Preparation and validation of WEC time corrections 2013

Keith Yearby, 22 January 2014

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 2013. The procedure used is the same as for 2009 to 2012, 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. Limited time correction data is available for this period.

2 Data and references

Source data:

WBD online level one data.
Cluster RDM for 2013.

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	5.6	2014-01-17
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
13_1_shla_files.txt	2014-01-13 15:48
13_2_shla_files.txt	2014-01-13 15:48
13_3_shla_files.txt	2014-01-13 15:48
13_4_shla_files.txt	2014-01-13 15:48

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
13_1_tcaldiff.txt	2014-01-13 16:28
13_2_tcaldiff.txt	2014-01-13 16:31
13_3_tcaldiff.txt	2014-01-13 15:50
13_4_tcaldiff.txt	2014-01-13 15:51

Point Valid DIFF files (validated WBD):

File name	Last modified date
13_1_wbddiff.txt	2014-01-13 16:34
13_2_wbddiff.txt	2014-01-13 16:37
13_3_wbddiff.txt	2014-01-13 16:38
13_4_wbddiff.txt	2014-01-13 16:39

ASCII TCOR files (validated):

File name	Last modified date
13_1_tcor_v.txt	2014-01-17 14:11
13_2_tcor_v.txt	2014-01-17 16:41
13_3_tcor_v.txt	2014-01-17 15:11
13_4_tcor_v.txt	2014-01-17 15:23

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 2012, and the first two days of 2014, to ensure that time corrections can be calculated for as much as possible of 2013.

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 (this is done by reading the spacecraft HK at the same time, as the ground station field of the TCAL files are set to 'not applicable').

The TCAL summary files (13_*_tcal_out.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 13_*_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

The WBD levelone files are made available (to the DWP team) on a web server at the University of Iowa. The files are organised in directories for each calendar month, which each file containing up to 10 minutes data. Most observations consist of more than one file. The listing of each directory is first downloaded, sorted into alphabetical order, then processed using the software tool 'wbdget' which creates scripts to download just the first file for each observation for each spacecraft.

```
1) Fetch index page on PC (eg. index_1301.htm).
2) sort index_1301.htm >index_1301.txt
3) cluster\miscsoft\debug\wbdget index_1301.txt wget_1301.bat
4) Transfer wget_1301.bat to iMac.
5) source wget_1301.bat
```

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. Note that the TCAL DIFFs must be processed as in section 3.2 before the WBD DIFFs.

```
cd cluster/timing/2013/wbd
ls *C1 >c1_files.txt
ls *C2 >c2_files.txt
ls *C3 >c3_files.txt
ls *C4 >c4_files.txt
../../bin/wbddiff2 -f c1_files.txt -c ../13_1_tcal_out.txt >wbd_13_1_diff.txt
../../bin/wbddiff2 -f c2_files.txt -c ../13_2_tcal_out.txt >wbd_13_2_diff.txt
../../bin/wbddiff2 -f c3_files.txt -c ../13_3_tcal_out.txt >wbd_13_3_diff.txt
../../bin/wbddiff2 -f c4_files.txt -c ../13_4_tcal_out.txt >wbd_13_4_diff.txt
```

3.4 Merging and Validation

The ESOC and WBD DIFF measurements are merged together. The output files (13_*_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.

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.

