Preparation and validation of WEC time corrections for year 2004

Keith Yearby, 6 June 2007

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 year 2004. In this case, the whole year has been processed in one batch.

2 Data and references

Source data:

ESOC DIFF measurements for 2004.
WBD data DVDs for 2004.
Cluster RDM for 2004.

Documents:

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

Software:

wbddiff, version 1.0, 2004-06-11
maketcor3, version 3.4, 2006-03-03
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. For a further validation, the DIFF just prior to each new time correlation is determined by analysis of the TCAL files on the Cluster RDM.

The DIFF measurements received from ESOC for most of 2004 are unsigned, so the sign is determined by comparison with the WBD or TCAL DIFFs.

The TCAL data was extracted from the RDM TCAL files using the following procedure.

```
find /data/disk2/cluster/RDM/04* -name '*la*1' > 04_1_la_files.txt
readtcal -f 04_1_la_files.txt > 04_1_new_tcal.txt
find /data/disk2/cluster/RDM/04* -name '*la*2' > 04_2_la_files.txt
readtcal -f 04_2_la_files.txt > 04_2_new_tcal.txt
find /data/disk2/cluster/RDM/04* -name '*la*3' > 04_3_la_files.txt
readtcal -f 04_3_la_files.txt > 04_3_new_tcal.txt
find /data/disk2/cluster/RDM/04* -name '*la*4' > 04_4_la_files.txt
readtcal -f 04_4_la_files.txt > 04_4_new_tcal.txt
```

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. Note that the vertical scale of each figure is different.

Some periods of 2004 were quite difficult to validate, and some manipulation was necessary, taking account of known problems with the configuration of the Maspalomas ground station.

SC	Start (mm-dd)	End (mm-dd)	Adjustment
1	11-19	12-02	add +44 us
1	12-10		use WBD - 20us
2	11-20	12-02	add +44 us
3	06-21	06-25	add +20 us
3	07-13	07-31	use WBD - 20us
3	08-01	11-20	add +44us
3	12-04	12-31	add +44us
4	06-21	06-25	add +20 us
4	07-18	11-19	add +44us
4	12-04	12-31	add +44us

The point valid DIFF files cover the whole year. The final validated DIFF measurements are saved in Text (space delimited) format using the default .prn file name extension.

Once the valid ESOC data has been selected, its accuracy is checked by comparing each WBD measurement with a linear interpolation between the nearest validated ESOC measurements before and after. For 2004, a new software tool WBDTCOR has been written to do this.

```
wbdtcor -w ..\wbddiff\wbd_all_c2_ncd.txt -p 04_2_diff.prn >04_2_delta_diff.txt
wbdtcor -w ..\wbddiff\wbd_all_c3_ncd.txt -p 04_3_diff.prn >04_3_delta_diff.txt
```

This comparison identifies a small number of anomalous WBD measurements.

SC	Date/time	error (wbd-esoc) (micro-sec)	DSN antenna
1	2004-03-20 05:49	+158	27
1	2004-05-17 15:29	-149	45
1	2004-05-19 22:49	-332	45
2	2004-02-29 00:59	+159	27
2	2004-05-17 15:29	-79	46
2	2004-05-19 22:45	-103	43
2	2004-05-20 10:19	-263	34
3	2004-03-27 09:49	+165	15
3	2004-05-19 23:40	-212	34
3	2004-11-23 04:39	-65	15
4	2004-02-25 22:39	+165	27
4	2004-05-27 00:29	-53	46
4	2004-11-20 12:49	-102	34

