International Laser Ranging Service

ASI AC&CC report

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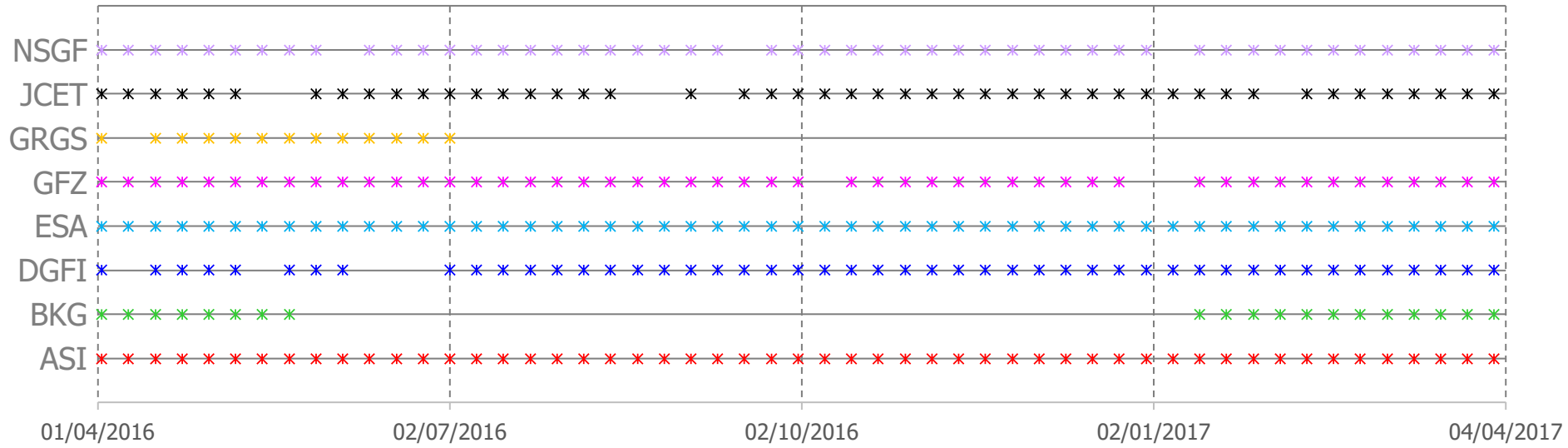
ILRS ASC Meeting, 22 April 2017, Vienna

Main activities

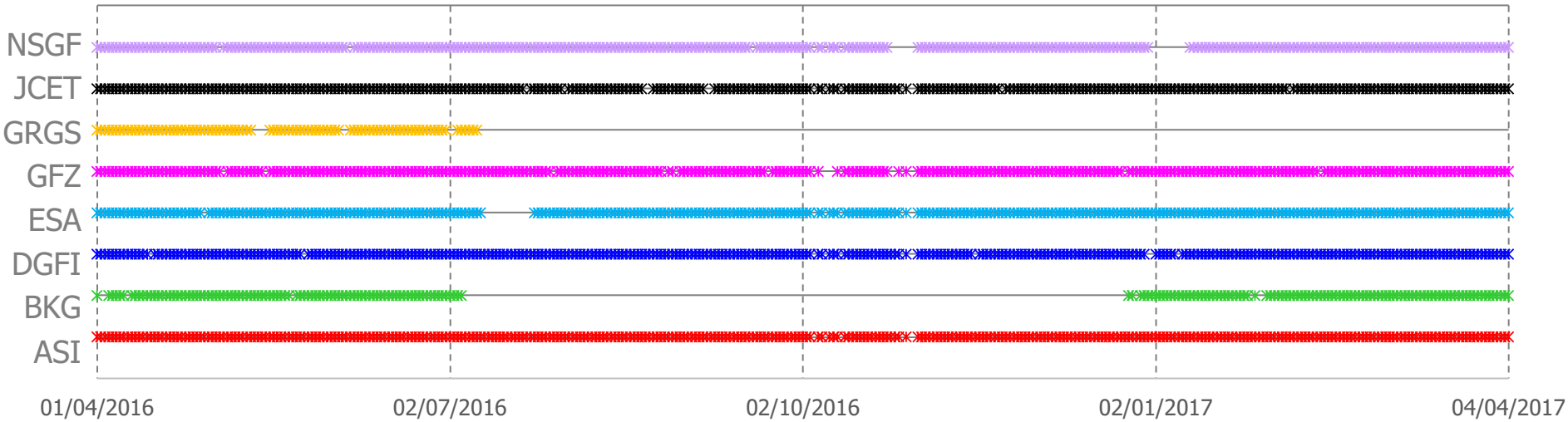
- AC performance
- ITRF2014 time series
- ASC Pilot Project on Systematic errors

AC submissions

weekly

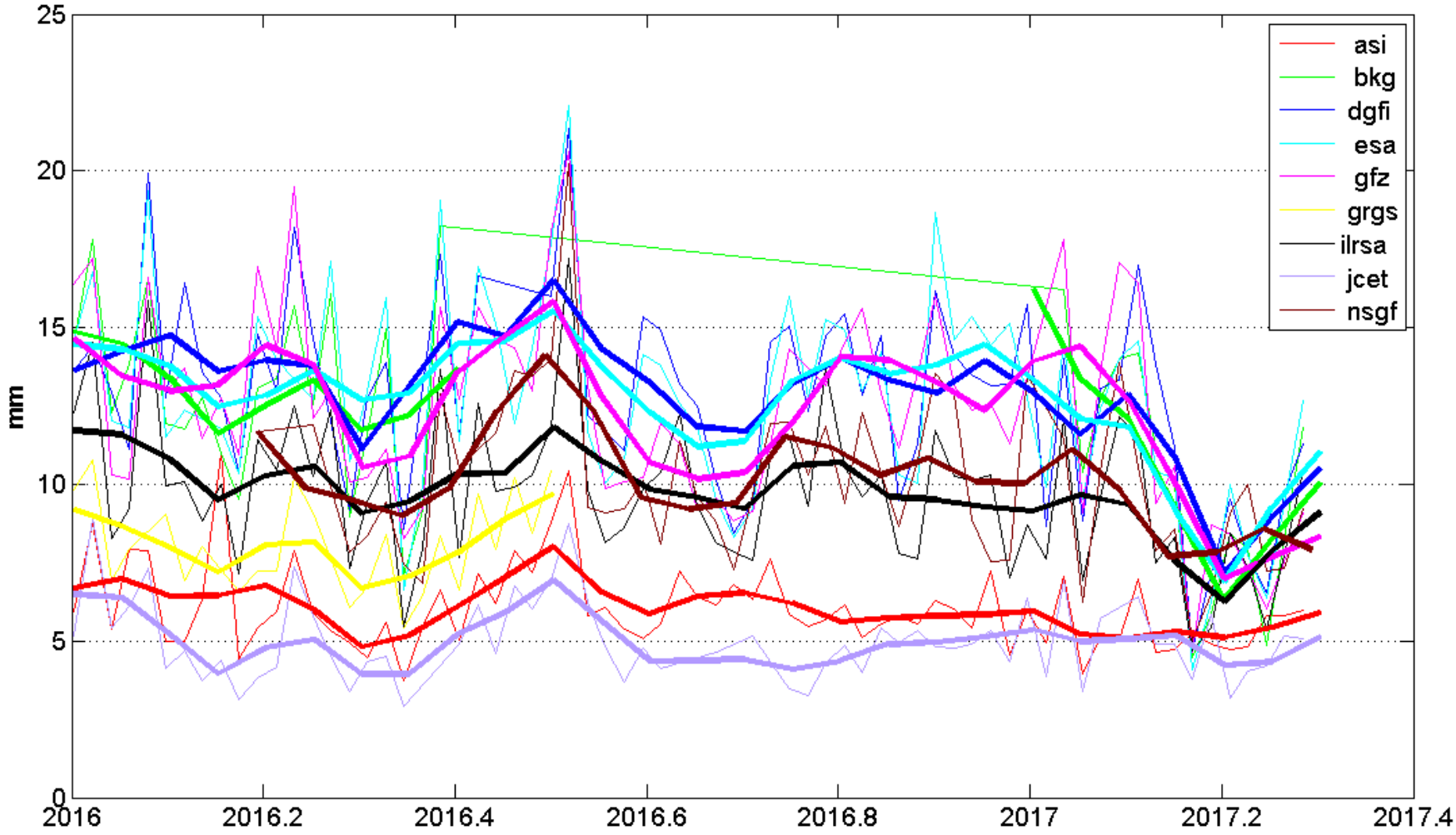


daily



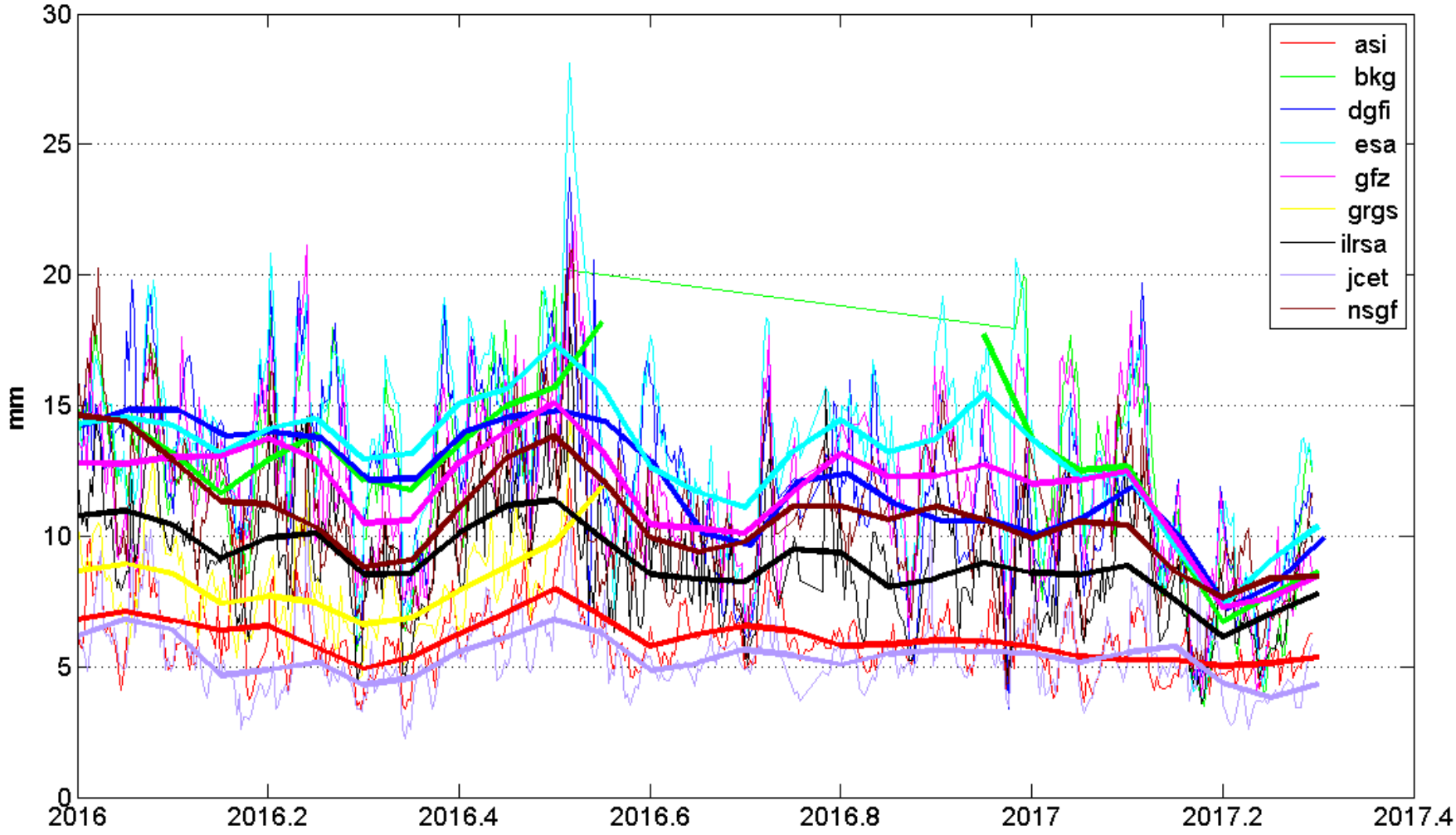
Weekly solutions

3D wrms of the residual w.r.t. SLRF2008
CORE SITES

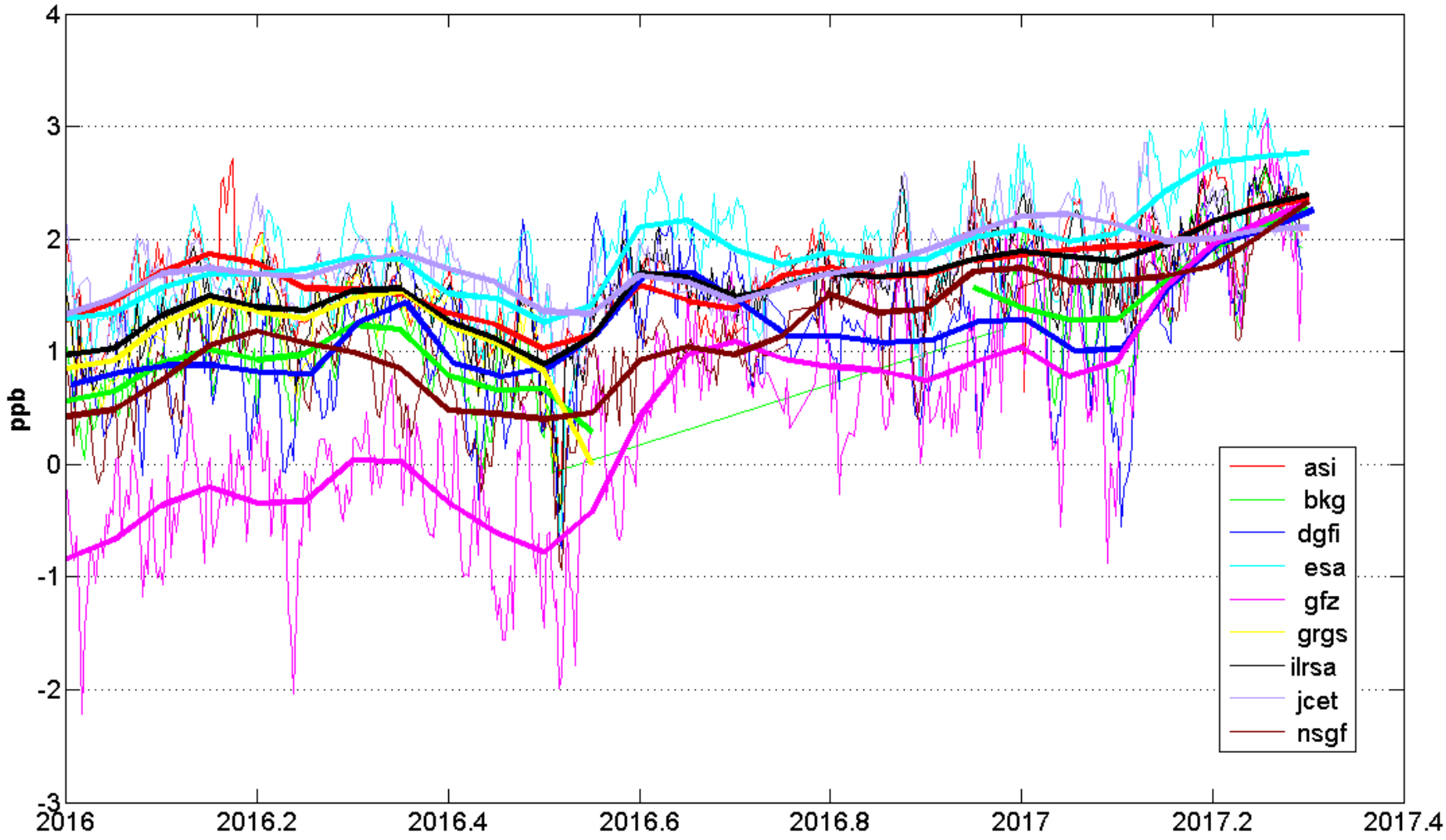


Daily solutions

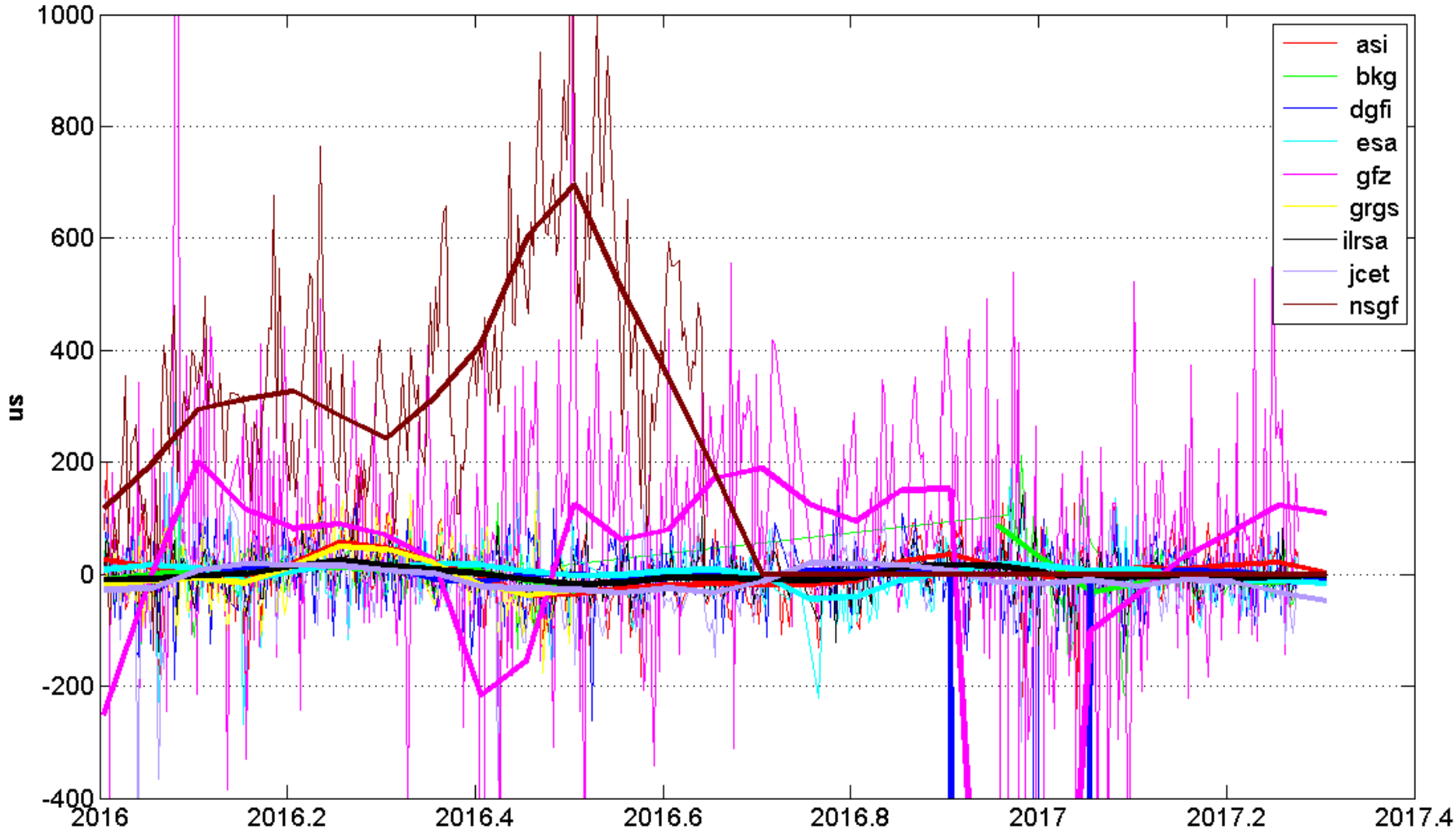
3D wrms of the residual w.r.t. SLRF2008
CORE SITES



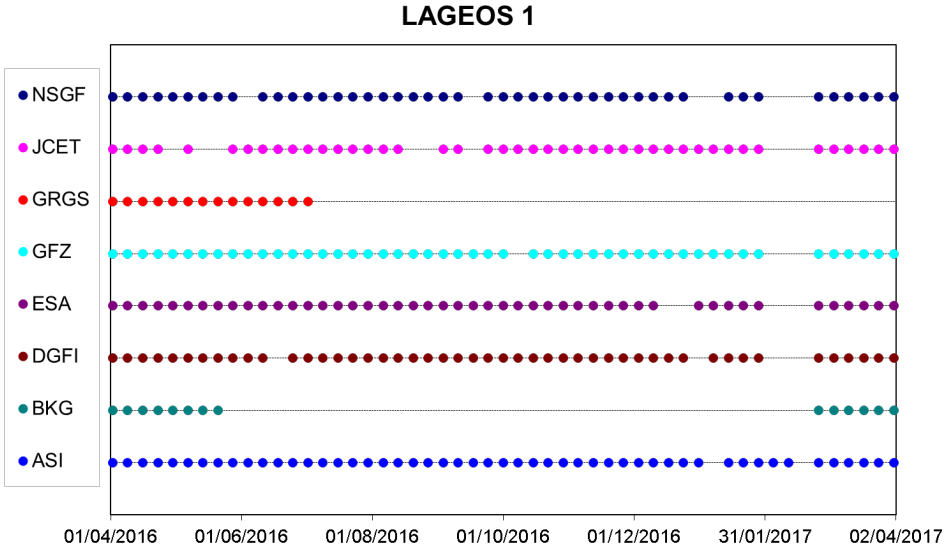
Scale from daily solutions

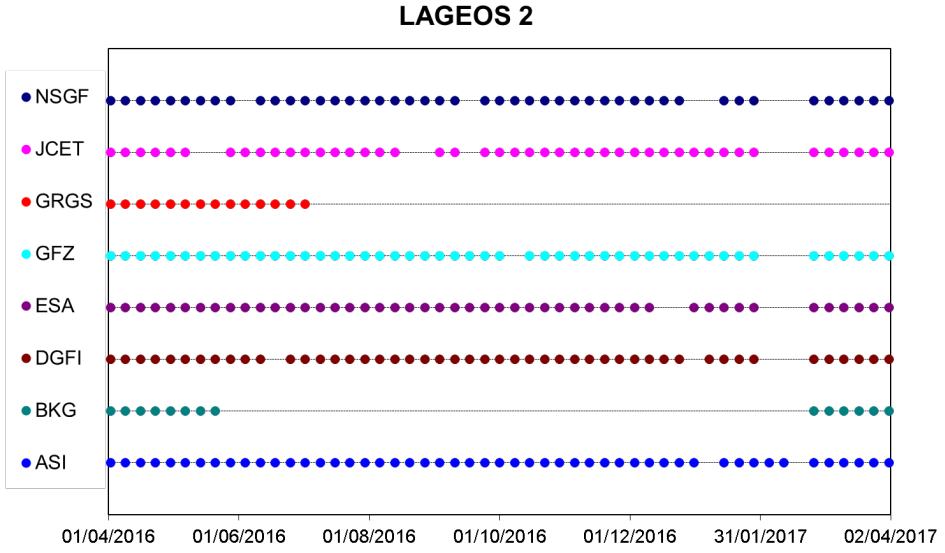


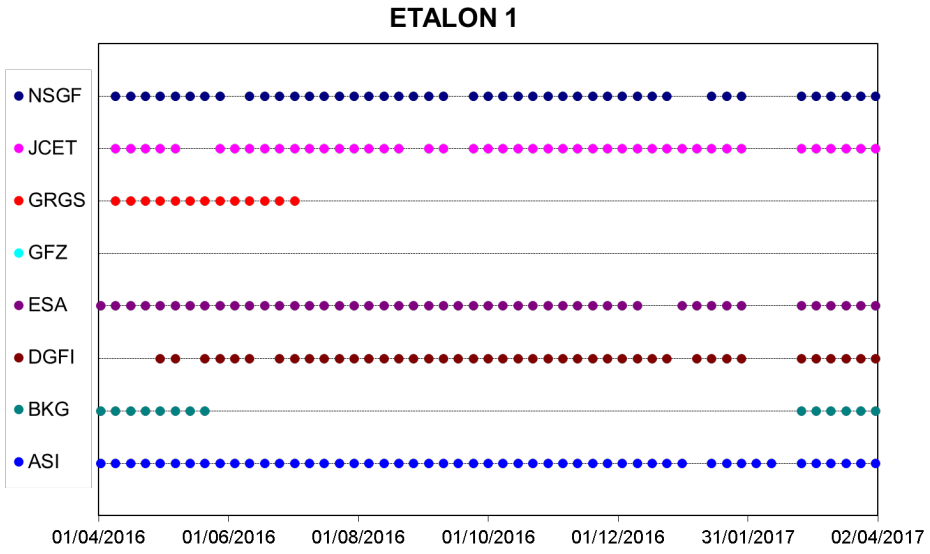
LOD from daily solutions

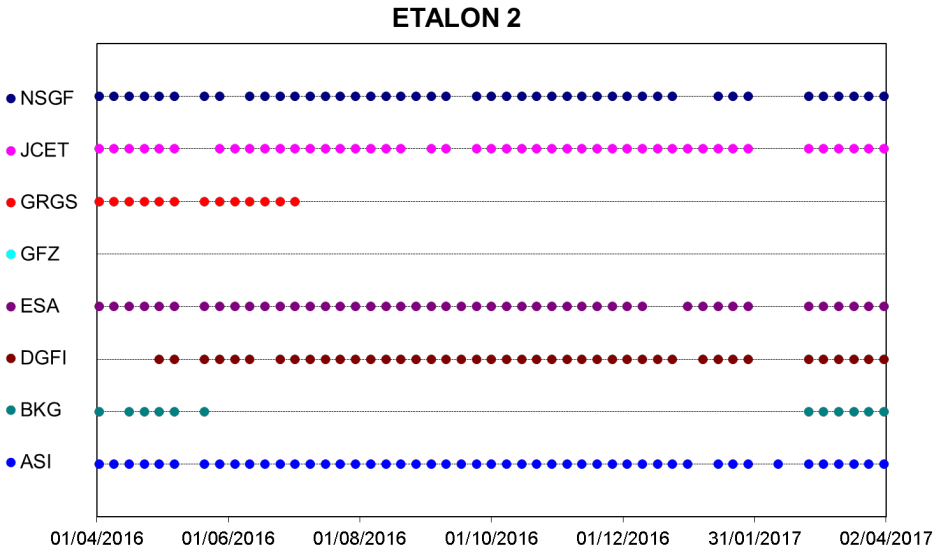


ILRS AC orbits

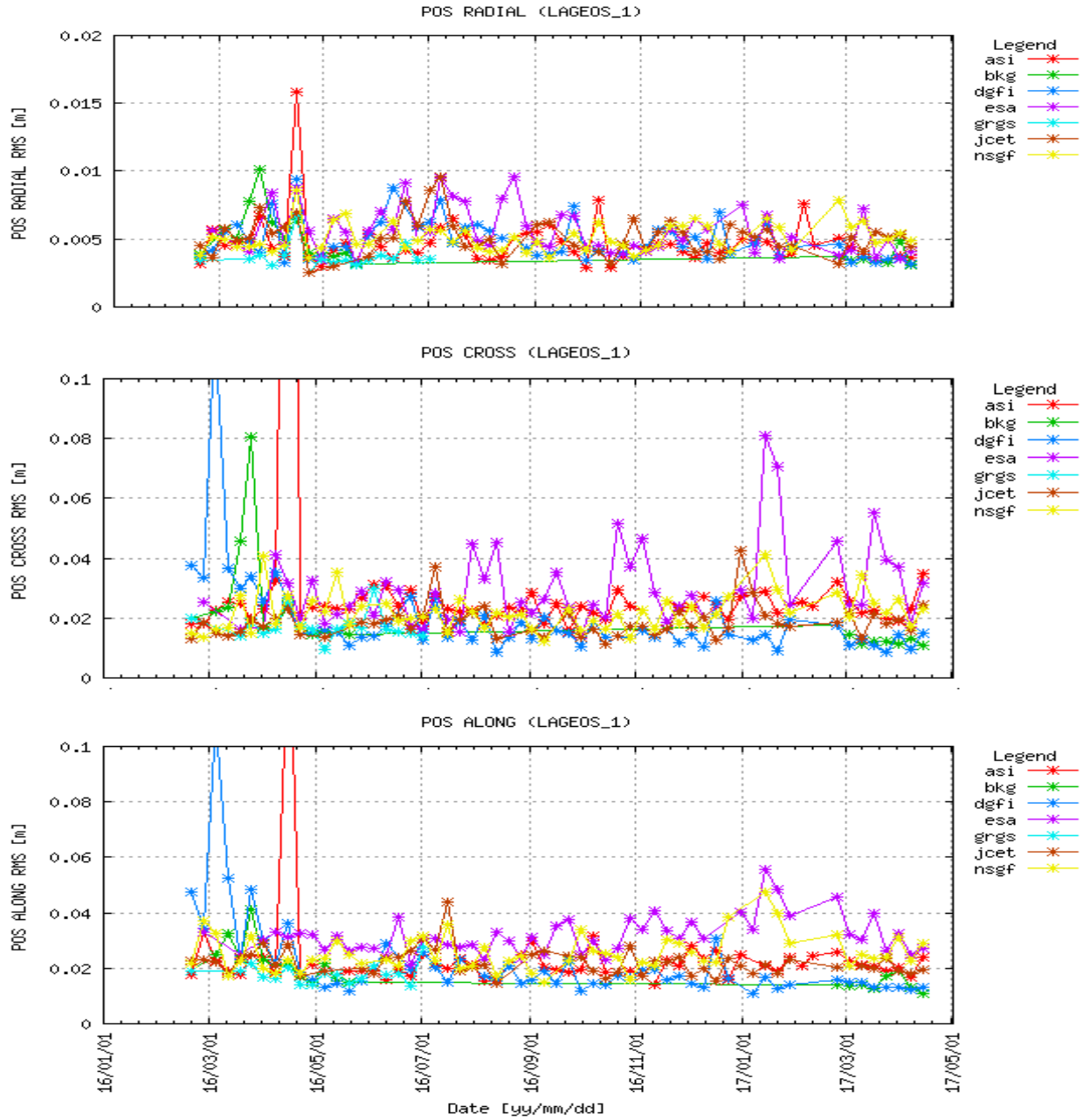




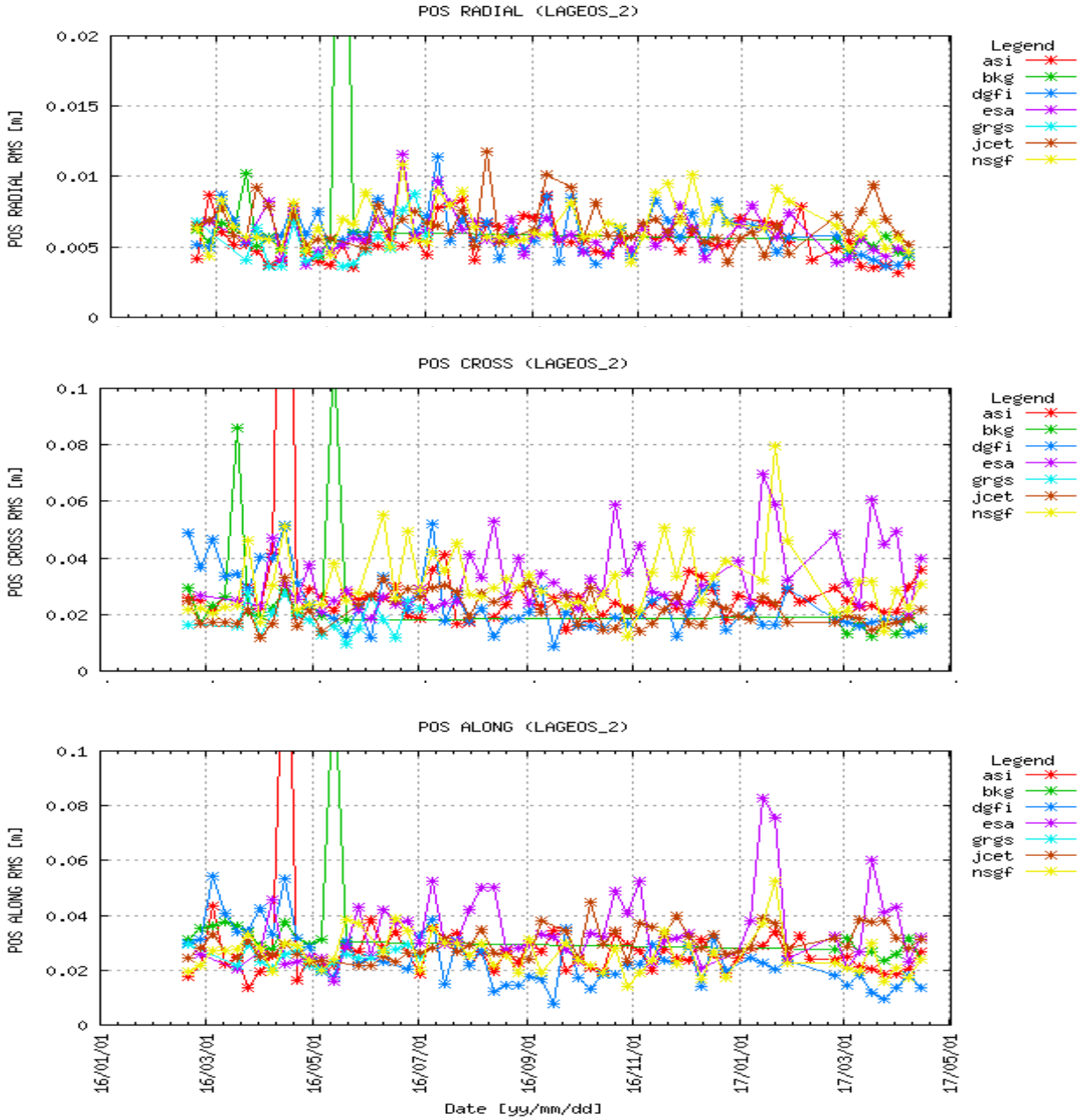




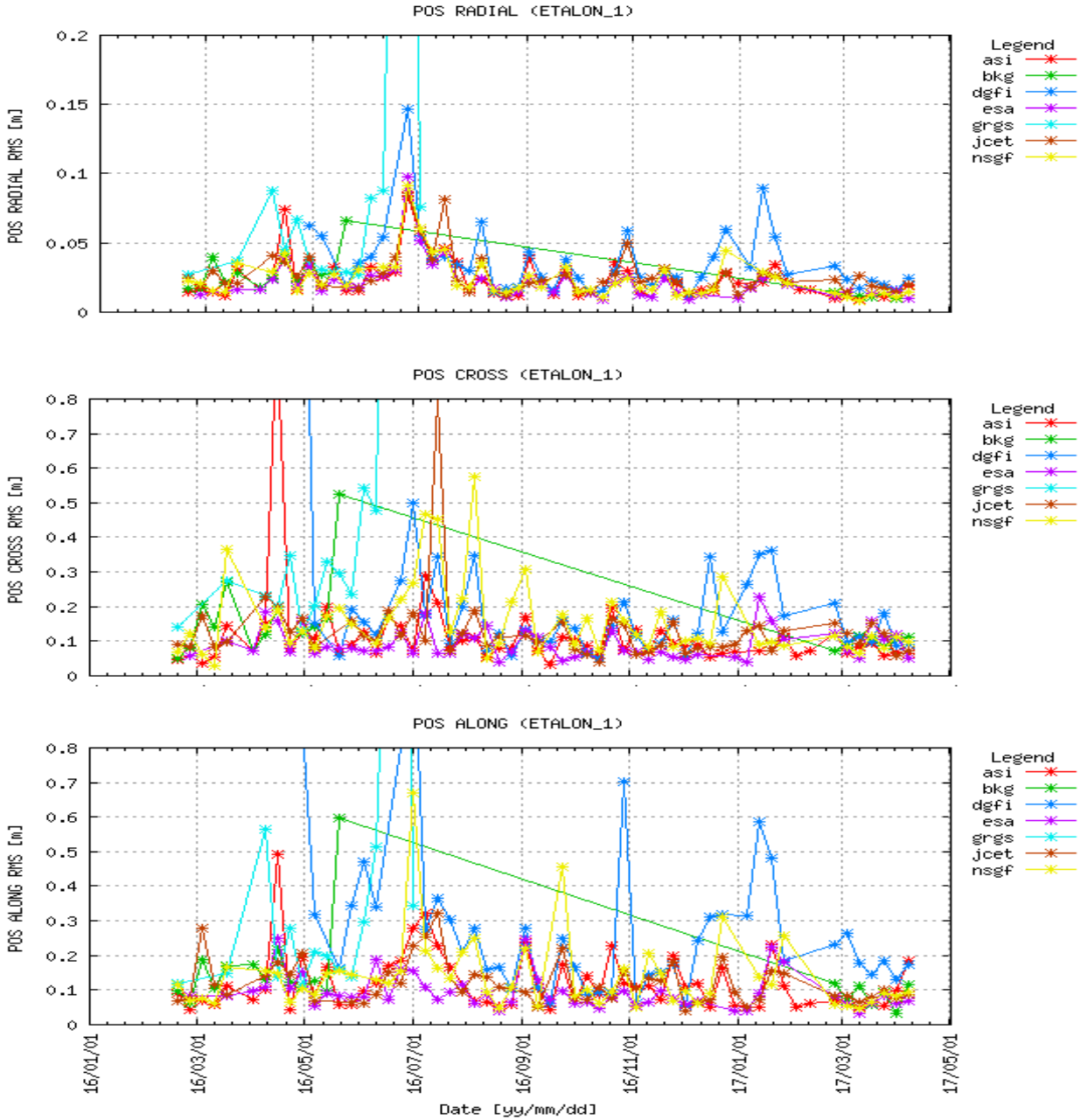
LAGEOS1 orbits – RMS of residuals w.r.t. combination



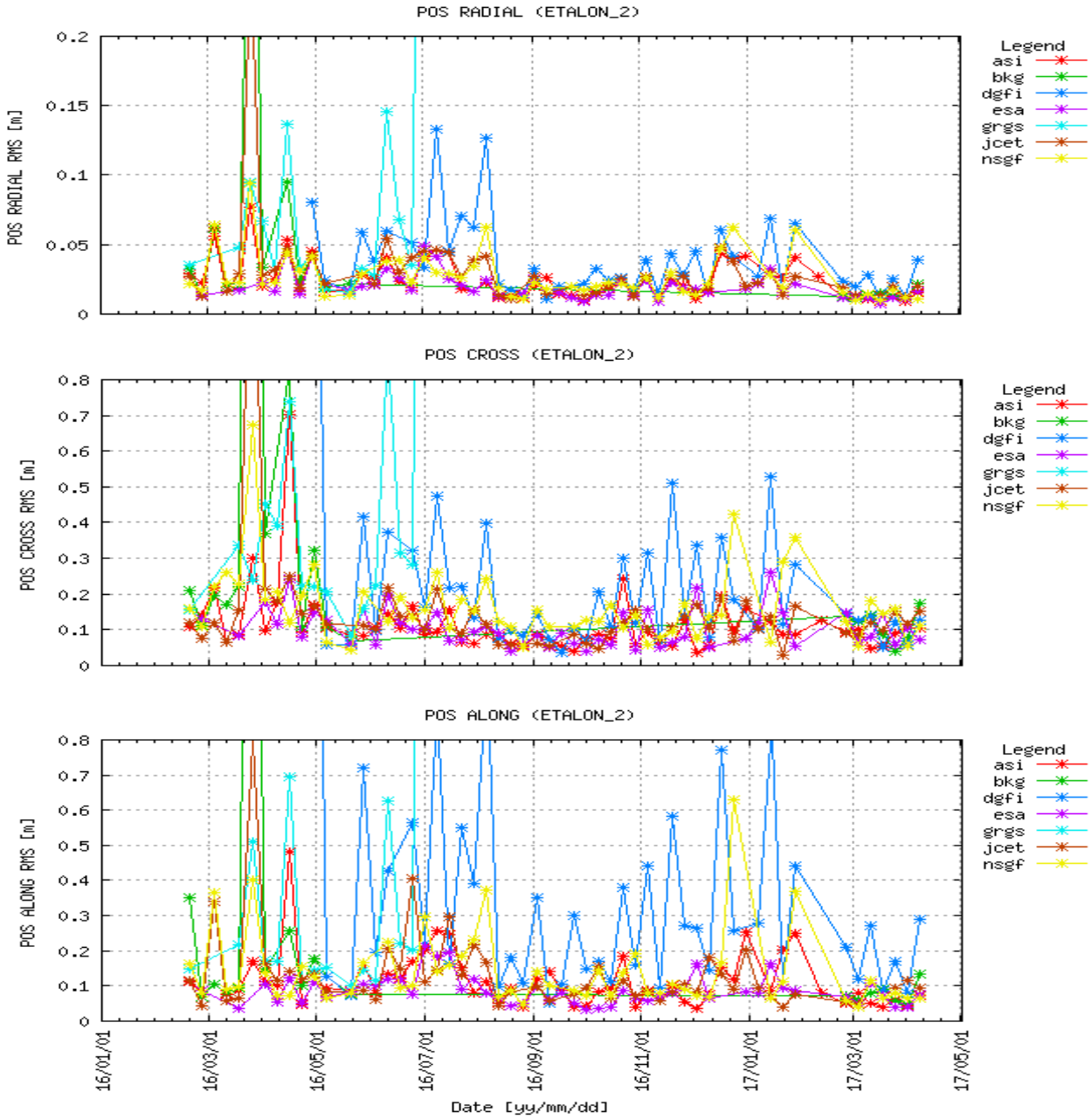
LAGEOS2 orbits – RMS of residuals w.r.t. combination



ETALON1 orbits – RMS of residuals w.r.t. combination



ETALON2 orbits – RMS of residuals w.r.t. combination

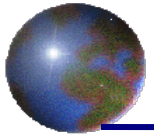


Summary on ILRS orbits

- Official ILRS orbits available since May 2016
- 6 ACs contributing to LAGEOS orbits
- 5 ACs contributing to ETALON
- The ACs orbits agreement, in terms of rms of the residuals w.r.t. the combination, is in the table below

	Radial (mm)	Cross-track (mm)	Along-track (mm)
LAGEOS1	5	22	22
LAGEOS2	7	28	30
ETALON1*	23	120	118
ETALON2*	22	112	110

*GRGS and DGFI not included



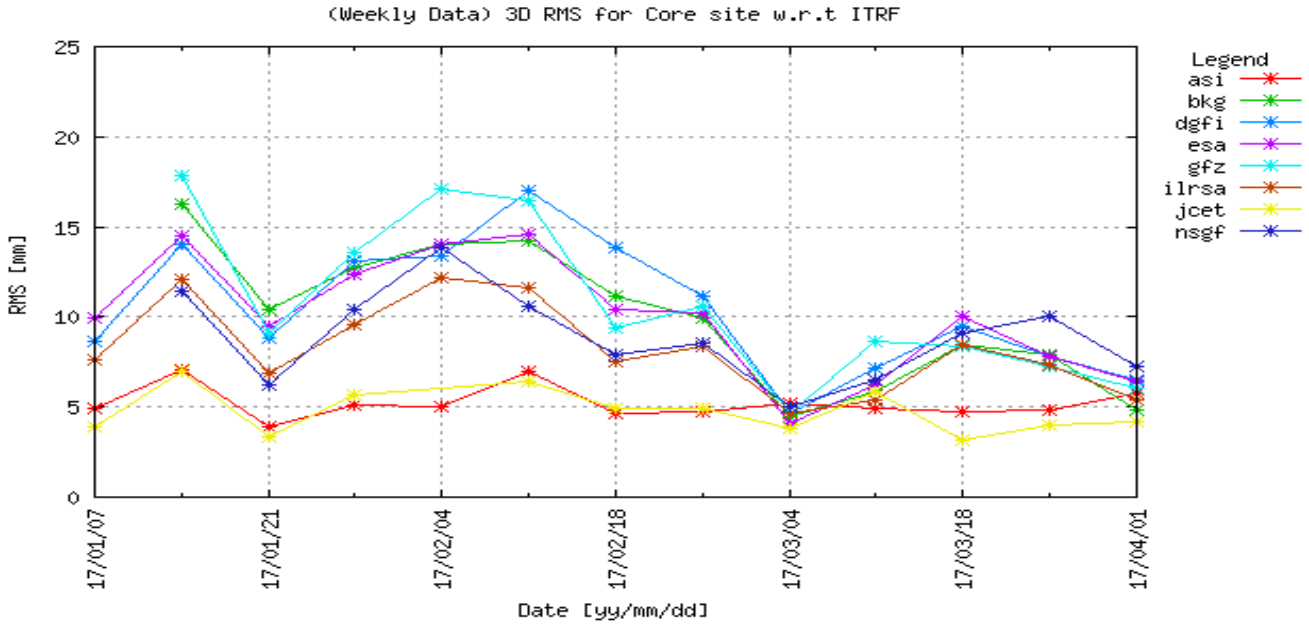
ITRF2014 weekly solutions v70

ITRF2014 weekly submissions

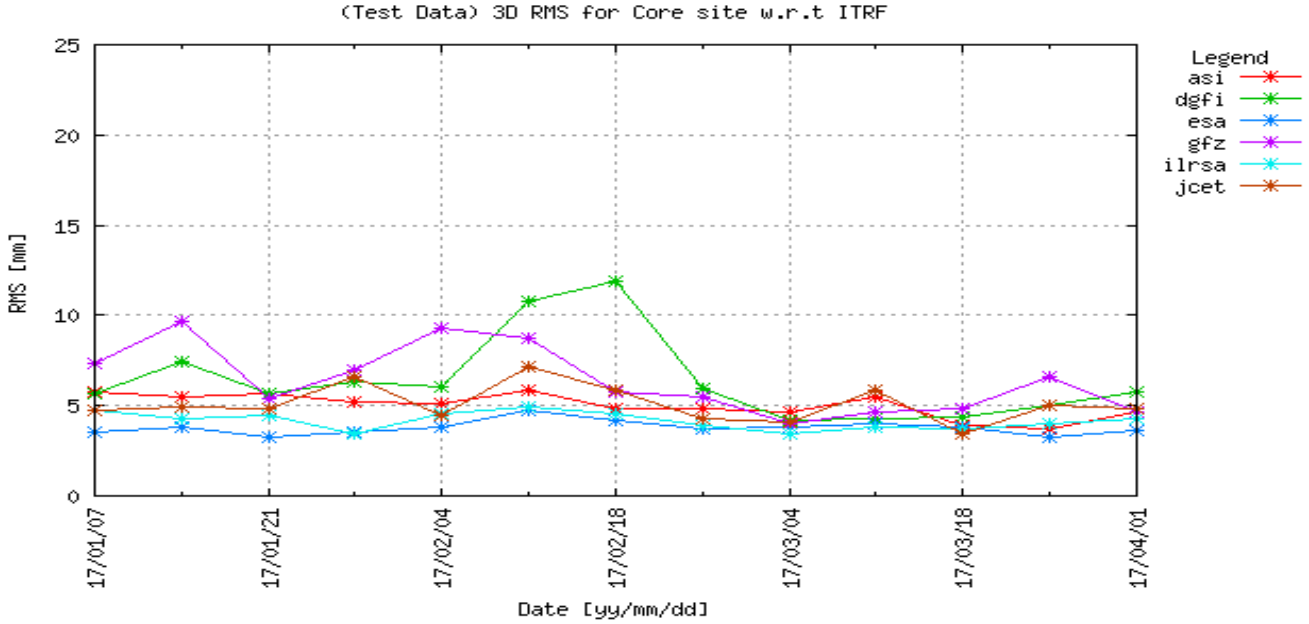
AC time series using ITRF2014 as *a priori*

Agency	Time series	Note
ASI	since 170107	
BKG	none	
DGFI	since 170107	Orbits available
ESA	since 170107	
GRGS	none	
GFZ	since 170107	
JCET	since 170107	
NSGF	none	

Site Coordinates

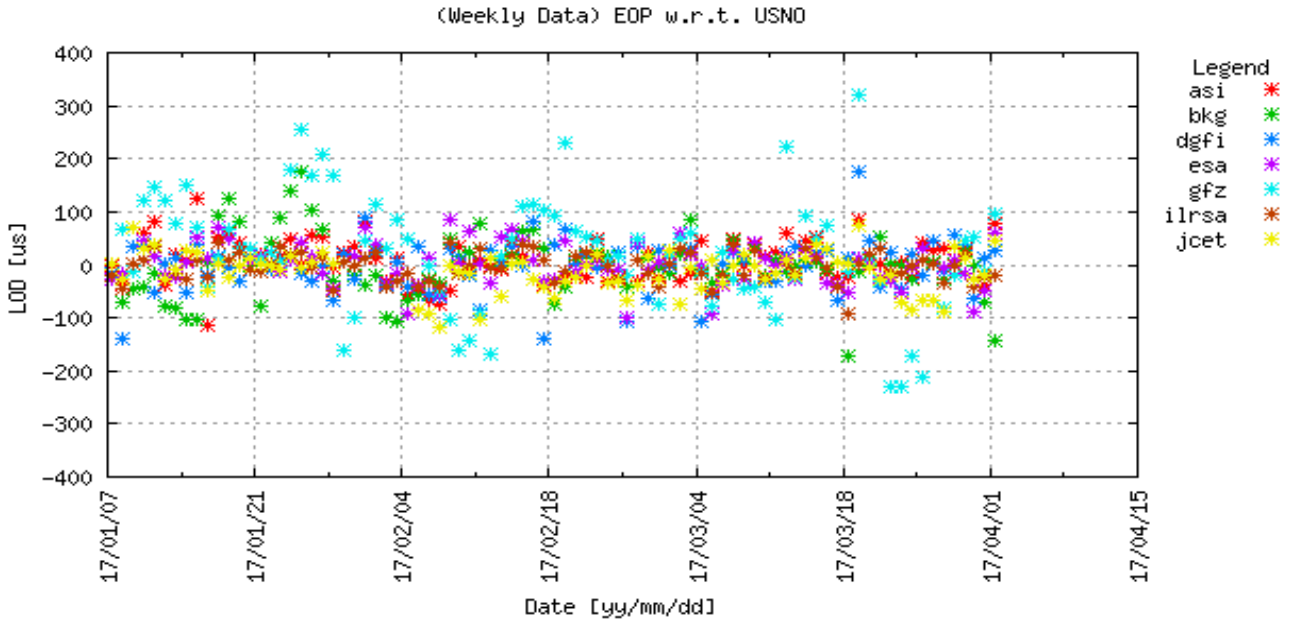


ITRF2008

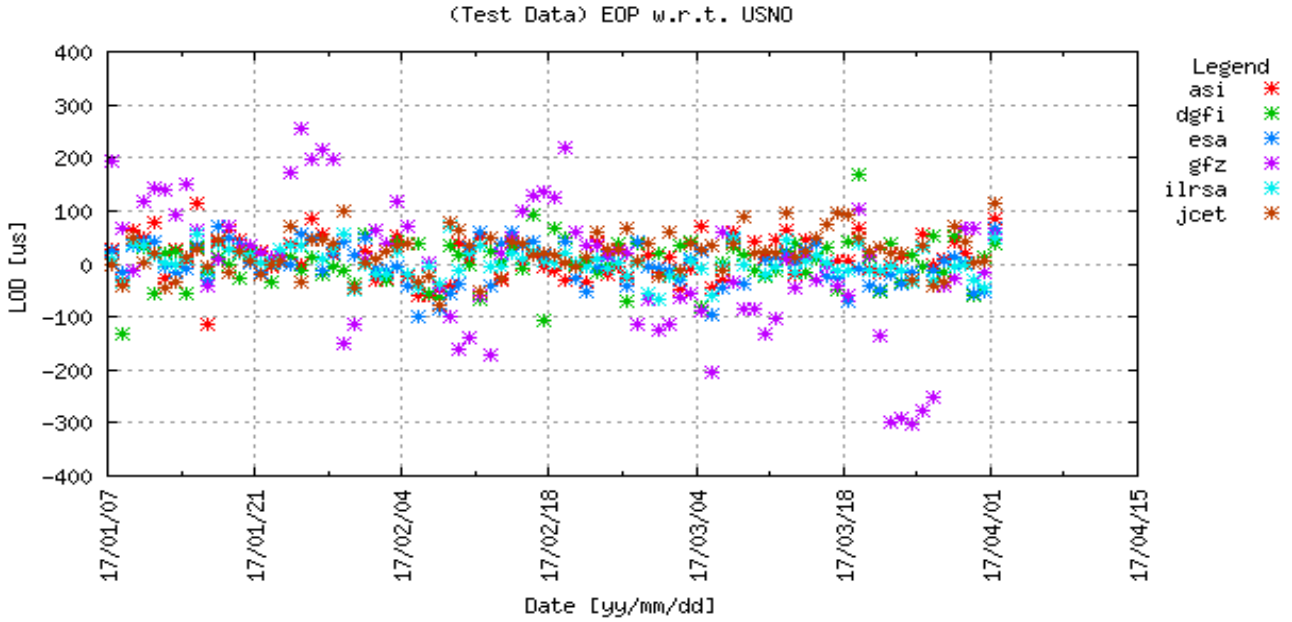


ITRF2014 (v70)

LOD



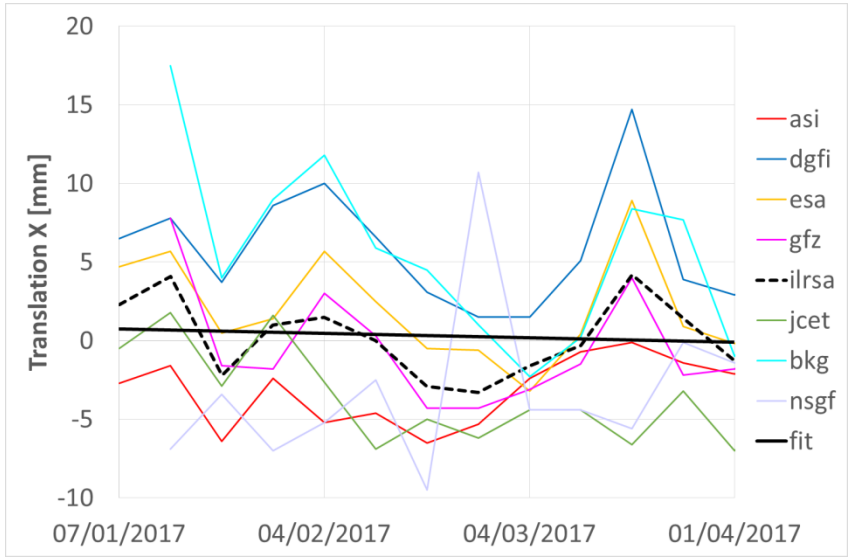
ITRF2008
nsgf excluded from the combination

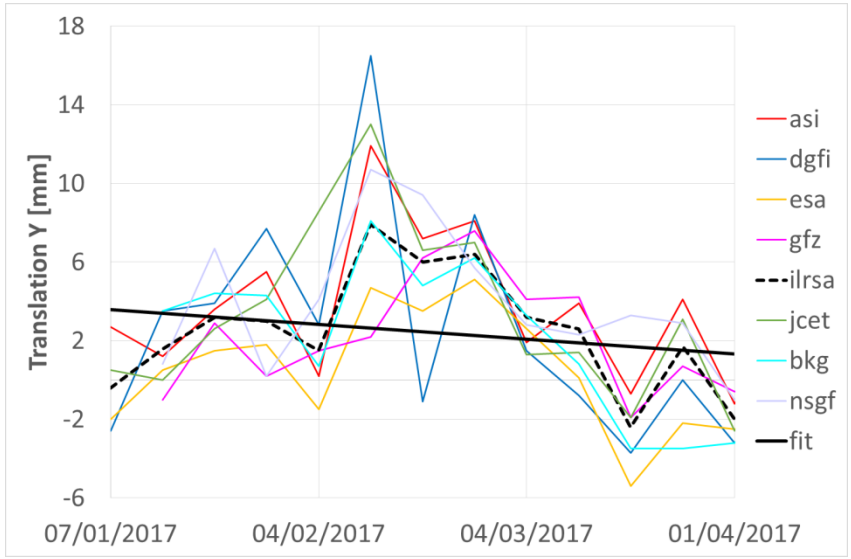


ITRF2014 (v70)

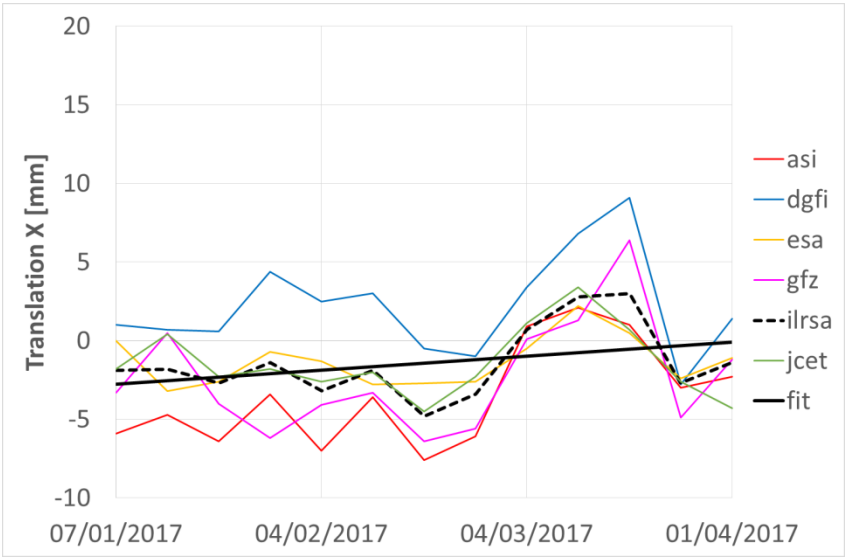
Reference Frame

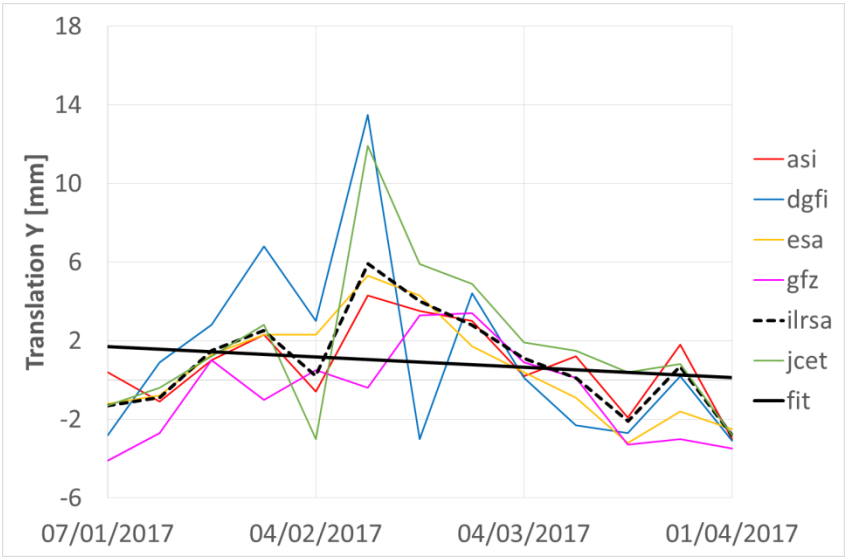
ITRF2008





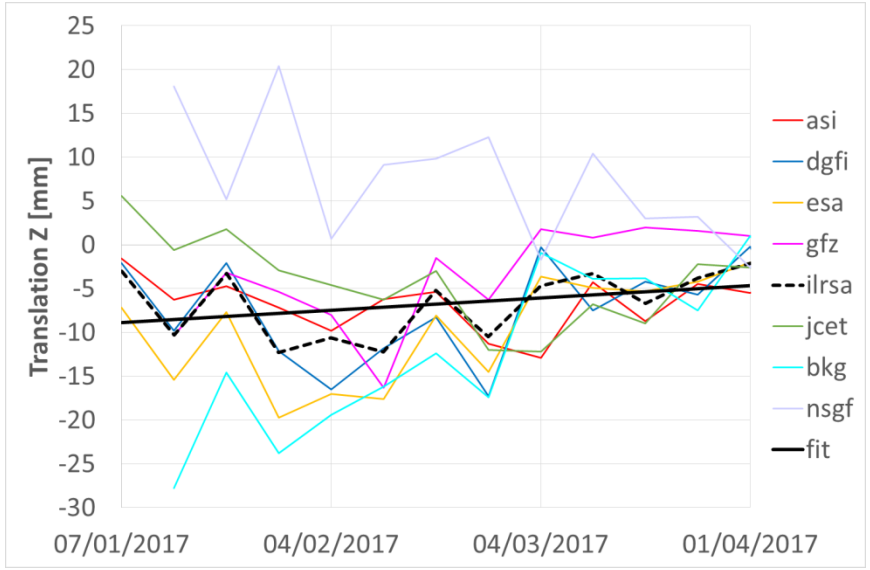
ITRF2014 (v70)

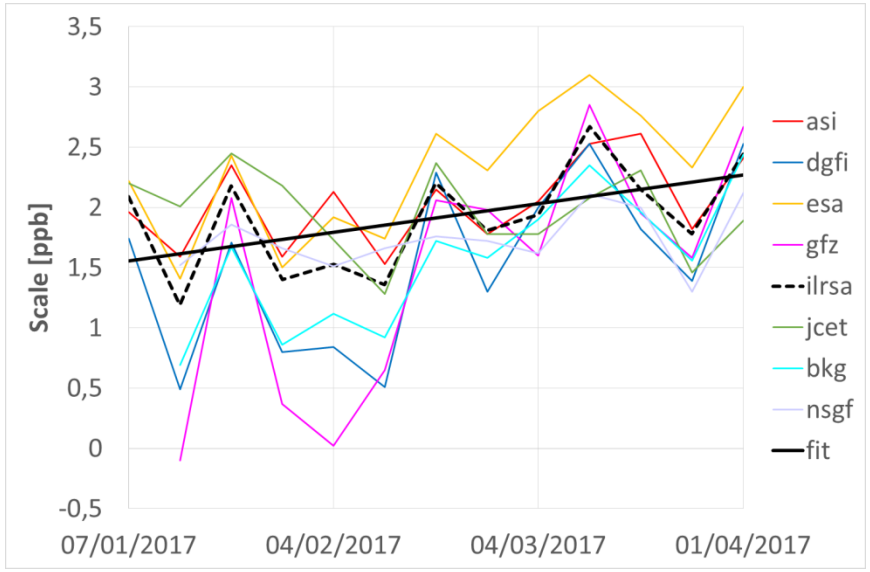




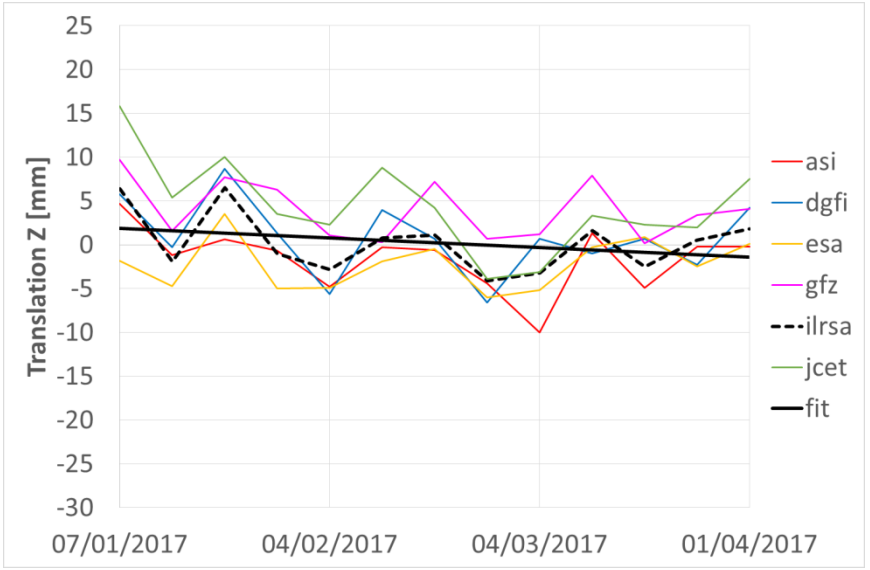
Reference Frame

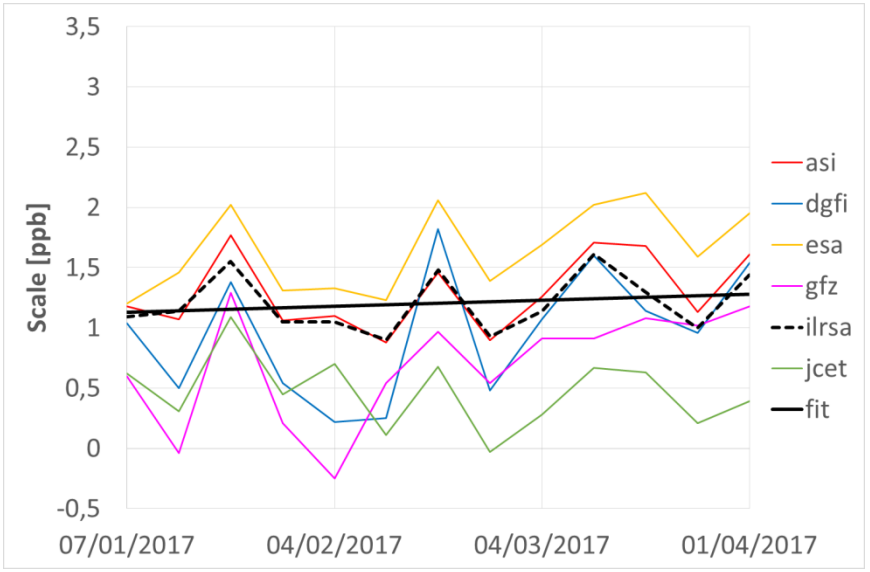
ITRF2008



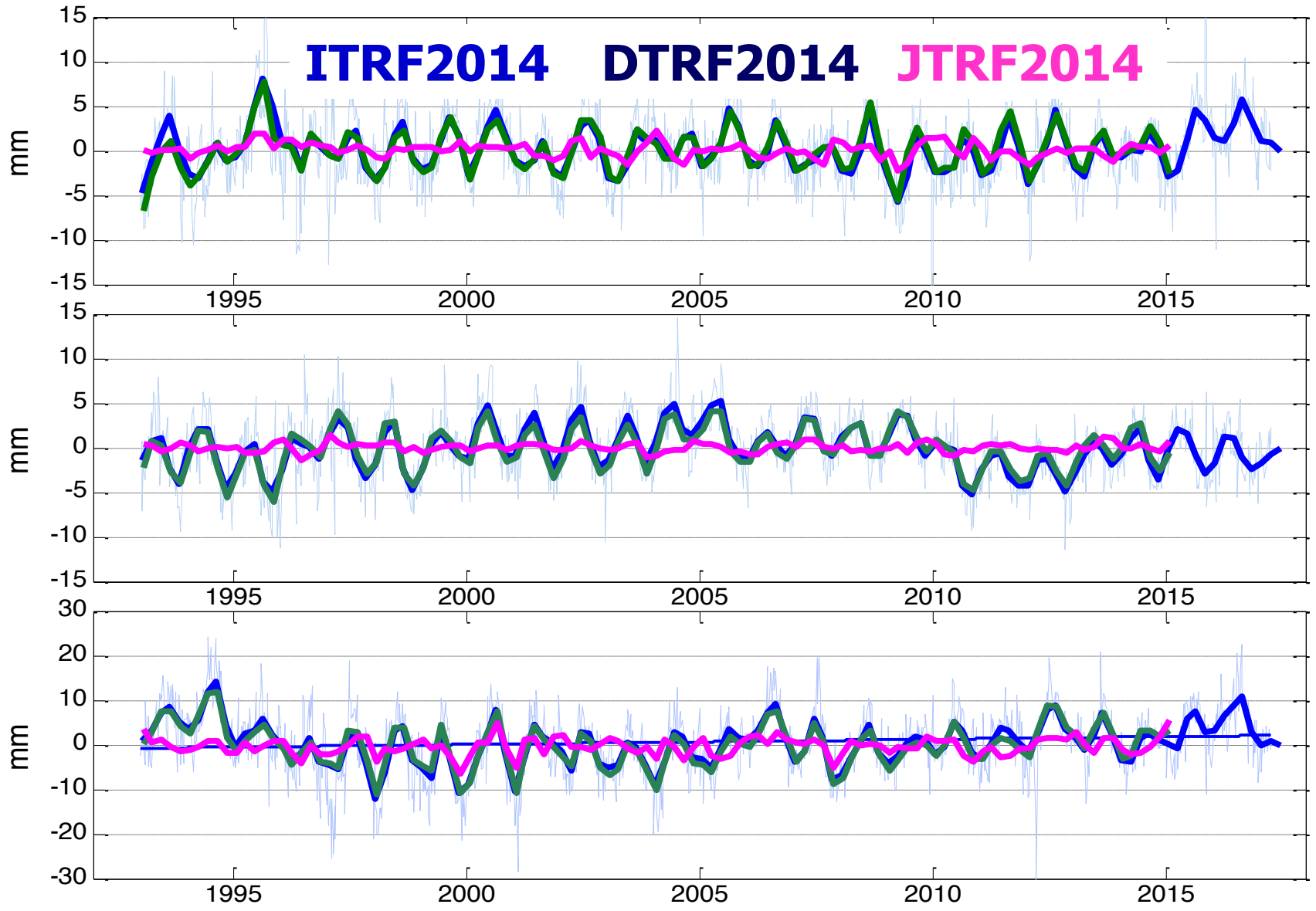


ITRF2014 (v70)

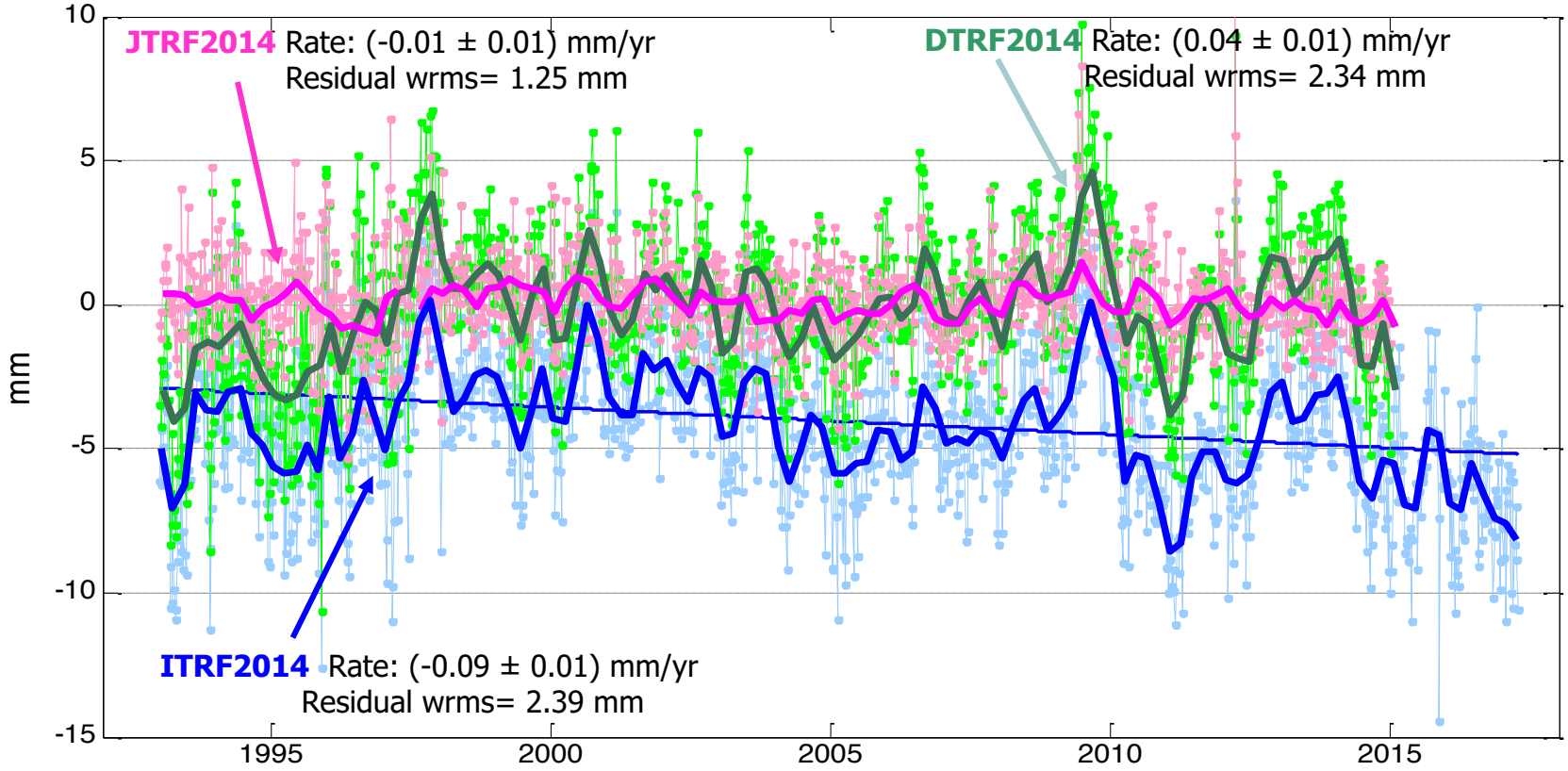




ILRSA Translations



ILRSA Scale

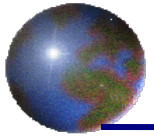

JTRF2014 Rate: (-0.01 ± 0.01) mm/yr
Residual wrms= 1.25 mm
DTRF2014 Rate: (0.04 ± 0.01) mm/yr
Residual wrms= 2.34 mm
ITRF2014 Rate: (-0.09 ± 0.01) mm/yr
Residual wrms= 2.39 mm
mm
10
5
0
-5
-10
-15
1995
2000
2005
2010
2015

ITRF2014 adoption

- BKG, GRGS and NSGF are not contributing

Next steps

- ITRF2014 must be used in the official products



SYSTEMATIC ERROR PILOT PROJECT

ILRS Pilot Project on systematic errors

PP Overview

- Weekly estimation of coordinates, EOP and biases
- Time frame: 2005-2008
- Data: L1 and L2
- 2 time series: unique and separate biases
- Available time series with the new conventions for wavelength

AC	Date of submission
ASI	v202
BKG	none
DGFI	V202 and v212
ESA	none
GFZ	none
GRGS	none
JCET	V202 and v212
NSGF	none

ASI combination SW update under test

Federal Agency for Cartography and Geodesy

BKG SLR Analysis Center Activities

Daniel Koenig, Daniela Thaller

Operational Products

- Daily and Weekly:
  - activities resumed
  - missing products reprocessed
- Epoch issue in Weekly SP3 files fixed
- ILRS-A combinations: strange editing of parameters

EGSIEM

- Special settings:
  - 30-d solutions for 2006+2007
  - homogeneous parameterization
  - low-degree GFC estimated, station positions fixed
- Significant adaptations to available procedures necessary
- Contradictions SINEX intervals/observations available
- BKG solutions approaching submission

Contact:

Bundesamt für Kartographie und Geodäsie (BKG)
Richard-Strauss-Allee 11
60598 Frankfurt, Germany

Daniel Koenig
daniel.koenig@bkg.bund.de
www.bkg.bund.de

GFZ AC Report

Rolf Koenig

Status Report

- Availability of daily pos+eop in 2016: 95.4 %
- Availability of weekly pos+eop in 2016: 100 %
- V70 pos+eop is running
  - Time variable gravity as requested by ECP not yet implemented
- PP systematic biases
  - Eventually, trick was found to transport frequencies to SINEX
  - V201 is in the queue
- ITRF2014 tests are ongoing
  - Had some problems to achieve same number of observations for comparisons
    - validity periods
      - e.g. Wettzell 88341001 has huge gap between FEB-14-2009 and NOV-11-2010 in ITRF2014
  - POD in 2014 showed improved orbital fits of ~1mm vs. SLRF2008
- DTRF2014, JTRF2014 tests not started yet

The JCET AC/CC Report to the ILRS ASC & Station Systematic Errors Monitoring PP Summary

April 22, 2017

E. C. Pavlis and M. Kuzmicz-Cieslak

Outline

- Operational Products Status
- Network support (Quarantined and Validated stations, etc.)
- Station Systematic Error Monitoring Pilot Project
- Release of SLRF2014 (ITRF2014+historical & new sites)
- Orbital files (SP3c) comparisons online
- Journal of Geodesy ILRS Special Issue

Operational Products Status

- Daily and Weekly series delivered routinely and consistently by seven of the eight ACs
- Since early July we have not received contributions from GRGS
  - Latest news from Florent indicate that a restart is imminent
- With the routinely contributing ACs down to six-seven, it is important that all ACs make an effort to deliver their contributions regularly, to maintain the quality of our products!

