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Determination of the coordinates of SLR stations from the LARES satellite

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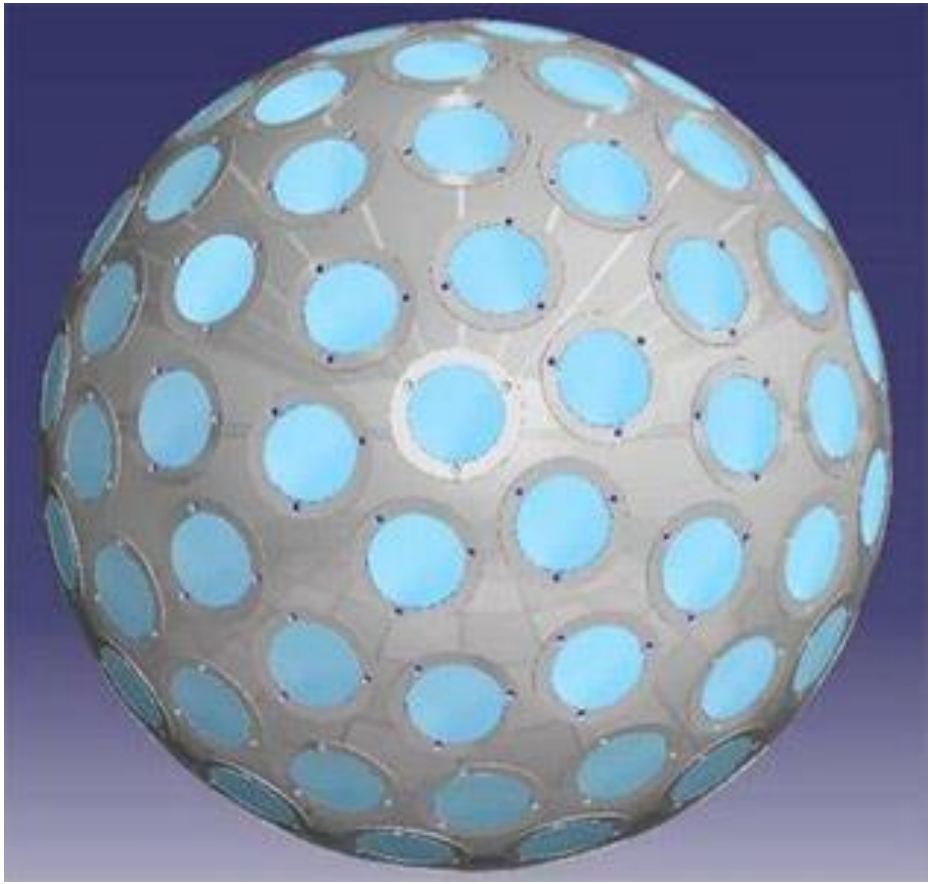
Objectives

Can the LARES satellite be used as a LAGEOS-3 satellite?

The quality of the station coordinates determined from the observation results of the LARES satellite

Comparizon with LAGEOS-1 and LAGEOS-2

LARES – LAser RElativity Satellite



LARES parameters

Launch: Guiana Space Center 13 February 2012

First SLR returns: 17 February 2012 - Yarragadee

Eccentricity: 0.0008

Perigee: 1437 km

Apogee: 1451 km

Inclination: 69.49 degrees

Period: 114.75 minutes

Mass: 386.8 kg

Satellite dimension: 364 mm

92 cube corner reflectors: 38.1 mm x 27.9 mm

LARES – main scientific targets

- Testing of General Relativity, mainly Lense-Thirring effect
- Geodynamics
- Satellite Geodesy

LARES for Satellite Geodesy

Advantages:

- great mass
- small cross section area
- small area to mass ratio

  A/M = 2.69 x10^{-4} m^2/kg

  the densest known object in the Solar System
- circular orbit, eccentricity 0.0008

Disadvatages:

- low satellite orbit – 1450 km

  high numbers of gravitational field coefficients: up to 100x100

  atmosheric drag

  Earth albedo

GSFC NASA orbital program GEODYN-II

models of forces and parameters - **LARES** satellite

Model of the Earth's gravity field: EGM2008, 100x100
Earth tide model: IERS Conventions 2003
Ocean tide model: GOT99.2
The tidal parameters of the earth's crust: k2 = 03, k3 = 0.093, phase k2 = 0.0
Gravity field of the Moon, Sun and planets: DE403
Solar radiation pressure: CR = 1.13
Earth albedo
Earth relativistic effects
Atmospheric drag: MSIS86
Precession and nutation: IAU2000
Position and velocity of the stations: ITRF2014
Pole motion and UT1: IERS C04 (every 1 day)
Love and Shida numbers: H2 = 0.6078, L2 = 0.0847
Tide pole

Input data

Results of SLR stations - 15 stations

Atmospheric parameters at the station level: pressure, temperature, humidity

Satellite Center of Mass correction: 13.1 cm

Cross section and mass of the satellite: 0.1041 m^2, 386.8 kg

Laser wavelength: 532 nm

Tropospheric correction: Mendes-Pavlis model

Output data

Satellite state vector: 6 parameters

Geocentric station coordinates: 3 parameters

Empirical acceleration: 9 parameters at 12 hours intervals

Numerical Integration

Cowell's method

Orbit integration step size: 30 sec

Arc length: 1 week

List of the base SLR stations for LARES orbits determination
29 February 2012 - 31 December 2016

Station No	Station	Number of week arcs / >50 NP/arc	Number of accepted NP	NP per arc
7090	Yarragadee (Australia)	178/168	50779	302
7105	Greenbelt (Maryland-USA)	164/132	19159	145
7110	Monument Peak (California-USA)	166/107	12105	113
7119	Haleakala (Hawaii-USA)	147/46	3991	87
7124	Tahiti (French Polinesia)	103/24	1581	66
7501	Hartebeesthoek (South Africa)	137/76	9967	131
7810	Zimmerwald (Switzerland)	130/122	27656	227
7825	Mount Stromlo (Australia)	176/127	14051	111
7838	Simosato (Japan)	131/31	2352	75
7839	Graz (Austria)	164/135	24045	178
7840	Herstmonceux (UK)	172/118	13105	111
7841	Potsdam (Germany)	153/115	15532	135
7845	Grasse (France)	70/14	1086	78
7941	Matera (Italy)	162/117	13720	117
8834	Wettzell (Germany)	156/94	11602	123

