Preparation and validation of WEC time corrections 2009

Keith Yearby, 23 July 2010

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 the year 2009.

The TCOR datasets include a correction for the UTC leap second inserted at the end of 2008, which caused 1 second timing errors until the first ESOC time correlations of 2009.

During 2009, ESOC time correlations were performed during each nominal pass, as done during 2008. However further updates to the time correction procedure have been made to improve the quality and availability of the results.

The software tool (readtcal) that extracts DIFF values from the TCAL files was updated to include estimates of the DIFF and TICK values by a least squares analysis of the HK data time stamps. This is to allow confirmation that time correlations recorded in the TCAL files have actually been applied to the data.

The new software tool 'diffmer' has been developed to automatically merge WBD DIFF measurements with the ESOC values, where this is necessary to keep the DIFF error below 10μs. 'diffmer' uses a ground station offset (GSO) file to allow for the known timing offsets of DSN and Panska Ves.

The software tool 'wbdtcor' which compares WBD DIFFs with ESOC DIFFs also uses the ground station offset file so the reported differences should be near zero.

The software tool 'maketcor' has been updated to version 5.1. The major change is that the Sun Reference Pulse, rather than the WEC sample clock, is used to track phase changes in the VC0 cycle (reflected in OBTM). TCOR availability now ranges from 93.7% to 99.4%. The main reason for failure is the discontinuity in the On Board Time at 'power down' or 'decoder only' eclipses, and CTU switchovers and reboots.

The software tool 'tcor2cef' has been updated to allow the file time span of the CEF file to be specified.

2 Data and references

Source data:

WBD data DVDs for 2009 (online data for July to December).
Cluster RDM for 2009.

Documents:

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

Software:

Software	Version	Date
readtcal	2.6	2009-09-29
wbddiff	2.3	2009-09-08
wbdtcor	1.2	2010-05-28
tcaltrend	1.3	2010-07-12
maketcor	5.1	2010-07-22
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
09_1_hkla_files.txt	
09_2_hkla_files.txt	
09_3_hklam_files.txt	
09_4_hkla_files.txt	

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
09_1_diffmer.txt	2010-06-30
09_2_diffmer.txt	2010-06-30
09_3_diffmer.txt	2010-07-22
09_4_diffmer.txt	2010-06-30

ASCII TCOR files:

File name	Last modified date
08_1_tcor5.txt	2010-07-22
08_2_tcor.txt	2010-06-30
08_3_tcor5.txt	2010-07-22
08_4_tcor5.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 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 WEC HK and TCAL files. The procedures for making these files were somewhat more complicated this year. Firstly, the RAID storage for the RDM data is completely full and not all 2009 data was available. Part of the data was instead loaded on the local hard drive of Sun workstation 'hoodie'. Secondly, to allow TCOR data to start right at the start of the year 2009, the RDM files for the last day of 2008 were also needed.

The following commands were used to make the file lists for 2009.

```
find /data/disk2/cluster/RDM/081231* -name '*wh*' \
                                      > 081231_hkla_files.txt
find /data/disk2/cluster/RDM/081231* -name '*la*' \
                                      >> 081231_hkla_files.txt
find /data/disk2/cluster/RDM/09* -name '*wh*' \
                                      > 09_disk2_hkla_files.txt
find /data/disk2/cluster/RDM/09* -name '*la*' \
                                      >> 09_disk2_hkla_files.txt
find /opt/public/krdm/09* -name '*wh*' > 09_opt_hkla_files.txt
find /opt/public/krdm/09* -name '*la*' >> 09_opt_hkla_files.txt
cat 081231_hkla_files.txt 09_disk2_hkla_files.txt \
                        09_opt_hkla_files.txt > scr.scr
~/CAA/weclog/purgedup scr.scr 09_hkla_files.txt
grep cluster1 09_hkla_files.txt | sort > 09_1_hkla_files.txt
grep cluster2 09_hkla_files.txt | sort > 09_2_hkla_files.txt
grep cluster3 09_hkla_files.txt | sort > 09_3_hkla_files.txt
grep cluster4 09_hkla_files.txt | sort > 09_4_hkla_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 09_1_hkla_files.txt -o 09_1_tcaldiff.txt
  >09_1_tcal.txt
../readtcal -f 09_2_hkla_files.txt -o 09_2_tcaldiff.txt
  >09_2_tcal.txt
../readtcal -f 09_3_hkla_files.txt -o 09_3_tcaldiff.txt
  >09_3_tcal.txt
```

```
../readtcal -f 09_4_hkla_files.txt -o 09_4_tcaldiff.txt
  >09_4_tcal.txt
```

The TCAL summary files (09_*_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 09_*_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 WBDDIFF. 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 to June was on DVDs as usual. The procedure used to download and process online WBD data for July to December is listed in appendix A.

3.5 Special procedure for SC3, 2009/02/20 to 2009/03/07

On on SC3, time correlations from 2009/02/20 20:24:33 to 2009/03/05 07:33:10 were not in fact used to calibrate SCET, and that data from 2009/02/20 20:24:33 to 2009/03/07 04:49:04 was all calibrated using the time correlation of 2009/02/19 05:58:09. References to these time correlations were removed from special versions of the file list (09_3_hklam_files.txt) and TCAL summary (09_3_tcalm.txt) files.

It was then necessary to calculate what the DIFFs were relative to the time correlation of 2009/02/19. This was done using the following procedure. The TCAL summary file 09_3_tcal.txt was edited to create a new file 09m _3_tcal.txt containing only the time correlations from 2009/02/19 05:58:09 to 2009/03/09 02:49:43. This file was processed using 'tcaltrend' version 1.3 (2010-07-12) using the following command:

```
\cluster\miscsoft\readtcal\debug\tcaltrend -c 09m_3_tcal.txt
```

The standard output listed below contains the required DIFFs and was manually inserted into the file 09_3_tcaldiff.txt.

```
# TCAL DIFFs relative to trend set 0, 2009/02/19 05:58:09.726998
2009/02/19 05:58:09.726998        0  3     4    -1
2009/02/20 20:24:33.233000       -6  3     4    -1
2009/02/21 08:26:07.346000       -8  3     4    -1
2009/02/23 05:12:39.733998      -17  3     4    -1
2009/02/25 04:23:07.245000      -15  3     4    -1
2009/02/25 17:37:09.832998      -19  3     4    -1
2009/02/27 02:58:22.344000      -18  3     4    -1
2009/03/01 04:40:23.525000      -43  3     4    -1
2009/03/02 06:48:17.928998      -61  3    11    -1
2009/03/03 07:23:17.629998      -76  3     4    -1
2009/03/04 21:53:12.376000      -97  3     4    -1
2009/03/05 07:33:10.477000     -100  3     4    -1
2009/03/07 04:48:54.619999     -124  3     4    -1
```

Note that the RDM **090220_2_2a** to **090307_1_2a** inclusive are inconsistent with the DDID specification because the TCAL files contain time correlations which have not been applied to the data. It is assumed that it is now impossible to reprocess the data to apply these missing time correlations (because the source telemetry data are no longer available), so any correction would involve re-issuing the RDM with the non-applied time correlations removed from the TCAL files. WBD level one data

for this period may also need to be reprocessed, as the present version (A) has been processed using the time correlations not applied to other Cluster data.

