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Restoration the TWSTFT link calibration using GPSPPP bridging after the satellite change on Mjd 55769/27 July 2011

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1. BIPM, 2. PTB, 3. NIST

1. Introduction

1.1 Background

On the 27 July 2009, the satellite switched from IS-3R to T-11N. In consequence, the calibration values CALR/ESDVAR were computed with the GPS bridge and implemented separately on 55102-55108 (28 Sept. – 4 Oct.) for the links between most of the UTC labs (TM166 [3]) and on 55502 (2 Nov. 2010) for the links related with AOS, IPQ, NPL and USNO (TM176 [4]).

On July 27 (55769), the applied frequency of T-11N changed for all the UTC links. And then on Aug. 3 (55776), the US-Europe frequency changed for a second time, cf. Annex I. To simplify the implementations, only the total jump is taken into account in the implementations.

As usual, the BIPM restored the CALR/ESDVAR values with the help of the GPS PPP data. The preliminary results have been used in the Circular T 283 (1107) and UTC/TAI computations. This TM presents all the computation results and proposes the implementation in the ITU TW data files the new CALR/ESDVAR values as well as the CI codes.

1.2 The method

We first use the GPS PPP bridge to restore the CALR of the UTC links (LABs-PTB, Table 1 and 3a) then use the Triangle Closure condition (TCC) to compute CALRs of the non-UTC links (LABs-LABs) and then estimate the uncertainty. See the Annex V for the runs of using Tsoft to compute the CALR/ESVAR values.

For UTC links, the ESDVAR values are kept as their original values. For the non-UTC links, there are two cases: for Europe labs: ESDVAR==999999999 (Table 3b) and for NIST and USNO keep their original ESDVAR values (Table 3c).

We finally implemented the new CALR values in the TW1108 data (up to 55784). There are N(N-1)/2 links, N=11. With the data available at BIPM, the new CALR-ESDVAR are computed and listed in **Tables 3a, 3b, 3c.** The reference [5] is an independent calculation of the CALR for the link NIST-PTB using a TW bridge.

A brief discussion is given in the chapter 4 on the uncertainty of the TCC (Triangle closure calibration) and a long-term comparions of the TW and GPS PPP time links. For all the details of the method used, c.f. [1-4].

2. Implementation date

Implementation schedule:

- **55797-55799 (24-26 Aug.):** The TW LABs check their own CALR and the related ESDVAR in **Table 3a, 3b, 3c**
- **55800 (27 Aug.):** The BIPM issues the final version of this TM with the CALR/ESDVAR values and the CI codes
- **55803-55804 (30 - 31 Aug.):** The TW labs implement the new CALR/ESDVAR and the CI codes in their ITU files then upload (re-upload) the corrected ITU files (back up to the frequency switch moment on 55769/27 July 2011) to the BIPM ftp site for UTC computation. The first MJD of the coming Circular T 284 is 55774.

Remark: there are no or not enough data for the links of NIST-USNO, NIST-AOS, NIST-IT, NIST-IPQ, NPL-NIST, NPL-USNO, NPL-IPQ, USNO-IT. Therefore the related CALR have not been computed with the method TCC [1].

3. Computations and results

The Tables 1 and 2 give the computation and the result of the restoration calibrations. Although Table 1 presents the statistical uncertainty estimation, this is only a reference to know the limit of the statistics. We use the conventional values which are rather conservative in order to cover the uncertainty in the worst case. Tables 1 and 2 are the so called UTC links (Lab-PTB). For the uncertainty estimations of the Non UTC links (Labi-Labj), c.f. [1,2].

3.1 The restoration computation

Table 1: Restore the UTC TW link calibration due GPSPPP bridge, unit in ns

TW-PPP	N1	D1	σ1	N2	D2	σ2	D1-D2	σ	N	ε'	ε
AOS/PTB	100	-0.815	1.220	162	-1.674	0.517	0.859	1.325	100	0.133	0.2
CH/PTB	99	-6.531	0.882	157	-6.154	0.902	-0.377	1.262	99	0.127	0.2
IPQ/PTB	80	6.451	1.143	82	6.327	1.328	0.124	1.752	80	0.196	0.2
IT/PTB	91	1.313	0.710	160	0.422	0.638	0.891	0.955	91	0.100	0.2
NIST/PTB[1]	104	-1.167	0.286	60	0.169	0.336	-1.336	0.441	60	0.057	0.2
NIST/PTB[2]	12	0.816	0.141	12	3.233	0.114	-2.417	0.181	12	0.052	0.2
NPL/PTB	101	2.416	0.684	17	2.343	0.343	0.073	0.765	17	0.186	0.2
OP/PTB	103	1.917	0.565	40	2.721	0.515	-0.804	0.764	40	0.121	0.2
ROA/PTB	107	-9.321	0.673	163	-8.748	0.742	-0.573	1.002	107	0.097	0.2
SP/PTB	88	-4.011	0.963	144	-3.472	0.619	-0.539	1.145	88	0.122	0.2
USNO/PTB	99	4.199	0.318	59	6.570	0.327	-2.371	0.456	59	0.059	0.2
VSL/PTB	100	-1.942	0.499	123	-1.507	0.529	-0.435	0.727	100	0.073	0.2

Note:

1. BIPM solution by the PPP bridge using 5-day averages to reduce the noises and diurnals
2. NIST solution by the odd hour TW bridge using one-day average, cf. Report V. Zhang V1.0 Aug. 5 2011 [5].

Remark:

D1 is the mean value of TW-PPP for the Period 1 = 55760.0~55769.0 (except for USNO-PTB 55764~55769) [Tsoft hint: both CALR/ESDVAR on], cf. **Annex II**

D2 is that for the Period 2 = 55769.0~55783.0 (except for NIST-PTB 55776.0~55781.0 and USNO-PTB 55776.0~55782.0) [Tsoft hint: both CALR/ESDVAR on ➔ CLAR(new)= CLAR(old)+(D1 - D2)], cf. **Annex III**

To average out the diurnals in the TW links, the period is at least of 5 days. D1 and D2 are the average of more than 5 days differences of TW-PPP. The Bridge=D1-D2 / ns

N1 and N2 are the comparison points in the period 1 and period 2. N is the smaller one in N1 and N2

σ is the standard deviation of the D1-D2 : $\boldsymbol{\sigma}=\sqrt{(\boldsymbol{\sigma}1^2+\boldsymbol{\sigma}2^2)}$

$\varepsilon'=\boldsymbol{\sigma}/\sqrt{N}$ is the statistic uncertainty of the CALR restoration which is the mean value of all the available points. $\varepsilon > \varepsilon'$ is a conventional value to cover the residual influence of the diurnals.

3.2 The total uncertainty and the result

Assuming that the uncertainty in CALR before the restoration is $\boldsymbol{u}$, the uncertainty of the combined ESDVAR is $\boldsymbol{v}$, the uncertainty of the bridging restoration is $\boldsymbol{\varepsilon}$ and the total uncertainty of the CALR after the restoration is $\boldsymbol{U}$:

$\boldsymbol{v} = \sqrt{[\boldsymbol{v}^2(\text{Lab}) + \boldsymbol{v}^2(\text{PTB})]}$
$\boldsymbol{U} = \sqrt{(u^2+\boldsymbol{v}^2/2+\boldsymbol{\varepsilon}^2)}$

For the $\boldsymbol{u}$ values 3, 5 or 7 ns, we take the corresponding conventional values 3, 5 and 7 ns for the total uncertainty $\boldsymbol{U}$. If the ESDVAR should be set to "0" or "999999999", the $\boldsymbol{v}$ has to be included in the CALR value.

Remark: The above is a theoretical estimation of the total uncertainty. However, in practices not all the terms are exactly available, e.g. the $\boldsymbol{v}$. We then take a conventional value: $\boldsymbol{v}$ = 0.5 ns.

CALRs in Table 2 are computed by:

CLAR(new)= CLAR(old)+(D1 - D2), here D1 - D2 are from Table 1.

Table 2: The CALR and related values for the UTC links

Link	EsdVar /ns	CALR_old /ns	CALR_new /ns	CI	S	*u* /ns*	*v* /ns	*ε* /ns	*U* /ns
AOSPTB	999999999	-165.000	-164.141	210	1	7.0	0.5	0.2	7.0
CHPTB	8.340	-209.500	-209.877	211	1	1.0	0.5	0.2	1.2
IPQPTB	999999999	-188.600	-188.476	212	1	7.0	0.5	0.2	5.0
ITPTB	999999999	-480.100	-479.209	213	1	1.2	0.5	0.2	1.3
NISTPTB[1]	-0.724	-197.200	-196.384	269	1	5.0	0.5	0.2	5.0
NISTPTB[2]	-0.724	-197.200	-199.617	214	1	5.0	0.5	0.2	5.0
NPLPTB	999999999	490.300	490.373	215	1	7.0	0.5	0.2	7.0
OPPTB	999999999	-7299.900	-7300.704	216	1	1.1	0.5	0.2	1.2
ROAPTB	272.616	-298.100	-298.673	217	1	5.0	0.5	0.2	5.0
SPPTB	999999999	-194.400	-194.939	218	1	1.1	0.5	0.2	1.2
USNOPTB	-379.910	214.500	212.129	219	1	3.0	0.5	0.2	3.0
VSLPTB	999999999	-471.500	-471.935	220	1	1.2	0.5	0.2	1.3
PTB	1035.000								

* *u* are the uncertainty values in the headers of the ITU files suggested by [2,3] and reported by the TW labs.

Remarks: 1 for the first step on 55769, cf. [5]
2 for the second step on 55776, cf. [5]

3.3 CALR/ESDVAR values for the implementation in the ITU files

3.3.1 The UTC links (Lab-PTB)

Table 3a CALR/ESDVAR for UTC links

CI	Labi	Labj	S	CALR/ns	U/ns	ESDVAR/ns
210	PTB	AOS	1	164.141	7.0	1035.000
	AOS	PTB	1	-164.141	7.0	999999999
211	PTB	CH	1	209.877	1.2	1035.000
	CH	PTB	1	-209.877	1.2	8.340
212	PTB	IPQ	1	188.476	5.0	1035.000
	IPQ	PTB	1	-188.476	5.0	999999999
213	PTB	IT	1	479.209	1.3	1035.000
	IT	PTB	1	-479.209	1.3	999999999
269[1]	PTB	NIST	1	196.384	5.0	1035.000
	NIST	PTB	1	-196.384	5.0	-0.724
214[2]	PTB	NIST	1	199.617	5.0	1035.000
	NIST	PTB	1	-199.617	5.0	-0.724
215	PTB	NPL	1	-490.373	7.0	1035.000
	NPL	PTB	1	490.373	7.0	999999999
216	PTB	OP	1	7300.704	1.2	1035.000
	OP	PTB	1	-7300.704	1.2	999999999
217	PTB	ROA	1	298.673	5.0	1035.000
	ROA	PTB	1	-298.673	5.0	272.616
218	PTB	SP	1	194.939	1.2	1035.000
	SP	PTB	1	-194.939	1.2	999999999
219	PTB	USNO	1	-212.129	3.0	1035.000
	USNO	PTB	1	212.129	3.0	-379.910
220	PTB	VSL	1	471.935	1.3	1035.000
	VSL	PTB	1	-471.935	1.3	999999999

TYPE: G.B. (GPS bridge)
Used Since: 30 Aug. 2011
Remark: BIPM TM198

Remarks: 1 for the first step on 55769, cf. [5]
2 for the second step on 55776, cf. [5]

3.3.2 The Non UTC links (Lab*i*-Lab*j*)

Following links had not data or not complete before/after the frequency changes and have not been calculated: NIST-USNO, NIST-AOS, NIST-IT, NIST-IPQ, NPL-NIST, NPL-USNO, NPL-IPQ, USNO-IT. In total, there are 54 non UTC links calibrated using the method TCC [1]. The only complete ITU data set at BIPM at present are those between 55776 and 55782 that are used to calculate the CALR values for the non-UTC links.

