# Preparation and validation of WEC time corrections for year 2005

Keith Yearby, 18 September 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 2005. In this case, the ASCII TCOR files were compiled in batches of 3, 3, and 6 months, while CEF generation and final validation were processed in one batch for the whole year.

## 2 Data and references

Source data:

ESOC DIFF measurements for 2005.
WBD data DVDs for 2005.
Cluster RDM for 2005.

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.

The DIFF measurements received from ESOC for 2005 include the sign, so the procedure used in previous years to determine the sign is no longer needed.

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.

The final validated DIFF measurements are saved in Text (space delimited) format using the default .prn file name extension.

For SC3 and 4 data it was necessary to apply a correction for the drift of the reference clock at the Maspalomas ground station. See CLUSTER Mission Operations Report No. 289, annex 1.

Two separate linear corrections were applied:

| | |
|---|---|
| 2004-07-11 | +35 us |
| 2005-03-01 | +55 us |

(applied from 2005-01-01 to 2005-03-01)

| | |
|---|---|
| 2005-03-04 | +0.0 us |
| 2006-02-13 | +37.5 us |

(applied from 2005-04-01 to 2005-12-31)

The correction for the second period is determined from data in the CLUSTER Mission Operations Report No. 289, and confirmed by comparison with WBD data. WBD data also suggest that the correction is required in the first period.

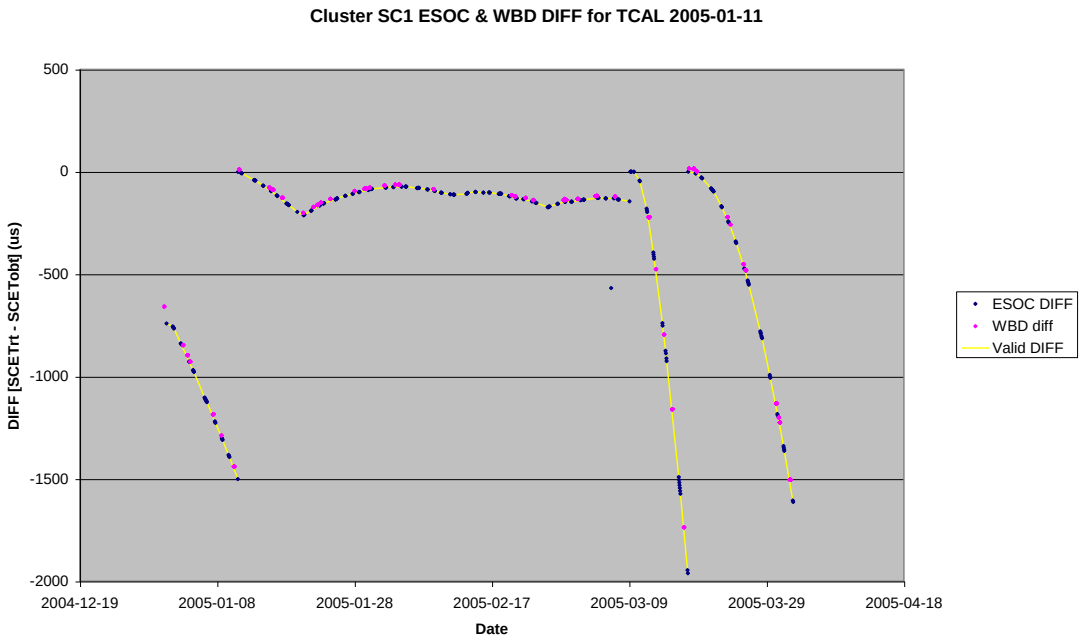
Once the valid ESOC data is selected, its accuracy is checked by comparing each WBD measurement with a linear interpolation between the nearest validated ESOC measurements before and after. This comparison identifies a small number of anomalous WBD measurements.

