From Time Transfer by Laser ranging to Space Geodetic Products

Alexandre Belli, Pierre Exertier, Erricos C. Pavlis and Frank G. Lemoine
Géoazur, France; Baltimore University, Nasa GSFC; USA
belli@geoazur.unice.fr

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)

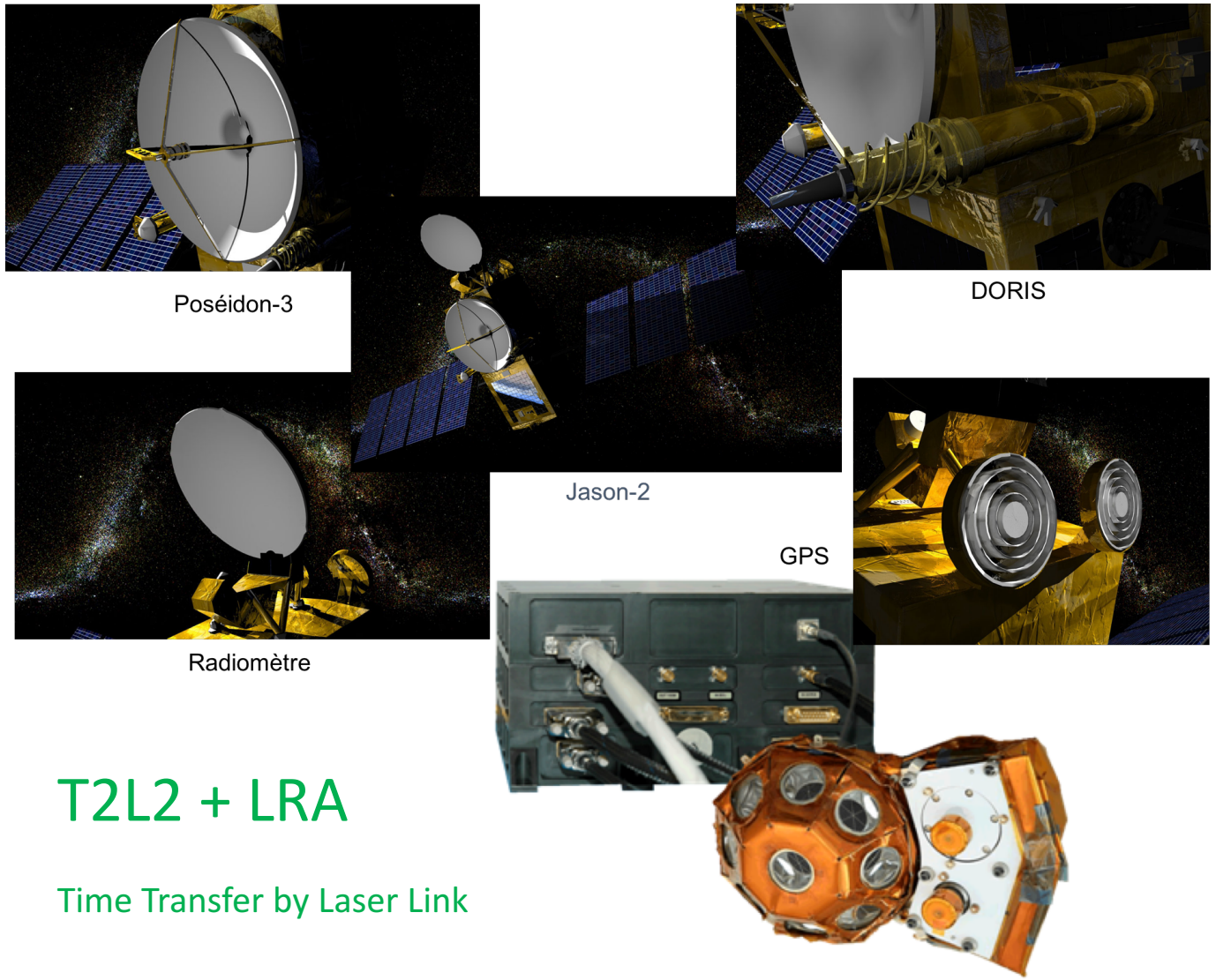
***Pearlman, M., et al. 2002**. The international laser ranging service. Advances in Space Research*

- 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



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 + LRA

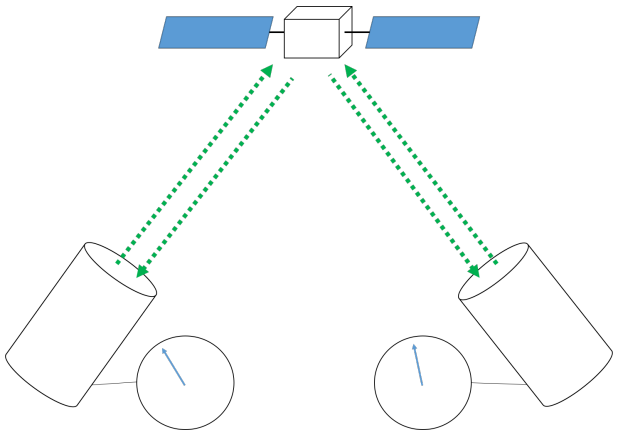
Time Transfer by Laser Link

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

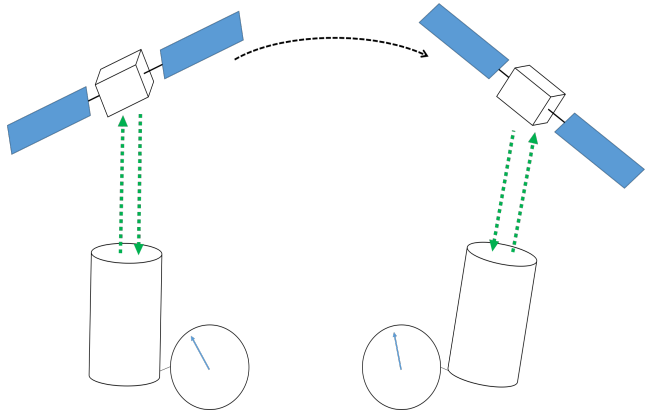
Exertier, P., et al. 2014. *Time transfer by laser link: data analysis and validation to the ps level. Advances in Space Research, 54(11), 2371-2385.*

