ASI AC&CC report

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ILRS ASC Meeting, 1 October 2017, Riga

Activities since last ASC meeting

- Daily and weekly time series adopting ITRF2014
- ACs performance check
- Combination SW update for the systematic error pilot project
- Pilot Project actviities with time series generation and combination

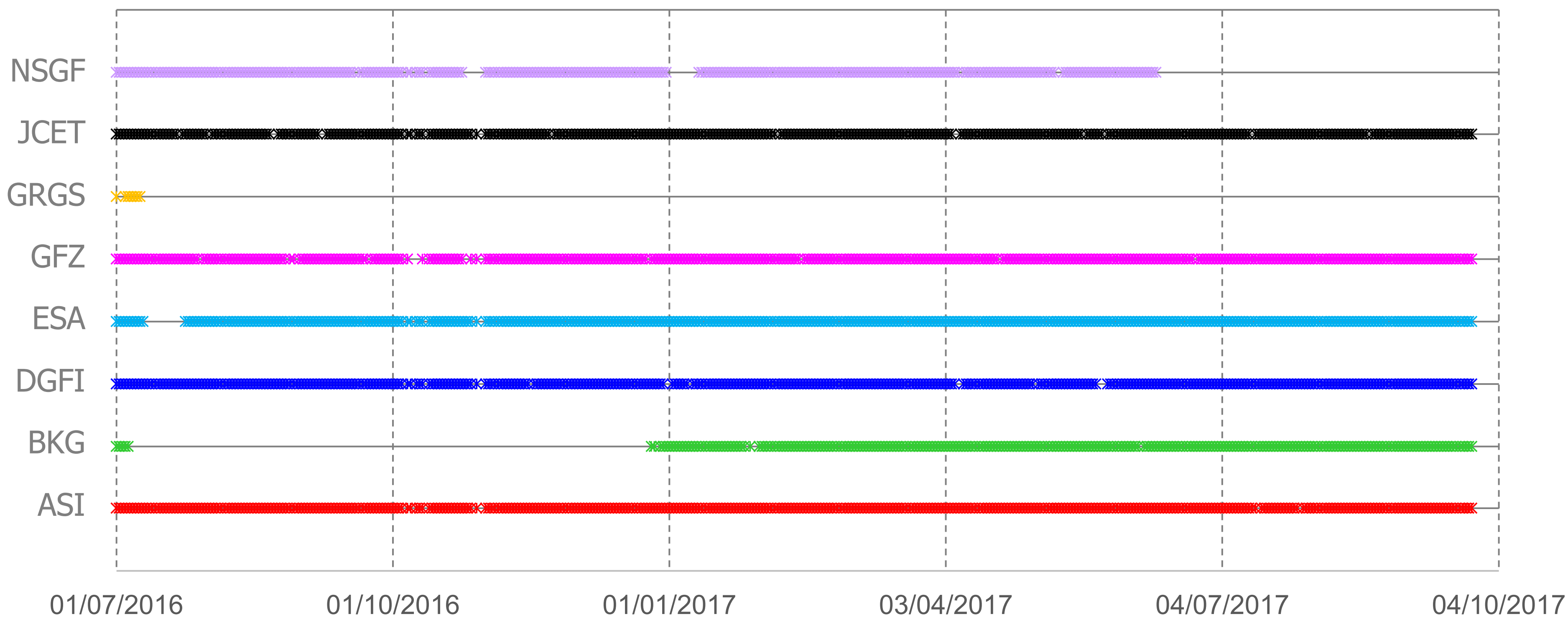
AC products

AC time series using ITRF2014 as *a priori*

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

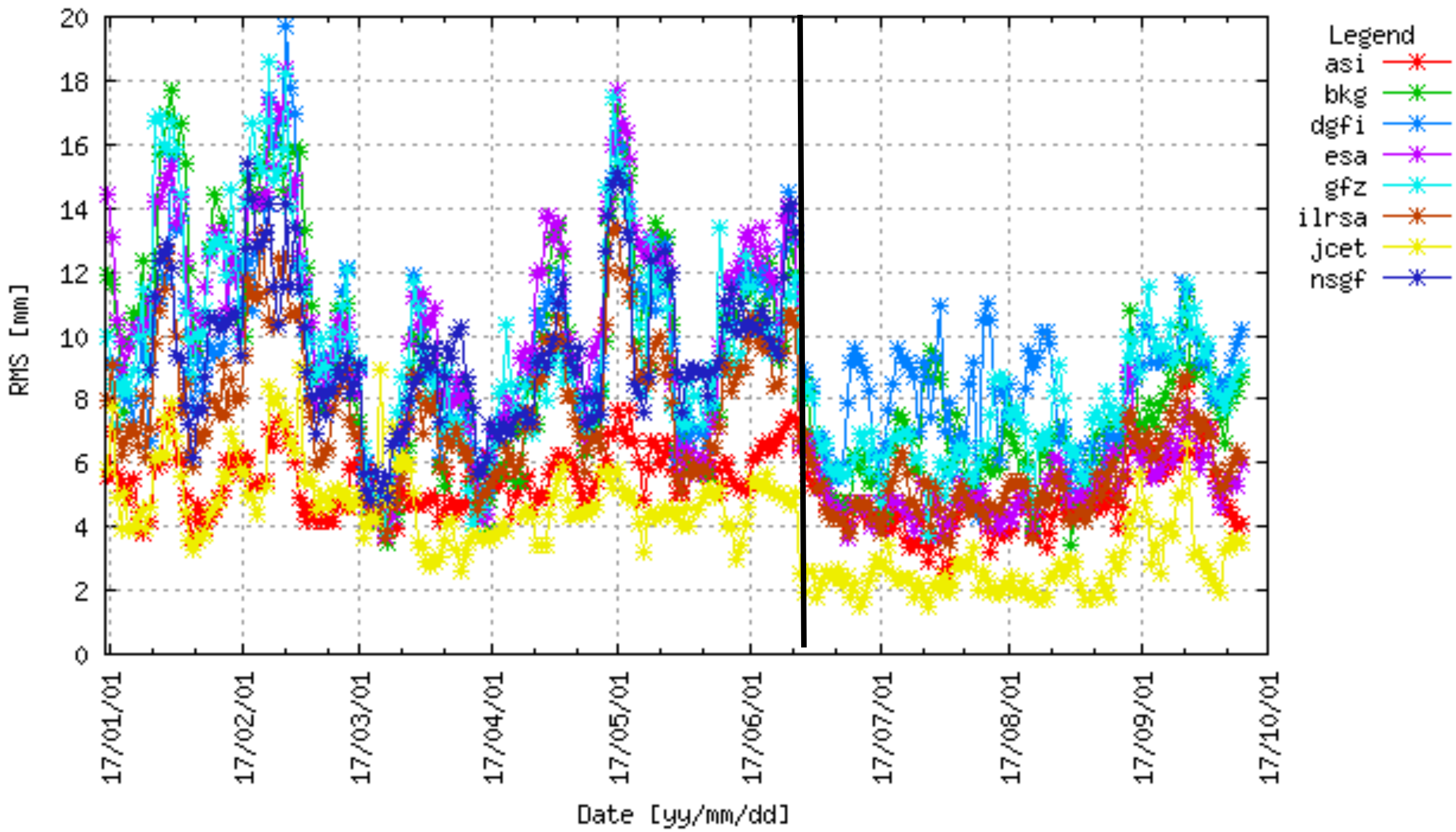
AC submissions

AC time series using ITRF2014 as *a priori* are the official products since 15 June 2017: daily (v170) and weekly (v70)

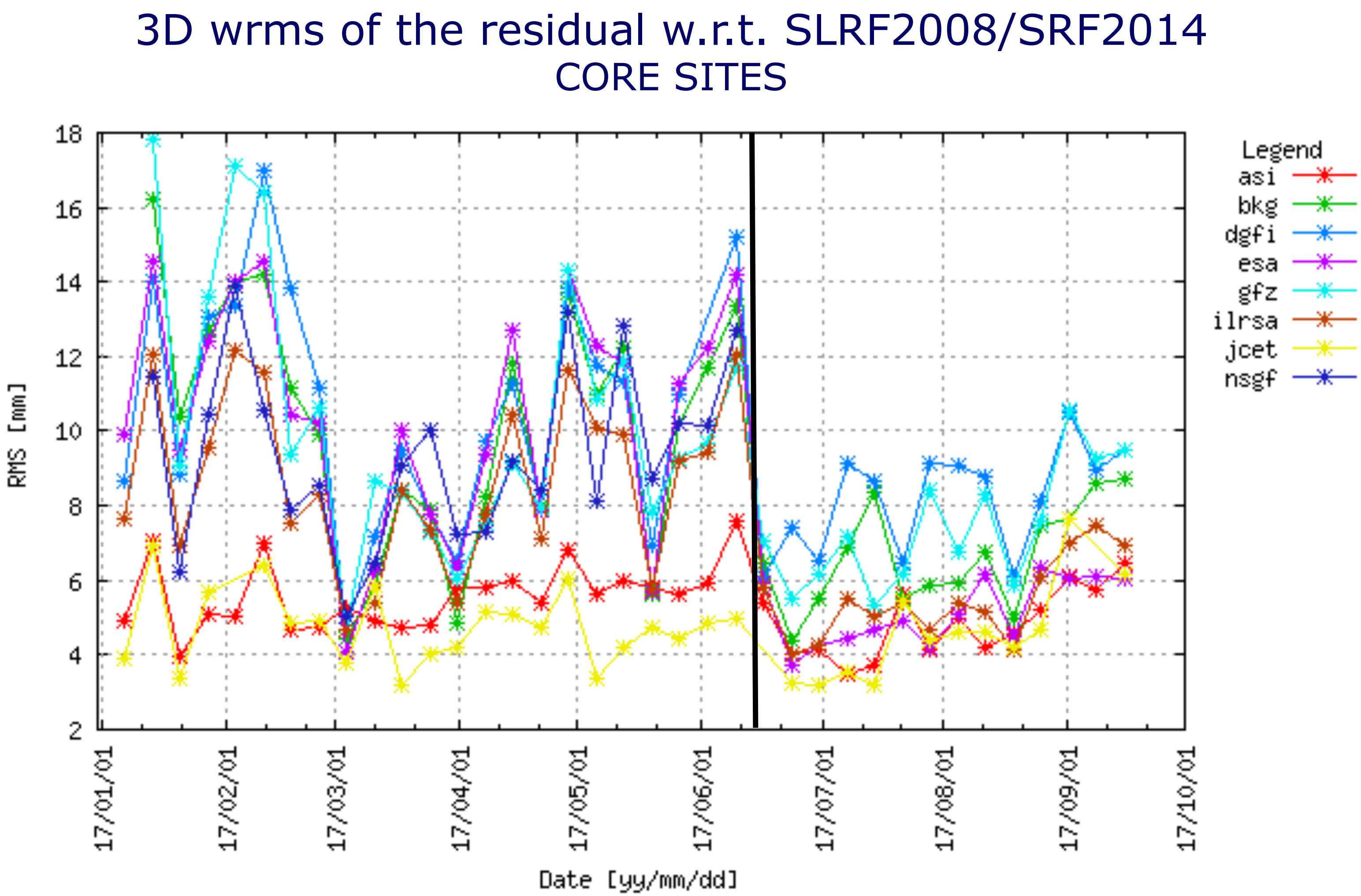


Daily solutions

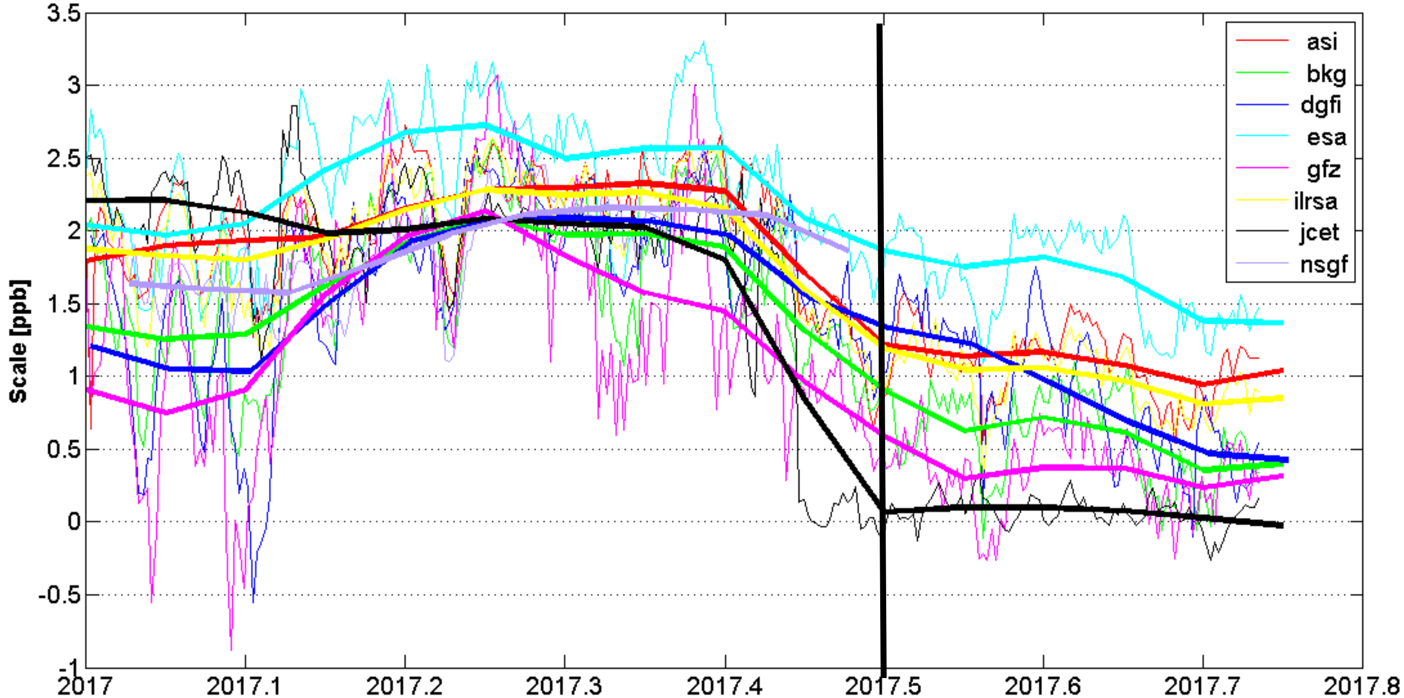
3D wrms of the residual w.r.t. SLRF2008/SLRF2014
CORE SITES



