Preparation and validation of WEC time corrections 2012

Keith Yearby, 21 February 2013

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 2012. The procedure used is the same as for 2009 to 2011, however the main production software now runs on an iMac. Note that this year, all instruments were off for the whole duration of the long eclipse season, that is 22 July to 7 August inclusive. No time corrections have been prepared for this period.

2 Data and references

Source data:

WBD online level one data.
Cluster RDM for 2012.

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	5.4	2012-01-23
veritcor	1.13	2012-02-22
tcorcomp	1.4	2012-02-23
tcor2cef	1.8	2012-01-26
diffmer	1.4	2010-06-24

RDM file lists:

File name	Last modified date
12_1_shla_files.txt	2013-01-19 16:49
12_2_shla_files.txt	2013-01-19 16:49
12_3_shla_files.txt	2013-01-19 16:49
12_4_shla_files.txt	2013-01-19 16:49

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 (validated ESOC):

File name	Last modified date
12_1_tcaldiff_v.txt	2013-02-06 14:15
12_2_tcaldiff_v.txt	2013-02-07 13:37
12_3_tcaldiff_v.txt	2013-02-07 13:37
12_4_tcaldiff_v.txt	2013-02-07 13:37

Point Valid DIFF files (validated ESOC merged with WBD):

File name	Last modified date
12_1_diffmer.txt	2013-02-06 14:16
12_2_diffmer.txt	2013-02-07 13:56
12_3_diffmer.txt	2013-02-07 13:56
12_4_diffmer.txt	2013-02-07 13:56

ASCII TCOR files:

File name	Last modified date
12_1_tcor_v.txt	2013-02-06 15:50
12_2_tcor_v.txt	2013-02-07 16:32
12_3_tcor_v.txt	2013-02-07 15:38
12_4_tcor.txt	2013-02-07 14:11

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 and obtaining the ESOC DIFFs

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. These also include the files for the last two days of 2011 to ensure that time corrections can be calculated for as much as possible of 2012.

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 TCAL summary files (12_*_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 12_*_tcaldiff.txt files contain the ESOC DIFF measurements derived by assuming the DIFF to be zero immediately after each new time correlation.

3.3 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.

3.4 Leap second of 2012-06-30

A positive Leap Second was introduced at the end of June 2012. Coordinated Universal Time (UTC) was retarded by 1.0s so that the sequence of times became:

2012-06-30 23:59:59
2012-06-30 23:59:60
2012-07-01 00:00:00

The Cluster mission operations systems at ESOC are not designed to handle leap seconds and this leads to timing errors of one second during the first day of July. Manual correction for these errors were applied in the files 12_*_tcaldiff_v.txt.

