Preparation and validation of WEC time corrections 2011 January to July

Keith Yearby, 18 October 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 January to July 2011 inclusive.

The procedure used is the same as for 2009 and 2010, with only some minor updates to software tools.

2 Data and references

Source data:

WBD online level one data.
Cluster RDM for January to July 2011.

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	1.10	2011-10-14
tcor2cef	1.7	2010-06-29
diffmer	1.4	2010-06-24

RDM file lists:

File name	Last modified date
11_1_shla_files.txt	2011-09-28
11_2_shla_files.txt	2011-09-28
11_3_shla_files.txt	2011-09-28
11_4_shla_files.txt	2011-09-28

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
1101_1_diffmer.txt	2011-10-05
1101_2_diffmer.txt	2011-10-05
1101_3_diffmer.txt	2011-10-05
1101_4_diffmer.txt	2011-10-05

ASCII TCOR files:

File name	Last modified date
1101_1_tcor.txt	2011-10-05
1101_2_tcor.txt	2011-10-05
1101_3_tcor.txt	2011-10-05
1101_4_tcor.txt	2011-10-05

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 2011. These also include the files for the last two days of 2010 to ensure that time corrections can be calculated right from the start of 2011.

```
find /data/disk2/cluster/RDM/11* -name '*sh*' > scr.scr
find /data/disk2/cluster/RDM/11* -name '*la*' >> scr.scr
~/CAA/weclog/purgedup scr.scr 11_shla_files.txt
find /data/disk2/cluster/RDM/10123* -name '*sh*' >>11_shla_files.txt
find /data/disk2/cluster/RDM/10123* -name '*la*' >>11_shla_files.txt
grep cluster1 11_shla_files.txt | sort > 11_1_shla_files.txt
grep cluster2 11_shla_files.txt | sort > 11_2_shla_files.txt
grep cluster3 11_shla_files.txt | sort > 11_3_shla_files.txt
grep cluster4 11_shla_files.txt | sort > 11_4_shla_files.txt
```

The above files cover up to mid September 2011, and can be used 'as is' for the production of the TCOR files for this period.