3.6 Merging of ESOC and WBD DIFFs

The ESOC and WBD DIFF measurements are merged together. The output files (09_*_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_all_c1_ncd.txt
  -d 09_1_tcaldiff.txt -c 09_1_tcal.txt
  -o 09_1_diffmer.txt -g gsotable.txt
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_all_c2_ncd.txt
  -d 09_2_tcaldiff.txt -c 09_2_tcal.txt
  -o 09_2_diffmer.txt -g gsotable.txt
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_all_c3_ncd.txt
  -d 09_3_tcaldiff.txt -c 09_3_tcalm.txt
  -o 09_3_diffmer.txt -g gsotable.txt
\cluster\miscsoft\debug\diffmer -w ..\wbddiff2\wbd_all_c4_ncd.txt
  -d 09_4_tcaldiff.txt -c 09_4_tcal.txt
  -o 09_4_diffmer.txt -g gsotable.txt
```

3.7 Incorrect time correlations on SC1 and 2

Some incorrect time correlations were performed on SC1 and 2, as reported in Cluster MOR 482 (week 44 - 2009). The merged DIFF files were manually edited to remove the DIFFs derived from incorrect time correlations.

(1), (2) A new software version was put on the MSP STC on 29/10/2009. It applied wrong ground station delays (**CLU-2608 "Wrong Time Correlation in MSP DOY302/303"**). This was discovered when the time correlation parameter "B_DIFF" went out of limit at the Cluster Mission Control system. Unfortunately, the Spacon performed the routine time correlation for C1 and C2 not recognizing that the "B_DIFF" parameter was not only 'Out of limit' but **"Out of scale**". At the next pass, C1 on NNO and C2 on Perth, the time correlation was corrected as shown on the graphs figure 3.1 and figure 3.2 next page.

The wrong time correlation coefficients are applied on VC0, VC2 and VC3 as follows:
- Spacecraft 1: from 302.04.20.00 to 302.20.49.00
- Spacecraft 2: from 301.21.51.00 to 303.10.27.12.

3.8 Summary of PVD files manually modified

The following files were manually modified. Note that on SC1 and 2, the merged ESOC+WBD files were modified, while on SC3 and 4, the ESOC files were modified before merging.

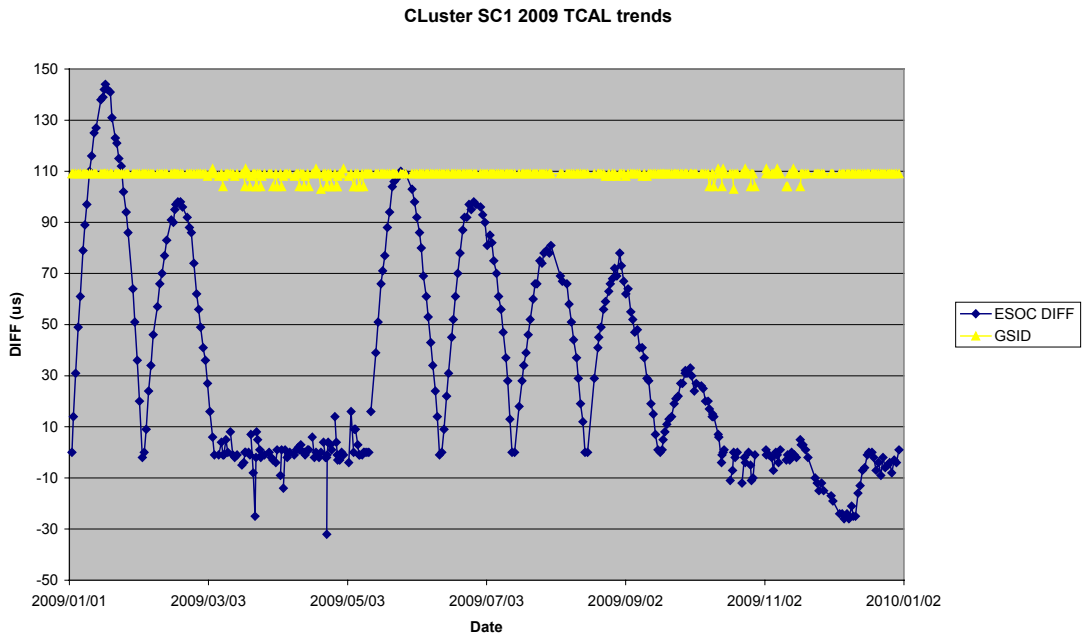
09_1_diffmer.txt
09_2_diffmer.txt
09_3_tcaldiff.txt
09_4_tcaldiff.txt

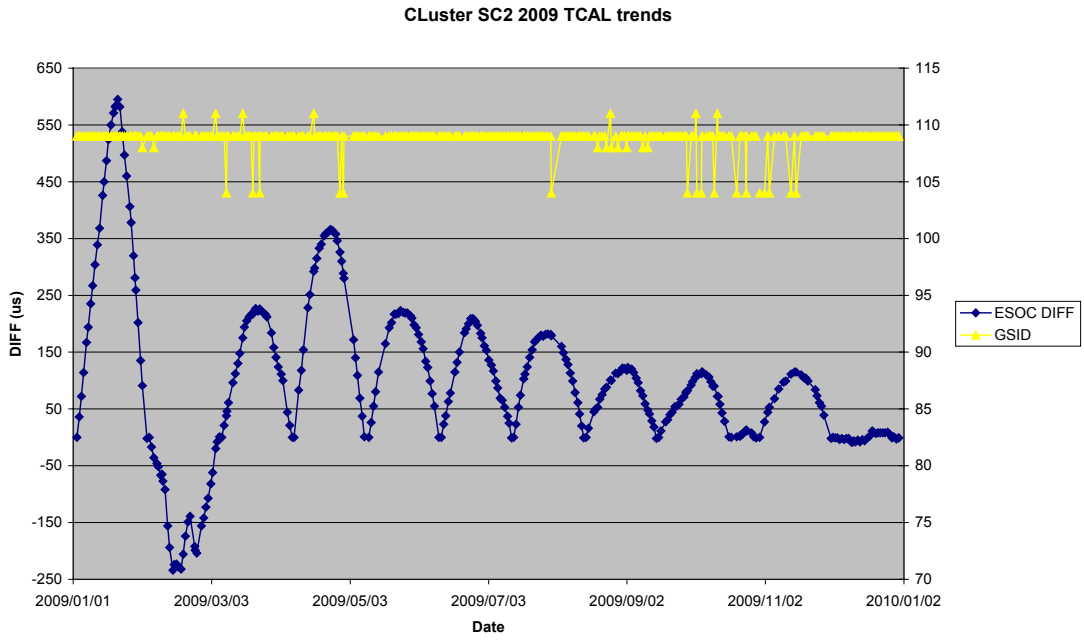
3.9 Validation using 'tcaltrend'

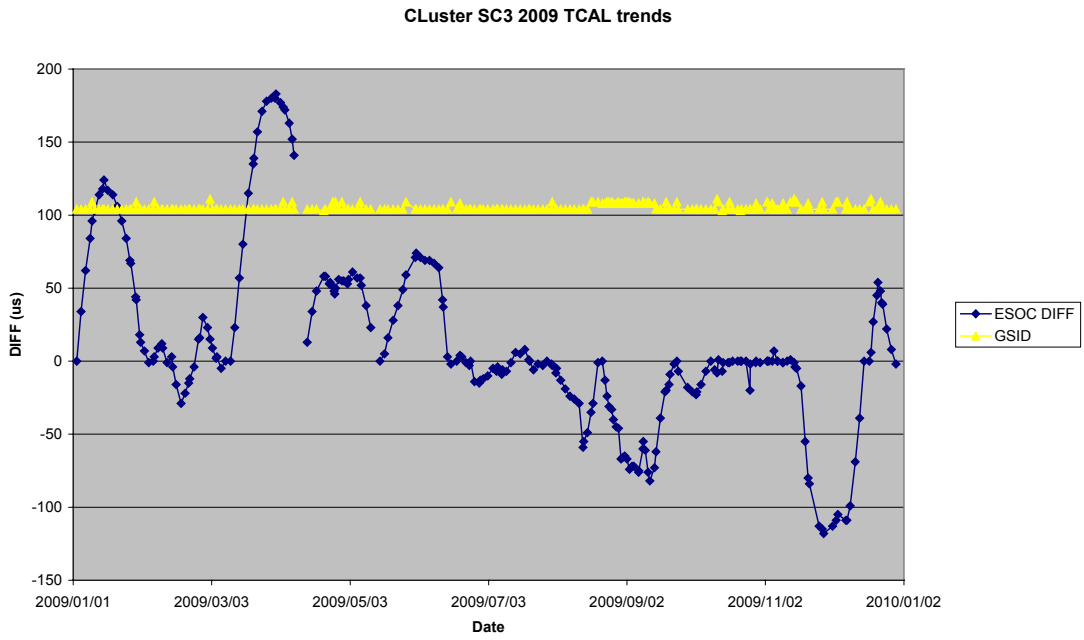
The long term trends of the clock drifts, as measured by the merged ESOC and WBD DIFFs together with the corresponding time calibrations (TCAL) are computed using **'tcaltrend'**. This calculates what

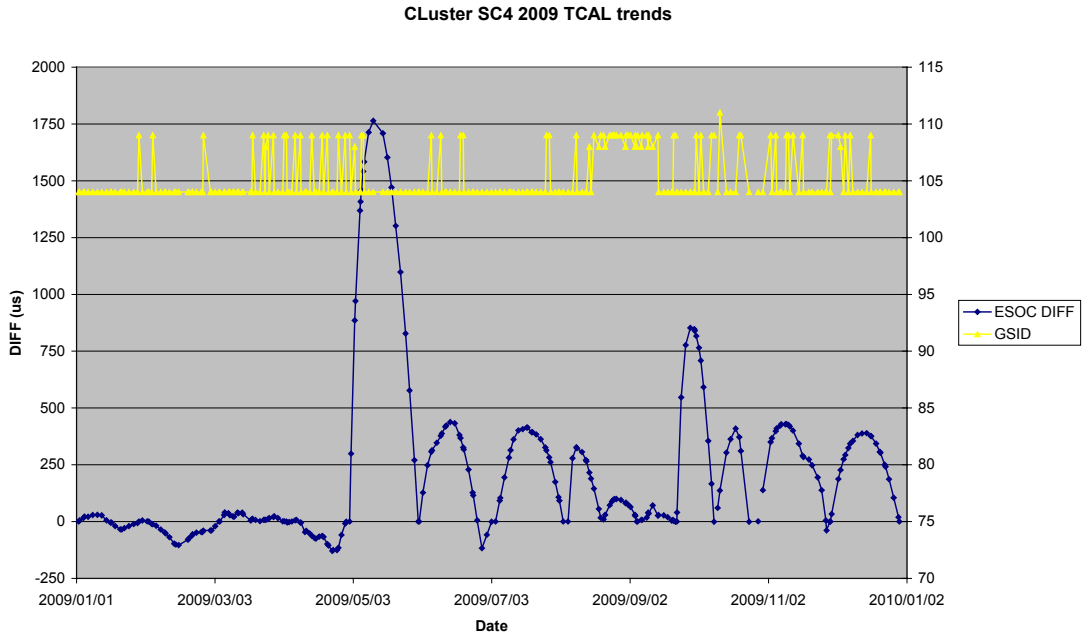
the DIFF would be with respect to an optimum time correlation performed at most every 30 days, and allows long term trends in the clock drift to be seen.

