Preparation and validation of WEC time corrections 2008

Keith Yearby, 21 October 2009

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 the year 2008. During this period a new operational procedure was used at ESOC, where time correlations were performed during each nominal pass. This in turn required a new procedure to prepare the time corrections. These changes had been piloted already at the end 2007, but applying the procedure to the 2008 data required further major changes. These were:

The software tool (readtcal) that extracts DIFF values from the TCAL files was updated to return also the identification of the ESA ground station in use when the time correlation was performed. This allows identification of timing errors relating to a particular ground station.

The interpolation of DIFF values was previously performed directly on DIFF itself. For example if the DIFF at 08:00 was 10μs, and the DIFF at 12:00 was 20μs, to obtain the DIFF at 10:00 a simple linear interpolation would return 15μs. However, this does not work if there has been a new time correlation in the intervening time. The new procedure performs interpolation in SCET/OBT values and then derives the DIFF at the required time.

A new software tool (tcaltrend) is used to determine what the DIFF values would be if the time correlations were performed at less frequent intervals, such as monthly. This allows trends in the clock drift to be seen, and helps to identify ground station timing errors.

Calculation of the OFFSET parameter requires knowledge of whether the spacecraft data handling system is operating in a real time mode, or via the solid state recorder. Previously this was determined using the 'stream' parameter of packet header of the WEC housekeeping data. However, sometimes data can be recorded on board *and* downlinked in real time, in which case the 'stream' parameter does not give the expected result. Now the spacecraft data handling mode is obtained directly using the TDA_MODE parameter in the spacecraft housekeeping.

2 Data and references

Source data:

WBD data DVDs for 2008 (online data for October and December).
Cluster RDM for 2008.

Documents:

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

Software:

Software	Version	Date
readtcal	2.2	2009-09-29
wbddiff	2.3	2009-09-08
wbdtcor	1.1	2009-09-08
tcaltrend	1.1	2009-09-30
maketcor	4.2c	2009-10-09
veritcor	1.5	2009-10-09
tcor2cef	1.6	2006-09-07

Point Valid DIFF files:

File name	Last modified date
08_1_tcaldiff.txt	2009-10-01 10:44
08_2_tcaldiff.txt	2009-10-01 10:43
08_3_tcaldiff.txt	2009-10-01 10:43
08_4_tcaldiff.txt	2009-10-02 13:44

ASCII TCOR files:

File name	Last modified date
08_1_tcor_4.2.txt	2009-10-07T14:06:25Z
08_2_tcor_4.2.txt	2009-10-07T14:31:18Z
08_3_tcor_4.2.txt	2009-10-09T14:21:54Z
08_4_tcor_4.2c.txt	2009-10-09T15:20:09Z

3 Preparation of the Point Valid DIFF measurements

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.

The ESOC DIFF values can be 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. 'readtcal' requires as input a list of the full path names of the WEC HK and TCAL files. The standard HK+TCAL list used by 'maketcor' is suitable. The following commands were used:

```
find /data/disk2/cluster/RDM/08* -name '*wh*' > scr.scr
find /data/disk2/cluster/RDM/08* -name '*la*' >> scr.scr
~/CAA/weclog/purgedup scr.scr 08_hkla_files.txt
grep cluster1 08_hkla_files.txt | sort > 08_1_hkla_files.txt
grep cluster2 08_hkla_files.txt | sort > 08_2_hkla_files.txt
grep cluster3 08_hkla_files.txt | sort > 08_3_hkla_files.txt
grep cluster4 08_hkla_files.txt | sort > 08_4_hkla_files.txt
../readtcal -f 08_1_hkla_files.txt -o 08_1_tcaldiff.txt
  >08_1_tcal.txt
../readtcal -f 08_2_hkla_files.txt -o 08_2_tcaldiff.txt
  >08_2_tcal.txt
../readtcal -f 08_3_hkla_files.txt -o 08_3_tcaldiff.txt
  >08_3_tcal.txt
../readtcal -f 08_4_hkla_files.txt -o 08_4_tcaldiff.txt
  >08_4_tcal.txt
```

The *_tcal.txt files 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 *_tcaldiff.txt files contain the ESOC DIFF measurements derived by assuming the DIFF to be zero immediately after each new time correlation.

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.

Next the long term trends of the clock drifts, as measured by the ESOC and WBD DIFFs together with the corresponding time calibrations (TCAL) are computed using TCALTREND.

```
\cluster\miscsoft\readtcal\debug\tcaltrend -c 08_1_tcal.txt
  -d 08_1_tcaldiff.txt -w ..\wbddiff2\wbd_all_c1_ncd.txt
  >08_1_tcaltrend.txt
```

The WBD DIFFs are compared to the ESOC DIFF using WBDTCOR.

```
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c1_ncd.txt
 -p 08_1_tcaldiff.txt -c 08_1_tcal.txt >08_1_delta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c2_ncd.txt
 -p 08_2_tcaldiff.txt -c 08_2_tcal.txt >08_2_delta.txt
```

```
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c3_ncd.txt
 -p 08_3_tcaldiff.txt -c 08_3_tcal.txt >08_3_delta.txt
\cluster\miscsoft\debug\wbdtcor -w ..\wbddiff2\wbd_all_c4_ncd.txt
 -p 08_4_tcaldiff.txt -c 08_4_tcal.txt >08_4_delta.txt
```

The results of both TCALTREND and WBDTCOR are plotted to allow inconsistencies to be identified and corrected. Figure 1 shows a Section of TCALTREND data for SC1. Inconsistencies are apparent between 2008-10-01 and 2008-10-13, with ~40µs steps between DIFFs taken on different ground stations, and abnormal differences between ESOC and WBD DIFFs. It was determined that a -40µs correction was required to ESOC DIFFs taken on ground station (GSID) 9, for all SC using this ground station (SC1, SC2). The TCALTREND data after correction is shown in figure 2.

