

Preparation and validation of WEC time corrections 2010

Keith Yearby, 23 June 2011

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1 Introduction

For precise time stamping of Cluster science data it is necessary to accurately determine the UT time at which each VC0 reset pulse occurs onboard. This pulse is time correlated with the transmission of the first bit of the housekeeping virtual channel (VC0) and the contents of the onboard time counter at this time is recorded in the On-board Time (OBT) field of the VC0 transfer frame (EID-A section 3.3.1.3.1 and 3.3.7.2.2). The time of the pulse is called the Spacecraft Event Time or SCET, and is given to a standard accuracy of ± 2 ms.

However for inter-spacecraft comparisons of EFW and STAFF waveform data a much higher accuracy is needed. This is achieved by preparing time correction (TCOR) files. The process is described in general in the document 'Precise reconstitution of the Spacecraft Event Time (SCET)'.

The purpose of the present document is to describe the precise procedure used for the year 2010, January to November inclusive. December is excluded as there are some unexplained variations in the DIFF measurements that require further investigation.

The procedure used is the same as for 2009, with only some minor updates to software tools.

2 Data and references

Source data:

WBD data DVDs for 2010 (online data for February to November).
Cluster RDM for 2010.

Documents:

Precise reconstitution of the Spacecraft Event Time (SCET), Keith Yearby, 2004 July 7

Software:

Software	Version	Date
readtcal	2.6	2010-07-15
wbddiff2	2.4	2011-05-18
wbdtcor	1.3	2011-05-18
tcaltrend	1.3	2011-04-11
maketcor	5.3	2011-05-24
veritcor	1.7	2010-07-22
tcor2cef	1.7	2010-06-29
diffmer	1.4	2010-06-24

RDM file lists:

File name	Last modified date
10_1_shla_files.txt	2011-01-13
10_2_shla_files.txt	2011-01-13
10_3_shla_files.txt	2011-01-13
10_4_shla_files.txt	2011-01-13

Ground Station Offset file: gsotable.txt

```
# Ground station offset table for DIFFMER etc.
# This version sets offsets for DSN and Panska Ves
# GSID1 GSID2 OFFSET (us)
 0 79 -5
46 46 -15
80 81 -30
#
```

Point Valid DIFF files:

File name	Last modified date
10_1_diffmer.txt	2011-05-24
10_2_diffmer.txt	2011-05-24
10_3_diffmer.txt	2011-05-24
10_4_diffmer.txt	2011-05-24

ASCII TCOR files:

File name	Last modified date
10_1_tcor.txt	2010-07-22
10_2_tcor.txt	2010-06-30
10_3_tcor.txt	2010-07-22
10_4_tcor.txt	2010-07-22

3 Preparation of the Point Valid DIFF measurements

3.1 Introduction

The Point Valid DIFF measurements give the difference between the actual UTC and that determined using the current time calibration (TCAL) at specific points in time. DIFF values are obtained from two sources, ESOC and WBD.

From 2007-11-24 onwards ESOC determine the time calibration during every nominal pass. This process is called a time correlation as it involves the correlation of the On Board Time with UTC. The DIFF usually remains small, typically less than 20 μ s. A linear interpolation between one time correlation and the next is normally quite sufficient to obtain DIFF to an acceptable accuracy. The DIFF value just after each time correlation can normally be assumed to be zero - this is what the time correlation achieves. The DIFF just before the same time correlation can be calculated using coefficients of the previous time correlation.

3.2 Making the file lists

Many of the TCOR preparation software tools require as input a list of the full path names of the spacecraft HK (sh) and TCAL (la) files. The following commands were used to make the file lists for 2010. The files cover the full year.

```
find /data/disk2/cluster/RDM/10* -name '*sh*' > scr.scr
find /data/disk2/cluster/RDM/10* -name '*la*' >> scr.scr
~/CAA/weclog/purgedup scr.scr 10_shla_files.txt
grep cluster1 10_shla_files.txt | sort > 10_1_shla_files.txt
grep cluster2 10_shla_files.txt | sort > 10_2_shla_files.txt
grep cluster3 10_shla_files.txt | sort > 10_3_shla_files.txt
grep cluster4 10_shla_files.txt | sort > 10_4_shla_files.txt
```

3.3 Obtaining ESOC DIFFs

The ESOC DIFF values are extracted from the TCAL files on the RDM. This is done automatically using the software tool 'readtcal'. The current version also returns the identification of the ground station used for the measurement. The following commands were used:

```
../readtcal -f 10_1_shla_files.txt -o 10_1_tcaldiff.txt
>10_1_tcal.txt
../readtcal -f 10_2_shla_files.txt -o 10_2_tcaldiff.txt
>10_2_tcal.txt
../readtcal -f 10_3_shla_files.txt -o 10_3_tcaldiff.txt
>10_3_tcal.txt
../readtcal -f 10_4_shla_files.txt -o 10_4_tcaldiff.txt
>10_4_tcal.txt
```

The TCAL summary files (10_*_tcal.txt) contain the raw TCAL SCET, OBT and TICK values. See the Cluster Data Delivery Interface Document (DDID) for more information. This TCAL information is needed by several subsequent software tools. The 10_*_tcaldiff.txt files contain the ESOC DIFF measurements derived by assuming the DIFF to be zero immediately after each new time correlation.

3.4 Obtaining WBD DIFFs

WBD DIFFs are obtained by processing the WBD level 1 files with the software tool WBDDIFF2.

As before, the accuracy of the DIFFs are checked by comparing each WBD measurement with a linear interpolation between the nearest validated ESOC (TCAL) measurements before and after. This interpolation is now done in SCET/OBT values rather than directly in DIFF. Data for January were on DVDs as usual. The procedure used to download and process online WBD data for February to November is listed in appendix A.

3.5 Merging of ESOC and WBD DIFFs

The ESOC and WBD DIFF measurements are merged together. The output files (10_*_diffmer.txt) contain mainly ESOC measurements with WBD points inserted only when they are separated by more than 8 hours in time (6 hours for SC4) from the nearest ESOC point, and differ by more than 10 μ s from a linear interpolation of the ESOC points.

```
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_2010_1_ncd.txt
-d 10_1_tcaldiff.txt -c 10_1_tcal.txt
-o 10_1_diffmer.txt -g gsotable.txt
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_2010_2_ncd.txt
-d 10_2_tcaldiff.txt -c 10_2_tcal.txt
-o 10_2_diffmer.txt -g gsotable.txt
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_2010_3_ncd.txt
-d 10_3_tcaldiff.txt -c 10_3_tcal.txt
-o 10_3_diffmer.txt -g gsotable.txt
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_2010_4_ncd.txt
-d 10_4_tcaldiff.txt -c 10_4_tcal.txt
-o 10_4_diffmer.txt -g gsotable.txt
```

3.6 Summary of PVD files manually modified

The following files were manually modified to correct errors in validation. Comments in the files indicate where changes have been made.

