1], Mimmo Palano [3], Alfredo Aparicio [1,4], Gema Rodríguez-Velasco [5], Eumenio Ancochea [6]

[1] Instituto de Geociencias (CSIC, UCM). C/ Doctor Severo Ochoa, nº 7. Ciudad Universitaria. 28040-Madrid, Spain; jescayo@ucm.es, jft@mat.ucm.es, antonio_camacho@mat.ucm.es, a.aparicioyague@gmail.com

[2] E.T.S. de Ingenieros en Topografía, Geodesia y Cartografía, Universidad Politécnica de Madrid, 28031-Madrid, Spain; juanf.prieto@upm.es

[3] Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo - Sezione di Catania, Piazza Roma 2, 95125 Catania, Italy; mimmo.palano@ingv.it

[4] Retired & now at Dpto. de Geología. Museo Nacional de Ciencias Naturales. CSIC. Calle de José Gutiérrez Abascal, 2, 28006-Madrid, Spain.

[5] Dpto. Física de la Tierra y Astrofísica, Unidad Departamental Astronomía y Geodesia, Universidad Complutense de Madrid, Fac. C. Matemáticas, Plaza de Ciencias, 3, 28040, Madrid, Spain. geos@mat.ucm.es

[6] Departamento de Mineralogía y Petrología, Fac. CC. Geológicas, Universidad Complutense de Madrid, 28040 Madrid, Spain; anco@ucm.es

* Correspondence: jft@mat.ucm.es; Tel.: +34-913944632 (J.F.)

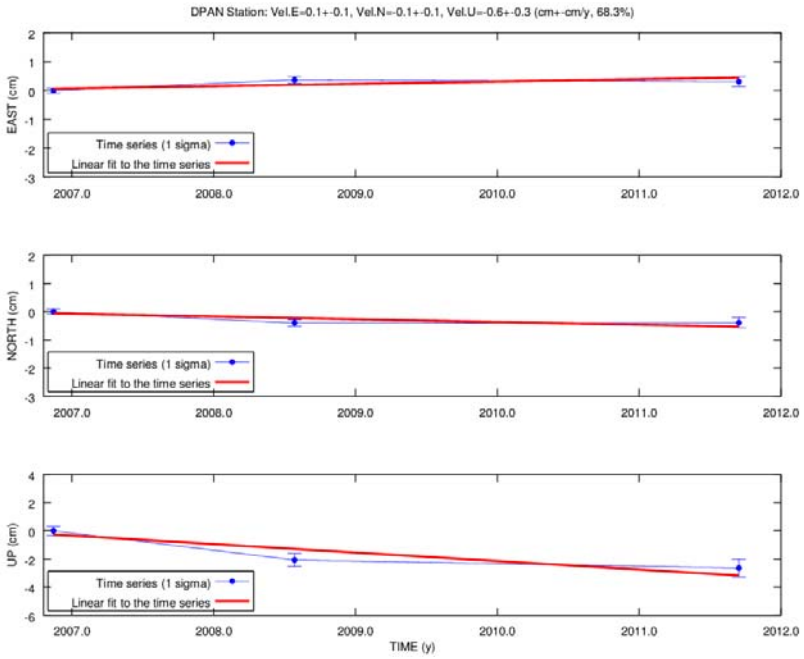

Figure S1. 3D GNSS displacement time series and adjusted linear fits for station DPAN. The red lines on the subfigures, and on the following figures, show the linear fit to the time series used to estimate the mean annual velocities.

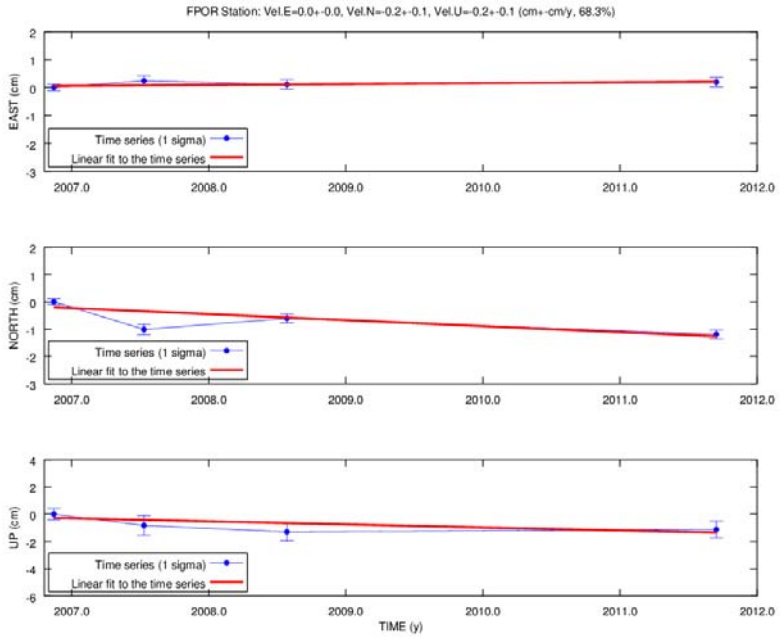

Figure S2. 3D GNSS displacement time series and adjusted linear fits for station FPOR.

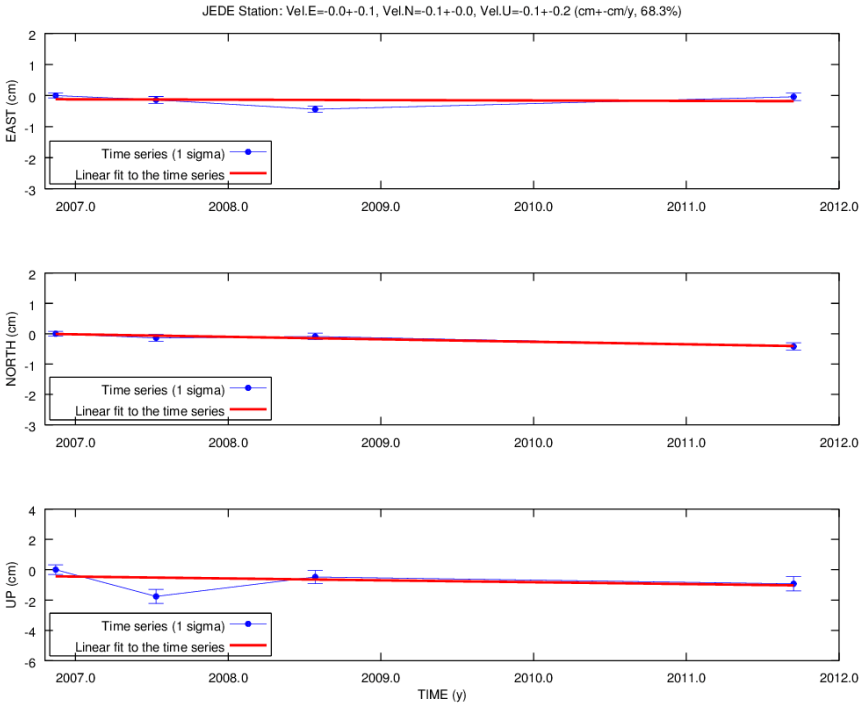

Figure S3. 3D GNSS displacement time series and adjusted linear fits for station JEDE.

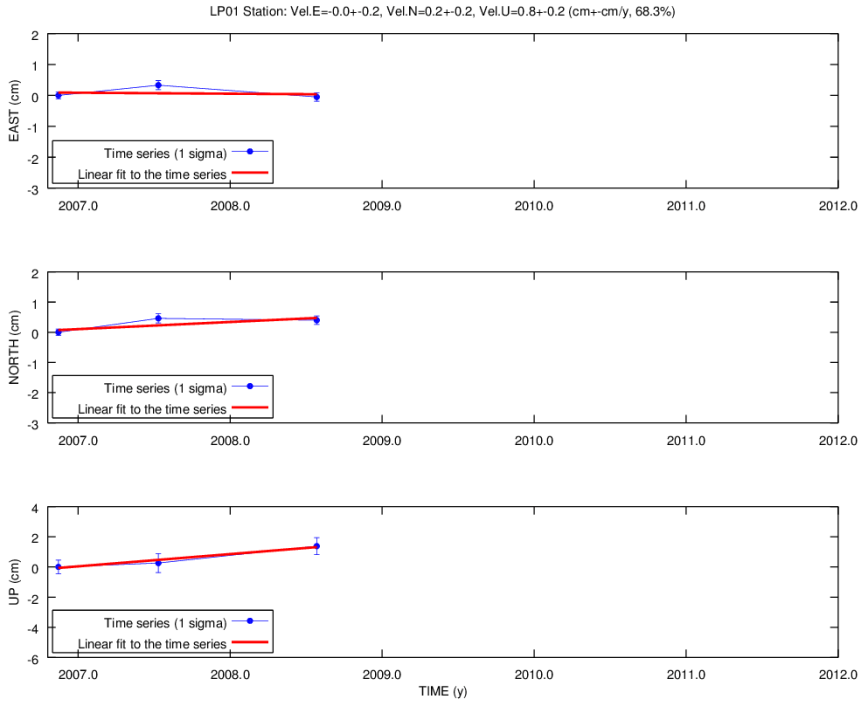

Figure S4. 3D GNSS displacement time series and adjusted linear fits for station LP01.