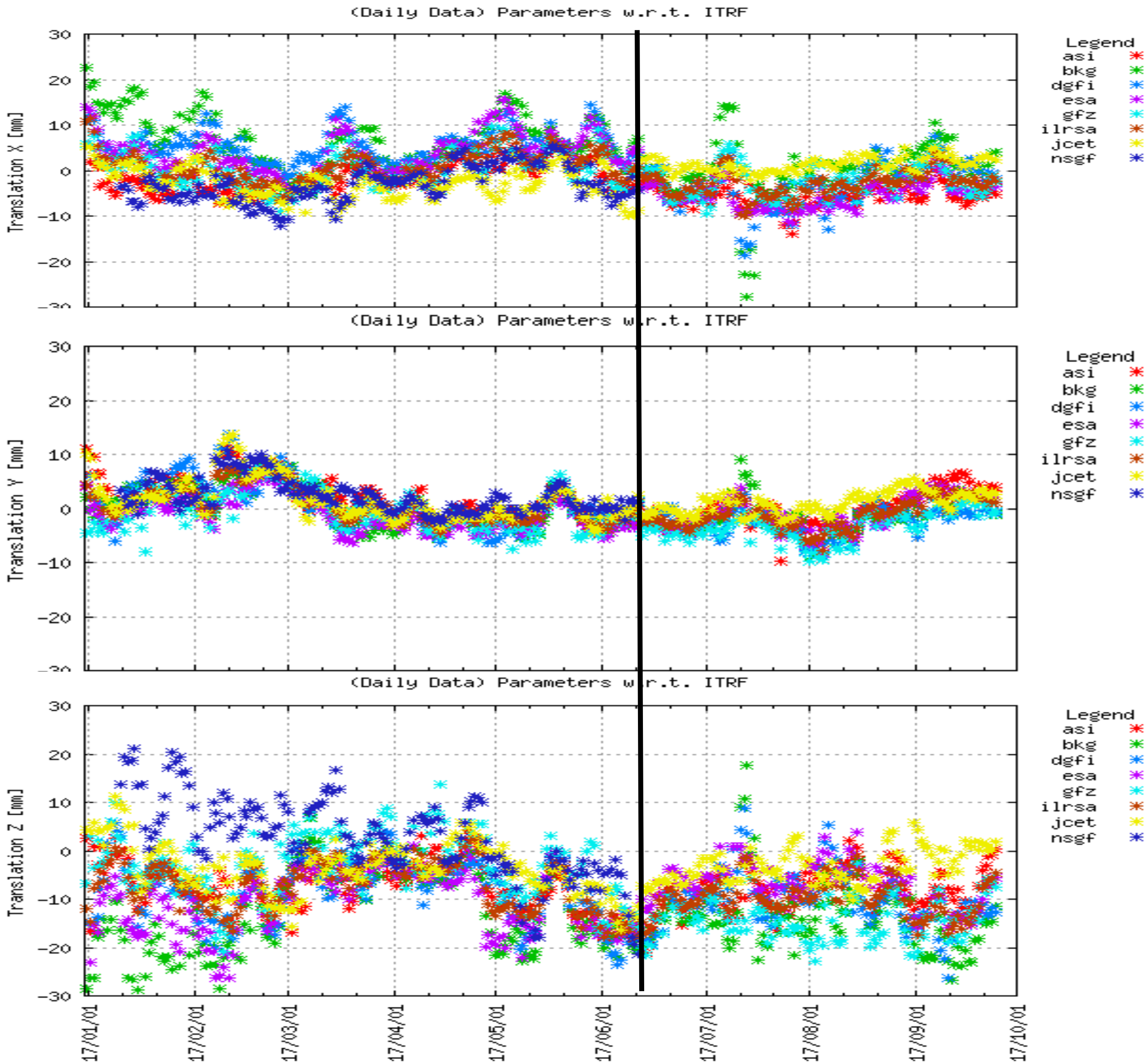
Weekly solutions



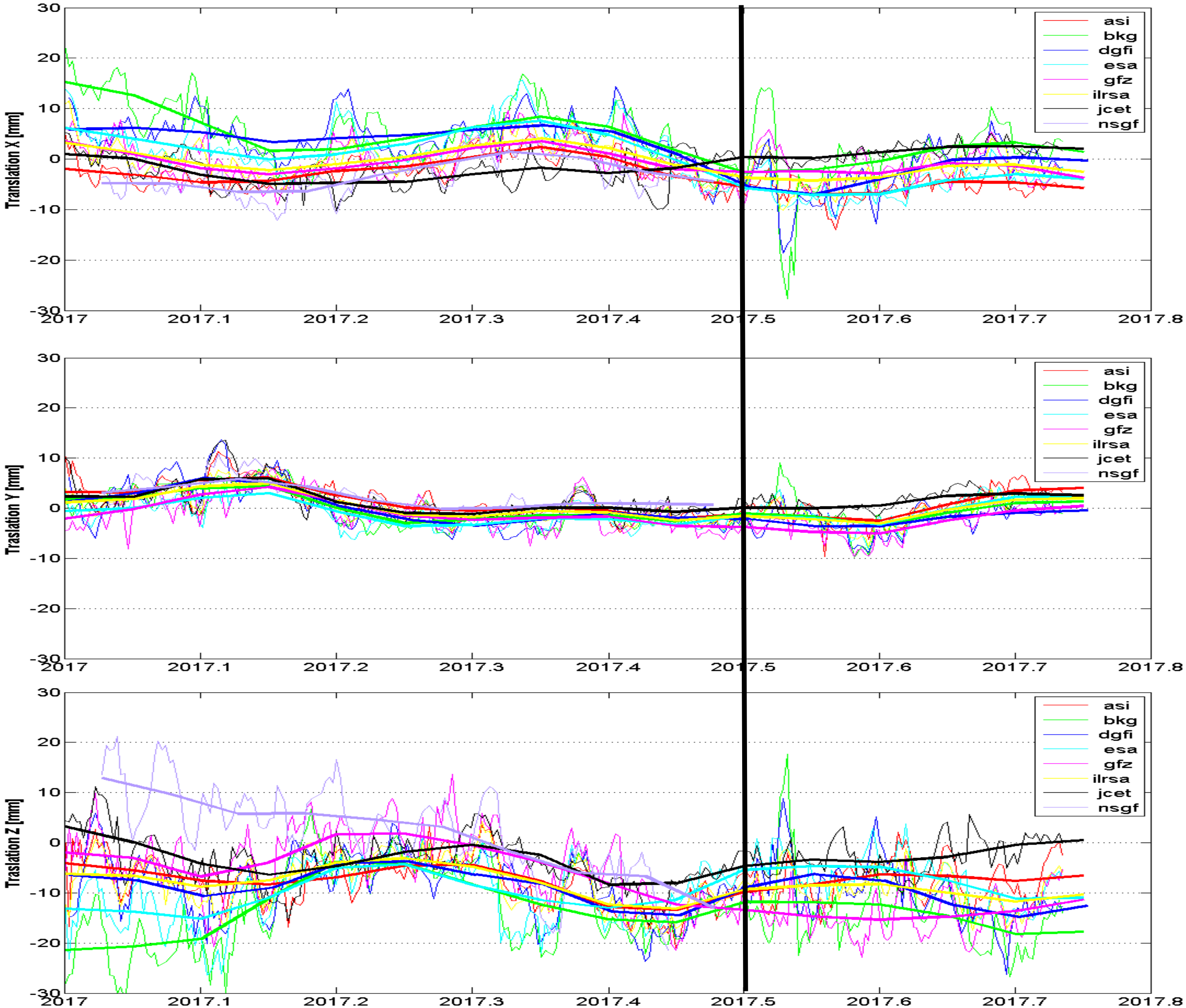
Scale from daily solutions



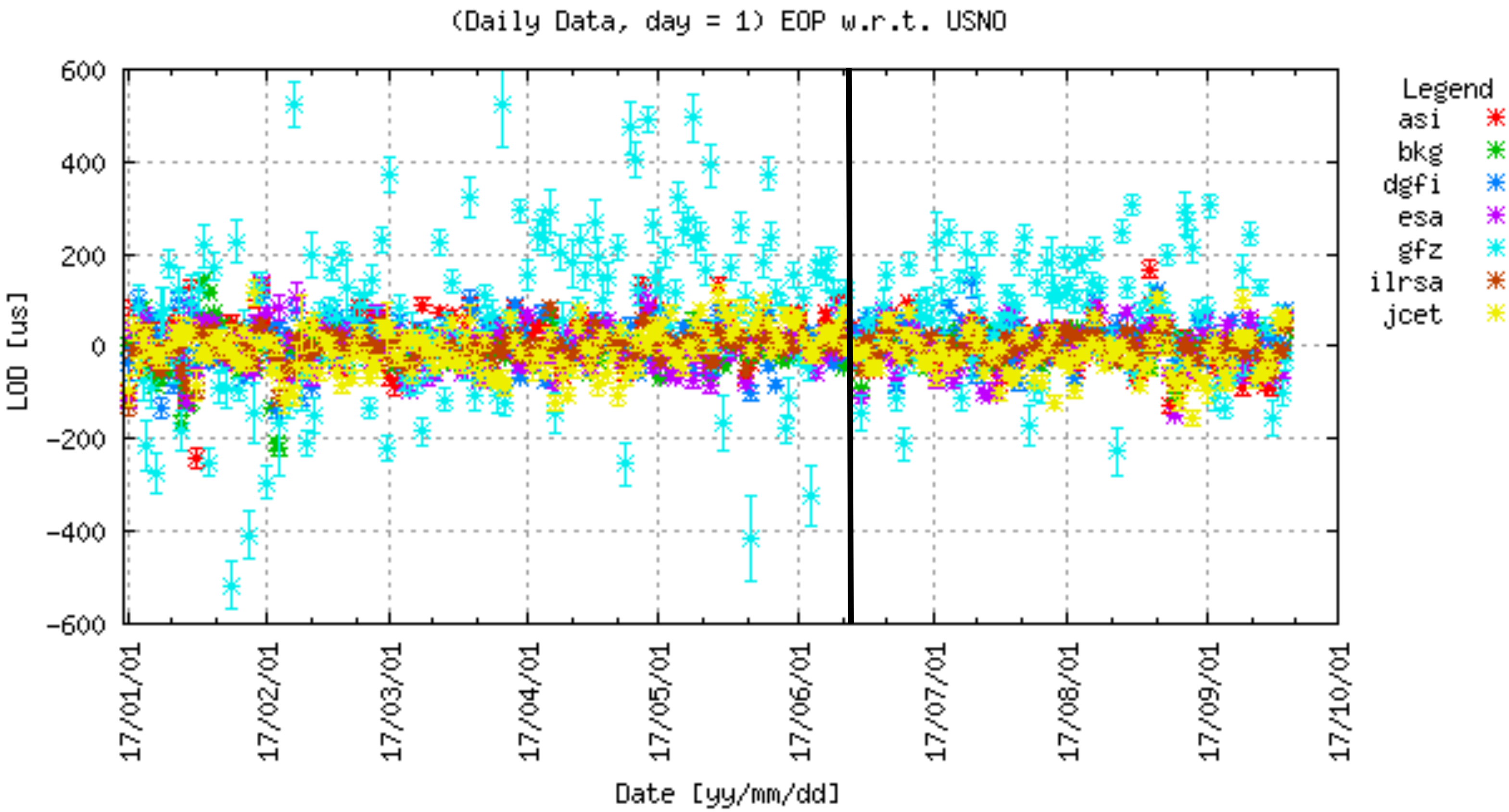
Geocenter motion from daily solutions



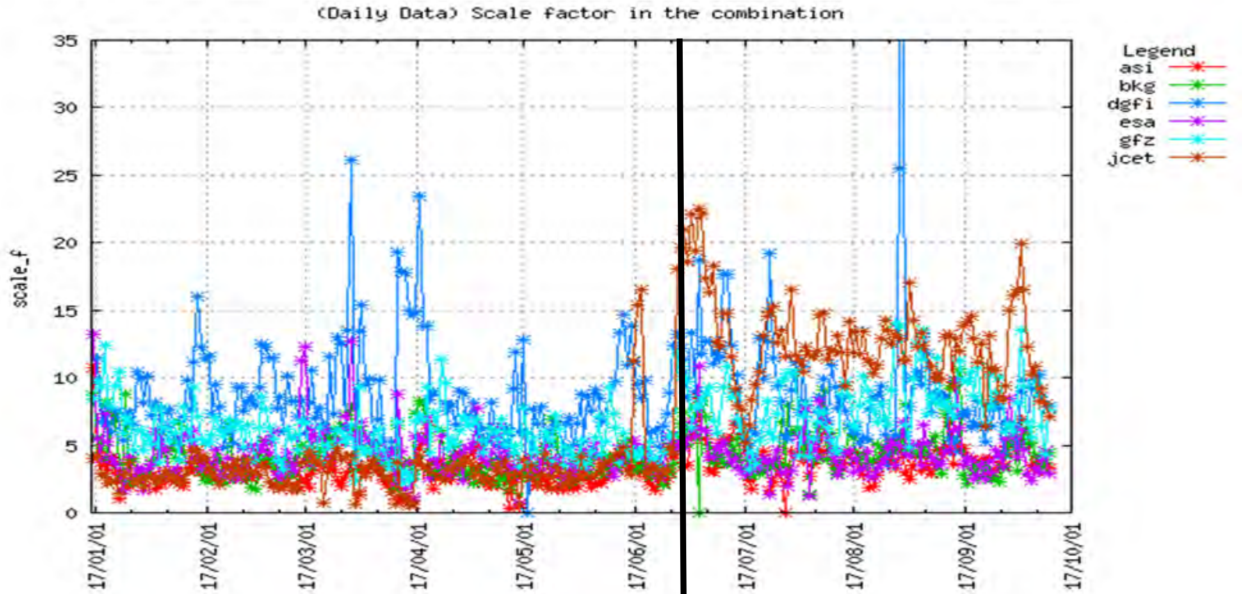
Geocenter motion from daily solutions

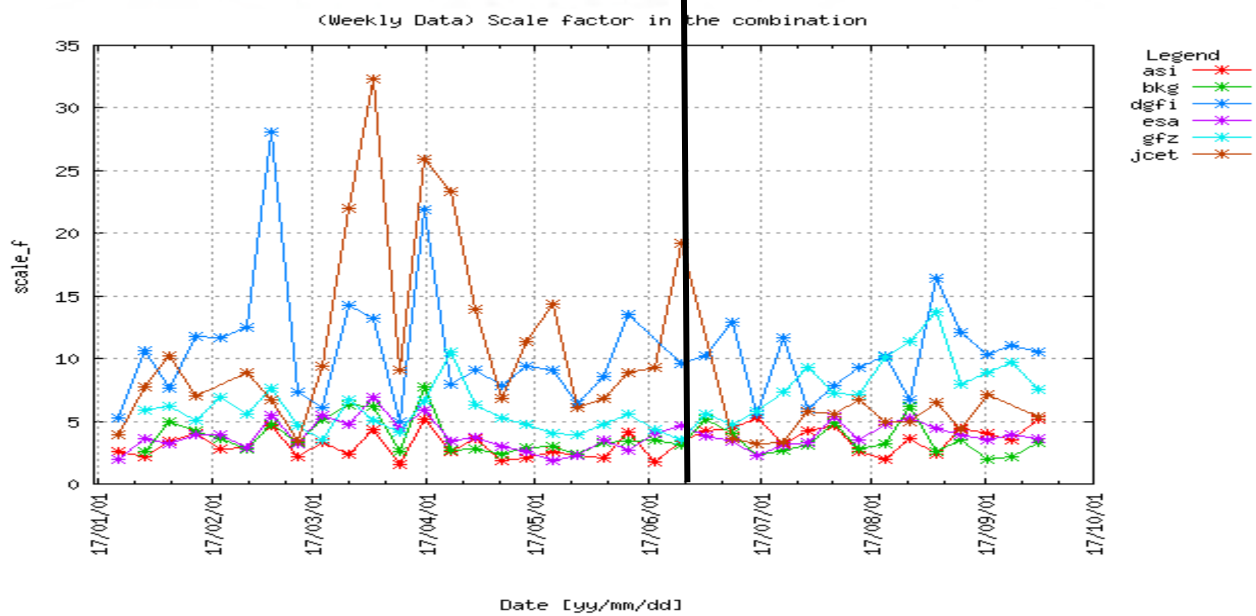


LOD from daily solutions



Combination scale factor

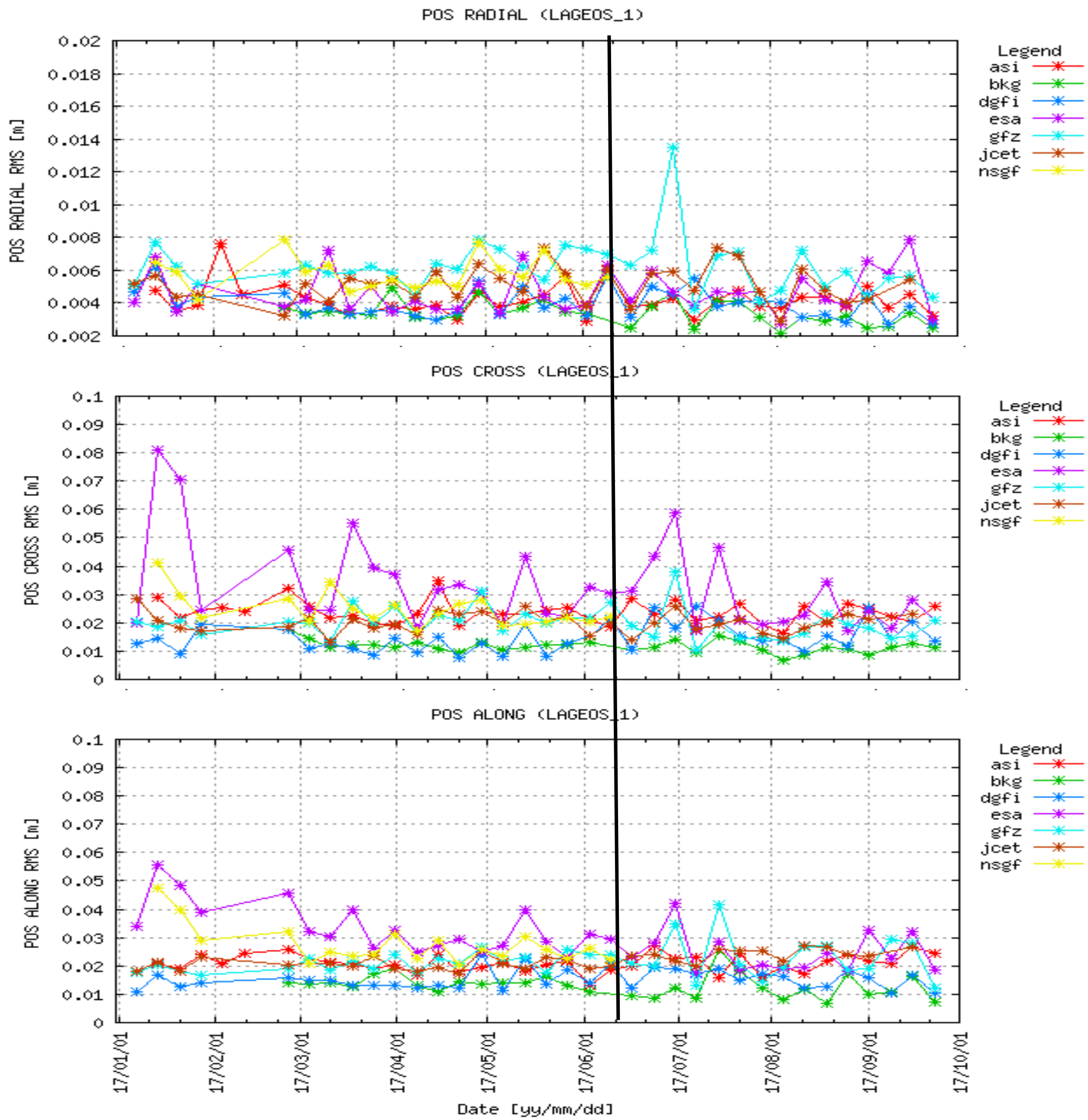




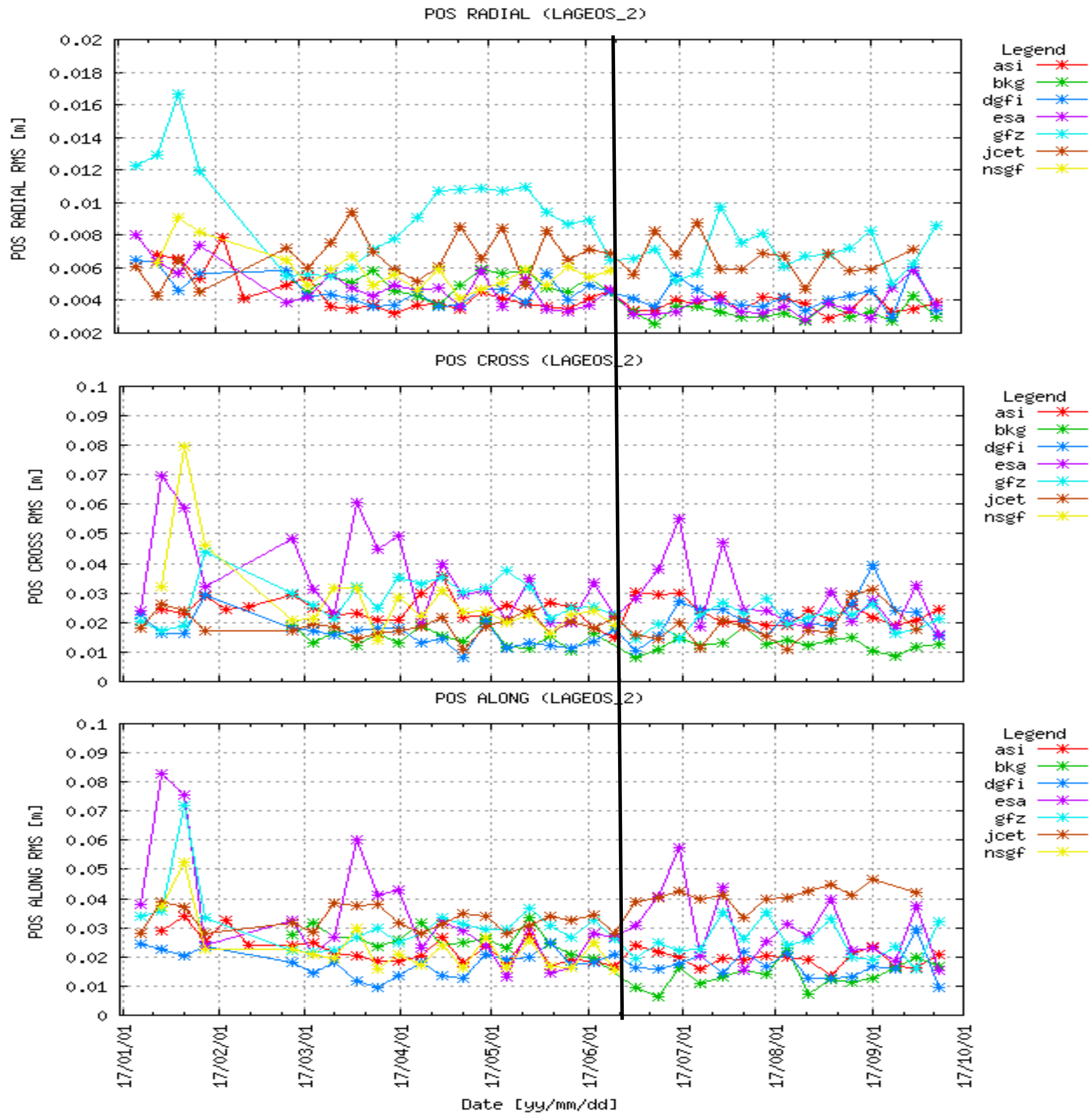
ILRS orbits

- Official ILRS orbits available since May 2016 using the weekly solutions
- Actually 6 ACs contributing to LAGEOS orbits:
  - GRGS orbits not available
  - NSGF orbits not available since June 2017
- 5 ACs contributing to ETALON
  - GFZ orbits not available
  - GRGS orbits not available
  - NSGF orbits not available since June 2017
- The ACs orbits agreement is checked in terms of rms of the residuals w.r.t. the combination

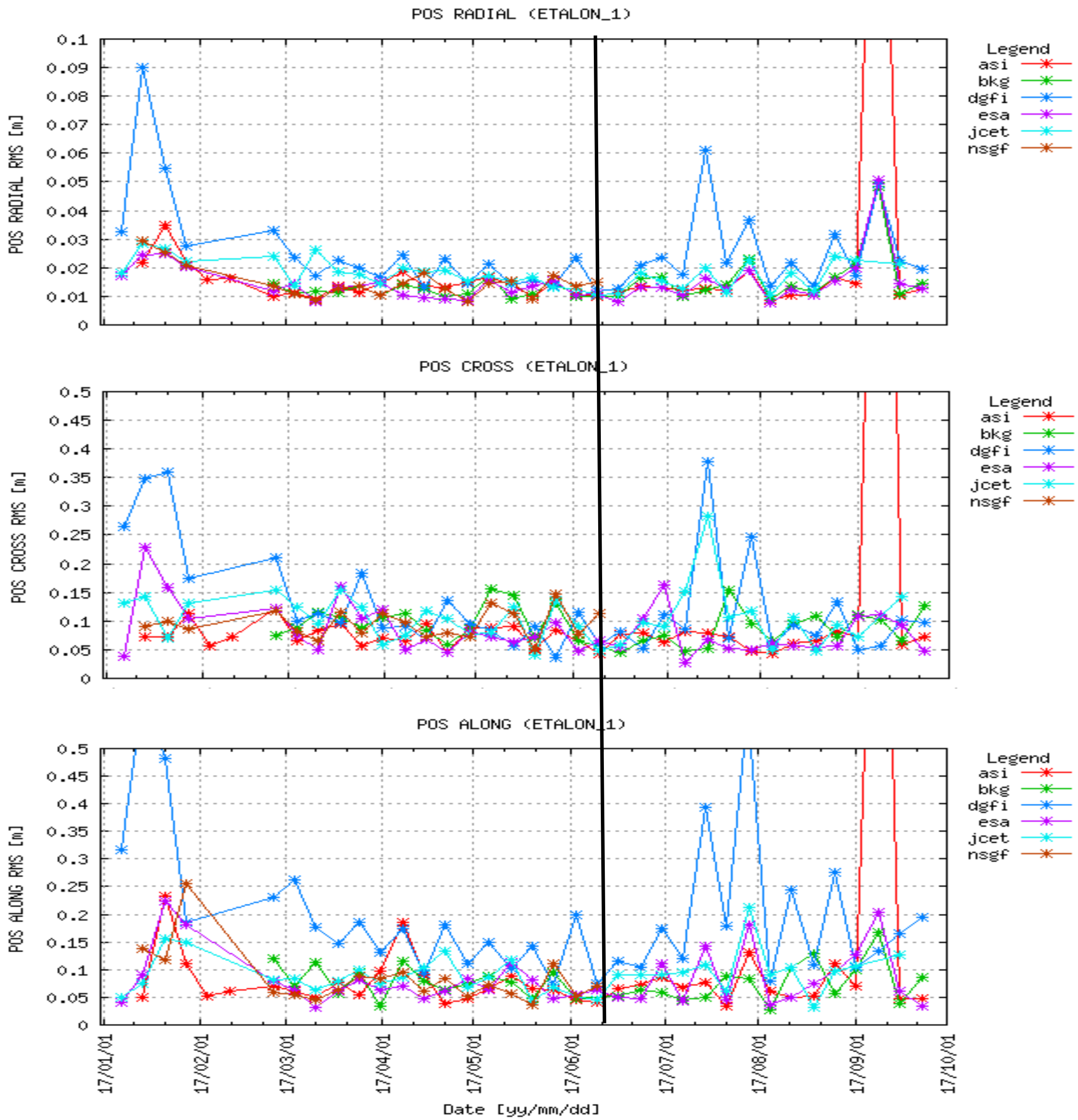
LAGEOS1 orbits – RMS of residuals w.r.t. combination



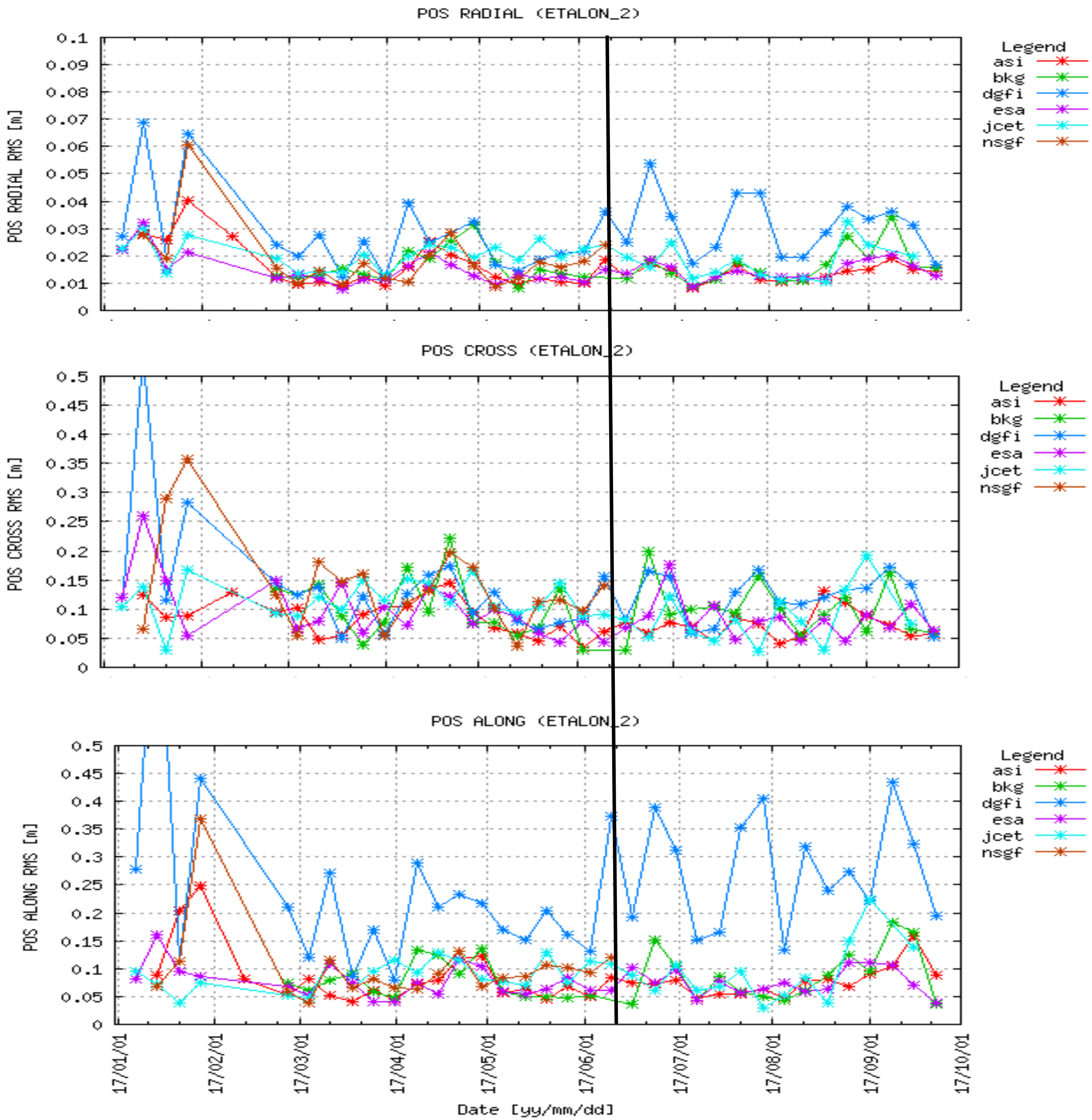
LAGEOS2 orbits – RMS of residuals w.r.t. combination



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



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



ILRS AC orbit agreement

	Radial (mm)	Cross-track (mm)	Along-track (mm)
LAGEOS1	5	20	21
LAGEOS2	5	22	24
ETALON1*	16	99	86
ETALON2*	16	93	81

*DGFI not included

SYSTEMATIC ERROR PILOT PROJECT

ILRS Pilot Project on systematic errors

- Weekly estimation of coordinates, EOP and biases
- Time frame: 2005-2008
- Data: L1 and L2
- time series with separate biases
- New conventions for wavelength indication in the SINEX files

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.

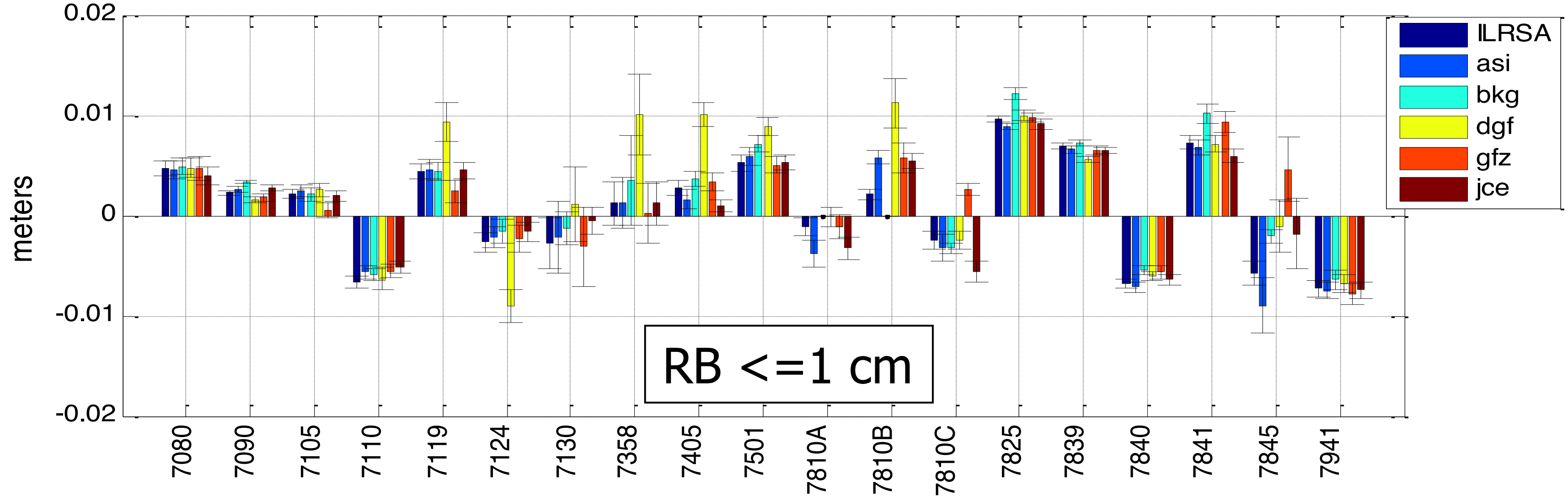
ILRS Pilot Project on systematic errors

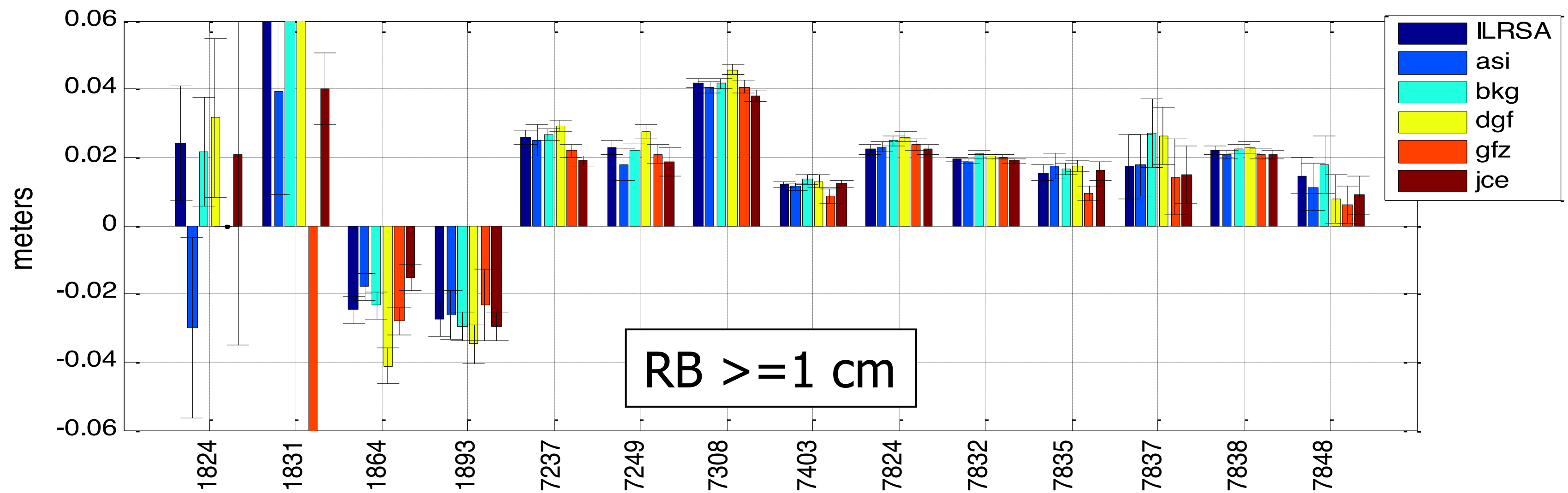
AC	Version of submission
ASI	v203
BKG	v201
DGFI	V202
ESA	none
GFZ	v201
GRGS	none
JCET	V202
NSGF	none

- AC time series without formal problems
- ~20 weeks not submitted by GFZ
- SINEX combination made last week,
- ILRSA v201 available at CDDIS and EDC

ILRS Pilot Project: LAGEOS-1

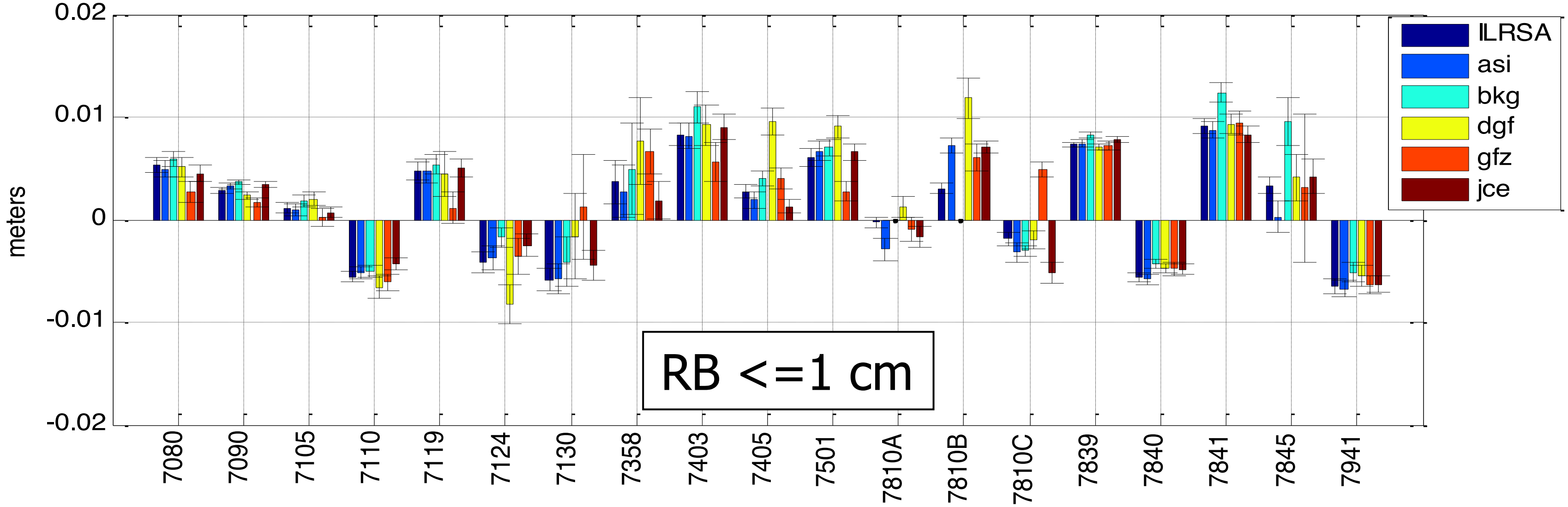
The Y-axis limits are different!

