Preparation and validation of WEC time corrections 2010 December

Keith Yearby, 19 July 2011

Contents

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 +/- 2ms.

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 December 2010.

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

2 Data and references

Source data:

WBD online level one data.
Cluster RDM for December 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

Gound 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	2011-07-01
10_2_diffmer.txt	2011-07-01
10_3_diffmer.txt	2011-07-01
10_4_diffmer.txt	2011-07-01

ASCII TCOR files:

File name	Last modified date
1012_1_tcor.txt	2011-07-01
1012_2_tcor.txt	2011-07-01
1012_3_tcor.txt	2011-07-05
1012_4_tcor.txt	2011-07-01

Reports from ESOC detailing time correlation errors in December 2010

ARTS1_CLU-2679_20110629_123401.pdf
Summary of the investigation from SW and FD.xls

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 μs. 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. They were then manually edited to include files for 2011-01-01 and 2011-01-02 to ensure that time corrections could be calculated right up to midnight on 2010-12-31.

```
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
```

The above files cover the whole of 2010, and can be used 'as is' for the production of the TCOR files for December. However, for the validation to proceed at a reasonable speed, file lists for December only were produced using the commands:

```
grep /1012 10_1_shla_files.txt > 1012_1_shla_files.txt
grep /1012 10_2_shla_files.txt > 1012_2_shla_files.txt
grep /1012 10_3_shla_files.txt > 1012_3_shla_files.txt
grep /1012 10_4_shla_files.txt > 1012_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.

For spacecraft 3 and 4, version 2 files named 10_3_tcaldiff_v2.txt and 10_4_tcaldiff_v2.txt were created by manually adding corrections for the incorrect orbit data used during the ESOC time correlation (see Anomaly Report CLU-2679).

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.

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 10μs from a linear interpolation of the ESOC points.

```
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_2010_3_ncd.txt
  -d 10_3_tcaldiff_v2.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_v2.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.

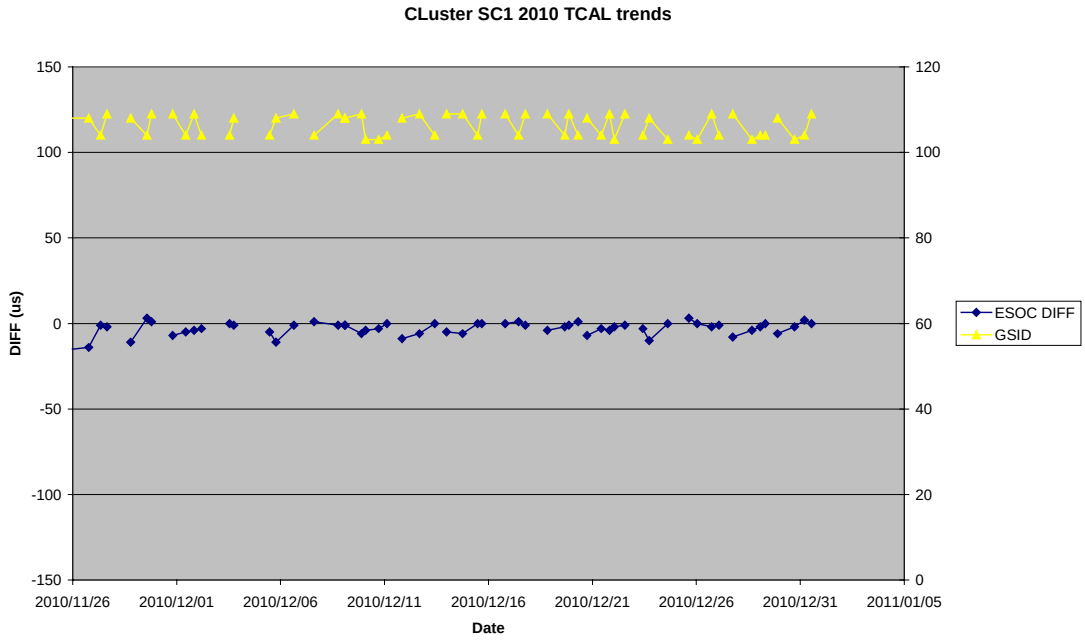
10_3_tcaldiff_v2.txt
10_4_tcaldiff_v2.txt

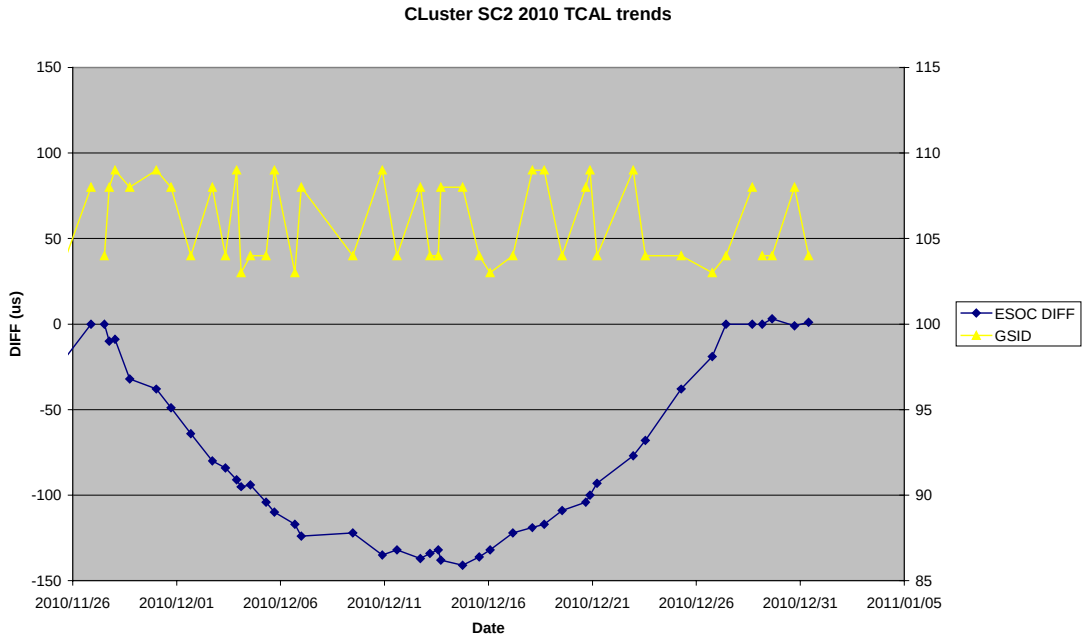
3.7 Validation using 'tcaltrend'

