Preparation and validation of WEC time corrections 2007-01-01 to 2007-11-23

Keith Yearby, 16 July 2008

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 most of year 2007. In this case, all files were compiled in one batch for the period 2007-01-01 to 2007-11-23. After this period a new operational procedure was used at ESOC, where time correlations were performed during each nominal pass. This in turn requires a new procedure to prepare the time corrections.

2 Data and references

Source data:

ESOC DIFF measurements for 2007.
WBD data DVDs for 2007.
Cluster RDM for 2007.

Documents:

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

Software:

wbddiff, version 1.0, 2004-06-11
maketcor3, version 3.8, 2008-03-20
veritcor, version 1.3, 2005-07-19
tcor2cef, version 1.6, 2006-03-02

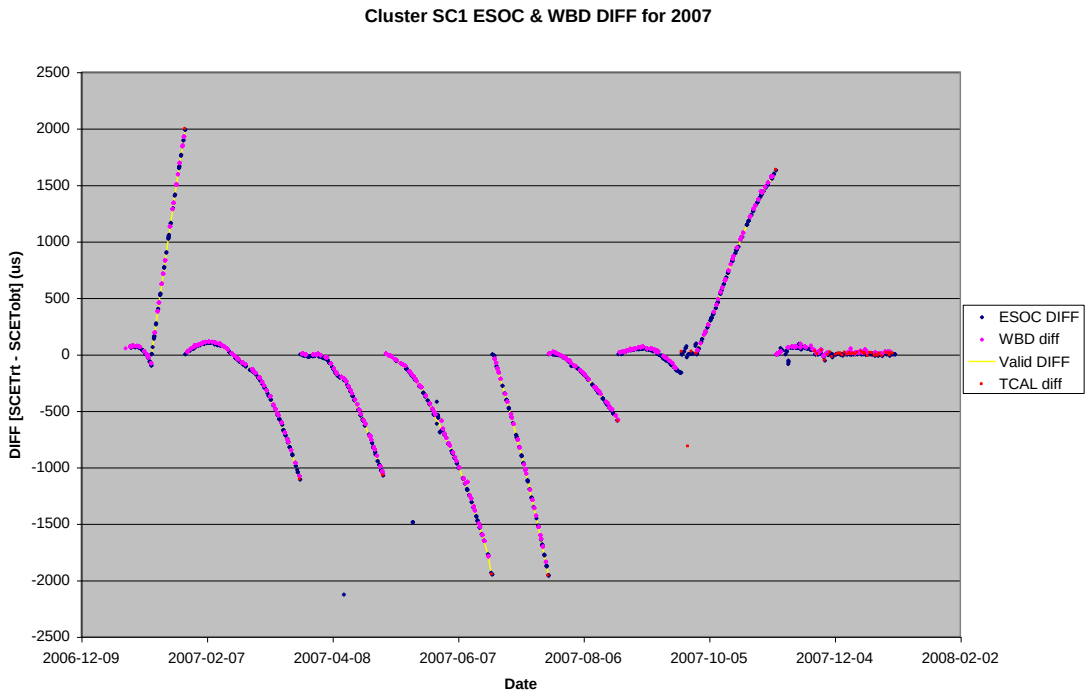
3 Preparation of the Point Valid DIFF measurements

The ESOC and WBD DIFF measurements are sometimes subject to errors so must be validated before use. The strategy used here is to regard the ESOC measurements as the primary measurement, and use the WBD data to validate it.

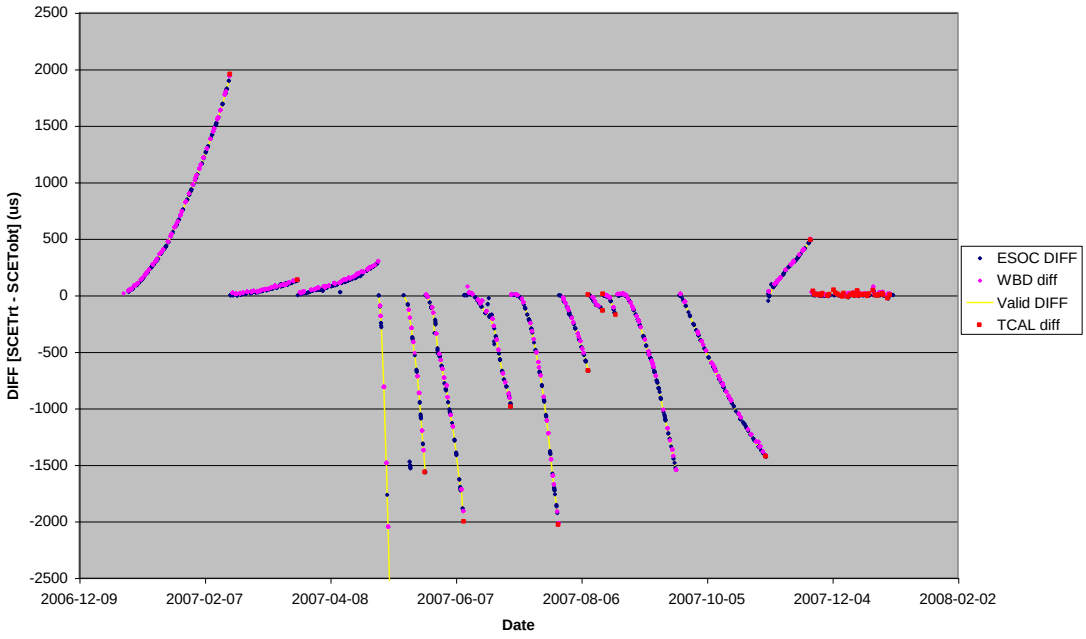
The DIFF measurements received from ESOC for 2007 include the sign, so the procedure used in previous years to determine the sign is no longer needed.

