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Quality of the SLR data 1983-2012

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SLR DATA

Positions and velocities of the all SLR stations
from September 1983 to December 2012

Number of sites: 137

Number of mobile sites: 63

Number of sites for velocity determination (> 3 year): 90

METHOD OF COMPUTATIONS

Orbital software: Goddard's NASA GEODYN-II

Common models and parameters - IERS Conventions 2010

Satellites: LAGEOS-1 + LAGEOS-2 (one LAGEOS to September 1992)

Monthly arcs

Orbital arcs determined from 10-20 the best SLR stations in each year in ITRF2008

Geocentric station coordinates were determined from normal equations of both satellites

Editing criteria:

normal points $> 5 \sigma$ for each station

positions with number of station normal points per month < 50

Geocentric station coordinates were determined for one station in each arc for reference epoch of first day of each month

Coordinates were transformed to common epoch 2005.0 by ITRF2008 velocities

Geocentric coordinates XYZ were transformed to topocentric NEU in reference to ITRF2008

Station velocities were determined if the period of observations was longer than 3 years

Station accuracy estimation criterion: 3D RMS of the station positions

Station accuracy was estimated for six 5 years spans

RESULTS

For each arc were determined the following parameters:

number of all normal points per arc

RMS of fit per arc

separately for **LAGEOS-1** i **LAGEOS-2** satellites:

number of normal points per station

range bias per station

RMS of fit per station

geocentric station coordinates X, Y, Z

standard deviation for each component

topocentric coordinates N, E, U in reference to ITRF2008

3D standard deviation of coordinates determination

3D, horizontal, vertical station velocity and azimuth

No	Station Name	Type of station (F-stationary)	Country	From (ym)	To (ym)	Period y m
1181	Potsdam	F	Germany	8506	9203	7 10
1824	Kiev	F	Ukraine	0101	1112	12 0
1831	Lviv	F	Ukraine	0205	0911	7 7
1863	Maidanak	F	Uzbekistan	0108	0401	2 6
1864	Maidanak	F	Uzbekistan	9310	0810	15 1
1868	Komsomolsk	F	Russia	9412	1111	17 0
1873	Simeiz	F	Ukraine	8907	1111	22 5
1879	Altay	F	Russia	0810	1111	3 2
1884	Riga	F	Latvia	8709	1112	23 4
1885	Riga	ULISS	Latvia	9610	9612	0 3
1886	Arkhyz	F	Russia	1102	1111	0 10
1893	Katzively	F	Ukraine	8901	1112	24 0
1953	Santiago de Cuba	F	Cuba	8803	9607	8 4
7035	Otay Mount	TLRS-3	USA, California	8808	8809	0 2
7046	Bear Lake	MTLRS-1, TLRS-4	USA, Utah	9008	9110	1 3
7062	Otay Mount	TLRS-2	USA, California	8310	8312	0 3
7080	McDonald	F	USA, Texas	8802	1112	24 11
7082	Bear Lake	TLRS-1	USA, Utah	8311	8401	0 3
7086	McDonald	F	USA, Texas	8309	8801	4 5
7090	Yarragadee	MOBLAS-5	West Australia	8310	1112	28 3
7091	Westford	TLRS-1	USA, Massachusetts	8808	9012	2 5
7097	Easter Isl	TLRS-2	Chile	8711	9209	4 11
7105	Greenbelt	MOBLAS-7,-2, TLRS-2	USA, Maryland	8309	1112	28 4
7106	Greenbelt	F	USA, Maryland	9510	9510	0 1
7109	Quincy	MOBLAS-8,TLRS-4	USA, California	8309	9705	13 9
7110	Monument Peak	MOBLAS-4	USA, California	8311	1112	28 2
7112	Platteville	MOB-2,MTLRS-1,TLRS-1,-4	USA, Colorado	8309	9112	8 4

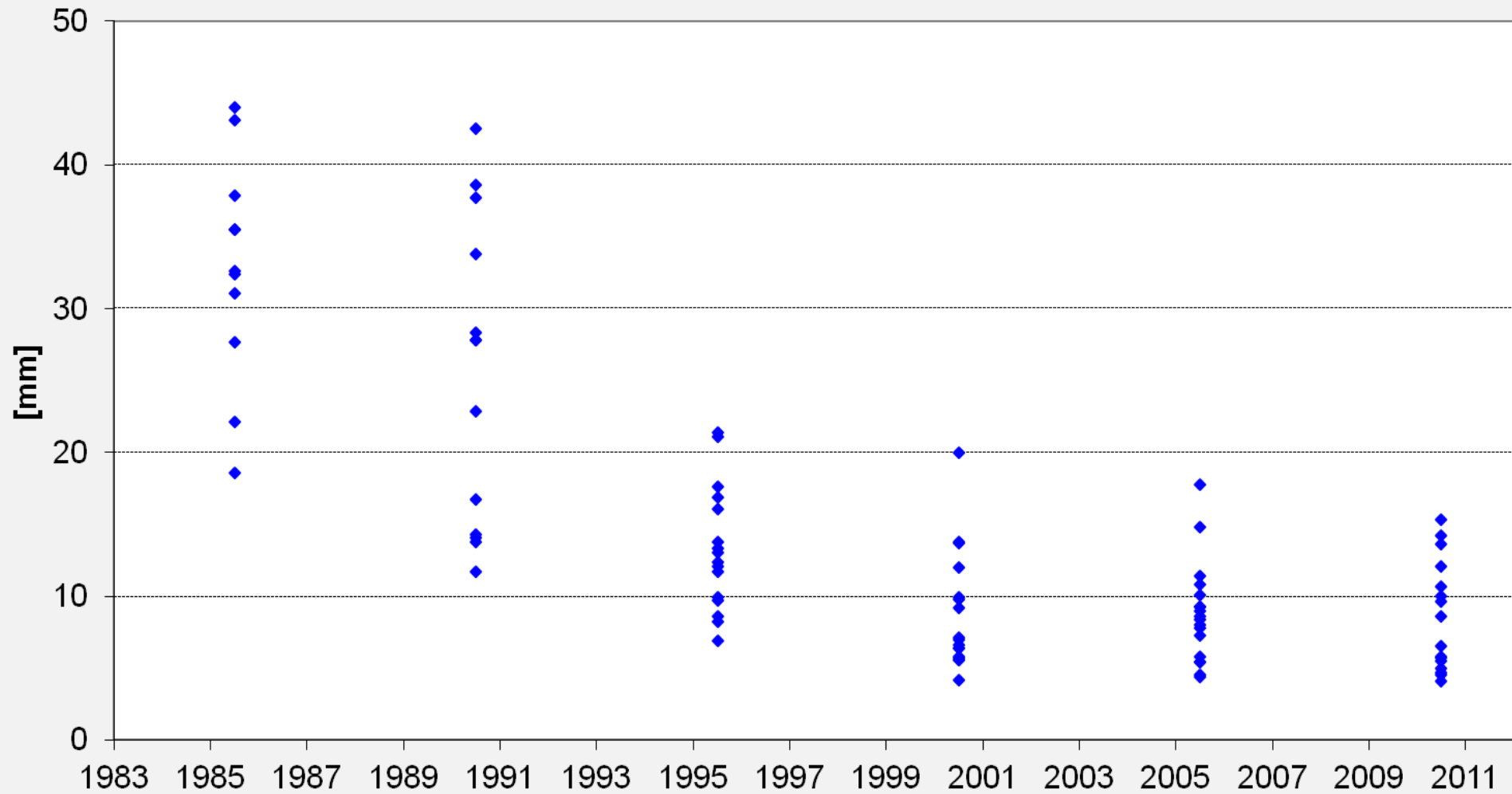
No	Station Name	Type of station (F-stationary)	Country	From (ym)	To (ym)	Period y m
7119	Haleakala	TLRS-4	USA, Hawaii	0611	1112	5 2
7121	Huahine	MOBLAS-1	French Polynesia	8309	8604	2 8
7122	Mazatlan	MOBLAS-6, TLRS-4	Meksyk	8309	9301	9 5
7123	Huahine	TLRS-2	French Polynesia	8707	9207	5 1
7124	Papeete	MOBLAS-8	Tahiti	9711	1112	14 1
7125	Greenbelt	MTLRS-1,TLRS-3, NGSLR	USA, Maryland	8506	8801	2 8
7130	Greenbelt	TLRS-2, -4	USA, Maryland	9906	0603	6 10
7210	Haleakala	F	USA, Hawaii	8309	0406	20 10
7220	Monument Peak	TLRS-1	USA, California	8309	8310	0 2
7231	Wuhan	F	China	0004	0412	4 9
7236	Wuhan	F	China	9210	9810	6 1
7237	Changchun	F	China	9108	1112	20 5
7249	Beijing	F	China	9506	1106	16 1
7288	Mojave	TLRS-3, -4	USA, California	8803	9102	3 0
7295	Richmond	MTLRS-1, TLRS-1,-4	USA, Florida	8804	9503	7 0
7308	Koganei	F	Japan	9211	1112	19 3
7328	Koganei	F	Japan	9811	1104	12 6
7335	Kashima	F	Japan	9811	0101	2 3
7337	Miura	F	Japan	9809	0005	1 9
7339	Tateyama	F	Japan	9809	0110	3 2
7343	Beijing	TROS	China	0008	0010	0 3
7355	Urumchi	TROS	China	0104	0509	4 6
7356	Lhasa	TROS	China	0108	0112	0 5
7357	Beijing	F	China	0308	0310	0 3
7358	Tanegashima	F	Japan	0409	1112	7 4
7370	Burnie	FTLRS	Australia, Tasmania	0712	0804	0 5
7400	Santiago de Chile	TLRS-1	Chile	8403	8405	0 3
7401	Cerro Tololo	TLRS-1, -3	Chile	8405	9103	6 11
7403	Arequipa	TLRS-3	Peru	9007	1110	20 4