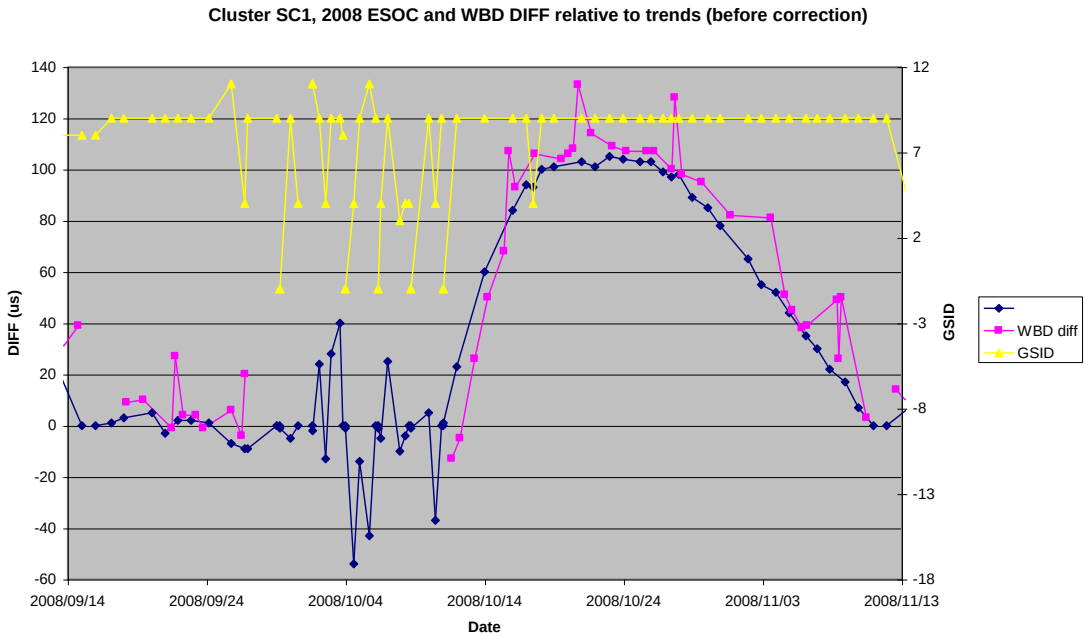

Figure 1. ESOC and WBD DIFF relative to long term clock drift, before correction.

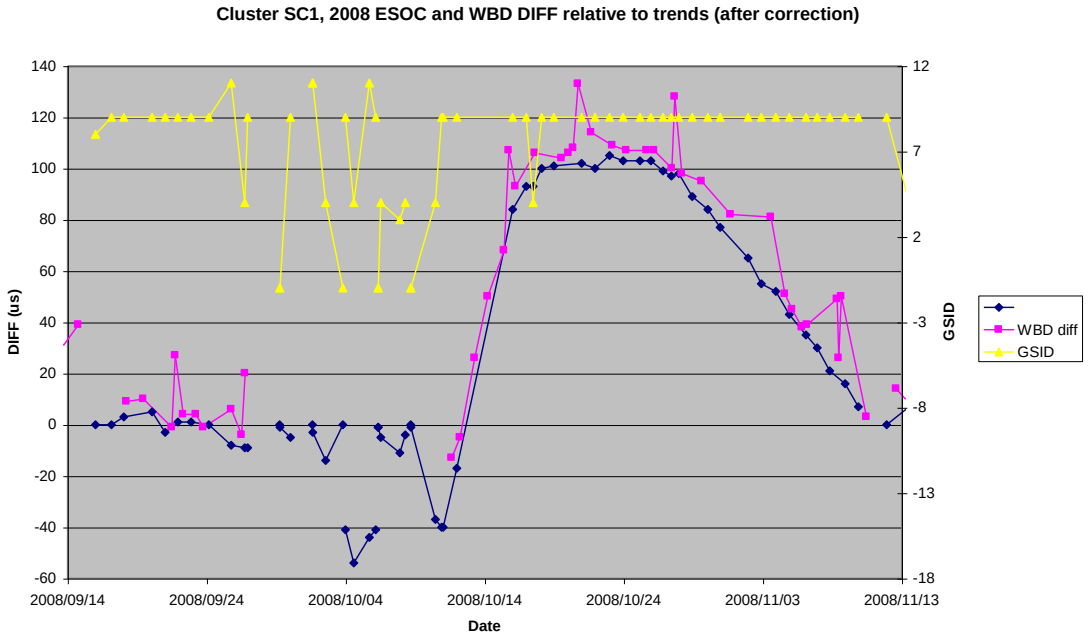

Figure 2. ESOC and WBD DIFF relative to long term clock drift, after correction.

The WBD-ESOC DIFFs are plotted in two ways: in figures 3, 5, 7, 9 as a function of date, and in figures 4, 6, 8 and 10 as a function of receiving antenna. It is known that there is a small difference between WBD and ESOCV DIFFs, and this depends on the antenna used to receive the data. For most antennae this difference averages about 10μs, but is about 15μs for antenna 46, and 35μs for antennae 80 and 81 (Panska Ves). These differences are consistently observed for all Cluster spacecraft, so are assumed to be a characteristic of the antennae (or its associated receiver).

Differences of about -65μs in mid-June are known to be due to a timing error at Panska Ves.