LARES results
29 February 2012 - 31 December 2016

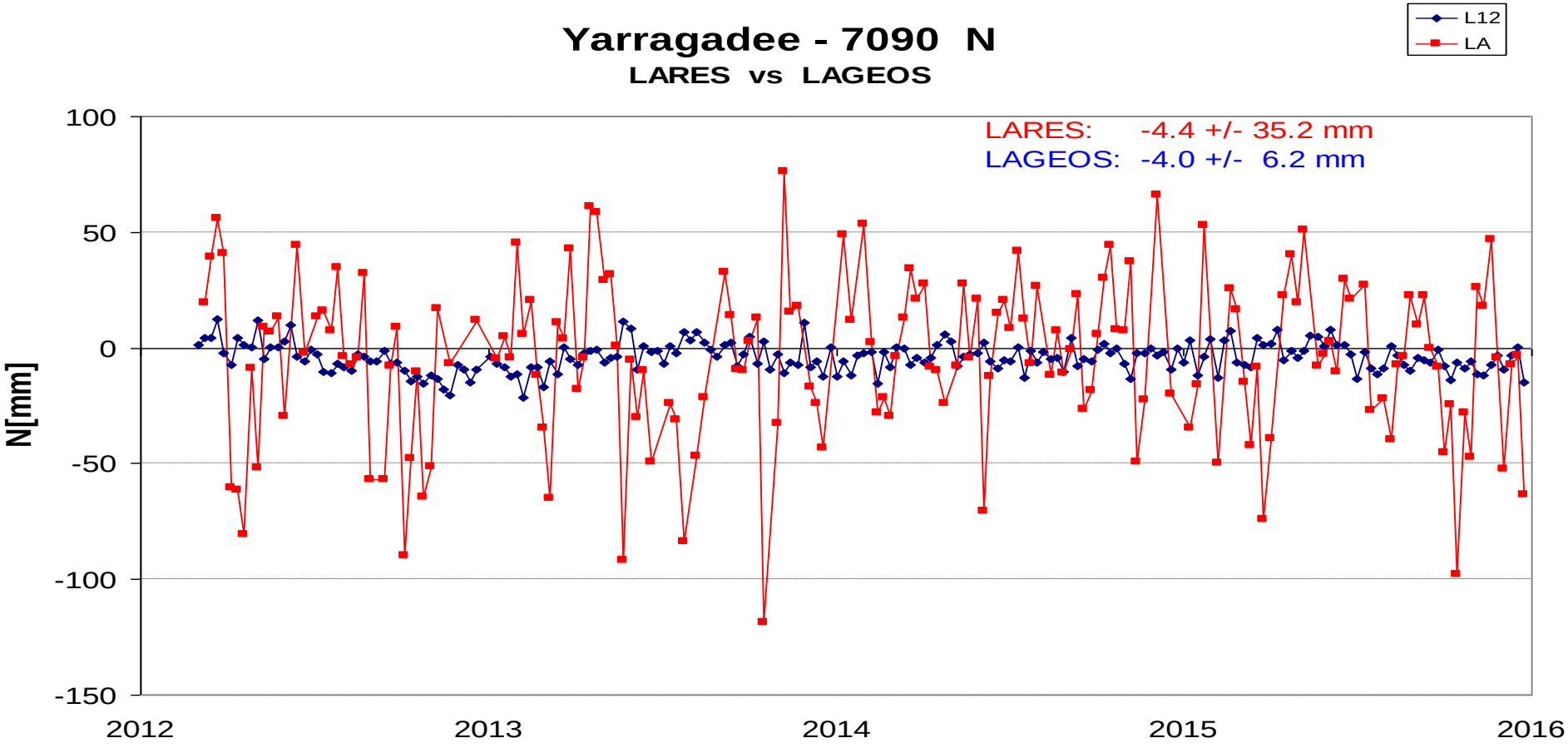
Station No	Station	RMS of station coordinates 3D [mm]	st. dev. coordinates determination [mm]	percent of accepted data
7810	Zimmerwald (Switzerland)	14.7	3.3	94
7839	Graz (Austria)	15.2	3.9	82
7840	Herstmonceux (UK)	19.1	5.1	69
7841	Potsdam (Germany)	15.3	4.3	75
7845	Grasse (France)	25.4	6.7	20
7941	Matera (Italy)	15.4	4.5	72
8834	Wettzell (Germany)	12.2	3.8	60
7105	Greenbelt (Maryland-USA)	27.5	5.9	80
7110	Monument Peak (California-USA)	31.9	6.6	64
7090	Yarragadee (Australia)	29.3	5.7	94
7825	Mount Stromlo (Australia)	30.0	6.3	72
7119	Haleakala (Hawaii-USA)	45.7	8.3	31
7124	Tahiti (French Polinesia)	70.2	9.9	23
7838	Simosato (Japan)	46.0	9.7	24
7501	Hartebeesthoek (South Africa)	42.3	7.9	55

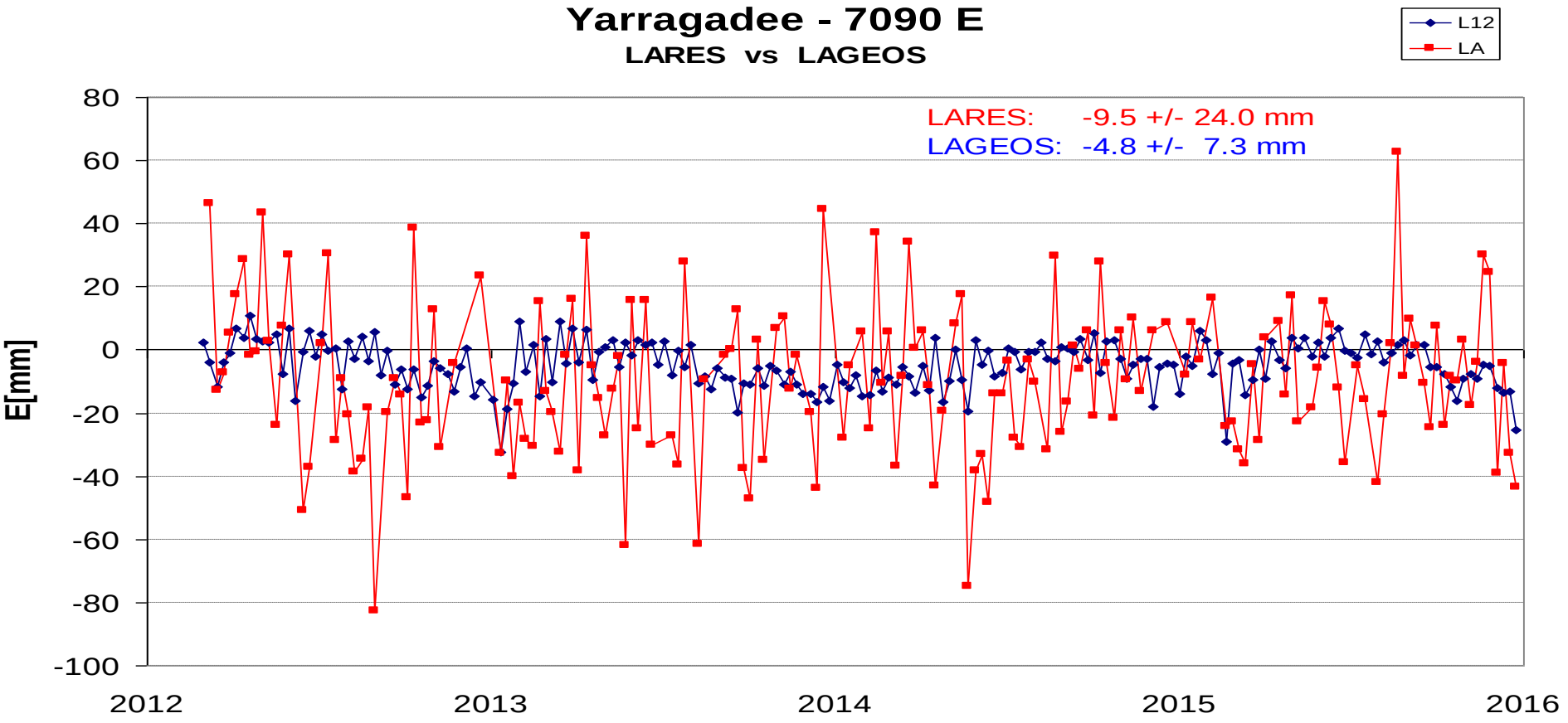
LAGEOS1+LAGEOS2 results
29 February 2012 - 31 December 2016