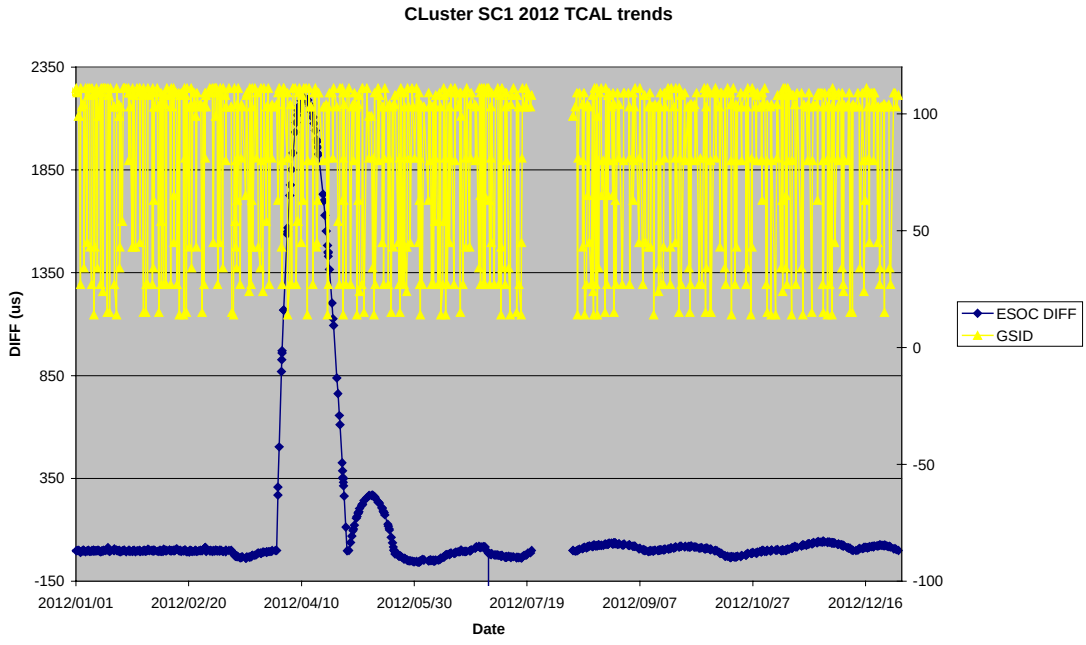
Note that neither TED nor any other software produced by the DWP team can correctly handle leap seconds, that is the time 23:59:60 cannot be represented internally. Using the TCOR time corrections will ensure that the timing is correct in the hours after the leap second. However, times in the immediate vicinity of the leap second (2012-06-30 23:59:54 to 2012-07-01 00:00:05) might still be incorrect by one second.

3.5 Merging of ESOC and WBD DIFFs

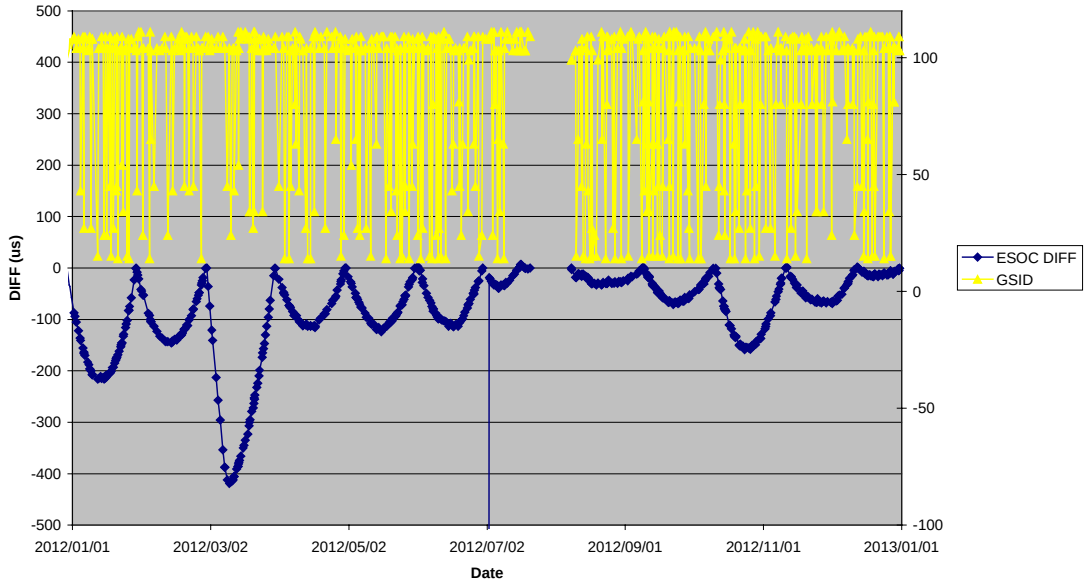
The ESOC and WBD DIFF measurements are merged together. The output files (12_*_diffmer.txt) contain mainly ESOC measurements with WBD points inserted only when they are separated by more than 8 hours in time from the nearest ESOC point, and differ by more than 10µs from a linear interpolation of the ESOC points.