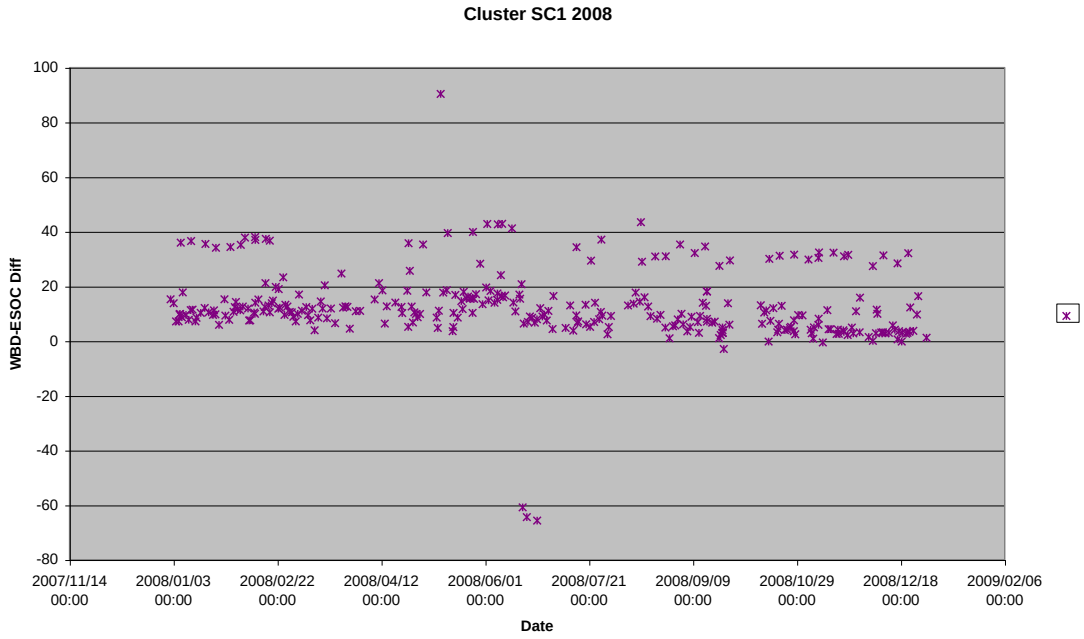

Figure 3.

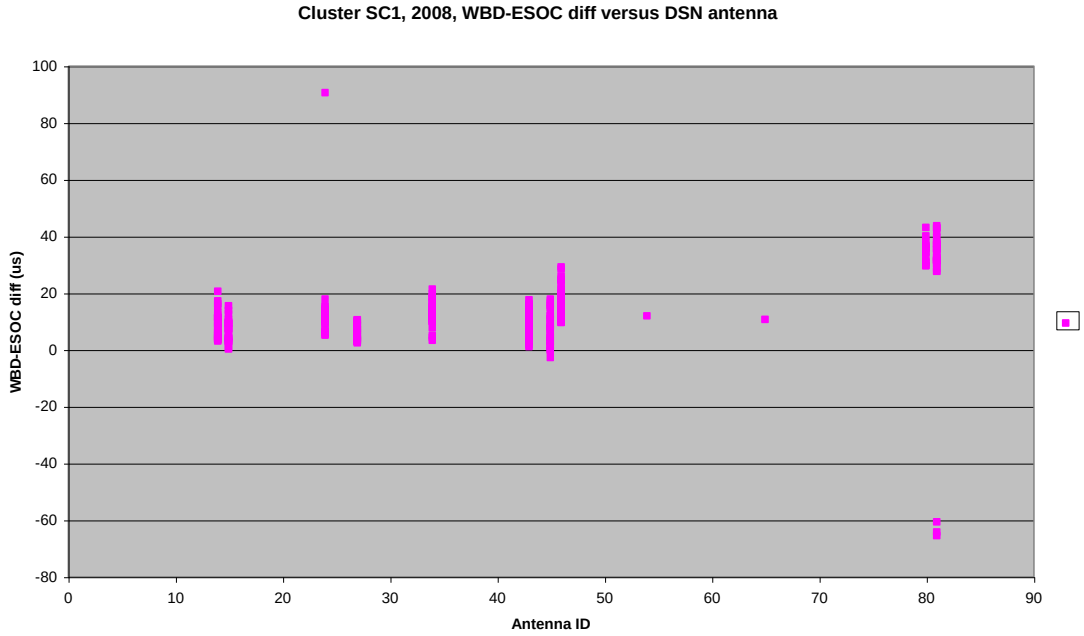

Figure 4.

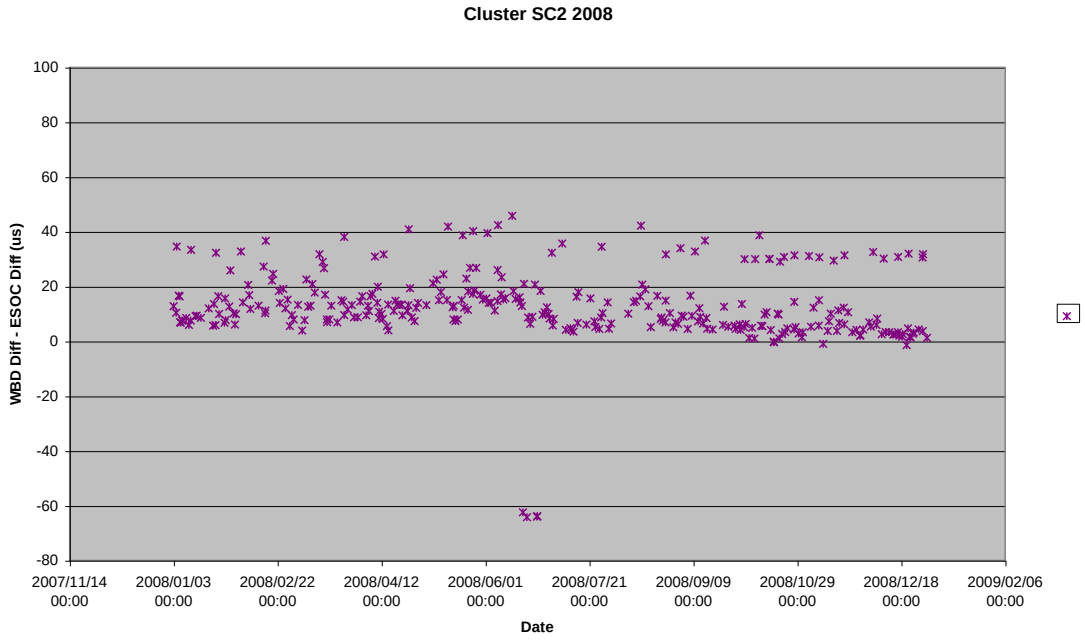

Figure 5.