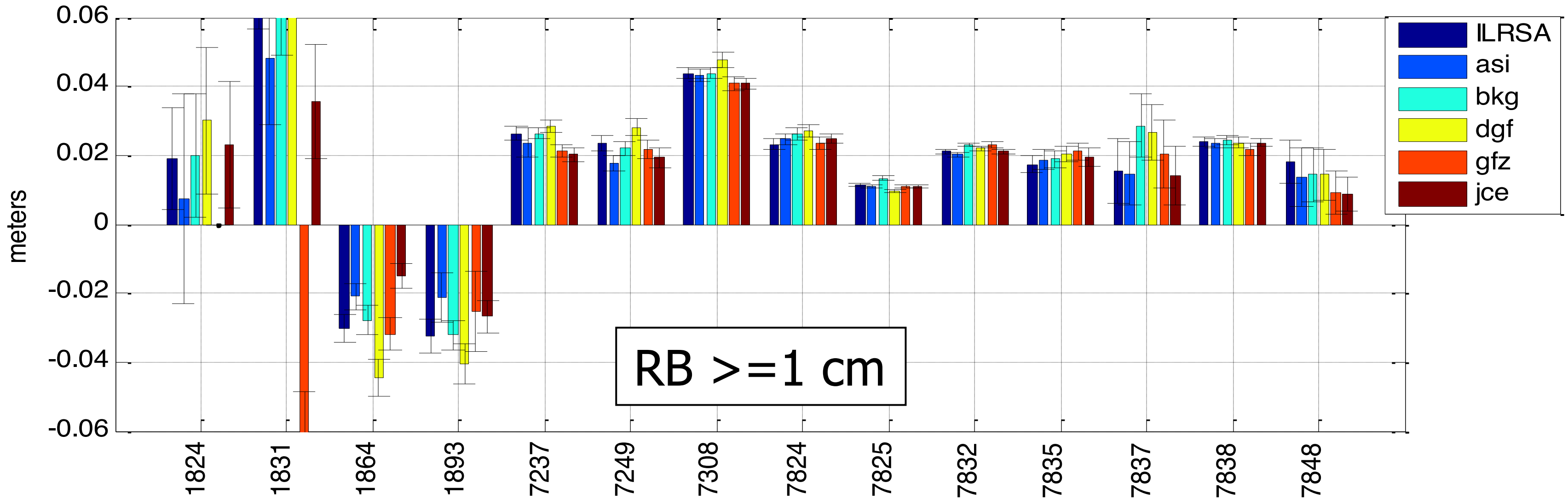




ILRS Pilot Project: LAGEOS-2

The Y-axis limits are different!





ILRS Pilot Project future

The ASC approach is:

- make a table of biases using the time series of combined range biases from 1983 up to now
- apply the bias values in the table for the official ILRS products
- keep the table updated

AND

- The UAW recommended to include applied R_B & T_B in SINEX file for next contribution to ITRF

Report DGFI AC

Horst Müller

Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

2017 ILRS Technical Workshop
Riga, Latvia, October 02 2017

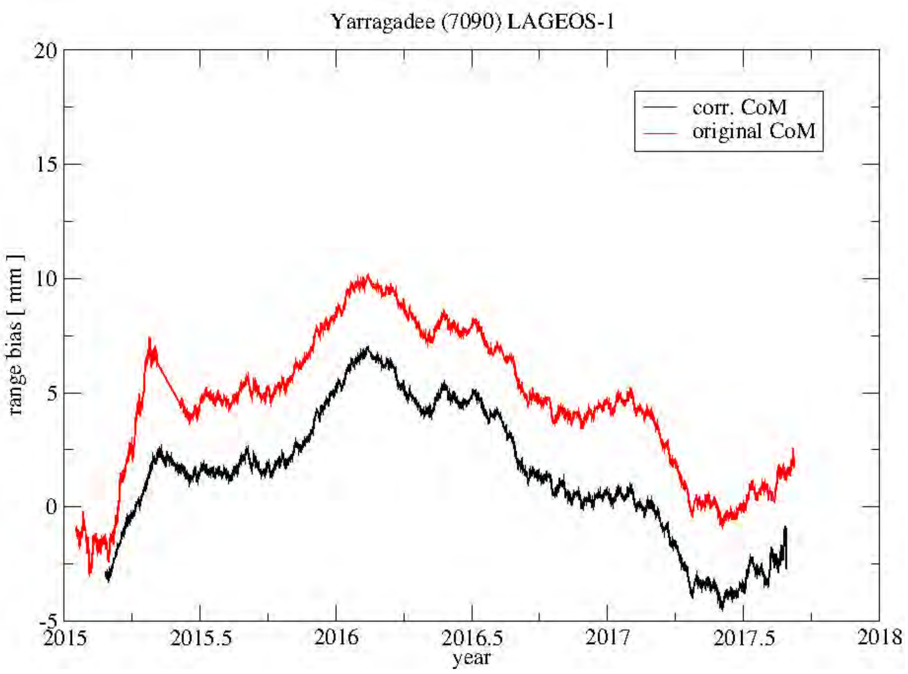
Routine work

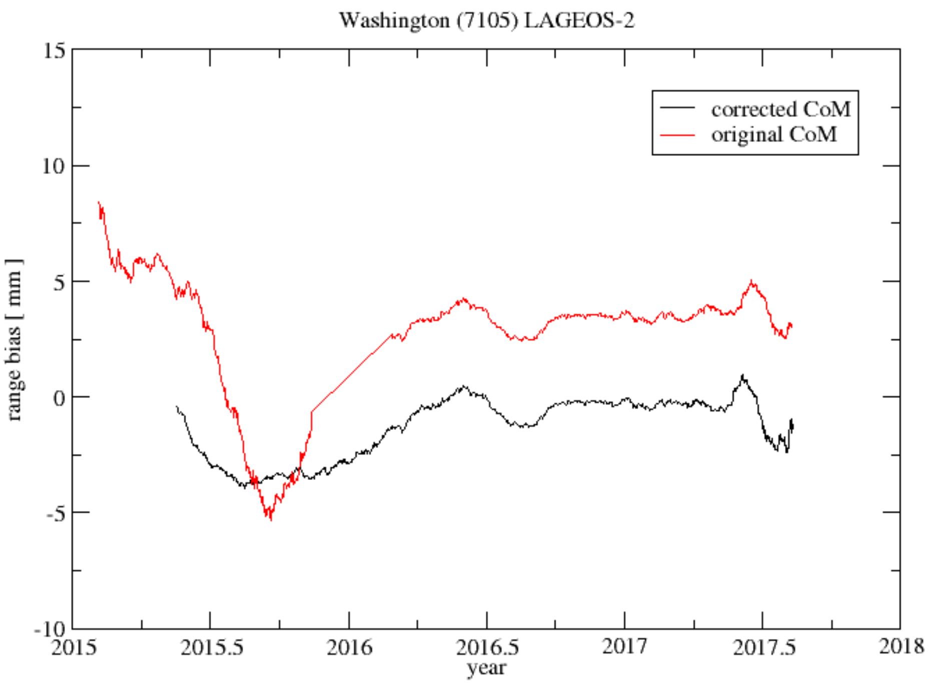
- Delivered products
  - Daily
  - Weekly
    - Sinex file
    - Orbit file in SP3 format
- Participation in pilot projects
  - Resubmitted sinex files, PP on range biases
- Data Handling file updated
  - New station Kunming 7119
  - Data problem Yarragadee June 6 2017
- Quality control, 24/7 every 4 hours

Test of Corrected Lageos CoM for NASA MCP stations

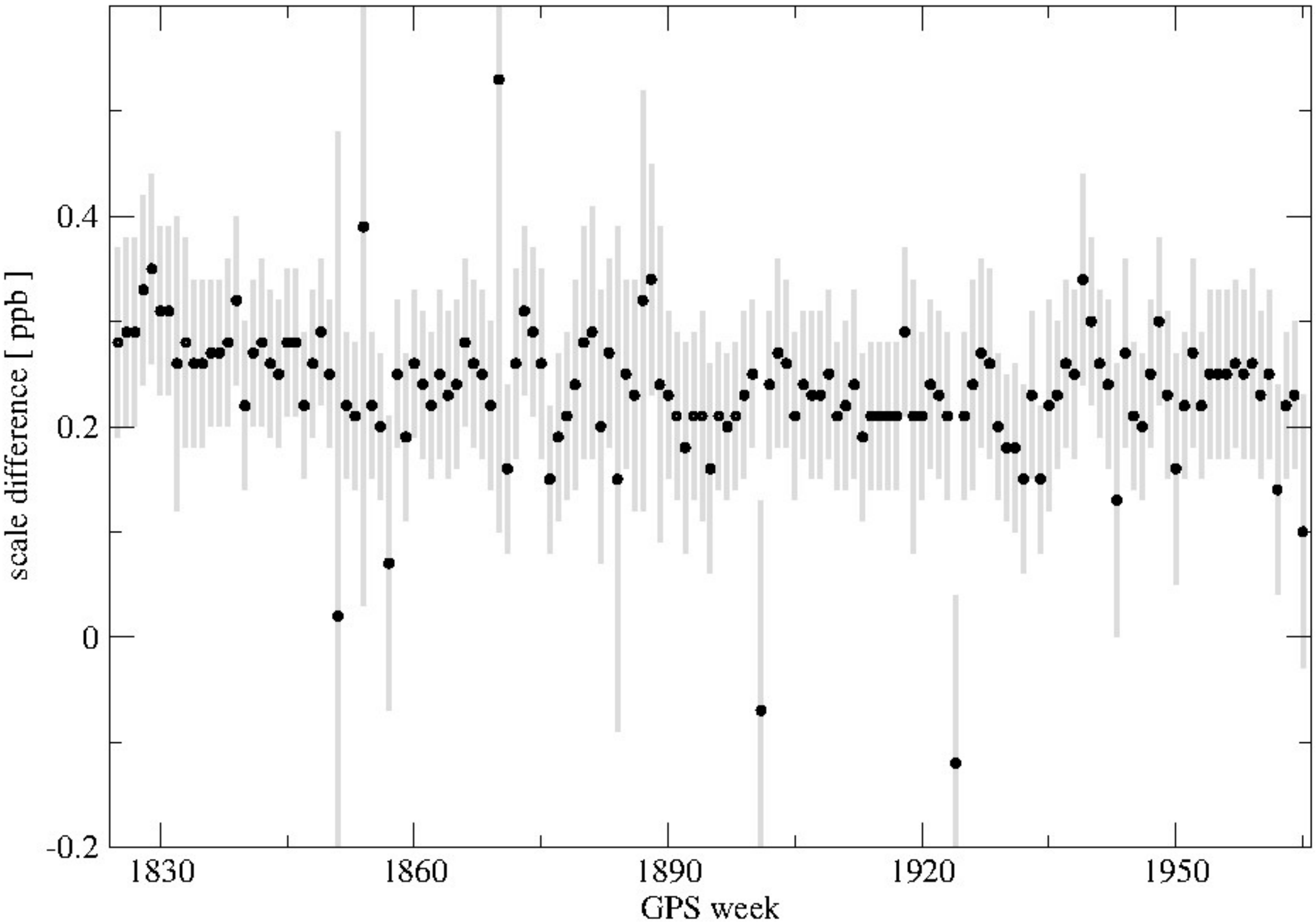
(provided by P. Dunn)

- New file with 2-4 mm shorter CoM correction
- Reprocessed weekly files from 2015 to now
- Range biases differ accordingly
- Scale of weekly solutions changed by 0.25 pbb

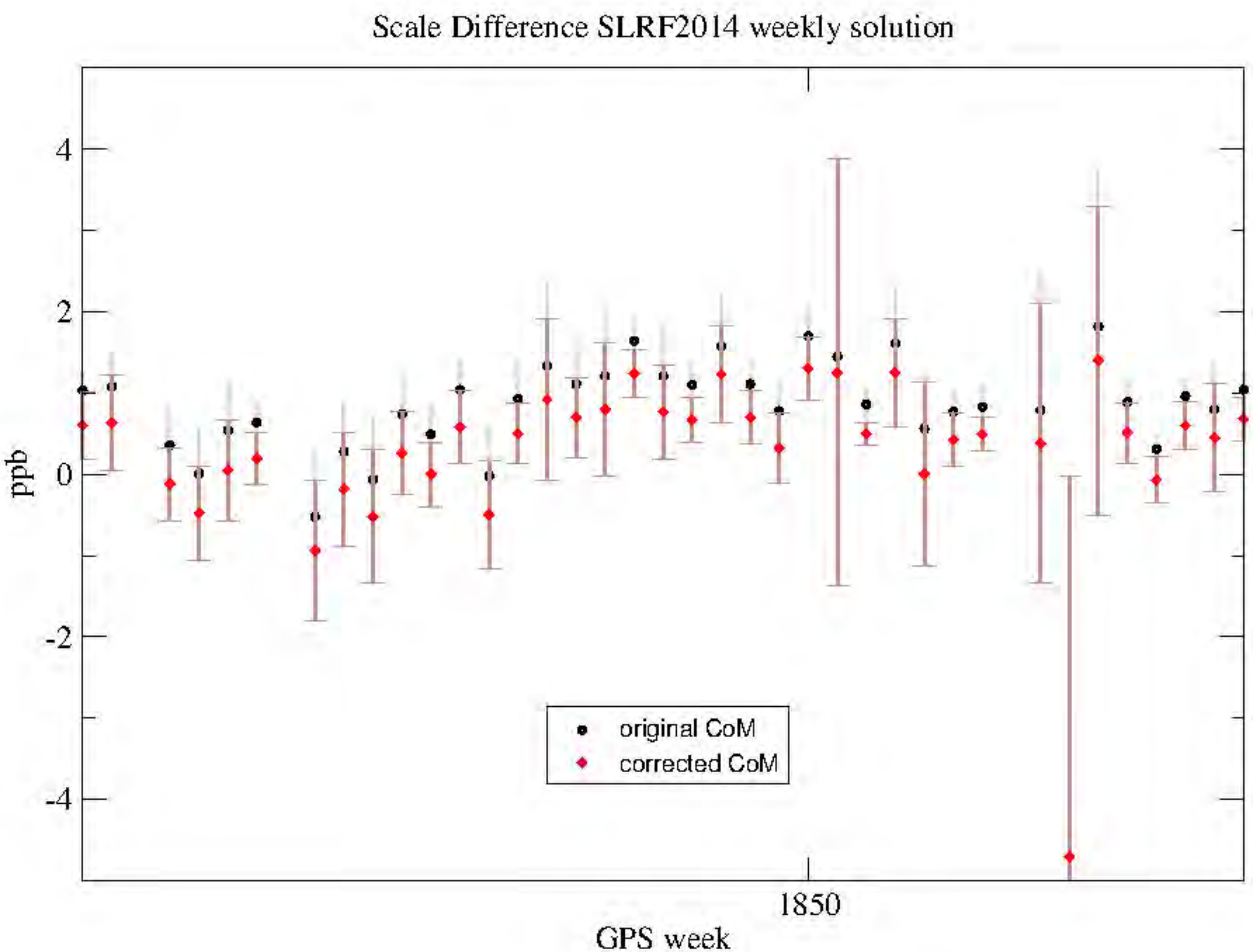




Weekly solutions, similarity transformation between two sets



Weekly solutions, similarity transformation to SLRF2014



GRGS ILRS AC: current status

Florent Deleflie[1], et al.

[1] Institut de Mécanique Céleste et de Calcul des Ephémérides/GRGS, Paris

1st October 2017

GRGS AC : headlines

- 2000 : GRGS/Toulouse (RBiancale et al.) may contribute to the AWG but not on a regular basis
- 2005 : FDeleflie gets a fix position as an astronomer
- 2005-2010 : GRGS/(OCA) is a new official ILRS AC : Gins / MATLO
- 2010 : FDeleflie leaves OCA and joins PO/IMCCE (GRGS/OP)
- 2012 : the location of OCA/Grasse is closed, and FDeleflie loses (w/o any transition phase) any access to the OCA IT : Set-up from scratch of a new architecture for the GRGS AC on the IMCCE/OP IT : Gins/locomotiv
- 2015, june : we disappeared from the ILRS combination for a couple of days, because of a catastrophic upgrade of the IMCCE IT
- 2015, autumn : the whole IMCCE IT is hackered, and some historical functionalities (internal, of the website) are lost,
- 2016, july, and then november : the whole IMCCE IT crashes down, and we discover that no backup are available

IMCCE : 2017 headlines

- Up to may 2017 : WE ARE DOWN
  - no support from the IT service
  - no back-ups
  - users must find their own solutions to fight against the problems
  - the head of IMCCE is fired in April 2017, as well as the previous IT manager
- From june 2017 : WE ARE UP
  - thanks to a new executive team which puts the whole situation right again concerning all issues within IMCCE
  - a new IT manager
  - a new IT architecture, fully documented, and robust. Back-ups correctly parameterized
  - 31st of AUGUST, 2017 : what was lost with the 2016 crash is partially recovered, as of December 2015 : I FINALLY GET AN ACCESS TO MY SCRIPTS !

GRGS AC : current status (1/2)

- Team : Florent Deleflie, D. Coulot, A. Pollet, F. Reinquin, A. Sammuneh, M. Gastineau (IT service), + 2 students
- SLR Data analysis : A new dedicated storage and computation space of the IT IMCCE system : dedicated machines.
- GINS-17 / and LOCOMOTIV 2017 package correctly set up.
- Changes of paths within the operational scripts still in progress
- A financial support for 2017-2018 by our scientific and administrative authorities : GOOD !

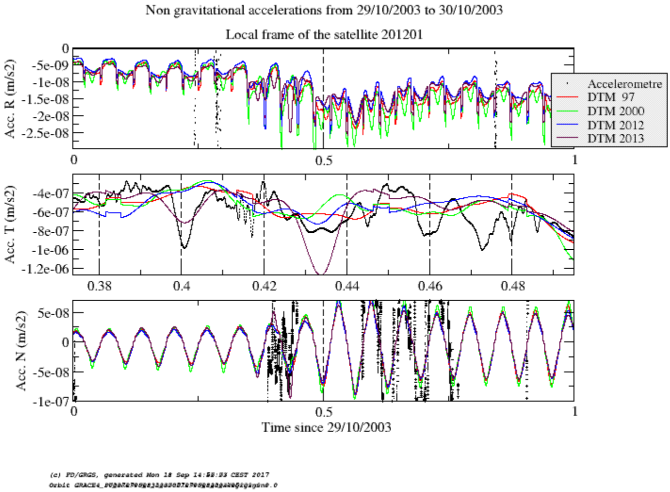
GRGS AC : current status (2/2)

- Let's hope a informal support from the ASC for an additional couple of days. Back to operational submissions by the end of next week (next issue on my TODO list)...
- ... and then our contribution to all the PPs and the operational products of the aSC
- ITRF2014 implementation ; new format of the TRF in GINS, automaticallly upgraded (including eccentricity files), no computation of the a priori SSCs outside GINS, new script for the generation of the SINEX
- Future : Parallelization of the operational scheme in IGN/LAREG, and access to the CNES cluster : robustness, efficiency, improvement of the codes. ALREADY partly in progress

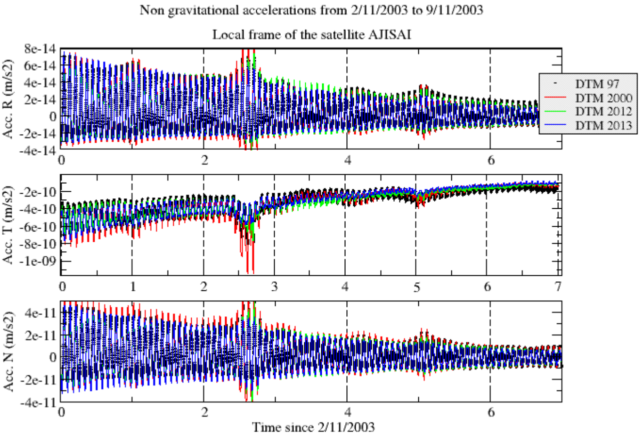
Studies over recent weeks

- Based on orbit computation ONLY, because scripts related to the combination resume only this month
- LARES orbit determination and parameterzation (master internship)
- Optimization (from geometrical point of view) of station scheduling (master internship)
- Perturbations induced on SLR satellite in case of major solar events (IAC presentation)

Examples of NG models validation from satellite perturbations : GRACE

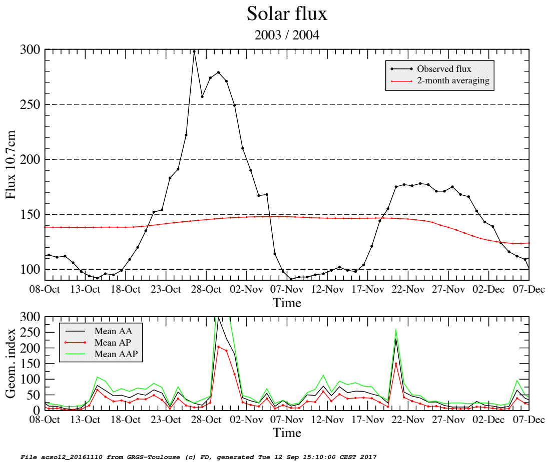


Examples of NG models validation from satellite perturbations : AJISAI

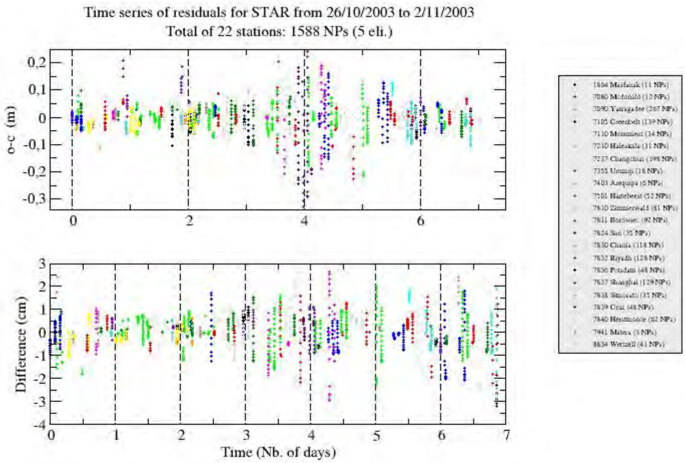


(c) PD/GRGS, generated Thu 14 Sep [illegible] CEST 2017
Orbit Ajisai_[illegible]

Solar activity : blow-up october 2003



How distinguishing the effects of the flare from the effects of the storms : Use of the mean flux instead of the "real" one



(c) PD/GRGS, generated Fri 8 Sep 18:57:39 CEST 2017
Files: STARLETTE_97_dff.170904_165200.170904_170313.gins.0 STARLETTE_97_dff_fluxmoyenne.170908_183743.170908_184858.gins.0

Conclusions

I hope each member of the ASC and the ILRS CB is ready to wait for an additional couple of days (end of next week, hopefully), before GRGS is contributing again

- I first had to organise the renewal of the full IMCCE IT, including the public service part
- the new architecture is ready and suitable for SLR analysis
- one final step before being operational again : generation of the SINEX files
- new capabilities and functionalities, to be in the future even more efficient than in the past (CNES cluster, up-to-date version of gins)

Finally back, by these days, to a nominal mode...

... close to the end of a really awful period for me.

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Gateway to the Earth

On centre of mass corrections

NSGF AC
Graham Appleby, José Rodríguez

ILRS ASC meeting. Riga, Oct-2017

Currently

- CoM correction tables derived from Otsubo & Appleby (2003)
- O&A 2003: empirical determination of satellite impulse response function (IRF)
    - Cube corner reflectivity + LRA geometry
    - Empirical fit of reflectivity parameter
    - Employ IRF to compute CoM for different systems
- Main factors affecting CoM well understood (return rate, transmit pulse length, electronic delays)
- But: some info not readily available (detector response), or even probably nonexistent (discriminator settings, specific operation setup)

Currently

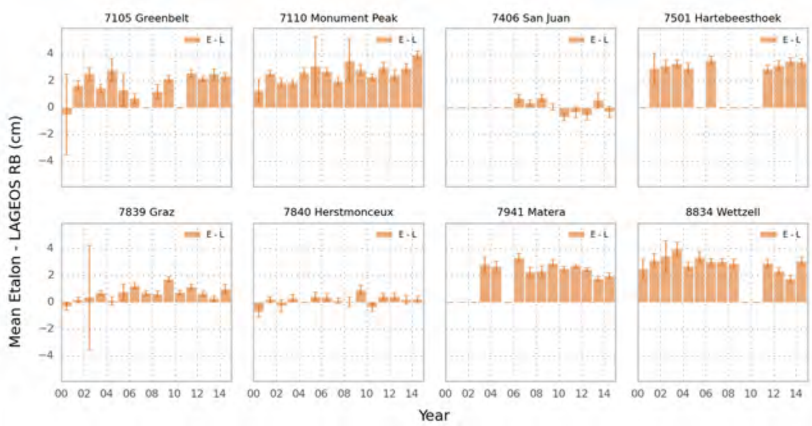
- Compromise, workable solution adopted: model what is known ("perfect is the enemy of good")
- O&A 2003 and CoM tables served the community well
- Consider the alternative: a single CoM correction for every system in existence since the beginning of time

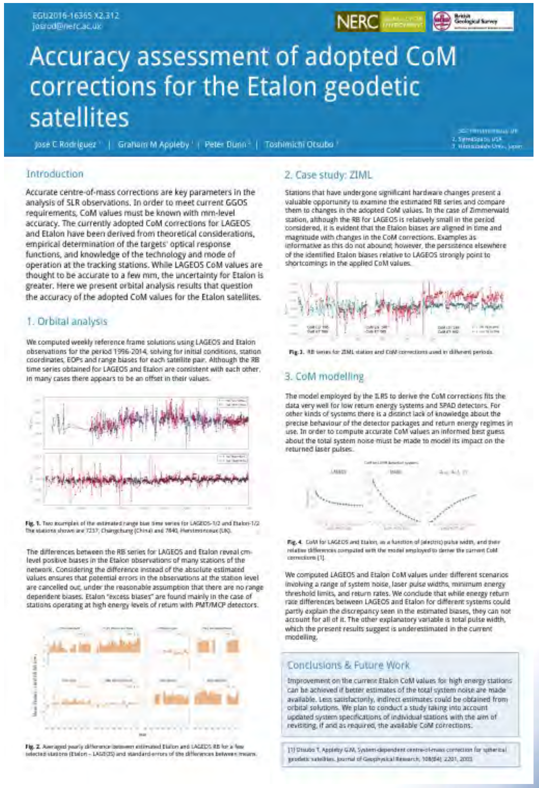
“The LAGEOS 2 range correction is very much dependent on receiver instrumentation. The wide variation in ground-based SLR system instrumentation suggests that range correction values reported in this document may lead to small systematic errors unless receiver operation is characterized properly using the LAGEOS 2 impulse response function. […] The range correction for LAGEOS taken from this report […] may be in error not from lack of configuration control but because of undetermined bandwidth and unique instrument limitations which may introduce a range bias. The range correction of the LAGEOS series satellites are constants and will not change. What will change is how new SLR systems will interpret the LAGEOS LRA as instrumentation and systems evolve in the future”.