No	Station Name	Type of station (F-stationary)	Country	From (ym)	To (ym)	Period y m
7404	Santiago de Chile	TLRS-2	Chile	9601	9609	0 9
7405B	Concepcion	TIGO	Chile	0204	0912	7 9
7405IR	Concepcion	TIGO	Chile	0208	1112	9 5
7406	San Juan	BEIJING-A	Argentina	0603	1112	5 10
7410	Algonquin	TLRS-4	Kanada, Ontario	9306	9309	0 4
7411	La Grande	TLRS-4	Kanada, Quebec	9407	9409	0 3
7501	Hartebeesthoek	MTLRS-1	RSA	9306	9308	0 3
7501	Hartebeesthoek	MOBLAS-6	RSA	0007	1112	11 6
7502	Sutherland	MTLRS-1	RSA	9308	9310	0 3
7505	Sofia	MTLRS-1	Bulgaria	9509	9510	0 2
7510	Askites	MTLRS-1, -2	Greece	8605	9207	6 3
7512	Katavia	MTLRS-1, -2	Greece	8609	9205	5 9
7515	Dionysos	MTLRS-1, -2	Greece	8607	9206	6 0
7517	Roumeli	MTLRS-2, -1, TLRS-1	Greece	8605	9208	6 4
7520	Karitsa	MTLRS-1	Greece	8603	9509	9 7
7525	Xrisokalaria	MTLRS-2, TLRS-1	Greece	8609	9410	8 2
7530	Bar Giyyora	MOBLAS-2	Israel	8607	9410	8 4
7540	Matera	MTLRS-1	Italy	8601	8603	0 3
7541	Matera	MTLRS-2, TLRS-1	Italy	8601	9503	9 3
7542	Monte Vende	MTLRS-2	Italy	9108	9109	0 2
7543	Noto	MTLRS-2, TLRS-1	Italy	9011	9310	3 0
7544	Lampedusa	MTLRS-2, -1	Italy	8709	9212	5 4
7545	Cagliari	MTLRS-2, TLRS-1	Italy	8511	9403	8 7
7546	Medicina	MTLRS-2, TLRS-1	Italy	8804	9412	6 9
7548	Cagliari	F	Italy	9405	0204	8 0
7550	Trieste	MTLRS-2	Italy	8603	8907	3 5
7560	Riga	MTLRS-1	Latvia	9108	9110	0 3
7561	Simeiz	MTLRS-1	Ukraine	9110	9111	0 2
7575	Diyarbakir	MTLRS-1	Turkey	8704	8909	2 6

No	Station Name	Type of station (F-stationary)	Country	From (ym)	To (ym)	Period y m
7580	Melengiclick	TLRS-1	Turkey	8704	9301	5 10
7585	Yozgat	MTLRS-1	Turkey	8706	9208	5 3
7587	Yiglica	TLRS-1, MTLRS-1	Turkey	8706	9412	7 7
7589	Ankara	TLRS-1	Turkey	9301	9306	0 6
7594	Wettzell	TIGO	Germany	9710	0111	4 2
7596	Wettzell	MTLRS-2, -1	Germany	8503	9504	10 2
7597	Wettzell	MTLRS-1	Germany	9407	9612	2 6
7602	Tromso	MTLRS-2	Norway	9008	9009	0 2
7604	Brest	FTLRS	France	0409	0412	0 4
7805	Metsahovi	F	Finland	8311	9701	13 3
7806	Metsahovi	F	Finland	9802	0503	7 2
7810	Zimmerwald	F	Switzerland	8506	9504	9 11
7810B	Zimmerwald	F	Switzerland	9612	0801	11 2
7810IR	Zimmerwald	F	Switzerland	0208	0801	5 6
7810G	Zimmerwald	F	Switzerland	0804	1112	3 9
7811	Borowiec	F	Poland	9307	1003	15 9
7820	Kunming	F	China	9901	0902	10 2
7821	Shanghai	F	China	0512	1112	6 1
7822	Papeete	FTLRS	Tahiti	1106	1109	0 4
7823	San Fernando	FTLRS	Spain	0406	0406	0 1
7824	San Fernando	F	Spain	9404	1112	17 9
7825	Mount Stromlo	F	Australia - Canberra	0408	1112	7 5
7830	Chania	FTLRS	Greece	0304	0311	0 8
7831	Helwan	F	Egypt	8310	0011	17 2
7832	Riyadh	F	Saudi Arabia	9601	1111	15 11
7833	Kootwijk	F	Holland	8309	8411	1 3
7834	Wettzell	F	Germany	8506	9102	5 9
7835	Grasse	F	France	8506	0507	20 2
7836	Potsdam	F	Germany	9301	0407	11 7