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



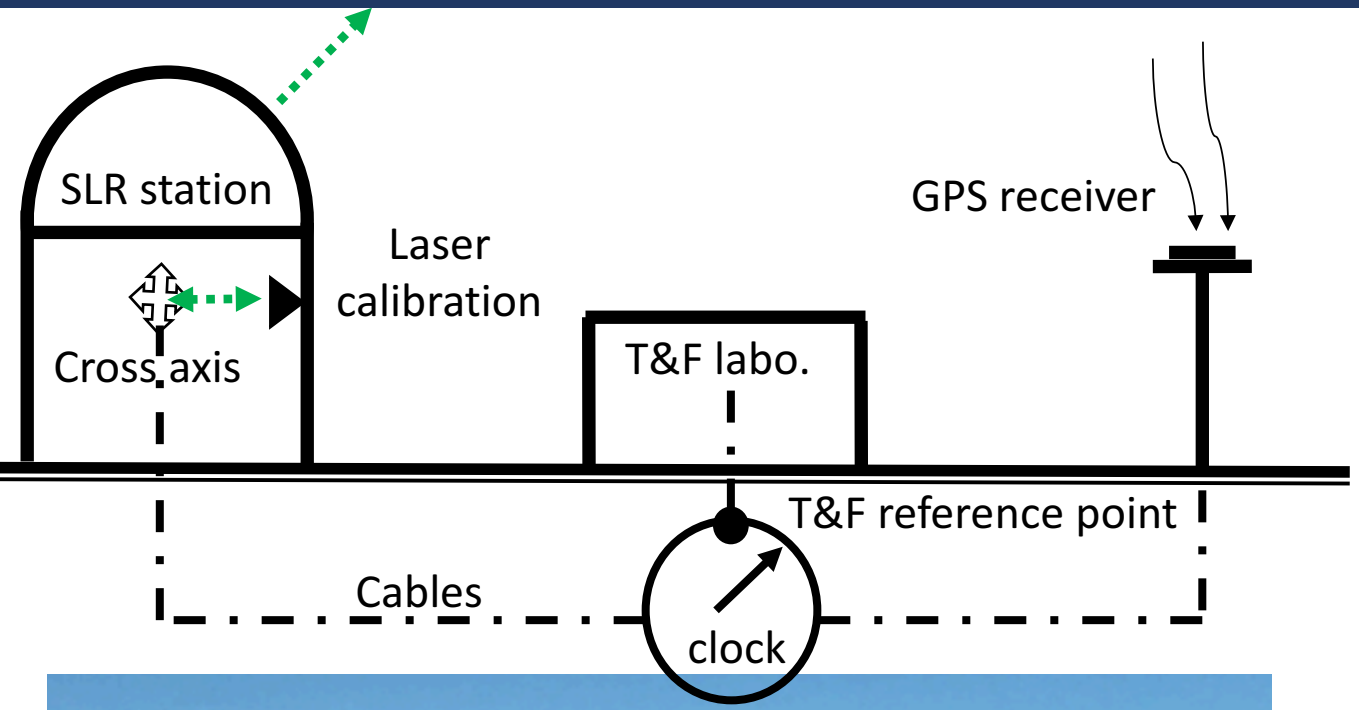
Based on the integration of an on-board model for the oscillator (when T2L2 is not observed)

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)

ELSEVIER

CrossMark

Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 60 (2017) 948–968

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

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

Pierre Exertier [a,*], A. Belli [a], J.M. Lemoine [b]

[a] UMR Geoazur, Université de Nice, Observatoire de la Côte d'Azur, 250 rue A. Einstein, F-06560 Valbonne, France
[b] CNES/GRGS, BPI 3100, 18 avenue E. Belin, F-31401 Toulouse cedex 9, France

Received 22 March 2017; received in revised form 10 May 2017; accepted 12 May 2017
Available online 17 May 2017