```
\cluster\miscsoft\readtcal\debug\tcaltrend -c 09_1_tcal.txt
   -d 09_1_diffmer.txt >09_1_tcaltrend.txt
\cluster\miscsoft\readtcal\debug\tcaltrend -c 09_2_tcal.txt
   -d 09_2_diffmer.txt >09_2_tcaltrend.txt
\cluster\miscsoft\readtcal\debug\tcaltrend -c 09_3_tcalm.txt
   -d 09_3_diffmer.txt >09_3_tcaltrend.txt
\cluster\miscsoft\readtcal\debug\tcaltrend -c 09_4_tcal.txt
   -d 09_4_diffmer.txt >09_4_tcaltrend.txt
```









3.10 Validation using 'wbdtcor'

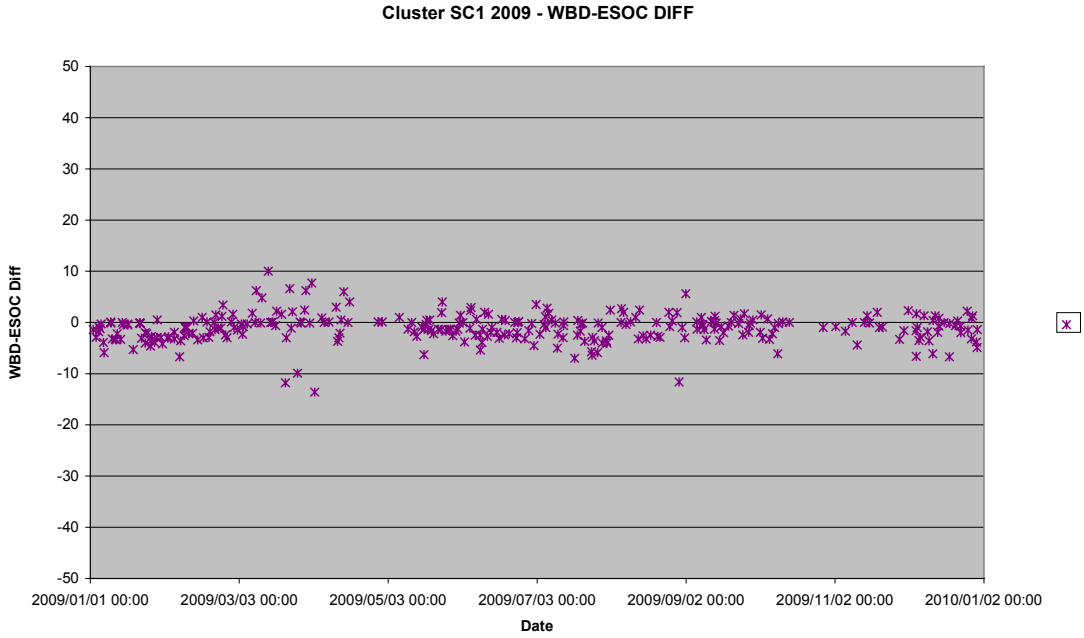
The WBD DIFFs are compared to the merged DIFF using **'wbdtcor'**. The current version of this software allows for the known timing offsets of the DSN stations (specified in `gsotable.txt`), so ideally the differences reported should be zero.

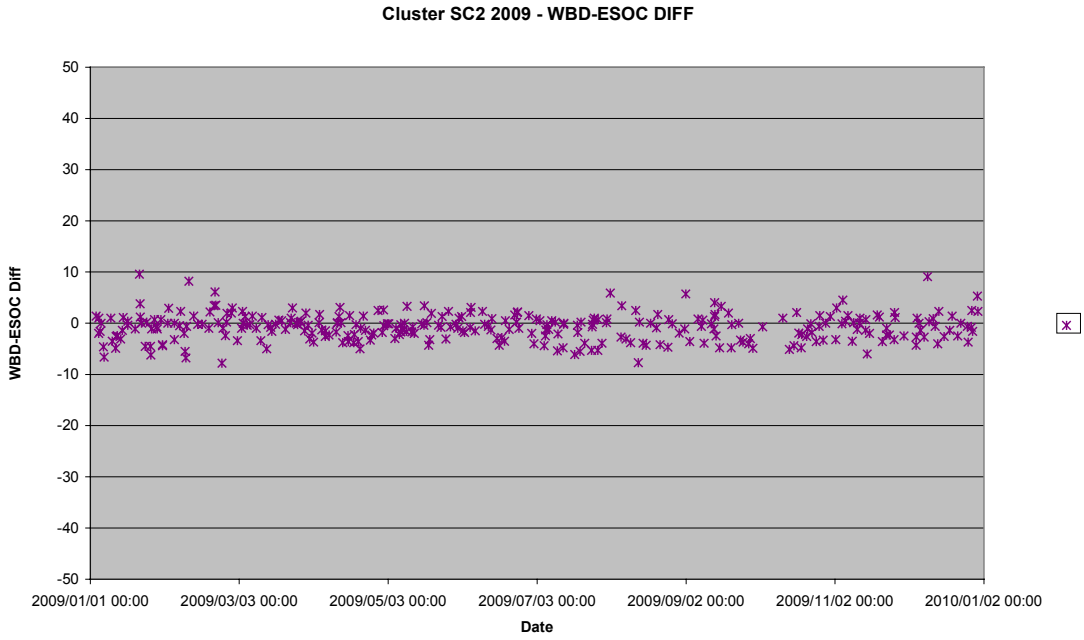
In the following plots it can be seen that the differences are usually well under 10μs (standard deviation 2.6 to 3.3μs), which provides a general confidence in the quality of the measurements. However, it should be noted that any WBD point with a difference more than 10μs, and more than 8 hours from 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.

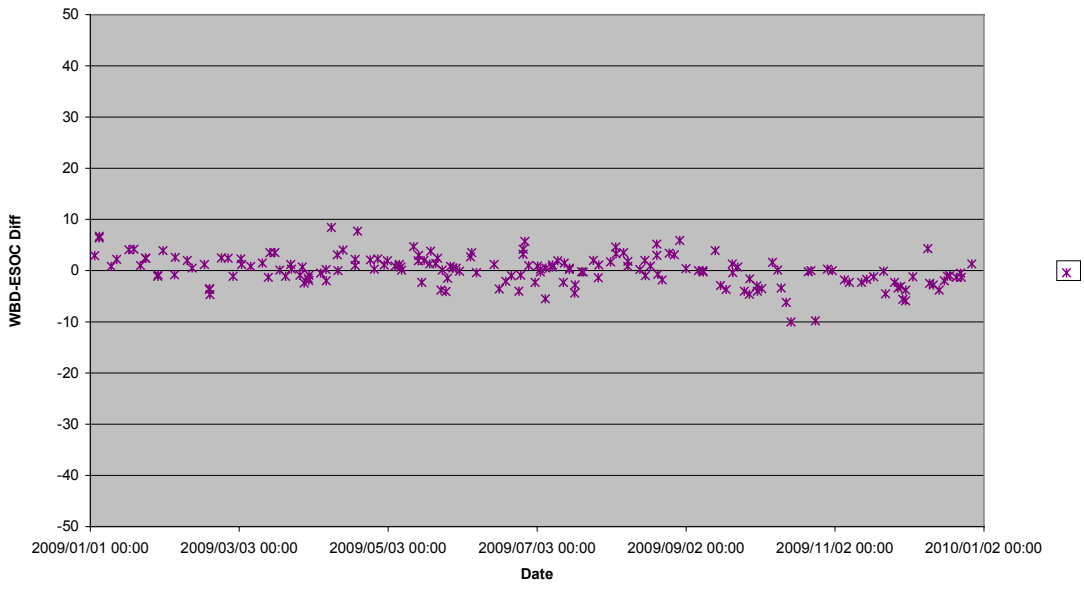
SC	WBD inserted	Total WBD points	STDEV (us)
1	14	690	2.7

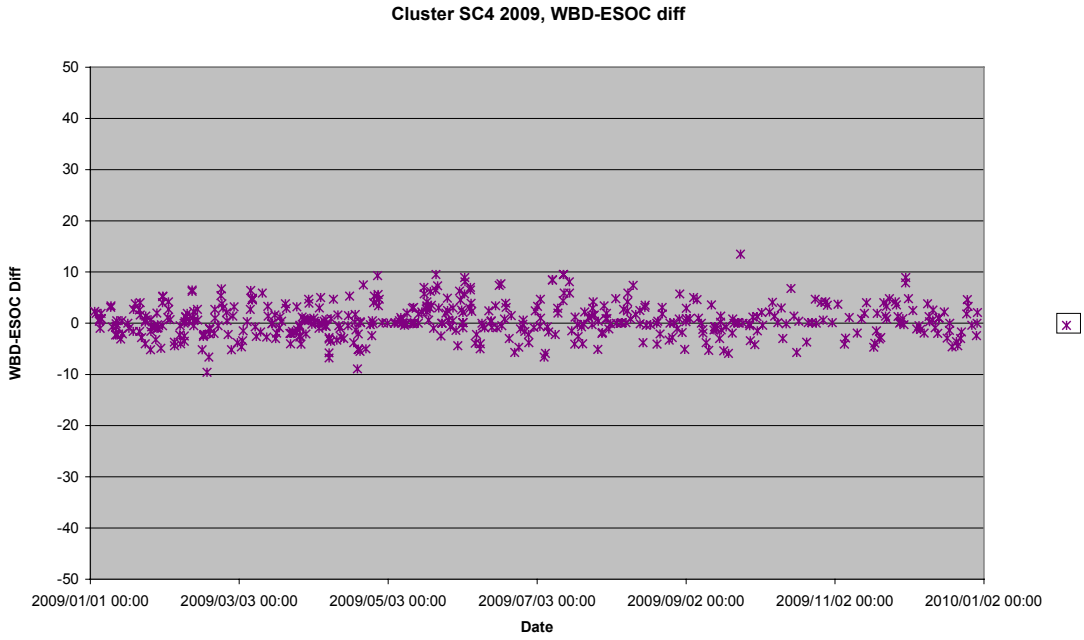
2	1	718	2.6
3	3	524	2.9
4	31	1093	3.3