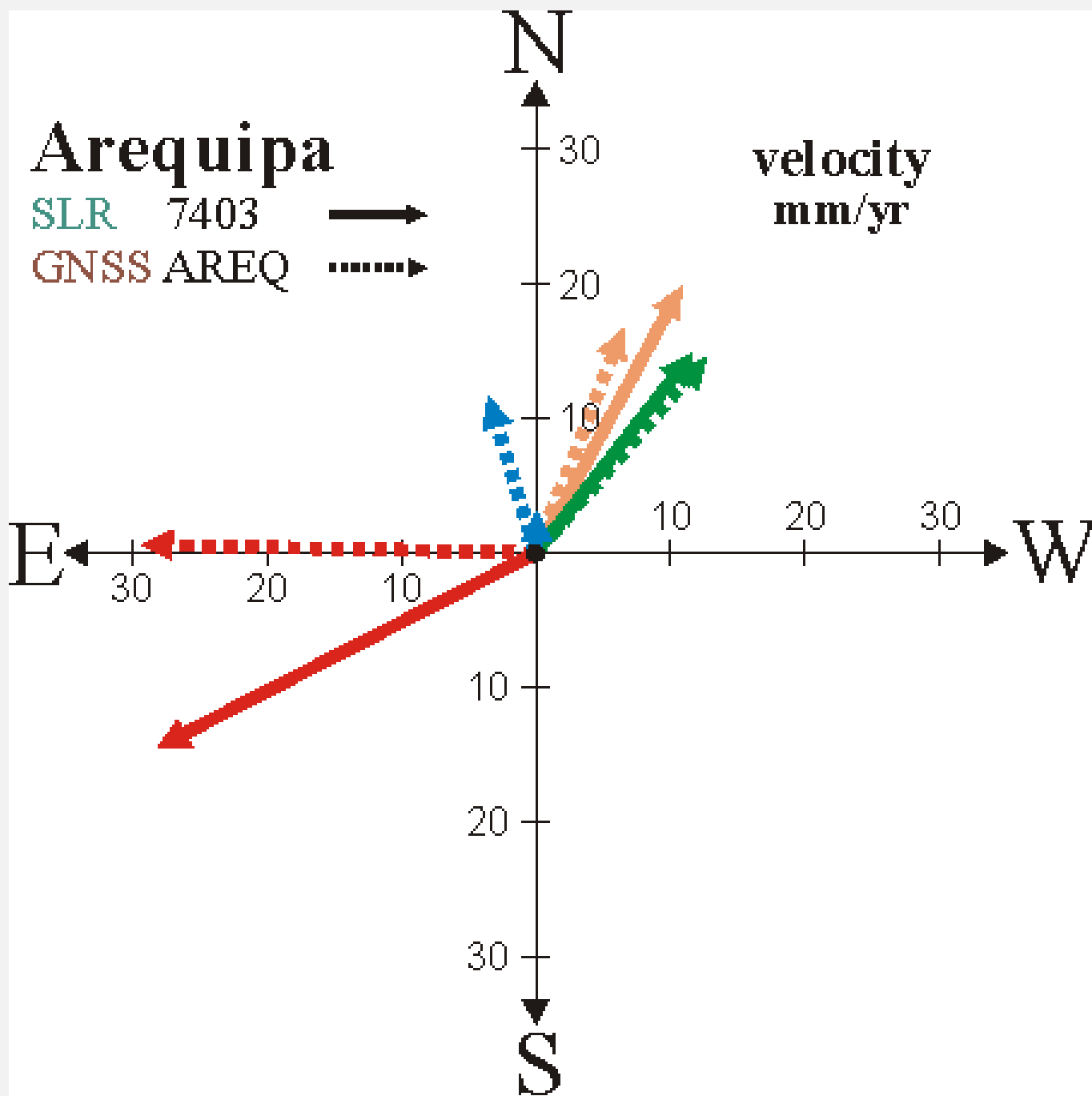
No	Station Name	Type of station (F-stationary)	Country	From (ym)	To (ym)	Period y m
7837	Shanghai	F	China	8311	0504	21 6
7838	Simosato	F	Japan	8506	1112	26 7
7839	Graz	F	Austria	8506	1112	26 7
7840	Herstmonceaux	F	UK	8506	1112	26 7
7841	Potsdam	F	Germany	0301	1112	9 0
7843	Orroral	F	Australia - Canberra	8708	9810	11 3
7845	Grasse	F	France	9711	1112	14 2
7847	Yarragadee	PSLR	West Australia	9603	9604	0 2
7848	Ajaccio	FTLRS	France	0202	0810	6 9
7849	Mount Stromlo	F	Australia - Canberra	9807	0301	4 7
7850	McDonald	TLRS-4	USA, Texas	9302	9304	0 3
7853	Owens Valley	MTLRS-1	USA, California	8810	9007	1 10
7882	Cabo San Lucas	TLRS-2, -1, -4	Mexico	8402	9405	10 4
7883	Ensenada	TLRS-4	Mexico	8905	9402	4 10
7884	Albuquerque	F	USA, New Mexico	9505	9701	1 9
7886	Quincy	TLRS-1	USA, California	8407	8410	0 4
7907	Arequipa	F	Peru	8309	9208	9 0
7918	Greenbelt	TLRS-3, -4, MOB LAS-6	USA, Maryland	9004	9707	7 4
7920	Greenbelt	TLRS-1,-3,-4	USA, Maryland	8812	9404	5 5
7939	Matera	F	Italy	8309	0011	17 3
7941	Matera	F	Italy	0107	1112	10 6
7943	Orroral	F	Australia-Canberra	8608	8610	0 3
8833	Kootwijk	MTLRS-1,-2	Holland	8404	9508	11 5
8834	Wettzell	F	Germany	9104	1112	20 9

