How UTC is computed: the Circular T behind the scenes

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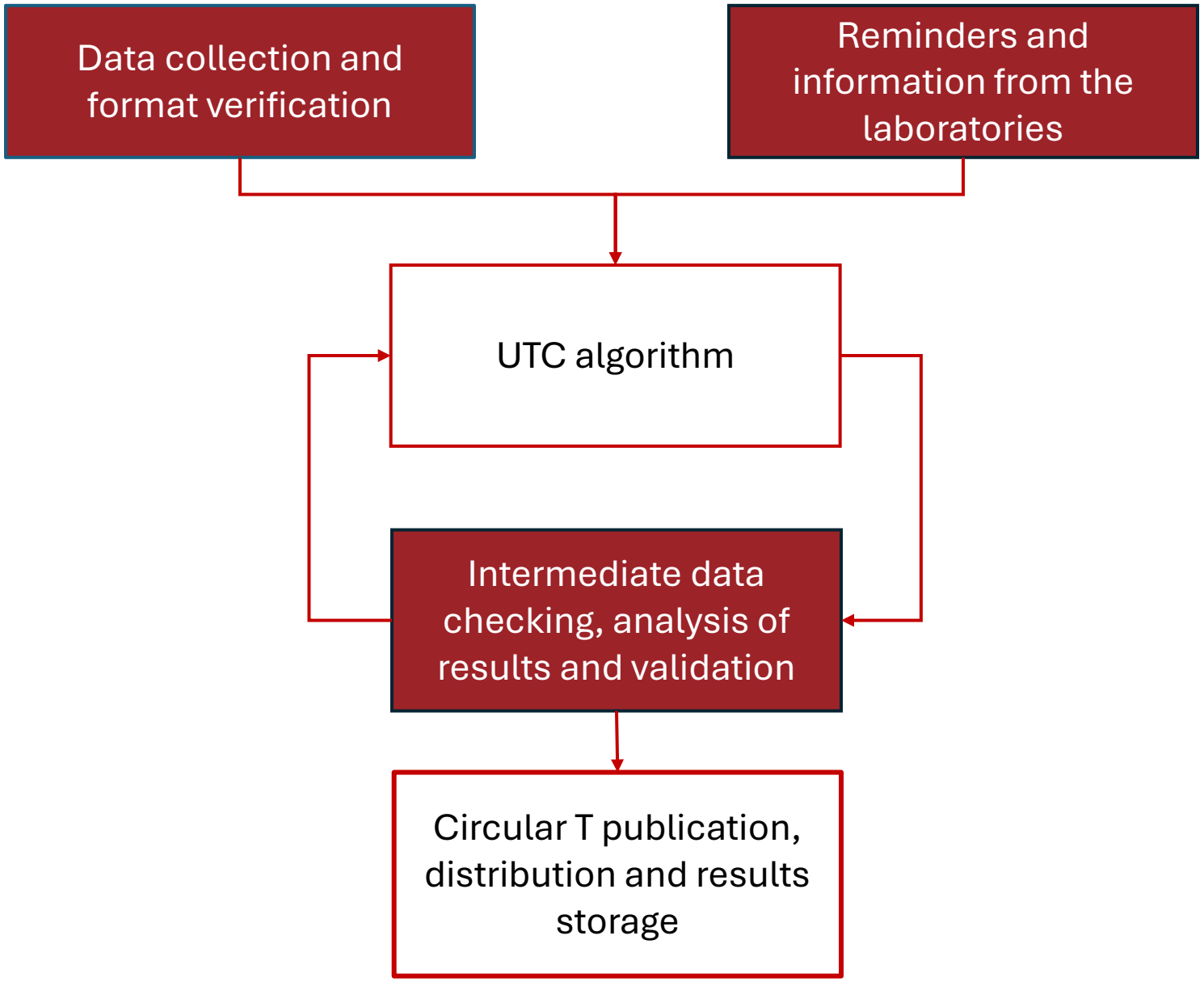
Disclaimer: examples of real UTC laboratory data are shown.
These are intended purely for illustrative purposes.

Outline


Data collection and format verification
Reminders and information from the laboratories
UTC algorithm
Intermediate data checking, analysis of results and validation
Circular T publication, distribution and results storage

Circular T computation

What happens at the BIPM Time Department each month before the publication of Circular T?

Data collection

By the 4th of the month, each laboratory should send the data of the month before:

- Time transfer: CGGTTS, RINEX, TWSTFT, Fiber…
- Clock: clocks file, PSFS

To obtain the results, we also collect IGS analysis centers' data (open access on the web):

- Broadcasted and post-processed ephemeris for GNSS satellites, ionospheric maps

GNSS data collection

For internal use only
http://193.104.127.98/utc/filelisting/cggtts.pl

CGGTTS

Legend
file status: exists missing

YYMM			2506			2507																												
MJD			**60854**	60855	60856	60857	60858	**60859**	60860	60861	60862	60863	**60864**	60865	60866	60867	60868	**60869**	60870	60871	60872	60873	**60874**	60875	60876	60877	60878	**60879**	60880	60881	60882	60883	**60884**	60885	60886	60887
labo	**llmo**	**type**																																	
DTAG	DT04	gz																																	
DTAG	DT05	gz																																	
ESA	ES07	gz																																	
ESA	ES07	ez																																	
ESA	ES08	gz																																	
ESA	ES08	ez																																	
HKO	HKO1	gm (*)																																	
HKO	HKO1	rm																																	
HKO	HKO1	ez																																	
IBM	BO__	gm																																	
ICE	CE1_	gm																																	
ICE	CE__	gm (*)																																	
ICE	CE__	rm																																	
ICE	CE__	ez																																	
IDN	KI03	gz																																	
IFAG	IF14	gz																																	
IFAG	IF20	gz																																	
IFAG	IF20	ez																																	

RINEX

YYMM		2506			2507																																		
MJD		**60854**	60855	60856	60857	60858	**60859**	60860	60861	60862	60863	**60864**	60865	60866	60867	60868	**60869**	60870	60871	60872	60873	**60874**	60875	60876	60877	60878	**60879**	60880	60881	60882	60883	**60884**	60885	60886	60887	60888
labo	**station**																																					
AOS	ao_4																																					
AOS	ao_5																																					
APL	apl4																																					
APL	apl5																																					
AUS	au04																																					
AUS	au06																																					
AZ	az01																																					
BEV	be1_																																					
BEV	be3_																																					
BIM	bm51																																					
BIPM	bp21																																					

YYMM			2506			2507																																	
MJD			**60854**	60855	60856	60857	60858	**60859**	60860	60861	60862	60863	**60864**	60865	60866	60867	60868	**60869**	60870	60871	60872	60873	**60874**	60875	60876	60877	60878	**60879**	60880	60881	60882	60883	**60884**	60885	60886	60887
labo	**FTP folder**	**folder**																																				
AOS	SATRE/Europe	SATRE/AOS01																																				
CH	SATRE/Europe	SATRE/CH01																																				
IT	SATRE/Europe	SATRE/IT01																																				
KRIS	SATRE/Eu-Asia	SATRE/KRIS03																																				
NICT	SATRE/Eu-Asia	SATRE/NICT01																																				
NIM	SATRE/Eu-Asia	SATRE/NIM01																																				
NIST	SATRE/NA-Eu	SATRE/NIST01																																				
NPL	SATRE/Europe	SATRE/NPL02																																				
NTSC	SATRE/Eu-Asia	SATRE/NTSC04																																				
OP	SATRE/Europe	SATRE/OP01																																				
PL	SATRE/Europe	SATRE/PL01																																				
PTB	SATRE/Europe	SATRE/PTB05																																				
PTB	SATRE/Eu-Asia	SATRE/PTB03																																				
ROA	SATRE/Europe	SATRE/ROA01																																				
SP	SATRE/Europe	SATRE/SP01																																				
SU	SATRE/Eu-Asia	SATRE/SU01																																				
UME	SATRE/Europe	SATRE/UME01																																				
USNO	SATRE/NA-Eu	SATRE/USNO01																																				
VSL	SATRE/Europe	SATRE/VSL01																																				

TWSTFT

Clocks collection

YYMM / labo	2410	2411	2412	2501	2502	2503	2504	2505	2506	2507	2508
NTSC											
ONBA											
ONRJ											
OP											
ORB											
PL											
PTB											
ROA											
SASO											
SCL											
SG											
SIQ											
SL (*)											
SMD											
SMU											
SP											
SU											
TL											
TP											
UA											
UAE											
UME											
USNO											
UZ											
VMI											
VSL											
ZA											

PSFS

Legend

file status: exists | missing | missing report(s)

number in box: number of report if not single

labo	type	standard report	YYMM 2410	2411	2412	2501	2502	2503	2504	2505	2506	2507	2508
CH	PFS												
CH		METAS-FOC2											
IT	PFS												
IT		IT-CsF2											
IT	SFS												
IT		IT-Yb1						2					
KRIS	PFS												
KRIS	SFS												
KRIS		KRISS-Yb1											
NICT	PFS												
NICT	SFS												
NIM	PFS												
NIM		NIM5											

IGS products collection

Ionosphere information

YYMM		2506			2507																												
MJD		**60854**	60855	60856	60857	60858	**60859**	60860	60861	60862	60863	**60864**	60865	60866	60867	60868	**60869**	60870	60871	60872	60873	**60874**	60875	60876	60877	60878	**60879**	60880	60881	60882	60883	**60884**	60885	60886	60887
code	**solution**																																		
COD*OPSFIN	final																																		
COD*OPSRAP	rapid																																		

Broadcast orbits

YYMM		2506			2507																													
MJD		**60854**	60855	60856	60857	60858	**60859**	60860	60861	60862	60863	**60864**	60865	60866	60867	60868	**60869**	60870	60871	60872	60873	**60874**	60875	60876	60877	60878	**60879**	60880	60881	60882	60883	**60884**	60885	60886	60887
name	**GNSS**																																		
BRDC00IGS_R	mixed																																		
BRDM00DLR_S	mixed																																		
MATE00ITA_R	mixed																																		
BRD400DLR_S	mixed																																		
BP2100FRA_R	mixed																																		

Precise orbits

YYMM			2506			2507																													
MJD			**60854**	60855	60856	60857	60858	**60859**	60860	60861	60862	60863	**60864**	60865	60866	60867	60868	**60869**	60870	60871	60872	60873	**60874**	60875	60876	60877	60878	**60879**	60880	60881	60882	60883	**60884**	60885	60886	60887
code	**format**	**solution**																																	
IGS*OPSFIN	sp3	final																																	
IGS*OPSFIN	clk	final																																	
IGS*OPSFIN	gpst	final																																	
IGS*OPSRAP	sp3	rapid																																	
IGS*OPSRAP	clk	rapid																																	
IGS*OPSRAP	gpst	rapid																																	
str	sp3	rapid																																	
str	clk	rapid																																	
sta	sp3	final																																	
sta	clk	final																																	
GFZ0MGXRAP	sp3	rapid																																	
GFZ0MGXRAP	clk	rapid																																	

Reminders

Example of missing data

UTC(k)-UTC(PTB)

Data completed after the reminder

UTC(k)-UTC(PTB)

TAI reminder

Reply | Reply All

Dear Colleague(s),

Could you please complete or confirm missing CGGTTS data from MJD 60877?

Thank you very much in advance.

Kind regards.
BIPM Time department

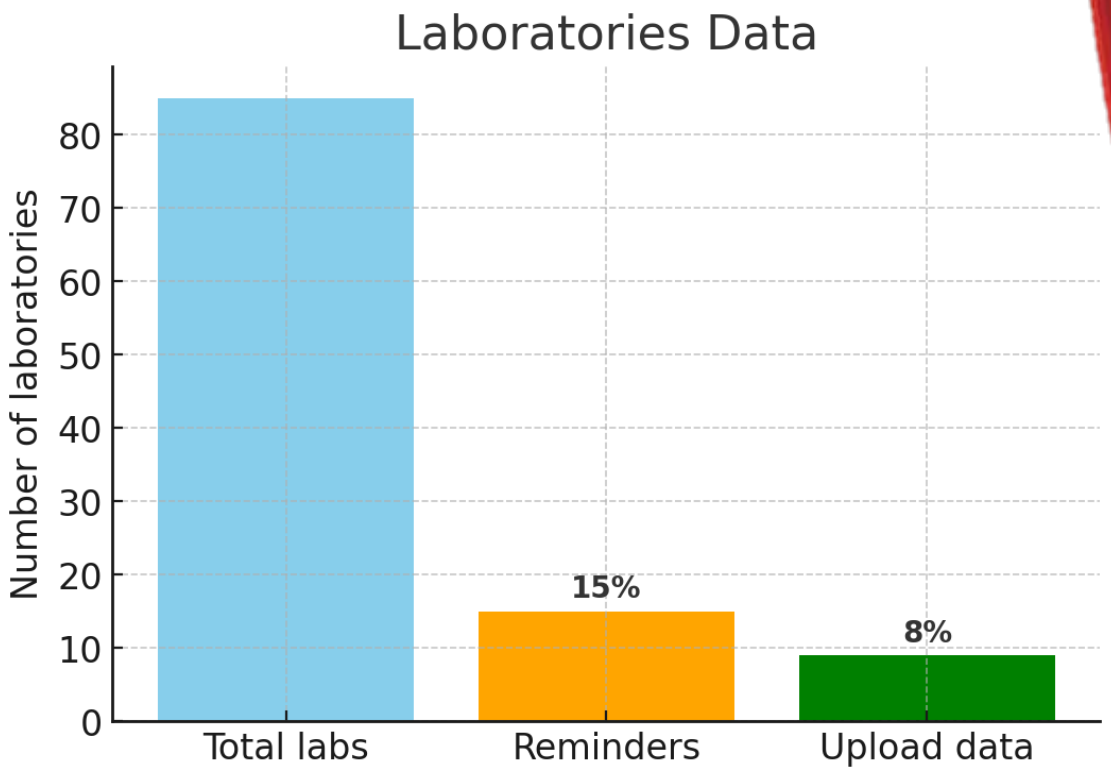
Contact the lab

Reminders - Statistics

On average, around 10-15 (out of nearly 85) laboratories receive reminders each month.