```
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c1_ncd.txt
   -p 09_1_diffmer.txt -c 09_1_tcal.txt -g gsotable.txt
   >09_1_mdelta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c2_ncd.txt
   -p 09_2_diffmer.txt -c 09_2_tcal.txt -g gsotable.txt
   >09_2_mdelta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c3_ncd.txt
   -d 09_3_diffmer.txt -c 09_3_tcalm.txt -g gsotable.txt
   >09_3_mdelta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c4_ncd.txt
   -d 09_4_diffmer.txt -c 09_4_tcal.txt -g gsotable.txt
   >09_4_mdelta.txt
```




Cluster SC2 2009 - WBD-ESOC DIFF
WBD-ESOC Diff
50
40
30
20
10
0
-10
-20
-30
-40
-50
2009/01/01 00:00
2009/03/03 00:00
2009/05/03 00:00
2009/07/03 00:00
2009/09/02 00:00
2009/11/02 00:00
2010/01/02 00:00
Date


Cluster SC3 2009 - WBD-ESOC DIFF
WBD-ESOC Diff
50
40
30
20
10
0
-10
-20
-30
-40
-50
2009/01/01 00:00
2009/03/03 00:00
2009/05/03 00:00
2009/07/03 00:00
2009/09/02 00:00
2009/11/02 00:00
2010/01/02 00:00
Date


Cluster SC4 2009, WBD-ESOC diff
WBD-ESOC Diff
50
40
30
20
10
0
-10
-20
-30
-40
-50
2009/01/01 00:00
2009/03/03 00:00
2009/05/03 00:00
2009/07/03 00:00
2009/09/02 00:00
2009/11/02 00:00
2010/01/02 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 5.1 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. For SC2, initial inspection showed that there were no OBTM changes during the whole year so a fixed OBTM was specified (-r option).

The following commands were used:

```
../maketcor5 -o 09_1_tcor5.txt -d 09_1_diffmer.txt
   -f 09_1_hkla_files.txt -s 090101 -e 091231
   -w ../wbddiff2/wbd_all_c1_ncd.txt
../maketcor5 -o 09_2_tcor5.txt -d 09_2_diffmer.txt
   -f 09_2_hkla_files.txt -s 090101 -e 091231 -r 29878192
../maketcor5 -o 09_3_tcor5.txt -d 09_3_diffmer.txt
   -f 09_3_hklam_files.txt -s 090101 -e 091231
   -w ../wbddiff2/wbd_all_c3_ncd.txt
./maketcor5 -o 09_4_tcor5.txt -d 09_4_diffmer.txt
   -f 09_4_hkla_files.txt -s 090101 -e 091231
   -w ../wbddiff2/wbd_all_c4_ncd.txt
```

```
# MAKETCOR, version 5.1
#
# DIFF FILE: 09_1_diffmer.txt
# File list: 09_1_hkla_files.txt (la)
# 473 TCAL records processed.
# File list: 09_1_hkla_files.txt (hk)
# First record: 2009/01/01 00:00:09.995147
# Last record:  2009/12/31 18:09:50.894950
# Total proc:    6001674 formats,  100.0%
# Done:          5626127 formats,   93.7%
# No diff:        321344 formats,    5.4%
# Non constant:        0 formats,    0.0%
# No offset:       48997 formats,    0.8%
# Outside:          3815 formats,    0.1%
# Missing:          1391 formats,    0.0%
```

```
# MAKETCOR, version 5.1
#
# DIFF FILE: 09_2_diffmer.txt
# File list: 09_2_hkla_files.txt (la)
# 347 TCAL records processed.
# File list: 09_2_hkla_files.txt (hk)
# Error:     2009-12-30T16:18:00 DIFF file out of sequence.
# First record: 2009/01/01 00:00:05.796391
# Last record:  2009/12/31 14:40:20.382828
# Total proc:    6127321 formats,  100.0%
# Done:          6093593 formats,   99.4%
# No diff:         20945 formats,    0.3%
# Non constant:     5892 formats,    0.1%
# No offset:           0 formats,    0.0%
# Outside:          6440 formats,    0.1%
# Missing:           451 formats,    0.0%
```

```
# MAKETCOR, version 5.1
#
# DIFF FILE: 09_3_diffmer.txt
# File list: 09_3_hklam_files.txt (la)
# 280 TCAL records processed.
# File list: 09_3_hklam_files.txt (hk)
# First record: 2009/01/01 00:00:05.312661
# Last record:  2009/12/31 10:32:24.027656
# Total proc:    6030553 formats,  100.0%
# Done:          5829826 formats,   96.7%
# No diff:        163381 formats,    2.7%
# Non constant:        0 formats,    0.0%
# No offset:       26985 formats,    0.4%
# Outside:          9390 formats,    0.2%
# Missing:           971 formats,    0.0%
```