3.6 Validation using 'tcaltrend'

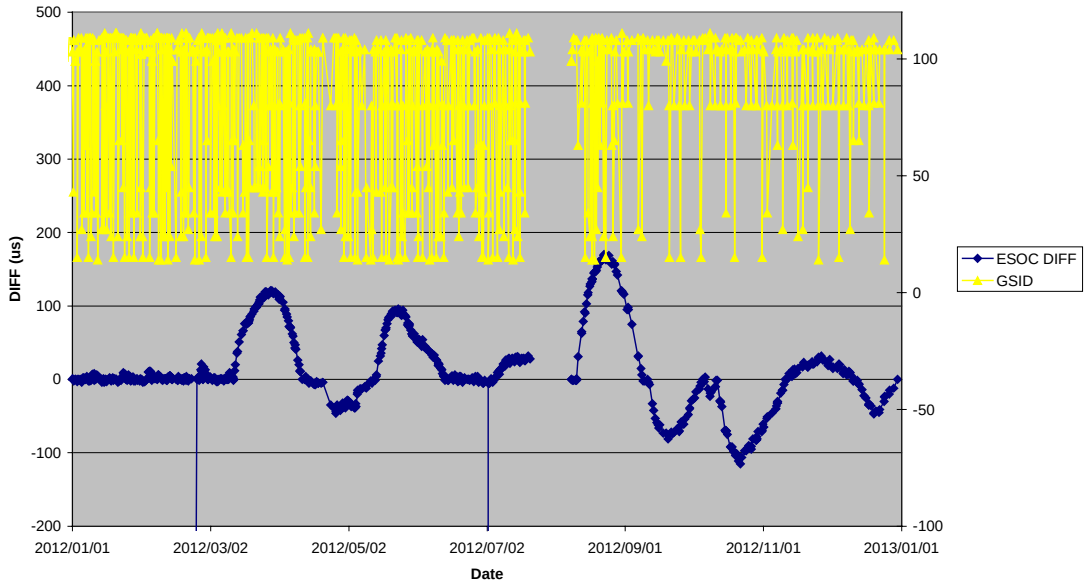
The long term trends of the clock drifts, as measured by the merged ESOC and WBD DIFFs together with the corresponding time calibrations (TCAL) are computed using **'tcaltrend'**. This calculates what the DIFF would be with respect to an optimum time correlation performed at most every 30 days, and allows long term trends in the clock drift to be seen.