Of these, almost always more than half upload data later.

The rest confirms the lack of data due to problems or does not respond.



Data on FTP repository is downloaded automatically, but a mail from the lab is appreciated (not to miss late submission!)

Missing data

If the one or more measures are not available, the UTC(k) results in Circular T is:

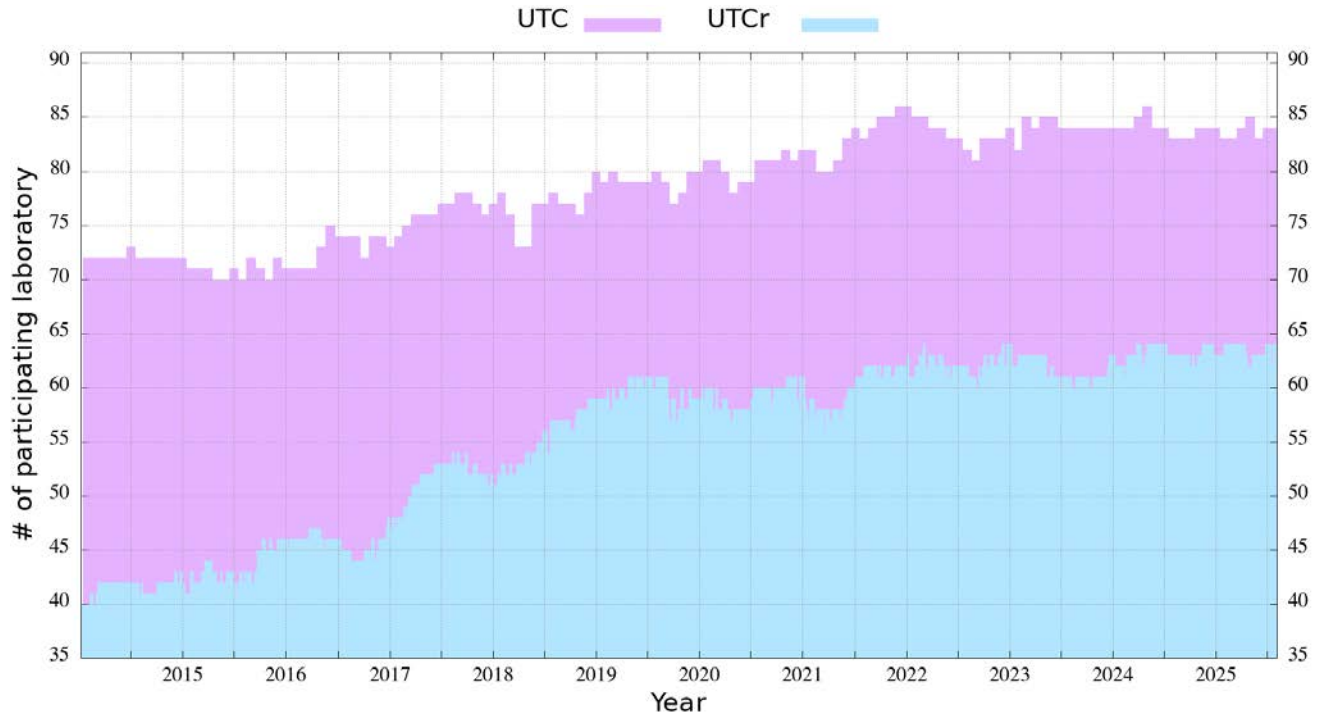
Date 2025 0h UTC	JUN 28	JUL 3	JUL 8	JUL 13	JUL 18	JUL 23	JUL 28	Uncertainty/ns			Notes
MJD	60854	60859	60864	60869	60874	60879	60884	uA	uB	u	
Laboratory k	[UTC-UTC(k)]/ns										
	1818.0	1811.0	1804.0	-	-	-	1812.0	0.7	3.1	3.2	

Typically, every month, 5-7 labs have missing data in the Circular T.

After one year of no data, we exclude the lab from Circular T.

Currently 4 lab have no data since several months.

Contact the lab



Information from the laboratories

Electrical Failure and UTC(k) time step

Reply | Reply All

T

To Tai

This message was AutoForwarded.

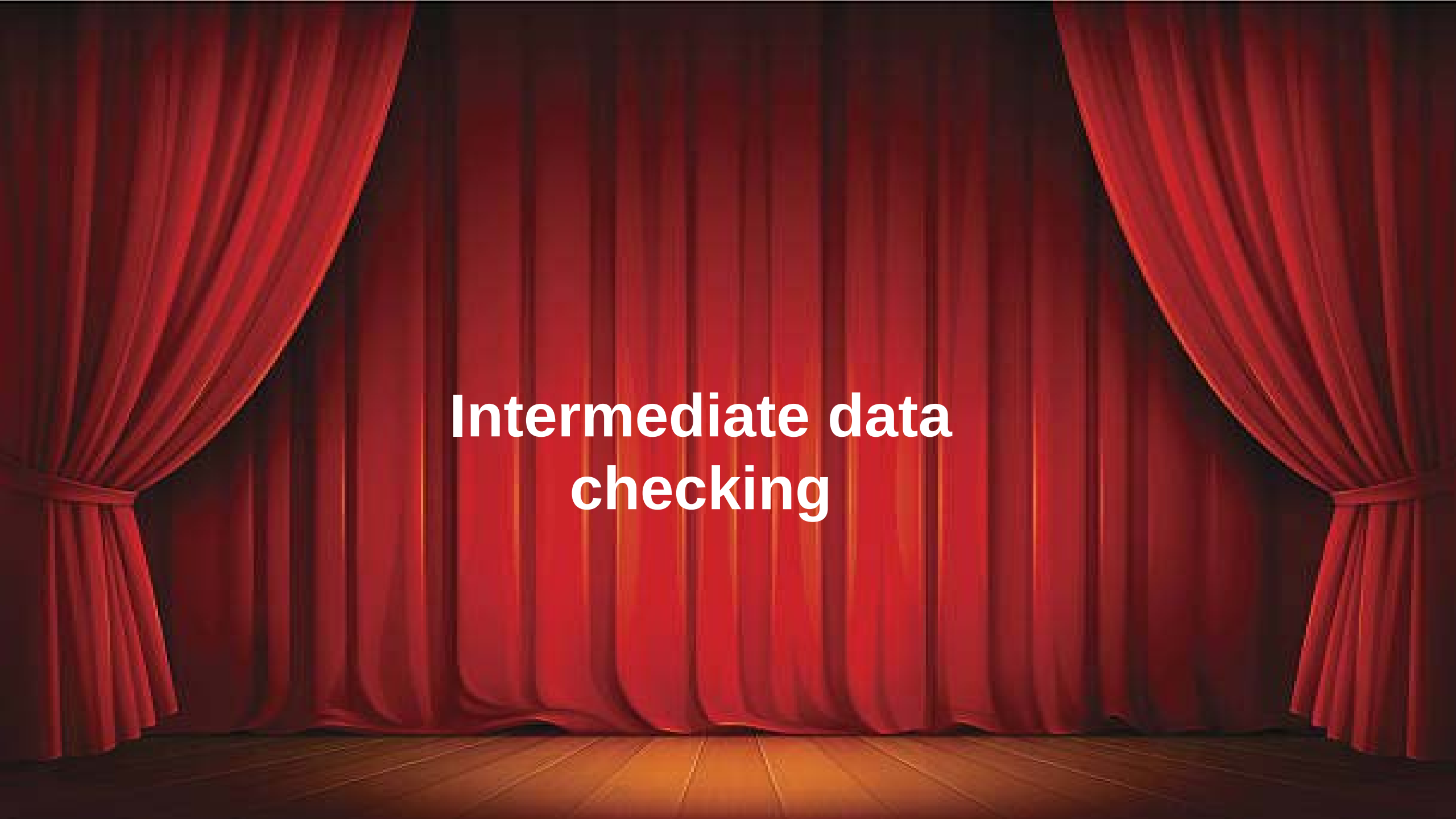
Dear BIPM Time Department,

I would like to inform you that at MJD 60880, there was an electrical failure in our laboratory till MJD 60881.
And in MJD 60881, we made a time step around 905 ns

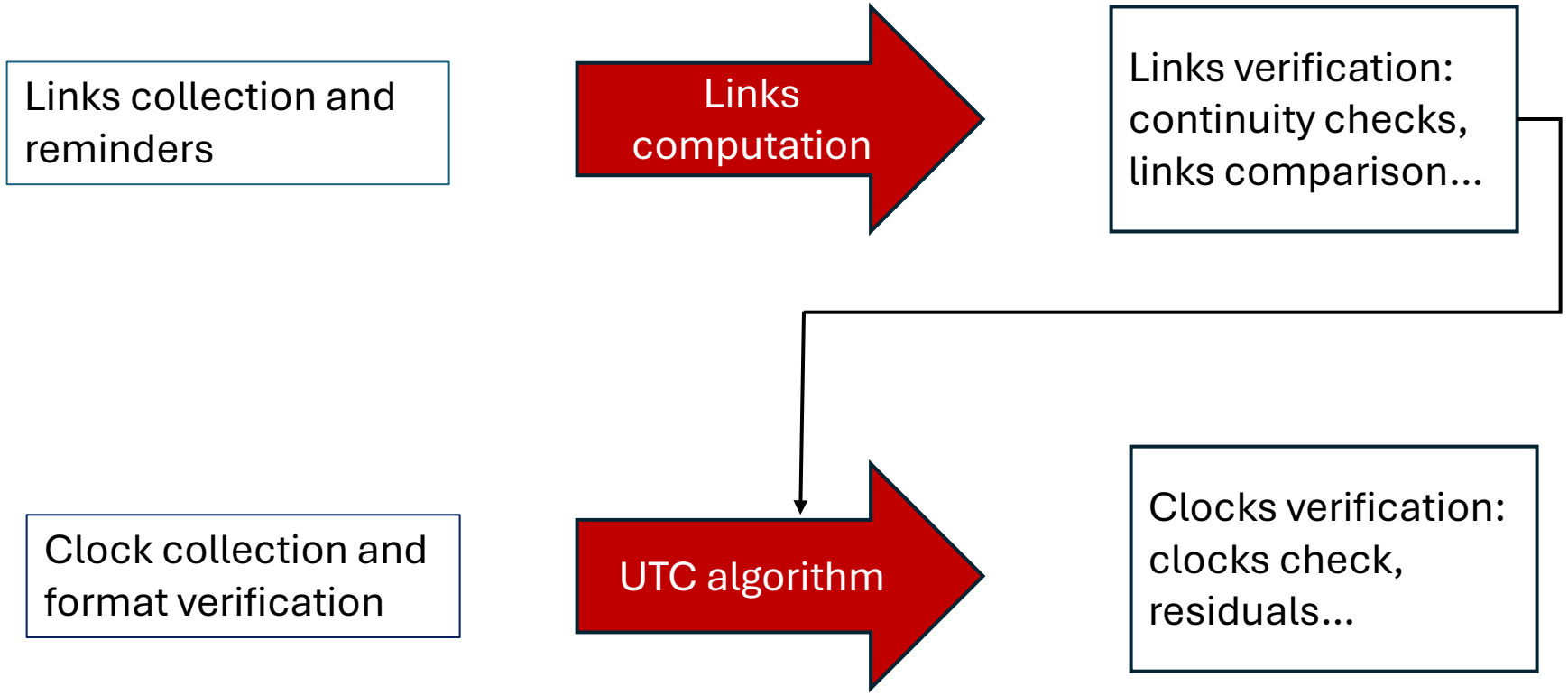
I hope this information will help you to understand our RINEX and CGGTTS Files' missing data or data corruption.

UTC(k)-UTC(PTB)

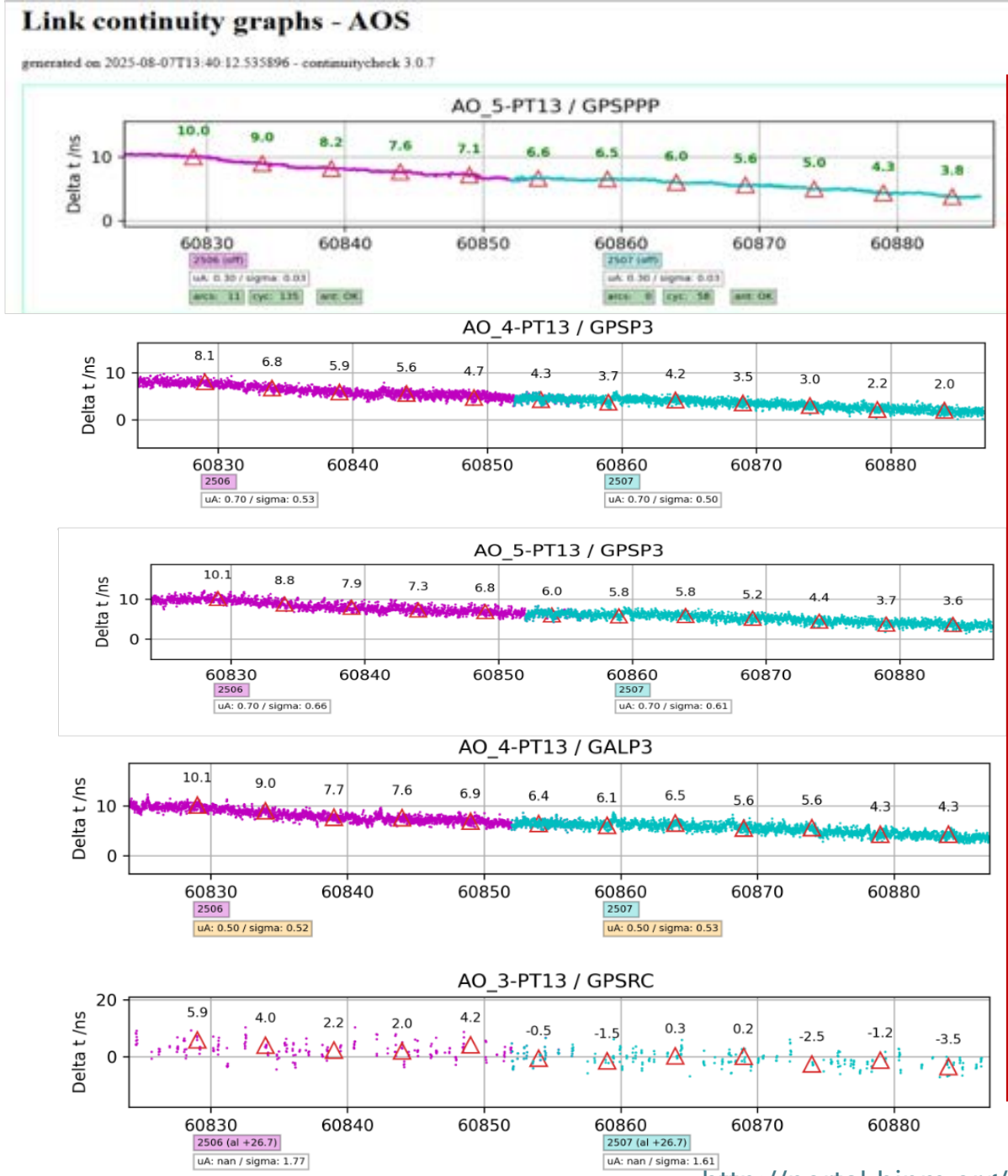
Letting us know about the specific problem helps us to interpret the data correctly. If needed, we include a note in the Circular T.