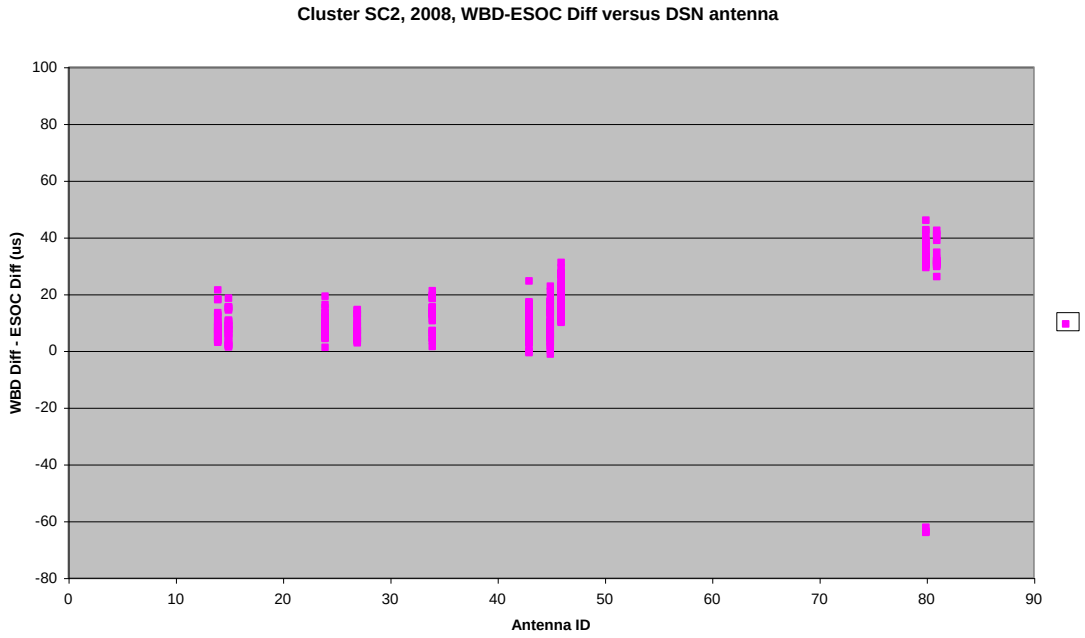

Figure 6.

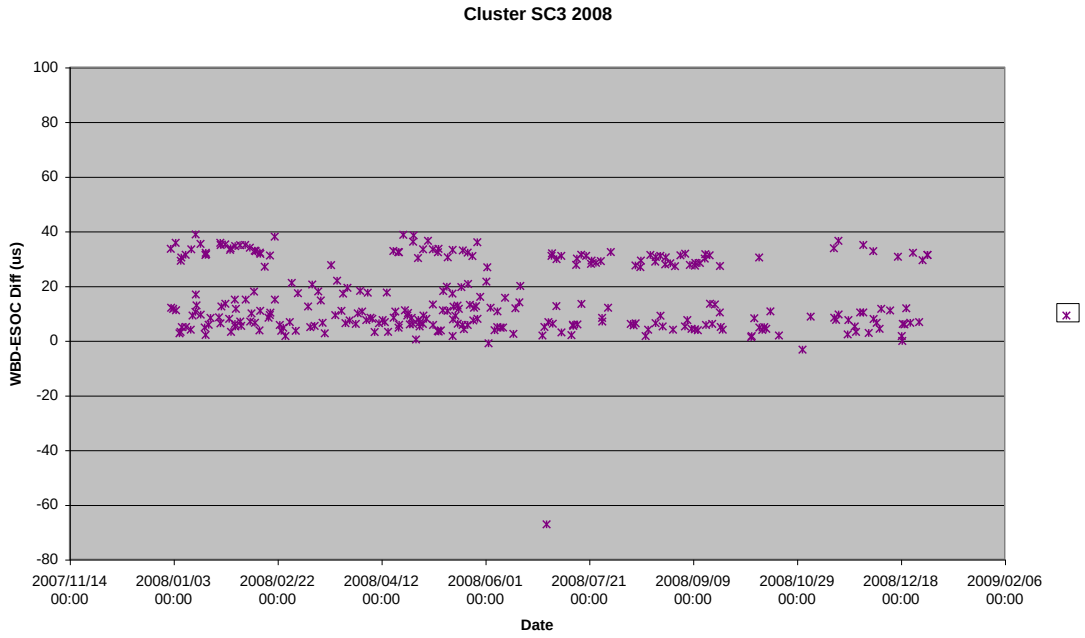

Figure 7.