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 11_1_shla_files.txt -o 11_1_tcaldiff.txt
  >11_1_tcal.txt
../readtcal -f 11_2_shla_files.txt -o 11_2_tcaldiff.txt
  >11_2_tcal.txt
../readtcal -f 11_3_shla_files.txt -o 11_3_tcaldiff.txt
  >11_3_tcal.txt
../readtcal -f 11_4_shla_files.txt -o 11_4_tcaldiff.txt
  >11_4_tcal.txt
```

The TCAL summary files (11_*_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 11_*_tcaldiff.txt files contain the ESOC DIFF measurements derived by assuming the DIFF to be zero immediately after each new time correlation.

For spacecraft 1, 2, and 3, version 2 files named 1101_1_tcaldiff_v2.txt, 1101_2_tcaldiff_v2.txt and 1101_3_tcaldiff_v2.txt were created by manually removing apparently incorrect values.

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 Summary of PVD files manually modified

The following files were manually modified to remove errors found during validation.

1101_1_tcaldiff_v2.txt
1101_2_tcaldiff_v2.txt
1101_3_tcaldiff_v2.txt

DIFF measurements at the following times were removed.

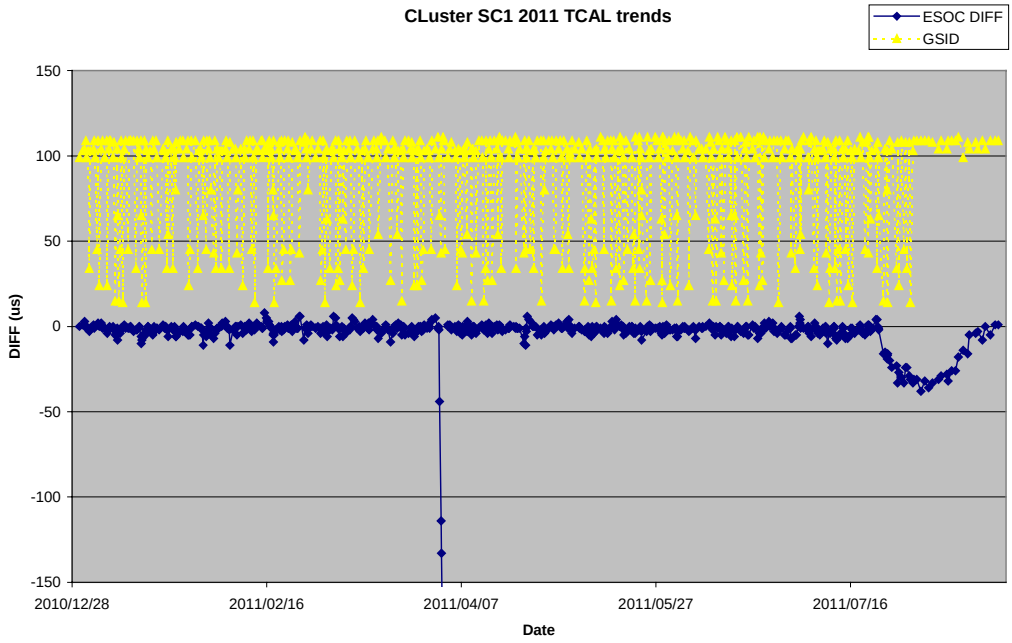
Spacecraft	Time range	GSID
C1	2011-04-03 07:39	3
C2	2011-06-03 09:15	8
	2011-06-05 15:21 - 2011-06-05 21:39	9, 11
	2011-06-19 01:21 - 2011-06-21 11:07	3, 4, 9, 11
	2011-07-26 19:44 - 2011-07-27 11:20	4, 11
C3	2011-04-23 18:16 - 2011-04-23 23:59	4
	2011-07-26 05:06 - 2011-07-27 04:23	8, 9

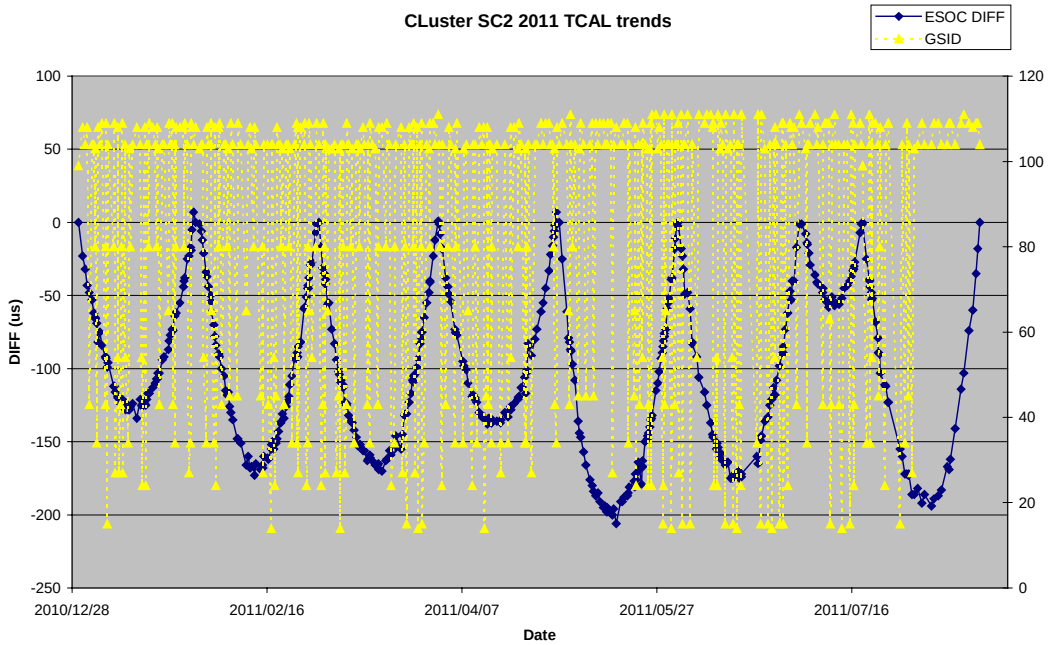
3.6 Merging of ESOC and WBD DIFFs

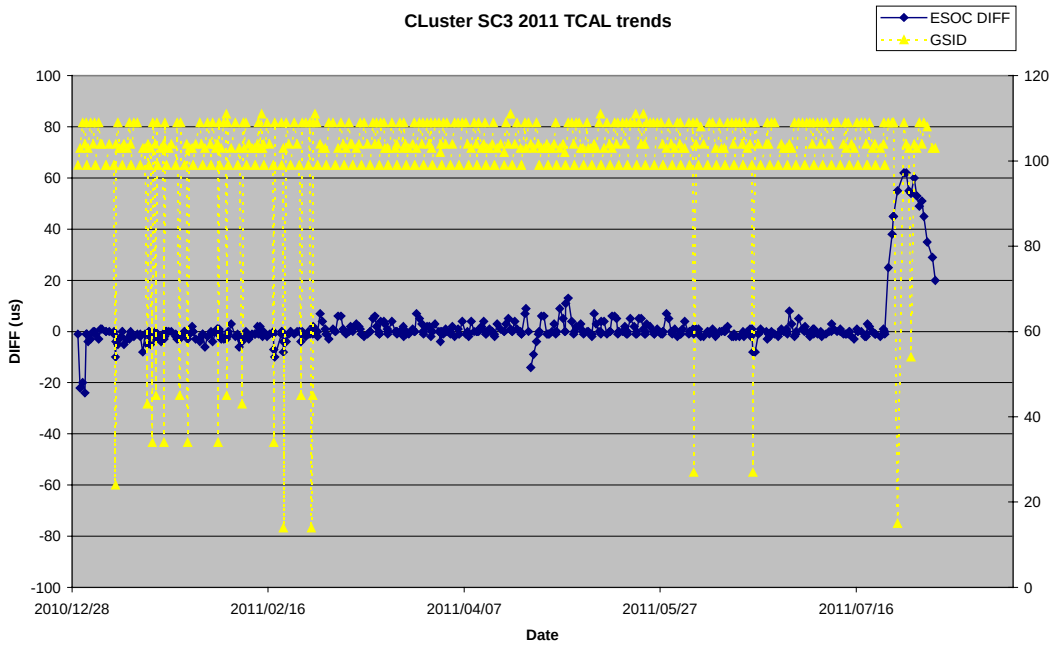
The ESOC and WBD DIFF measurements are merged together. The output files (1101_*_diffmer.txt) contain mainly ESOC measurements with WBD points inserted only when they are separated by more than 8 hours in time (0.1 hours for SC4) from the nearest ESOC point, and differ by more than 10μs from a linear interpolation of the ESOC points.

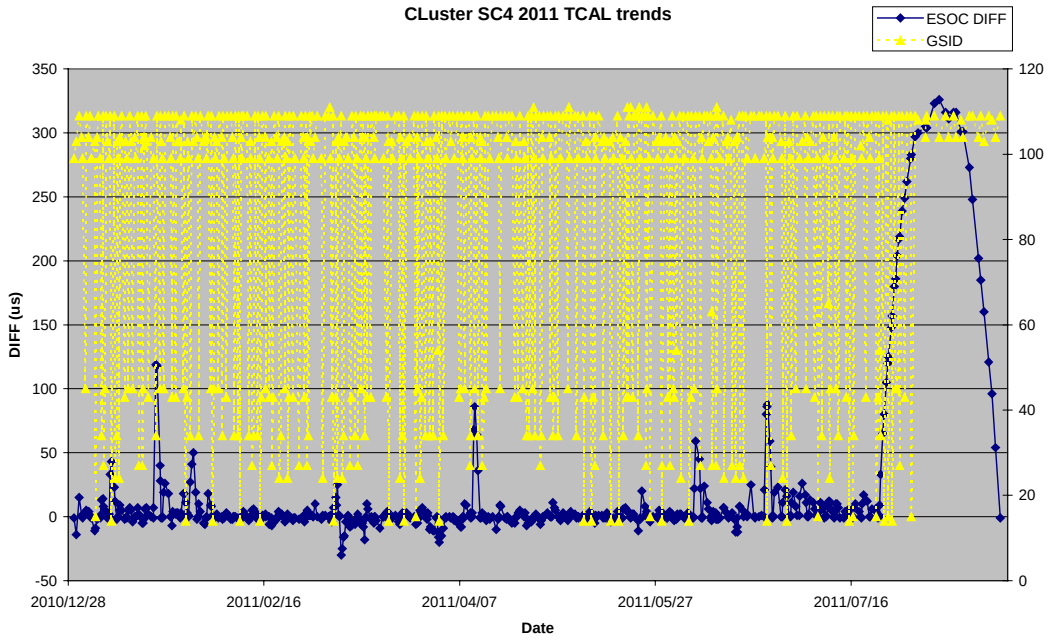
3.7 Validation using 'tcaltrend'

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. All available WBD diffs are merged with the ESOC DIFFs to make the trend plots, not just those used in the final TCOR production.