Table 3b CALR for Non-UTC links

CI	Labi	Labj	S	CALR/ns	U/ns	ESDVAR/ns
221	AOS	CH	1	41.819	7.0	999999999
	CH	AOS	1	-41.819	7.0	999999999
222	AOS	IT	1	314.810	7.0	999999999
	IT	AOS	1	-314.810	7.0	999999999
223	AOS	IPQ	1	24.602	7.0	999999999
	IPQ	AOS	1	-24.602	7.0	999999999
224	AOS	NPL	1	-655.324	7.0	999999999
	NPL	AOS	1	655.324	7.0	999999999
225	AOS	OP	1	7136.225	7.0	999999999
	OP	AOS	1	-7136.225	7.0	999999999
226	AOS	ROA	1	-1.628	7.0	999999999
	ROA	AOS	1	1.628	7.0	999999999
227	AOS	SP	1	30.309	7.0	999999999
	SP	AOS	1	-30.309	7.0	999999999
228	AOS	VSL	1	307.772	7.0	999999999
	VSL	AOS	1	-307.772	7.0	999999999
229	CH	IT	1	272.387	2.0	999999999
	IT	CH	1	-272.387	2.0	999999999
230	CH	IPQ	1	-17.283	7.0	999999999
	IPQ	CH	1	17.283	7.0	999999999
231	CH	NPL	1	-697.217	7.0	999999999
	NPL	CH	1	697.217	7.0	999999999
232	CH	OP	1	7094.590	2.0	999999999
	OP	CH	1	-7094.590	2.0	999999999
233	CH	ROA	1	-42.911	5.0	999999999
	ROA	CH	1	42.911	5.0	999999999
234	CH	SP	1	-10.978	2.0	999999999
	SP	CH	1	10.978	2.0	999999999
235	CH	VSL	1	265.085	2.0	999999999
	VSL	CH	1	-265.085	2.0	999999999
236	IT	IPQ	1	-290.485	7.0	999999999
	IPQ	IT	1	290.485	7.0	999999999
237	IT	NPL	1	-970.315	7.0	999999999
	NPL	IT	1	970.315	7.0	999999999
238	IT	OP	1	6821.756	2.0	999999999
	OP	IT	1	-6821.756	2.0	999999999
239	IT	ROA	1	-317.141	6.0	999999999
	ROA	IT	1	317.141	6.0	999999999
240	IT	SP	1	-283.892	2.0	999999999
	SP	IT	1	283.892	2.0	999999999
241	IT	VSL	1	-7.118	2.0	999999999
	VSL	IT	1	7.118	2.0	999999999
242	IPQ	NPL	1	-5.707	7.0	999999999
	NPL	IPQ	1	5.707	7.0	999999999
243	IPQ	OP	1	7112.121	7.0	999999999
	OP	IPQ	1	-7112.121	7.0	999999999
244	IPQ	ROA	1	-25.465	7.0	999999999
	ROA	IPQ	1	25.465	7.0	999999999
245	IPQ	SP	1	6.052	7.0	999999999
	SP	IPQ	1	-6.052	7.0	999999999
246	IPQ	VSL	1	283.164	7.0	999999999
	VSL	IPQ	1	-283.164	7.0	999999999
247	NPL	OP	1	7791.938	7.0	999999999
	OP	NPL	1	-7791.938	7.0	999999999
248	NPL	ROA	1	653.195	7.0	999999999
	ROA	NPL	1	-653.195	7.0	999999999
249	NPL	SP	1	686.378	7.0	999999999
	SP	NPL	1	-686.378	7.0	999999999
250	NPL	VSL	1	963.017	7.0	999999999
	VSL	NPL	1	-963.017	7.0	999999999
251	OP	ROA	1	-7137.879	6.0	999999999
	ROA	OP	1	7137.879	6.0	999999999
252	OP	SP	1	-7105.715	2.0	999999999
	SP	OP	1	7105.715	2.0	999999999
253	OP	VSL	1	-6829.083	2.0	999999999
	VSL	OP	1	6829.083	2.0	999999999
254	ROA	SP	1	32.071	6.0	999999999
	SP	ROA	1	-32.071	6.0	999999999
255	ROA	VSL	1	309.113	6.0	999999999
	VSL	ROA	1	-309.113	6.0	999999999
256	SP	VSL	1	276.495	2.0	999999999
	VSL	SP	1	-276.495	2.0	999999999

TYPE: T.C. (triangle closure)
Used Since: 30 Aug. 2011
Remark: BIPM TM198

Table 3c CALR/ESDVAR for Non-UTC links (Original/Errata)

				Original (28 Aug. 2011)			Errata (18 May. 2013)		
CI	Labi	Labj	S	CALR/ns	U/ns	ESDVAR/ns	CALR/ns	U/ns	ESDVAR/ns
257	AOS	USNO	1	-186.089	7.0	999999999	-376.044	7.0	999999999
	USNO	AOS	1	186.089	7.0	-379.910	376.044	7.0	-379.910
258	CH	NIST	1	-7.048	6.0	999999999	-7.410	6.0	999999999
	NIST	CH	1	7.048	6.0	-0.724	7.410	6.0	-0.724
259	CH	USNO	1	-228.492	3.0	999999999	-418.447	3.0	999999999
	USNO	CH	1	228.492	3.0	-379.910	418.447	3.0	-379.910
260	IPQ	USNO	1	-209.777	7.0	999999999	-399.732	7.0	999999999
	USNO	IPQ	1	209.777	7.0	-379.910	399.732	7.0	-379.910
261	NIST	OP	1	7100.696	6.0	-0.724	7101.058	6.0	-0.724
	OP	NIST	1	-7100.696	6.0	999999999	-7101.058	6.0	999999999
262	NIST	ROA	1	-36.568	6.0	-0.724	-36.206	6.0	-0.724
	ROA	NIST	1	36.568	6.0	999999999	36.206	6.0	999999999
263	NIST	SP	1	-5.037	6.0	-0.724	-4.675	6.0	-0.724
	SP	NIST	1	5.037	6.0	999999999	4.675	6.0	999999999
264	NIST	VSL	1	271.391	6.0	-0.724	271.753	6.0	-0.724
	VSL	NIST	1	-271.391	6.0	999999999	-271.753	6.0	999999999
265	OP	USNO	1	-7321.940	3.0	999999999	-7511.895	3.0	999999999
	USNO	OP	1	7321.940	3.0	-379.910	7511.895	3.0	-379.910
266	ROA	USNO	1	-184.505	6.0	999999999	-374.460	6.0	999999999
	USNO	ROA	1	184.505	6.0	-379.910	374.460	6.0	-379.910
267	SP	USNO	1	-216.605	3.0	999999999	-406.560	3.0	999999999
	USNO	SP	1	216.605	3.0	-379.910	406.560	3.0	-379.910
268	USNO	VSL	1	492.410	3.0	-379.910	682.365	3.0	-379.910
	VSL	USNO	1	-492.410	3.0	999999999	-682.365	3.0	999999999

TYPE: T.C. (triangle closure)
Used Since: 30 Aug. 2011
Remark: BIPM TM198

4. Discussion

In this chapter, we will make some detailed discussions which are rather for the BIPM technical back up and documentation of this work. The section 4.1 presents the statistic results of the TCC (triangle closure calibration [1]). This may be helpful for those who want to deeply study the TW error source including the diurnals, calibration variations, TW triangle behaviors, time link comparisons etc. Those who are not interesting in these details can ignore the section 4.1. The section 4.2 presents the results of the link comparisons between TW and GPS PPP. As we can see, the difference of between TW and PPP changed significantly for certain baselines. We do not know the cause or which of the TW and GPS PPP links changed. We should draw more attention to the calibration variations.

4.1 Statistics of the triangle closures

The TCC uncertainty is 2 ns, cf. [1]. We observe that in the Table 4. The term d is the closure values after implementing the CALR/ESDVAR values determined with TCC method. The d should be zero theoretically. The non zero d contains the errors, mainly the measurement noises. The d is mostly very small and much smaller than 1 ns. In fact, we used the TW data between 55776 and 55782 to compute the CALR and use the same data set to verify their residuals. Further investigation is required afterwards, e.g. over one year to verify their variations.

Table 4. Verification of the new CALR values with the Triangle closures using data set of MJD 55776-55782

(some outliers are not presented here)

Labi	Labj	d±StDev/ns	N	ESIG
AOS01	CH01	-0.004±0.152	84	0.017
CH01	AOS01	0.004±0.152	84	0.017
AOS01	IT02	0.005±0.302	84	0.033
IT02	AOS01	-0.005±0.302	84	0.033
AOS01	IPQ01	0.038±0.569	52	0.079
IPQ01	AOS01	-0.038±0.569	52	0.079
AOS01	NPL01	0.119±0.159	18	0.037
NPL01	AOS01	-0.119±0.159	18	0.037
AOS01	OP01	0.289±0.288	11	0.087
OP01	AOS01	-0.289±0.288	11	0.087
AOS01	ROA01	-0.017±0.268	84	0.029
ROA01	AOS01	0.017±0.268	84	0.029
AOS01	SP01	0.005±0.195	79	0.022
SP01	AOS01	-0.005±0.195	79	0.022
AOS01	USNO01	-0.022±0.230	62	0.029
USNO01	AOS01	0.022±0.230	62	0.029
AOS01	VSL01	0.004±0.305	78	0.035
VSL01	AOS01	-0.004±0.305	78	0.035
CH01	IT02	0.001±0.248	84	0.027
IT02	CH01	-0.001±0.248	84	0.027
CH01	IPQ01	0.007±0.697	51	0.098
IPQ01	CH01	-0.007±0.697	51	0.098
CH01	NIST01	0.024±0.619	84	0.068
NIST01	CH01	-0.024±0.619	84	0.068
CH01	NPL01	0.051±0.195	18	0.046
NPL01	CH01	-0.051±0.195	18	0.046
CH01	OP01	0.081±0.439	32	0.078
OP01	CH01	-0.081±0.439	32	0.078
CH01	ROA01	-0.009±0.164	84	0.018
ROA01	CH01	0.009±0.164	84	0.018
CH01	SP01	-0.002±0.302	77	0.034
SP01	CH01	0.002±0.302	77	0.034
CH01	USNO01	-0.029±0.607	63	0.076
USNO01	CH01	0.029±0.607	63	0.076
CH01	VSL01	0.008±0.520	78	0.059
VSL01	CH01	-0.008±0.520	78	0.059
IT02	NPL01	0.066±0.205	18	0.048
NPL01	IT02	-0.066±0.205	18	0.048
IT02	OP01	0.172±0.548	14	0.147
OP01	IT02	-0.172±0.548	14	0.147
IT02	ROA01	-0.005±0.194	84	0.021
ROA01	IT02	0.005±0.194	84	0.021
IT02	SP01	0.005±0.094	80	0.011
SP01	IT02	-0.005±0.094	80	0.011
IT02	VSL01	0.020±0.286	78	0.032
VSL01	IT02	-0.020±0.286	78	0.032
IPQ01	OP01	0.096±0.348	16	0.087
OP01	IPQ01	-0.096±0.348	16	0.087
IPQ01	ROA01	0.044±0.326	55	0.044
ROA01	IPQ01	-0.044±0.326	55	0.044
IPQ01	SP01	-0.004±0.780	37	0.128
SP01	IPQ01	0.004±0.780	37	0.128
IPQ01	USNO01	0.001±0.871	22	0.186
USNO01	IPQ01	-0.001±0.871	22	0.186
IPQ01	VSL01	-0.115±0.592	48	0.085
VSL01	IPQ01	0.115±0.592	48	0.085
NIST01	OP01	0.023±0.610	32	0.108
OP01	NIST01	-0.023±0.610	32	0.108
NIST01	SP01	-0.006±0.408	80	0.046
SP01	NIST01	0.006±0.408	80	0.046
NIST01	VSL01	0.003±0.424	78	0.048
VSL01	NIST01	-0.003±0.424	78	0.048
NPL01	OP01	0.166±0.344	6	0.140
OP01	NPL01	-0.166±0.344	6	0.140
NPL01	ROA01	-0.062±0.390	18	0.092
ROA01	NPL01	0.062±0.390	18	0.092
NPL01	SP01	-0.843±0.575	13	0.159
SP01	NPL01	0.843±0.575	13	0.159
NPL01	VSL01	-0.262±0.853	17	0.207
VSL01	NPL01	0.262±0.853	17	0.207
OP01	ROA01	-0.093±0.448	32	0.079
ROA01	OP01	0.093±0.448	32	0.079
OP01	SP01	-0.035±0.499	28	0.094
SP01	OP01	0.035±0.499	28	0.094
OP01	USNO01	-0.075±0.763	19	0.175
USNO01	OP01	0.075±0.763	19	0.175
OP01	VSL01	-0.104±0.553	23	0.115
VSL01	OP01	0.104±0.553	23	0.115
ROA01	SP01	-0.016±0.178	78	0.020
SP01	ROA01	0.016±0.178	78	0.020
ROA01	USNO01	0.006±0.330	59	0.043
USNO01	ROA01	-0.006±0.330	59	0.043
ROA01	VSL01	-0.002±0.324	78	0.037
VSL01	ROA01	0.002±0.324	78	0.037
SP01	USNO01	-0.018±0.376	60	0.049
USNO01	SP01	0.018±0.376	60	0.049
SP01	VSL01	-0.028±0.368	72	0.043
VSL01	SP01	0.028±0.368	72	0.043
USNO01	VSL01	0.027±0.396	57	0.052
VSL01	USNO01	-0.027±0.396	57	0.052

4.2 Comparison of the TW and GPS PPP UTC time links

The Table 5 is a comparison of the double differences of the UTC link differences between TW and GPS PPP computed during the restorations of the TW calibrations due satellite/frequency changes in 2009 and 2011. As seen, four of them are bigger than 2 ns. We do not know the reasons. But this may show that the variation of the UTC link calibration is not negligible, e.g. the changes may come simply from the set-up of the receiver instead of the electronics/hardware. Further investigations are required.