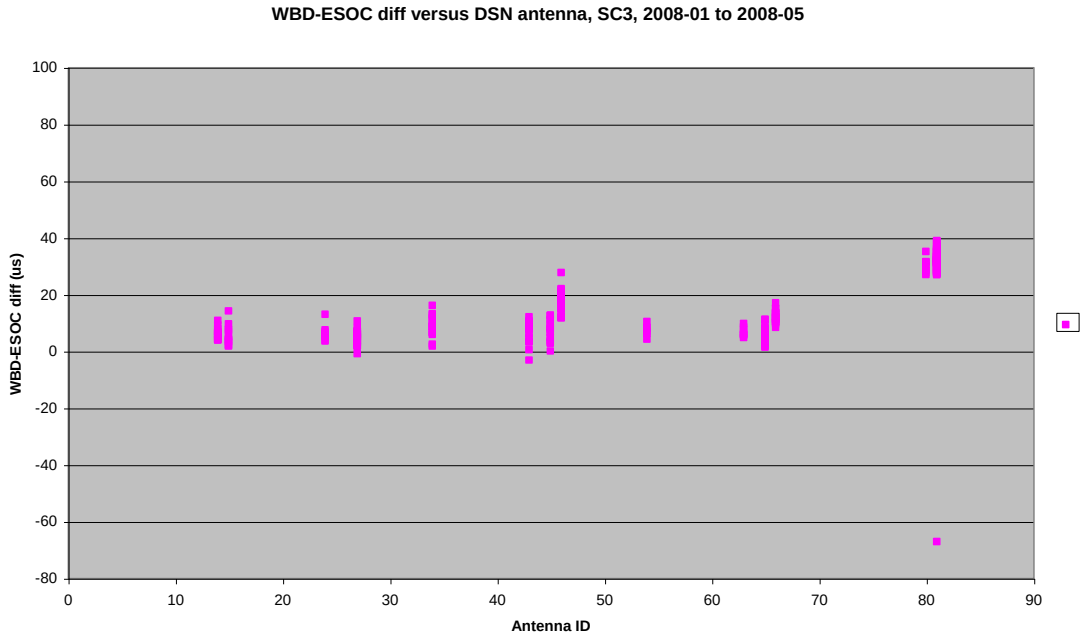

Figure 8.

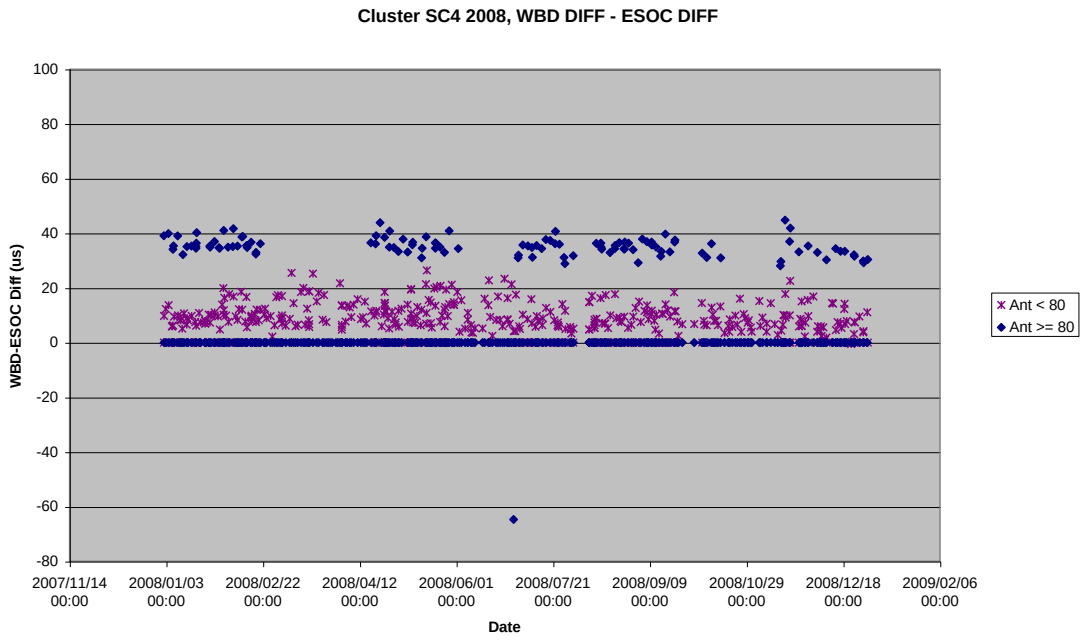

Figure 9.

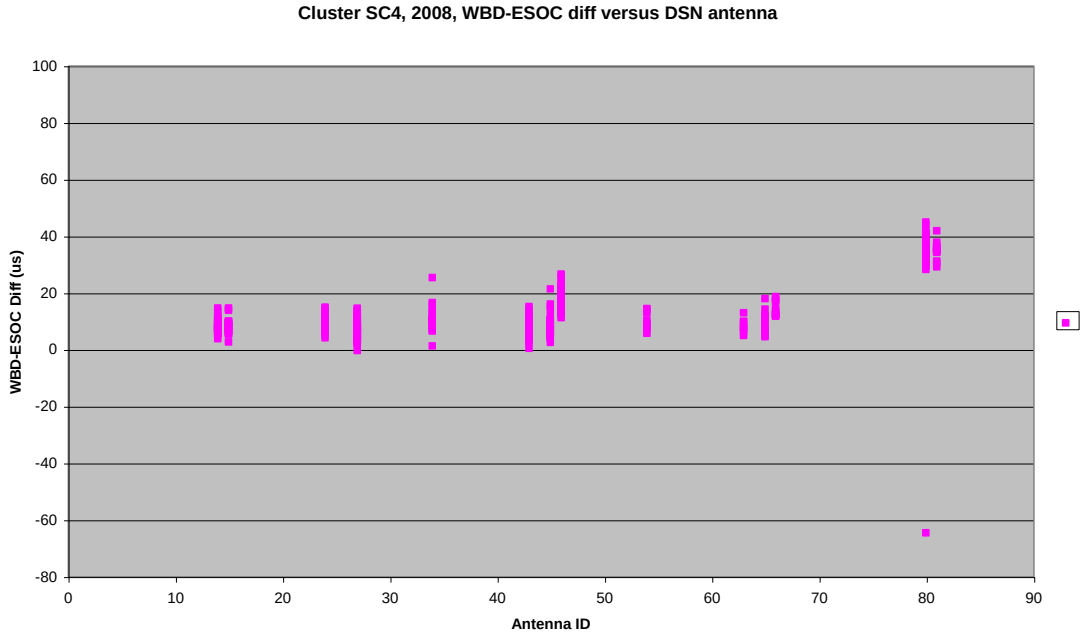

Figure 10.