Prelaunch Optical Characterization of the Laser Geodynamic Satellite (LAGEOS 2). Minott et al. NASA-TP-3400. Sep-1993

Evidence for insufficient model quality

- Range bias time series for Etalon satellites
- EGU2016
- ASC meeting Vienna 2016





- Problem: RB estimates only flag the existence of an issue
- Rodriguez et al. Accuracy assessment of CoM corrections for Etalon geodetic satellites. Potsdam, 2016: CoM model augmented:
    - Separation of optical and electronic effects
    - Empirical detector signatures
    - Intensity effects modeling (Poisson statistics)
    - Constant fraction timing
- Etalon CoM results change significantly

Table 1 – Etalon CoM results for two example configurations

	CoM (mm)	
	current value	this work
150 ps FWHM ITT F4129f	603(5)	587
50 ps FWHM Photek210	610(3)	600

- Consequences for all satellites? Yes
- But effect less dramatic for smaller targets, e.g.:

Table 2 – LAGEOS CoM results for two example configurations

	CoM (mm)	
	current value	this work
150 ps FWHM ITT F4129f	249(1)	245
50 ps FWHM Photek210	250(2)	248

- Significant? For LAGEOS, for some stations, probably. Likely not at all for the smallest satellites

- The correlation between RB and CoM is perfect: RB conveys no specific information about CoM errors
- So: single-satellite RB time series can not inform CoM modeling/parameterisation choices. This is a logical impossibility
- RB series from multiple satellites may inform about relative differences about CoM issues, but this comes with tremendous caveats (orbit height differences, LRA sizes, operation settings) which demote this approach to a blunt, tentative, qualitative level

- As a consequence, the argument must stem from physical/engineering considerations about how the measuring process works
- Agreement with RB estimates is a nice thing to have, not a quantitative driver (*)
- CoM modeling is to be carried out without any regard for the computed RB
- Comparisons come later
- Elephant in the room: LAGEOS 2 pre-launch testing results

(*) One might as well solve for "CoM Bias" and call it a day

- No single value can possibly “fix” the time series (1 mm is truly a hard goal)
- Year-to-year variations are in many cases higher than the 2-4 mm attributed to CoM
- Horst’s tests: 0.25 ppb. Important, but a fraction of the 0.75-1.00 ppb total scale change found with RB estimation
- RB estimation is the only solution to extract the maximum accuracy out of SLR
- Considering all this, the urgency for tweaking existing CoM models is not justified

At NSGF

- Our work to **update** the CoM models is ongoing
- Plan: apply it systematically to all system configurations/targets
- Input:
  - Detector data (system logs when lacking)
  - Calibration RMS, NP return rates
  - Other details: from the literature and/or direct inquiry (e.g. typical threshold and discriminator settings)
- Status:
  - IRF from all satellites available
  - Updating IRF from LAGEOS, Ajisai and Etalon to make use of best possible data (all kHz + Poisson filtering + data stacking)
  - Input data collection to be completed

The incredulity of Saint Thomas. Caravaggio, 1602

- Never do an experiment without first knowing what the result will be
- D. Arnold proposal to range to a target designed to respond like LAGEOS
- Simpler experiment ongoing at Herstmonceux: what's true for two reflectors must be true for 426
- No surprises expected (we can model this) , but interesting to see empirically the upper return rate limit of single photon data and the CoM correction continuum

In conclusion

- Curent CoM tables are not “wrong” or “unfair”, but simply from a model that can be improved upon
- RB on its own must not inform CoM modeling choices
- NSGF working towards CoM update for all systems and all geodetic spheres
- Simple tweaking of model parameters insufficiently justified

Thank you

The JCET AC/CC Report to the ILRS ASC

E. C. Pavlis and M. Kuzmicz-Cieslak

Riga, Latvia,

October 1, 2017

Outline

- Operational Products Status
- Network support (Quarantined and Validated stations, etc.)
  - NASA systems' switch to ET units in place of the old TIUs
- Station Systematic Error Monitoring Pilot Project
- LAGEOS/LARES Data distribution in elevation and pass duration
- Release of SLRF2014 (UPDATE)
- UAW 2017 proceedings and implications for the ILRS ASC, etc.
- Journal of Geodesy ILRS Special Issue Status Report

Operational Products Status

- Daily and Weekly series delivered routinely and consistently by six of the eight ACs
- We have not received contributions from GRGS for over a year
  - Latest news from Florent indicate that a restart is imminent (AGAIN)
- 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!
- ACs that do not participate in test PPs and demonstrate their ability to deliver quality products, delay us from wrapping up PPs and moving to the next phase or PP. We need to establish a process to move such cases to the ACC group and move on, until they can recover and come back.

Currently Quarantined Sites

Quarantine Stations

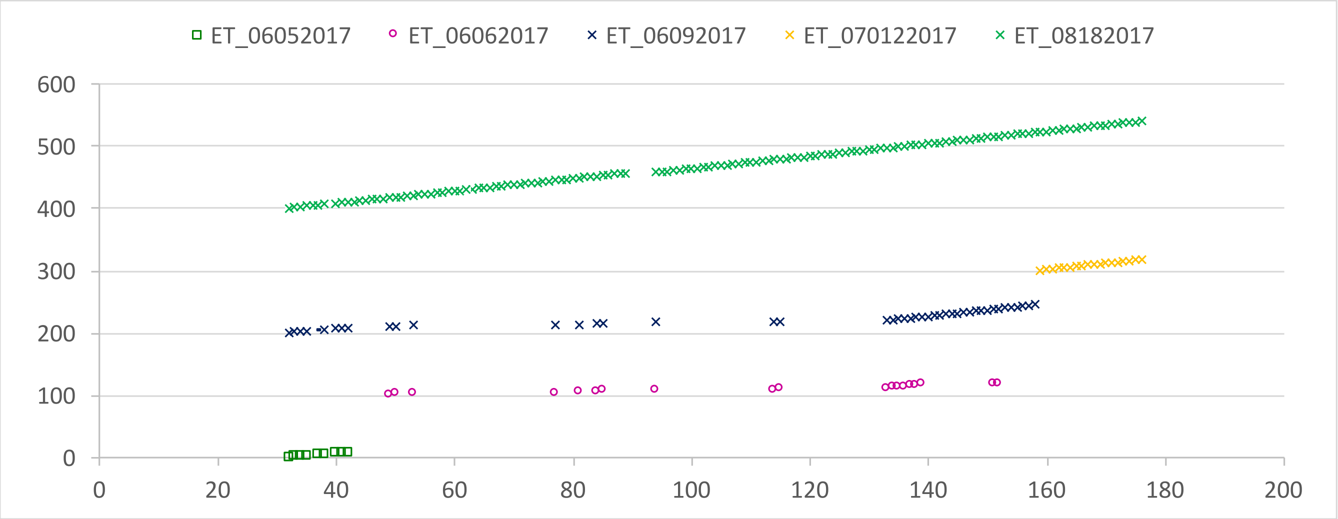
Station	Code	Site	DC	SOD	DOMES	First Data	Last Data	
1831	LVIL	Lviv, Ukraine	EDC	18318501	12368S001	2002-07-01	2009-11-26	2864 day(s)
1864	MAIL	Maidanak 1, Uzbekistan	EDC	18645401	12340S002	1992-06-02	2007-10-29	3624 day(s)
1888	SVEL	Svetloe, Russia	EDC	18889801	12350S002	2012-02-03	2017-05-26	127 day(s)
7231	WUHL	Wuhan, China	CDDIS	72312901	21602S004	2000-08-26	2005-12-18	4303 day(s)
7308	KOGC	Koganei, Japan (CRL)	CDDIS	73085001	21704S002	1995-02-10	2015-01-07	996 day(s)
7358	GMSL	Tanegashima, Japan	CDDIS	73588901	21749S001	2004-09-01	2017-09-19	11 day(s)
7395	GEOL	Geochang, Republic of Korea	EDC	73956501	23910S001	0000-00-00	0000-00-00	None day(s)
7406	SJUL	San Juan, Argentina	EDC	74068801	41508S003	2006-02-23	2014-11-19	1045 day(s)
7503	HRTL	Hartebeesthoek, South Africa	EDC	75036401	30301S010	0000-00-00	0000-00-00	None day(s)
7806	METL	Metsahovi, Finland	CDDIS	78067601	10503S014	1998-09-06	2005-05-20	4516 day(s)
7816	UROL	Stuttgart, Germany	EDC	78165201	10916S001	0000-00-00	0000-00-00	None day(s)
7819	KUN2	Kunming, China	EDC	78198201	21609S004	2017-01-23	2017-09-29	1 day(s)
7824	SFEL	San Fernando, Spain	EDC	78244502	13402S007	1999-04-08	2017-07-01	91 day(s)
7831	HLWL	Helwan, Egypt	EDC	78314601	30101S001	1983-10-25	2007-12-30	3561 day(s)
7832	RIYL	Riyadh, Saudi Arabia	EDC	78325501	20101S001	1996-01-30	2012-03-14	2026 day(s)

Greenbelt (MOB7) 7105 TIU-ET Stats

MISSION or s/c	AVG	STD	COMMON NUMBER of RANGES	Mission Altitude (km)	Orbit Class	GRANT AVG	STD	COMMON NUMBER of RANGES per Orbit Calss
SWARMA	-4.21	1.72	35	460	LEO			
SWARMB	-4.57	3.38	25	460	LEO			
TADEMX	-3.45	2.81	58	514	LEO			
SWARMC	-3.56	2.69	27	530	LEO			
KOMPSAT5	-4.28	3.25	52	550	LEO			
LARETS	-2.75	2.30	22	691	LEO			
CRYOSAT2	-4.37	1.92	76	720	LEO			
SARAL	-3.76	3.21	38	814	LEO			
SENTINEL3A	-3.75	1.88	65	814.5	LEO			
STELLA	-3.89	2.10	44	815	LEO			
HY2A	-4.21	1.91	40	971	LEO			
STARLETTE	-4.58	2.04	68	1100	LEO	-3.98	0.65	550
JASON3	-3.77	2.48	86	1336	MEO			
JASON2	-4.39	2.44	105	1336	MEO			
LARES	-4.24	3.67	42	1450	MEO			
AJISAI	-3.95	1.75	89	1485	MEO	-4.04	1.17	322

GRAND AVG	**-3.99**	**0.57**	**872**

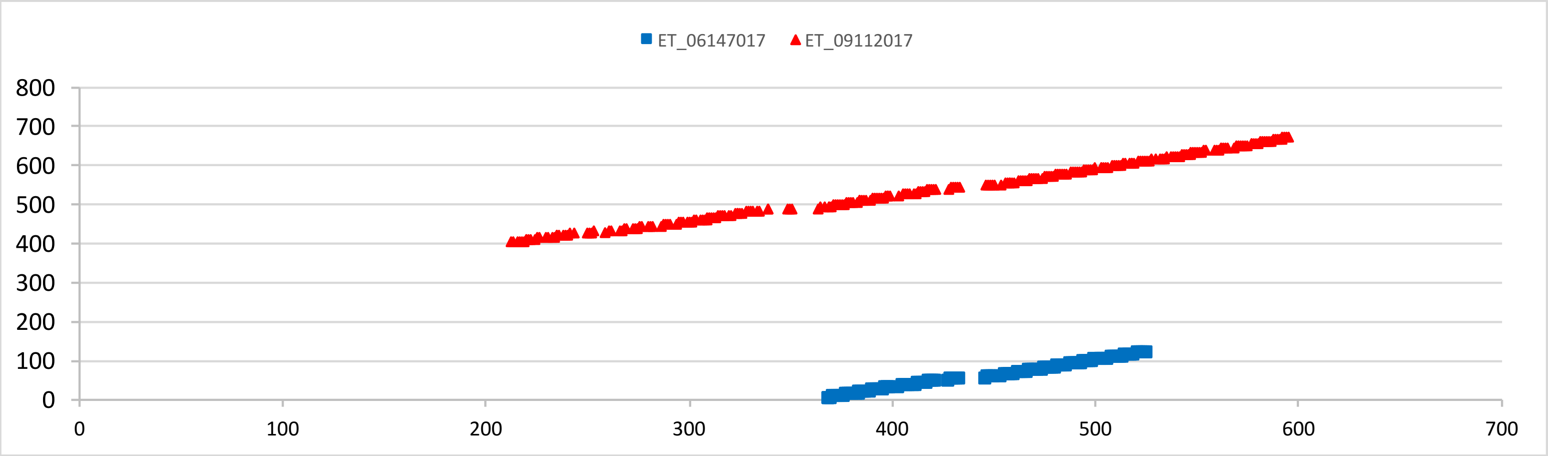
Yarragadee (MOB5) 7090 TIU-ET Stats



RELEASES	DATA SENT TO JCET/UMBC				CDDIS DATA SET	
SERIES	06.05.2017	06.06.2017	06.09.2017	07.01.2017	8.18.2017 Pt. 1	8.18.2017 Pt. 2
START	32	49	32	159	32	153
END	42	152	158	176	152	176
RECORDS	4570	16105	40353	15402	126513	23205

TIME PERIOD	ORBITAL CLASS	GRANT AVG	STD. DEV.	COMMON NUMBER of RANGES
BEFORE DOY 152	LEO	-1.43	0.63	7582
ET011	MEO	-1.63	0.93	4992
	HEO	0.92	0.48	1415
	GEO	0.16	3.51	49
	GRANT AVG	-0.17	0.35	14038
AFTER DOY 152	LEO	-1.62	0.82	11837
ET010	MEO	-1.49	1.16	6163
	HEO	1.20	0.56	2409
	GEO	0.56	2.21	149
	GRANT AVG	0.08	0.42	20558

Haleakala (T4) 7119 TIU-ET Stats



RELEASES	DATA SENT TO JCET/UMBC	CDDIS DATA SET
SERIES	**06.14.2017**	**9.11.2017**
START	2 (2017)	212 (2016)
END	159 (2017)	229 (2017)
RECORDS	19197	37894

TIME PERIOD	ORBITAL CLASS	GRANT AVG	STD. DEV.	COMMON NUMBER of RANGES per Orbit Class
	LEO	-0.32	0.85	8518
2017	MEO	0.05	1.23	7871
	GRANT AVG	**-0.20**	**0.70**	**16389**

Station Systematic Error Monitoring PP- SSEM

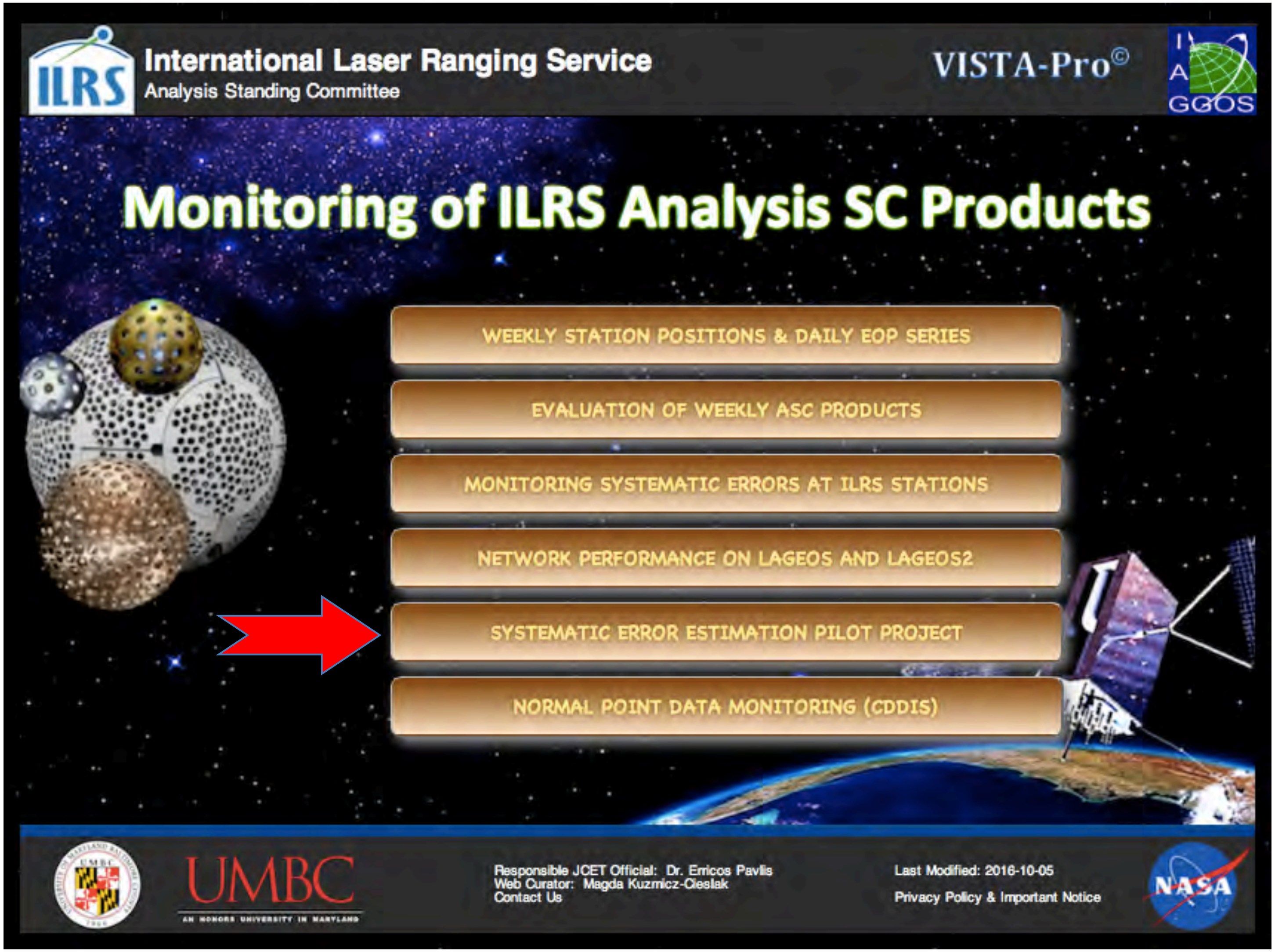
- Seven ACs contributed series so far but ONLY FIVE have updated their contributions with series following the new “labeling” of the biases according to the used wavelength
  - This will result in excluding their contribution in a future operational product, until they demonstrate they can comply
  - The present results are already available online for 2005-2008
  - The ILRSB combination is based on the original submissions and it will be updated soon, using all of the correctly labeled series
- We need commitment from the ACs (hopefully more than the six that participated in the PP) that they will support a weekly product, now that the PP is completed and we will launch the operational phase
- We need to start immediately after the workshop and do a “dry run” until the end of the year, then go operational soon after January 1st 2018.

ACs Supporting the SSEM PP

- AC-contributed series that we received so far:

Analysis Center	Date of Submission
ASI	April 11, 2017
BKG	Sept. 19, 2017
DGFI	March 24, 2017
ESA	*Nov. 25, 2016*
JCET	April 14, 2017
NSGF	April 15, 2016
GFZ	May 17, 2017

JCET Portal



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

Station 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 v203	**ASI v203**	**ASI v211**
BKG v201	**BKG v201**	*BKG v210**
DGFI v201	**DGFI v201**	**DGFI v210**
ESA v200	**ESA v200**	**ESA v210**
*GRGS v200**	*GRGS v200**	*GRGS v211**
GFZ v201	**GFZ v201**	**GFZ v210**
JCET v202	**JCET v202**	**JCET v212**
NSGF v200	**NSGF v200**	**NSGF v210**
ILRSA v201	**ILRSA v201**	*ILRSA v212**
ILRSB v200	**ILRSB v200**	**ILRSB v210**

Start (MM-DD-YYYY): 1-01-2005

End Date (MM-DD-YYYY) 12-31-2008

Station 7105 Greenbelt

"*" indicates no submission available from that AC

Plot Size Minimum Maximum

Y axis -100 100

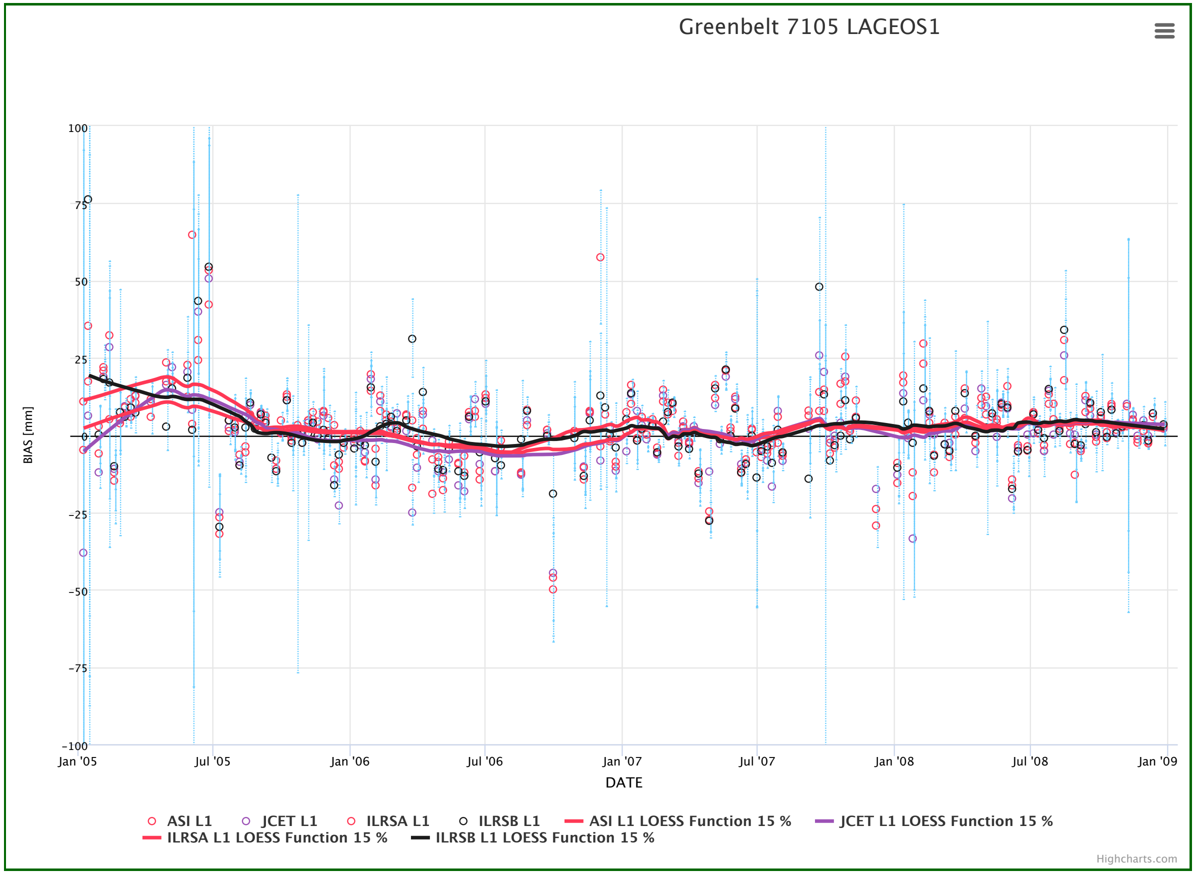
LOESS regression 15 %

New feature for smoothing the input data

Submit Reset form

Station Systematic Error PP Results

MONITORING SYSTEMATIC ERRORS AT ILRS STATIONS



ASI LAGEOS1	Mean/Std. Dev.:3.23±14.12 Count:161
ILRSA LAGEOS1	Mean/Std. Dev.:1.65±10.34 Count:162
ILRSB LAGEOS1	Mean/Std. Dev.:2.58±12.99 Count:151
JCET LAGEOS1	Mean/Std. Dev.:1.3±12.31 Count:161

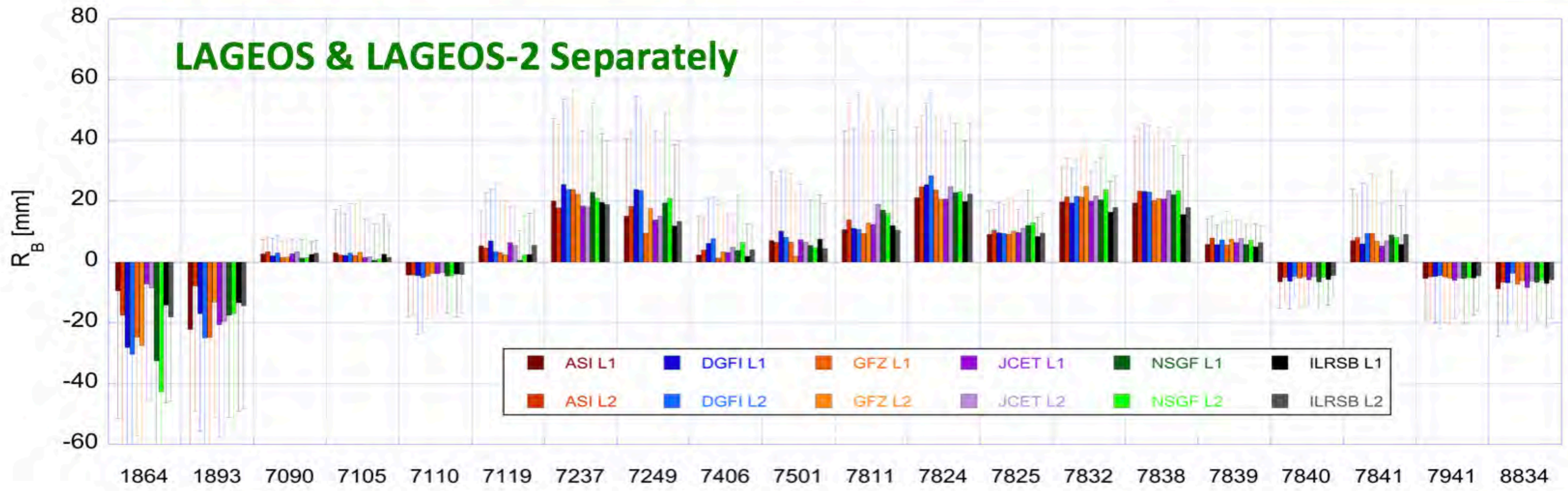
Multiple Wavelength Flag Table

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

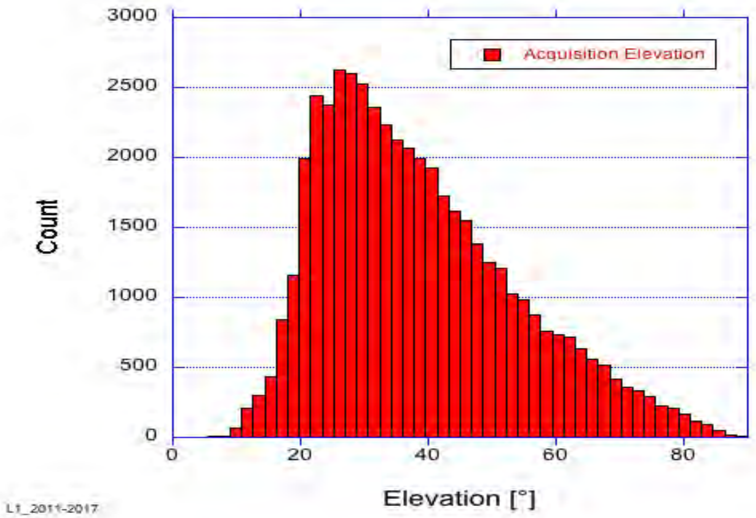
Use the hundreds of the wavelength instead of 1,2,3, etc.