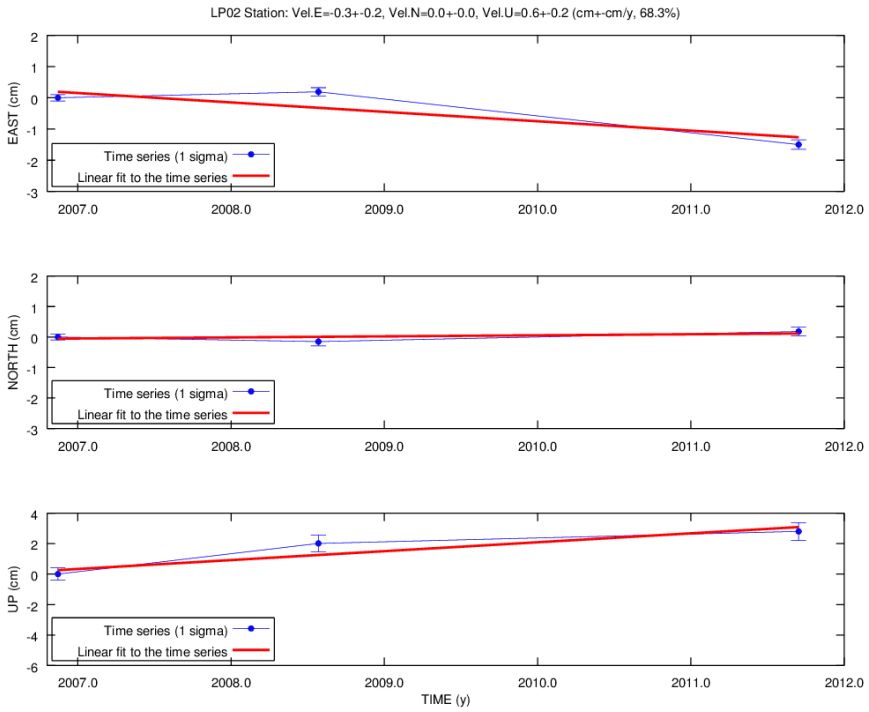

Figure S5. 3D GNSS displacement time series and adjusted linear fits for station LP02.

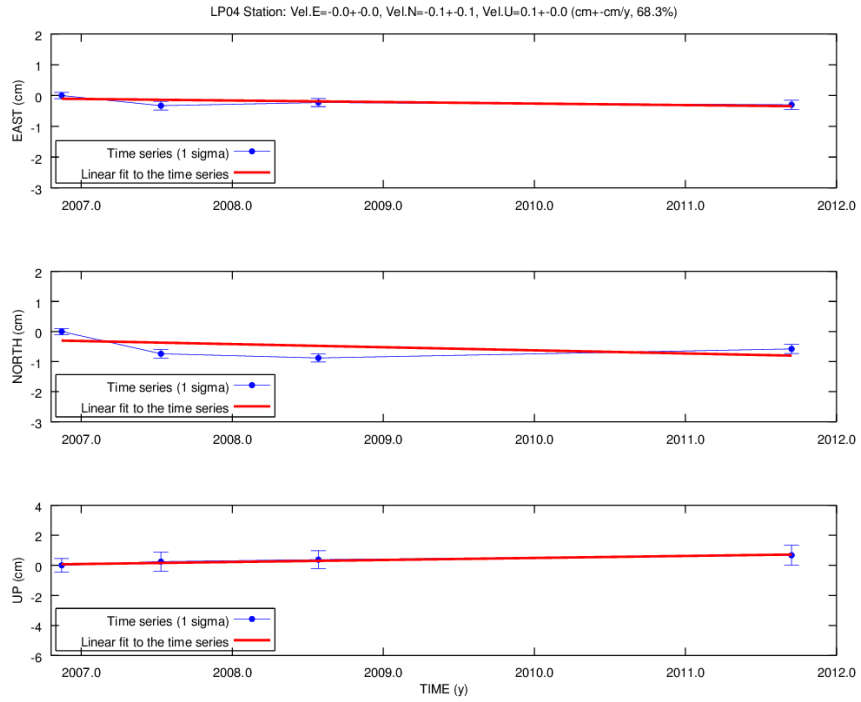

Figure S6. 3D GNSS displacement time series and adjusted linear fits for station LP04.

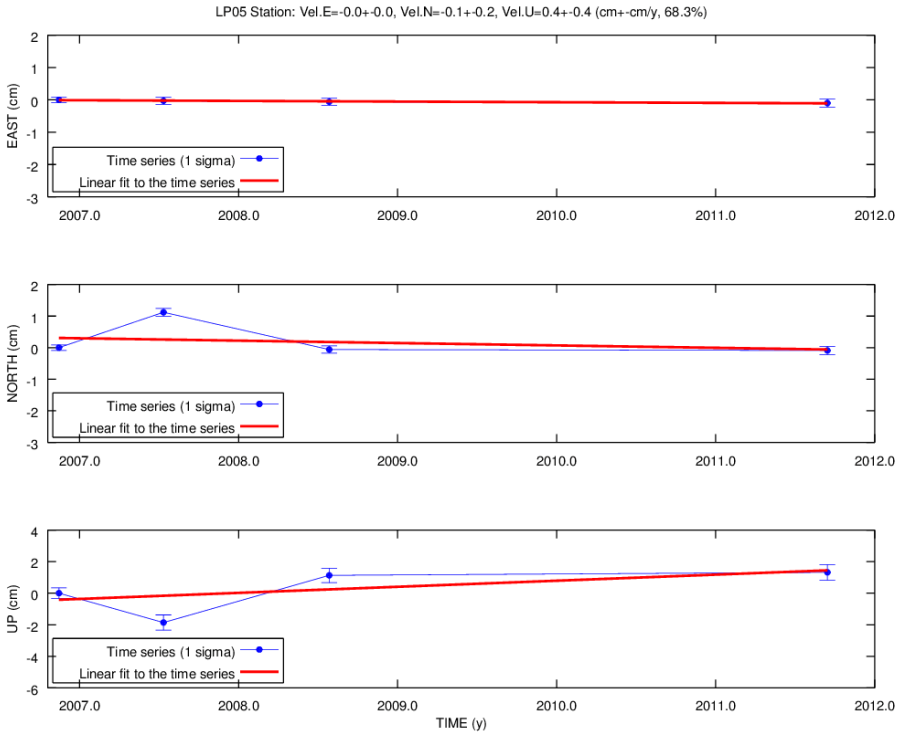

Figure S7. 3D GNSS displacement time series and adjusted fits for station LP05.

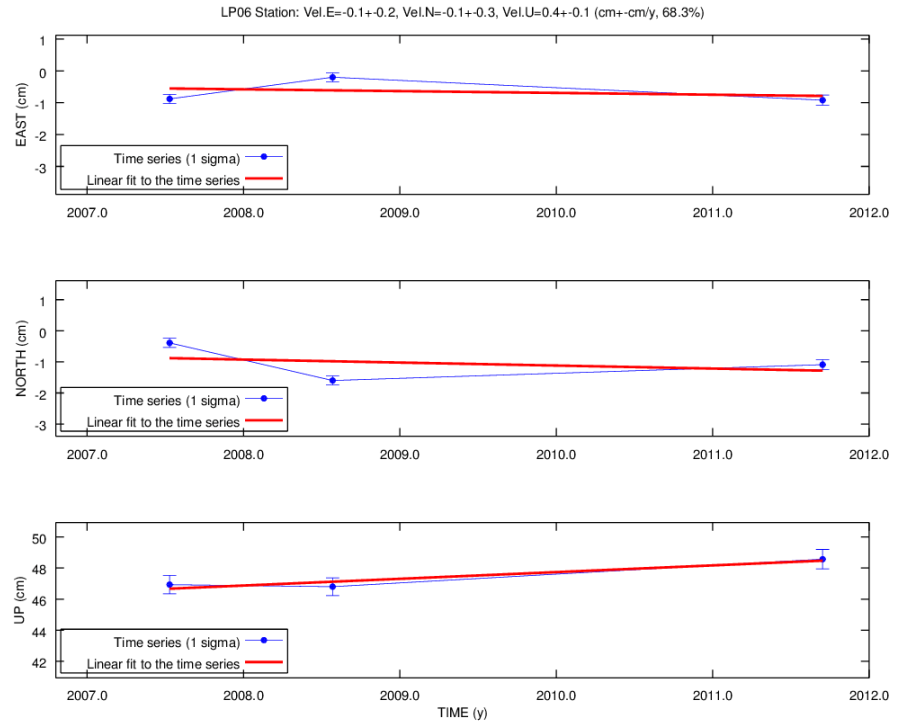

Figure S8. 3D GNSS displacement time series and adjusted linear fits for station LP06.