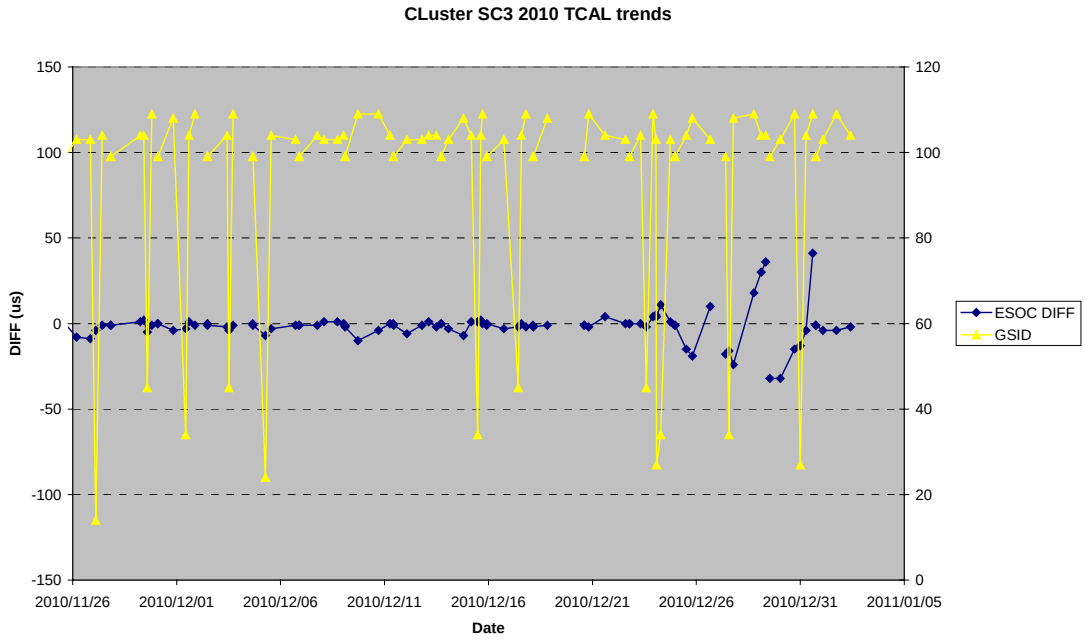
The long term trends of the clock drifts, as measured by the merged ESOC and WBD DIFFs together with the corresponding time calibrations (TCAL) are computed using **'tcaltrend'**. This calculates what the DIFF would be with respect to an optimum time correlation performed at most every 30 days, and allows long term trends in the clock drift to be seen. The plots cover just December 2010. For SC3 and SC4, all available WBD diffs are merged with the ESOC DIFFs to make the trend plots, not just those used in the final TCOR production.

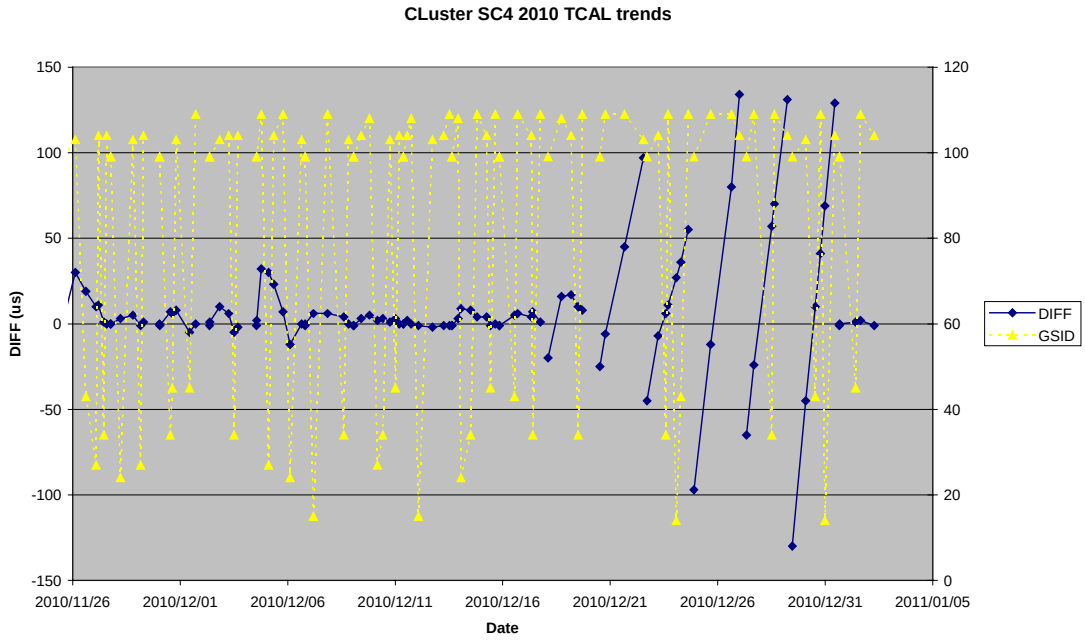
```
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_2010_3_ncd.txt
  -d 10_3_tcaldiff_v2.txt -c 10_3_tcal.txt -o scr.scr -g gsotable.txt
  -m -1

\cluster\miscsoft\readtcal\debug\tcaltrend -c 10_3_tcal.txt
  -d scr.scr -g gsotable.txt  >10_3_tcaltrend.txt
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_2010_4_ncd.txt
  -d 10_4_tcaldiff_v2.txt -c 10_4_tcal.txt -o scr.scr -g gsotable.txt
```

```
   -m -1
□
\cluster\miscsoft\readtcal\debug\tcaltrend -c 10_4_tcal.txt
   -d scr.scr -g gsotable.txt  >10_4_tcaltrend.txt
```