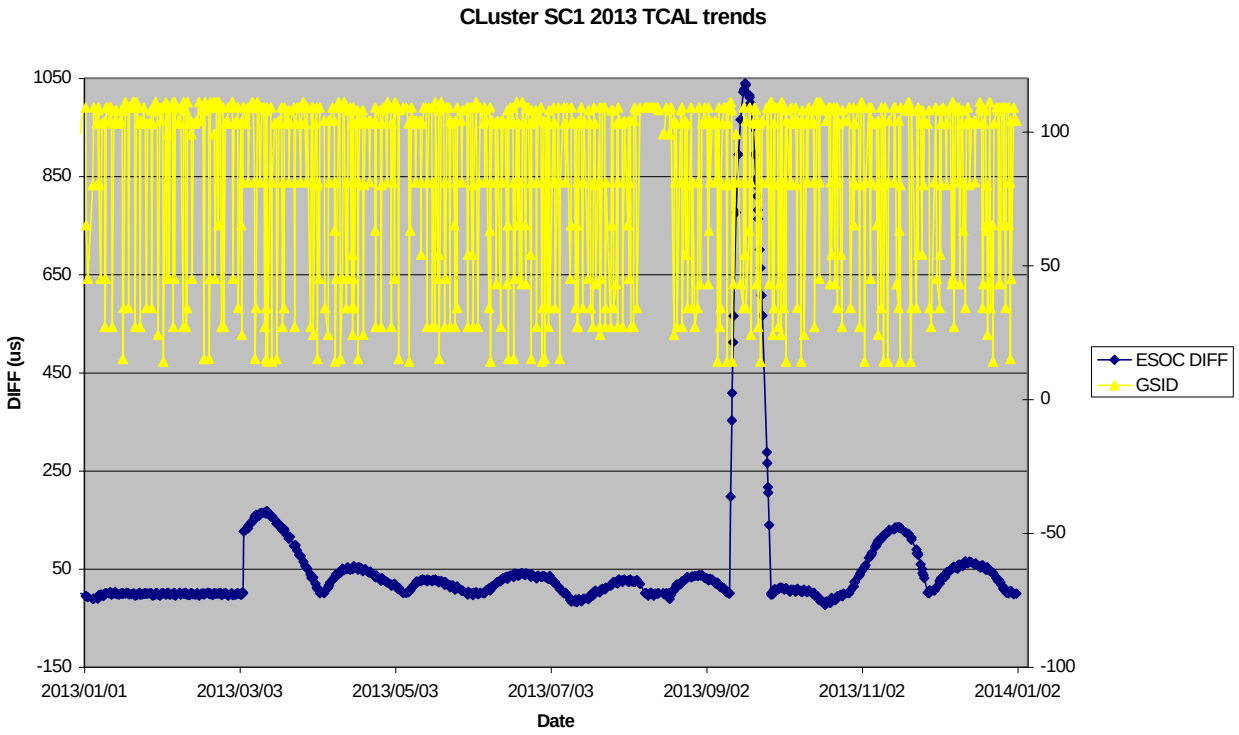
The WBD DIFFs are compared to the merged DIFF using **'wbdtcor'**. The current version of this software allows for the known timing offsets of the DSN stations (specified in `gsotable.txt`), so ideally the differences reported should be zero. Following the manual corrections below all differences (WBD-ESOC) are under 10μs.

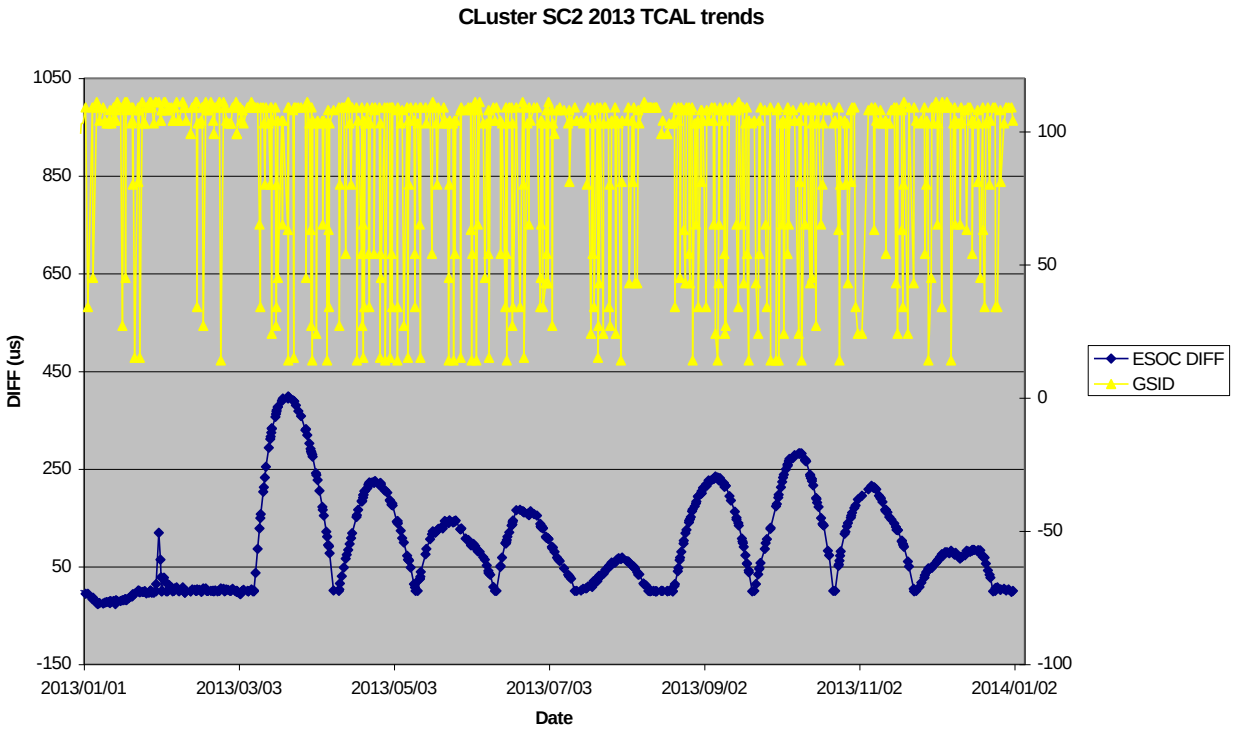
ESOC DIFF, spacecraft 1, 2013-09-13 16:00: A point was added by polynomial interpolation, as the large rate of change of the clock rate around this time meant that the normal linear interpolation resulted in an error larger than 10μs.