3D RMS 1983 - 2012



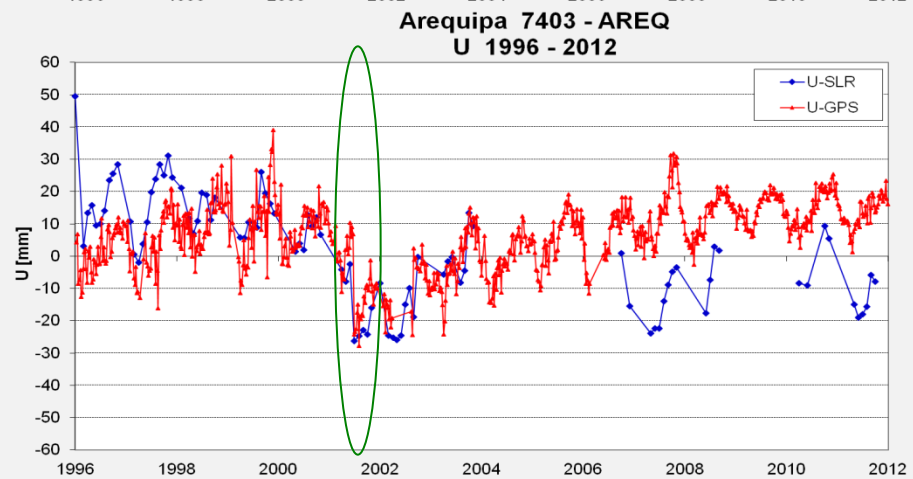
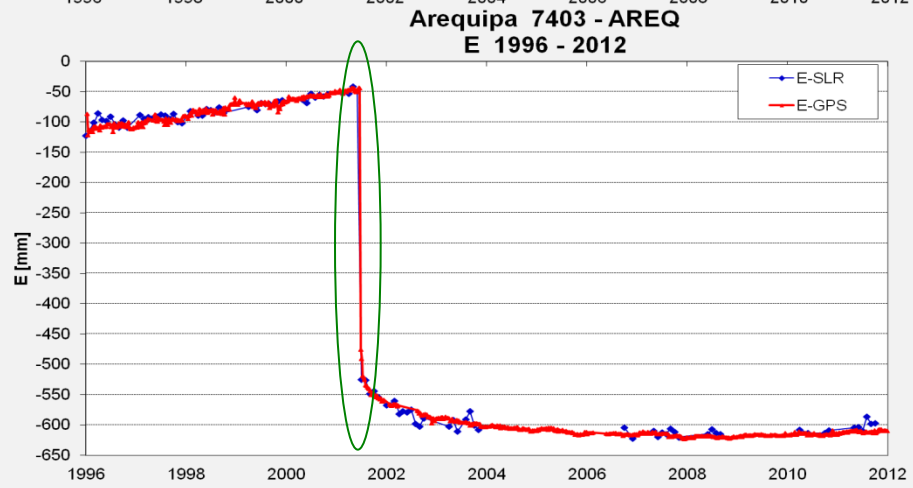
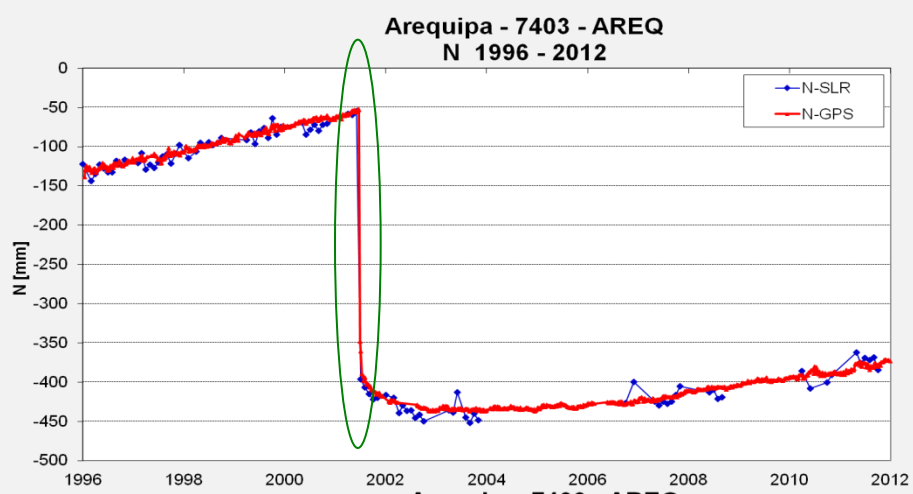
Earthquakes SLR-GNSS stations

STATION		Date	SLR Shift [mm]	GNSS Shift [mm]	
Arequipa	7403 AREQ	2001-06-23	3D = 719.4 N = -419.3 E = -584.4 U = -12.0	3D = 739.8 N = -430.7 E = -601.4 U = -8.2	Earthquake, Arequipa 2001
Concepcion	7405 CONZ	2010-02-27	3D = 3291.1 N = 673.4 E = 3221.1 U = -49.4	3D = 3286.8 N = 671.1 E = 3217.0 U = -59.5	Earthquake, Concepcion 2010
San Juan	7406	2010-02-27	3D = 50.6 N = -31.2 E = -34.7 U = 19.5	No GNSS data	Earthquake, Concepcion 2010
Arequipa	7403 AREQ	2010-02-27	3D = 36.1 N = 23.2 E = 25.1 U = -11.7	3D = 8.0 N = 1.8 E = 1.6 U = -7.6	Earthquake, Concepcion 2010 ???
Monument Peak	7110 MONP	2010-04-03	3D = 20.4 N = -4.8 E = -19.0 U = -5.8	3D = 30.1 N = -3.5 E = -27.6 U = -11.6	Earthquake
Koganei	7308 KGNI	2011-03-11	3D = 343.6 N = 52.5 E = 339.5 U = 8.5	3D = 371.6 N = 63.4 E = 366.1 U = 2.2	Tsunami, Japan 2011
Simosato	7838	2011-03-11	3D = 36.9 N = 13.3 E = 26.9 U = 21.5	No GNSS data	Tsunami, Japan 2011
Changchun	7237 CHAN	2011-03-11	3D = 20.7 N = -3.9 E = 16.8 U = 11.4	3D = 16.8 N = -6.8 E = 14.2 U = 5.9	Tsunami, Japan 2011

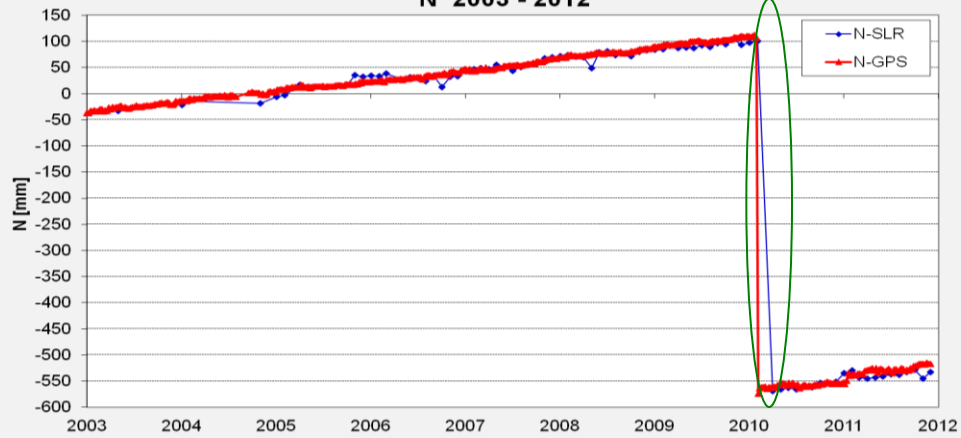


Stations velocities and their directions (azimuths) before and after the earthquakes