Station Systematic Error Monitoring PP- SSEM

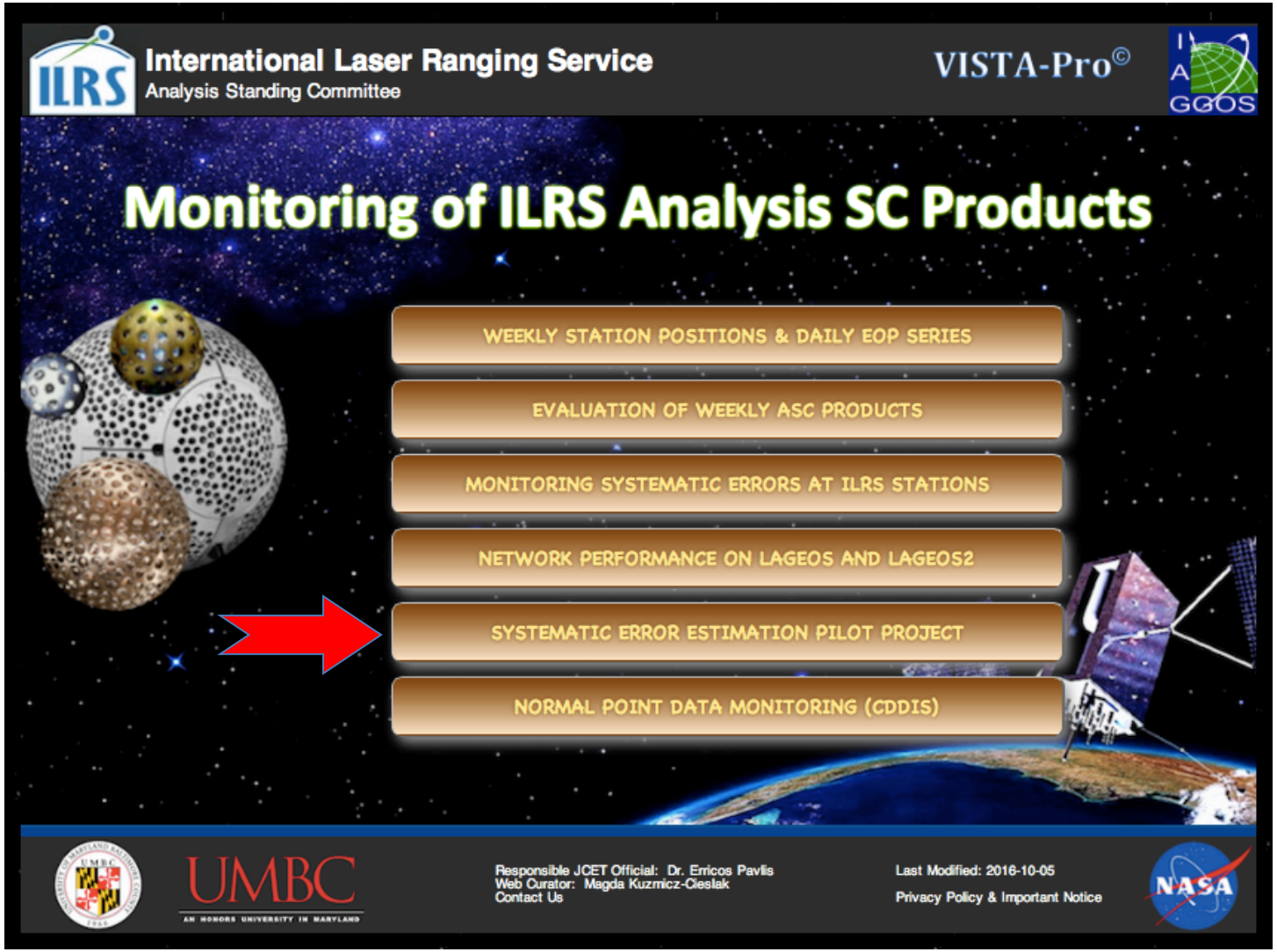
- Six ACs contributed series so far (see next)
- Two combinations completed ASI & JCET;
- We need to ensure that the common convention of identifying which estimate belongs to which wavelength for sites that support ranging in more than one wavelength is used correctly by all ACs
- We need commitment from the ACs (hopefully more than the six that participated in the PP) that they will support a weekly product, once the PP is completed and we launch the operational phase

ACs Supporting the SSEM PP

- AC-contributed series that we received so far:

Analysis Center	Date of Submission
ASI	April 11, 2017
DGFI	March 24, 2017
ESA	Nov. 25, 2016
JCET	April 14, 2017
NSGF	April 15, 2016
GFZ	July 13, 2016

JCET Portal



http://geodesy.jcet.umbc.edu/ILRS_AWG_MONITORING/

Systematic Error PP Results

Systematic Errors Estimated from LAGEOS and LAGEOS-2 SLR DATA

Pilot Project Results from period 2005-2009

INDIVIDUAL ESTIMATE L1	INDIVIDUAL ESTIMATE L2	COMBINED ESTIMATE L1+L2
ASI v201	**ASI v201**	**ASI v211**
*BKG v200**	*BKG v200**	*BKG v210**
DGFI v201	**DGFI v201**	**DGFI v210**
ESA v200	**ESA v200**	**ESA v210**
*GRGS v200**	*GRGS v200**	*GRGS v211**
GFZ v200	**GFZ v200**	**GFZ v210**
JCET v202	**JCET v202**	**JCET v212**
NSGF v200	**NSGF v200**	**NSGF v210**
*ILRSA v200**	*ILRSA v200**	*ILRSA v212**
ILRSB v200	**ILRSB v200**	**ILRSB v210**

Some very recent uploads not reflected here (ASI ;-)

Start (MM-DD-YYYY):

End Date (MM-DD-YYYY)

Station: Station

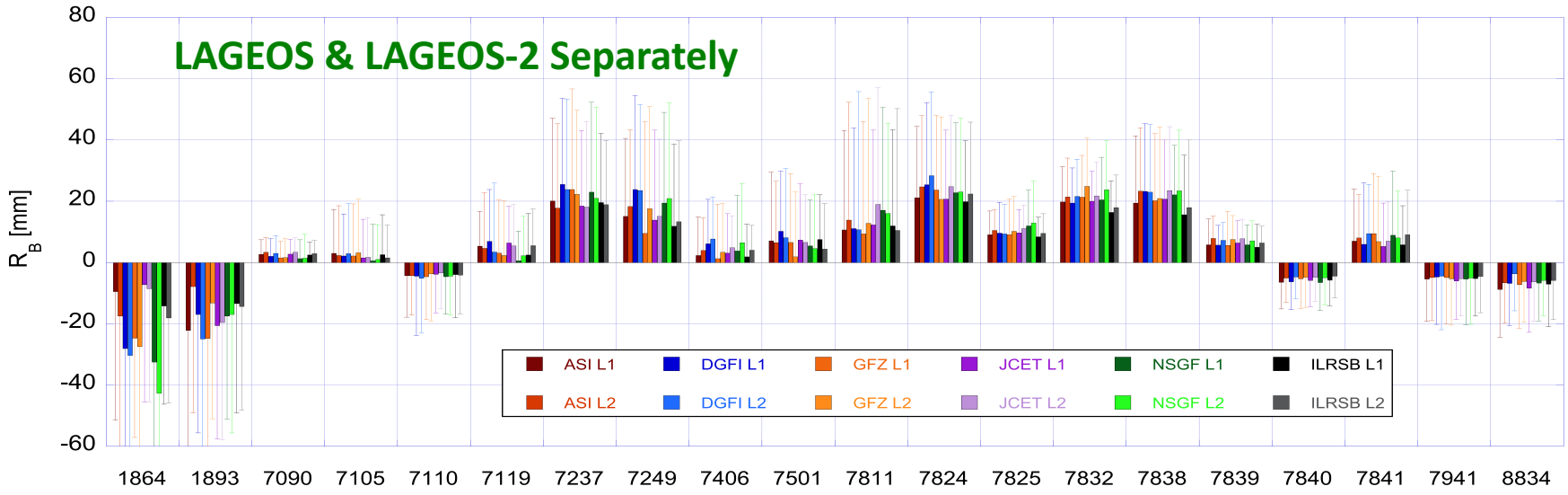
Plot Size: Minimum Maximum

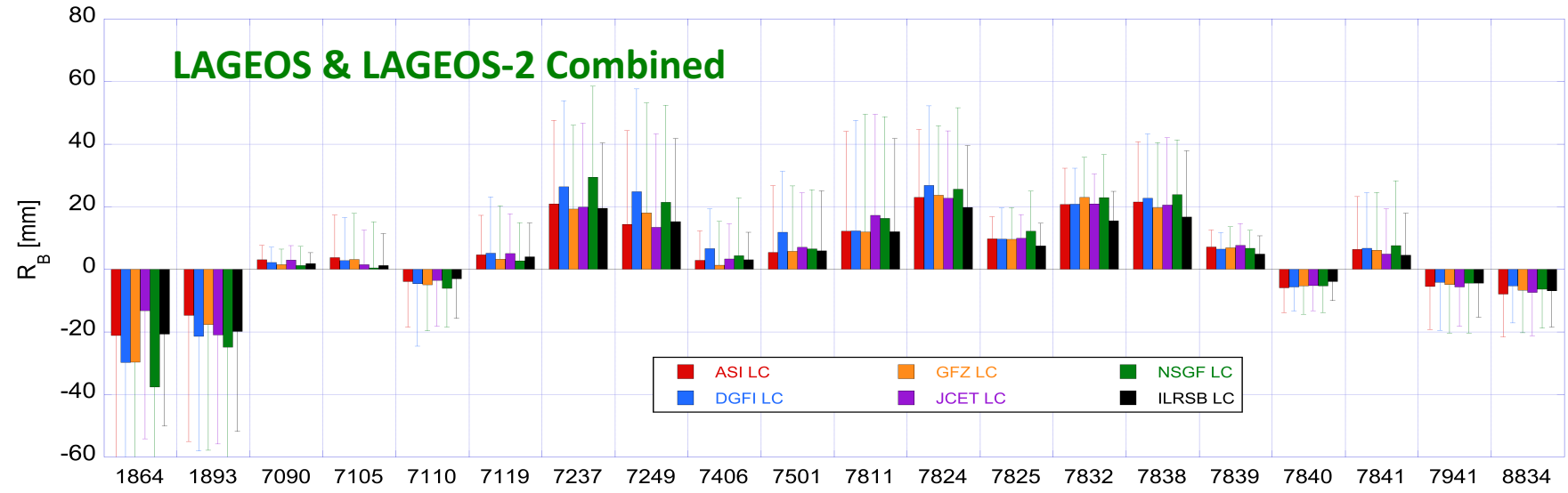
Y axis

Submit Reset form

"*" indicates no submission available from that AC

Average Error over 2005 - 2008





Multiple Wavelength Flag Table

System	CDP ID#	SOLN Flag	Wavelength
Concepcion	7405	400	423
Concepcion	7405	800	846
Zimmerwald	7810	400	423
Zimmerwald	7810	500	532
Zimmerwald	7810	800	846
SOS Wettzell	7827	400	425
SOS Wettzell	7827	800	850
Matera	7941	300	355
Matera	7941	500	532

Use the hundreds of the wavelength instead of 1,2,3, etc.

Adoption of SLRF2014 (ITRF2014 enhanced)

- The final ITRF2014 is available since over a year, the corresponding EOP series aligned with it is now the official IERS EOP product since February 9, 2017;
- The availability of the new series in early 2017 was to coincide with the time that a new Mean Pole series and corresponding routine would be available from IERS;
- There is no updated routine on the IERS ftp as of now;
- Using the available tabular file of the Mean Pole on the IERS website, formed a hybrid routine that incorporates the past MP and the new values for 2016 and some extrapolated values for the near future.
- This routine can be made available with the understanding that it is NOT an official IERS s/w

Steps on the way to using SLRF2014/ITRF2014

- We released SLRF2014 to be used as the official a priori TRF for all ILRS applications: **we must agree on the starting date now**
- We have generated already an extension of the long-wavelength gravity terms from UT/CSR's 15^d series in ITRF2014 and our own "predictions", they can be obtained in the same form as for the ITRF2014 reanalysis from:
- http://geodesy.jcet.umbc.edu/ILRS_ASC_2017_ITRF2014_IMPLEMENTATION

ILRS ASC 2017 ITRF2014 IMPLEMENTATION

Files that may be downloaded by others:

*** UPDATED Feb. 19 ***

Gravitational HCs for the 2017 ITRF2014 Implementation: FOR NON-GEODYN USERS ONLY

*** UPDATED Feb. 19 ***

Gravitational HCs for the 2017 ITRF2014 Implementation: FOR GEODYN USERS ONLY

- We have used the new SLRF2014 and the above models to reanalyze the LAGEOS 1 & 2 and ETALON 1 & 2 data from 2012 to present.

Eccentricity Data Base Clean-up

- A review of the current station site log files indicated some inconsistencies between what is on file in there and the information in our eccentricity data base and files (SINEX-like)
- After looking further into this issue, we identified some stations:
  - that show small discrepancies between the two data bases (likely due to the transformation from Cartesian to NEU or vice versa) and
  - some stations where there are bona fide mistakes or omissions
- We will look into the first to correct things and notify the second group about their errors.
- The latest release of February 2017 is our best current knowledge of station eccentricity survey results (online at the ILRS web site)

IERS 2010 Conventions Update

For this purpose, a Conventional Mean Pole (CMP) model is provided by the IERS Conventions. The CMP was provided previously in the IERS Conventions (2003) as a linear model and in the IERS Conventions (2010) as a cubic model with a linear extrapolation after 2010.0. However, in view of present-day ice sheet mass losses, the motion of the mean pole is not likely to be predictable (see e.g., Chen, et al. 2013) at the level required for the pole tide correction. Therefore, starting with year 2015, the CMP of the IERS Conventions will no longer be represented by a polynomial but will be provided by a FORTRAN subroutine, updated yearly and referenced as IERS CMP YYYY.f for year YYYY, based on observations made available by the IERS Earth Orientation Centre. At the beginning of year YYYY, the IERS Earth Orientation Centre will generate a table of observed values of the mean pole with the last point at epoch YYYY.0 by filtering periodic terms in the EOP(IERS) C01 series <[8]>. The IERS Convention Center then incorporates it in the subroutine **IERS CMP YYYY.f**, updated annually at <[9]>, that generates the components $\bar{x}_p$ and $\bar{y}_p$ of the IERS CMP(YYYY) for epochs after 1970.

These values are computed by linear interpolation of the yearly values taken from the observations provided by the IERS Earth Orientation Centre. Because of the filtering process, the values of the mean pole are likely to change as the polar motion time series is extended, but the changes should remain within the range of the required accuracy. The subroutine also provides options to obtain the CMP coordinates as described in previous versions of the IERS Conventions. The use of the most recent version is recommended as significant departures from observations may result using earlier versions for years that lie outside of the range for which they were designed. In any case, users should document the version they use.

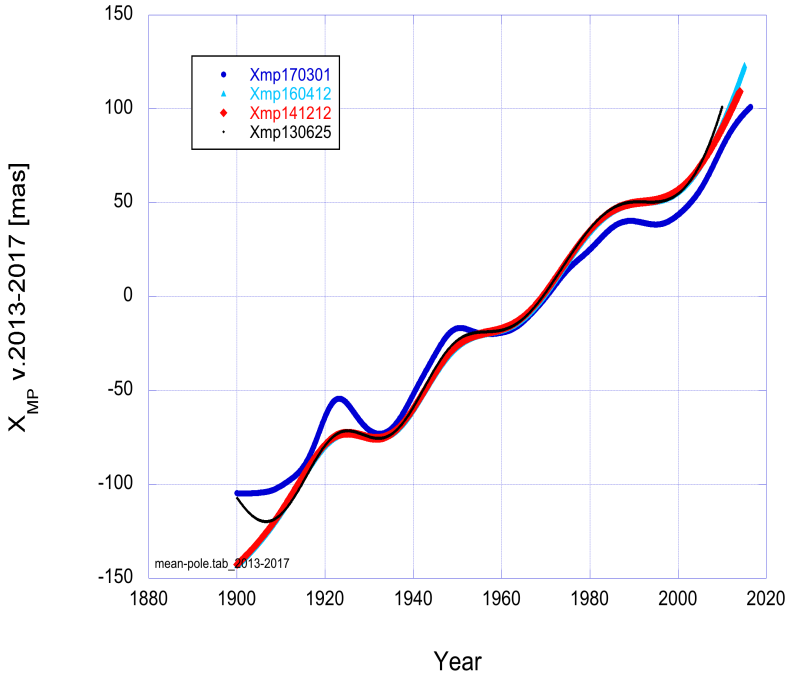
Chapter 7, section 7.1.4

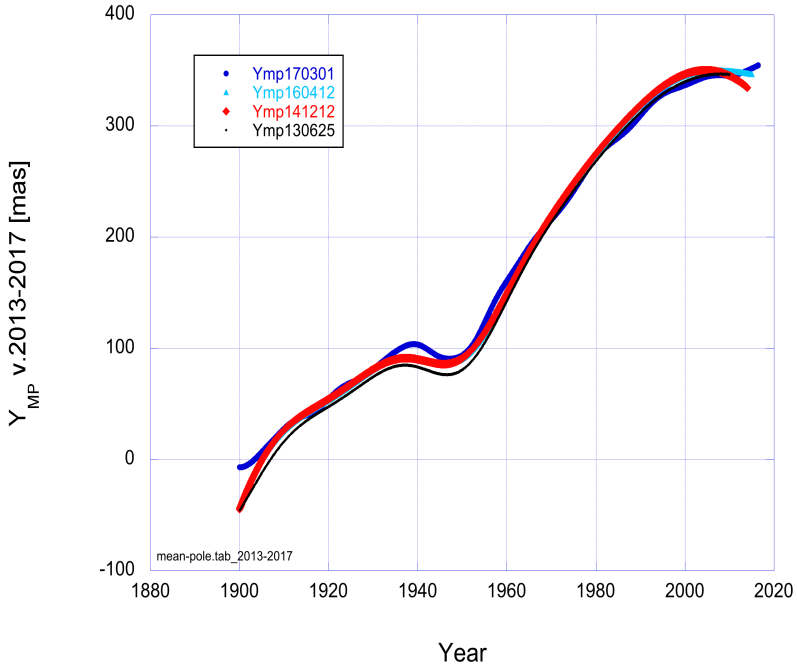
8 ftp://hpiers.obspm.fr/iers/eop/eopc01

9 ftp://tai.bipm.org/iers/convupdt/chapter7/

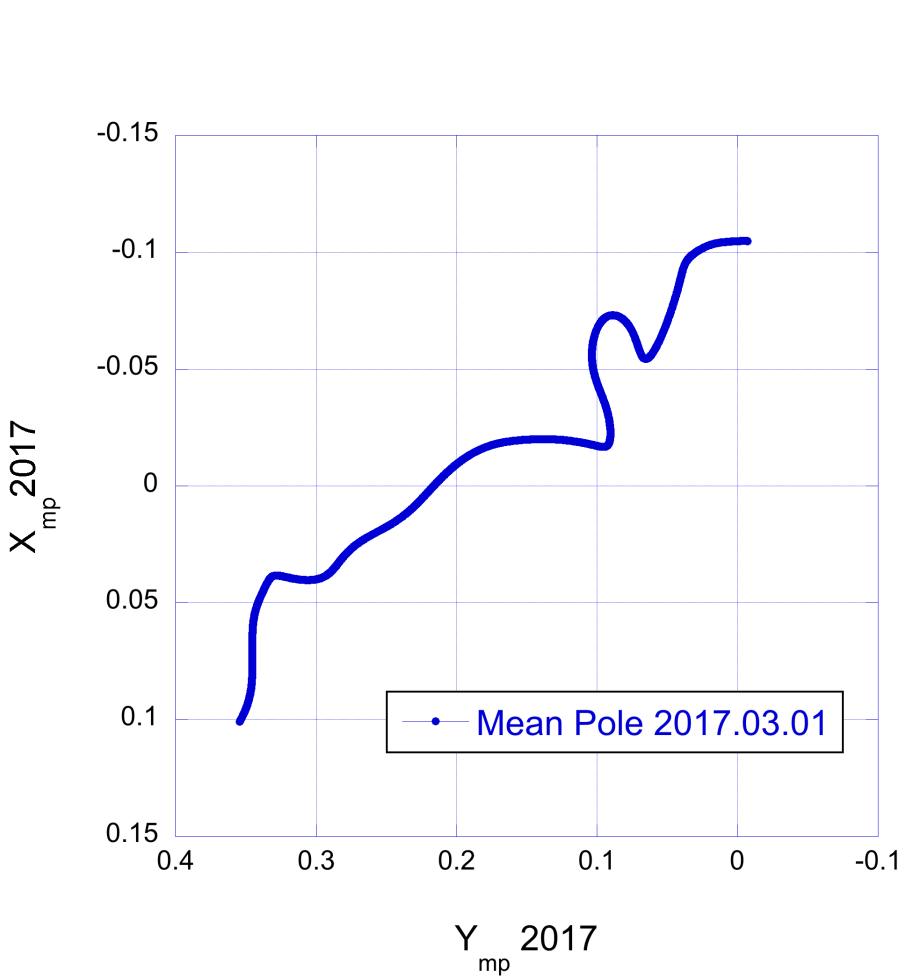
IERS CMP (YYYY-1).f

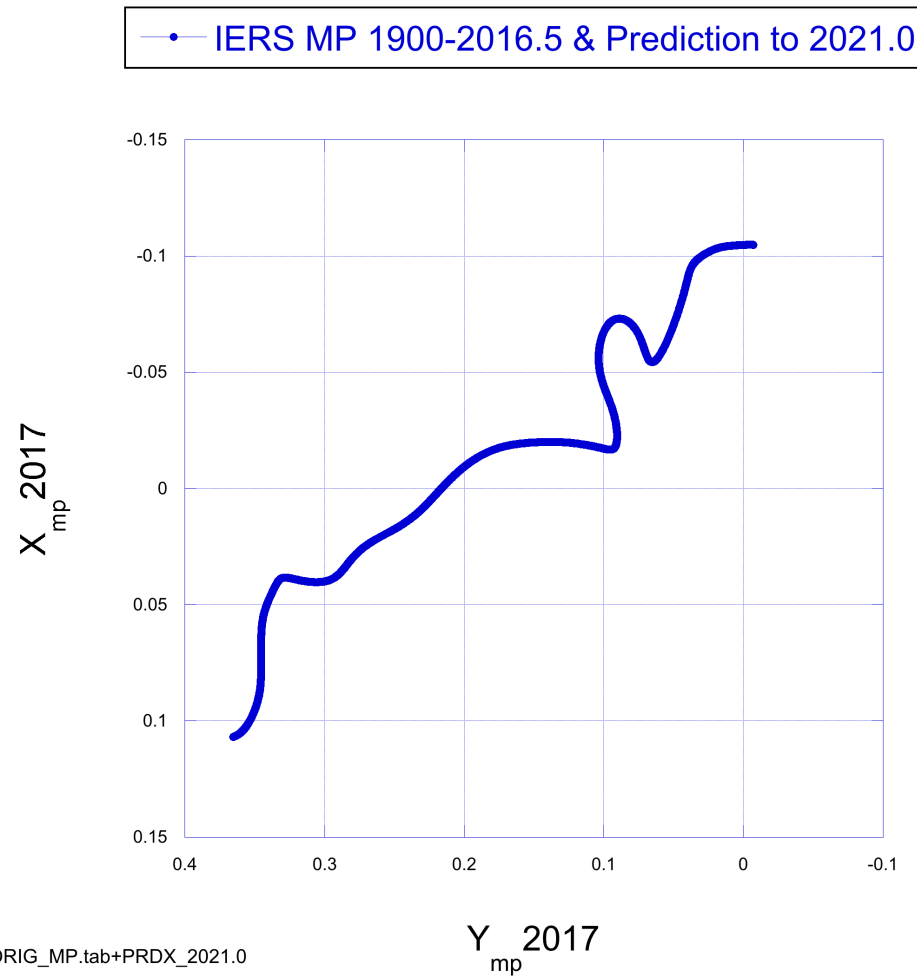
IERS CMP Comparison





IERS CMP Polhode plus Prediction





ILRS CMP 2016.f from JCET

```
      SUBROUTINE ILRS_CMP_2016   (version, epoch,x,y,error)
*+
*
*************************************************************************************************************
*  THIS ROUTINE IS NOT THE IERS ROUTINE FOR THE MEAN POLE COMPUTATION
*************************************************************************************************************
*
*  This routine is BASED on the IERS_CMP_2015.f of the International Earth Rotation and
*  Reference Systems Service (IERS) Conventions software collection.
*
* This subroutine provides the angular coordinates of the IERS Conventional Mean Pole (CMP)
* to be used in the analysis of space geodesy data after 1970.
* Starting with the version CMP(2015), the coordinates are
* based on the table of values from ftp://hpiers.obspm.fr/iers/eop/eopc01/mean-pole.tab
* See IERS Conventions Section 7.1.4 at http://tai.bipm.org/iers/convupdt/convupdt.html for details.
* The subroutine also provides previous versions of the CMP in the IERS Conventions (2003) and (2010)
*
*
*  In general, Class 1, 2, and 3 models represent physical effects that
*  act on geodetic parameters while canonical models provide lower-level
*  representations or basic computations that are used by Class 1, 2, or
*  3 models.
*
*  Status: Class 1
*
*     Class 1 models are those recommended to be used a priori in the
*     reduction of raw space geodetic data in order to determine
*     geodetic parameter estimates.
*     Class 2 models are those that eliminate an observational
*     singularity and are purely conventional in nature.
*     Class 3 models are those that are not required as either Class
*     1 or 2.
*     Canonical models are accepted as is and cannot be classified as a
*     Class 1, 2, or 3 model.
*
```

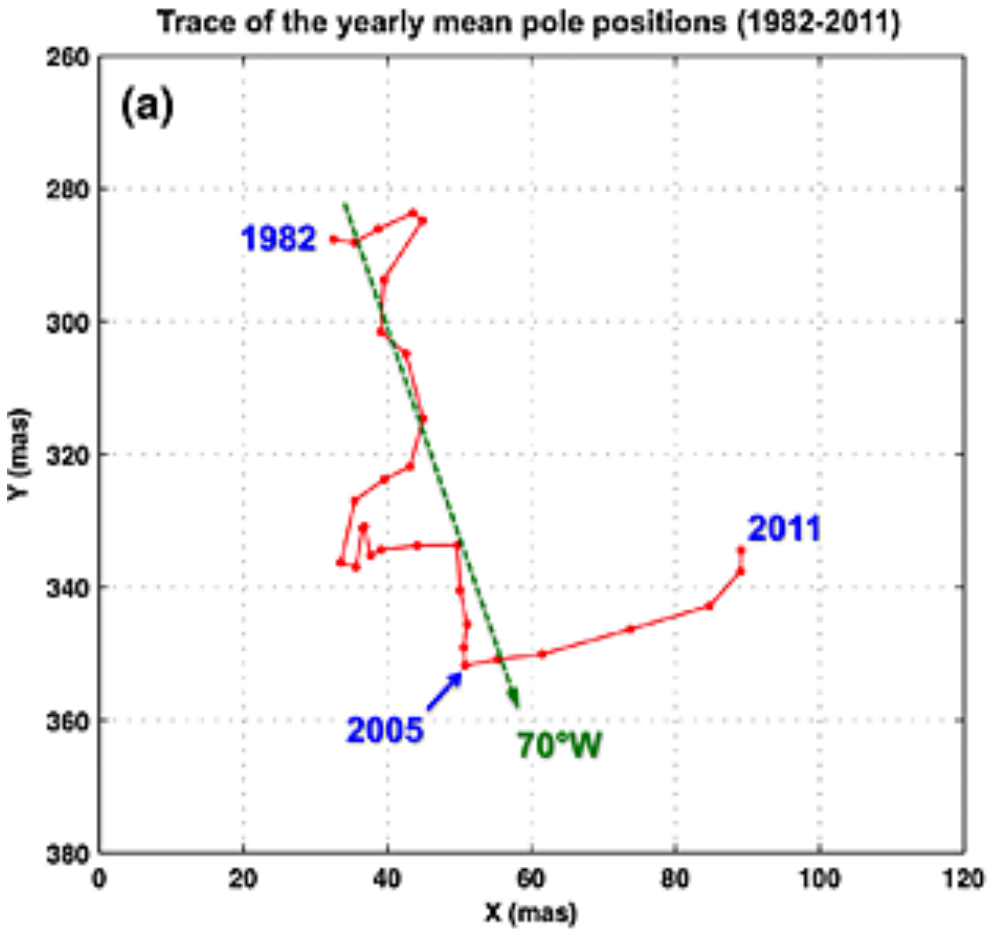
ILRS Tech. Workshop 2017: Riga, Latvia

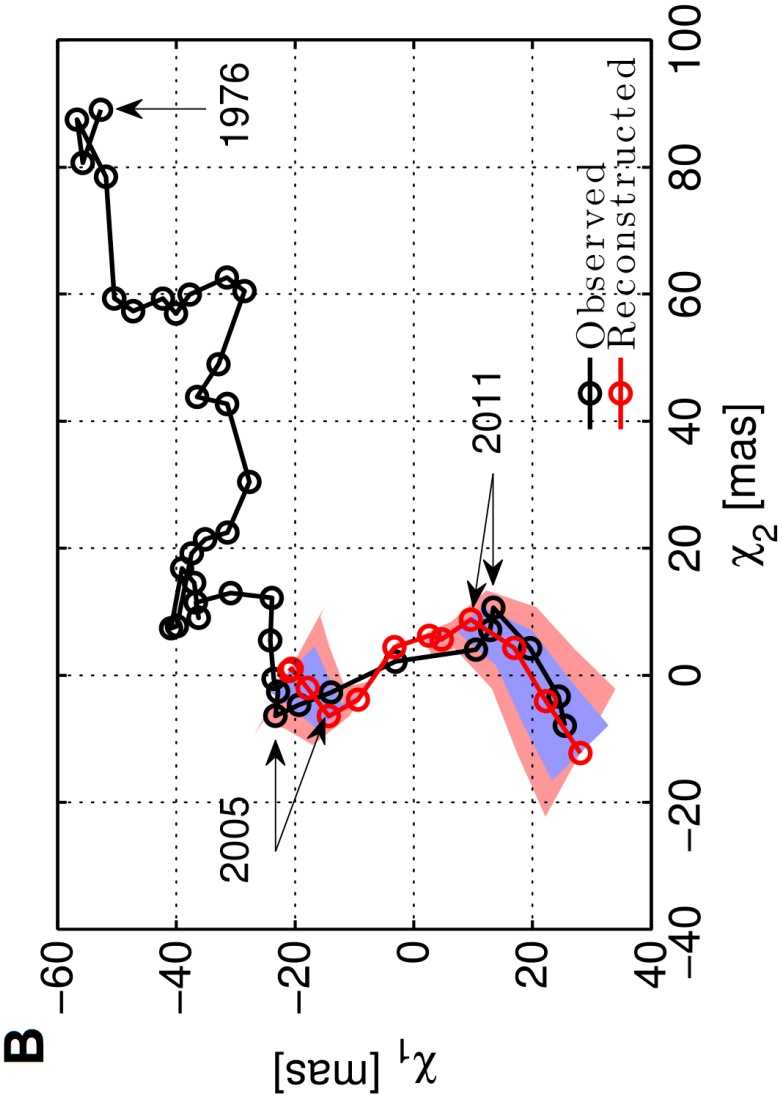
- **How do we evaluate our current performance?**
  (**Session 2 Chairs**: Erricos Pavlis, Toshi Otsubo, Horst Mueller, Cinzia Luceri)
  - What is the status of the Range bias pilot project and the other evaluation tools used by the AC's
  - What tools do we have at the stations? Are they the right ones? Can we define diagnostic procedures?
  - Reporting procedures (feedback)
  - How does the performance of the new technology stations compare with the legacy
  - stations? What are the observed differences? What should the differences be?
  - Do differences in data screening procedures have any impact on the consistency of our
  - data products?

Climate-driven Polar Motion: 2003-2015

S. Adhikari & Erik R. Ivins

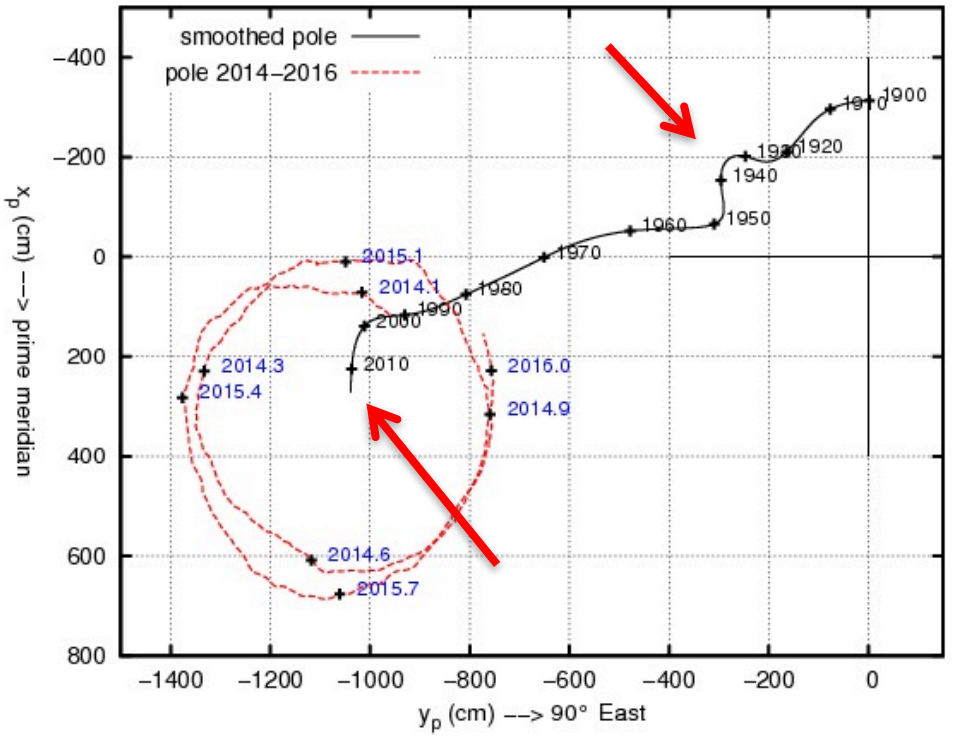
JPL





IERS CMP Plots Online

Downloaded: 2016.05.17



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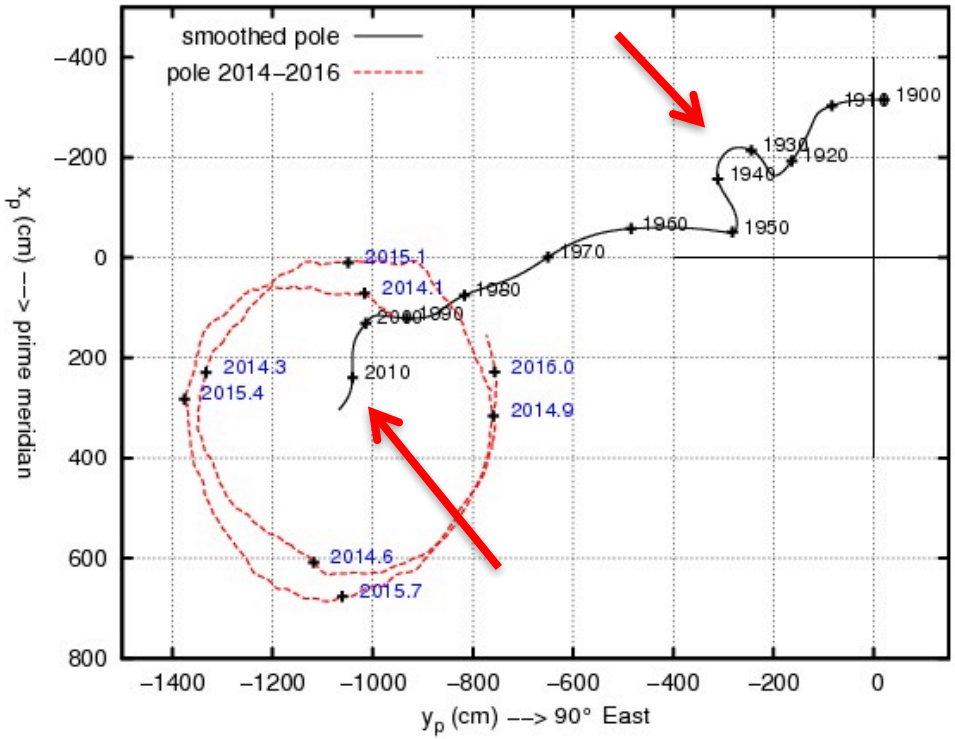
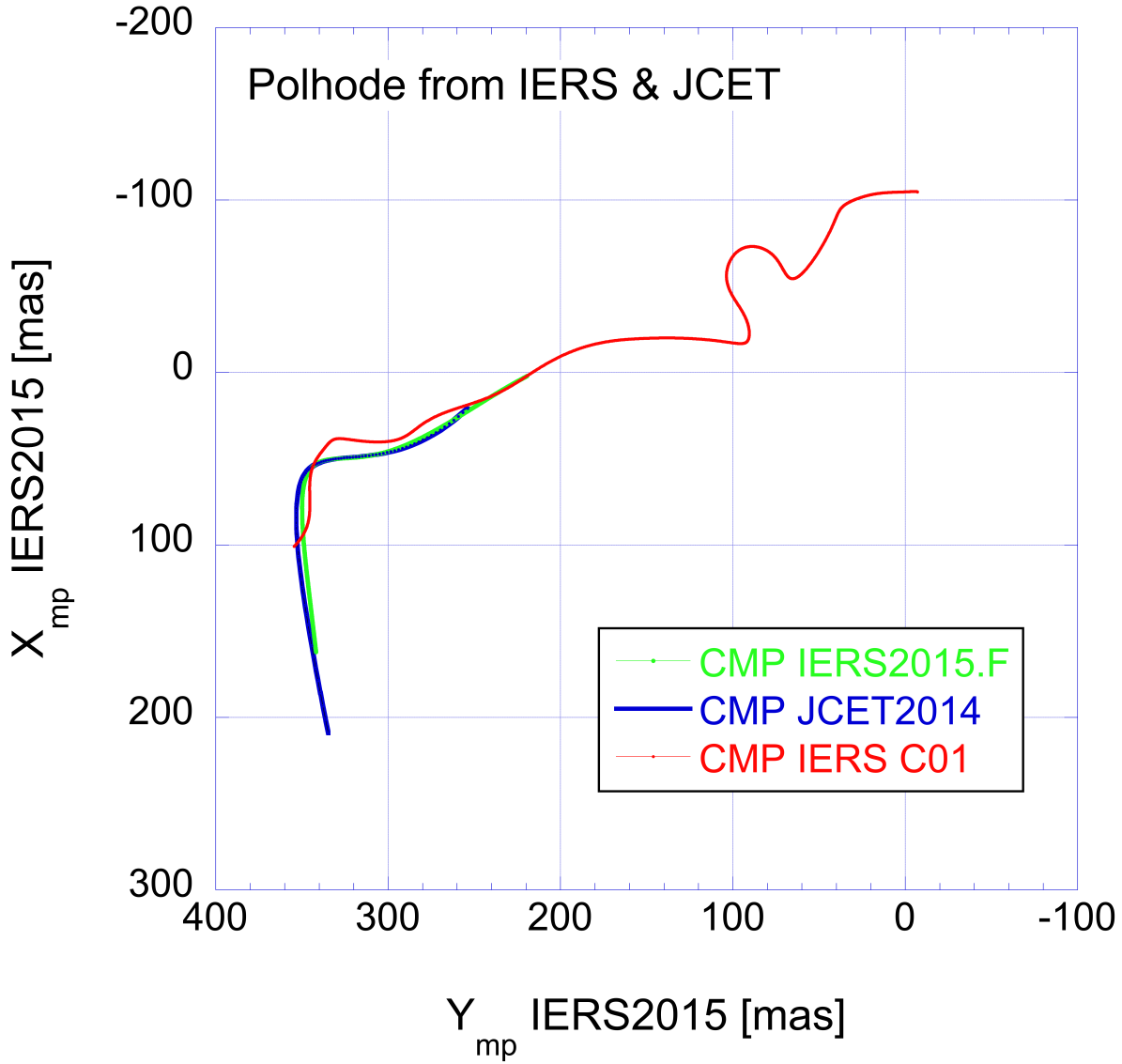
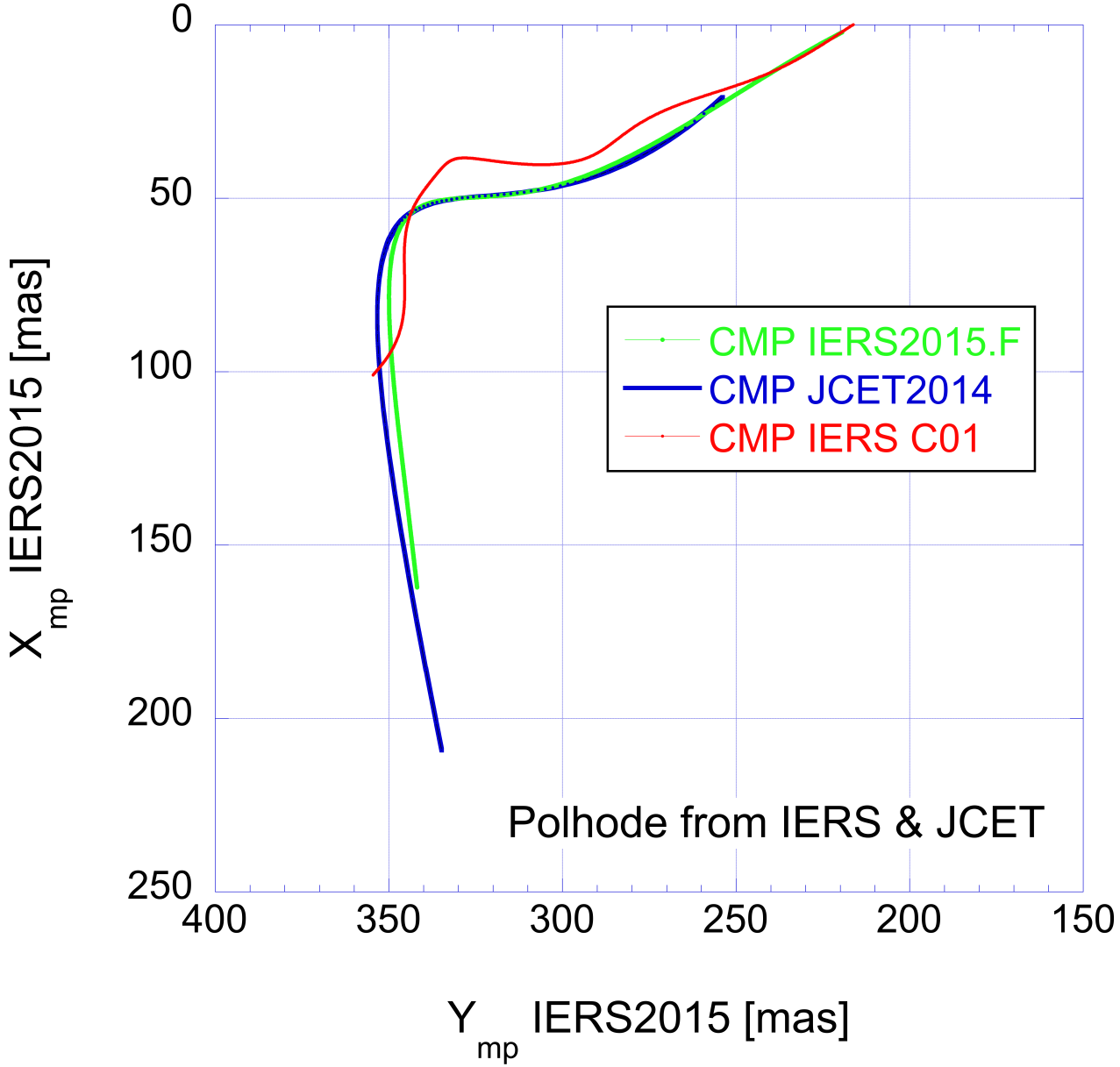


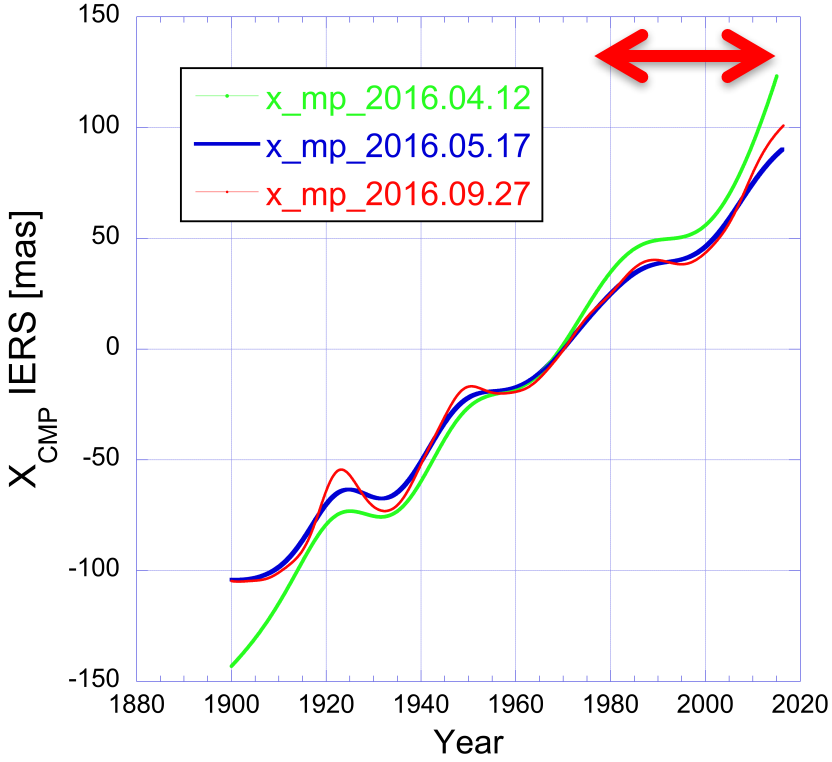
IERS CMP Comparison

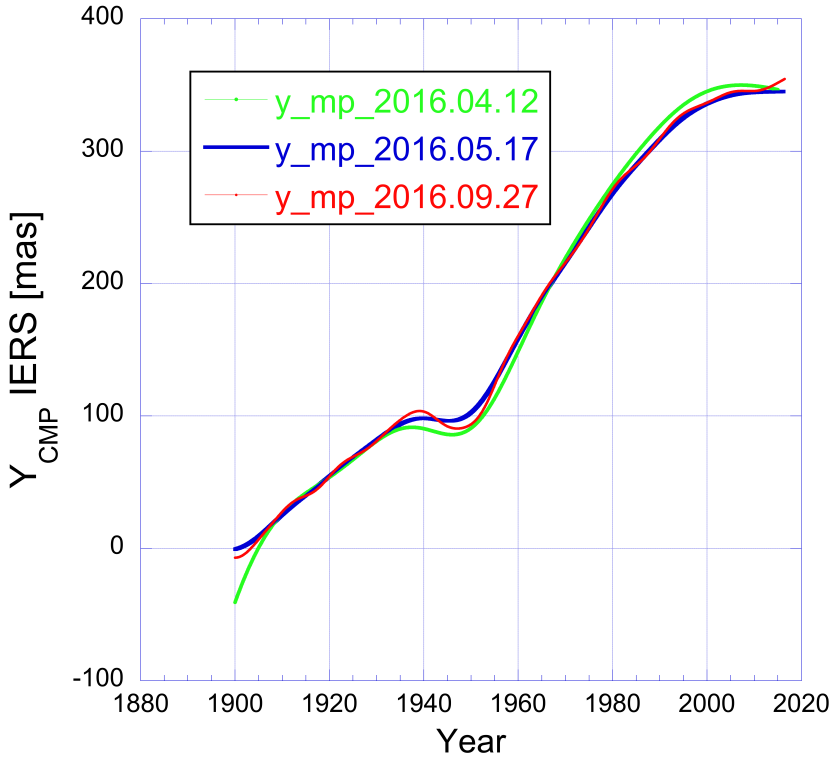


IERS CMP Comparison - detail



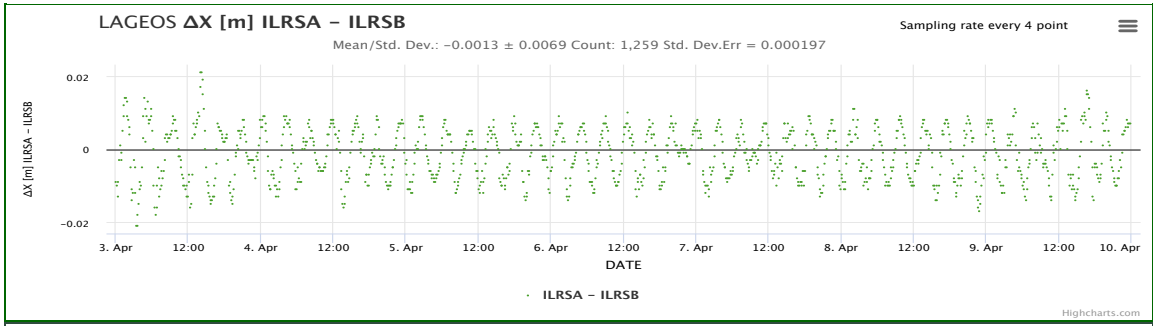
CMP Differences of IERS Updates

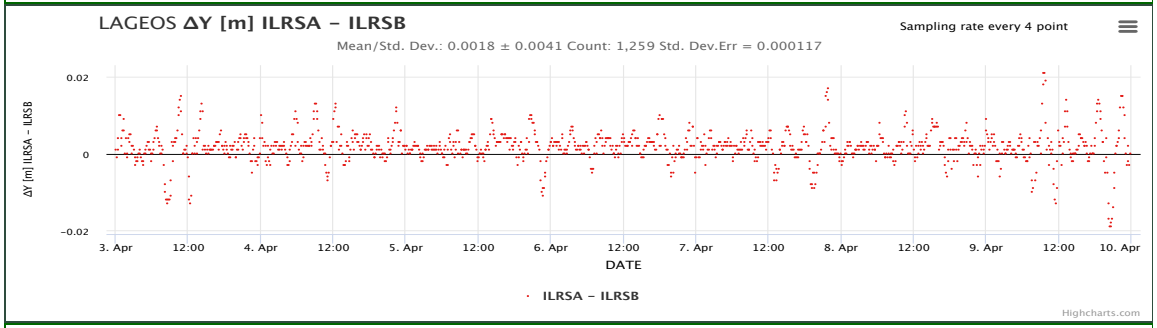


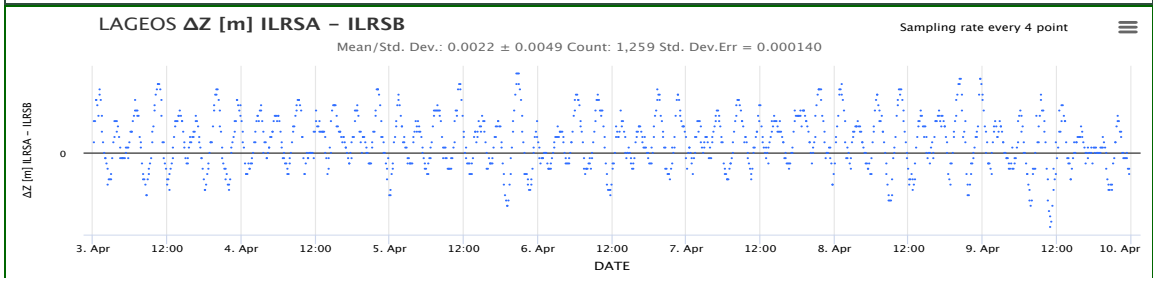


These modifications of the series in the special table "*mean-pole.tab*" were not announced and to this point no one has documented anywhere that they ever happened. Unless someone checked the file often, we do not know how many times it was changed.

LAGEOS SP3c ΔPOSITION: ILRSA-ILRSB

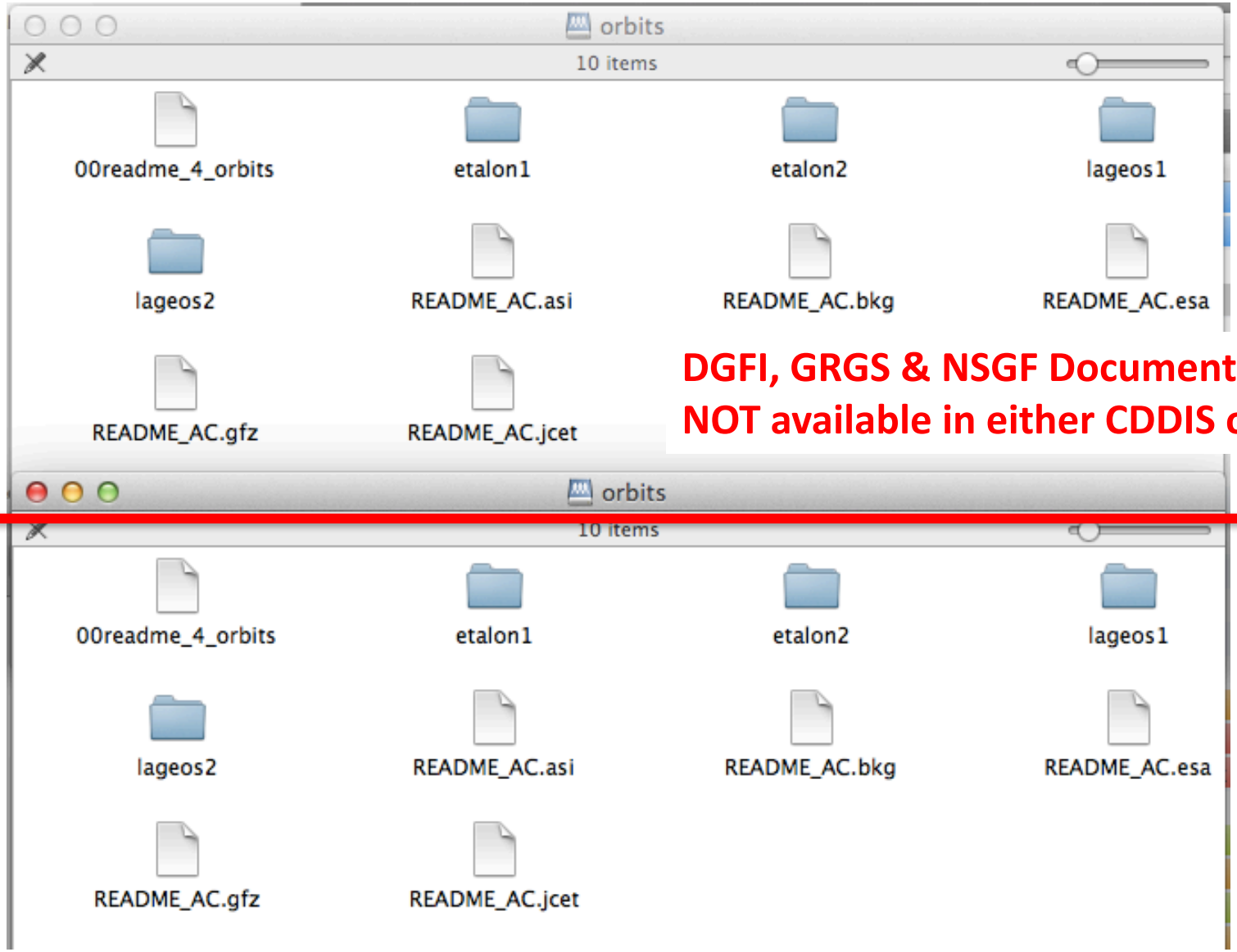






ΔX [m] ILRSA - ILRSB LAGEOS	ΔY [m] ILRSA - ILRSB LAGEOS	ΔZ [m] ILRSA - ILRSB LAGEOS	ΔVX [mm/s] ILRSA - ILRSB LAGEOS	ΔVY [mm/s] ILRSA - ILRSB LAGEOS	ΔVZ [mm/s] ILRSA - ILRSB LAGEOS
Mean/Std. Dev.: -0.0013 ± 0.0069 Count: 1,259 Std. Dev.Err = 0.000197	Mean/Std. Dev.: 0.0018 ± 0.0041 Count: 1,259 Std. Dev.Err = 0.000117	Mean/Std. Dev.: 0.0022 ± 0.0049 Count: 1,259 Std. Dev.Err = 0.000140	Mean/Std. Dev.: -0.0000 ± 0.0029 Count: 1,259 Std. Dev.Err = 0.000083	Mean/Std. Dev.: 0.0002 ± 0.0030 Count: 1,259 Std. Dev.Err = 0.000086	Mean/Std. Dev.: 0.0001 ± 0.0032 Count: 1,259 Std. Dev.Err = 0.000091

ILRS Orbital Product Archives: Status



CDDIS

DGFI, GRGS & NSGF Documentation NOT available in either CDDIS or EDC !!!

EDC

Journal of Geodesy ILRS Special Issue

#	TITLE	Lead Author(s)
0	**Foreword**	**The Guest EB**
1	**The International Laser Ranging Service (ILRS): The First Decade and Beyond**	**Pearlman, Appleby, Noll, Pavlis, Torrence**
2	**Information Resources Supporting Scientific Research for the International Laser Ranging Service**	**Noll, Horvath, Ricklefs, Schwatke, Torrence**
3	*Past, Present and Future of the ILRS Global Tracking Network*	***Dunn**, Torrence, Pearlman, Varghese and McCormick ???*
4	**Next Generation Satellite Laser Ranging Systems**	**Degnan, McGarry, Kirchner, Appleby, Prochazka, Jäggi, Moore, Artyukh, Samain, Schreiber**
5	**Geodetic satellites: a high accuracy positioning tool**	**Pearlman, Arnold, Davis, Barlier, Biancale, Vasiliev, Paolozzi. Ciufolini, Pavlis**
5a	**Altimetric missions and SLR (???)**	**Lemoine, ???**
6	**Satellite Laser Ranging to Global Navigation Satellite Systems**	**Thaller, Dell'Agnello, Fumin, Govind, Nakamura, Noda, Springer**
7	**Lunar Laser Ranging – A Tool for General Relativity, Lunar Geophysics and Earth Science**	**J. Müller, Murphy, Schreiber, Shelus, Torre, Williams, Boggs**
8	**Interplanetary Ranging**	**Degnan, Schreiber, McGarry, Sun, Zagwodzki, Murphy, Samain, Turyshev**
9	**Target Signature Systematic Errors for Geodetic Satellites and Novel LR Array Design**	**Appleby, Otsubo, Arnold, Kirchner, Neubert, Grunwaldt, Vasilliev**
10	**Data Quality Control Service for the ILRS Tracking Network**	**Otsubo, H. Müller, Pavlis, Torrence, Thaller, Glotov, Xiaoya, Appleby**
11	**Systematic errors in SLR Data: Documentation and Discussion of their Sources**	**Luceri, H. Müller, Vei, Appleby and Pavlis**
12	**Operational and Definitive Products of the ILRS Analysis Working Group**	**Luceri and Pavlis**
13	*Monitoring Mass Redistribution in the Earth System with SLR*	*Pavlis, König, Ries, Deleflie, Cheng, H. Müller, ???*
14	*The ILRS Contribution to the International Terrestrial Reference Frame (ITRF)*	*Pavlis and the ASC ACs and CCs*

We also had EIGHT (8) "un-solicited" abstracts (still interested???)

1) **BOLD** indicates working title from author(s) for a submitted abstract
2) **RED** indicates lead author
3) *Non-bold entries in italics are still pending!!!*

ILRS Orbital Product Monitoring (SP3 Formatted Files)

http://geodesy.jcet.umbc.edu/SP3/

WEEKLY PRODUCT | Statistics

Analysis Center: Please Select the first / vs. Please choose the secon

Start (MM-DD-YYYY):

End (MM-DD-YYYY):

Satellite: Choose Satellite

Plot Size (Y axis)	Minimum	Maximum	
X [m]	Green		Filed Square
Y [m]	Red		Filed Square
Z [m]	Blue		Filed Square
VX [mm/s]	Purple		Filed Square
VY [mm/s]	Aqua		Filed Square
VZ [mm/s]	Yellow		Filed Square

Submit | Reset form

UMBC
AN HONORS UNIVERSITY IN MARYLAND

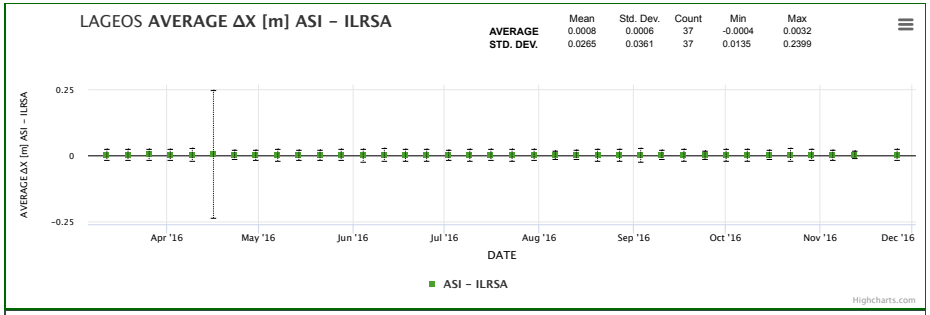
International Laser Ranging Service

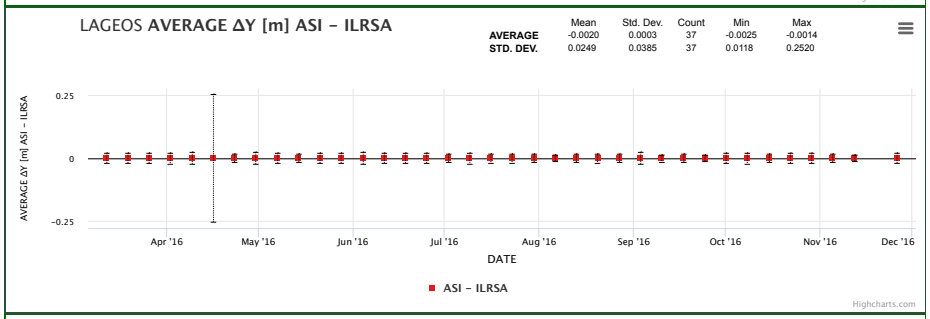
Responsible JCET Official: Dr. Erricos Pavlis

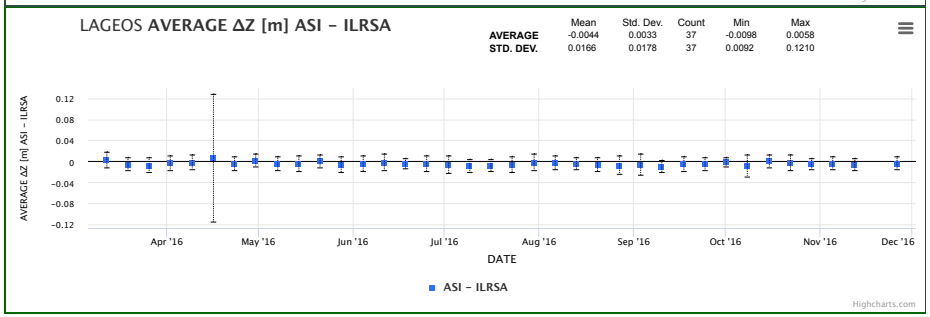
Last modified 2017-04-14

Maintained and Created by: Magda Kuzmicz-Cieslak

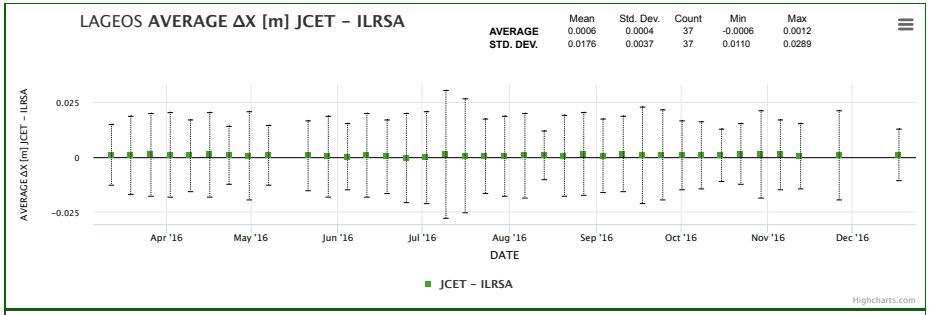
MONITORING SP3 STATISTICS

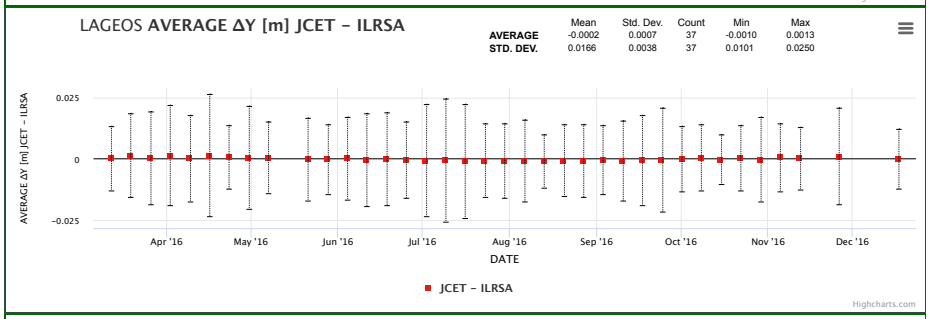


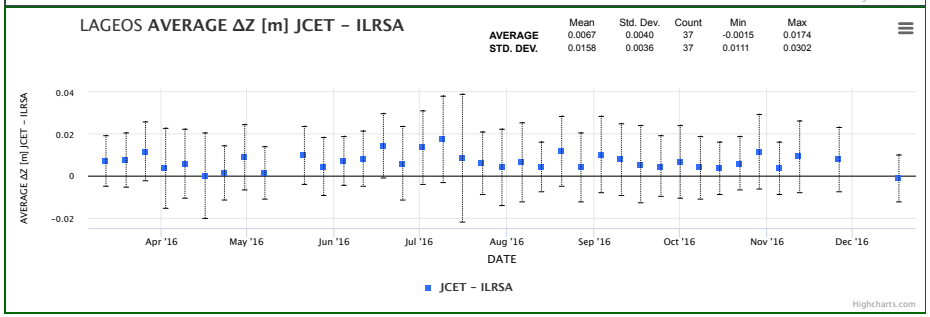




MONITORING SP3 STATISTICS

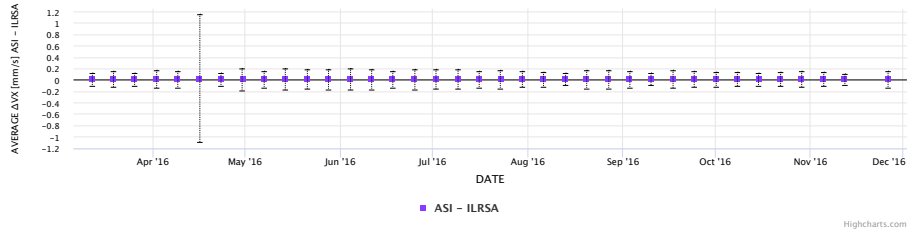






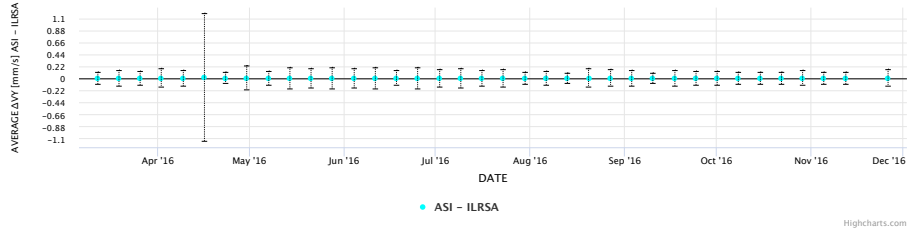
LAGEOS AVERAGE ΔVX [mm/s] ASI – ILRSA

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0009	0.0037	37	-0.0023	0.0218
STD. DEV.	0.1708	0.1617	37	0.1027	1.1167



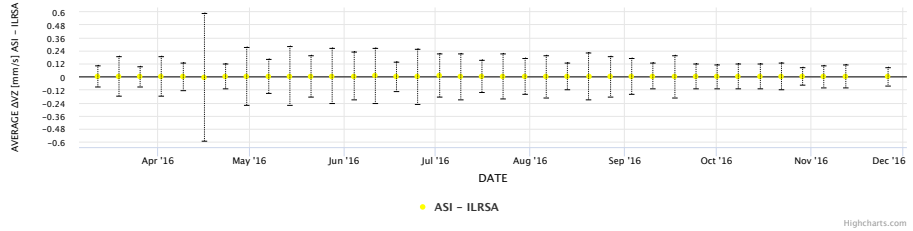
LAGEOS AVERAGE ΔVY [mm/s] ASI – ILRSA

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0010	0.0029	37	-0.0031	0.0155
STD. DEV.	0.1714	0.1710	37	0.0914	1.1647



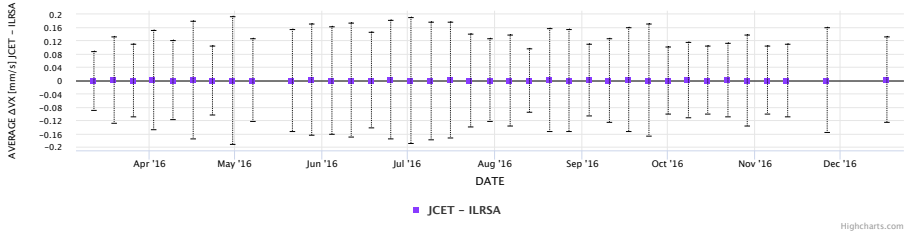
LAGEOS AVERAGE ΔVZ [mm/s] ASI – ILRSA

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0010	0.0024	37	-0.0066	0.0071
STD. DEV.	0.1740	0.0891	37	0.0790	0.5836



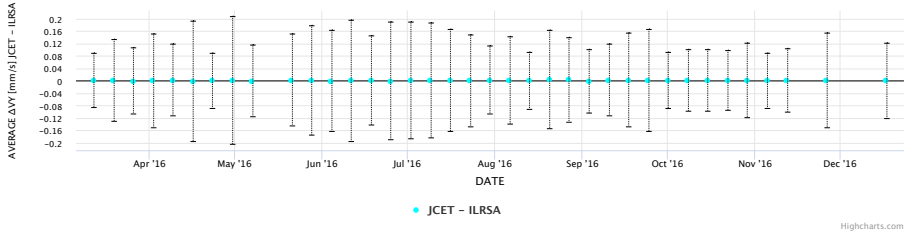
LAGEOS AVERAGE ΔVX [mm/s] JCET – ILRSA

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	-0.0001	0.0010	37	-0.0018	0.0024
STD. DEV.	0.1389	0.0293	37	0.0887	0.1911



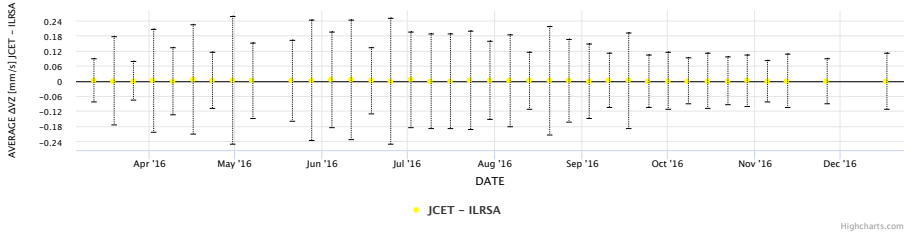
LAGEOS AVERAGE ΔVY [mm/s] JCET – ILRSA

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0002	0.0011	37	-0.0021	0.0025
STD. DEV.	0.1364	0.0359	37	0.0874	0.2053



LAGEOS AVERAGE ΔVZ [mm/s] JCET – ILRSA

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0011	0.0018	37	-0.0024	0.0054
STD. DEV.	0.1532	0.0529	37	0.0771	0.2528



AVERAGE ΔX [m] ASI - ILRSA LAGEOS	AVERAGE ΔY [m] ASI - ILRSA LAGEOS	AVERAGE ΔZ [m] ASI - ILRSA LAGEOS	AVERAGE ΔVX [mm/s] ASI - ILRSA LAGEOS	AVERAGE ΔVY [mm/s] ASI - ILRSA LAGEOS	AVERAGE ΔVZ [mm/s] ASI - ILRSA LAGEOS
Mean/Std. Dev.: 0.0008 ± 0.0006 Count: 37	Mean/Std. Dev.: -0.0020 ± 0.0003 Count: 37	Mean/Std. Dev.: -0.0044 ± 0.0033 Count: 37	Mean/Std. Dev.: 0.0009 ± 0.0037 Count: 37	Mean/Std. Dev.: 0.0010 ± 0.0029 Count: 37	Mean/Std. Dev.: 0.0010 ± 0.0024 Count: 37