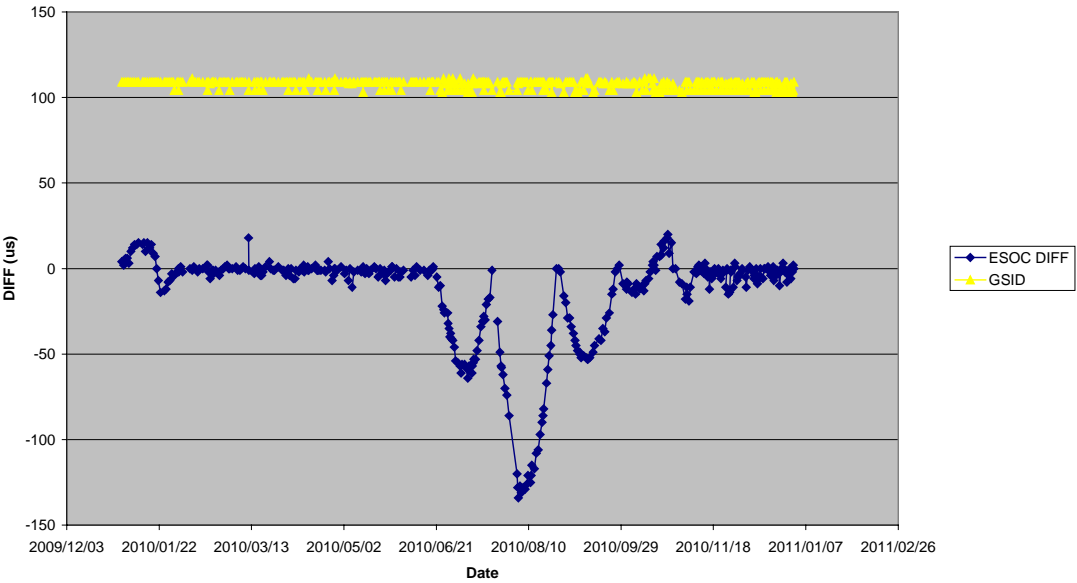
10_1_tcaldiff.txt
10_2_tcaldiff.txt
10_3_tcaldiff.txt
10_4_tcaldiff.txt

3.7 Validation using 'tcaltrend'

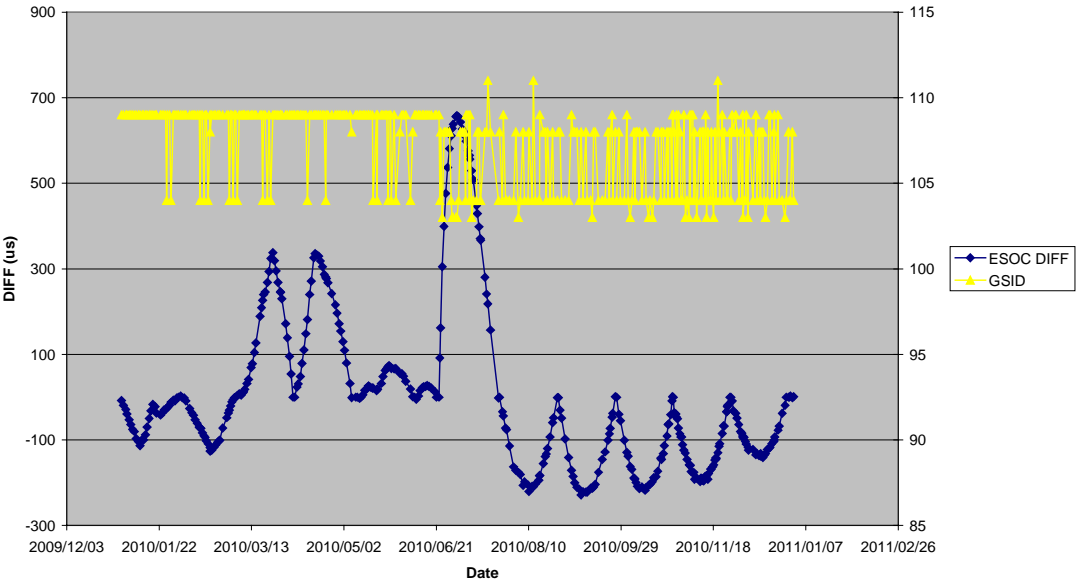
The long term trends of the clock drifts, as measured by the merged ESOC and WBD DIFFs together with the corresponding time calibrations (TCAL) are computed using 'tcaltrend'. This calculates what the DIFF would be with respect to an optimum time correlation performed at most every 30 days, and allows long term trends in the clock drift to be seen. The plots cover the whole of 2010, including December which is not included in the final TCOR files.