Table 5 Comparison of the double differences of the TW-PPP between 2010[1] and 2011[2]

Baseline	N1/N2	Dif2011[1]	Dif2010[2]	dif[3]
AOSPTB	262/363	0.8±0.9	0.2±1.2	0.6
CHPTB	256/382	6.5±0.9	6.9±0.8	-0.4
IPQPTB	162/342	-6.5±1.2	-2.1±1.9	-4.4
ITPTB	251	-1.3±0.7		
NISTPTB	130/401	1.3±0.3	2.9±0.4	-1.6
NPLPTB	118/118	-2.4±0.6	-1.1±0.4	-1.3
OPPTB	143/400	-1.9±0.6	-0.6±0.7	-1.3
ROAPTB	270/391	9.3±0.7	5.1±1.2	4.2
SPPTB	232/388	4.0±0.8	6.2±0.8	-2.2
USNOPTB	158/372	-4.2±0.3	1.2±1.3	-5.4
VSLPTB	223/372	1.9±0.5	2.6±1.2	-0.7

Note :

1. difference of the TW – GPSPPP over the UTC baselines in 2010 (1009 Mjd 55442-55469, cf. TM176 [4]). N1 is the number of points compared.
2. difference of the TW – GPSPPP over the UTC baselines in 2011 (1108 Mjd 55760-55782, this TM) . N2 is the number of points compared.
3. dif=Dif2011-Dif2010

References:

[1] Jiang Z, Lewandowski W, Piester D (2008) *Calibration of TWSTFT Links Through the Triangle Closure Condition*, Proc. PTTI 2008

[2] Jiang, Piester and Liang, *Restoring a TWSTFT Calibration with a GPS Bridge - A standard procedure for UTC time transfer*, Proc. EFTF 2010

[3] BIPM TM166 (2009) *Restoration the TWSTFT link calibration using GPS bridging after the satellite switch from IS-3R to T-11N in July/August 2009 (around MJD 55043)*, ftp://tai.bipm.org/TimeLink/LkC/

[4] BIPM TM176 (2010), *BIPM Calibrations of AOS, IPQ, NPL and USNO TWSTFT Time Links,* ftp://tai.bipm.org/TimeLink/LkC/

[5] Zhang V. *Estimate of Delay change in NIST/PTB TWSTFT link introduced by New Uplink/Downlink frequencies*, V1.0; Aug. 5 2011