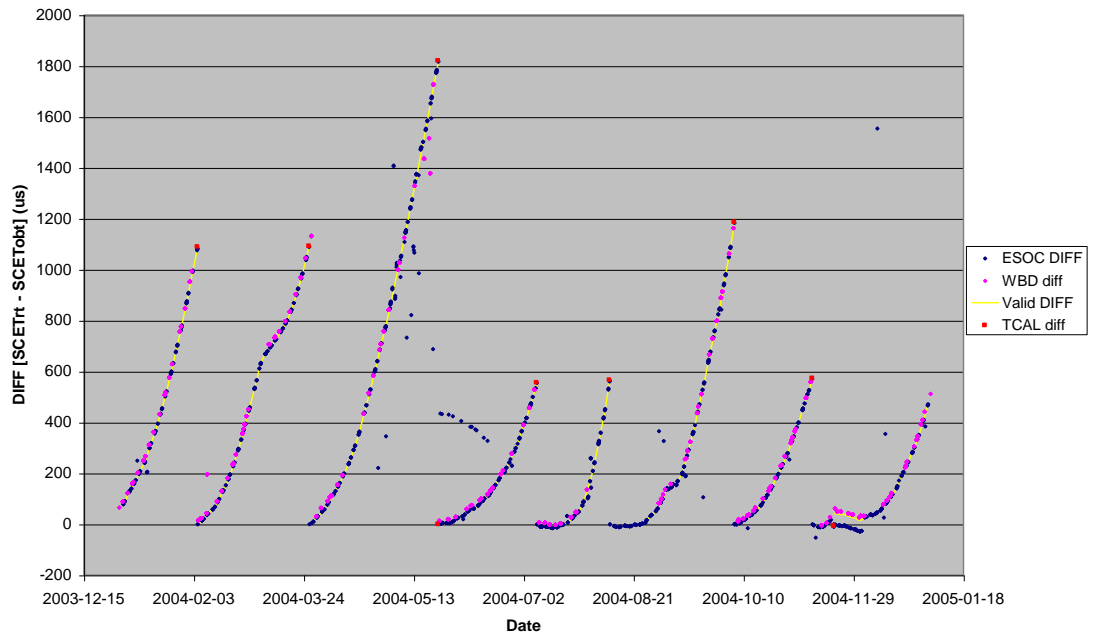The average and standard deviation of the remaining measurements were calculated.

SC	Average wbd-esoc (micro-sec)	St Dev wbd-esoc (micro-sec)
1	15.51	6.48
2	12.15	4.05
3	21.49	8.29
4	18.41	9.07