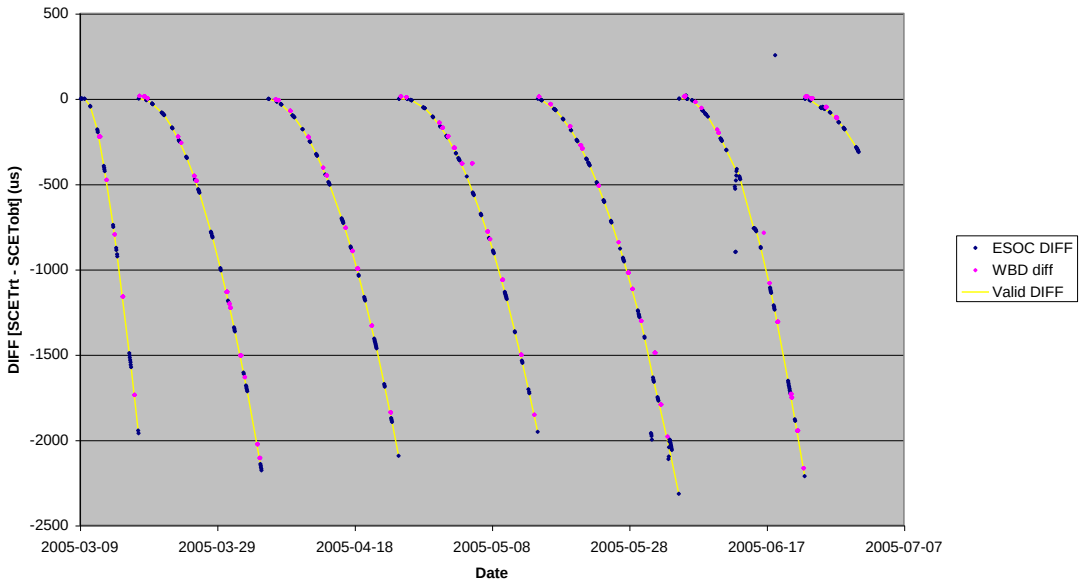
| **Date time** | **Spacecraft** | **DSN antenna** | **wbd-esoc (micro-sec)** |
|---|---|---|---|
| 2005/05/05 02:49 | 1 | 27 | 161.3 |
| 2005/05/31 17:09 | 1 | 27 | 191.9 |
| 2005/06/16 14:19 | 1 | 27 | 164.2 |
| 2005/06/10 13:19 | 2 | 27 | 159.0 |
| 2005/06/18 13:49 | 2 | 27 | 160.5 |
| 2005/06/20 12:39 | 2 | 27 | 161.5 |
| 2005/06/07 18:59 | 3 | 27 | 159.5 |
| 2005/09/03 08:59 | 3 | 15 | -25.4 |
| 2005/03/23 18:49 | 4 | 27 | 162.2 |
| 2005/03/26 17:09 | 4 | 27 | 162.3 |
| 2005/04/13 22:19 | 4 | 27 | 159.2 |
| 2005/04/16 16:30 | 4 | 27 | 161.2 |
| 2005/06/21 11:19 | 4 | 27 | 159.5 |
| 2005/06/25 14:59 | 4 | 27 | 143.6 |