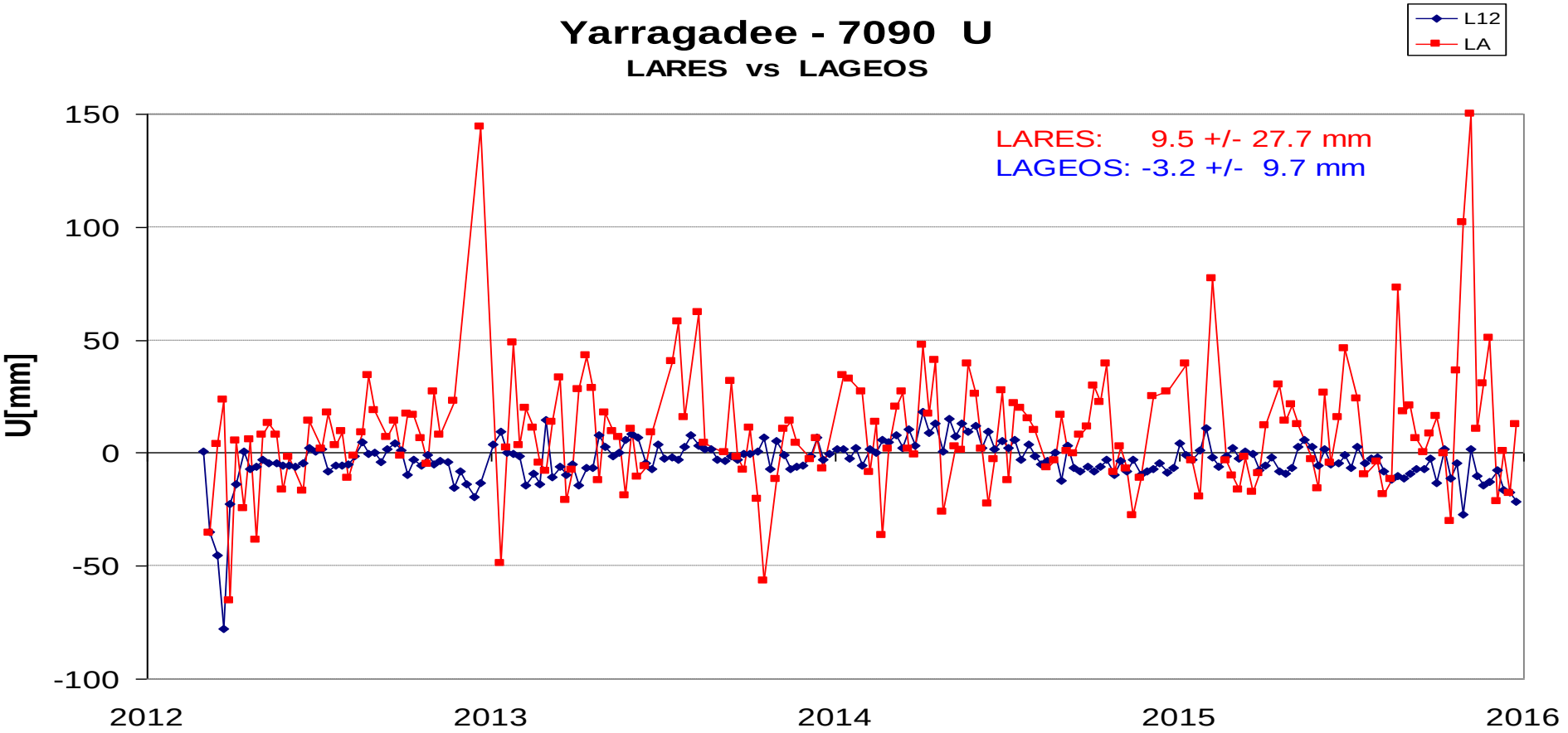
Station No	Station	RMS of station coordinates 3D [mm]	st. dev. coordinates determination [mm]	percent of accepted data
7810	Zimmerwald (Switzerland)	5.8	1.9	95
7839	Graz (Austria)	6.8	3.0	74
7840	Herstmonceux (UK)	6.9	2.8	87
7841	Potsdam (Germany)	8.6	3.7	60
7845	Grasse (France)	9.1	3.1	75
7941	Matera (Italy)	7.4	2.2	95
8834	Wettzell (Germany)	8.1	3.2	65
7105	Greenbelt (Maryland-USA)	7.7	2.5	89
7110	Monument Peak (California-USA)	10.5	2.9	88
7090	Yarragadee (Australia)	7.9	1.9	100
7825	Mount Stromlo (Australia)	8.1	2.7	93
7119	Haleakala (Hawaii-USA)	13.7	3.3	80
7124	Tahiti (French Polinesia)	12.7	3.9	36
7838	Simosato (Japan)	14.0	3.1	80
7501	Hartebeesthoek (South Africa)	14.3	2.7	82

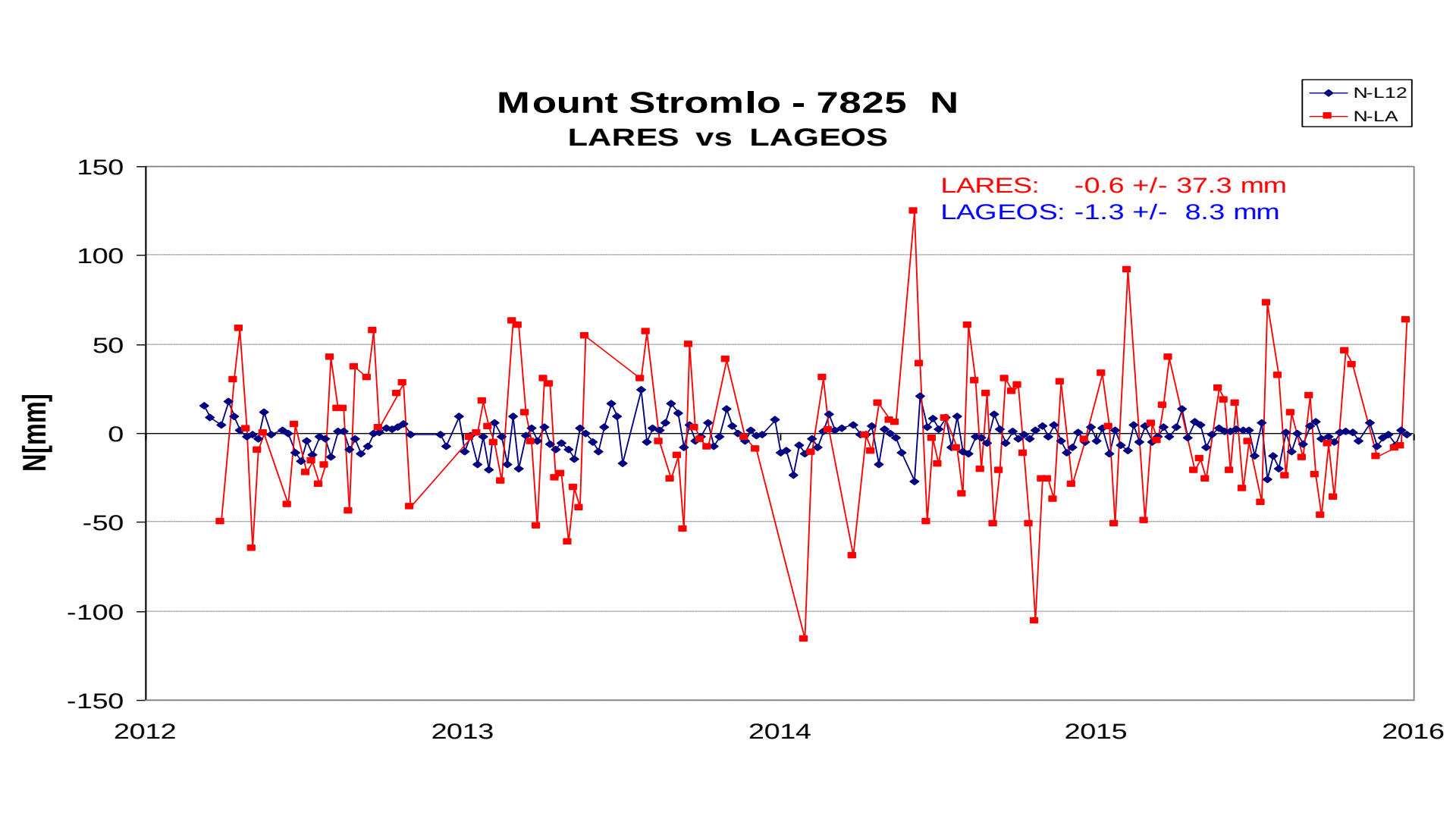
LARES+LAGEOS1+LAGEOS2 results
29 February 2012 - 31 December 2016