STD. DEV. ΔX [m] ASI - ILRSA LAGEOS	STD. DEV. ΔY [m] ASI - ILRSA LAGEOS	STD. DEV. ΔZ [m] ASI - ILRSA LAGEOS	STD. DEV. ΔVX [mm/s] ASI - ILRSA LAGEOS	STD. DEV. ΔVY [mm/s] ASI - ILRSA LAGEOS	STD. DEV. ΔVZ [mm/s] ASI - ILRSA LAGEOS
Mean/Std. Dev.: 0.0265 ± 0.0361 Count: 37	Mean/Std. Dev.: 0.0249 ± 0.0385 Count: 37	Mean/Std. Dev.: 0.0166 ± 0.0178 Count: 37	Mean/Std. Dev.: 0.1708 ± 0.1617 Count: 37	Mean/Std. Dev.: 0.1714 ± 0.1710 Count: 37	Mean/Std. Dev.: 0.1740 ± 0.0891 Count: 37

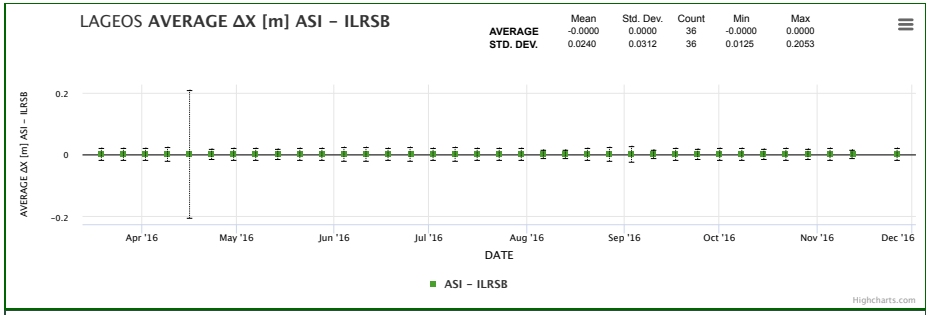
AVERAGE ΔX [m] JCET - ILRSA LAGEOS	AVERAGE ΔY [m] JCET - ILRSA LAGEOS	AVERAGE ΔZ [m] JCET - ILRSA LAGEOS	AVERAGE ΔVX [mm/s] JCET - ILRSA LAGEOS	AVERAGE ΔVY [mm/s] JCET - ILRSA LAGEOS	AVERAGE ΔVZ [mm/s] JCET - ILRSA LAGEOS
Mean/Std. Dev.: 0.0006 ± 0.0004 Count: 37	Mean/Std. Dev.: -0.0002 ± 0.0007 Count: 37	Mean/Std. Dev.: 0.0067 ± 0.0040 Count: 37	Mean/Std. Dev.: -0.0001 ± 0.0010 Count: 37	Mean/Std. Dev.: 0.0002 ± 0.0011 Count: 37	Mean/Std. Dev.: 0.0011 ± 0.0018 Count: 37

STD. DEV. ΔX [m] JCET - ILRSA LAGEOS	STD. DEV. ΔY [m] JCET - ILRSA LAGEOS	STD. DEV. ΔZ [m] JCET - ILRSA LAGEOS	STD. DEV. ΔVX [mm/s] JCET - ILRSA LAGEOS	STD. DEV. ΔVY [mm/s] JCET - ILRSA LAGEOS	STD. DEV. ΔVZ [mm/s] JCET - ILRSA LAGEOS
Mean/Std. Dev.: 0.0176 ± 0.0037 Count: 37	Mean/Std. Dev.: 0.0166 ± 0.0038 Count: 37	Mean/Std. Dev.: 0.0158 ± 0.0036 Count: 37	Mean/Std. Dev.: 0.1389 ± 0.0293 Count: 37	Mean/Std. Dev.: 0.1364 ± 0.0359 Count: 37	Mean/Std. Dev.: 0.1532 ± 0.0529 Count: 37

MONITORING SP3 STATISTICS

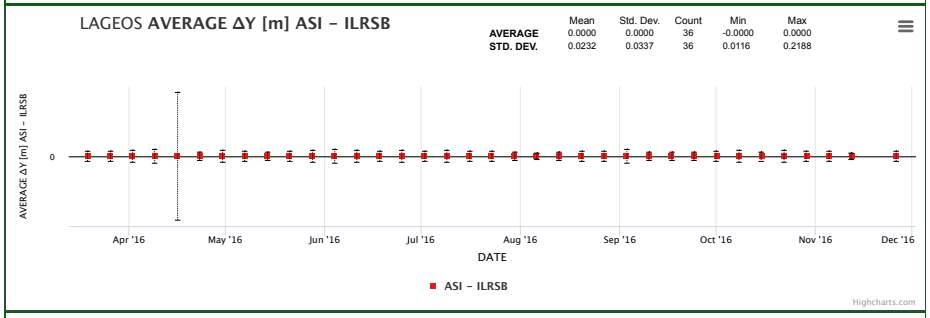
LAGEOS **AVERAGE ΔX [m] ASI – ILRSB**

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	-0.0000	0.0000	36	-0.0000	0.0000
STD. DEV.	0.0240	0.0312	36	0.0125	0.2053



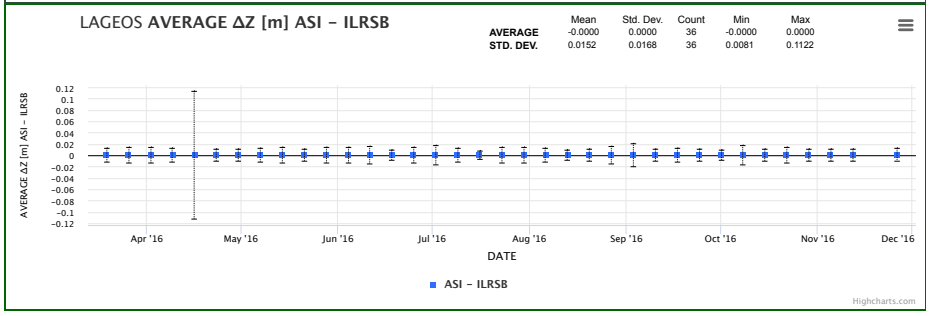
LAGEOS **AVERAGE ΔY [m] ASI – ILRSB**

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0000	0.0000	36	-0.0000	0.0000
STD. DEV.	0.0232	0.0337	36	0.0116	0.2188



LAGEOS **AVERAGE ΔZ [m] ASI – ILRSB**

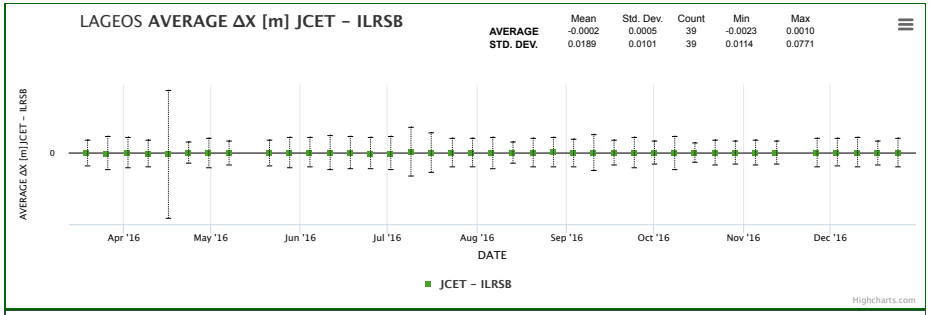
	Mean	Std. Dev.	Count	Min	Max
AVERAGE	-0.0000	0.0000	36	-0.0000	0.0000
STD. DEV.	0.0152	0.0168	36	0.0081	0.1122



MONITORING SP3 STATISTICS

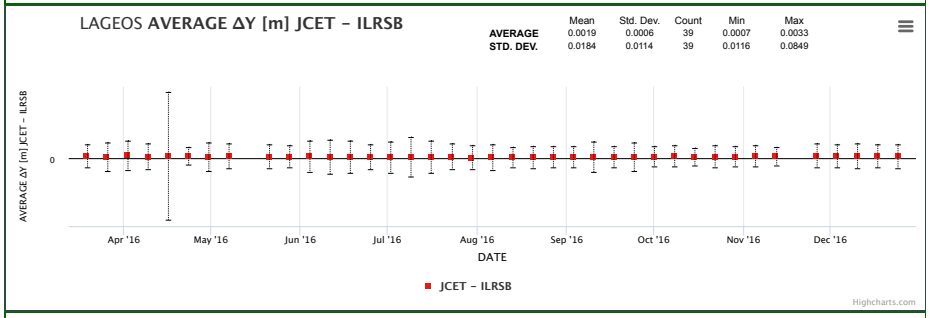
LAGEOS **AVERAGE ΔX [m] JCET – ILRSB**

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	-0.0002	0.0005	39	-0.0023	0.0010
STD. DEV.	0.0189	0.0101	39	0.0114	0.0771



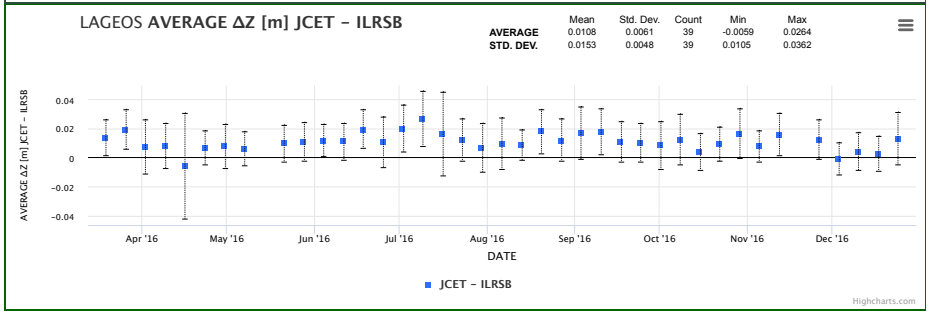
LAGEOS **AVERAGE ΔY [m] JCET – ILRSB**

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0019	0.0006	39	0.0007	0.0033
STD. DEV.	0.0184	0.0114	39	0.0116	0.0849



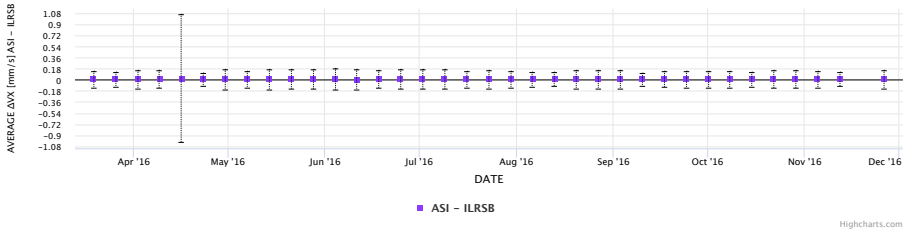
LAGEOS **AVERAGE ΔZ [m] JCET – ILRSB**

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0108	0.0061	39	-0.0059	0.0264
STD. DEV.	0.0153	0.0048	39	0.0105	0.0362



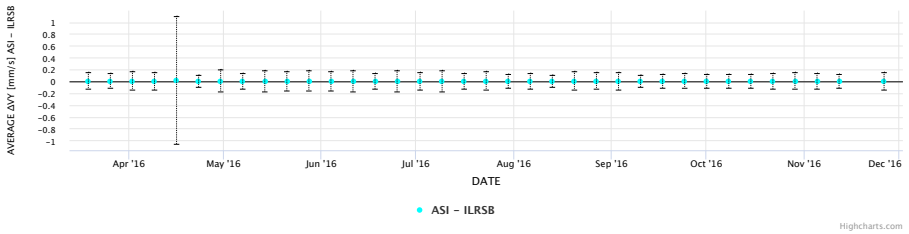
LAGEOS AVERAGE ΔVX [mm/s] ASI – ILRSB

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0007	0.0035	36	-0.0027	0.0197
STD. DEV.	0.1651	0.1493	36	0.1043	1.0301



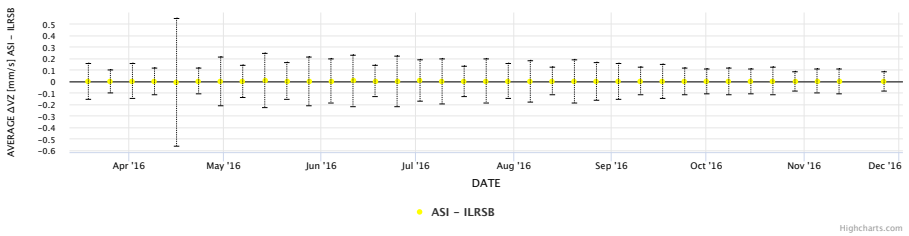
LAGEOS AVERAGE ΔVY [mm/s] ASI – ILRSB

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0008	0.0027	36	-0.0024	0.0143
STD. DEV.	0.1666	0.1572	36	0.0951	1.0734



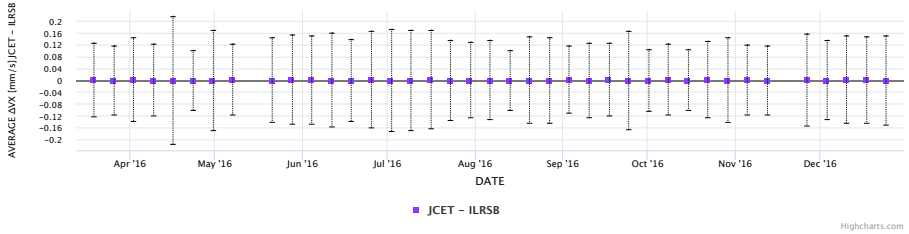
LAGEOS AVERAGE ΔVZ [mm/s] ASI – ILRSB

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0007	0.0022	36	-0.0084	0.0049
STD. DEV.	0.1608	0.0790	36	0.0827	0.5524



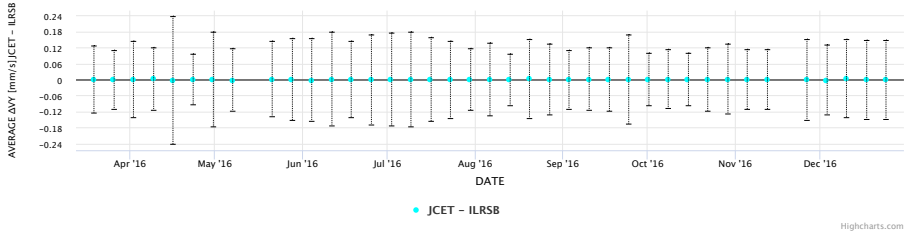
LAGEOS AVERAGE ΔVX [mm/s] JCET – ILRSB

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	-0.0002	0.0010	39	-0.0023	0.0018
STD. DEV.	0.1388	0.0237	39	0.1018	0.2149



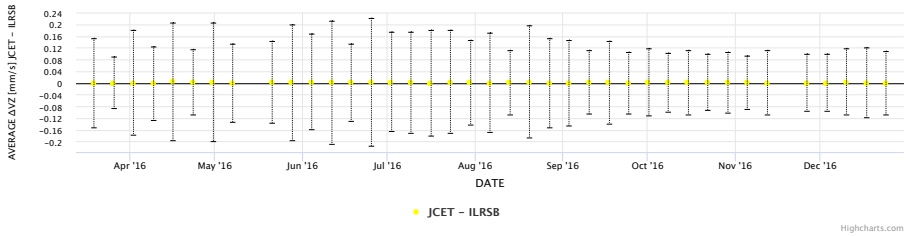
LAGEOS AVERAGE ΔVY [mm/s] JCET – ILRSB

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0000	0.0013	39	-0.0033	0.0030
STD. DEV.	0.1372	0.0290	39	0.0944	0.2376



LAGEOS AVERAGE ΔVZ [mm/s] JCET – ILRSB

	Mean	Std. Dev.	Count	Min	Max
AVERAGE	0.0008	0.0013	39	-0.0018	0.0036
STD. DEV.	0.1403	0.0382	39	0.0865	0.2166



AVERAGE ΔX [m] ASI - ILRSB LAGEOS	AVERAGE ΔY [m] ASI - ILRSB LAGEOS	AVERAGE ΔZ [m] ASI - ILRSB LAGEOS	AVERAGE ΔVX [mm/s] ASI - ILRSB LAGEOS	AVERAGE ΔVY [mm/s] ASI - ILRSB LAGEOS	AVERAGE ΔVZ [mm/s] ASI - ILRSB LAGEOS
Mean/Std. Dev.: -0.0000 ± 0.0000 Count: 36	Mean/Std. Dev.: 0.0000 ± 0.0000 Count: 36	Mean/Std. Dev.: -0.0000 ± 0.0000 Count: 36	Mean/Std. Dev.: 0.0007 ± 0.0035 Count: 36	Mean/Std. Dev.: 0.0008 ± 0.0027 Count: 36	Mean/Std. Dev.: 0.0007 ± 0.0022 Count: 36

STD. DEV. ΔX [m] ASI - ILRSB LAGEOS	STD. DEV. ΔY [m] ASI - ILRSB LAGEOS	STD. DEV. ΔZ [m] ASI - ILRSB LAGEOS	STD. DEV. ΔVX [mm/s] ASI - ILRSB LAGEOS	STD. DEV. ΔVY [mm/s] ASI - ILRSB LAGEOS	STD. DEV. ΔVZ [mm/s] ASI - ILRSB LAGEOS
Mean/Std. Dev.: 0.0240 ± 0.0312 Count: 36	Mean/Std. Dev.: 0.0232 ± 0.0337 Count: 36	Mean/Std. Dev.: 0.0152 ± 0.0168 Count: 36	Mean/Std. Dev.: 0.1651 ± 0.1493 Count: 36	Mean/Std. Dev.: 0.1666 ± 0.1572 Count: 36	Mean/Std. Dev.: 0.1608 ± 0.0790 Count: 36

AVERAGE ΔX [m] JCET - ILRSB LAGEOS	AVERAGE ΔY [m] JCET - ILRSB LAGEOS	AVERAGE ΔZ [m] JCET - ILRSB LAGEOS	AVERAGE ΔVX [mm/s] JCET - ILRSB LAGEOS	AVERAGE ΔVY [mm/s] JCET - ILRSB LAGEOS	AVERAGE ΔVZ [mm/s] JCET - ILRSB LAGEOS
Mean/Std. Dev.: -0.0002 ± 0.0005 Count: 39	Mean/Std. Dev.: 0.0019 ± 0.0006 Count: 39	Mean/Std. Dev.: 0.0108 ± 0.0061 Count: 39	Mean/Std. Dev.: -0.0002 ± 0.0010 Count: 39	Mean/Std. Dev.: 0.0000 ± 0.0013 Count: 39	Mean/Std. Dev.: 0.0008 ± 0.0013 Count: 39

STD. DEV. ΔX [m] JCET - ILRSB LAGEOS	STD. DEV. ΔY [m] JCET - ILRSB LAGEOS	STD. DEV. ΔZ [m] JCET - ILRSB LAGEOS	STD. DEV. ΔVX [mm/s] JCET - ILRSB LAGEOS	STD. DEV. ΔVY [mm/s] JCET - ILRSB LAGEOS	STD. DEV. ΔVZ [mm/s] JCET - ILRSB LAGEOS
Mean/Std. Dev.: 0.0189 ± 0.0101 Count: 39	Mean/Std. Dev.: 0.0184 ± 0.0114 Count: 39	Mean/Std. Dev.: 0.0153 ± 0.0048 Count: 39	Mean/Std. Dev.: 0.1388 ± 0.0237 Count: 39	Mean/Std. Dev.: 0.1372 ± 0.0290 Count: 39	Mean/Std. Dev.: 0.1403 ± 0.0382 Count: 39

ILRS QC Products on Station Systematic Errors

http://geodesy.jcet.umbc.edu/QC/

Analysis Center:	Choose AC
Satellite	Choose
Start (MM-DD-YYYY):	
End (MM-DD-YYYY):	
Quantities to display:	Choose quantity
Station:	Choose Station
Plot Size	Minimum Maximum
Y axis	Min Max
	Green Filled Square
REGRESSION	NO Green
Moving Average Interval	1 weeks
	Submit Reset form

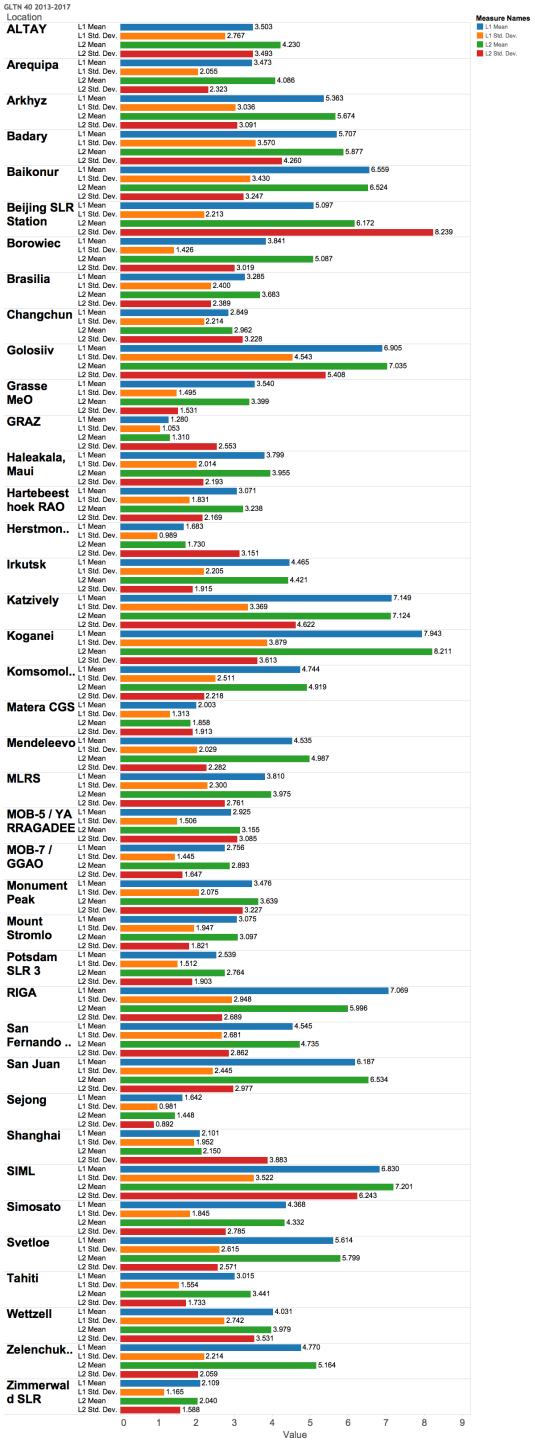
UMBC
AN HONORS UNIVERSITY IN MARYLAND

International Laser Ranging Service

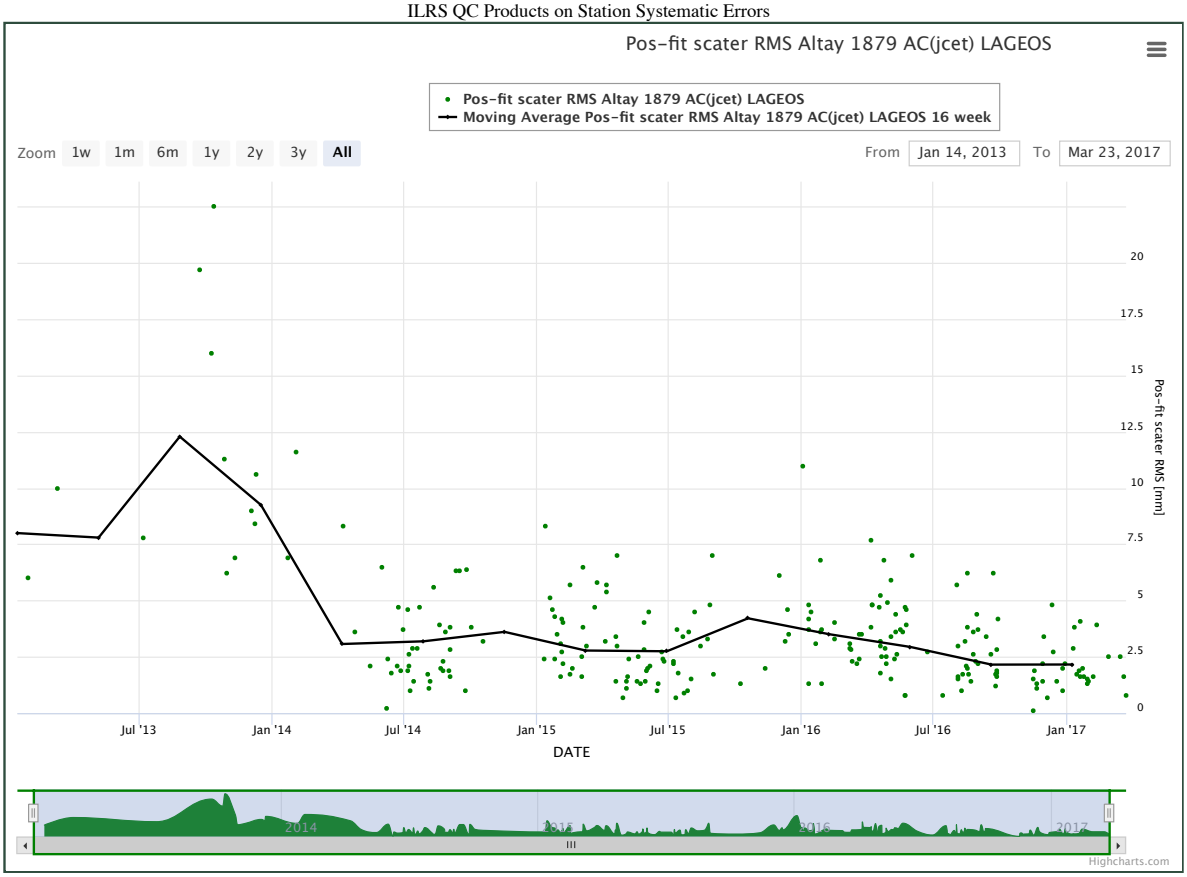
Responsible JCET Official: Dr. Erricos Pavlis

Last modified 2017-04-14

Maintained and Created by: Magda Kuzmicz-Cieslak

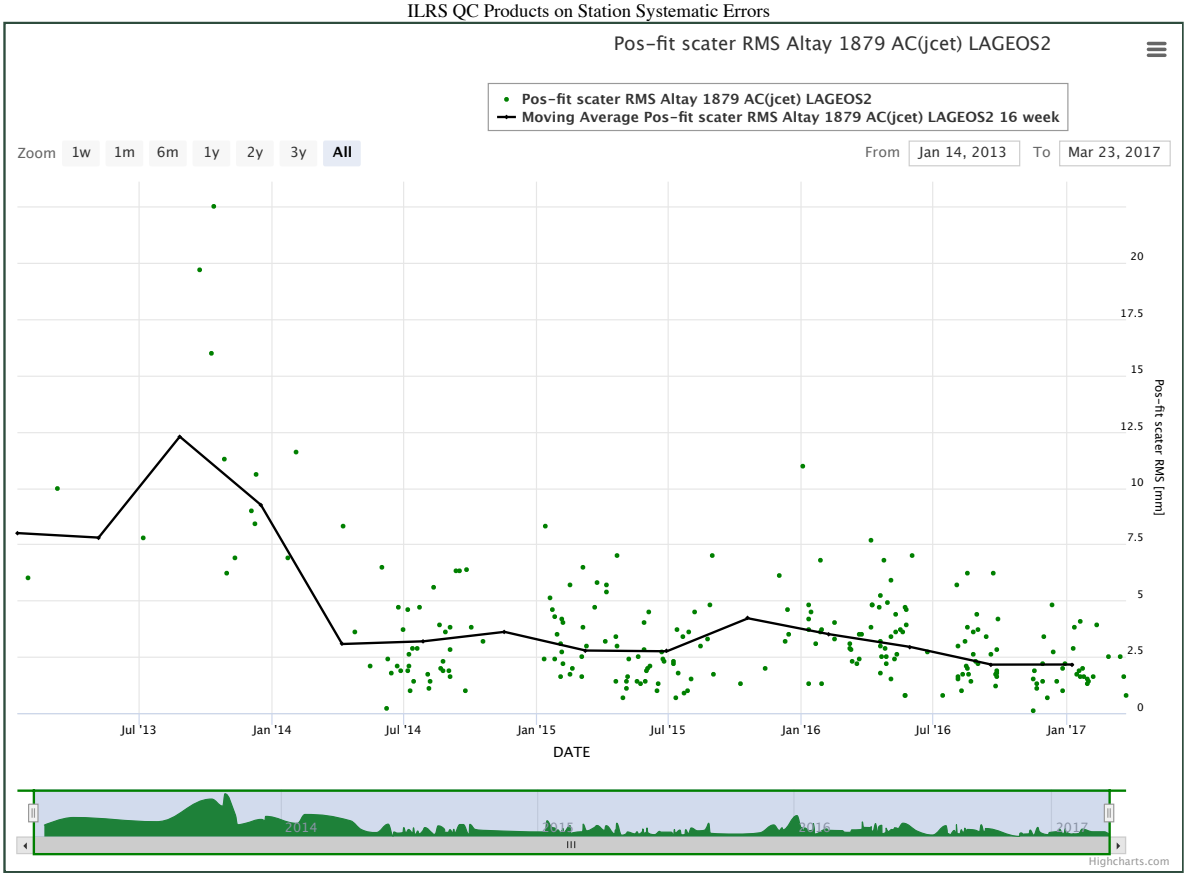

GLTN 40 2013-2017
Location
Measure Names
L1 Mean
L1 Std. Dev.
L2 Mean
L2 Std. Dev.
ALTAY 3.503 2.767 4.230 3.493
Arequipa 3.473 2.055 4.086 2.323
Arkhyz 5.363 3.036 5.674 3.091
Badary 5.707 3.570 5.877 4.260
Baikonur 6.559 3.430 6.524 3.247
Beijing SLR Station 5.097 2.213 6.172 8.239
Borowiec 3.841 1.426 5.087 3.019
Brasilia 3.285 2.400 3.683 2.389
Changchun 2.849 2.214 2.962 3.228
Golosiiv 6.905 4.543 7.035 5.408
Grasse MeO 3.540 1.495 3.399 1.531
GRAZ 1.280 1.053 1.310 2.553
Haleakala, Maui 3.799 2.014 3.955 2.193
Hartebeest hoek RAO 3.071 1.831 3.238 2.169
Herstmon.. 1.683 0.989 1.730 3.151
Irkutsk 4.465 2.205 4.421 1.915
Katzively 7.149 3.369 7.124 4.622
Koganei 7.943 3.879 8.211 3.613
Komsomol.. 4.744 2.511 4.919 2.218
Matera CGS 2.003 1.313 1.858 1.913
Mendeleevo 4.535 2.029 4.987 2.282
MLRS 3.810 2.300 3.975 2.761
MOB-5 / YARRAGADEE 2.925 1.506 3.155 3.085
MOB-7 / GGAO 2.756 1.445 2.893 1.647
Monument Peak 3.476 2.075 3.639 3.227
Mount Stromlo 3.075 1.947 3.097 1.821
Potsdam SLR 3 2.539 1.512 2.764 1.903
RIGA 7.069 2.948 5.996 2.689
San Fernando .. 4.545 2.681 4.735 2.862
San Juan 6.187 2.445 6.534 2.977
Sejong 1.642 0.981 1.448 0.892
Shanghai 2.101 1.952 2.150 3.883
SIML 6.830 3.522 7.201 6.243
Simosato 4.368 1.845 4.332 2.785
Svetloe 5.614 2.615 5.799 2.571
Tahiti 3.015 1.554 3.441 1.733
Wettzell 4.031 2.742 3.979 3.531
Zelenchuk.. 4.770 2.214 5.164 2.059
Zimmerwald SLR 2.109 1.165 2.040 1.588
0 1 2 3 4 5 6 7 8 9
Value

ILRS QC Products on Station Systematic Errors

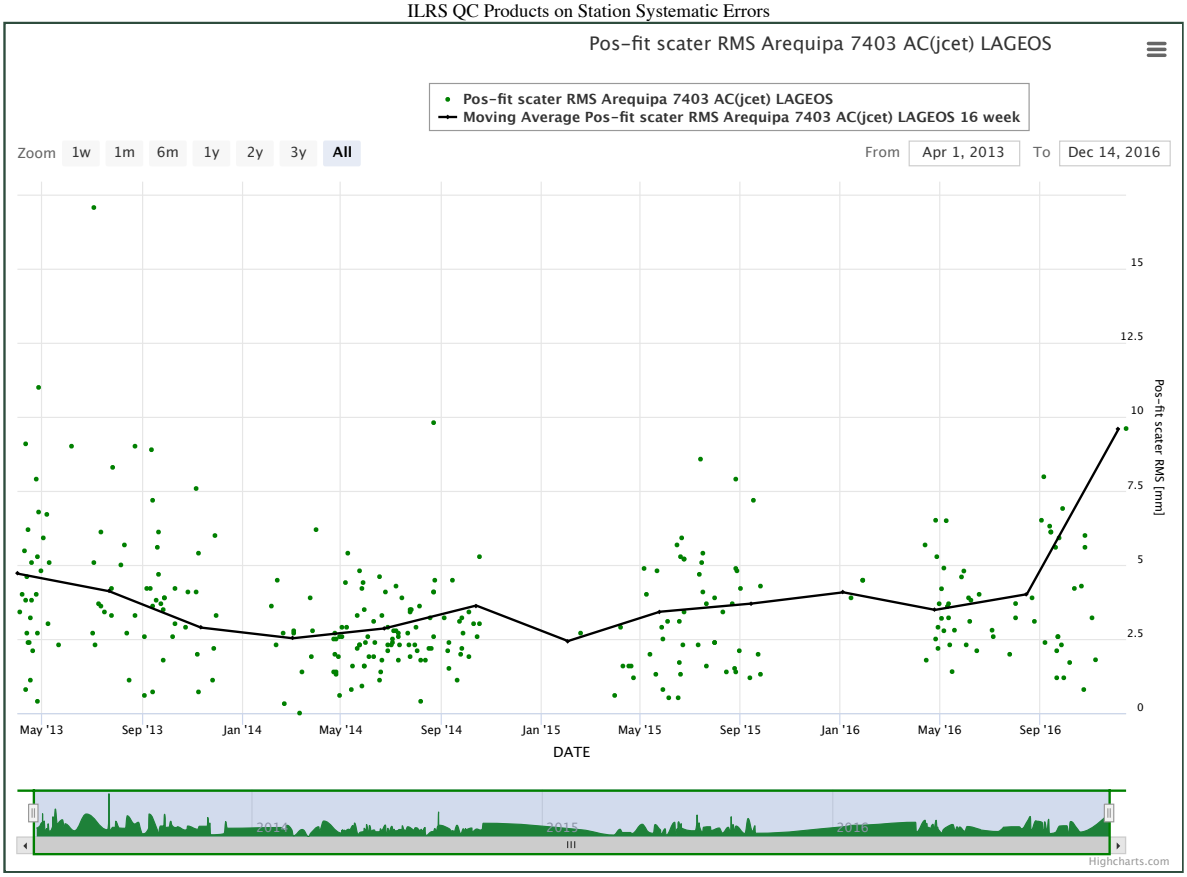


ALTAY 1879

ILRS QC Products on Station Systematic Errors

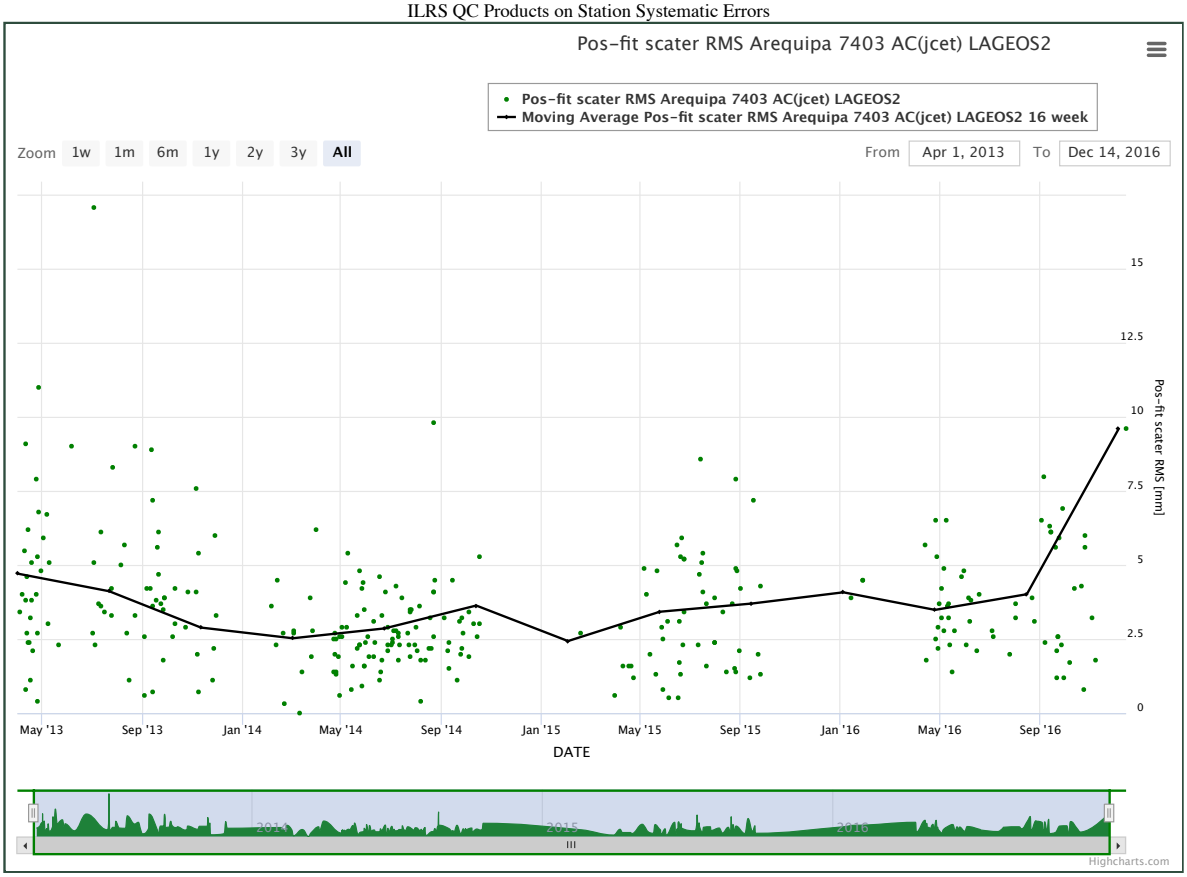


ILRS QC Products on Station Systematic Errors

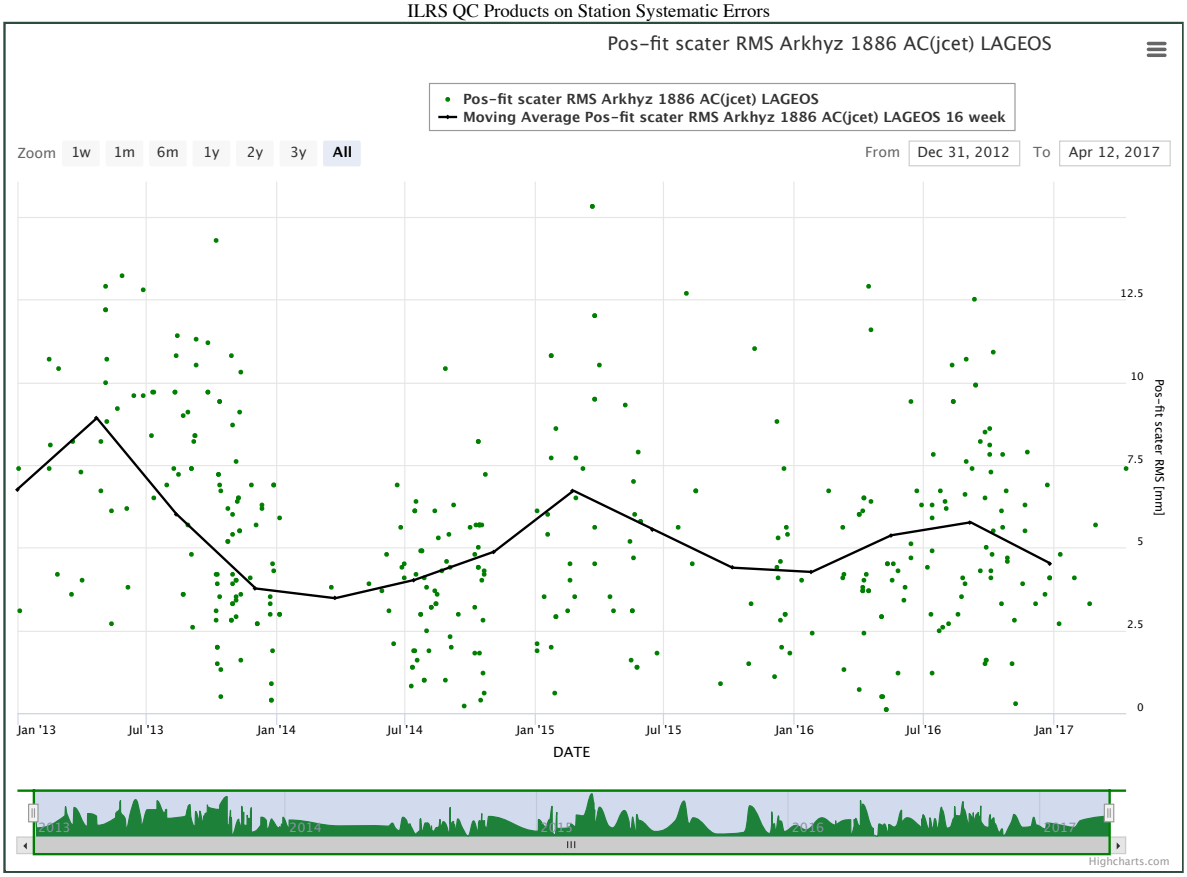


AREQUIPA 7403

ILRS QC Products on Station Systematic Errors

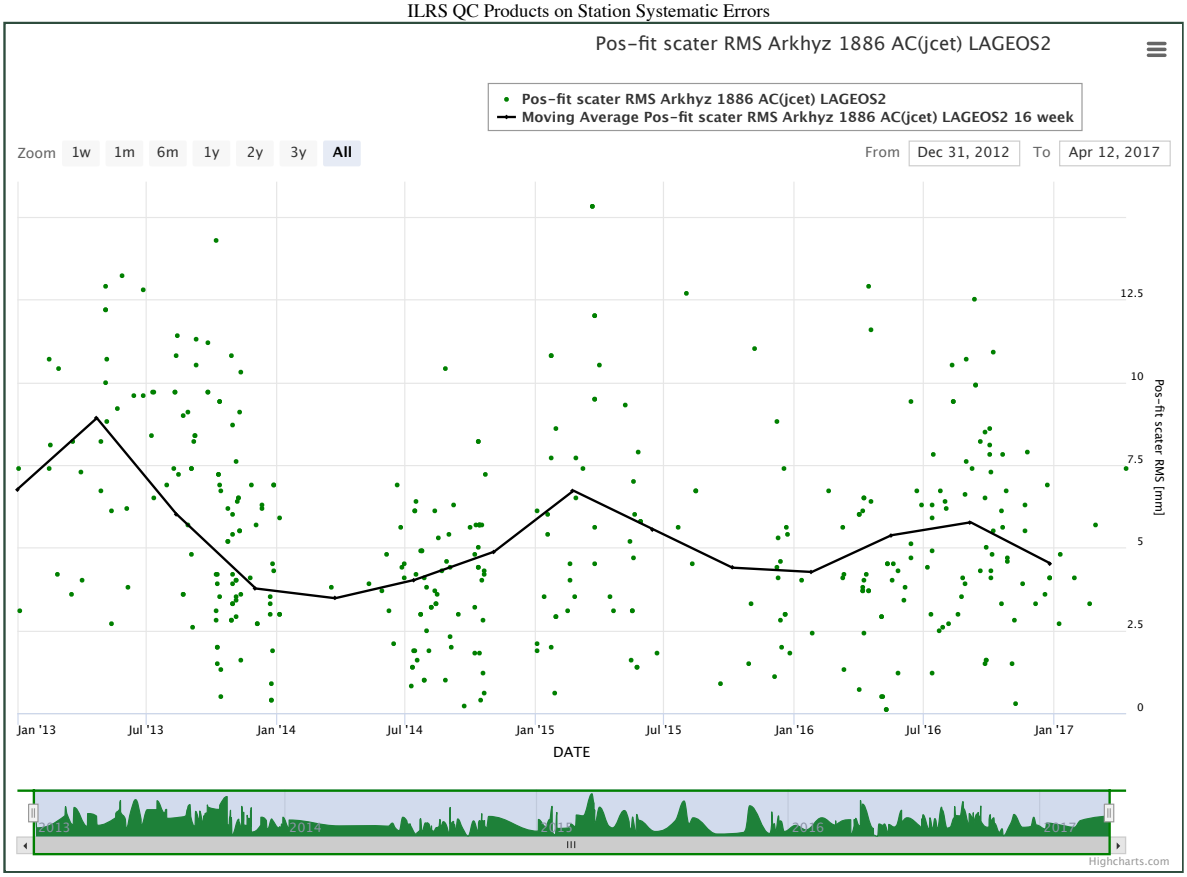


ILRS QC Products on Station Systematic Errors

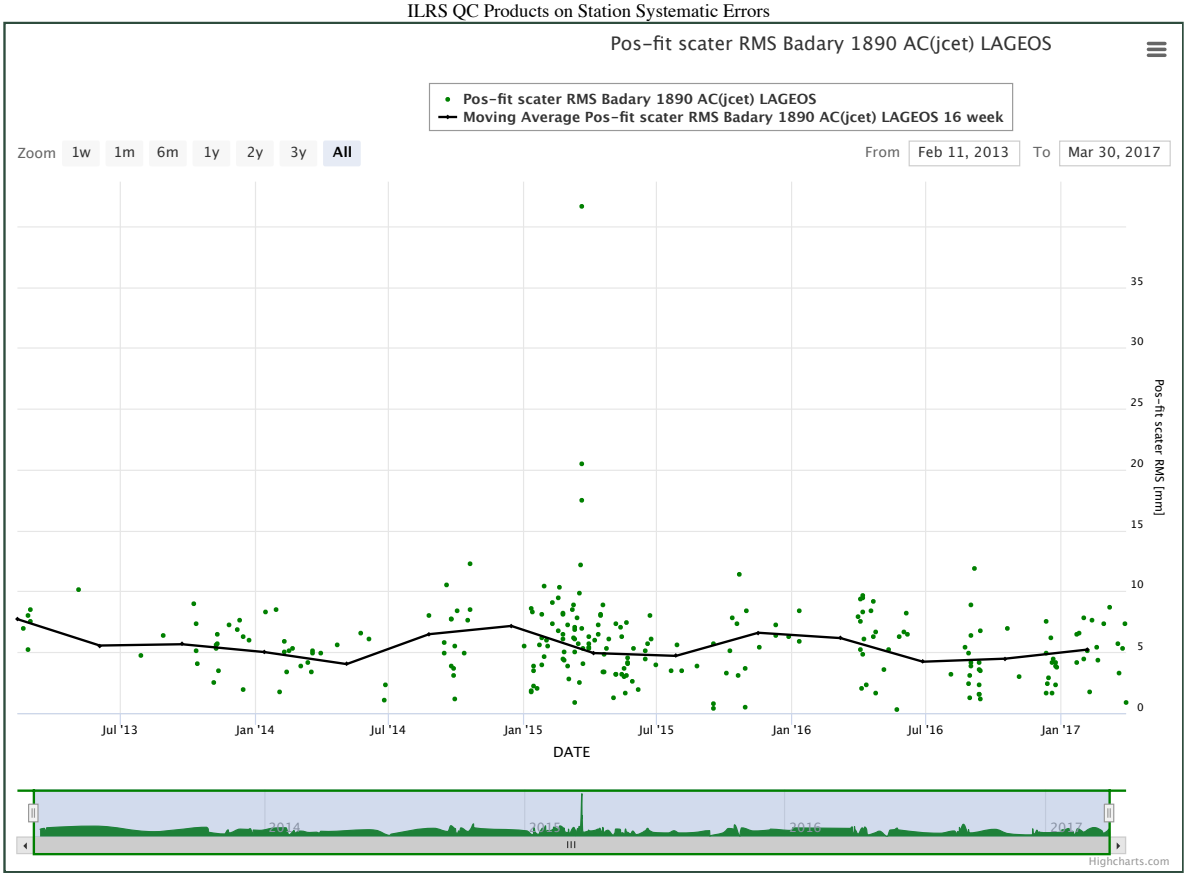


ARKHYZ 1886

ILRS QC Products on Station Systematic Errors

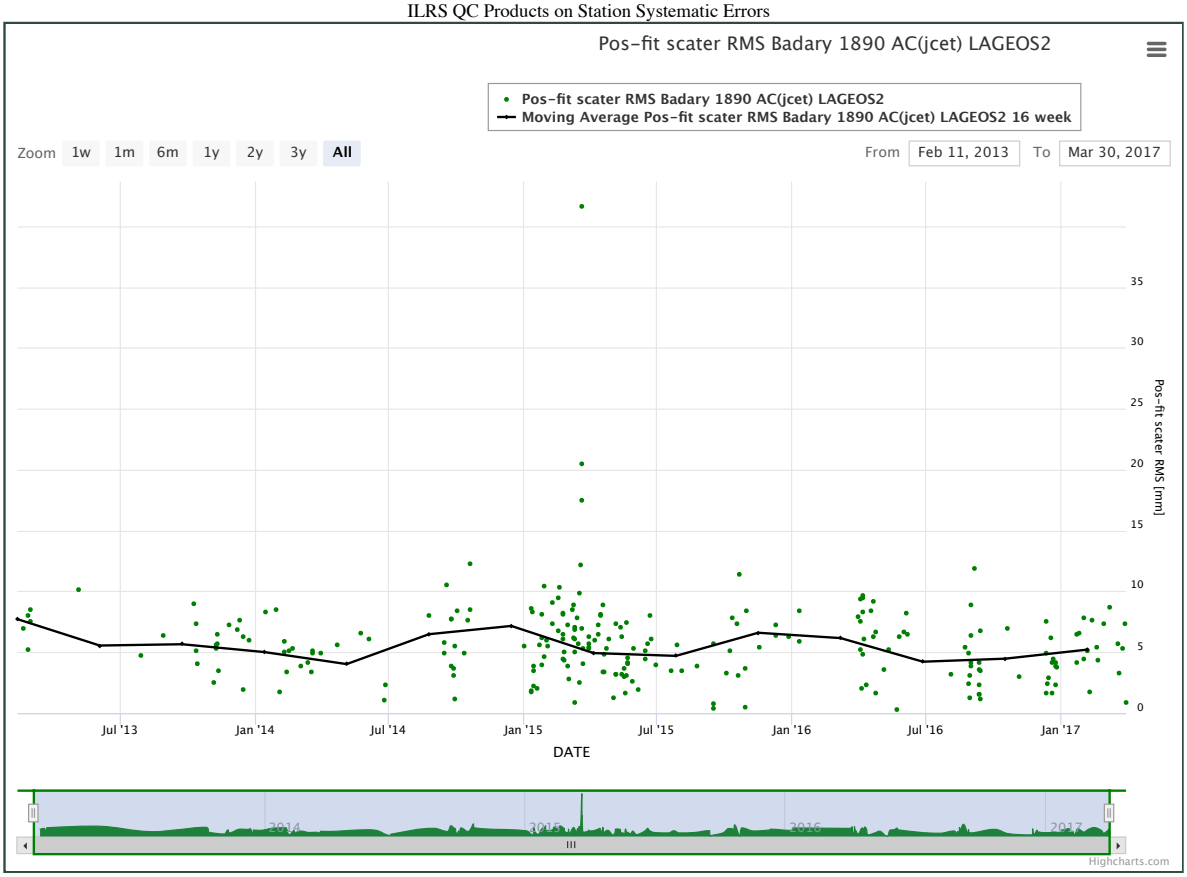


ILRS QC Products on Station Systematic Errors

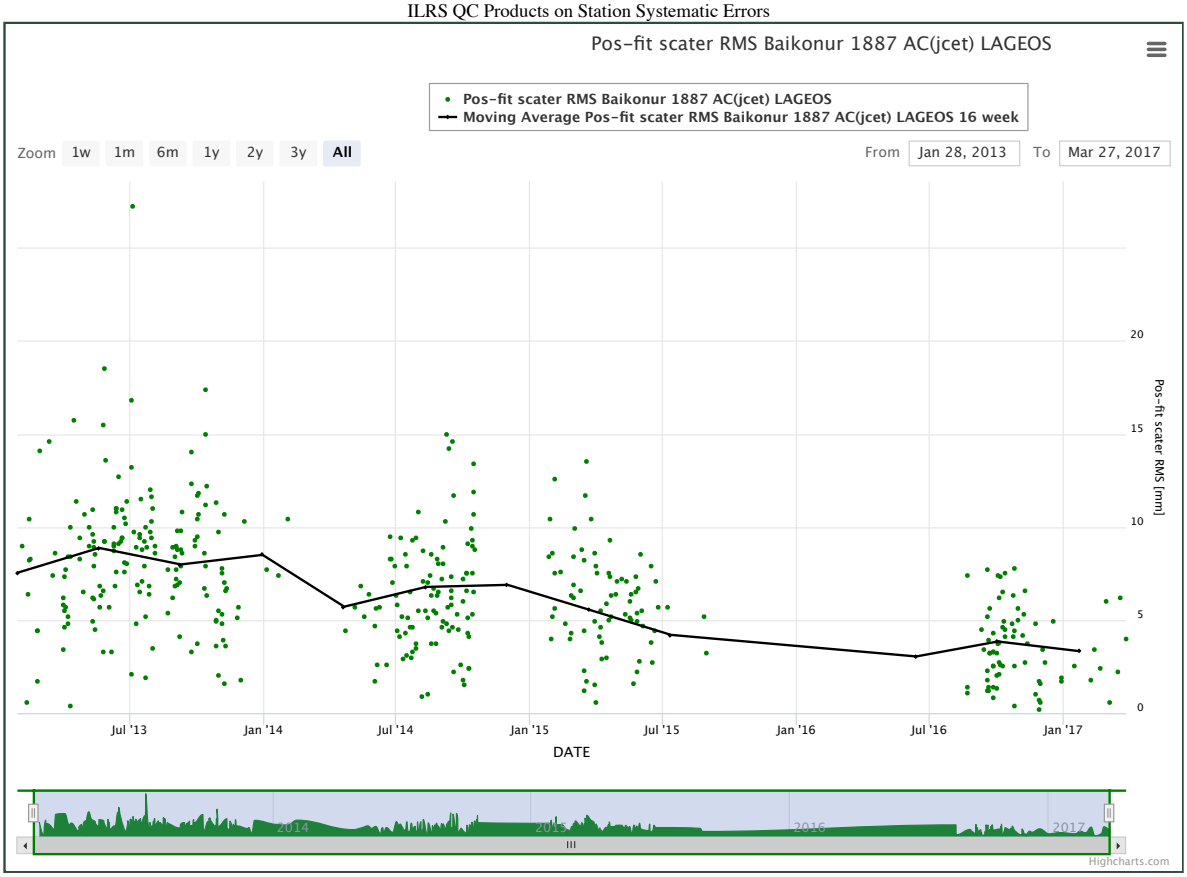


BADARY 1890

ILRS QC Products on Station Systematic Errors

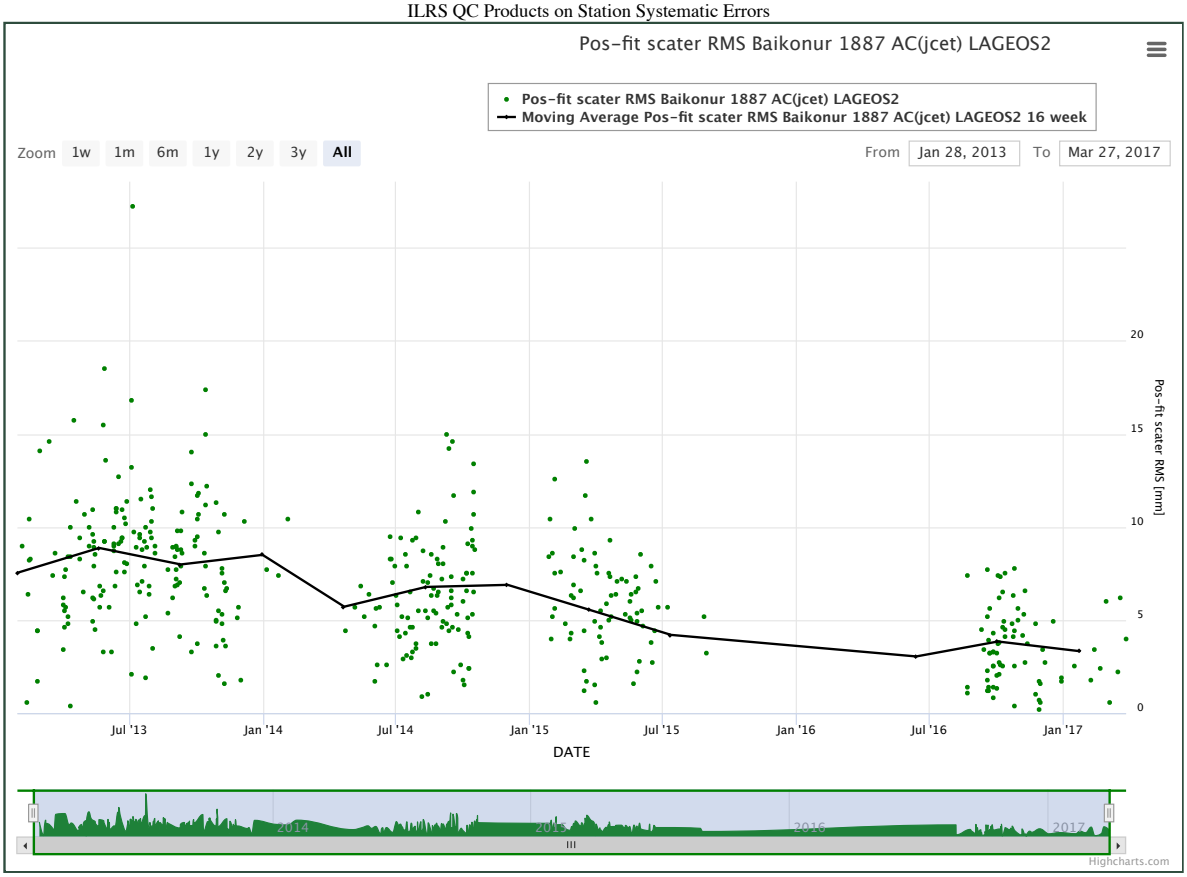


ILRS QC Products on Station Systematic Errors

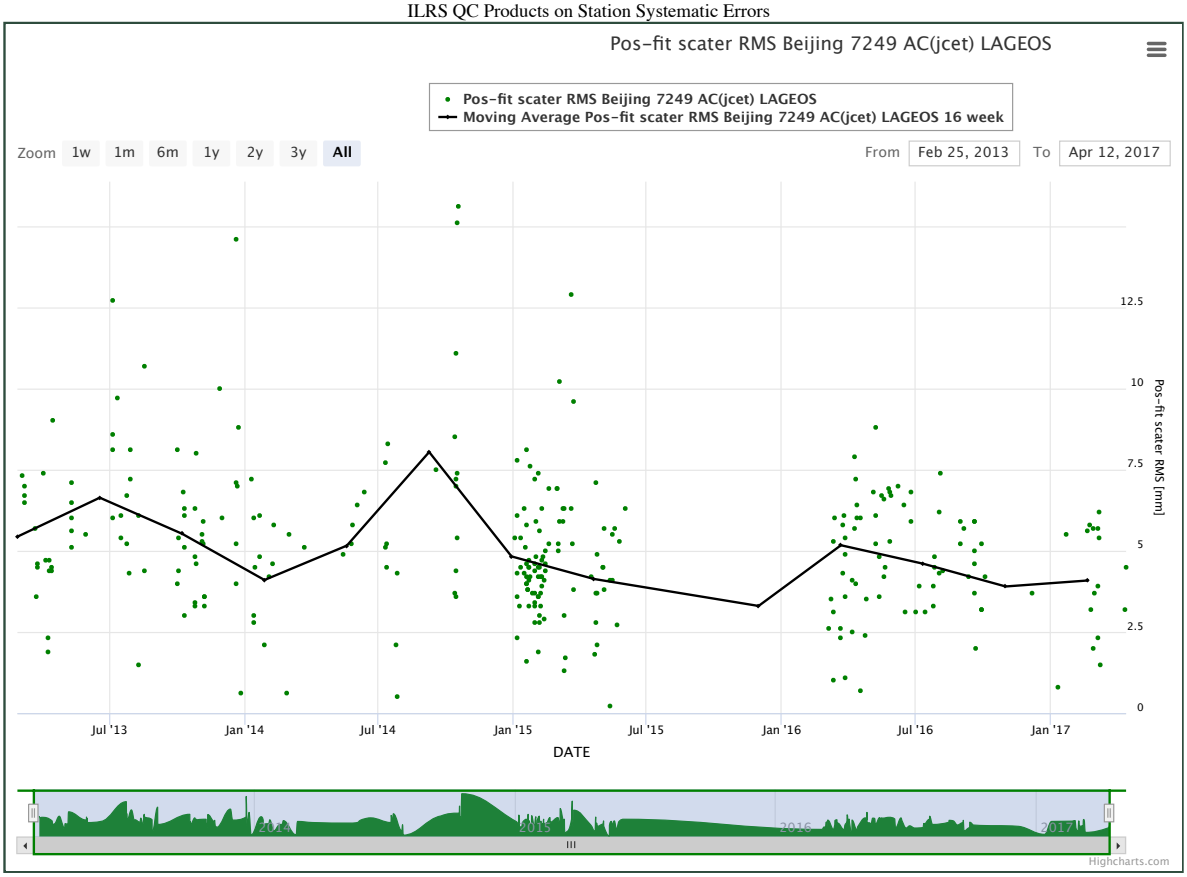


BAIKONUR 1887

ILRS QC Products on Station Systematic Errors

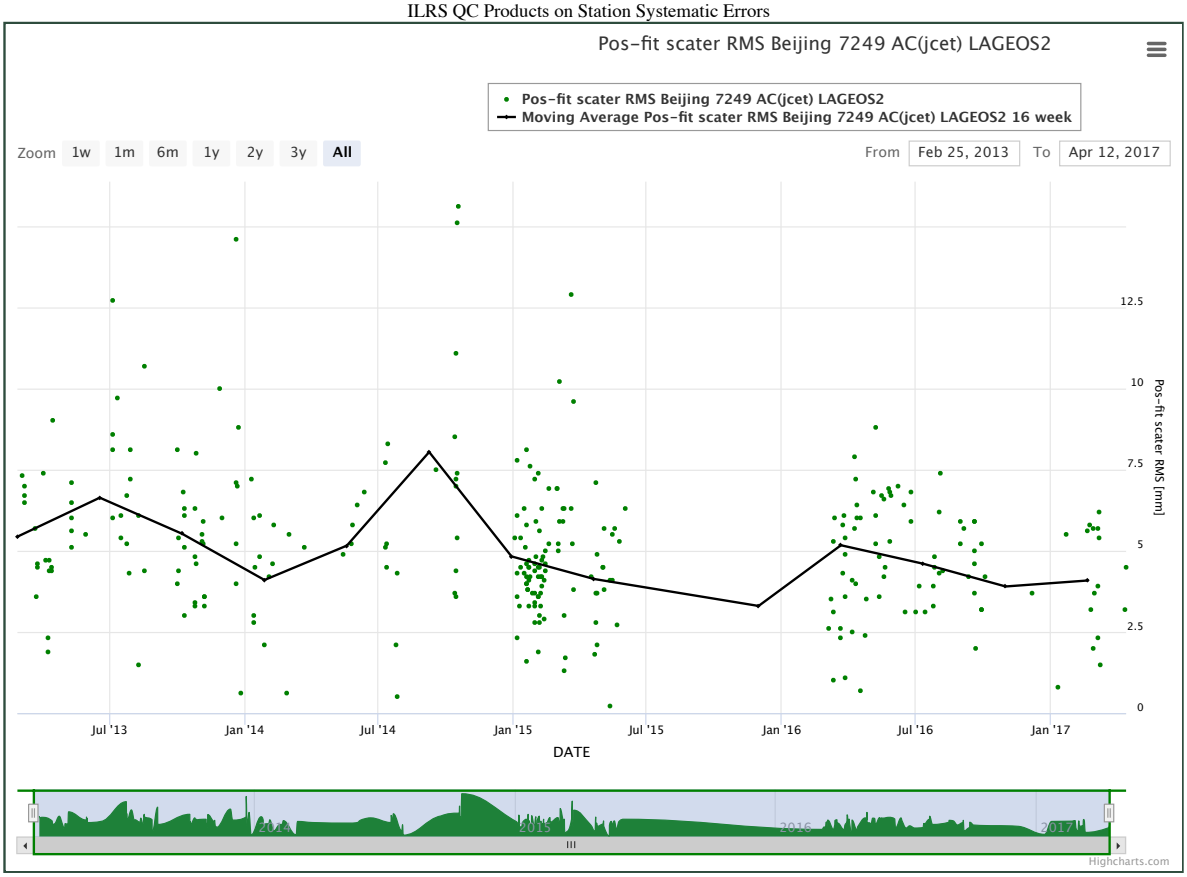


ILRS QC Products on Station Systematic Errors

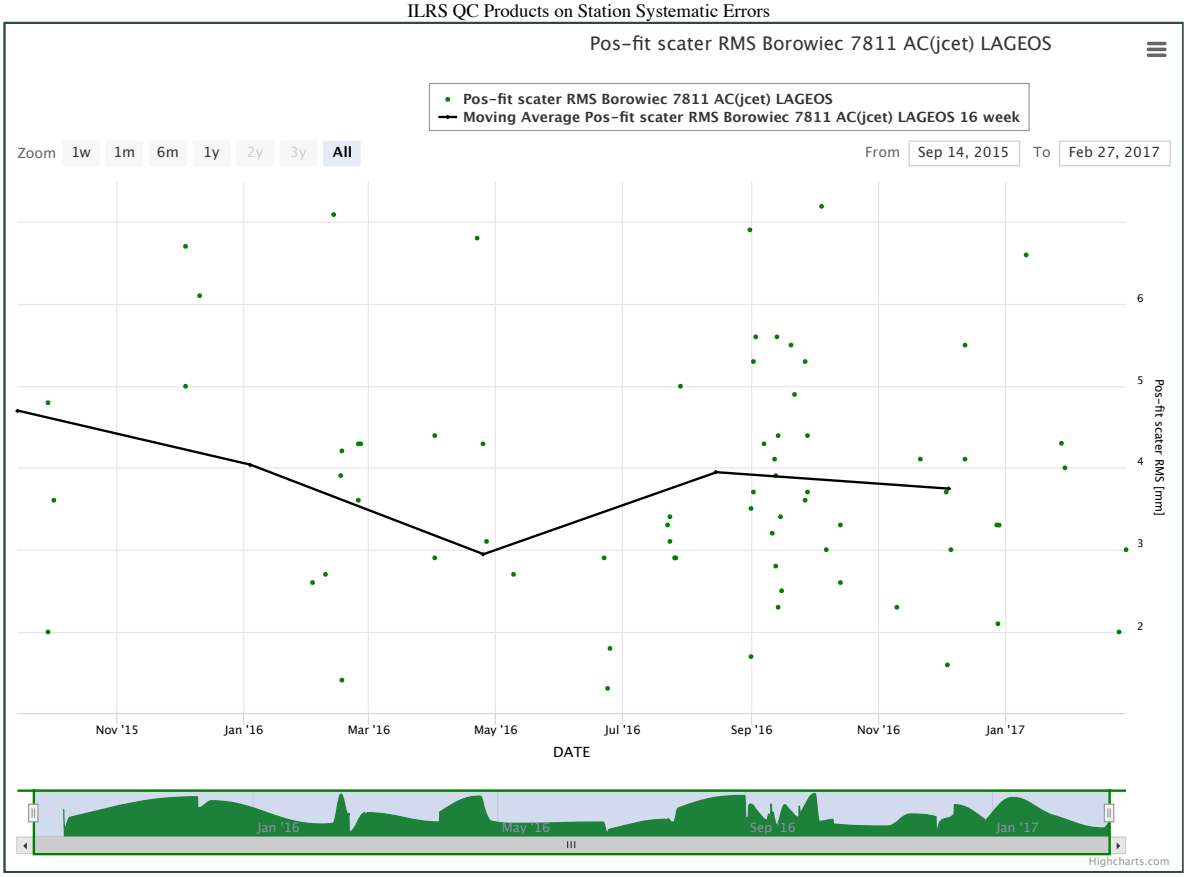


BEIJING 7249

ILRS QC Products on Station Systematic Errors

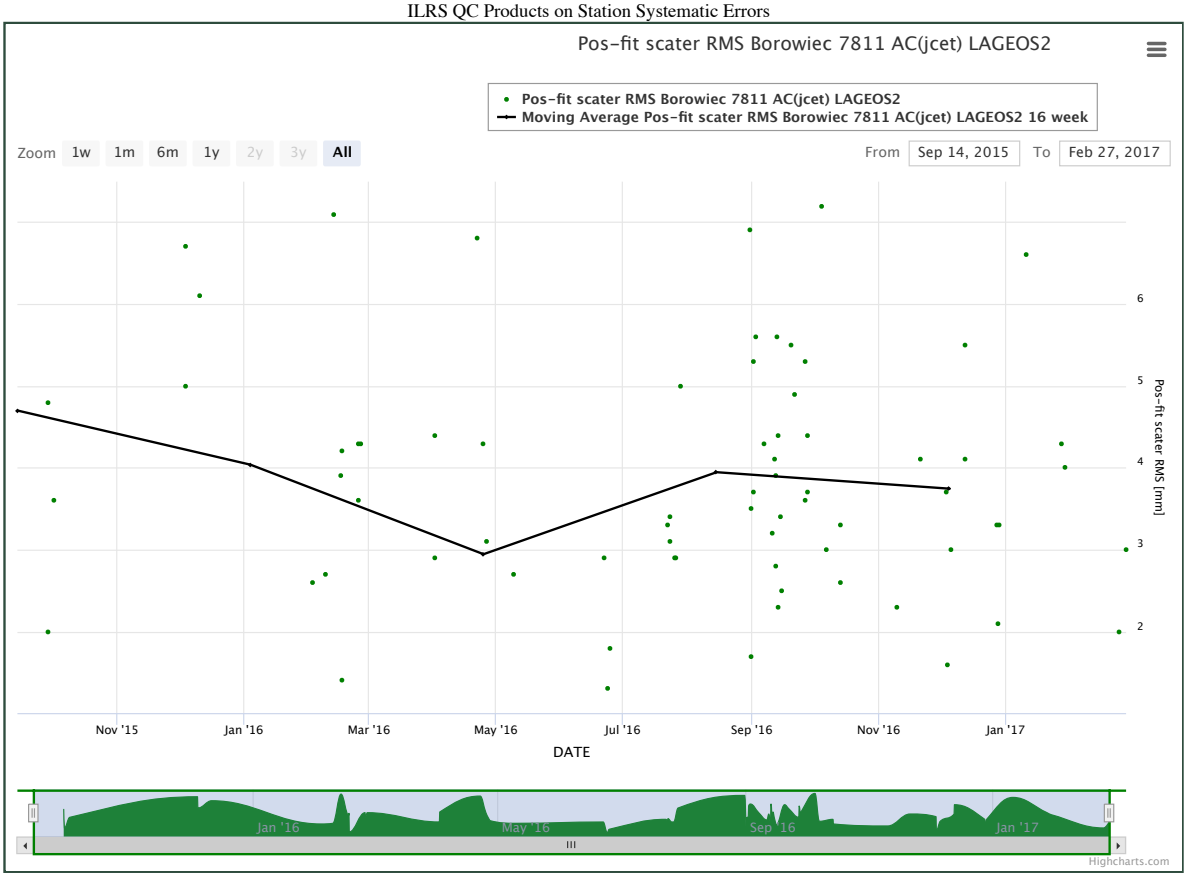


ILRS QC Products on Station Systematic Errors

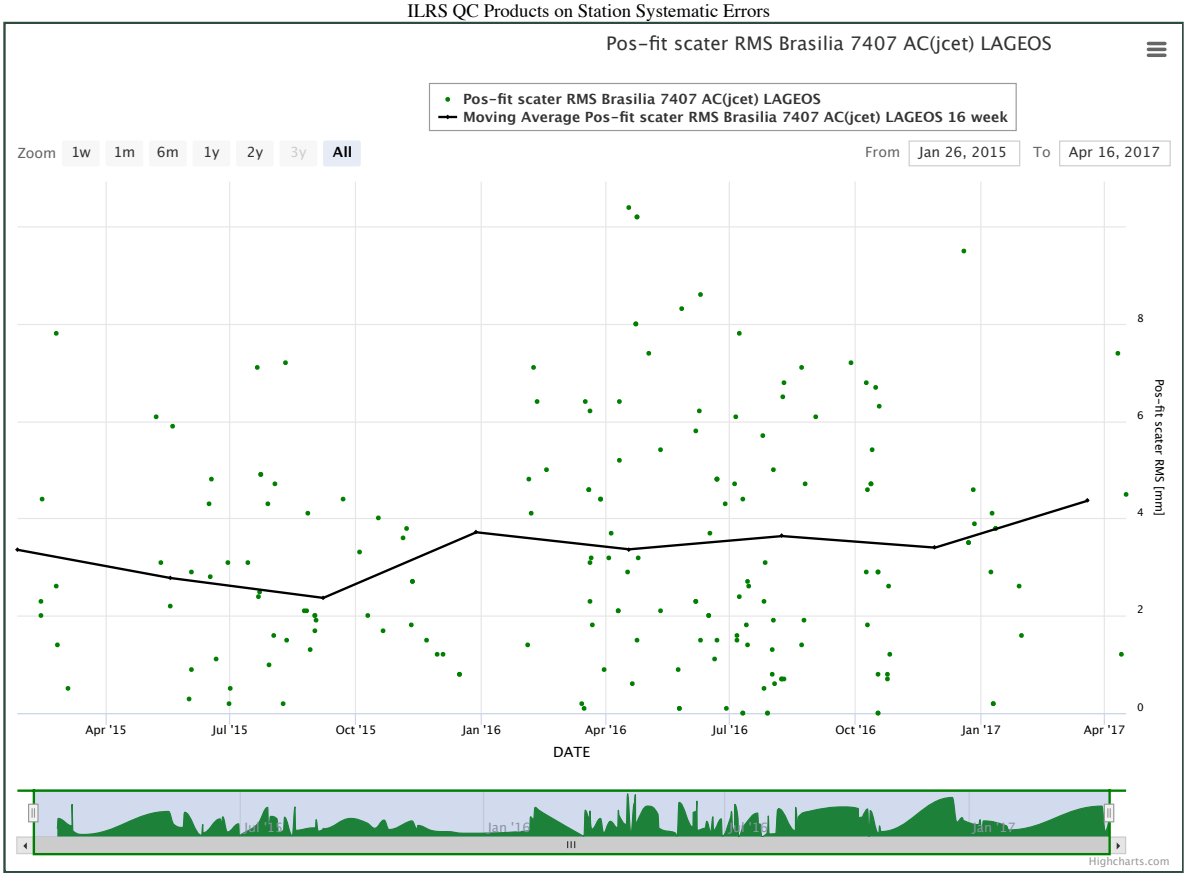


BOROWIEC 7811

ILRS QC Products on Station Systematic Errors



ILRS QC Products on Station Systematic Errors



BRASILIA 7407

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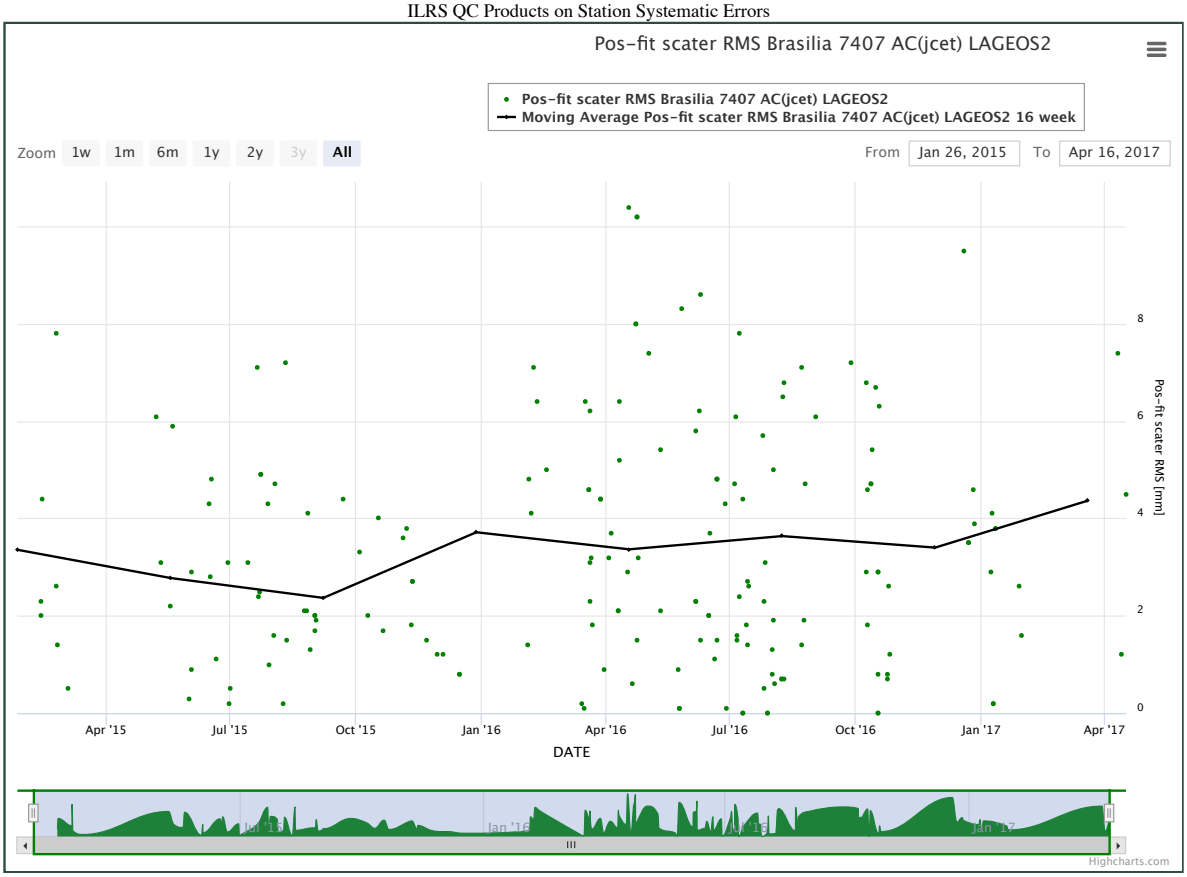
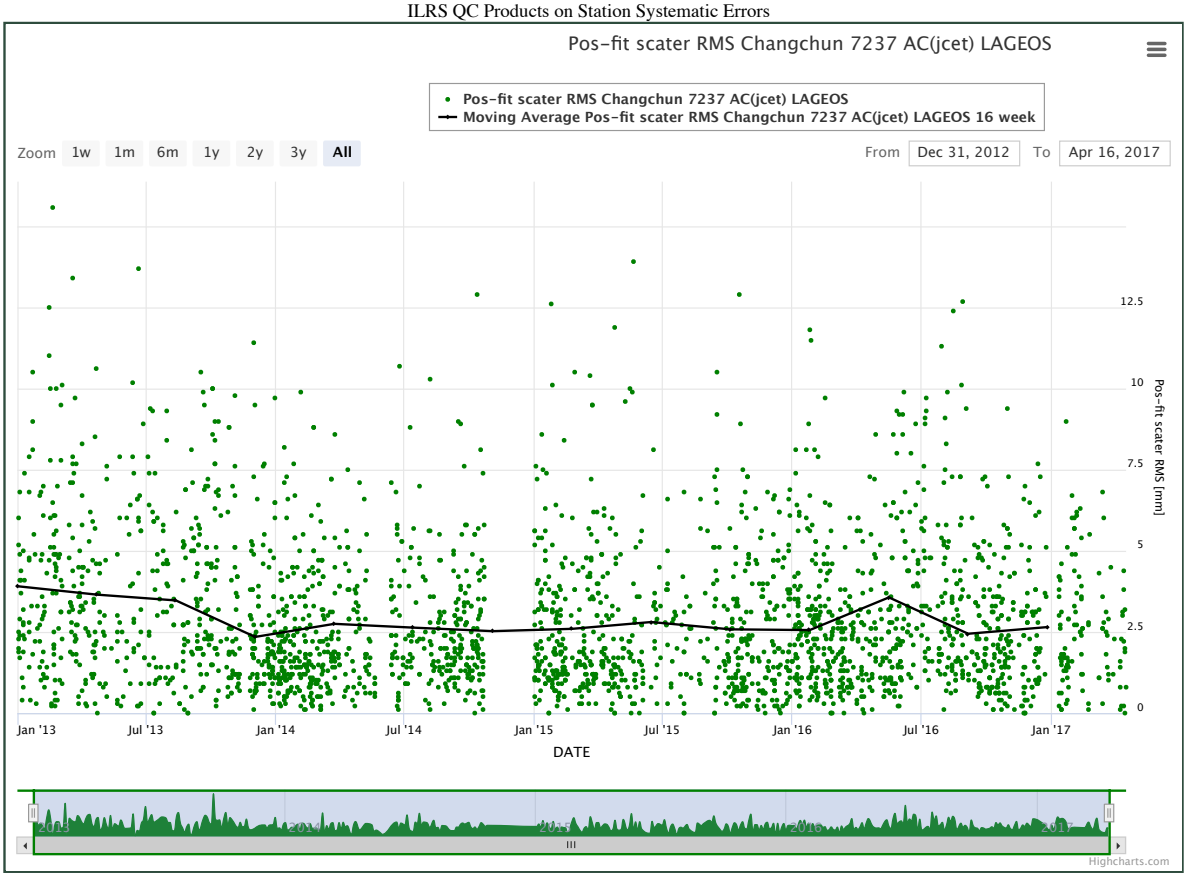
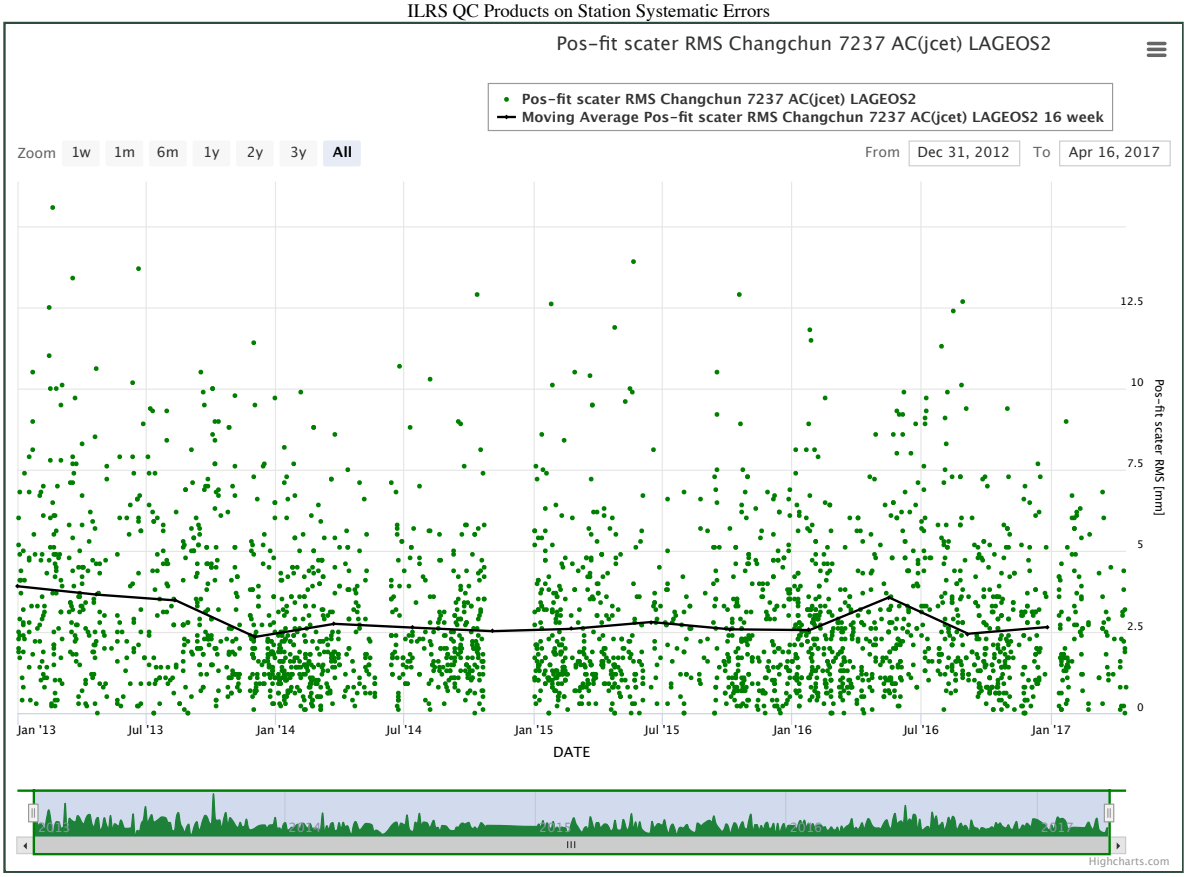