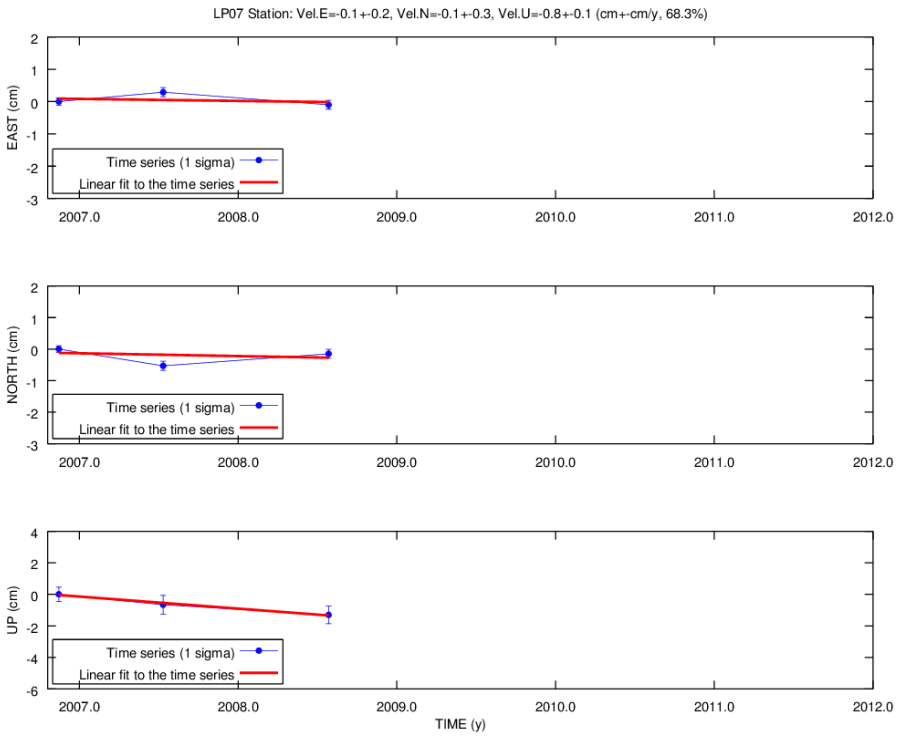

Figure S9. 3D GNSS displacement time series and adjusted linear fits for station LP07.

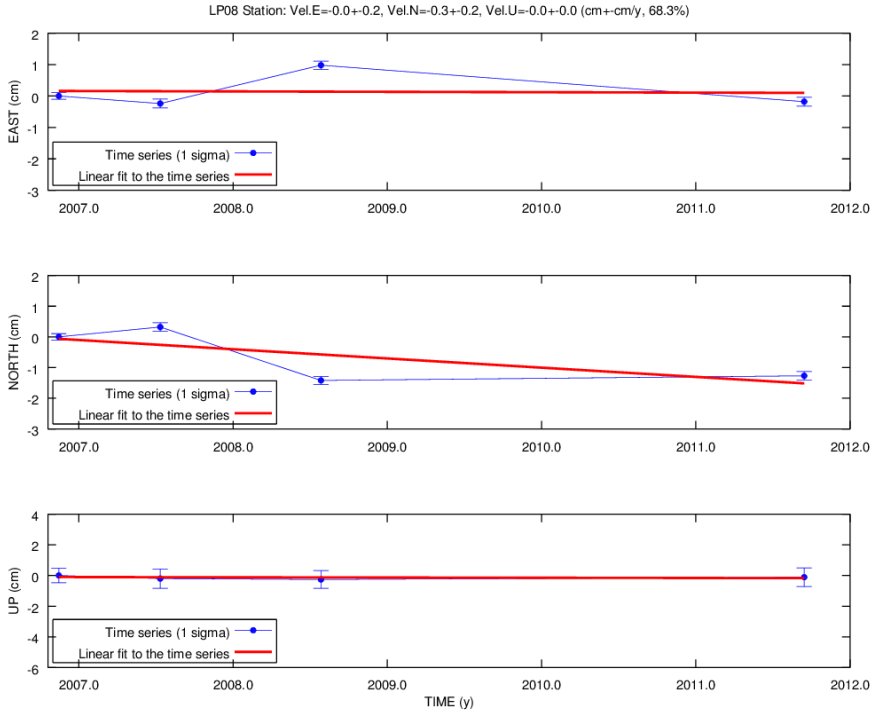

Figure S10. 3D GNSS displacement time series and adjusted linear fits for station LP08.

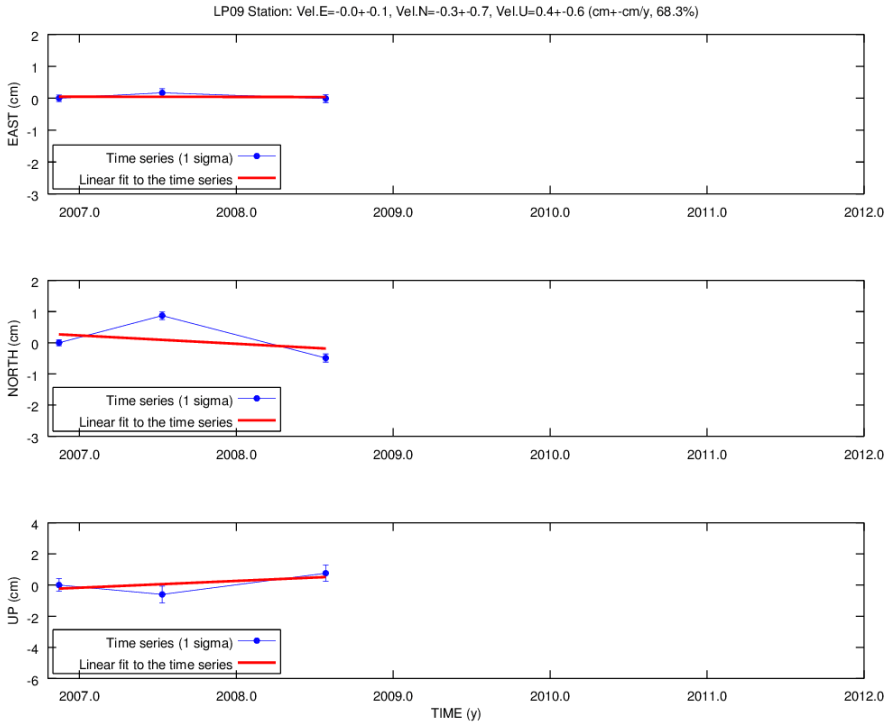

Figure S11. 3D GNSS displacement time series and adjusted linear fits for station LP09.

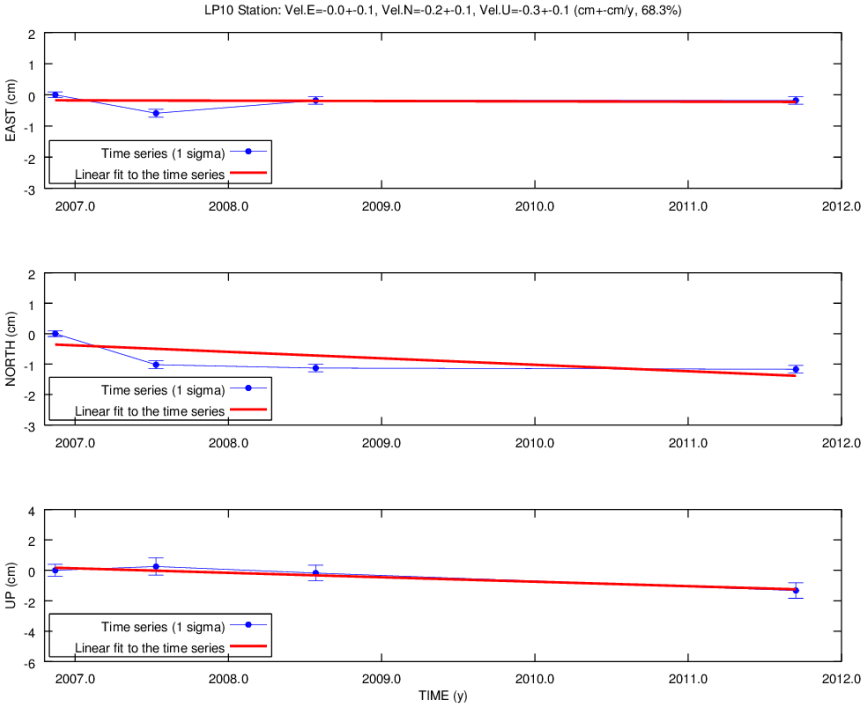

Figure S12. 3D GNSS displacement time series and adjusted linear fits for station LP10.