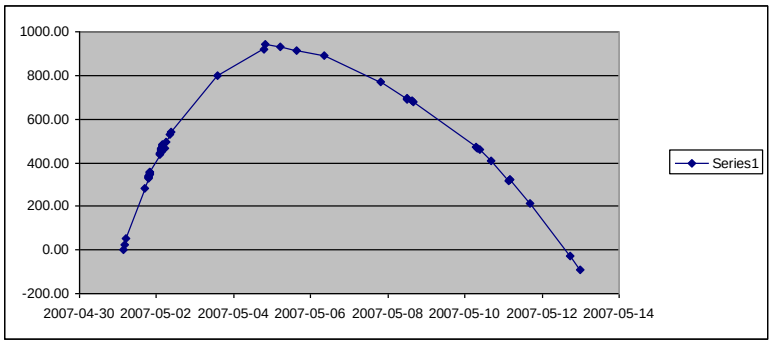
The ESOC and WBD data are copied into Excel worksheets. A duplicate is made of the ESOC data which will become the final validated data. A chart (XY scatter) is then produced, plotting points only for the raw ESOC and WBD data, and a line for the validated data.

It is fairly clear which points have large errors and these are simply deleted from the validated data worksheet. The following charts show the data for the four spacecraft. In some cases, where the rate of change of DIFF was very large, supplementary charts with the linear component removed were drawn. These allow any discontinuities to be more easily identified.