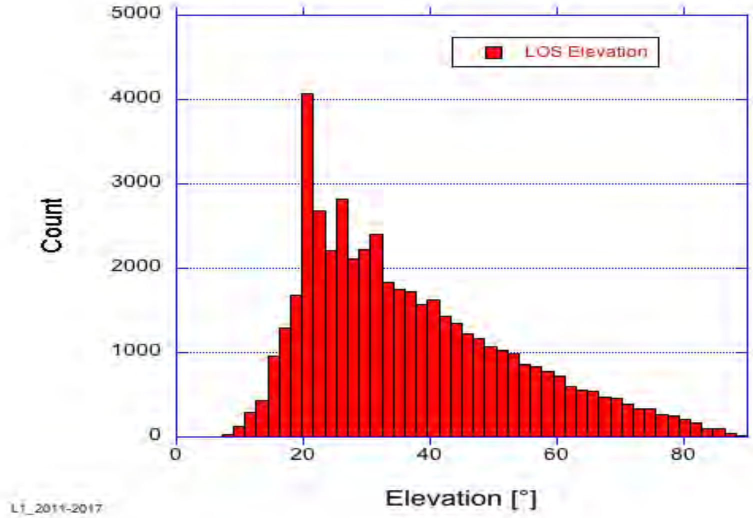
Starting Point for Future Operational Product

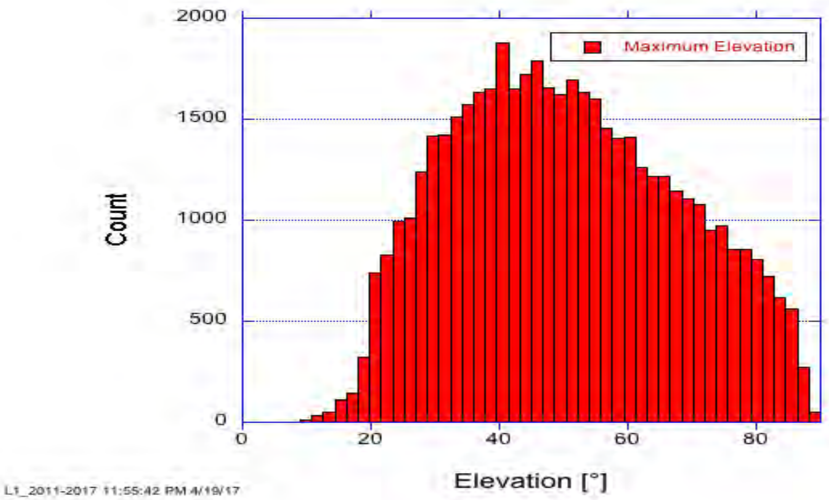
Average Error over 2005 - 2008

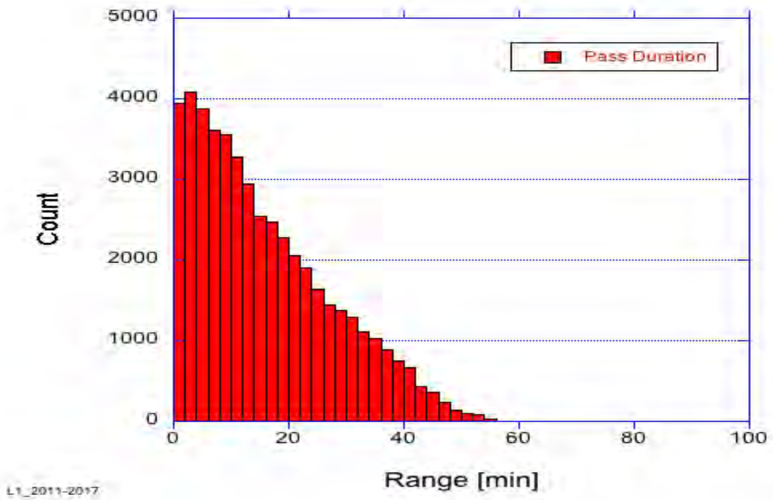


LAGEOS 1 Statistics for 2011-2017

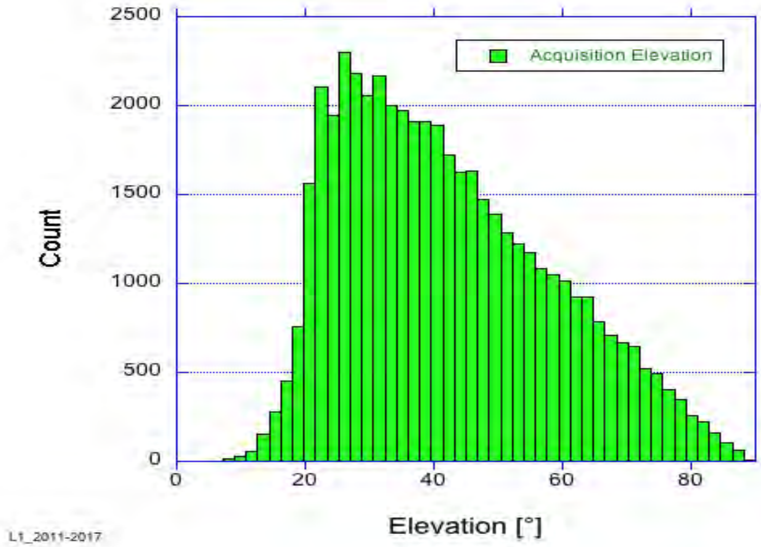


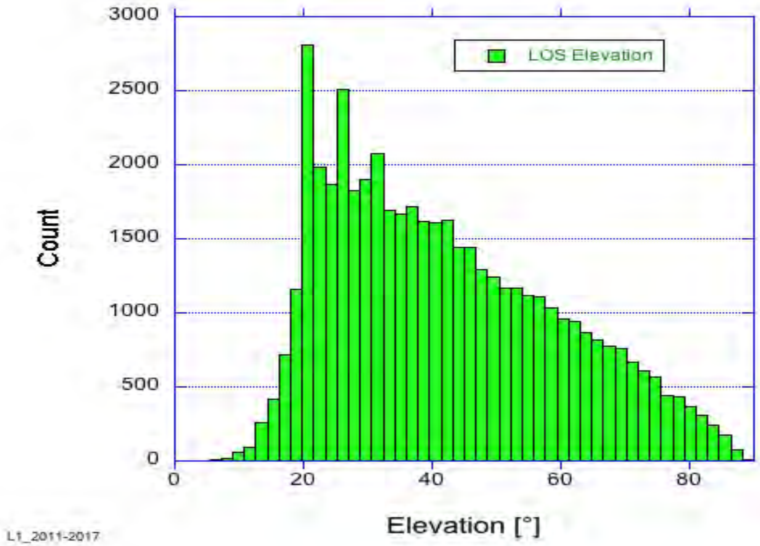


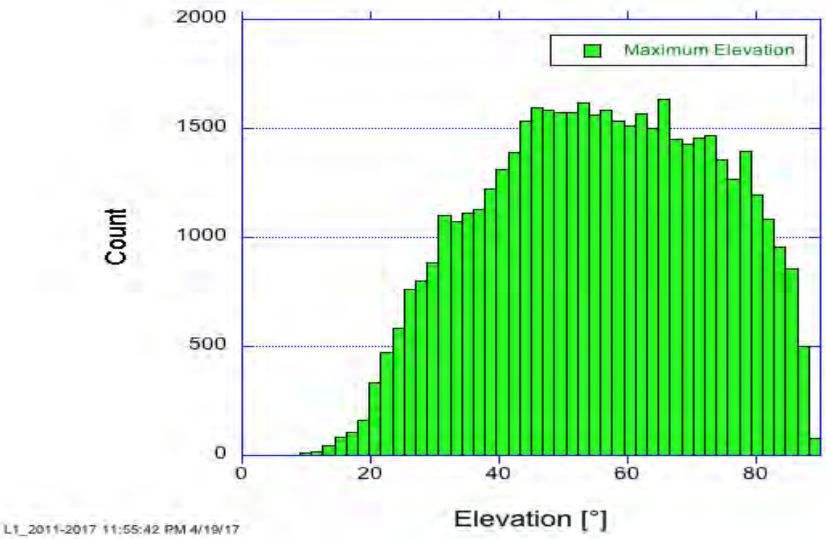


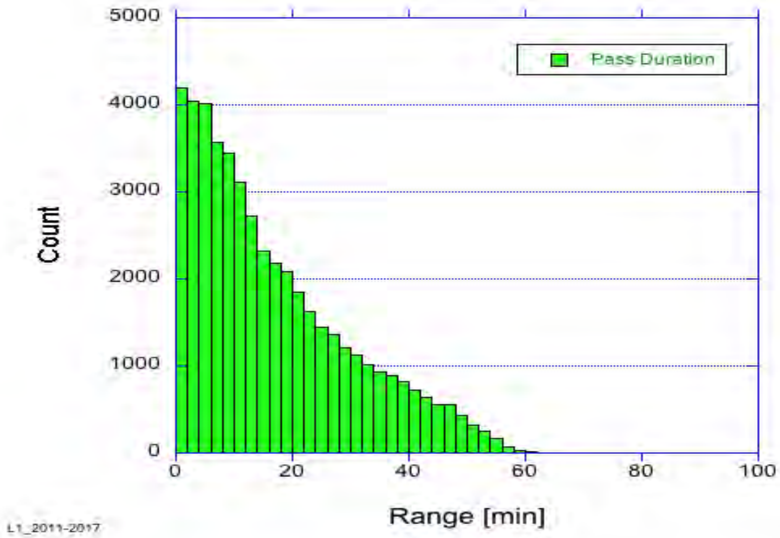


LAGEOS 2 Statistics for 2011-2017

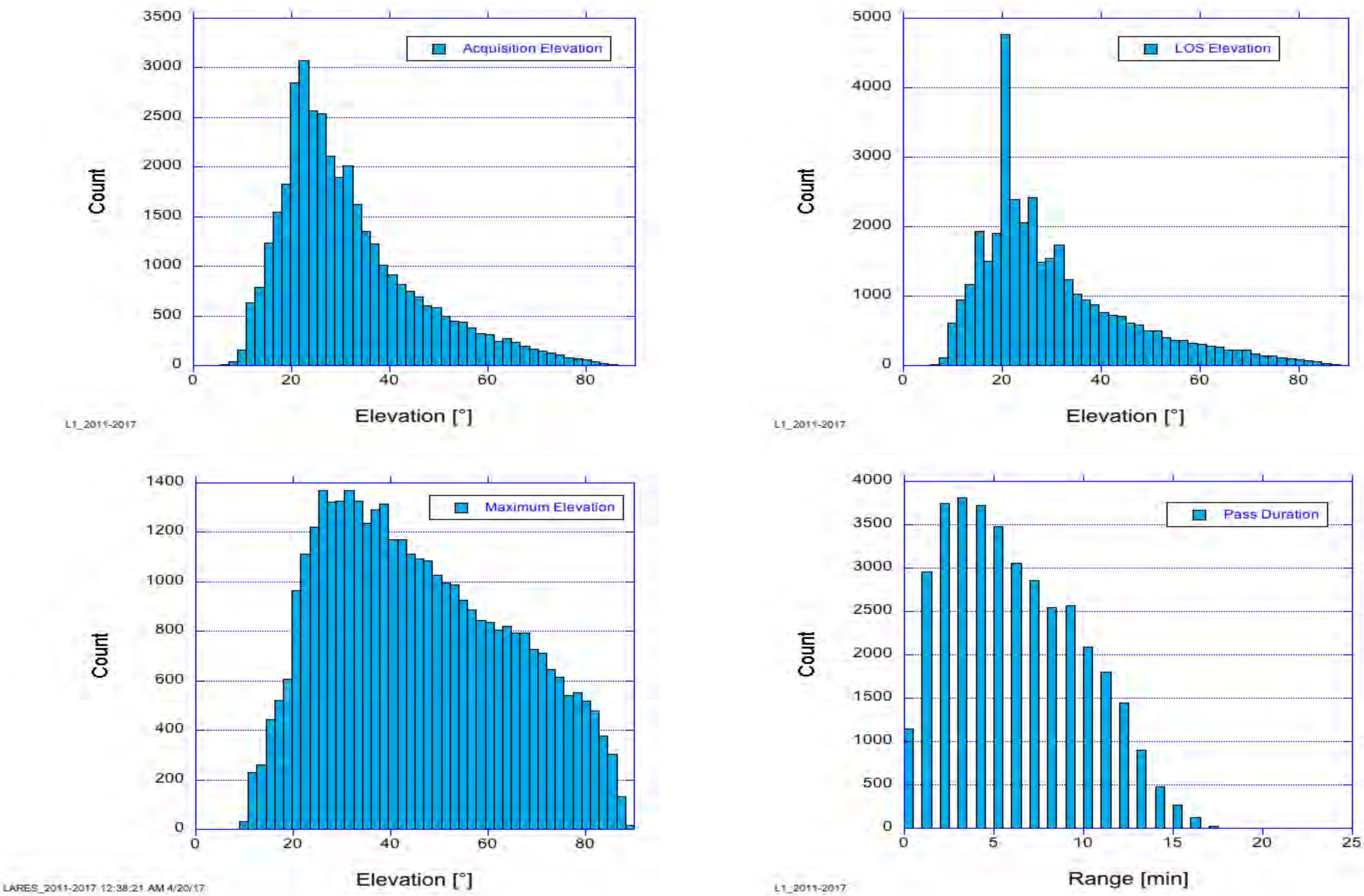








LARES Statistics for 2012-2017



Statistics for LAGEOS ½ & LARES for 2011-2017

LAGEOS 1	Pass Duration	Acquisition Elevation	LOS Elevation	Maximum Elevation
Minimum	0	6.1	6.0	8.2
Maximum	89	88.8	89.6	89.6
Points	48138	48101	48101	47912
Mean	15.7	38.5	37.0	50.4
Median	13	35.8	33.1	49.2
Std Deviation	12.0	15.2	16.3	17.4
Std Error	0.1	0.1	0.1	0.1

LAGEOS 2	Pass Duration	Acquisition Elevation	LOS Elevation	Maximum Elevation
Minimum	0	6.0	5.8	8.1
Maximum	87	89.3	89.5	89.8
Points	47677	47645	47645	47440
Mean	16.5	42.2	41.9	55.6
Median	13	39.6	39.0	55.9
Std Deviation	13.4	16.3	17.6	17.5
Std Error	0.1	0.1	0.1	0.1

LARES	Pass Duration	Acquisition Elevation	LOS Elevation	Maximum Elevation
Minimum	0	5.9	-2.9	8.6
Maximum	24	88.5	88.1	89.4
Points	37024	36993	36993	36911
Mean	5.9	31.6	30.5	45.8
Median	5	28.0	25.9	43.5
Std Deviation	3.7	14.0	15.2	18.8
Std Error	0.1	0.1	0.1	0.1

Update of SLRF2014 (ITRF2014 enhanced)

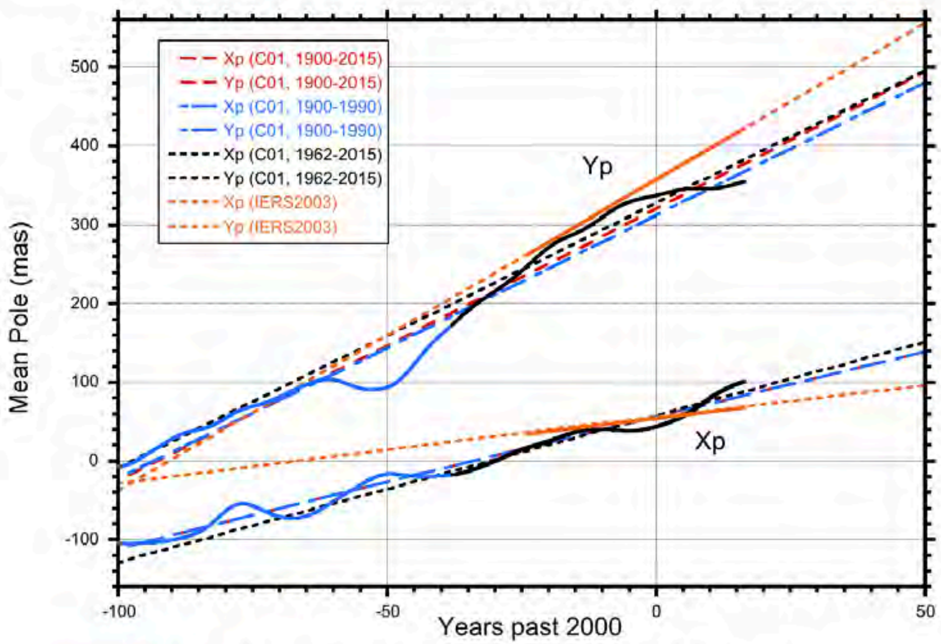
- The final SLRF2014 was made available earlier this year, with several improvements and updates almost as soon as it was received by the users;
- The network however has become very dynamic (this is good!), with new stations coming online very frequently now and several of the existing ones upgrading their systems;
- These efforts require validation of the new systems and in case of the entirely new sites, a good set of coordinates in the SLRF2014 frame;
- As such sets of improved coordinates become available, we need to update SLRF2014 more frequently; sometimes the initial set is further improved as more data become available and a second update is necessary, not too long since the initial one;
- One such case is that of the new Kunming 2 system (7819); look out for a new release in the next few days, with improved coordinates generated by Tochi Otsubo.

Re-analysis using SLRF2014/ITRF2014

- We had planned for a reanalysis of all data (1983 to present) using SLRF2014 to be used as the official a priori TRF for all ILRS applications, with a tentative delivery date end of August 2017;
- The decisions taken at the recent UAW 2017 require us to change the definition of the Conventional Mean Pole that we use to the new standard adopted at that meeting, so fortuitously, the delayed response of the ASC in this case saved (some of us) a second reanalysis;
- We need to agree to a date at which ALL ACs will deliver their reanalyzed series with the new standards, and at that point we will adopt these new standards for our operational series as well. This way there will be a seamless transition from the old to the new and all of the available products will be referenced to the same CMP.
- We expect this coming week an extension of the long-wavelength gravity terms from UT/CSR's 15^{d} series in ITRF2014 and a similar extension of our own "predictions", at least for the coming year;
- These new UT/CSR series should be the ones that we will use for the reanalysis.

Filtered & Linear Mean Pole Definitions

Determining an appropriate linear mean pole (1)



IERS2003 is the linear mean pole from the IERS2003 Conventions
(based on a linear fit to the IERS mean pole over 1976-2000)

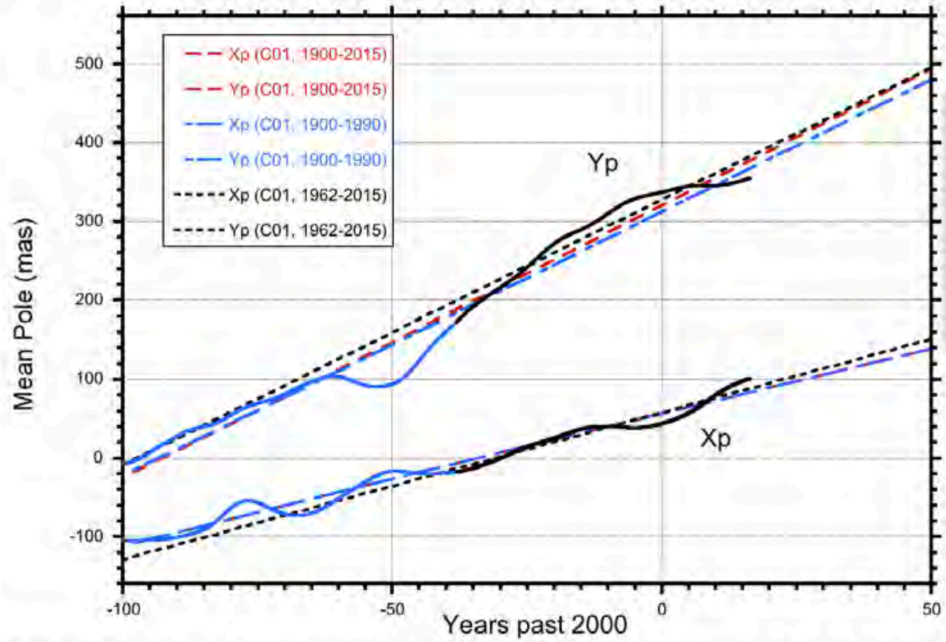
C01 is the IERS filtered mean pole at ftp://iers.obspm.fr/iers/eop/eopc01/mean-pole.tab

Three intervals fitted: 1900-2015 (longest baseline)
1900-1990 (avoids effects of recent ice mass loss)
and 1962-2015 (avoids more uncertain C01 data before 1962)

CSR

IERS CMP Definition Update

Determining an appropriate linear mean pole (2)



In milliarcsec:

Xp = 55.0 + t*1.677

Yp = 320.5 + t*3.460

t is years past 2000

Any of these fits to C01 seem reasonable and internally consistent, though the span of 1900-2015 provides the longest baseline for a linear (presumably GIA-dominated) mean pole

More important, even if we cannot be sure this represents the true effect on the mean pole due to GIA, it is likely to best represent the future linear trend of the IERS polar motion, and that variations about this are the variations we wish to preserve in the pole tide model

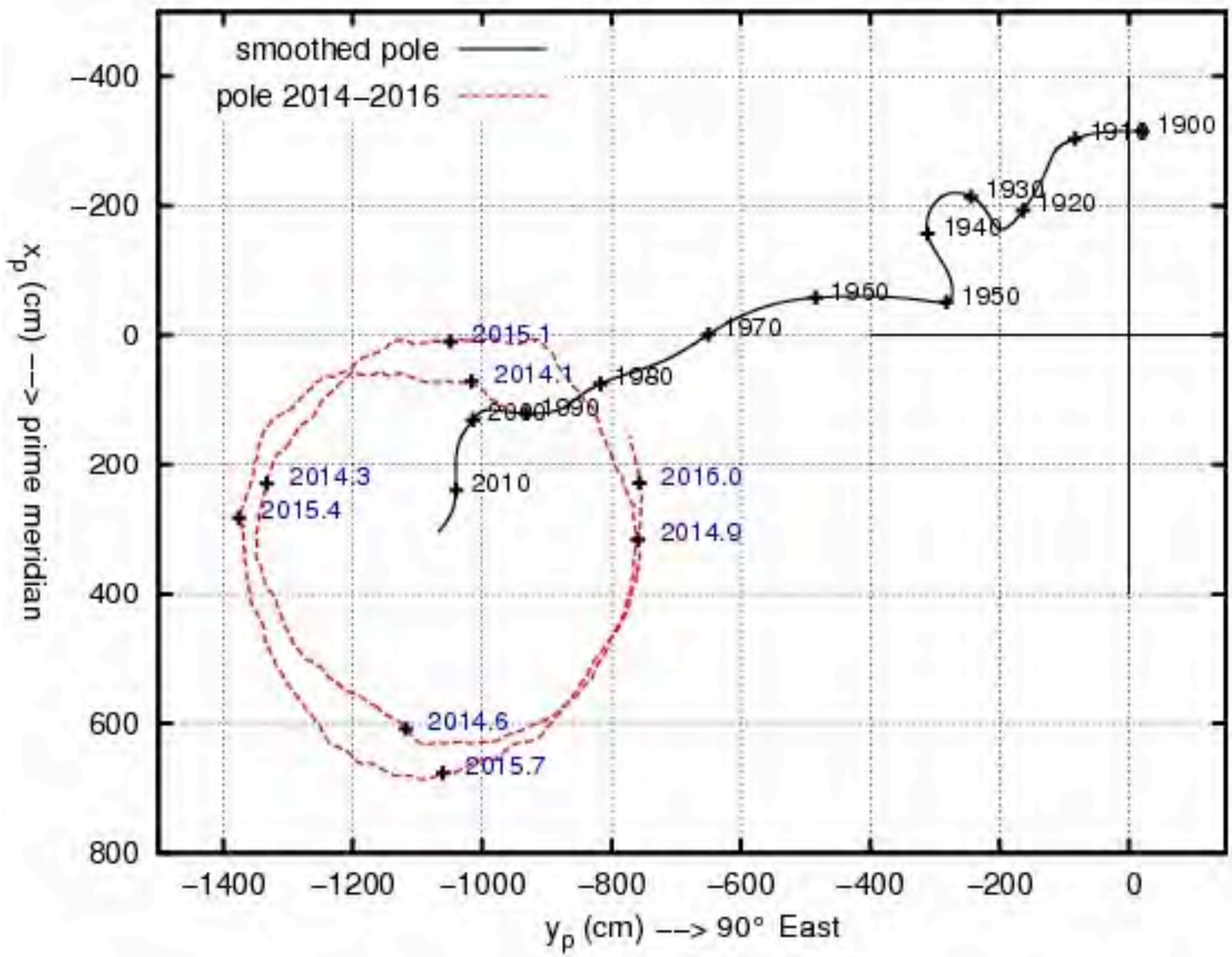
C S R

Recommendations

- IERS conventions should be updated to replace filtered mean pole with a linear mean pole model and a clear recommendation to all analysis groups (including altimetry) to adopt a common linear mean pole model (ASAP)
  - Basic pole tide model is unchanged (ocean, solid earth, site displacement); only the mean pole subtracted from the IERS polar motion changes (relatively simple code change)
  - Issue is relatively urgent with GRACE and T/P altimeter data reprocessing planned for this summer
  - All of the fits to the C01 series do not differ by much more than the nominal 10 mas goal, even when extended up to 2050; a special study group to evaluate different options does not seem warranted
- IERS continues to provide a filtered mean pole table for purposes of modeling/comparing the long-term trend in C21/S21
  - Could be especially useful in forward modeling C21/S21 for precision orbit determination
  - C21/S21 are well characterized by the (full) mean pole and a seasonal variation

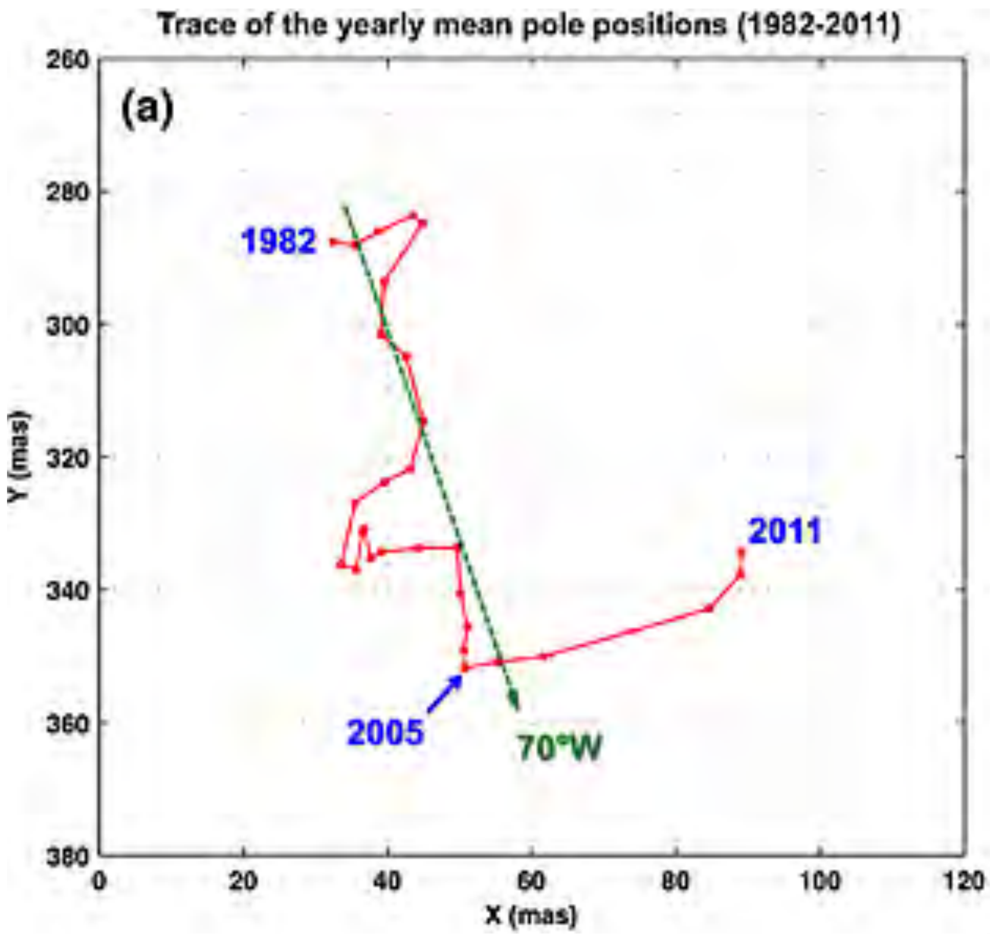
CSR

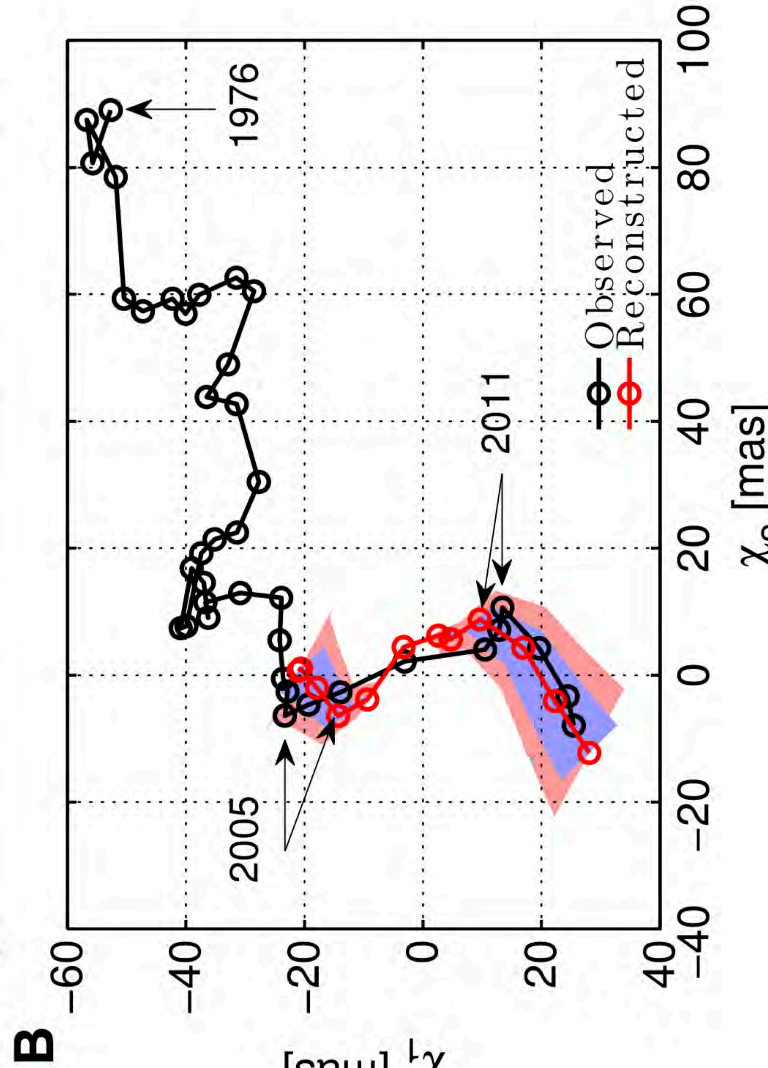
“OLD” IERS CMP Still Useful



”OLD” Style IERS CMP Good Proxy for $C/S_{(2,1)}$

Climate-driven Polar Motion: 2003-2015: S. Adhikari & Erik R. Ivins JPL





UAW 2017 Recommendations to ILRS

Recommendations
SLR Systematic Errors and Biases Session

- **SLR Network improve communication and response to errors identified through QC process (for ILRS CB)**
- **Develop complete (accurate) metadata for discoverability of ILRS data and products** – Carey Noll is working on this.
- **Time biases:**
  - **Obtain a table of T_B from T2L2 (AI: P. Exertier)**
  - Compare with time biases estimated from QC pass-by-pass analyses (**T_B**)
  - **Compare with J. C. Ries results – (**assumes a reference frame is fixed, and not adjusting stations, so compare to QC **T_B**)
  - **Refine the data handling file for the T_B**
- **Deliver EOP and SSC in a defined TRF (prevailing ITRF)**
- **Atmospheric loading PP with a follow-up product series**
- **Include applied R_B & T_B in SINEX file for next contribution to ITRF**

Journal of Geodesy Special Issue (JOGSI) on Laser Ranging

- We finally received 39 abstracts!
- We (guest editors) did not turn down any submission;
- Submitted to the Editor in Chief of JoG (Jürgen Küsche) for initial approval and estimation of total pages;
- Petra van Steenbergen (senior editor and the one who we worked with for the 1st SLR SI in Survey of Geophysics 2001), estimated about 300 pages total, i.e. TWO issues;
- Jürgen had other pointers for us which we will be discussing with the individual lead authors on a case by case basis;
- The Springer depository site should open up before the end of the month;
- We are looking at an end of January/February closing date for the submission process
- Reviews will start as soon as papers are submitted!

