BIPM first analysis of NICT-PTB TW link and comparison with GPS CV-AV P3 links

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Resume

- The NICT-PTB TW link data available at the BIPM since MJD 53664, 21 Oct. 2005
- First analysis shows the quality of the TW link is similar as the Europe-American KU band data
- This analysis confirms the diurnal variation in the TW link reported in [2]
- The two months' mean value of the difference TW - GPS is 992.3 +/- 0.8 ns
- The TW link is closer to GPS AV than CV

Reference

[1] Z Jiang : Smoothing and interpolation techniques for a TW measurement series, http://www.bipm.fr/wg/CCTF/TWSTFT/Allowed/WG_13th_Meeting/13_09_PresentationBIPM_TW-Interpol.pdf ,13th CCTF WG TW Meeting, 15-16 Nov. 2005, VSL, Delft, Netherlands
[2] NICT: Maeno H., Fujieda M., Aida M., Lam Q.T., Gotoh T., Takahashi Y., PTB: Piester D., Becker J. and Bauch A. : Establishment of a TWSTFT link between NICT and PTB, 13th CCTF WG TW Meeting, 15-16 Nov. 2005, VSL, Delft, Netherlands, http://www.bipm.fr/wg/CCTF/TWSTFT/Allowed/WG_13th_Meeting/13_13_PresentationLinkNICT_PTB.pdf , 13th CCTF WG TW Meeting, 15-16 Nov. 2005, VSL, Delft, Netherlands
[3] Parker T.E., Zhang V. : Sources of instabilities in TWO-WAY time transfer, http://www.bipm.fr/wg/CCTF/TWSTFT/Allowed/WG_13th_Meeting/13_18_PresentationNIST_instab.TWSTFT.pdf , 13th CCTF WG TW Meeting, 15-16 Nov. 2005, VSL, Delft, Netherlands
[4] NICT: TWSTFT WG activity and future plan in the Asia-Pacific-Rim Region, http://www.bipm.fr/wg/CCTF/TWSTFT/Allowed/WG_13th_Meeting/13_12_Report_NICT_2005_11.pdf
[5] Jiang Z. BIPM TM141: USNO-PTB TW X-band Time Link , ftp://tai.bipm.org/TimeLink/LkC/Doc/TM141.doc
[6] Jiang Z. BIPM TM142: One Year Comparison of USNO-PTB TW KU and X-bands , ftp://tai.bipm.org/TimeLink/LkC/Doc/TM142.doc
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[9] Miho Fujieda : 200512pas4_20060113.pdf, personnel communication, mercredi 18 janvier 2006 02:00

Introduction

The TWSTFT link, with the new NICT modern, between NICT and PTB was installed between Oct. 2004 and July 2005 [2,4]. The NICT supports the substantial techniques, including provision of hardware Earth-station design and remote operation of the station. Operational timing link tests started on 22 July 2005. Regular operation is performed since 1 Nov. 2005. The NICT-PTB is the longest baseline of about 10 000 km in the TAI world-wide network.

The data in the ITU standard format is reported to the BIPM since today: 17 Jan. 2006. At present, the equipment concerned is not calibrated. The terms, CALR and ESDVAR, are filled with 99999 [8]. In principle, there are 24 measured points per day.

The goal of this analysis is:

- to estimate the general quality of this new link
- to determine the alignment constant of the TW to GPS: preliminary calibration the NICT-PTB TW link via GPS
- to compare the TW link to the GPS P3 links obtained separately with the GPS Common View (CV) and All in View (AV) techniques

We use the Tsoft monthly standard processing to make this analysis with two TAI months data sets of 0511 and 0512: Mjd: 53674 – 53736 (31 Oct. 2005 to 1 Jan. 2006). The data concerted are almost complete except the small missing periods of MJD 53672-673, 53685-687, the MJD 53 730 data are not complete. See following the status of the numbers of the measurements per MJD :

Status of Total Existing TW observations for **TAI 0511:**

```
No Lab1 Lab2 53676  77 78 79/ 80 81 82 83 84/ 85 86 87 88 89/ 90 91 92 93 94/ 95 96 97 98 99/100101102103104/105106

 1  PTB NICT   641  24 24 24  24 22 24 24 24   2______ 22 24  24 23 24 24 24  23 24 24 23 24  24 24 24 24 22  24 24
 2 NICT  PTB   641  24 24 24  24 22 24 24 24   2______ 22 24  24 23 24 24 24  23 24 24 23 24  24 24 24 24 22  24 24
```

Status of Total Existing TW observations for **TAI 0512:**

```
No Lab1 Lab2 53706   7  8  9/ 10 11 12 13 14/ 15 16 17 18 19/ 20 21 22 23 24/ 25 26 27 28 29/ 30 31 32 33 34/ 35 36

 1  PTB NICT   688  24 24 15  24 24 24 24 24  24 24 24 24 24  24 24 24 24 24  24 24 24 24 24   1 24 24 24 24  24 24
 2 NICT  PTB   688  24 24 15  24 24 24 24 24  24 24 24 24 24  24 24 24 24 24  24 24 24 24 24   1 24 24 24 24  24 24
```

Form now on, the results of link computations and link comparisons will be monthly published in the TAI ftp site: ftp://tai.bipm.org/TimeLink/LkC/

For details about the data files and the plots on the ftp, please refer to ftp://tai.bipm.org/TimeLink/LkC/ReadMe_LinkComparison_ftp_v6.doc

1. The TW NICT-PTB link

The time links of TAI 0511 and 0512 are computed. The link plots, statistics of Sigma (Standard Deviation), the Mod. Alain deviation and the Time Deviation are shown in Annex I. With a first look, the quality of the NICT-PTB is similar as the Europe-America TW links.