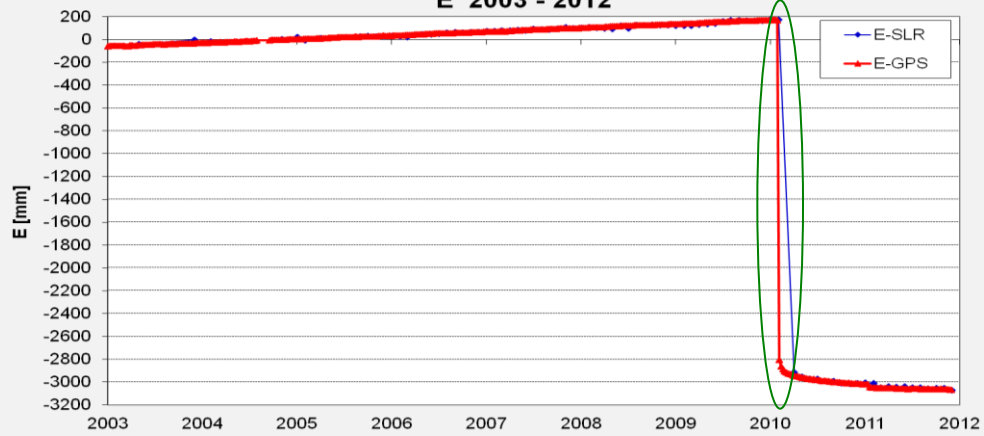
Station	Period	V [mm/yr]		A [deg.]	
		SLR	GNSS	SLR	GNSS
7403/AREQ	96.01 – 01.06	18.9	19.2	37.9	41.0
7403/AREQ	01.07 – 03.11	31.5	29.2	242.8	271.2
7403/AREQ	06.10 – 08.09	2.4	12.1	0.0	343.2
7403/AREQ	10.04 – 11.12	22.5	11.5	28.4	21.0
7405/CONZ	03.05 – 10.02	37.5	39.1	57.6	58.2
7405/CONZ	10.04 – 11.12	76.1	92.4	286.5	287.6
7406	06.03 – 10.02	18.5	No data	36.0	No data
7406	10.03 – 11.11	13.7		36.4	
7110/MONP	96.01 – 10.03	42.6	42.7	294.8	295.1
7110/MONP	10.04 – 11.12	48.4	49.5	290.7	293.5