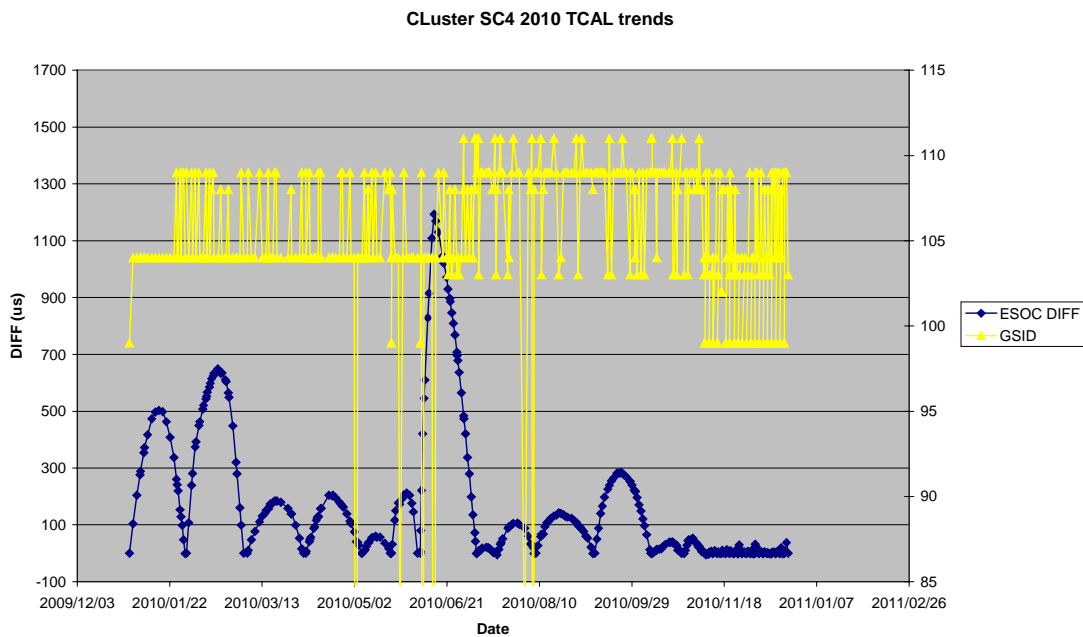
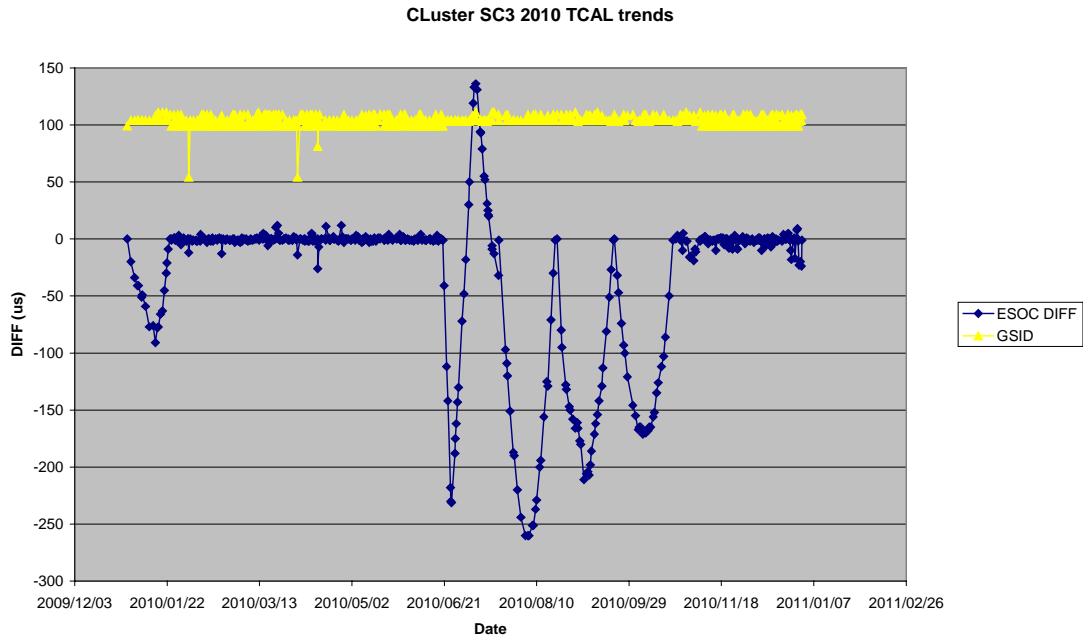
```
\cluster\miscsoft\readtcal\debug\tcaltrend -c 10_1_tcal.txt
-d 10_1_diffmer.txt >10_1_tcaltrend.txt
\cluster\miscsoft\readtcal\debug\tcaltrend -c 10_2_tcal.txt
-d 10_2_diffmer.txt >10_2_tcaltrend.txt
\cluster\miscsoft\readtcal\debug\tcaltrend -c 10_3_tcal.txt
-d 10_3_diffmer.txt >10_3_tcaltrend.txt
\cluster\miscsoft\readtcal\debug\tcaltrend -c 10_4_tcal.txt
-d 10_4_diffmer.txt >10_4_tcaltrend.txt
```

CLuster SC1 2010 TCAL trends



CLuster SC2 2010 TCAL trends





3.8 Validation using 'wbdtcor'

The WBD DIFFs are compared to the merged DIFF using '**wbdtcor**'. The current version of this software allows for the known timing offsets of the DSN stations (specified in `gsotable.txt`), so ideally the differences reported should be zero.

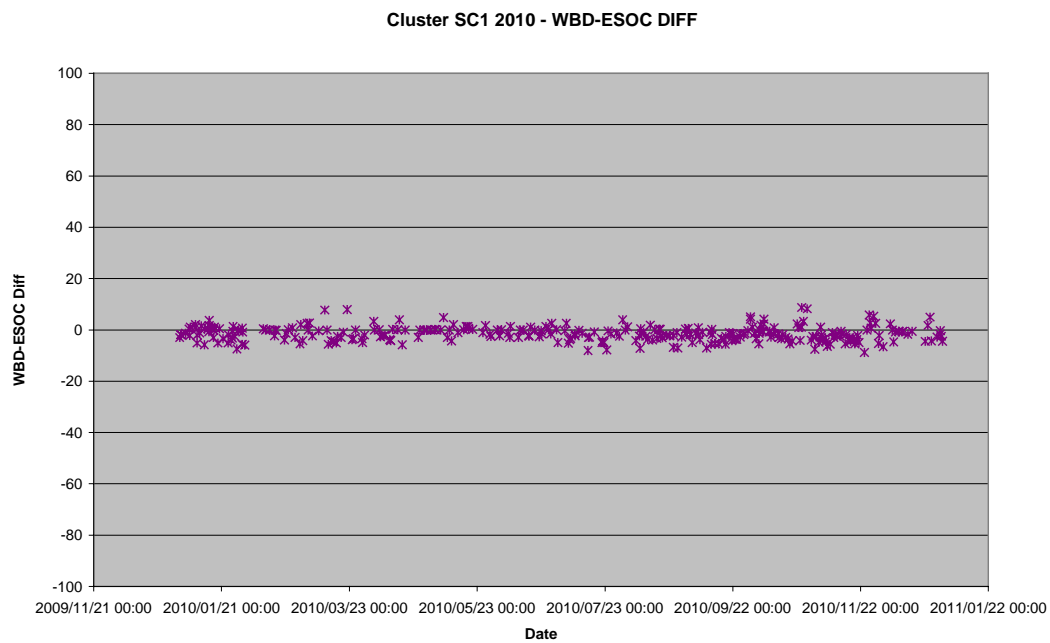
In the following plots it can be seen that the differences are usually well under $10\mu\text{s}$ (standard deviation 2.8 to $3.8\mu\text{s}$), which provides a general confidence in the quality of the measurements. However, it should be noted that any WBD point with a difference more than $10\mu\text{s}$, and more than 8 hours from any other measurement, will have been inserted into merged DIFF making the difference zero. Also there may be long periods with no WBD DIFF measurement, particularly on SC3. These plots cover the whole of 2010, including December which is not included in the final TCOR files.