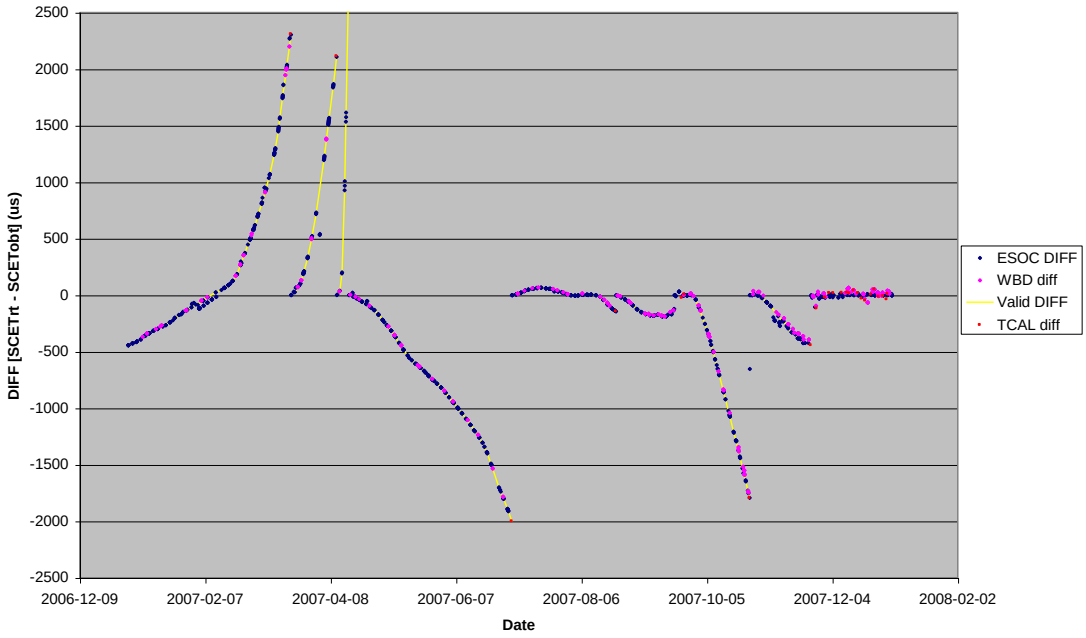


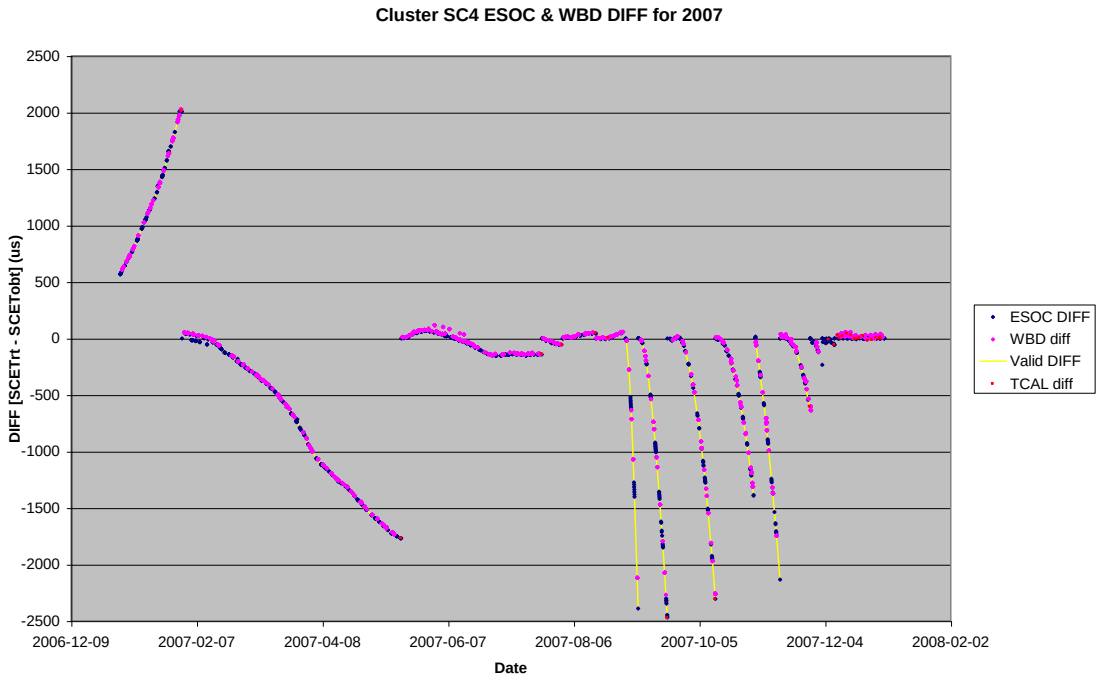
Cluster SC2 ESOC & WBD DIFF for 2007





Cluster SC3 ESOC & WBD DIFF for 2007





The final validated DIFF measurements are saved in Text (space delimited) format using the default .prn file name extension.

Once the valid ESOC data is selected, its accuracy is checked by comparing each WBD measurement with a linear interpolation between the nearest validated ESOC measurements before and after. The average and standard deviation of all measurements were calculated. The standard deviations are again somewhat higher than in previous years - this is probably due to the relatively high rate of change of DIFF and frequent time correlations at times.

SC	Average wbd-esoc (micro-sec)	St Dev wbd-esoc (micro-sec)
1	12.1	7.6
2	12.3	6.4
3	12.9	12.4
4	11.6	10.6

It also appears that there were problems with specific DSN antennae at certain times, specifically DSN 27 from 2007/05/30 to 2007/06/19, and DSN 80 and 81 from 2007/10/20 onwards.

Date/time	SC	SC id.	ANT id.	Delta (WBD-ESOC)(us)
2007/05/30 03:59	1	183	27	71.6
2007/05/31 12:59	4	196	27	65.5
2007/06/04 13:39	4	196	27	72.6
2007/06/07 13:19	4	196	27	68.7
2007/06/11 13:49	1	183	27	75.0
2007/06/12 13:39	4	196	27	66.2
2007/06/14 11:59	4	196	27	67.2
2007/06/19 12:40	2	185	27	61.4
2007/10/20 02:39	4	196	80	37.8
2007/10/20 02:49	3	194	81	37.5
2007/10/22 08:09	3	194	80	52.0
2007/10/22 08:09	4	196	81	36.9
2007/10/22 17:39	3	194	80	48.2

2007/10/22 17:40	4	196	81	37.9
2007/10/27 04:29	4	196	81	33.3
2007/10/27 04:49	3	194	80	32.1
2007/10/29 11:29	4	196	81	33.6
2007/10/29 11:39	3	194	80	31.4
2007/10/29 15:39	2	185	80	40.5
2007/10/29 16:19	2	183	81	41.6
2007/10/29 16:19	1	183	81	41.6
2007/10/29 18:59	3	194	80	32.5
2007/10/31 22:59	3	194	80	31.9
2007/11/03 06:39	4	196	80	35.4
2007/11/05 17:59	4	196	80	43.6
2007/11/05 22:39	4	196	81	43.1
2007/11/10 20:19	3	194	80	33.8
2007/11/12 20:19	4	196	81	36.8
2007/11/12 20:29	3	194	80	38.4
2007/11/15 03:49	4	196	81	35.4
2007/11/15 03:59	3	194	80	36.7
2007/11/17 11:49	3	194	80	46.2
2007/11/17 14:59	4	196	81	39.1
2007/11/17 15:19	2	183	80	30.9
2007/11/17 15:19	1	183	80	30.9
2007/11/17 16:39	4	196	80	40.4
2007/11/17 17:39	3	194	81	44.9
2007/11/17 22:19	4	196	80	43.1
2007/11/19 23:19	4	196	81	35.8
2007/11/19 23:29	3	194	80	60.2
2007/11/22 15:19	2	183	80	30.4
2007/11/22 15:19	1	183	80	30.4
2007/11/22 17:59	3	194	81	35.1
2007/11/24 16:19	4	196	81	38.0
2007/11/24 21:59	4	196	81	62.8

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.A list of the full path names of all HK and TCAL files for each spacecraft, for the whole year, is obtained using the Unix 'find' command, and various greps, and sorts. The individual lists must be in chronological order. They are written to files named like 07_*s*_hkla_files.txt.