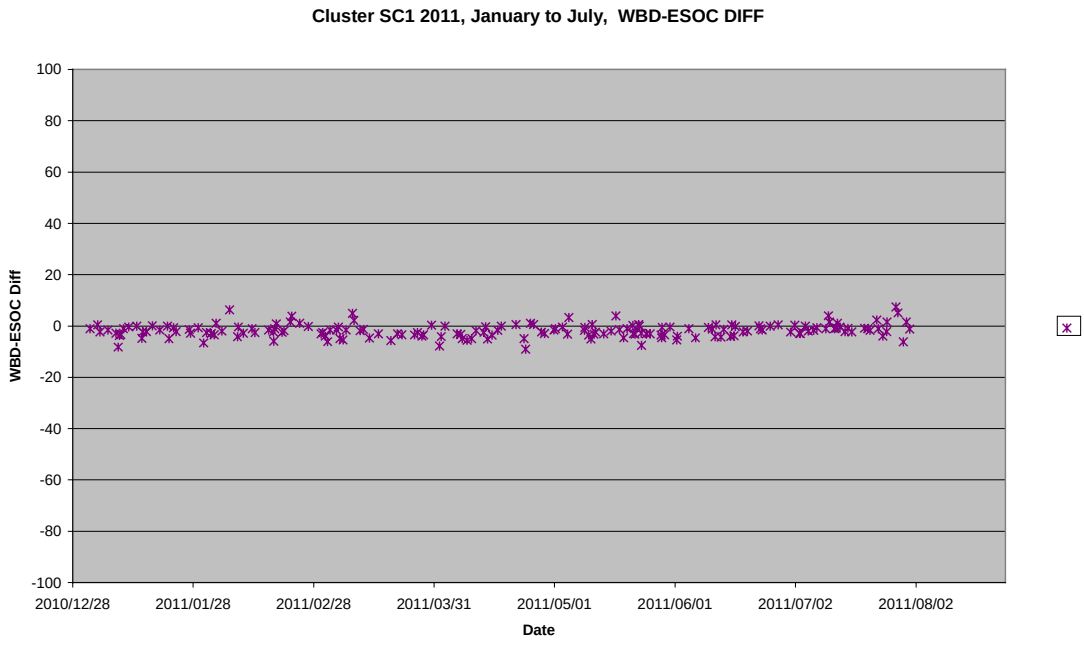


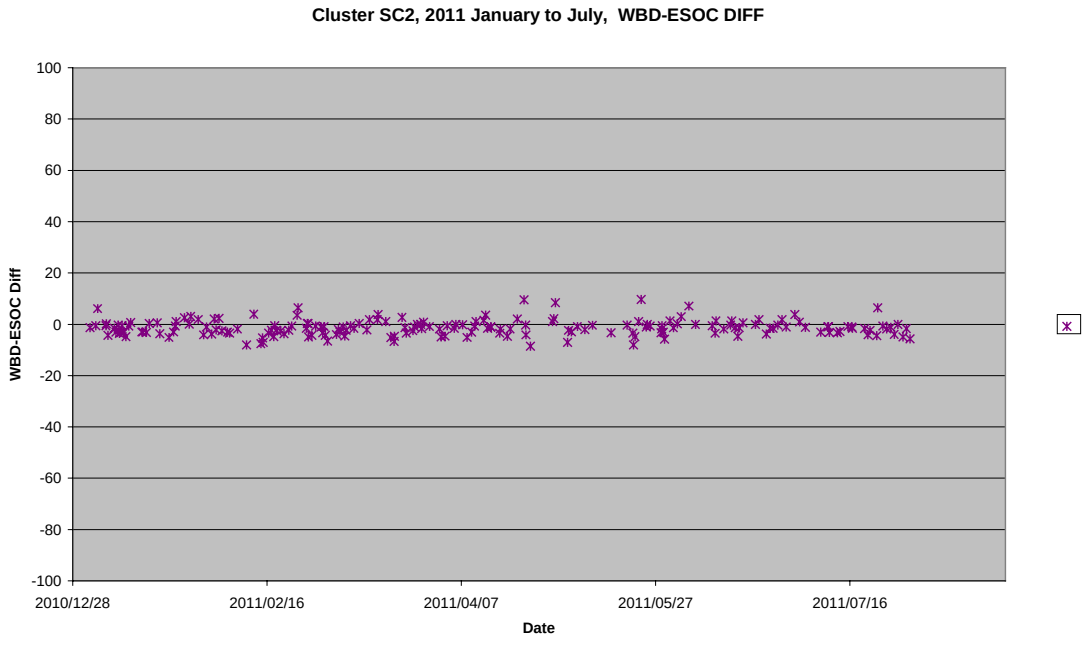
3.8 Validation using 'wbdtcor'

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.

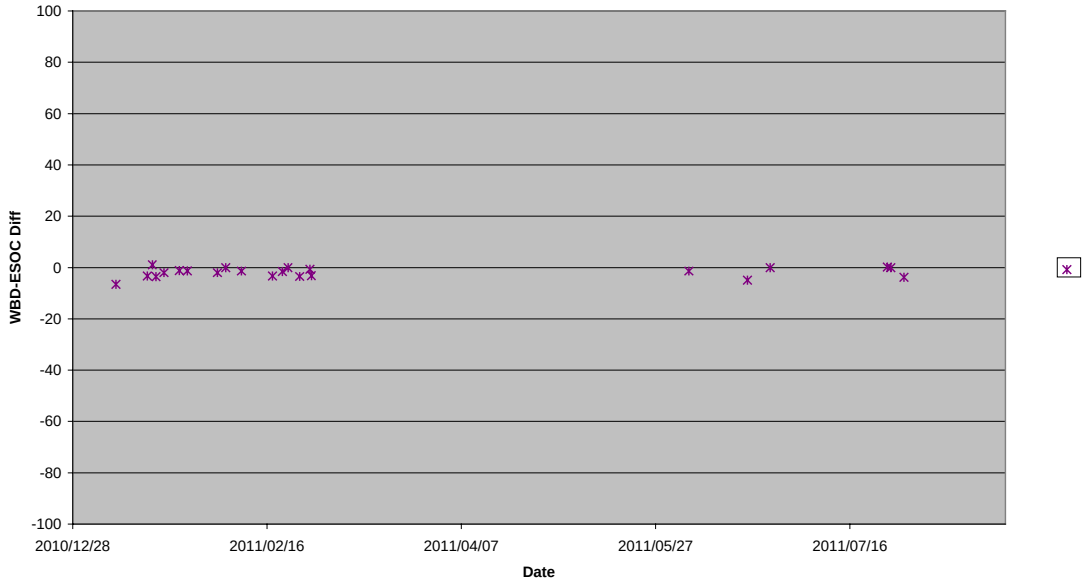
In the following plots it can be seen that the differences are usually well under 10µs (standard deviation 1.9 to 3.1µs), which provides a general confidence in the quality of the measurements. However, it should be noted that any WBD point with a difference more than 10µs, and more than 8 hours (0.1 for C4) from any other measurement, will have been inserted into merged DIFF making the difference zero. The number of points inserted are given in the table below, and range from 1.6 to 14% of the total. Also there may be long periods with no WBD DIFF measurement, particularly on SC3.

SC	WBD inserted	Total WBD points	STDEV (us)
1	3	177	2.54
2	3	193	3.01
3	3	22	1.89
4	8	184	3.11

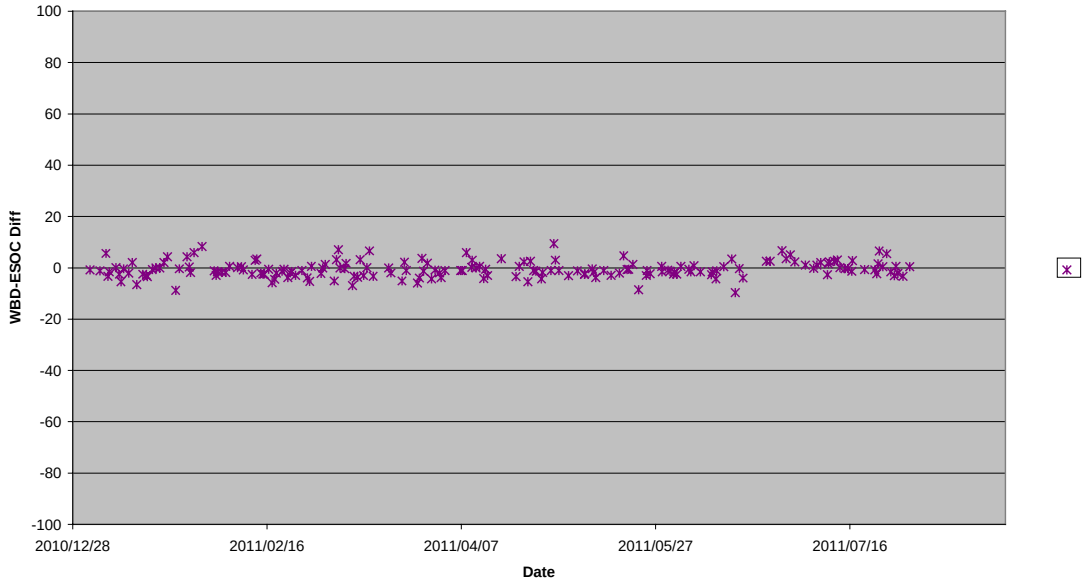




Cluster SC3, 2011 January to July, WBD-ESOC DIFF



Cluster SC4 2011, January to July, 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:

```
hoodie% ../maketcor5 -o 1101_1_tcor.txt -d 1101_1_diffmer.txt \
  -f 11_1_shla_files.txt -s 110101 -e 110731 -w 1101_1_wbddiff.txt
# MAKETCOR, version 5.3
#
# DIFF FILE: 1101_1_diffmer.txt
# File list: 11_1_shla_files.txt (la)
# 635 TCAL records processed.
# File list: 11_1_shla_files.txt (hk)
# First record: 2011/01/01 00:00:00.000000
# Last record:  2011/07/31 23:59:59.000000
# Total proc:    3296419 formats,  100.0%
# WEC on:        3019724 formats,   91.6%
# Done:          3078832 formats,   93.4%
# No diff:        135767 formats,    4.1%
# Non constant:        0 formats,    0.0%
# No offset:       36196 formats,    1.1%
# Outside:         43760 formats,    1.3%
# Missing:          1864 formats,    0.1%
```

```
hoodie% ../maketcor5 -o 1101_2_tcor.txt -d 1101_2_diffmer.txt \
  -f 11_2_shla_files.txt -s 110101 -e 110731 -w 1101_2_wbddiff.txt
# MAKETCOR, version 5.3
#
# DIFF FILE: 1101_2_diffmer.txt
# File list: 11_2_shla_files.txt (la)
# 349 TCAL records processed.
# File list: 11_2_shla_files.txt (hk)
# First record: 2011/01/01 00:00:00.000000
# Last record:  2011/07/31 23:59:59.000000
# Total proc:    3556641 formats,  100.0%
# WEC on:        3285307 formats,   92.4%
# Done:          3405718 formats,   95.8%
# No diff:         39447 formats,    1.1%
# Non constant:     7558 formats,    0.2%
# No offset:       54533 formats,    1.5%
# Outside:         48968 formats,    1.4%
# Missing:           417 formats,    0.0%
```