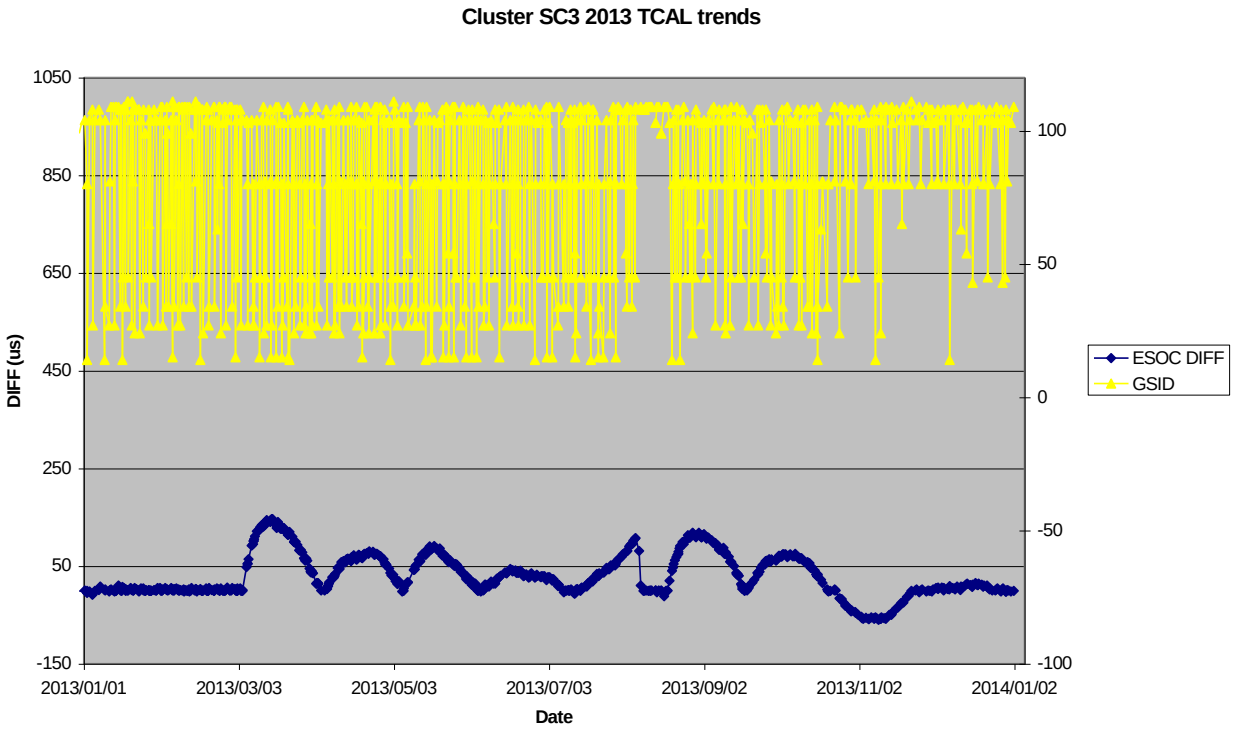
ESOC DIFF, spacecraft 2, 2013-06-21 07:06: Apparently incorrect point deleted.