SC	WBD inserted	Total WBD points	STDEV (us)
1	33	298	2.8
2	6	281	3.6
3	8	125	3.8
4	27	370	3.6

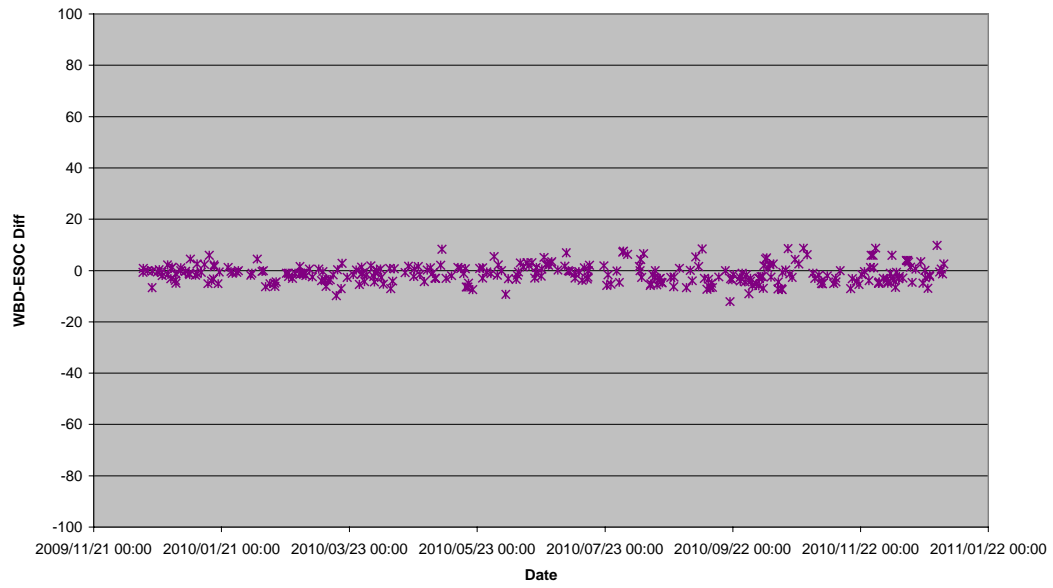
```

\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_2010_1_ncd.txt
-c 10_1_tcal.txt -d 10_1_diffmer.txt -g gsotable.txt
>10_1_mdelta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_2010_2_ncd.txt
-c 10_2_tcal.txt -d 10_2_diffmer.txt -g gsotable.txt
>10_2_mdelta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_2010_3_ncd.txt
-c 10_3_tcal.txt -d 10_3_diffmer.txt -g gsotable.txt
>10_3_mdelta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_2010_4_ncd.txt
-c 10_4_tcal.txt -d 10_4_diffmer.txt -g gsotable.txt
>10_4_mdelta.txt

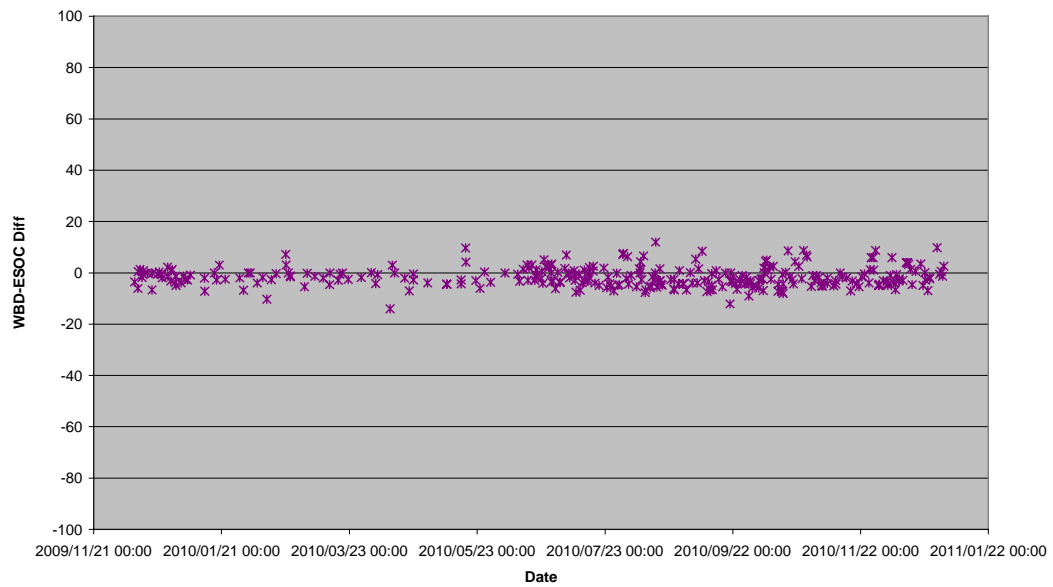
```



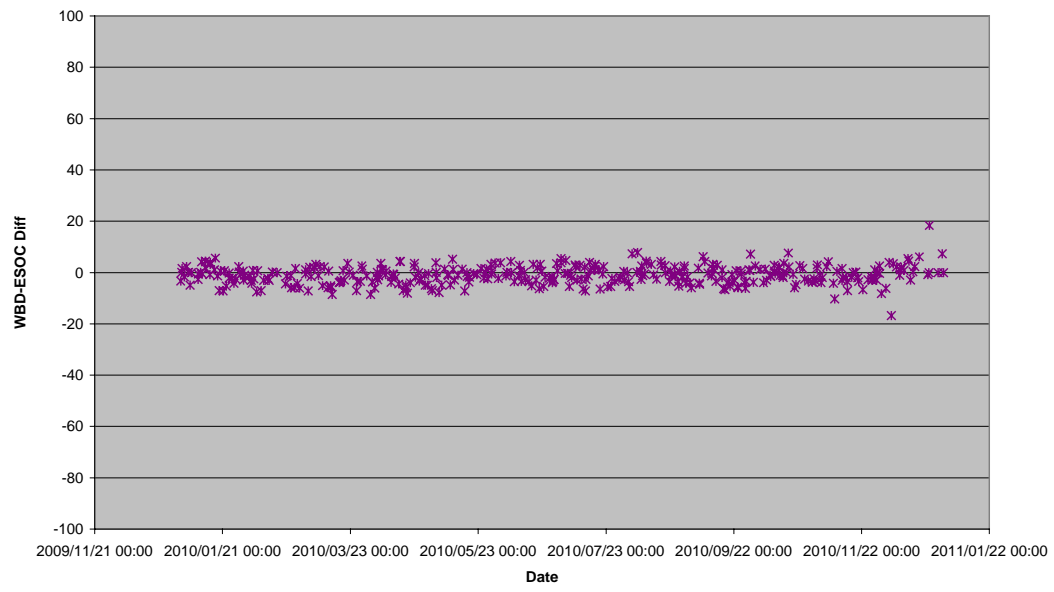
Cluster SC2 2010 - WBD-ESOC DIFF



Cluster SC3 2010 - WBD-ESOC DIFF



Cluster SC4 2010 - WBD-ESOC DIFF



4 Generation of the ASCII TCOR files

The generation of the ASCII TCOR files is performed on the Sun network where direct access to the Cluster RDM is available. 'maketcor' is used to generate the ASCII TCOR files. For this period version 5.3 was used. This uses the Sun Reference Pulse to track OBTM changes, rather than the WEC clock. This has the advantages that the short term stability is better, and it is available even when WEC is off.