With a closer look, we find that the NICT-PTB TW links are affected, as the Europe-America KU TW links, by a diurnal variation [2], [3], [5], [6]. The deviations can be seen clearly in the Fig. 1-1a and 1-1b, a 5 days' link and the corresponding Tdev. In fact, [2] pointed out already the existence of the diurnal variation and we confirm it by our analysis. From the Annex I, we see, although not very clear, that the diurnal deviations exist all along the measurement periods. [3] shows, there is a correlation between the diurnal disturbance and the temperature changes. The peak to peak amplitudes may be up to 3 ns.

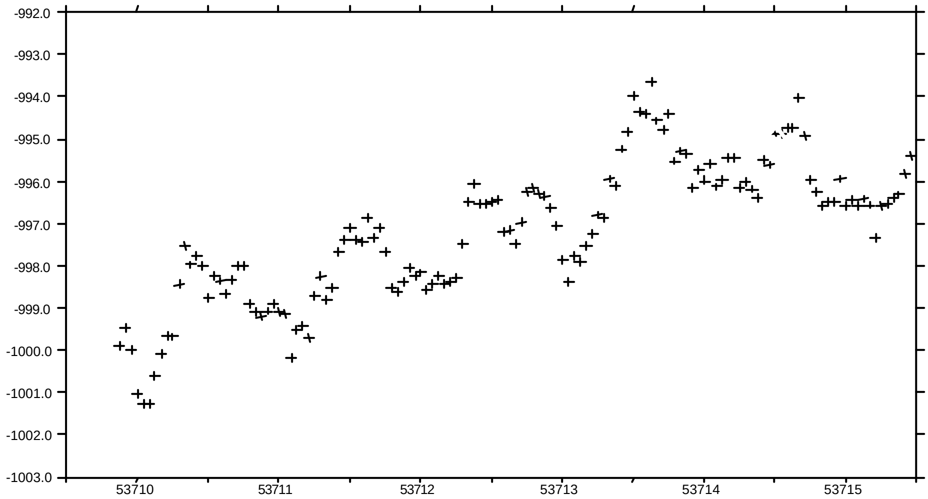


Fig. 1-1a Diurnal disturbance in a 5 days' NICT-PTB TW link

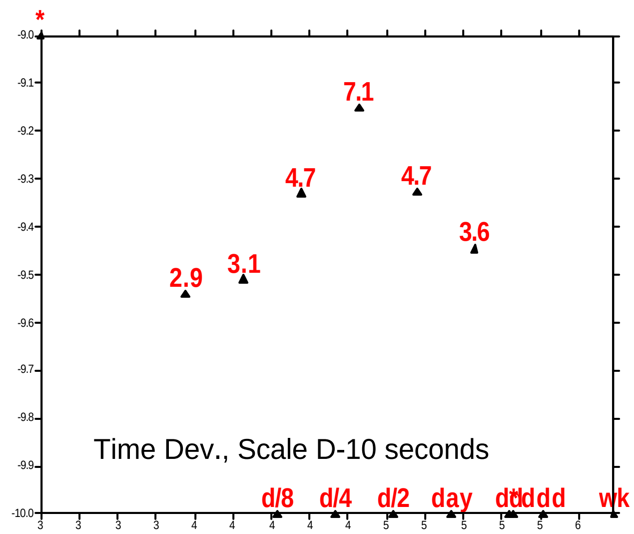


Fig. 1-1b Tdev of the diurnal disturbance in the 5 days' NICT-PTB TW link

2. The GPS NICT-PTB CV and AV link

The purpose to discuss the GPS links are:

- Preliminary calibration of the TW link via the well calibrated GPS P3 link which is the official TAI link
- To study the GPS AV and CV time links via the TW link for this very long baseline

The GPS AV (All in View) time transfer method is discussed by several authors [8]. It is believed advantageous with respect to the traditional GPS CV (Common View) time transfer, especially for long distance. As we know, the TW is usually more accurate than the GPS techniques thanks to its symmetric measurement principal. TW is therefore often used as an independent reference to judge the quality of different GPS techniques.

The GPS P3 data of TAI 0511 and 0512 are used.

The two figures in Annex II are the GPS P3 AV link (left) and its differences with the CV link (right) for the TAI 0512 (Dec. 2005). The sigma of the differences of the two methods is 0.263 ns.

For this very long baseline, the number of the total CV epochs is 2272 and that of AV is 2955, 30% more than the CV. In addition to the total epoch number, on each epoch, the number of observed satellites for CV is the simultaneous observed low elevation satellites of PTB and NICT while for AV it is the number of all the satellites in the views of PTB and NICT. These may explain the better stability of the AV than that of CV, cf. the Figure 2-1. It should be pointed out that, from the Tdev of both the AV and CV, we don't observe considerable diurnal variations. This will be helpful to study the TW diurnal disturbances. Of cause, all electronic equipment and signals through the near Earth atmosphere may be influenced by diurnal variable parameters such the temperature etc. This, according to our experiences, is far less than 1 ns.

This agrees with the conclusions of the earlier studies [6,7].