The following commands were used:

```
find /data/disk2/cluster/RDM/07* -name '*wh*' > scr.scr
find /data/disk2/cluster/RDM/07* -name '*la*' >> scr.scr
~/CAA/weclog/purgedup scr.scr 07_hkla_files.txt
grep cluster1 07_hkla_files.txt | sort > 07_1_hkla_files.txt
grep cluster2 07_hkla_files.txt | sort > 07_2_hkla_files.txt
grep cluster3 07_hkla_files.txt | sort > 07_3_hkla_files.txt
grep cluster4 07_hkla_files.txt | sort > 07_4_hkla_files.txt
```

Then maketcor3 is used to generate the ASCII TCOR files.

```
../maketcor3.8 -d 07_1_diff.prn -f 07_1_hkla_files.txt \
   -s 070101 -e 071131 -w ../wbd/wbd_all_c1_ncd.txt > 07_1_tcor.txt
../maketcor3.8 -d 07_2_diff.prn -f 07_2_hkla_files.txt \
   -s 070101 -e 071131 -w ../wbd/wbd_all_c2_ncd.txt > 07_2_tcor.txt
etc.
```

Readtcal was also used to obtain a list of all time correlations, including the DIFF just prior to each new time correlation.

```
../readtcal -f 07_1_hkla_files.txt > 07_1_new_tcal.txt
../readtcal -f 07_2_hkla_files.txt > 07_2_new_tcal.txt
../readtcal -f 07_3_hkla_files.txt > 07_3_new_tcal.txt
../readtcal -f 07_4_hkla_files.txt > 07_4_new_tcal.txt
```

5 Validation of the TCOR files

The software tool ‘maketcor3’ performs some automatic validation as the files are produced. Data that fails automatic validation are not included in the output files.

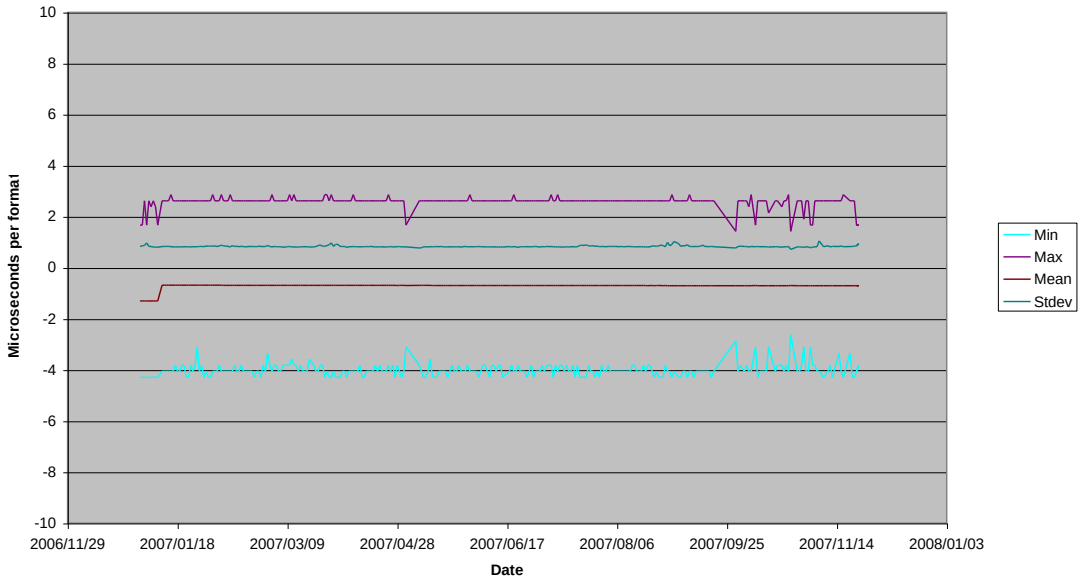
Further validation of the TCOR files is performed by generating version 0 CEF files, using these to apply time corrections, then analysing the time tags of the corrected data. Anomalies identified in the corrected data may then be related to errors noted in the TCOR file comments, and the TCOR records deleted or corrected. The process is then repeated until no anomalies are found. Comments in the ASCII TCOR files indicate where such corrections have been made.

The time tags are analysed using ‘veritcor’. This takes the time increment between each pair of records in the file, subtracts the nominal value of 5.15222168 seconds, and accumulates the minimum, maximum, mean and standard deviation over each 24 hour period. On SC1 and SC3 it is known that time jumps of -125.9 us 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.