The following commands were used:

```
../maketcor5 -o 10_1_tcor.txt -d 10_1_diffmer.txt
-f 10_1_shla_files.txt -s 100101 -e 101130 -w wbd_2010_1_ncd.txt
../maketcor5 -o 10_2_tcor.txt -d 10_2_diffmer.txt
-f 10_2_shla_files.txt -s 100101 -e 101130 -w wbd_2010_2_ncd.txt
../maketcor5 -o 10_3_tcor.txt -d 10_3_diffmer.txt
-f 10_3_shla_files.txt -s 100101 -e 101130 -w wbd_2010_3_ncd.txt
../maketcor5 -o 10_4_tcor.txt -d 10_4_diffmer.txt
-f 10_4_shla_files.txt -s 100101 -e 101130 -w wbd_2010_4_ncd.txt
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_1_diffmer.txt
# File list: 10_1_shla_files.txt (la)
# 647 TCAL records processed.
# File list: 10_1_shla_files.txt (hk)
# First record: 2010/01/01 00:00:01.651923
# Last record: 2010/11/30 23:59:59.000000
# Total proc: 5325730 formats, 100.0%
# WEC on: 5025221 formats, 94.4%
# Done: 4875953 formats, 91.6%
# No diff: 344425 formats, 6.5%
# Non constant: 0 formats, 0.0%
# No offset: 89065 formats, 1.7%
# Outside: 14586 formats, 0.3%
# Missing: 1701 formats, 0.0%
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_2_diffmer.txt
# File list: 10_2_shla_files.txt (la)
# 387 TCAL records processed.
# File list: 10_2_shla_files.txt (hk)
# First record: 2010/01/01 00:00:02.553784
# Last record: 2010/11/30 23:59:59.000000
# Total proc: 5596304 formats, 100.0%
# WEC on: 5387414 formats, 96.3%
# Done: 5477383 formats, 97.9%
# No diff: 27144 formats, 0.5%
# Non constant: 7274 formats, 0.1%
# No offset: 69398 formats, 1.2%
# Outside: 14608 formats, 0.3%
# Missing: 497 formats, 0.0%
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_3_diffmer.txt
# File list: 10_3_shla_files.txt (la)
# 624 TCAL records processed.
# File list: 10_3_shla_files.txt (hk)
# First record: 2010/01/01 00:00:00.666800
# Last record: 2010/11/30 23:59:59.000000
# Total proc: 5301451 formats, 100.0%
# WEC on: 4970734 formats, 93.8%
# Done: 4665036 formats, 88.0%
# No diff: 551966 formats, 10.4%
# Non constant: 10724 formats, 0.2%
# No offset: 59410 formats, 1.1%
# Outside: 12481 formats, 0.2%
# Missing: 1834 formats, 0.0%
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_4_diffmer.txt
# File list: 10_4_shla_files.txt (la)
# 453 TCAL records processed.
# File list: 10_4_shla_files.txt (hk)
# First record: 2010/01/01 00:00:00.581833
# Last record: 2010/11/30 23:59:59.000000
# Total proc: 5454836 formats, 100.0%
# WEC on: 5267006 formats, 96.6%
# Done: 5290343 formats, 97.0%
# No diff: 68913 formats, 1.3%
# Non constant: 0 formats, 0.0%
# No offset: 84628 formats, 1.6%
# Outside: 9879 formats, 0.2%
# Missing: 1073 formats, 0.0%
```

5 Validation of the TCOR files

The software tool 'maketcor' performs some automatic validation as the files are produced. Data that fails automatic validation are not included in the output files.

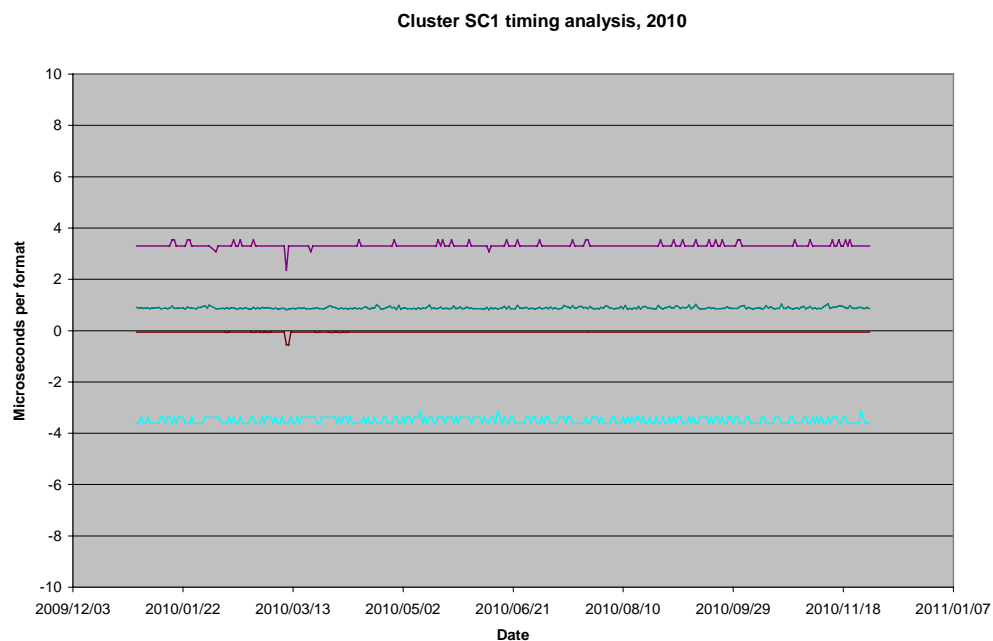
Further validation of the TCOR files is performed by generating version 0 CEF files, using these to apply time corrections, then analysing the time tags of the corrected data. The time tags are analysed using 'veritcor'. This takes the time increment between each pair of records in the file, subtracts the nominal value (by default 5.15222168 seconds), and accumulates the minimum, maximum, mean and standard deviation over each 24 hour period. On SC1, 3 and 4 it is known that time jumps of $-125.9 \mu\text{s}$ occur occasionally. These are counted and removed before further analysis. Gaps in the file are allowed for, and by default 'veritcor' only processes records that are time corrected.

It uses the same HK+TCAL file list file as 'maketcor', although only the HK files are used. 'veritcor' includes the same code module used by TED to apply the TCOR corrections, and requires CEF TCOR files to be installed with the same index files. The '-T .' option specifies that the TCOR files (and the index files) are located in the default directory.