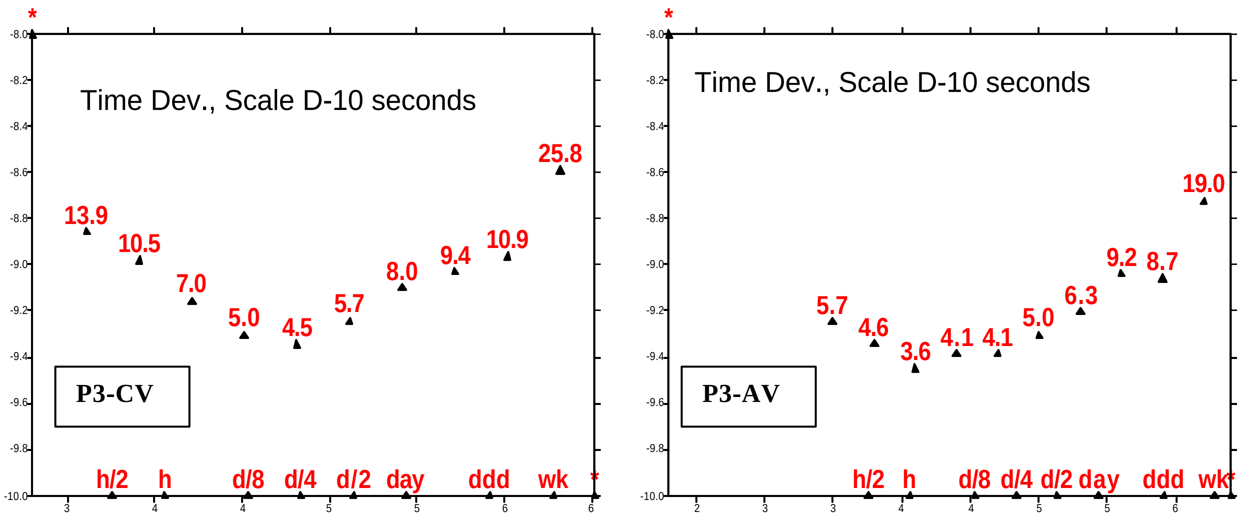


Fig. 2-1 TDEV of the NICT-PTB GPS P3 links: CV (left) and AV (right)

3. Comparison of the TW and GPS links

We have observed the diurnal disturbances in the TW links. The comparisons of TW with the GPS links (CV and AV) and the related TDEV (for the same period as the Figure 1-1) are shown in Figure 3-1.

Clearly enough, by the comparisons and by the TDEV, the diurnal variations of 2-3 ns exist in the TW link but small in the GPS links as pointed out above. The sigma of the differences between the AV and CV is 0.263 ns (Annex II, right figure), smaller than the arguments of the diurnal variation in TW.

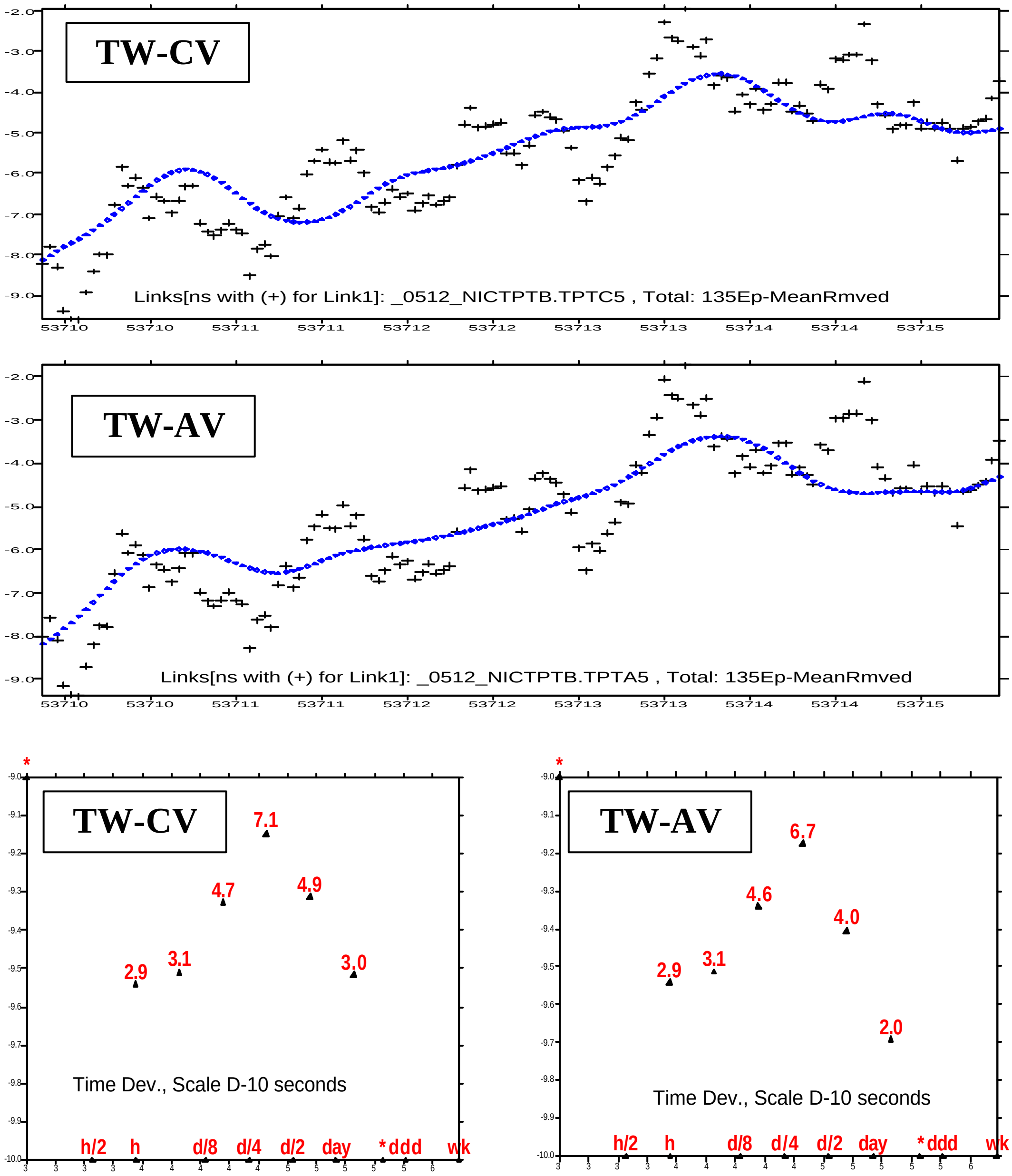


Fig. 3-1 5 Days' comparison of TW with the CV and AV
TW-black cross and GPS-blue circle

On the other side, as mentioned above, the TW link is a good reference to judge the quality of the different GPS techniques. The figures in Annex III show these comparisons and the statistical results. The sigma of the differences are listed in Table 3-1. We can see that globally the AV links are closer than the CV to the TW links. For 0511 (Nov. 2005), the AV-TW sigma is 0.766 ns against 0.932 of CV-TW. The total measured points in 0511+0512 is a little bigger than the sum of 0511 and 0512 because there are a few repeated points in the latter.