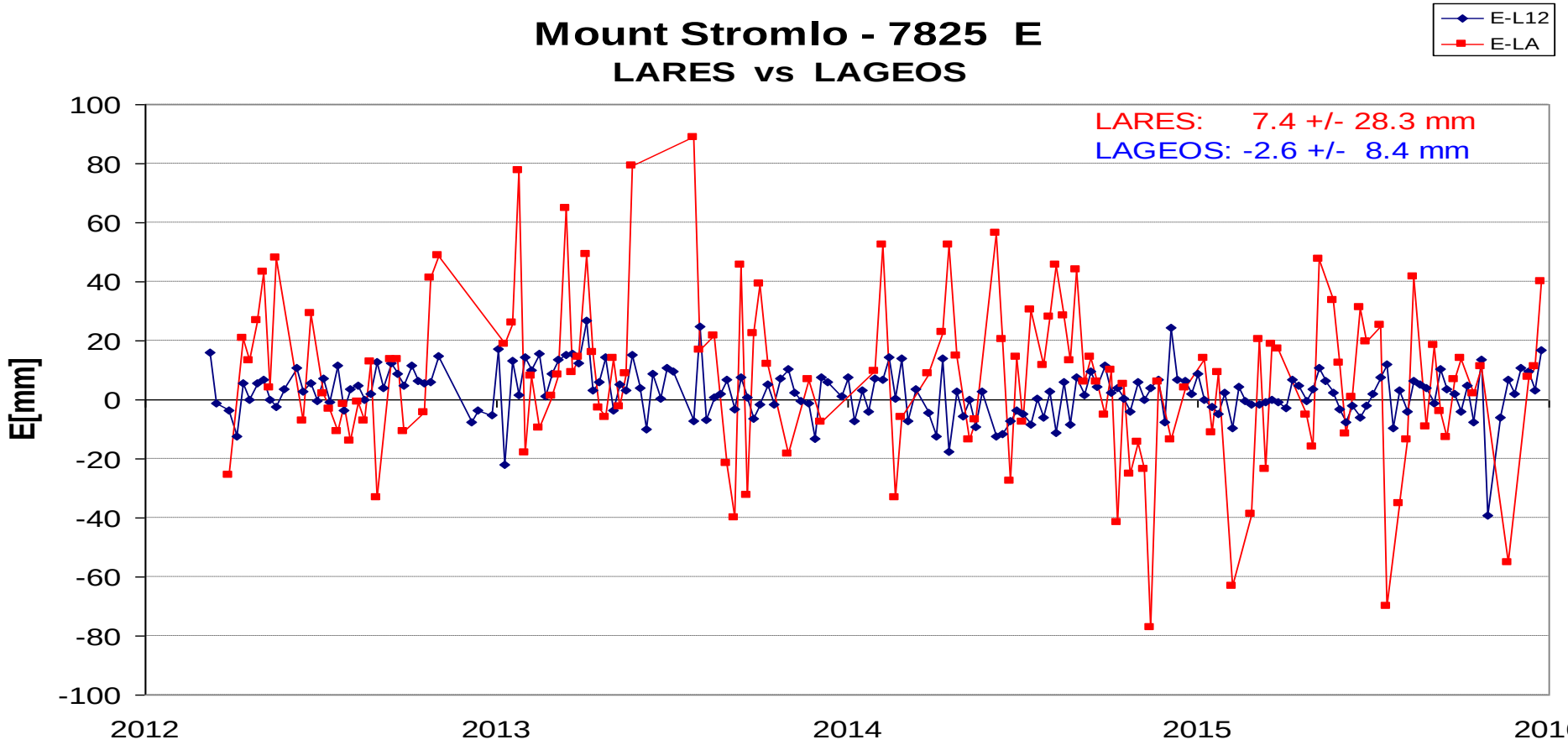
Station No	Station	RMS of station coordinates 3D [mm]	st. dev. coordinates determination [mm]	percent of accepted data
7810	Zimmerwald (Switzerland)	5.6	1.6	91
7839	Graz (Austria)	7.3	2.5	86
7840	Herstmonceux (UK)	7.2	2.5	91
7841	Potsdam (Germany)	8.6	2.8	78
7845	Grasse (France)	7.4	2.7	40
7941	Matera (Italy)	7.0	2.0	94
8834	Wettzell (Germany)	7.7	2.7	79
7105	Greenbelt (Maryland-USA)	8.1	2.3	91
7110	Monument Peak (California-USA)	11.8	2.7	91
7090	Yarragadee (Australia)	7.6	1.7	93
7825	Mount Stromlo (Australia)	8.9	2.5	96
7119	Haleakala (Hawaii-USA)	14.2	3.1	81
7124	Tahiti (French Polinesia)	15.8	4.0	43
7838	Simosato (Japan)	14.5	3.0	75
7501	Hartebeesthoek (South Africa)	14.8	2.6	84