Intermediate data checking

Intermediate data checking



The UTC algorithm can only be run once all the necessary data (links and clocks) have been collected and meet the required specifications.



Example of time transfer measurements between the AOS laboratory and the PTB (used as the reference).

Different receivers and techniques (GPS, TWSTFT..) are computed.

The continuity with respect to the previous month is verified.

For internal use only

http://portal.bipm.org/utc/pctsoft//2507/Plt/continuitycheck/AOS.html

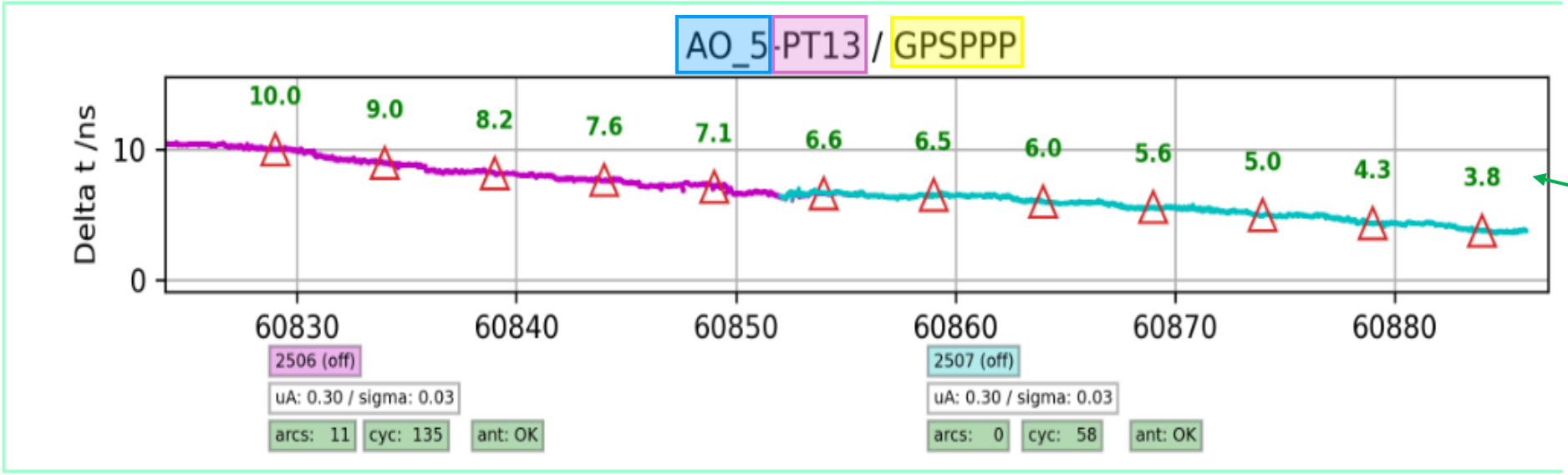
Link continuity graphs - AOS

Name of the receiver used by PTB

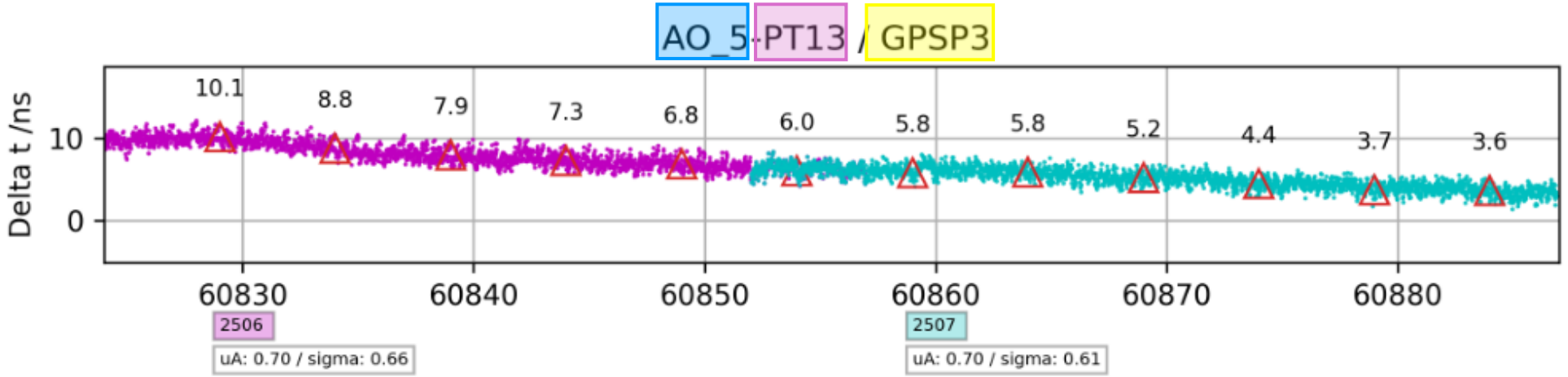
Name of the receiver used by AOS

Technique used to compute the link

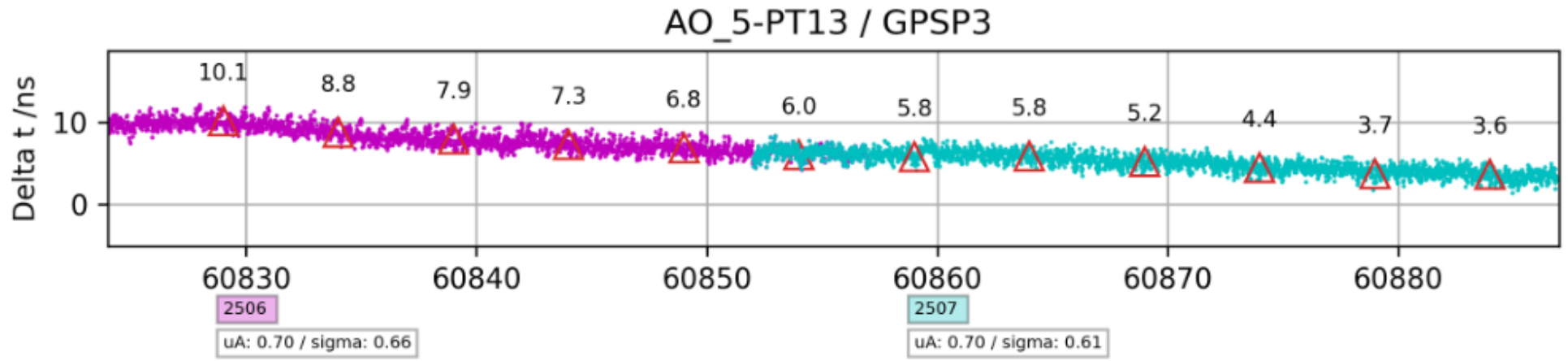
Example of the same receiver with two different techniques

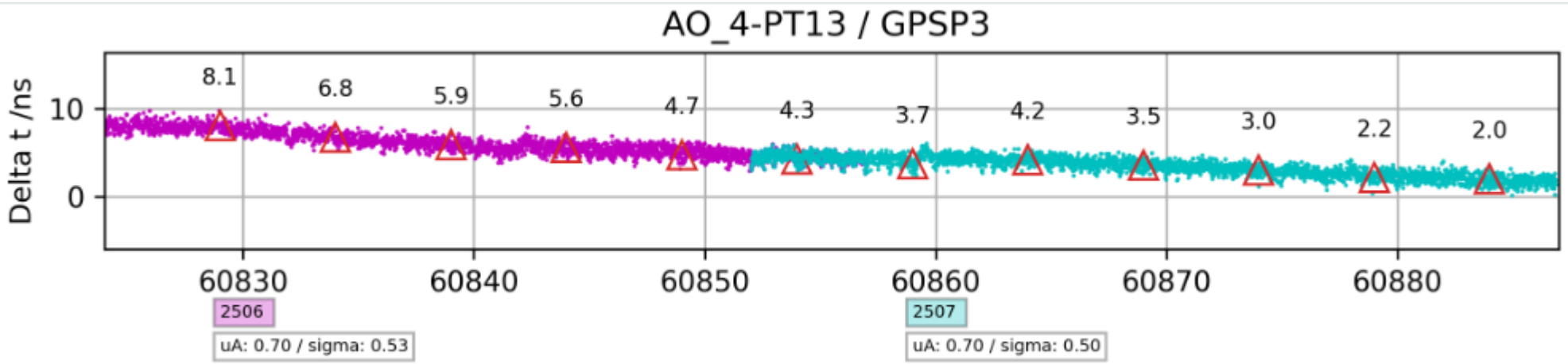


OFFICIAL link used for the AOS laboratory



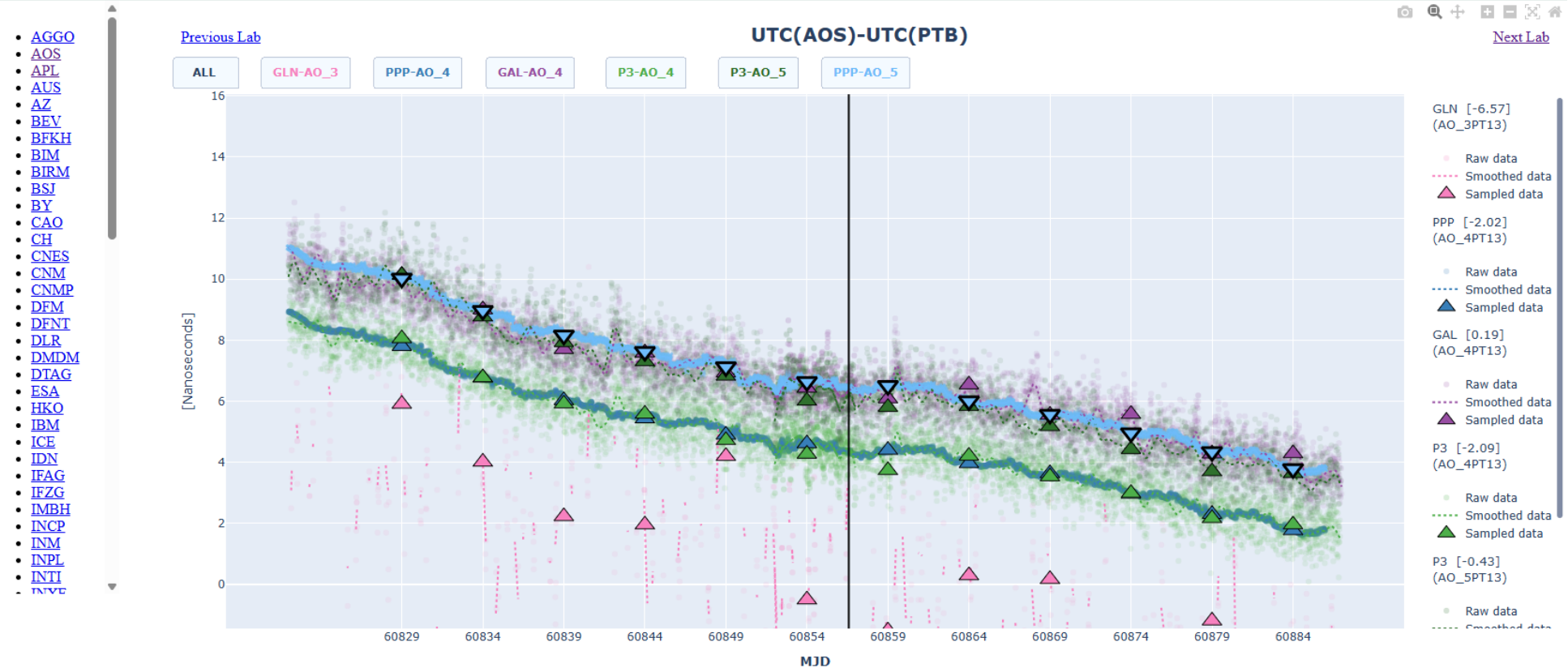
Example of two different receivers with the same technique