```
# MAKETCOR, version 5.1
#
# DIFF FILE: 09_4_diffmer.txt
# File list: 09_4_hkla_files.txt (la)
# 289 TCAL records processed.
# File list: 09_4_hkla_files.txt (hk)
# First record: 2009/01/01 00:00:05.528055
# Last record:  2009/12/31 04:36:02.231225
# Total proc:    6063449 formats,  100.0%
# Done:          5924186 formats,   97.7%
# No diff:         72160 formats,    1.2%
# Non constant:        0 formats,    0.0%
# No offset:       53758 formats,    0.9%
# Outside:         12577 formats,    0.2%
# Missing:           768 formats,    0.0%
```

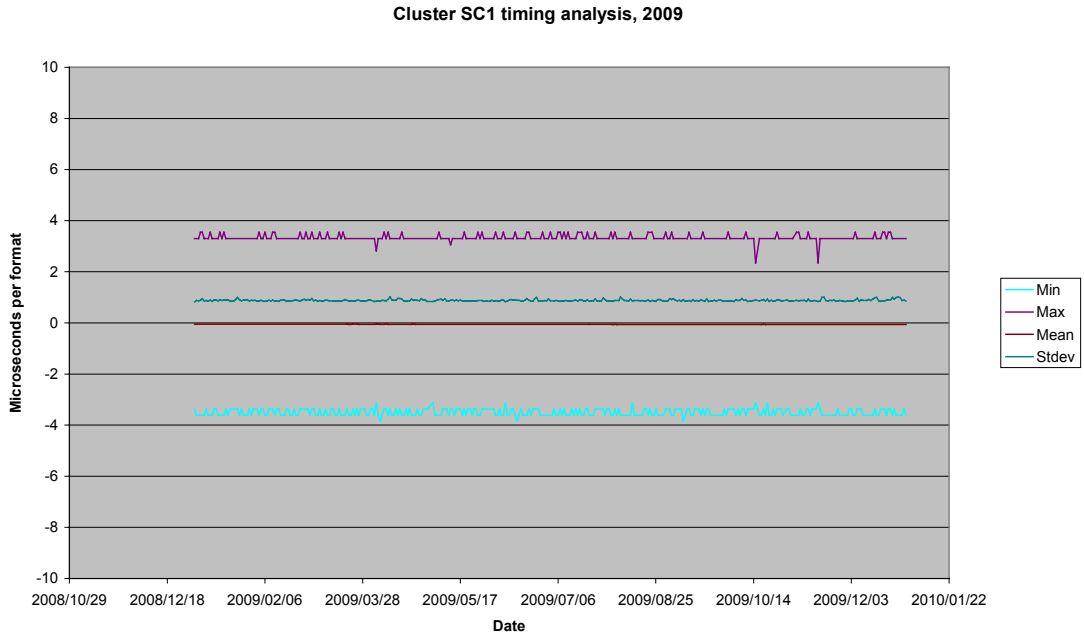
5 Validation of the TCOR files

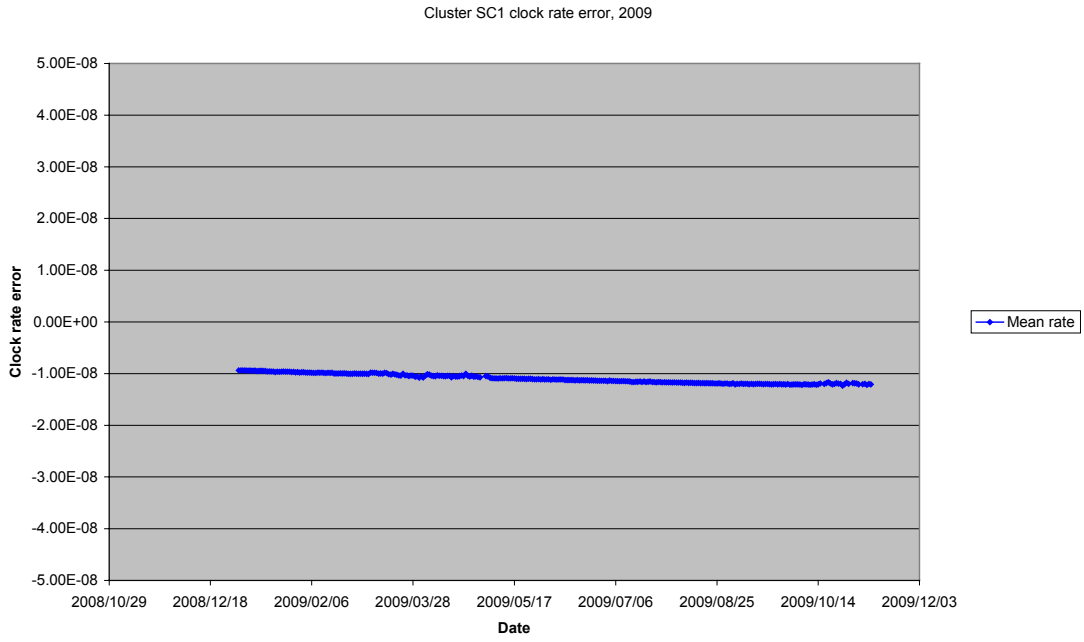
The software tool ‘maketcor’ performs some automatic validation as the files are produced. Data that fails automatic validation are not included in the output files.

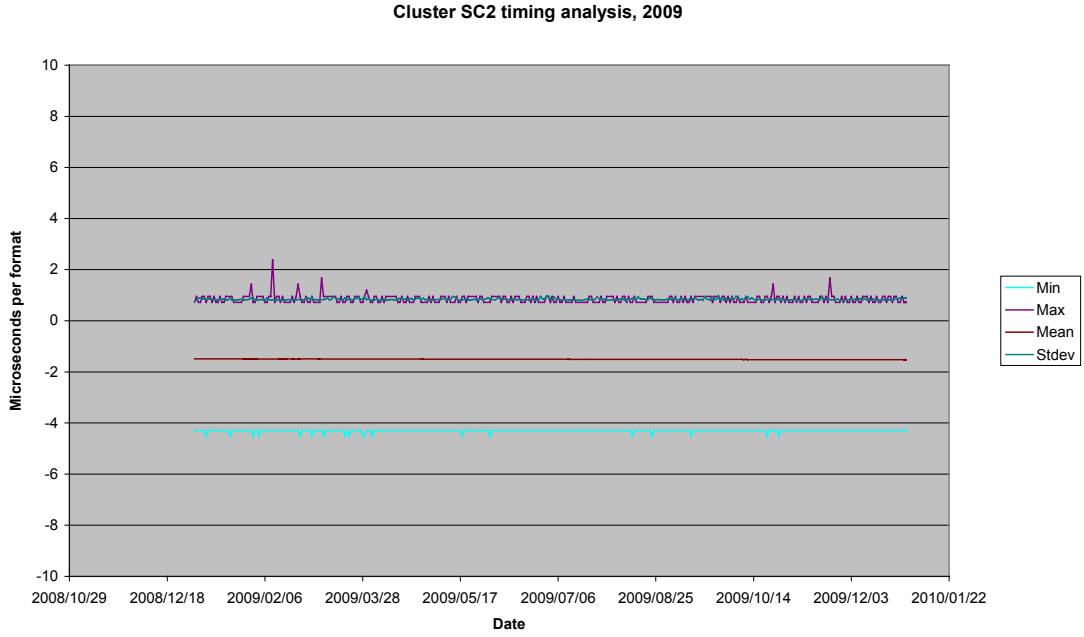
Further validation of the TCOR files is performed by generating version 0 CEF files, using these to apply time corrections, then analysing the time tags of the corrected data. The time tags are analysed using ‘veritcor’. This takes the time increment between each pair of records in the file, subtracts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

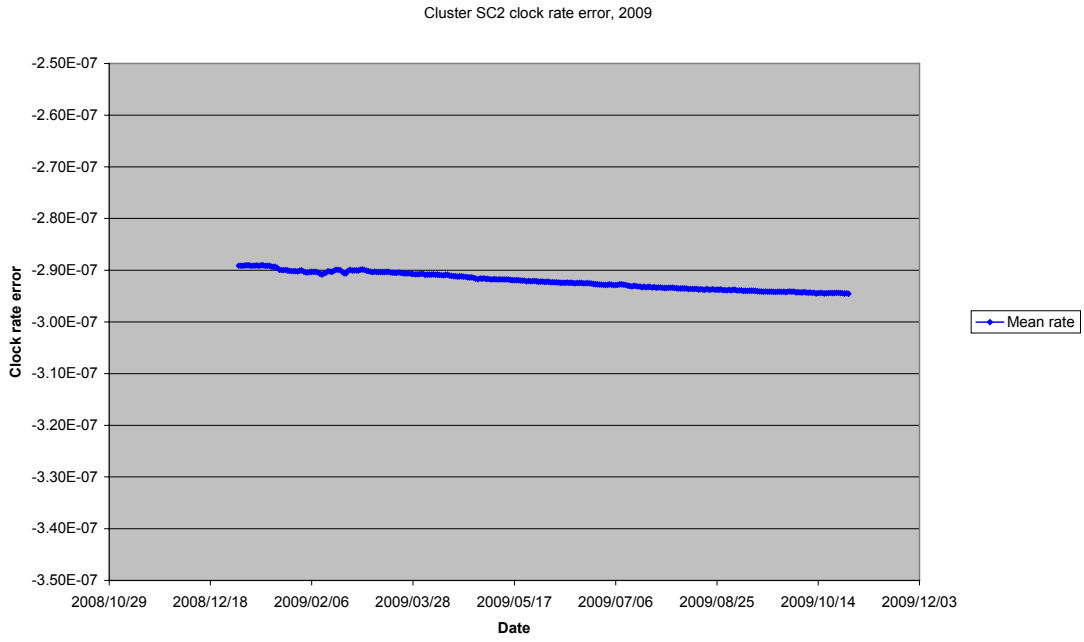
It uses the same HK+TCAL file list file as 'maketcor', although only the HK files are used. 'veritcor' includes the same code module used by TED to apply the TCOR corrections, and requires CEF TCOR files to be installed with the same index files. The '-T .' option specifies that the TCOR files (and the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

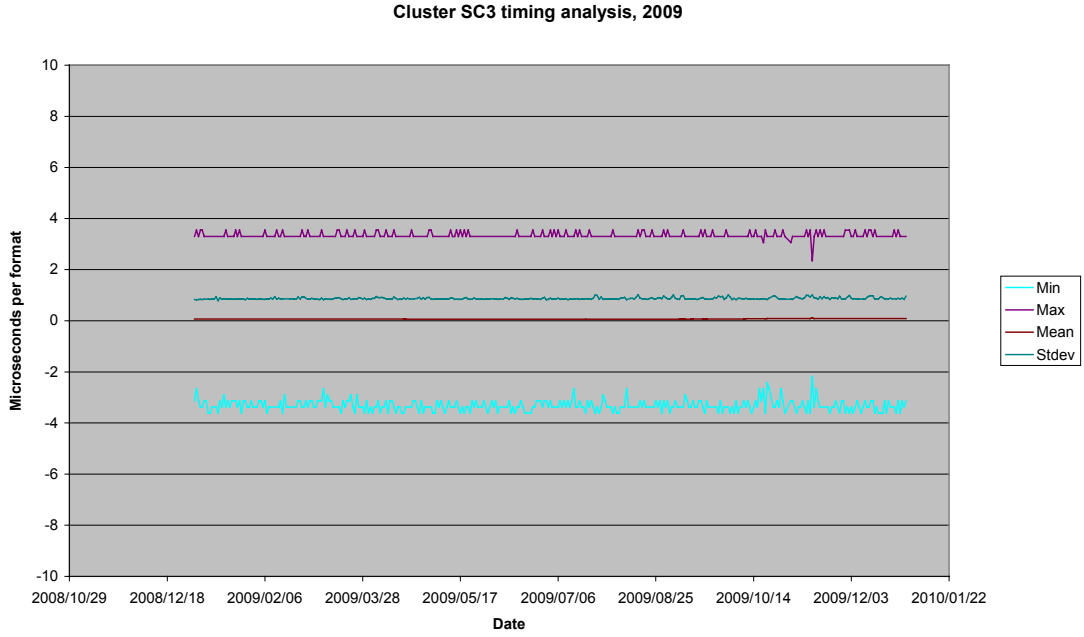
```
../veritcor -f 09_1_hkla_files.txt  -T . -v 4 -i 5.152221