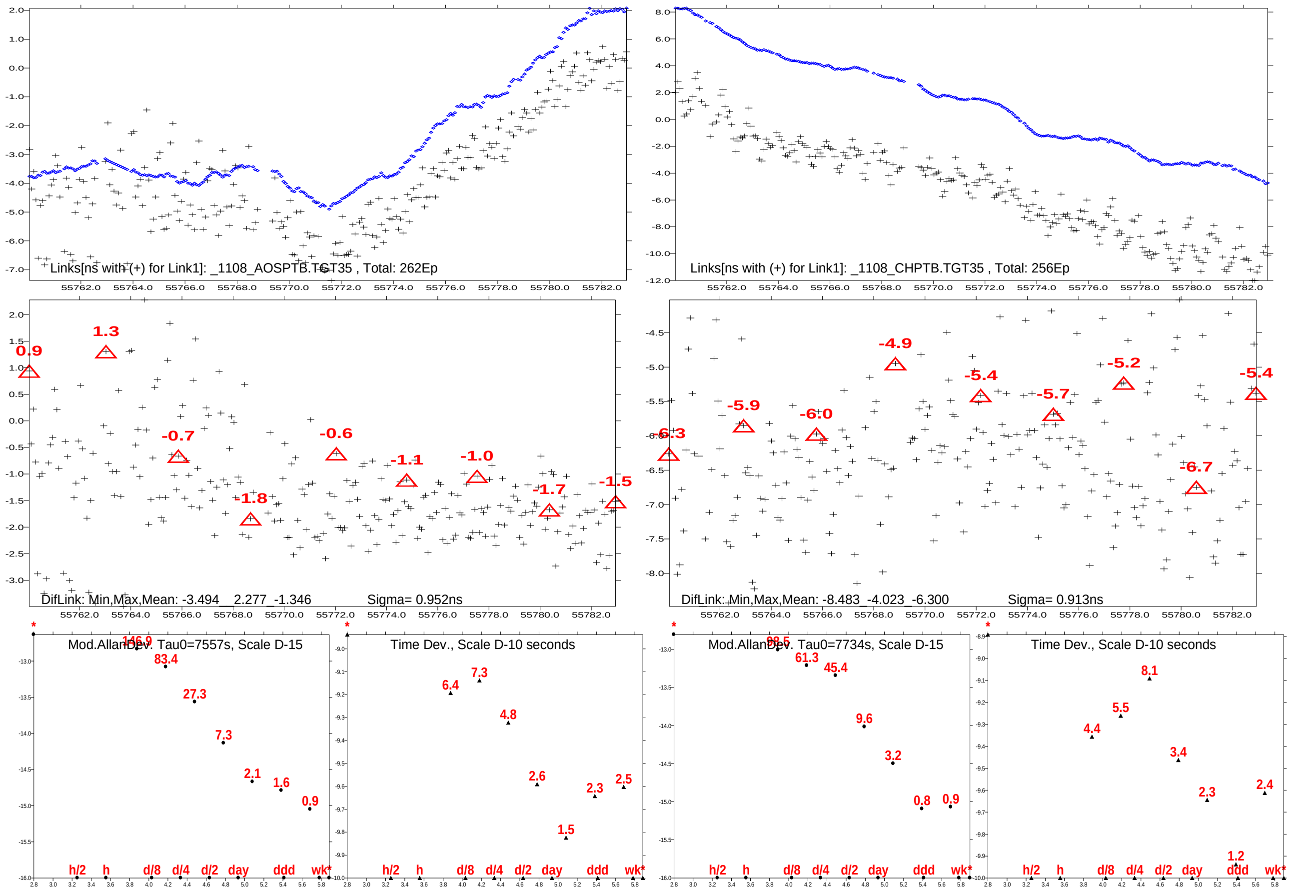
Annex I Period-0: 55760-55783

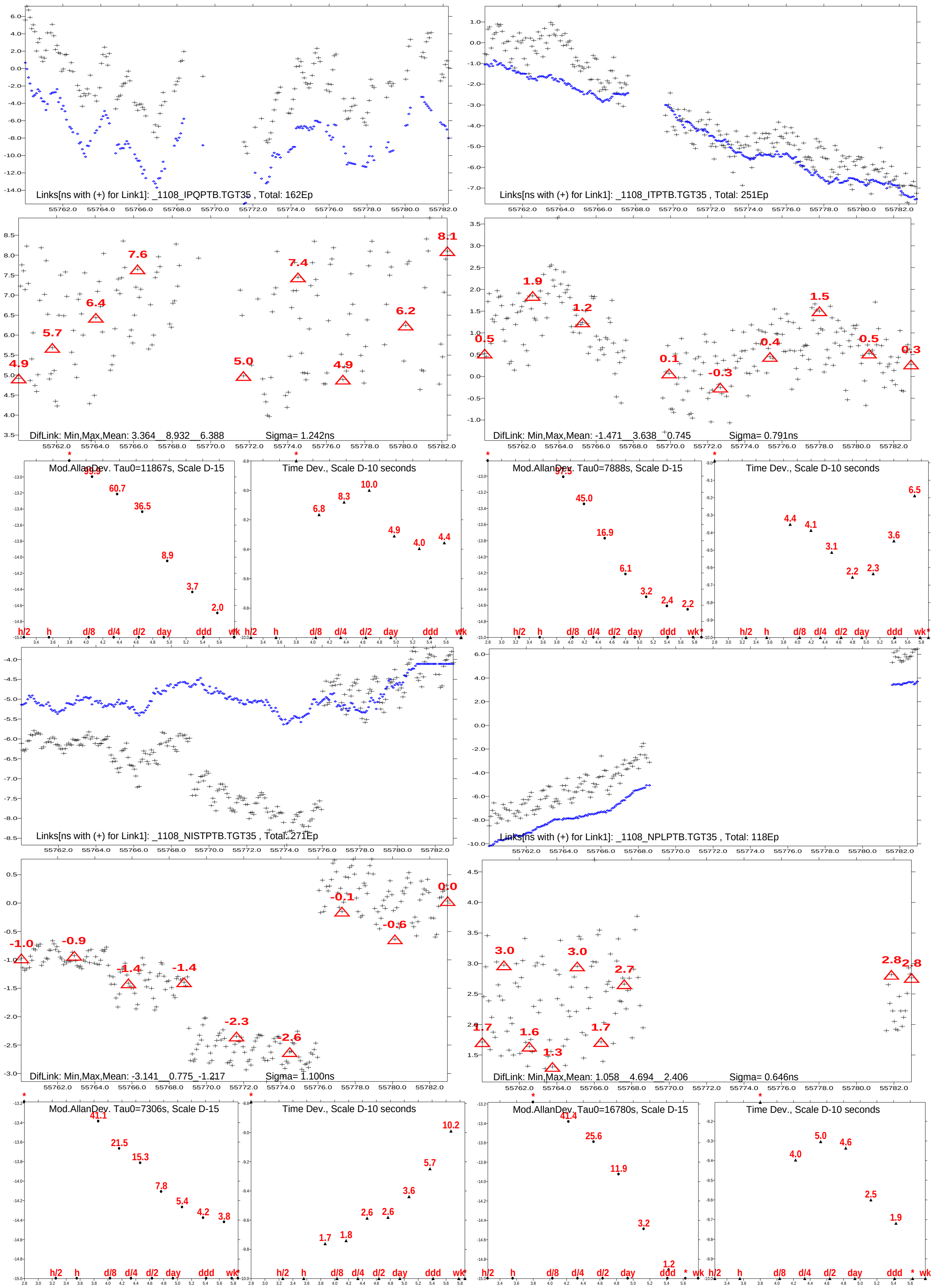
55760-783

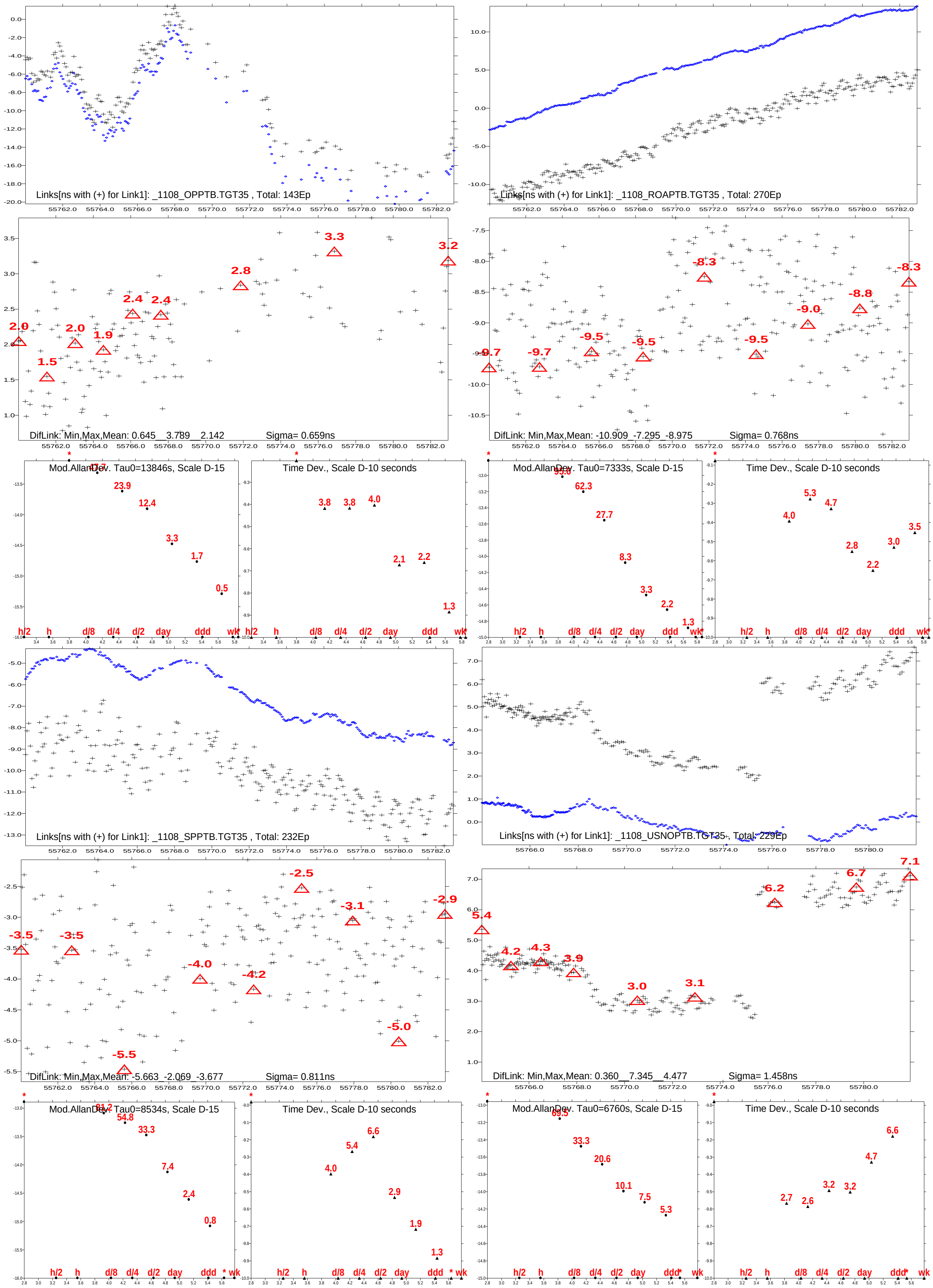
TW-PPP	N	Min	Max	Mean	Rms	Sigma
AOSPTB	262	-3.494	2.277	-1.346	1.649	0.952
CHPTB	256	-8.483	-4.023	-6.300	6.365	0.913
IPQPTB	162	3.364	8.932	6.388	6.508	1.242
ITPTB	251	-1.471	3.638	0.745	1.087	0.791
NISTPTB	271	-3.141	0.775	-1.217	1.641	1.101
NPLPTB	118	1.058	4.694	2.406	2.491	0.646
OPPTB	143	0.645	3.789	2.142	2.241	0.659
ROAPTB	270	-10.909	-7.295	-8.975	9.008	0.768
SPPTB	232	-5.663	-2.069	-3.677	3.765	0.811
USNOPTB	229	0.360	7.345	4.477	4.708	1.458
VSLPTB	223	-3.223	-0.128	-1.702	1.792	0.559

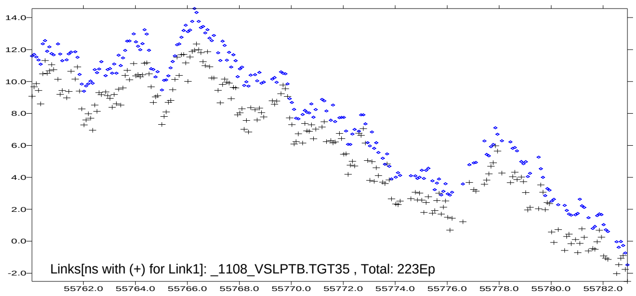
55764-783

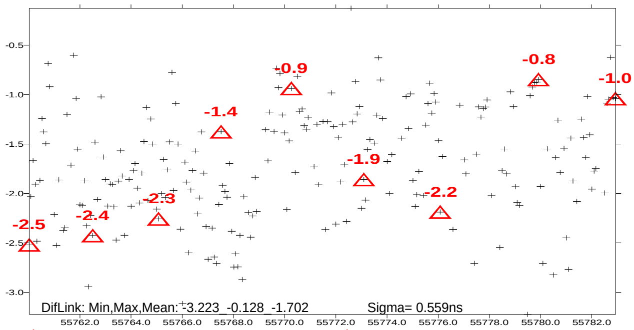
TW-PPP	N	Min	Max	Mean	Rms	Sigma
USNOPTB	229	0.360	7.345	4.477	4.708	1.458

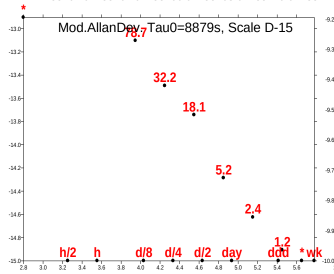


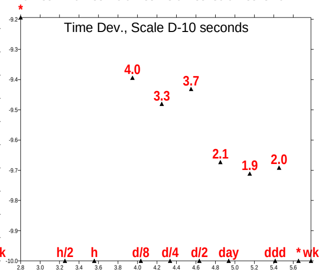

Links[ns with (+) for Link1]: _1108_IPQPTB.TGT35 , Total: 162Ep
Links[ns with (+) for Link1]: _1108_ITPTB.TGT35 , Total: 251Ep
DifLink: Min,Max,Mean: 3.364 8.932 6.388
Sigma= 1.242ns
DifLink: Min,Max,Mean: -1.471 3.638 0.745
Sigma= 0.791ns
Mod.AllanDev. Tau0=11867s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7888s, Scale D-15
Time Dev., Scale D-10 seconds
Links[ns with (+) for Link1]: _1108_NISTPTB.TGT35 , Total: 271Ep
Links[ns with (+) for Link1]: _1108_NPLPTB.TGT35 , Total: 118Ep
DifLink: Min,Max,Mean: -3.141 0.775 -1.217
Sigma= 1.100ns
DifLink: Min,Max,Mean: 1.058 4.694 2.406
Sigma= 0.646ns
Mod.AllanDev. Tau0=7306s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=16780s, Scale D-15
Time Dev., Scale D-10 seconds


Links[ns with (+) for Link1]: _1108_OPPTB.TGT35 , Total: 143Ep
Links[ns with (+) for Link1]: _1108_ROAPTB.TGT35 , Total: 270Ep
DifLink: Min,Max,Mean: 0.645__3.789__2.142
Sigma= 0.659ns
DifLink: Min,Max,Mean: -10.909_-7.295_-8.975
Sigma= 0.768ns
Mod.AllanDev. Tau0=13846s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7333s, Scale D-15
Time Dev., Scale D-10 seconds
Links[ns with (+) for Link1]: _1108_SPPTB.TGT35 , Total: 232Ep
Links[ns with (+) for Link1]: _1108_USNOPTB.TGT35 , Total: 229Ep
DifLink: Min,Max,Mean: -5.663_-2.069_-3.677
Sigma= 0.811ns
DifLink: Min,Max,Mean: 0.360__7.345__4.477
Sigma= 1.458ns
Mod.AllanDev. Tau0=8534s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=6760s, Scale D-15
Time Dev., Scale D-10 seconds


Links[ns with (+) for Link1]: _1108_VSLPTB.TGT35 , Total: 223Ep


DifLink: Min,Max,Mean: -3.223 -0.128 -1.702
Sigma= 0.559ns


Mod.AllanDev, Tau0=8879s, Scale D-15
78.7
32.2
18.1
5.2
2.4
1.2
h/2
h
d/8
d/4
d/2
day
ddd
*wk


Time Dev., Scale D-10 seconds
4.0
3.3
3.7
2.1
1.9
2.0
h/2
h
d/8
d/4
d/2
day
ddd
*wk