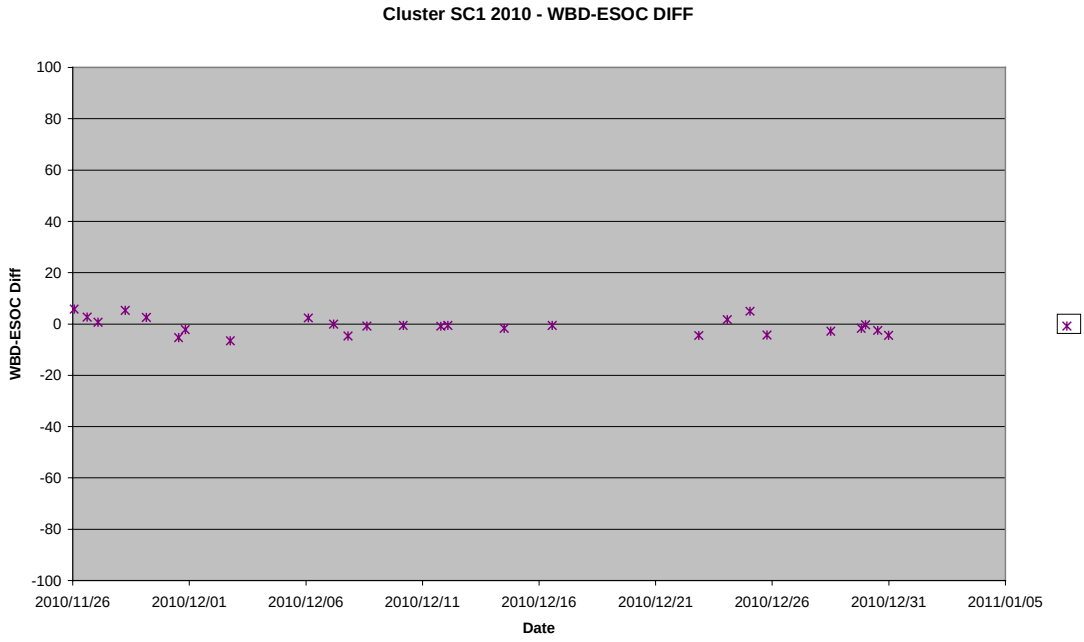
3.8 Validation using 'wbdtcor'

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.

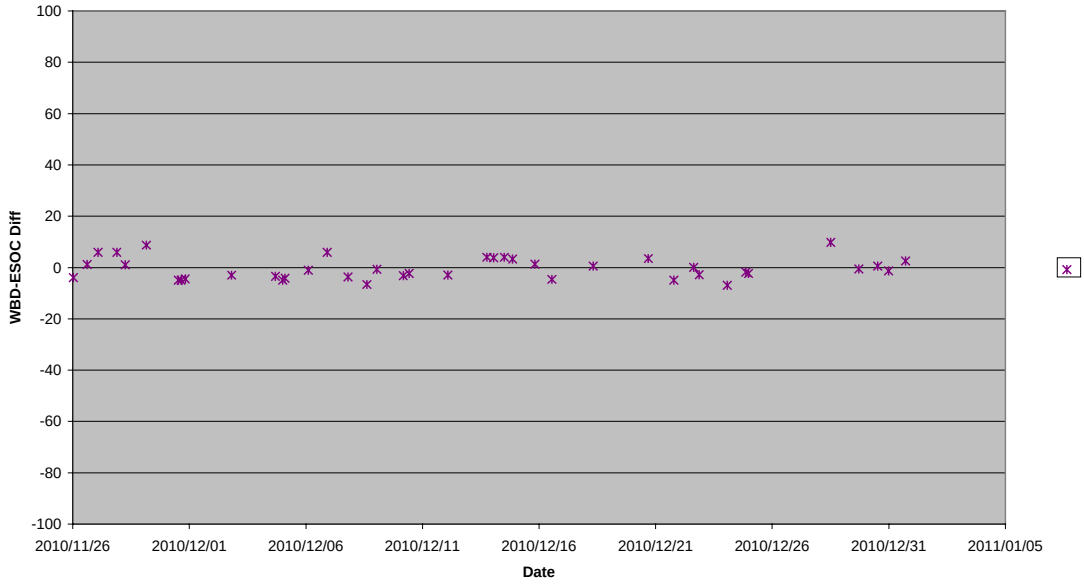
In the following plots it can be seen that the differences are usually well under 10µs (standard deviation 2.8 to 3.8µs), which provides a general confidence in the quality of the measurements. However, it should be noted that any WBD point with a difference more than 10µs, and more than 8 hours from 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