```
hoodie% ../maketcor5 -o 1101_3_tcor.txt -d 1101_3_diffmer.txt \
  -f 11_3_shla_files.txt -s 110101 -e 110731 -w 1101_3_wbddiff.txt
# MAKETCOR, version 5.3
#
# DIFF FILE: 1101_3_diffmer.txt
# File list: 11_3_shla_files.txt (la)
# 622 TCAL records processed.
# File list: 11_3_shla_files.txt (hk)
# First record: 2011/01/01 00:00:00.000000
# Last record:  2011/07/31 23:59:59.000000
# Total proc:    3296482 formats,  100.0%
# WEC on:        1828282 formats,   55.5%
# Done:          2875465 formats,   87.2%
```

```
# No diff:        275721 formats,    8.4%
# Non constant:        0 formats,    0.0%
# No offset:       99096 formats,    3.0%
# Outside:         44332 formats,    1.3%
# Missing:          1868 formats,    0.1%
```

```
hoodie% ../maketcor5 -o 1101_4_tcor.txt -d 1101_4_diffmer.txt \
  -f 11_4_shla_files.txt -s 110101 -e 110731 -w 1101_4_wbddiff.txt
# MAKETCOR, version 5.3
#
# DIFF FILE: 1101_4_diffmer.txt
# File list: 11_4_shla_files.txt (la)
# 607 TCAL records processed.
# File list: 11_4_shla_files.txt (hk)
# First record: 2011/01/01 00:00:00.000000
# Last record:  2011/07/31 23:59:59.000000
# Total proc:    3269289 formats,  100.0%
# WEC on:        3017590 formats,   92.3%
# Done:          3071902 formats,   94.0%
# No diff:        126961 formats,    3.9%
# Non constant:      245 formats,    0.0%
# No offset:       22432 formats,    0.7%
# Outside:         46003 formats,    1.4%
# Missing:          1746 formats,    0.1%
```