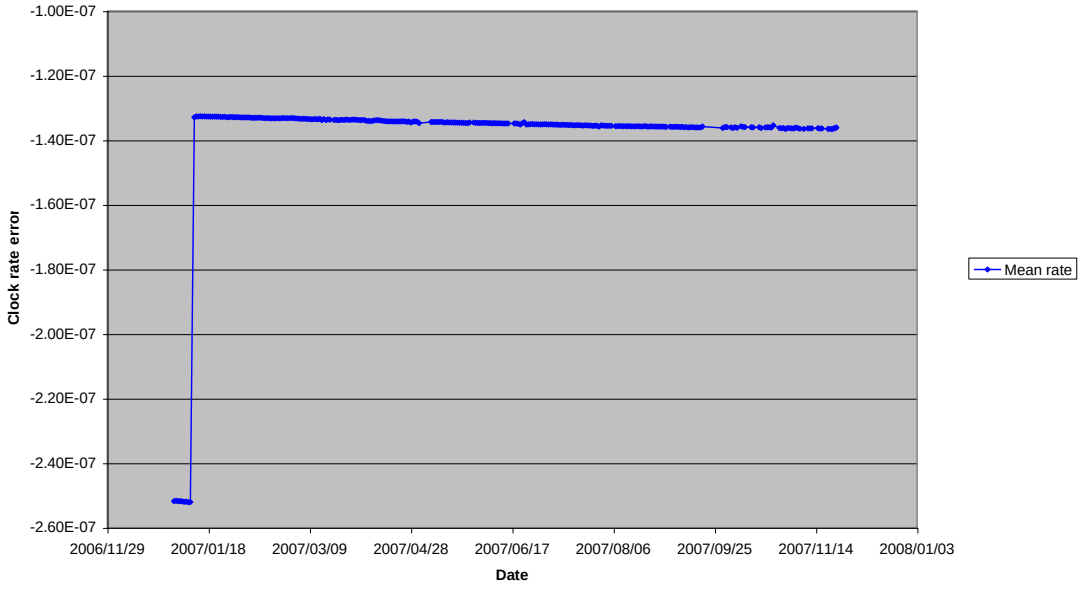
It uses the same HK+TCAL file list file as 'maketcor3', although only the HK files are used. 'veritcor' includes the same code module used by TED to apply the TCOR corrections, and requires CEF TCOR files to be installed with the same index files. The '-T .' option specifies that the TCOR files (and the index files) are located in the default directory.

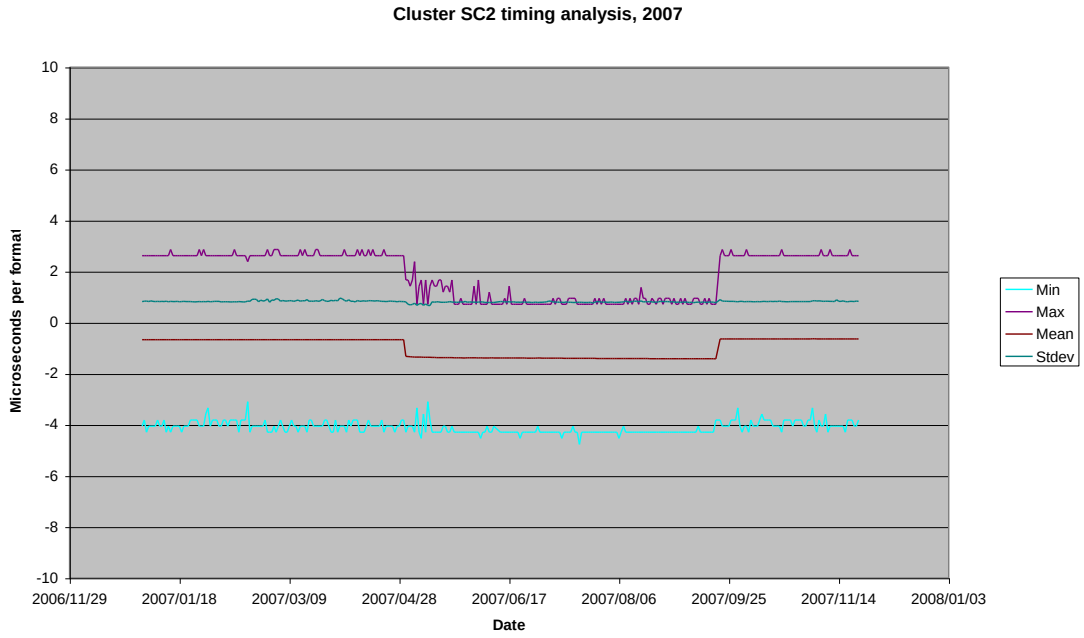
```
../tcor2cef -t 07_1_tcor.txt
...
../veritcor -f 07_3_hkla_files.txt -T . -v 4 > 07_3_veritcor.txt
../veritcor -f 07_4_hkla_files.txt -T . -v 4 > 07_4_veritcor.txt
```