Abstract

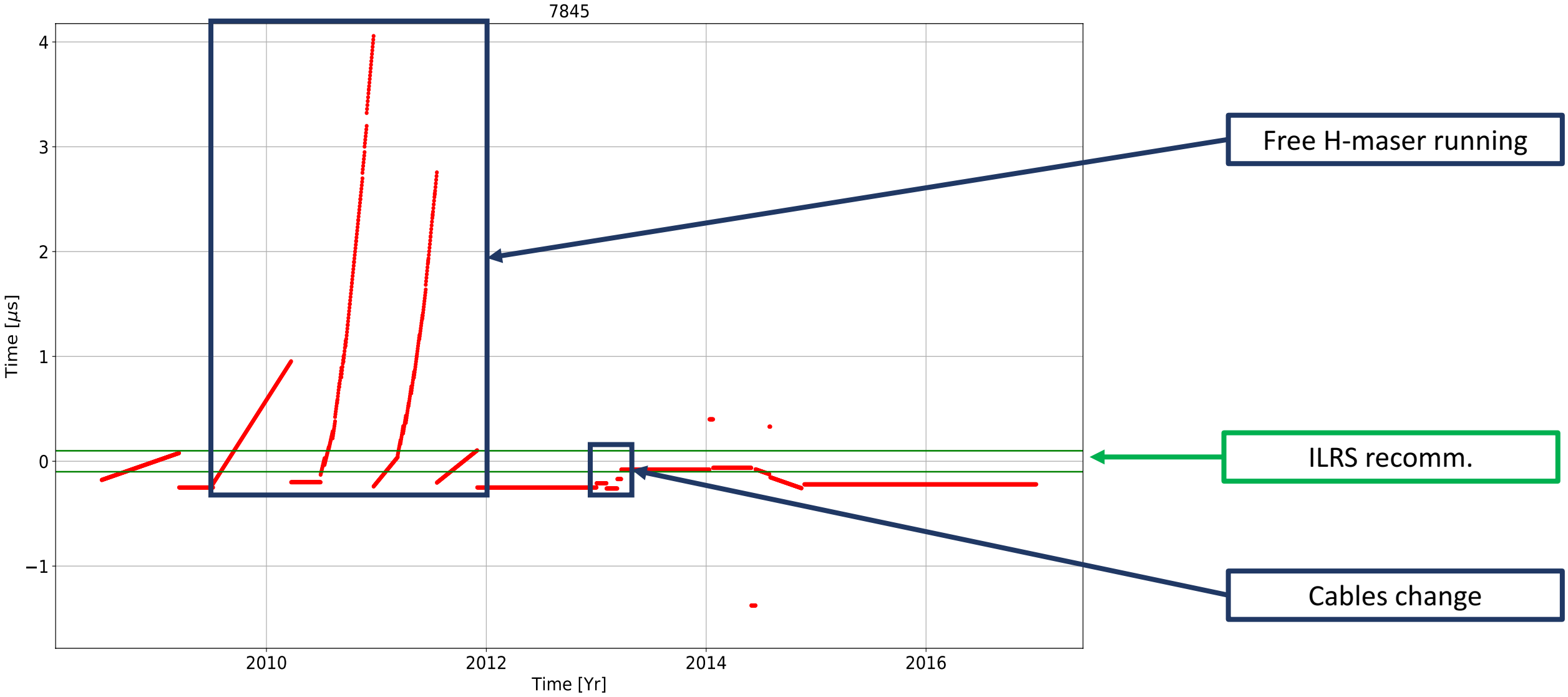
Time transfer by Laser Ranging (LR) recently demonstrated a remarkable stability (a few ps over ~1000 s) and accuracy (<1 ns) in synchronizing both space and ground clocks over distances from a few thousands to tens of thousands kilometers. Given its potential role in navigation, fundamental physics 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

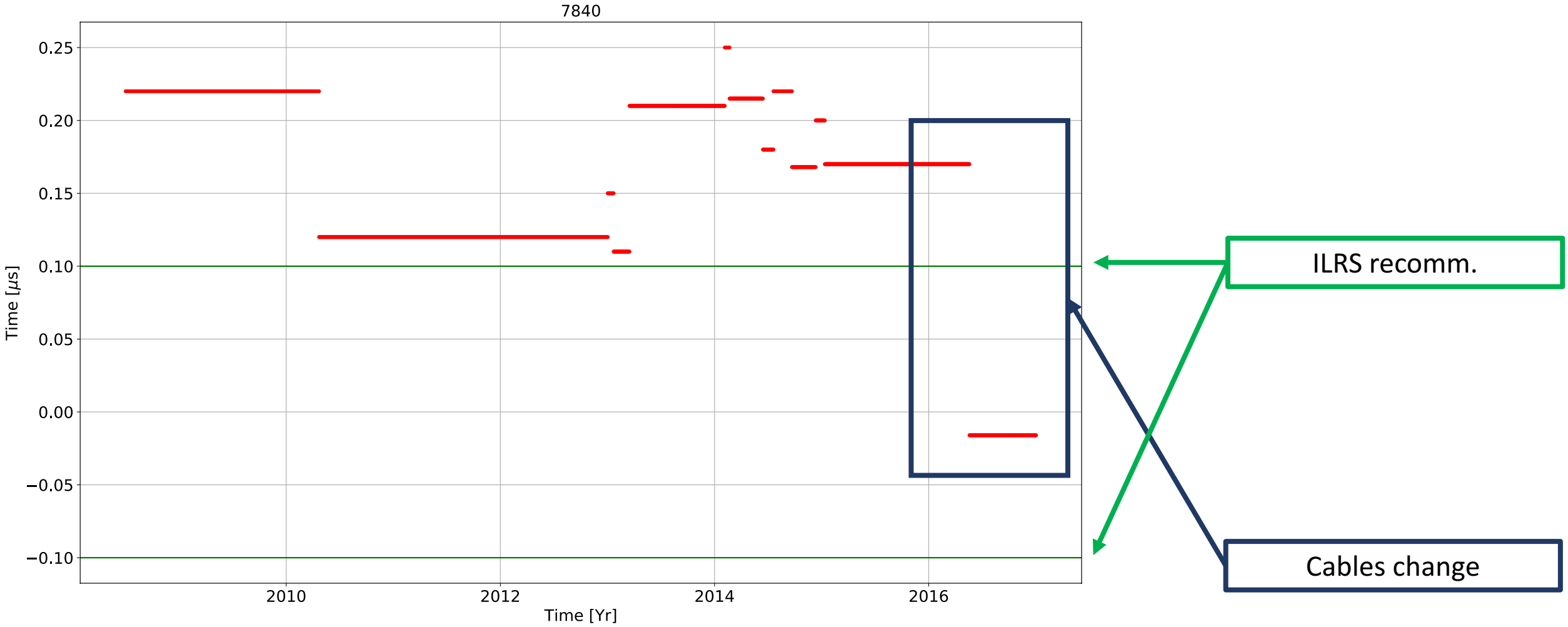
Involved Stations id :
To perform T2L2 calculation, we need full rate data !