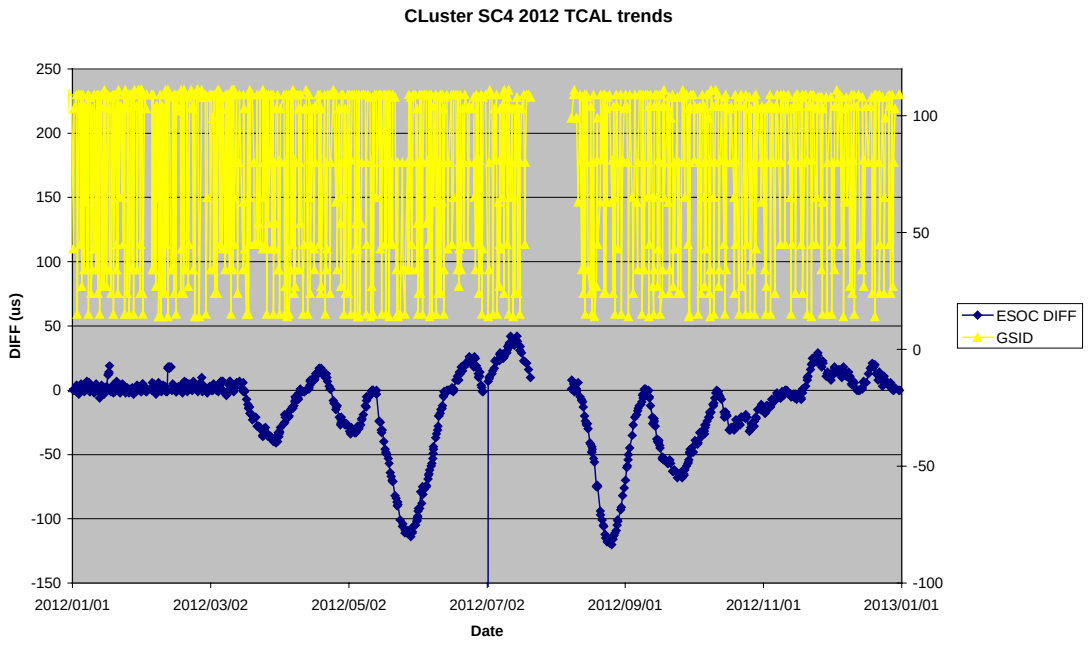


CLuster SC2 2012 TCAL trends



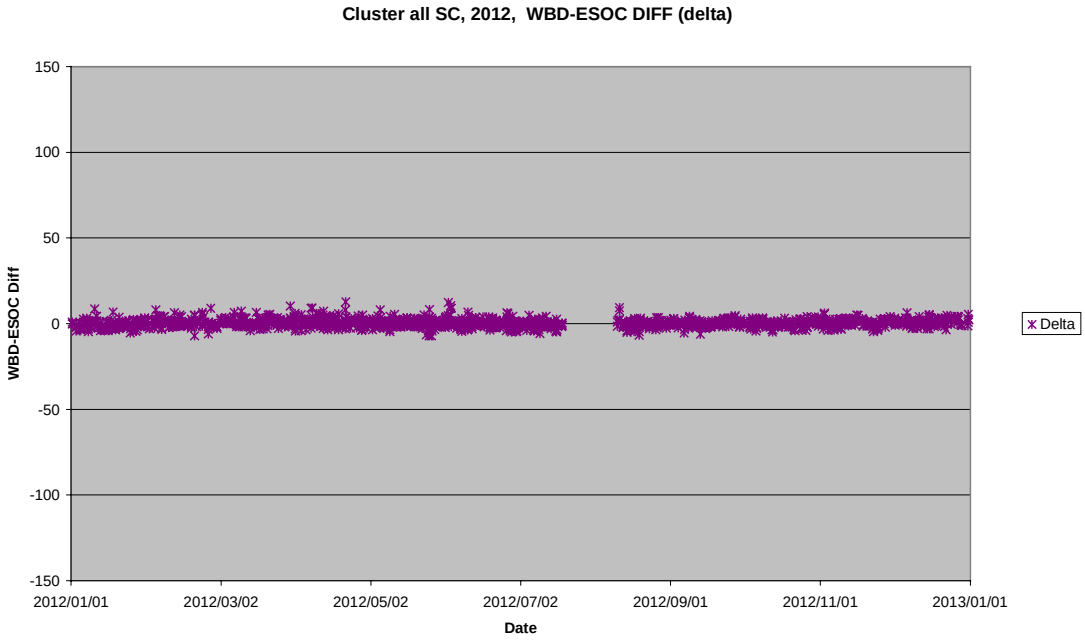
CLuster SC3 2012 TCAL trends





3.7 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. Following the manual correction of the ESOC DIFFs above, nearly all differences (WBD-ESOC) are under 10µs (stdev 2.4µs, max 12.7µs).



4

Generation of the ASCII TCOR files

The generation of the ASCII TCOR files is performed on the iMac where direct access to the Cluster RDM is available. 'maketcor' is used to generate the ASCII TCOR files. For this period version 5.4 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:

```
../bin/maketcor5 -o 12_1_tcor.txt -d 12_1_diffmer.txt
   -f 12_1_shla_files.txt -s 120101 -e 121231 -w 12_1_wbddiff.txt
../bin/maketcor5 -o 12_2_tcor.txt -d 12_2_diffmer.txt
   -f 12_2_shla_files.txt -s 120101 -e 121231 -w 12_2_wbddiff.txt
../bin/maketcor5 -o 12_3_tcor.txt -d 12_3_diffmer.txt
   -f 12_3_shla_files.txt -s 120101 -e 121231 -w 12_3_wbddiff.txt
../bin/maketcor5 -o 12_4_tcor.txt -d 12_4_diffmer.txt
   -f 12_4_shla_files.txt -s 120101 -e 121231 -w 12_4_wbddiff.txt
```

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.