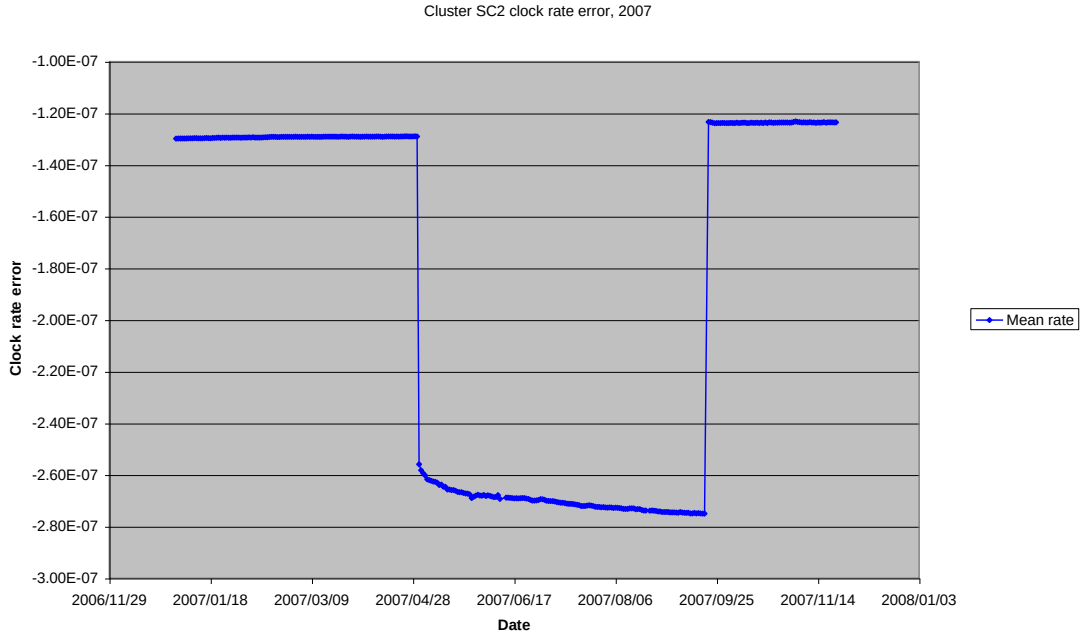
Cluster SC1 timing analysis, 2007



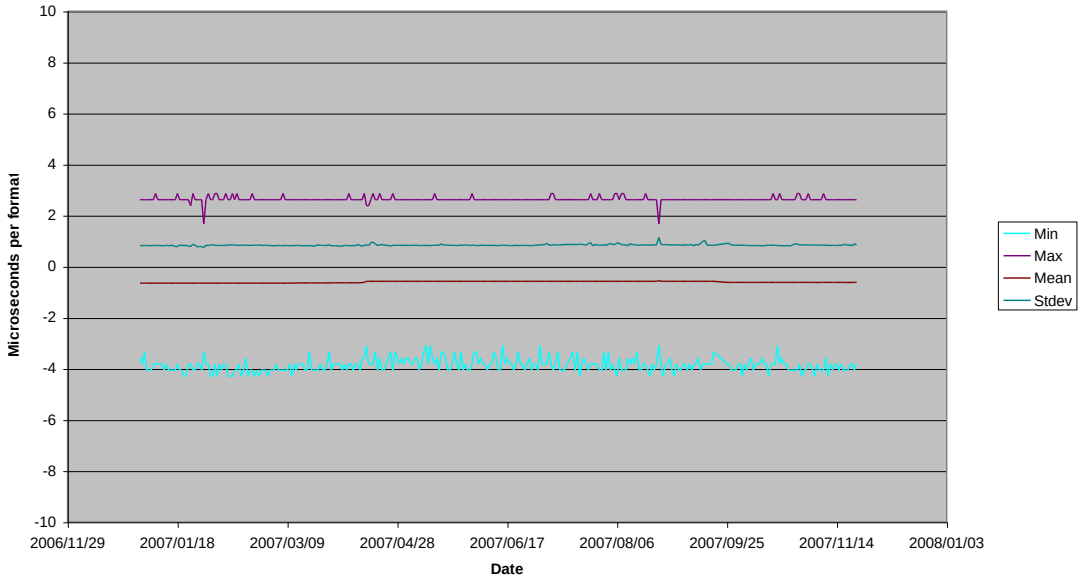
Cluster SC1 clock rate error, 2007



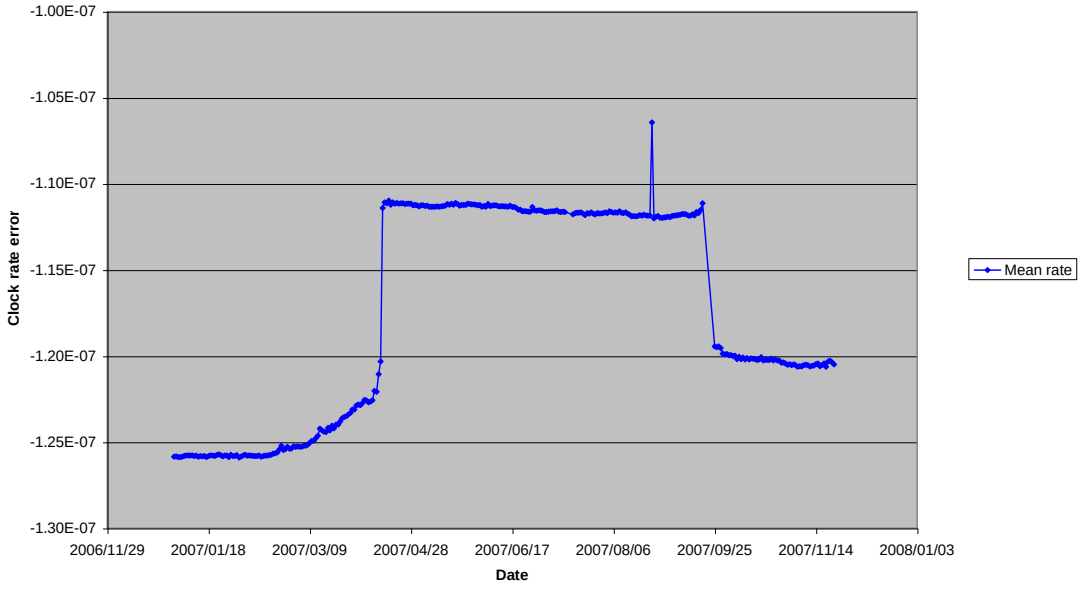

Cluster SC2 timing analysis, 2007
Microseconds per format
10
8
6
4
2
0
-2
-4
-6
-8
-10
2006/11/29
2007/01/18
2007/03/09
2007/04/28
2007/06/17
2007/08/06
2007/09/25