Tab. 3-1 Comparisons of TW with GPS CV and CV

TAI YYMM	Link comparison	Point Number	Sigma/ns
0511	TW – GPS CV	686	0.932
	TW – GPS AV		0.766
0512	TW – GPS CV	734	0.922
	TW – GPS AV		0.864
0511+0512	TW – GPS AV	1374	0.951
	TW – GPS CV		0.815

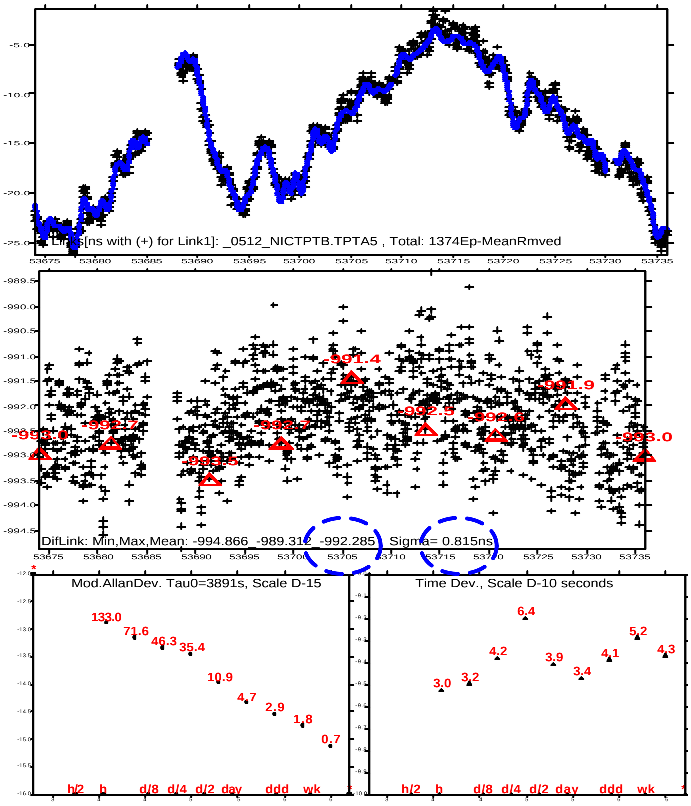
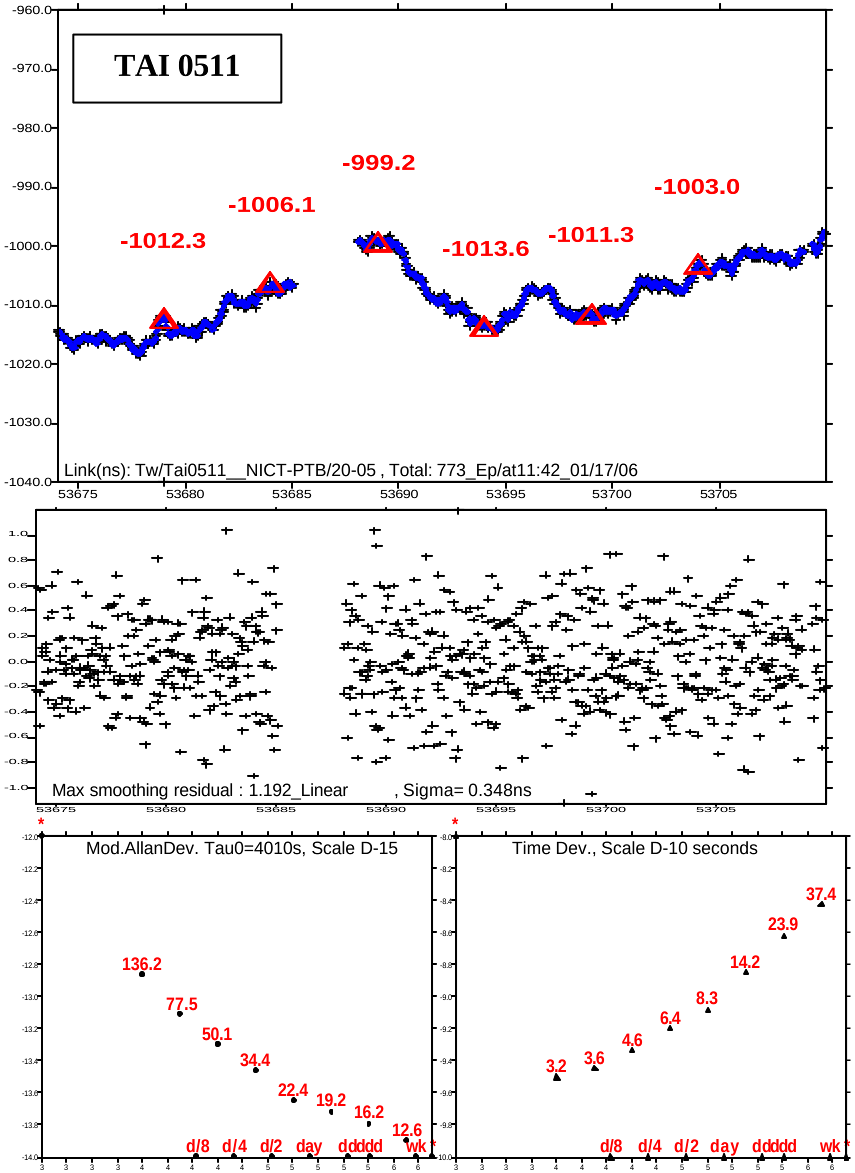
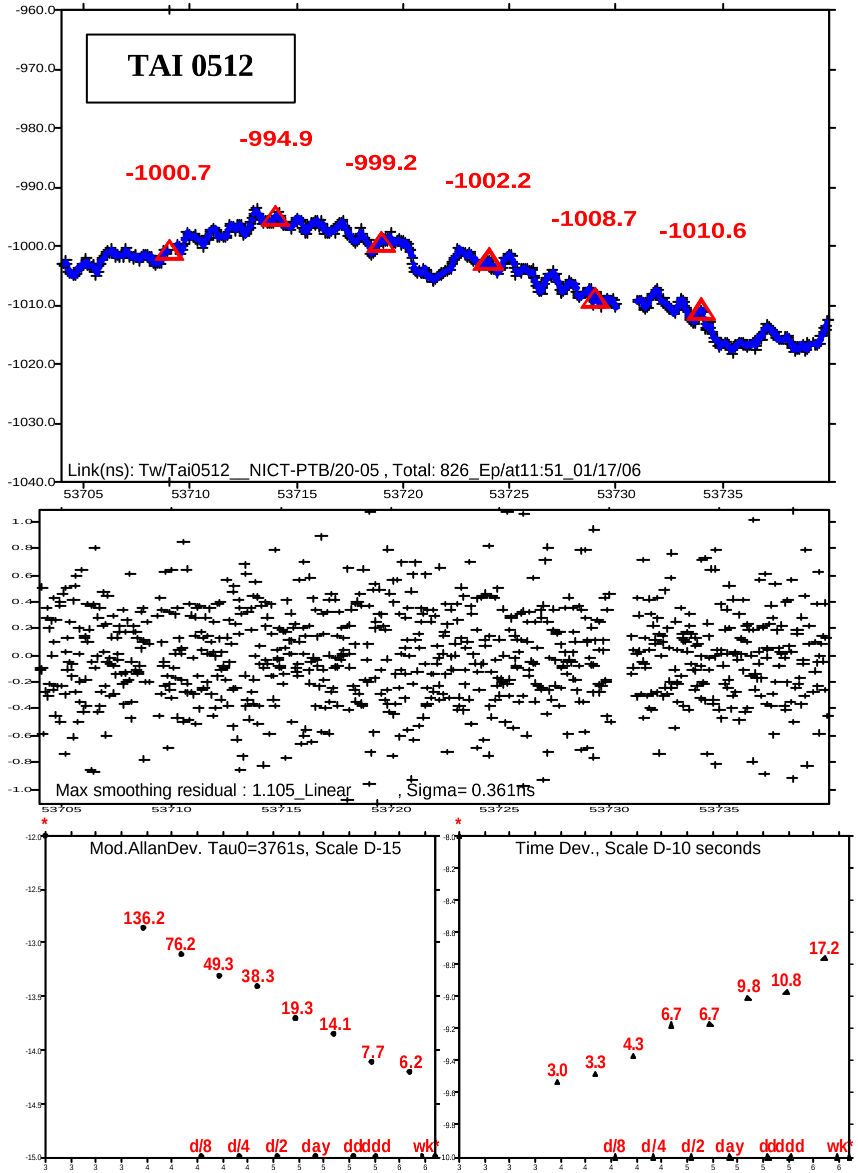