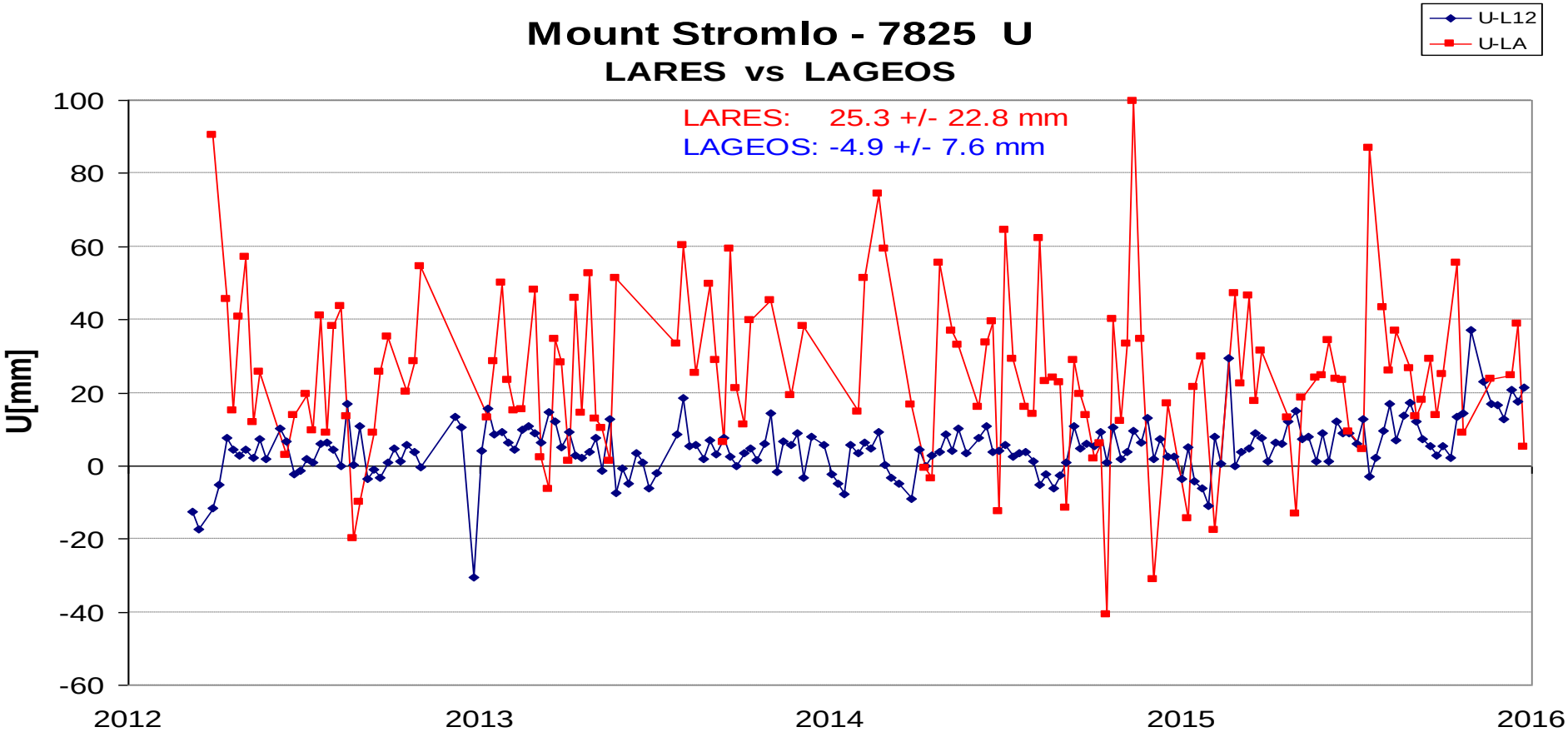

Yarragadee - 7090 N
LARES vs LAGEOS
L12
LA
LARES: -4.4 +/- 35.2 mm
LAGEOS: -4.0 +/- 6.2 mm
N[mm]
100
50
0
-50
-100
-150
2012
2013
2014
2015
2016


Yarragadee - 7090 E
LARES vs LAGEOS
L12
LA
LARES: -9.5 +/- 24.0 mm
LAGEOS: -4.8 +/- 7.3 mm
E[mm]
80
60
40
20
0
-20
-40
-60
-80
-100
2012
2013
2014
2015
2016


Yarragadee - 7090 U
LARES vs LAGEOS
L12
LA
LARES: 9.5 +/- 27.7 mm
LAGEOS: -3.2 +/- 9.7 mm
U[mm]
150
100
50
0
-50
-100
2012
2013
2014
2015
2016


Mount Stromlo - 7825 N
LARES vs LAGEOS
N-L12
N-LA
LARES: -0.6 +/- 37.3 mm
LAGEOS: -1.3 +/- 8.3 mm
N[mm]
150
100
50
0
-50
-100
-150
2012
2013
2014
2015
2016


Mount Stromlo - 7825 E
LARES vs LAGEOS
E-L12
E-LA
LARES: 7.4 +/- 28.3 mm
LAGEOS: -2.6 +/- 8.4 mm
E[mm]
100
80
60
40
20
0
-20
-40
-60
-80
-100
2012
2013
2014
2015
2016


Mount Stromlo - 7825 U
LARES vs LAGEOS
U-L12
U-LA
LARES: 25.3 +/- 22.8 mm
LAGEOS: -4.9 +/- 7.6 mm
U[mm]
100
80
60
40
20
0
-20
-40
-60
2012
2013
2014
2015
2016