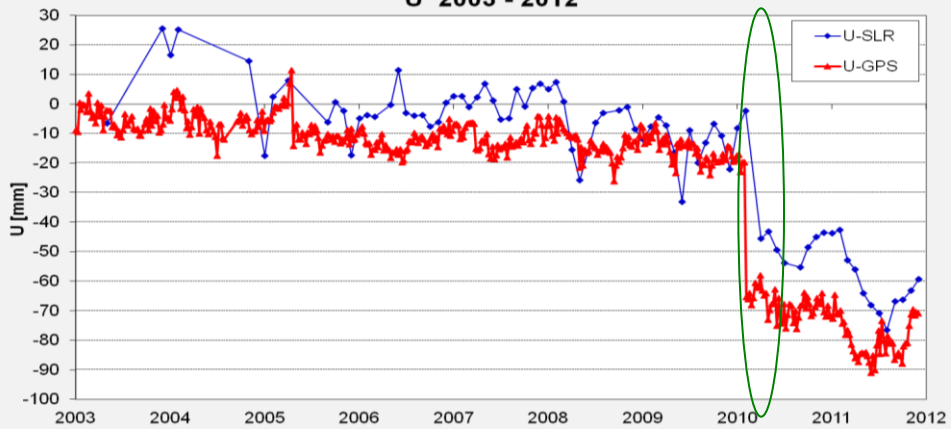
Concepcion 7405 - CONZ
N 2003 - 2012



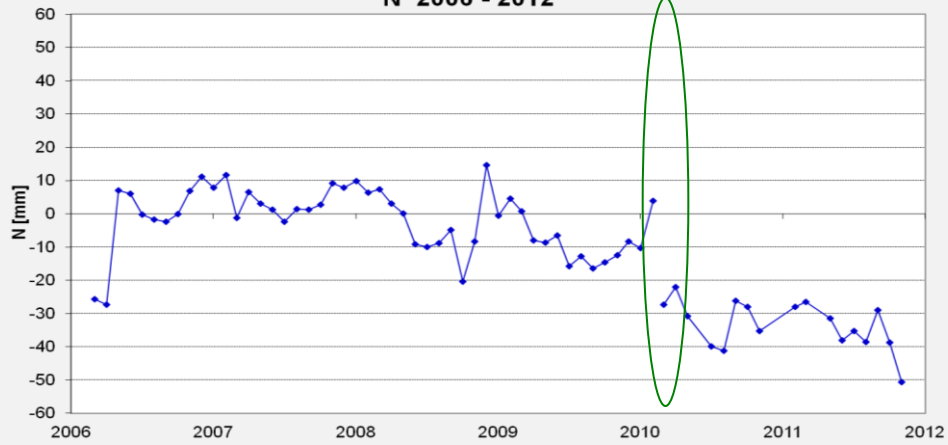
Concepcion 7405 - CONZ
E 2003 - 2012



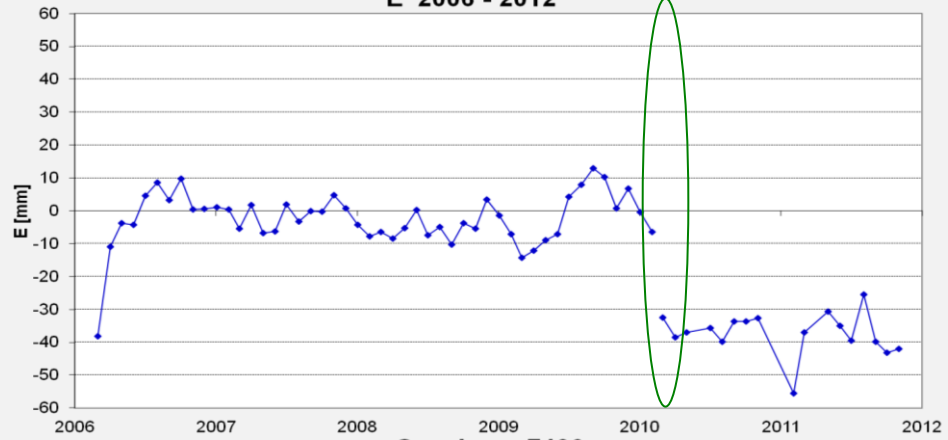
Concepcion 7405 - CONZ
U 2003 - 2012



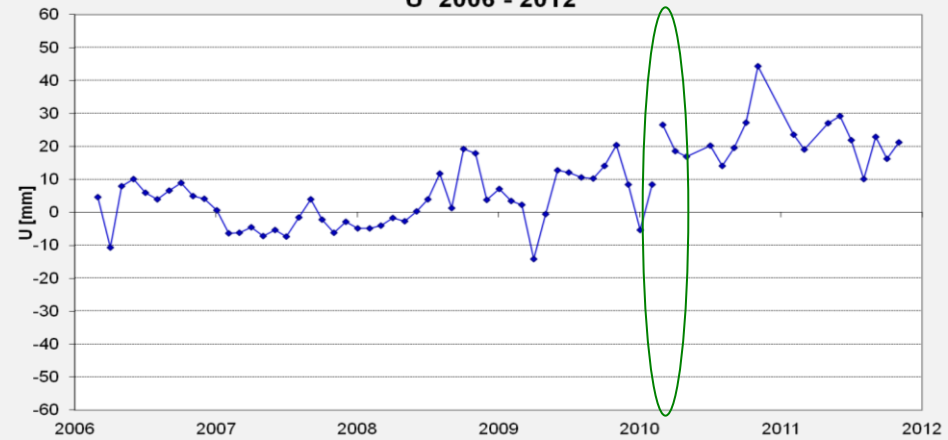
**San Juan 7406
N 2006 - 2012**



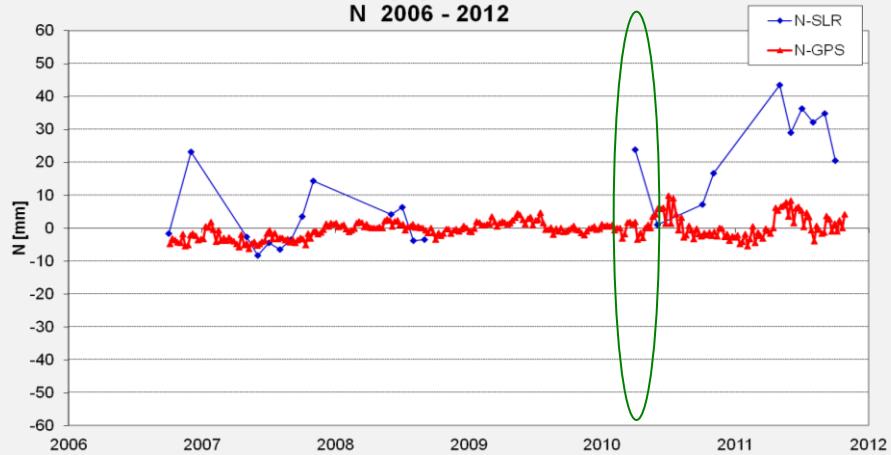
**San Juan 7406
E 2006 - 2012**



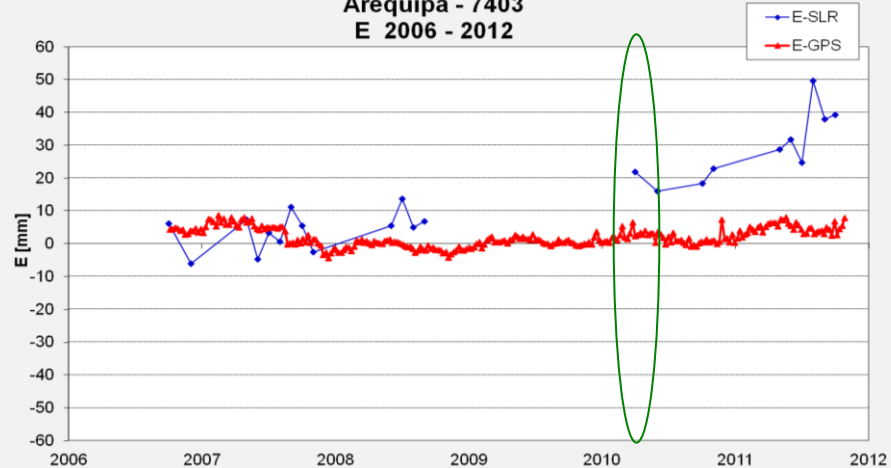
**San Juan 7406
U 2006 - 2012**