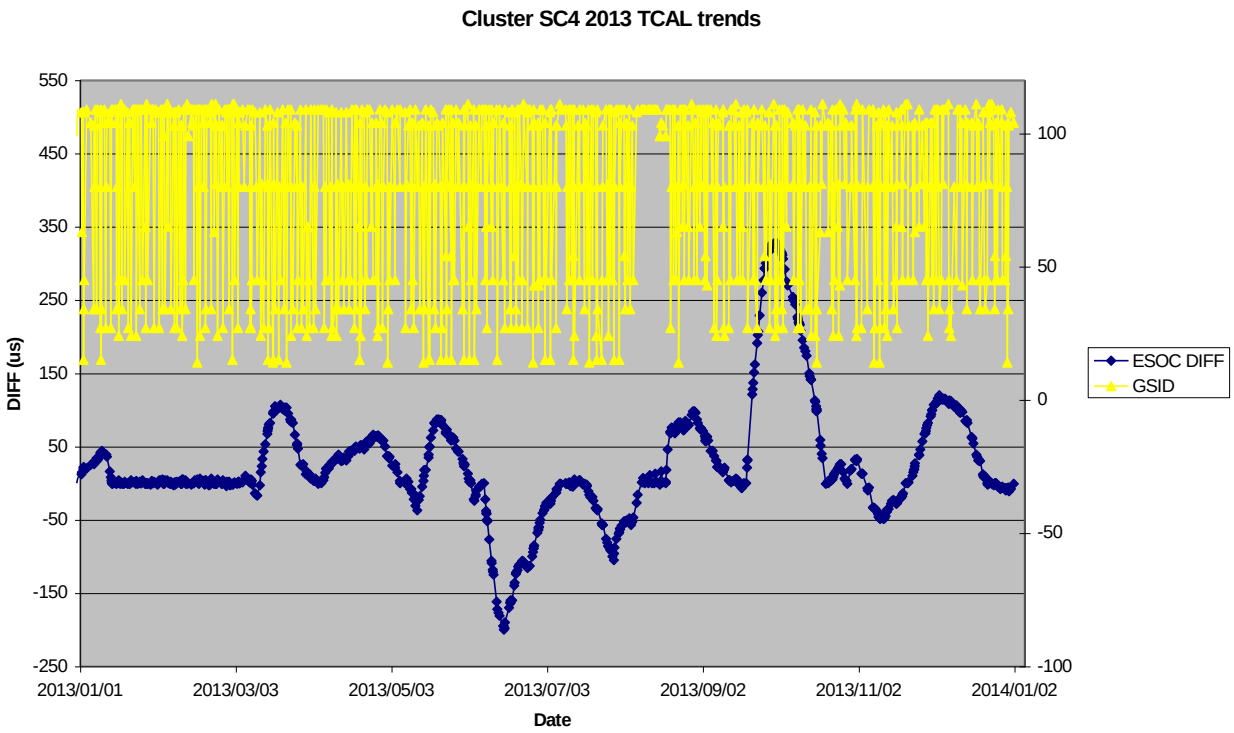
WBD DIFF, spacecraft 3, 2013-05-08, 2013-06-22 and 2013-06-25: The following tracks had apparently incorrect ground receive times and were excluded.

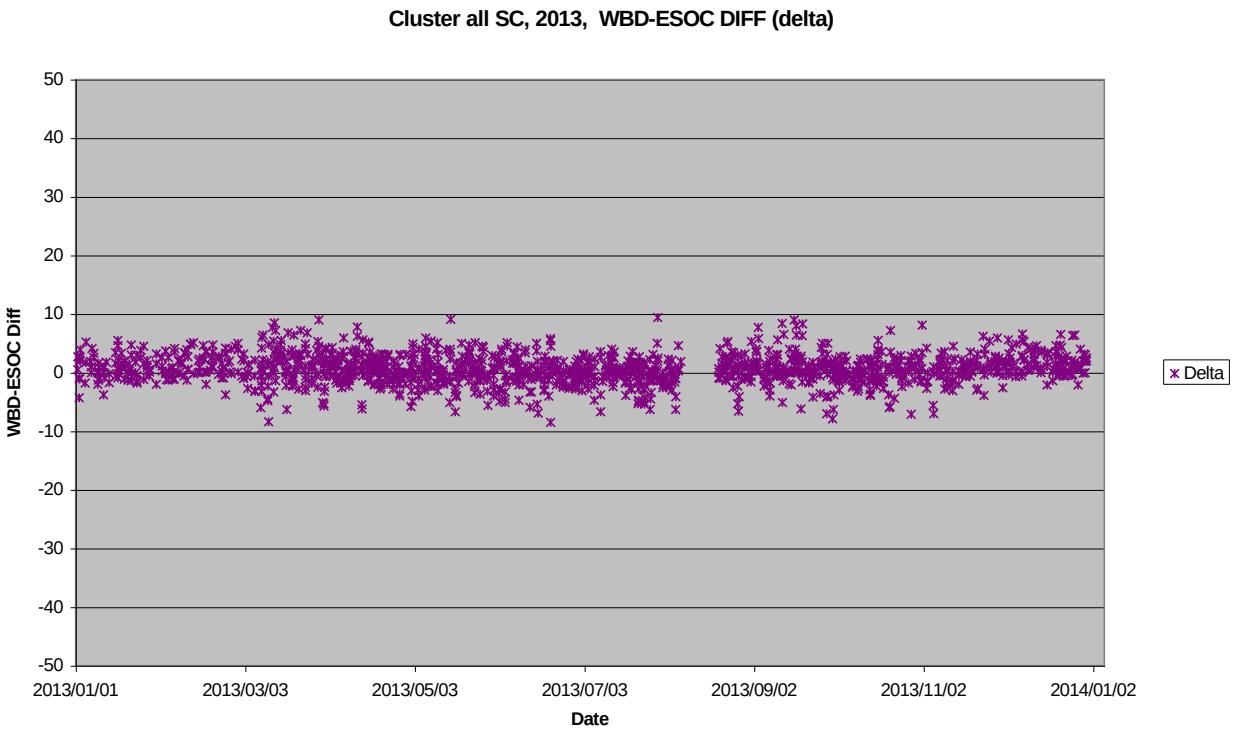
Date/time	GRT-OBT	SC	ANT	OBTM	WBD-ESOC
2013-05-08T20:59:57	122	194	81	34776368	90
2013-05-08T22:09:56	126	194	81	34776368	91
2013-06-22T22:49:57	291	194	81	34755248	220
2013-06-25T03:29:59	-264	194	80	34755248	-271
2013-06-25T04:39:58	-239	194	80	34755248	-248
2013-06-25T05:49:57	-209	194	80	34755248	-221