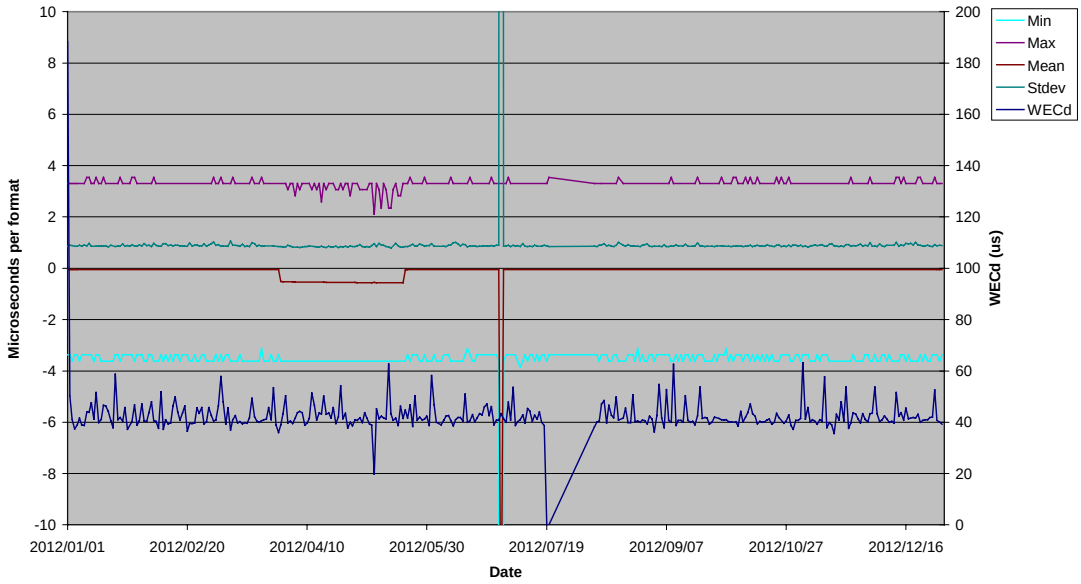
The current version also checks the increment of the WEC master clock pulse as measured by the EW5SSOFF parameter in the WEC HK. This provides an independent check that the phase jumps in the VC0 reset pulse cycle have been correctly indentified. The WEC master clock pulse is measured once every telemetry format (5.15222168 seconds). The clock pulses occur every 1.1111 milliseconds, so the time difference between two consecutive measurements should be a multiple of 1.1111 milliseconds. The deviation between each actual measured time and a prediction based on previous pulses is plotted as the 'WECd' parameter in the charts below. The plotted quantity is the maximum deviation at any point in the day. The value typically around 40 μs represents the maximum error of the validated WEC clock measurements.

The initial validation of the data indicated a number of jumps apparently due to incorrect tracking of the VC0 phase. This occurs mainly where two telemetry mode changes occurred only one minute apart, and a jump in VC0 phase was assigned to the wrong one. The ASCII TCOR files for C1, C2 and C3 were manually modified to correct these. The modified files were called `12_*_tcor_v.txt`. No corrections were needed for C4. The few remaining spikes are due to instrument malfunctions.