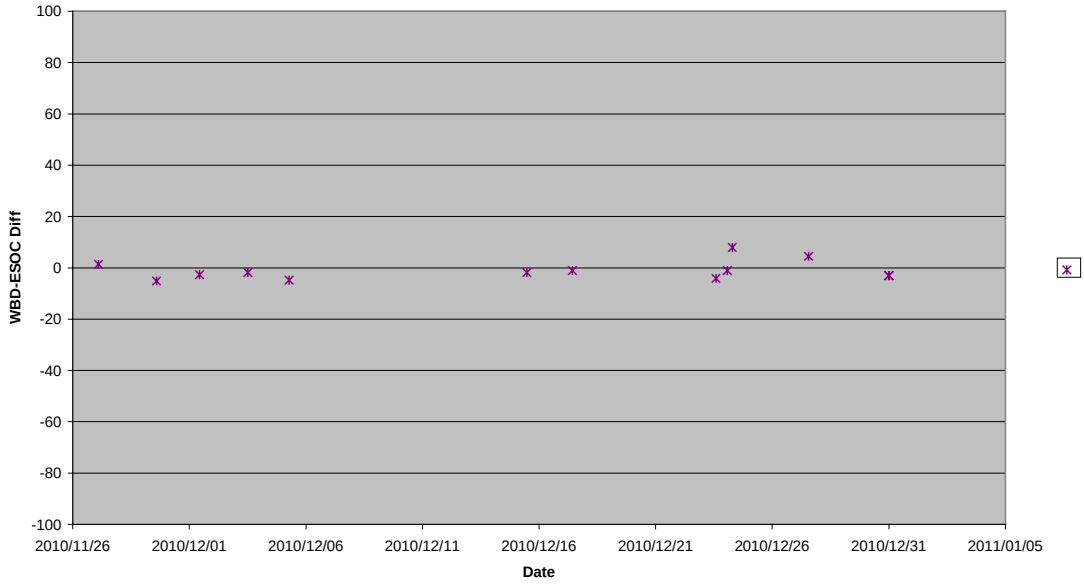
```
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_2010_3_ncd.txt
   -c 10_3_tcal.txt -d 10_3_tcaldiff_v2.txt -g gsotable.txt
   >10_3_mdelta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_2010_4_ncd.txt
   -c 10_4_tcal.txt -d 10_4_tcaldiff_v2.txt -g gsotable.txt
   >10_4_mdelta.txt
```

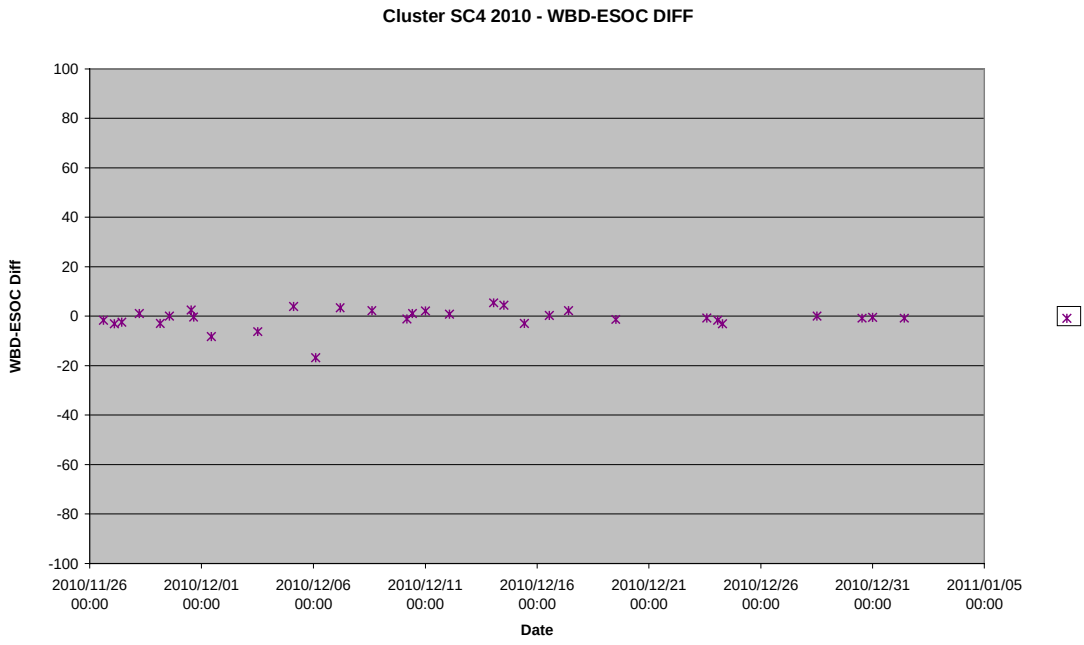


Cluster SC2 2010 - WBD-ESOC DIFF



Cluster SC3 2010 - WBD-ESOC DIFF




Cluster SC4 2010 - WBD-ESOC DIFF
WBD-ESOC Diff
100
80
60
40
20
0
-20
-40
-60
-80
-100
2010/11/26 00:00
2010/12/01 00:00
2010/12/06 00:00
2010/12/11 00:00
2010/12/16 00:00
2010/12/21 00:00
2010/12/26 00:00
2010/12/31 00:00
2011/01/05 00:00
Date

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 1012_1_tcor.txt -d 10_1_diffmer.txt
  -f 10_1_shla_files.txt -s 101201 -e 101231 -w wbd_2010_1_ncd.txt
../maketcor5 -o 1012_2_tcor.txt -d 10_2_diffmer.txt
  -f 10_2_shla_files.txt -s 101201 -e 101231 -w wbd_2010_2_ncd.txt
../maketcor5 -o 1012_3_tcor.txt -d 10_3_diffmer.txt
  -f 10_3_shla_files.txt -s 101201 -e 101231 -w wbd_2010_3_ncd.txt
../maketcor5 -o 1012_4_tcor.txt -d 10_4_diffmer.txt
  -f 10_4_shla_files.txt -s 101201 -e 101231 -w wbd_2010_4_ncd.txt
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_1_diffmer.txt
# File list: 10_1_shla_files.txt (la)
# 654 TCAL records processed.
# File list: 10_1_shla_files.txt (hk)
# First record: 2010/12/01 00:00:00.000000
# Last record:  2010/12/31 23:59:59.000000
# Total proc:     523340 formats,  100.0%
# WEC on:         490562 formats,   93.7%
# Done:           454527 formats,   86.9%
# No diff:         40524 formats,    7.7%
# Non constant:        0 formats,    0.0%
# No offset:           0 formats,    0.0%
# Outside:         27995 formats,    5.3%
# Missing:           294 formats,    0.1%
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_2_diffmer.txt
# File list: 10_2_shla_files.txt (la)
# 389 TCAL records processed.
# File list: 10_2_shla_files.txt (hk)
# First record: 2010/12/01 00:00:00.000000
# Last record:  2010/12/31 23:59:59.000000
# Total proc:     569727 formats,  100.0%
# WEC on:         540692 formats,   94.9%
# Done:           509805 formats,   89.5%
# No diff:           481 formats,    0.1%
# Non constant:     1141 formats,    0.2%
# No offset:       10672 formats,    1.9%
# Outside:         47560 formats,    8.3%
# Missing:            68 formats,    0.0%
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_3_diffmer.txt
# File list: 10_3_shla_files.txt (la)
# 629 TCAL records processed.
# File list: 10_3_shla_files.txt (hk)
# First record: 2010/12/01 00:00:00.000000
# Last record:  2010/12/31 23:59:59.000000
# Total proc:     515176 formats,  100.0%
# WEC on:         484402 formats,   94.0%
# Done:           419113 formats,   81.4%
# No diff:         43757 formats,    8.5%
# Non constant:        0 formats,    0.0%
# No offset:        8460 formats,    1.6%
# Outside:         43539 formats,    8.5%
# Missing:           307 formats,    0.1%
```