ILRS Operations Center Quality Check Harmonization Project

Kate Stevenson

2017 ILRS Technical Workshop

Riga

Background & Purpose

- ILRS Operations Centers perform quality checks (QC) on CRD received from stations. Currently, the QC performed at the EDC and NASA OC are different.
- The purpose of the QC upgrade is to align the QC with the CRD format update (currently in progress), implement identical checks at both OCs, and to make the QC more thorough and valuable to the user community.
- The goal of this review is to elicit feedback from the ILRS community on the proposed QC.

Filling in the Blanks

- Target Header – what info is really needed?
  - Is one of SIC, COSPAR, NORAD, target name the most or least important?
  - If they don't match, should the pass be rejected?

- Wavelength – how many variations are okay?
  - Is within 1% of 355, 423, 532, 694, 847, 1064, or 1550 precise enough?

Filling in the Blanks

- Calibration – what should we be looking for?

Field	Format Specification	Proposed Standard
Calibration System Delay (ps)		[-1.e4,…,1.e8]
Calibration Delay Shift (ps)		[-1.e5,…,1.e5]
RMS of raw system delay	[-1,…,2.e5]	[-1,…,2.e5]
Skew of raw system delay values from the mean		??
Kurtosis of raw system delay values from the mean		??
System delay peak – mean		[-1.e5,..,1.e5]

Filling in the Blanks

- Pass Statistics – what should we be looking for?

Field	**Format Specification**	**Proposed Standard**
Session RMS from the mean of raw, accepted time of flight values minus the trend function		[0,…,2.e4]
Session skewness from the mean of raw accepted time of flight values minus the trend function		?
Session Kurtosis from the mean of raw accepted time of flight values minus the trend function		?
Session peak – mean		[-1.e5,..,1.e5]

Filling in the Blanks

- Normal Point Statistics – what should we be looking for?

Field	**Format Specification**	**Proposed Standard**
Normal point window length (sec)		[0,1,…,3600]
Bin RMS from mean of raw accepted time of flight values minus the trend function (ps)		[0,1,…1.e5]
Bin skew from mean of raw accepted time of flight values minus the trend function		?
Bin kurtosis from mean of raw accepted time of flight values minus the trend function		?
Bin peak – mean (ps)		[-1.e5,..,1.e5]

Filling in the Blanks

- Transponders – what should we be looking for?

Field	**Format Specification**	**Proposed Standard**
Estimated Station UTC offset (nanosec)		[-5e8,…5e8]
Estimated Station Oscillator Drift		Numerical Test TBD
Estimated Transponder UTC offset		Numerical Test TBD
Estimated Transponder Oscillator Drift		Numerical Test TBD
Transponder Clock Reference Time		Numerical Test TBD

Review Comments

- If you haven't received the spreadsheet and comments form, please notify me.
- If you have input, please submit written feedback!
- Reply to the email or email katherine.s.stevenson@nasa.gov with your comments.
- Deadline: October 20th

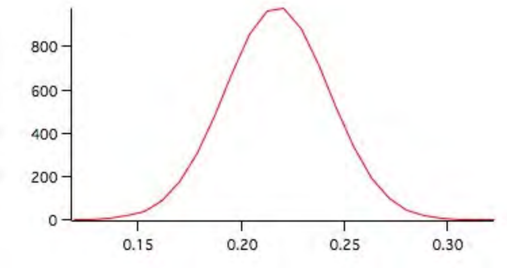
Range correction for LAGEOS-2 vs

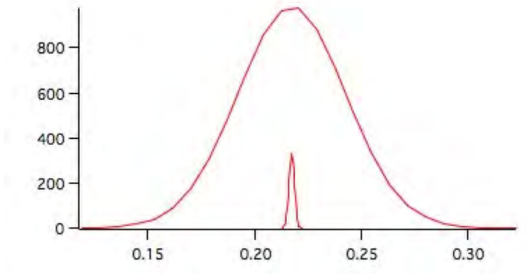
Pulse width, detector rise time, signal strength, and type of detection system

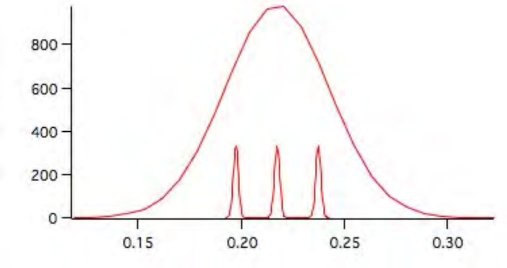
Dave Arnold, SAO Retired

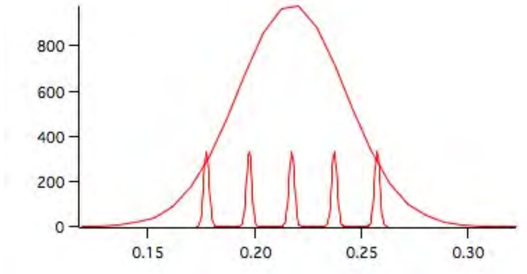
- Quantization
- Pulse histogram
- Data clipping
- Sample pulse shapes
- Range correction vs pulse length
- Range correction vs receiver rise time
- Range correction vs number of photoelectrons
- Range correction for various detection systems
- Target calibration
- Range correction for various stations
- CSPAD target test

Quantization



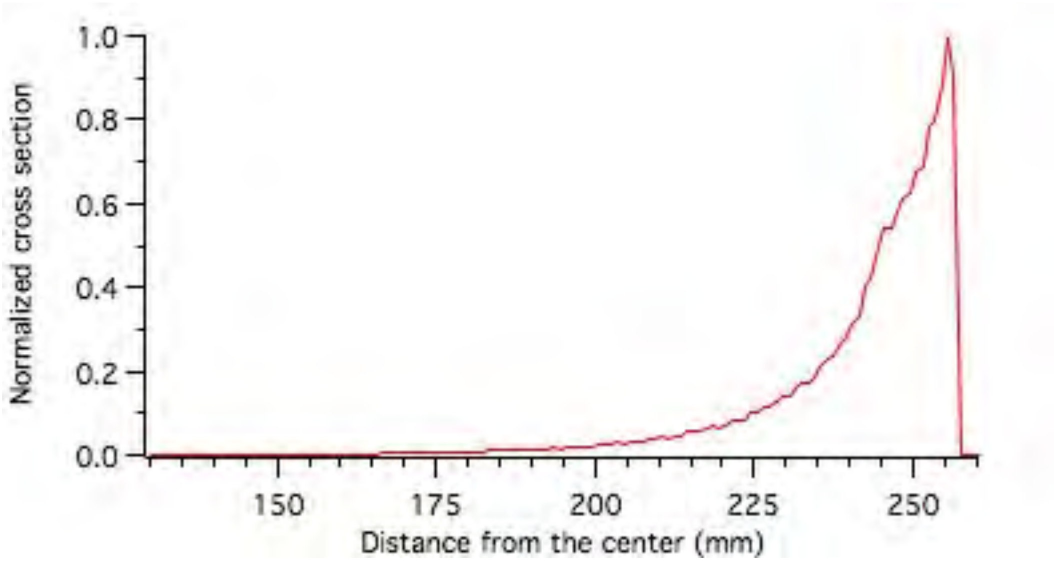






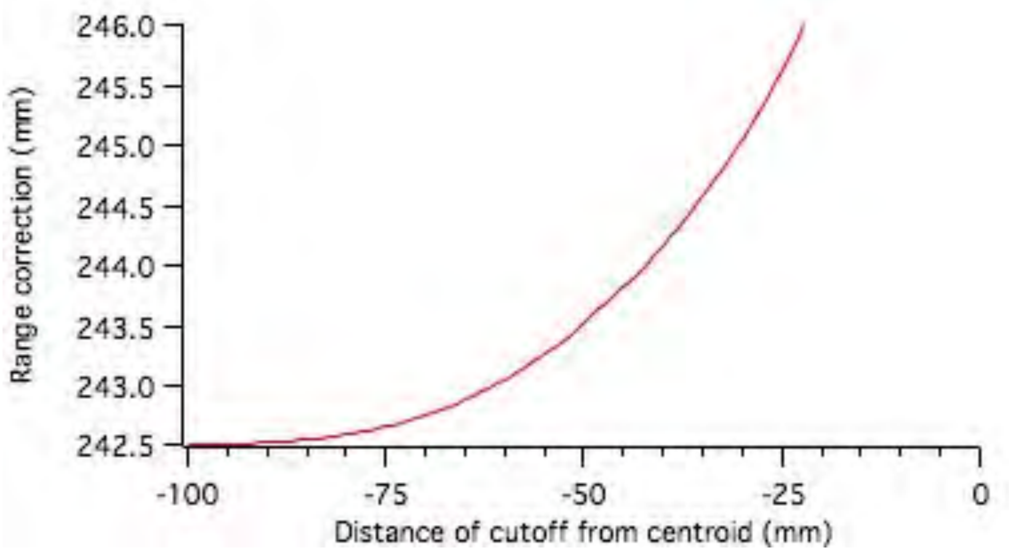
Histogram for LAGEOS-2

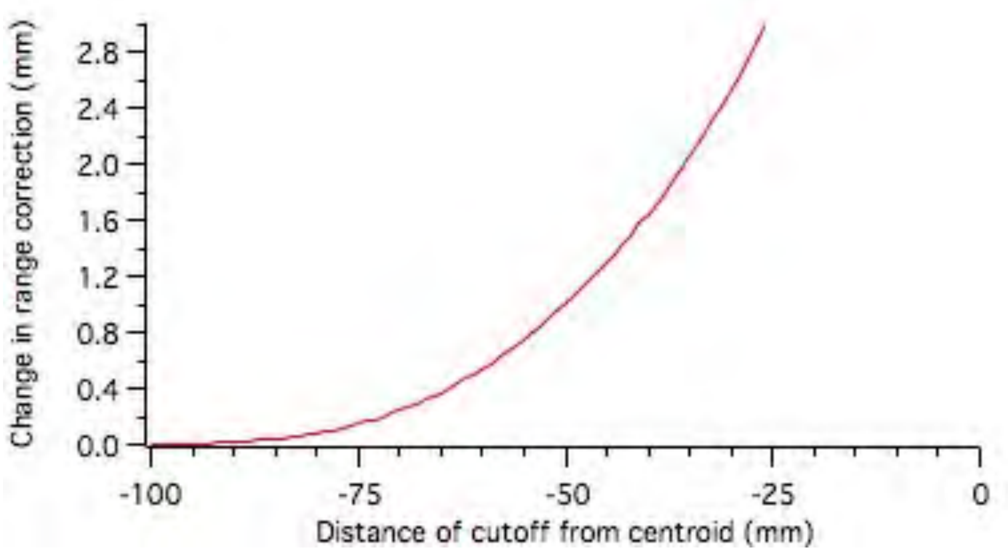
- Tail = 135.5 mm, Centroid = 242.5 mm, Leading edge = 256.5
- Leading edge – Centroid = 14 mm



Data Clipping

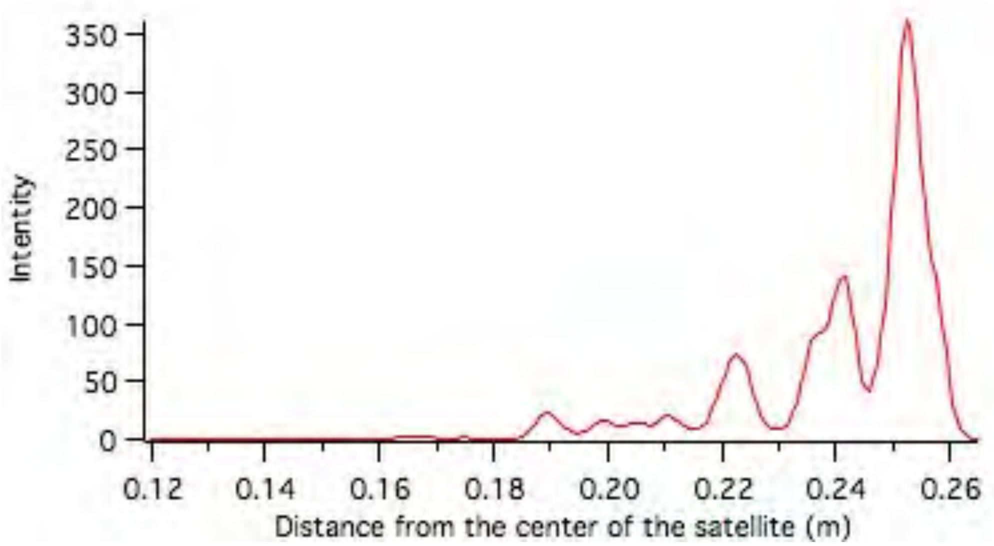
- Change in range correction vs distance of the cutoff from the centroid
- Possible solution – fit the pulse shape rather than use the average

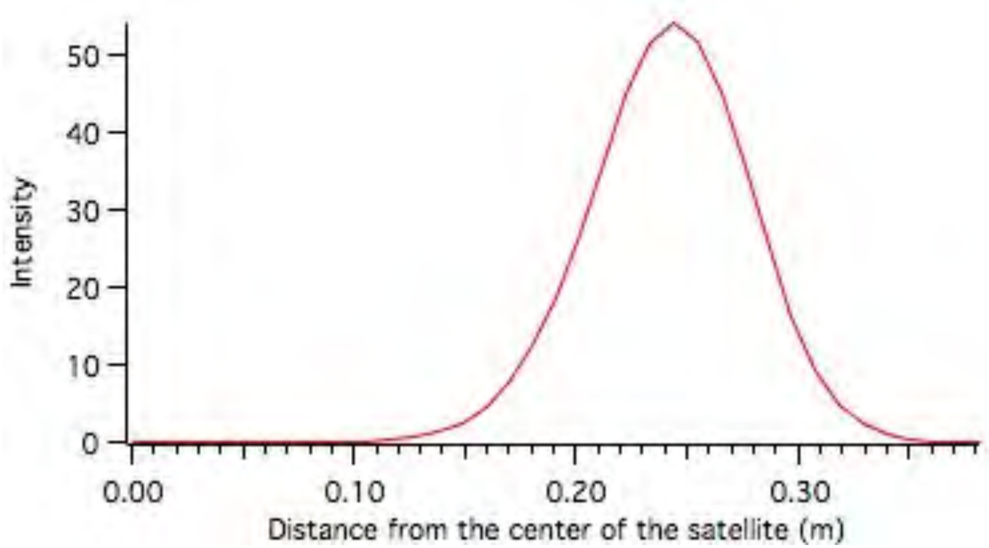




Sample pulse shapes

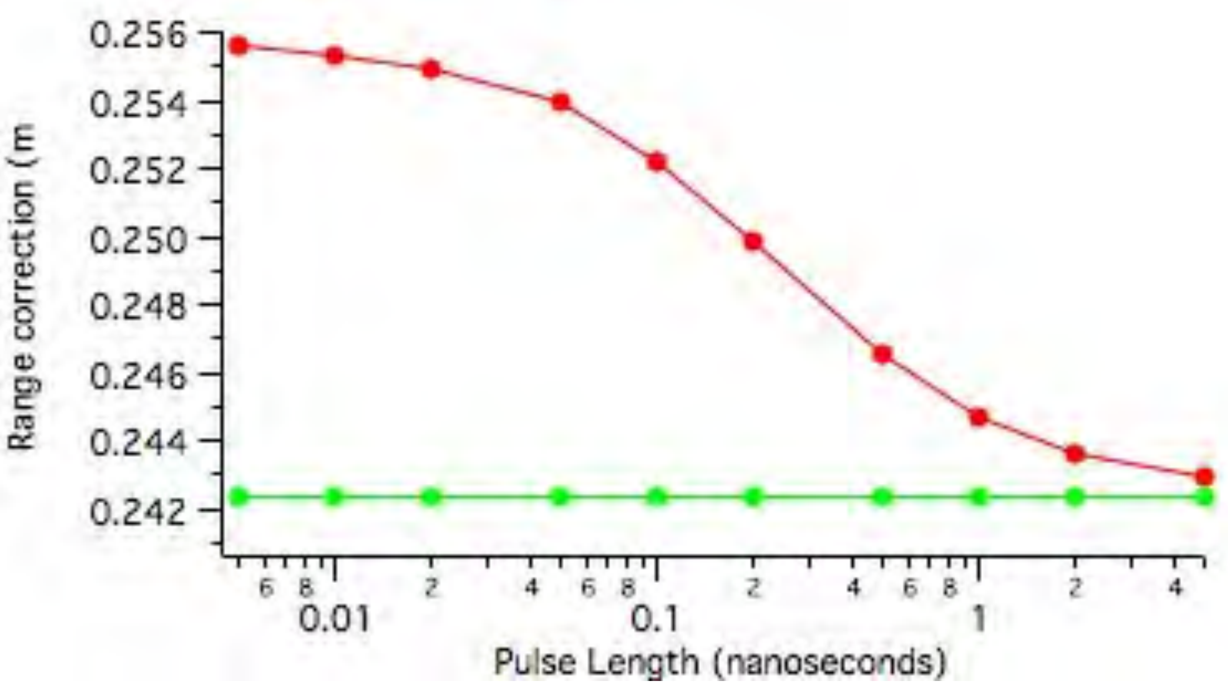
- Pulse width .03 ns .50 ns





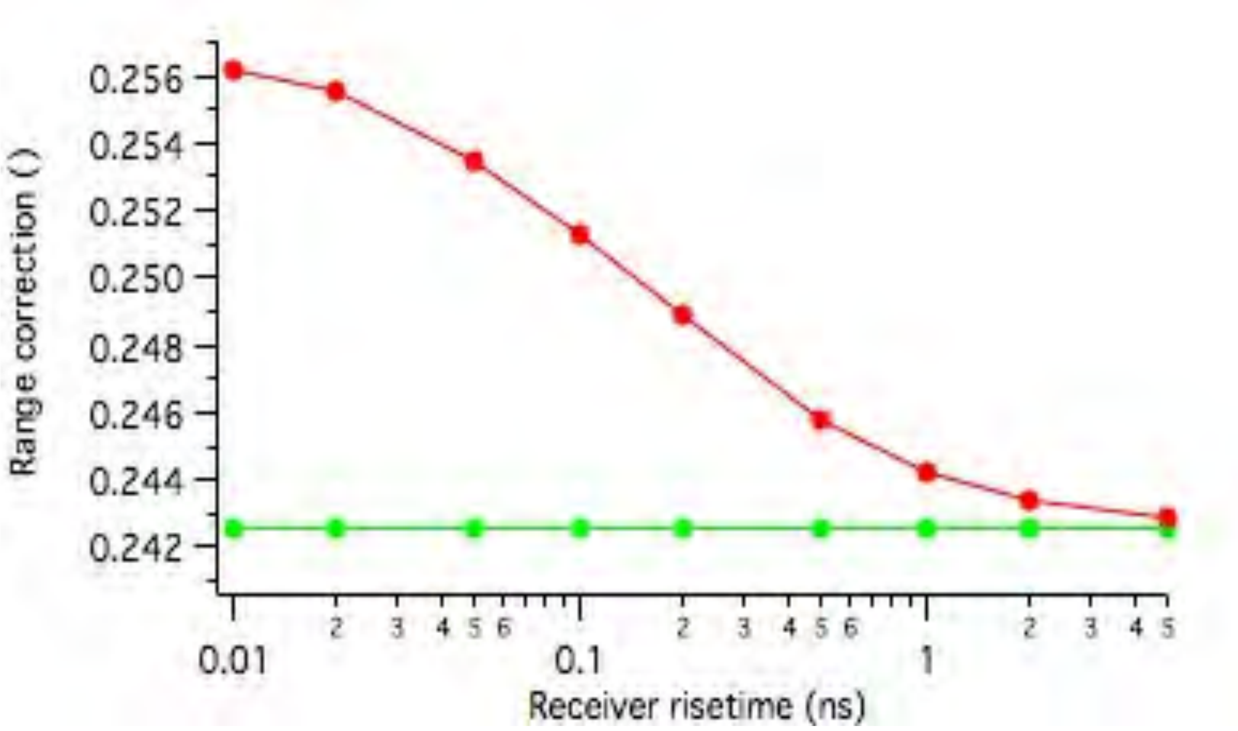
Range correction vs pulse width

- Red = halfmax, Green = Centroid



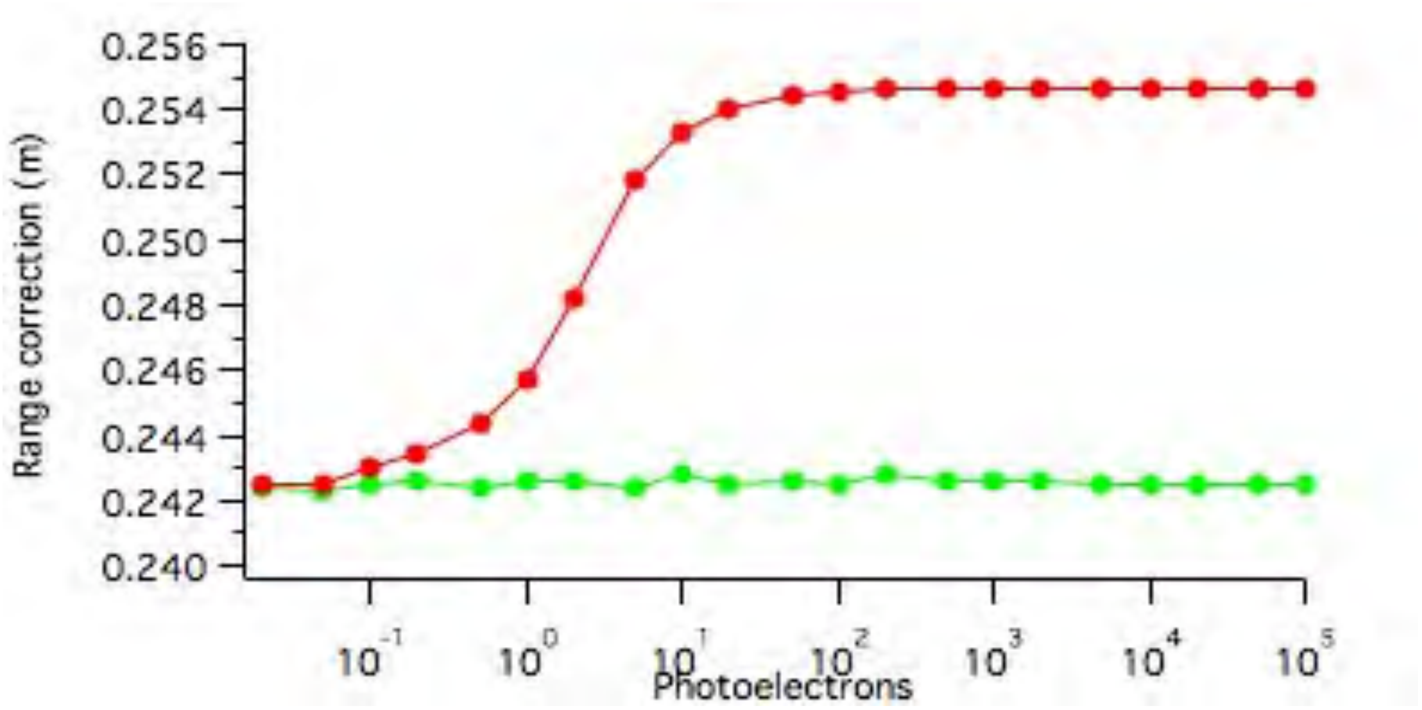
Range Correction vs Receiver Rise Time

- Red = halfmax, Green = Centroid



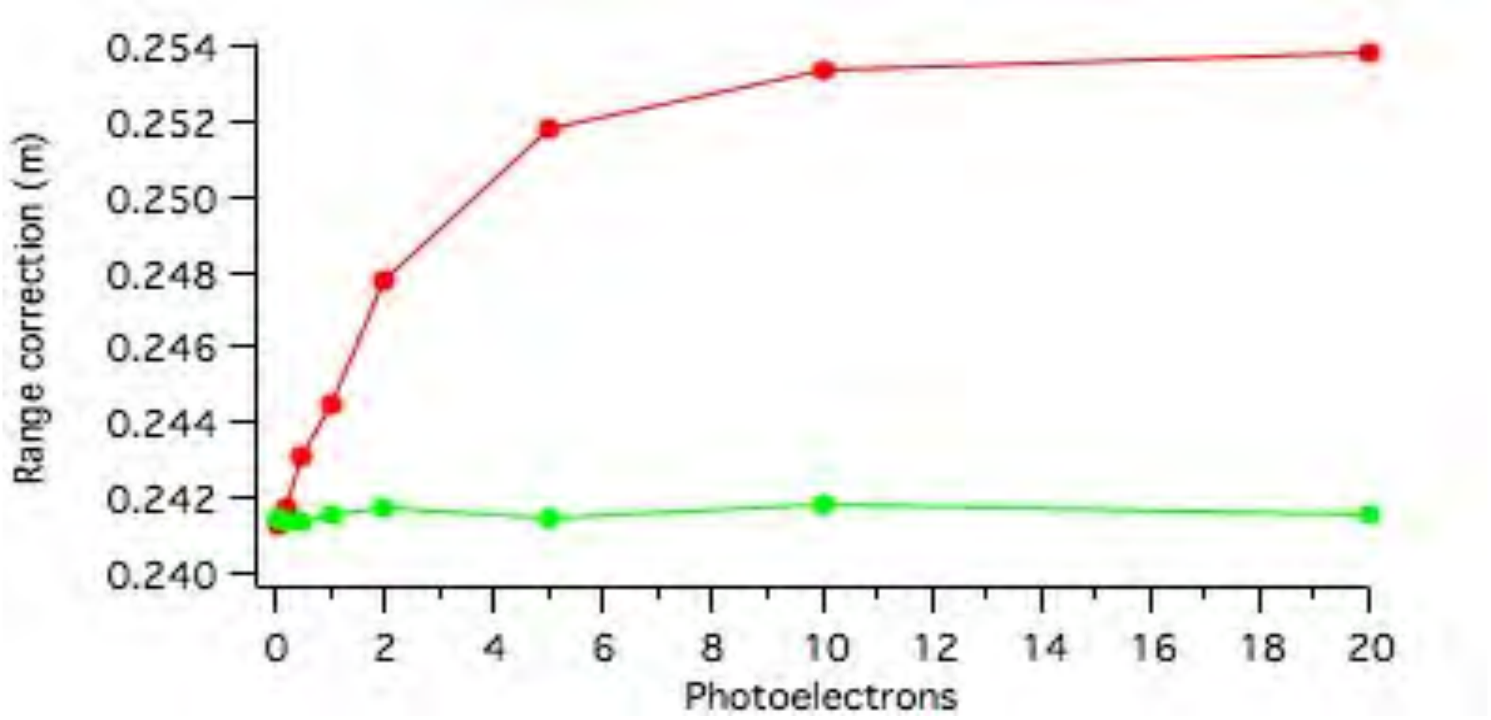
Range Correction vs number of photoelectrons