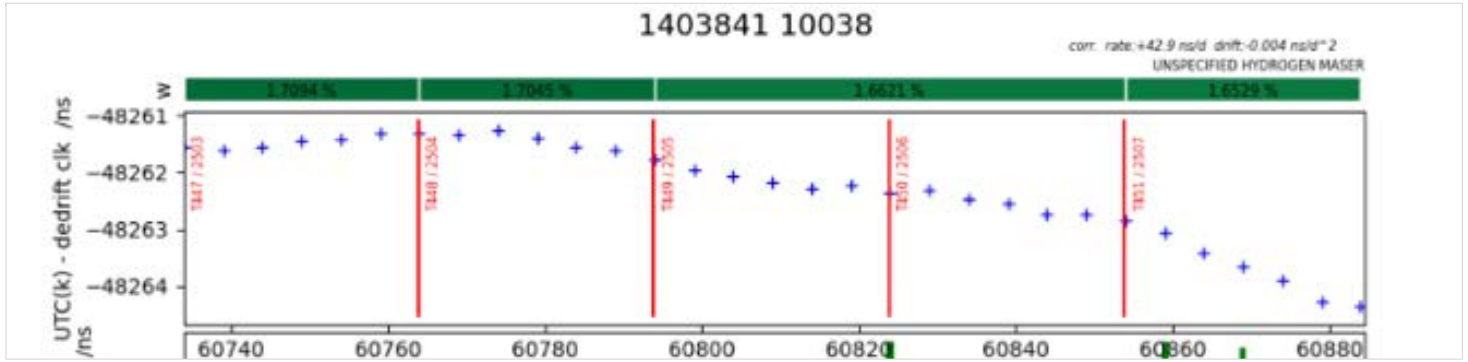
Link comparison

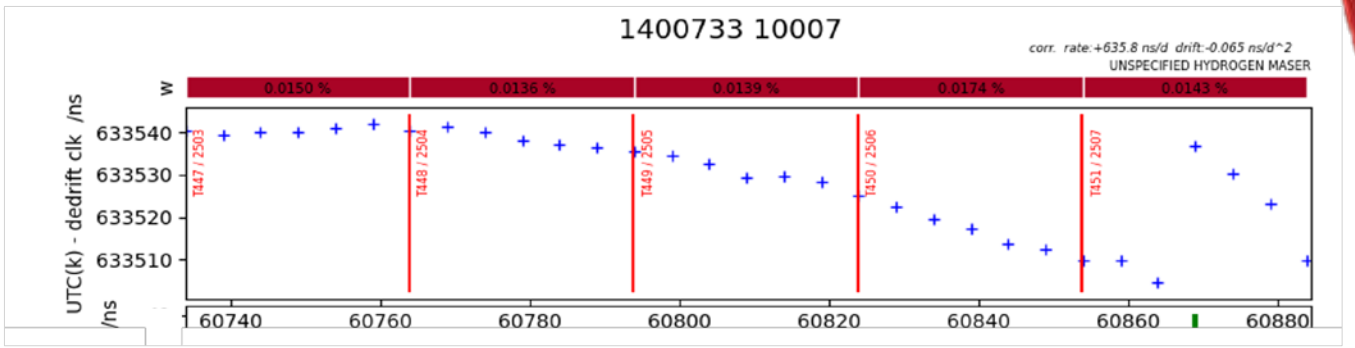
Single graph showing all receivers and techniques available for the AOS laboratory

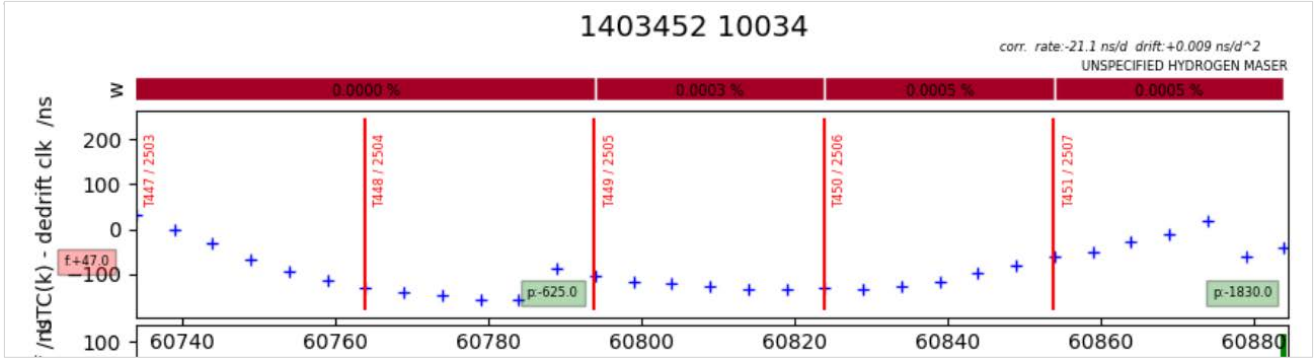


	2506								2507							
Receiver	align	arcs	cycles	antenna	tot_dly	cal_id	uStb	sigma	align	arcs	cycles	antenna	tot_dly	cal_id	uStb	sigma
PPP (AO_4PT13)	-	1	8	OK	179.54	1012-2024/1001-2022	0.3	0.03	-	0	0	OK	179.54	1012-2024/1001-2022	0.3	0.03
PPP (AO_5PT13)	-	11	135	OK	75.63	1012-2024/1001-2022	0.3	0.03	-	0	58	OK	75.63	1012-2024/1001-2022	0.3	0.03
GLN (AO_3PT13)	26.7	-	-	-	75.61	-	-	1.77	26.7	-	-	-	75.61	-	-	1.61
GAL (AO_4PT13)	-	-	-	-	172.7	1012-2024/1001-2022	0.5	0.52	-	-	-	-	172.7	1012-2024/1001-2022	0.5	0.53
P3 (AO_4PT13)	-	-	-	-	179.54	1012-2024/1001-2022	0.7	0.53	-	-	-	-	179.54	1012-2024/1001-2022	0.7	0.5
P3 (AO_5PT13)	-	-	-	-	75.63	1012-2024/1001-2022	0.7	0.66	-	-	-	-	75.63	1012-2024/1001-2022	0.7	0.61

Clock verification on UTC(k) – clock measures







For internal use only
2507/Plt/clockscheck/index.html

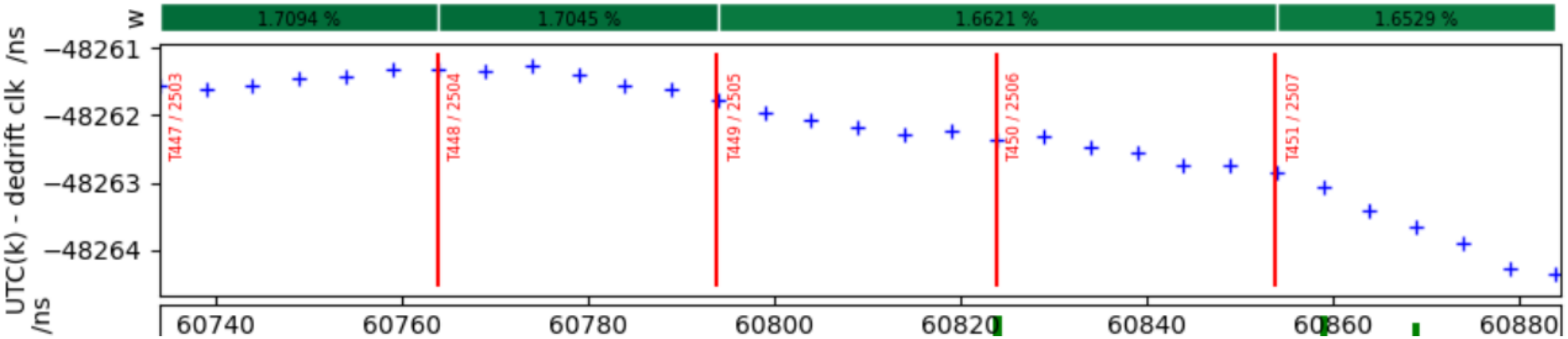
Example of “good clock”

Clock code

Laboratory code

1403841 10038

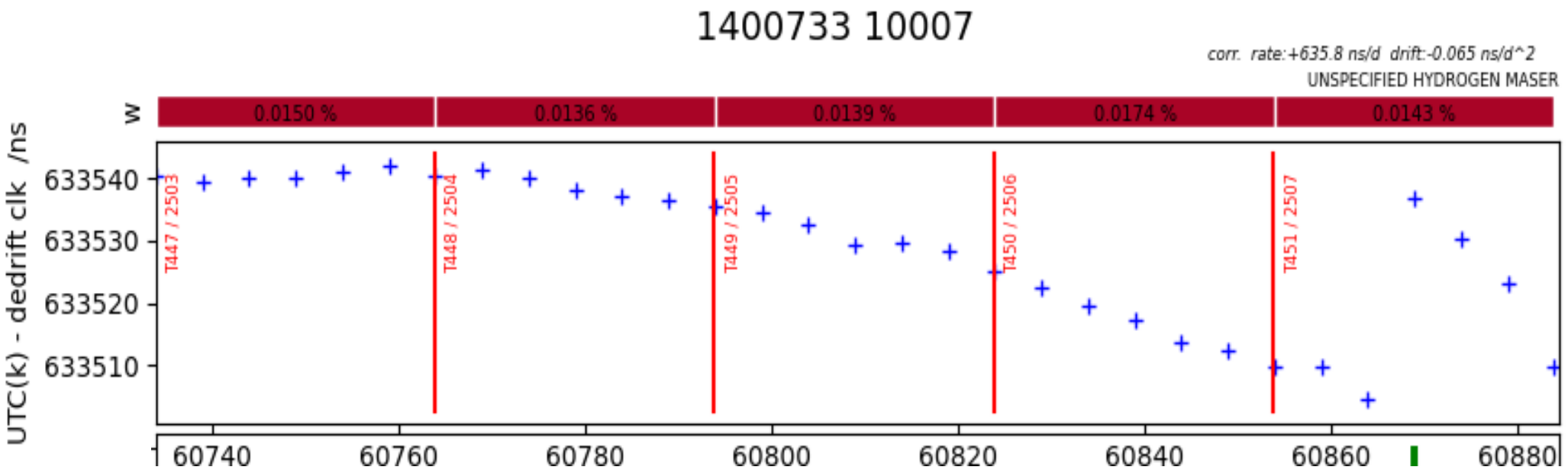
Clock weight in each month



Modified Julian Date

Each 5 days there is a + representing the measures of the difference of UTC(k)-clock

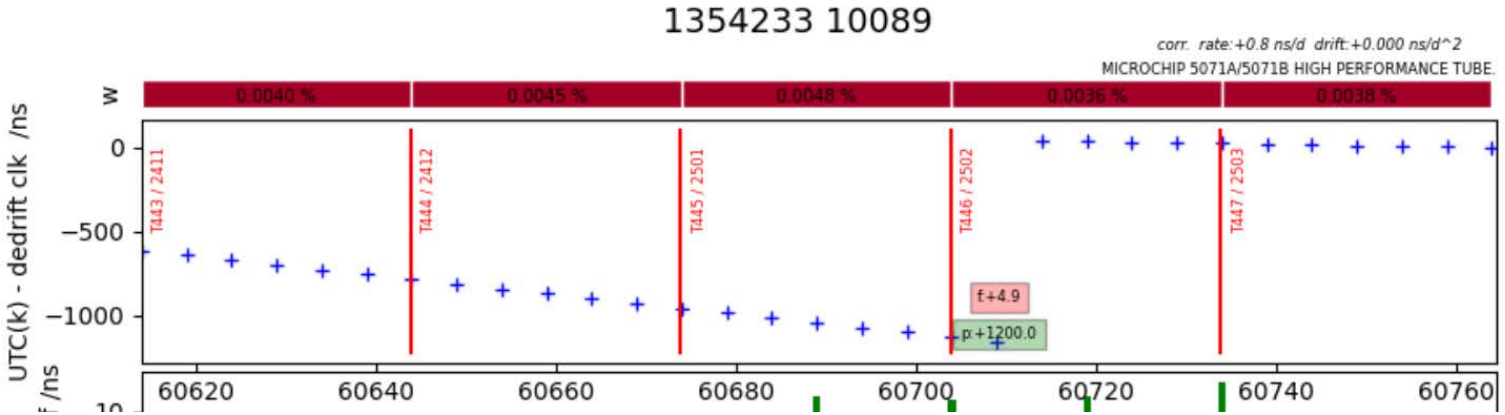
Example of jump on UTC(k)-clock

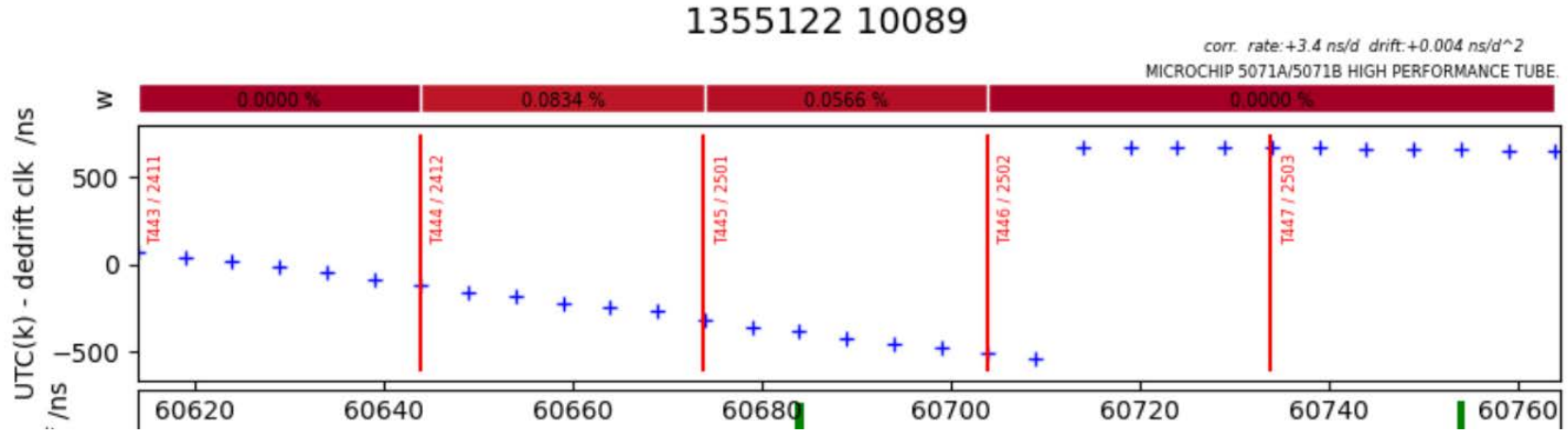


The jump is on the clock or on UTC(k)?