ILRS QC Products on Station Systematic Errors

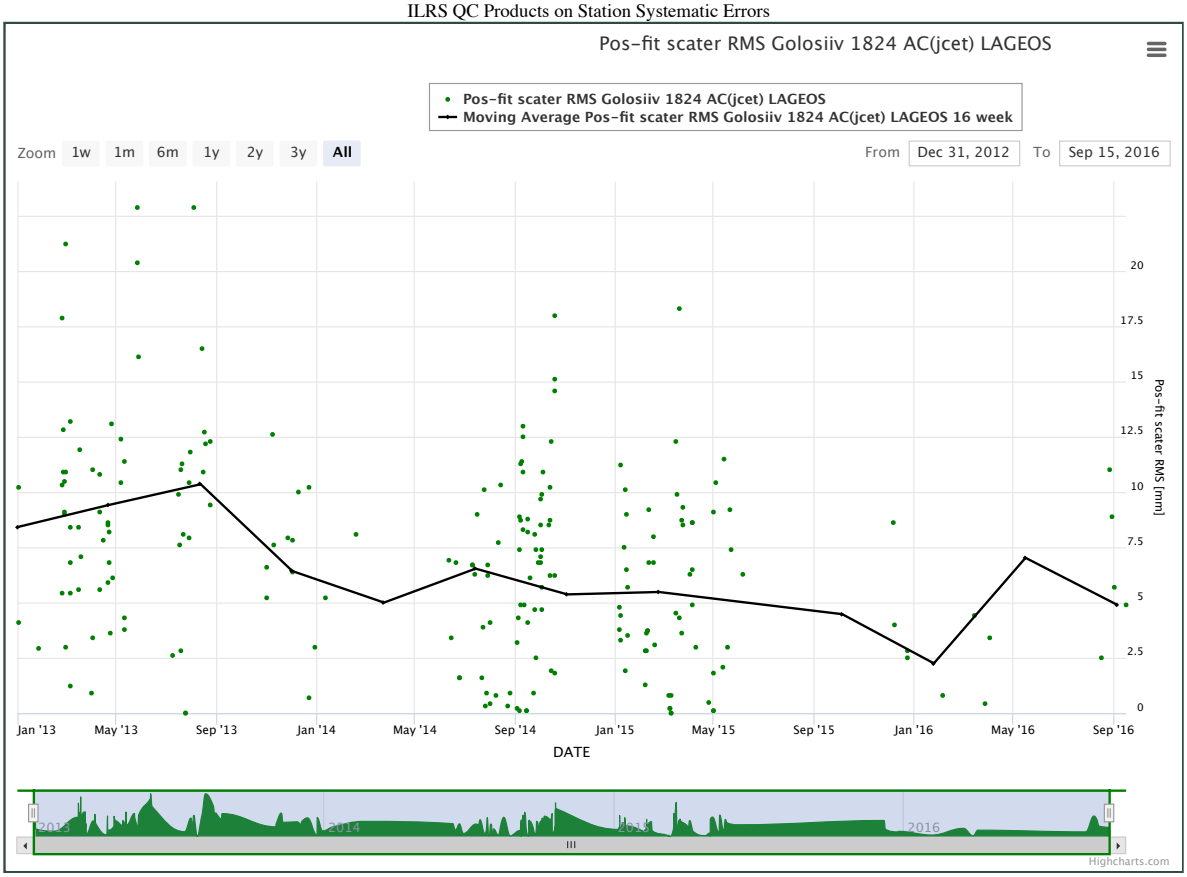


CHANGCHUN 7237

ILRS QC Products on Station Systematic Errors

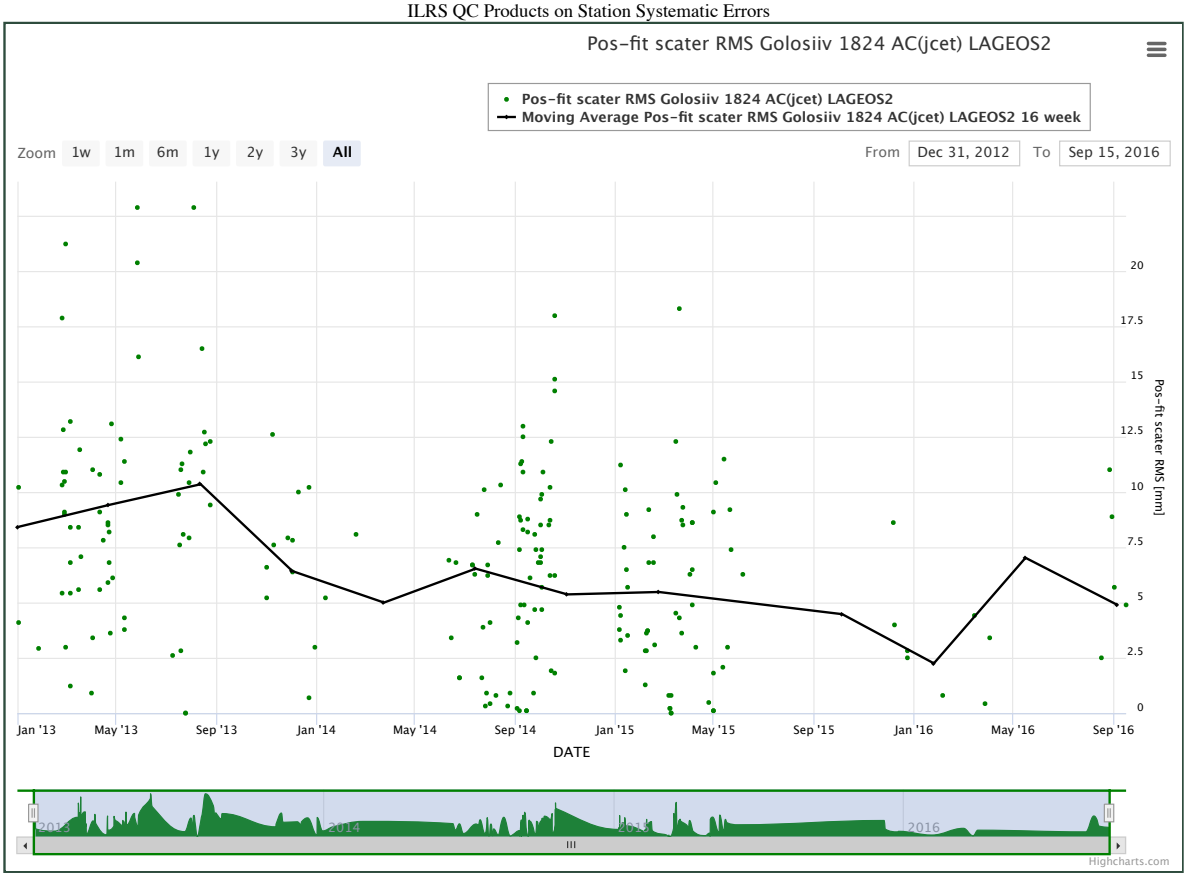


ILRS QC Products on Station Systematic Errors



GOLOSIIV 1824

ILRS QC Products on Station Systematic Errors



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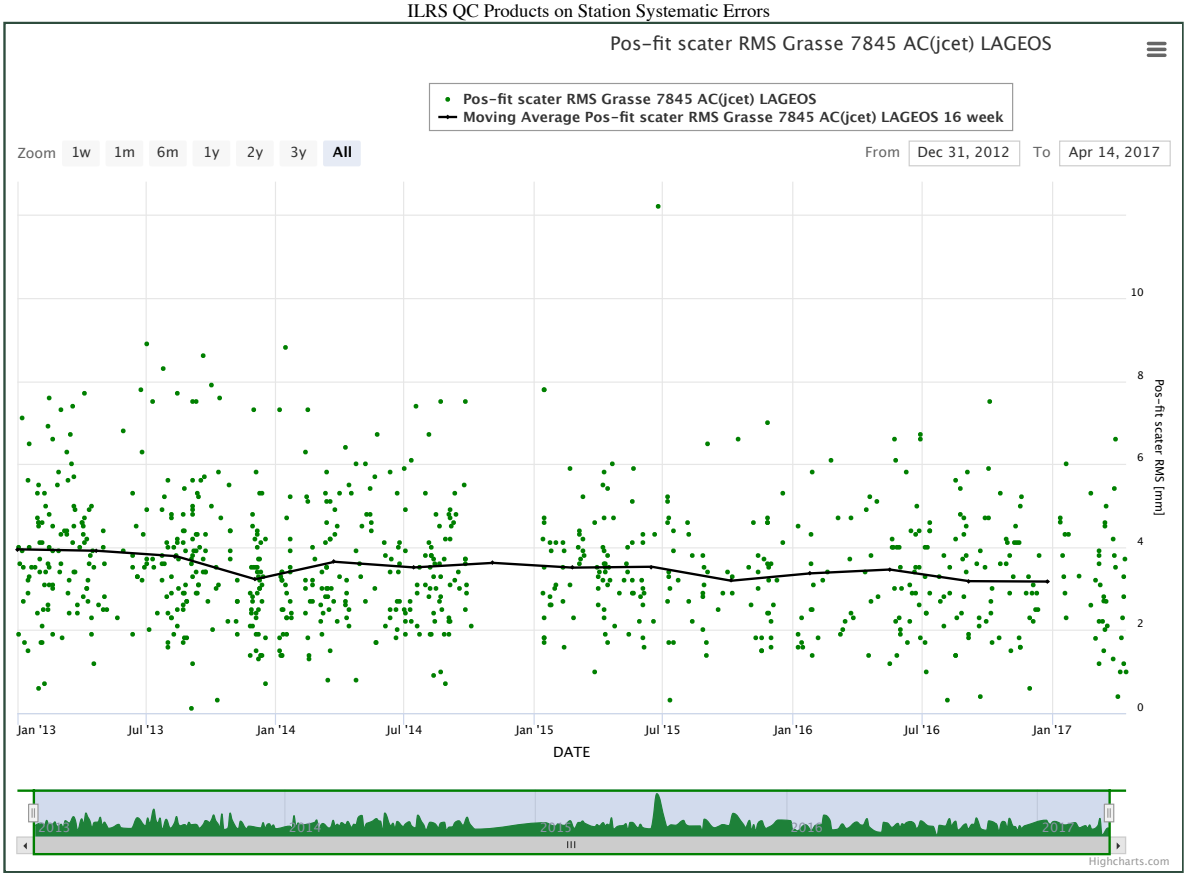
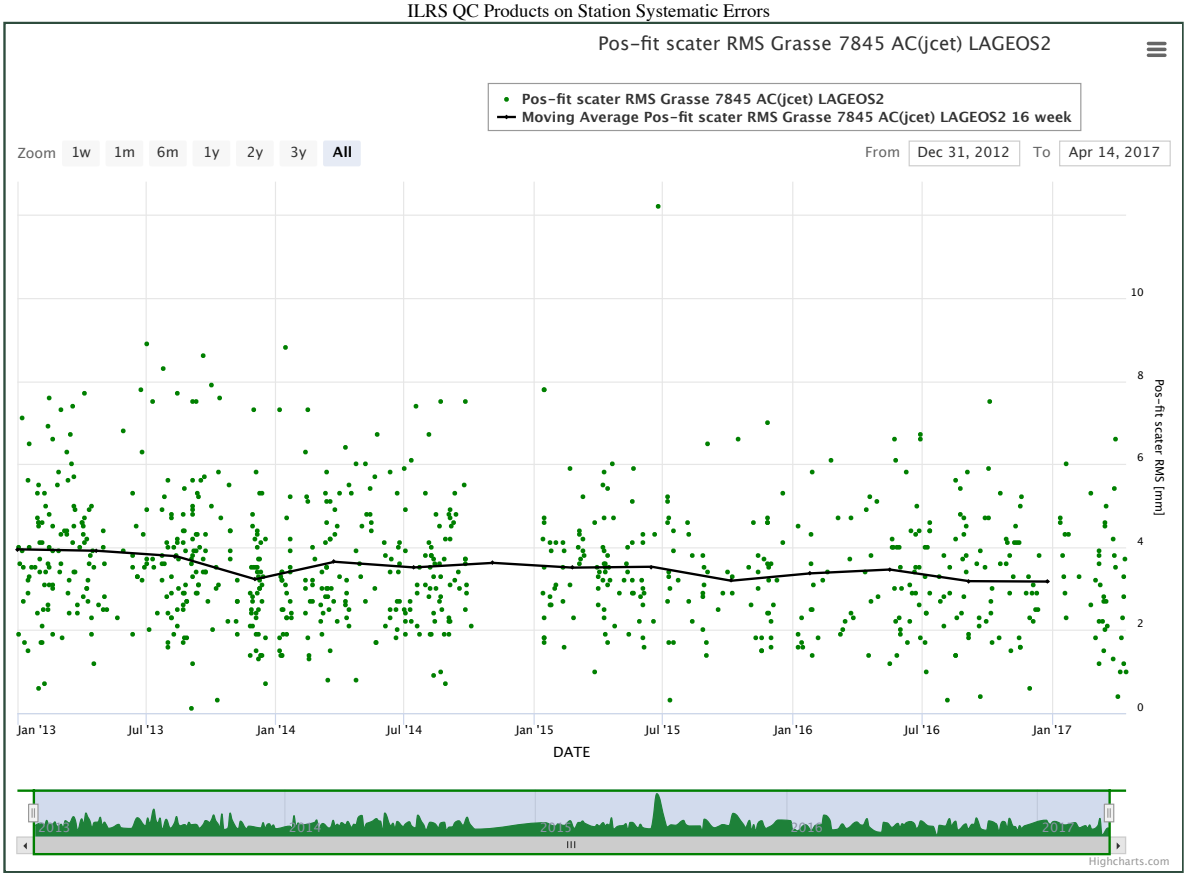
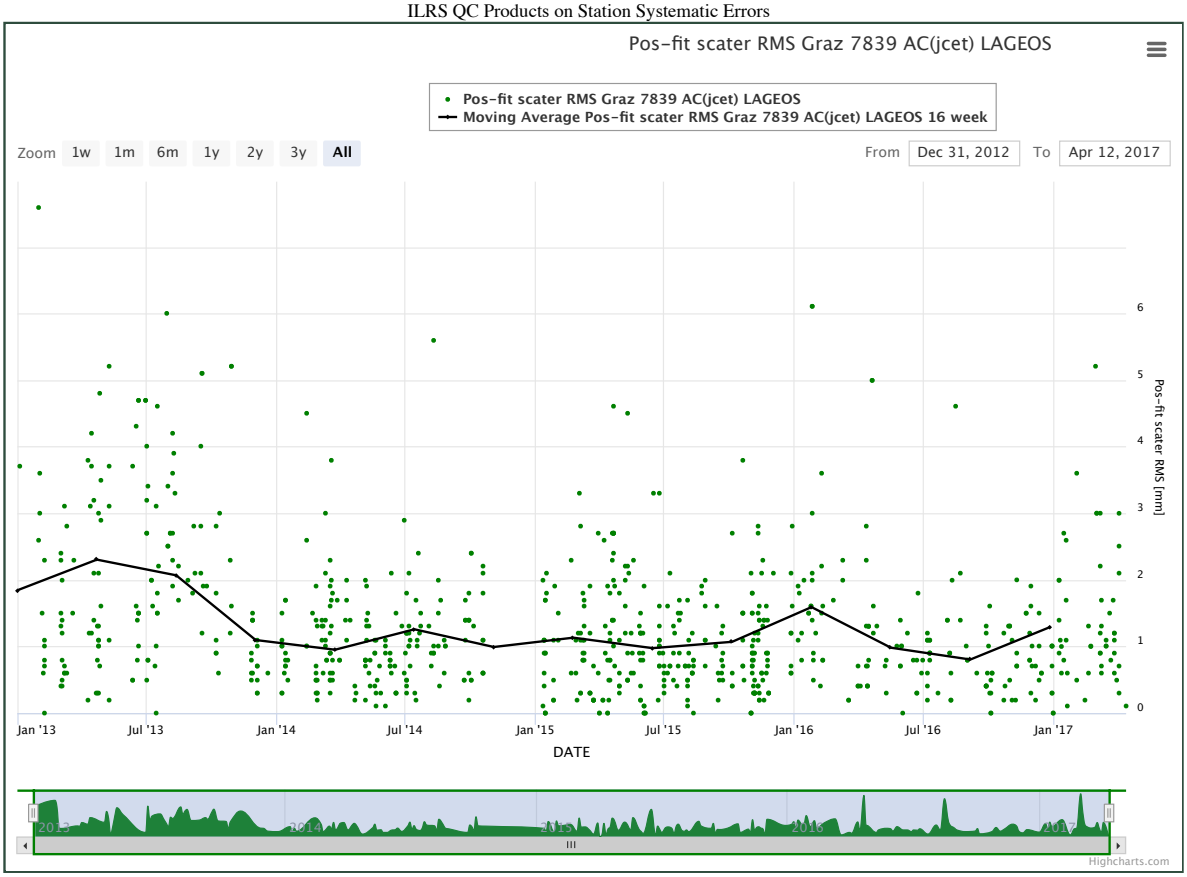


GRASSE 7845

ILRS QC Products on Station Systematic Errors

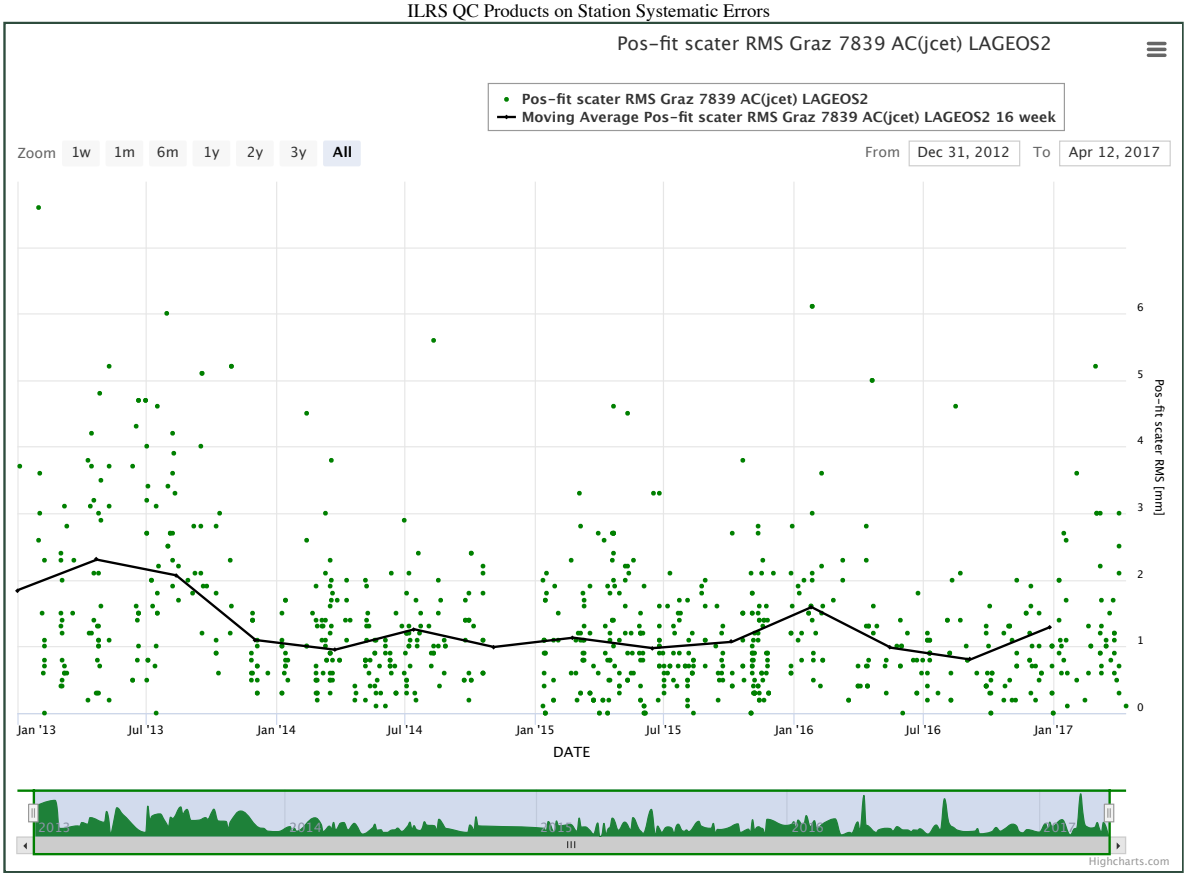


ILRS QC Products on Station Systematic Errors

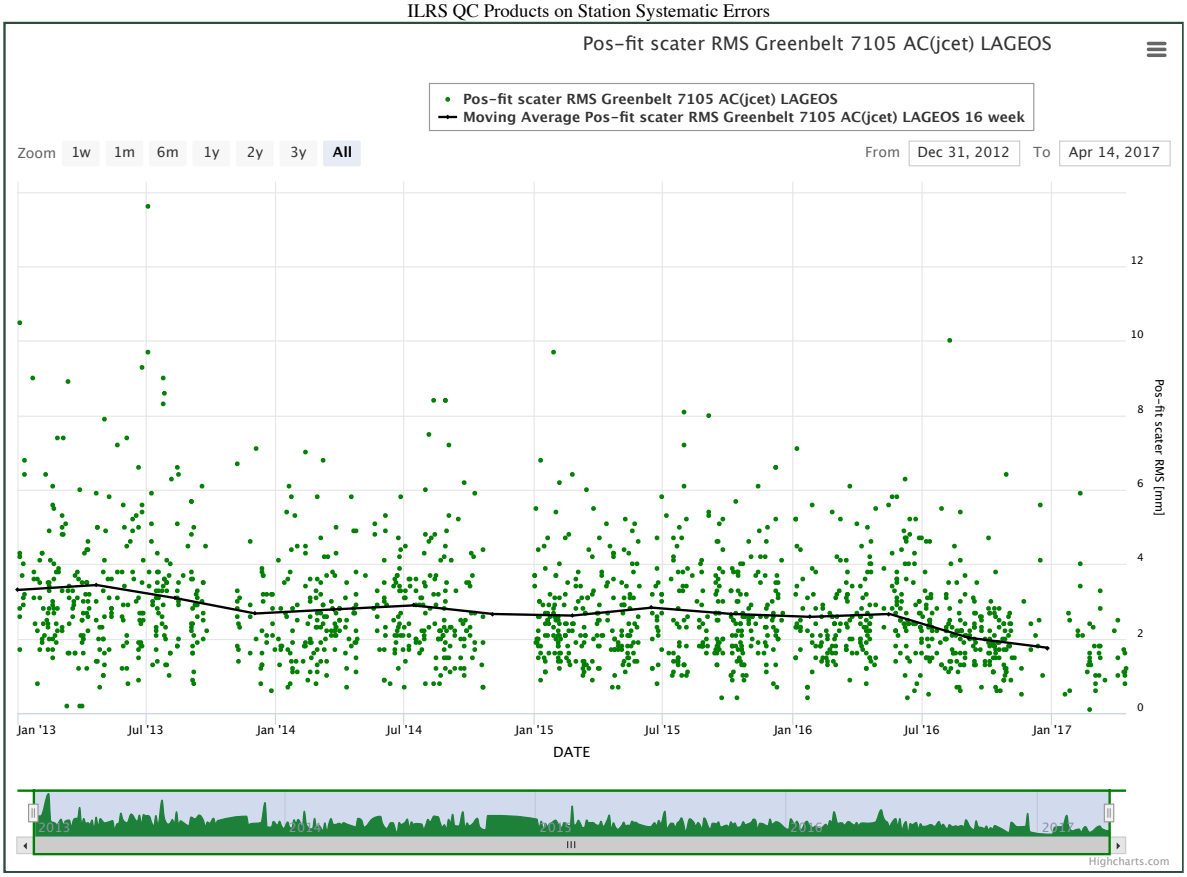


GRAZ 7839

ILRS QC Products on Station Systematic Errors



ILRS QC Products on Station Systematic Errors



GGAO 7105

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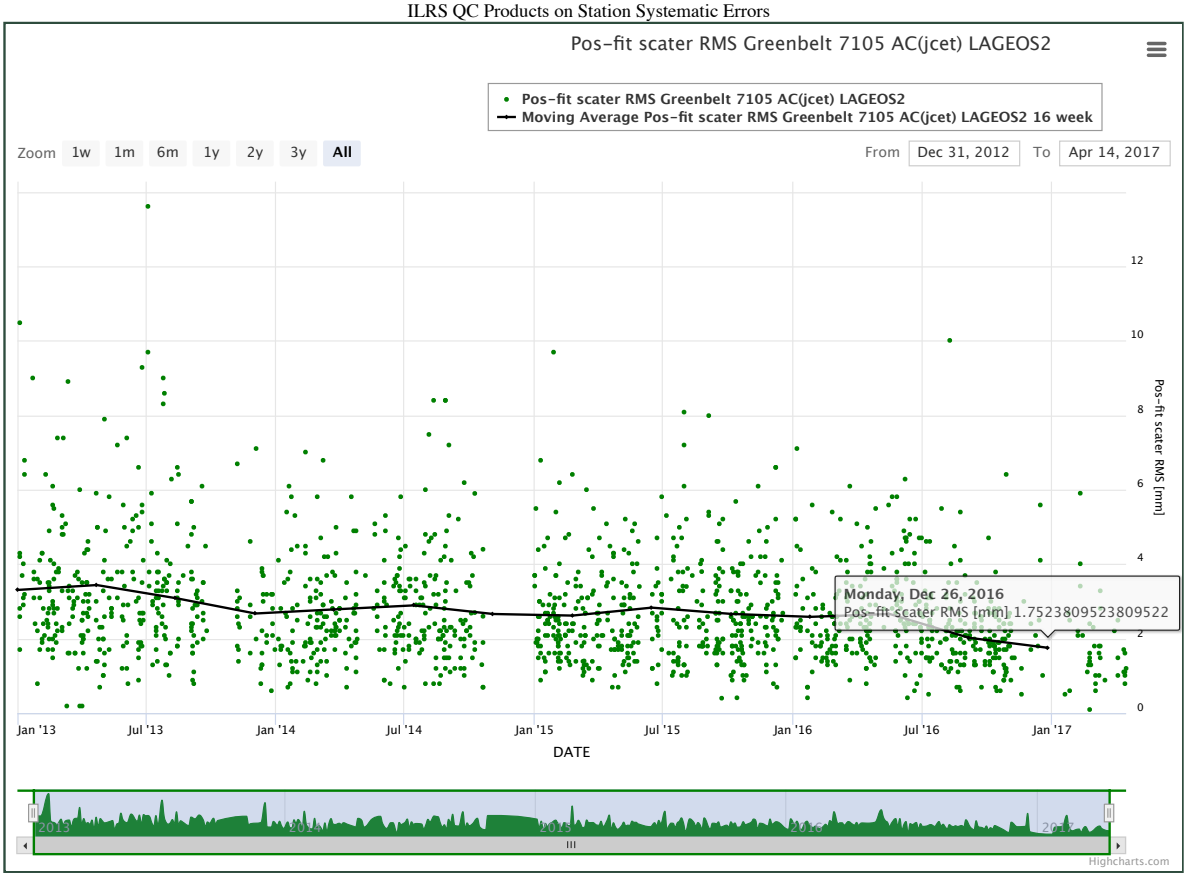
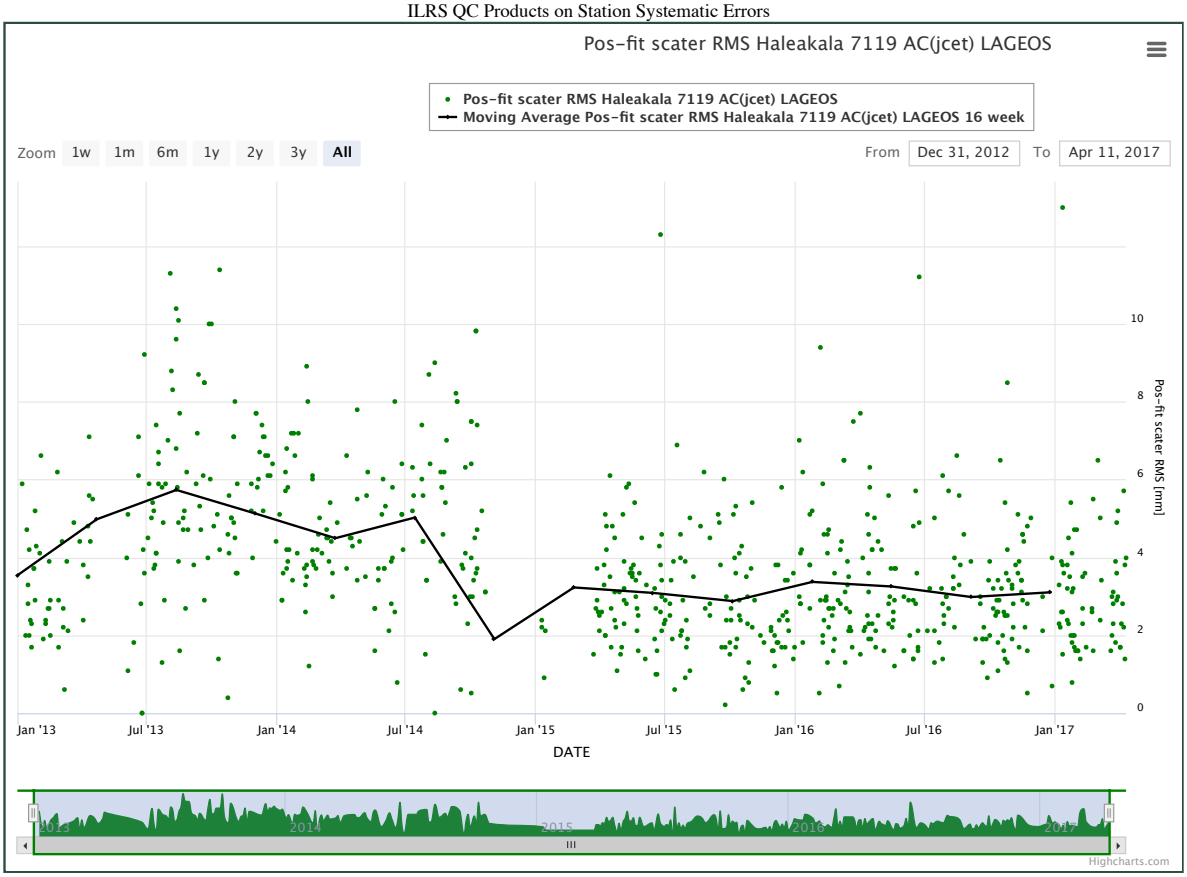


ILRS QC Products on Station Systematic Errors



HALEAKALA 7119

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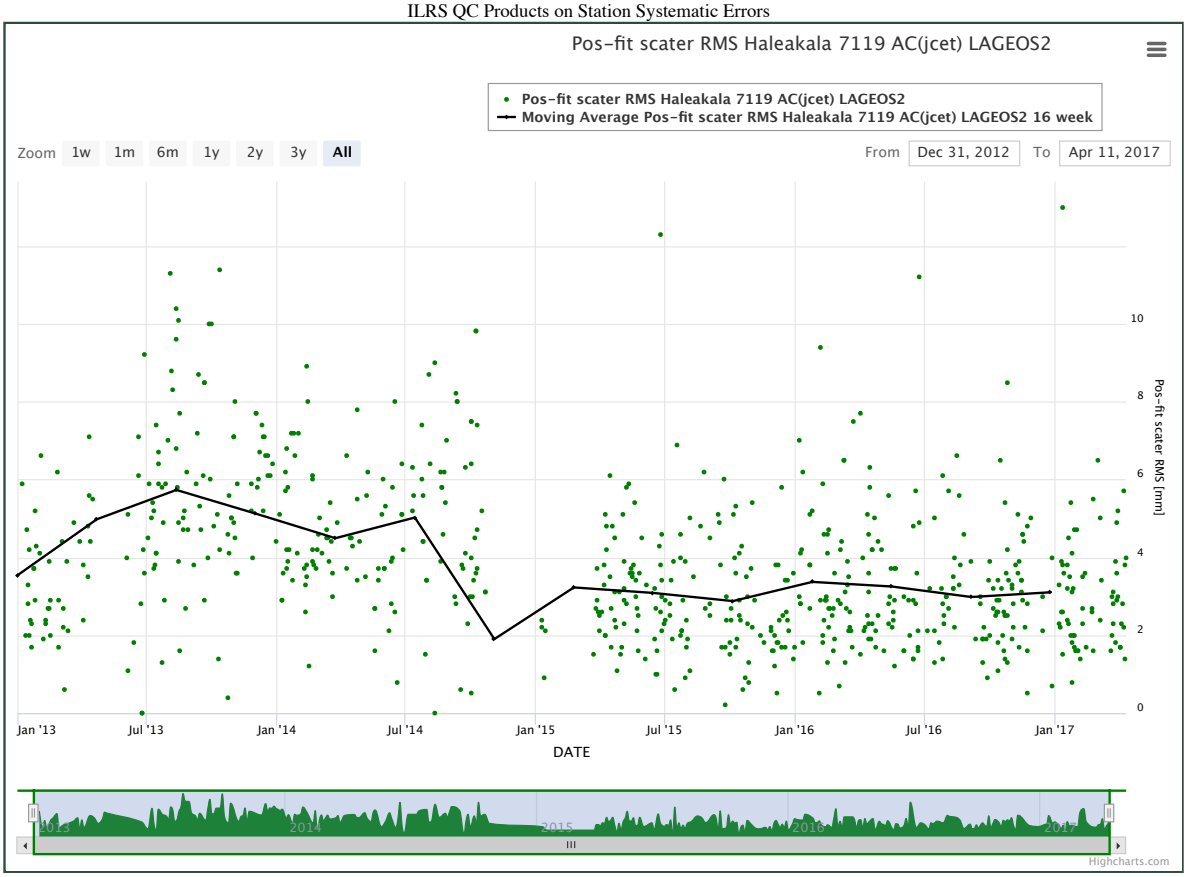
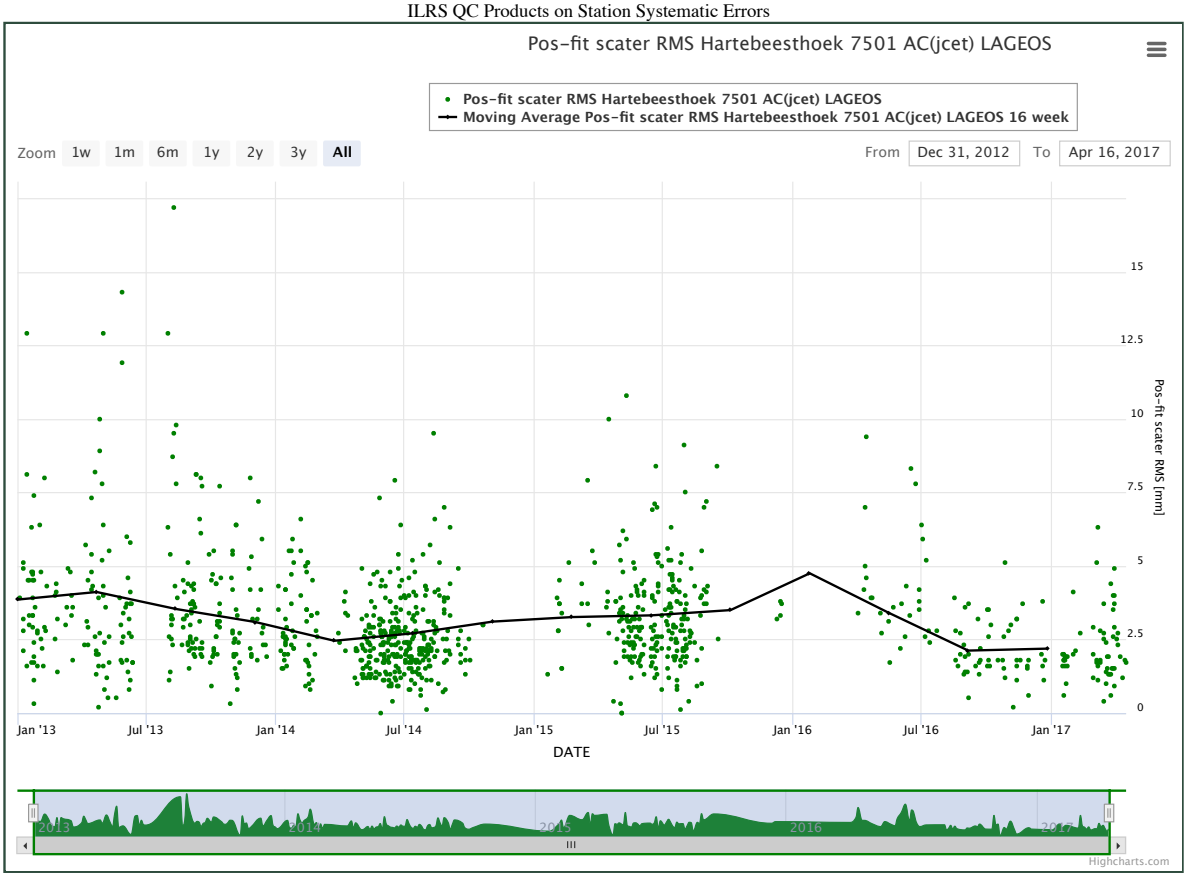


ILRS QC Products on Station Systematic Errors



HARTEBEESTHOEK 7501

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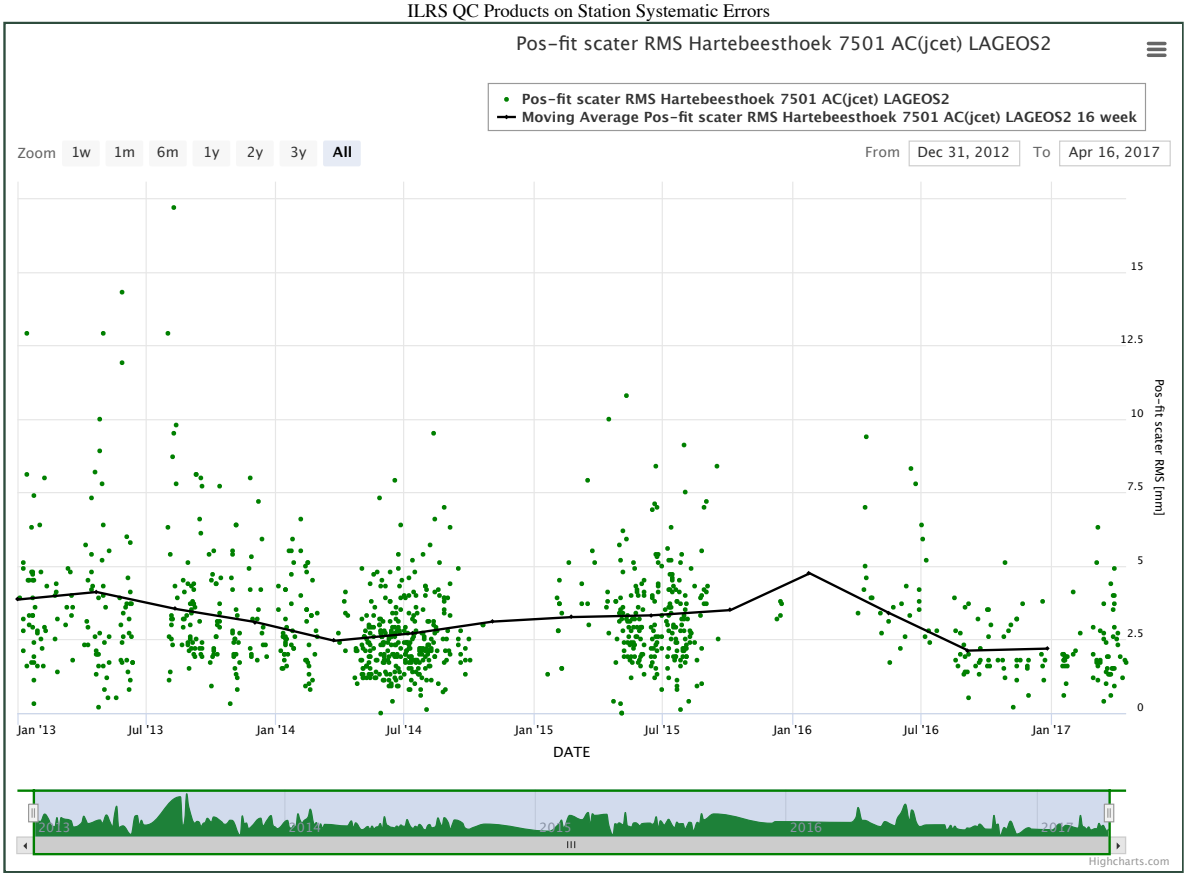

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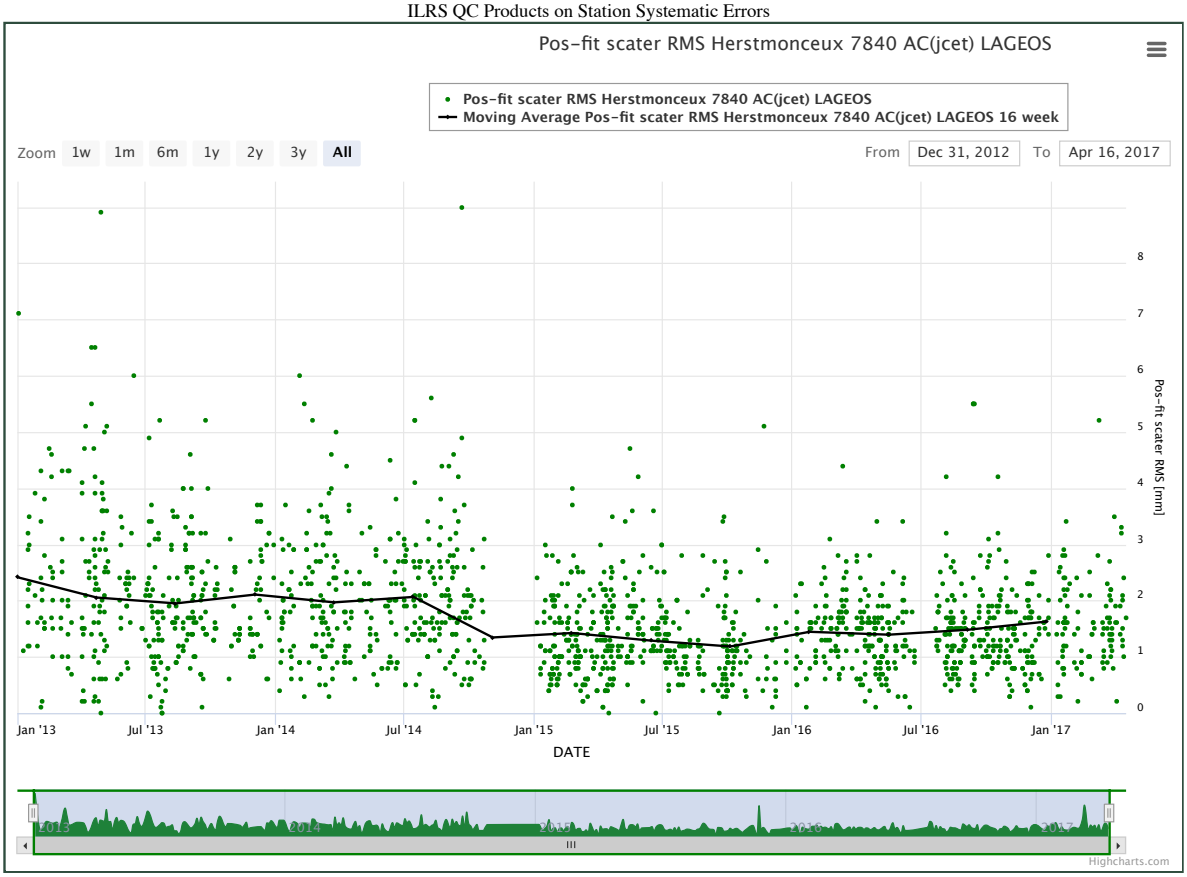
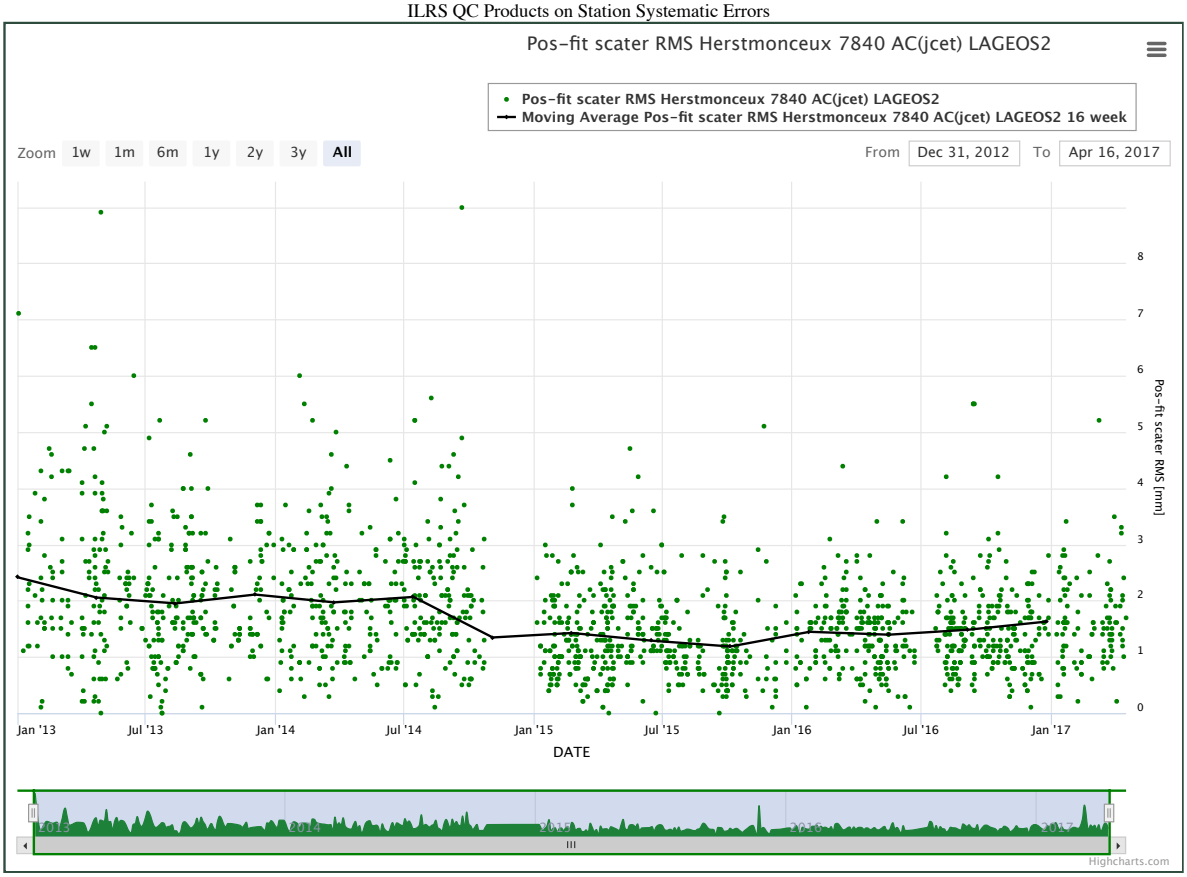


HERSTMONCEUX 7840

ILRS QC Products on Station Systematic Errors



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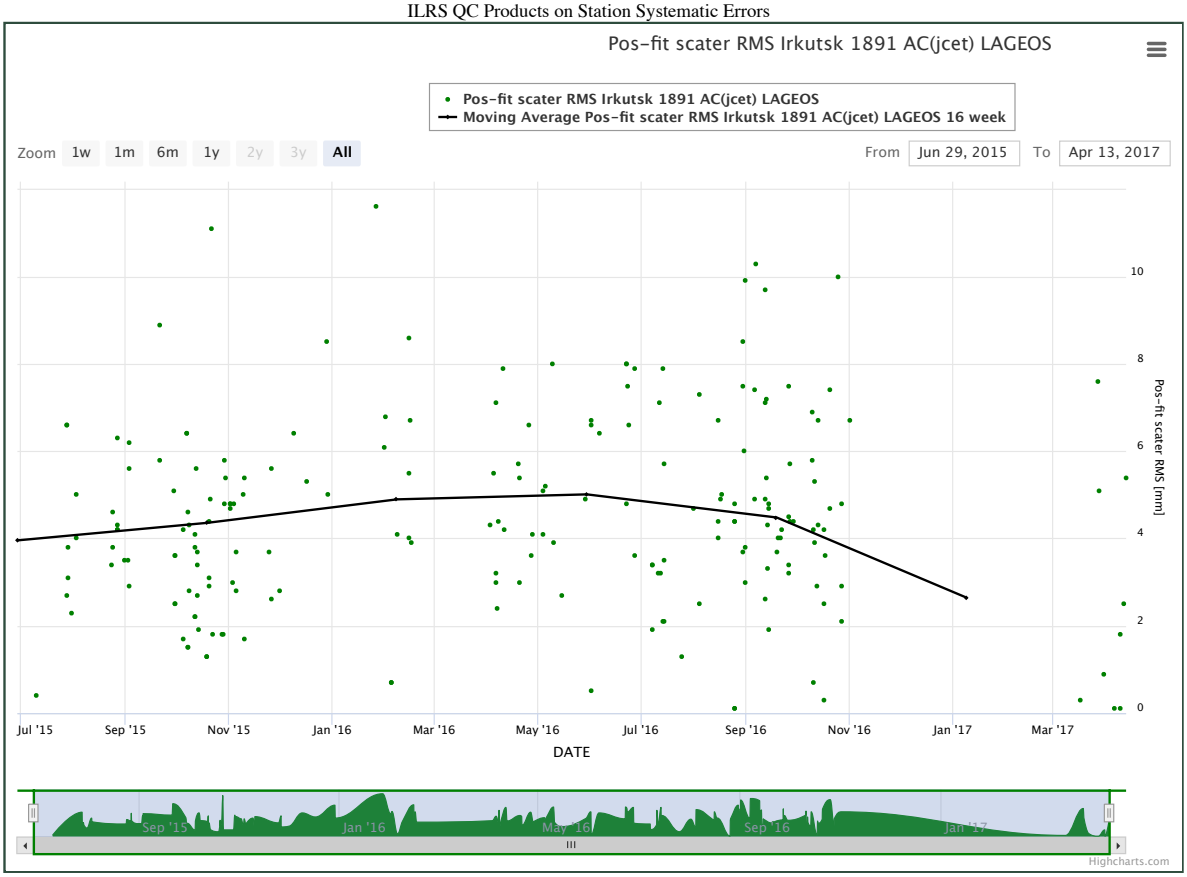
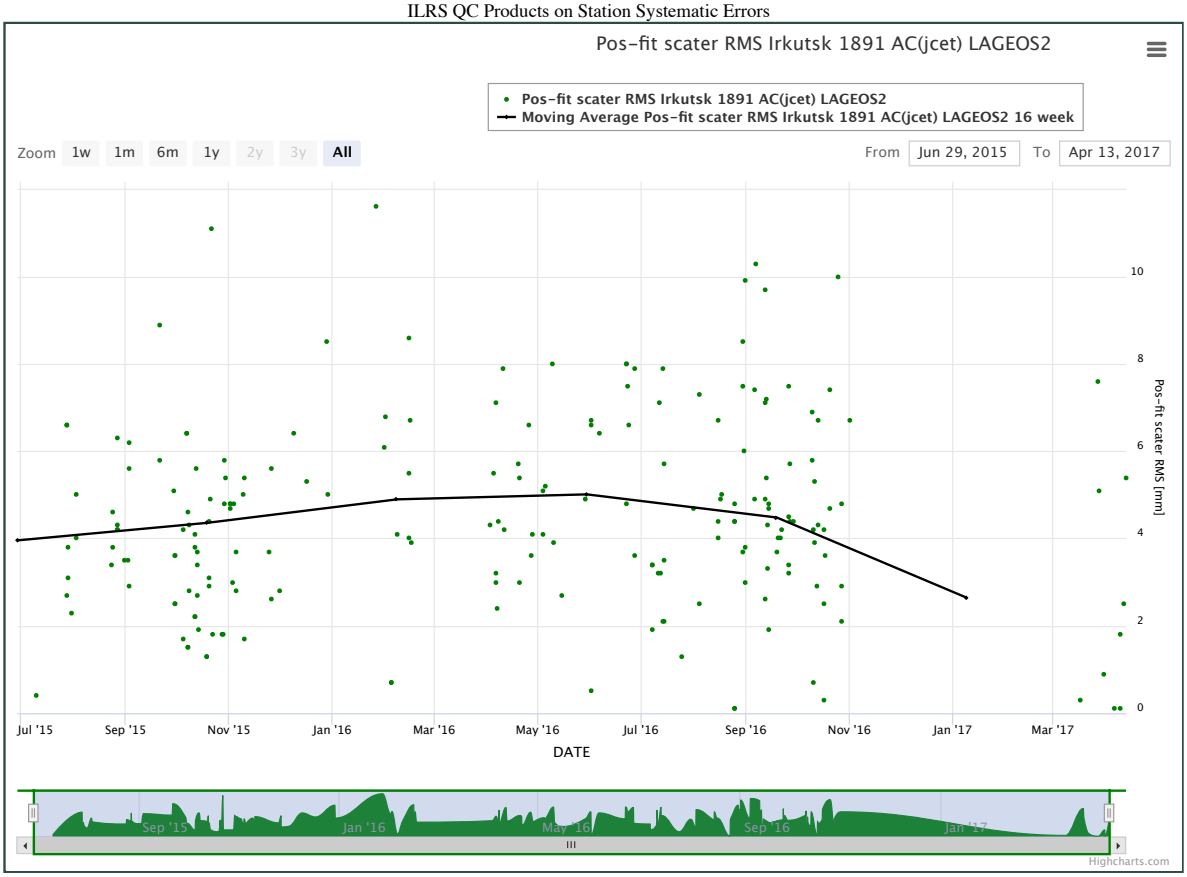


IRKUTSK 1891

ILRS QC Products on Station Systematic Errors



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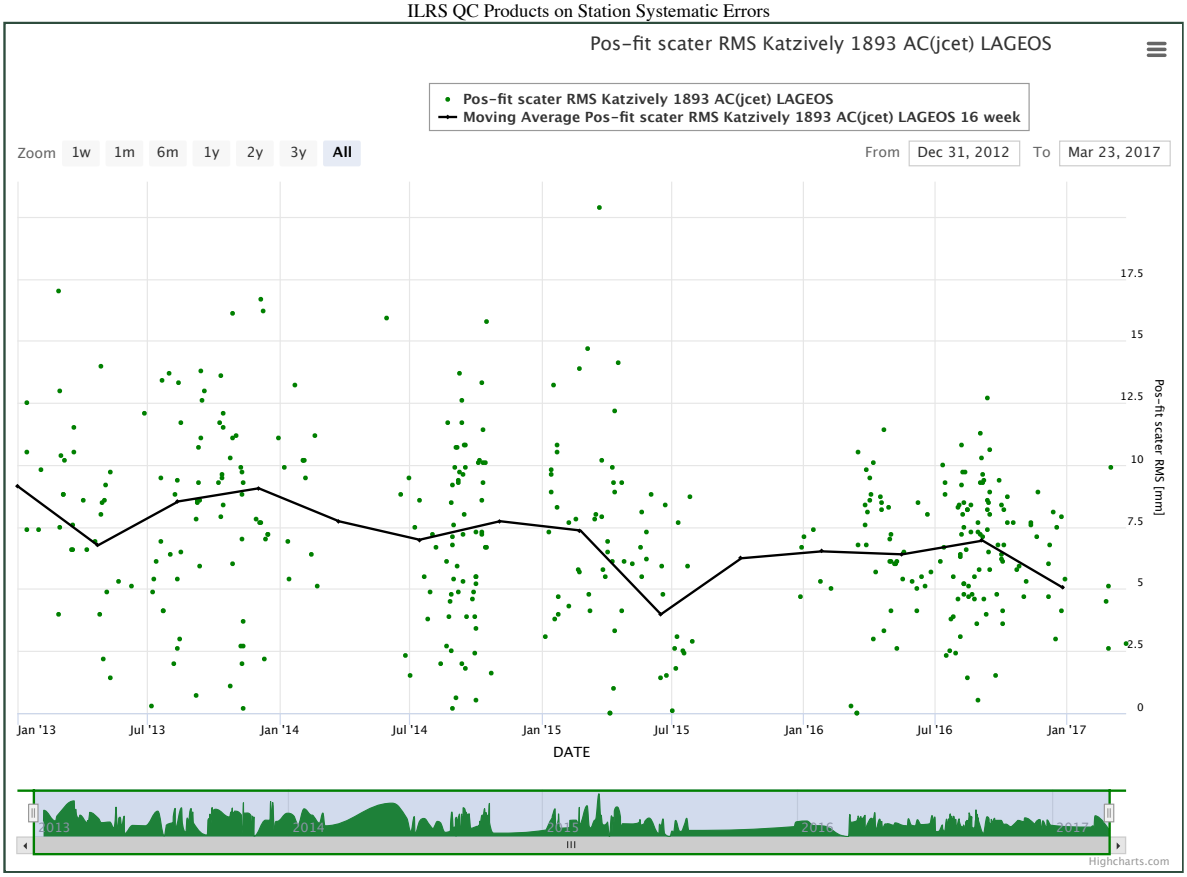

KATZIVELY 1893

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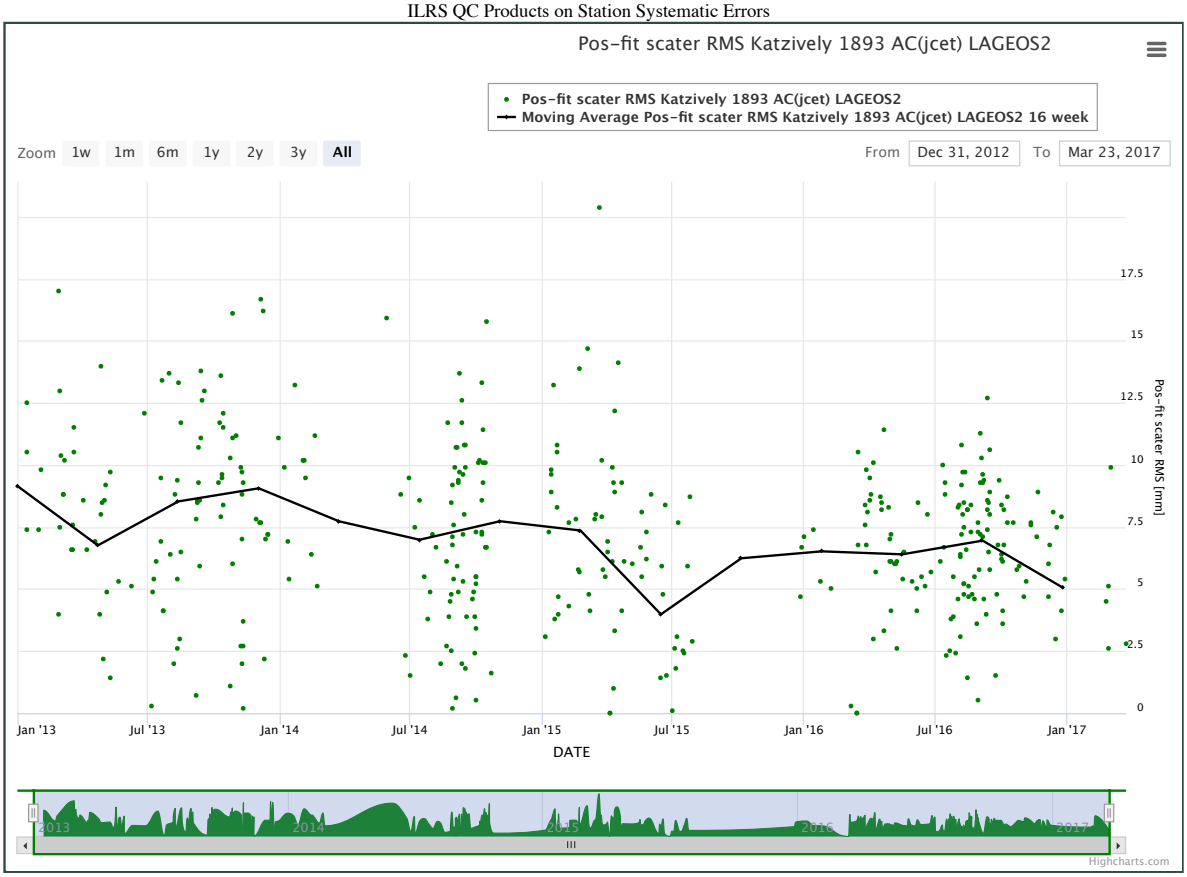