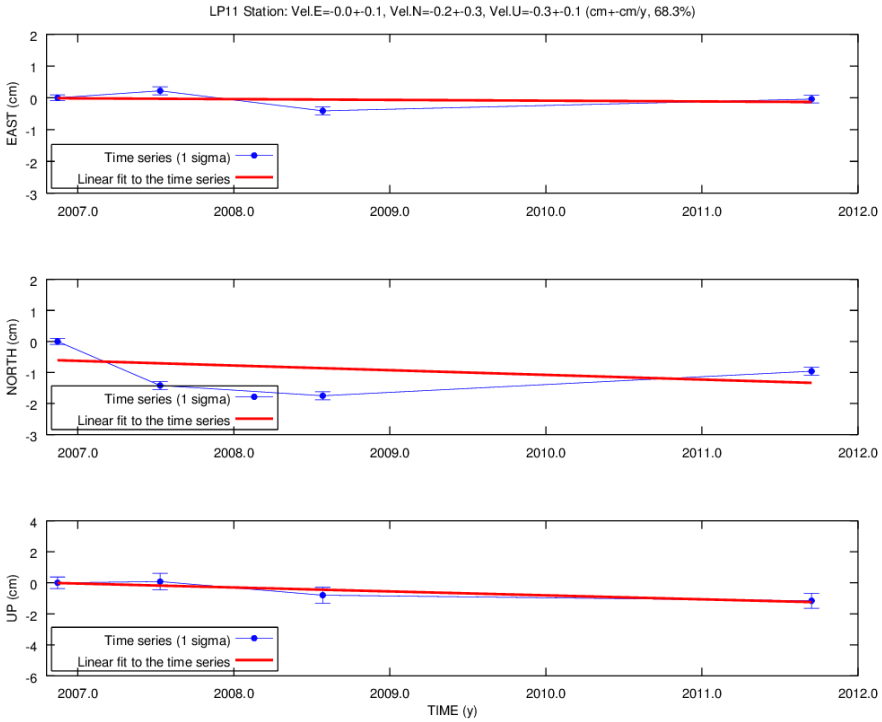

Figure S13. 3D GNSS displacement time series and adjusted linear fits for station LP11.

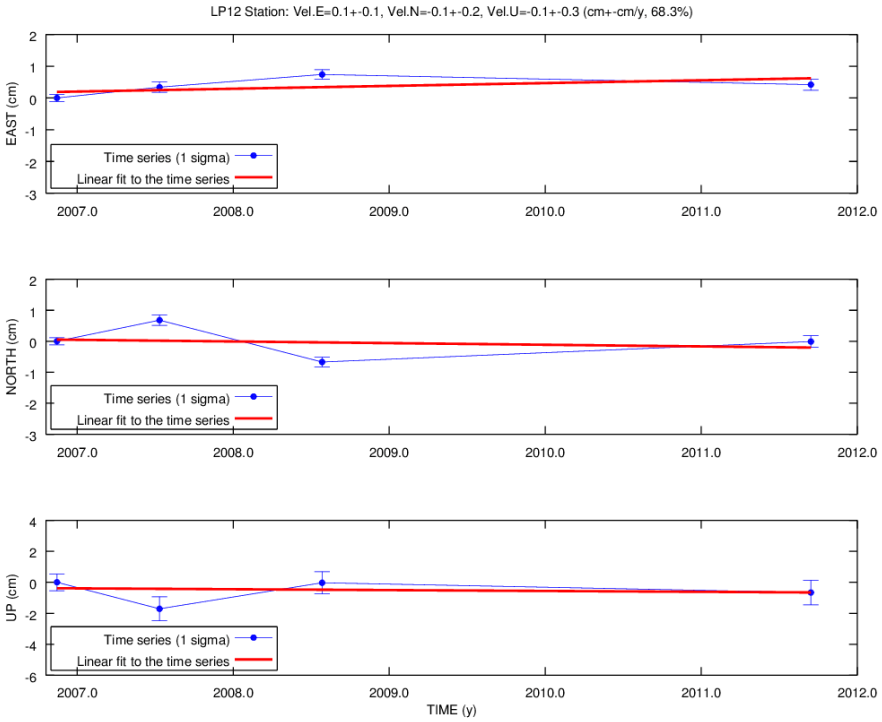

Figure S14. 3D GNSS displacement time series and adjusted linear fits for station LP12.

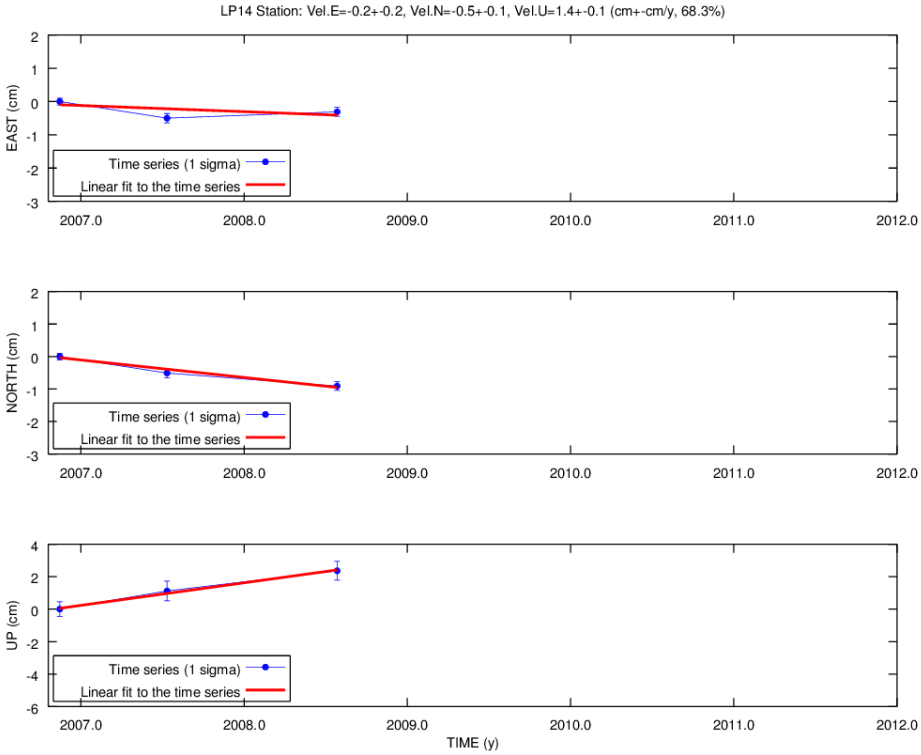

Figure S15. 3D GNSS displacement time series and adjusted linear fits for station LP14.

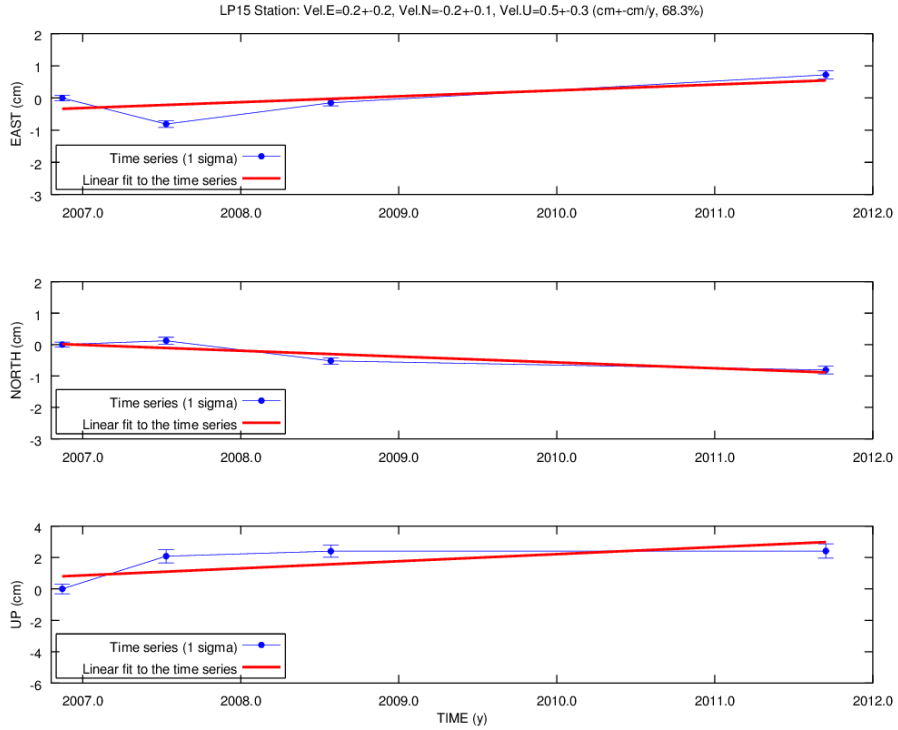

Figure S16. 3D GNSS displacement time series and adjusted linear fits for station LP15.