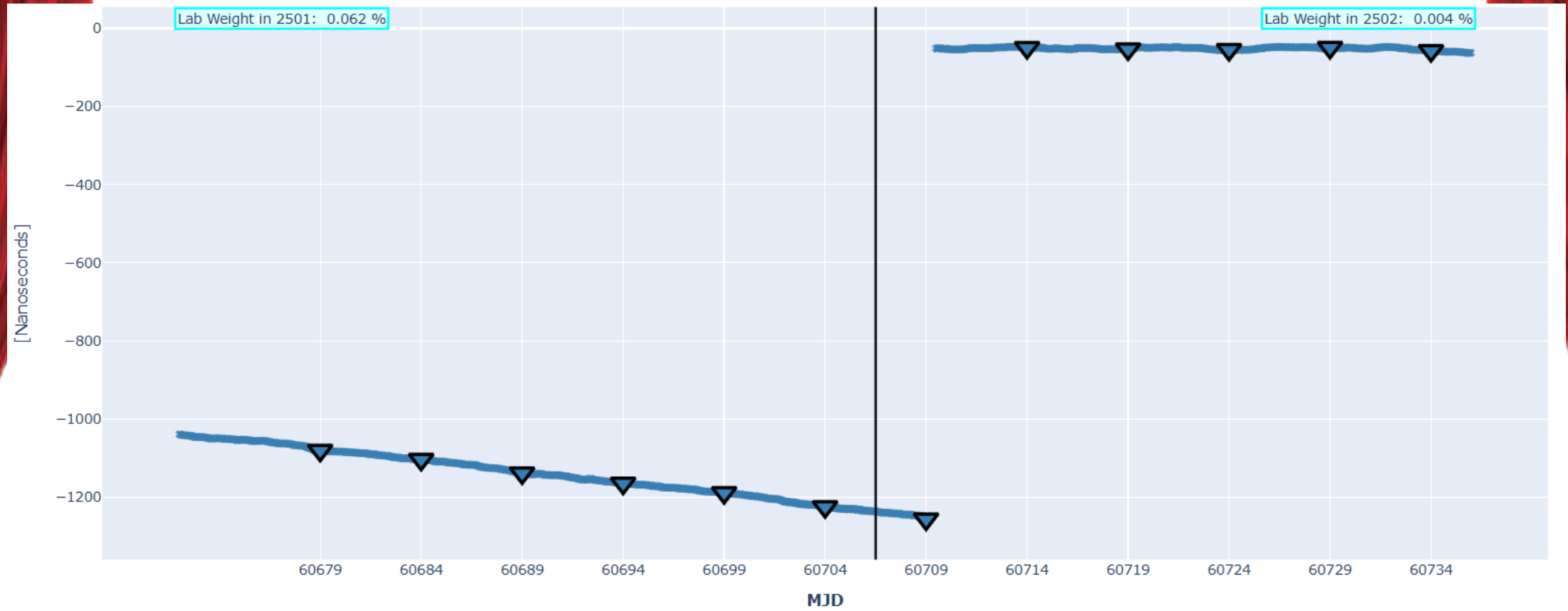
Contact the lab

- If the jump is on UTC(k), it should also be visible on UTC(k)-UTC(PTB) and UTC-UTC(k), as well as on all clocks in that laboratory.





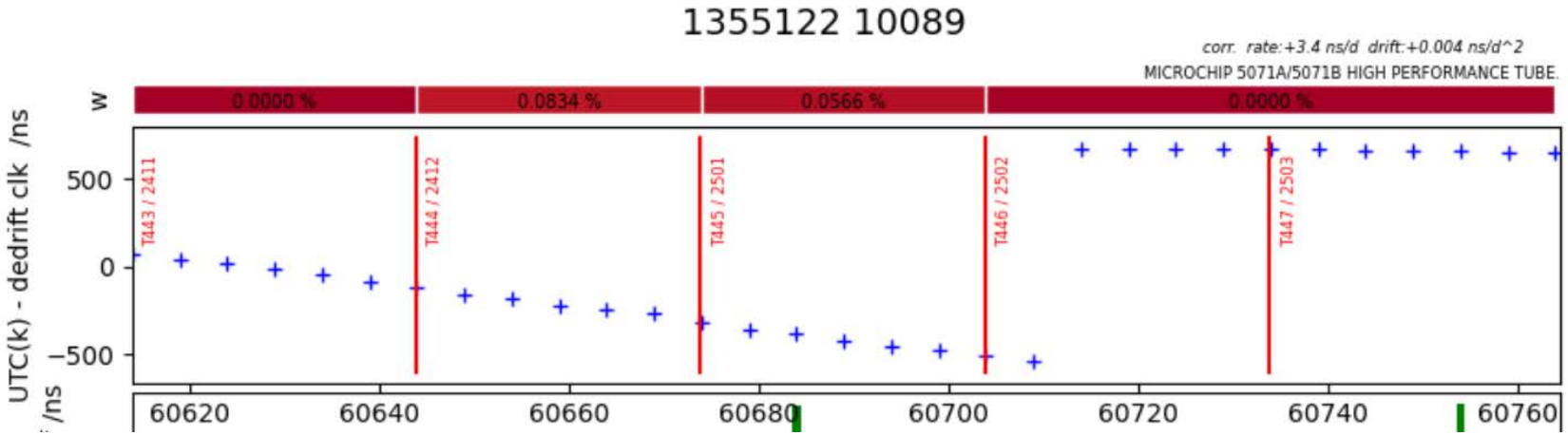
UTC(k)-UTC(PTB)


Lab Weight in 2501: 0.062 %
Lab Weight in 2502: 0.004 %
0
−200
−400
−600
−800
−1000
−1200
[Nanoseconds]
60679
60684
60689
60694
60699
60704
60709
60714
60719
60724
60729
60734
MJD

The jump is on the clock or on UTC(k)?

- If the jump is on UTC(k), it should also be visible on UTC(k)-UTC(PTB) and UTC-UTC(k), as well as on all clocks in that laboratory.

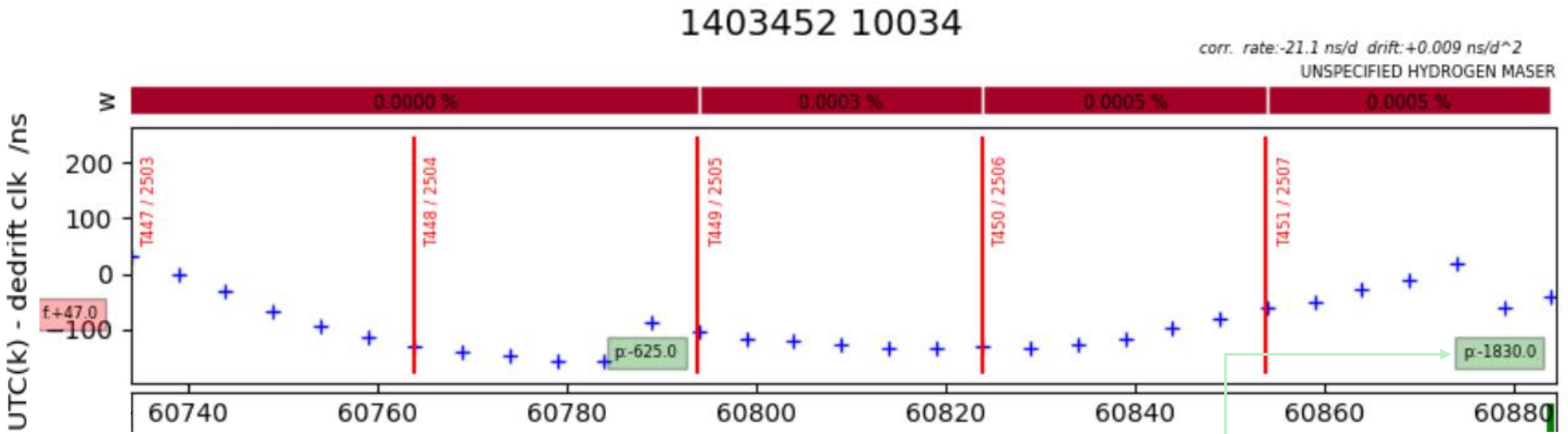
Contact the lab



- If the jump in on the clock, either there is a precise jump declaration by the lab, or the clock is de-weighted

Example of declared “time step”

Validation of the jump declaration sign



Phase step declared by the lab and applied by BIPM

Clock prediction residuals

In the monthly algorithm of UTC, each clock contributes with:

- Its *weight*: to optimize the long-term frequency stability of the time scale, a clock weighting procedure has been designed so that the sum of all the weights is equal to one and the weight value is limited.

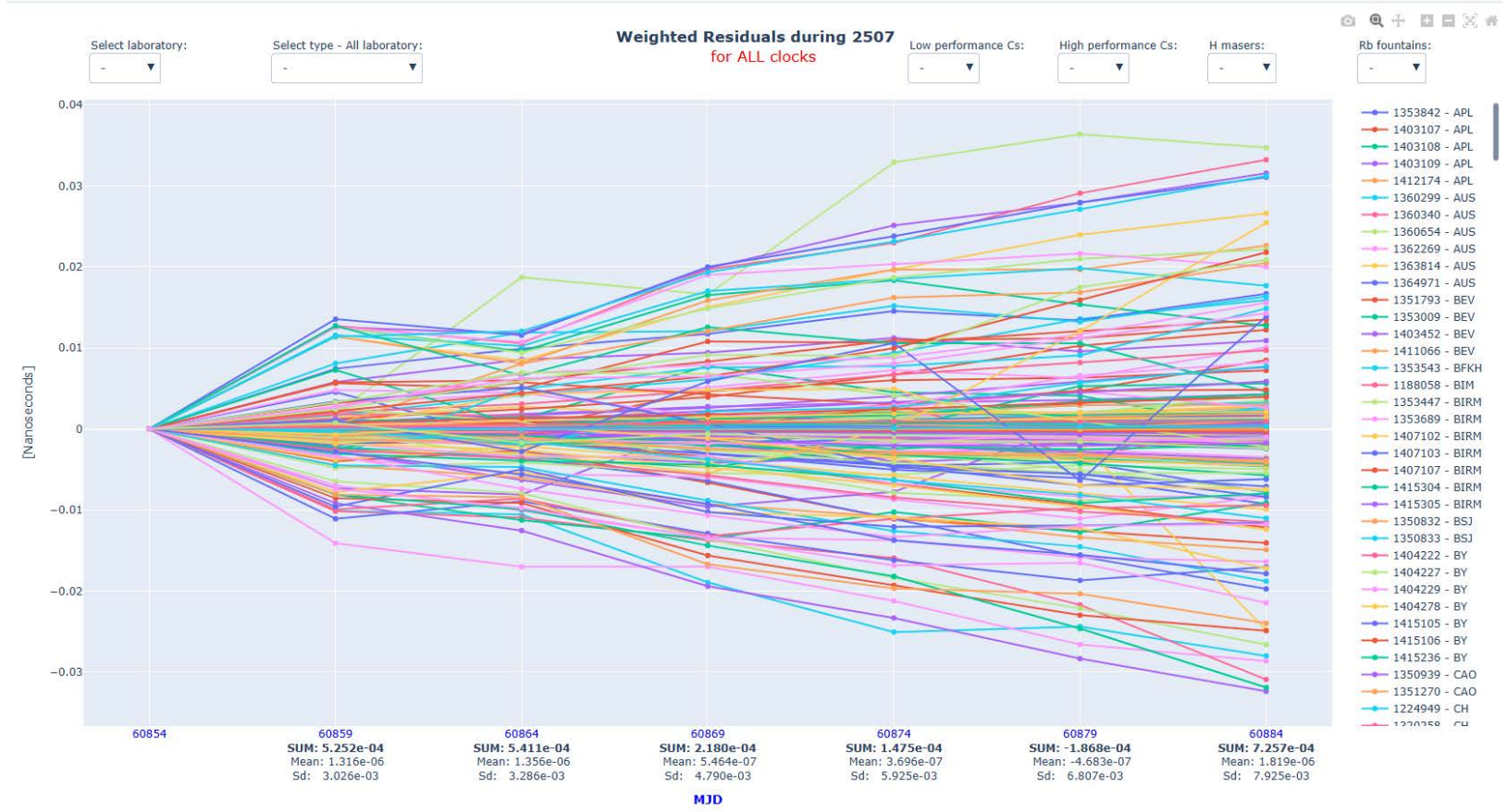
- The *prediction* of its frequency. If the clock is correctly predicted, the clock is stable and will gain weight.

Clock prediction residuals

Residuals

The analysis of the prediction is important each month to detect anomalies.