```
# MAKETCOR, version 5.3
#
# DIFF FILE: 10_4_diffmer.txt
# File list: 10_4_shla_files.txt (la)
# 459 TCAL records processed.
# File list: 10_4_shla_files.txt (hk)
# First record: 2010/12/01 00:00:00.000000
# Last record:  2010/12/31 23:59:59.000000
# Total proc:     515062 formats,  100.0%
# WEC on:         488078 formats,   94.8%
# Done:           438241 formats,   85.1%
# No diff:         37254 formats,    7.2%
# Non constant:        0 formats,    0.0%
# No offset:          15 formats,    0.0%
# Outside:         39272 formats,    7.6%
# Missing:           280 formats,    0.1%
```

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.

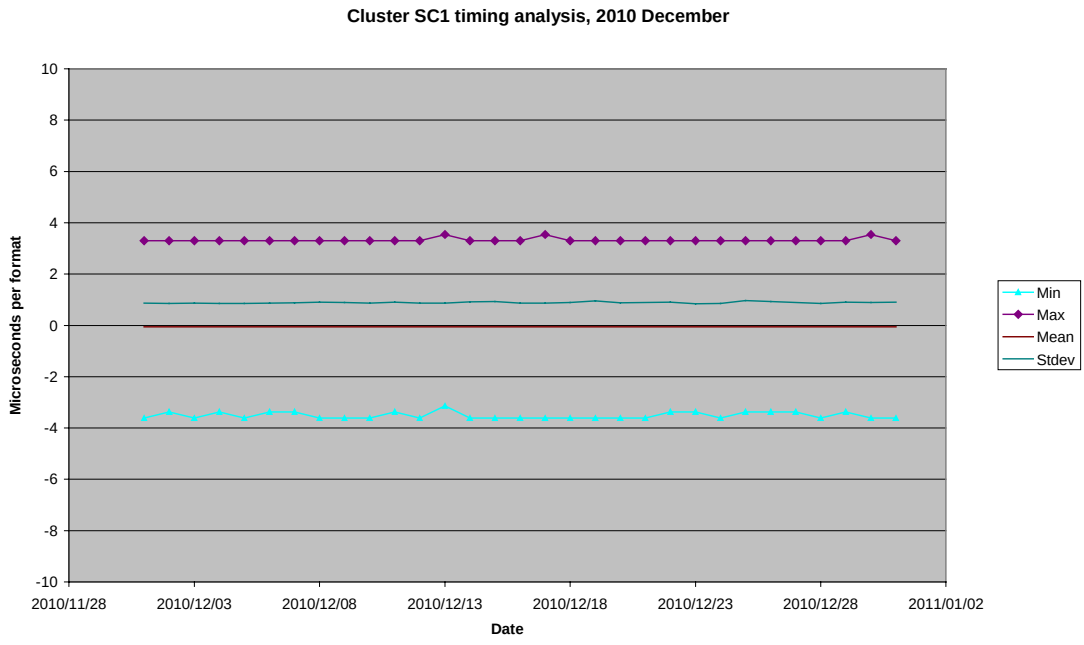
Further validation of the TCOR files is performed by generating version 0 CEF files, using these to apply time corrections, then analysing the time tags of the corrected data. The time