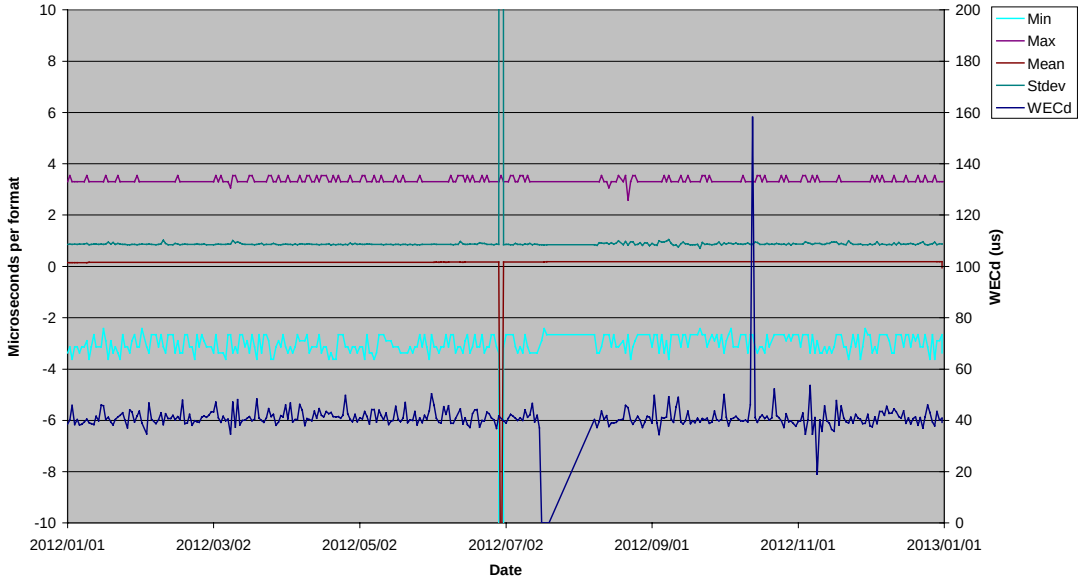
Veritcor is run using the following commands:

```
../veritcor -f 12_1_shla_files.txt -T . -v 4 -i 5.152221   > 12_1_veri.txt
../veritcor -f 12_2_shla_files.txt -T . -v 4 -i 5.152221   > 12_2_veri.txt
../veritcor -f 12_3_shla_files.txt -T . -v 4 -i 5.152221   > 12_3_veri.txt
../veritcor -f 12_4_shla_files.txt -T . -v 4 -i 5.152221   > 12_4_veri.txt
```