The charts below show the ESOC, WBD, and final validated DIFF measurements.
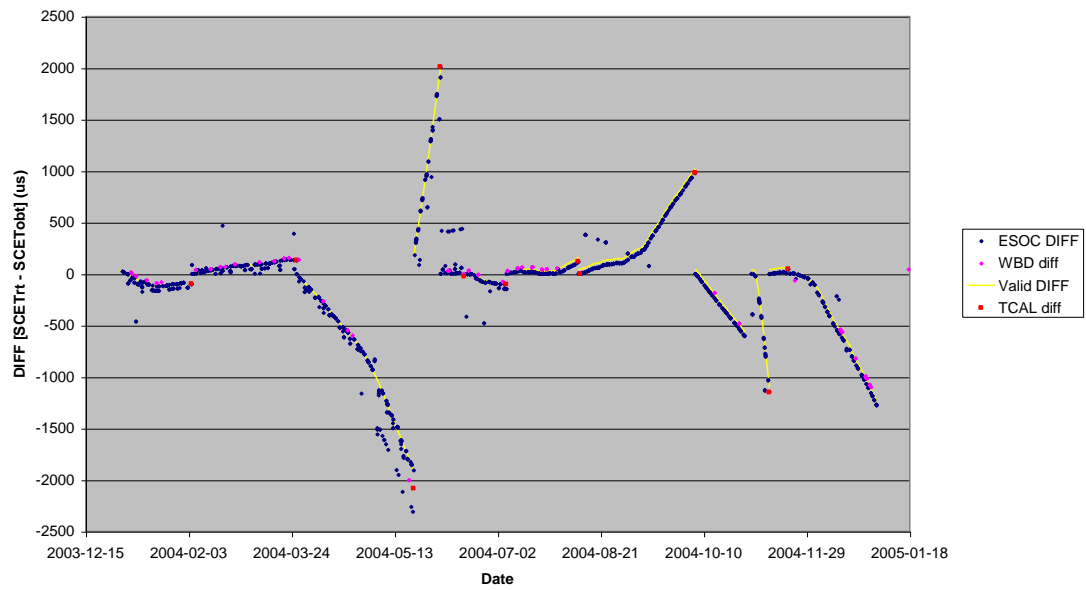
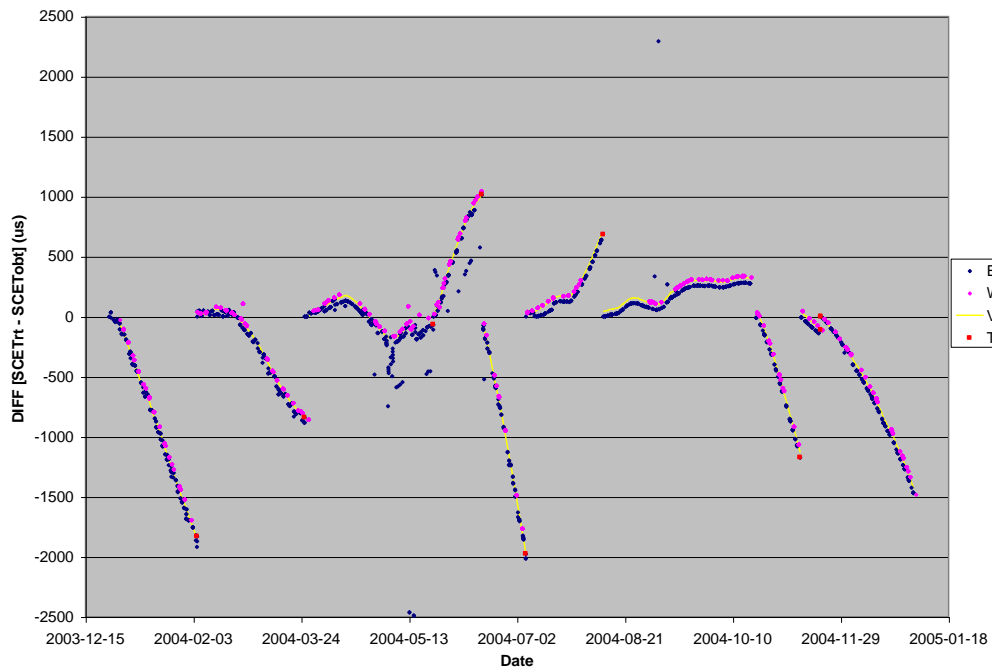**Cluster SC1 ESOC & WBD DIFF for 2004**
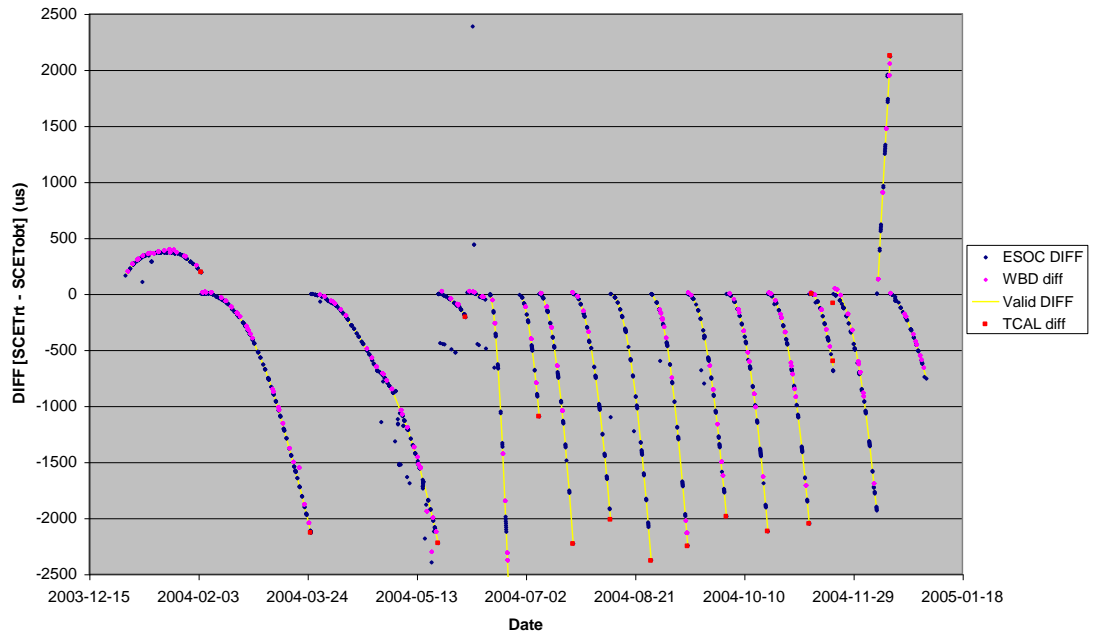
Cluster SC2 ESOC & WBD DIFF for 2004