tags are analysed using ‘veritcor’. This takes the time increment between each pair of records in the file, subtracts 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 µs 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.

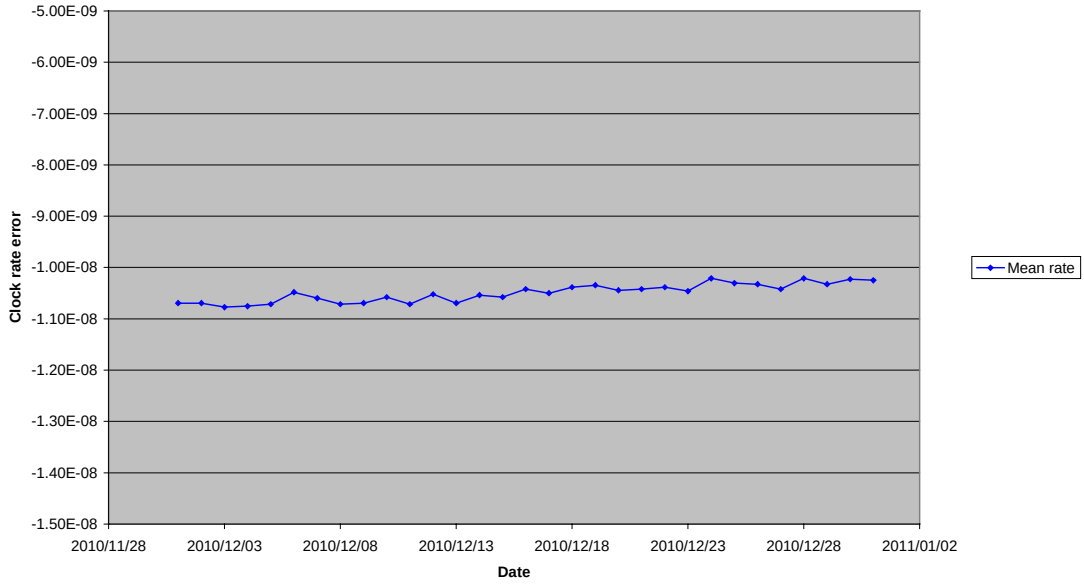
One error was found during validation, which was manually corrected by editing the ASCII TCOR file. On SC3, from 2010-01-13 16:02 to 2010/01/14 00:23 the offset was incorrect. Probable cause was a Sun Reference Pulse tracking error due to nutation following a manoeuvre.

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

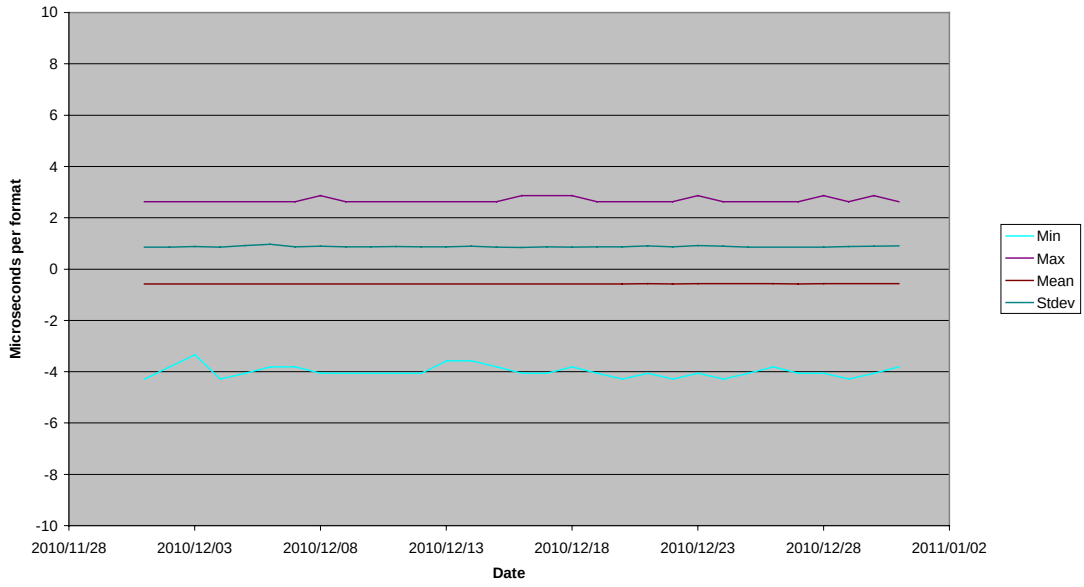
```
../veritcor -f 1012_1_hkla_files.txt -T . -v 4 -i 5.152221
   > 1012_1_veritcor.txt
../veritcor -f 1012_2_shla_files.txt -T . -v 4
   > 1012_2_veritcor.txt
../veritcor -f 1012_3_shla_files.txt -T . -v 4
   > 1012_3_veritcor.txt