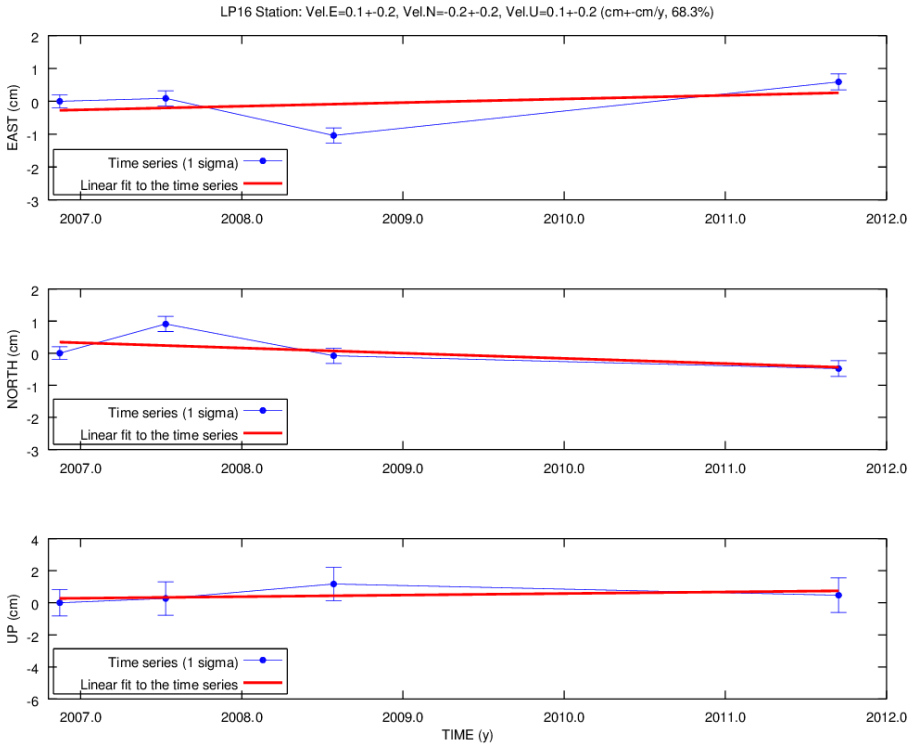

Figure S17. 3D GNSS displacement time series and adjusted linear fits for station LP16.

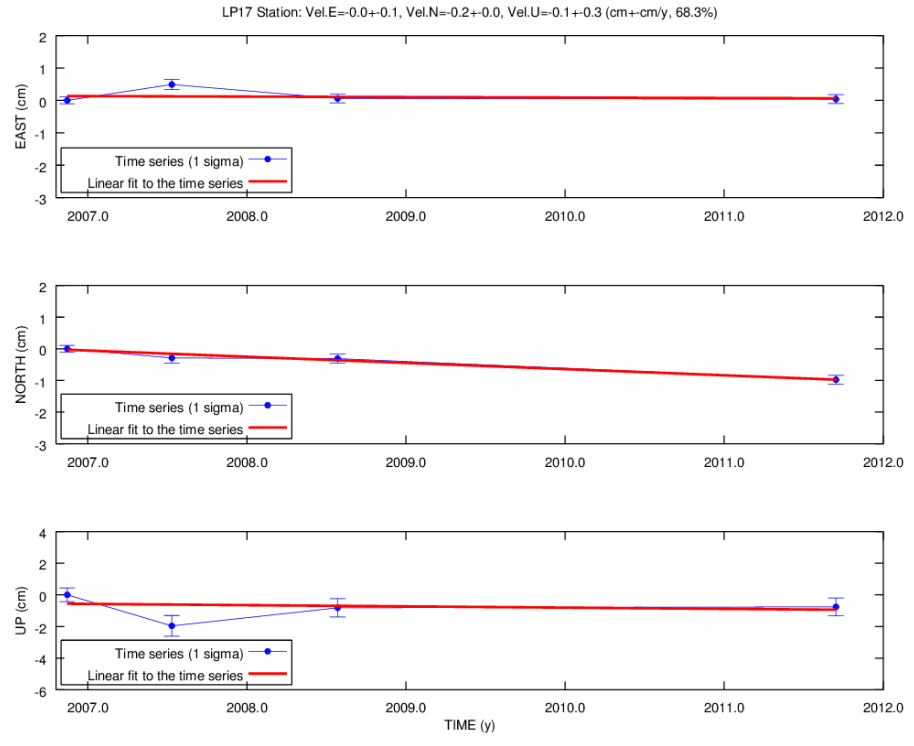

Figure S18. 3D GNSS displacement time series and adjusted linear fits for station LP17.

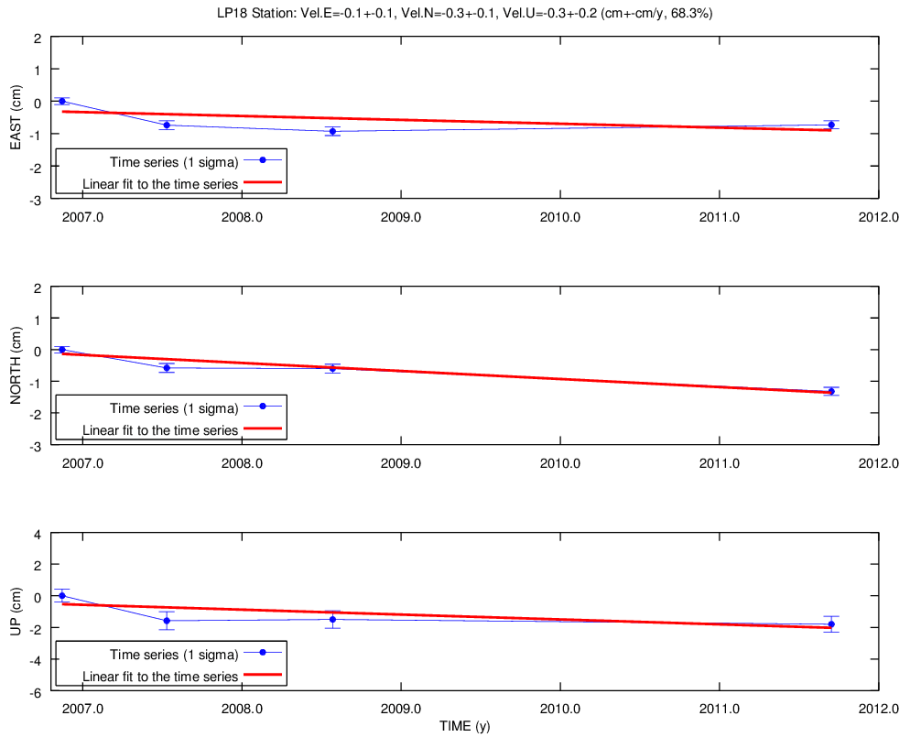

Figure S19. 3D GNSS displacement time series and adjusted linear LP18.

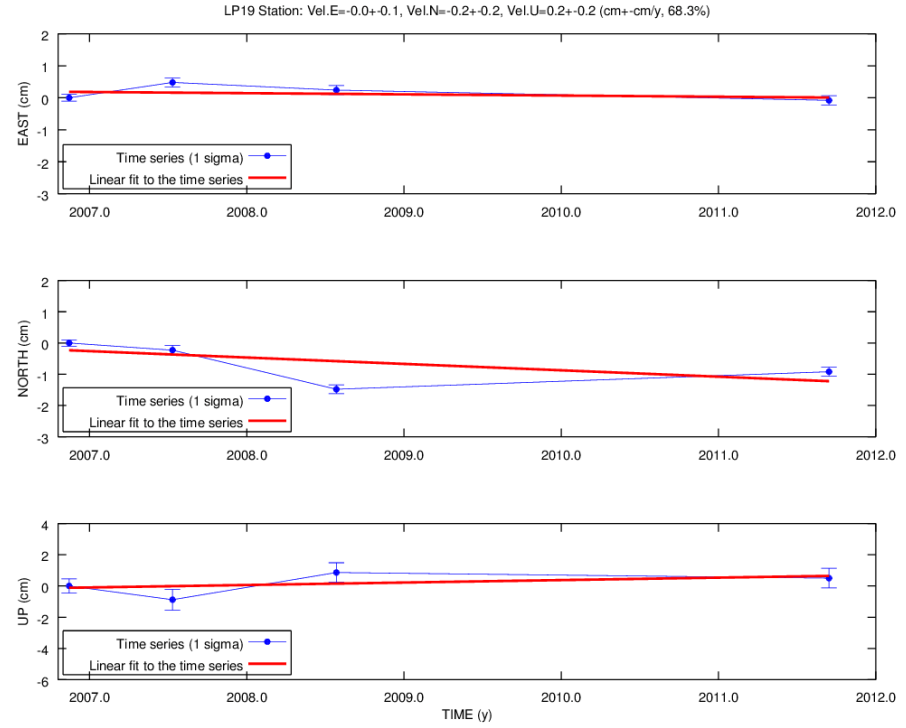

Figure S20. 3D GNSS displacement time series and adjusted fits for station LP19.