- Red = halfmax, Green = Centroid



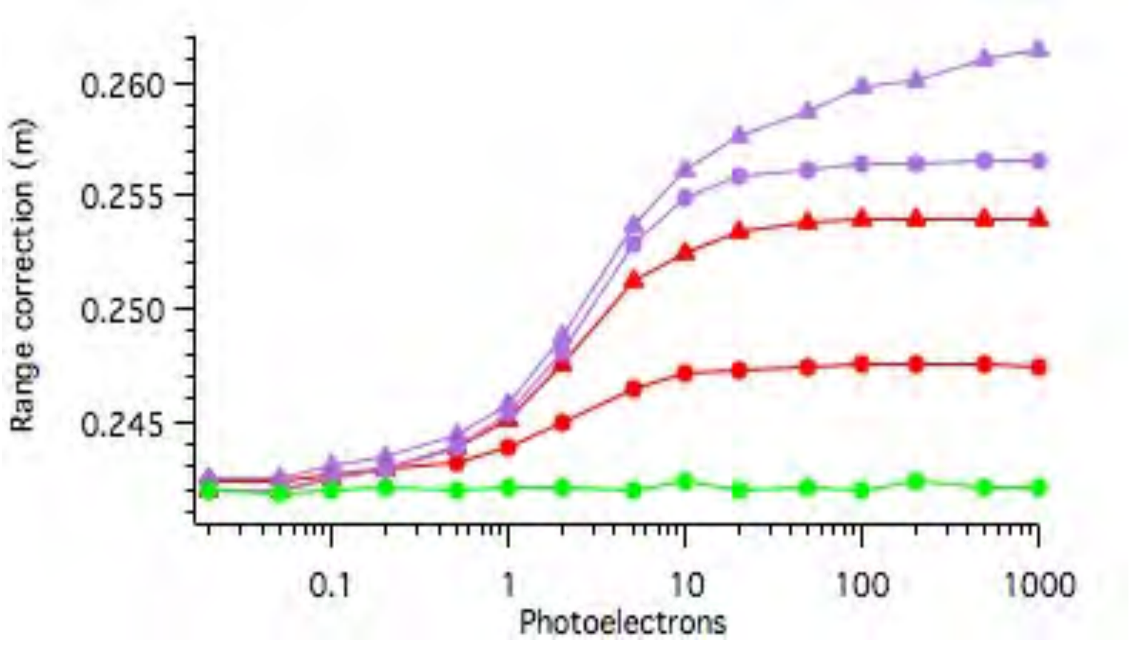
Expanded plot

- Red = Halfmax, Green = centroid



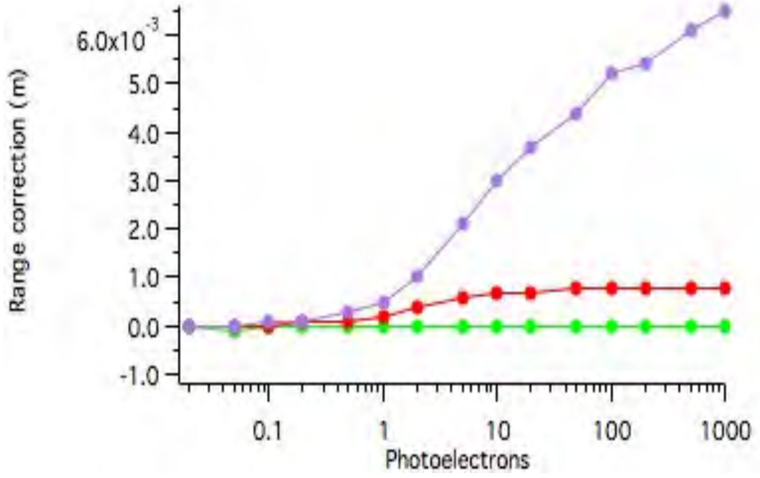
Range correction for various detection systems

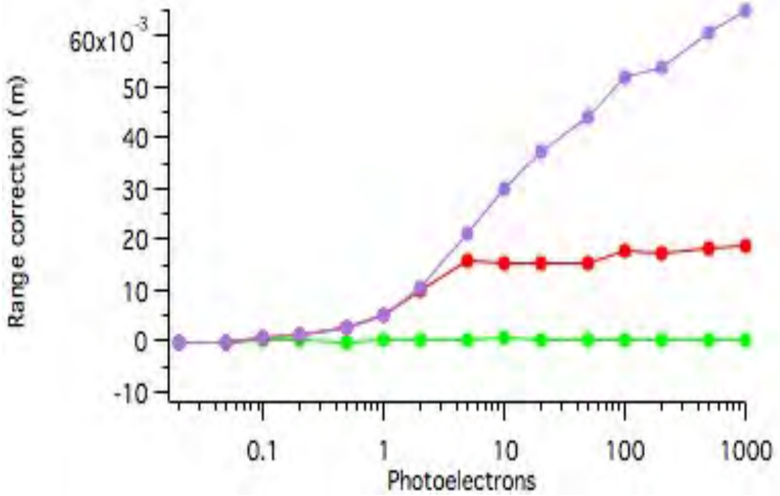
- Green = Centroid, Red circles = Halfmax (.3ns risetime), Red triangles = Halfmax(.03 ns rise time), Purple circles = first photoelectron (zero pulse length), purple triangles = first photoelectron (.03 ns risetime)



Target Calibration

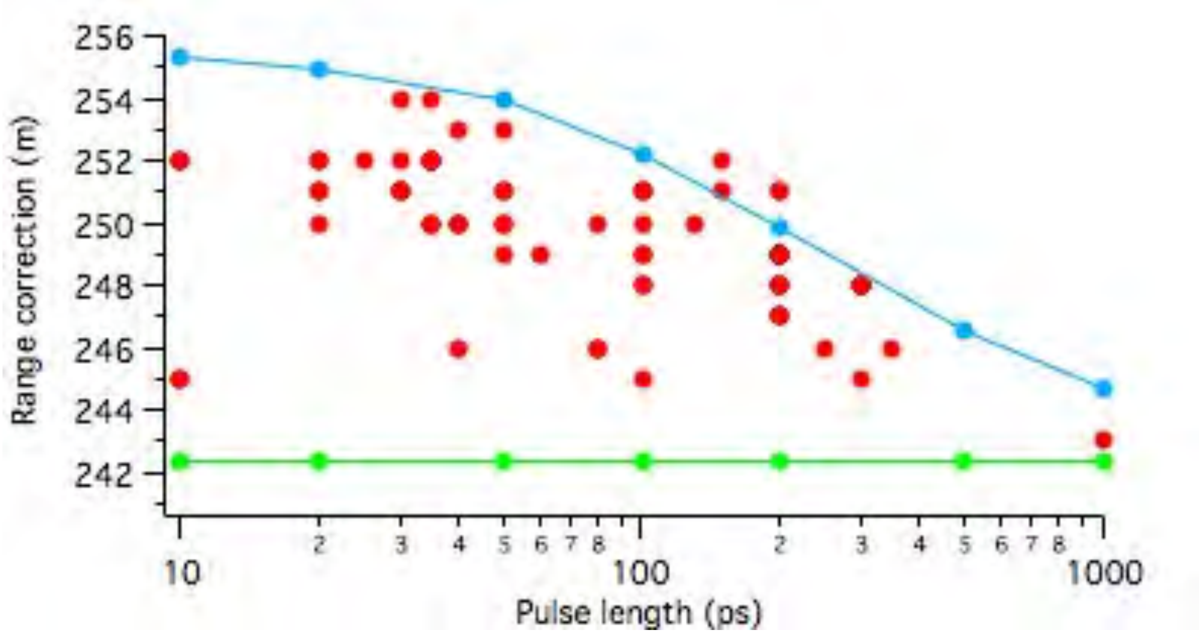
- Green = Centroid, Red = Halfmax, Purple = first photoelectron
- Pulse .03 ns .30 ns
- Scale 6 mm 60 mm





Range corrections for the stations

- Blue = Theoretical Halfmax, Green = Centroid
- Red = stations (each dot may represent several overlapping stations)



CSPAD Target Test

- Construct a target using the histogram for LAGEOS that will reproduce the return pulse from LAGEOS
- Use attenuation to get a return rate around %10. This is a signal strength of .1 pe
- Decrease the attenuation in convenient steps up to perhaps 1000 pe
- Plot the range correction vs number of photoelectrons.

From Time Transfer by Laser ranging to Space Geodetic Products

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GeoAZUR TERRE - OCÉAN - ESPACE

GRGS GROUPE DE RECHERCHE DE GEODESIE SPATIALE

NASA Goddard SPACE FLIGHT CENTER

Goals of the presentation

We dedicated a whole new method in order to determine Time Biases in Laser Ranging stations

We used the Time Transfer by Laser Link (T2L2) experiment for 8 years

Main goals :

- Synchronize the whole network at +/- 100 ns from the UTC (ILRS recommendations)

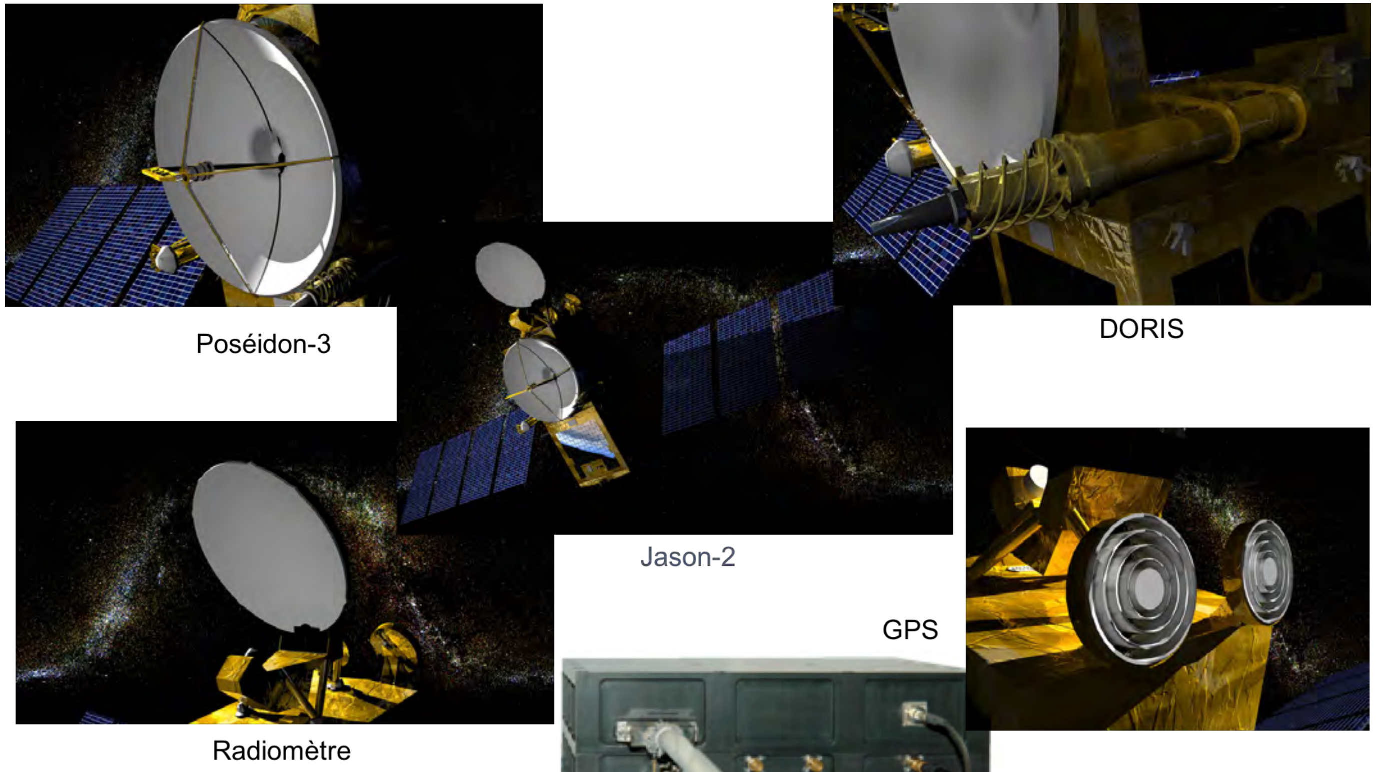
Pearlman, M., et al. 2002. The international laser ranging service. Advances in Space Research

- Have a network accurate at 1 mm and stable at 0.1 mm/yr

Plag, H.-P. and Pearlman, M. 2009. Global geodetic observing system Meeting the requirements of a global society on a changing planet in 2020. Springer Science & Business Media.

The effect of Time Bias on geodetic products (orbit, coordinates) ?

The Time Transfer by Laser Link (T2L2) experiment



T2L2 + LRA

Time Transfer by Laser Link

Jason-2, oceanographic satellite :

- Launched the 06/20/2008
- At an altitude of 1336 km
- Orbit of 66°
- Orbital period ~110 min

Passengers :

- LPT
- CARMEN-2

***Bezerra, F et al. 2011**. Carmen2/mex : An in-flight laboratory for the observation of radiation effects on electronic devices. In Radiation and Its Effects on Components and Systems (RADECS).*

- T2L2

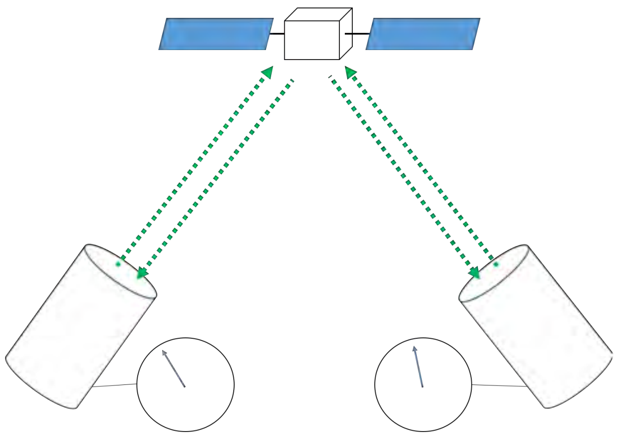
***Samain, E., et al. 2008.** Time transfer by laser link–the t2l2 experiment on jason-2 and further experiments. International Journal of Modern Physics D.*

T2L2 offered a time colocation on-board and with the ground network (SLR stations).

Common View and Non common view Time Transfer

Common View Time Transfer

The on-board oscillator stability could be neglected



Accuracy at 150 ps

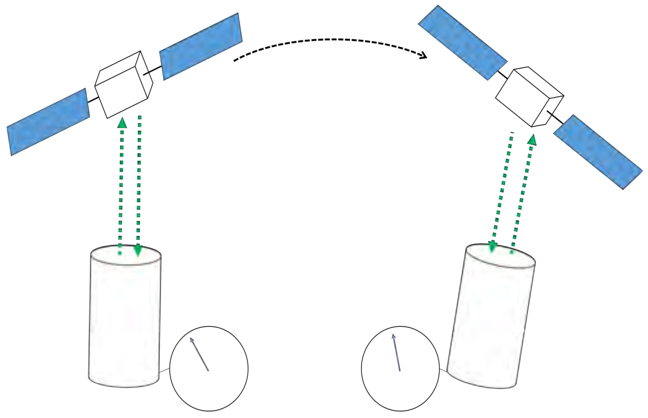
Exertier, P., et al. 2014. Time transfer by laser link: data analysis and validation to the ps level. Advances in Space Research, 54(11), 2371-2385.

Stability at ~ ps @ 75 s

Exertier, P., et al. 2010. Status of the t2l2/jason2 experiment. Advances in Space Research. DORIS : Precise Orbit Determination and Applications to Earth Sciences.

Non-Common View Time Transfer

The on-board oscillator stability should be take into account



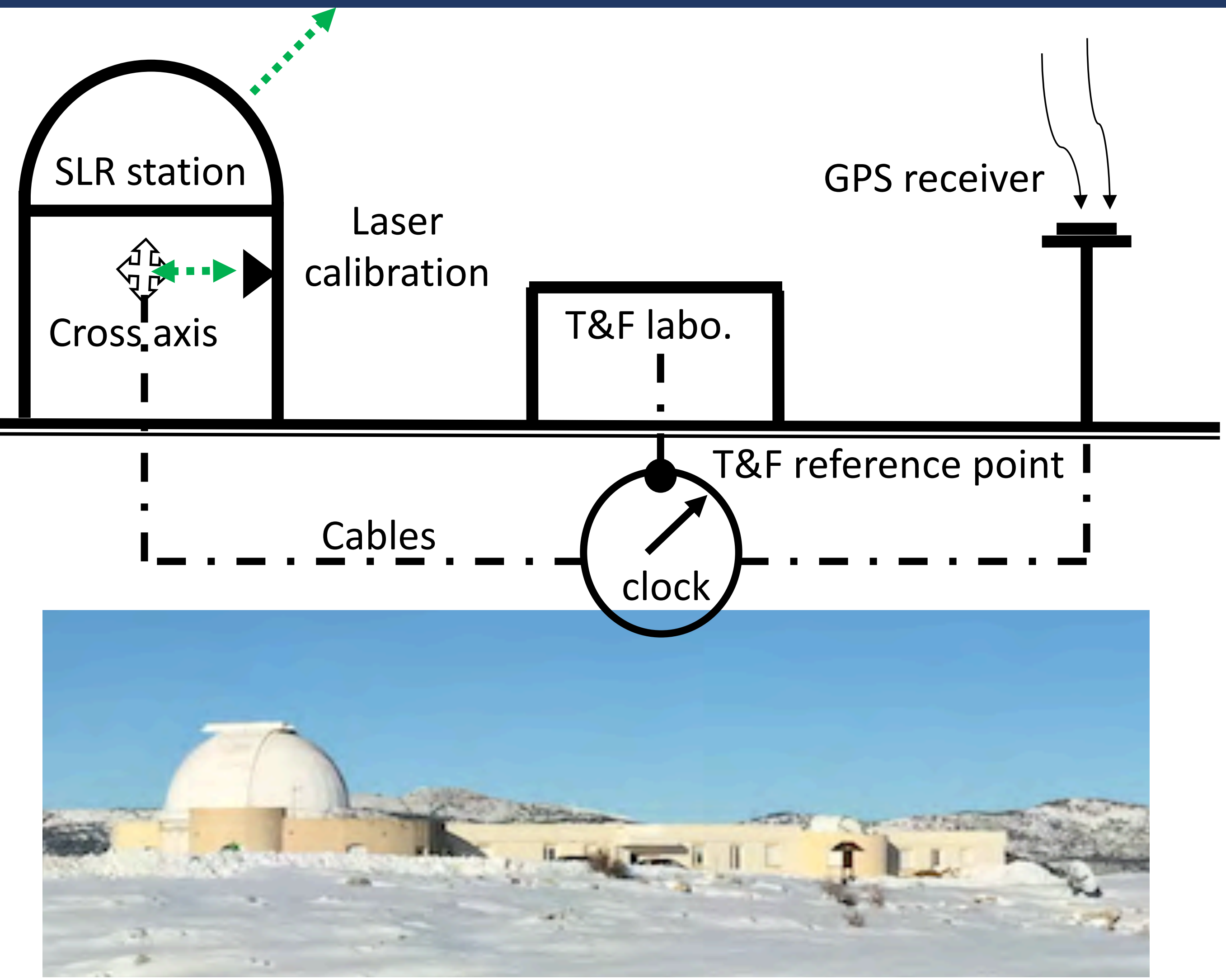
Based on the integration of an on-board model for the oscillator (when T2L2 is not observed)

Accuracy +/- 15 ns to 5 ns (using Grasse as master station)

Compared to GPS at 0.2 ns

Samain E., et al., 2017, (submitted), Time Transfer by Laser Link (T2L2) in non common view between Europe and China.

Ground technologies and Time Biases



We need a reference (A station linked to UTC/TAI)

Samain, E., et al. 2015. *Time transfer by laser link : a complete analysis of the uncertainty budget. Metrologia.*

Laas-Bourez, et al. 2013. *Time and frequency distribution improvement in calern/geoazur laboratory for t2l2 campaigns. In European Frequency and Time Forum International Frequency Control Symposium (EFTF/IFC).*

Grasse master station → TB monitored +/- 5 ns UTC

Time Bias included :

- Stability of the clock
- Calibration (antenna, cables…)
- Event timer (ns, ps resolution)
- Manual operation, changes…

$$E(t)_i = UTC(t) + TB_i$$

Method, results for 2013 and impact on geodetic products (P.O.D, station coordinates)

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Time biases in laser ranging observations: A concerning issue of Space Geodesy

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Available online 17 May 2017

Abstract

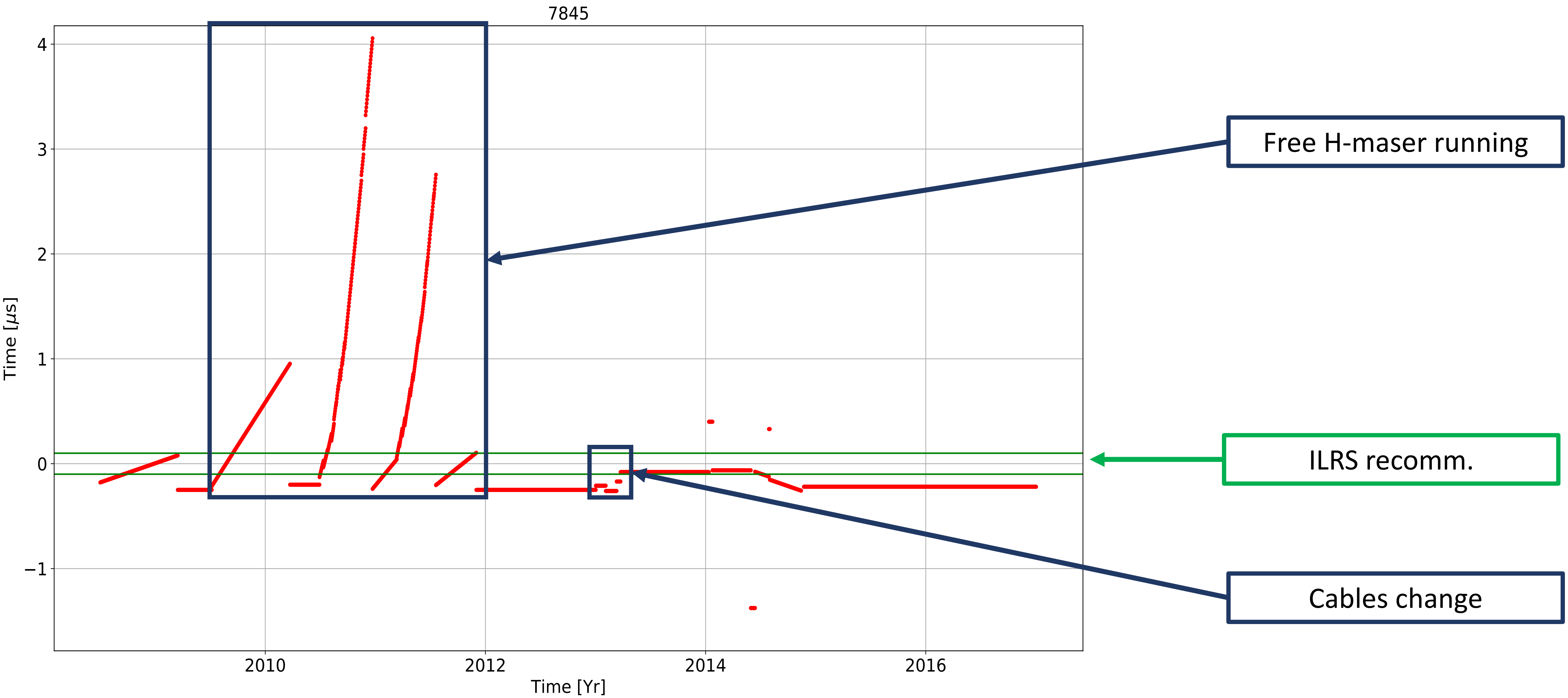
Time transfer by Laser Ranging (LR) recently demonstrated a remarkable stability (a few ps over ~1000 s) and accuracy (<1 ns) in synchronizing both space and ground clocks over distances from a few thousands to tens of thousands kilometers. Given its potential role in navigation, fundamental physics and metrology, it is crucial that synergy between laser ranging and Time&Frequency (T/F) technologies improves to meet the present and future space geodesy requirements. In this article, we examine the behavior of T/F systems that are used in LR tracking stations of the international laser ranging service. The approach we investigate is to compute time synchronization between clocks used at LR stations using accurate data of the Time Transfer by Laser Link (T2L2) experiment onboard the satellite Jason-2 (Samain et al., 2014). Systematic time biases are estimated against the UTC time scale for a set of 22 observing stations in 2013, in the range of zero to a few µs. Our results suggest that the ILRS network suffers from accuracy issues, due to time biases in the laser ranging observations. We discuss how these systematic effects impact the precise orbit determination of LAGEOS geodetic satellites over a 1-year analysis, and additionally give a measure of the local effect into station coordinates, regarding in particular the effect in the east–west component that is of 2–6 mm for a typical systematic time bias of one µs.