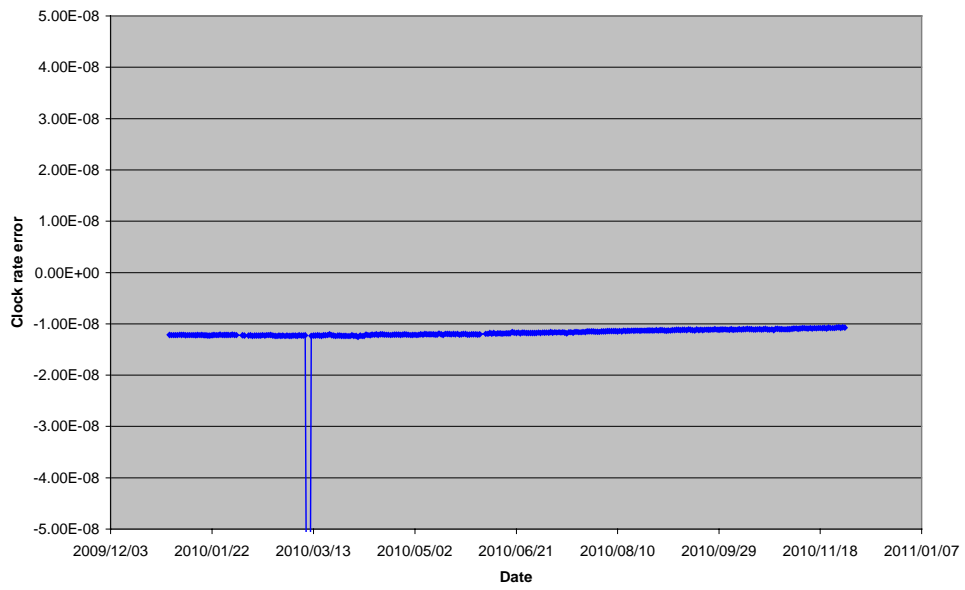
One error was found during validation, which was manually corrected by editing the ASCII TCOR file. On SC3, from 2010-01-13 16:02 to 2010/01/14 00:23 the offset was incorrect. Probable cause was a Sun Reference Pulse tracking error due to nutation following a manoeuvre.

The glitch on SC1, around 2010-03-11, was due to an OBDH switch-over.

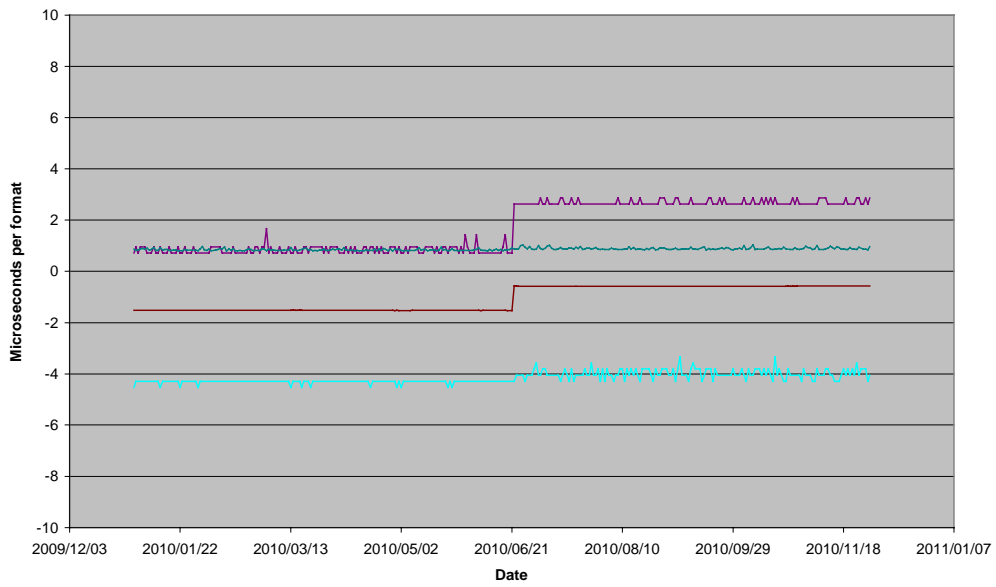
```
../veritcor -f 10_1_hkla_files.txt -T . -v 4 -i 5.152221
> 10_1_veritcor.txt
../veritcor -f 10_2_shla_files.txt -T . -v 4
> 10_2_veritcor.txt
../veritcor -f 10_3_shla_files.txt -T . -v 4
> 10_3_veritcor.txt
../veritcor -f 10_4_shla_files.txt -T . -v 4 -i 5.1522207
> 10_4_veritcor.txt
```