../veritcor -f 1012_4_shla_files.txt -T . -v 4 -i 5.1522207
   > 1012_4_veritcor.txt
```



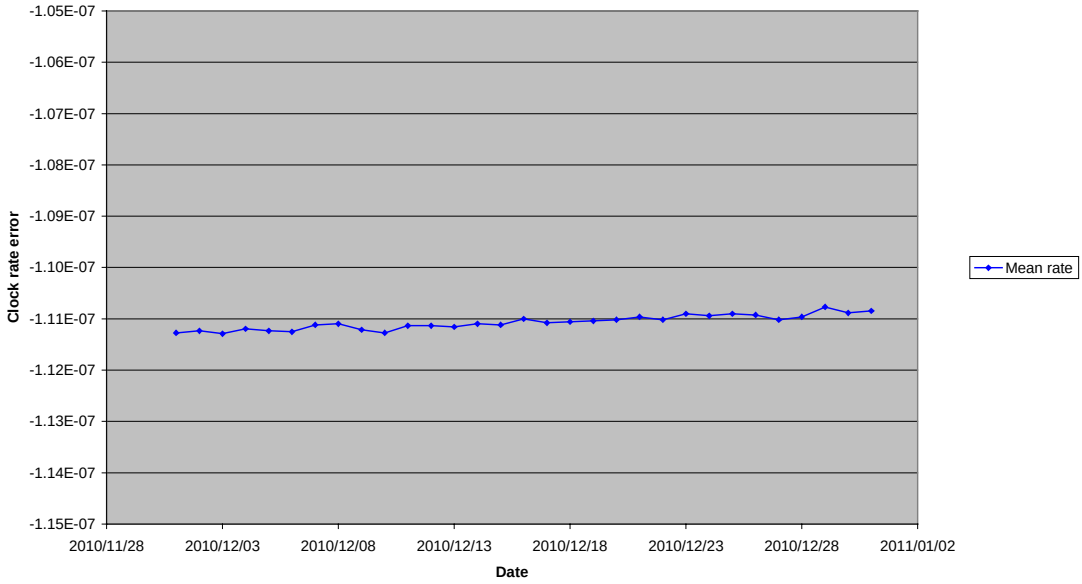
Cluster SC1 clock rate error, 2010



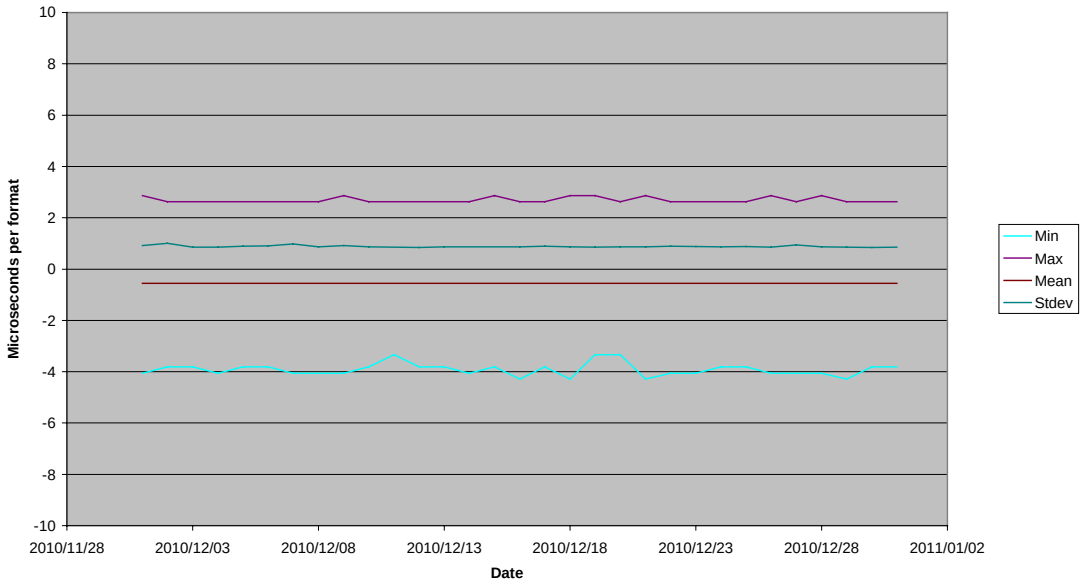
Cluster SC2 timing analysis, 2010 December



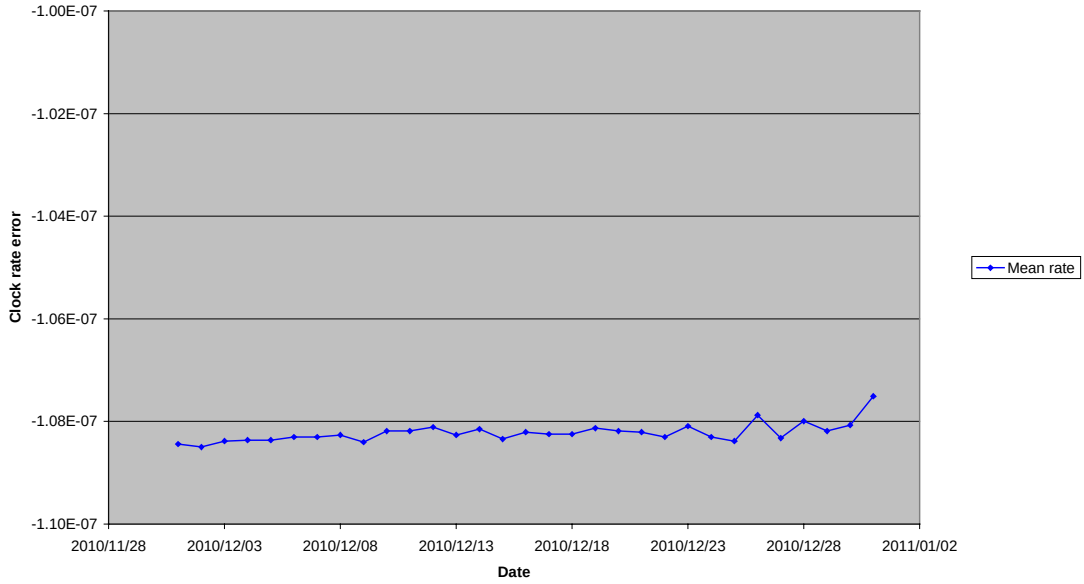
Cluster SC2 clock rate error, 2010



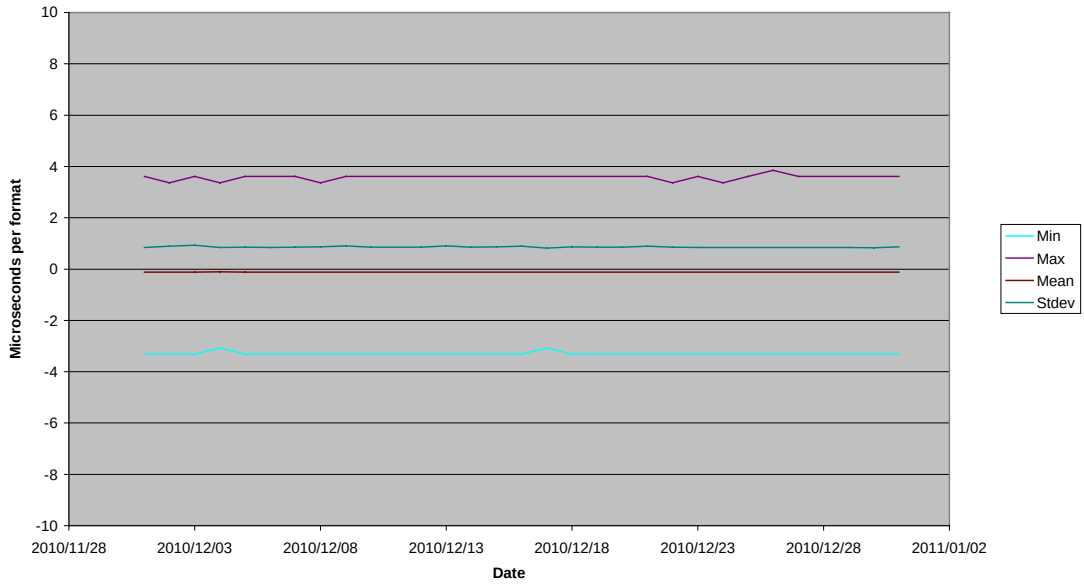
Cluster SC3 timing analysis, 2010 December

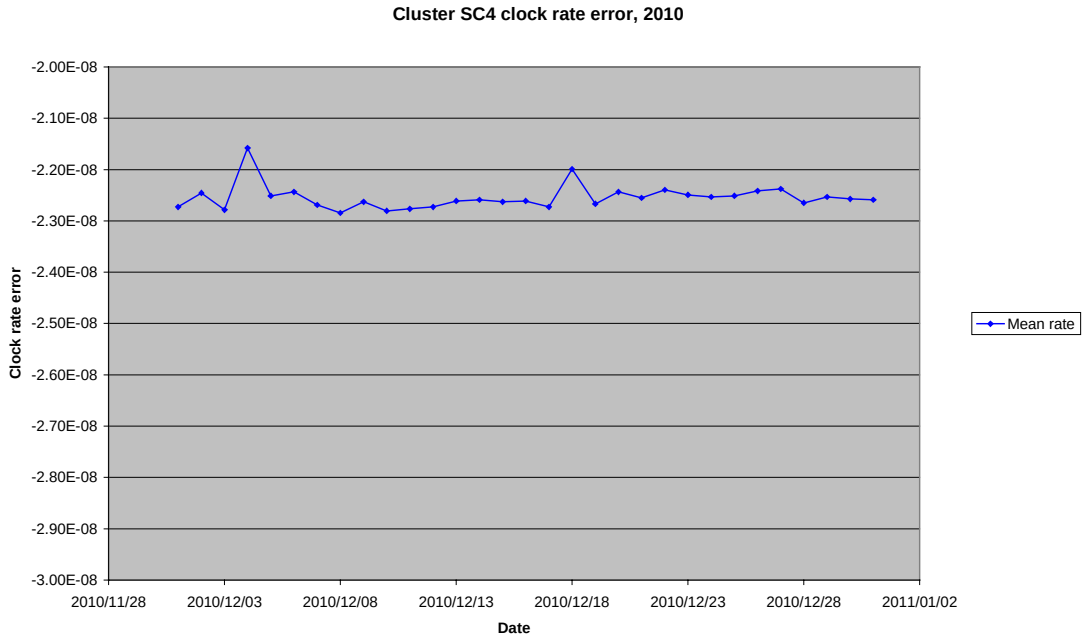


Cluster SC3 clock rate error, 2010



Cluster SC4 timing analysis, 2010 December




Cluster SC4 clock rate error, 2010
-2.00E-08
-2.10E-08
-2.20E-08
-2.30E-08
-2.40E-08
-2.50E-08
-2.60E-08
-2.70E-08
-2.80E-08
-2.90E-08
-3.00E-08
Clock rate error
2010/11/28
2010/12/03
2010/12/08
2010/12/13
2010/12/18
2010/12/23
2010/12/28
2011/01/02
Date
Mean rate

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.