Time Biases : Overview and remarks

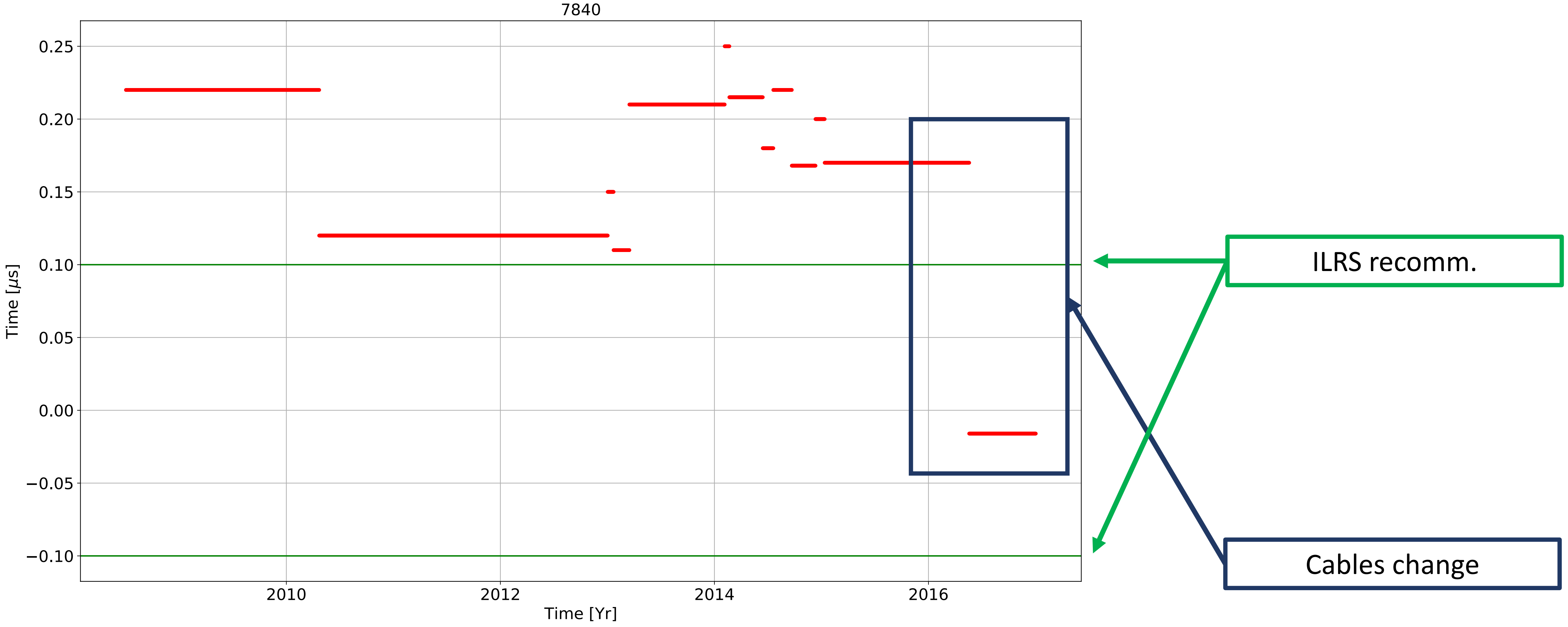
Involved Stations id :
To perform T2L2 calculation, we need full rate data !

1888	7124	7821	7941	1884
1889	7403	7822	8834	
1890	7406	7824	1886	2016-2017
1891	7501	7825	1824	2008-2017
7407	7237	7848	1831	2009-2017
7080	7308	7832	1873	2012-2017
7090	7358	7838	1873	2008-2011
7105	7394	7840	1893	2011 (5 mths)
7110	7810	7841	1868	2010-2011 (5 mths)
7119	7811	7845	1874	2010-2017

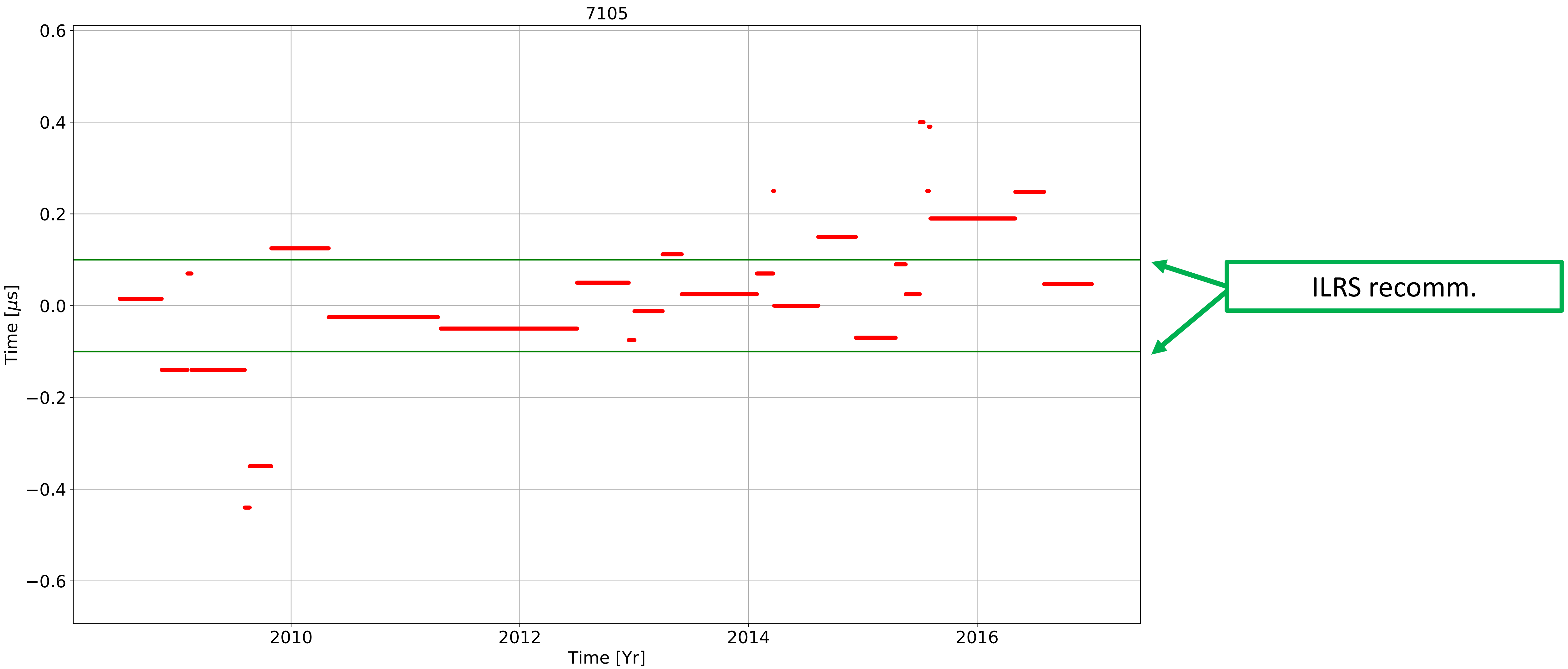
Grasse (Master station)



Herstmonceux

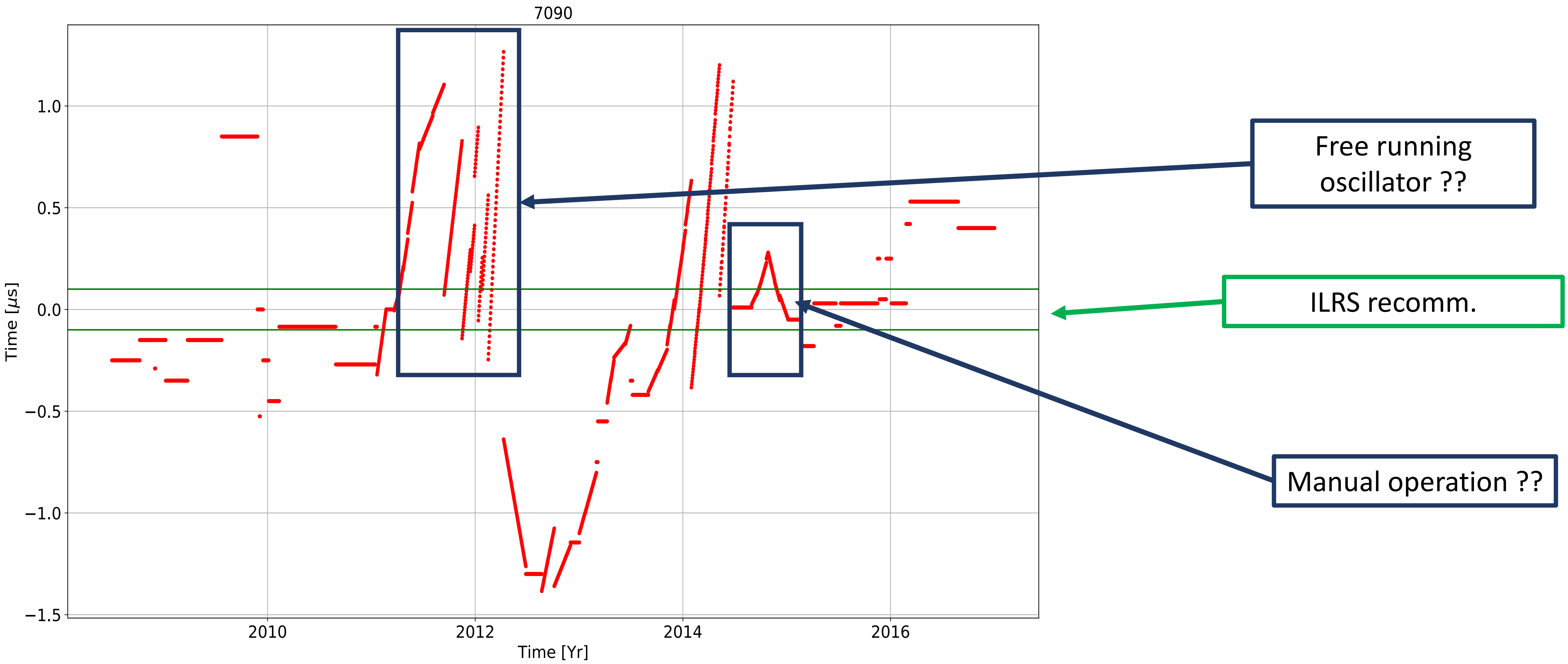


Greenbelt

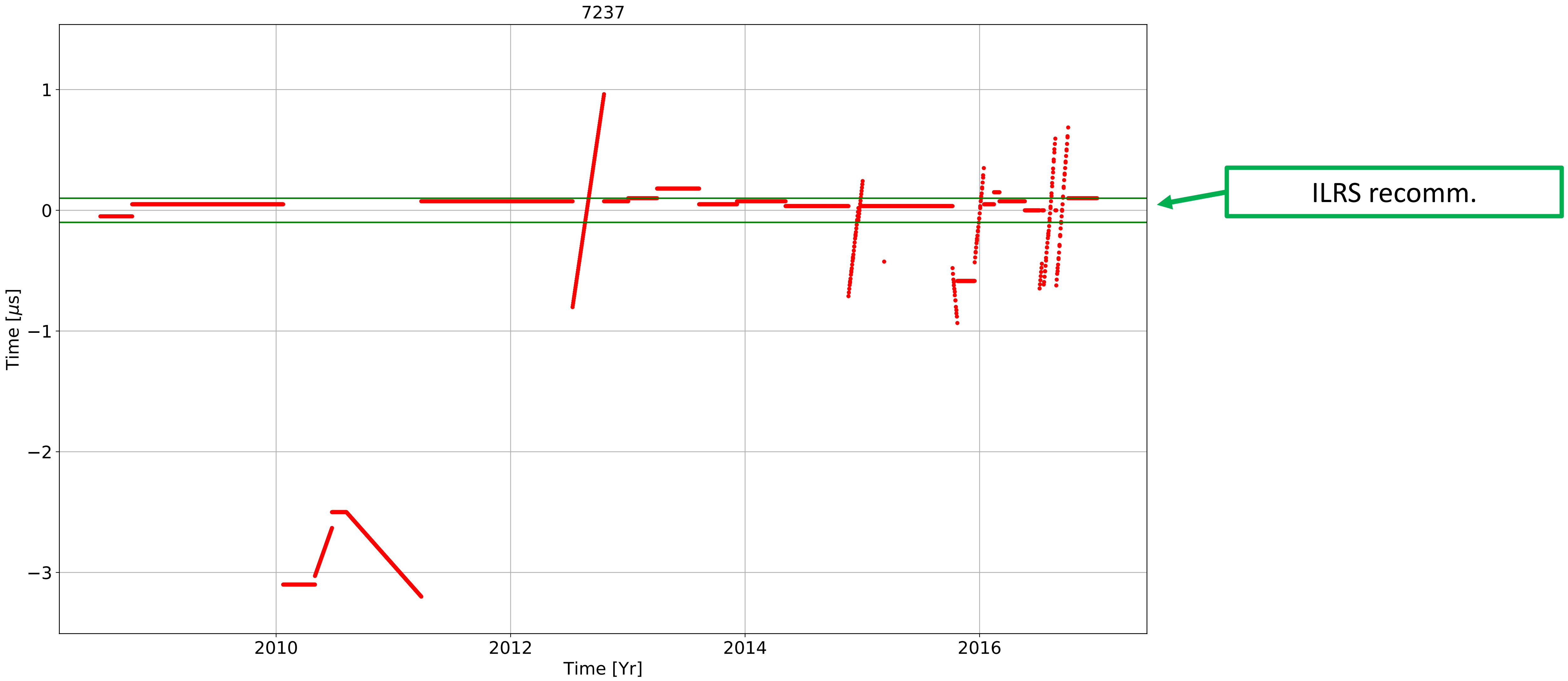


7105
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
Time [μs]
2010
2012
2014
2016
Time [Yr]
ILRS recomm.

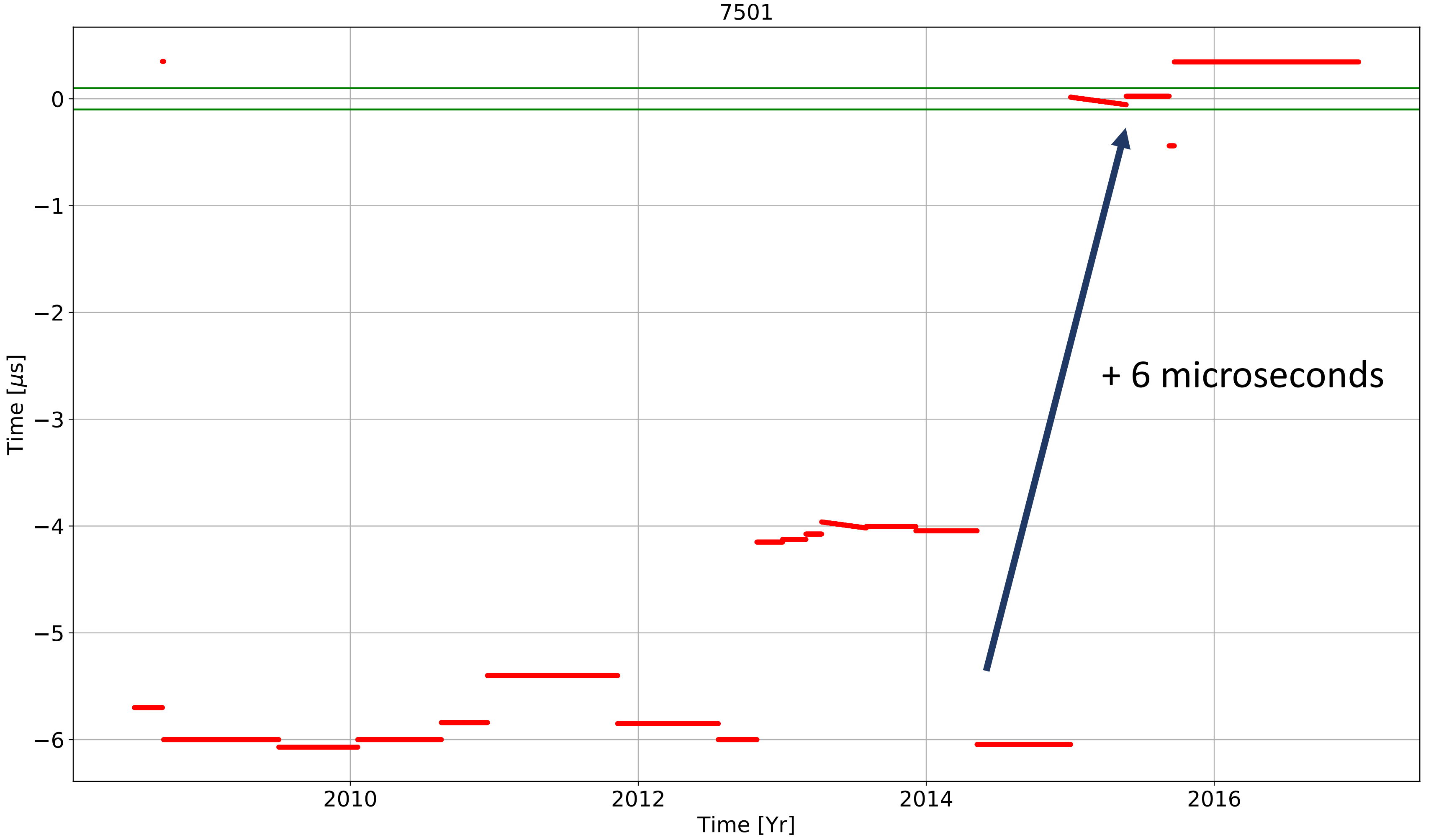
Yarragadee


7090
1.0
0.5
0.0
−0.5
−1.0
−1.5
Time [μs]
2010
2012
2014
2016
Time [Yr]
Free running oscillator ??
ILRS recomm.
Manual operation ??

Changchun

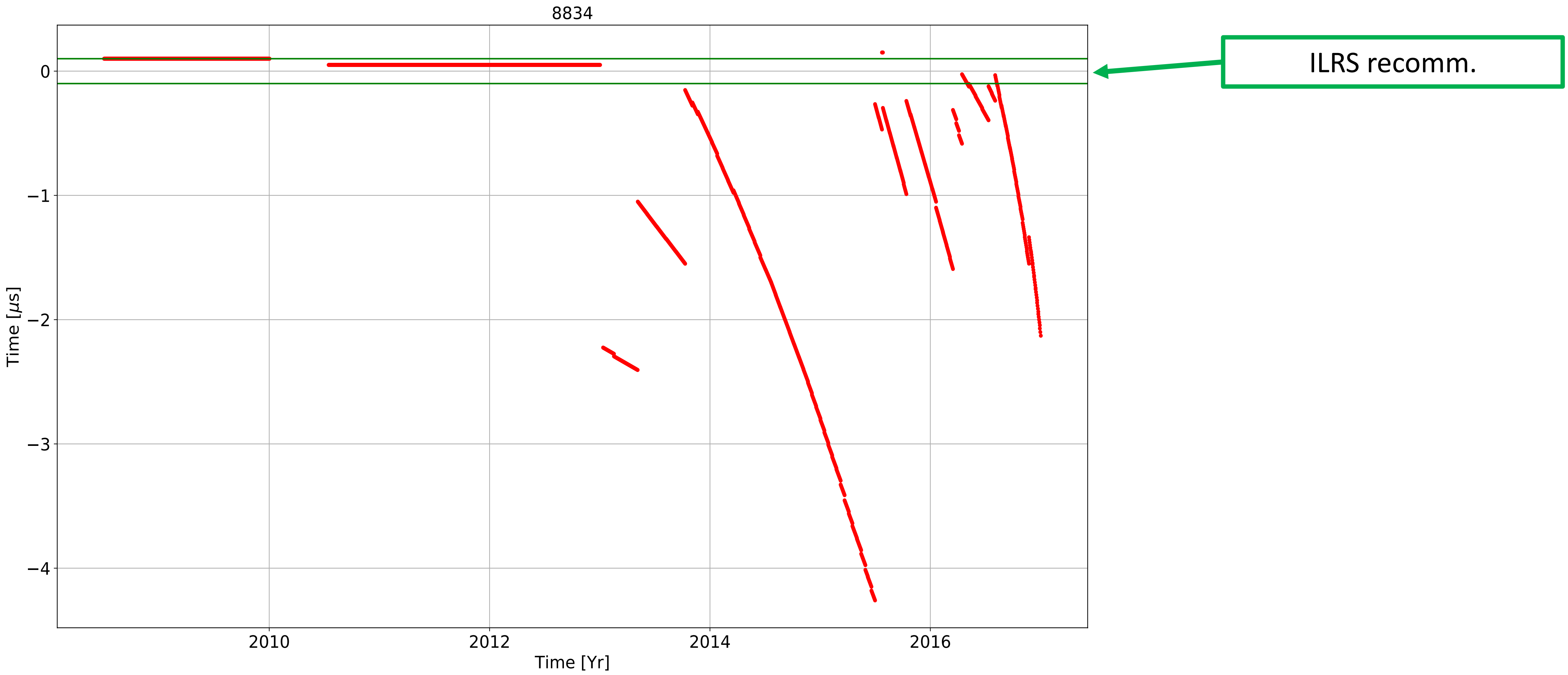


Hartebeesthoek



ILRS recomm.

Wettzell



On-line website !

http://www.geoazur.fr/t2l2/en/data/v4/

Help | Station | Board | Energy | Ground to Space | Ground to Ground | DORIS oscillator | Ephemeris | Obs 2016 | Obs 16-08 | Obs 16-09 | Obs 16-10 | Obs 16-11 | Obs 16-12

Start : 01-10-2008

End : 31-12-2016

Station : 8834 Wettzell

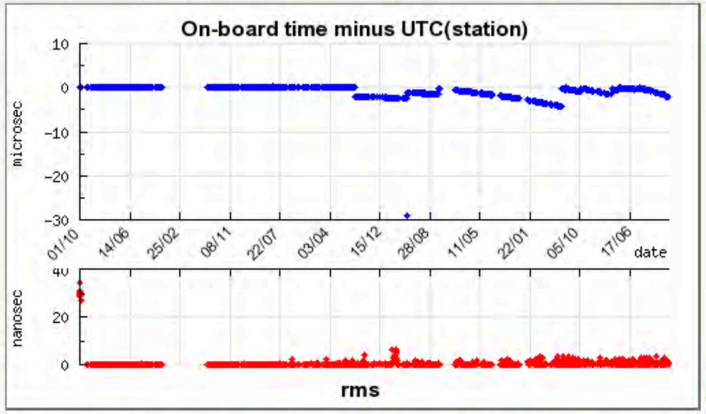
UTC(station)

Get all files for one day by email

Download CrdReader.jar

Data Table

Help

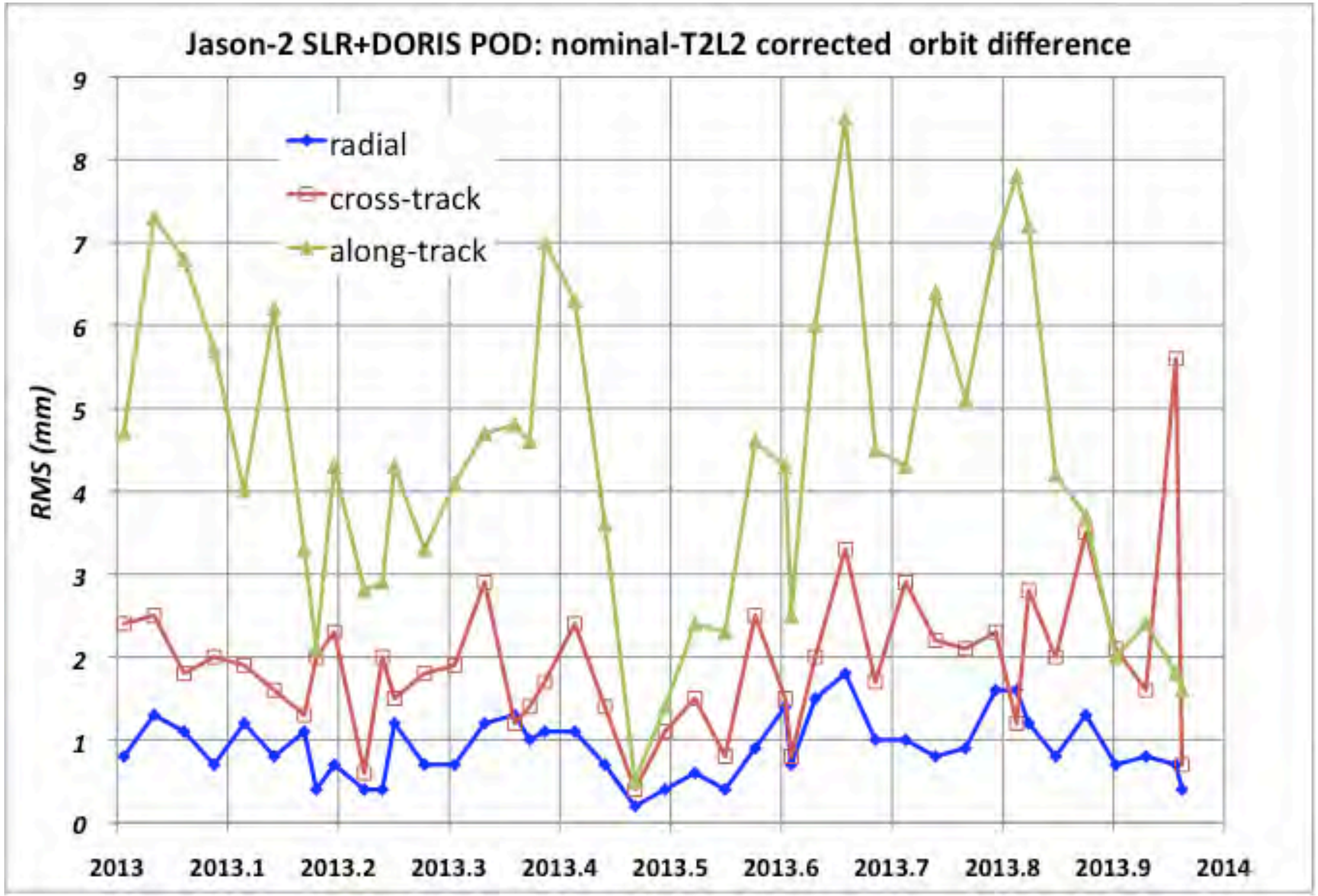


Date		# Passage (click for graph)	Start	End	Shots nb	Triplets nb	Energy Max (μJoul/m²)	Onboard time minus ground time (μs)	rms (ns)
54740	01/10/2008	1	18:08:44	18:11:17	205	150	27.556	+0.0883	**30.000**
54740	01/10/2008	2	20:06:27	20:08:18	86	83	22.988	+0.1027	**31.003**
54743	04/10/2008	1	17:24:19	17:24:47	68	53	4.779	+0.0850	**30.310**
54743	04/10/2008	2	21:21:29	21:21:57	23	20	2.501	+0.1097	34.411
54743	04/10/2008	3	23:16:35	23:23:15	509	285	6.580	+0.0983	**28.712**
54744	05/10/2008	1	01:11:45	01:16:13	480	432	36.348	+0.0785	**28.927**
54744	05/10/2008	2	13:52:39	13:55:09	61	56	6.016	+0.0983	**26.644**
54744	05/10/2008	3	15:49:23	15:53:54	192	119	6.549	+0.0991	**29.479**
54773	03/11/2008	1	11:13:12	11:15:10	253	182	21.251	+0.1330	**0.071**
54773	03/11/2008	2	19:07:20	19:09:00	30	20	24.714	+0.1183	0.106
54774	04/11/2008	1	07:51:37	07:05:05	58	53	4.191	+0.1241	**0.047**

How to deal with Time Biases ?

- Stations need to do a complete calibration, which include cables, time distribution, antenna (GPSDO)…
- Control the stability of the clock, avoid free running oscillators
- Have an event timer with a good resolution
- Time Biases need to be follow continuously
- Every changes on the technology should be noticed, any change will lead to an inevitable Time Bias

Effects on geodetic products



Work in progress.

Effect of Time Biases on the Jason-2 POD.

Effects on geodetic products

P.O.D (along-track component) For Jason-2 (1336 km)	Est-West component for laser station (uni-satellite solution)	DORIS Time Bias improvement (accuracy)
Several mm	2-3 micros = 6 mm	1 microseconds

Several studies in progress, see OSTST 2017 and AGU Fall meeting 2017

Keep in mind :

Microseconds Time Bias lead to **mm effects** on geodetic products

Conclusions

- We develop a complete new method thanks T2L2 to determine time bias
- This method is direct and independent of the orbit calculation
- First demonstration of optical time transfer in non common view (intercontinental) at the level of 5 ns
- For ~30 laser stations, 8 years of data available, will be included in Data Handling Files
- Accuracy at +/- 15 ns
- Compared to GPS at a level of 0.2 ns (2016 Campaign)
- Non negligible effects on orbit components and on the station coordinates

Thank you for your attention !

belli@geoazur.unice.fr

http://www.geoazur.fr/t2l2/en/data/v4/