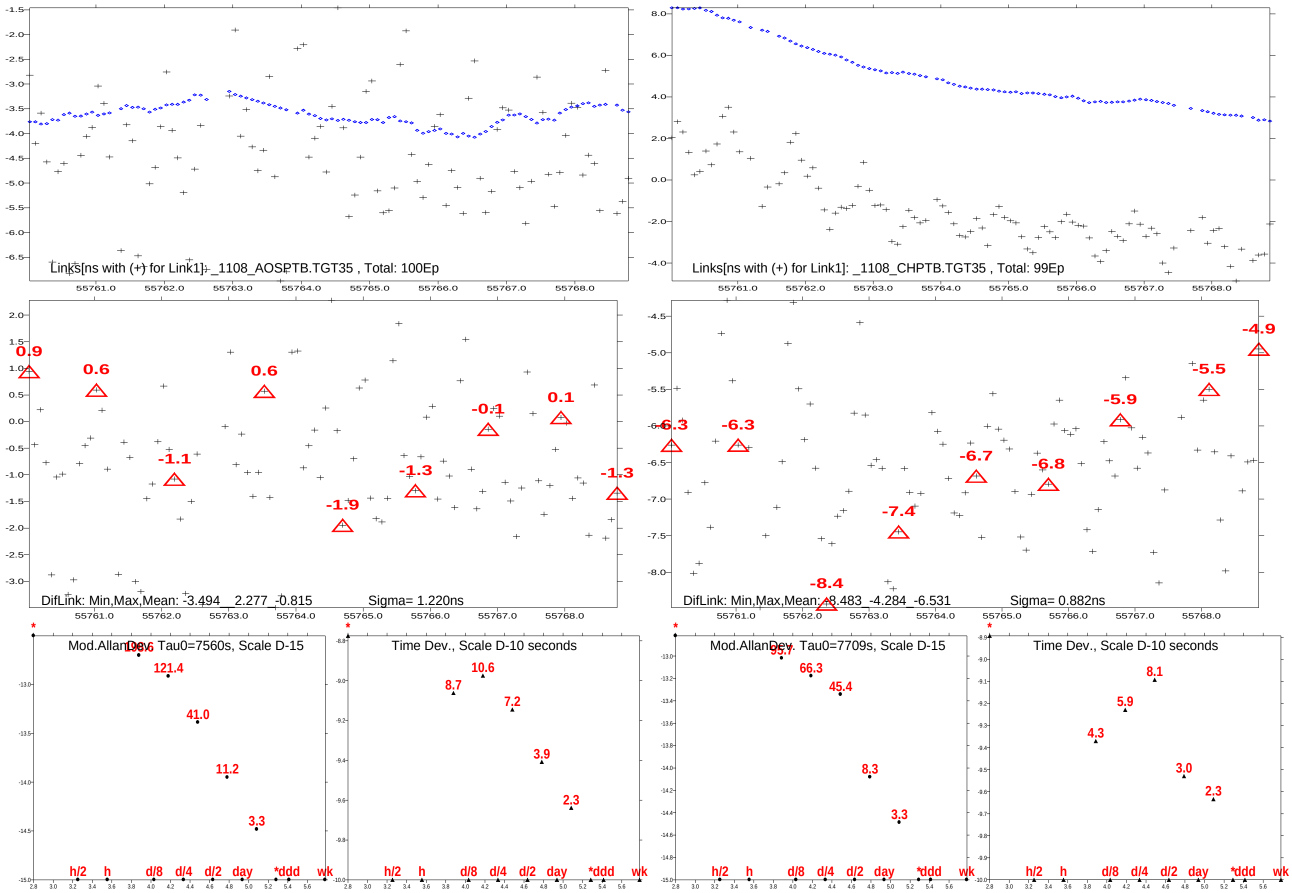
Annex II Period-1: 55760-55769

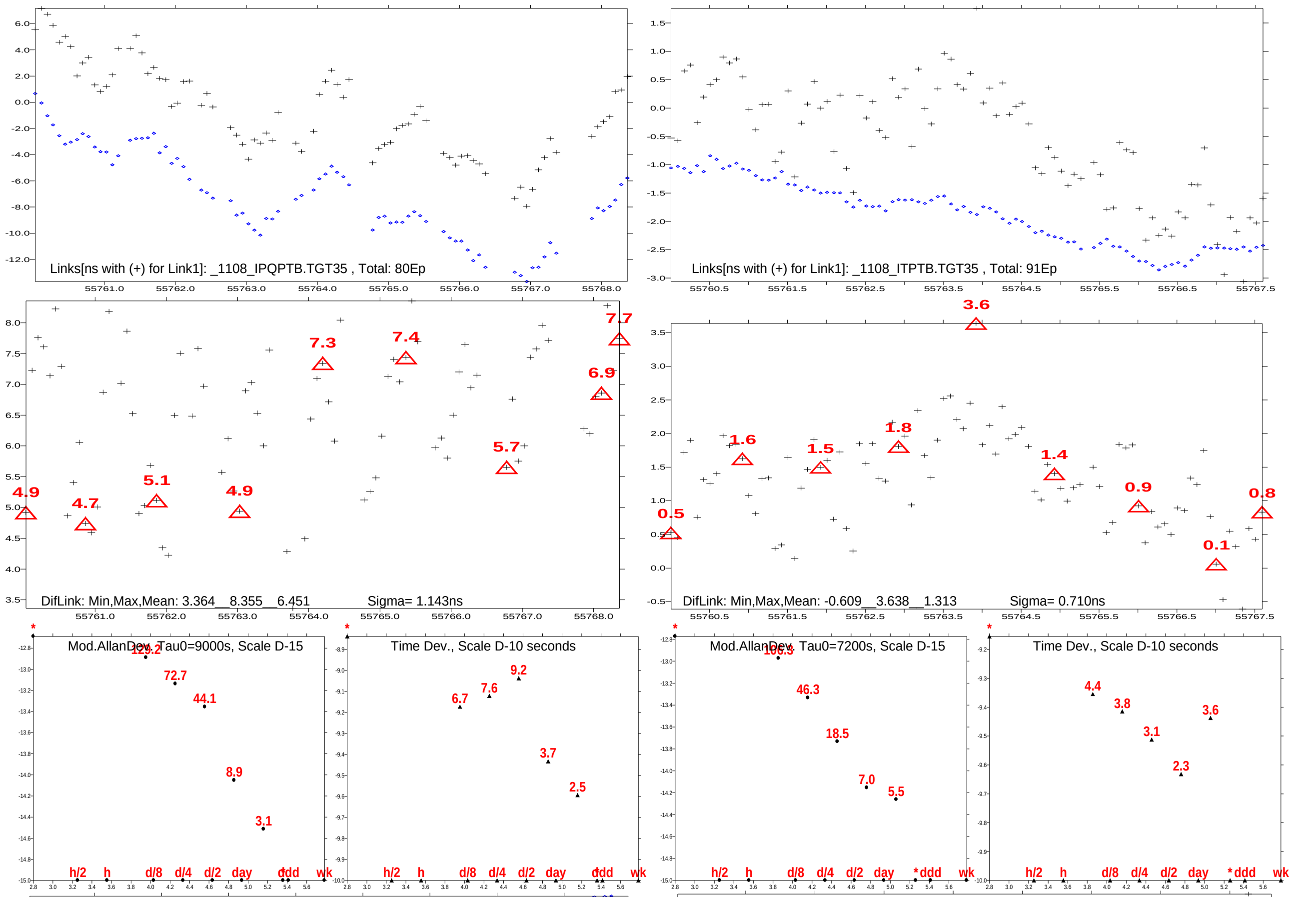
55760-769

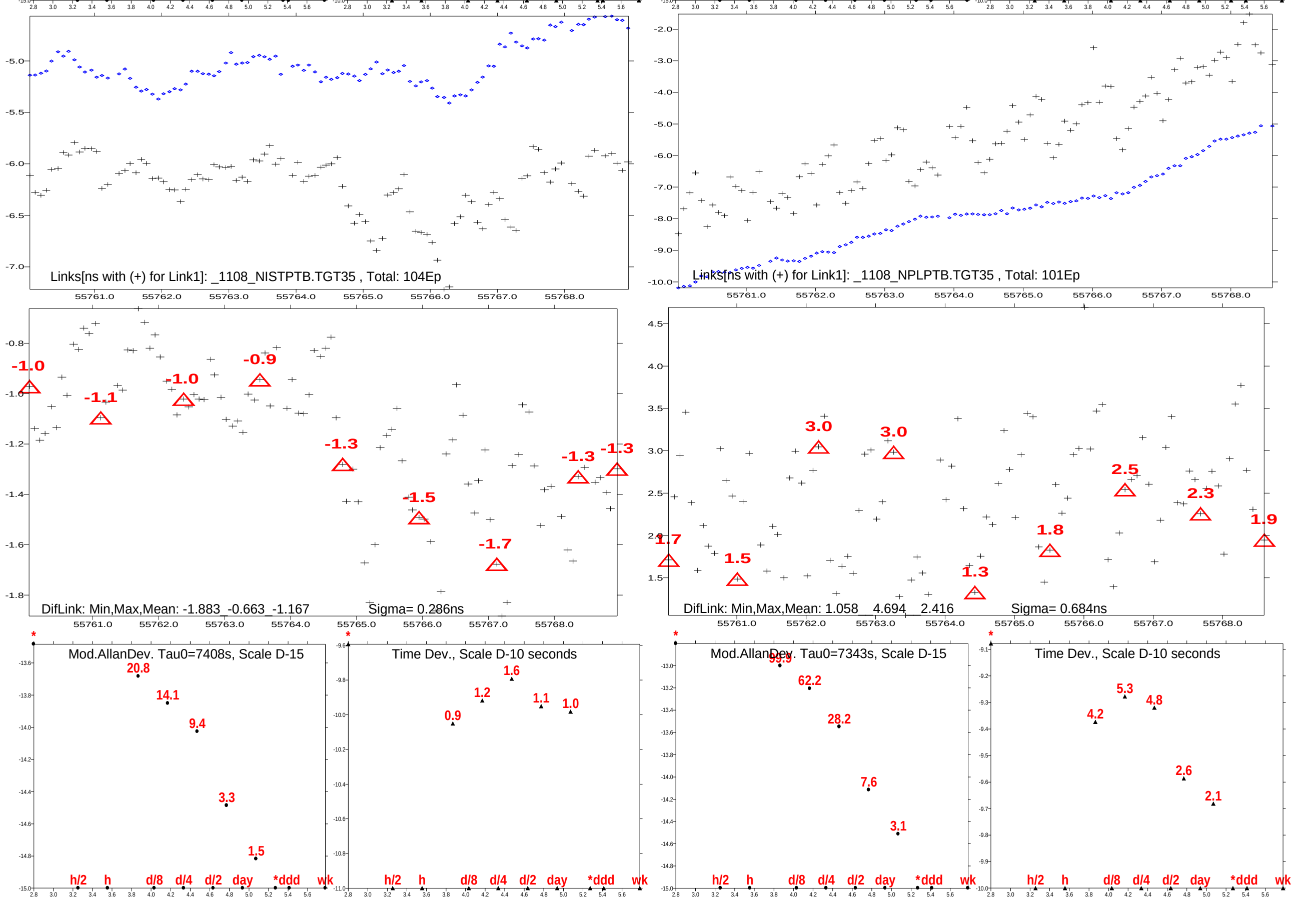
TW-PPP	N	Min	Max	Mean	Rms	Sigma
AOSPTB	100	-3.494	2.277	-0.815	1.467	1.220
CHPTB	99	-8.483	-4.284	-6.531	6.591	0.882
IPQPTB	80	3.364	8.355	6.451	6.551	1.143
ITPTB	91	-0.609	3.638	1.313	1.492	0.710
NISTPTB	104	-1.883	-0.663	-1.167	1.201	0.286
NPLPTB	101	1.058	4.694	2.416	2.511	0.684
OPPTB	103	0.645	3.164	1.917	1.999	0.565
ROAPTB	107	-10.909	-7.760	-9.321	9.345	0.673
SPPTB	88	-5.663	-2.069	-4.011	4.125	0.963
USNOPTB	99	2.962	5.355	4.199	4.211	0.318
VSLPTB	100	-3.113	-0.603	-1.942	2.006	0.499