Fig. 3-2 Two months' comparison of TW-GPS (AV)
Mean values of the differences:
-992.285 +/- 0.815 ns (AV)
-992.262 +/- 0.951 ns (CV)

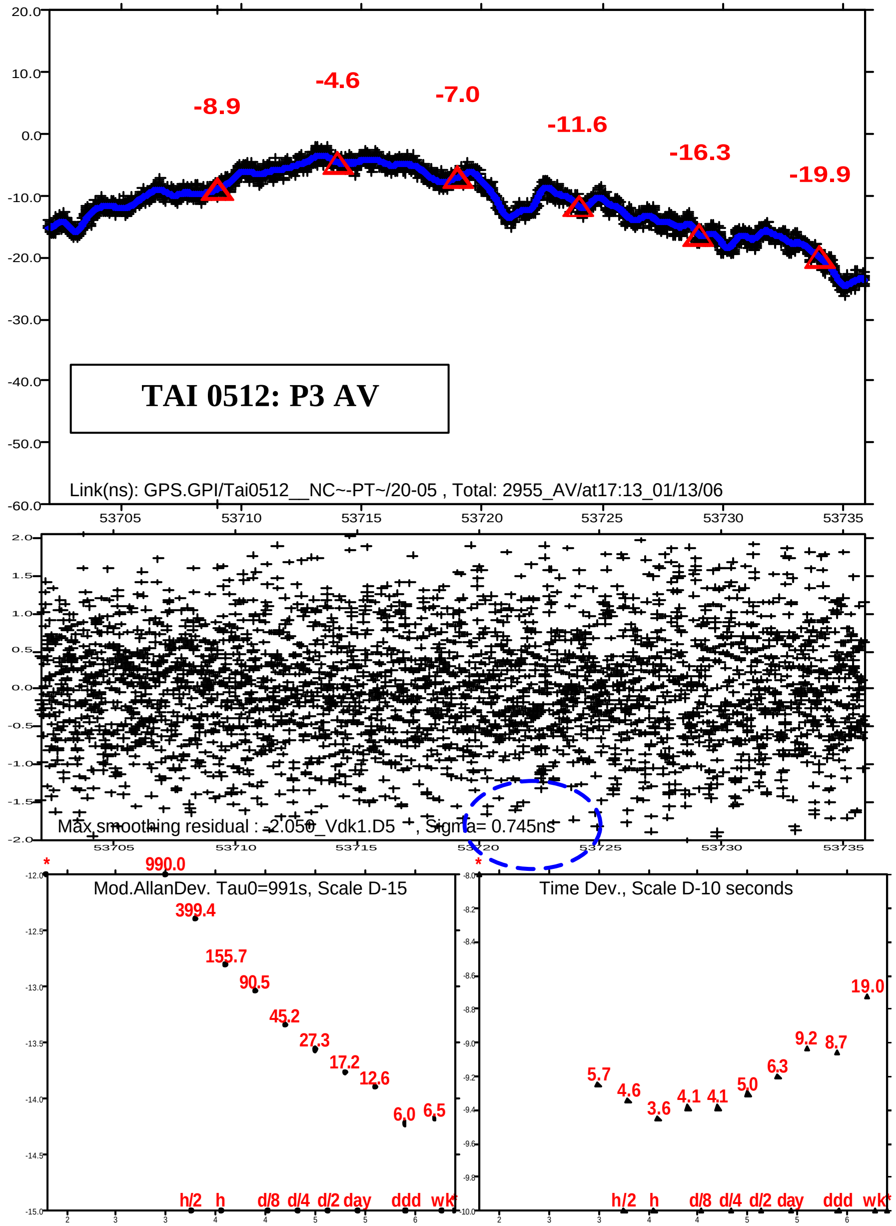
Figure 3-2 is two months' comparison. The averaged mean value of the differences is –992.3 +/- 0.8 ns. Because the PTB and NICT P3 receivers were well calibrated in Aug. 2003 and June 2005, this value can be used as a preliminary calibration correction before the performance of the absolute TW calibrations. [9] gives an independent evaluation: 992.48+/-0.93 ns.