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 it was updated to version 4.2 (4.2c for SC4). The following commands were used:

```
../maketcor4.2 -o 08_1_tcor_4.2.txt -d 08_1_tcaldiff.txt \\
  -f 08_1_hkla_files.txt -s 080101 -e 081231 \\
  -w ../wbddiff2/wbd_all_c1_ncd.txt
../maketcor4.2 -o 08_2_tcor_4.2.txt -d 08_2_tcaldiff.txt \\
  -f 08_2_hkla_files.txt -s 080101 -e 081231 \\
  -w ../wbddiff2/wbd_all_c2_ncd.txt
../maketcor4.2 -o 08_3_tcor_4.2.txt -d 08_3_tcaldiff.txt \\
  -f 08_3_hkla_files.txt -s 080101 -e 081231 \\
  -w ../wbddiff2/wbd_all_c3_ncd.txt
../maketcor4.2 -o 08_4_tcor_4.2c.txt -d 08_4_tcaldiff.txt \\
  -f 08_4_hkla_files.txt -s 080101 -e 081231 \\
  -w ../wbddiff2/wbd_all_c4_ncd.txt -g 300.0
```

```
# MAKETCOR, version 4.2
#
# DIFF FILE: 08_1_tcaldiff.txt
# File list: 08_1_hkla_files.txt (la)
# 406 TCAL records processed.
# File list: 08_1_hkla_files.txt (hk)
# First record: 2008/01/01 00:00:02.794728
# Last record:  2008/12/31 18:31:27.293468
# Total proc:    5998893 formats,  100.0%
# Done:          5376306 formats,   89.6%
# WEC off:        228155 formats,    3.8%
# No diff:        121681 formats,    2.0%
# Non constant:    23468 formats,    0.4%
# No offset:      248496 formats,    4.1%
# Outside:             0 formats,    0.0%
# Missing:           787 formats,    0.0%
```

```
# MAKETCOR, version 4.2
#
# DIFF FILE: 08_2_tcaldiff.txt
# File list: 08_2_hkla_files.txt (la)
# 332 TCAL records processed.
# File list: 08_2_hkla_files.txt (hk)
# First record: 2008/01/01 00:00:00.785157
# Last record:  2008/12/31 14:45:48.214965
# Total proc:    6040880 formats,  100.0%
# Done:          5927911 formats,   98.1%
# WEC off:         57748 formats,    1.0%
# No diff:         12841 formats,    0.2%
# Non constant:    16335 formats,    0.3%
# No offset:       25610 formats,    0.4%
# Outside:             0 formats,    0.0%
# Missing:           435 formats,    0.0%
```

```
# MAKETCOR, version 4.2
#
# DIFF FILE: 08_3_tcaldiff.txt
# File list: 08_3_hkla_files.txt (la)
# 272 TCAL records processed.
# File list: 08_3_hkla_files.txt (hk)
# First record: 2008/01/01 00:00:03.502749
# Last record:  2008/12/31 10:32:38.978074
# Total proc:    6083740 formats,  100.0%
# Done:          5712424 formats,   93.9%
# WEC off:        237504 formats,    3.9%
# No diff:         22404 formats,    0.4%
# Non constant:       70 formats,    0.0%
# No offset:      110812 formats,    1.8%
# Outside:             0 formats,    0.0%
# Missing:           526 formats,    0.0%
```

```
# MAKETCOR, version 4.2
#
# DIFF FILE: 08_4_tcaldiff.txt
# File list: 08_4_hkla_files.txt (la)
# 251 TCAL records processed.
# File list: 08_4_hkla_files.txt (hk)
# First record: 2008/01/01 00:00:05.017119
# Last record:  2008/12/31 05:59:04.221304
# Total proc:    6052788 formats,  100.0%
# Done:          5523473 formats,   91.3%
# WEC off:        162280 formats,    2.7%
# No diff:         18726 formats,    0.3%
# Non constant:    28086 formats,    0.5%
# No offset:      319525 formats,    5.3%
# Outside:             0 formats,    0.0%
# Missing:           698 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. 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 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.

```
../tcor2cef -t 08_1_tcor_4.2.txt
../tcor2cef -t 08_2_tcor_4.2.txt
../tcor2cef -t 08_3_tcor_4.2.txt
../tcor2cef -t 08_4_tcor_4.2c.txt
```