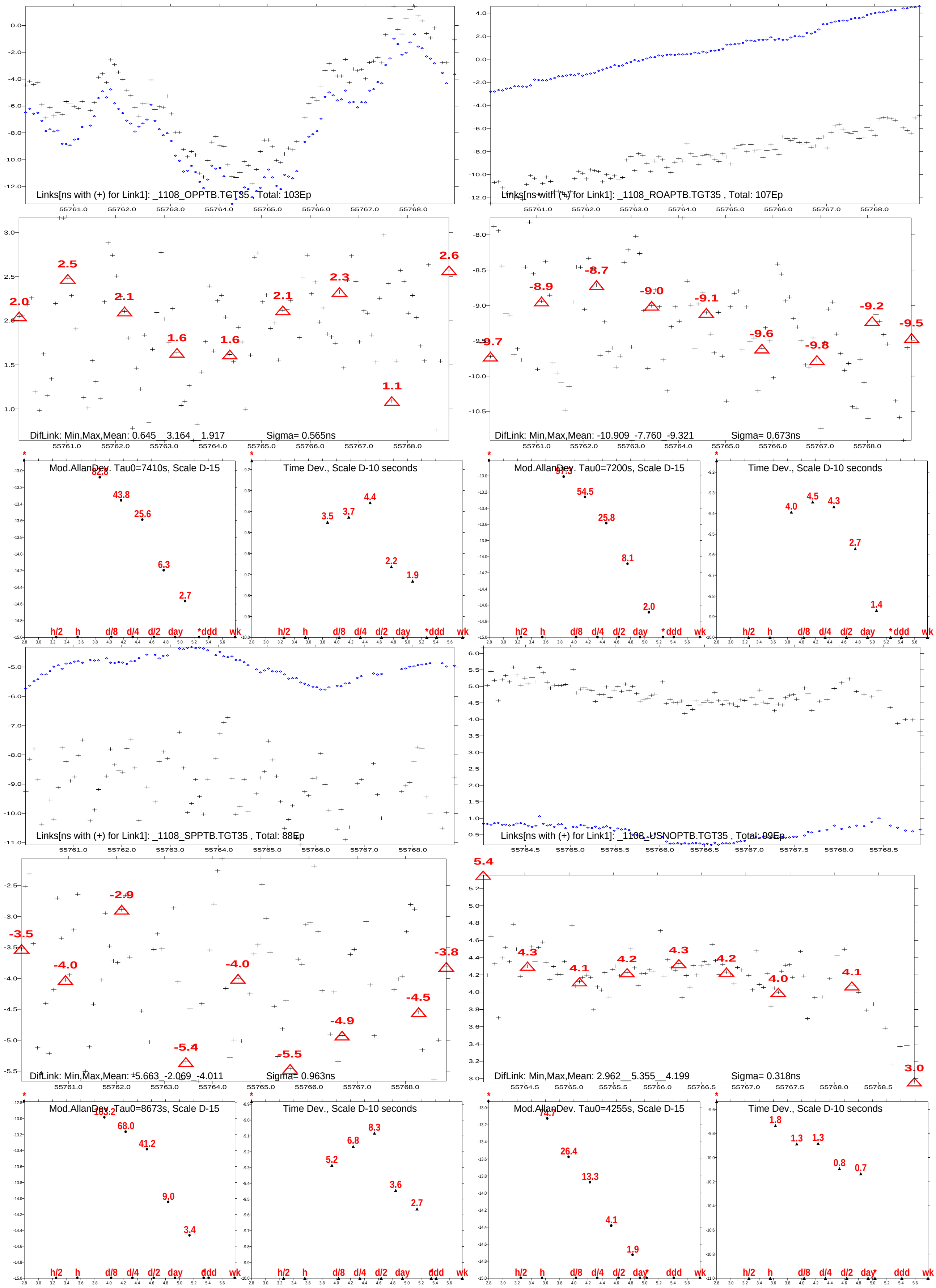
55764-769

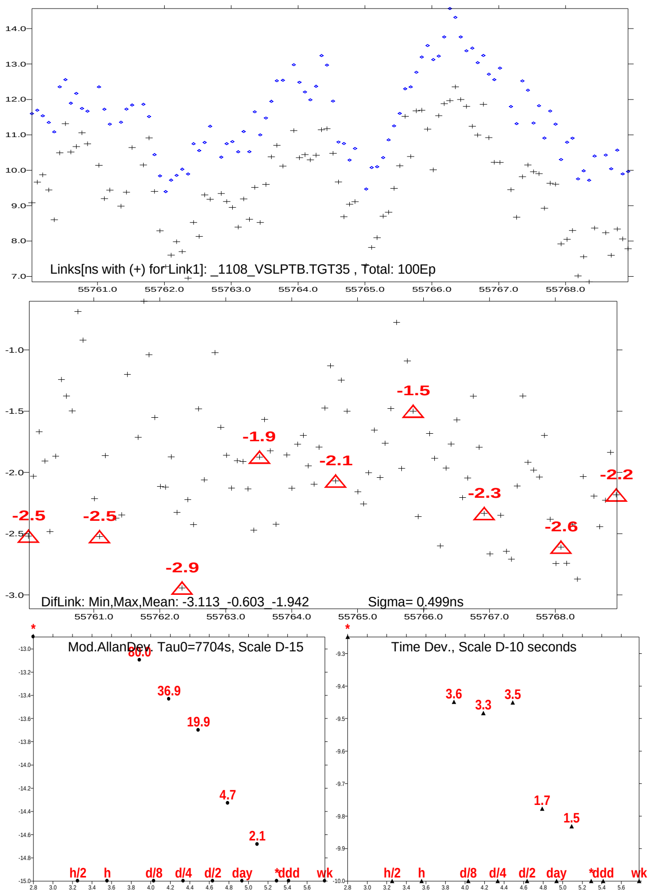
TW-PPP	N	Min	Max	Mean	Rms	Sigma
USNOPTB	99	2.962	5.355	4.199	4.211	0.318




Links[ns with (+) for Link1]: _1108_IPQPTB.TGT35 , Total: 80Ep
Links[ns with (+) for Link1]: _1108_ITPTB.TGT35 , Total: 91Ep
DifLink: Min,Max,Mean: 3.364__8.355__6.451
Sigma= 1.143ns
DifLink: Min,Max,Mean: -0.609__3.638__1.313
Sigma= 0.710ns
Mod.AllanDev. Tau0=9000s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds
h/2 h d/8 d/4 d/2 day ddd wk


Links[ns with (+) for Link1]: _1108_NISTPTB.TGT35 , Total: 104Ep
Links[ns with (+) for Link1]: _1108_NPLPTB.TGT35 , Total: 101Ep
DifLink: Min,Max,Mean: -1.883_-0.663_-1.167
Sigma= 0.286ns
DifLink: Min,Max,Mean: 1.058__4.694__2.416
Sigma= 0.684ns
Mod.AllanDev. Tau0=7408s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7343s, Scale D-15
Time Dev., Scale D-10 seconds
h/2 h d/8 d/4 d/2 day *ddd wk


Links[ns with (+) for Link1]: _1108_OPPTB.TGT35 , Total: 103Ep
Links[ns with (+) for Link1]: _1108_ROAPTB.TGT35 , Total: 107Ep
DifLink: Min,Max,Mean: 0.645__3.164__1.917
Sigma= 0.565ns
DifLink: Min,Max,Mean: -10.909__-7.760__-9.321
Sigma= 0.673ns
Mod.AllanDev. Tau0=7410s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds
Links[ns with (+) for Link1]: _1108_SPPTB.TGT35 , Total: 88Ep
Links[ns with (+) for Link1]: _1108_USNOPTB.TGT35 , Total: 99Ep
DifLink: Min,Max,Mean: -5.663__-2.069__-4.011
Sigma= 0.963ns
DifLink: Min,Max,Mean: 2.962__5.355__4.199
Sigma= 0.318ns
Mod.AllanDev. Tau0=8673s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=4255s, Scale D-15
Time Dev., Scale D-10 seconds
h/2 h d/8 d/4 d/2 day ddd wk


Links[ns with (+) for Link1]: _1108_VSLPTB.TGT35 , Total: 100Ep
DifLink: Min,Max,Mean: -3.113 -0.603 -1.942
Sigma= 0.499ns
Mod.AllanDev. Tau0=7704s, Scale D-15
Time Dev., Scale D-10 seconds

Annex III Period-2: 55769-55783

55769-783

TW-PPP	N	Min	Max	Mean	Rms	Sigma
AOSPTB	162	-2.780	0.023	-1.674	1.752	0.517
CHPTB	157	-8.062	-4.023	-6.154	6.219	0.902
IPQPTB	82	3.962	8.932	6.327	6.465	1.328
ITPTB	160	-1.471	1.706	0.422	0.765	0.638
NISTPTB	60	-0.637	0.775	0.169	0.376	0.336
NPLPTB	17	1.899	2.928	2.343	2.368	0.343
OPPTB	40	1.610	3.789	2.721	2.770	0.515
ROAPTB	163	-10.809	-7.295	-8.748	8.779	0.742
SPPTB	144	-5.009	-2.069	-3.472	3.527	0.619
USNOPTB	59	6.075	7.345	6.570	6.578	0.327
VSLPTB	123	-3.223	-0.128	-1.507	1.597	0.529

55776-781

TW-PPP	N	Min	Max	Mean	Rms	Sigma
NISTPTB	60	-0.637	0.775	0.169	0.376	0.336

55776-782

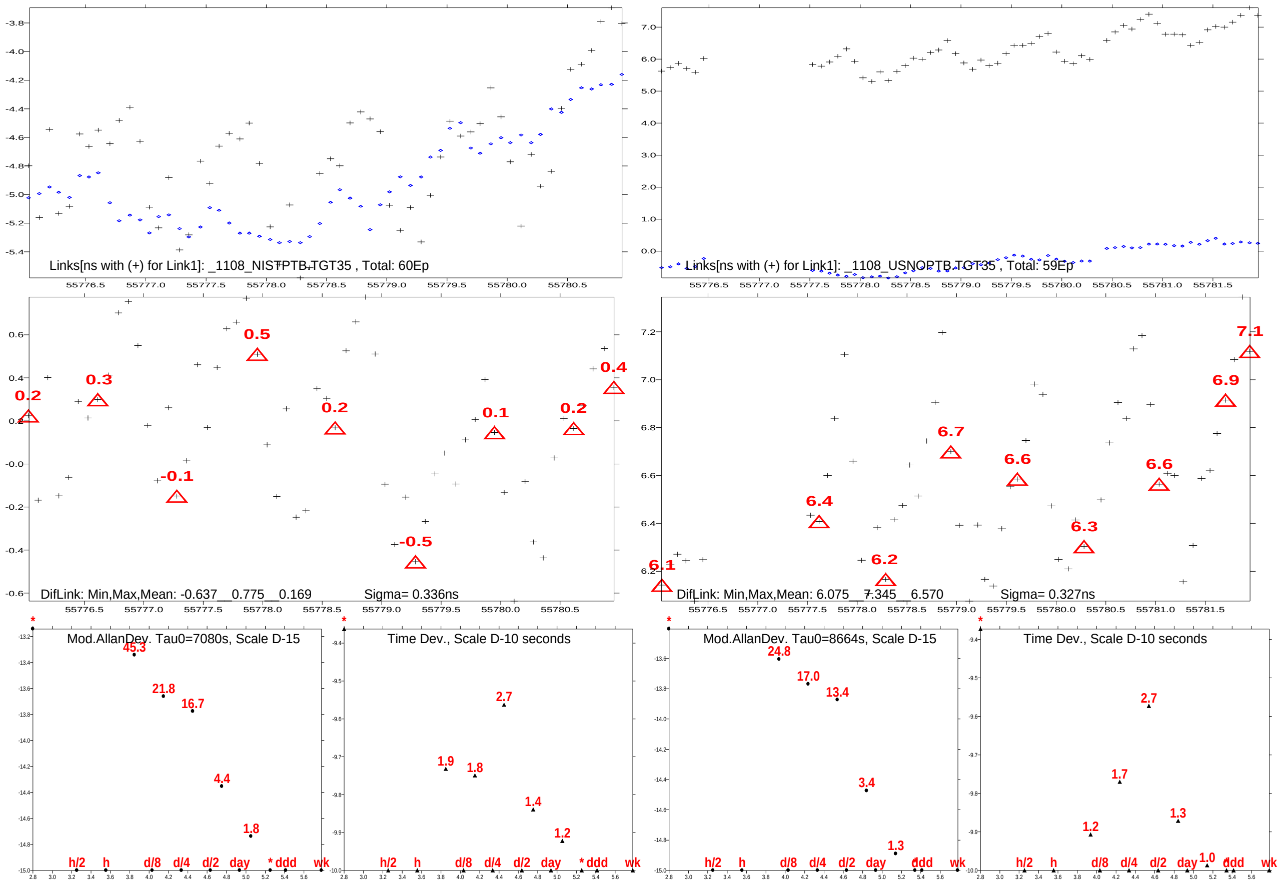
TW-PPP	N	Min	Max	Mean	Rms	Sigma
USNOPTB	59	6.075	7.345	6.570	6.578	0.327