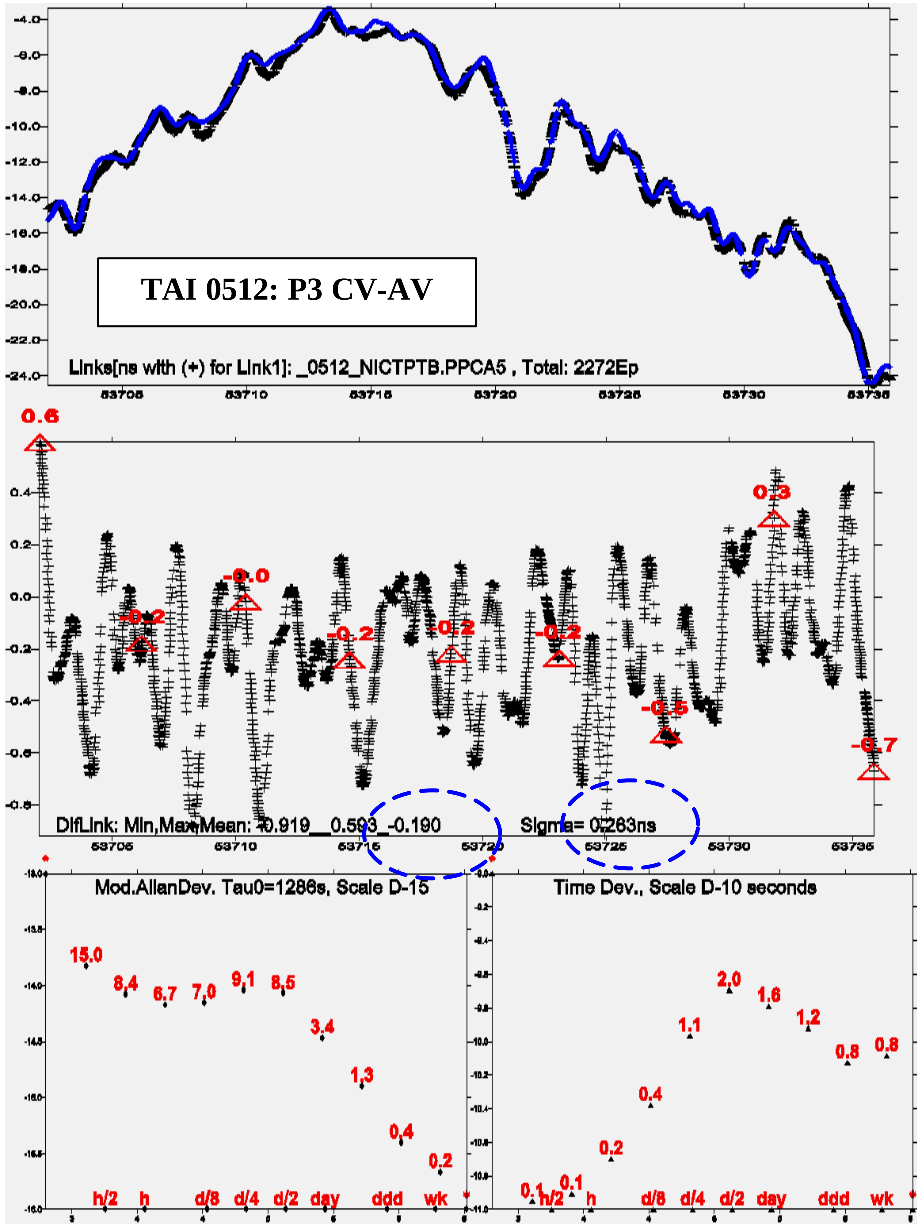
Annex I The NICT-PTB TW link



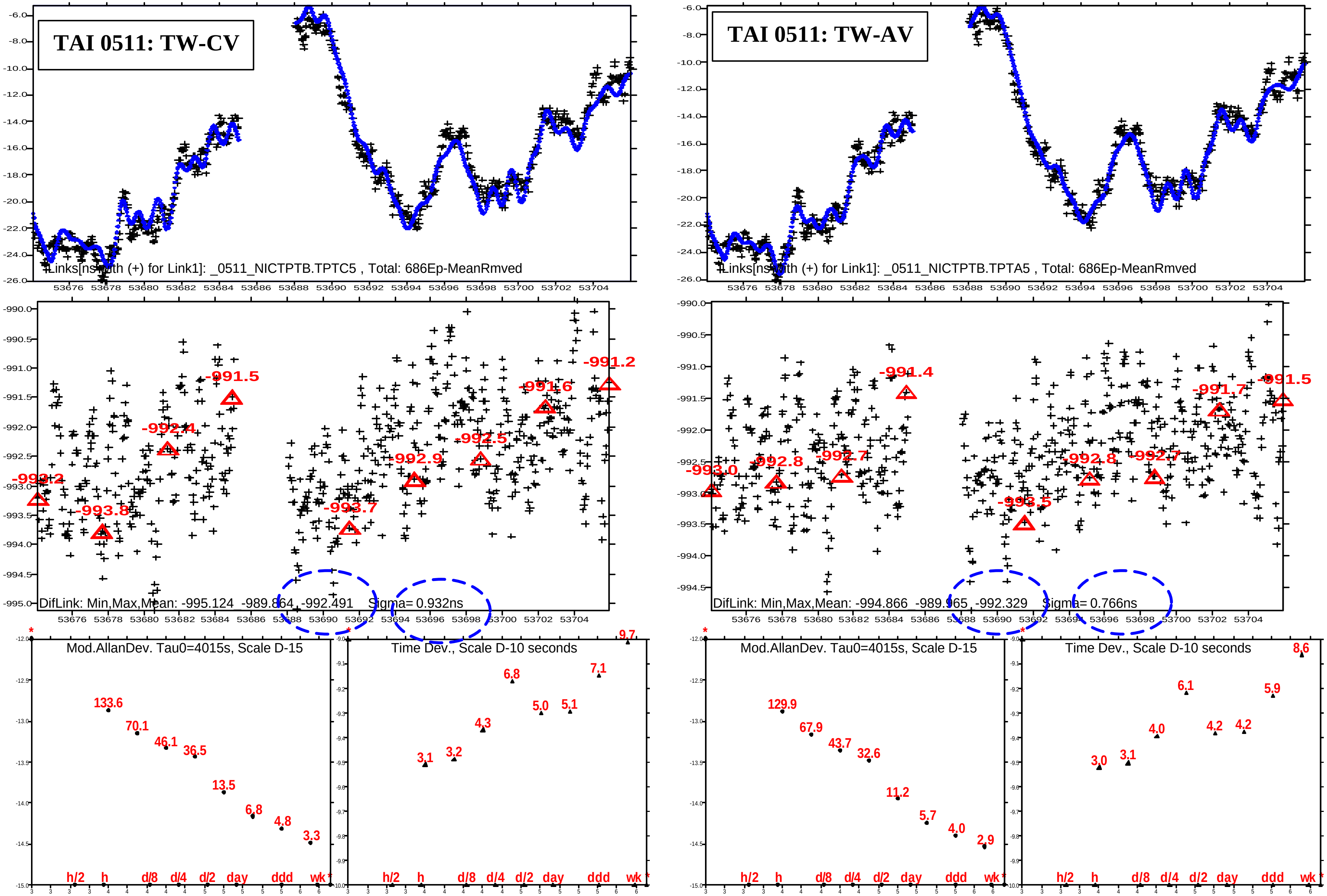