2007/11/14
2008/01/03
Date
Min
Max
Mean
Stdev

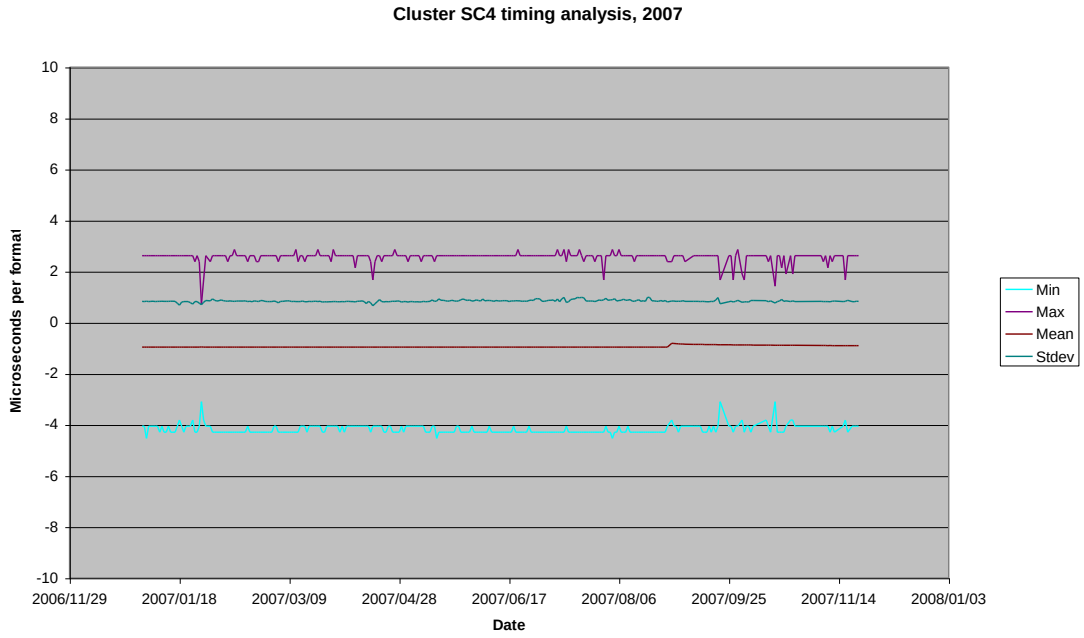

Cluster SC2 clock rate error, 2007
Clock rate error
-1.00E-07
-1.20E-07
-1.40E-07
-1.60E-07
-1.80E-07
-2.00E-07
-2.20E-07
-2.40E-07
-2.60E-07
-2.80E-07
-3.00E-07
2006/11/29
2007/01/18
2007/03/09
2007/04/28
2007/06/17
2007/08/06
2007/09/25
2007/11/14
2008/01/03
Date
Mean rate