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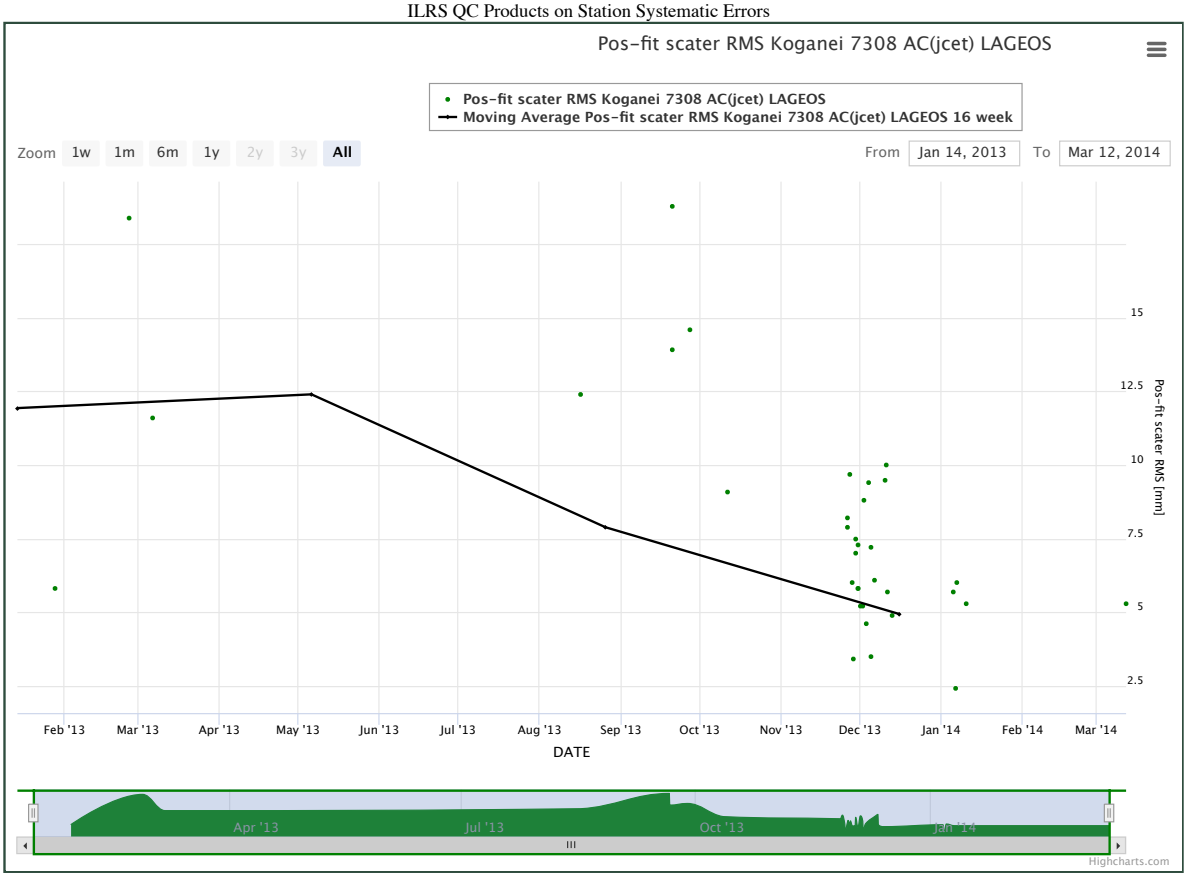
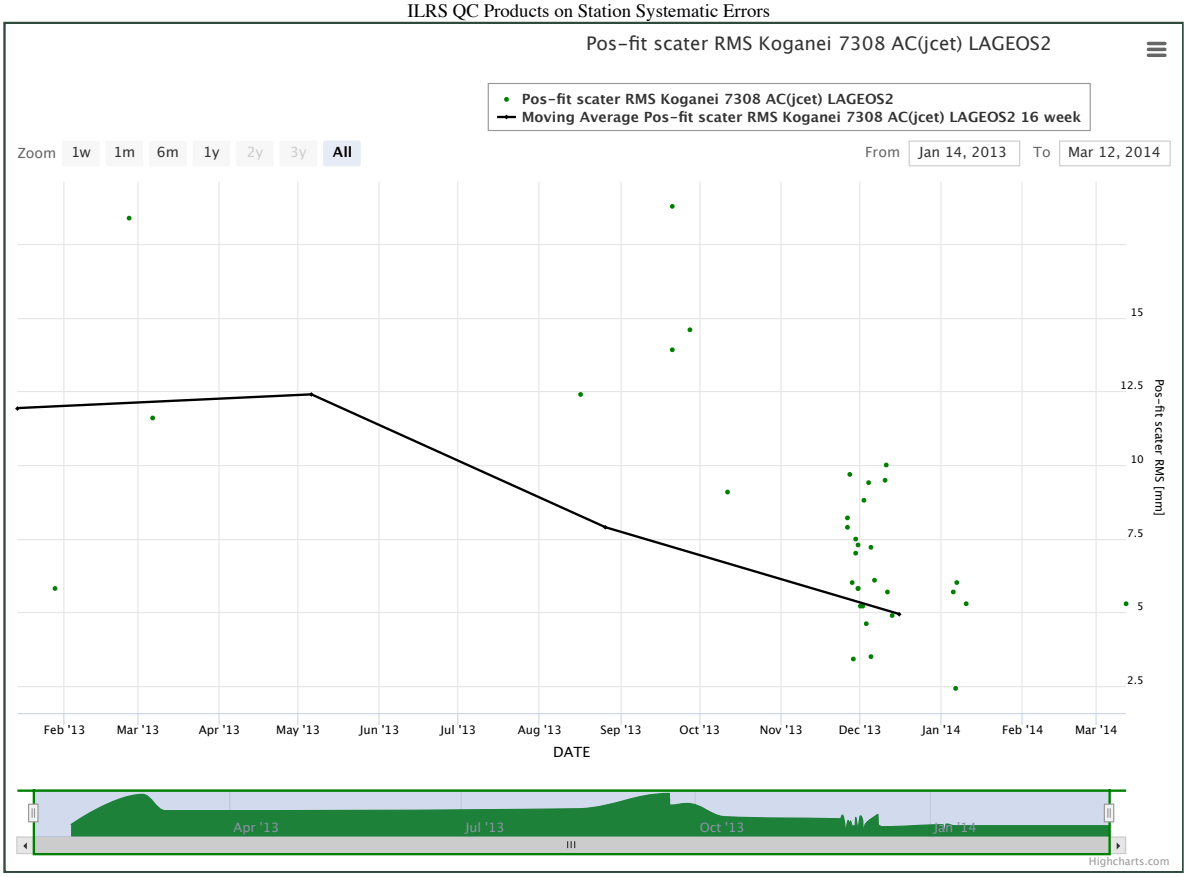
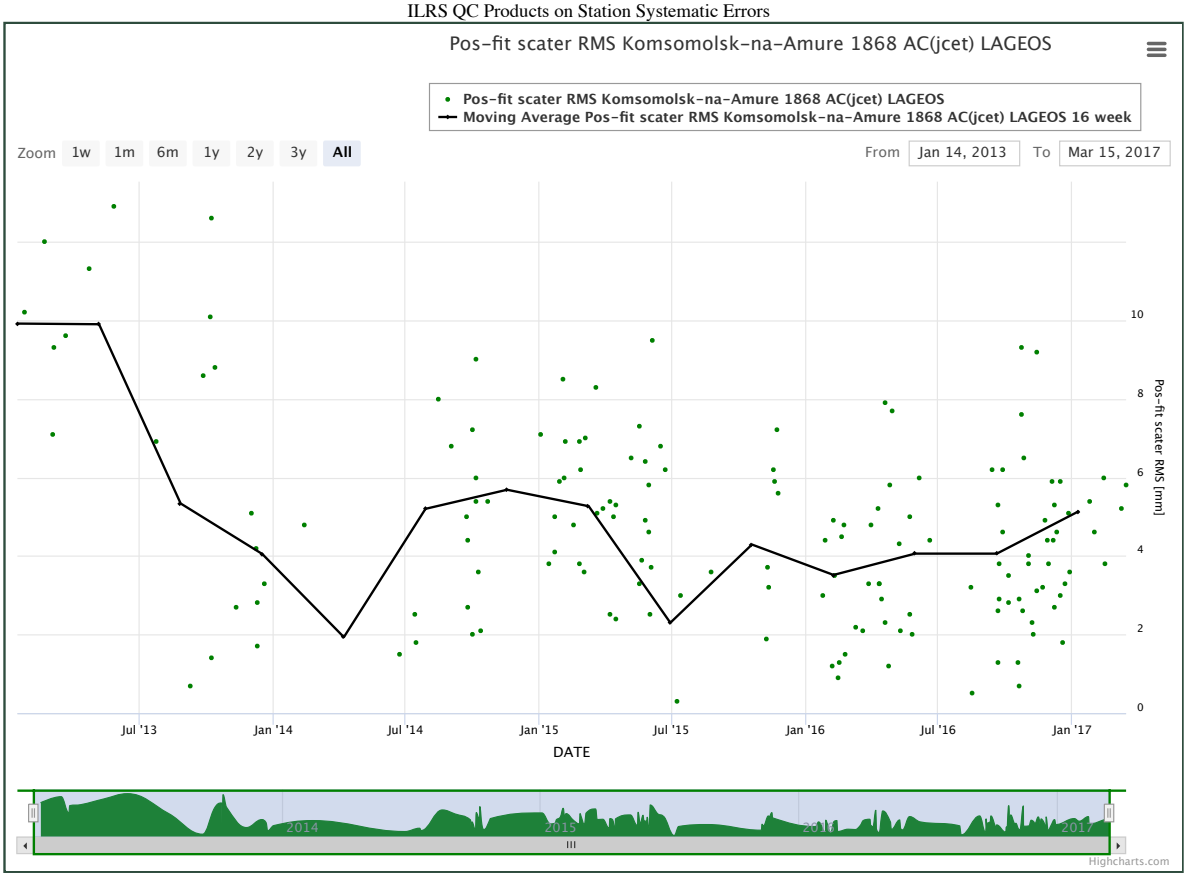


KOGANEI 7308

ILRS QC Products on Station Systematic Errors

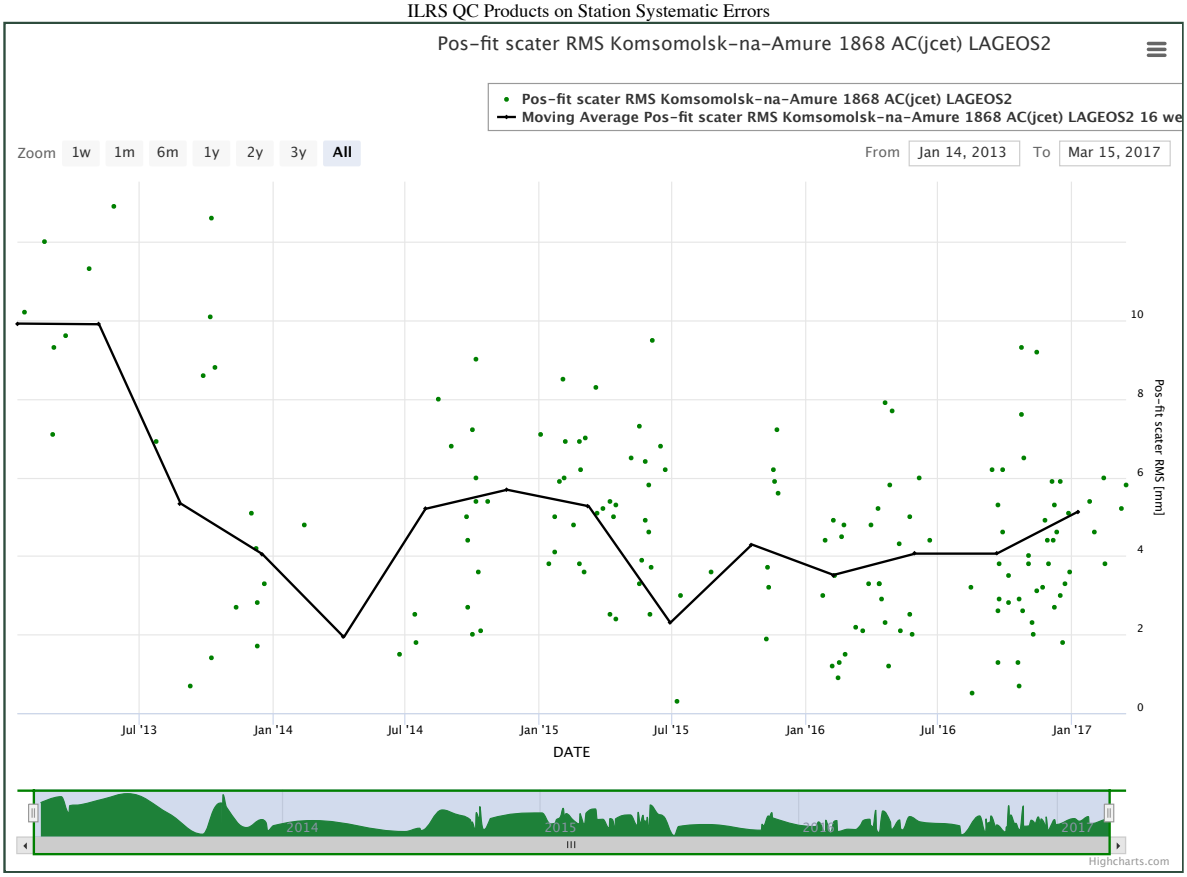


ILRS QC Products on Station Systematic Errors



KOMSOMOLSK-na-AMURE 1868

ILRS QC Products on Station Systematic Errors



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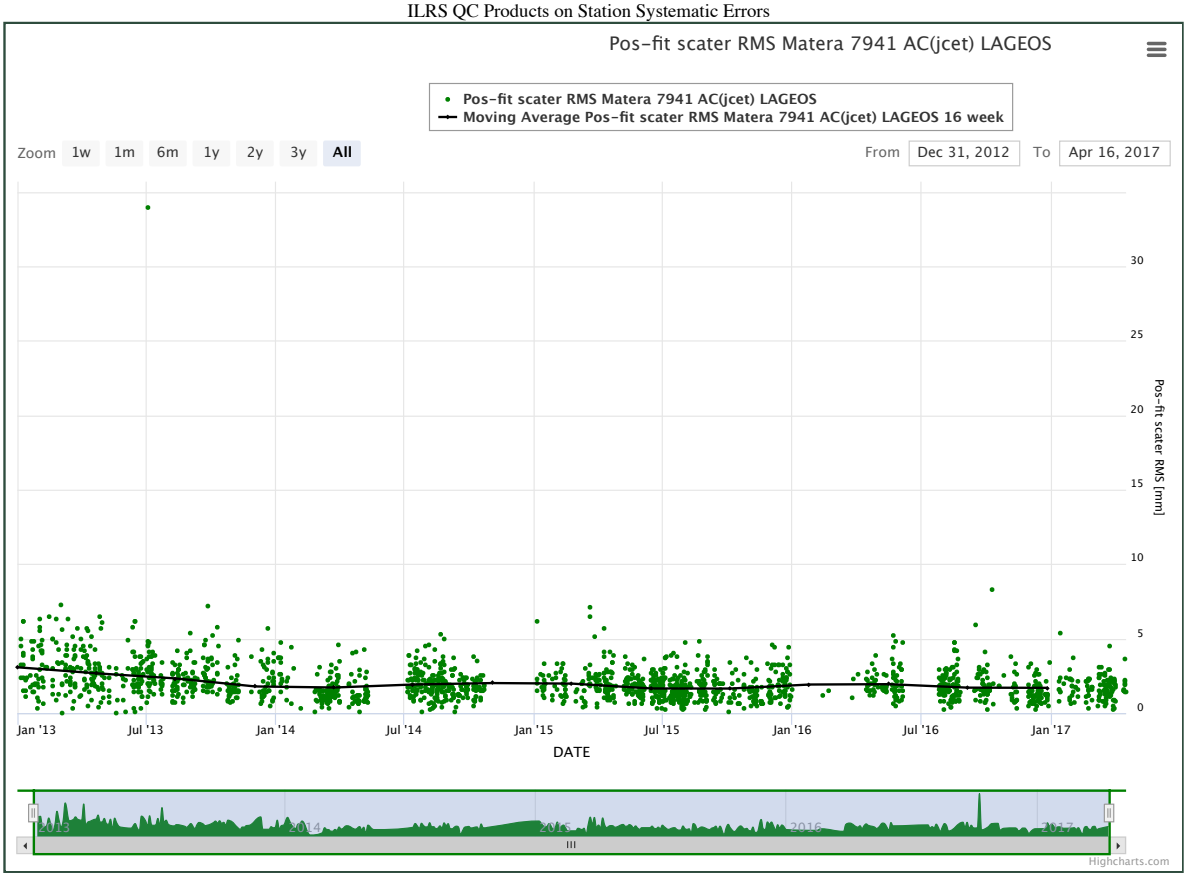

MATERA 7941

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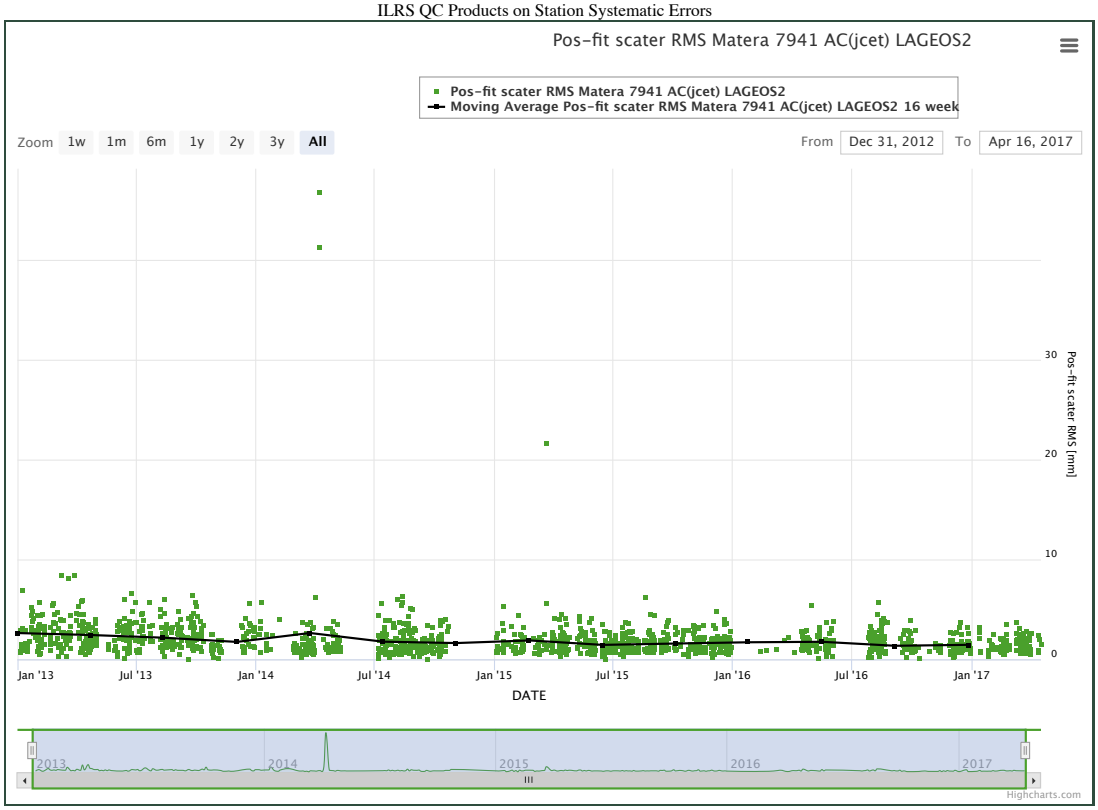
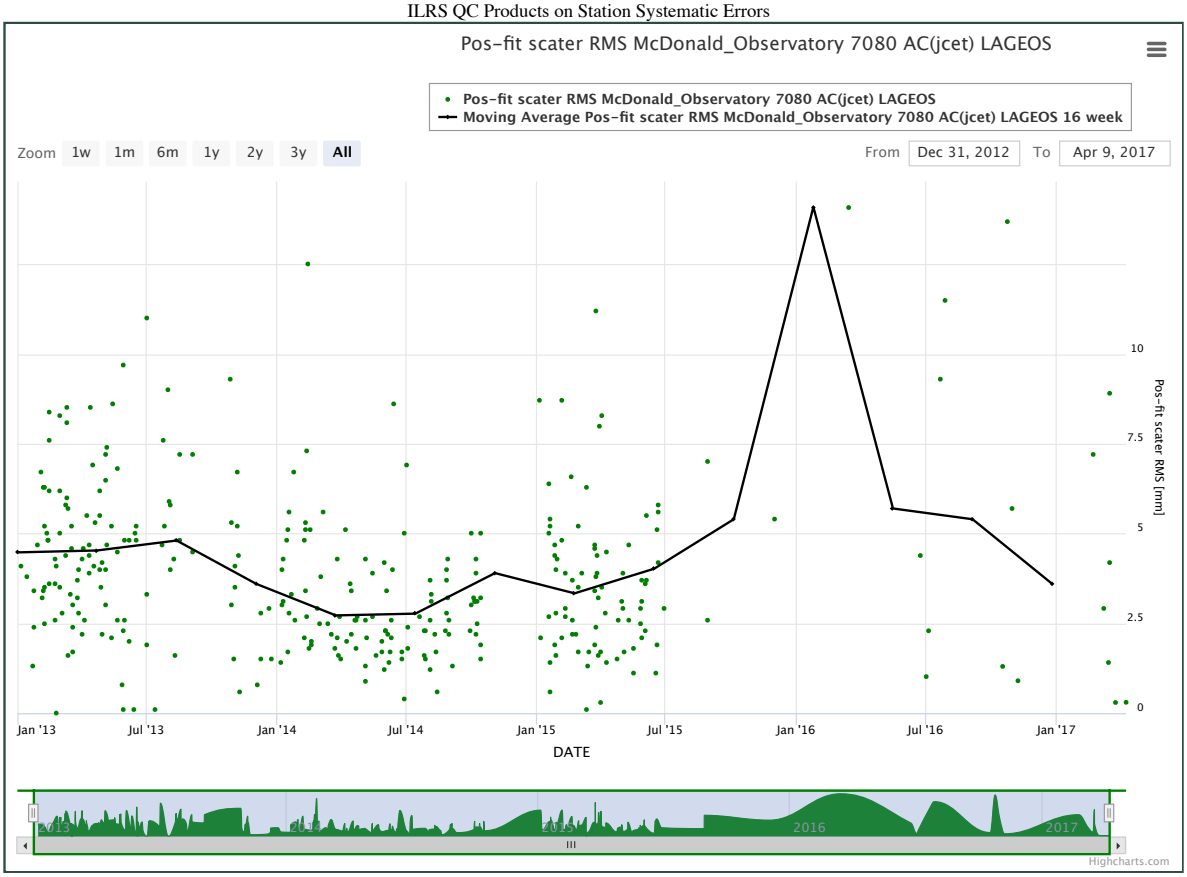


ILRS QC Products on Station Systematic Errors



MLRS 7080

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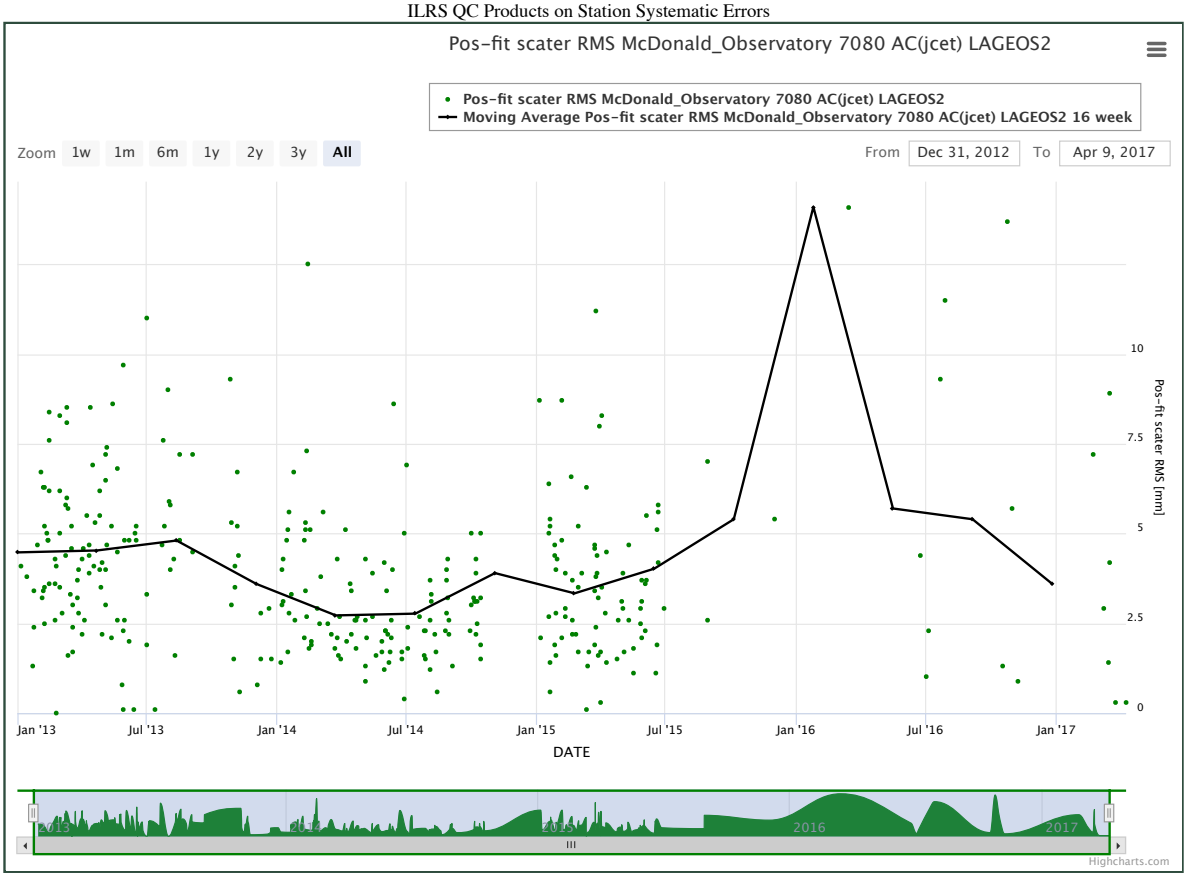

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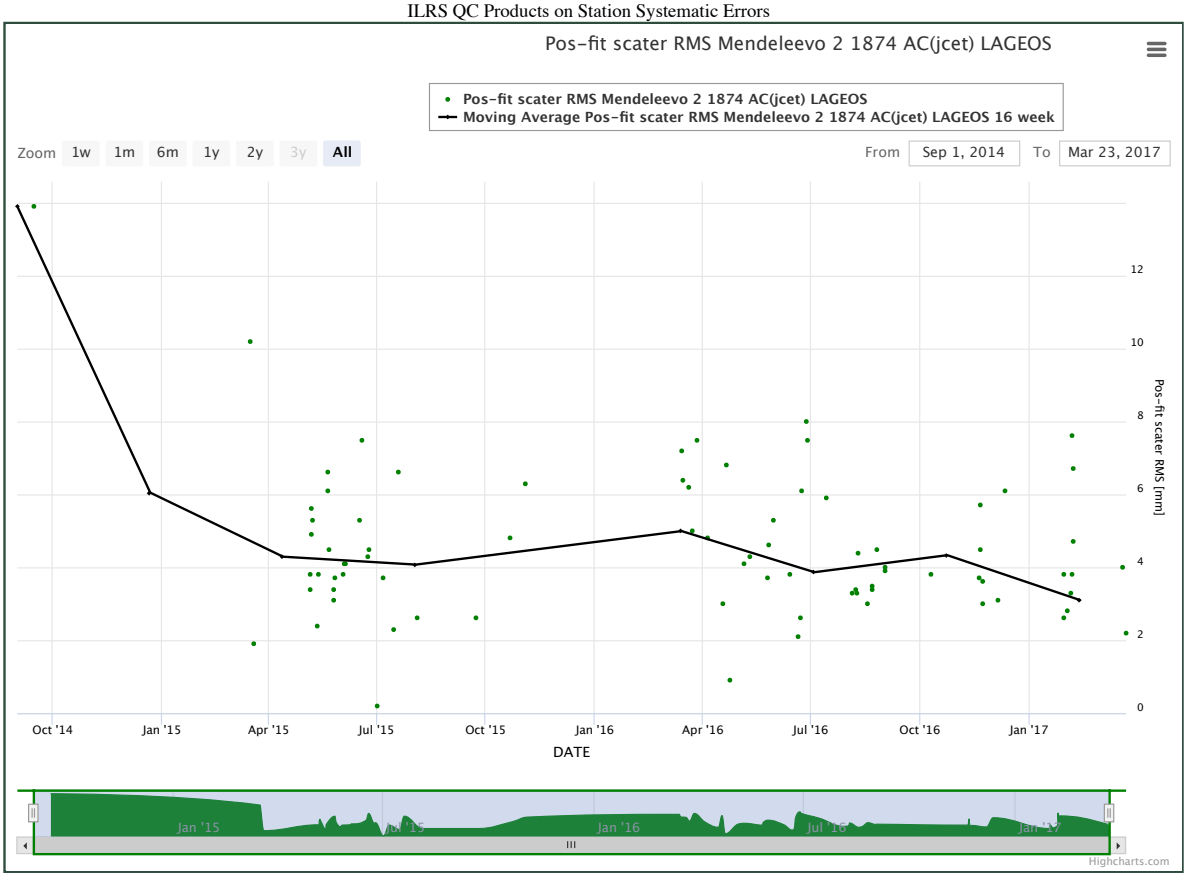

MENDELEEVO 1874

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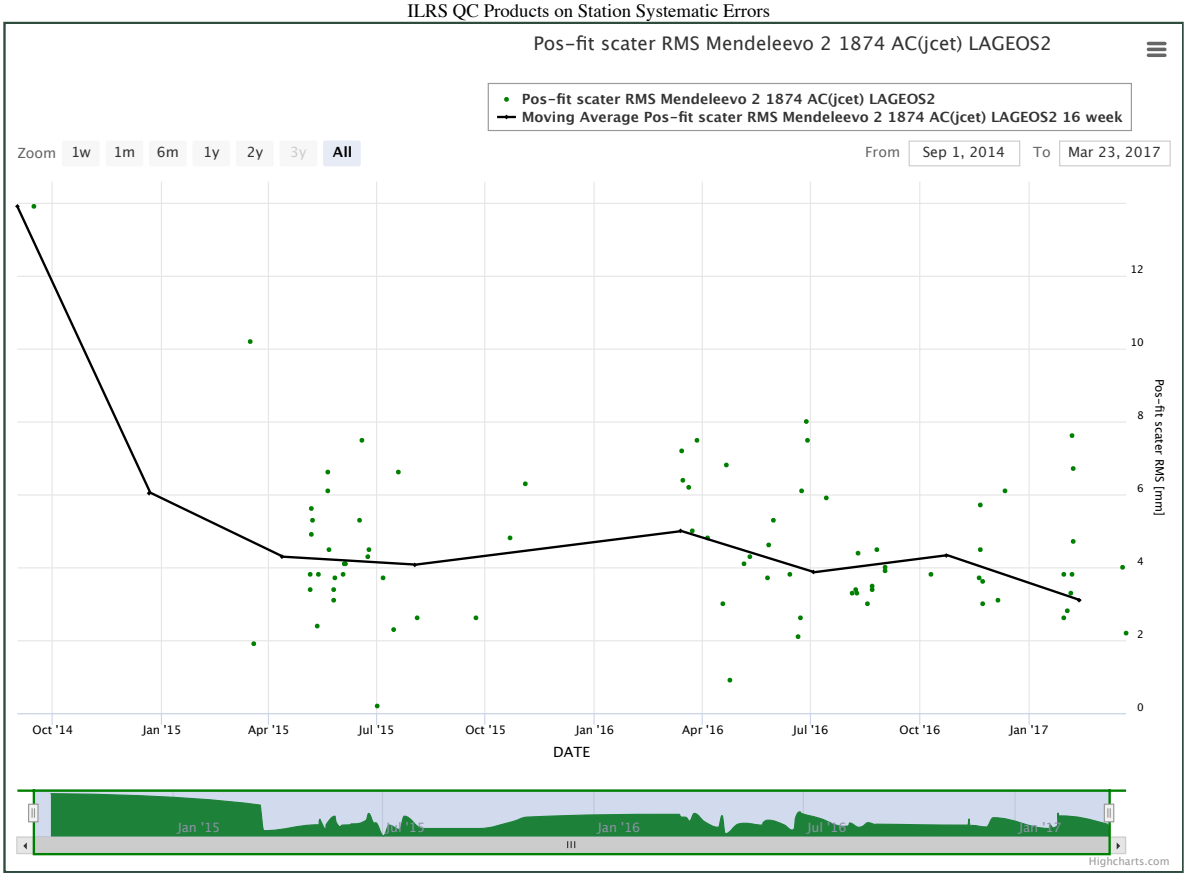

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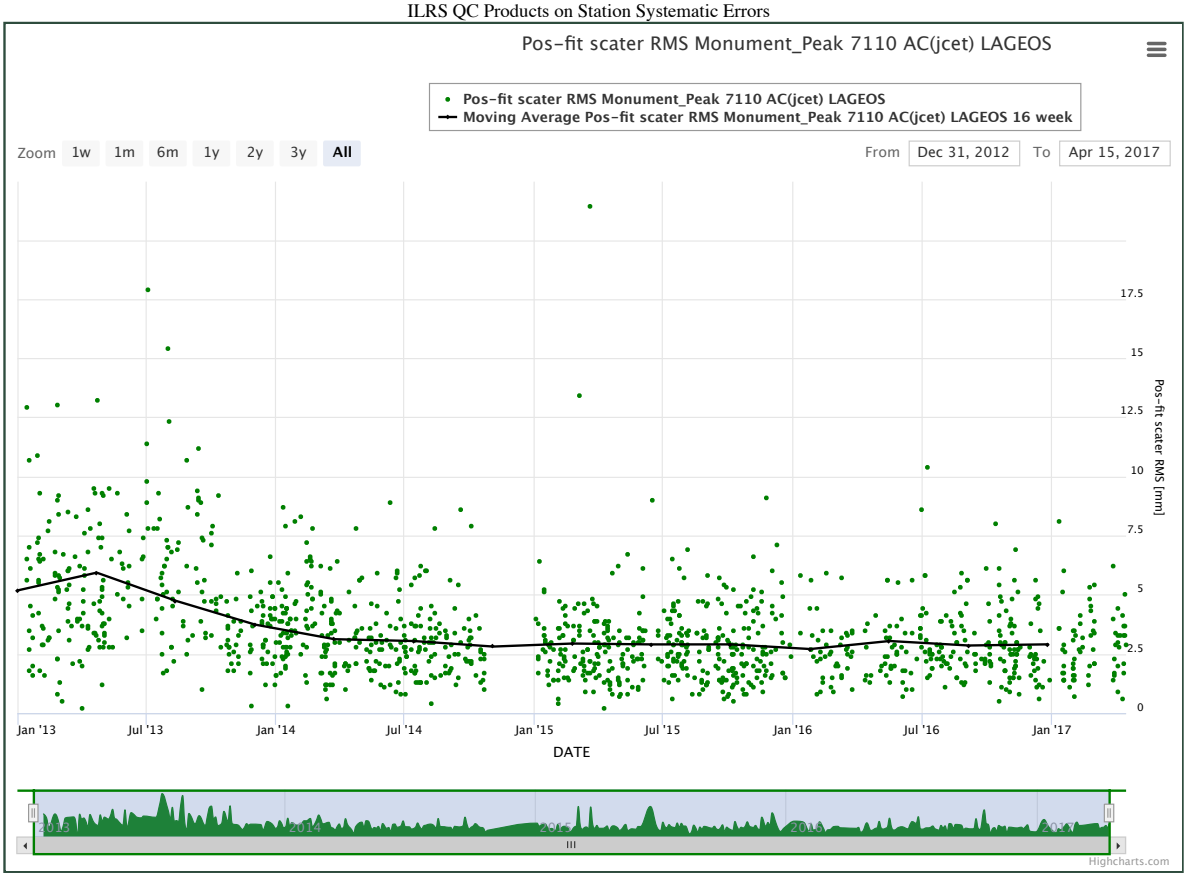
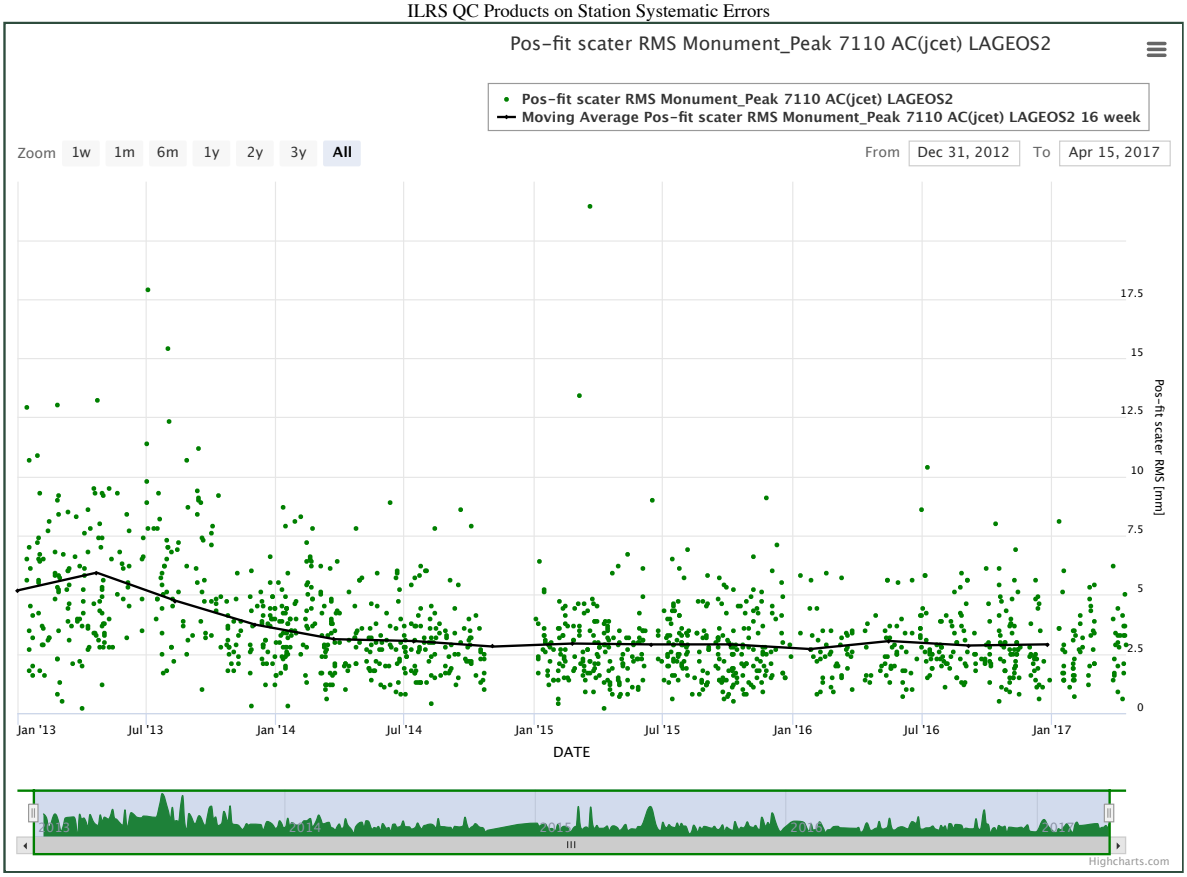


MONUMENT PEAK 7110

ILRS QC Products on Station Systematic Errors



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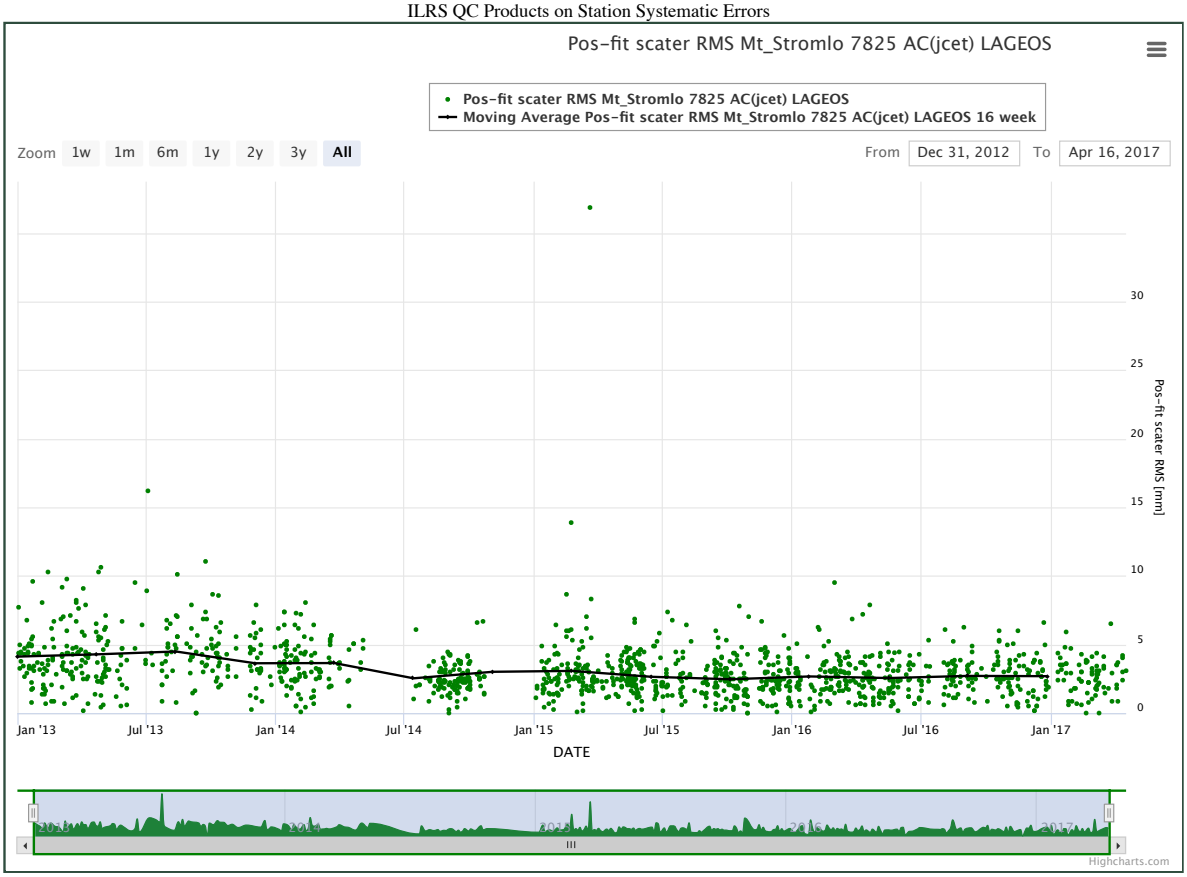

Mt. STROMLO 7825

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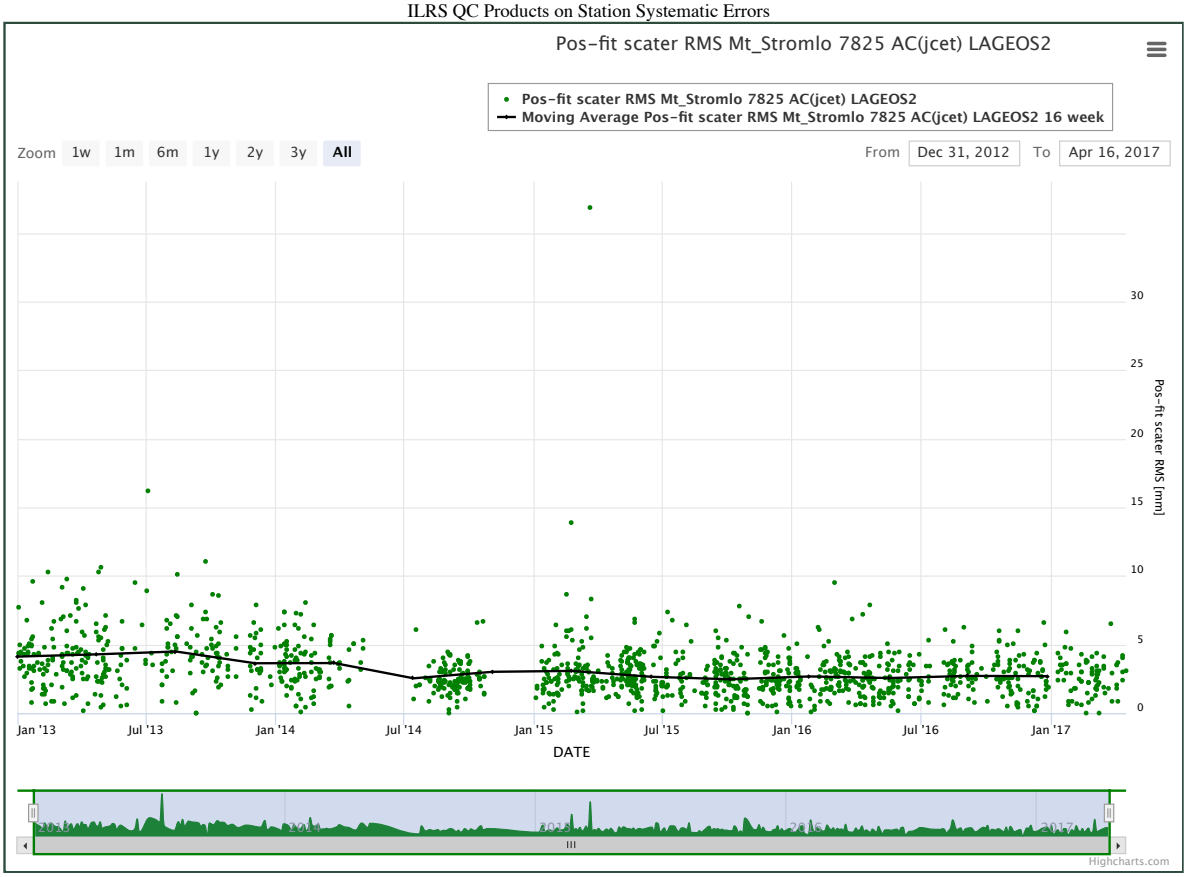

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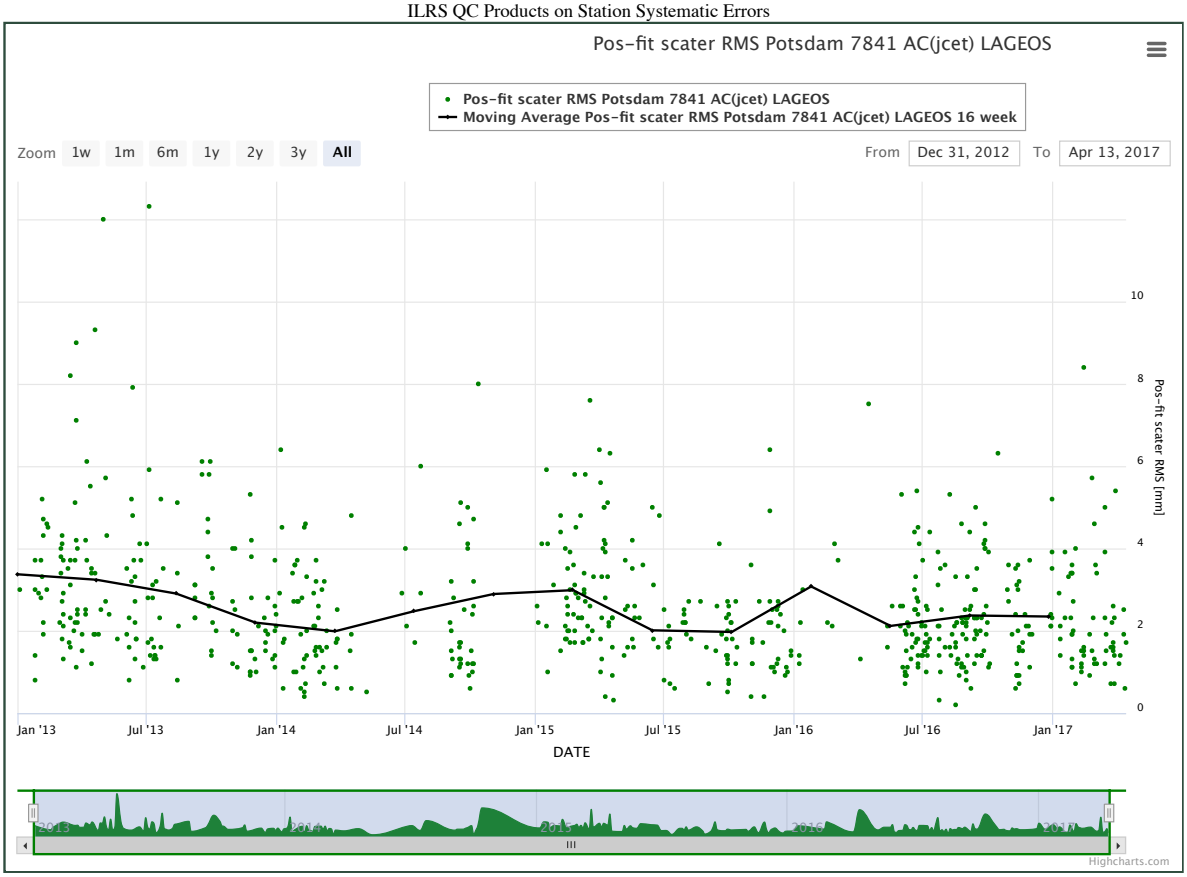

POTSDAM 7841

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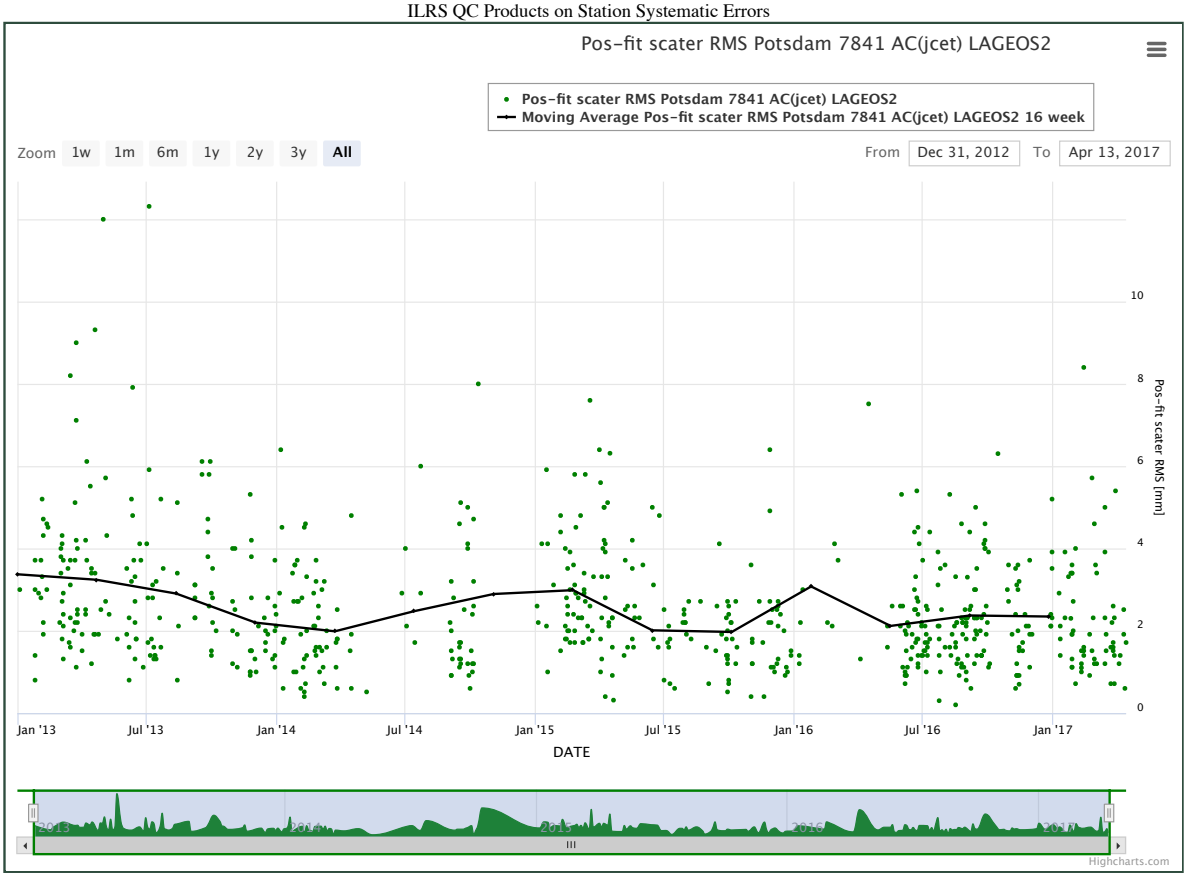

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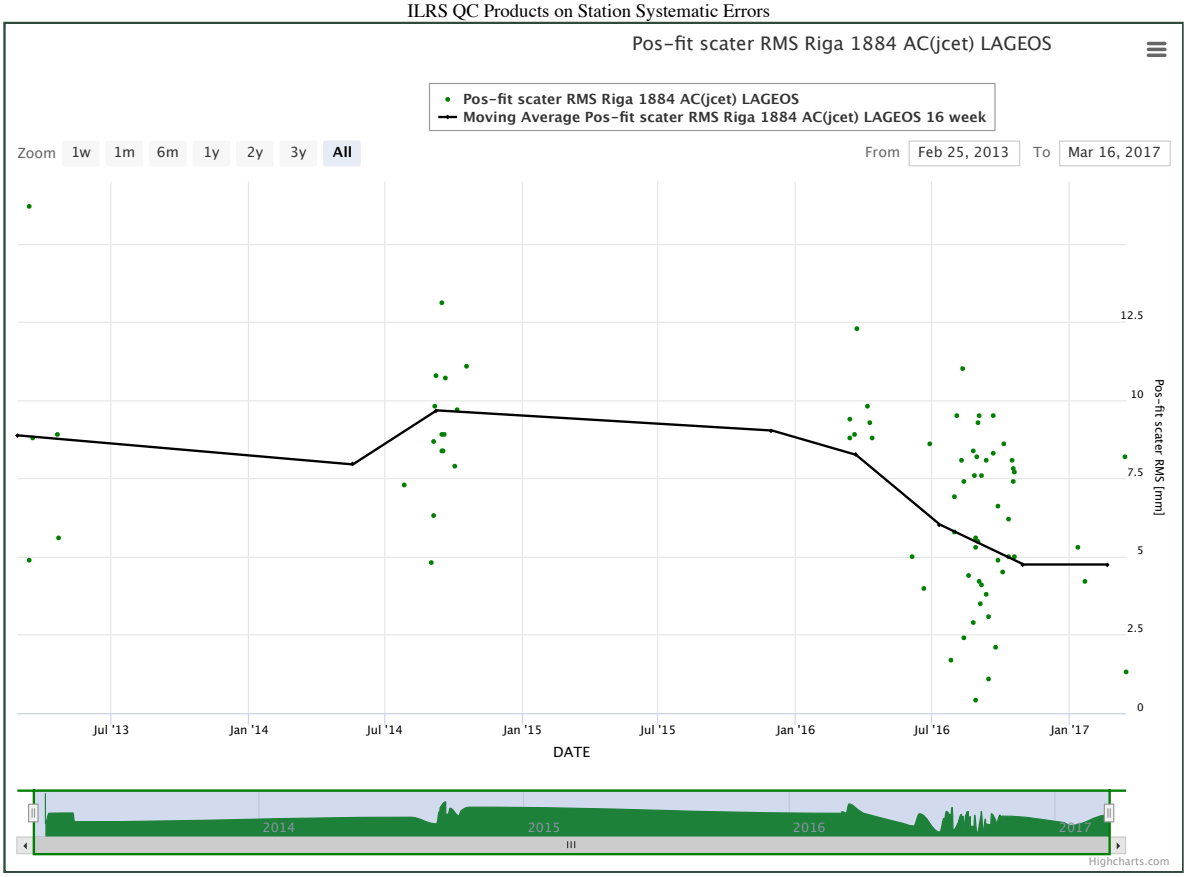
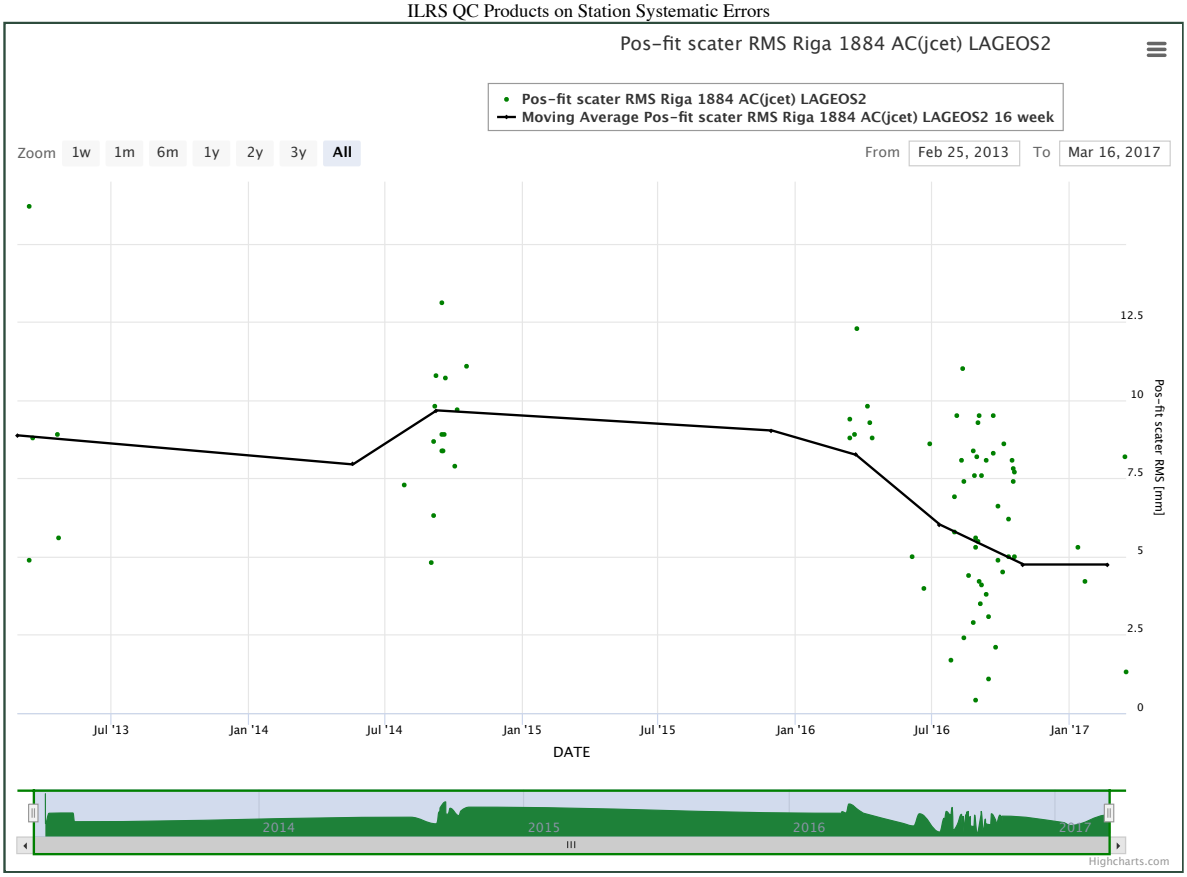


RIGA 1884

ILRS QC Products on Station Systematic Errors



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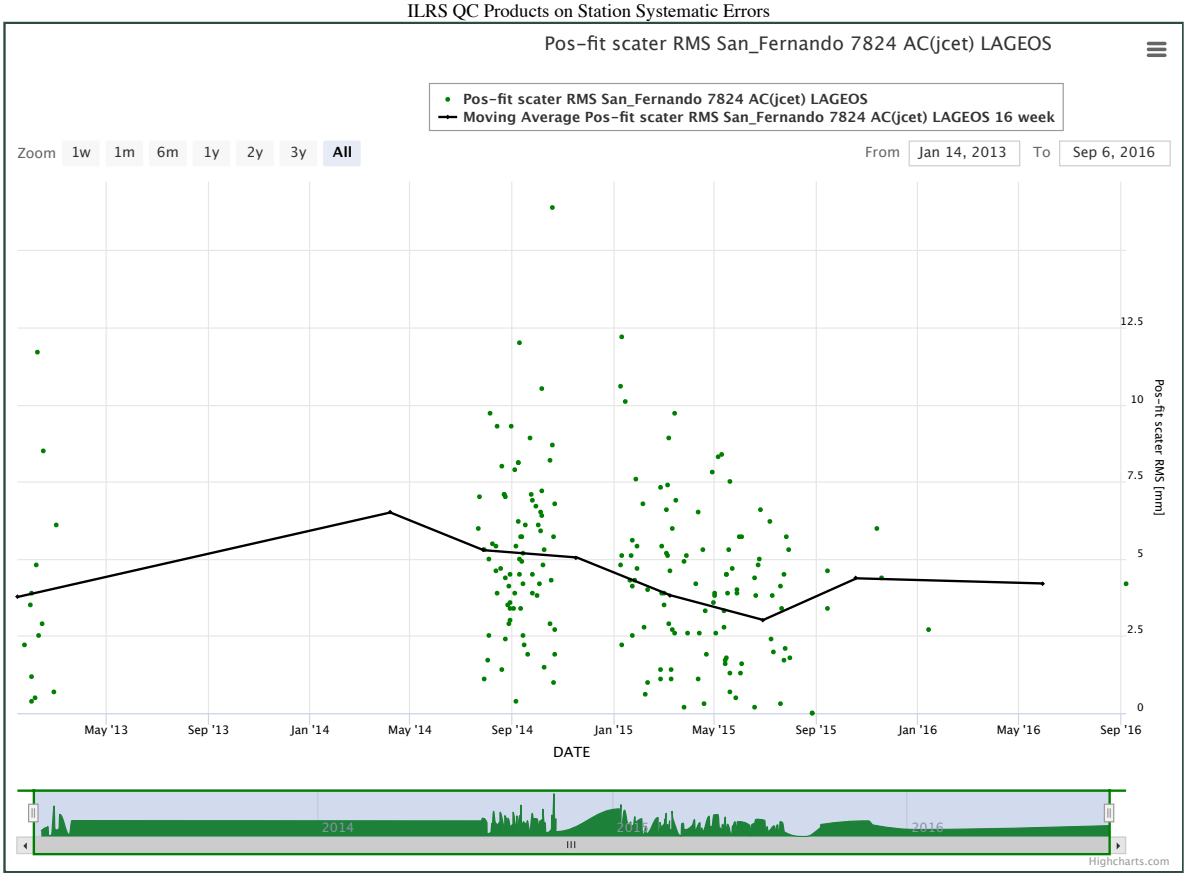

SAN FERNANDO 7824

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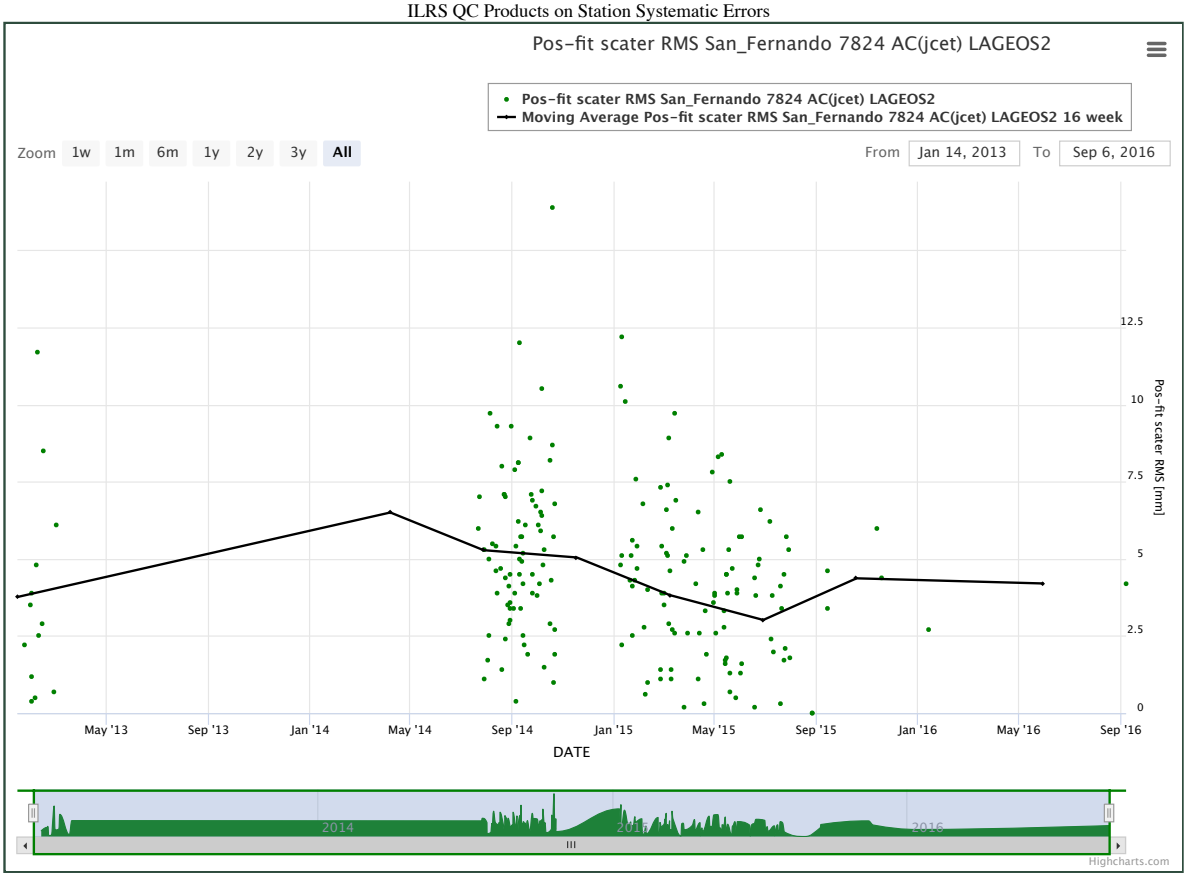

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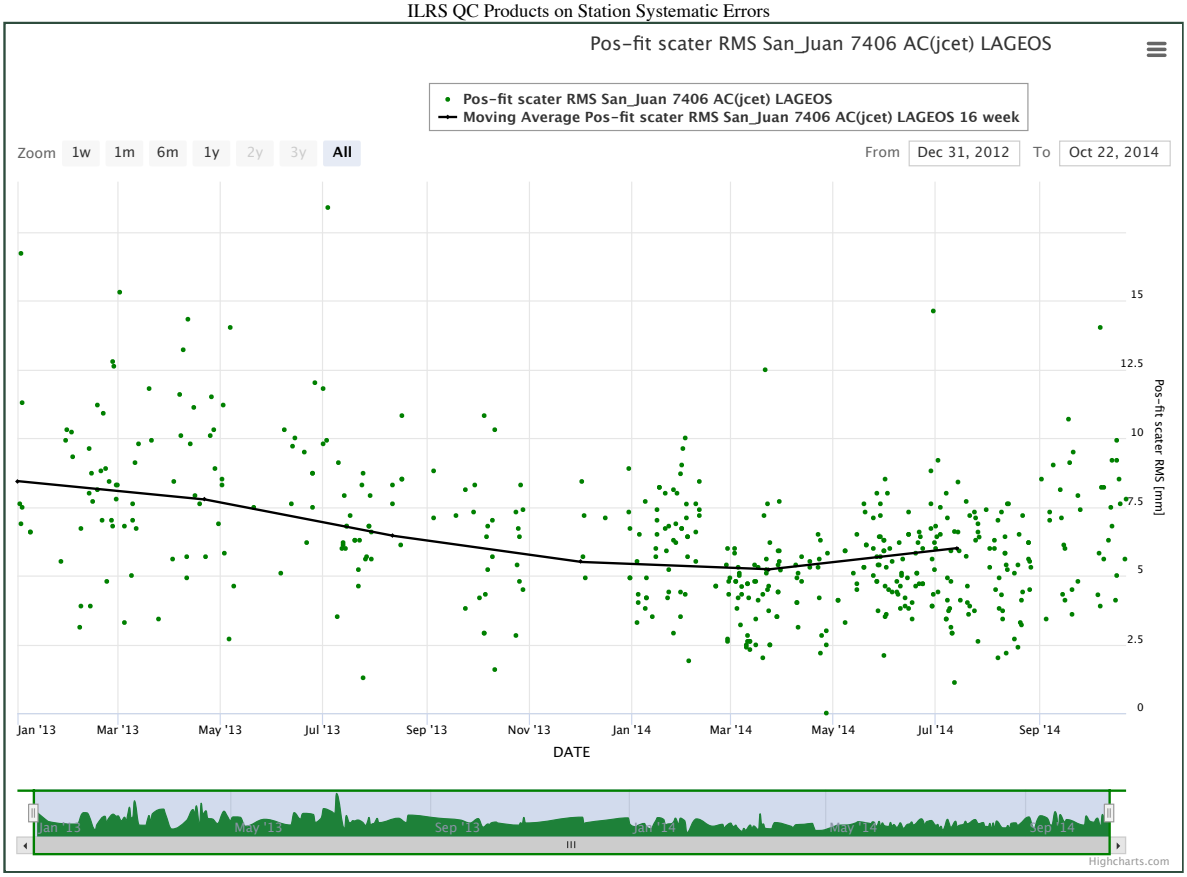

SAN JUAN 7406

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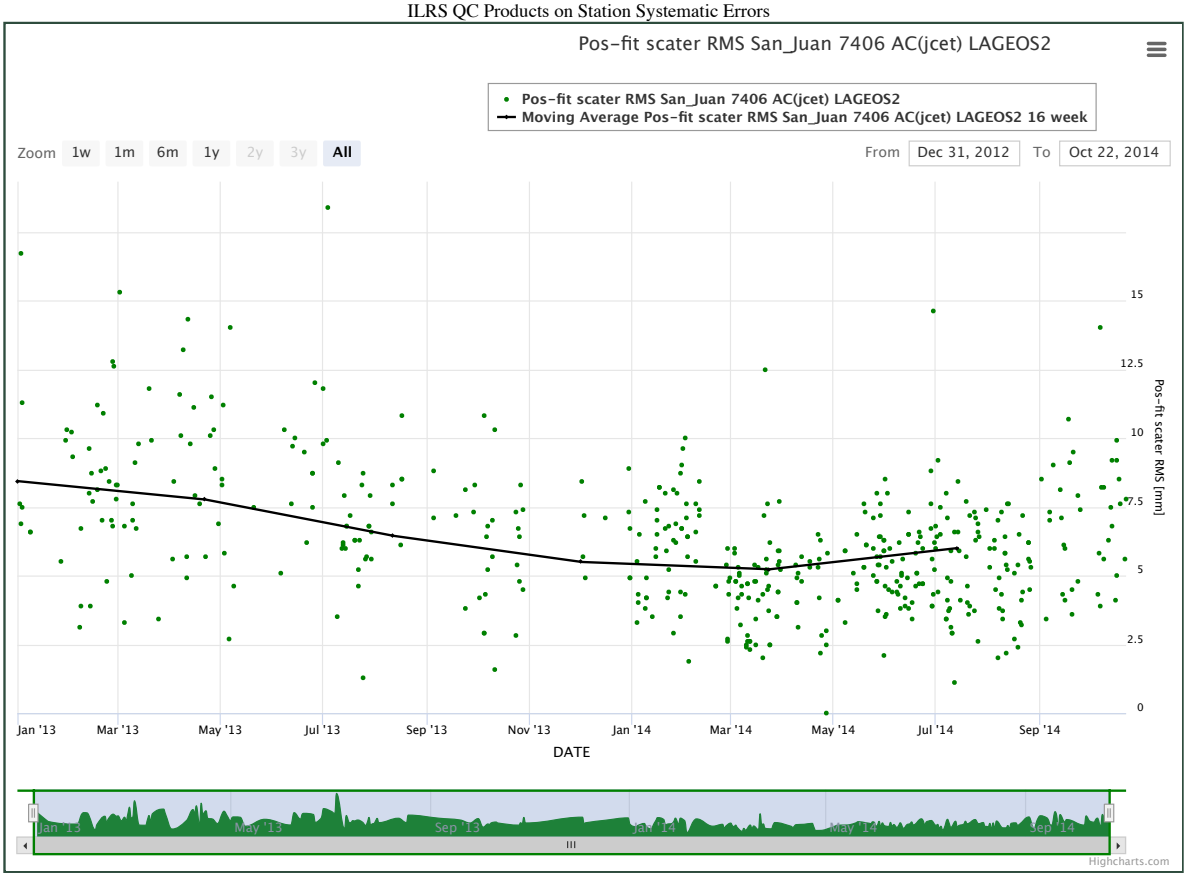

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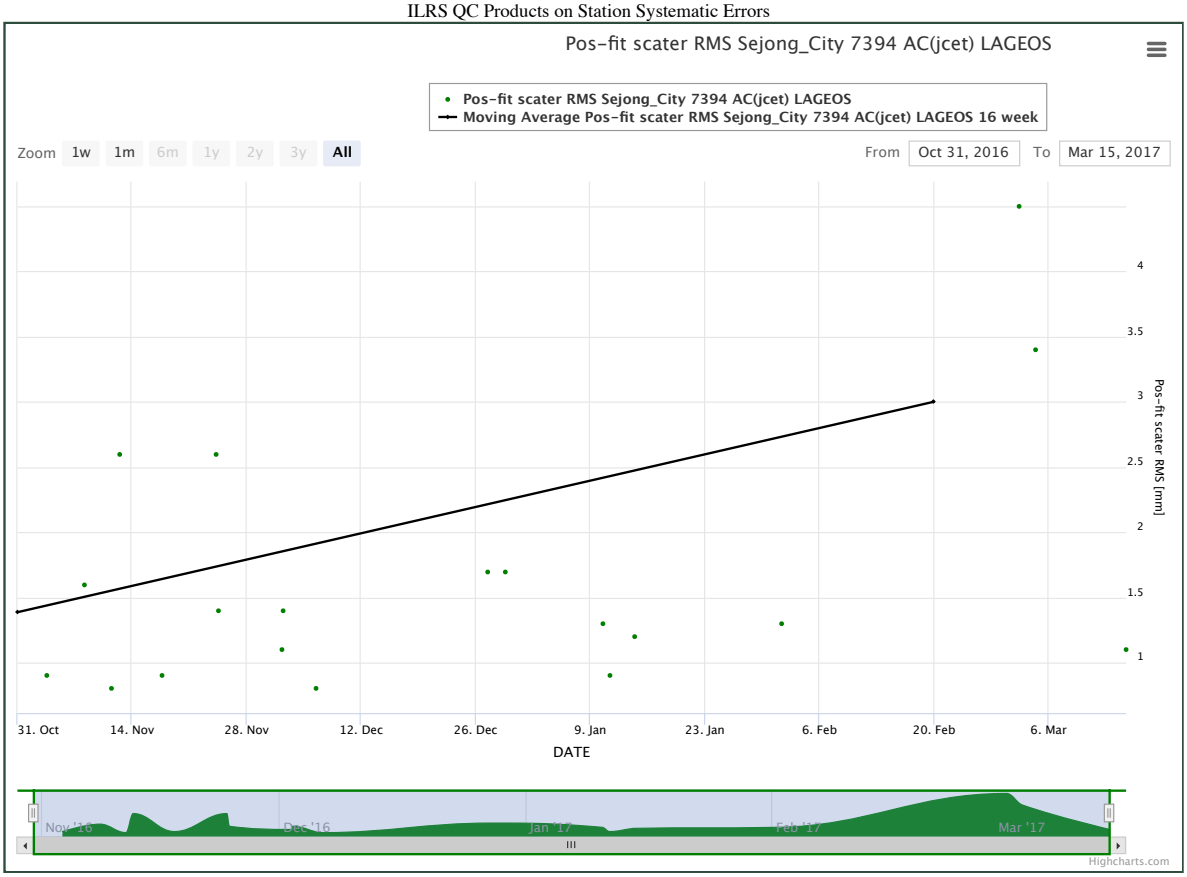

SEJONG 7394

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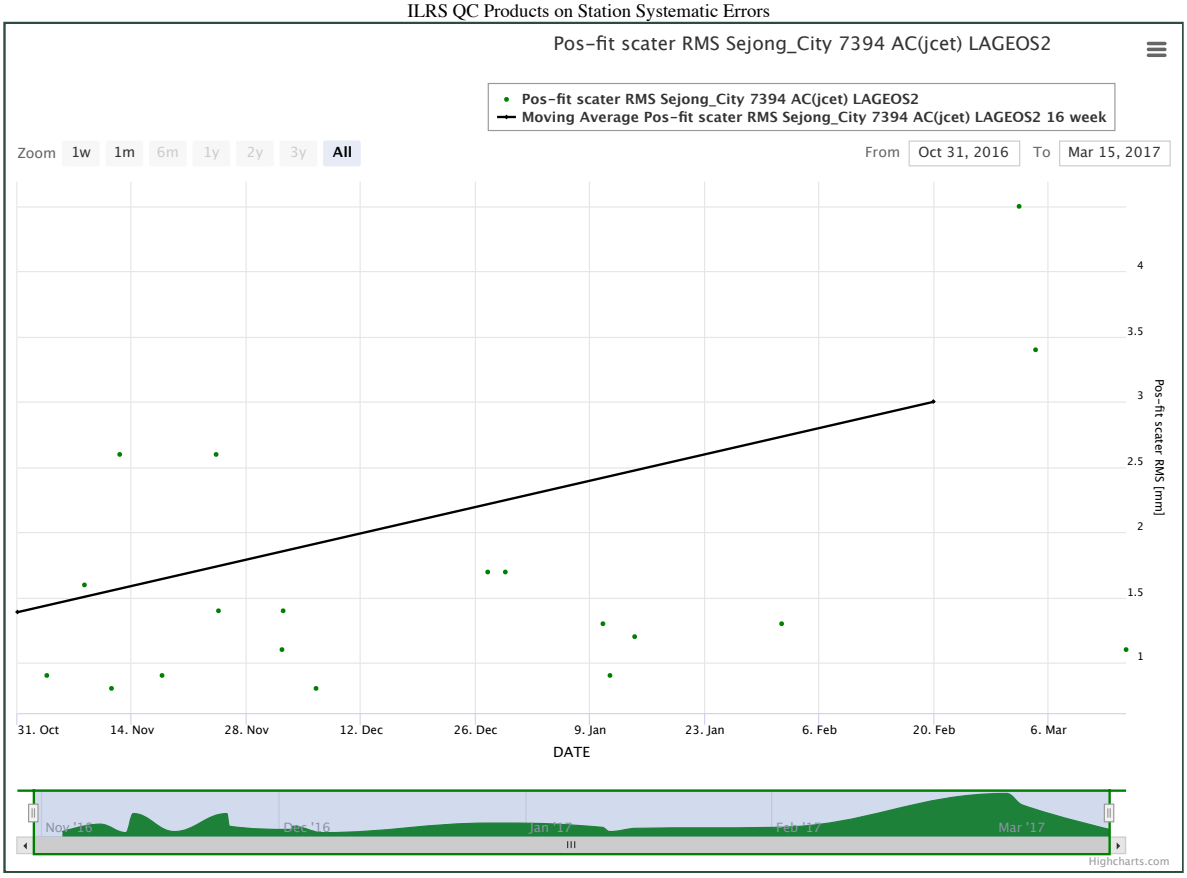