```
../tcor2cef -t 1012_1_tcor.txt -s 101201 -e 101231 -v 01
TCOR2CEF, version 1.7
TCOR file:          1012_1_tcor.txt, s/c: 1, records: 436
Generated CEF name: C1_CP_DWP_TCOR__20101201_V01
Time range:         2010-12-01T00:00:00Z/2010-12-31T23:59:59Z
Finished, CEF size: 47858 bytes
Total duration:     2678399 seconds
Corrected:          2326252 seconds (86.9 %)

../tcor2cef -t 1012_2_tcor.txt -s 101201 -e 101231 -v 01
TCOR2CEF, version 1.7
TCOR file:          1012_2_tcor.txt, s/c: 2, records: 456
Generated CEF name: C2_CP_DWP_TCOR__20101201_V01
Time range:         2010-12-01T00:00:00Z/2010-12-31T23:59:59Z
Finished, CEF size: 50064 bytes
Total duration:     2678399 seconds
Corrected:          2611274 seconds (97.5 %)

../tcor2cef -t 1012_3_tcor.txt -s 101201 -e 101231 -v 01
TCOR2CEF, version 1.7
TCOR file:          1012_3_tcor.txt, s/c: 3, records: 417
Generated CEF name: C3_CP_DWP_TCOR__20101201_V01
Time range:         2010-12-01T00:00:00Z/2010-12-31T23:59:59Z
Finished, CEF size: 45886 bytes
Total duration:     2678399 seconds
Corrected:          2144088 seconds (80.1 %)

../tcor2cef -t 1012_4_tcor.txt -s 101201 -e 101231 -v 01
TCOR2CEF, version 1.7
TCOR file:          1012_4_tcor.txt, s/c: 4, records: 445
Generated CEF name: C4_CP_DWP_TCOR__20101201_V01
Time range:         2010-12-01T00:00:00Z/2010-12-31T23:59:59Z
Finished, CEF size: 49377 bytes
Total duration:     2678399 seconds
Corrected:          2243748 seconds (83.8 %)
```

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__20101201_V00.cef \
     C1_CP_DWP_TCOR__20101201_V01.cef
diff C2_CP_DWP_TCOR__20101201_V00.cef \
     C2_CP_DWP_TCOR__20101201_V01.cef
diff C3_CP_DWP_TCOR__20101201_V00.cef \
     C3_CP_DWP_TCOR__20101201_V01.cef
diff C4_CP_DWP_TCOR__20101201_V00.cef \
     C4_CP_DWP_TCOR__20101201_V01.cef
```

Finally, the CEF files are checked using CEFpass.

```
setenv CEFPATH ~/CAA/headers
~/CAAtools/CEFpass C1_CP_DWP_TCOR__20101201_V01.cef
~/CAAtools/CEFpass C2_CP_DWP_TCOR__20101201_V01.cef
~/CAAtools/CEFpass C3_CP_DWP_TCOR__20101201_V01.cef
~/CAAtools/CEFpass C4_CP_DWP_TCOR__20101201_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 μs), 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.