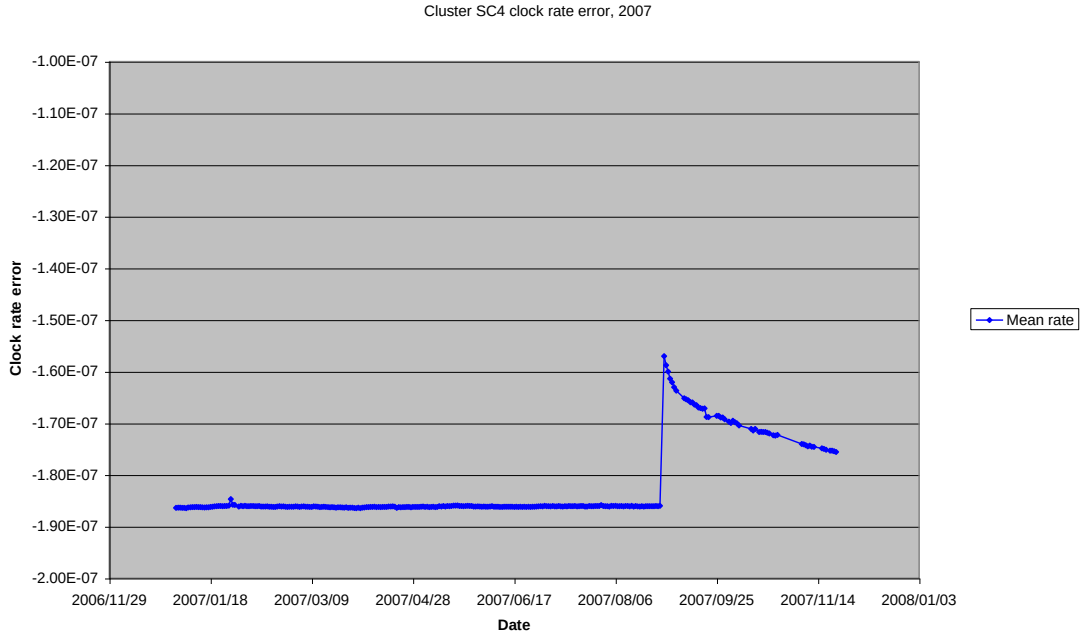
Cluster SC3 timing analysis, 2007



Cluster SC3 clock rate error, 2007




Cluster SC4 timing analysis, 2007
Microseconds per format
10
8
6
4
2
0
-2
-4
-6
-8
-10
2006/11/29
2007/01/18
2007/03/09
2007/04/28
2007/06/17
2007/08/06
2007/09/25
2007/11/14
2008/01/03
Date
Min
Max
Mean
Stdev


Cluster SC4 clock rate error, 2007
Clock rate error
-1.00E-07
-1.10E-07
-1.20E-07
-1.30E-07
-1.40E-07
-1.50E-07
-1.60E-07
-1.70E-07
-1.80E-07
-1.90E-07
-2.00E-07
2006/11/29
2007/01/18
2007/03/09
2007/04/28
2007/06/17
2007/08/06
2007/09/25
2007/11/14
2008/01/03
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. 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.

The CEF file name is generated automatically using information contained in the file (except for the version number which is specified). Note that the date included in the name is the date of the first data actually present in the file, which may not be the same as the start of the nominal period covered by the file.

```
hoodie% ../tcor2cef -t 07_1_tcor.txt -v 1
TCOR2CEF, version 1.6

TCOR file:          07_1_tcor.txt, s/c: 1, records: 1514
Generated CEF name: C1_CP_DWP_TCOR__20070101_V01
Time range:         2007-01-01T18:00:26Z/2007-11-24T16:49:15Z
Finished, CEF size: 171930 bytes
Total duration:     28248529 seconds
Corrected:          22194981 seconds (78.6 %)
hoodie% ../tcor2cef -t 07_2_tcor.txt -v 1
TCOR2CEF, version 1.6

TCOR file:          07_2_tcor.txt, s/c: 2, records: 1779
Generated CEF name: C2_CP_DWP_TCOR__20070101_V01
Time range:         2007-01-01T14:00:26Z/2007-11-23T17:00:25Z
Finished, CEF size: 199763 bytes
Total duration:     28177199 seconds
Corrected:          26132651 seconds (92.7 %)
hoodie% ../tcor2cef -t 07_3_tcor.txt -v 1
TCOR2CEF, version 1.6

TCOR file:          07_3_tcor.txt, s/c: 3, records: 1450
Generated CEF name: C3_CP_DWP_TCOR__20070101_V01
Time range:         2007-01-01T04:00:25Z/2007-11-23T18:27:43Z
Finished, CEF size: 164028 bytes
Total duration:     28218438 seconds
Corrected:          26017151 seconds (92.2 %)
hoodie% ../tcor2cef -t 07_4_tcor.txt -v 1
TCOR2CEF, version 1.6

TCOR file:          07_4_tcor.txt, s/c: 4, records: 1548
Generated CEF name: C4_CP_DWP_TCOR__20070101_V01
Time range:         2007-01-01T10:00:30Z/2007-11-26T18:35:57Z
Finished, CEF size: 174592 bytes
Total duration:     28456527 seconds
Corrected:          22703576 seconds (79.8 %)
hoodie%
```

Finally, the CEF files are checked using CEFpass.

```
setenv CEFPATH ~/CAA/headers
~/CAAtools/CEFpass C1_CP_DWP_TCOR__20070101_V01.cef
~/CAAtools/CEFpass C2_CP_DWP_TCOR__20070101_V01.cef
~/CAAtools/CEFpass C4_CP_DWP_TCOR__20070101_V01.cef
~/CAAtools/CEFpass C3_CP_DWP_TCOR__20070101_V01.cef
```

7 Caveats

The following general caveats apply to year 2007 TCOR data (to 2007-11-23):

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 simply deleted from the files. For 2007, TCOR coverage is typically around 80 to 90%. Gaps are mainly around the times when a new time correlation is performed.

In the 2 days or so prior to a new time correlation, it is not certain whether the old or new time correlation applies to a particular period of data. Incorrect determination of which time correlation was used could result in an error of 2ms or more in the corrected time. In most cases, data in error will have been removed during validation, but there is a small chance some may remain.

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.