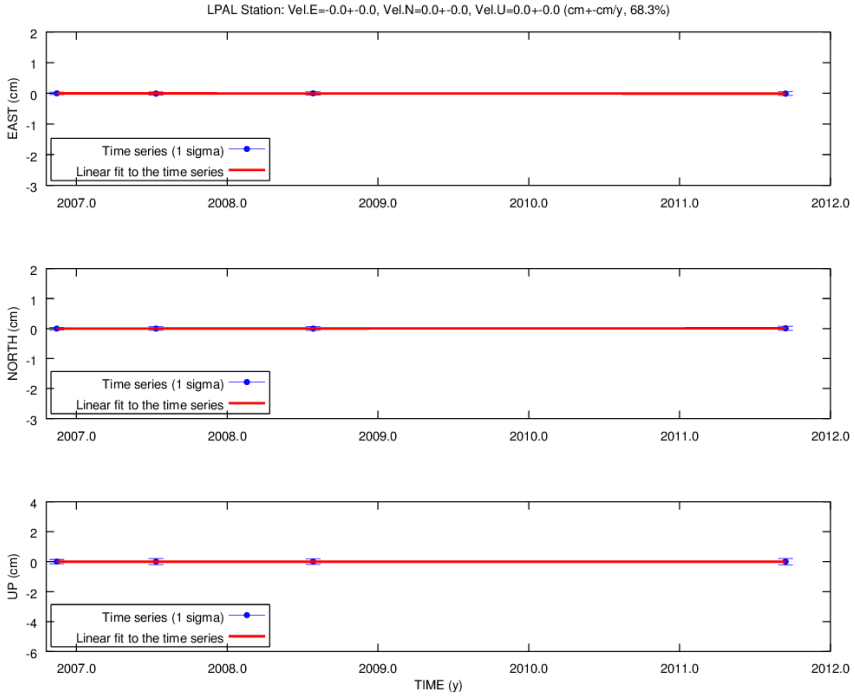

Figure S21. 3D GNSS displacement time series and adjusted linear fits for station LPAL.

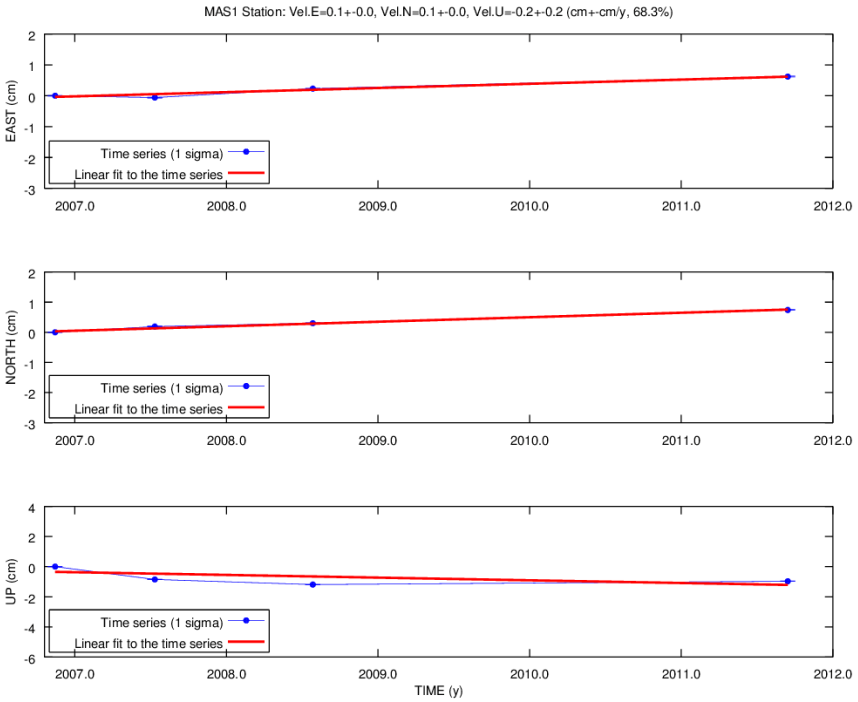

Figure S22. 3D GNSS displacement time series and adjusted linear fits for station MAS1.

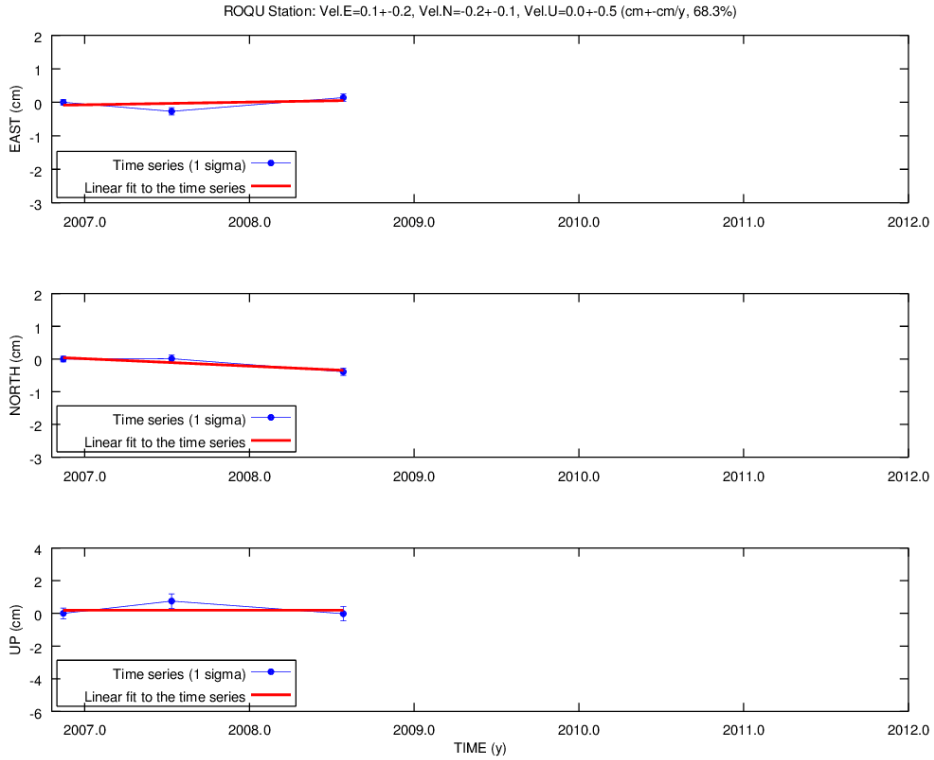

Figure S23. 3D GNSS displacement time series and adjusted linear fits for station ROQU.

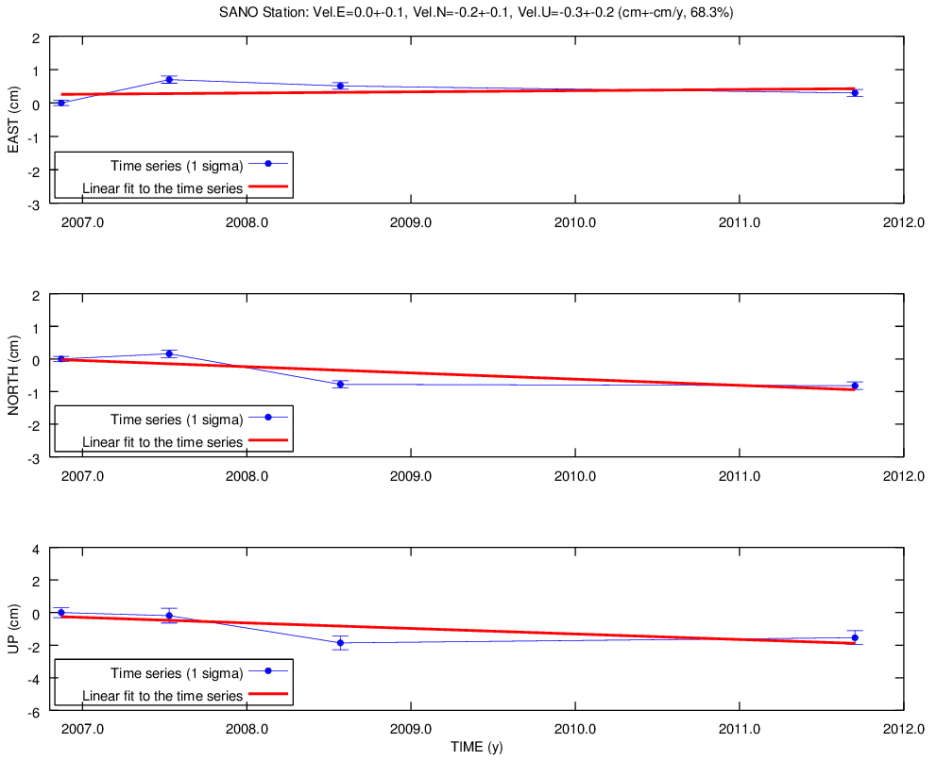

Figure S24. 3D GNSS displacement time series and adjusted linear fits for station SANO.