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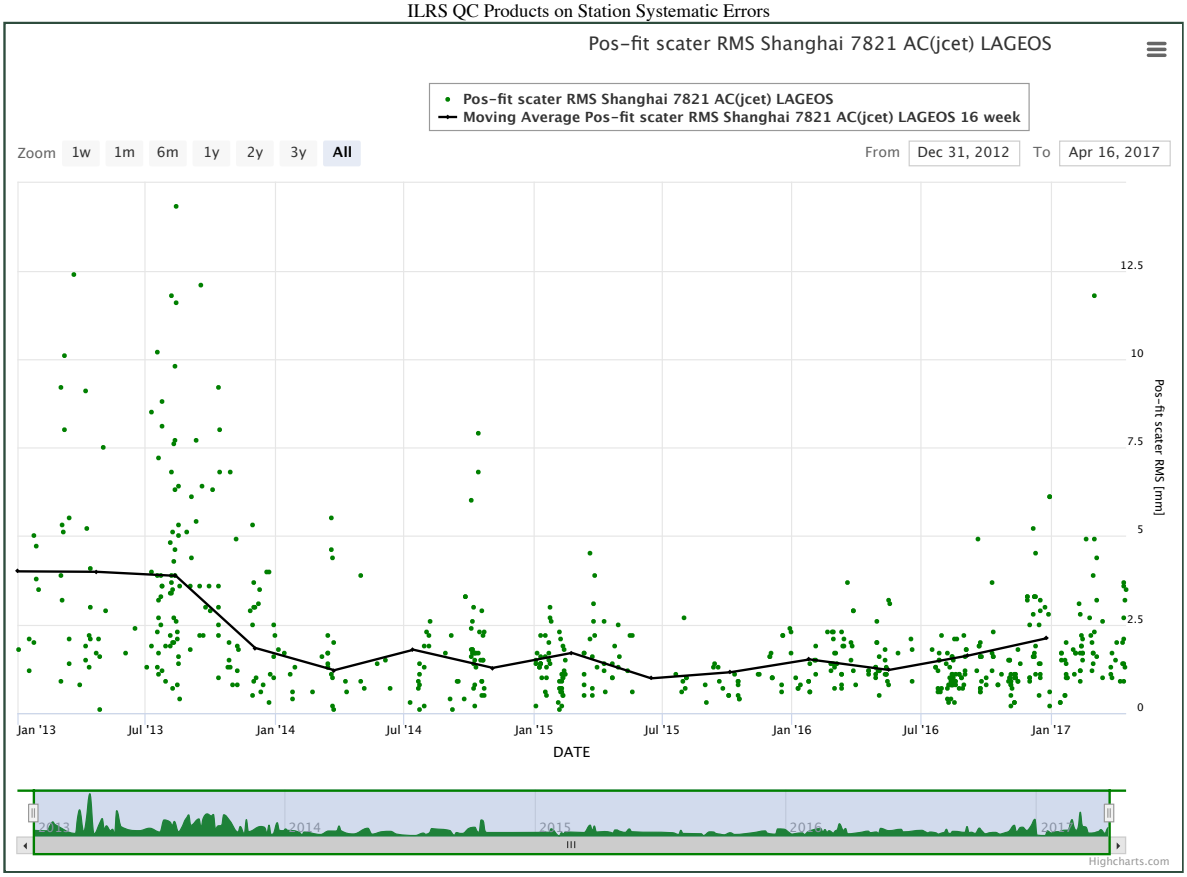

SHANGHAI 7821

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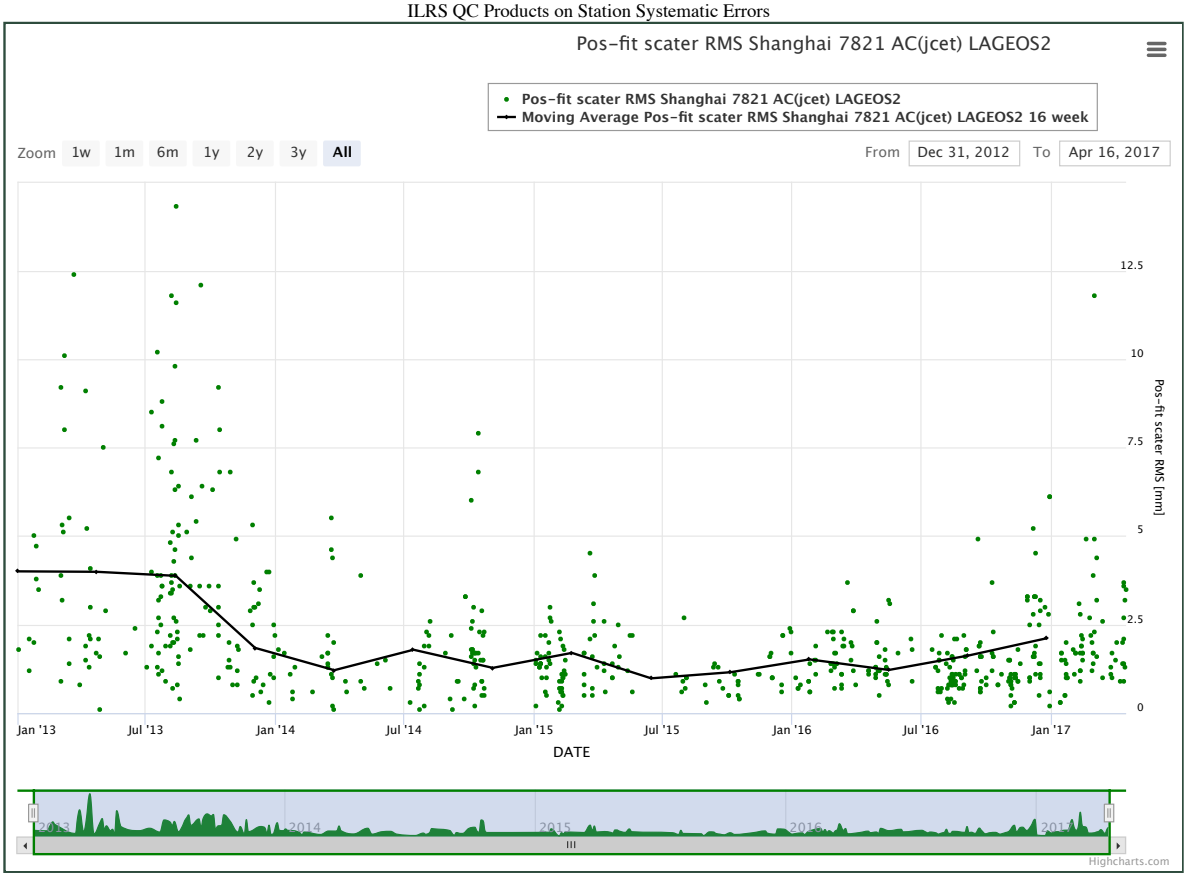

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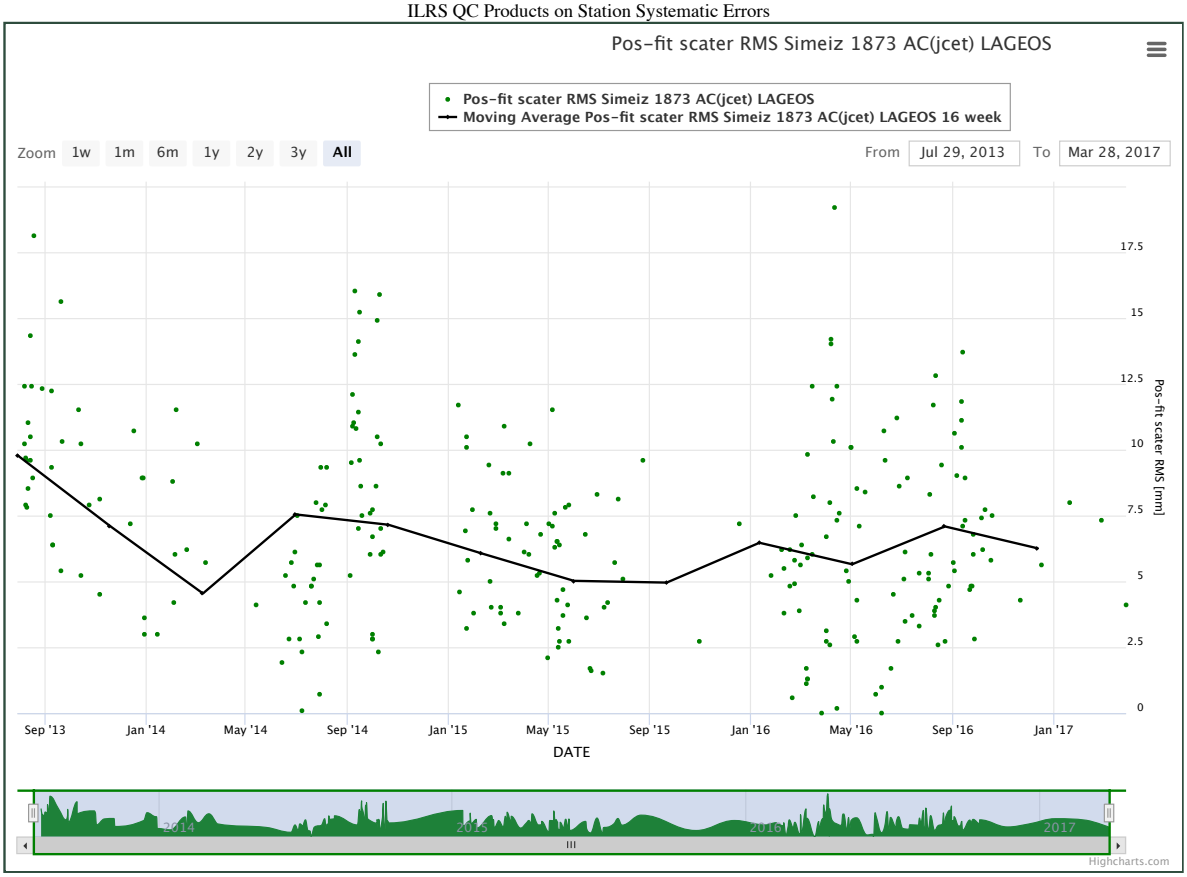

SIMEIZ 1873

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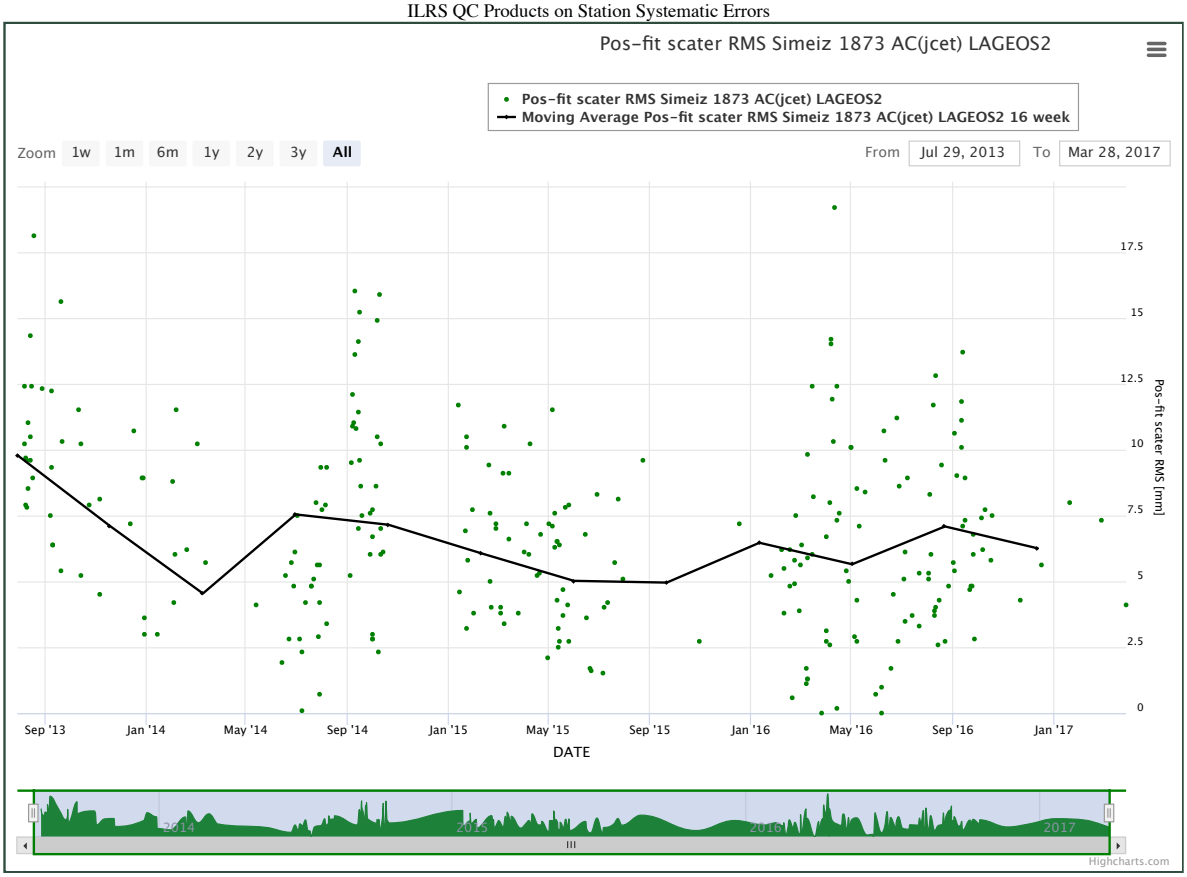

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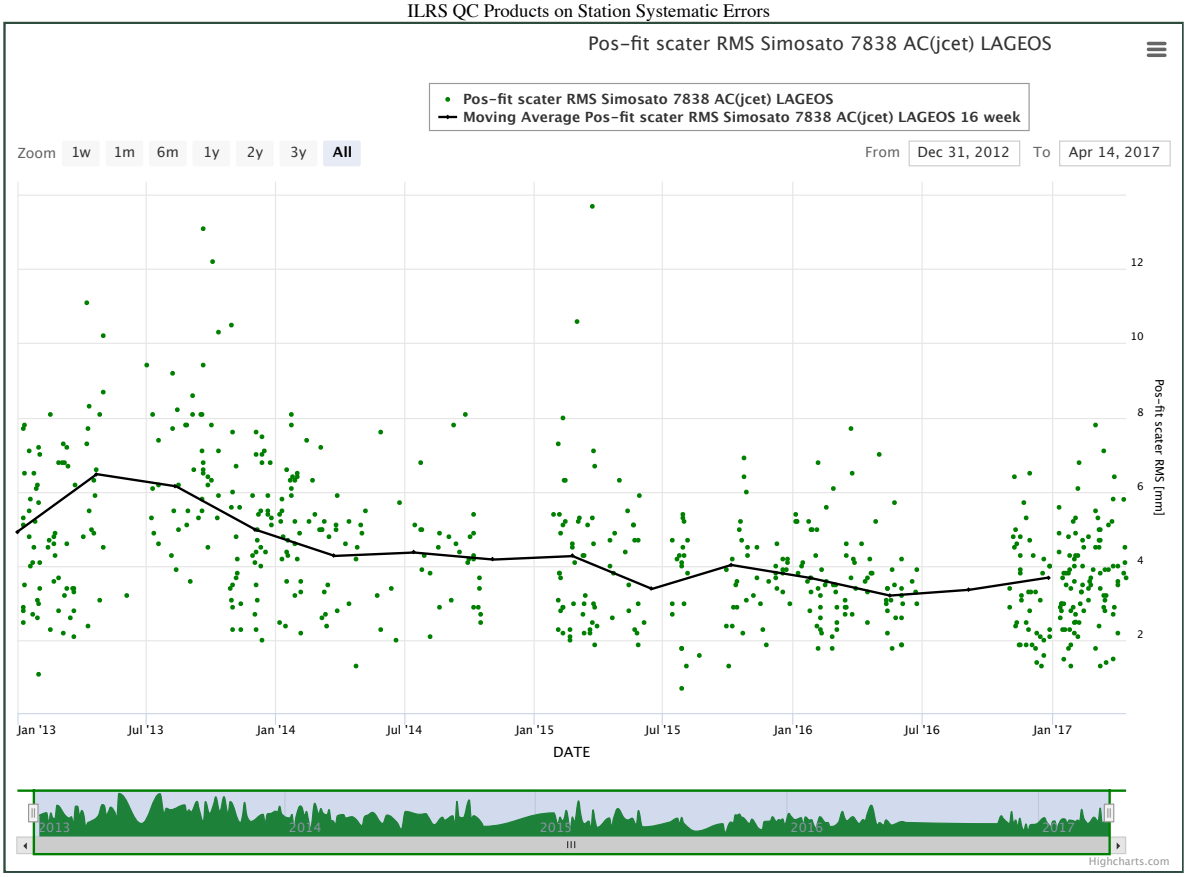

SIMOSATO 7838

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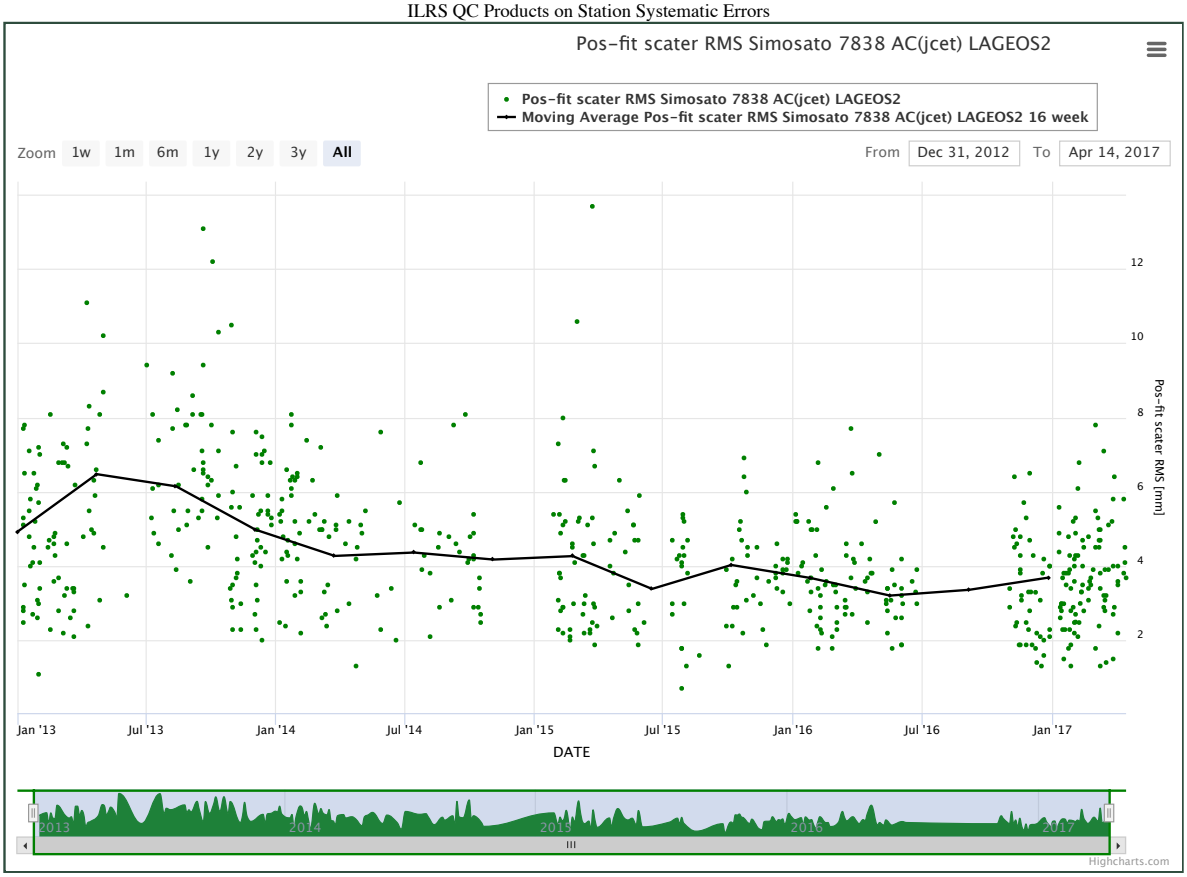

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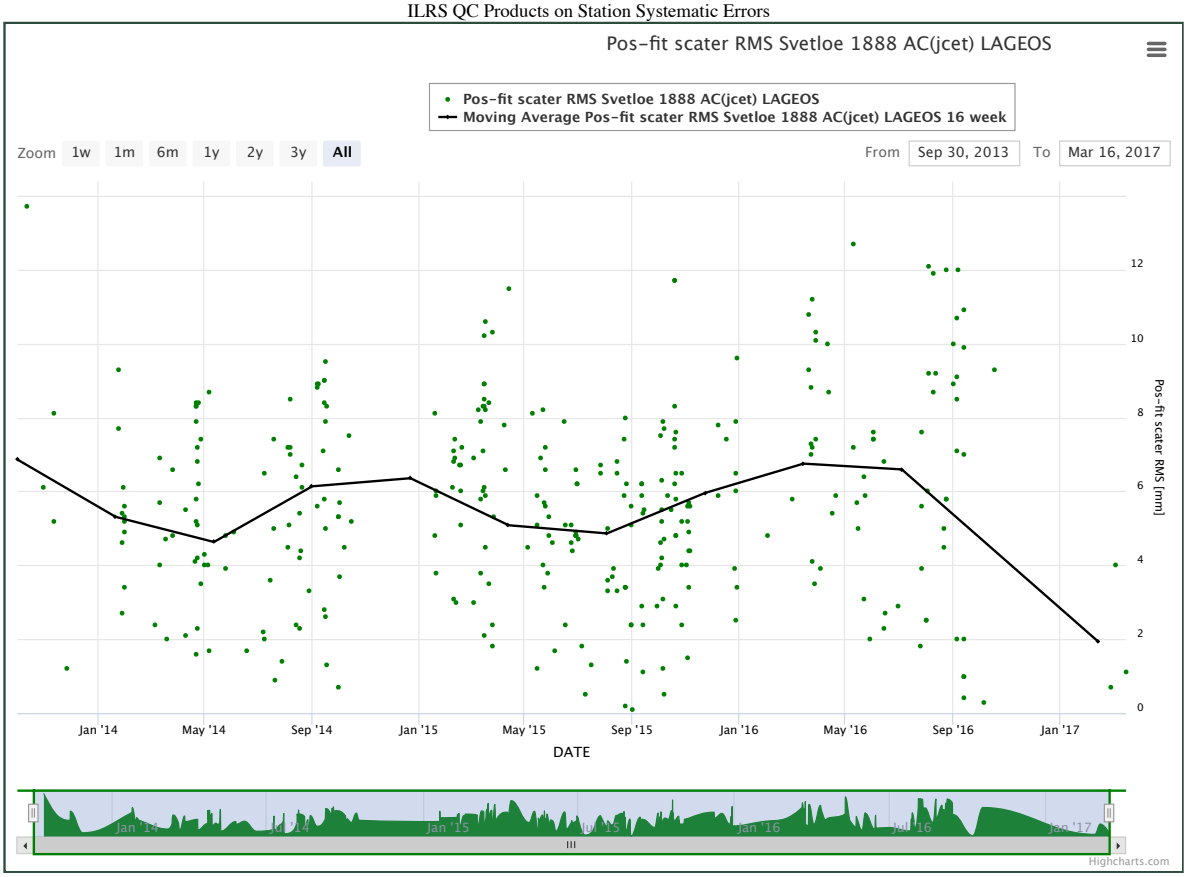
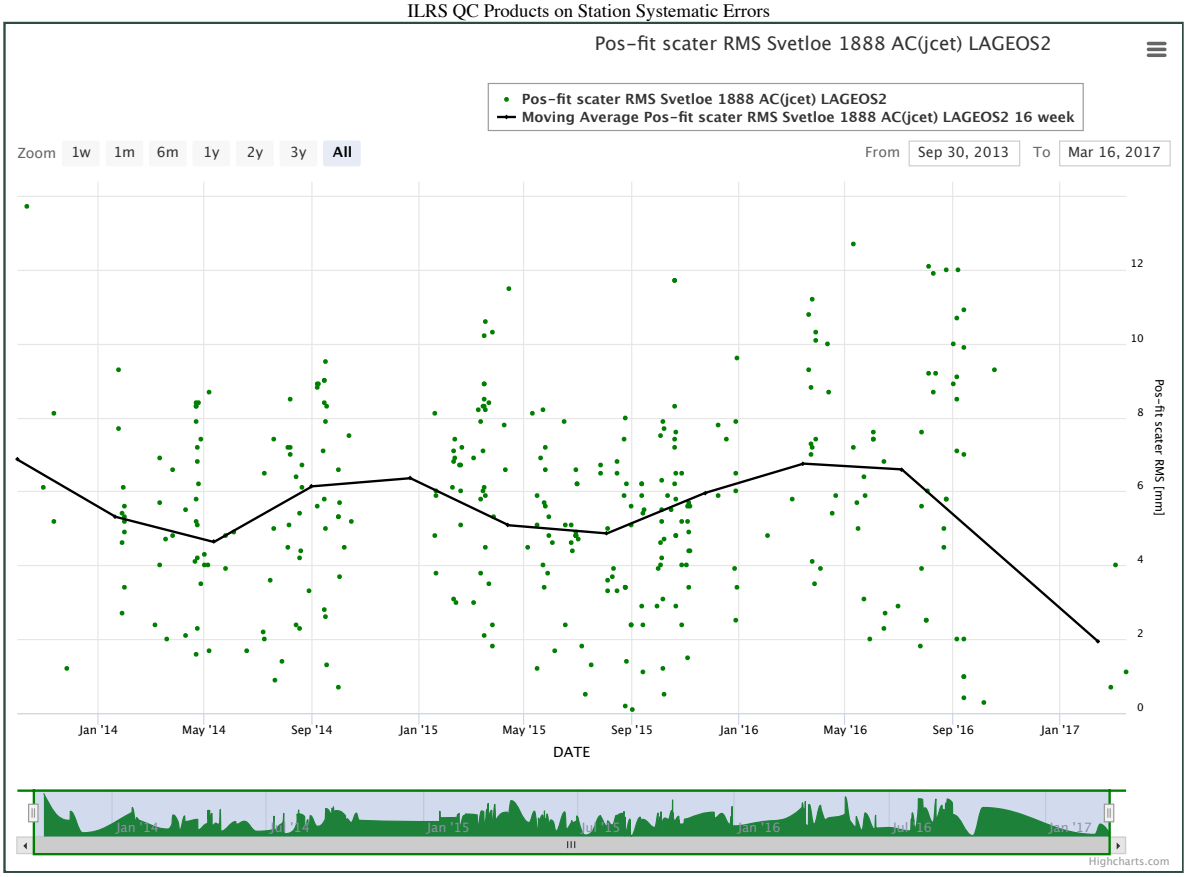


SVETLOE 1888

ILRS QC Products on Station Systematic Errors



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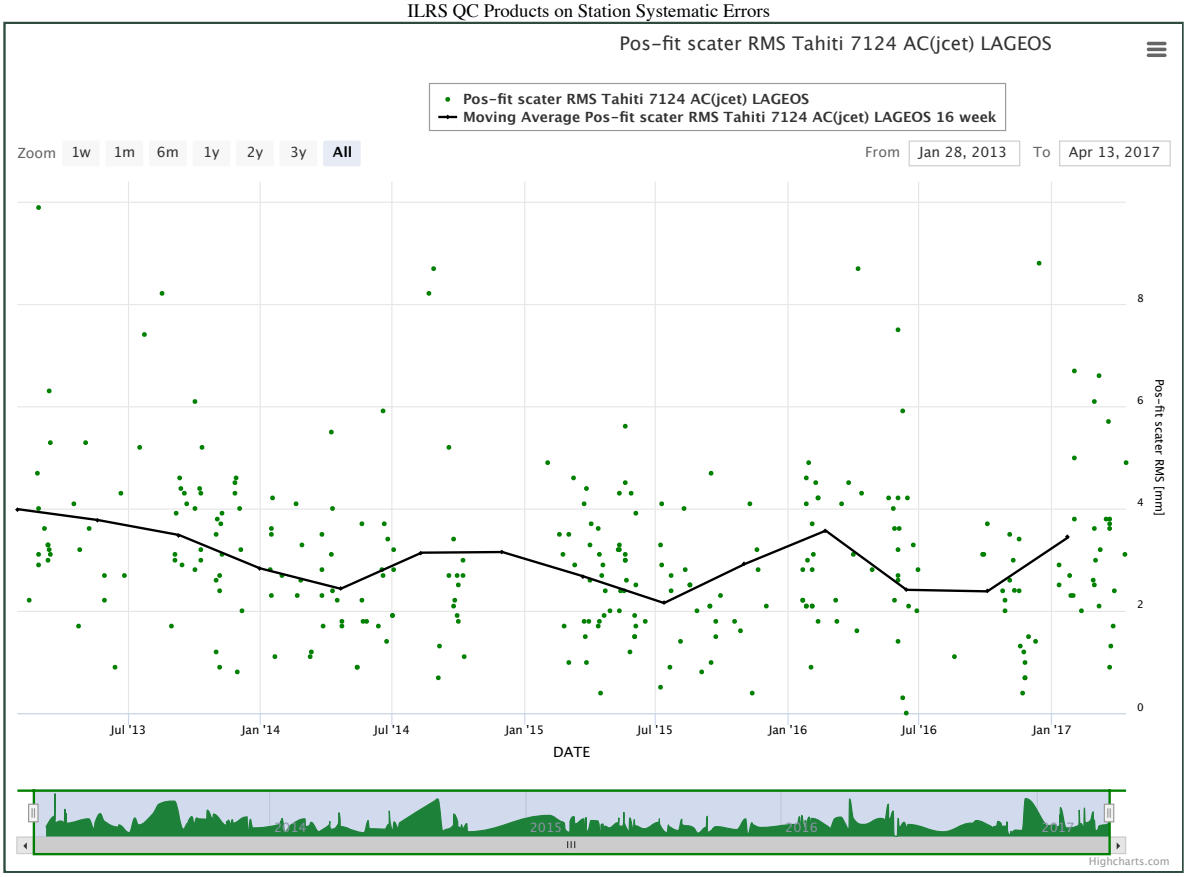

TAHITI 7124

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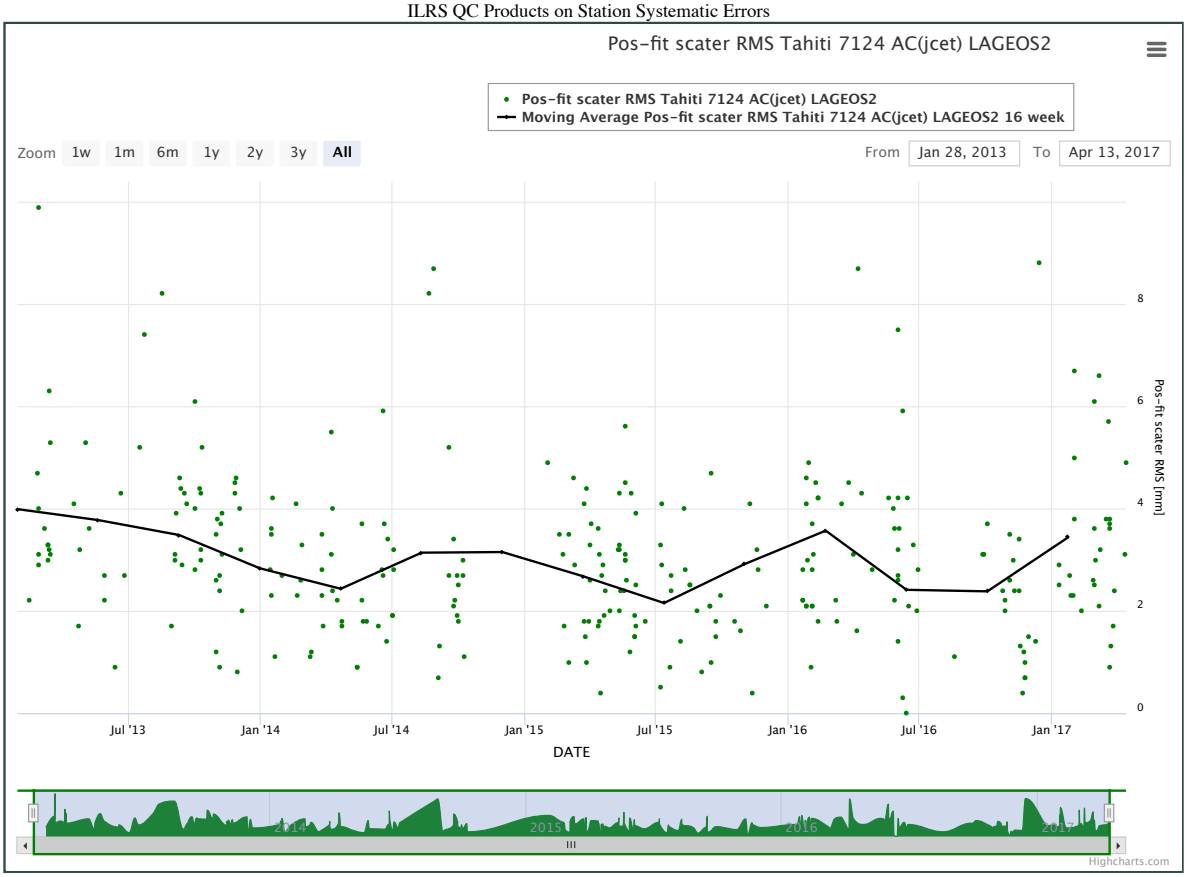

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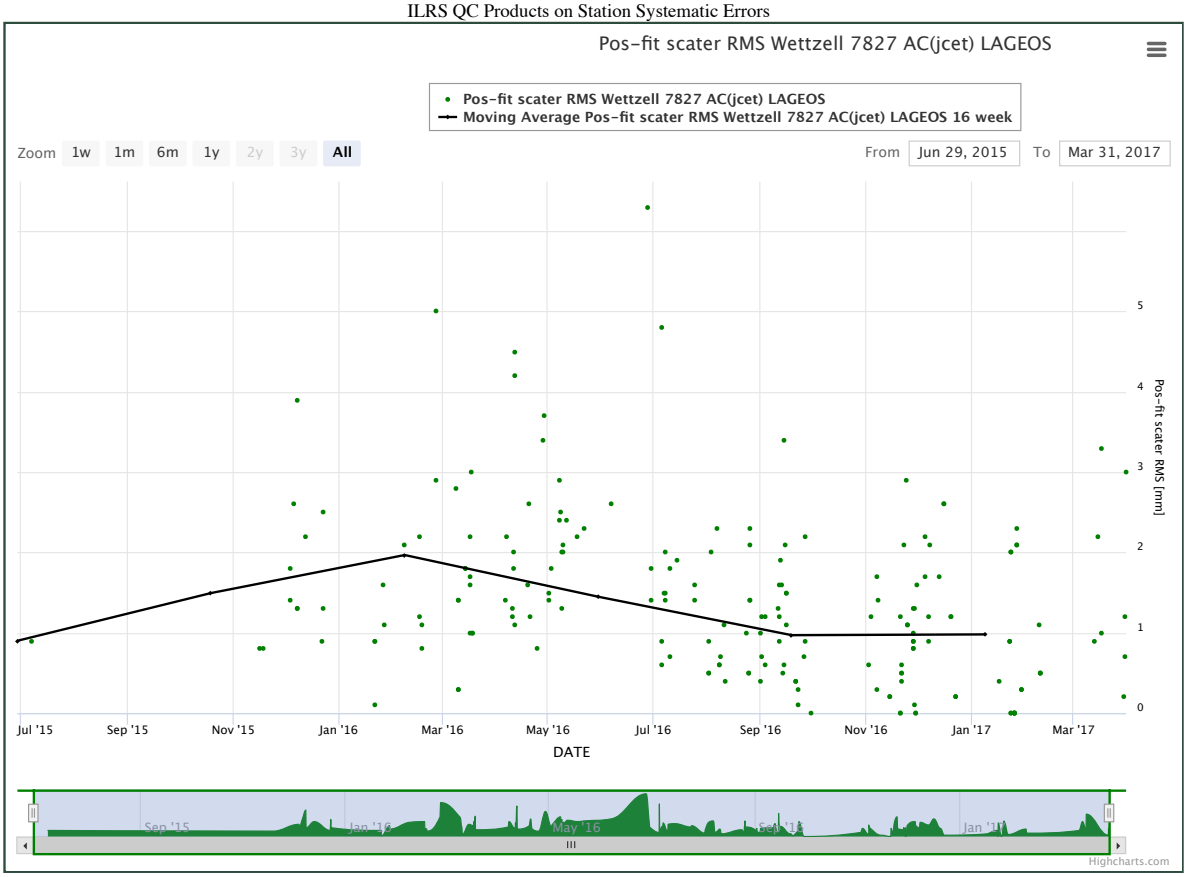

WETTZELL SOS 7827

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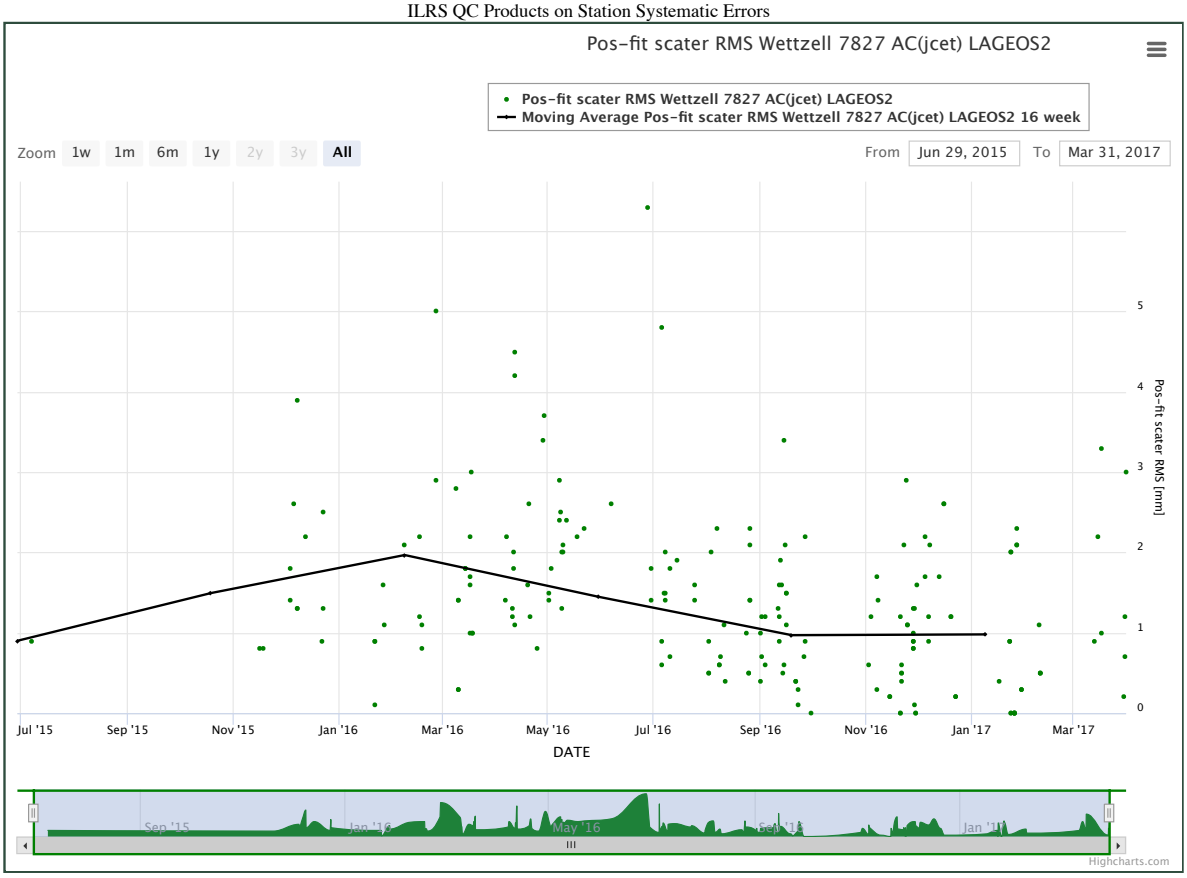

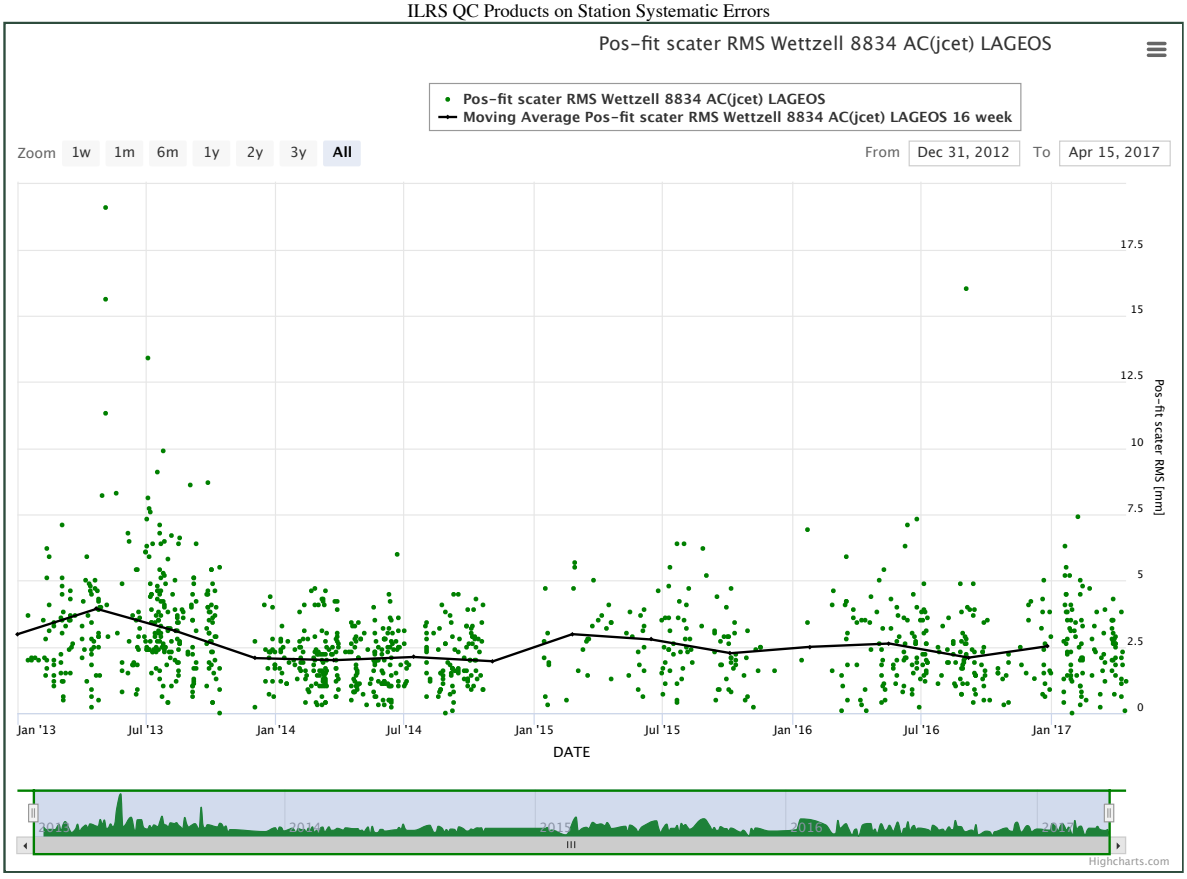

WETTZELL 8834

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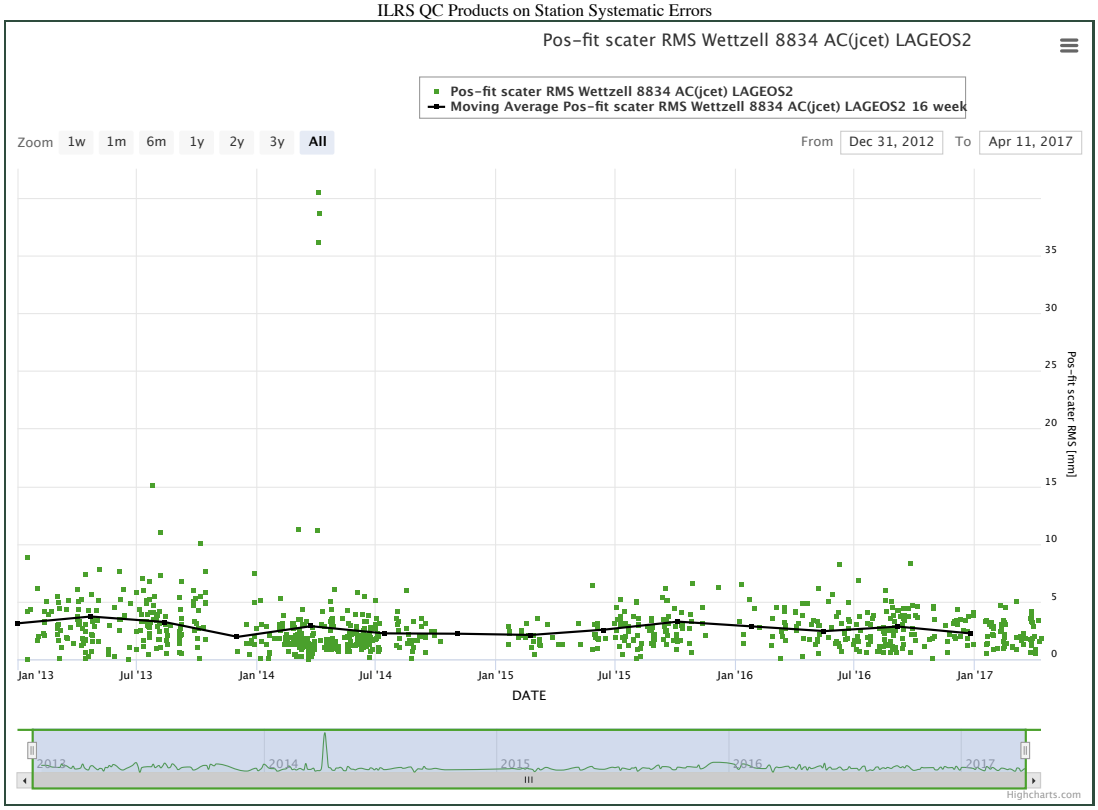

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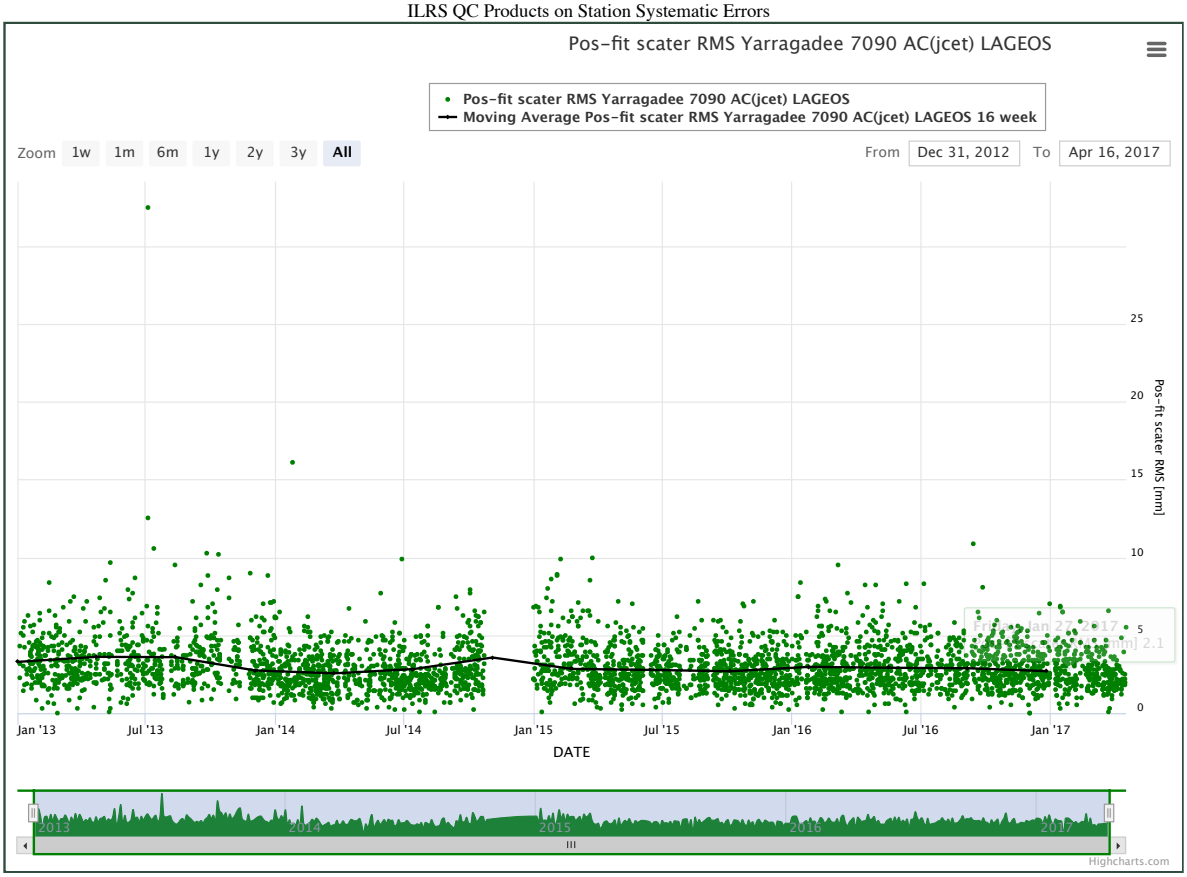

YARRAGADEE 7090

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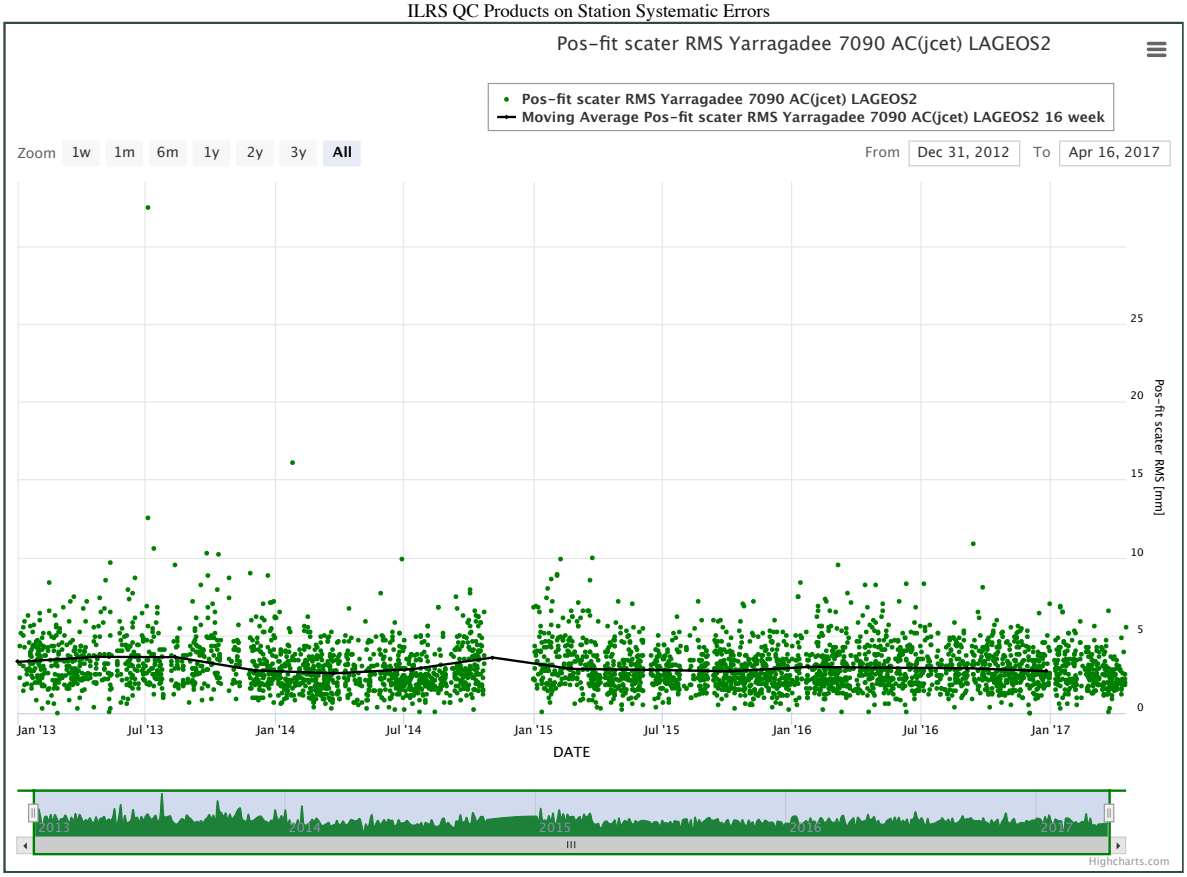

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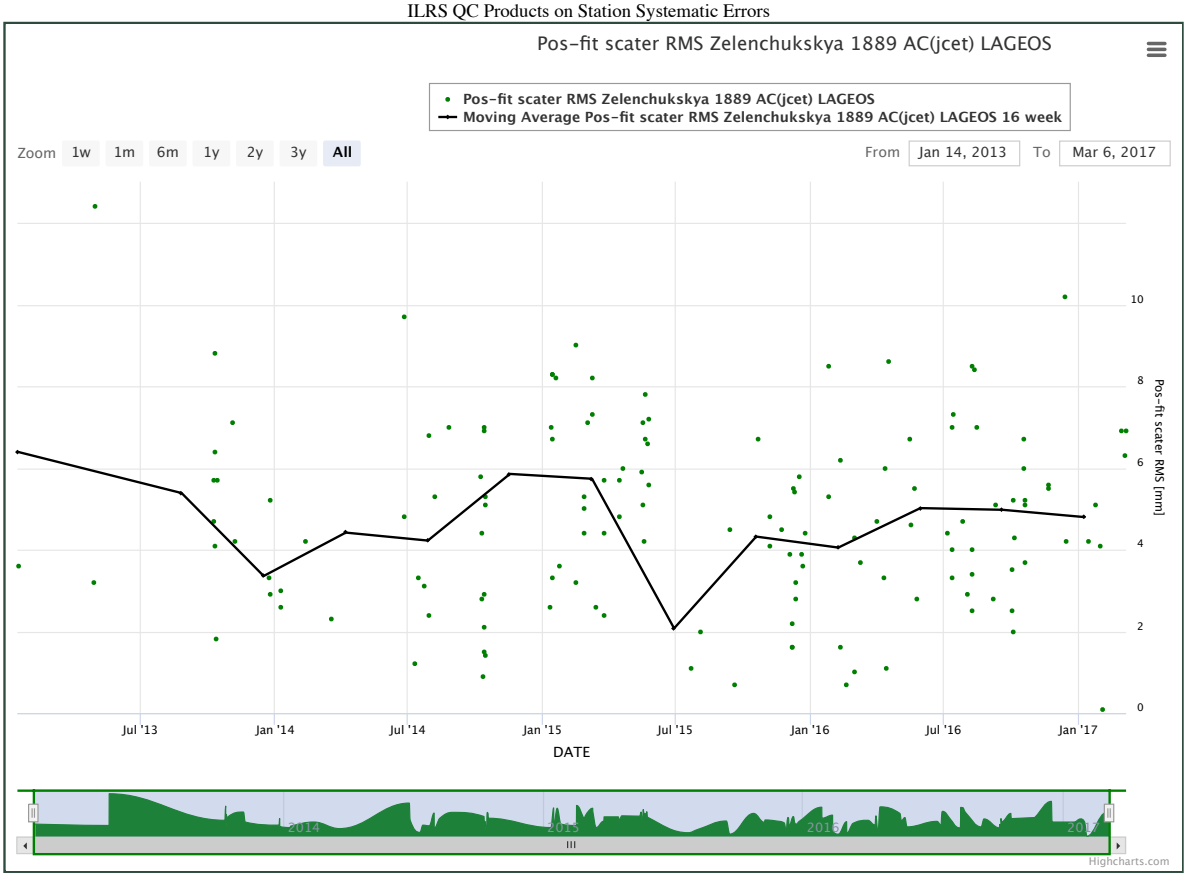
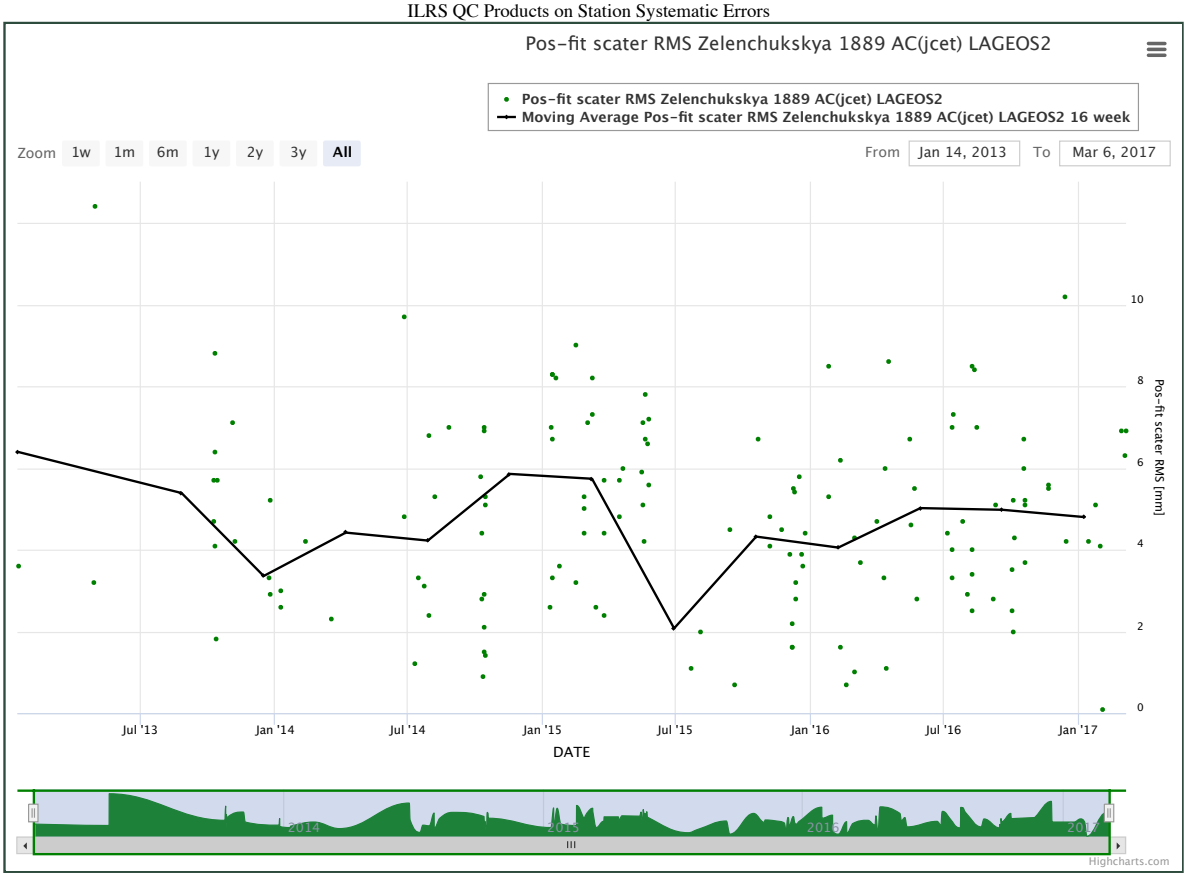


ZELENCHUKSKYA 1889

ILRS QC Products on Station Systematic Errors



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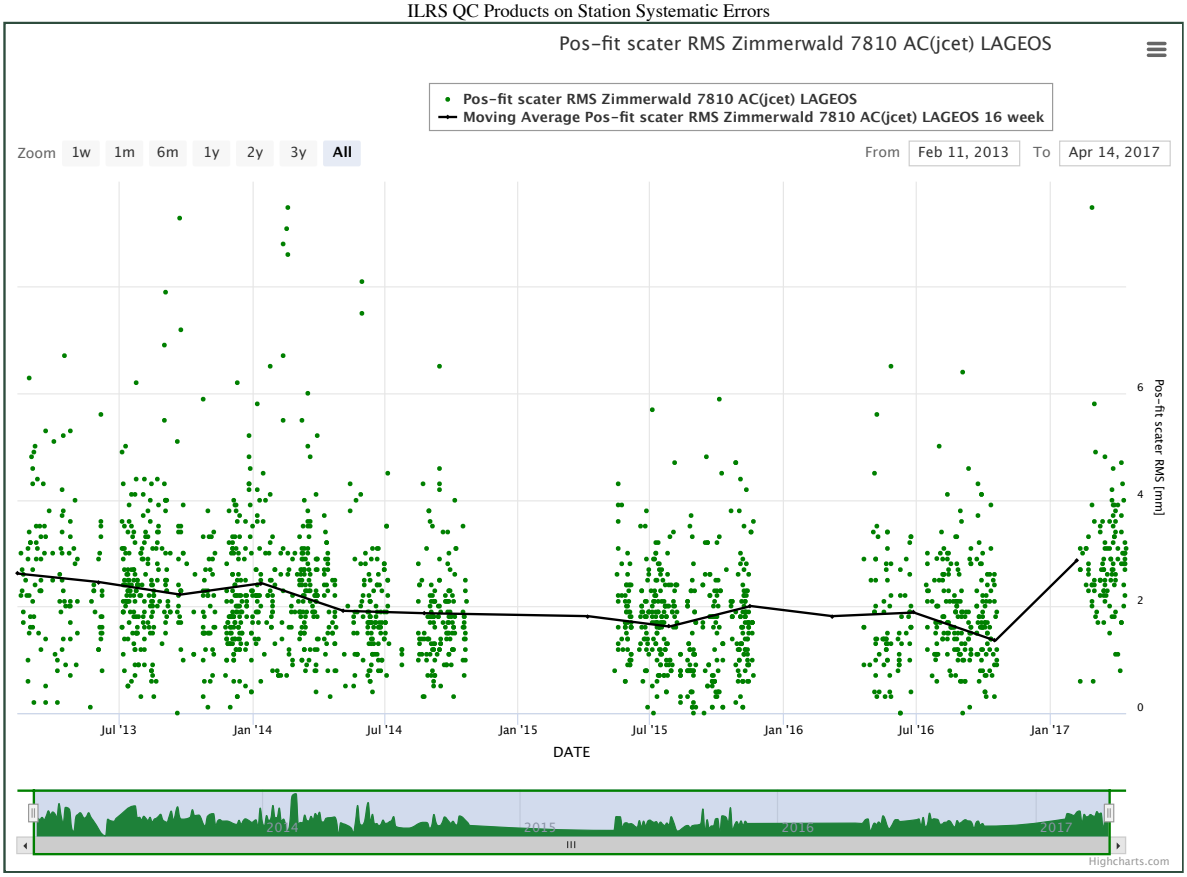

ZIMMERWALD 7810

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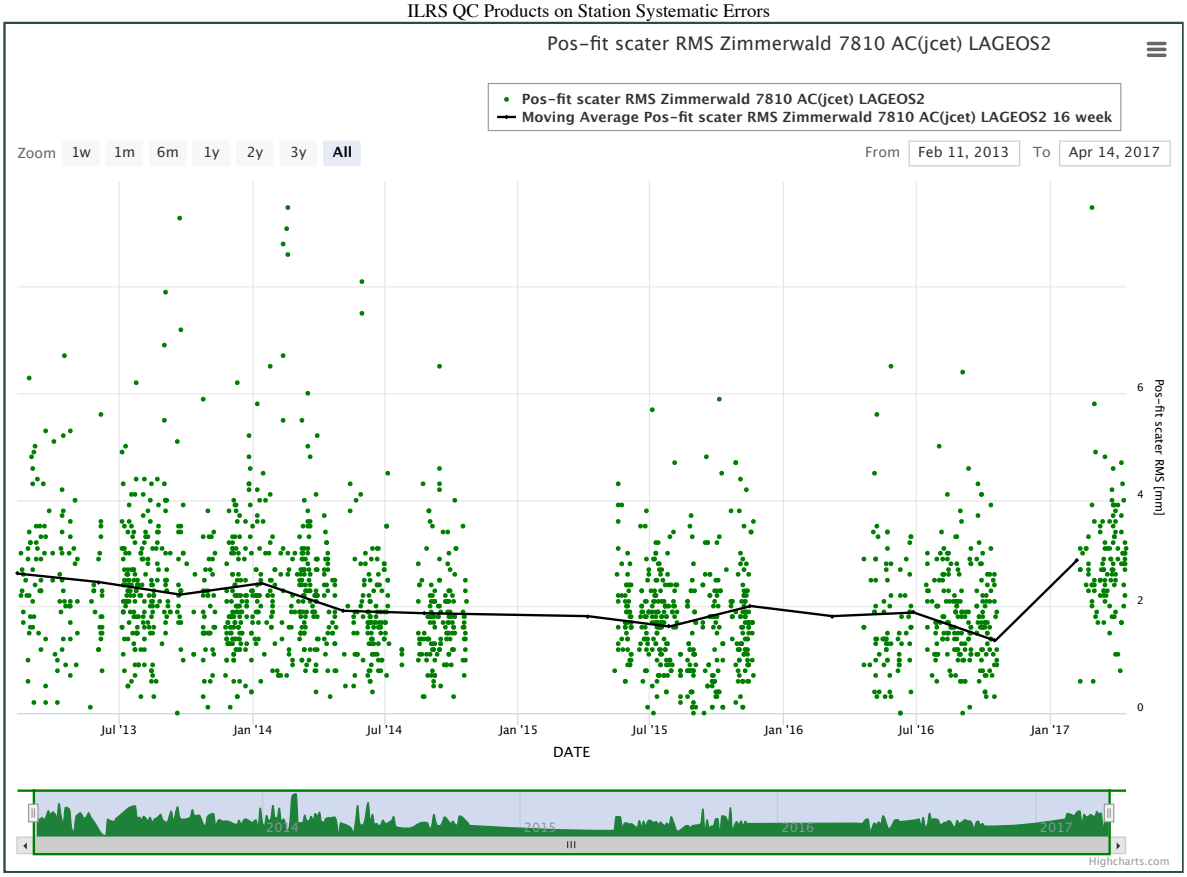


ILRS System Performance from QC Analysis

ILRS REPORT CARD

Start (MM-DD-YYYY): 2010 02 01

End (MM-DD-YYYY): 2016 10 31

Station: 7090 Yarragadee

Submit Reset form

http://geodesy.jcet.umbc.edu/ILRS_REPORT_CARD/

UMBC
AN HONORS UNIVERSITY IN MARYLAND

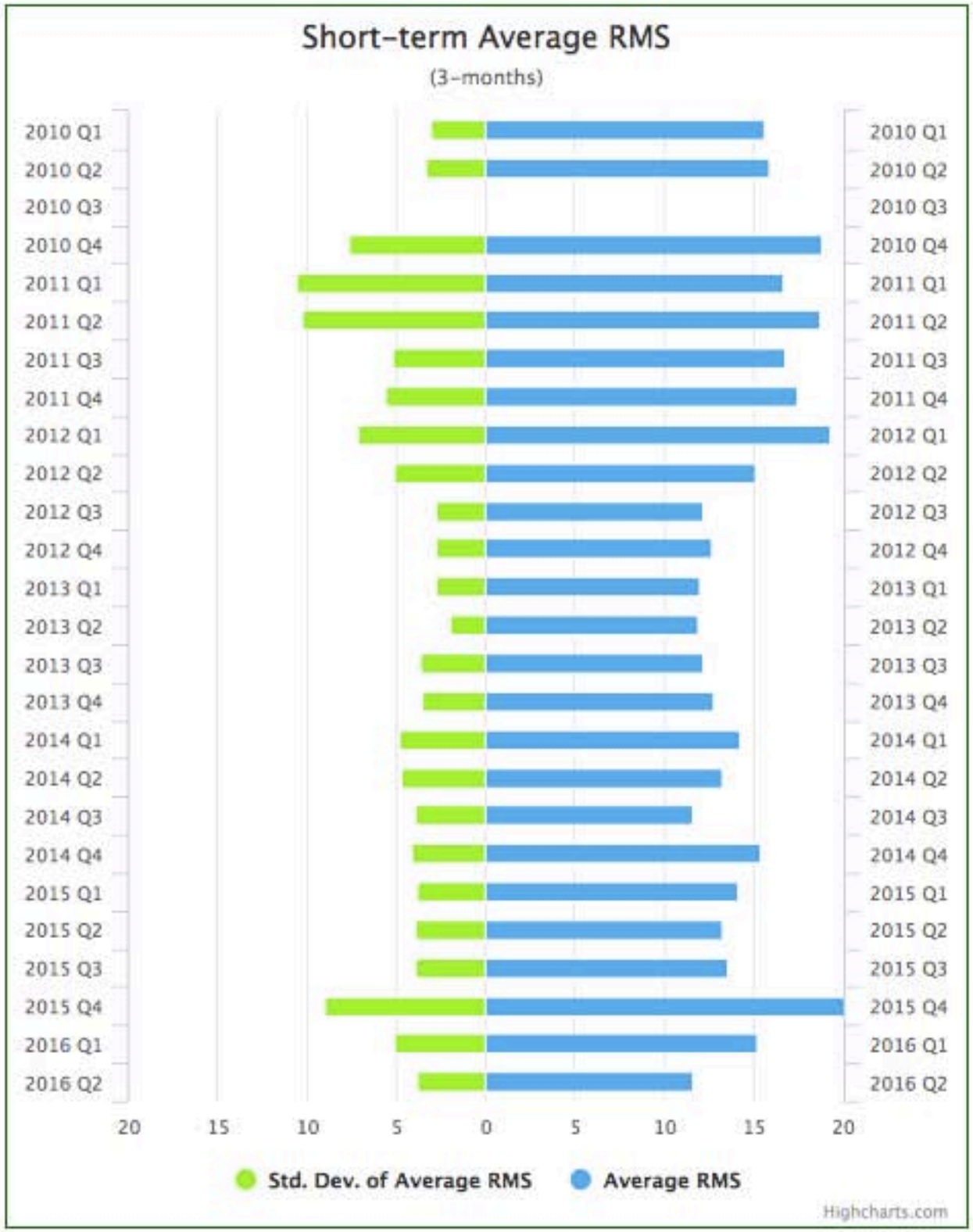
International Laser Ranging Service

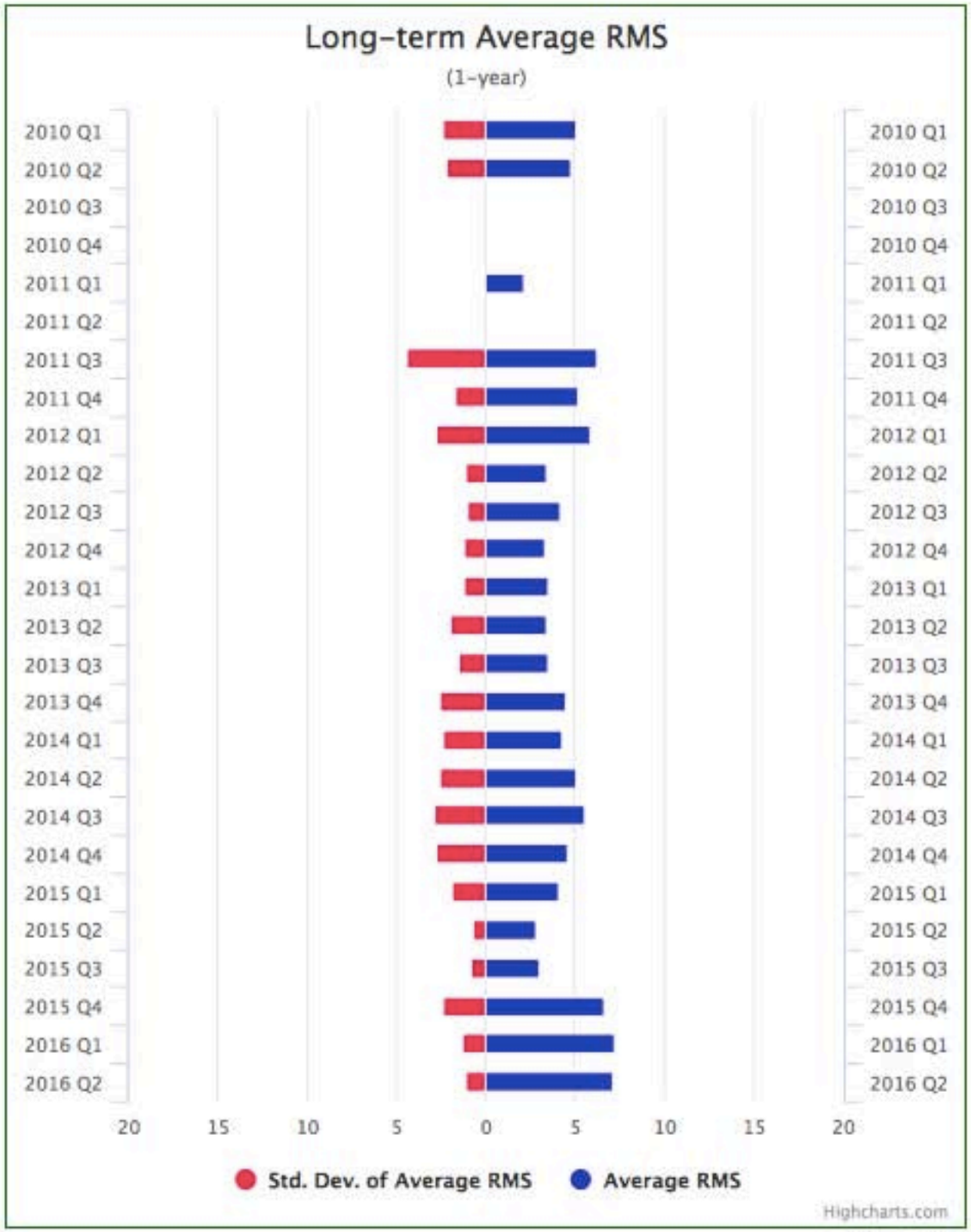
Responsible JCET Official: Dr. Erricos Pavlis