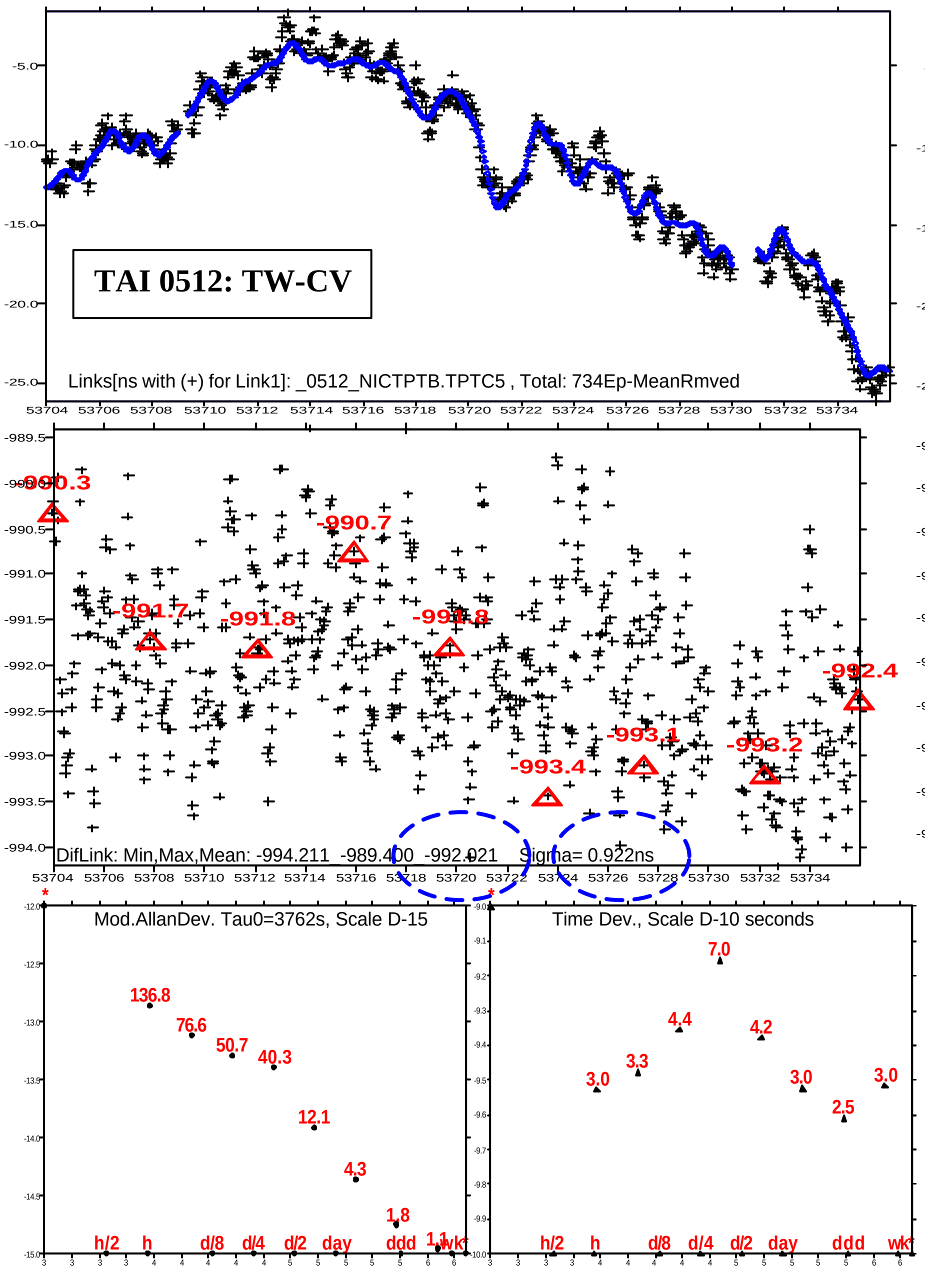
Annex II The NICT-PTB GPS P3 AV link and its comparison with the CV link