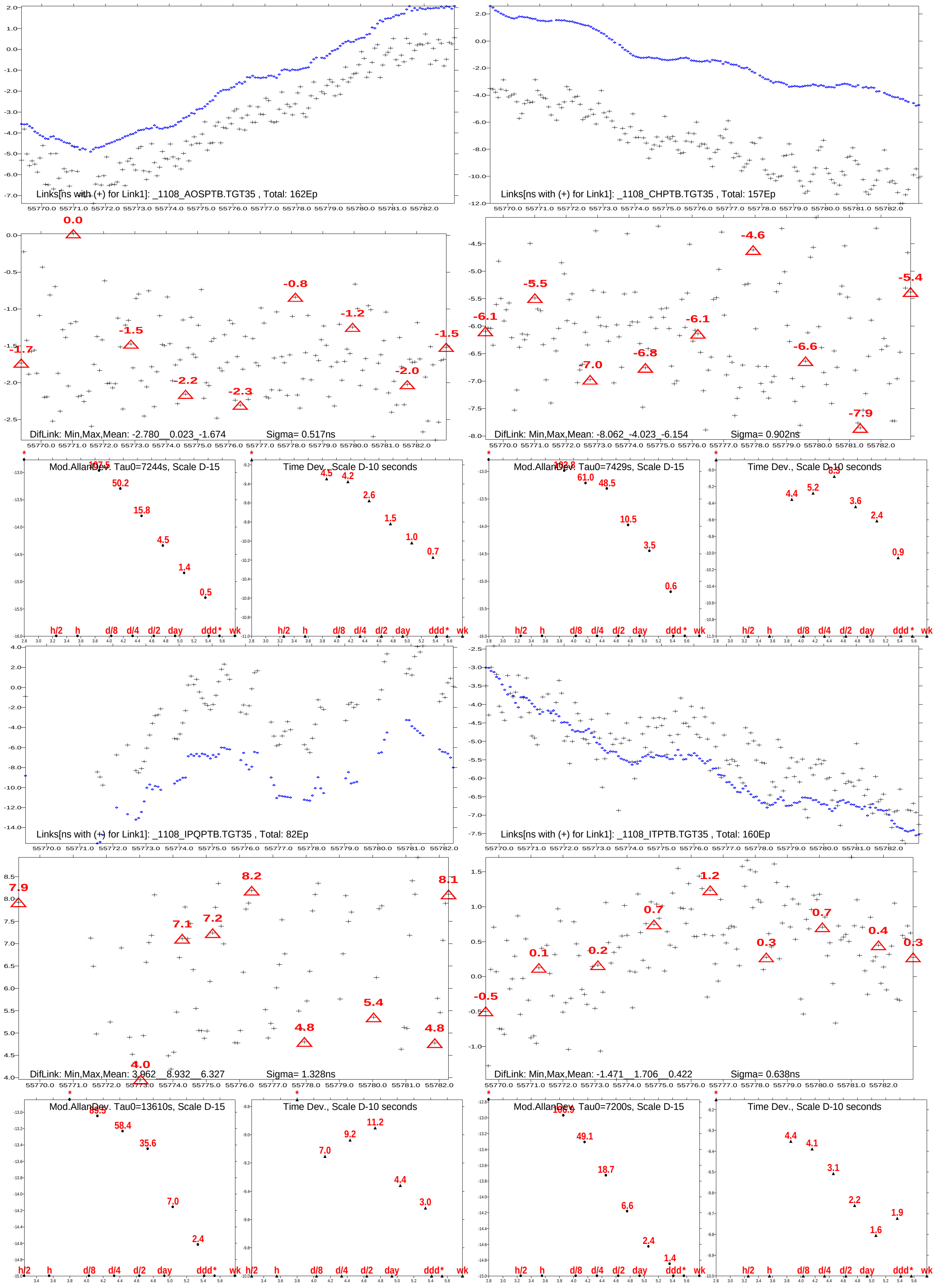
55769-775

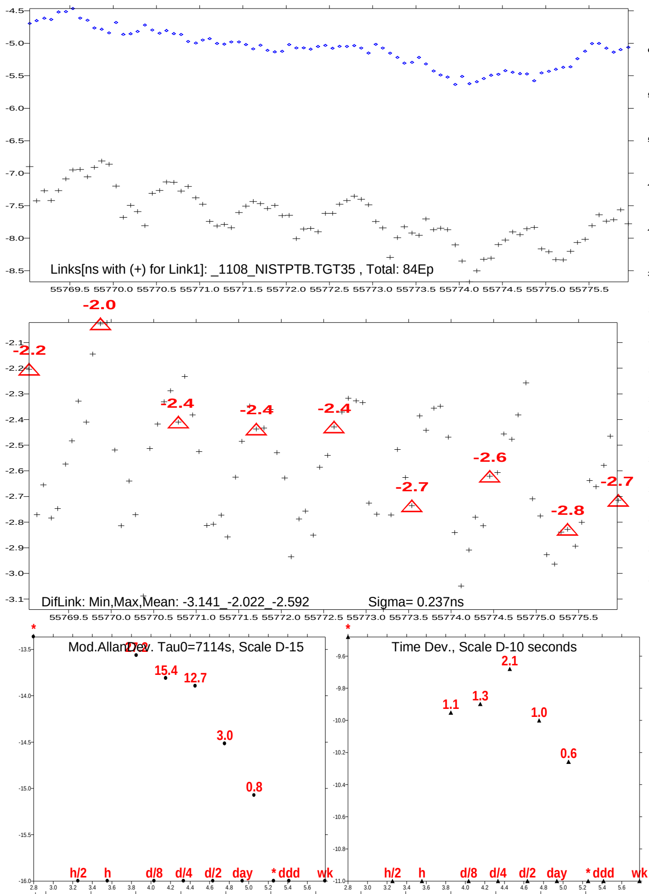
TW-PPP	N	Min	Max	Mean	Rms	Sigma
USNOPTB	60	0.360	3.335	2.881	2.906	0.379

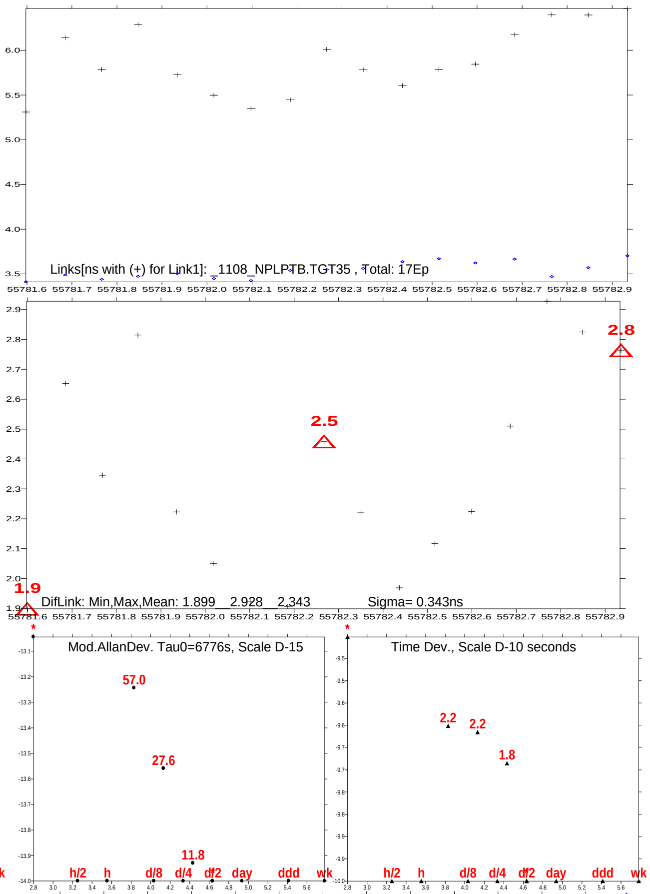
55769-776

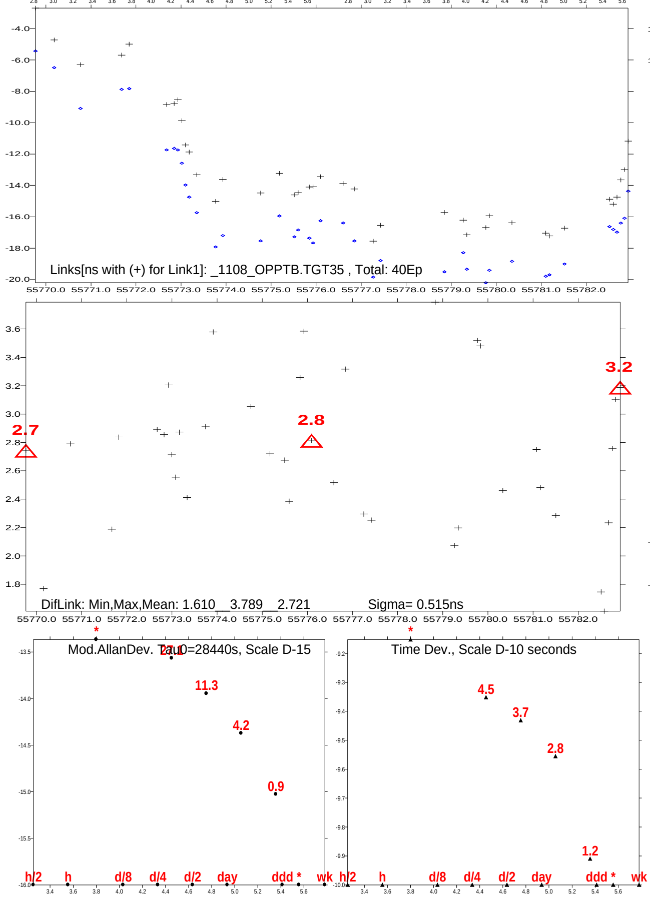
TW-PPP	N	Min	Max	Mean	Rms	Sigma
NISTPTB	84	-3.141	-2.022	-2.592	2.602	0.237

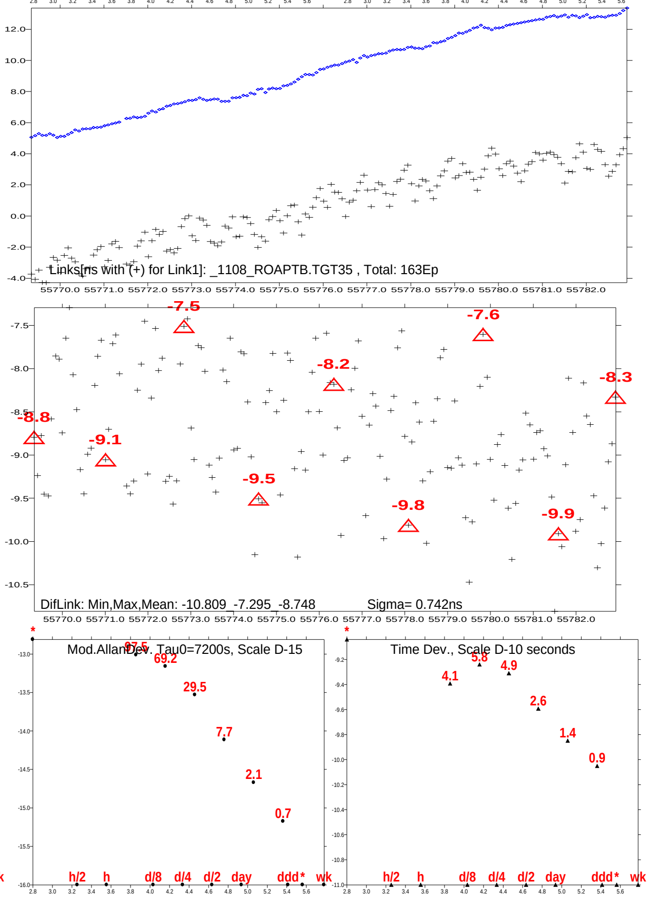


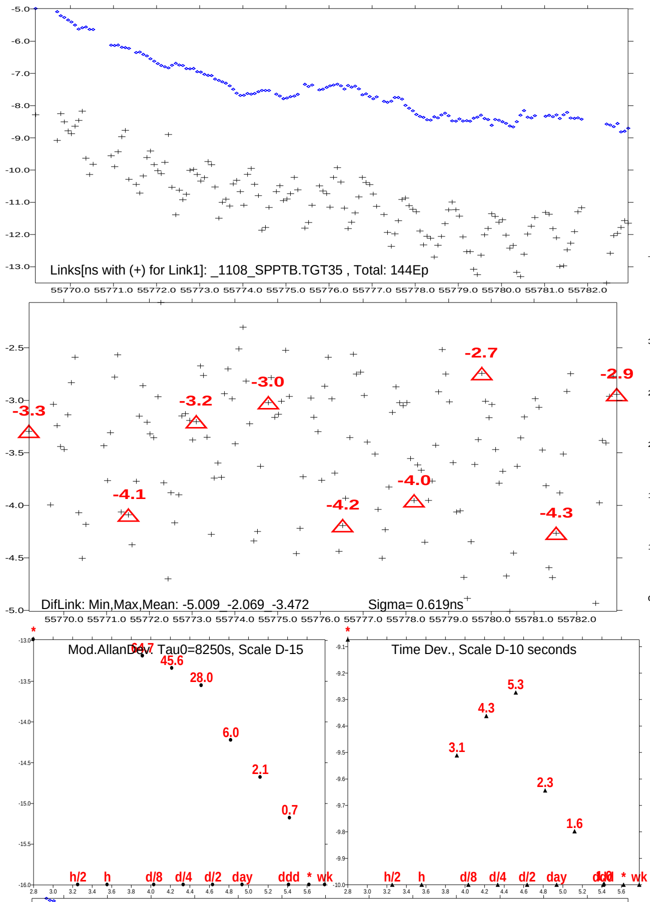

Links[ns with (+) for Link1]: _1108_AOSPTB.TGT35 , Total: 162Ep
Links[ns with (+) for Link1]: _1108_CHPTB.TGT35 , Total: 157Ep
DifLink: Min,Max,Mean: -2.780__0.023__-1.674 Sigma= 0.517ns
DifLink: Min,Max,Mean: -8.062__-4.023__-6.154 Sigma= 0.902ns
Mod.AllanDev. Tau0=7244s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7429s, Scale D-15
Time Dev., Scale D-10 seconds
Links[ns with (+) for Link1]: _1108_IPQPTB.TGT35 , Total: 82Ep
Links[ns with (+) for Link1]: _1108_ITPTB.TGT35 , Total: 160Ep
DifLink: Min,Max,Mean: 3.962__8.932__6.327 Sigma= 1.328ns
DifLink: Min,Max,Mean: -1.471__1.706__0.422 Sigma= 0.638ns
Mod.AllanDev. Tau0=13610s, Scale D-15
Time Dev., Scale D-10 seconds
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds
h/2 h d/8 d/4 d/2 day ddd* wk