```
../veritcor -f 08_1_hkla_files.txt -T . -v 4 > 08_1_veritcor.txt
../veritcor -f 08_2_hkla_files.txt -T . -v 4 > 08_2_veritcor.txt
../veritcor -f 08_3_hkla_files.txt -T . -v 4 > 08_3_veritcor.txt
../veritcor -f 08_4_hkla_files.txt -T . -v 4 > 08_4_veritcor.txt
```

The 'veritcor' output is plotted in figures 11 to 14.

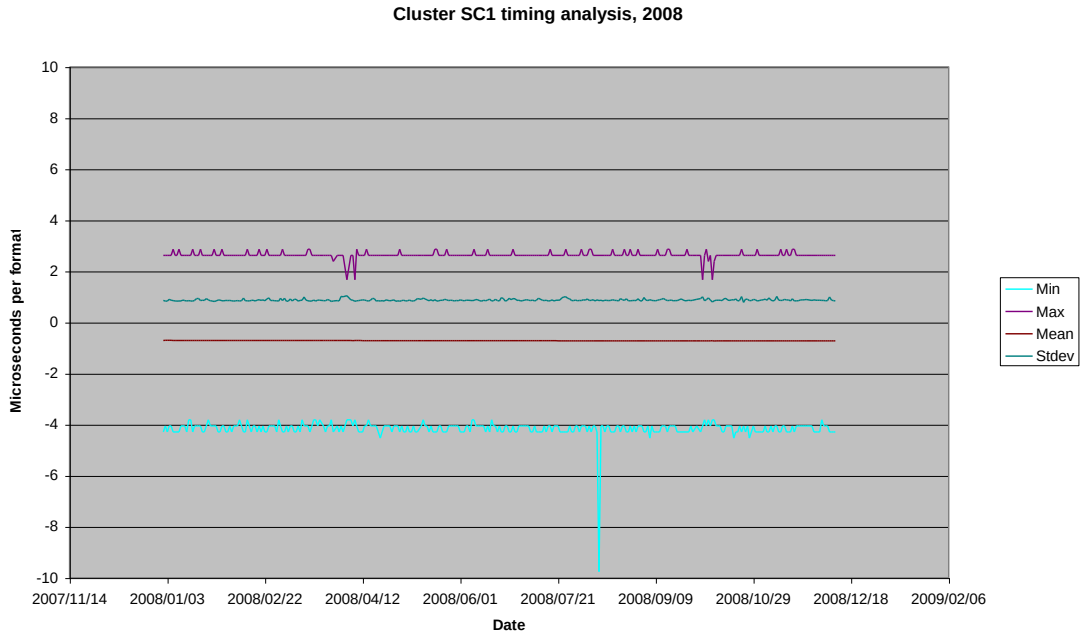

Figure 11.

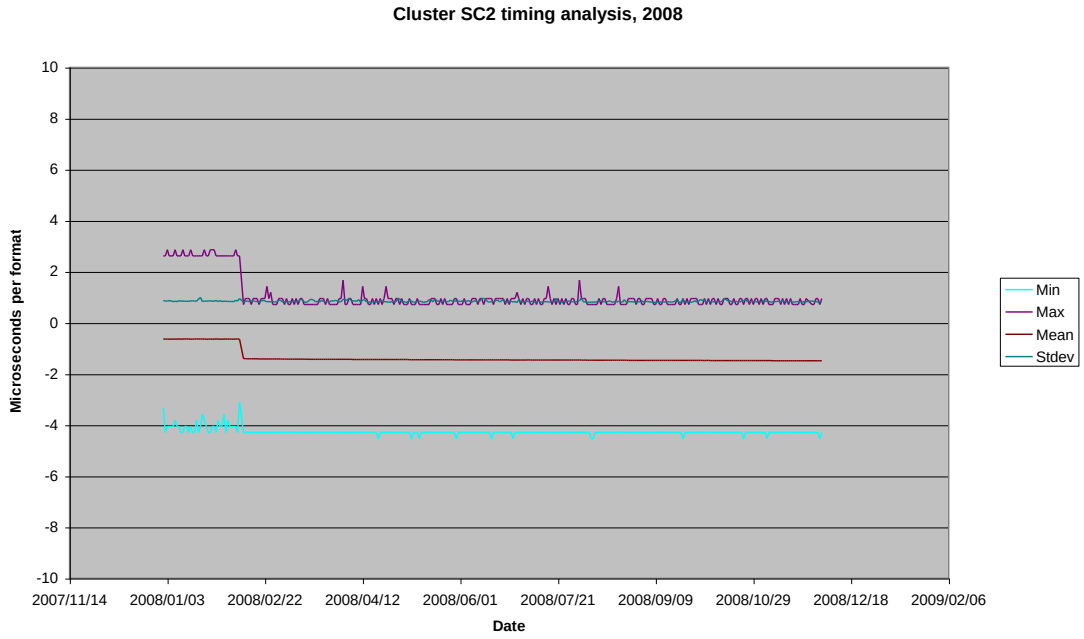

Figure 12.

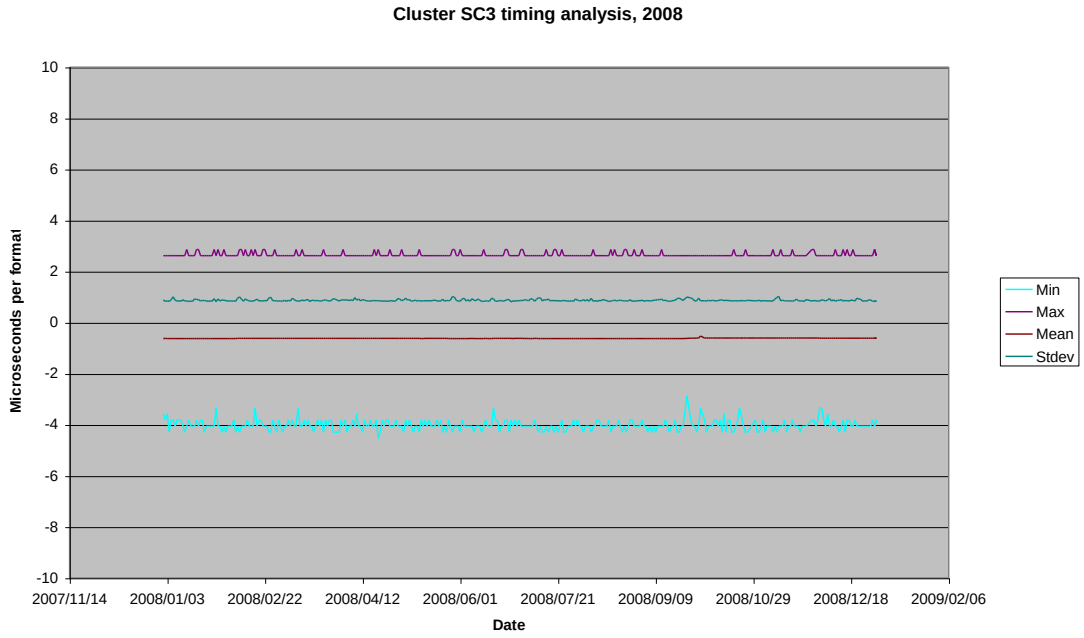

Figure 13.

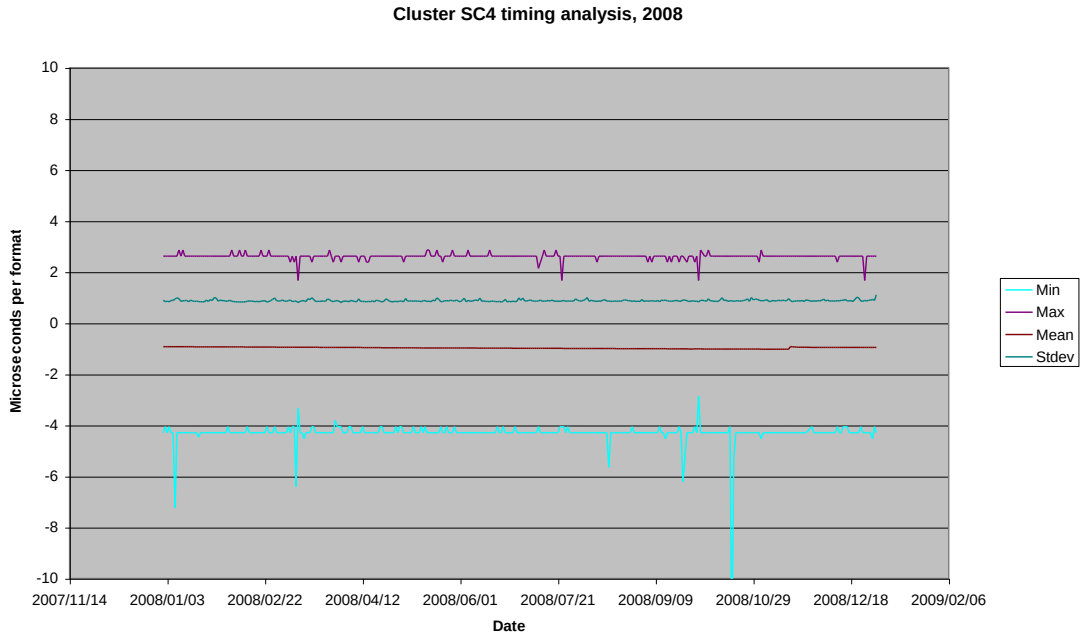

Figure 14.

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 08_1_tcor_4.2.txt -v 1
TCOR2CEF, version 1.6
TCOR file:          08_1_tcor_4.2.txt, s/c: 1, records: 3791
Generated CEF name: C1_CP_DWP_TCOR__20080101_V01
Time range:         2008-01-01T15:39:12Z/2008-12-31T18:31:27Z
Finished, CEF size: 407955 bytes
Total duration:     31546335 seconds
Corrected:          27699045 seconds (87.8 %)

hoodie% ../tcor2cef -t 08_2_tcor_4.2.txt -v 1
TCOR2CEF, version 1.6
TCOR file:          08_2_tcor_4.2.txt, s/c: 2, records: 3974
Generated CEF name: C2_CP_DWP_TCOR__20080101_V01
Time range:         2008-01-01T20:37:19Z/2008-12-31T14:45:48Z
Finished, CEF size: 426775 bytes
Total duration:     31514909 seconds
Corrected:          30545903 seconds (96.9 %)

hoodie% ../tcor2cef -t 08_3_tcor_4.2.txt -v 1
TCOR2CEF, version 1.6
TCOR file:          08_3_tcor_4.2.txt, s/c: 3, records: 3505