Last modified 2017-04-14

Maintained and Created by: Magda Kuzmicz-Cieslak

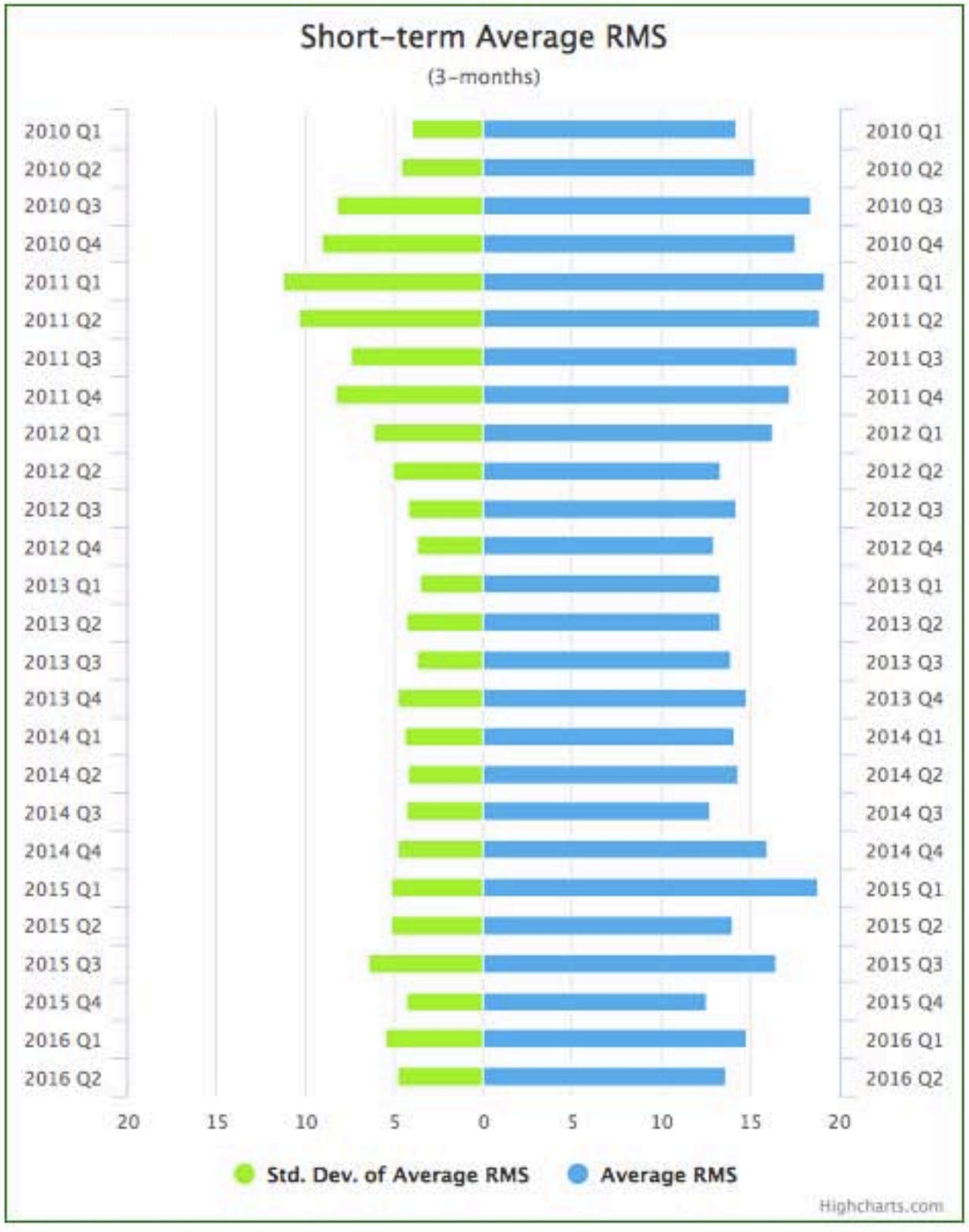
Greenbelt 7105

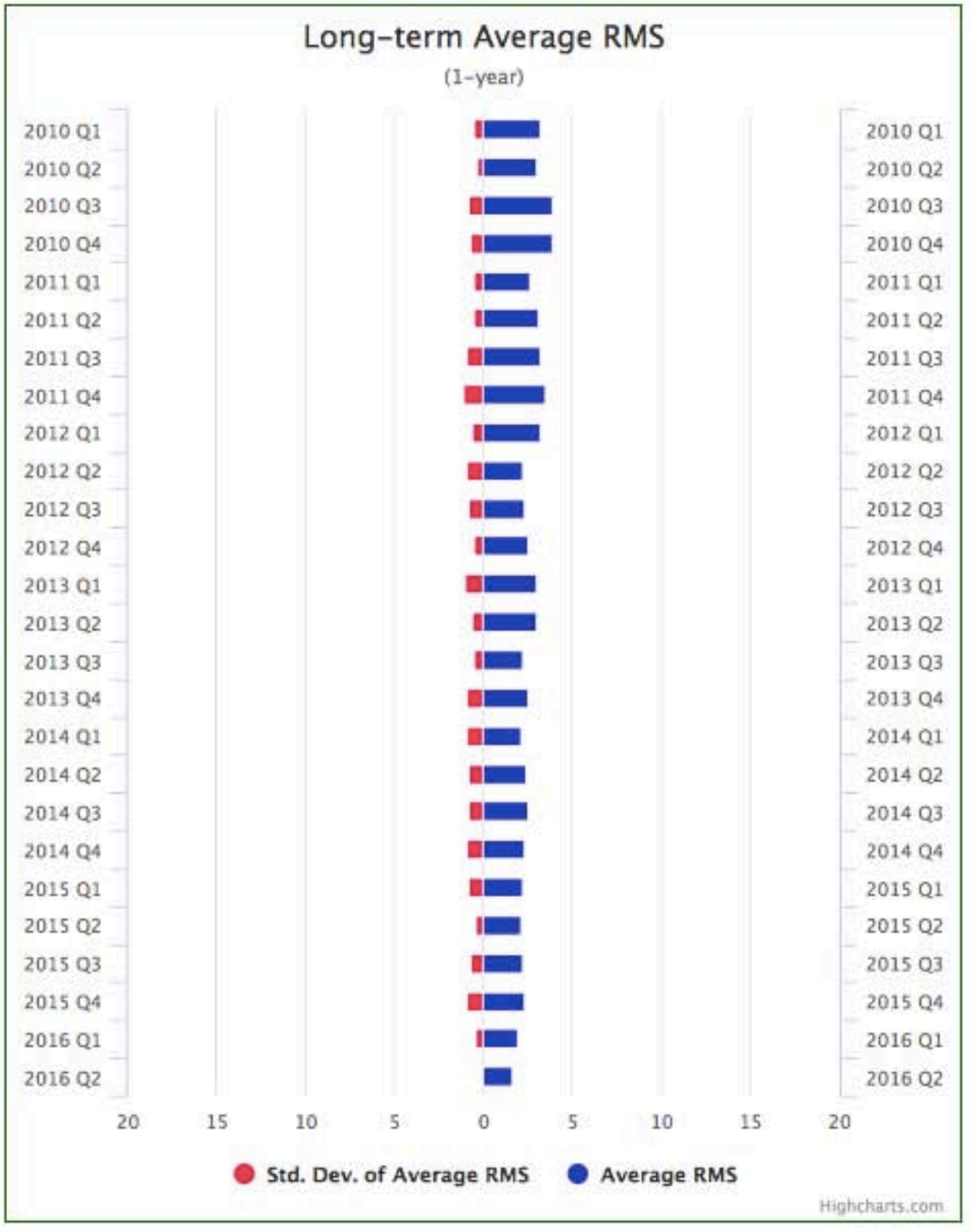




Export to PNG Export to PDF

Yarragadee 7090





Export to PNG Export to PDF

ILRS NSGF report
ILRS ASC meeting Vienna 2017

Graham Appleby, José Rodríguez

NSGF AC

- New CoM correction tables and Fortran subroutine released (LAGEOS, Etalon, LARES, Ajisai, Starlette, Stella): http://ilrs.dgfi.tum.de/fileadmin/data_handling/

  (no format changes, no model changes)
- Implementation of gravity field estimation done
- Implemented DTRF2014 for IERS TN (how to use it?)
- Switch to ITRF2014-like branch for operational product not done yet
- Chasing LoD estimation problems: WIP

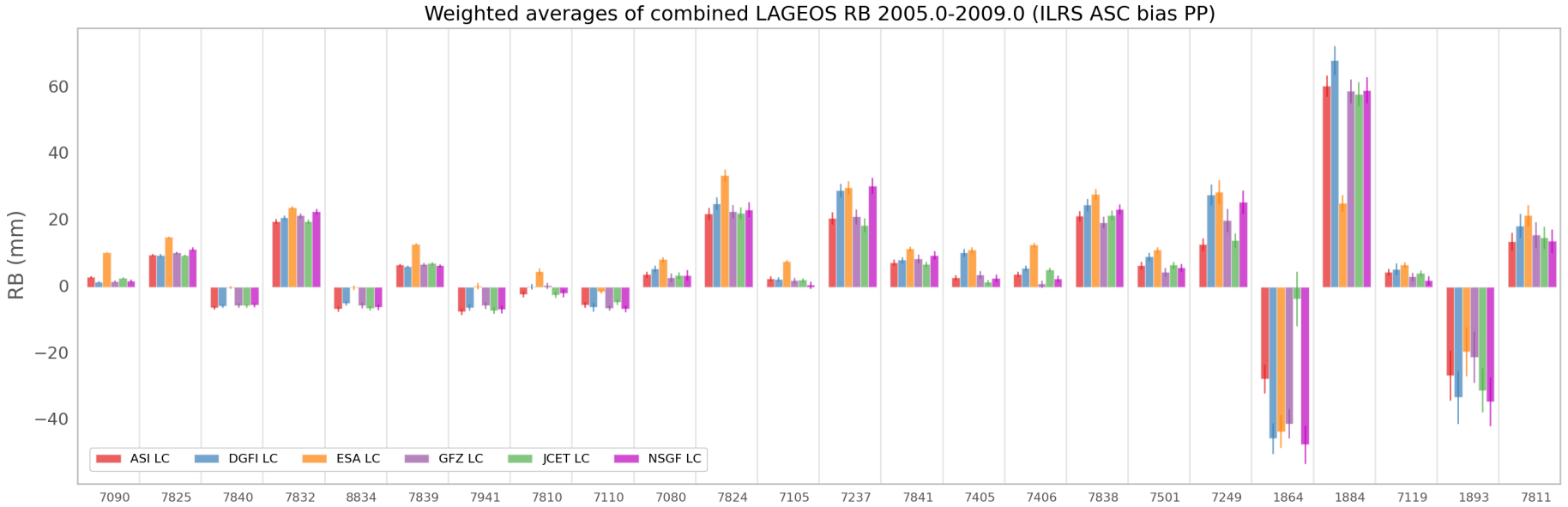
RB PP

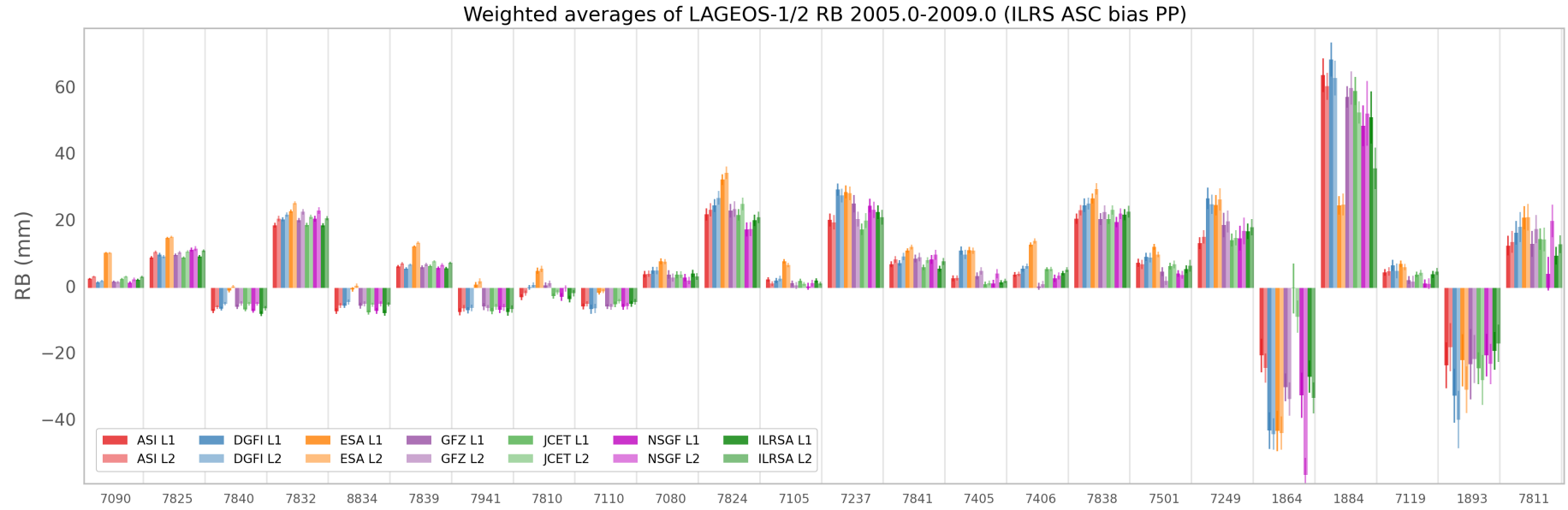
- Coding laser wavelength in SOLN field of SINEX files not done yet
- Run some comparisons with updated and newly delivered PP RB solutions
- Some formatting problems found in a few GFZ files

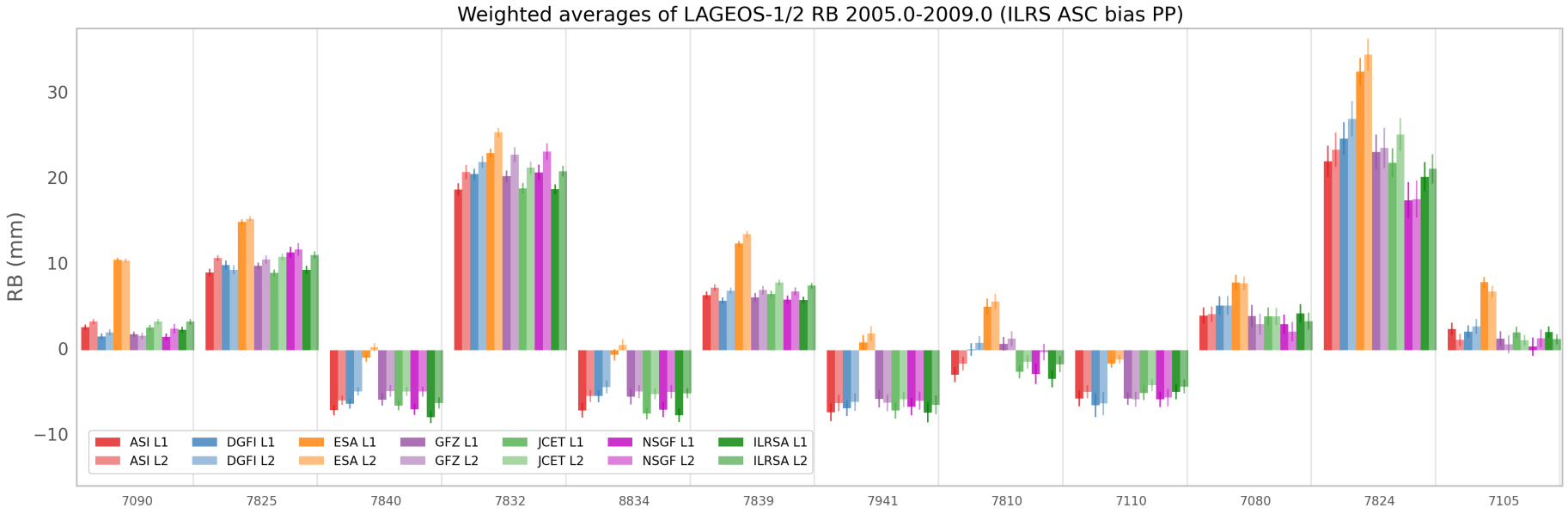
  eg. gfz.pos+eop.050709.v210.snx.Z:

```
70 STAX   7249  A    1 05:187:43200 m    2 -2.14876101078250e+06 2.05374e-01
71 STAY   7249  A    1 05:187:43200 m    2 +4.42675927854290e+06 1.33560e-01
72 STAZ   7249  A    1 05:187:43200 m    2 +4.04451012521780e+06 9.53604e-02
73 RBIAS  7249 LC    1  m    2  72496101 +2.16247359646090e-01 2.98527e-02
```

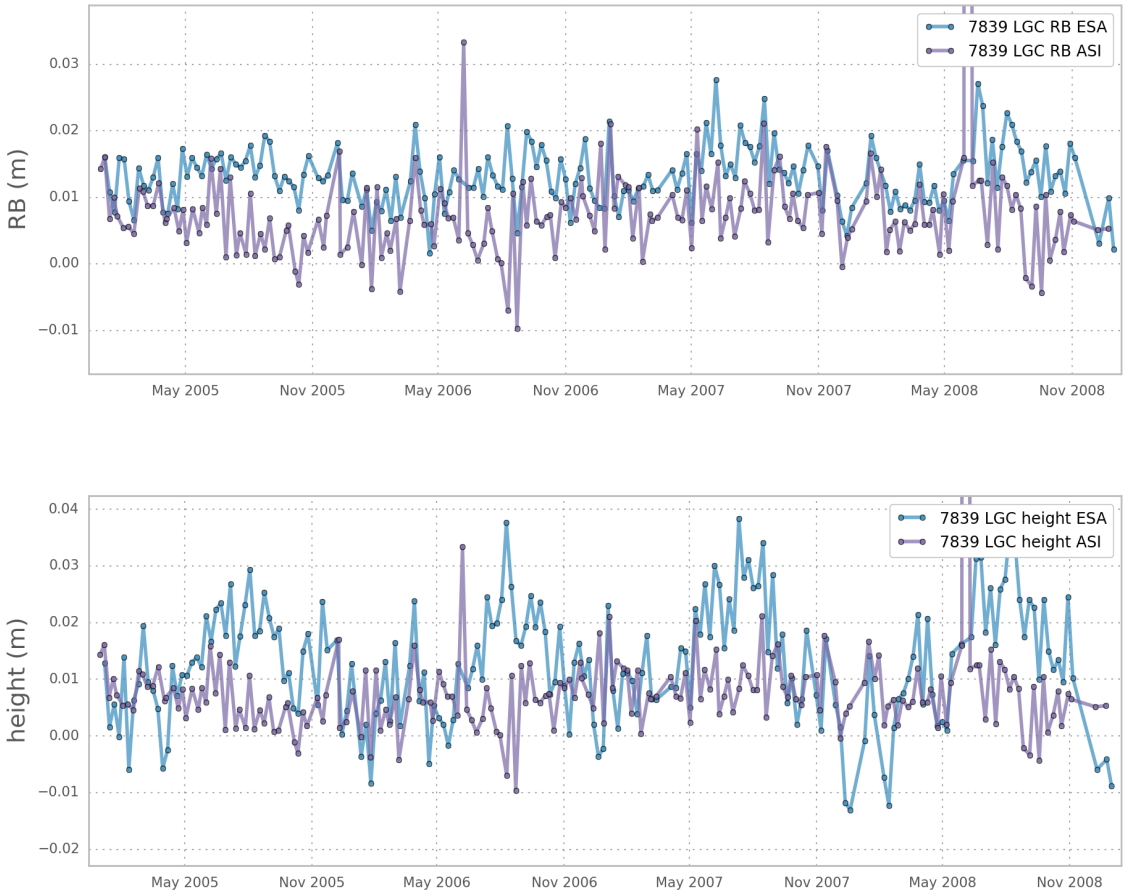
- Previous findings regarding overall inter-AC agreement in per station RB, scale change magnitude and direction maintained
- ...although some ACs are more equal than others


Weighted averages of combined LAGEOS RB 2005.0-2009.0 (ILRS ASC bias PP)
RB (mm)
60
40
20
0
−20
−40
ASI LC
DGFI LC
ESA LC
GFZ LC
JCET LC
NSGF LC
7090
7825
7840
7832
8834
7839
7941
7810
7110
7080
7824
7105
7237
7841
7405
7406
7838
7501
7249
1864
1884
7119
1893
7811

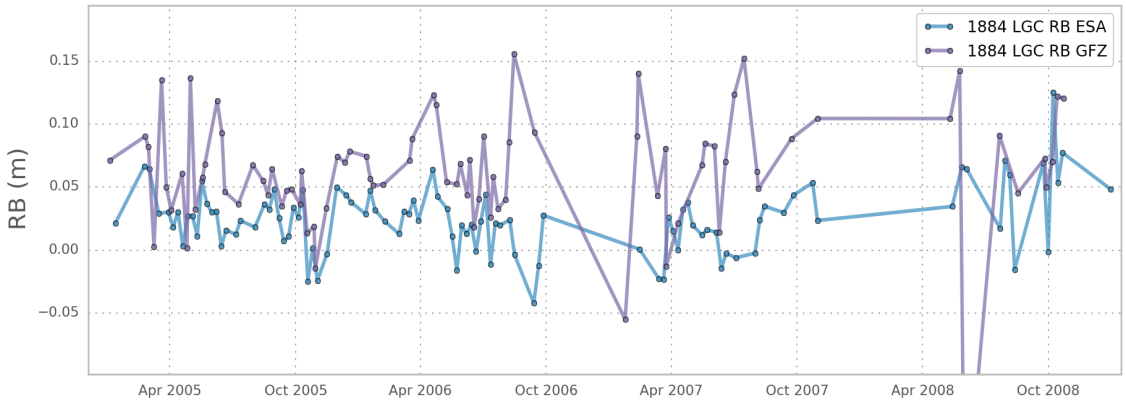

Weighted averages of LAGEOS-1/2 RB 2005.0-2009.0 (ILRS ASC bias PP)
RB (mm)
60
40
20
0
−20
−40
ASI L1
ASI L2
DGFI L1
DGFI L2
ESA L1
ESA L2
GFZ L1
GFZ L2
JCET L1
JCET L2
NSGF L1
NSGF L2
ILRSA L1
ILRSA L2
7090
7825
7840
7832
8834
7839
7941
7810
7110
7080
7824
7105
7237
7841
7405
7406
7838
7501
7249
1864
1884
7119
1893
7811

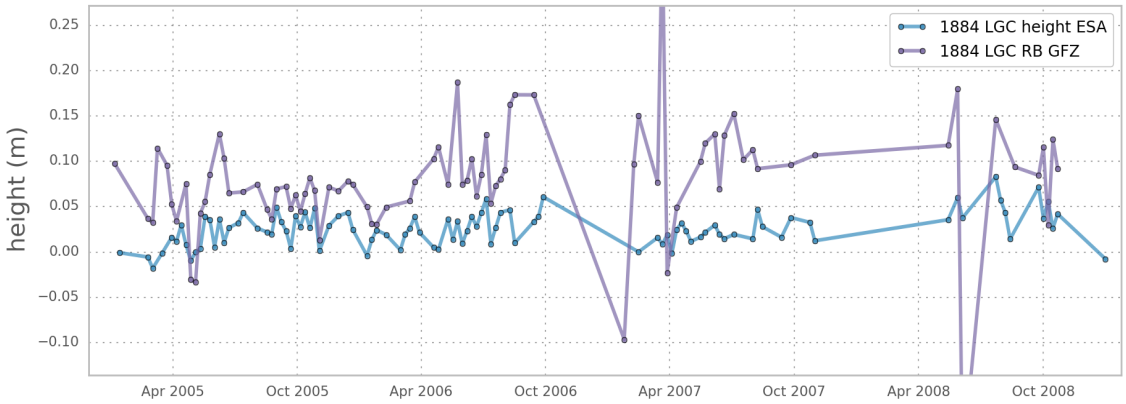


- CC solution contains, for some stations, a few arcs with unusually small SE
- Of all solutions available so far, ESA appears to stand out from the rest in quite a few cases

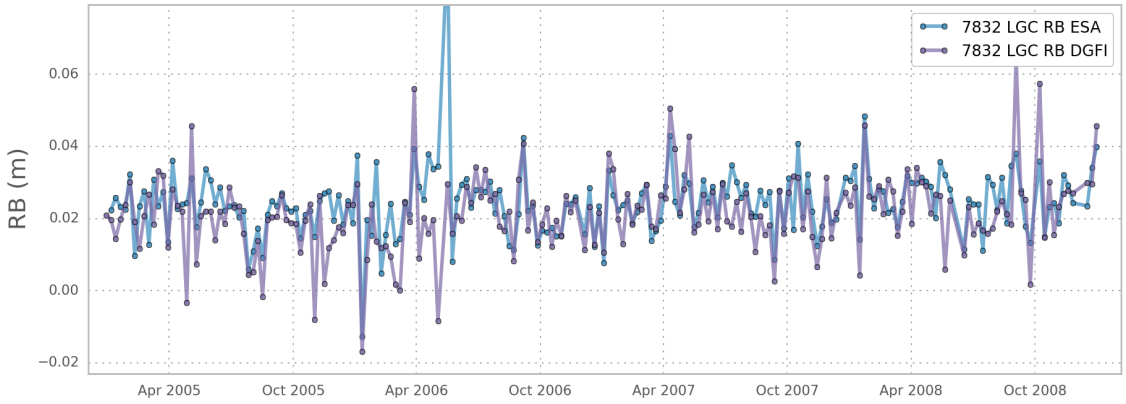


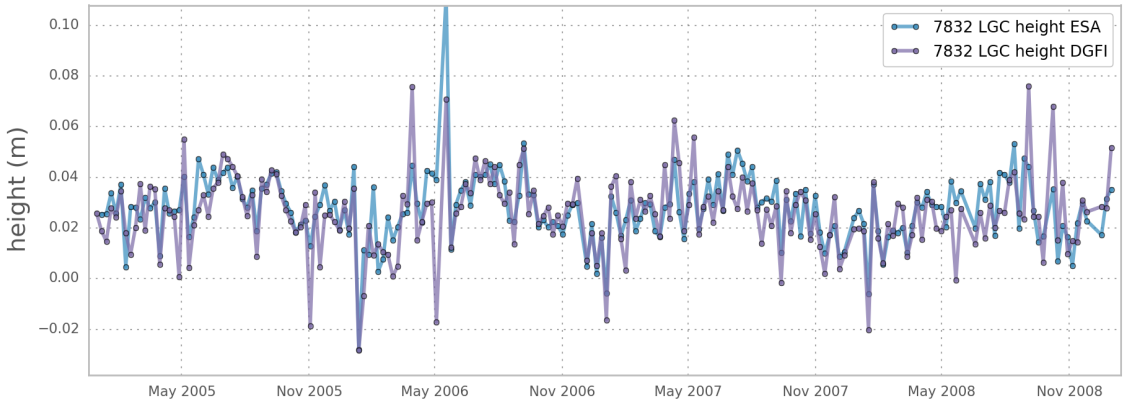
- ESA's RB estimates are in some cases evidently offset
- This impacts station heights in the expected way



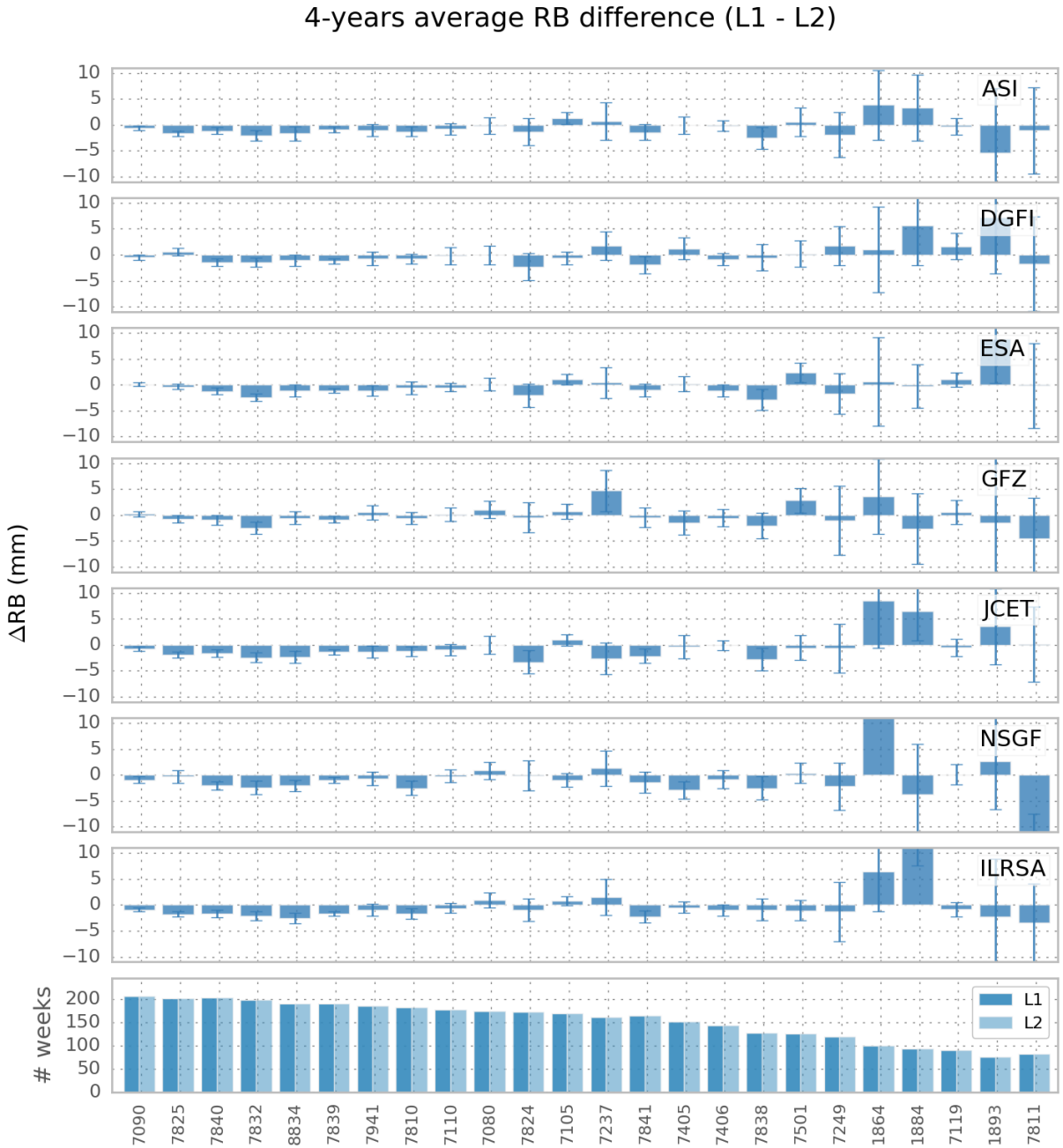


- ESA's RB estimates are in some cases evidently offset
- This impacts station heights in the expected way

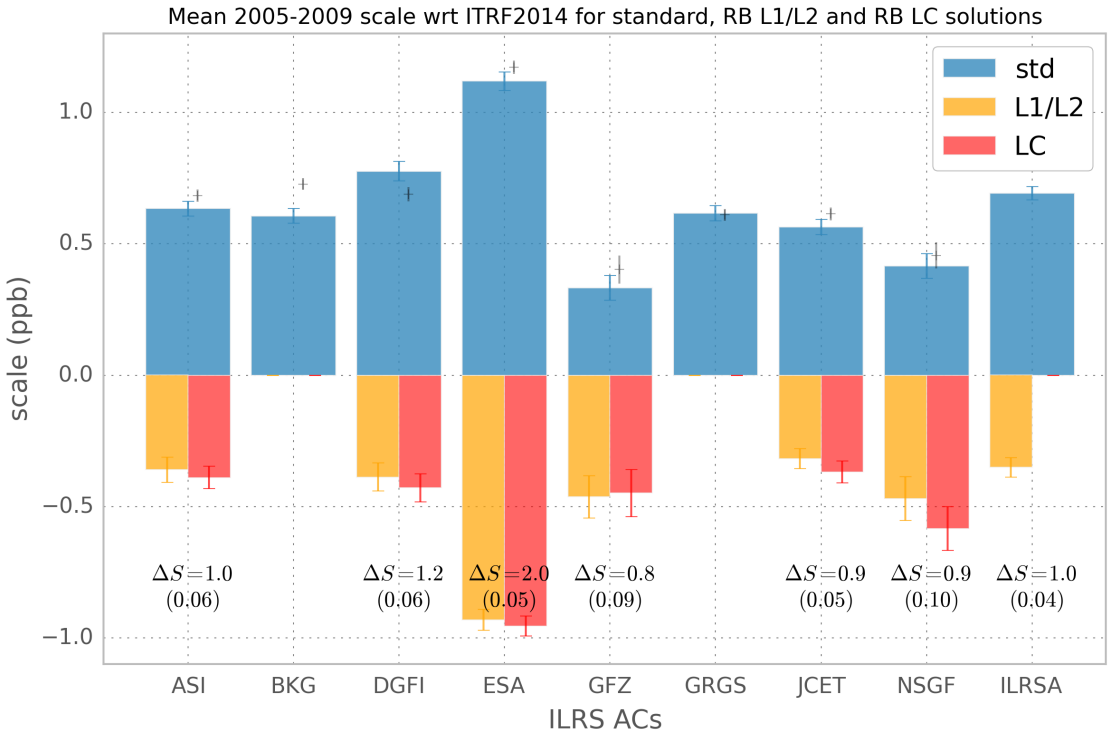




- ESA's RB estimates are in some cases evidently offset from the rest
- This impacts station heights in the expected way
- No obvious underlying pattern



Differences between L1 and L2 RB are not significant (mostly)

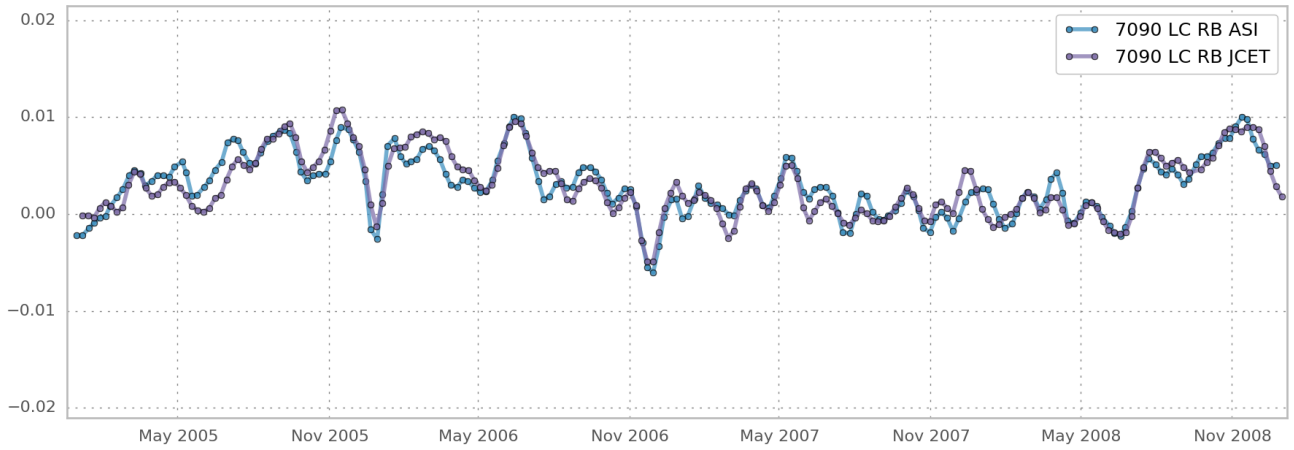


1 ppb difference between standard and RB solutions

(on average for 2005 – 2009)

Good agreement on average, but how do we compare when we zoom in?

Good agreement on average, but how do we compare when we zoom in?



Good agreement on average, but how do we compare when we zoom in?

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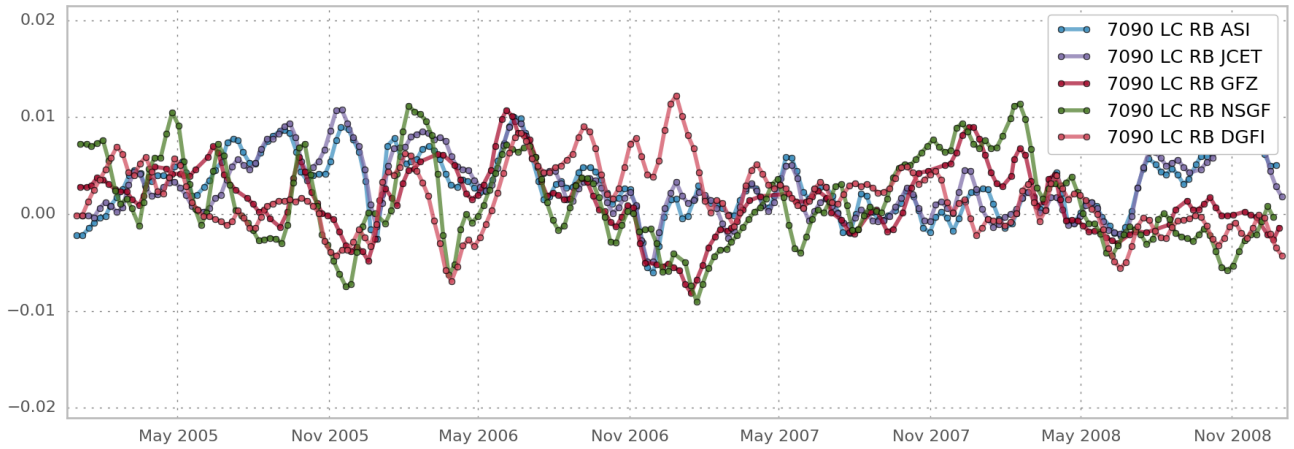
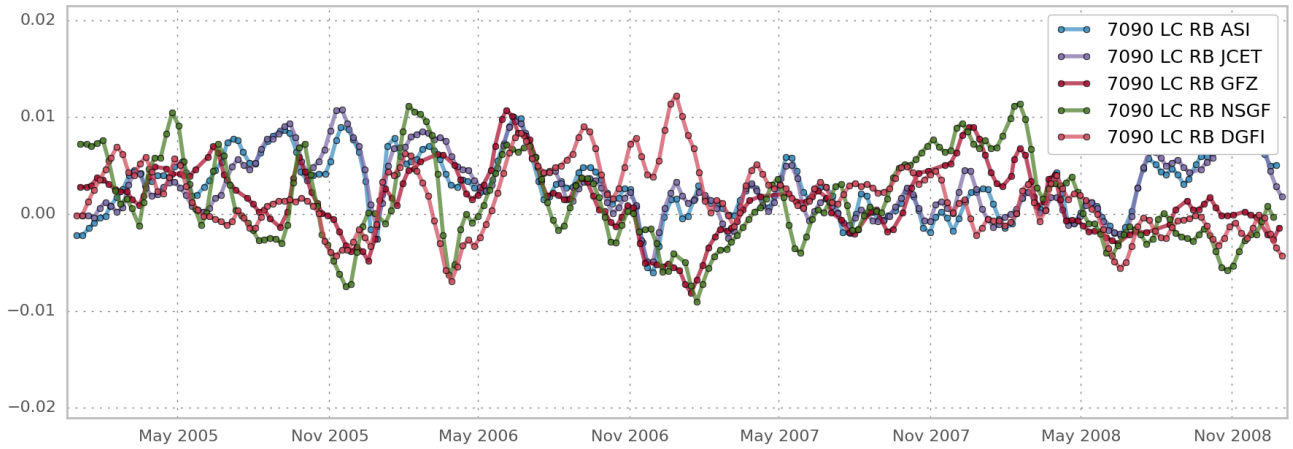


Good agreement on average, but how do we compare when we zoom in?



- Noticeable differences between AC solutions at time scales of several months
- Hints of different groups of solutions (ASI/JCET, GFZ/NSGF, DGFI)
- Re-introducing RB estimates from external solutions will degrade results (and it appears to us to be a rather questionable approach)
- CC best option for 3rd party users (e.g. altimetry community)

DTRF2014 usage issues

DTRF2014 usage issues

https://www.dgfi.tum.de/fileadmin/w00btu/www/DTRF2014_readme.pdf

Application of epoch-wise corrections

$$\boldsymbol{X}(t_i) = \boldsymbol{X}_{\mathrm{DTRF}}(t_0) + \dot{\boldsymbol{X}}_{\mathrm{DTRF}}(t_0) \cdot (t_i - t_0) + \boldsymbol{X}_{\mathrm{origin}}(t_i) + \boldsymbol{X}_{\text{NT-L}}(t_i) + \boldsymbol{X}_{\mathrm{resid}}(t_i)$$

with $\boldsymbol{X}_{\text{NT-L}}(t_i) = \boldsymbol{X}_{\text{NT-CWSL}}(t_i) + \boldsymbol{X}_{\text{NT-ATML}}(t_i)$.

DTRF2014 usage issues

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with $\boldsymbol{X}_{\mathrm{NT\text{-}L}}(t_i) = \boldsymbol{X}_{\mathrm{NT\text{-}CWSL}}(t_i) + \boldsymbol{X}_{\mathrm{NT\text{-}ATML}}(t_i)$.

Loading time series

Weekly averaged atmospheric ($\boldsymbol{X}_{\mathrm{NT\text{-}ATML}}$) and hydrological $\boldsymbol{X}_{\mathrm{resid}}$ non-tidal loading corrections applied in DTRF2014 computation for the correction of the respective signals. The data are provided by Tonie van

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Application of epoch-wise corrections

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DTRF2014_SLRorigin.txt	Translation time series of origin.

DTRF2014 usage issues

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Application of epoch-wise corrections

$$\boldsymbol{X}(t_i) = \boldsymbol{X}_{\mathrm{DTRF}}(t_0) + \dot{\boldsymbol{X}}_{\mathrm{DTRF}}(t_0) \cdot (t_i - t_0) + \boldsymbol{X}_{\mathrm{origin}}(t_i) + \boldsymbol{X}_{\mathrm{NT\text{-}L}}(t_i) + \boldsymbol{X}_{\mathrm{resid}}(t_i)$$

with $\boldsymbol{X}_{\mathrm{NT\text{-}L}}(t_i) = \boldsymbol{X}_{\mathrm{NT\text{-}CWSL}}(t_i) + \boldsymbol{X}_{\mathrm{NT\text{-}ATML}}(t_i)$.

Loading time series Weekly averaged atmospheric ($\boldsymbol{X}_{\mathrm{NT\text{-}ATML}}$) and hydrological $\boldsymbol{X}_{\mathrm{resid}}$ non-tidal loading corrections applied in DTRF2014 computation for the correction of the respective signals. The data are provided by Tonie van

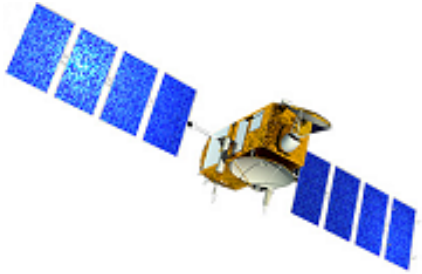
DTRF2014_SLRorigin.txt Translation time series of origin.

Station position residuals Transformation residual time series $\boldsymbol{X}_{\mathrm{resid}}$ obtained from similarity transformations of the technique-specific epoch-wise solutions w.r.t. the DTRF2014 combined solution. The temporal resolution of the resid-

Thank you

Time transfer (T2L2) between SLR stations: Applications to space geodesy

A. Belli, P. Exertier
(OCA/Geoazur, Astrogeo group)

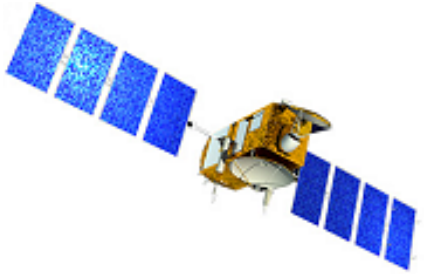


ILRS, April, 22 2017

INTRODUCTION

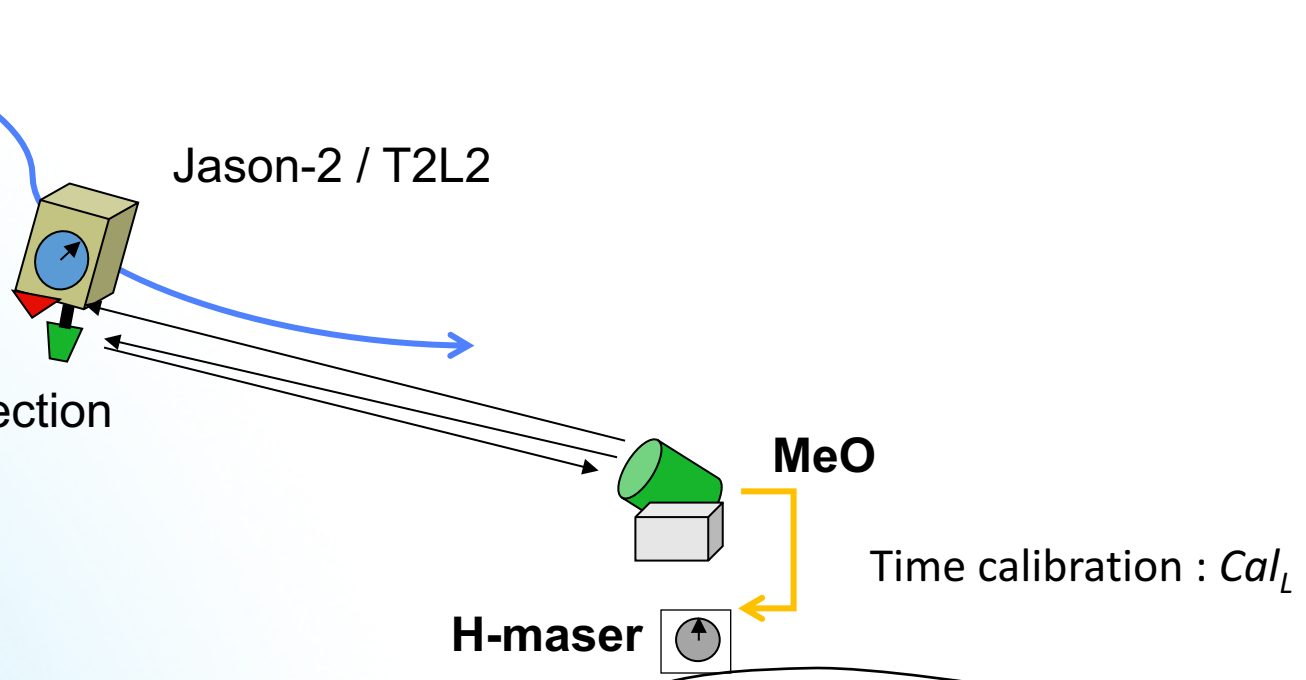
- T2L2/Jason-2: launched in June 2008 (for 2 yrs):
  - Instrument: built in OCA; continued for 6 yrs
  - Organisation: ILRS network // CNES <-J2 mission-> OCA, daily operations
  - Objectives:
    - Metrological (performance, comparison with other techniques)
    - Scientific (space geodesy and fundamental physics)
    - Modeling of the DORIS oscillator (Jason-2 →... Jason-3)

- Time transfer between SLRs
  - Consequences on space geodesy (LAGEOS and Jason)
  - Interest for the international service (ILRS -> ITRF)



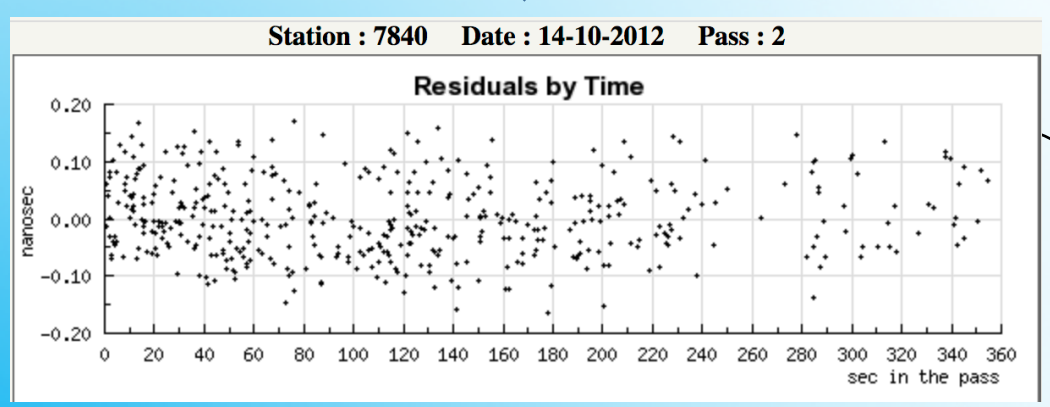
Ground-to-Space Time Transfer

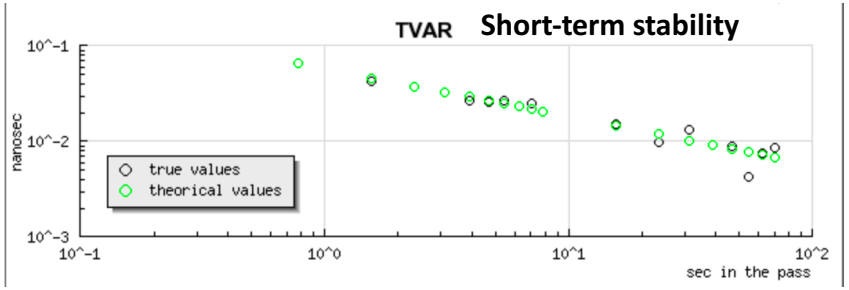
t^G_e , dt^{2w} , t^B : « triplets »



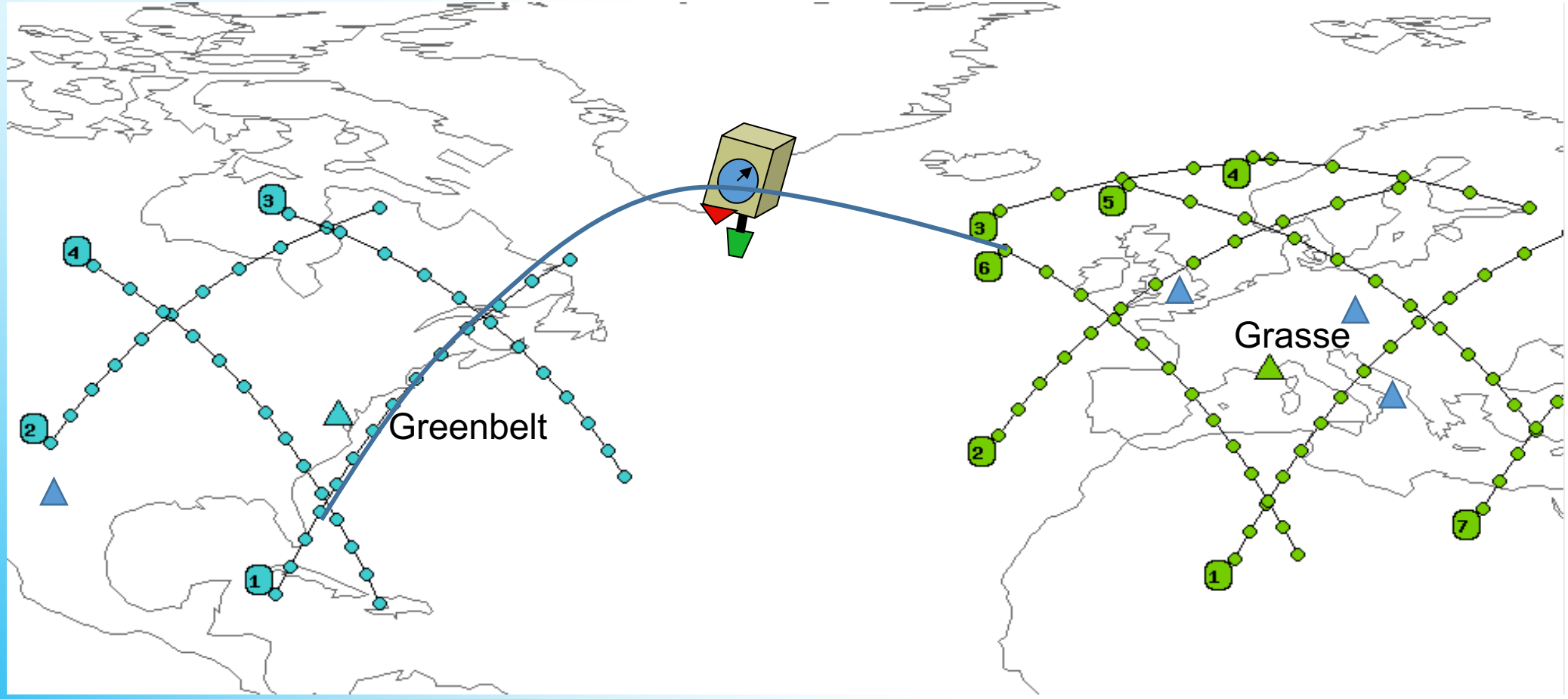
dt^{1wa} is computed from dt^{2w} & Sagnac correction

$gsTT = t^B - (t^G_e + dt^{1wa}) + correct.$

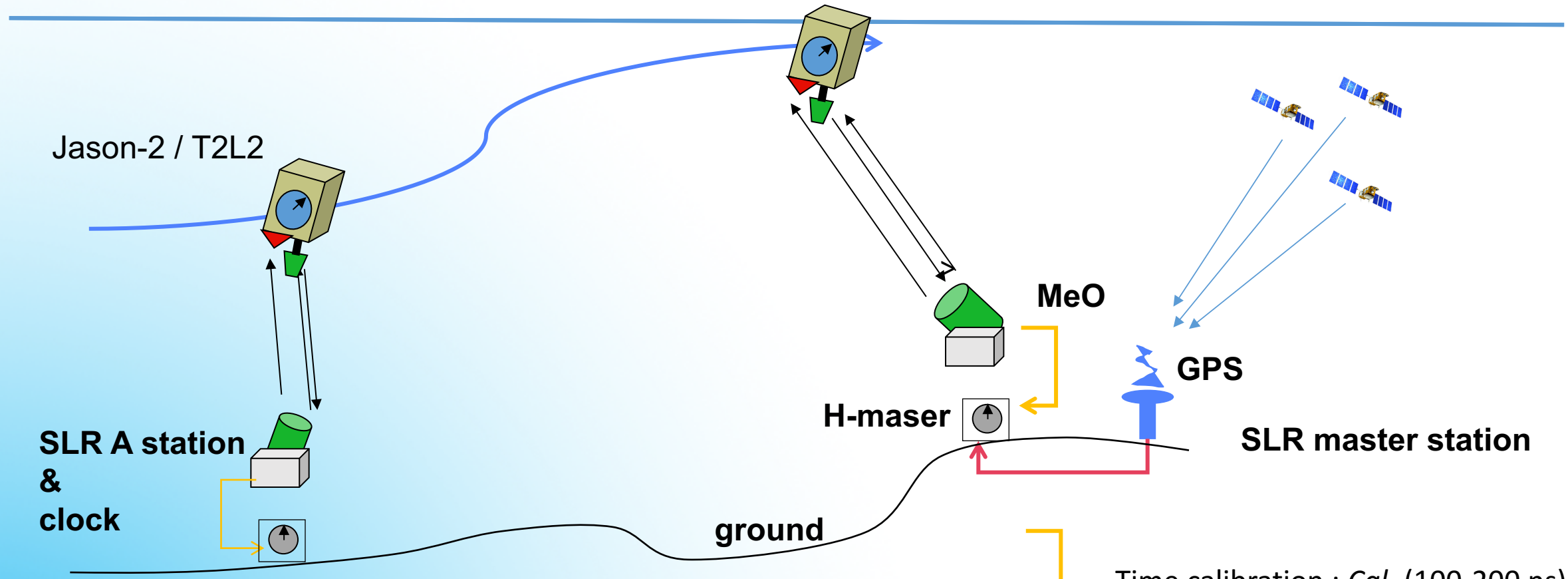




Time Transfer in non COMMON VIEW



Non Common View: method



$gsTT(A) = \tau\,(A)^B - (\,t(A)^G_e + dt\_A^{1wa}\,) + correct$

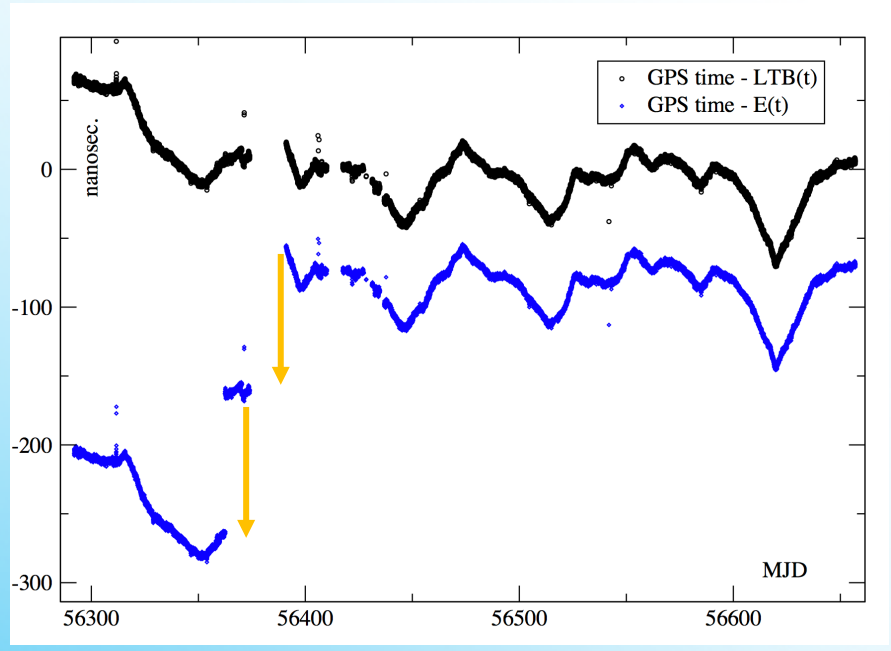
$gsTT(M) = \tau\,(M)^B - (\,t(M)^G_e + dt\_M^{1wa}\,) + correct$

$\tau\,(A)^B - \tau\,(M)^B = \mathrm{INT}(d\ \nu/\nu 0)\ d\tau \Rightarrow \mathbf{t(A)^G_e - t(M)^G_e}$

Time calibration : Cal_L (100-200 ns)

Ground link -> time server (*GPS time*)
Cal_G + *[distribution timing signal]*

MASTER station -> GPS time (~UTC)



$LTB(t) = STC(t) + Cal_G + Zph(t)$

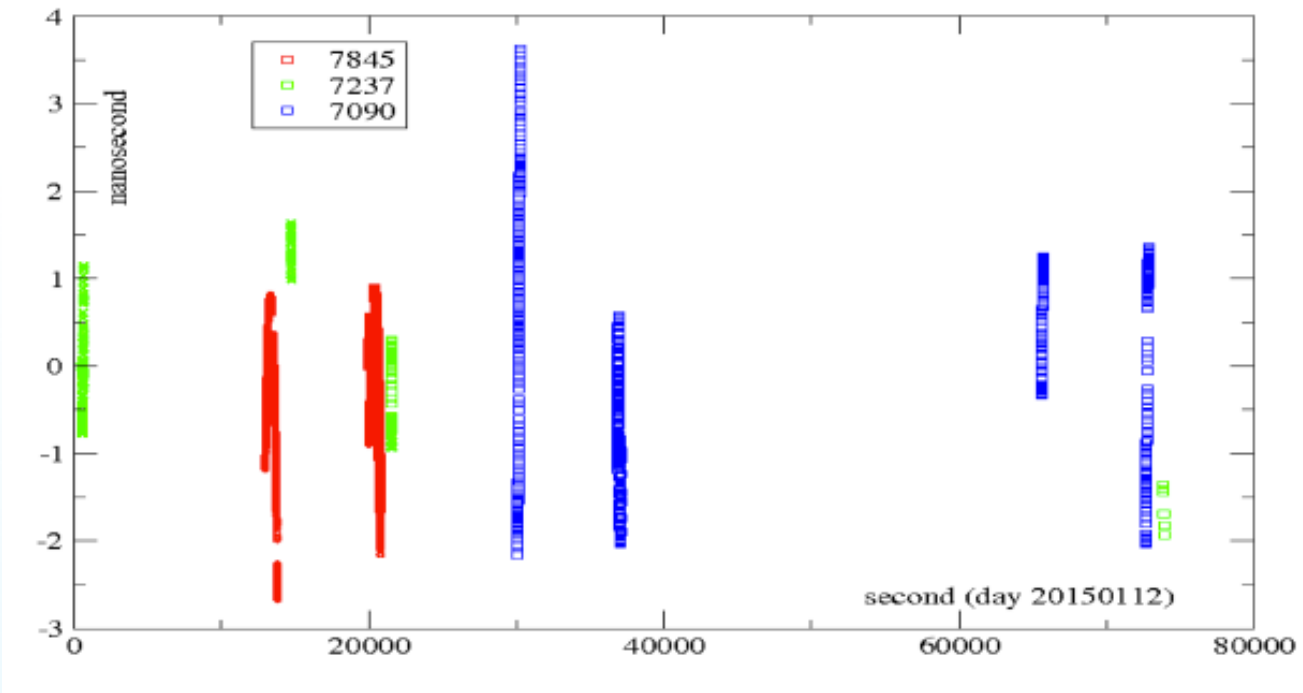
$t(x)^G_e = LTB(t) + Cal_L$

Time calibration : Cal_L (100-200 ns)

Ground link -> time server (*GPS time*)
Cal_G + *[distribution timing signal]*

TIME TRANSFER in nCV

November, 5 2013 : nCV 2h (03:00 →)				
Station, P	nb data	Δsec	TB	σ
7845, 2	742	0	-73.13	0.03
7845, 3	624	7004	-73.14	0.05
7941, 1	271	7503	234.08	0.35
7110, 1	322	-1337	393.36	2.27
7110, 2	453	5441	382.83	1.57
7501, 1	48	8713	-3986.59	0.47
nCV 4h (01:00 →)				
7845, 1	225	0	-73.14	0.03
7845, 2	742	6963	-73.02	0.06
7845, 3	624	13967	-73.15	0.22
7941, 1	271	14466	234.12	0.36
7110, 1	322	5625	393.43	2.28
7110, 2	453	12404	382.78	1.57
7403, 1	34	-1728	193.86	0.08
7501, 1	48	15676	-3986.24	0.48

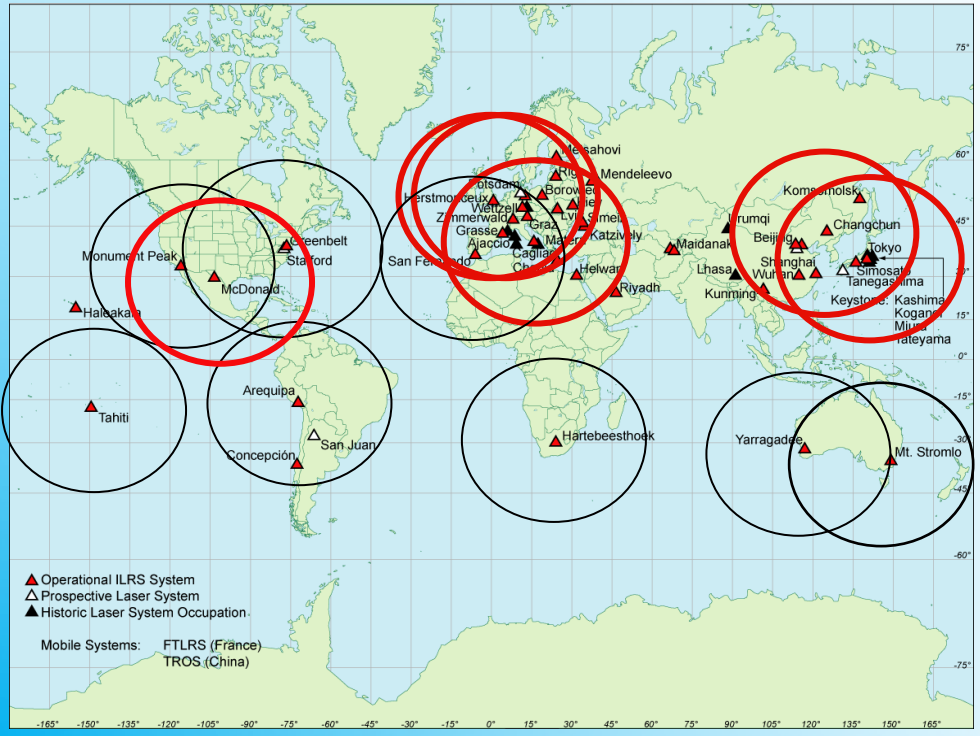


$t(x)^G_e = STC(t) + TB(t)$

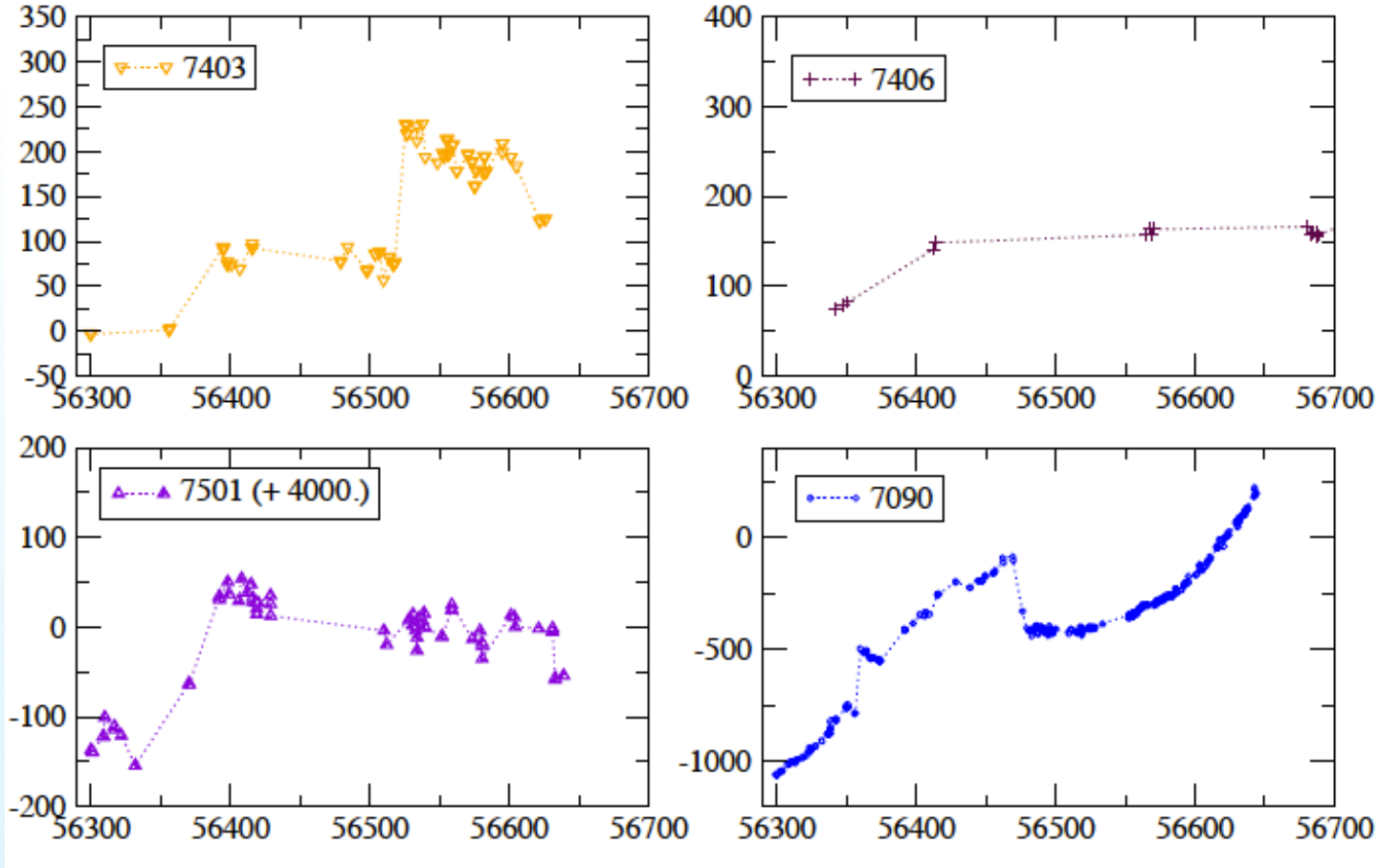
$t(A)^G_e - t(M)^G_e = TB(A) - TB(M)$

Long-term SLR clocks

T2L2 as a time link between SLR's



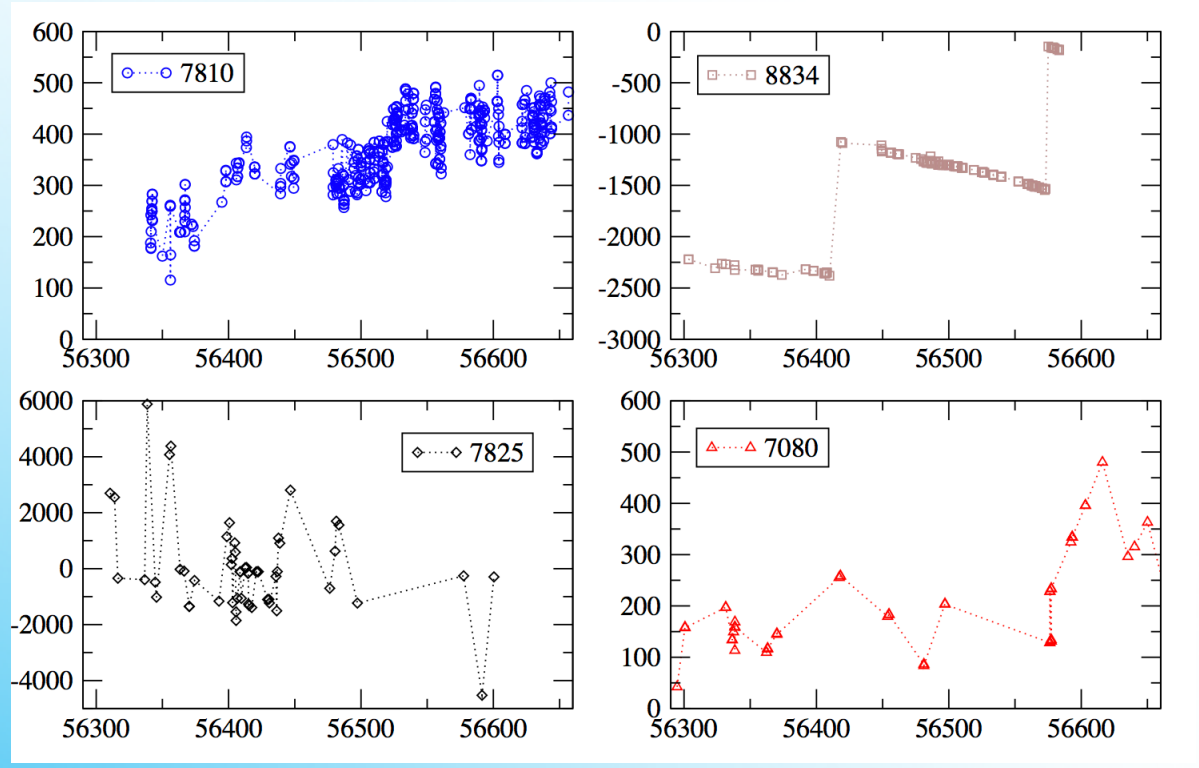
nanosec



ILRS, April, 22 2017

Long-term SLR clocks

nanosec

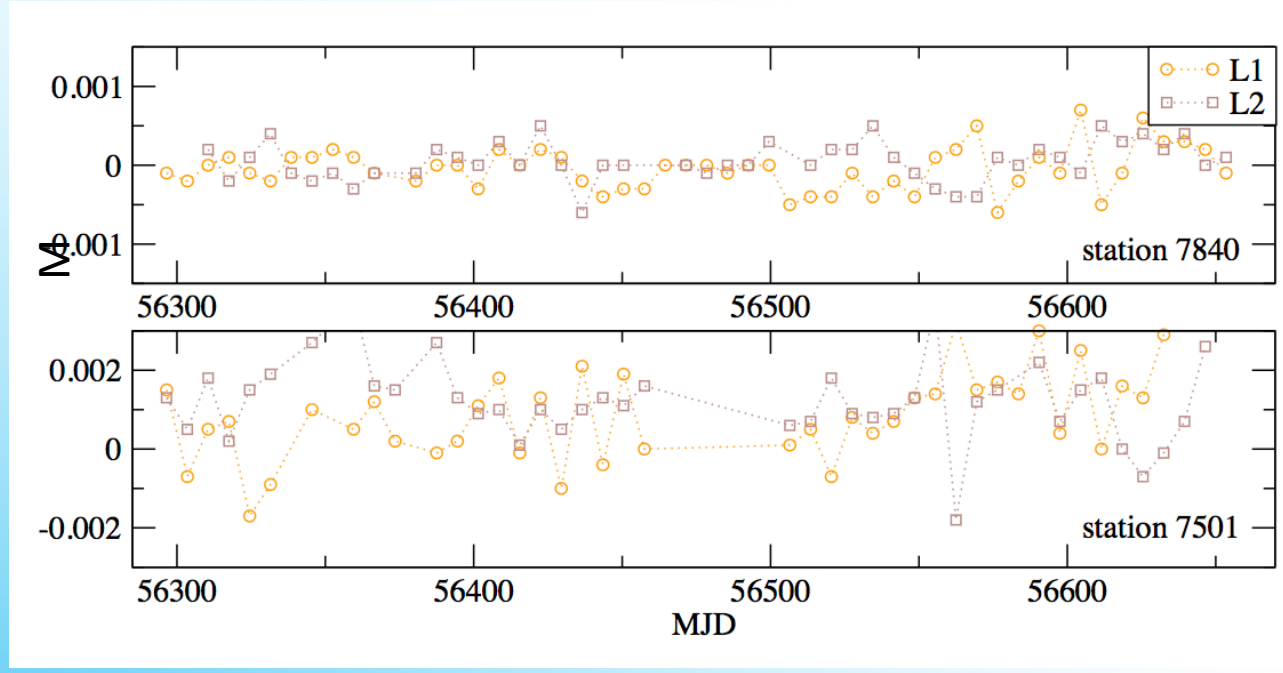


1-year process: 2013

Table 10: Huge time biases per period (MJD) and main phase jump **microsec.**

Station	Dates	Time bias	Jump
7090	56296-	-1.0	
	56786-	+1.2	-1.2
	56834-	+1.0	-1.0
7105	57216-227	+14.6	
7124	57286-372	+8.3	
	57408-429	+16.0	
	57456-555	+8.0	
7237	57413-414	+26.1	
	57318-371	- 0.6	
7403	56824-998	+2.1	
7501	56226-785	-4.0	
	56786-992	-6.0	
	57041		+6.0
7810	57209-210	-2.6	
7838	56552-667	-7.0	
	56672-744	-14.	
7845	56811-820	-1.4	
	56974-982	-61.1	
7941	55773	-13.5	
	55777-778	-13.0	
8834			
	56417	-29.0	
	56418-573	< -1.0	
	56575		+1.4
	56576-7203	< -1.0	
	57204		+4.0

TB: impact on POD

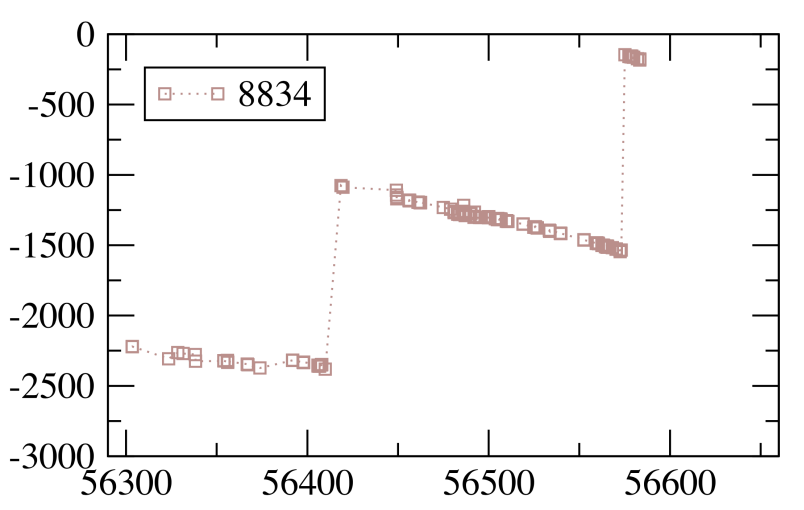


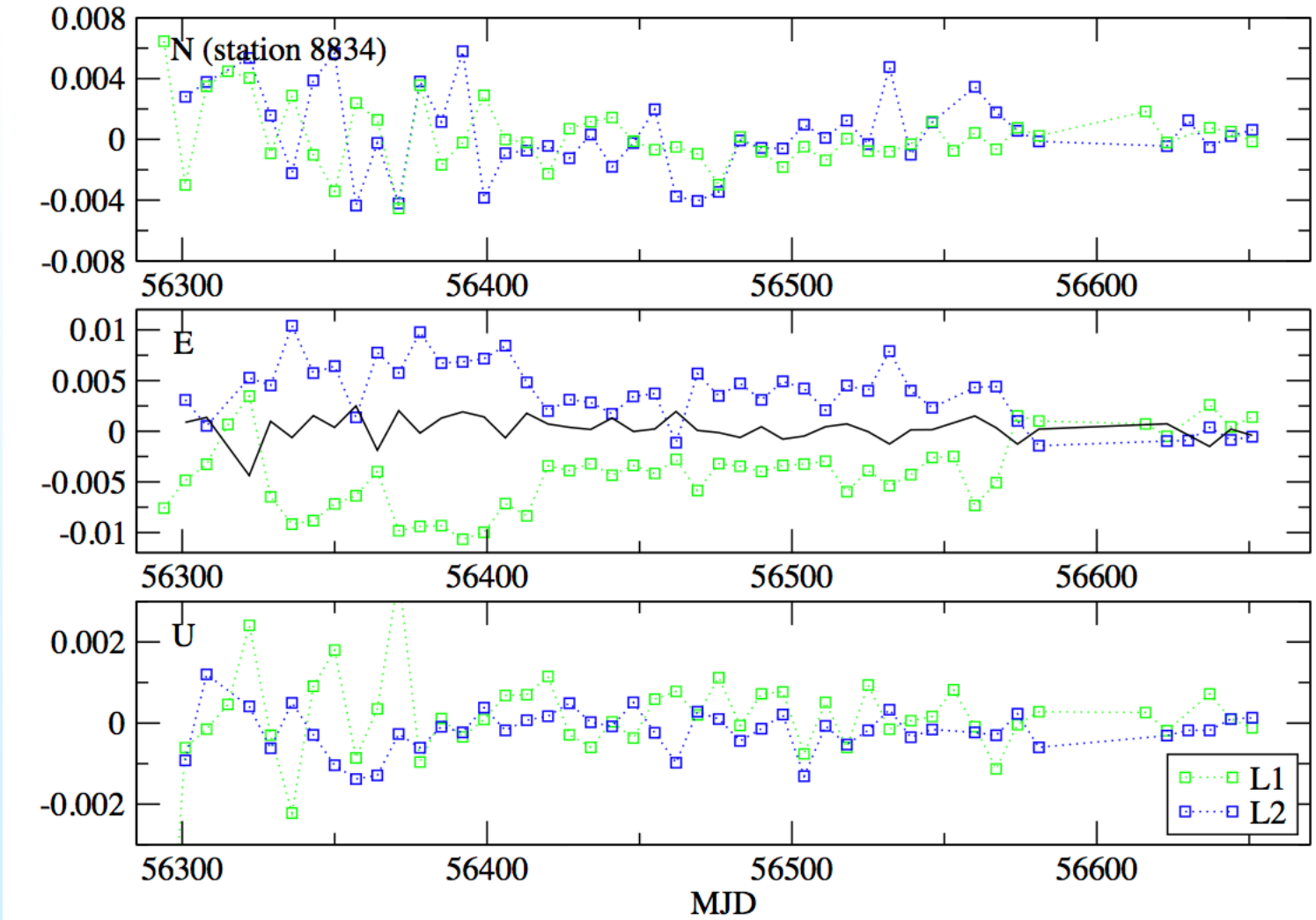
satellite	NP	arcs	average RMS	stations
L1	standard	52	8.7 ± 1.1	all
		51	7.8 ± 2.9	7840
		42	8.2 ± 2.1	7501
	TB-applied	52	8.5 ± 1.0	all
		51	7.8 ± 2.8	7840
		42	7.3 ± 1.9	7501
L2	standard	52	8.8 ± 1.2	all
		46	8.4 ± 2.2	7840
		41	8.7 ± 2.5	7501
	TB-applied	52	8.6 ± 1.1	all
		46	8.3 ± 2.2	7840
		41	7.5 ± 2.8	7501

1-year process: 2013

TB: impact on Positionning

TB, in nanosec.