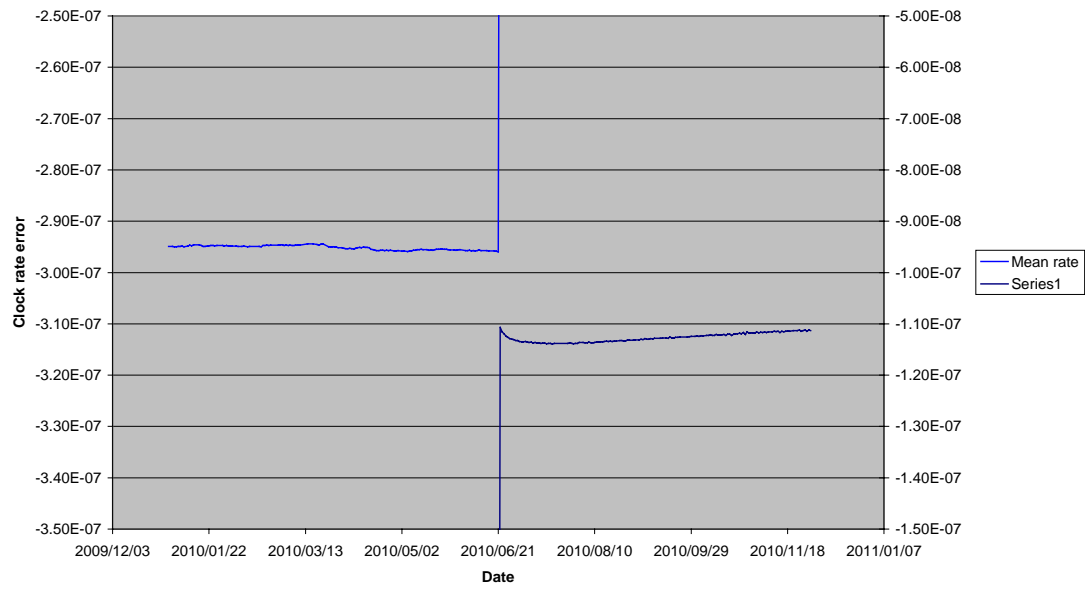
Cluster SC1 clock rate error, 2010



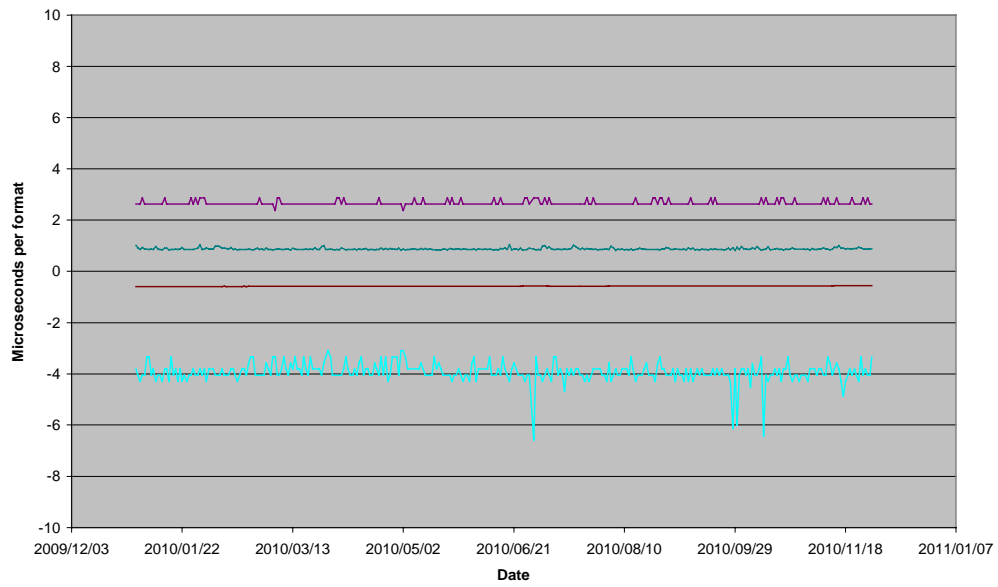
Cluster SC2 timing analysis, 2010



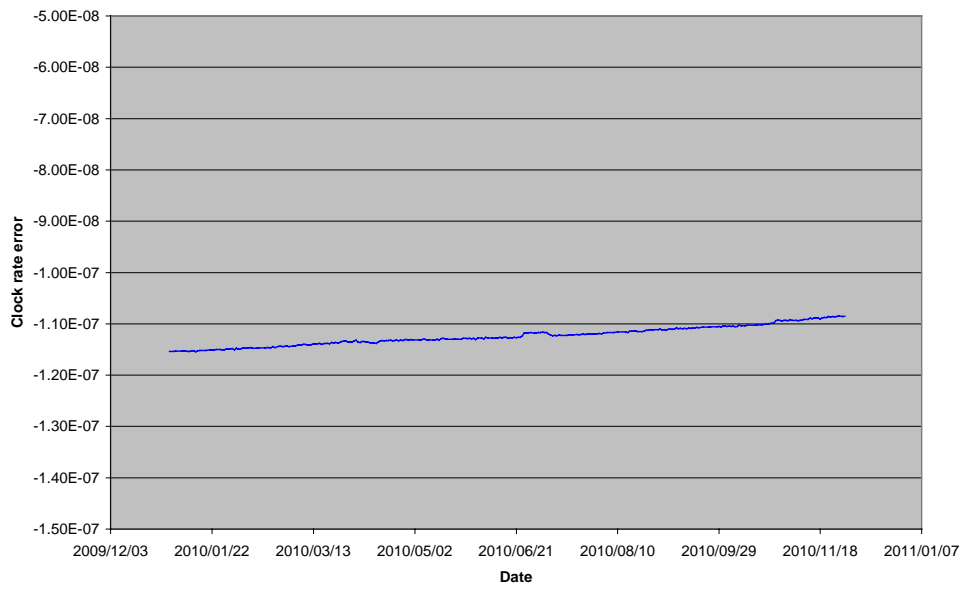
Cluster SC2 clock rate error, 2010



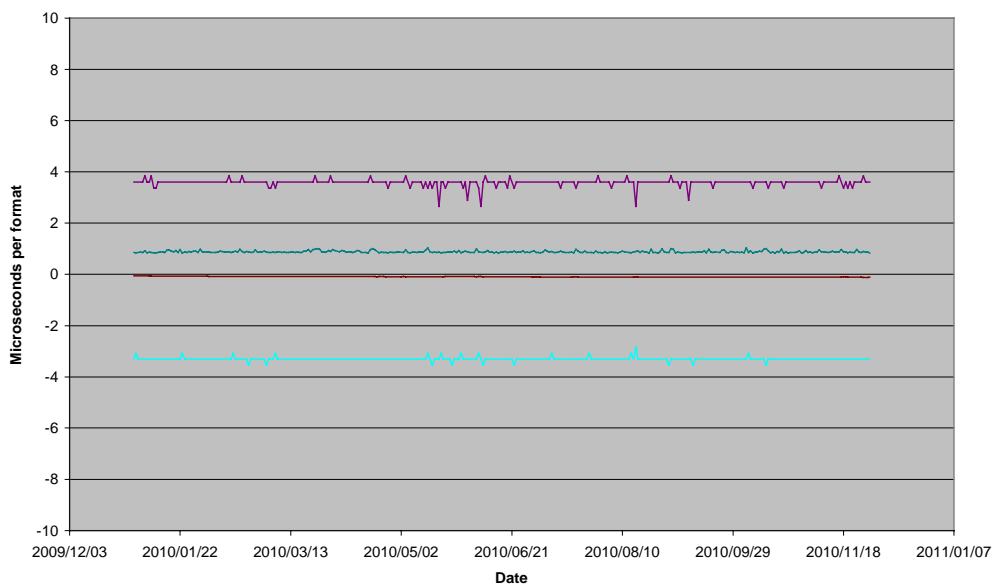
Cluster SC3 timing analysis, 2010



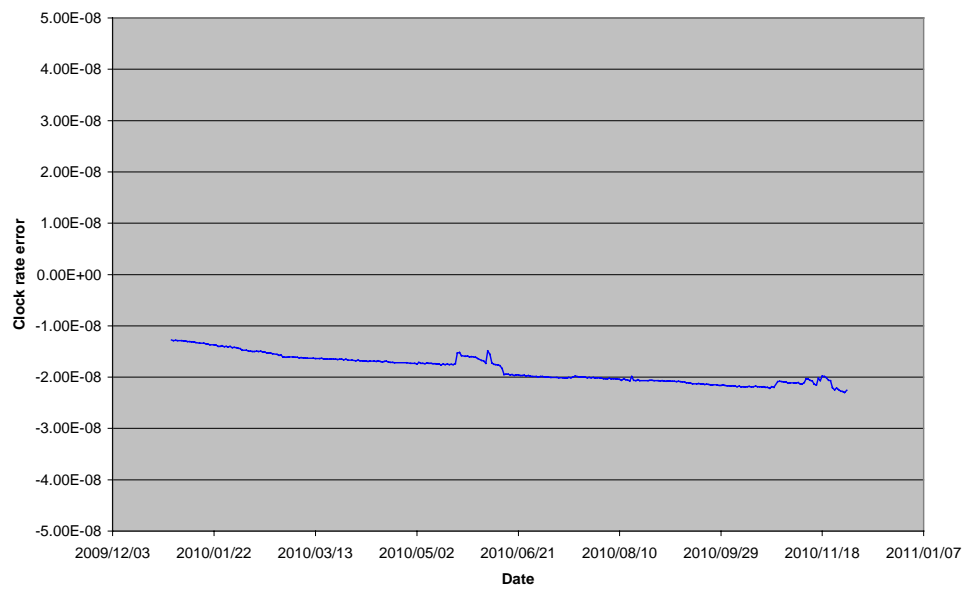
Cluster SC3 clock rate error, 2010



Cluster SC4 timing analysis, 2010



Cluster SC4 clock rate error, 2010



6 Production of the CEF files

The final CEF files were produced by running TCOR2CEF on the validated ASCII format TCOR files, with version number 1 specified.

```
hoodie% ../tcor2cef -t 10_1_tcor.txt -s 100101 -e 101130 -v 1
TCOR2CEF, version 1.7

TCOR file:          10_1_tcor.txt, s/c: 1, records: 3905
Generated CEF name: C1_CP_DWP_TCOR__20100101_V01
Time range:         2010-01-01T00:00:01Z/2010-11-30T23:59:59Z
Finished, CEF size: 421393 bytes
Total duration:     28857598 seconds
Corrected:          25098229 seconds (87.0 %)
hoodie% ../tcor2cef -t 10_2_tcor.txt -s 100101 -e 101130 -v 1
TCOR2CEF, version 1.7

TCOR file:          10_2_tcor.txt, s/c: 2, records: 4059
Generated CEF name: C2_CP_DWP_TCOR__20100101_V01
Time range:         2010-01-01T12:35:06Z/2010-11-30T23:59:59Z
Finished, CEF size: 435201 bytes
Total duration:     28812293 seconds
Corrected:          28193863 seconds (97.9 %)
hoodie% ../tcor2cef -t 10_3_tcor.txt -s 100101 -e 101130 -v 1
TCOR2CEF, version 1.7

TCOR file:          10_3_tcor.txt, s/c: 3, records: 3371
Generated CEF name: C3_CP_DWP_TCOR__20100101_V01
Time range:         2010-01-01T15:04:08Z/2010-11-30T23:59:59Z
Finished, CEF size: 363689 bytes
Total duration:     28803351 seconds
Corrected:          24011585 seconds (83.4 %)
hoodie% ../tcor2cef -t 10_4_tcor.txt -s 100101 -e 101130 -v 1
TCOR2CEF, version 1.7

TCOR file:          10_4_tcor.txt, s/c: 4, records: 4571
Generated CEF name: C4_CP_DWP_TCOR__20100101_V01
Time range:         2010-01-01T00:00:00Z/2010-11-30T23:59:59Z
Finished, CEF size: 493749 bytes
Total duration:     28857599 seconds
Corrected:          27235169 seconds (94.4 %)
```

The file comparison utility (diff) was used to check that the only changes between the version 0 files used for validation, and the final version, are in the filenames, version numbers, and generation date.

```
diff C1_CP_DWP_TCOR__20100101_V00.cef \
    C1_CP_DWP_TCOR__20100101_V01.cef
diff C2_CP_DWP_TCOR__20100101_V00.cef \
    C2_CP_DWP_TCOR__20100101_V01.cef
diff C3_CP_DWP_TCOR__20100101_V00.cef \
    C3_CP_DWP_TCOR__20100101_V01.cef
diff C4_CP_DWP_TCOR__20100101_V00.cef \
    C4_CP_DWP_TCOR__20100101_V01.cef
```

Finally, the CEF files are checked using CEFpass.

```
setenv CEFPATH ~/CAA/headers
~/CAAtools/CEFPass C1_CP_DWP_TCOR__20100101_V01.cef
```

```
~/CAAtools/CEFpass C2_CP_DWP_TCOR__20100101_V01.cef  
~/CAAtools/CEFpass C3_CP_DWP_TCOR__20100101_V01.cef  
~/CAAtools/CEFpass C4_CP_DWP_TCOR__20100101_V01.cef
```

7 Caveats

The following general caveats apply to 2010 TCOR data.

Use with caution. If published results depend critically on timing accuracy it is recommended that the DWP team should re-verify the TCOR data in question.