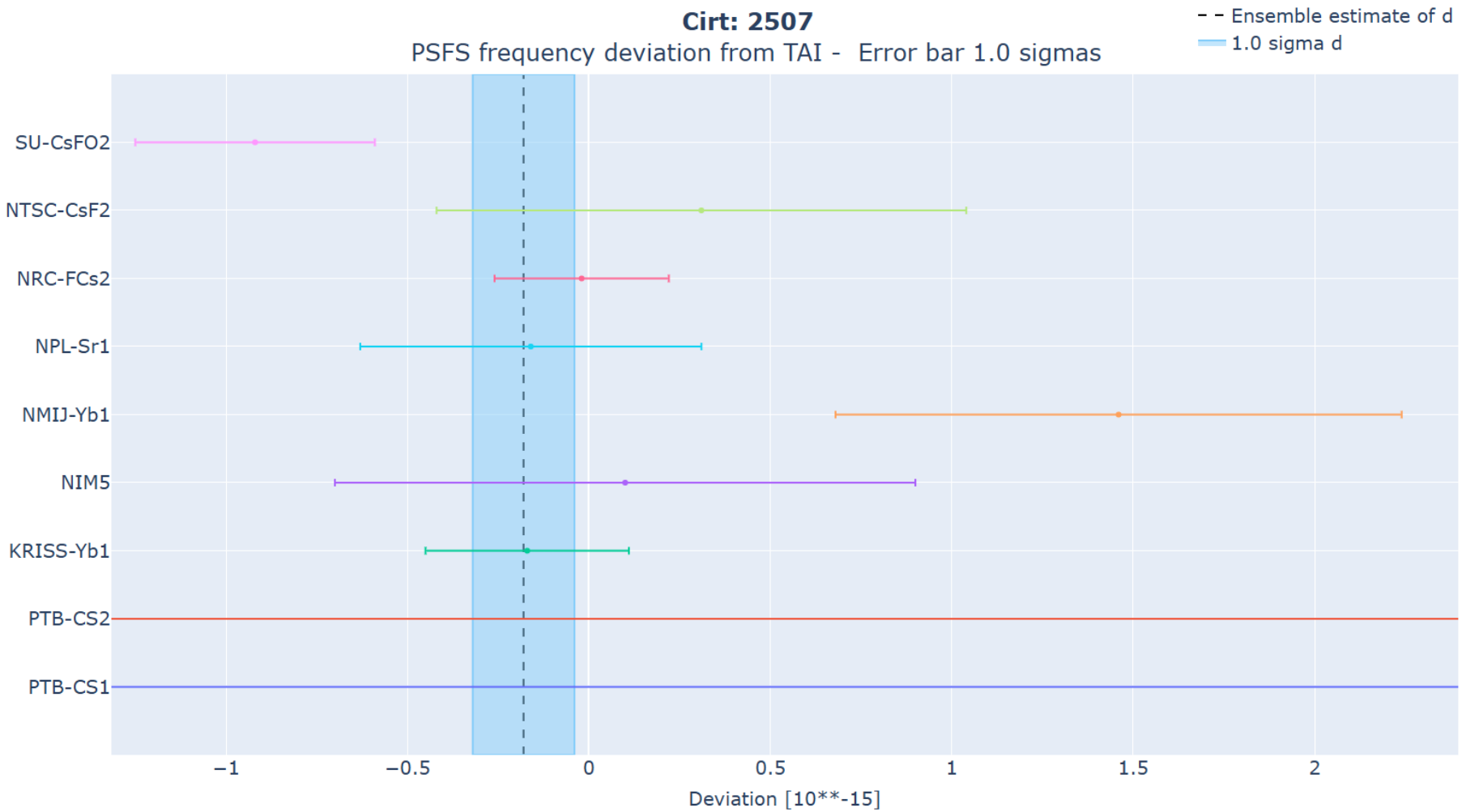
We evaluate the *residual*: the difference between the clock prediction and the “true” value obtained through the processing of the measures.



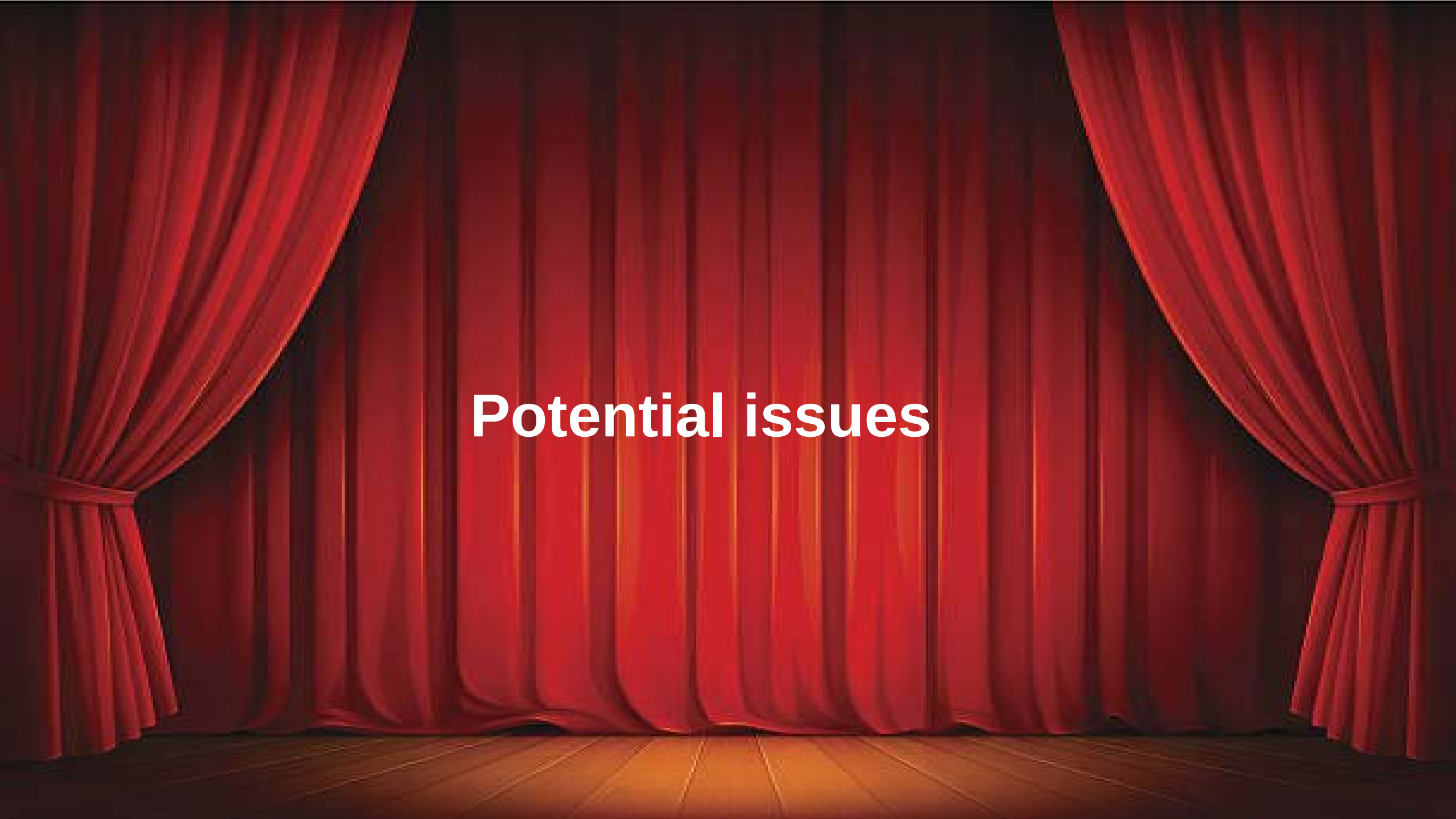
This graph displays the value of the difference between the prediction and the measured clock values, every 5 days, over a period of one month.

PSFS – Primary and Secondary Frequency Standards

The PSFS measurements must be in the file related to the month in which you want them to be processed, even if the were carried out in previous months



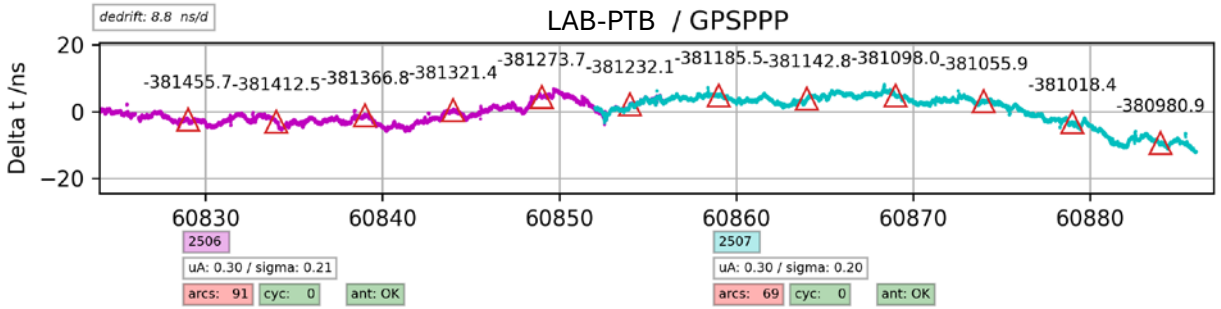
Deviation = frequency of PSFS – frequency of TAI


Potential issues

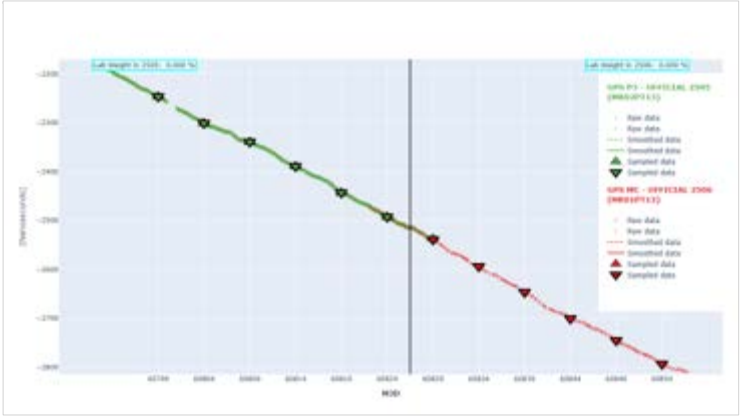
Time transfer measurement interruption or format not compliant

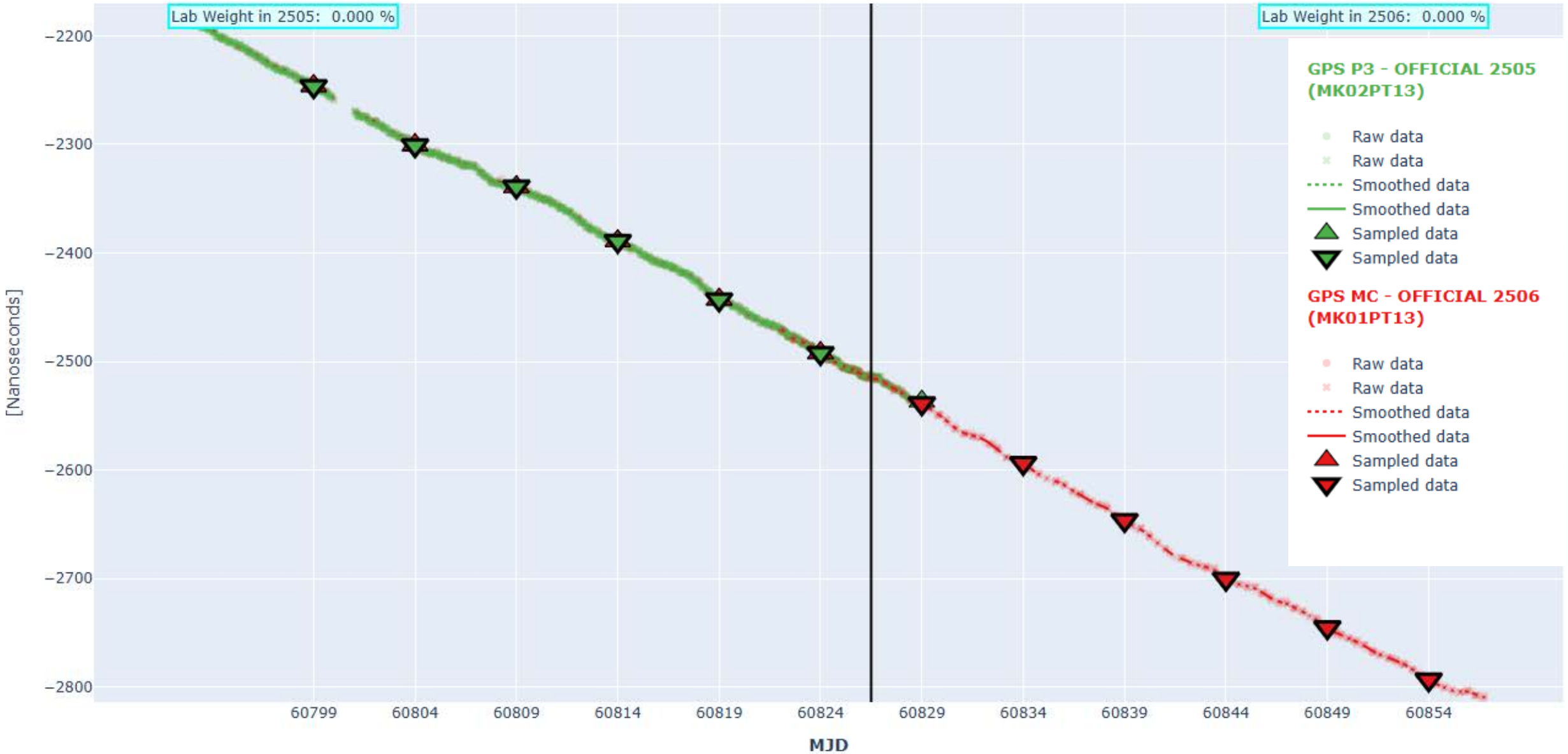
- If the difference between UTC and UTC(k) is greater than hundreds of microseconds, our system cannot process the data. In this case, we kindly ask you to apply a time correction to reduce the offset.