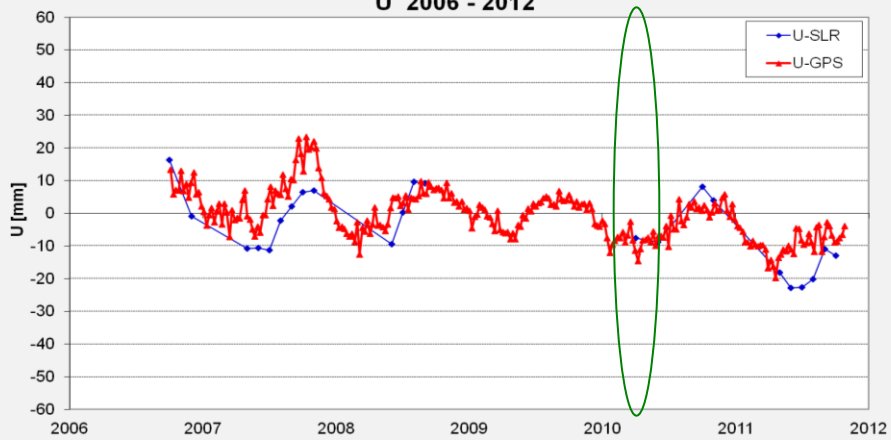
**Arequipa 7403
N 2006 - 2012**



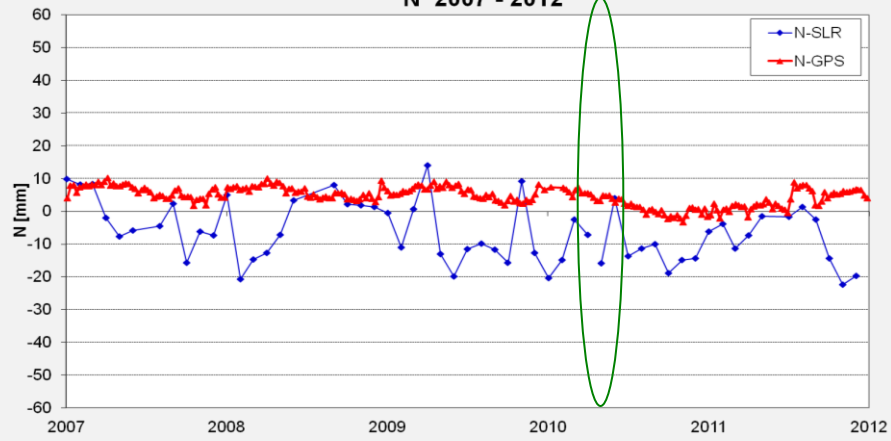
**Arequipa - 7403
E 2006 - 2012**



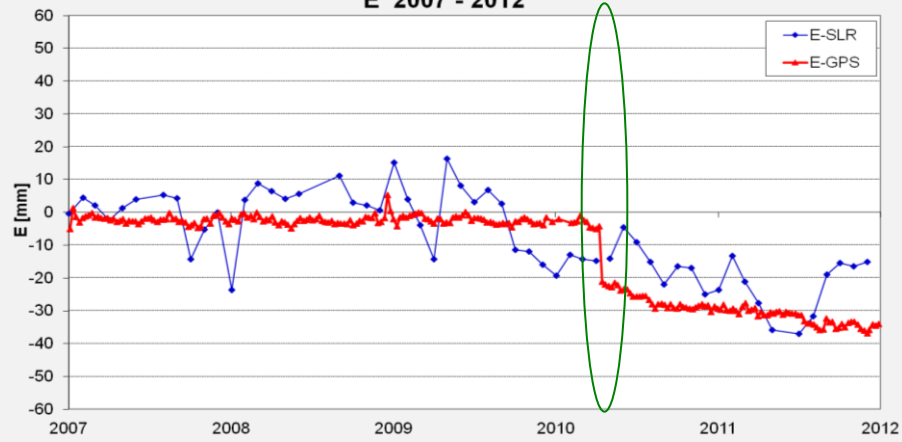
**Arequipa 7403
U 2006 - 2012**



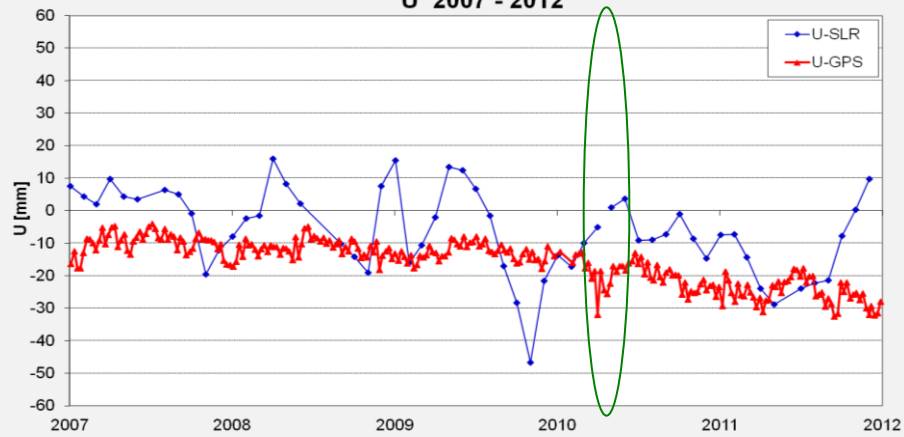
Monument Peak 7110 - MONP
N 2007 - 2012

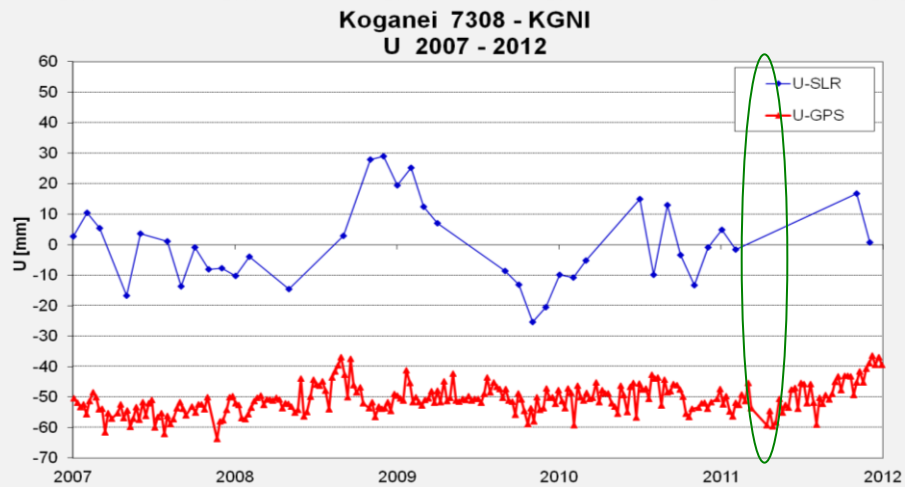
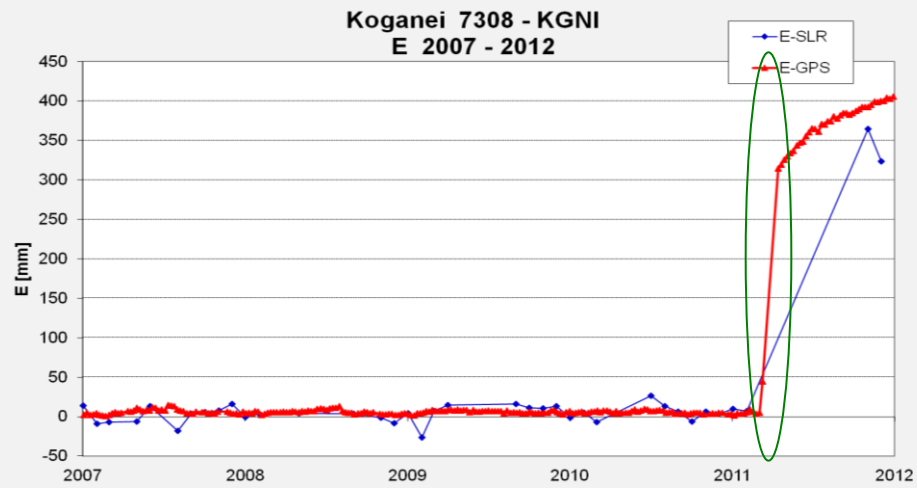
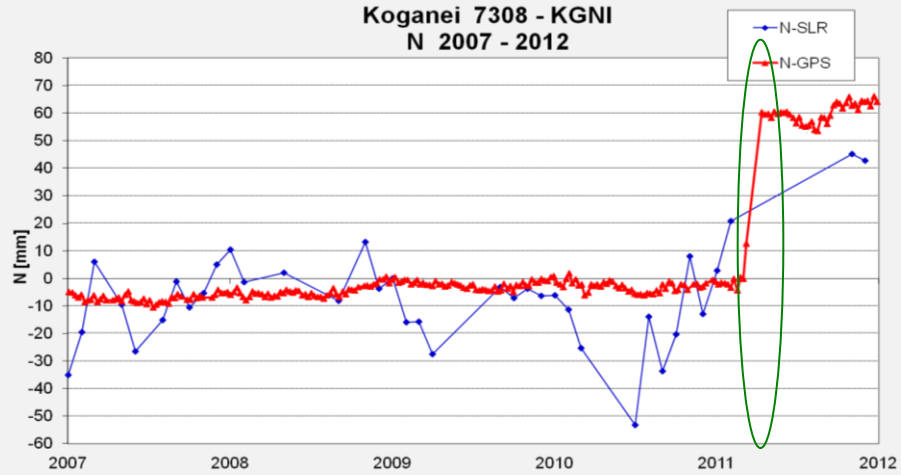