LARES+LAGEOS1+LAGEOS2 results
29 February 2012 - 31 December 2016

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8834	Wettzell (Germany)	7.7	2.7	79
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7110	Monument Peak (California-USA)	11.8	2.7	91
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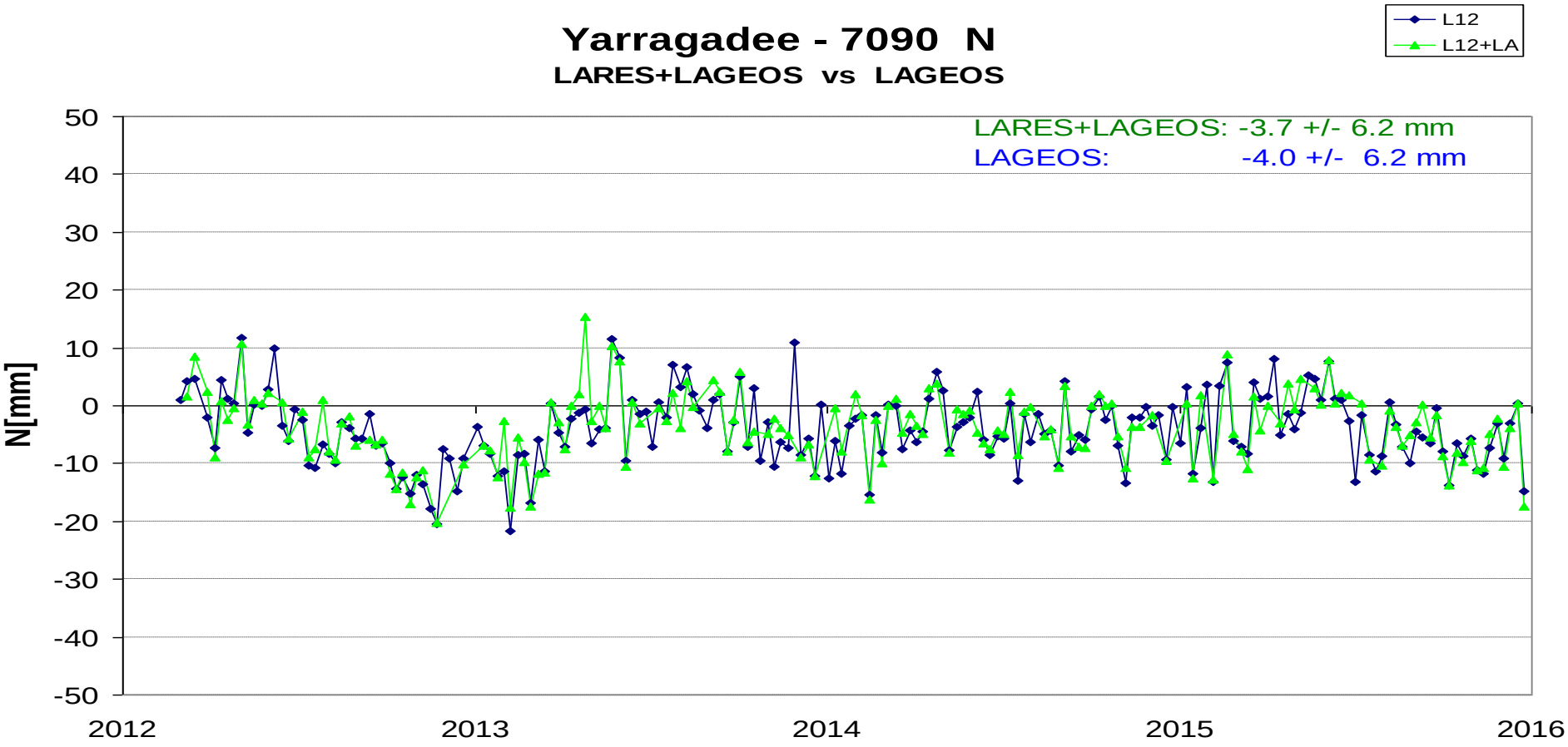
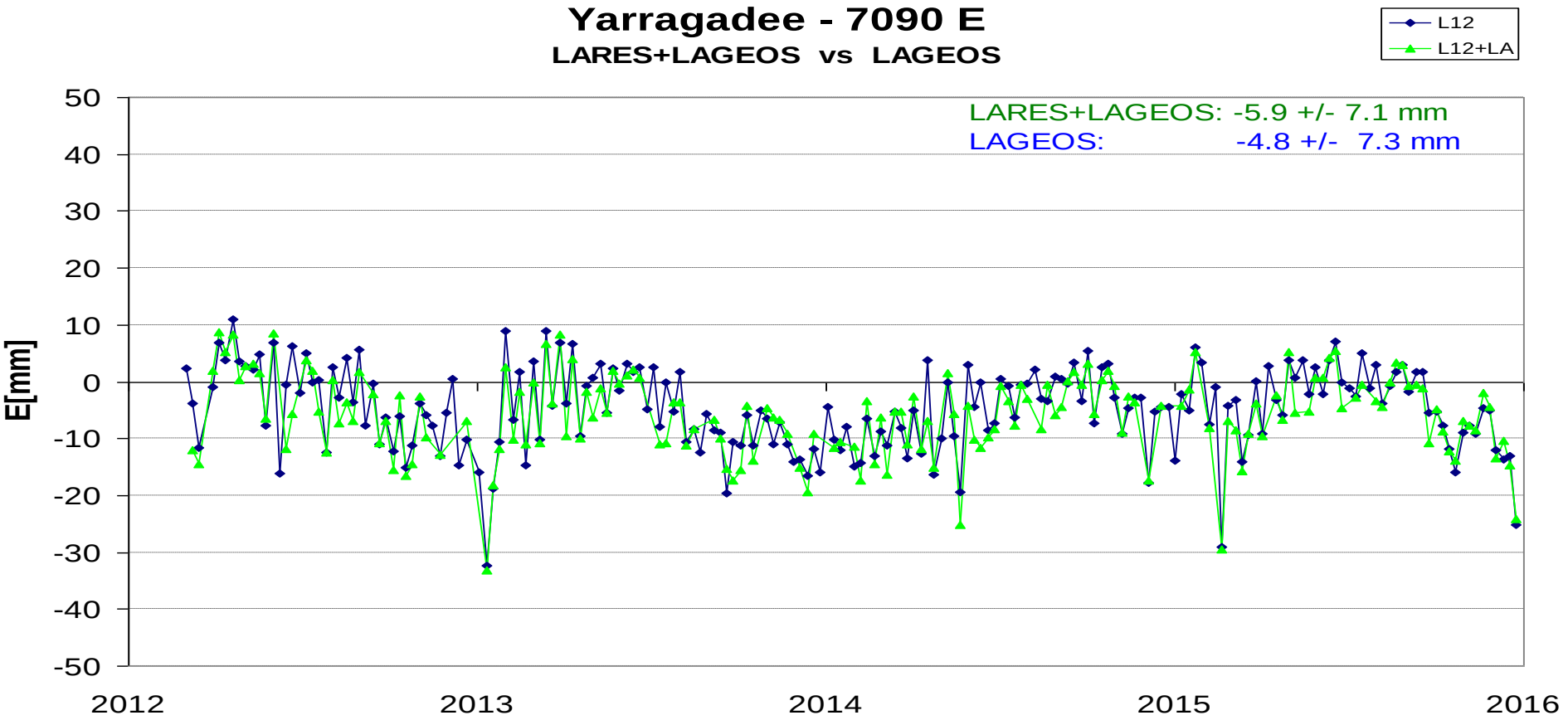
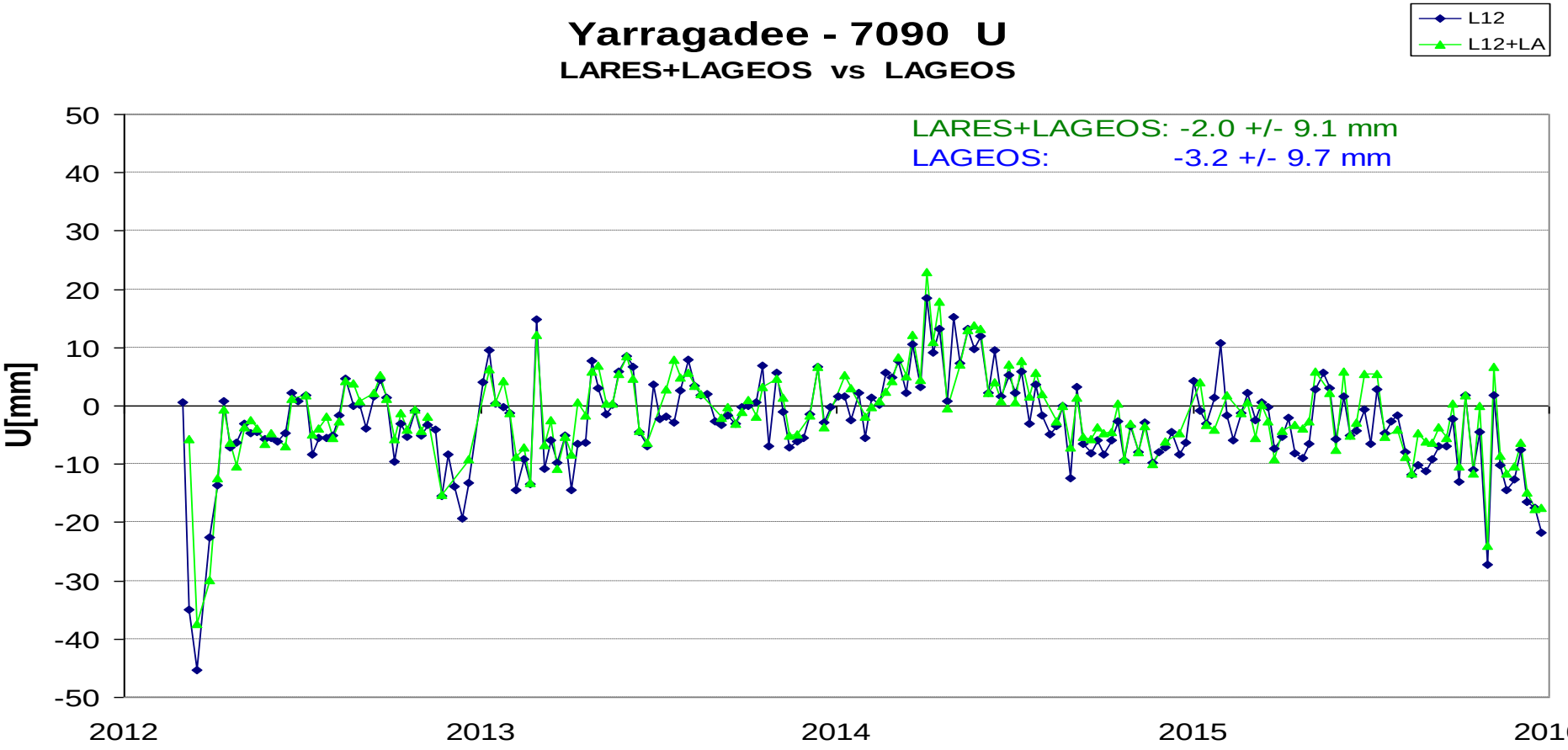
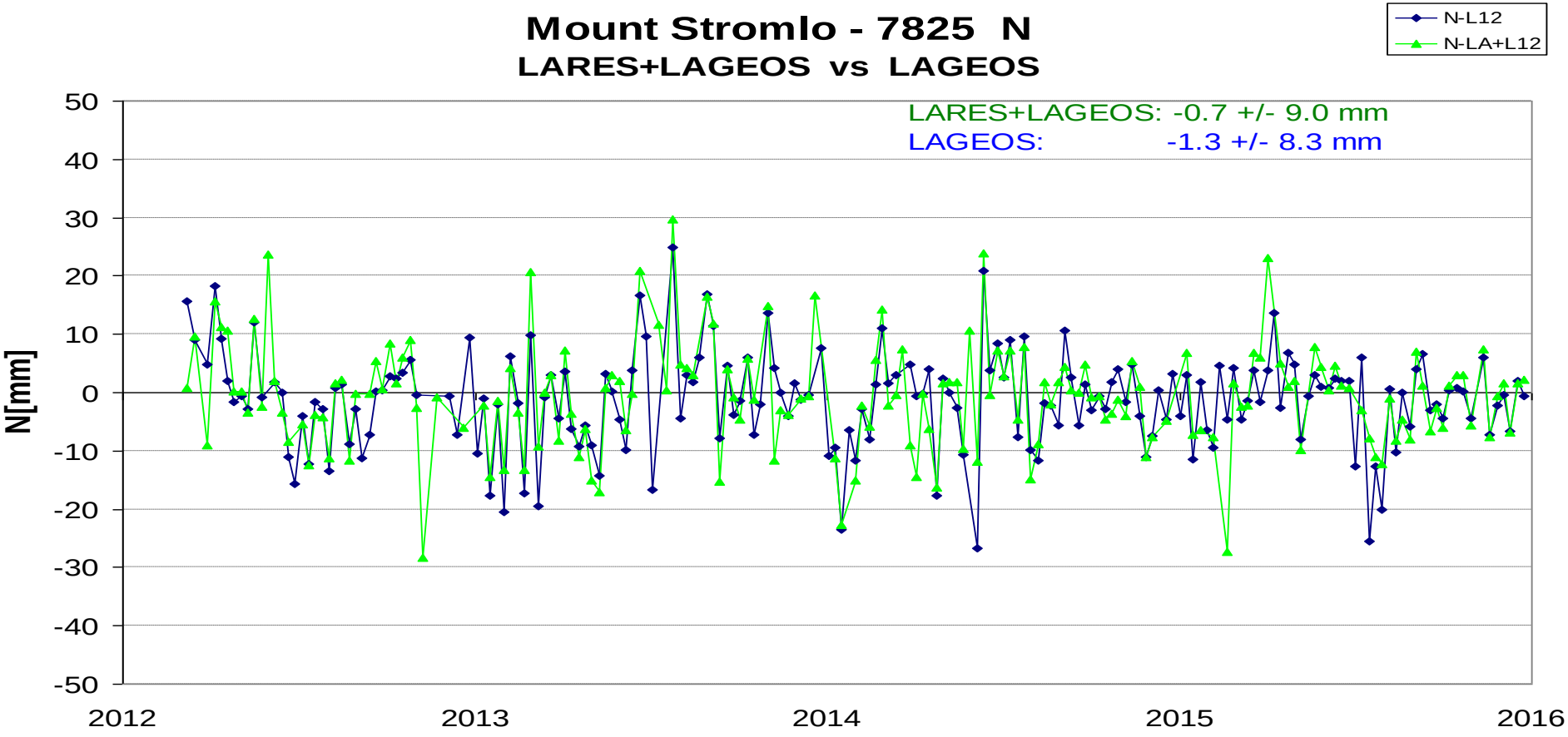
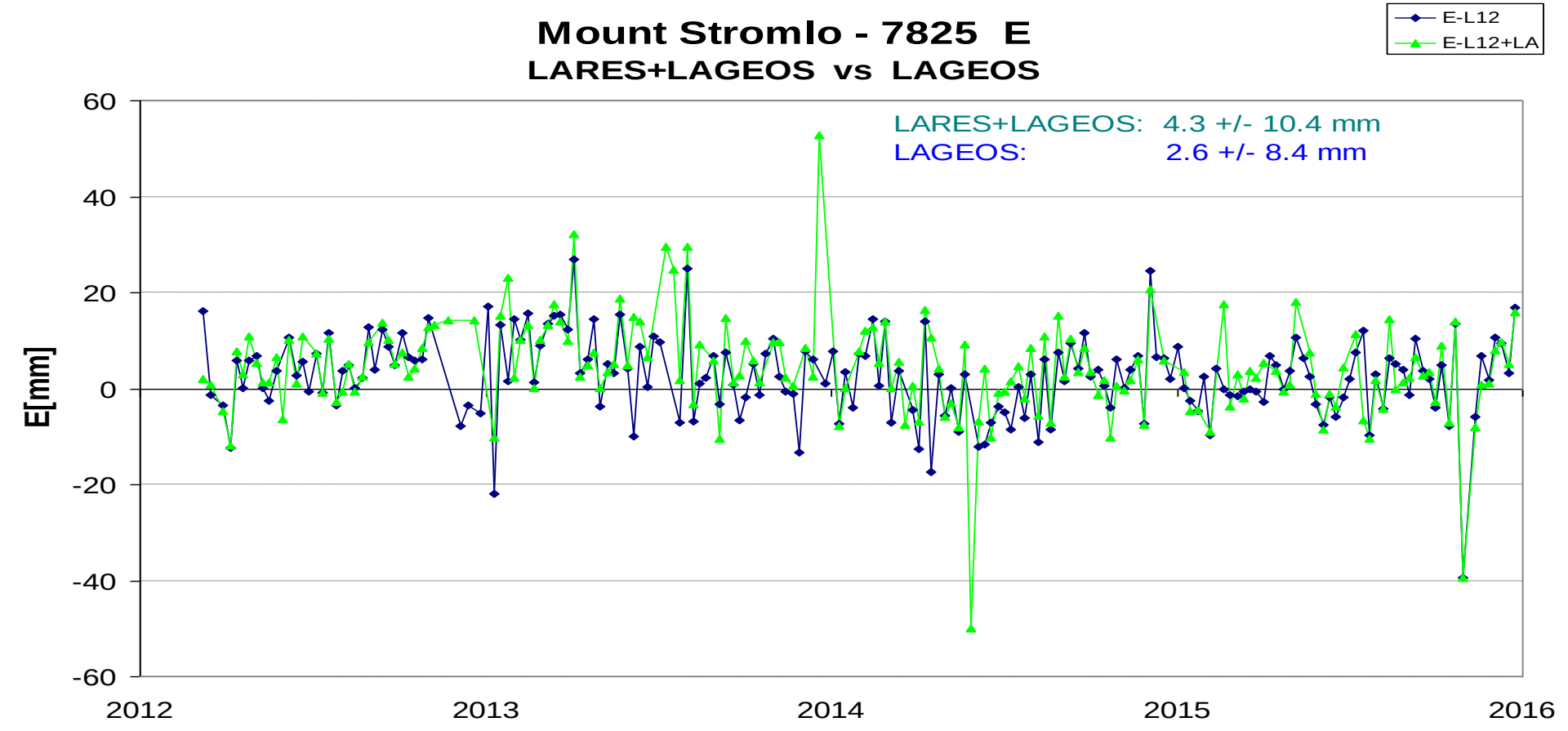
7838	Simosato (Japan)	14.5	3.0	75
7501	Hartebeesthoek (South Africa)	14.8	2.6	84