CLuster SC1 2013 TCAL trends
1050
850
650
450
250
50
-150
100
50
0
-50
-100
DIFF (us)
2013/01/01
2013/03/03
2013/05/03
2013/07/03
2013/09/02
2013/11/02
2014/01/02
Date
ESOC DIFF
GSID


CLuster SC2 2013 TCAL trends
1050
850
650
450
250
50
-150
100
50
0
-50
-100
DIFF (us)
2013/01/01
2013/03/03
2013/05/03
2013/07/03
2013/09/02
2013/11/02
2014/01/02
Date
ESOC DIFF
GSID


Cluster SC3 2013 TCAL trends
1050
850
650
450
250
50
-150
DIFF (us)
100
50
0
-50
-100
2013/01/01
2013/03/03
2013/05/03
2013/07/03
2013/09/02
2013/11/02
2014/01/02
Date
ESOC DIFF
GSID


Cluster SC4 2013 TCAL trends
550
450
350
250
150
50
-50
-150
-250
DIFF (us)
100
50
0
-50
-100
2013/01/01
2013/03/03
2013/05/03
2013/07/03
2013/09/02
2013/11/02
2014/01/02
Date
ESOC DIFF
GSID


Cluster all SC, 2013, WBD-ESOC DIFF (delta)
WBD-ESOC Diff
50
40
30
20
10
0
-10
-20
-30
-40
-50
2013/01/01
2013/03/03
2013/05/03
2013/07/03
2013/09/02
2013/11/02
2014/01/02
Date
Delta

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 5.6 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 13_1_tcor.txt -d 13_1_diffmer.txt
   -f 13_1_shla_files.txt -s 130101 -e 131231 -w 13_1_wbddiff.txt
../bin/maketcor5 -o 13_2_tcor.txt -d 13_2_diffmer.txt
   -f 13_2_shla_files.txt -s 130101 -e 131231 -w 13_2_wbddiff.txt
../bin/maketcor5 -o 13_3_tcor.txt -d 13_3_diffmer.txt
   -f 13_3_shla_files.txt -s 130101 -e 131231 -w 13_3_wbddiff.txt
../bin/maketcor5 -o 13_4_tcor.txt -d 13_4_diffmer.txt
   -f 13_4_shla_files.txt -s 130101 -e 131231 -w 13_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.