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

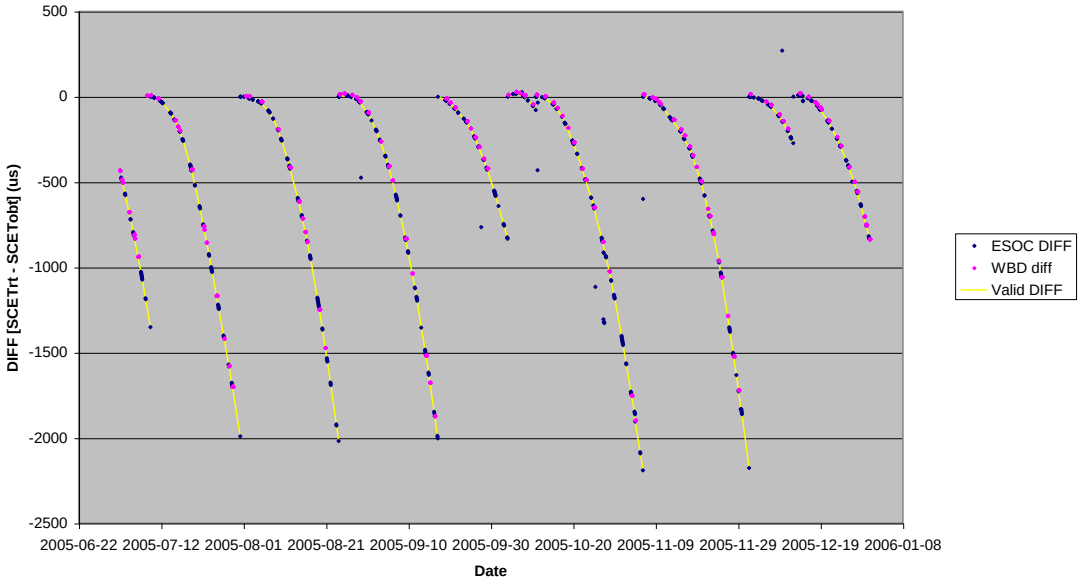
| SC | Average wbd-esoc (micro-sec) | St Dev wbd-esoc (micro-sec) |
|---|---|---|
| 1 | 12.38 | 2.93 |
| 2 | 11.26 | 3.13 |
| 3 | 13.01 | 4.63 |
| 4 | 13.22 | 4.72 |

The charts below show the ESOC, WBD, and final validated DIFF measurements.

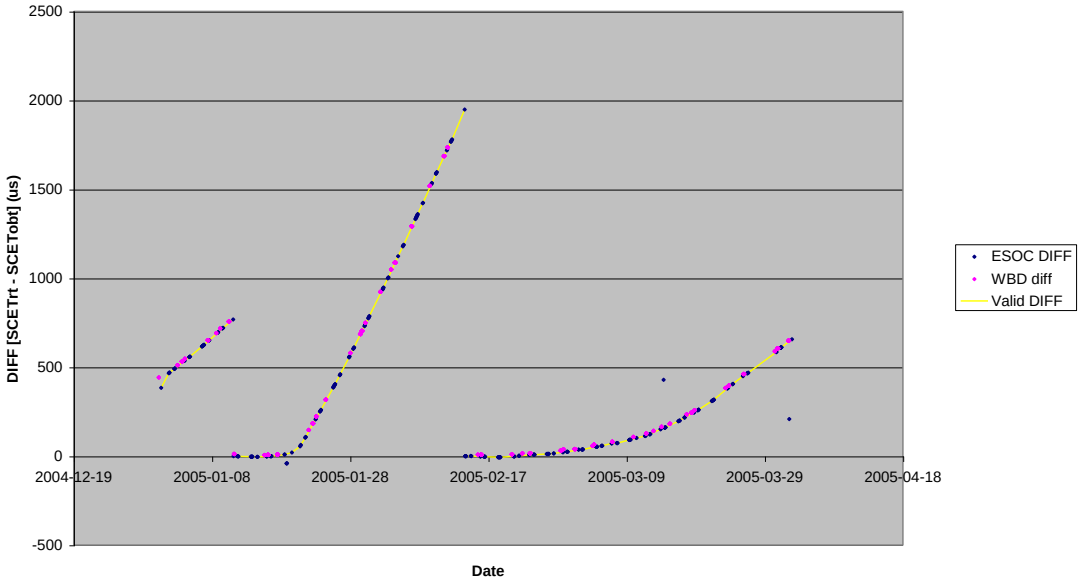

Cluster SC1 ESOC & WBD DIFF for TCAL 2005-01-11
500
0
-500
-1000
-1500
-2000
DIFF [SCETrt - SCETobt] (us)
2004-12-19
2005-01-08
2005-01-28
2005-02-17
2005-03-09
2005-03-29
2005-04-18
Date
ESOC DIFF
WBD diff
Valid DIFF


Cluster SC1 ESOC & WBD DIFF for TCAL 2005-01-11
500
0
-500
-1000
-1500
-2000
-2500
DIFF [SCETrt - SCETobt] (us)
2005-03-09
2005-03-29
2005-04-18
2005-05-08
2005-05-28
2005-06-17
2005-07-07
Date
ESOC DIFF
WBD diff
Valid DIFF