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

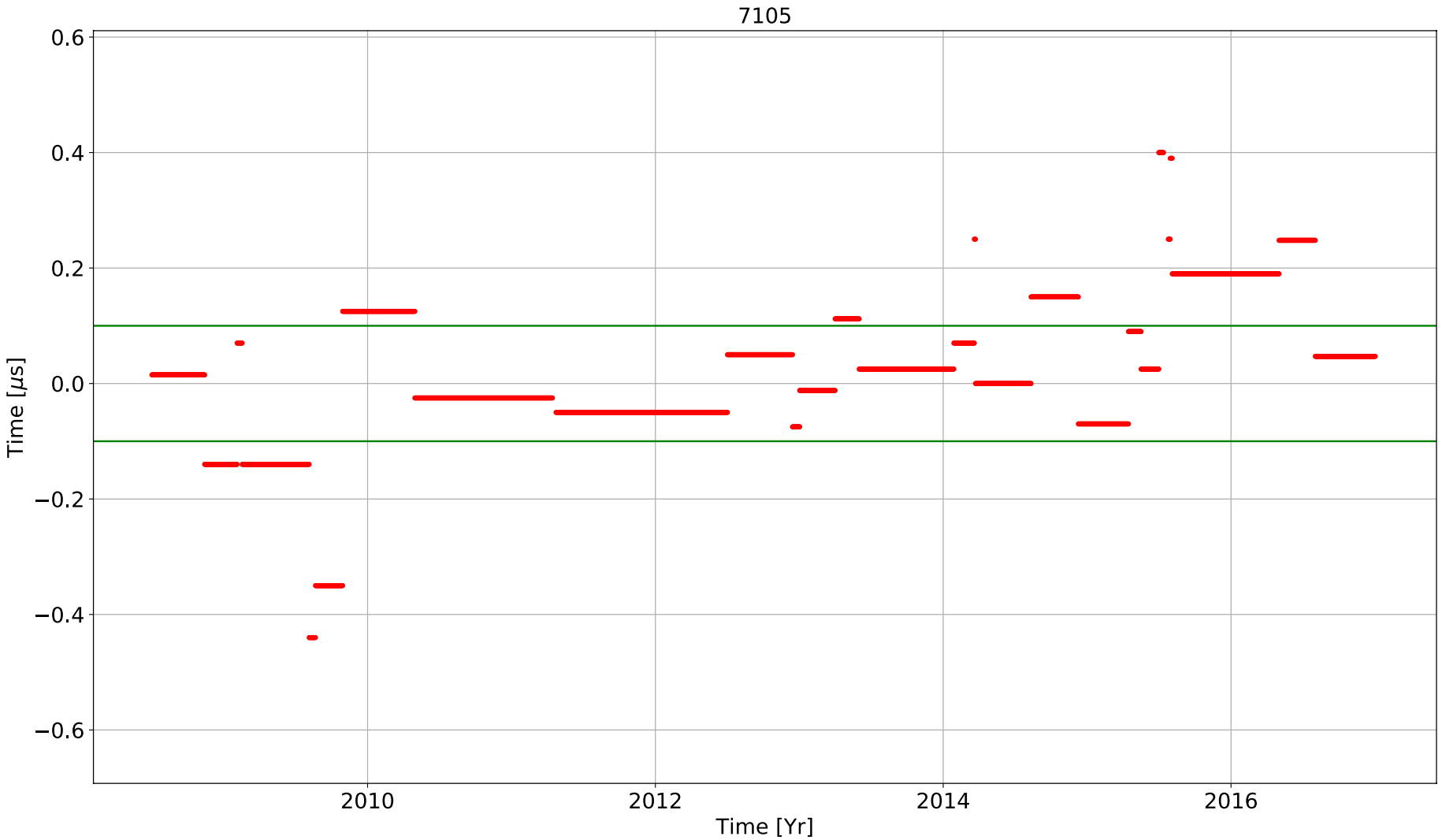
Grasse (Master station)