   > 09_1_veritcor.txt
../veritcor -f 09_2_hkla_files.txt  -T . -v 4
   > 09_2_veritcor.txt
../veritcor -f 09_3_hklam_files.txt -T . -v 4 -i 5.152221
   > 09_3_veritcor.txt
../veritcor -f 09_4_hkla_files.txt  -T . -v 4 -i 5.1522207
   > 09_4_veritcor.txt
```



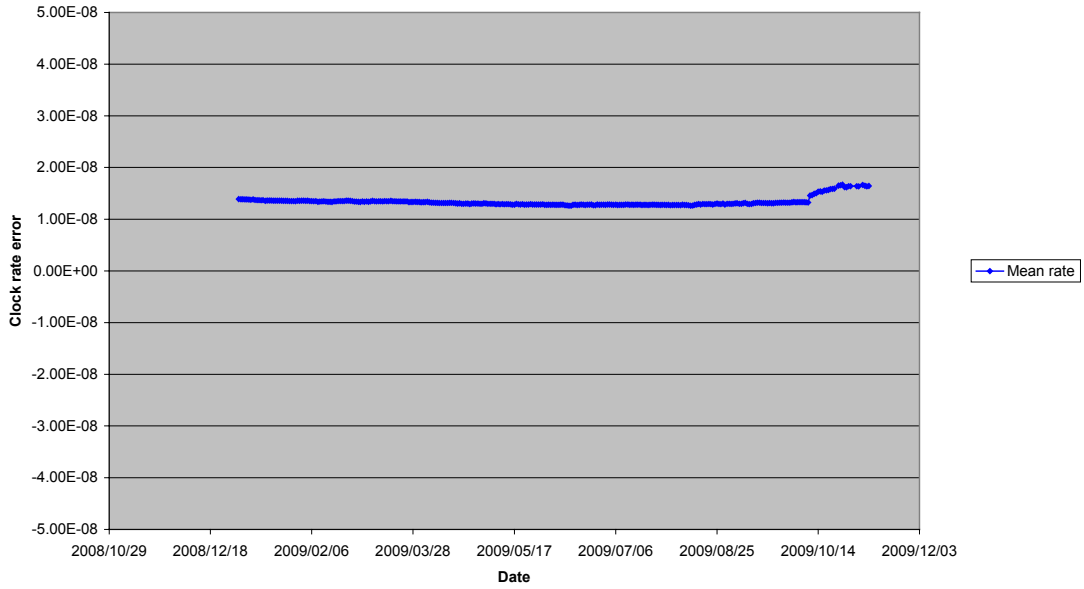

Cluster SC1 clock rate error, 2009
5.00E-08
4.00E-08
3.00E-08
2.00E-08
1.00E-08
0.00E+00
-1.00E-08
-2.00E-08
-3.00E-08
-4.00E-08
-5.00E-08
Clock rate error
2008/10/29
2008/12/18
2009/02/06
2009/03/28
2009/05/17
2009/07/06
2009/08/25
2009/10/14
2009/12/03
Date
Mean rate


Cluster SC2 timing analysis, 2009
10
8
6
4
2
0
-2
-4
-6
-8
-10
Microseconds per format
2008/10/29
2008/12/18
2009/02/06
2009/03/28
2009/05/17
2009/07/06
2009/08/25
2009/10/14
2009/12/03
2010/01/22
Date
Min
Max
Mean
Stdev

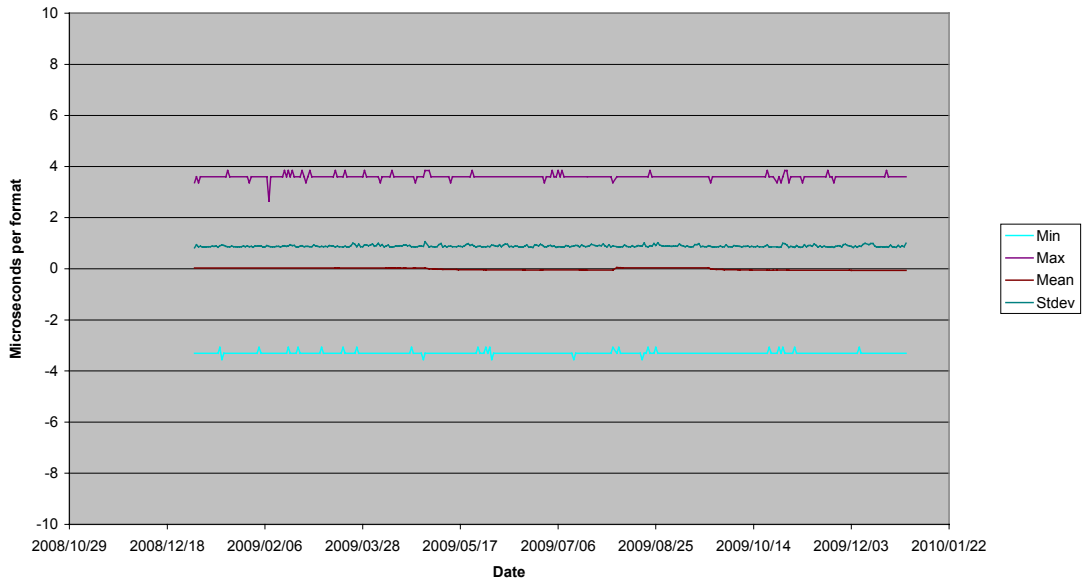

Cluster SC2 clock rate error, 2009
-2.50E-07
-2.60E-07
-2.70E-07
-2.80E-07
-2.90E-07
-3.00E-07
-3.10E-07
-3.20E-07
-3.30E-07
-3.40E-07
-3.50E-07
Clock rate error
2008/10/29
2008/12/18
2009/02/06
2009/03/28
2009/05/17
2009/07/06
2009/08/25
2009/10/14
2009/12/03
Date
Mean rate

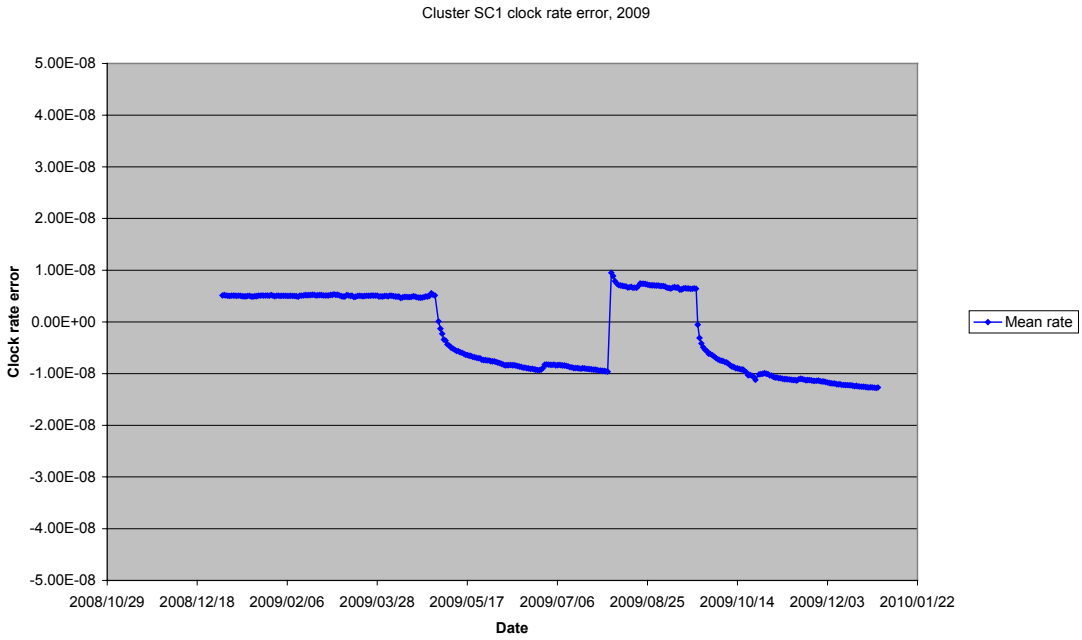

Cluster SC3 timing analysis, 2009
10
8
6
4
2
0
-2
-4
-6
-8
-10
Microseconds per format
2008/10/29
2008/12/18
2009/02/06
2009/03/28
2009/05/17
2009/07/06
2009/08/25
2009/10/14
2009/12/03
2010/01/22
Date
Min
Max
Mean
Stdev

Cluster SC3 clock rate error, 2008



Cluster SC4 timing analysis, 2009




Cluster SC1 clock rate error, 2009
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
2008/10/29
2008/12/18
2009/02/06
2009/03/28
2009/05/17
2009/07/06
2009/08/25
2009/10/14
2009/12/03
2010/01/22
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.