Contact the lab



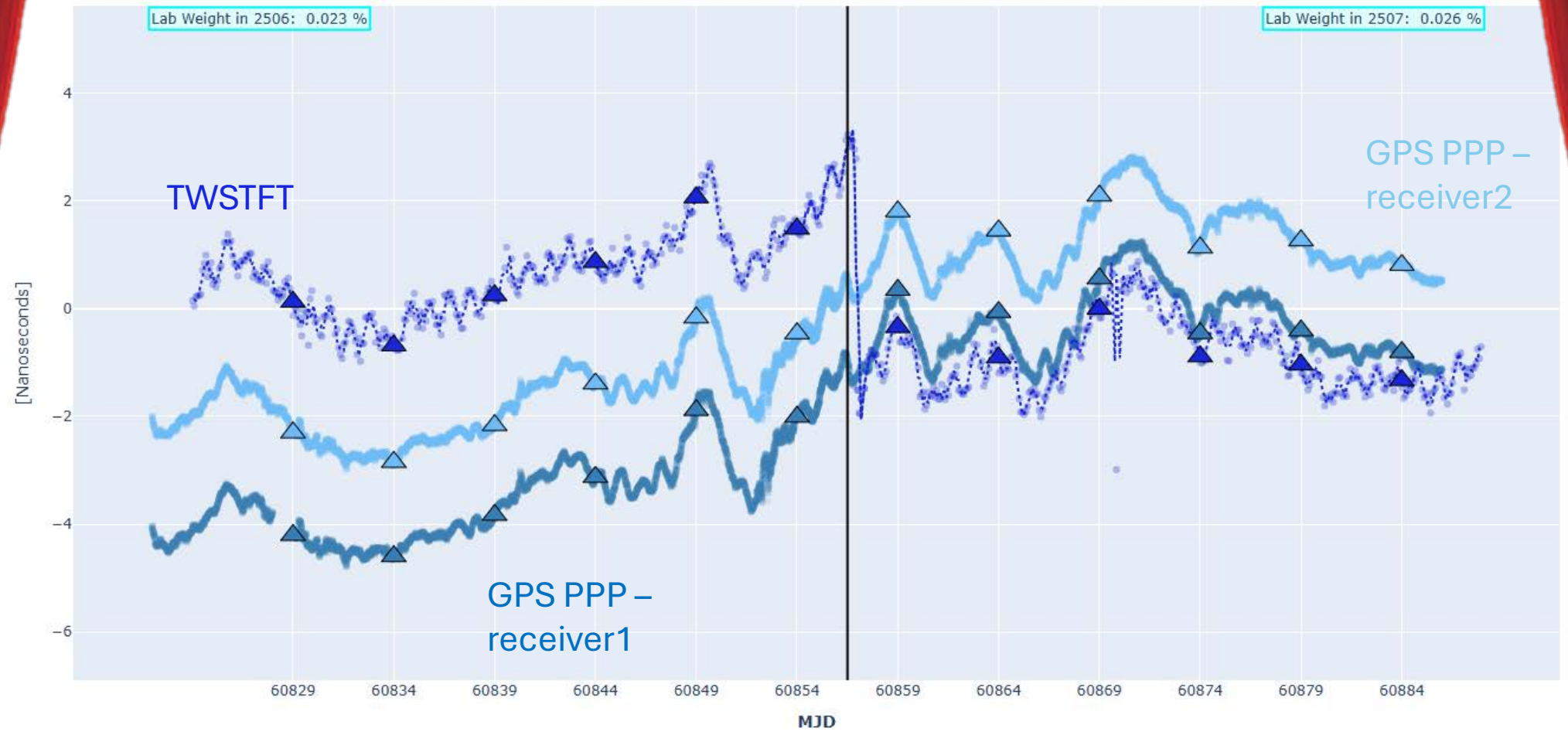
- When data from a receiver are interrupted, we need to switch to another receiver or another time transfer technique, if available. We compare the available measures with the backup receivers and other time transfer techniques (if available) to verify that everything is consistent.




Lab Weight in 2505: 0.000 %
Lab Weight in 2506: 0.000 %
GPS P3 - OFFICIAL 2505 (MK02PT13)
Raw data
Raw data
Smoothed data
Smoothed data
Sampled data
Sampled data
GPS MC - OFFICIAL 2506 (MK01PT13)
Raw data
Raw data
Smoothed data
Smoothed data
Sampled data
Sampled data
[Nanoseconds]
−2200
−2300
−2400
−2500
−2600
−2700
−2800
60799
60804
60809
60814
60819
60824
60829
60834
60839
60844
60849
60854
MJD

Different time transfer techniques not in agreement

Example of calibration of TWSTFT time transfer



June 2025

July 2025

PPP missing antenna

PPP is the most precise technique, but the antenna type should be specified and included in the IGS official list of “known” antennas.

Contact the lab

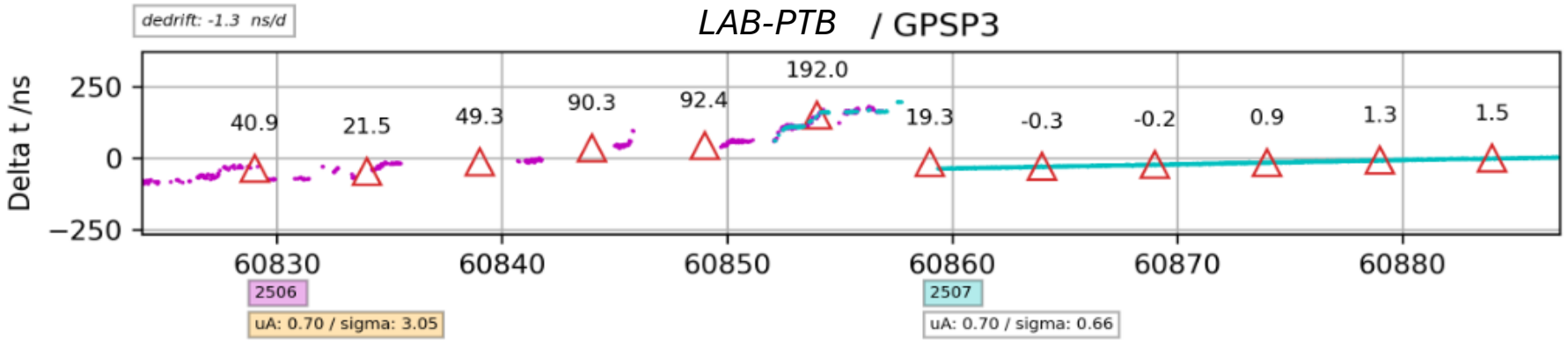
```
################################################################################################################
# ANTENNA:
#          antenna type change in rinex file between MJD 60852 and 60886
#          antenna type check from file /home/tai/GPSPPP/general/igs20_bipm.atx (week change: 2375)
#
#station   MJD         ANT #              TYPE                  [found/NOT found]
--------------------------------------------------------------------------------------------------------
          60852       Unknown            Unknown          NONE           NOT found
--------------------------------------------------------------------------------------------------------
```

PPP alert!

PPP link can’t be evaluated (even if data are uploaded) when the antenna is *unkown*

The IGS updated list of antennas recognized for the calculation can be found here: https://files.igs.org/pub/station/general/igs20.atx

Changes in headers



New header for llmo on MJD **60859**

cggttsHD_totdly = 401.800 -> 0.0

cggttsHD_tot_GP1 = 414.900 -> 0.0

cggttsHD_tot_GP2 = 423.400 -> 0.0

We monitor and check all the changes in the CGGTTS and HD header file as they create jumps in our solution

Contact the lab

Clock file format

1 The clock format is :

```
0000000001111111111222222222233333333334444444445
1234567890123456789012345678901234567890123456---
XXXXX 100YY 00200YY aaaaaaa.a CCCCCCC ccccccc.c---
```

Description of a line containing clock data:

- field 01 to 05 : XXXXX is MJD on 5 digits
- field 06 : blank character
- field 07 to 11 : 100YY is the laboratory code
- field 12 : blank character
- field 13 to 19 : 00200YY is the TA code of the lab if exists
- field 20 : blank character
- field 21 to 29 : aaaaaaa.a is [UTC(lab) - TA(lab)] in format F9.1, in ns
- field 30 : blank character
- field 31 to 37 : CCCCCCC is the code of one clock on 7 digits
- field 38 : blank character
- field 39 to 47 : ccccccc.c is [UTC(lab) - clock] in format F9.1, in ns
  follow other 18-digit fields, as required;

each line may contain up to five 18-digit fields (101 characters maximum) are accepted for the TA and/or clock data

2 The step format is :

```
0000000001111111111222222222233333333334444444445
1234567890123456789012345678901234567890123456---
XXXXX.XX CCCCCCC ccccccc.c bbbbb.bbb    AAAA 100YY
```

Description of a line containing clock step data:

- field 01 to 08 : XXXXX.XX is MJD on 5 digits and the fraction of day of the step
- field 09 : blank character
- field 10 to 16 : CCCCCCC is the code of the clock on 7 digits
- field 17 : blank character
- field 18 to 26 : ccccccc.c is the amount of the time step in format F9.1, in ns
- field 27 : blank character
- field 28 to 36 : bbbbb.bbb is the amount of the frequency step in format F9.3, in ns/d
- field 37 to 40 : blank characters
- field 41 to 44 : AAAA is the laboratory acronym, up to 4 characters, left aligned
- field 45 : blank character
- field 46 to 50 : 100YY is the laboratory code on 5 digits

lab2507.clo

```
60859 10034 1351793 0000000.0 1353009 -001076.5 1403452 -001354.5 1411066 -005447.9
60864 10034 1351793 0000000.0 1353009 -001167.0 1403452 -001434.8 1411066 -005511.5
60869 10034 1351793 0000000.0 1353009 -001274.8 1403452 -001523.6 1411066 -005590.9
60874 10034 1351793 0000000.0 1353009 -001368.1 1403452 -001602.3 1411066 -005666.2
60879 10034 1351793 0000000.0 1353009 -001456.6 1403452 +000043.1 1411066 -005744.1
60884 10034 1351793 0000000.0 1353009 -001561.3 1403452 -000043.0 1411066 -005835.0
60870.36 1351793 0000000.0 -0001.642    LAB  10034
60878.51 1403452 -001830.0 00000.000    LAB  10034
60887.36 1351793 0000000.0 -0001.037    LAB  10034
```

https://webtai.bipm.org/database/documents/clock-data_format.pdf

Clock data out of range

```
W : @ overflow value :      60859 1408620     416935649.2 removed
W : @ overflow value :      60859 1415303     578148191.3 removed
W : @ overflow value :      60864 1415303     578148108.2 removed
W : @ overflow value :      60854 1320192     155610882.3 removed
W : @ overflow value :      60854 1320193    -373456877.7 removed
W : @ overflow value :      60859 1320192     511877330.9 removed
W : @ overflow value :      60859 1320193     187972620.7 removed
W : @ overflow value :      60864 1320192     884693201.8 removed
W : @ overflow value :      60864 1320193    -247140202.7 removed
W : @ overflow value :      60869 1320192     234643330.0 removed
W : @ overflow value :      60869 1320193     315306424.5 removed
W : @ overflow value :      60874 1320192     587375503.5 removed
W : @ overflow value :      60874 1320193    -120499079.4 removed
W : @ overflow value :      60879 1320192     -59735940.1 removed
W : @ overflow value :      60879 1320193     444575221.8 removed
W : @ overflow value :      60884 1320192     311940270.9 removed
W : @ overflow value :      60884 1320193      14400693.6 removed
W : @ overflow value :      60854 1351628     -34582553.9 removed
W : @ overflow value :      60859 1351628     -35218448.7 removed
W : @ overflow value :      60864 1351628     -35811488.4 removed
W : @ overflow value :      60879 1351628     -37693038.5 removed
W : @ overflow value :      60884 1351628     -38301246.3 removed
W : @ overflow value :      60854 1352710      -7941616.2 removed
W : @ overflow value :      60854 1352710      -7941616.2 removed
```

Example of clock file with MJD standard date NOT correct. July standard date were 60659-60XXX

Any clock data that does not respect the required format or whose value is out of accepted range is automatically excluded from the computation.

Contact the lab

lab2507.clo

```
60859 10033 1353543          0.0
60894 10033 1353543          0.0
60899 10033 1353543          0.0
60904 10033 1353543          0.0
60909 10033 1353543          0.0
60914 10033 1353543          0.0
```

Clock jump wrongly declared

If your clock experiences a voluntary a time step, it has to be reported as:

NEW[clock value] - OLD[clock value]

(even if the value in the file is UTC(k)-clock!)

```
60799 10044                  1361167    2147.2 1361173    1151.1 1361629    4007.6 1361732    2740.2
60799 10044 1361798    3115.4 1404439    6715.9 1404418     515.3
60804 10044                  1361167    2123.3 1361173    1146.5 1361629    4104.9 1361732    2803.0
60804 10044 1361798    3084.9 1404439    6661.3 1404418     503.3
60809 10044                  1361167    2128.6 1361173    1163.0 1361629    4209.0 1361732    2866.0
60809 10044 1361798    3067.9 1404439    6620.3 1404418     505.9
60814 10044                  1361167    2133.3 1361173    1166.8 1361629    4297.9 1361732    2928.9
60814 10044 1361798    3039.0 1404439    6559.7 1404418     489.1
60819 10044                  1361167    2131.8 1361173    1168.0 1361629    4387.2 1361732    2991.7
60819 10044 1361798    3010.4 1404439    6500.6 1404418     476.0
60824 10044                  1361167    2093.1 1361173    1170.2 1361629    4476.5 1361732    3054.6
60824 10044 1361798    2972.0 1404439    6636.1 1404418     458.6
60821.43 1404439  000199.3 00000.000     LAB   10044
```