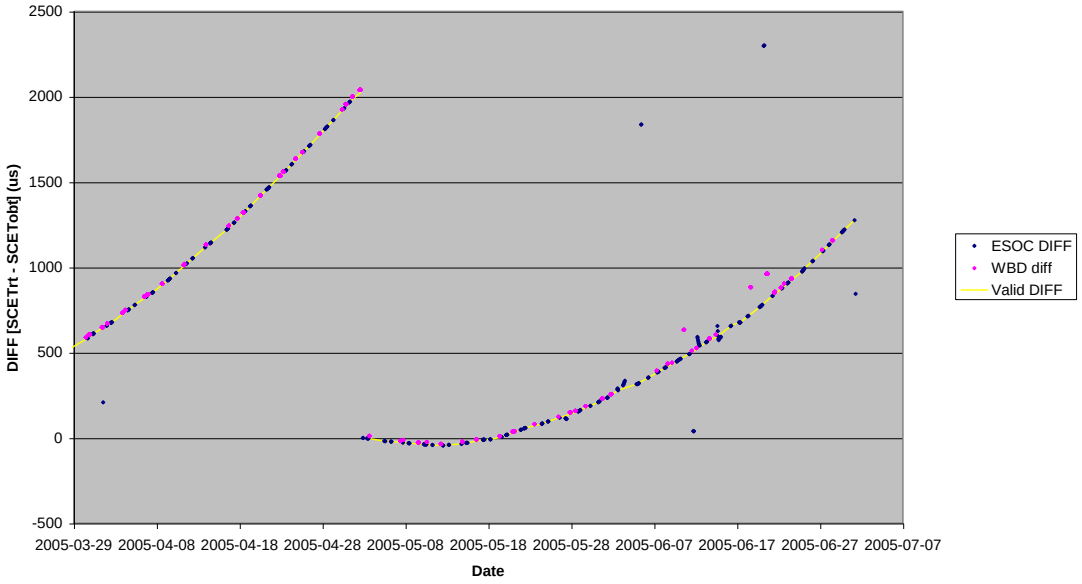
**Cluster SC1 ESOC & WBD DIFF for TCAL 2005-01-11**