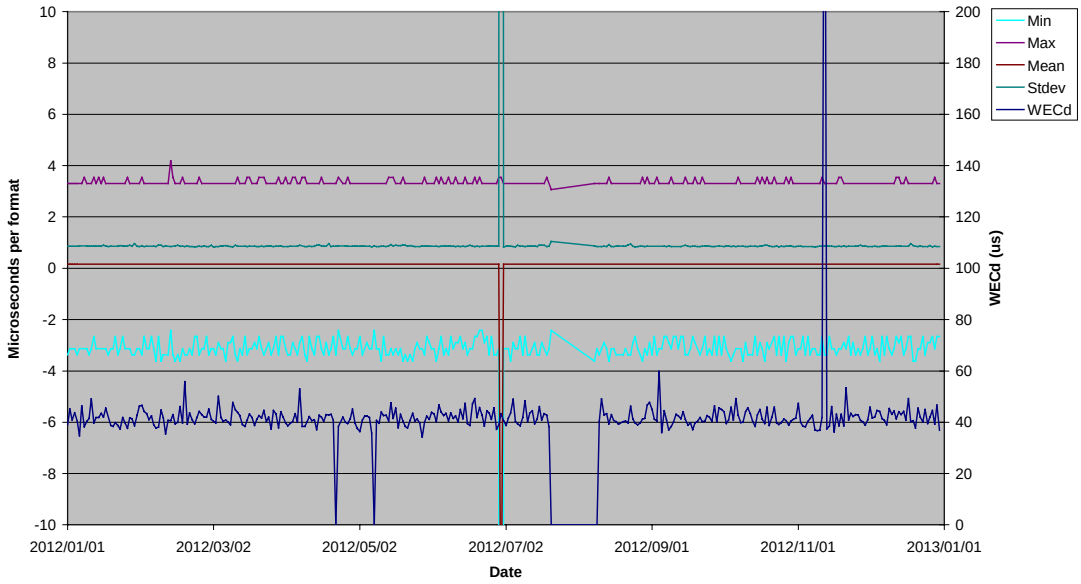
Cluster SC1 timing analysis, 2012



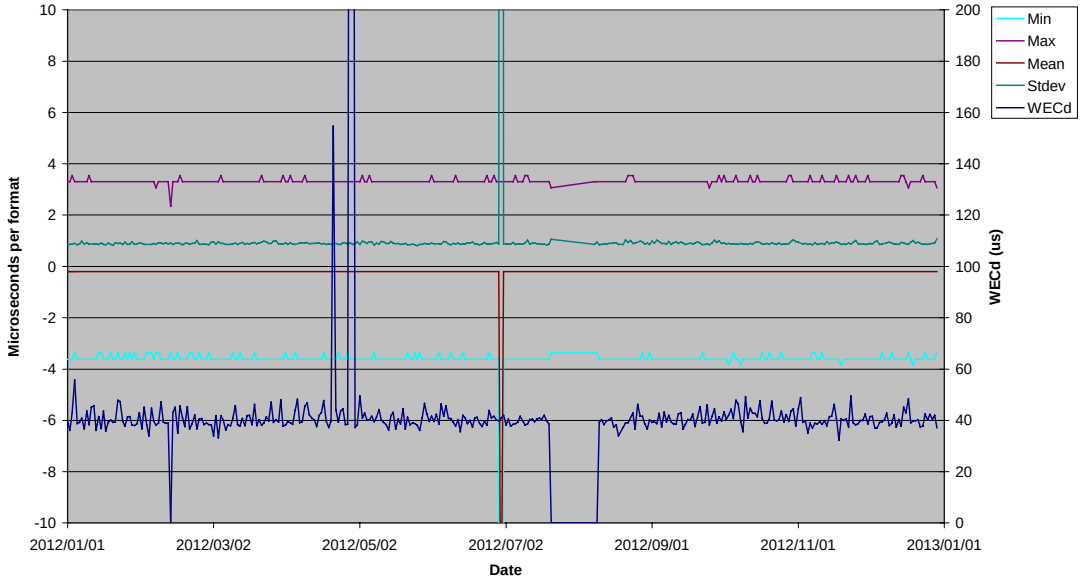
Cluster SC2 timing analysis, 2012



Cluster SC3 timing analysis, 2012



Cluster SC4 timing analysis, 2012



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 12_1_tcor_v.txt -v 1
../tcor2cef -t 12_2_tcor_v.txt -v 1
../tcor2cef -t 12_3_tcor_v.txt -v 1
../tcor2cef -t 12_4_tcor.txt -v 1
```

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__20120101_V*.cef
diff C2_CP_DWP_TCOR__20120101_V*.cef
diff C3_CP_DWP_TCOR__20120101_V*.cef
diff C4_CP_DWP_TCOR__20120101_V*.cef
```

Finally, the CEF files are checked using CEFpass.

```
../bin/CEFpass -I ../headers C1_CP_DWP_TCOR__20120101_V01.cef
../bin/CEFpass -I ../headers C2_CP_DWP_TCOR__20120101_V01.cef
../bin/CEFpass -I ../headers C3_CP_DWP_TCOR__20120101_V01.cef
../bin/CEFpass -I ../headers C4_CP_DWP_TCOR__20120101_V01.cef
```

7 Caveats

The following general caveats apply to 2012 TCOR data.

TCOR data is not available at all times. 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.

An unexplained discontinuity of about 30μs in the DIFF correction occurred between 2012-04-20 and 2012-04-23 on C3 only. Given that other spacecraft using the same ground stations are not effected, a probable explanation is that slightly incorrect orbit data was used when calculating the propagation time from spacecraft to ground. The TCOR files simply apply a linear interpolation across this gap, and it is possible that a larger than usual residual error may be present during this period.

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.