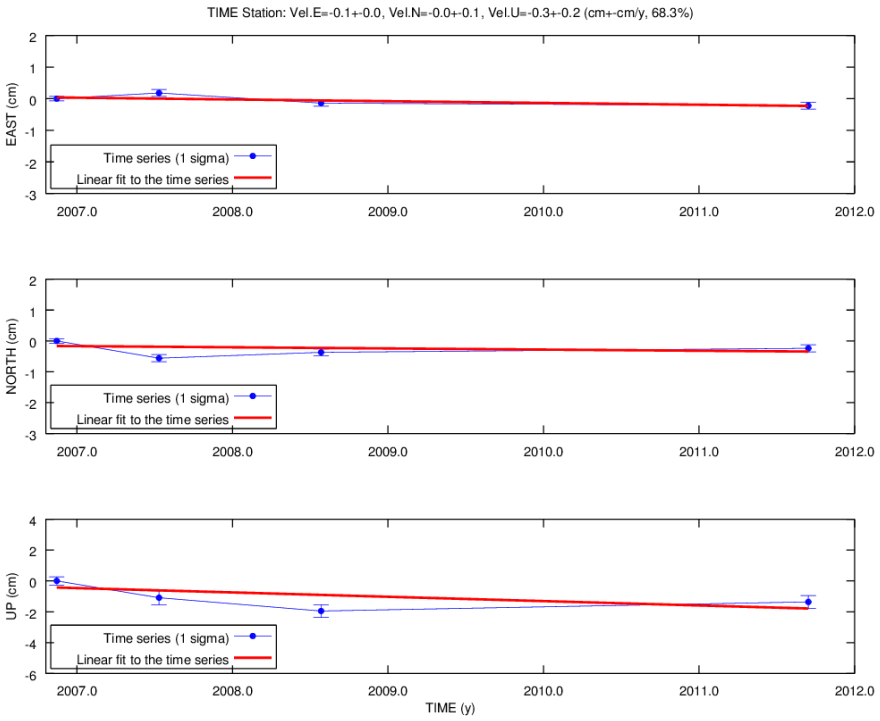

Figure S25. 3D GNSS displacement time series and adjusted linear fits for station TIME.

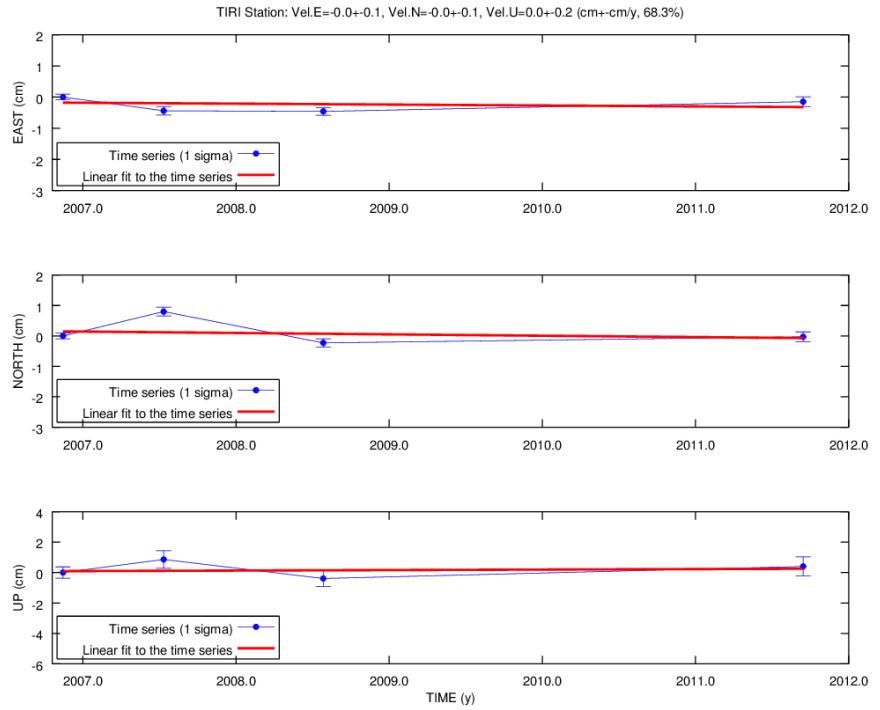

Figure S26. 3D GNSS displacement time series and adjusted linear fits for station TIRI.

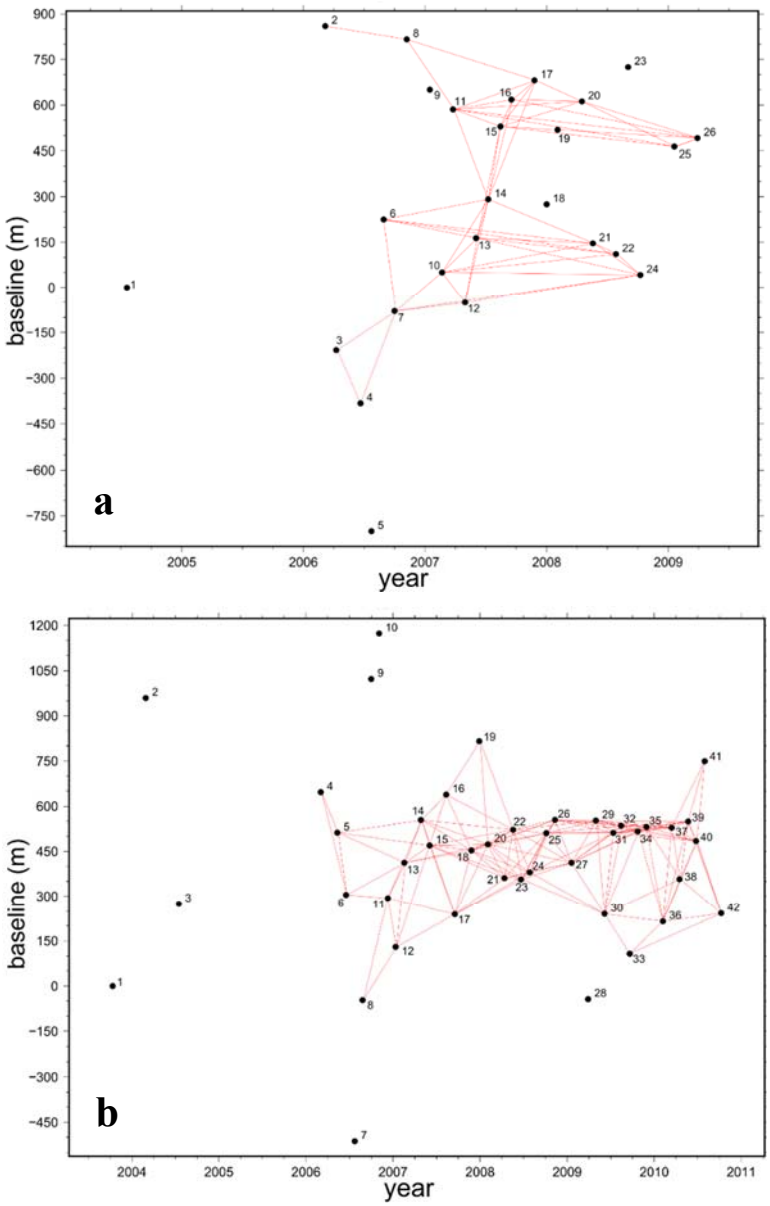

Figure S27. Interferogram clouds for both processed orbits. The criteria for choosing interferometric pairs is the same in both cases: all pairs within 350-m and 400-days perpendicular and temporal baselines, respectively, and discarding interferograms with temporal and spatial baselines over 150m and 150days simultaneously. The SLC's numbers are referred to Table S1. (**a**) Ascending orbit, (**b**) descending orbit.

Table S1. Annual mean velocities for the GNSS monitoring stations in La Palma with their uncertainties, for the period 2006-2011.

Mean velocities for La Palma 2006-2011 (mm/yr)			
Station	**East**	**North**	**Up**
DPAN	0.8 ± 0.7	-1.0 ±0.7	-6.0 ±3.0
FPOR	0.3 ±0.3	-2.2 ±1.1	-2.2 ±1.4
JEDE	-0.1 ±0.7	-0.8 ±0.2	-1.2 ±2.5
LP01	-0.3 ±2.1	2.4 ±1.8	8.1 ±1.6
LP02	-3.0 ±1.7	0.3 ±0.5	5.8 ±2.3
LP04	-0.5 ±0.5	-1.0 ±1.3	1.3 ±0.3
LP05	-0.2 ±0.0	-0.8 ±1.8	3.8 ±3.6
LP06	-0.6 ±1.9	-1.0 ±2.8	4.3 ±1.5
LP07	-0.6 ±2.0	-0.9 ±2.9	-7.6 ±1.0
LP08	-0.1 ±1.8	-3.0 ±1.9	-0.2 ±0.4
LP09	-0.1 ±1.1	-2.7 ±6.7	4.4 ±5.6
LP10	-0.1 ±0.8	-2.1 ±1.5	-2.9 ±0.7
LP11	-0.2 ±0.8	-1.5 ±2.5	-2.5 ±0.8
LP12	0.9 ±1.0	-0.5 ±1.8	-0.6 ±2.7
LP14	-1.8 ±2.3	-5.4 ±1.0	13.9 ±1.3
LP15	1.8 ±1.5	-1.9 ±0.6	4.5 ±3.4
LP16	1.1 ±2.1	-1.6 ±1.5	1.0 ±1.6
LP17	-0.1 ±0.7	-2.0 ±0.2	-0.8 ±2.5
LP18	-1.2 ±1.2	-2.5 ±0.6	-3.1 ±2.0
LP19	-0.4 ±0.8	-2.0 ±1.8	1.6 ±2.0
ROQU	0.8 ±2.0	-2.3 ±1.0	0.0 ±4.7
SANO	0.4 ±1.0	-1.9 ±1.0	-3.4 ±2.1
TIME	-0.6 ±0.4	-0.4 ±0.8	-2.8 ±2.4
TIRI	-0.3 ±0.9	-0.5 ±1.5	0.3 ±1.8

Table S2. SLC images in this study with their acquisition dates and relative ENVISAT orbit numbers. In bold, the images that were discarded due to their high baselines or high Doppler differences.