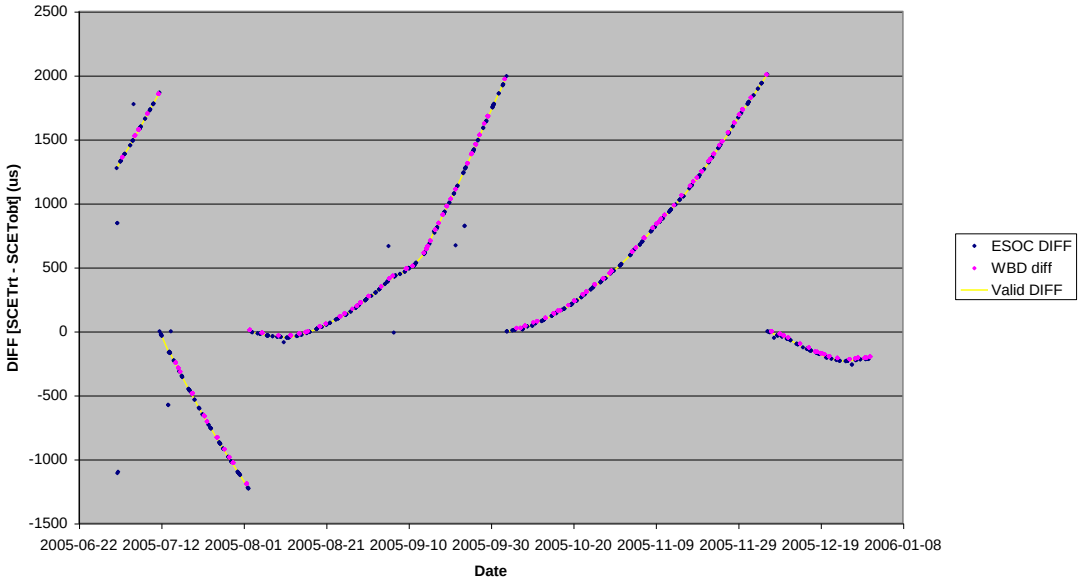

**Cluster SC2 ESOC & WBD DIFF for TCAL 2005-01-11**



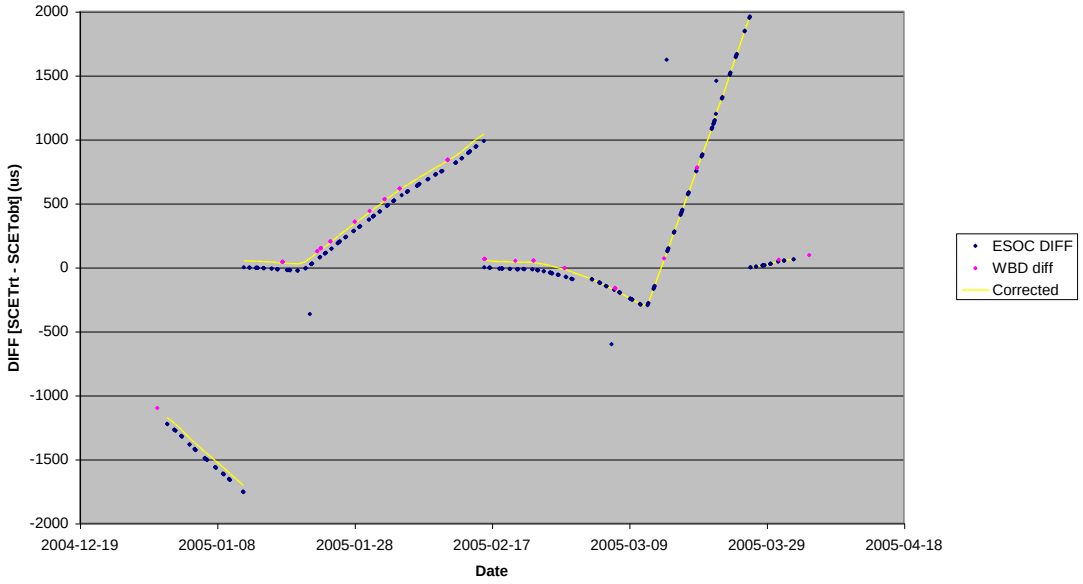
**Cluster SC2 ESOC & WBD DIFF for 2005 April, May, June**