Herstmonceux

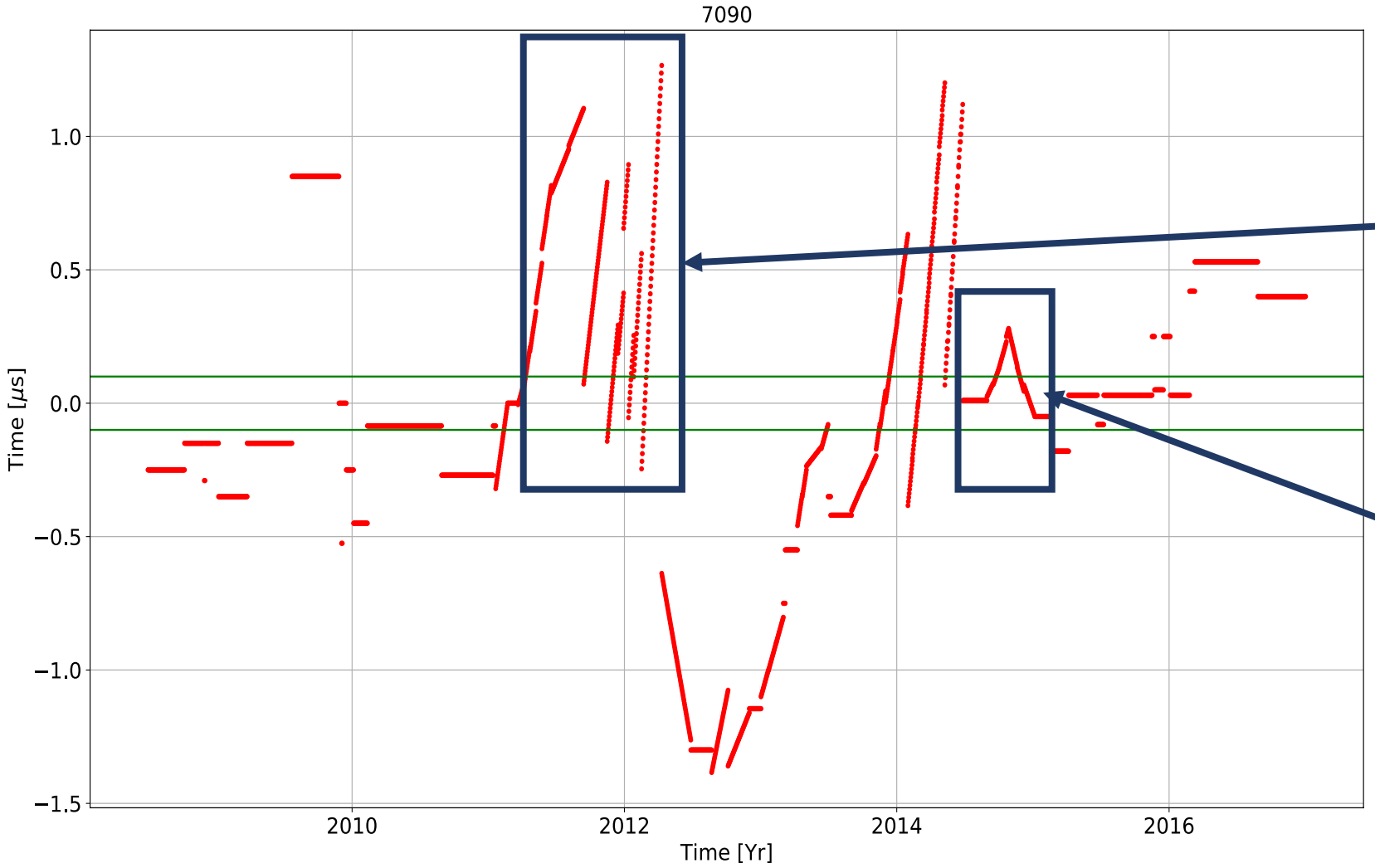


Greenbelt



ILRS recomm.