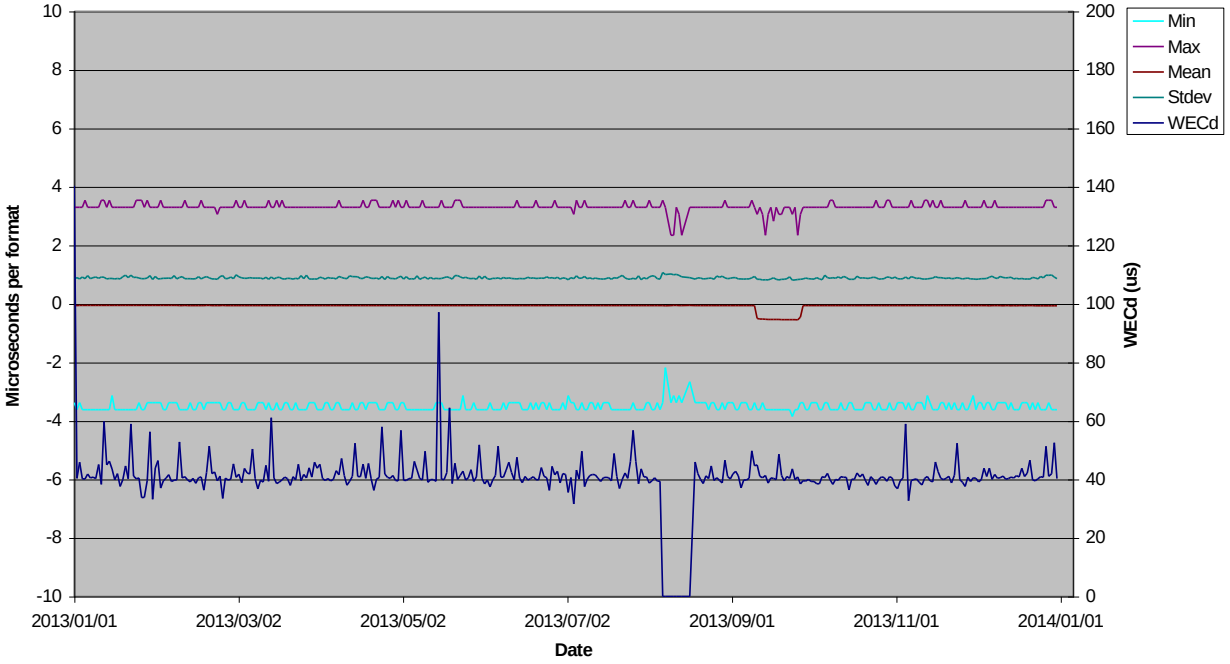
The current version also checks the increment of the WEC master clock pulse as measured by the EW5SSOFF parameter in the WEC HK. This provides an independent check that the phase jumps in the VC0 reset pulse cycle have been correctly indentified. The WEC master clock pulse is measured once every telemetry 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 large number of jumps apparently due to incorrect tracking of the VC0 phase where two telemetry mode changes occurred only one minute apart, and a jump in VC0 phase was assigned to the wrong one. The 'maketcor' software was updated (to version 5.6) to handle this situation better. However some jumps remained due to this and other causes and were manually corrected or the data removed. The modified files were called `13_*_tcor_v.txt`. The few remaining spikes are due to instrument malfunctions.

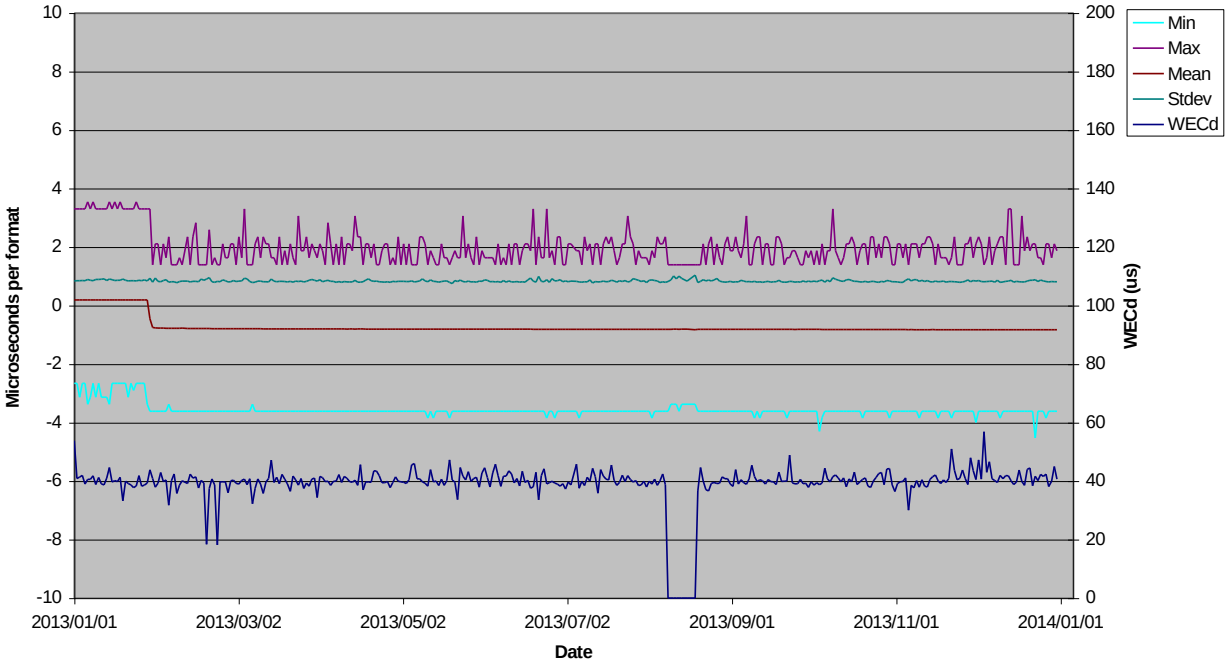
Veritcor is run using the following commands:

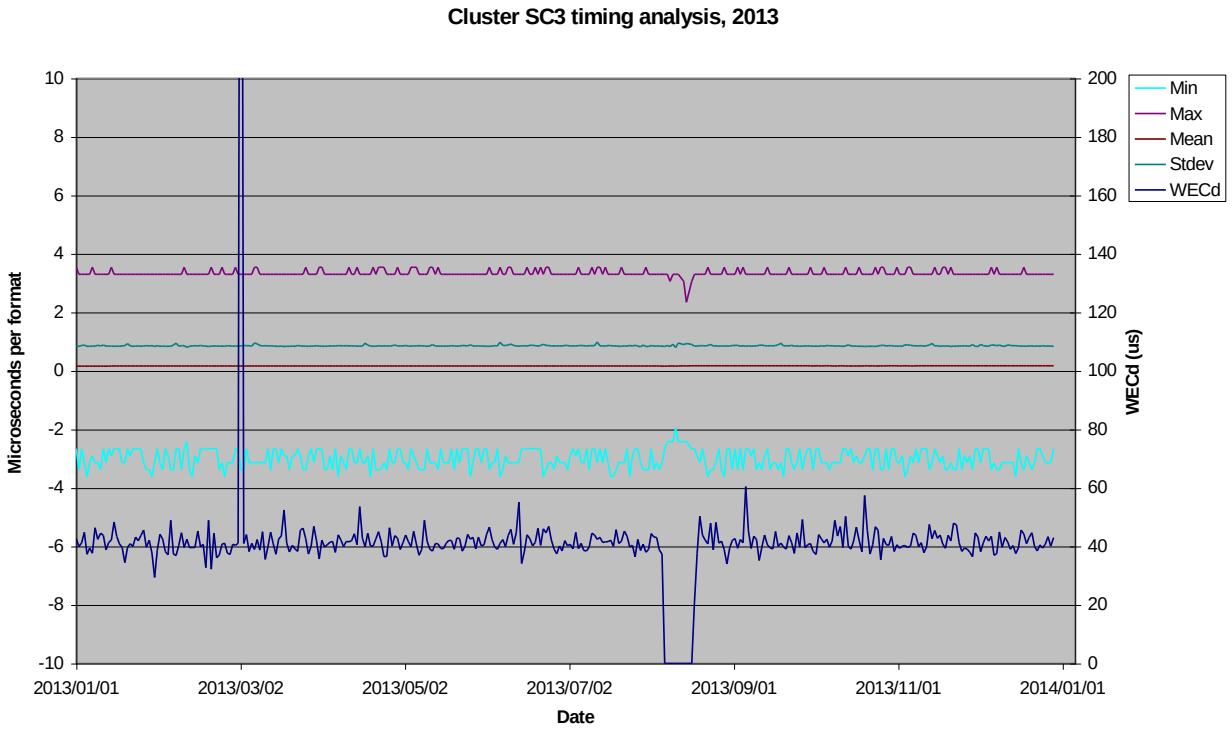
```
../veritcor -f 13_1_shla_files.txt -T . -v 4 -i 5.152221   > 13_1_veri.txt
../veritcor -f 13_2_shla_files.txt -T . -v 4 -i 5.152221   > 13_2_veri.txt
../veritcor -f 13_3_shla_files.txt -T . -v 4 -i 5.152221   > 13_3_veri.txt
../veritcor -f 13_4_shla_files.txt -T . -v 4 -i 5.152221   > 13_4_veri.txt
```