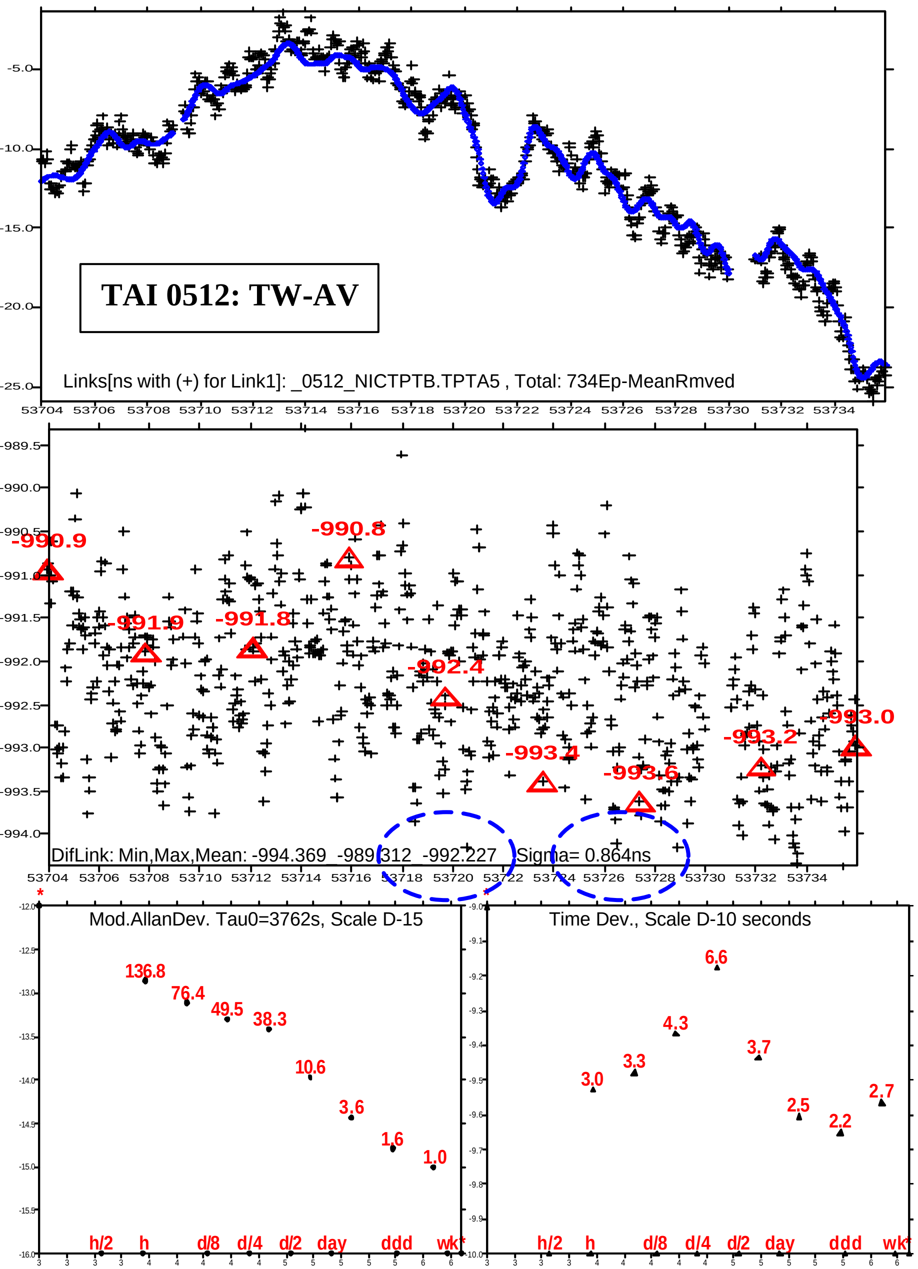




Annex III Comparison of the TW and GPS P3 CV/AV links




TAI 0512: TW-CV
Links[ns with (+) for Link1]: _0512_NICTPTB.TPTC5 , Total: 734Ep-MeanRmved
DifLink: Min,Max,Mean: -994.211 -989.400 -992.921 Sigma= 0.922ns
Mod.AllanDev. Tau0=3762s, Scale D-15
Time Dev., Scale D-10 seconds
h/2
h
d/8
d/4
d/2
day
ddd
wk


TAI 0512: TW-AV
Links[ns with (+) for Link1]: _0512_NICTPTB.TPTA5 , Total: 734Ep-MeanRmved
DifLink: Min,Max,Mean: -994.369 -989.312 -992.227 Sigma= 0.864ns
Mod.AllanDev. Tau0=3762s, Scale D-15
Time Dev., Scale D-10 seconds
h/2
h
d/8
d/4
d/2
day
ddd
wk