Yarragadee

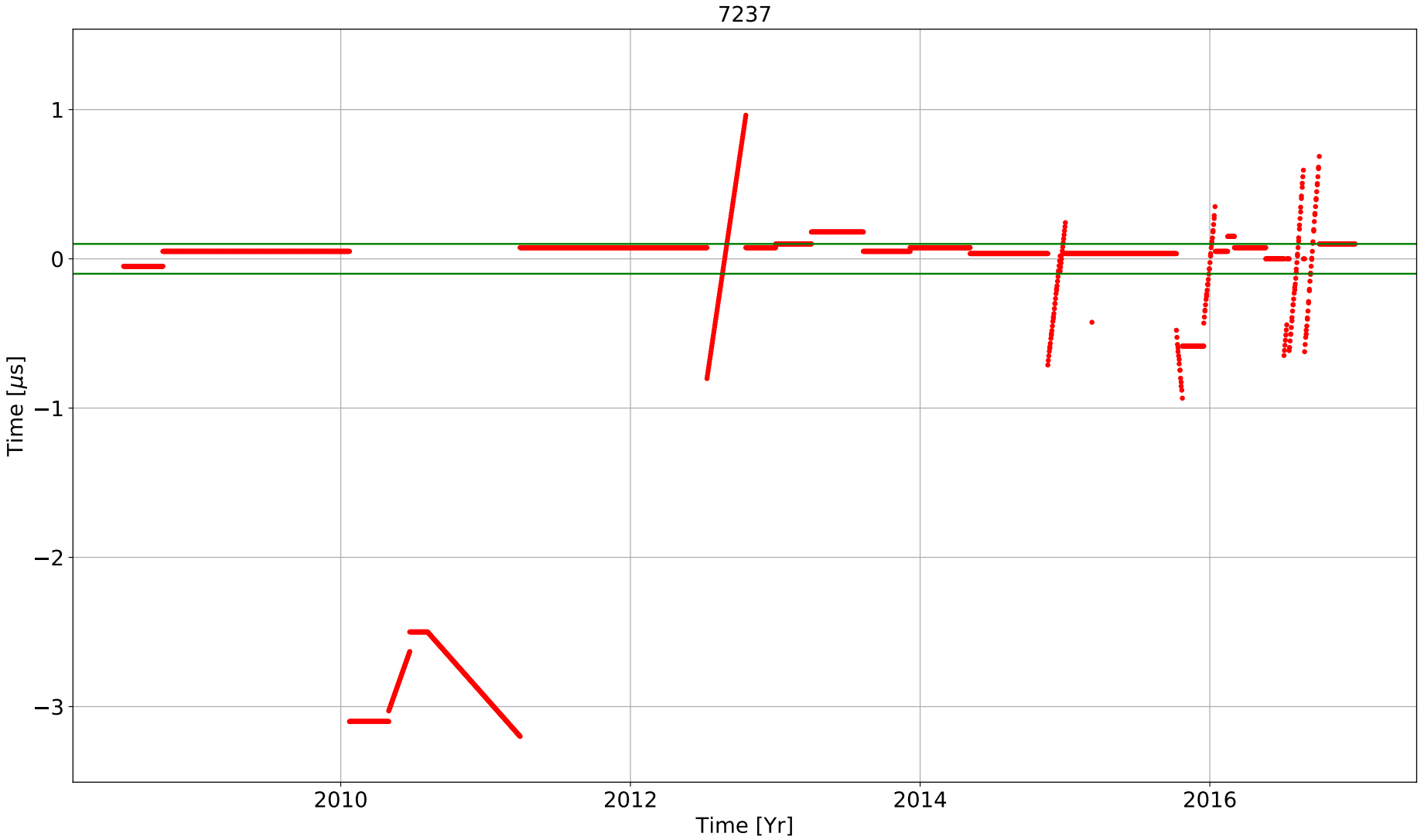


Free running oscillator ??

ILRS recomm.

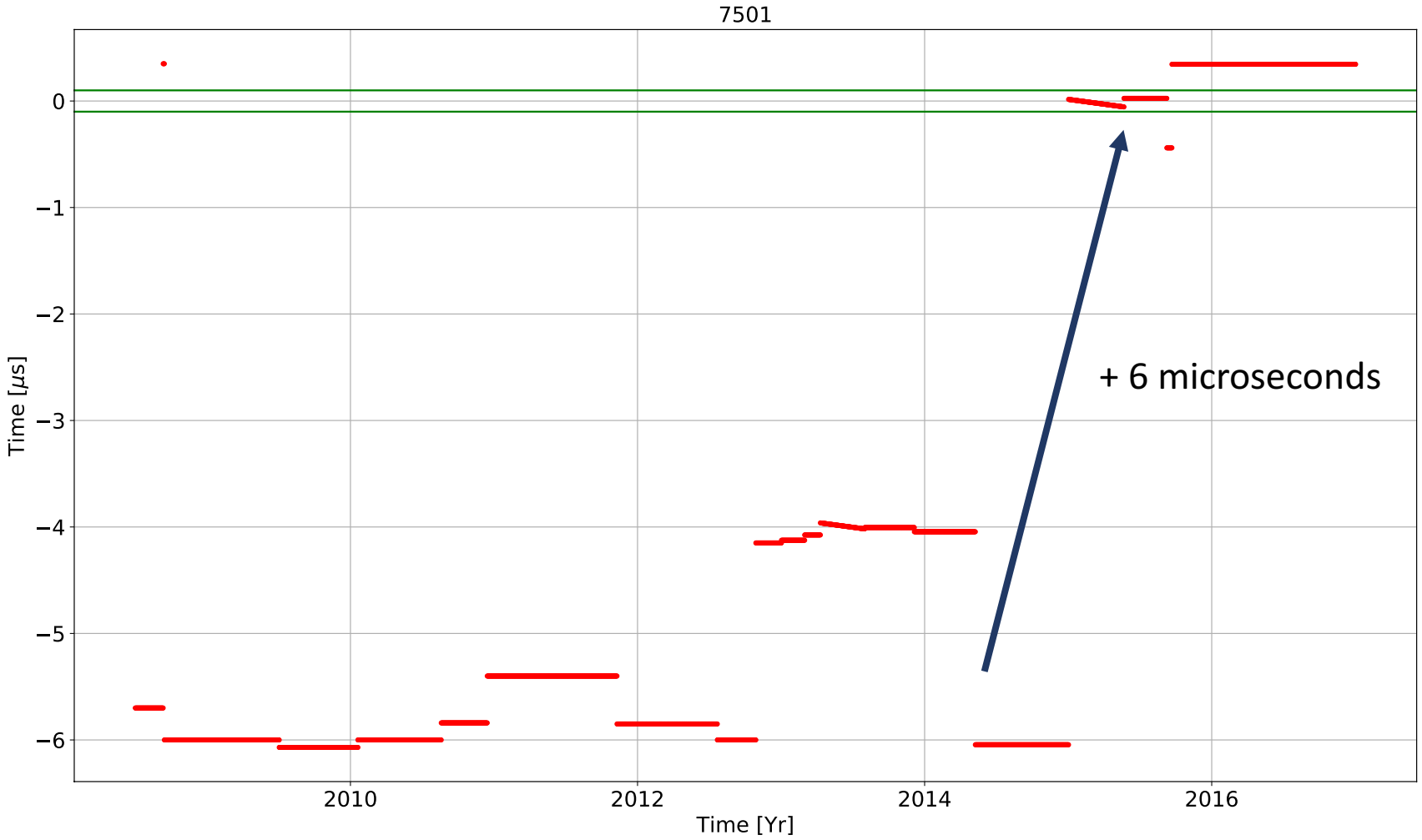
Manual operation ??