CONCLUSIONS

T2L2 was launch in June 2008 (as a two-way+one-way optical TT technique)

It has been tracked by 22-24 SLR stations of the ILRS network, that provided the FR data to CDDIS/EDC data centers; rencently, 9 stations (1868 to, 1891) provided CDDIS with their FR data from 2016.

Time transfer from Grasse master SLR station (accurately tied to UTC) to the other SLRs (TT in non CV) has been developed to establish a « on-board time » available on a continuous basis;

- The synchronization of the station clocks to the same time reference, revealed time offsets (TB) os 0 to a few microseconds.
- The technological diagnosis is:
  - lack of time calibration of laser systems (delays in cables and devices), access to the time server (GPS), etc.

TB as a systematic error

TB have small but non negligeable effects in station coordinates, depending on the station and the period of time

AC's analyses are able to detect range errors in the measurements (mm level) whereas time errors are very difficult to estimate although recent improvements made :

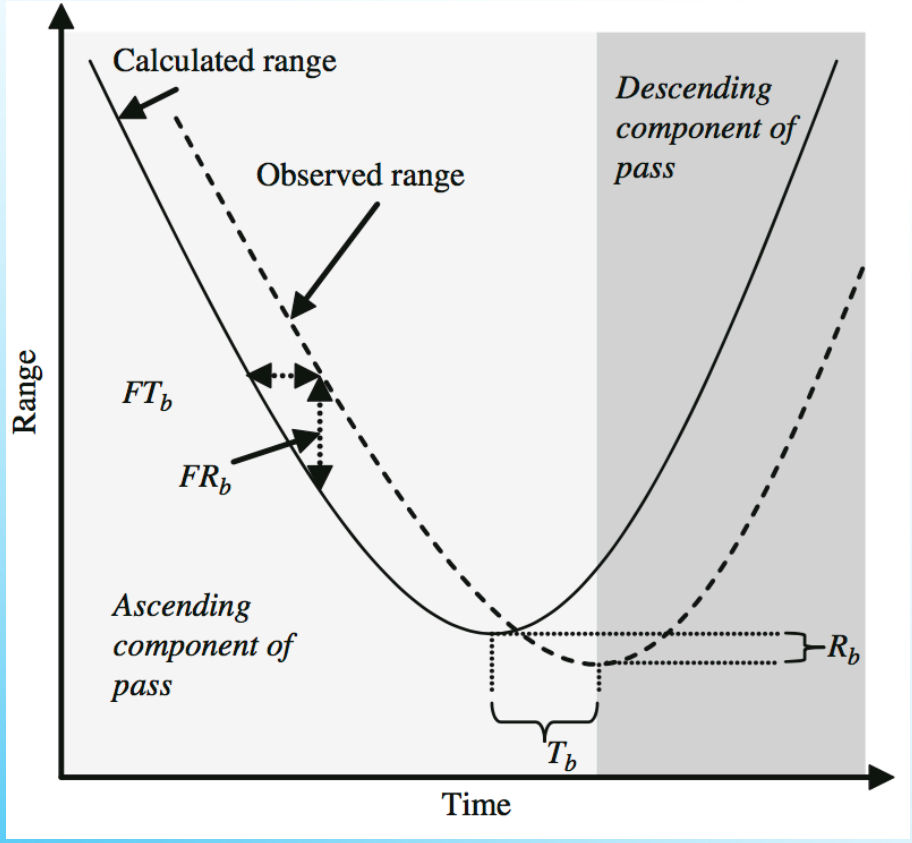
- In monitoring the engineering feedback : "data_handling_file"
- In the precise orbit determination process

TB cannot be determined by POD actually, and its effect is entirely transfered on station coordinates (east-west component);

- The impact on ITRF-like solutions (LAGEOS) should be accurately estimated and TB multi-yr time series included in the « standard »
- The SLR data analysis methods (QC daily, multi-yr, etc.) should consider TB in addition to rangeB.

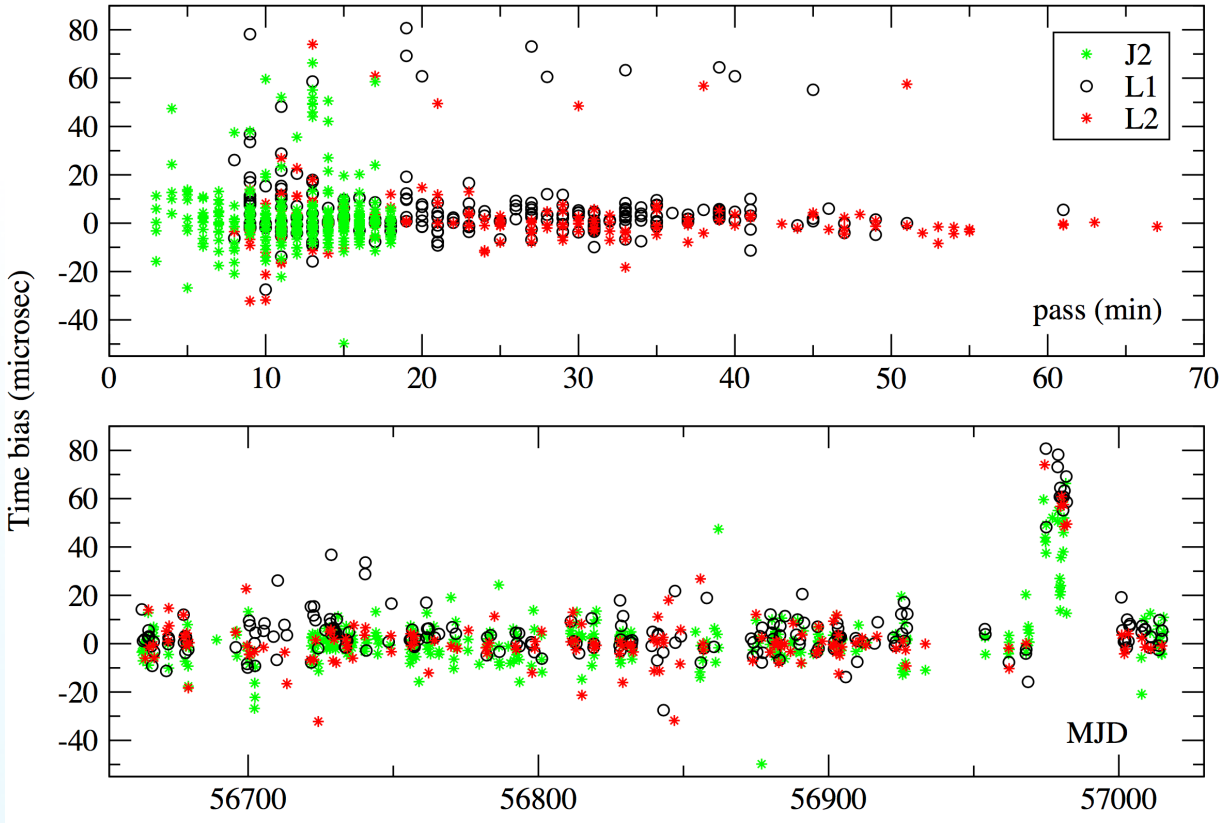
Thank You

QC daily Analysis



Combrinck, 2010

Grasse(56974-982: +61.1 μs); *T. Otsubo, Japan*

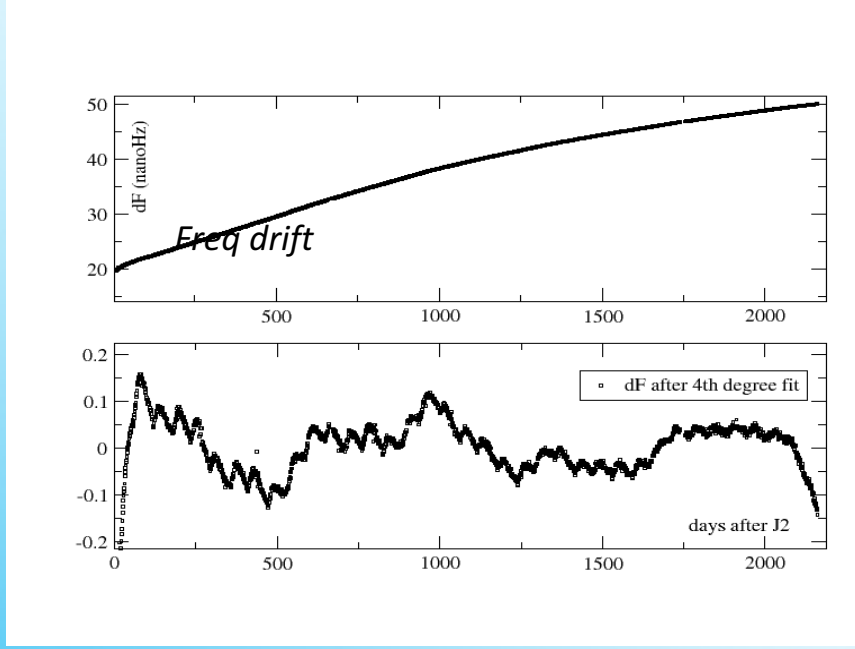


TB.*Vsat* <-> a few mm Along-T / μsec.

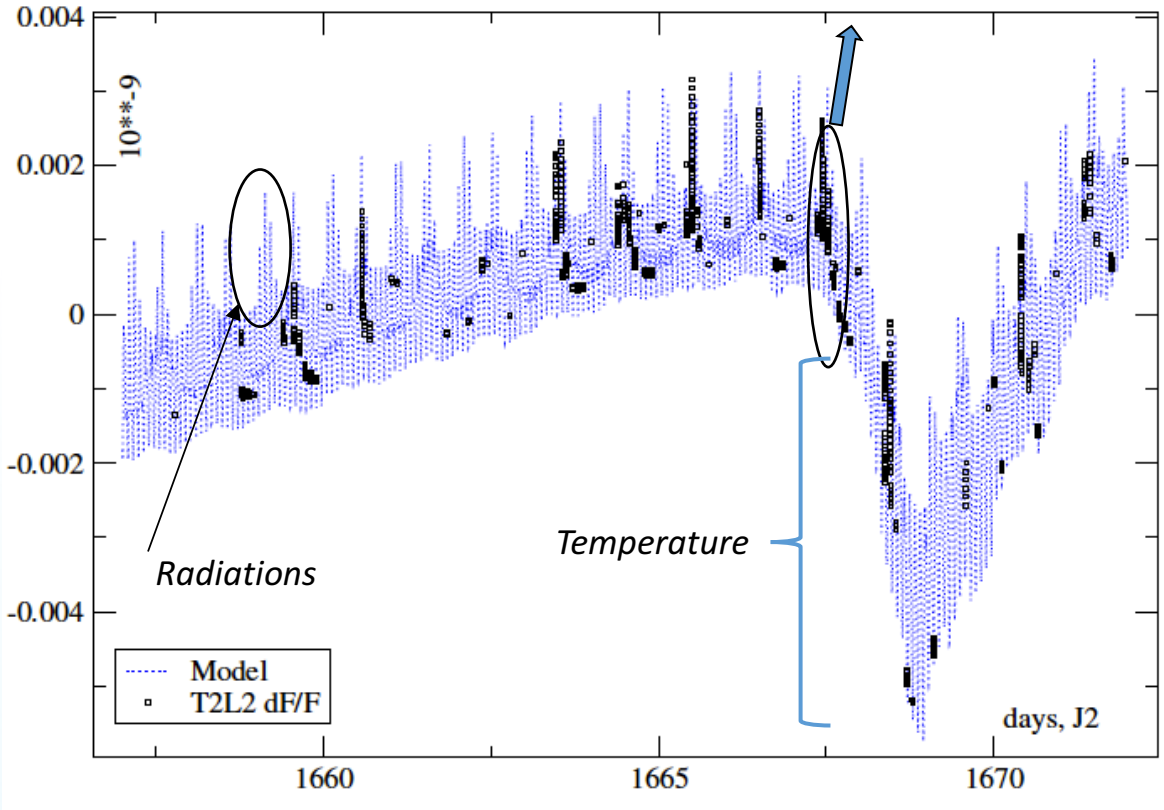
Current LAGEOS A-Track sensitivity : 20mm // 5μsec

DORIS oscillator

Long-term history (drift: aging + …)



USO model & **T2L2 freq. data**



Model: precision of few 10^{-13} (df/f), and accuracy 10^{-12}

Belli at al., 2015; *Jayles et al. 2016*

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New ILRS Associated Analysis Center

for processing SLR observations to multi-GNSS

Krzysztof Sośnica, Radosław Zajdel, Grzegorz Bury

Institute of Geodesy and Geoinformatics, WUELS, Wroclaw, Poland

Overview

- **New ILRS Associate Analysis Center** at the Institute of Geodesy and Geoinformtics, WUELS, Wroclaw, Poland

- **Main goal**: Processing SLR observations to **new GNSS systems**: **GLONASS, Galileo, BeiDou, QZSS, GPS Block III** (in future) and supporting the MGEX/LARGE activities (ILRS Study Group: LAser Ranging to GNSS s/c Experiment)

- **Current activities**:
  1. Comparison of microwave GNSS orbits and SLR observations (operational analysis, reports generated once-per-day)
  2. Development of an on-line service for the analysis of SLR residuals to GNSS and with a database with all SLR@GNSS residual data.

- **Future activities**:
  1. Generating GNSS orbits on the basis of SLR observations
  2. Combined LAGEOS+GNSS products.

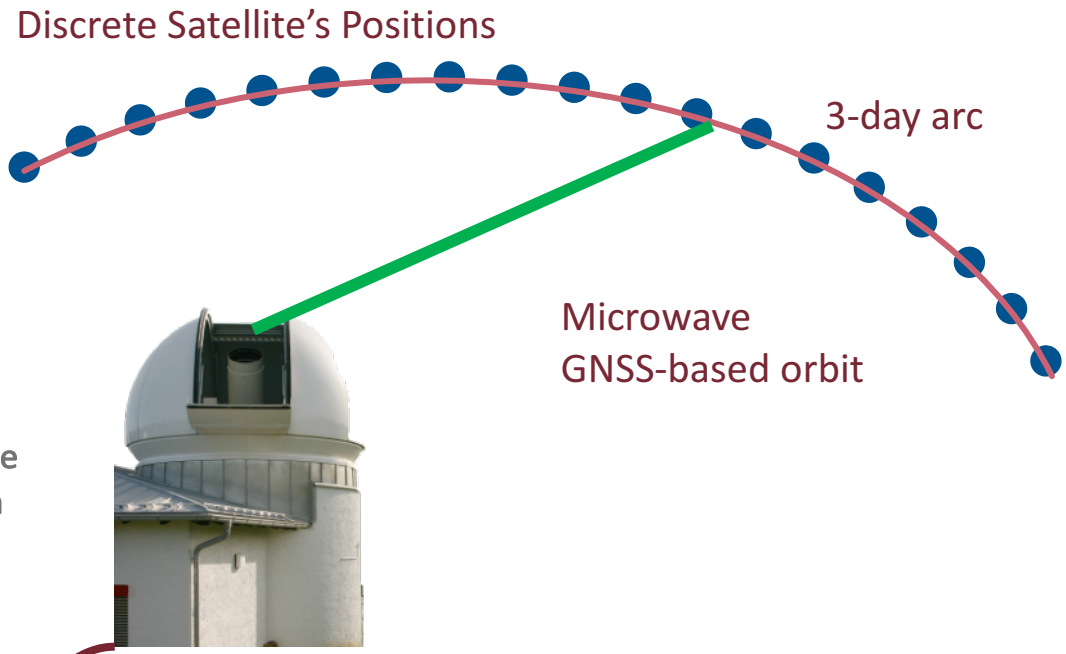
IGS Multi-GNSS Pilot Project (MGEX)

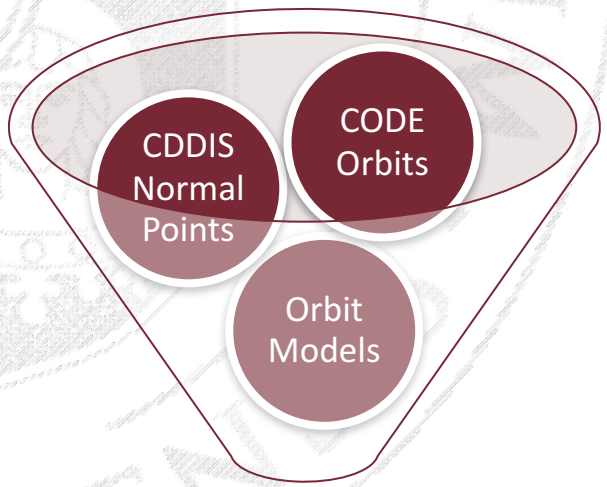
System	GLONASS		Galileo			BeiDou			QZSS
Type	GLONASS-M	GLONASS-K	IOV	FOC (extended orbit)	FOC	MEO	IGSO	GEO	QZS-1
PRN Number	R01-R08 R10-R19 R21-R25	R09, R20	E11, E12, E19, E20	E18, E14	E26, E22, E24, E30, E08, E09, E01, E02, E07, E03, E04, E05	C11, C12, C13 (retired), C14, C33, C34 , C35	C06, C07, C08, C09, C10, C31, C32, C13	C01, C03, C04, C05, C02, C17	J01
Retroreflectors	115	132	84	60	60	42	42	90	42
Mass [kg]	1450	750	695-697	661/662	706-709	1 900	1 900	1 550	1 800
Semi-major axis [km]	25 500	25 520	29 600	27 978	29 600	27 878	42 164	42 164	42 164
Altitude [km]	19 130	19 130	23 225	17 178-26 019	23 226	21 507	35 793	35 793	32 000 - 40 000
Orbit	MEO	MEO	MEO	MEO	MEO	MEO	Geosynchronous	Geostationary	Geosynchronous
Eccentricity	0.0001	0.0001	0.0001-0.0002	0.1585/0.1584	0.0001-0.0004	< 0.003	0.0023	0.0002	0.099
Inclination [deg]	64.8	68.8	54.93-55.57	50.10/50.16	54.94-57.25	55.00	55.60	~0.0-1.8	43.0

Orbit validation

Comparation between satellite's orbits based on microwave GNSS double-difference observations with the SLR observations provided by the global network of ILRS stations.

The microwave GNSS solutions are generated by the Center for Orbit Determination in Europe (CODE) in the framework of the IGS Multi-GNSS Experiment (MGEX).





Bernese GNSS Software

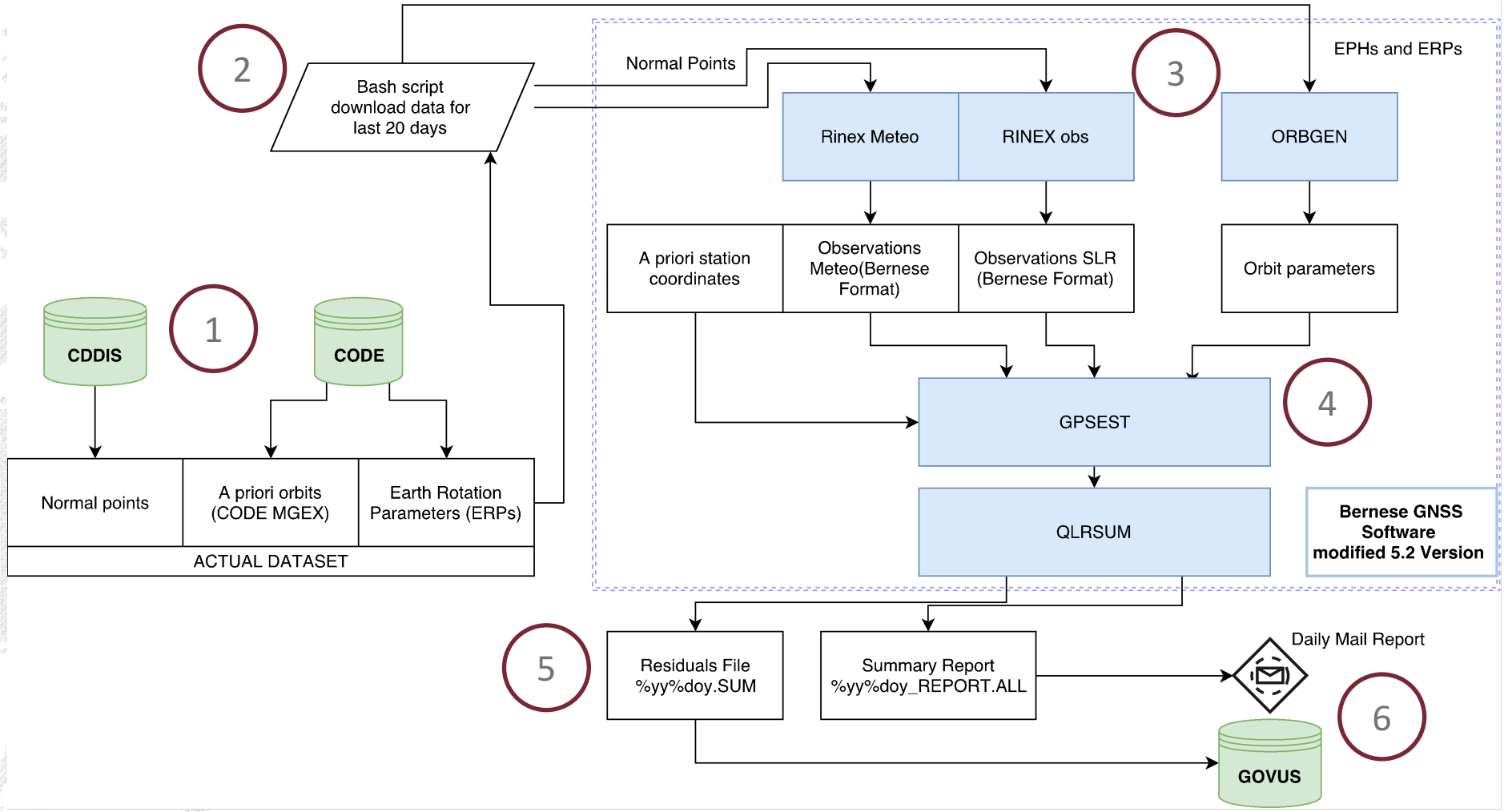
Since 2014, CODE has been providing five satellite system solutions based on GPS, GLONASS, Galileo, BeiDou, and QZSS on an operational basis. Post-processing / 2 weeks delay

Since 2015, CODE uses the new ECOM2 model for the orbit generation.

Prange L, Orliac E, Dach R, Arnold D, Beutler G, Schaer S, Jäggi A (2016) CODE's five-system orbit and clock solution-the challenges of multi-GNSS data analysis. J Geod, 2016.

Generating Near Real Time operational products

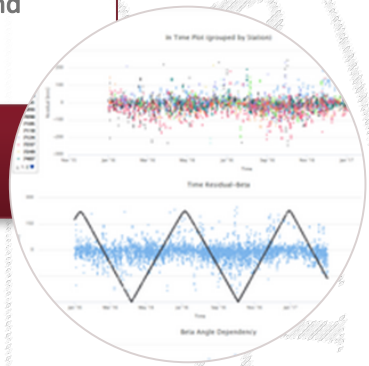
Application is generating scientific products based on the SLR observations to new GNSS systems on the operational basis. GOVUS generates daily reports that include a comparison between IGS MGEX orbits of GLONASS, Galileo, BeiDou MEO, BeiDou IGSO and QZSS satellites and SLR observations collected by a global network of ILRS stations



Functions – Semi-Final Product

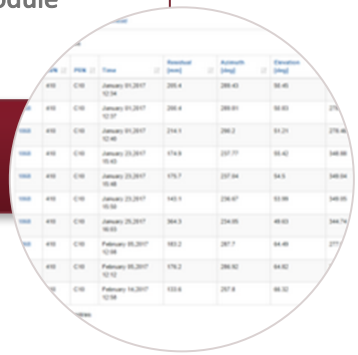
Plot analyses

- Tool responsible for creating plots and statistical values, based on dataset, assigned using available filters and restrictions.



Tables Charts

- Tool responsible for visualizing raw residual dataset in tables and simple plot with additional download module

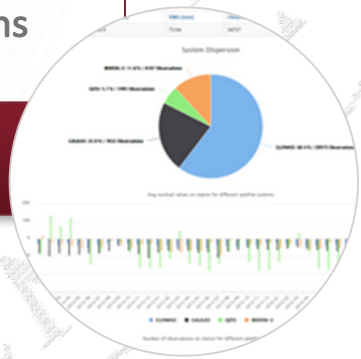


Map

- Map presenting SLR station placement with connection to its statistics

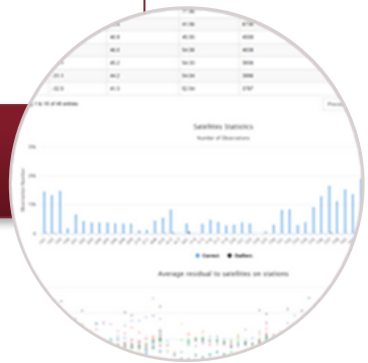
Station statistics

- Tool presenting general statistics about all active SLR stations



Satellite Statistics

- Tool presenting general statistics about the satellites



Daily Reports

- Official products explorer, updating in daily bases routine

Daily Report

```
Authors: Krzysztof Sosnica (krzysztof.sosnica@igig.up.wroc.pl),
         Radoslaw Zajdel (radoslaw.zajdel@igig.up.wroc.pl),
         Grzegorz Bury (grzegorz.bury@igig.up.wroc.pl)
         Institute of Geodesy and Geoinformatics (IGiG)
         Wroclaw University of Environmental and Life Sciences (WUELS)

multiGNSS Quick-Look Residual Analysis Report
---------------------------------------
Remarks: - Residuals are referred to the SLRF2008.
         - GPS satellites are indicated with the character 'G',
           GLONASS satellites with the character 'R'
           Galileo satellites with the character 'E'
           BeiDou satellites with the character 'C'
           QZSS satellites with the character 'J'
         - The SLR residuals are calculated w.r.t. official microwave
           MGEX CODE 3-day GNSS orbits.
```

About the authors and solution

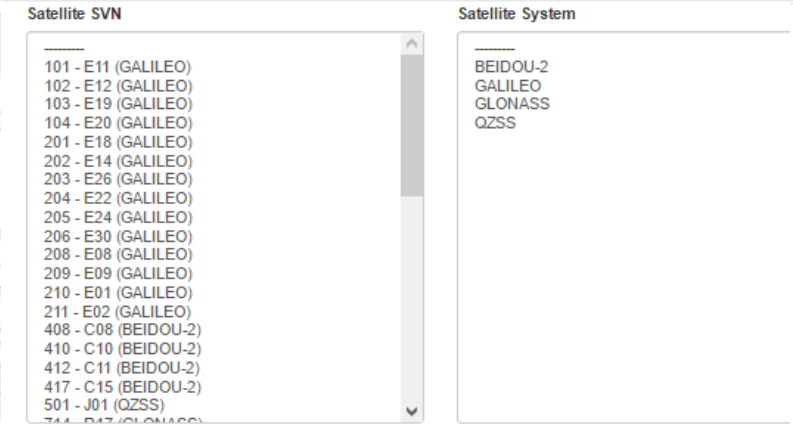
```
More statistics and the description of the solutions are available at:
multiGNSS Orbit Validation Visualizer Using SLR (GOVUS)
http://www.multi-slrgnss.rhcloud.com
```

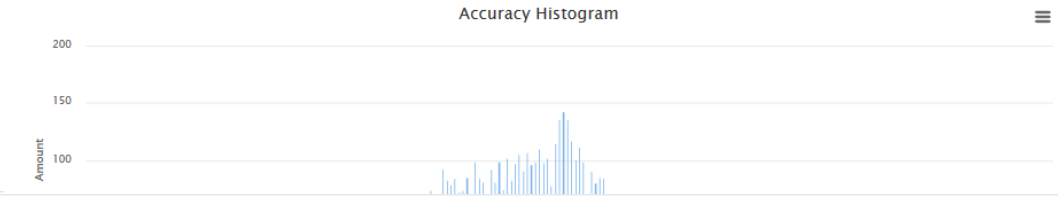
Reference

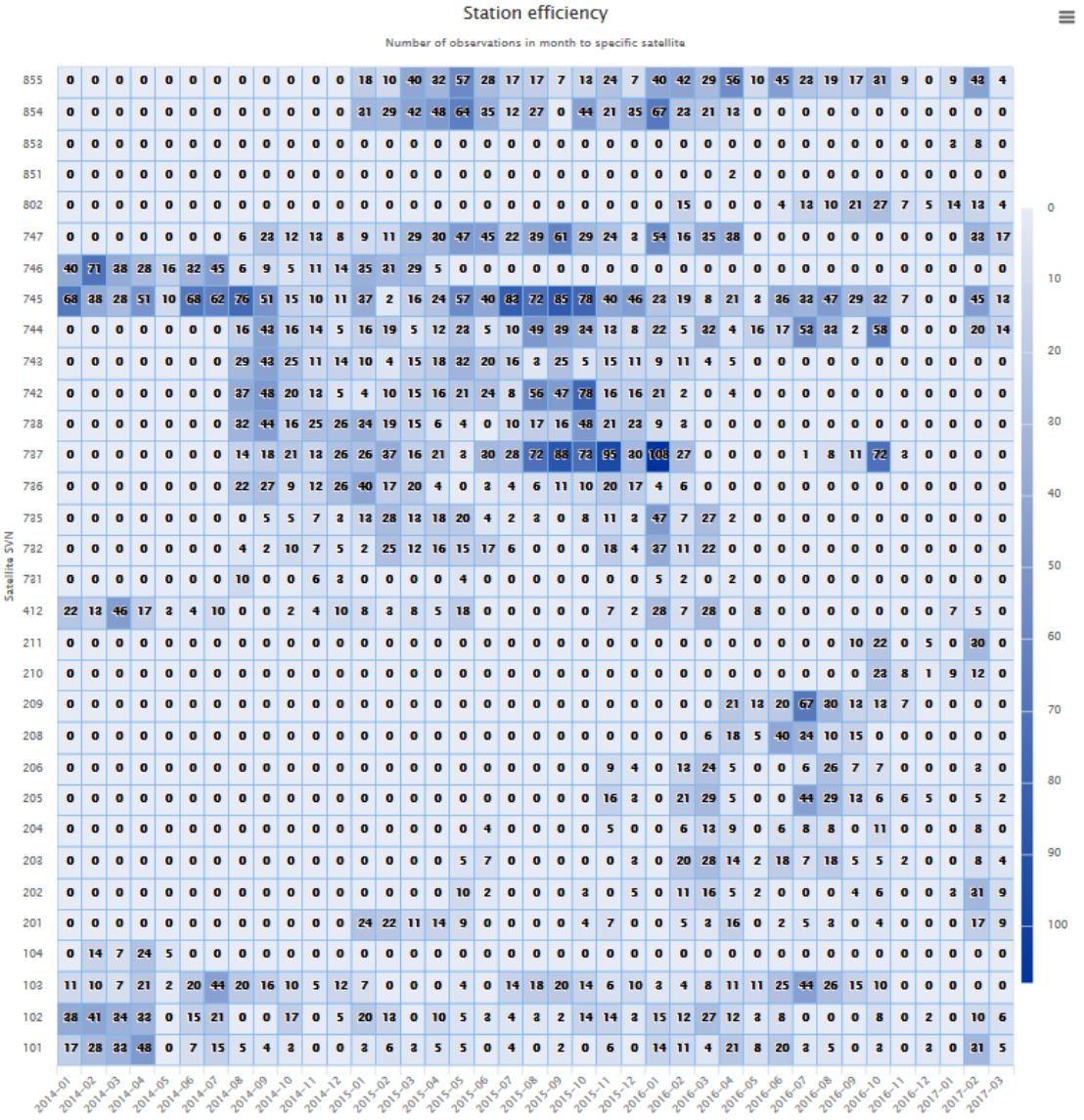
STATION ID	SAT PRN	START PASSAGE yy/mm/dd hh:mm	DUR (min)	#OBS GOOD	MEAN (mm)	STD (mm)	#OBS BAD	MEAN (m)	STD (m)
1873 12337S003	E14	17/03/05 22:24	72	9	-113	40			
1879 12372S001	R09	17/03/05 13:29	131	7	-42	33			
1879 12372S001	R16	17/03/05 13:40	10	4	-12	1			
1879 12372S001	R18	17/03/05 14:04	10	4	21	3			
1879 12372S001	R21	17/03/05 17:38	86	5	21	8			
1879 12372S001	C08	17/03/05 18:28	7	3	-23	5			
1879 12372S001	R22	17/03/05 19:53	62	5	-45	11			
1879 12372S001	R07	17/03/05 20:10	10	4	-88	4			
1886 12373S001	E14	17/03/05 22:34	6	3	66	3			

Summary of validation result covering last 20 days from submmision date in reference to the availability of new ephemeris end earth rotation parameters

Screenshots







Screenshots – station options

Laser type

DPRAL
ND:VAN
ND-YAG
ND:YAG
ND:YVO
Ti:SAP

Detector type

APD
CSPAD
MCP
PMT
SPAD

Max repetition [Hz]

<kHz
>kHz

Wavelength

423,5
532
849,8

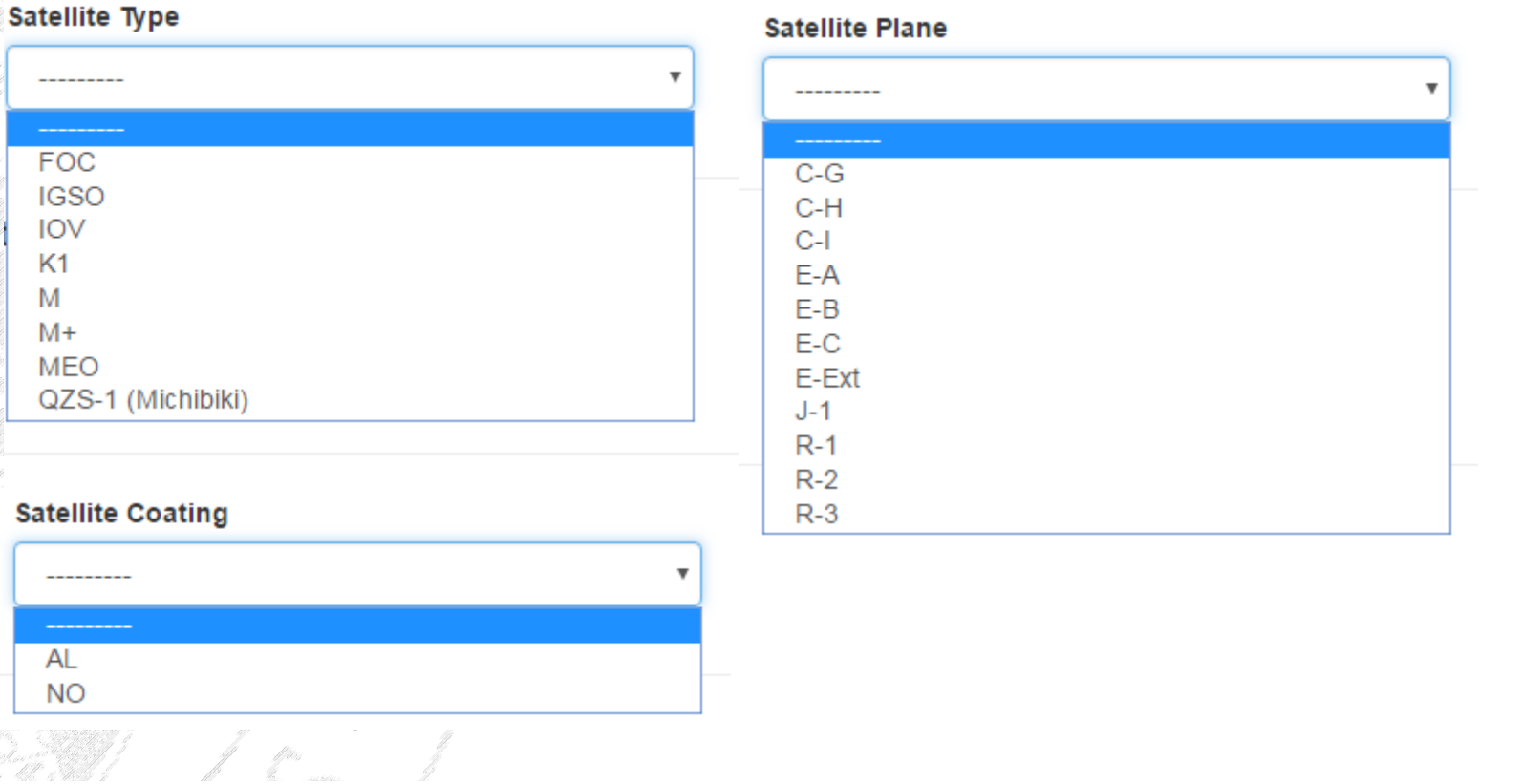
Timer type

---
clock count plus TDC
Event
Interval

Mode of operation

Few to Multi Photons
Multi Photons
Single Photon
Single to Few Photons
Single to Multi Photons

Screenshots – satellite options



Outliers:

Outlier Threshold [mm]*

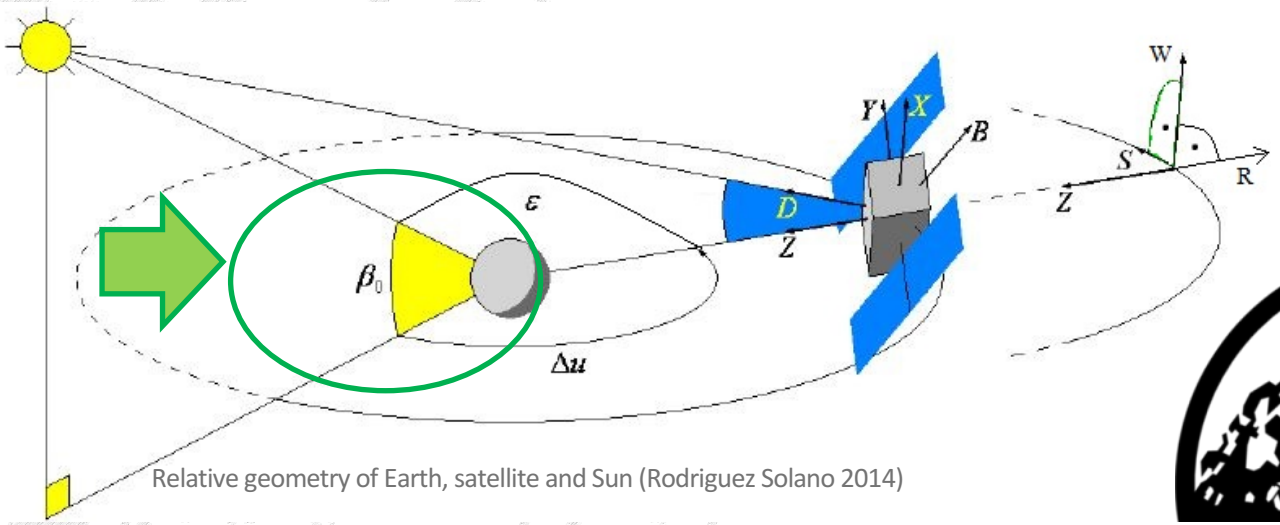
250

Beta Angle Restriction*

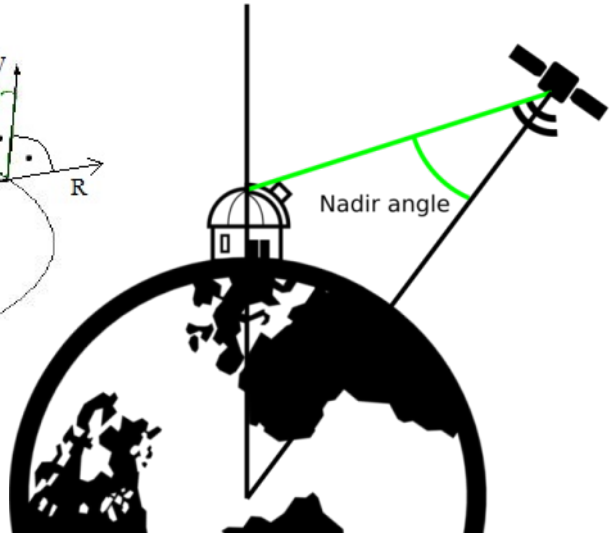
14

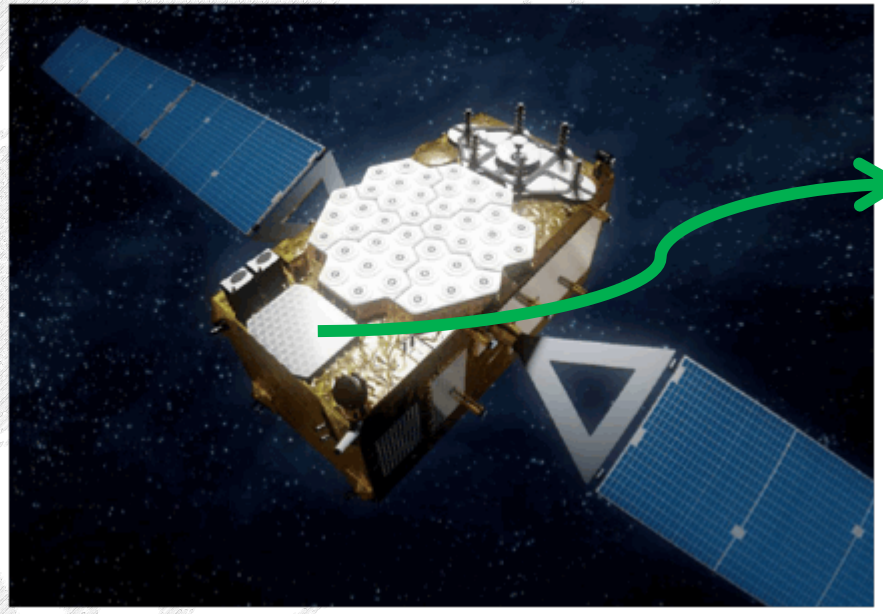
Exclude

GNSS data analysis using GOVUS: multi-slrgnss.rhcloud.com

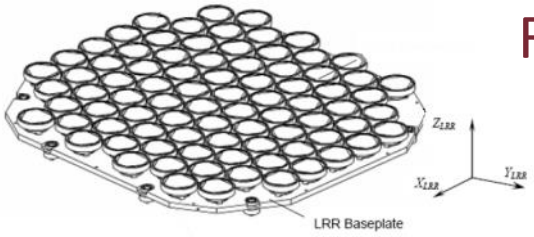


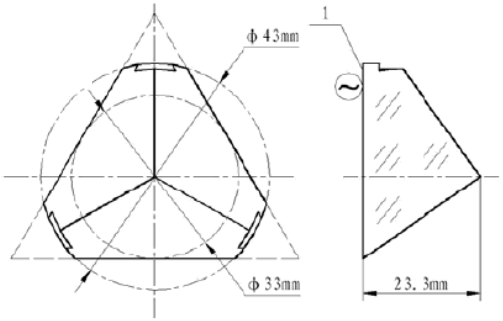
Relative geometry of Earth, satellite and Sun (Rodriguez Solano 2014)





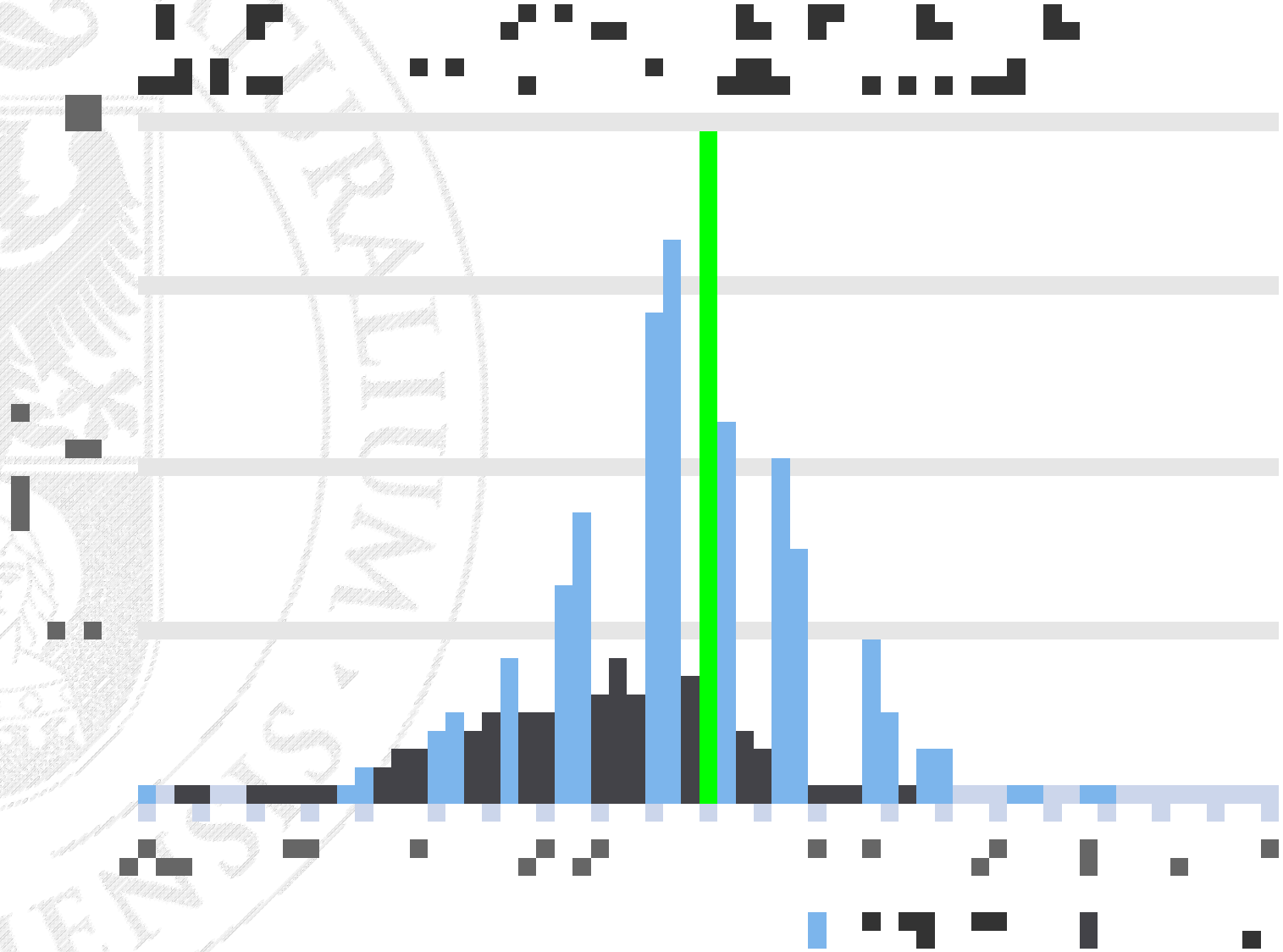
Retroreflectors



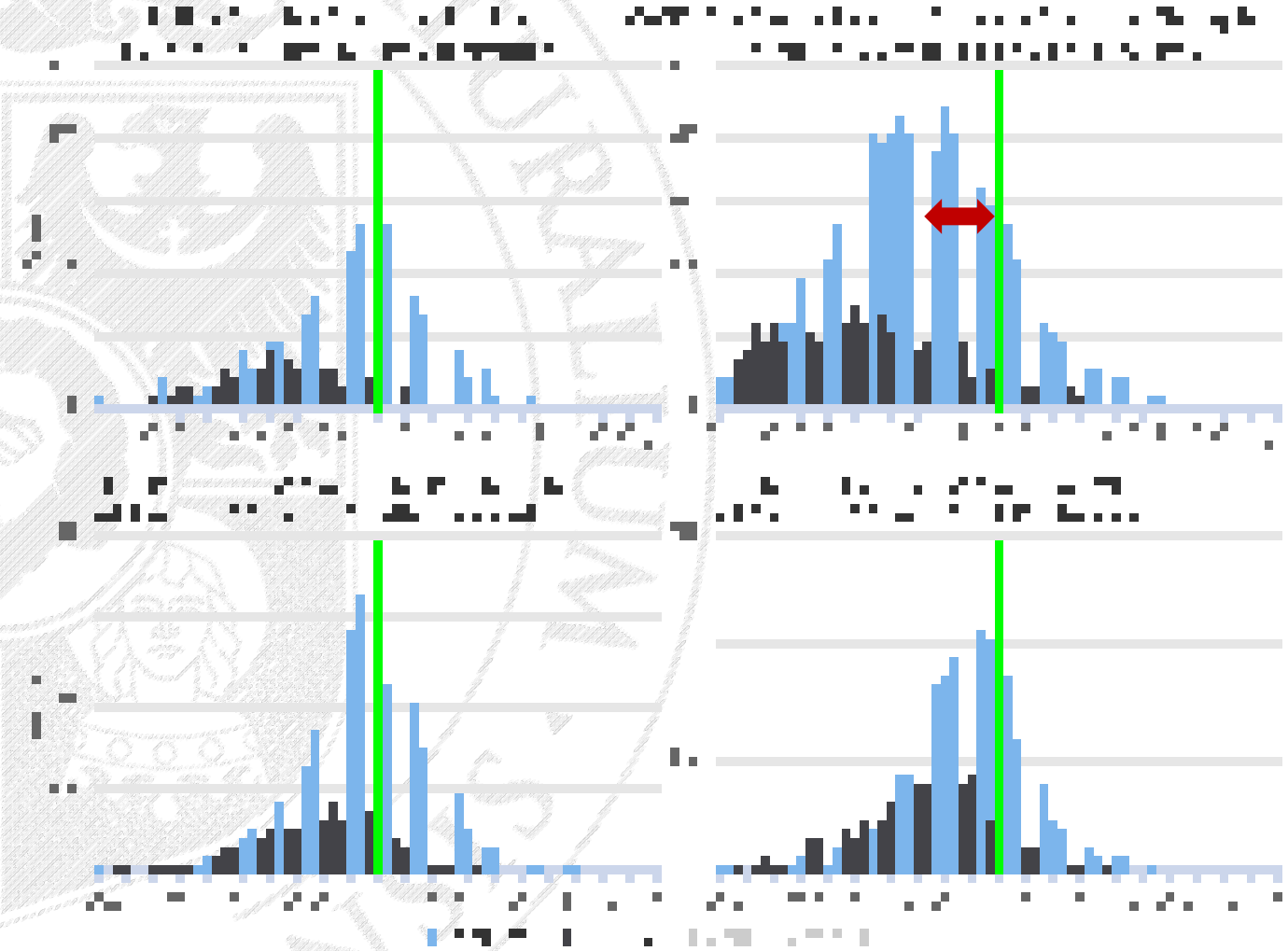


Galileo retroreflector (ILRS)

Station statistics - histograms



Station statistics depending on detector type



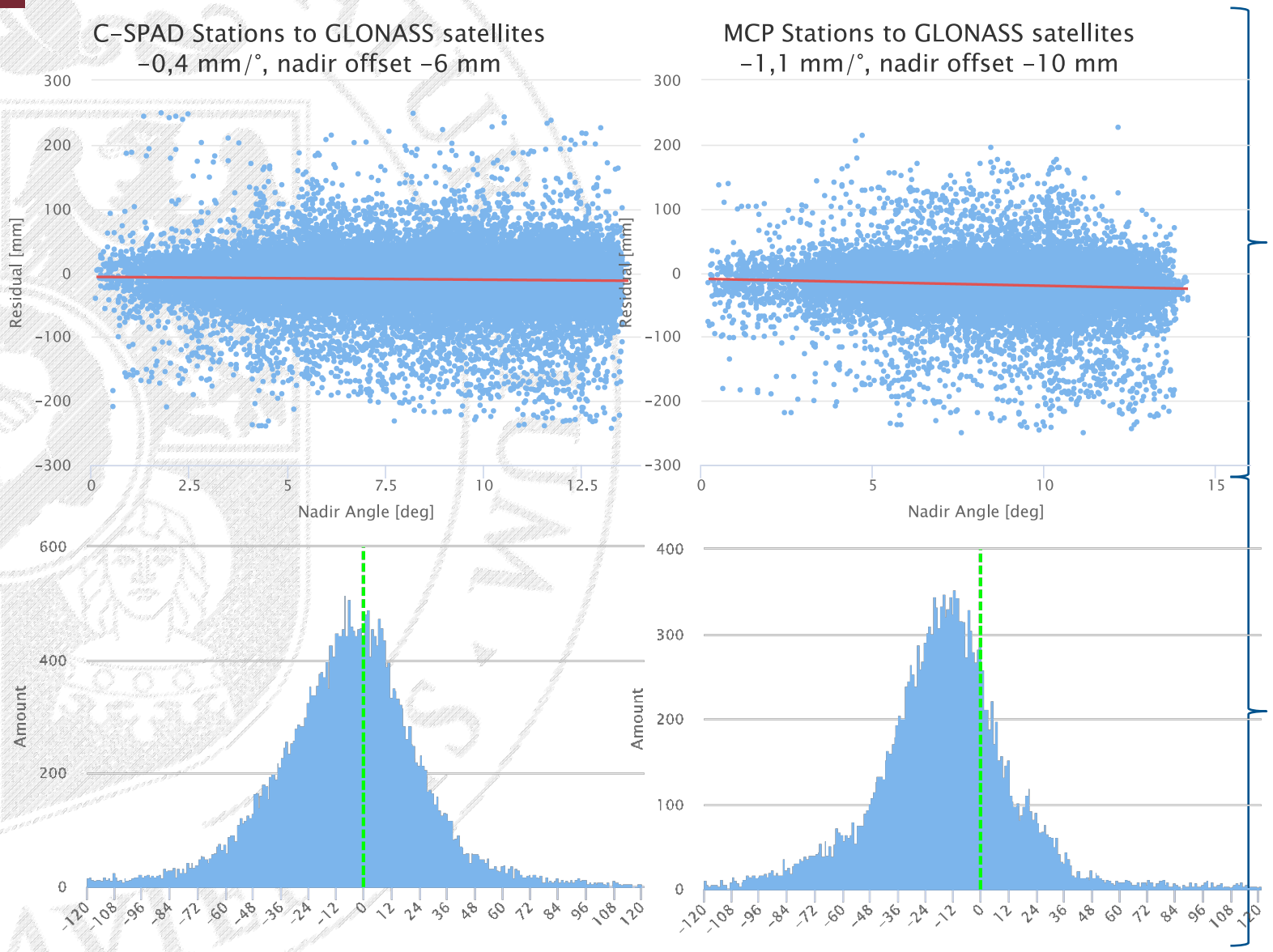
Nr	Avg [mm]	Std Dev [mm]	RMS [mm]	Obs. No
7090	-23,0	48,8	54,0	52583
8834	-19,8	37,2	42,2	20386
7941	-15,5	37,4	40,5	19454
7839	-10,0	37,3	38,6	37965
7840	-12,7	37,3	39,4	23449
7810	-15,5	43,9	46,5	20217
7237	-44,5	57,9	73,0	34866
7825	-3,6	40,1	40,2	27301
7821	-14,0	49,1	51,1	18873
1879	-16,6	45,9	48,8	14042
7407	-19,0	44,4	48,2	6569

MCP	Multi Photons	CSPAD	Single Photon	PMT	*Few Photons*

*C-SPAD – Graz (7939), Herstmonceux (7940), Zimmerwald (7810), Mount Stromlo (7825)

*MCP – Wettzel (8834), Yarragadee (7090), Matera (7941)

Dependency of SLR residuals on the incidence angle of the laser beam



Signature effect caused by multi-photons detector limitation in multiple reflection from flat array recognition

Nadir angle has no dependence on SLR residuals

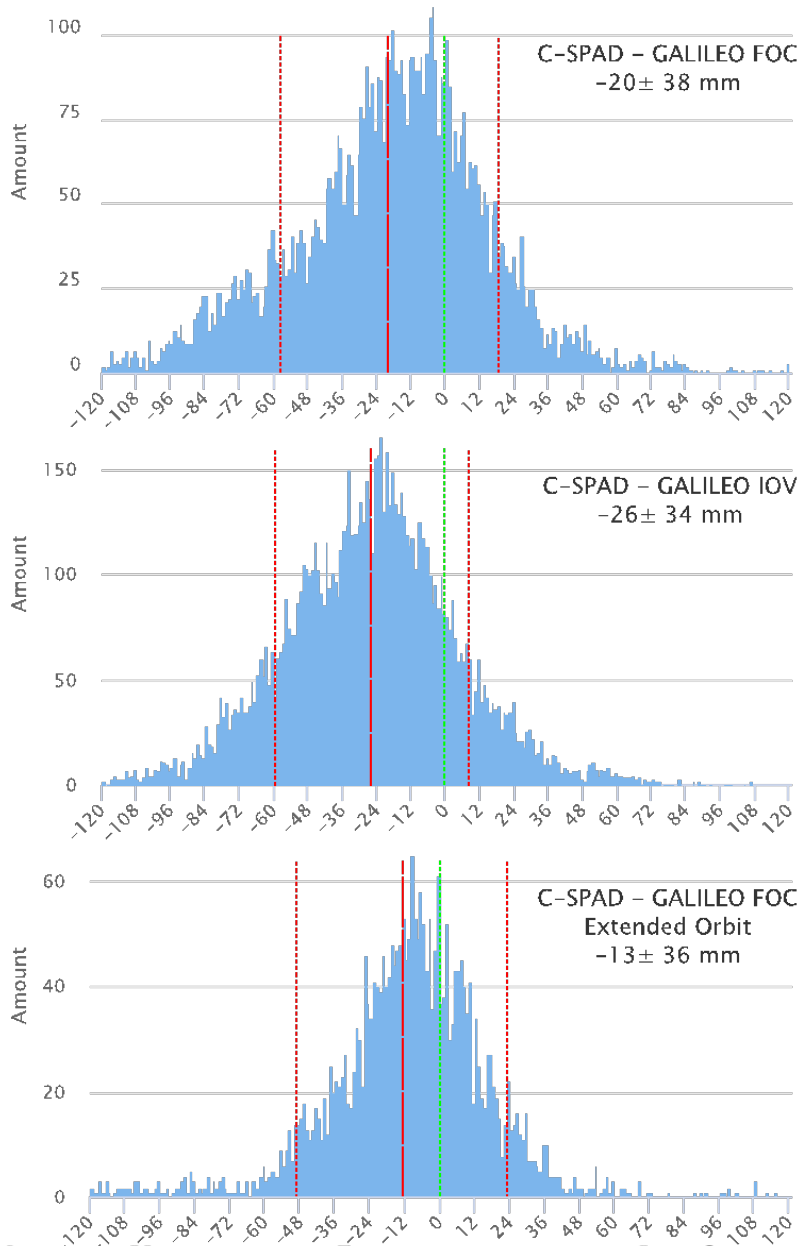
Dependency of SLR residuals on station's detector type
Different types of Galileo satellites

	Type	No. Obs.	Avg [mm]	Std. Dev [mm]	RMS [mm]
MCP*	IOV	10417	-37,9	36,0	52,3
	FOC	9293	-29,5	39,8	49,5
	FOC-Ext	3618	-20,9	34,5	40,3
C-SPAD*	IOV	10870	-26,8	33,1	42,6
	FOC	9139	-24,6	38,1	45,3
	FOC-Ext	3549	-14,9	33,2	36,3

		C-SPAD*		MCP*		
Type	SVN	Avg [mm]	RMS [mm]	Avg [mm]	RMS [mm]	Plane
IOV	101	-24,3	41,1	-35,4	50,5	E-B
	102	-26,9	39,6	-36,5	48,9	E-B
	103	-29,2	46,3	-41,8	56,9	E-C
Ext	201	-13,6	35,1	-20,7	38,7	E-Ext
	202	-16,5	37,8	-21,1	42,8	E-Ext
FOC	203	-22,4	44,7	-24,8	48,6	E-B
	204	-21,3	44,4	-28,7	52,3	E-B
	205	-28,2	48,0	-28,0	48,9	E-A
	206	-28,4	45,0	-32,7	49,3	E-A
	208	-22,8	44,3	-32,2	52,5	E-C
	209	-19,9	41,6	-31,9	48,9	E-C
	210	-28,9	50,5	-26,4	38,4	E-A
	211	-27,6	45,9	-28,3	46,4	E-A

*C-SPAD – Graz (7939), Herstmonceux (7940), Zimmerwald (7810), Mt Stromlo (7825)

*MCP – Wettzel (8834), Yarragadee (7090), Matera (7941)



Comparison of the classical and extended ECOM

	2014					2015					2016			
	No. Obs	Avg [mm]	Std. Dev [mm]	RMS [mm]		No. Obs	Avg [mm]	Std. Dev [mm]	RMS [mm]		No. Obs	Avg [mm]	Std. Dev [mm]	RMS [mm]
GLONASS	50776	-6,9	38,8	39,4	ECOM2	53224	-12,0	41,9	43,6		34221	-8,2	33,8	34,8
Galileo	10139	-36,2	67,3	76,3		17039	-30,1	37,6	48,2		23564	-25,4	37,8	45,6
BeiDou	4664	-5,3	50,8	51,1		3599	-15,4	51,0	53,3		2903	0,8	54,8	54,8
QZSS	622	-30,3	113,4	117,4		855	-85,8	60,2	104,8		375	-53,2	90,8	105,2

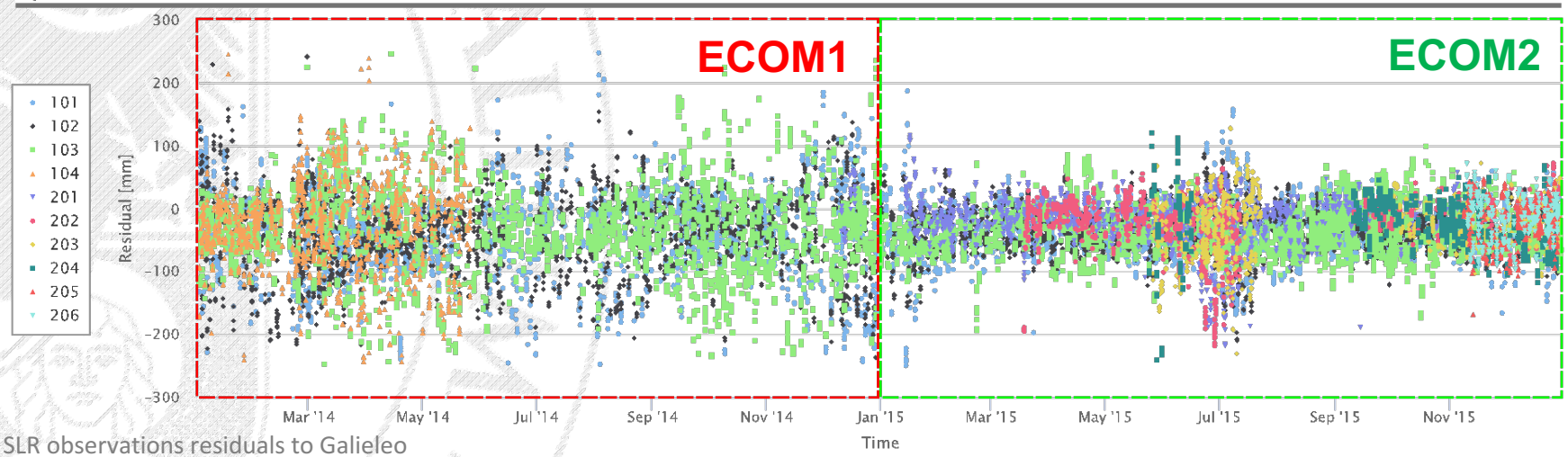


Fig. SLR observations residuals to Galieleo satellites as a function of time

New Empirical CODE Model (Arnold et al., 2015)

$$\begin{cases} D = D_0 + D_{S2}sin2\Delta u + D_{S2}cos2\Delta u \\ \quad +D_{S4}sin4\Delta u + D_{S4}cos4\Delta u \\ Y = Y_0 \\ X = X_0 + X_s \sin\Delta u + X_c \cos\Delta u \end{cases}$$

Galileo: clear benefits from ECOM2

QZSS: significant benefit while in yaw attitude mode

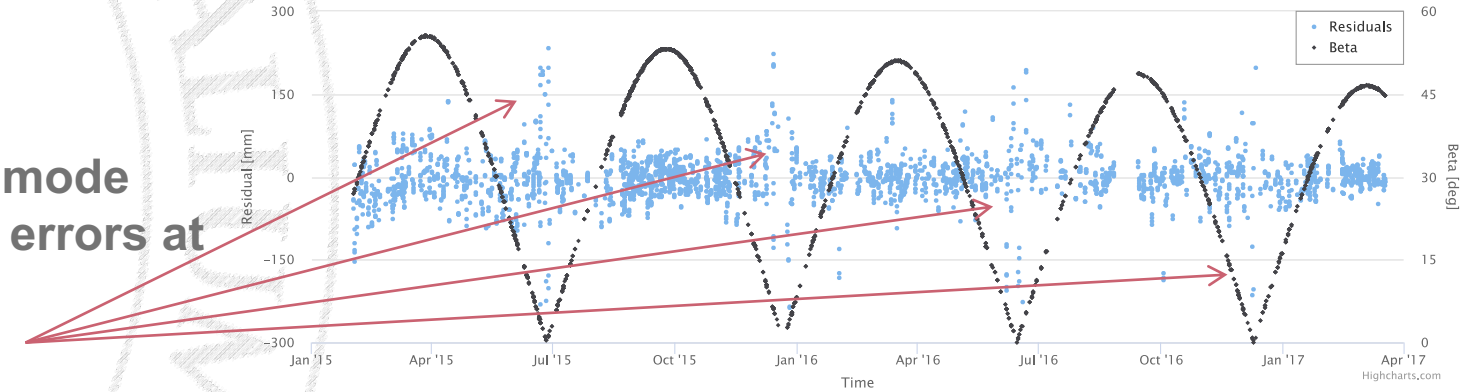
GLONASS: moderate benefits for majority of satellites, overall statistics on comparable level

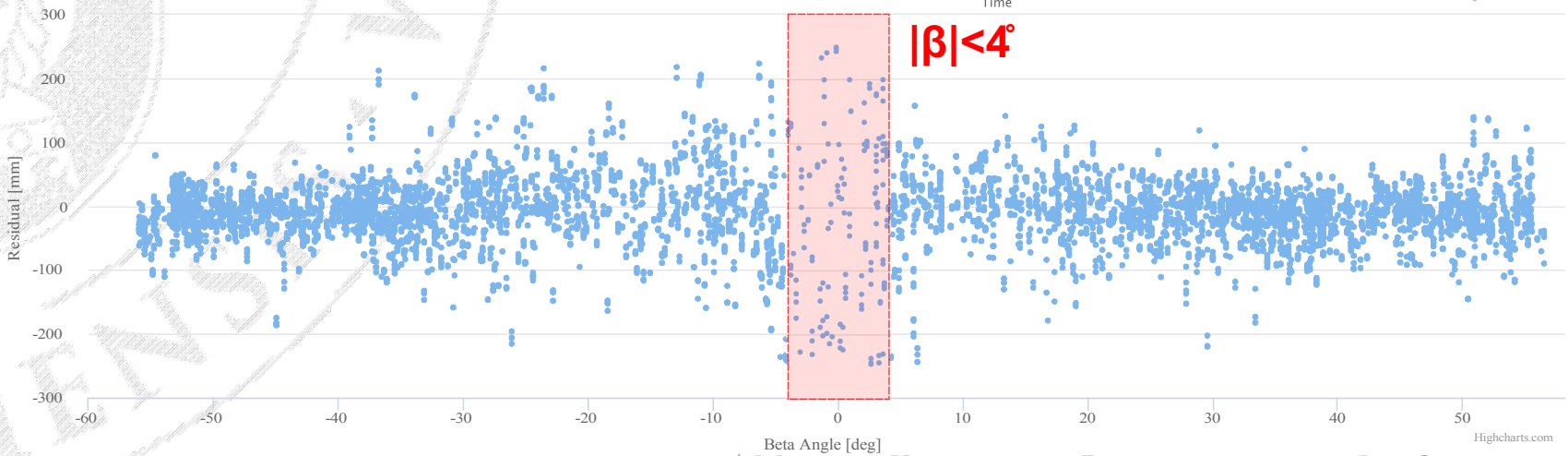
BeiDou: overall statistics on comparable good level

Orbit modelling issues for satellites in normal mode of BeiDou Navigation Satellite System

	PRN	No. Obs.	Avg [mm]	Std. Dev. [mm]	RMS [mm]		No. Obs.	Avg [mm]	Std. Dev. [mm]	RMS [mm]	Plane	CC
	C08	84	2,1	122,0	122,0		1483	-22,4	48,9	53,7	C-I	42
|β|<4	C10	41	-3,4	116,4	116,5	|β|>4	2090	-3,1	58,3	58,4	C-G	90
	C11	34	-63,7	149,2	162,2		3349	-3,1	35,2	35,4	C-H	90
		159	**-13,4**	**129,7**	**130,3**		**6922**	**-7,2**	**46,9**	**47,5**		

Normal attitude mode dominates orbit errors at low Beta angles (< 4 degress)





Summary

- The Web application is working with the functionality of:
  - ✓ storing and updating database in a daily routine
  - ✓ visualising data and allow ing for plot analyses
  - ✓ creating dataset filtred by a user, ready for download
- New GNSS systems are analyzed: GLONASS, Galileo, BeiDou and QZSS
- Current coverage: 2014.0-2017.4 (today)
- Reports distributed via ILRS e-mail?

http://multi-slrgnss.rhcloud.com/slr/

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Thank You for Your Attention

MULTI-GNSS ORBIT VALIDATION VISUALIZER USING SLR

http://multi-slrgnss.rhcloud.com/slr/

Krzysztof Sośnica, Radoslaw Zajdel

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