Cluster SC3 ESOC & WBD DIFF for 2004

Cluster SC4 ESOC & WBD DIFF for 2004

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, cats and sorts. The individual lists must be in chronological order. They are written to files named like 04_*s*_hkla_files.txt. Then maketcor3 is used to generate the ASCII TCOR files for each 3 month period.

```
find /data/disk2/cluster/RDM/04* -name '*wh*' > scr.scr
~/CAA/weclog/purgedup scr.scr 04_hk_files.txt
grep cluster1 04_hk_files.txt > 04_1_hk_files.txt
grep cluster2 04_hk_files.txt > 04_2_hk_files.txt
grep cluster3 04_hk_files.txt > 04_3_hk_files.txt
grep cluster4 04_hk_files.txt > 04_4_hk_files.txt
cat 04_1_hk_files.txt 04_1_la_files.txt | sort > 04_1_hkla_files.txt
cat 04_2_hk_files.txt 04_2_la_files.txt | sort > 04_2_hkla_files.txt
cat 04_3_hk_files.txt 04_3_la_files.txt | sort > 04_3_hkla_files.txt
cat 04_4_hk_files.txt 04_4_la_files.txt | sort > 04_4_hkla_files.txt
```

```
../maketcor3 -d 04_1_diff.prn -f 04_1_hkla_files.txt \
  -s 040101 -e 041231 > 04_1_tcor.txt
../maketcor3 -d 04_2_diff.prn -f 04_2_hkla_files.txt \
  -s 040101 -e 041231 > 04_2_tcor.txt
../maketcor3 -d 04_3_diff.prn -f 04_3_hkla_files.txt \
  -s 040101 -e 041231 > 04_3_tcor.txt
../maketcor3 -d 04_4_diff.prn -f 04_4_hkla_files.txt \
  -s 040101 -e 041231 > 04_4_tcor.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 is 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.

A typical 'veritcor' command is:

```
veritcor -f 02_1_hkla_files.txt -T . -v 4 > 02_1_veritcor.txt
```

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.

The mean increment is a measure of the rate error of the on board clock. A similar measure may be obtained from the TICK values in the TCAL files (rate error = (TICK - 1.0e12) / 1.0e12). The two measures are compared in the following charts.

```
../tcor2cef -t 04_1_tcor.txt
TCOR2CEF, version 1.6

TCOR file:       04_1_tcor.txt, s/c: 1, records: 1294
Generated CEF name: C1_CP_DWP_TCOR__20040101_V00
Time range:      2004-01-01T20:26:53Z/2004-12-31T07:45:52Z
Finished, CEF size: 147690 bytes
Total duration:    31490339 seconds
Corrected:        22651877 seconds (71.9 %)

../tcor2cef -t 04_2_tcor.txt
TCOR2CEF, version 1.6

TCOR file:       04_2_tcor.txt, s/c: 2, records: 1688
Generated CEF name: C2_CP_DWP_TCOR__20040102_V00
Time range:      2004-01-02T00:41:33Z/2004-12-31T07:45:50Z
Finished, CEF size: 187258 bytes
Total duration:    31475057 seconds
Corrected:        30155133 seconds (95.8 %)

../tcor2cef -t 04_3_tcor.txt
TCOR2CEF, version 1.6

TCOR file:       04_3_tcor.txt, s/c: 3, records: 1437
Generated CEF name: C3_CP_DWP_TCOR__20040101_V00
Time range:      2004-01-01T20:56:34Z/2004-12-31T03:56:00Z
Finished, CEF size: 161488 bytes
Total duration:    31474766 seconds
Corrected:        29161893 seconds (92.7 %)
```
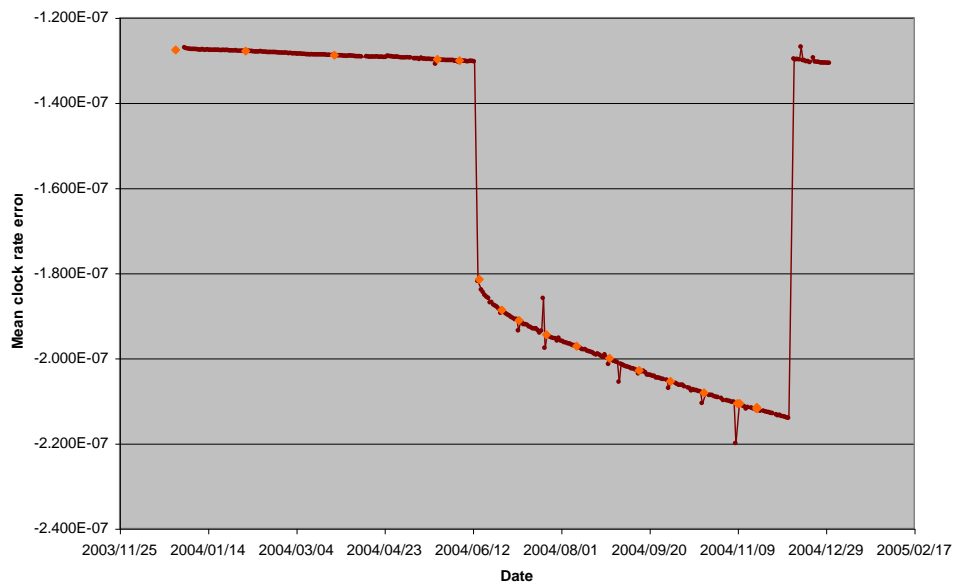
```
../tcor2cef -t 04_4_tcor.txt
TCOR2CEF, version 1.6