Generated CEF name: C3_CP_DWP_TCOR__20080101_V01
Time range:         2008-01-01T07:29:04Z/2008-12-31T10:32:38Z
Finished, CEF size: 377075 bytes
Total duration:     31547014 seconds
Corrected:          29213927 seconds (92.6 %)

hoodie% ../tcor2cef -t 08_4_tcor_4.2c.txt -v 1
TCOR2CEF, version 1.6
TCOR file:          08_4_tcor_4.2c.txt, s/c: 4, records: 3746
Generated CEF name: C4_CP_DWP_TCOR__20080101_V01
Time range:         2008-01-01T00:48:25Z/2008-12-31T05:59:04Z
Finished, CEF size: 405388 bytes
Total duration:     31554639 seconds
Corrected:          28273962 seconds (89.6 %)
```

Finally, the CEF files are checked using CEFpass.

```
setenv CEFPATH ~/CAA/headers
~/CAAtools/CEFpass C1_CP_DWP_TCOR__20080101_V01.cef
~/CAAtools/CEFpass C2_CP_DWP_TCOR__20080101_V01.cef
~/CAAtools/CEFpass C3_CP_DWP_TCOR__20080101_V01.cef
~/CAAtools/CEFpass C4_CP_DWP_TCOR__20080101_V01.cef
```

7 Caveats

The following general caveats apply to 2008 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 typically around 88 to 97%. The reasons for lack of availability are usually:

- WEC is OFF or no telemetry. Corrections are of no use during these periods.
- Failure to consistently track OFFSET changes from one period of real time telemetry to the next - usually due to an offset change occurring during a period when WEC is off or no telemetry.

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.