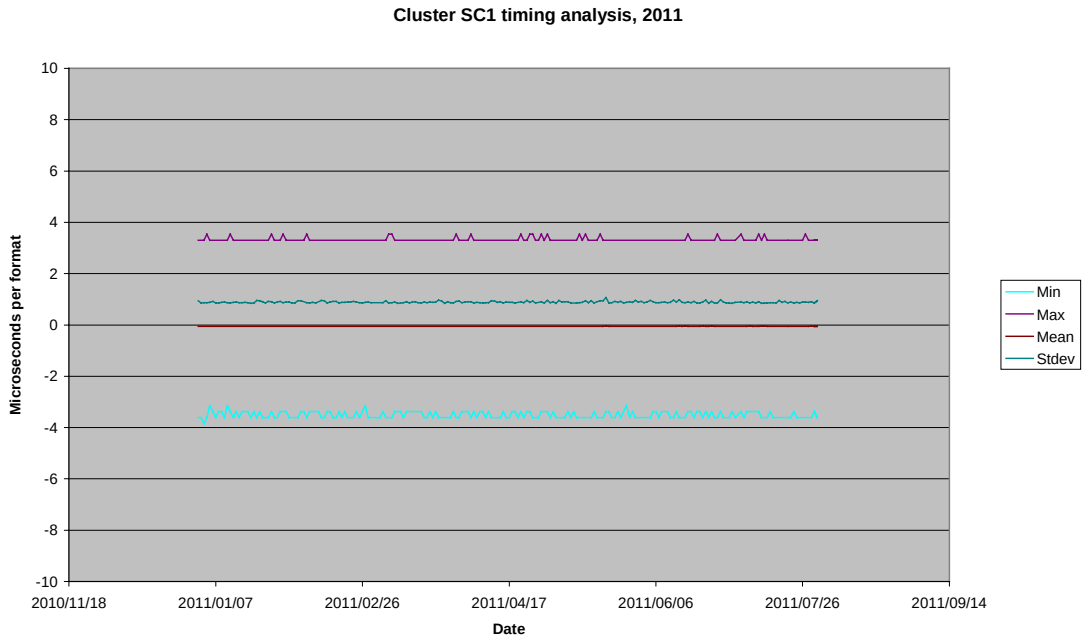
5 Validation of the TCOR files

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.

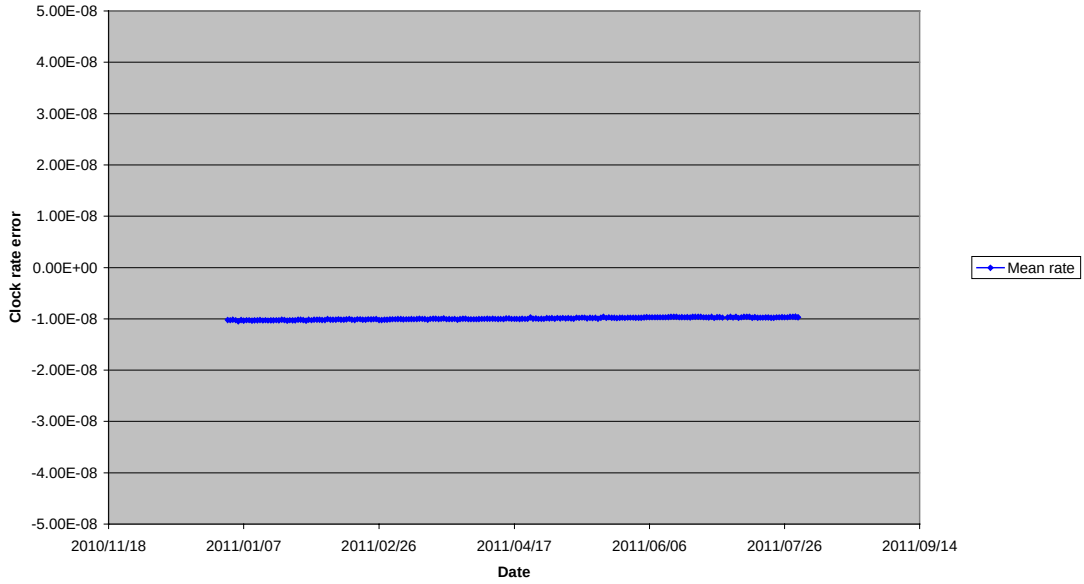
Further validation of the TCOR files is performed by generating version 0 CEF files, using these to apply time corrections, then analysing the time tags of the corrected data. The time tags are analysed using ‘veritcor’. This takes the time increment between each pair of records in the file, subtracts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

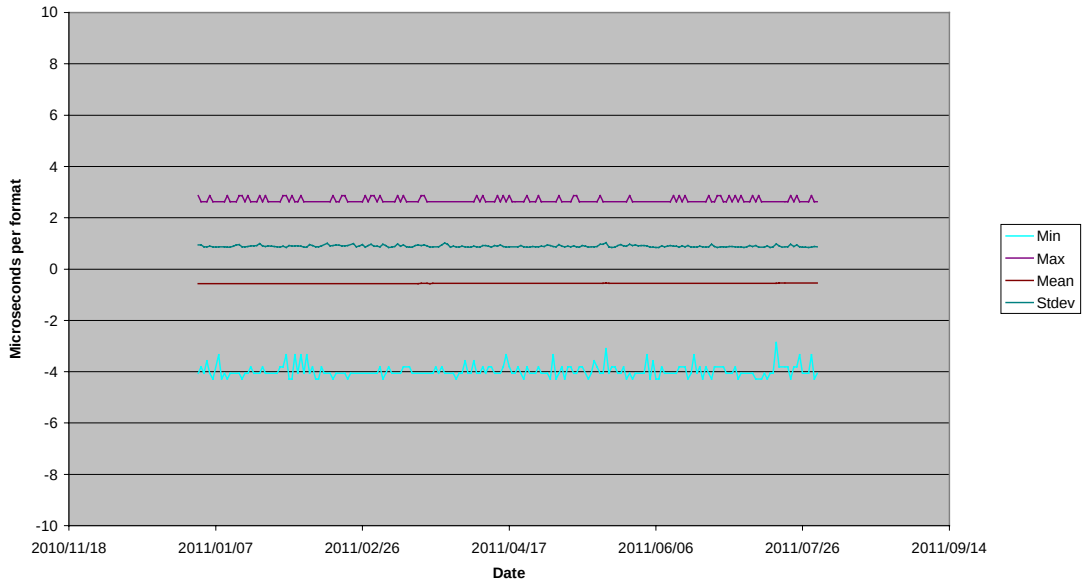
ASCII TCOR files for C1 and C3 were manually modified to remove jumps apparently due to incorrect tracking of the VC0 phase. the modified files were called `1101_1_tcor_v2.txt` and `1101_3_tcor_v2.txt`.



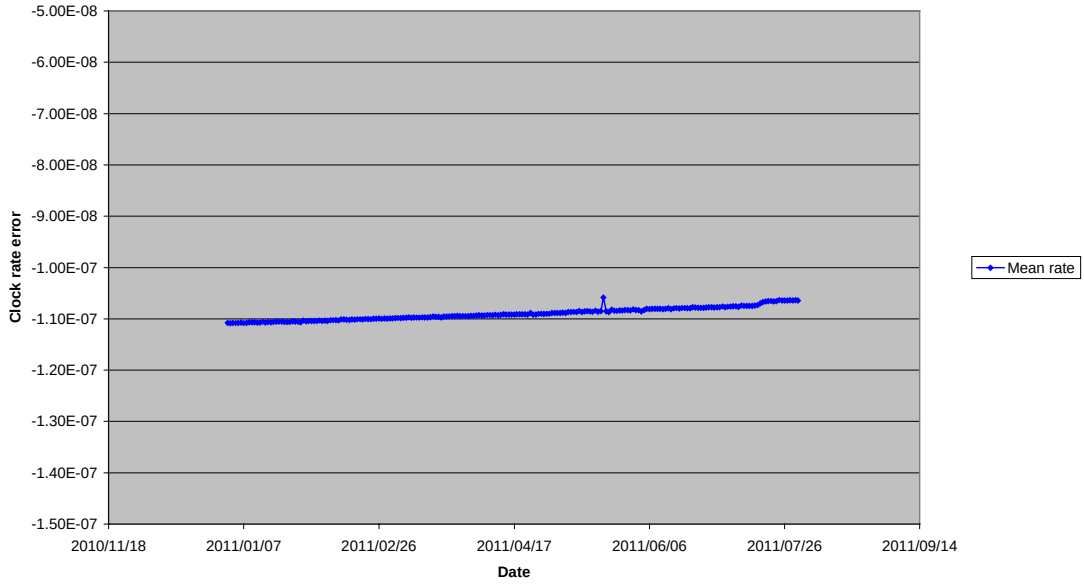
Cluster SC1 clock rate error, 2010



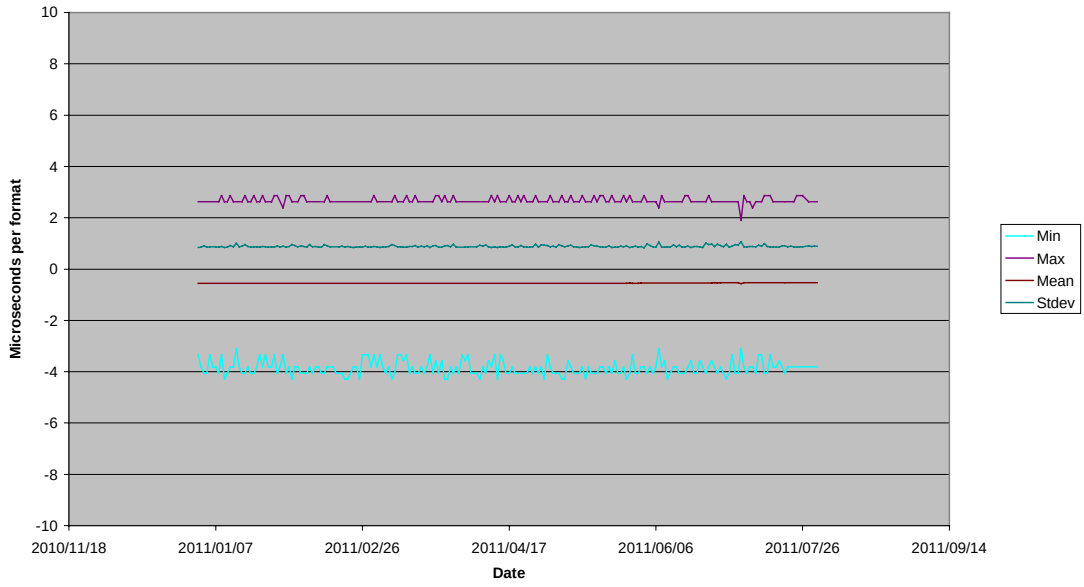
Cluster SC2 timing analysis, 2011



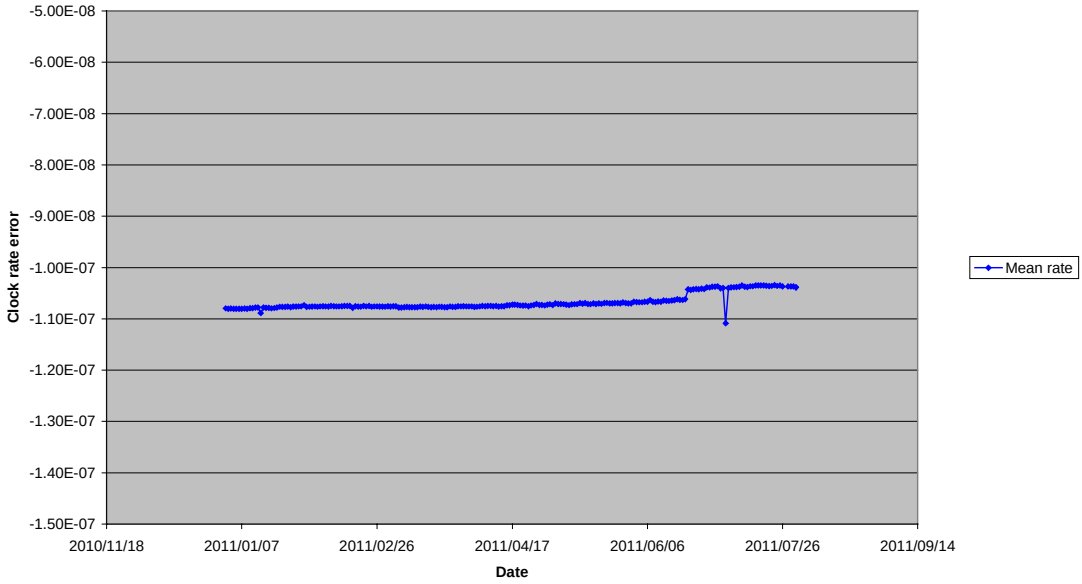
Cluster SC2 clock rate error, 2011



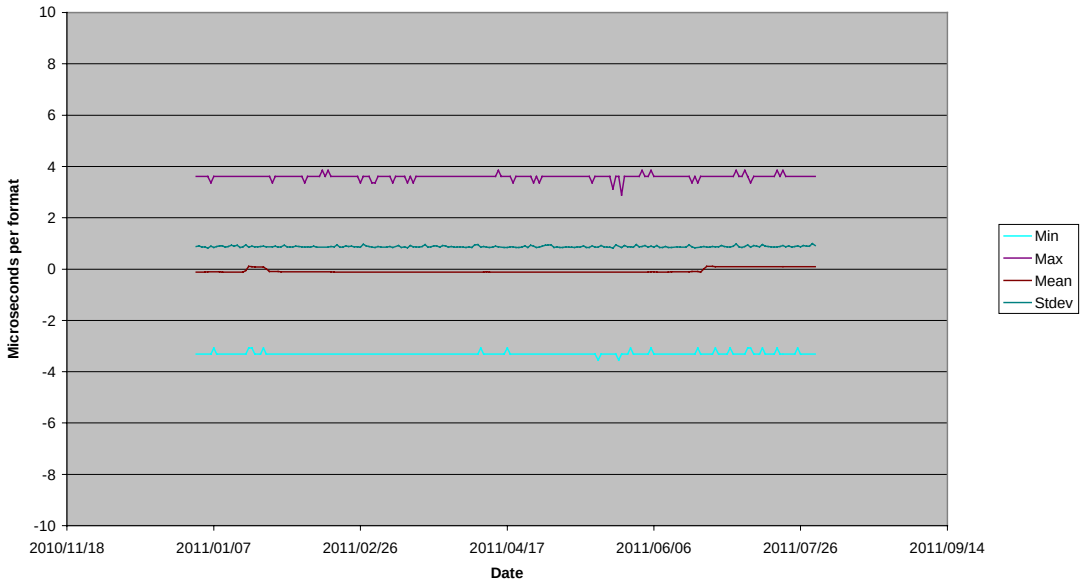
Cluster SC3 timing analysis, 2011

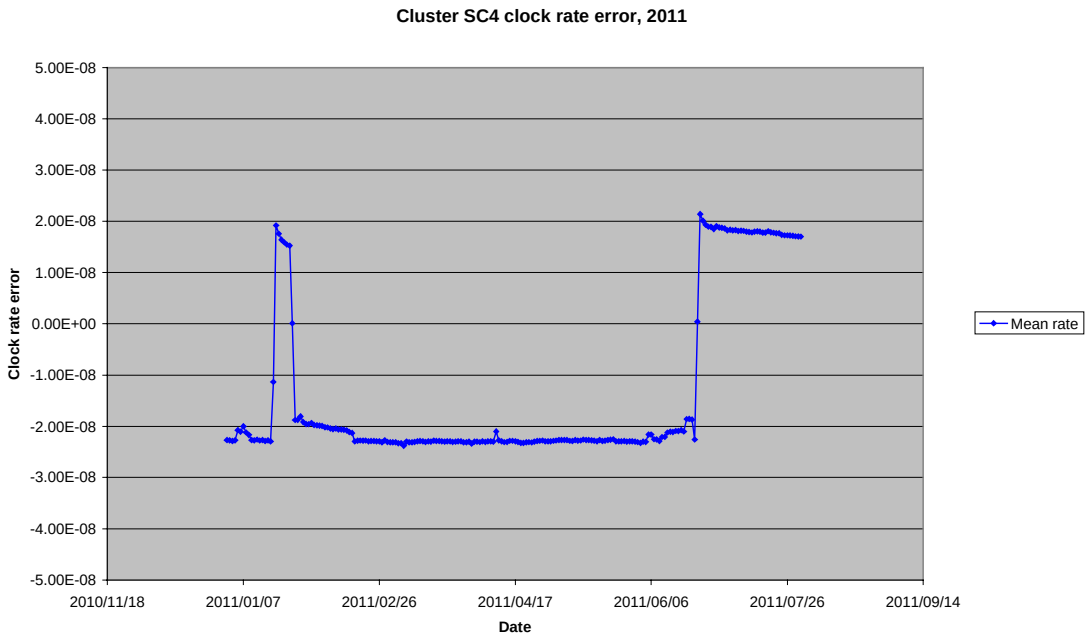