TCOR file:        04_4_tcor.txt, s/c: 4, records: 1746
Generated CEF name: C4_CP_DWP_TCOR__20040101_V00
Time range:       2004-01-01T22:42:52Z/2004-12-31T07:45:53Z
Finished, CEF size: 195749 bytes
Total duration:   31482181 seconds
Corrected:        29217457 seconds (92.8 %)
```
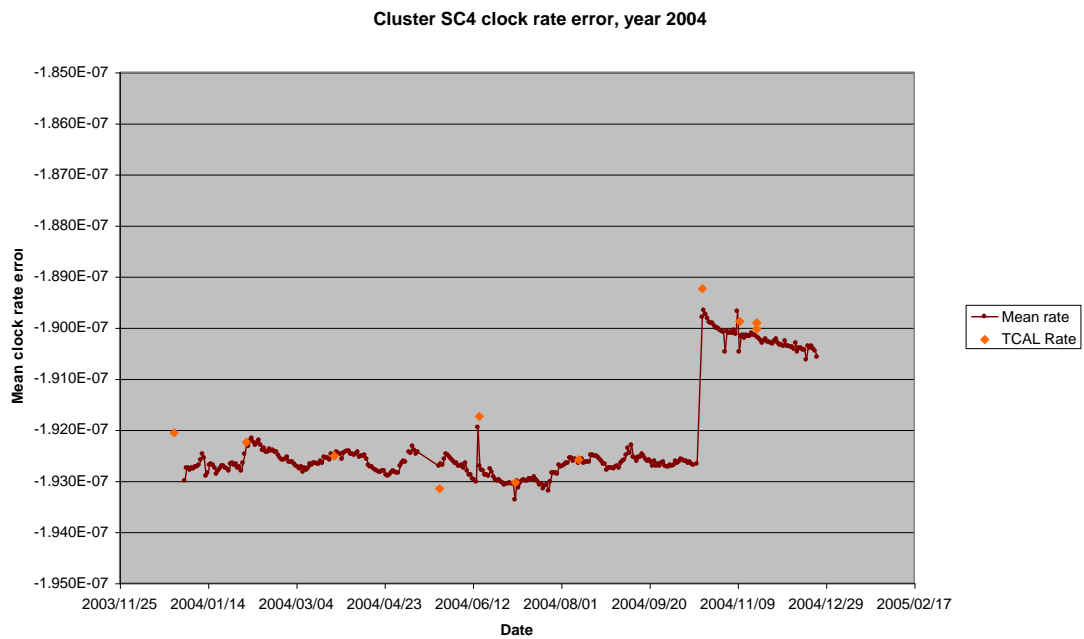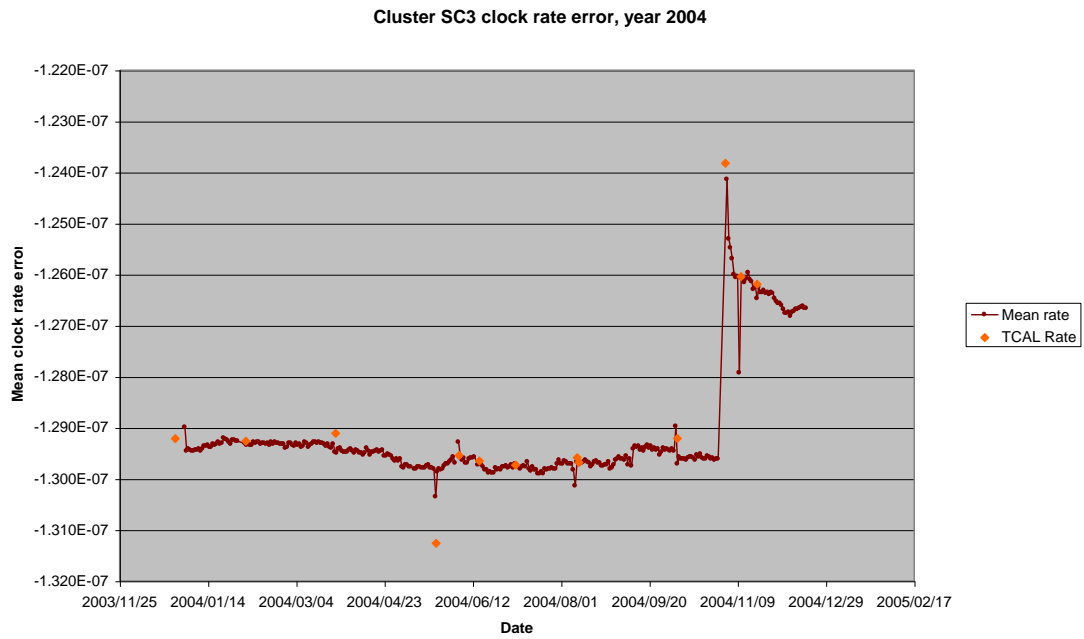
Cluster SC1 clock rate error, year 2004

Cluster SC2 clock rate error, year 2004

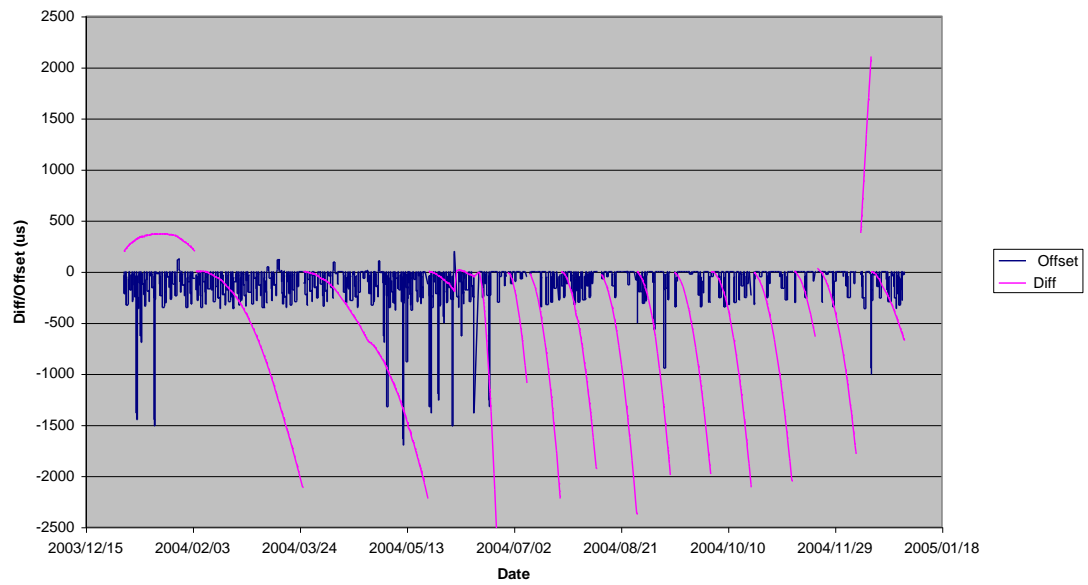**Cluster SC3 clock rate error, year 2004**

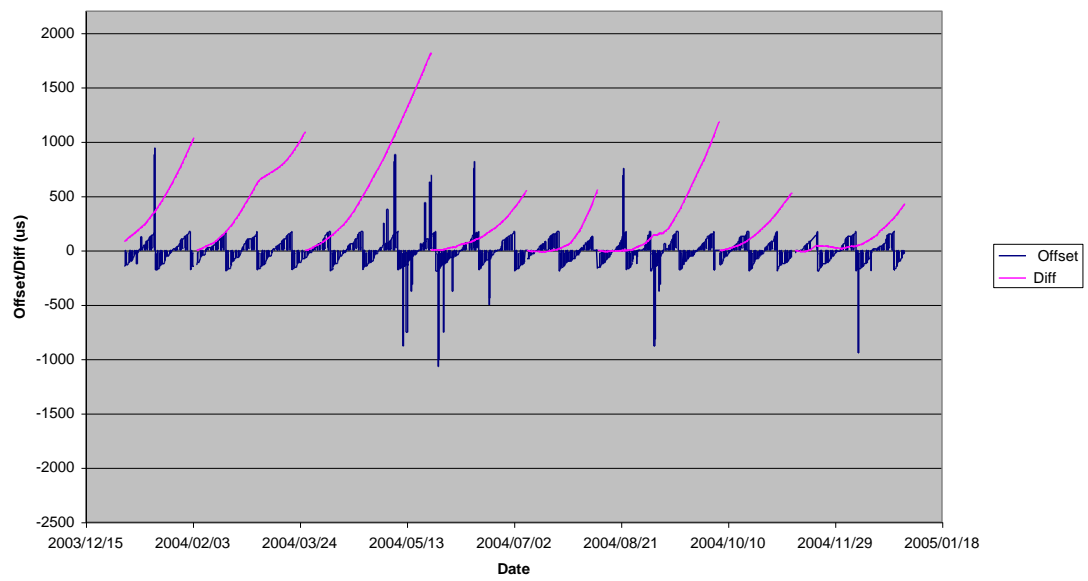**Cluster SC4 clock rate error, year 2004**