Changchun



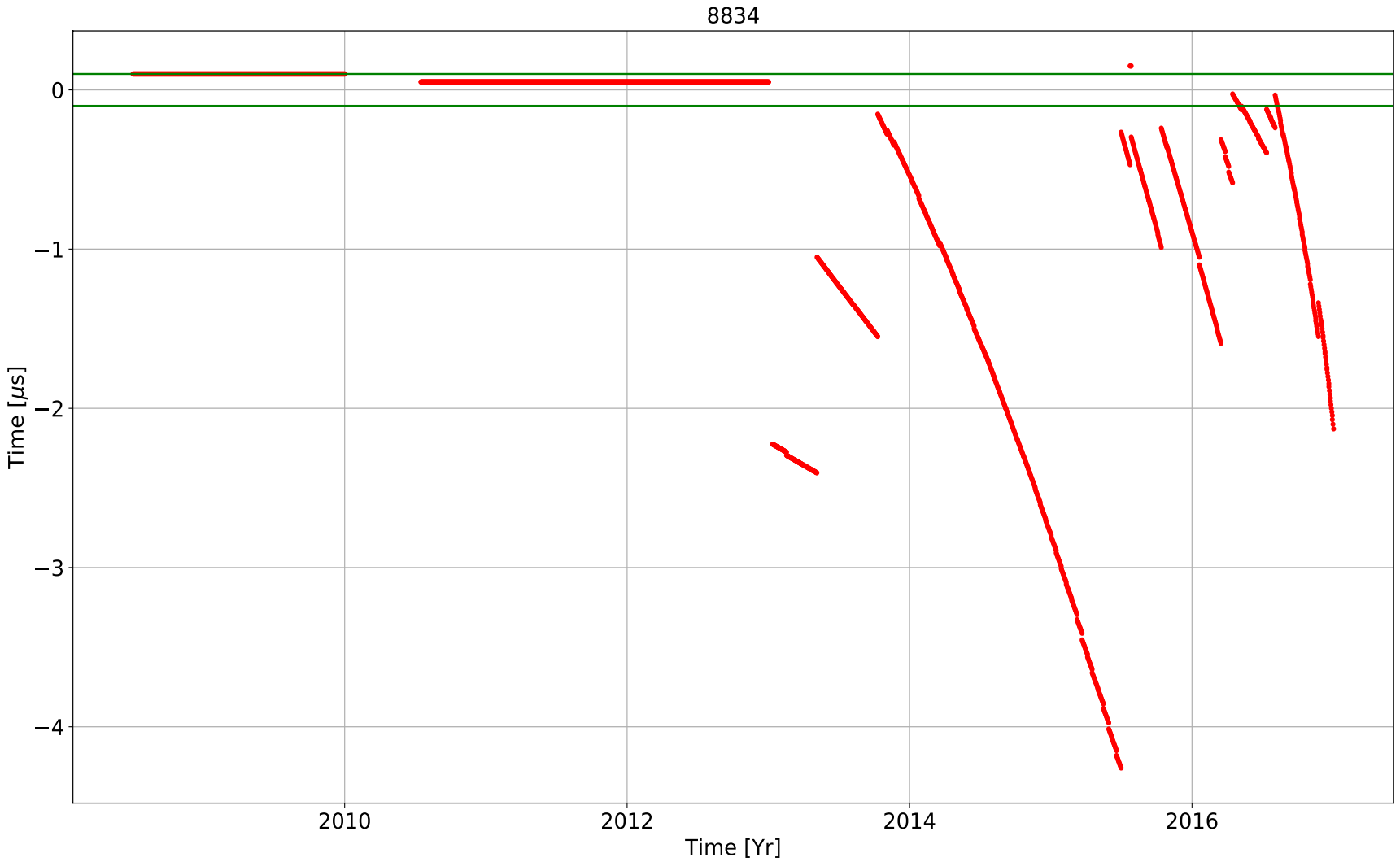
ILRS recomm.

Hartebeesthoek



ILRS recomm.