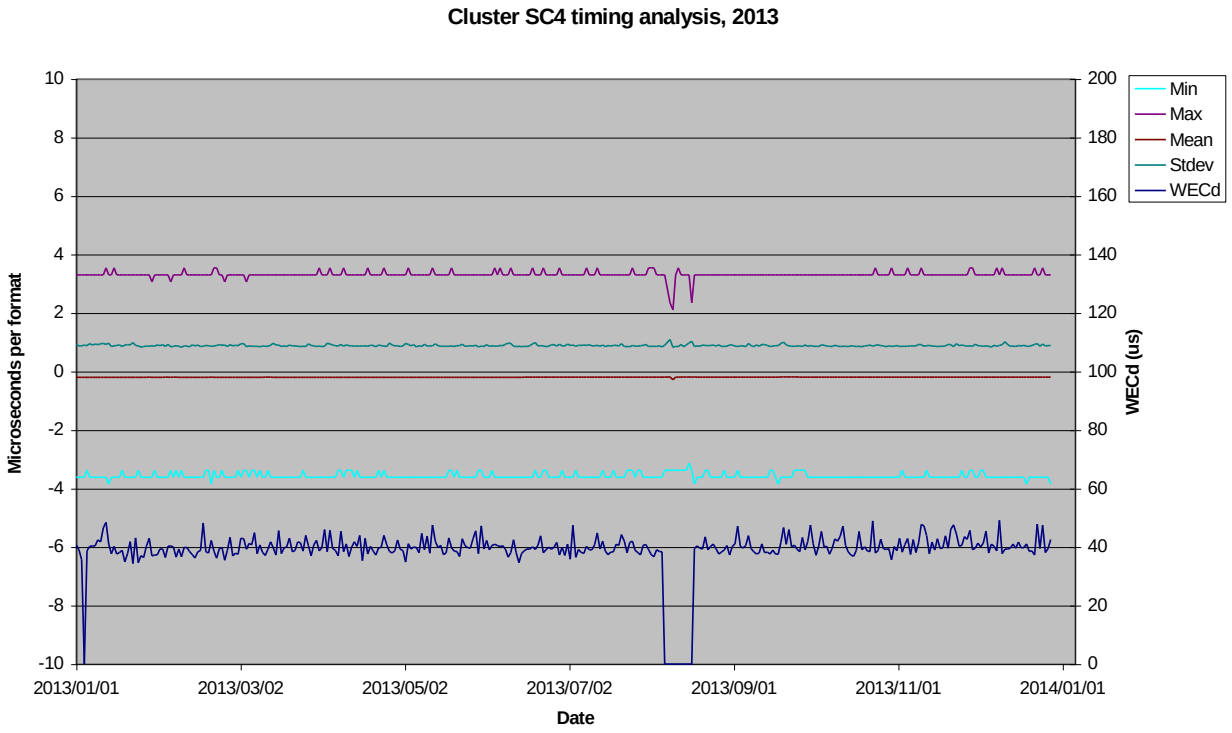
Cluster SC1 timing analysis, 2013



Cluster SC2 timing analysis, 2013




Cluster SC3 timing analysis, 2013
Microseconds per format
WECd (us)
Date
Min
Max
Mean
Stdev
WECd
10
8
6
4
2
0
-2
-4
-6
-8
-10
200
180
160
140
120
100
80
60
40
20
0
2013/01/01
2013/03/02
2013/05/02
2013/07/02
2013/09/01
2013/11/01
2014/01/01


Cluster SC4 timing analysis, 2013
Microseconds per format
WECd (us)
Date
Min
Max
Mean
Stdev
WECd
10
8
6
4
2
0
-2
-4
-6
-8
-10
200
180
160
140
120
100
80
60
40
20
0
2013/01/01
2013/03/02
2013/05/02
2013/07/02
2013/09/01
2013/11/01
2014/01/01

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 13_1_tcor_v.txt -v 1
../tcor2cef -t 13_2_tcor_v.txt -v 1
../tcor2cef -t 13_3_tcor_v.txt -v 1
../tcor2cef -t 13_4_tcor_v.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__20130101_V*.cef
diff C2_CP_DWP_TCOR__20130101_V*.cef
diff C3_CP_DWP_TCOR__20130101_V*.cef
diff C4_CP_DWP_TCOR__20130101_V*.cef
```

Finally, the CEF files are checked using CEFpass.

```
../bin/CEFpass -I ../headers C1_CP_DWP_TCOR__20130101_V01.cef
../bin/CEFpass -I ../headers C2_CP_DWP_TCOR__20130101_V01.cef
../bin/CEFpass -I ../headers C3_CP_DWP_TCOR__20130101_V01.cef
../bin/CEFpass -I ../headers C4_CP_DWP_TCOR__20130101_V01.cef
```

7 Caveats

The following general caveats apply to 2013 TCOR data.

TCOR data is not available at all times. For this period, TCOR coverage is around 90% to 93%. 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.