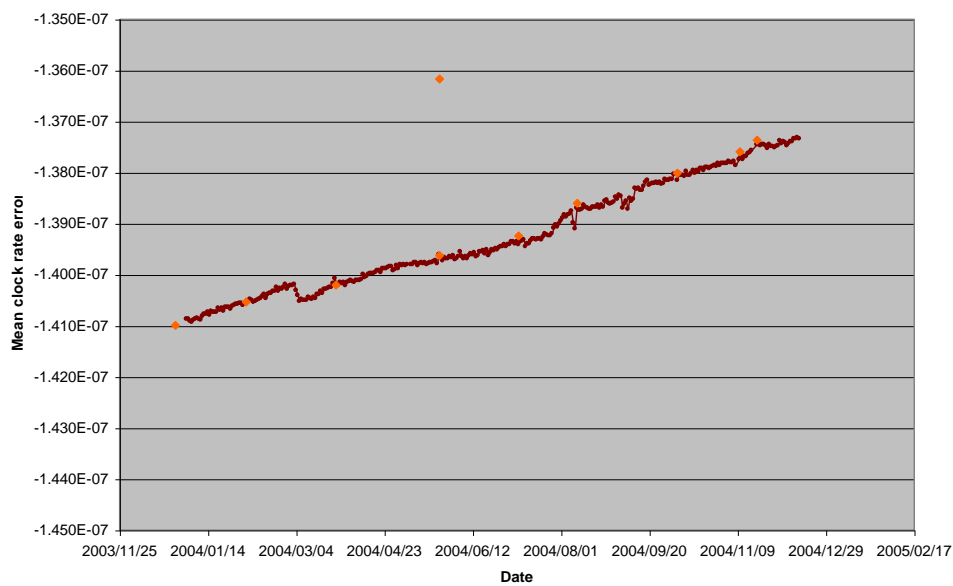
A final validation of the CEF files maybe performed by importing them to Excel and plotting charts of the data. A sample is included below.
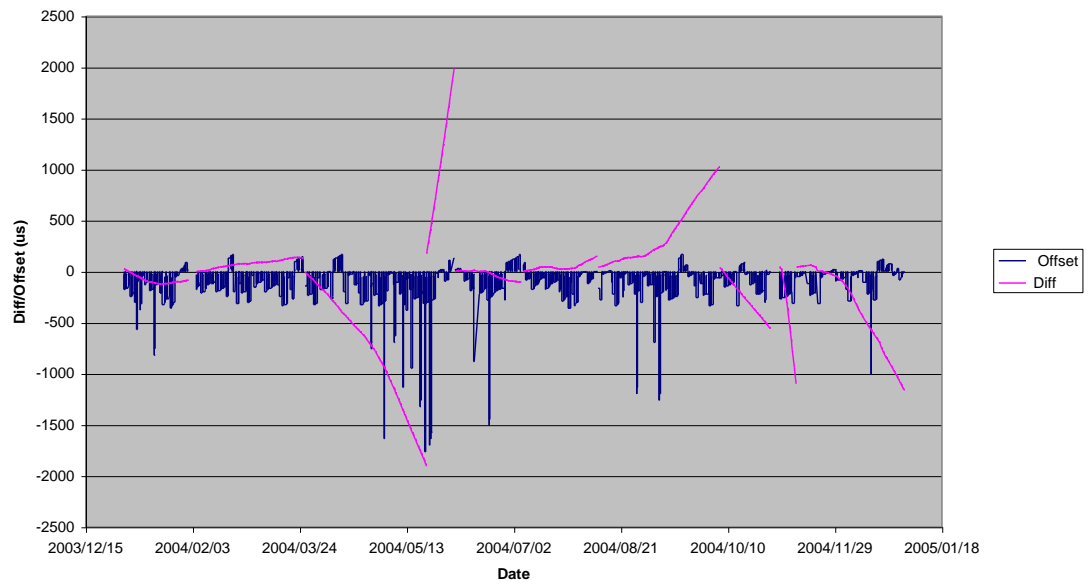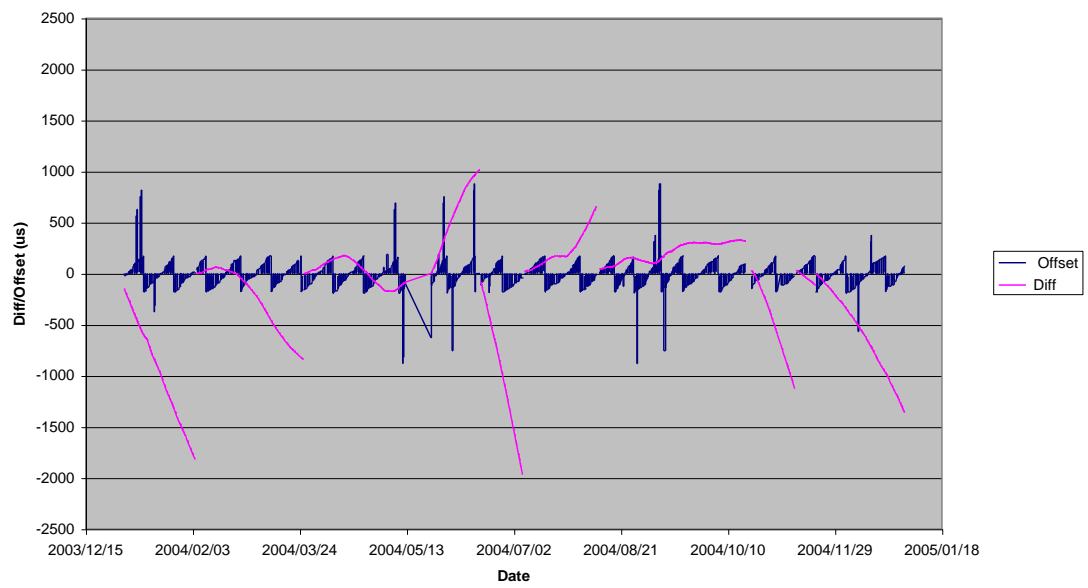
C1_CP_DWP_TCOR__20040101

C2_CP_DWP_TCOR__20040102

C3_CP_DWP_TCOR__20040101

C4_CP_DWP_TCOR__20040101

6 Production of the CEF files

The final CEF files are produced by running TCOR2CEF on the validated ASCII format TCOR files, with the appropriate version number specified. A standard 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. The files are version 2, to avoid conflict with previously submitted files covering part of 2004.

The latest version of TCOR2CEF (1.6) includes the name and last modification date of the ASCII TCOR file within the file caveats of the CEF file. Previous versions only included the name.

7 Caveats

The following general caveats apply to year 2004 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. Any data that fails validation is simply deleted from the files. For 2004, TCOR coverage is typically around 93% for SC234, but only 72% for SC1. Low coverage is mainly in the second half of the year, when the onboard clock rate was changing relatively quickly, and frequent time correlations were needed.

The DIFF measurements received from ESOC for most of 2004 are unsigned, so the sign is determined by comparison with the WBD or TCAL DIFFs. There are some periods when it is difficult to be sure that the sign has been determined correctly. However, this is always when the DIFF is small, so the error that would be introduced by an incorrect sign is also small (typically less than 50 μs).

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.