```
hoodie% ../tcor2cef -t 09_1_tcor5.txt -s 090101 -e 091231 -v 1
TCOR2CEF, version 1.7
TCOR file:          09_1_tcor5.txt, s/c: 1, records: 3946
Generated CEF name: C1_CP_DWP_TCOR__20090101_V01
Time range:         2009-01-01T00:00:09Z/2009-12-31T18:09:50Z
Finished, CEF size: 426639 bytes
Total duration:     31514981 seconds
Corrected:          28972783 seconds (91.9 %)

hoodie% ../tcor2cef -t 09_2_tcor5.txt -s 090101 -e 091231 -v 1
TCOR2CEF, version 1.7
TCOR file:          09_2_tcor5.txt, s/c: 2, records: 4129
Generated CEF name: C2_CP_DWP_TCOR__20090101_V01
Time range:         2009-01-01T00:00:05Z/2009-12-31T14:40:20Z
Finished, CEF size: 443026 bytes
Total duration:     31502415 seconds
Corrected:          31377872 seconds (99.6 %)

hoodie% ../tcor2cef -t 09_3_tcor5.txt -s 090101 -e 091231 -v 1
TCOR2CEF, version 1.7
TCOR file:          09_3_tcor5.txt, s/c: 3, records: 3562
Generated CEF name: C3_CP_DWP_TCOR__20090101_V01
Time range:         2009-01-01T00:00:05Z/2009-12-31T10:32:24Z
Finished, CEF size: 385198 bytes
Total duration:     31487539 seconds
Corrected:          30022271 seconds (95.3 %)

hoodie% ../tcor2cef -t 09_4_tcor5.txt -s 090101 -e 091231 -v 1
TCOR2CEF, version 1.7
TCOR file:          09_4_tcor5.txt, s/c: 4, records: 4501
Generated CEF name: C4_CP_DWP_TCOR__20090101_V01
Time range:         2009-01-01T00:00:05Z/2009-12-31T04:36:02Z
Finished, CEF size: 486479 bytes
Total duration:     31466157 seconds
Corrected:          30507761 seconds (97.0 %)
```

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__20090101_V00.cef
     C1_CP_DWP_TCOR__20090101_V01.cef
diff C2_CP_DWP_TCOR__20090101_V00.cef
     C2_CP_DWP_TCOR__20090101_V01.cef
diff C3_CP_DWP_TCOR__20090101_V00.cef
     C3_CP_DWP_TCOR__20090101_V01.cef
diff C4_CP_DWP_TCOR__20090101_V00.cef
     C4_CP_DWP_TCOR__20090101_V01.cef
```

Finally, the CEF files are checked using CEFpass.

```
setenv CEFPATH ~/CAA/headers
~/CAAtools/CEFpass C1_CP_DWP_TCOR__20090101_V01.cef
~/CAAtools/CEFpass C2_CP_DWP_TCOR__20090101_V01.cef
~/CAAtools/CEFpass C3_CP_DWP_TCOR__20090101_V01.cef
~/CAAtools/CEFpass C4_CP_DWP_TCOR__20090101_V01.cef
```

7 Caveats

The following general caveats apply to 2009 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 simply deleted from the files. For this period, TCOR coverage is around 93.7% to 99.4%. 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.

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.

The SC3 TCOR dataset (version 1) should not be applied to WBD data (version A) between 2009/02/20 20:24:33 and 2009/03/07 04:49:04. This is because this WBD data has been processed using time correlation coefficients different to those applied to other Cluster science data, and assumed as the basis for the TCOR corrections.

Appendix A. Getting and processing online WBD data 2009 July to December

Open web page:

http://www-pw.physics.uiowa.edu/~rmm/keith_yearby/

Save in text format as wbd_files_2009.txt (short form wbd_fi~1.txt).

Extract list of files for each spacecraft:

```
grep 9C1 \cluster\timing\wbddiff2\wbd_fi~1.txt >wbd_c1_files.txt
grep 6C2 \cluster\timing\wbddiff2\wbd_fi~1.txt >wbd_c2_files.txt
grep 7C3 \cluster\timing\wbddiff2\wbd_fi~1.txt >wbd_c3_files.txt
grep 8C4 \cluster\timing\wbddiff2\wbd_fi~1.txt >wbd_c4_files.txt
```

Use 'wbdget.c' to make wget batch files:

```
\cluster\miscsoft\debug\wbdget wbd_c1_files.txt wget_c1_files.bat
\cluster\miscsoft\debug\wbdget wbd_c2_files.txt wget_c2_files.bat
\cluster\miscsoft\debug\wbdget wbd_c3_files.txt wget_c3_files.bat
\cluster\miscsoft\debug\wbdget wbd_c4_files.txt wget_c4_files.bat
```

Run each script, making sure there is enough space (~3 Gbyte per SC) for the files.

For each SC get list of retrieved files, eg.:

```
dir *.6c2 /b >c2files.scr
dir *.8c4 /b >c4files.scr
```

Run 'wbddiff2' to get DIFFs:

```
wbddiff2 -f c3files.scr -c \cluster\timing\2009\09_3_tcal.txt >wbd_20090701_1231_c3_diff.txt
wbddiff2 -f c4files.scr -c \cluster\timing\2009\09_4_tcal.txt >wbd_20090701_1231_c4_diff.txt
```

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
```