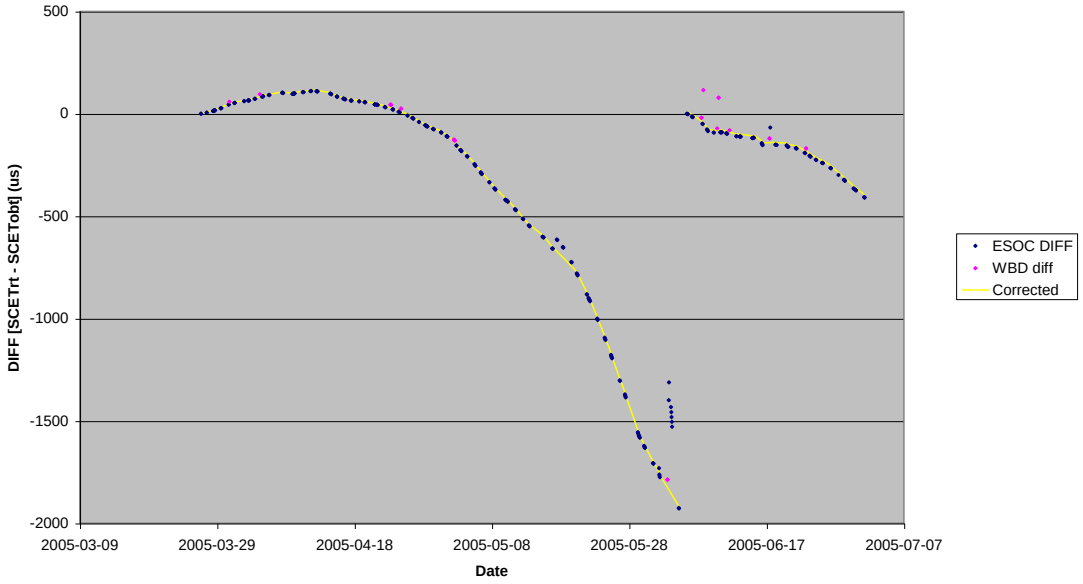

**Cluster SC2, ESOC & WBD DIFF for 2005, July to December**



**Cluster SC3 ESOC & WBD DIFF for 2005-01 to 2005-03**

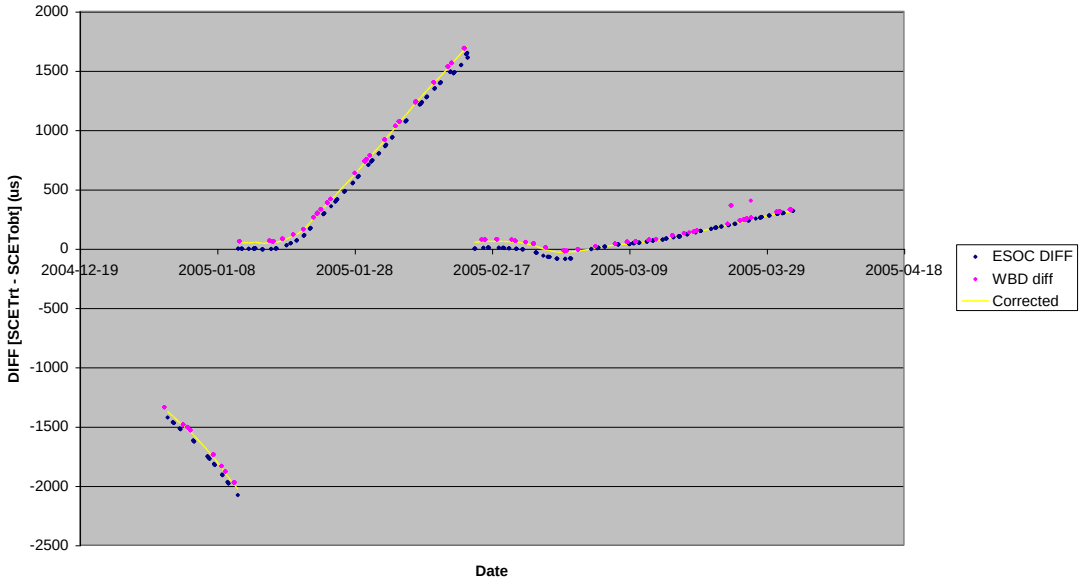



**Cluster SC3 ESOC & WBD DIFF for TCAL 2005-01-11**

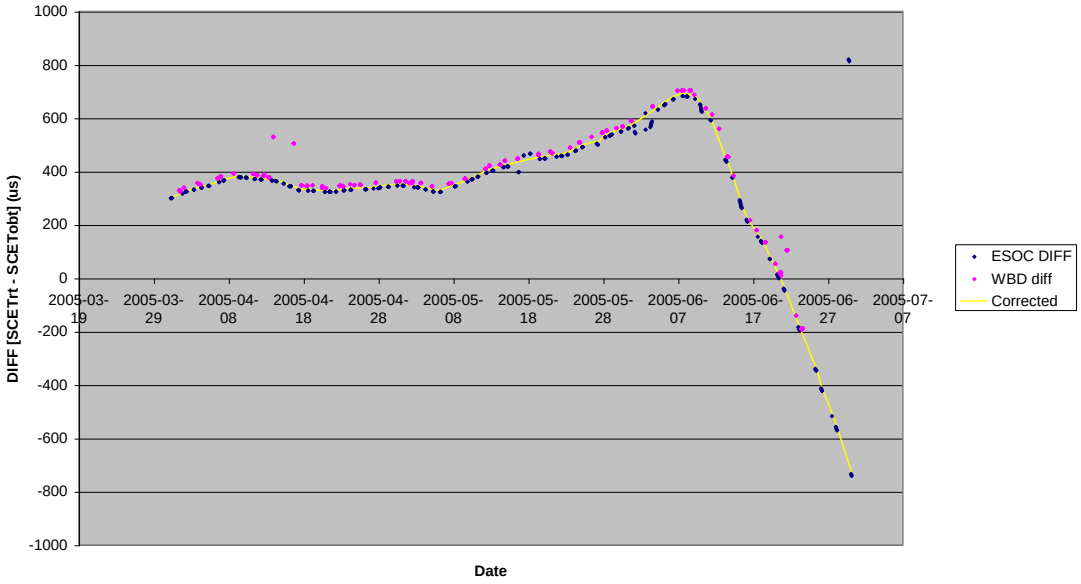


**Cluster SC3 ESOC & WBD DIFF for 2005 July to December**

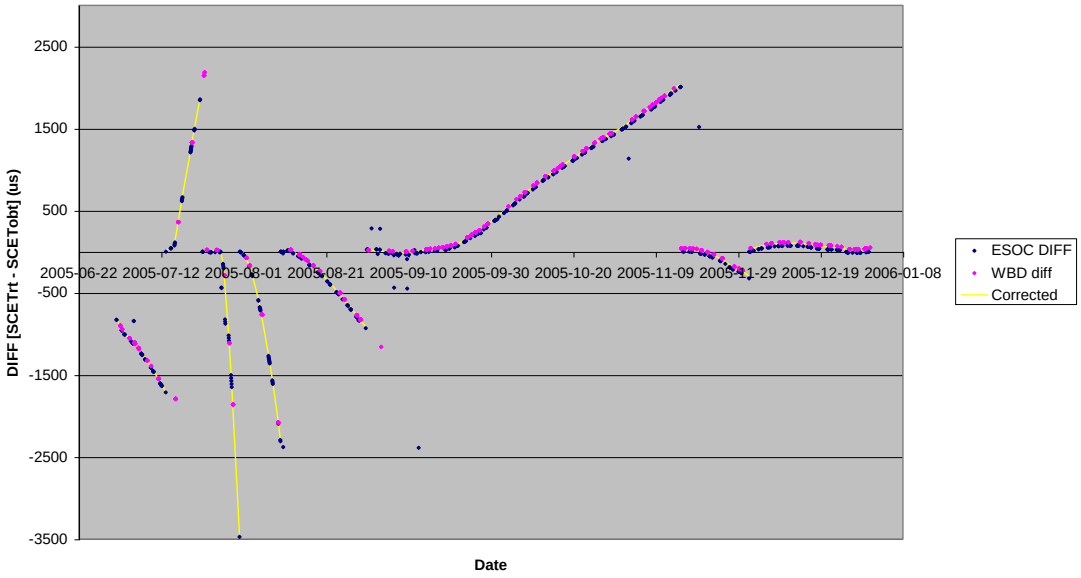

**Cluster SC4 ESOC & WBD DIFF for 2005-01 to 2005-03**



**Cluster SC4 ESOC & WBD DIFF for 2005-01 to 2005-03**




**Cluster SC4 ESOC & WBD DIFF for 2005-07 to 2005-12**



## 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 05_*s*_hkla_files.txt.

```
find /data/disk2/cluster/RDM/05* -name '*wh*' > scr.scr
~/CAA/weclog/purgedup scr.scr 05_hk_files.txt
grep cluster1 05_hk_files.txt > 05_1_hk_files.txt
grep cluster2 05_hk_files.txt > 05_2_hk_files.txt
grep cluster3 05_hk_files.txt > 05_3_hk_files.txt
grep cluster4 05_hk_files.txt > 05_4_hk_files.txt

cat 05_1_hk_files.txt 05_1_la_files.txt | sort > 05_1_hkla_files.txt
cat 05_2_hk_files.txt 05_2_la_files.txt | sort > 05_2_hkla_files.txt
cat 05_3_hk_files.txt 05_3_la_files.txt | sort > 05_3_hkla_files.txt
cat 05_4_hk_files.txt 05_4_la_files.txt | sort > 05_4_hkla_files.txt
```