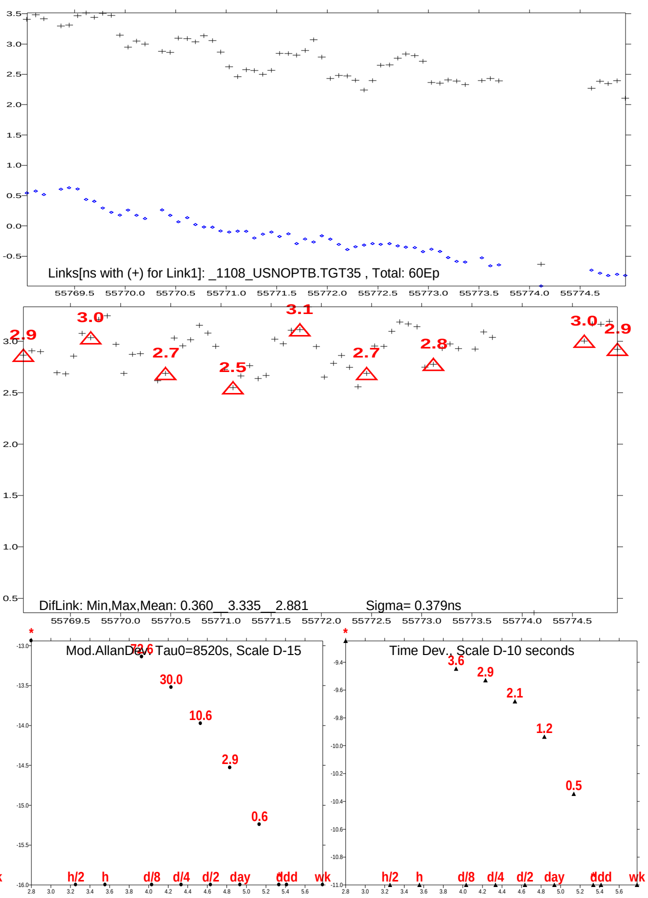

Links[ns with (+) for Link1]: _1108_NISTPTB.TGT35 , Total: 84Ep
DifLink: Min,Max,Mean: -3.141_-2.022_-2.592
Sigma= 0.237ns
Mod.AllanDev. Tau0=7114s, Scale D-15
Time Dev., Scale D-10 seconds

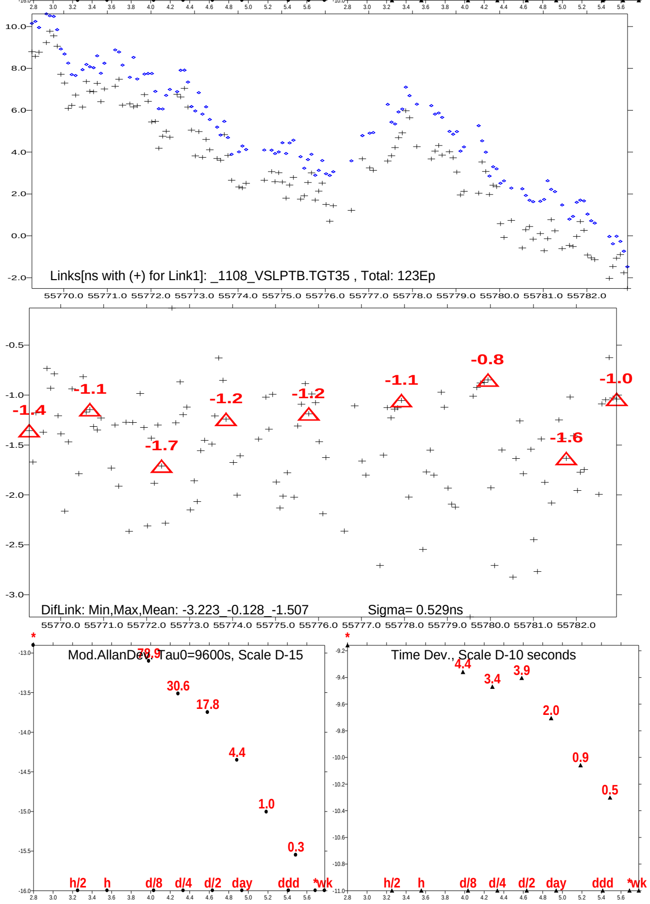

Links[ns with (+) for Link1]: _1108_NPLPTB.TGT35 , Total: 17Ep
DifLink: Min,Max,Mean: 1.899__2.928__2.343
Sigma= 0.343ns
Mod.AllanDev. Tau0=6776s, Scale D-15
Time Dev., Scale D-10 seconds


Links[ns with (+) for Link1]: _1108_OPPTB.TGT35 , Total: 40Ep
DifLink: Min,Max,Mean: 1.610__3.789__2.721
Sigma= 0.515ns
Mod.AllanDev. Tau0=28440s, Scale D-15
Time Dev., Scale D-10 seconds


Links[ns with (+) for Link1]: _1108_ROAPTB.TGT35 , Total: 163Ep
DifLink: Min,Max,Mean: -10.809_-7.295_-8.748
Sigma= 0.742ns
Mod.AllanDev. Tau0=7200s, Scale D-15
Time Dev., Scale D-10 seconds


Links[ns with (+) for Link1]: _1108_SPPTB.TGT35 , Total: 144Ep
DifLink: Min,Max,Mean: -5.009 -2.069 -3.472
Sigma= 0.619ns
-3.3
-4.1
-3.2
-3.0
-4.2
-4.0
-2.7
-4.3
-2.9
Mod.AllanDev, Tau0=8250s, Scale D-15
54.7
45.6
28.0
6.0
2.1
0.7
Time Dev., Scale D-10 seconds
3.1
4.3
5.3
2.3
1.6
h/2
h
d/8
d/4
d/2
day
ddd
wk


Links[ns with (+) for Link1]: _1108_USNOPTB.TGT35 , Total: 60Ep
DifLink: Min,Max,Mean: 0.360 3.335 2.881
Sigma= 0.379ns
2.9
3.0
2.7
2.5
3.1
2.7
2.8
3.0
2.9
Mod.AllanDev, Tau0=8520s, Scale D-15
30.0
10.6
2.9
0.6
Time Dev., Scale D-10 seconds
3.6
2.9
2.1
1.2
0.5
h/2
h
d/8
d/4
d/2
day
ddd
wk


Links[ns with (+) for Link1]: _1108_VSLPTB.TGT35 , Total: 123Ep
DifLink: Min,Max,Mean: -3.223 -0.128 -1.507
Sigma= 0.529ns
-1.4
-1.1
-1.7
-1.2
-1.2
-1.1
-0.8
-1.6
-1.0
Mod.AllanDev, Tau0=9600s, Scale D-15
30.6
17.8
4.4
1.0
0.3
Time Dev., Scale D-10 seconds
4.4
3.4
3.9
2.0
0.9
0.5
h/2
h
d/8
d/4
d/2
day
ddd
wk

Annex IV. How to make the Implementation

We give here some ‘old’ example to recall how to make the implantation.

A4.1 ITU data file header entries

Here are listed examples to be implemented into the “TW” file header. Because the UTC-links are bridged links the header entry should be `“CAL 125 BRIDGED”` (see CH01 – PTB01).

According to the latest version of the Recommendations for Operational Use of TWSTFT a bridging shall be reported e.g. as follows:

```
* CAL   211 TYPE: CAL 139 BRIDGED   MJD: 55769  EST. UNCERT.:   1.200 ns
* CAL   214 TYPE: CAL 141 BRIDGED   MJD: 55769  EST. UNCERT.:   5.000 ns
* CAL   213 TYPE: CAL 142 BRIDGED   MJD: 55769  EST. UNCERT.:   1.300 ns
* CAL   216 TYPE: CAL 142 BRIDGED   MJD: 55769  EST. UNCERT.:   1.200 ns
* CAL   217 TYPE: CAL 144 BRIDGED   MJD: 55769  EST. UNCERT.:   5.000 ns
* CAL   218 TYPE: CAL 145 BRIDGED   MJD: 55769  EST. UNCERT.:   1.200 ns
* CAL   220 TYPE: CAL 146 BRIDGED   MJD: 55769  EST. UNCERT.:   1.300 ns
* CAL   210 TYPE: CAL 171 BRIDGED   MJD: 55769  EST. UNCERT.:   7.000 ns
* CAL   212 TYPE: CAL 172 BRIDGED   MJD: 55769  EST. UNCERT.:   7.000 ns
* CAL   215 TYPE: CAL 173 BRIDGED   MJD: 55769  EST. UNCERT.:   7.000 ns
* CAL   219 TYPE: CAL 174 BRIDGED   MJD: 55769  EST. UNCERT.:   3.000 ns
```

A4.2 Examples for ITU-format data recordings

Examples for the data lines are listed in the following. Changes to be applied are in bold and blue numbers.

```
* EARTH-STAT   LI   MJD   STTIME NTL         TW         DRMS SMP ATL      REFDELAY      RSIG   CI S     CALR      ESDVAR    ESIG TMP HUM PRES
* LOC     REM             hhmmss  s          s           ns        s          s           ns               ns        ns        ns degC  %  mbar

TWIPQ55.437

Currently :
  IPQ01   PTB01 12 55437 004000 119   0.260344277075 0.114 121 120   0.000000793149 0.090 999 9 999999999 999999999 99999 999 999 9999

Replaced :
  IPQ01   PTB01 12 55437 004000 119   0.260344277075 0.114 121 120   0.000000793149 0.090 172 1  -188.600 999999999 99999 999 999 9999
```

Annex V. Runs of the Tsoft standard procedure

```
END --- below from TM 151. This file is D:\TS\TaN\DAT\Y20_EsdVar.txt

This section is only for the BIPM time section staff:
We use the Tsoft/F2/F3162 to calculate TCC the calibration following the steps below:
1. run1: Y4 - UTC links with PTB with the options ON: CALR  EDSVAR
2. run2: Y4 - Non UTC links (No PTB) with the options OFF: -CALR  -EDSVAR
3. run3: F2 - CalR by triangle method, better with the option ON:  LKTY4i (Lab1==PTB)
4. run4:Y20 - Set CalR calculated/ESDVAR==0 into TwYYMM.lk (using this file)
5. run5: Y4 - UTC+Non UTC links with the option ON:  CALR  EDSVAR
6. run6: F2 - Verify if all the triangle closures -- >0
The calibration results are in Table 4 TW Calibrations of CALR and ESDVAR. Certainly,
if any of the non-UTC links are hardware calibrated, the values here can be used as a
check (cf. section 6).
(Job for F2: 0804 LKTY4i -LKGY3i -ALIGN -ALIGN.G2T -ALIGN.T2G -Out888 OutStep=1
HistScale=1000 HistIntv=250 MjdCol01_09 LinkCol18_30)

If a laboratory wants to keep its ESDVAR value, this value should be subtracted from
the originally determined CalR values (X:\TaN\0804\Adj\CalR0804.Tf2) which is
computed by F2 supposing EsdVar==0. The new CalR value with EsdVar-removed can be
computed by:
CalR1(new)= -CalR2(new)={CalR1(old) + ( [EsdVar2-EsdVar1]/2 ) }
```

Use Y20 option:
```
RmEsdVar ON to make an iteration to remove EsdVar from the original
file X:\TaN\0804\Adj\CalR0804.Tf2 and then re-establish the big TW file for TAI
computation:
1. run1: Type in Link_LAB1_Non-Zero_EsdVar value in X:\TaN\0804\Adj\CalR0804.Tf2
   (note here for a link in CalR0804.Tf2 type in the Lab1 value. For example:
   USNO01 CH01: S=1 CALR= 425.057 +/-0.426, ESDVAR=  -387.250  375 0.022 14
2. run2: Y20 with Calib & RmEsdVar ON. This will read the above copied file in which
   the ESdVar(sb) should be removed from the listed CalR values: Output new files is
   X:\TaN\0804\Adj\CalR0804.Tf2.Y20
3. run3: Copy the NewCalR file: X:\TaN\0804\Adj\CalR0804.Tf2.Y20 (present only the
   non-zero-EsdVar labs) into the old: X:\TaN\0804\Adj\CalR0804.Tf2
4. run4: Re-do Y20 with Calib ON and RmEsdVar OFF

1108 LKTY4i -LKGY3i -ExtCmb=.TGT34.Dat -ALIGN -ALIGN.G2T -ALIGN.T2G -Out888 OutStep=1
HistScale=1000 HistIntv=250 MjdCol01_09 LinkCol18_30   !(21+13+32) Use Cor.
Lab2Lab1.lkG/T or *.Y3/Y4i to calib., Template list X:\TAN\Tri-Clos.Lst
```