ASCENDING				DESCENDING					
#	DATE	#	DATE	#	DATE	#	DATE	#	DATE
1	**20040721**	14	20070711	1	**20031013**	15	20070604	29	20090504
2	20060308	15	20070815	2	**20040301**	16	20070813	30	20090608
3	20060412	16	20070919	3	**20040719**	17	20070917	31	20090713
4	20060621	17	20071128	4	20060306	18	20071126	32	20090817
5	**20060726**	18	**20080102**	5	20060515	19	20071231	33	20090921
6	20060830	19	**20080206**	6	20060619	20	20080204	34	20091026
7	20061004	20	20080416	7	**20060724**	21	20080414	35	20091130
8	20061108	21	20080521	8	22060828	22	20080519	36	20100208
9	**20070117**	22	20080730	9	**20061002**	23	20080623	37	20100315
10	20070221	23	**20080903**	10	**20061106**	24	20080728	38	20100419
11	20070328	24	20081008	11	20061211	25	20081006	39	20100524
12	20070502	25	20090121	12	20070115	26	20081110	40	20100628
13	20070606	26	20090401	13	20070219	27	20090119	41	20100802
				14	20070430	28	**20090330**	42	201001011

Table S3. A list of the interferograms used in this study for the ascending orbit. The selection criterion is to use all possible pairs within a 350-m of perpendicular baseline and 400-days of temporal baseline, removing those pairs with perpendicular and temporal baselines simultaneously exceeding 150-m and 150-days, respectively.

List of interferograms for ascending orbit (SLC 1 – SLC 2)			
20060308-20061108	20070221-20070502	20070502-20070711	20070815-20090121
20060412-20060621	20070221-20070606	20070502-20081008	20070815-20090401
20060412-20061004	20070221-20070711	20070606-20070711	20070919-20071128
20060621-20061004	20070221-20080521	20070606-20070815	20070919-20080416
20060830-20061004	20070221-20080730	20070606-20080521	20070919-20090401
20060830-20070606	20070221-20081008	20070606-20080730	20071128-20080416
20060830-20070711	20070328-20070711	20070606-20081008	20080416-20090121
20060830-20080521	20070328-20070815	20070711-20070815	20080416-20090401
20060830-20080730	20070328-20070919	20070711-20070919	20080521-20080730
20061004-20070221	20070328-20071128	20070711-20071128	20080521-20081008
20061004-20070502	20070328-20080416	20070711-20080521	20080730-20081008
20061004-20081008	20070328-20090121	20070815-20070919	20090121-20090401
20061108-20070328	20070328-20090401	20070815-20071128	
20061108-20071128	20070502-20070606	20070815-20080416	

Table S4. A list of the interferograms used in this study for the descending orbit. The selection criterion is to use all possible pairs within a 350-m of perpendicular baseline and 400-days of temporal baseline, removing those pairs with perpendicular and temporal baselines simultaneously exceeding 150-m and 150-days, respectively.

List of interferograms for descending orbit (SLC 1 – SLC 2)			
20060306-20060515	20070917-20080204	20080728-20090119	20090713-20100524
20060306-20060619	20070917-20080414	20080728-20090608	20090713-20100628
20060515-20060619	20070917-20080623	20080728-20090713	20090817-20091026
20060515-20070219	20070917-20080728	20081006-20081110	20090817-20091130
20060515-20070430	20071126-20080204	20081006-20090119	20090817-20100315
20060515-20070604	20071126-20080414	20081006-20090504	20090817-20100524
20060619-20061211	20071126-20080519	20081006-20090713	20090817-20100628
20060619-20070219	20071126-20080623	20081006-20090817	20090921-20100208
20060828-20061211	20071126-20080728	20081006-20091026	20090921-20101011
20060828-20070115	20071126-20081006	20081110-20090119	20091026-20091130
20061211-20070115	20071126-20081110	20081110-20090504	20091026-20100208
20061211-20070219	20071231-20080204	20081110-20090713	20091026-20100315
20061211-20070430	20071231-20080519	20081110-20090817	20091026-20100524
20061211-20070917	20080204-20080414	20081110-20091026	20091026-20100628
20070115-20070219	20080204-20080519	20081110-20091130	20091130-20100208
20070115-20070604	20080204-20080623	20090119-20090504	20091130-20100315
20070115-20070917	20080204-20080728	20090119-20090608	20091130-20100419
20070219-20070430	20080204-20081006	20090119-20090713	20091130-20100524
20070219-20070604	20080204-20081110	20090119-20090817	20091130-20100628
20070219-20071126	20080204-20090119	20090119-20091026	20100208-20100315
20070219-20080204	20080414-20080519	20090119-20091130	20100208-20100419
20070430-20070604	20080414-20080623	20090504-20090608	20100208-20100524
20070430-20070813	20080414-20080728	20090504-20090713	20100208-20100628
20070430-20070917	20080414-20081006	20090504-20090817	20100208-20101011
20070430-20071126	20080414-20090119	20090504-20091026	20100315-20100419
20070430-20080204	20080519-20080623	20090504-20091130	20100315-20100524
20070430-20080519	20080519-20080728	20090504-20100315	20100315-20100628
20070604-20070813	20080519-20081006	20090504-20100524	20100315-20100802
20070604-20070917	20080519-20081110	20090608-20090713	20100419-20100524
20070604-20071126	20080519-20090119	20090608-20090817	20100419-20100628
20070604-20080204	20080519-20090504	20090608-20090921	20100419-20101011
20070604-20080414	20080623-20080728	20090608-20091026	20100524-20100628
20070604-20080519	20080623-20081006	20090608-20100208	20100524-20100802
20070604-20080623	20080623-20081110	20090608-20100419	20100524-20101011
20070813-20071126	20080623-20090119	20090713-20090817	20100628-20100802
20070813-20071231	20080623-20090608	20090713-20091026	20100628-20101011
20070813-20080519	20080728-20081006	20090713-20091130	20090713-20100524
20070917-20071126	20080728-20081110	20090713-20100315	20090713-20100628
20060306-20060515	20070917-20080204	20080728-20090119	20090817-20091026
20060306-20060619	20070917-20080414	20080728-20090608	20090817-20091130
20060515-20060619	20070917-20080623	20080728-20090713	20090817-20100315
20060515-20070219	20070917-20080728	20081006-20081110	20090817-20100524
20060515-20070430	20071126-20080204	20081006-20090119	20090817-20100628

20060515-20070604	20071126-20080414	20081006-20090504	20090921-20100208
20060619-20061211	20071126-20080519	20081006-20090713	20090921-20101011
20060619-20070219	20071126-20080623	20081006-20090817	
20060828-20061211	20071126-20080728	20081006-20091026	

Table S5. Coordinates UTM and altitudes (in meters) of the 12 microgravimetric stations

Station	X	Y	Height
Hotel	230200	3172000	65
Cancajos	230239	3172193	76
Pista10	221403	3168769	1390
Pista20	220433	3166681	1273
Pista30	221082	3160151	1296
Gasolinera	222652	3156308	812
Teneguia10	220713	3153251	420
Teneguia20	220845	3153098	431
PIRS	219352	3162374	799
Jedey	218401	3165613	669
LasManchas	218141	3167859	637
Tajuya	218007	3169782	576

Table S6. Adjusted values for relative gravity (μGal) and standard errors for each station and each campaign after the reduction process. Heights in meters

Station	Height	2008	e	2009	e	2011	e	2014	e
Hotel	65	0	15	0	15	0	15	0	5
Cancajos	76	-967	15	-967	15	-967	15	-938	5
Pista10	1390	-291411	15	-291454	16	-291415	16	-291492	5
Pista20	1273	-282534	15	-282577	16	-282518	16	-282580	6
Pista30	1296	-314796	15	-314835	16	-314750	16	-314822	7
Gasolinera	812	-215229	15	-215243	16	-215209	16	-215254	7
Teneguia10	420	-131790	15	-131808	16	-131779	16	-131798	7
Teneguia20	431	-135080	15	-135082	16	-135055	15	-135069	7
PIRS	799	-192441	15	-192438	16	-192443	15	-192464	7
Jedey	669	-147448	15	-147476	16	-147439	15	-147456	7
LasManchas	637	-128671	15	-128698	16	-128662	15	-128694	7
Tajuya	576	-104812	15	-104818	16	-104804	15	-104811	7

Table S7. Adjusted additional instrumental scale factor for the four observation campaigns carried out in La Palma

Campaign	Gravimeter	Additional scale factor	Standard deviation
2008	G665	-0.00005	±0.00003
2009	G665	+0.00007	±0.00002
2011	G665	-0.00011	±0.00002
2014	CG5	+0.00009	±0.00006