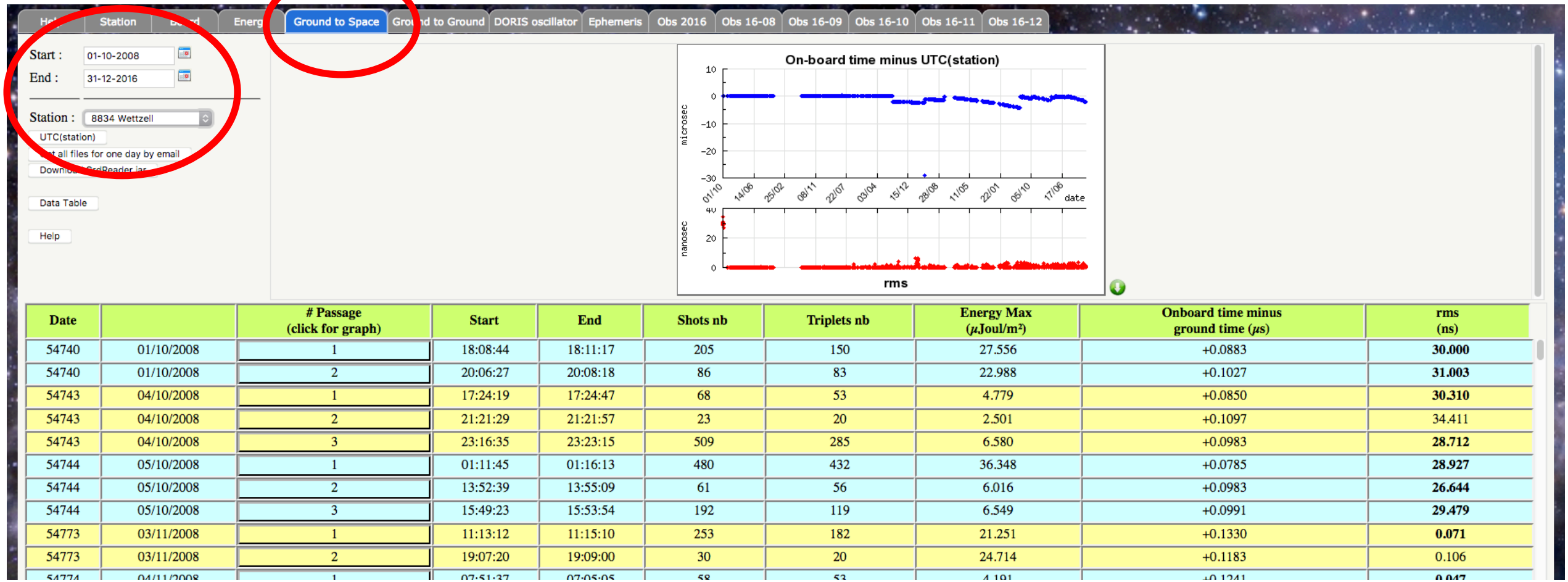
Wettzell



ILRS recomm.

On-line website !

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

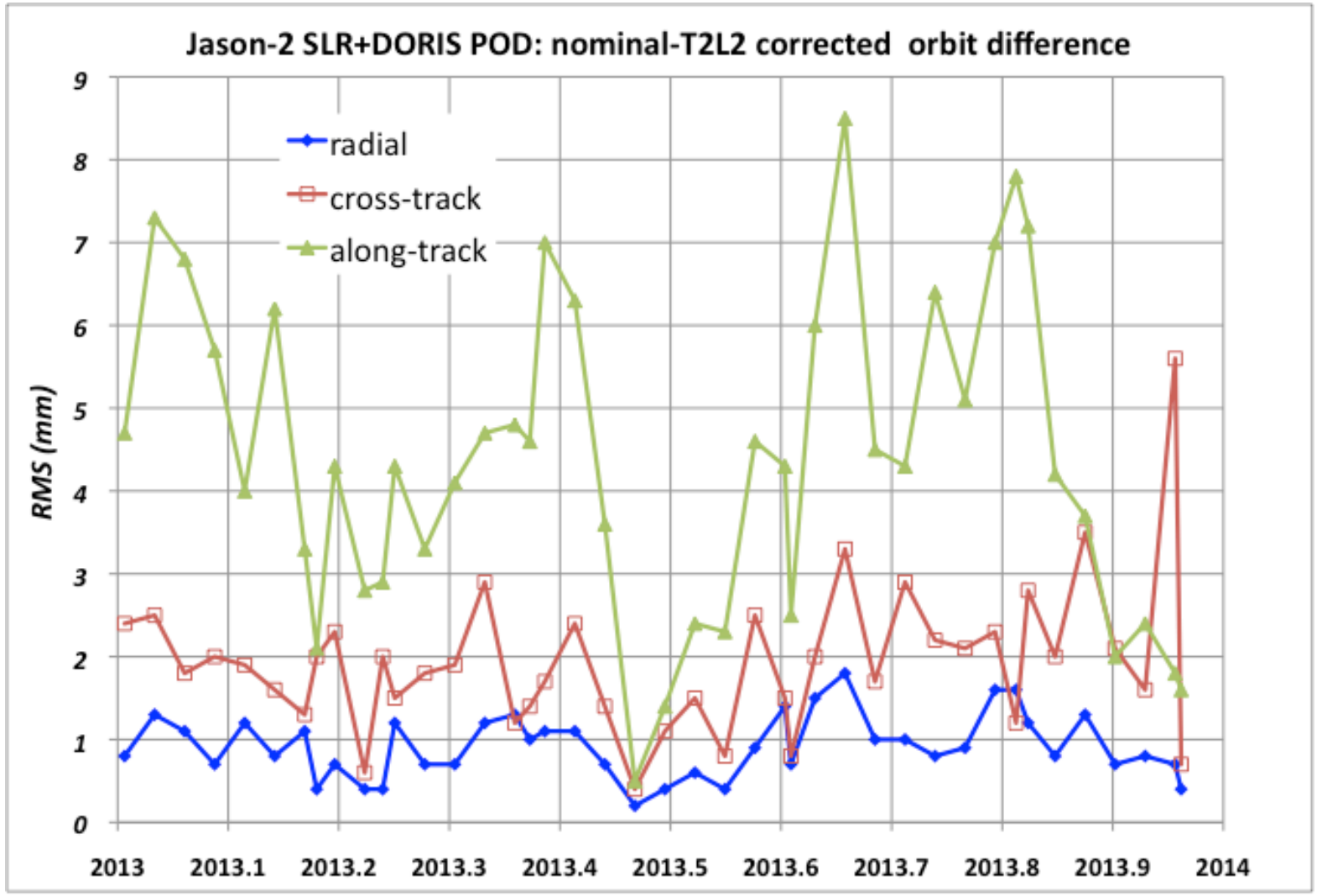


Date		# Passage (click for graph)	Start	End	Shots nb	Triplets nb	Energy Max (μJoul/m^2)	Onboard time minus ground time (μs)	rms (ns)
54740	01/10/2008	1	18:08:44	18:11:17	205	150	27.556	+0.0883	**30.000**
54740	01/10/2008	2	20:06:27	20:08:18	86	83	22.988	+0.1027	**31.003**
54743	04/10/2008	1	17:24:19	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

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/