Monument Peak 7110 - MONP
E 2007 - 2012

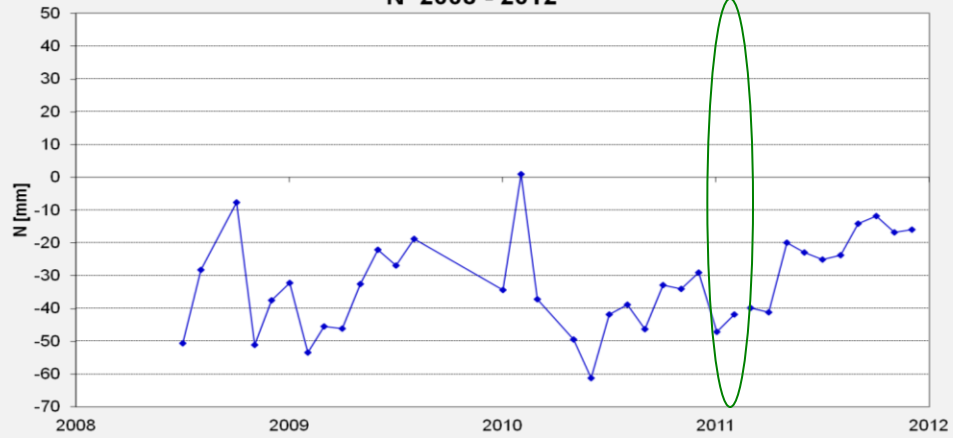


Monument Peak 7110 - MONP
U 2007 - 2012

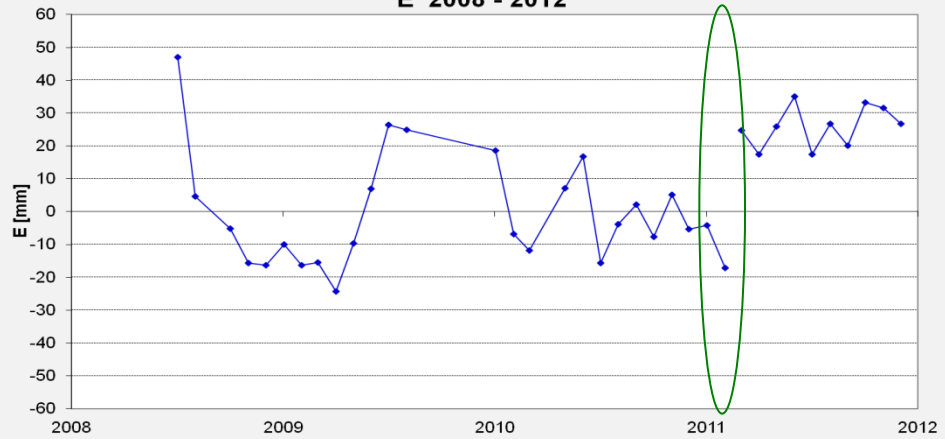




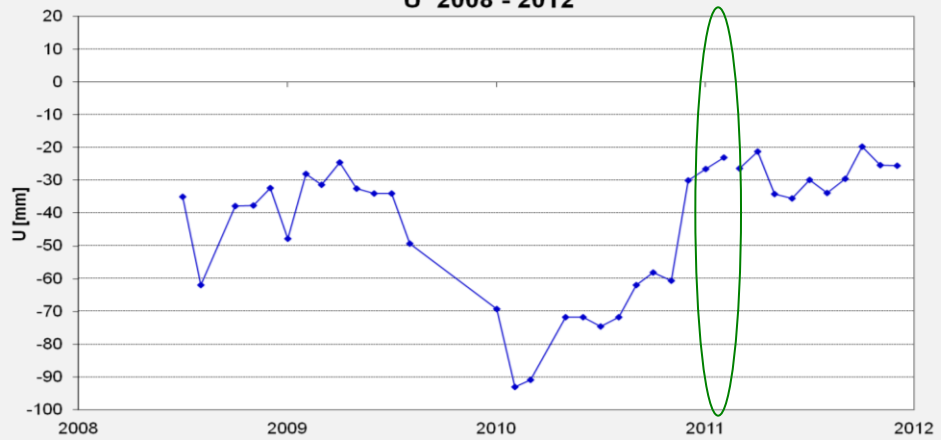
**Simosato 7838
N 2008 - 2012**



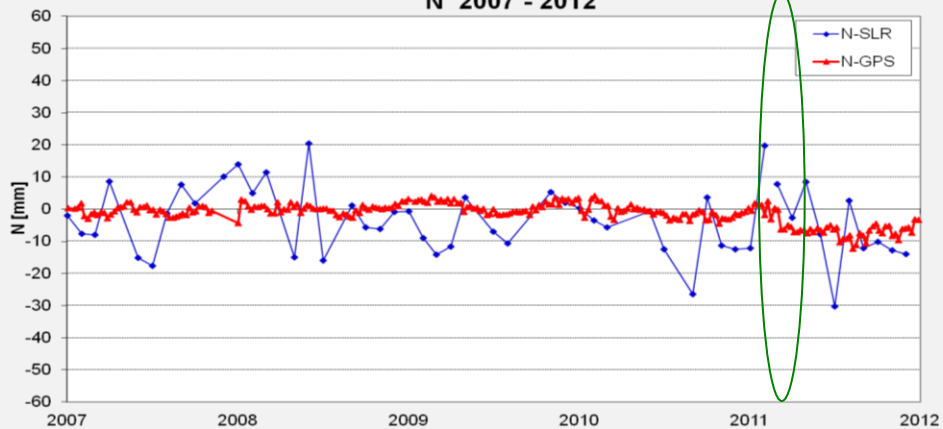
**Simosato 7838
E 2008 - 2012**



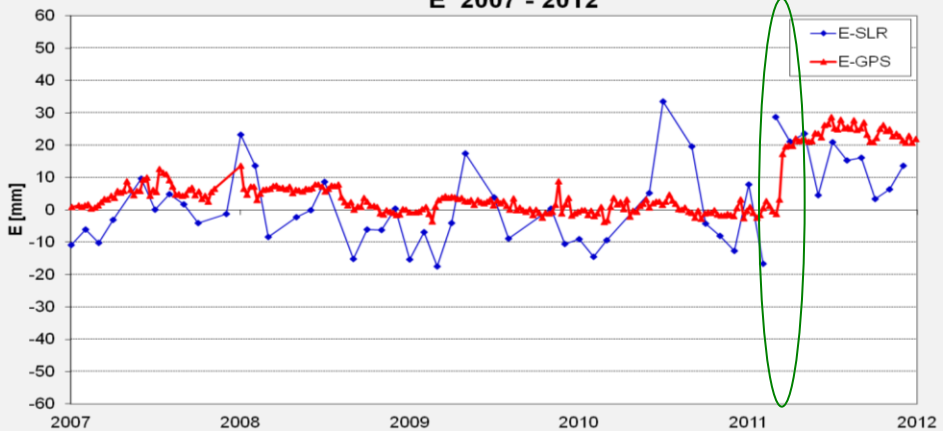
**Simosato 7838
U 2008 - 2012**



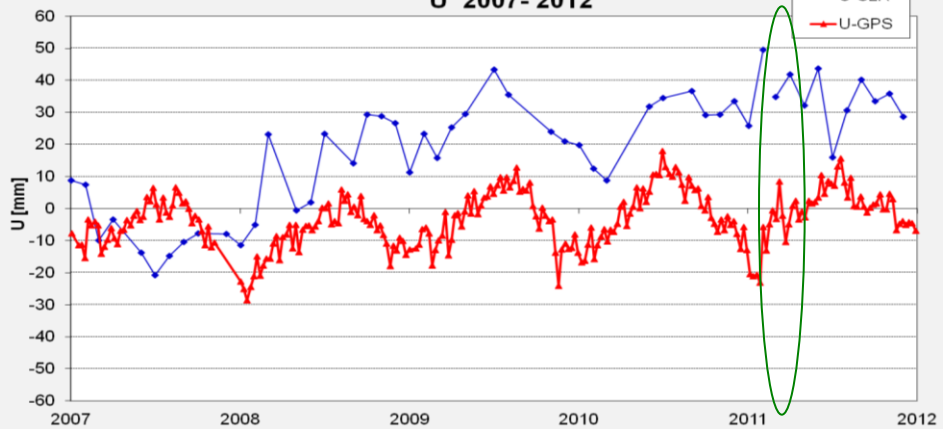
Changchun 7237 - CHAN
N 2007 - 2012



Changchun 7237 - CHAN
E 2007 - 2012



Changchun 7237 - CHAN
U 2007 - 2012



CONCLUSIONS

Results before 1993 have three times worse accuracy due to only one LAGEOS satellite and lower technical parameters of the SLR stations

Results in the span 1993 – 1996 have significant systematic biases for the most important stations

Results during a span 1997 – 2012 show good stability, 24 SLR stations had accuracy below 10 mm, the best stations reached 4 mm 3D RMS

We observed slight deterioration of quality of the results in the last several years due to systematic biases and effects of earthquakes of the main stations

Earthquakes are significant problem in ITRF2008, in the last three years six SLR stations changed position and their results can't to be use for precise orbits determination

Strong earthquakes (eg. Arequipa, Concepcion) changed station direction of the movement near 180 degrees, the come back to initial position is the long time process up to more than 10 years and then velocity and directions of this movement are not precise determined

ACKNOWLEDGEMENTS

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ILRS and IGS stations for their continuous efforts to provide
high-quality SLR and GNSS data**

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No. N N526 231839 and N N526 159540**

Thank you