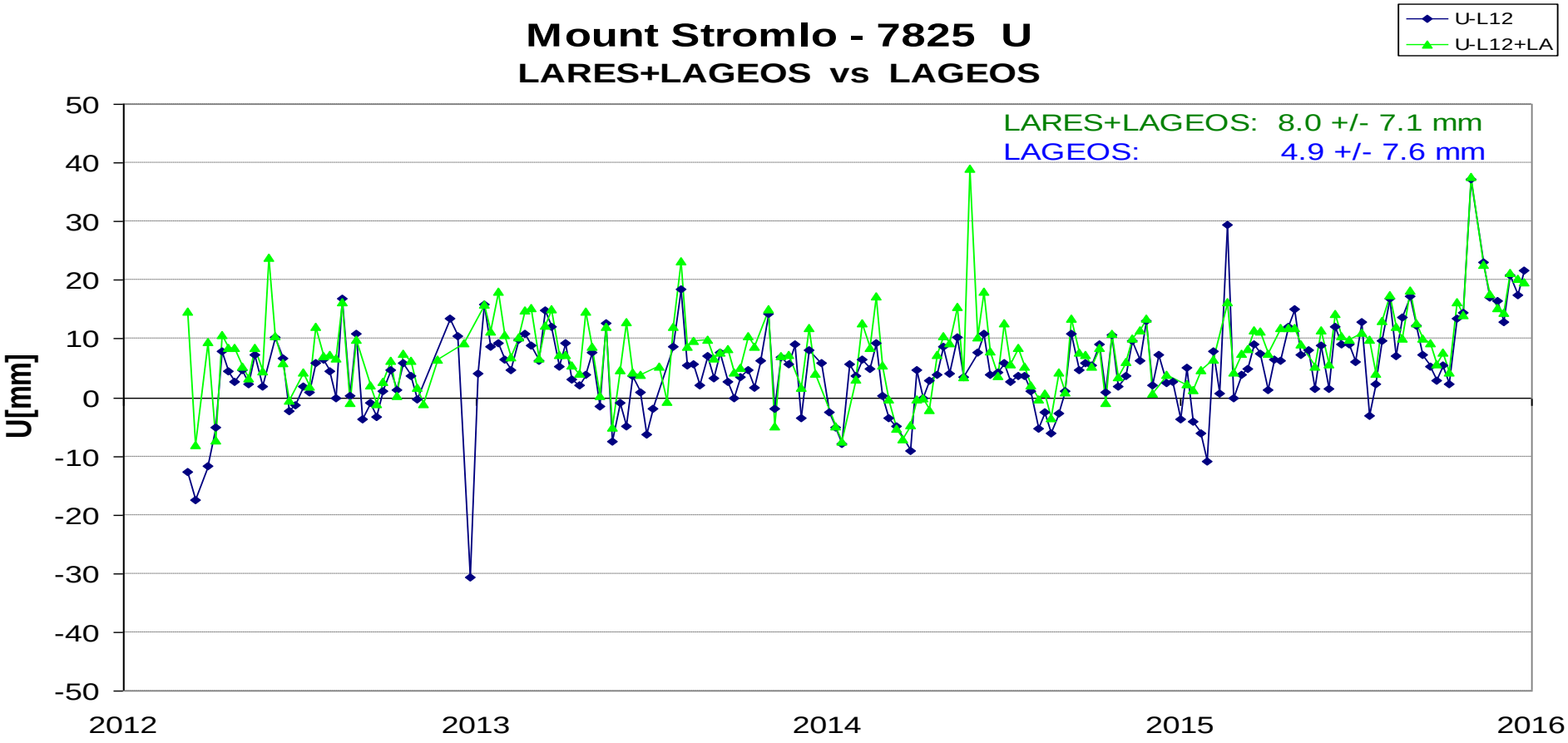

Yarragadee - 7090 N
LARES+LAGEOS vs LAGEOS
L12
L12+LA
LARES+LAGEOS: -3.7 +/- 6.2 mm
LAGEOS: -4.0 +/- 6.2 mm
N[mm]
50
40
30
20
10
0
-10
-20
-30
-40
-50
2012
2013
2014
2015
2016


Yarragadee - 7090 E
LARES+LAGEOS vs LAGEOS
L12
L12+LA
LARES+LAGEOS: -5.9 +/- 7.1 mm
LAGEOS: -4.8 +/- 7.3 mm
E[mm]
50
40
30
20
10
0
-10
-20
-30
-40
-50
2012
2013
2014
2015
2016


Yarragadee - 7090 U
LARES+LAGEOS vs LAGEOS
L12
L12+LA
LARES+LAGEOS: -2.0 +/- 9.1 mm
LAGEOS: -3.2 +/- 9.7 mm
U[mm]
50
40
30
20
10
0
-10
-20
-30
-40
-50
2012
2013
2014
2015
2016


Mount Stromlo - 7825 N
LARES+LAGEOS vs LAGEOS
N-L12
N-LA+L12
LARES+LAGEOS: -0.7 +/- 9.0 mm
LAGEOS: -1.3 +/- 8.3 mm
N[mm]
50
40
30
20
10
0
-10
-20
-30
-40
-50
2012
2013
2014
2015
2016


Mount Stromlo - 7825 E
LARES+LAGEOS vs LAGEOS
E-L12
E-L12+LA
LARES+LAGEOS: 4.3 +/- 10.4 mm
LAGEOS: 2.6 +/- 8.4 mm
E[mm]
60
40
20
0
-20
-40
-60
2012
2013
2014
2015
2016


Mount Stromlo - 7825 U
LARES+LAGEOS vs LAGEOS
U-L12
U-L12+LA
LARES+LAGEOS: 8.0 +/- 7.1 mm
LAGEOS: 4.9 +/- 7.6 mm
U[mm]
50
40
30
20
10
0
-10
-20
-30
-40
-50
2012
2013
2014
2015
2016

CONCLUSIONS

Too small number of normal points especially in winter time

Some SLR stations have too small number of NP per week (below 50)

Good orbital RMS (14.3 mm) comparable to LAGEOS satellites

The accuracy of determining the station coordinates depends on the continent

Necessity to use results from all SLR stations instead 15

Very good solution of station coordinates determination from three satellites: LAGEOS-1, LAGEOS-2 and LARES

Will the results from multi satellites (LAGEOS-1, LAGEOS-2, ETALON-1, ETALON-2, LARES, Starlette, Stella, Ajisai) allow for better accuracy in determining station coordinates?

Acknowledgments

The authors wishes to thanks NASA GSFC for consent to use the GEODYN-II program, and to the ILRS stations for their continuous efforts to provide high quality SLR data.


Thank you