TCOR data is not available at all times. In this first release, data that fails validation is deleted from the files. For this period, TCOR coverage is around 83% to 98%. The reasons for lack of availability are usually:

- The discontinuity in the On Board Time at 'power down' or 'decoder only' eclipses, or CTU reboots, leading to non-availability of the DIFF measurements.
- It should be noted however, that in many cases missing TCOR data occurs when the payload is off, so is of no consequence.

Interpolation between TCOR records in CEF files is only permitted in limited circumstances. The time corrections are provided at the start and end times of each period of the same telemetry mode. The OFFSET is constant throughout each period, and the same value will be written in the records at the start and end of the period. If the OFFSET values before and after the required time are different, or either has the fill value of -1e31, then OFFSET is not available for that period. No interpolation between different OFFSET values is allowed. The DIFF may be obtained by linear interpolation of the DIFF values immediately before and after the required time. However, if either DIFF has the fill value of -1e31, then DIFF is not available for that period. It is not allowed to interpolate over a fill value.

In this version TCOR data is not produced if either DIFF or OFFSET is not available. However, DIFF values are now usually small ($< 20 \mu\text{s}$), and OFFSET values are not needed for WBD data, so it may be useful to produce TCOR data when only one quantity is available, the other being set to fill values. This will be considered for future versions.

Appendix A. Getting and processing online WBD data 2010 February to December

The WBD online level one data for 2010 is located in a separate directory for each month. Each directory was saved into a file by saving the web page, eg.:

```
Index_2010_1009.html
```

Then used 'wbdget.c' to make wget batch file for each directory:

```
\cluster\miscsoft\debug\wbdget Index_2010_1009.html wget_1009.bat
```

Each batch files contains a series of wget commands. Run each script, making sure there is enough space (~3 Gbyte per SC) for the files. Eg.:

```
source wget_1009.bat
```

The following batch file (proc_dlw.bat) was used to process the data for each month.

```
if "%2"==" " goto proc_all

dir %1*c%2 /b /s >files.scr
wbddiff2 -f files.scr -c \cluster\timing\2010\10_%2_tcal.txt
    >wbd_%1_%2_diff.txt
rm files.scr
goto exit

:proc_all
call proc_dlw %1 1
call proc_dlw %1 2
call proc_dlw %1 3
call proc_dlw %1 4

:exit
```

Append all the WBD DIFF files, and make the 'no comment' versions

```
copy wbd_20*_c2_diff.txt wbd_all_c2_diff.txt
grep -v # <wbd_all_c2_diff.txt | grep -v 0000-00-00 >wbd_all_c2_ncd.txt
copy wbd_20*_c3_diff.txt wbd_all_c3_diff.txt
grep -v # <wbd_all_c3_diff.txt | grep -v 0000-00-00 >wbd_all_c3_ncd.txt
```

For 2010, the wget batch files were run on the Sun network, while all other processing was performed on a PC, with files being transferred as needed. However, all processing could be done on a single machine if the necessary software (eg. wget) is installed.