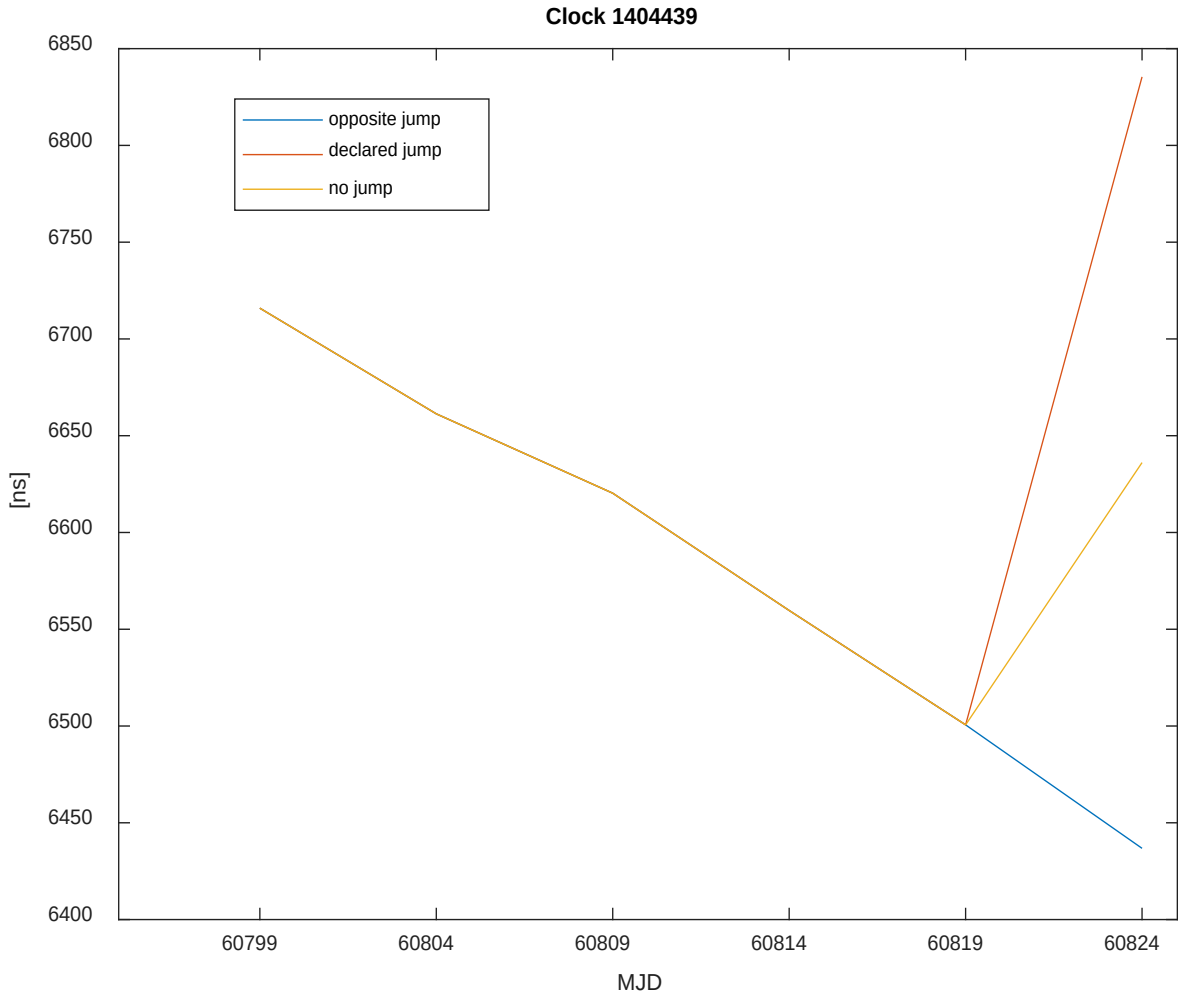
WRONG SIGN!
The clock is automatically excluded.

We test the jump with opposite sign and

sometimes

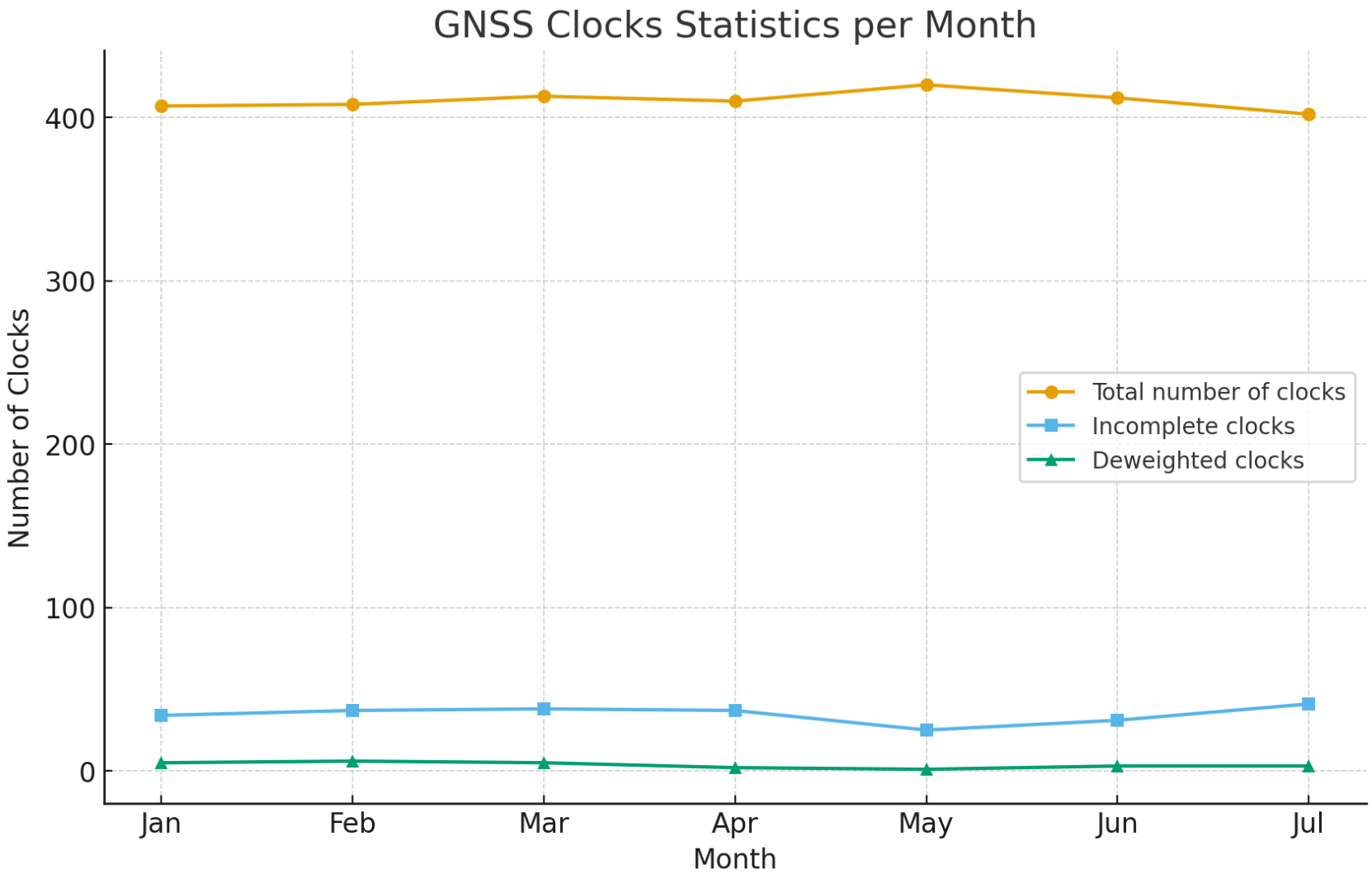
it looks better.

Clock jump wrongly declared



Clock statistics

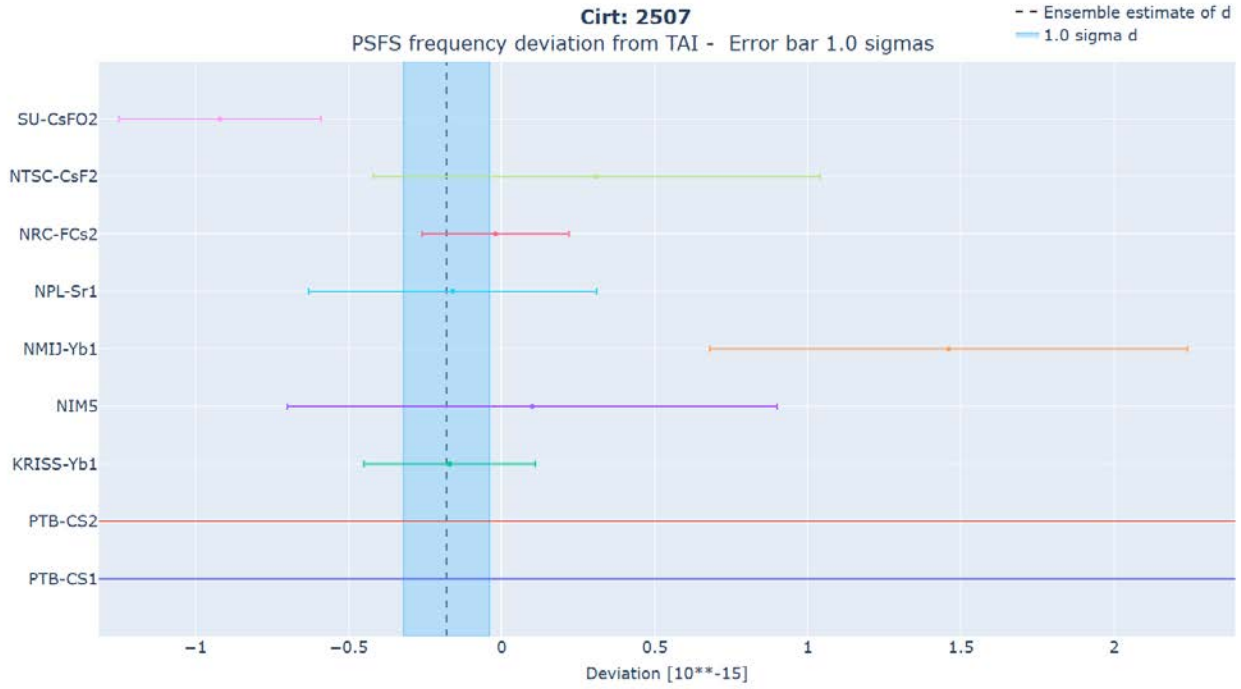
On average, less then 10% of clocks are incomplete each month, while 1% of clocks is excluded from the computation because strange behavior

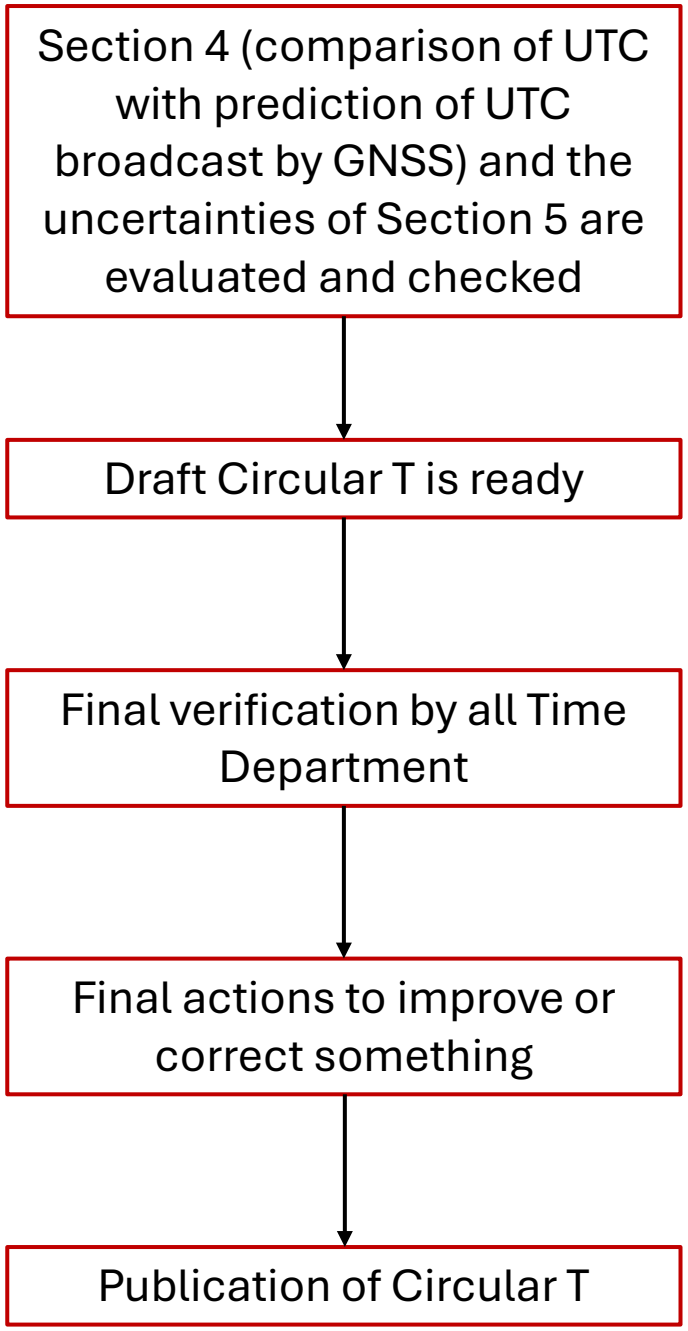


PSFS – Possible issues

- Cases of offset >> 2 sigma
- Sometimes the PSFS evaluation period is modified to avoid jumps of the clock or of UTC(k) or new calibration
- In rare cases the PSFS data are withdrawn

Contact the lab




Section 4 (comparison of UTC with prediction of UTC broadcast by GNSS) and the uncertainties of Section 5 are evaluated and checked
Draft Circular T is ready
Final verification by all Time Department
Final actions to improve or correct something
Publication of Circular T

To sum up…

Data collection and format verification

4th/5th

6th/7th

First check on the links, clocks verification and recovery of missing data (if available)

UTC algorithm, section 4 and section5 of Circular T. Round of checks.

8th/9th

from the 10th onwards

Final verification and last improvement actions

CIRCULAR T publication!

Conclusions

Key points for UTC computation

- The availability and the good quality of **the input** data are essential
- We rely on **tools** and **checks** to keep the process under control
- With the CBKT secondees, we are **developing tools** to improve your preliminary data checking
- Possible issues during the process:
  - Missing, empty, or incorrectly formatted data
  - Undeclared or incorrectly declared data changes (clock step, UTC(k) steps, discontinuity of the time link…)
  - Discrepancies between techniques (GNSS receivers or GNSS vs. TWSTFT)
  - The expected application of calibration is delayed
- The prompt **support from the laboratory** is fundamental!


Thanks for your data
and your support!