Cluster SC3 clock rate error, 2011



Cluster SC4 timing analysis, 2011




Cluster SC4 clock rate error, 2011
5.00E-08
4.00E-08
3.00E-08
2.00E-08
1.00E-08
0.00E+00
-1.00E-08
-2.00E-08
-3.00E-08
-4.00E-08
-5.00E-08
Clock rate error
2010/11/18
2011/01/07
2011/02/26
2011/04/17
2011/06/06
2011/07/26
2011/09/14
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 1101_1_tcor_v2.txt -v 01
../tcor2cef -t 1101_2_tcor.txt -v 01
../tcor2cef -t 1101_3_tcor_v2.txt -v 01
../tcor2cef -t 1101_4_tcor.txt -v 01
```

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__20110101_V00.cef \
     C1_CP_DWP_TCOR__20110101_V01.cef
diff C2_CP_DWP_TCOR__20110101_V00.cef \
     C2_CP_DWP_TCOR__20110101_V01.cef
diff C3_CP_DWP_TCOR__20110101_V00.cef \
     C3_CP_DWP_TCOR__20110101_V01.cef
diff C4_CP_DWP_TCOR__20110101_V00.cef \
     C4_CP_DWP_TCOR__20110101_V01.cef
```

Finally, the CEF files are checked using CEFpass.

```
setenv CEFPATH ~/CAA/headers
~/CAAtools/CEFpass C1_CP_DWP_TCOR__20110101_V01.cef
~/CAAtools/CEFpass C2_CP_DWP_TCOR__20110101_V01.cef
~/CAAtools/CEFpass C3_CP_DWP_TCOR__20110101_V01.cef
~/CAAtools/CEFpass C4_CP_DWP_TCOR__20110101_V01.cef
```

7 Caveats

The following general caveats apply to 2011 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.