Then maketcor3 is used to generate the ASCII TCOR files. SC1 and 2 data was processed in batches of 3, 3, and 6 months, then the resulting ASCII TCOR files concatenated to make year long files. Initially the same procedure was used for SC3 and 4. When this data was reprocessed to include the Maspalomas reference clock correction, the Point Valid Diff files were concatenated to make a year long file, and the ASCII TCOR files generated in one batch.

```
../maketcor3 -d 050701_1_diff.prn -f 05_1_hkla_files.txt \
  -s 050701 -e 051231 >0507_1_tcor.txt
../maketcor3 -d 050701_2_diff.prn -f 05_2_hkla_files.txt \
  -s 050701 -e 051231 >0507_2_tcor.txt

cat 050101_1_tcor.txt 0504_1_tcor.txt 0507_1_tcor.txt > 05_1_tcor.txt
cat 050101_2_tcor.txt 0504_2_tcor.txt 0507_2_tcor.txt > 05_2_tcor.txt

../maketcor3 -d 05_3_diff.prn -f 05_3_hkla_files.txt \
  -s 050101 -e 051231 > 05_3_tcor.txt
../maketcor3 -d 05_4_diff.prn -f 05_4_hkla_files.txt \
  -s 050101 -e 051231 > 05_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.

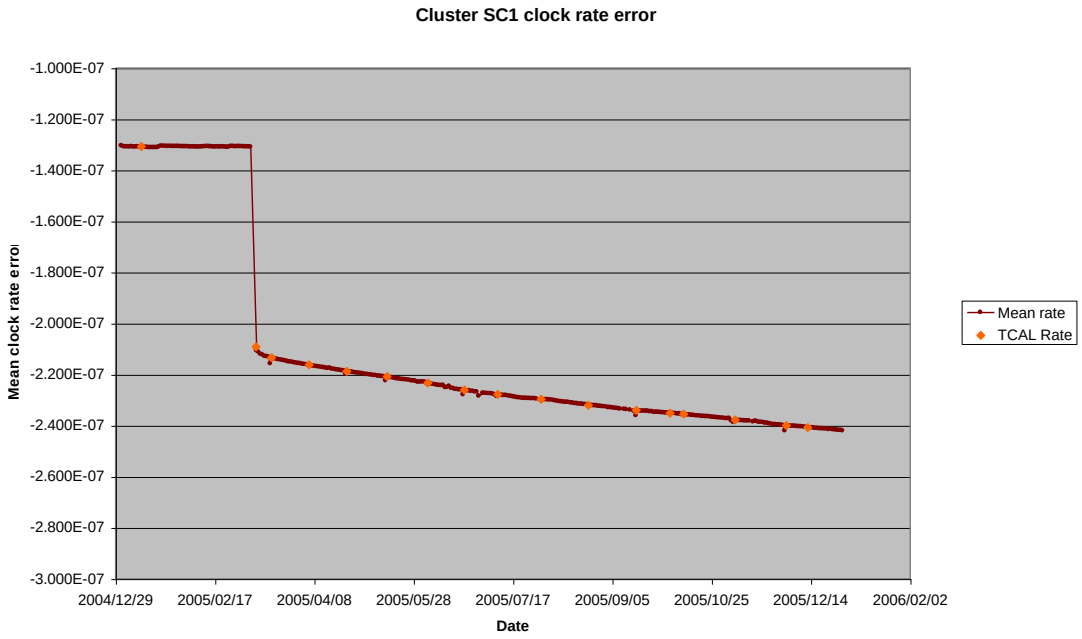
The time tags are analysed using ‘veritcor’. This takes the time increment between each pair of records in the file, subtracts the nominal value of 5.15222168 seconds, and accumulates the minimum, maximum, mean and standard deviation over each 24 hour period. On SC1 and SC3 it is known that time jumps 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.

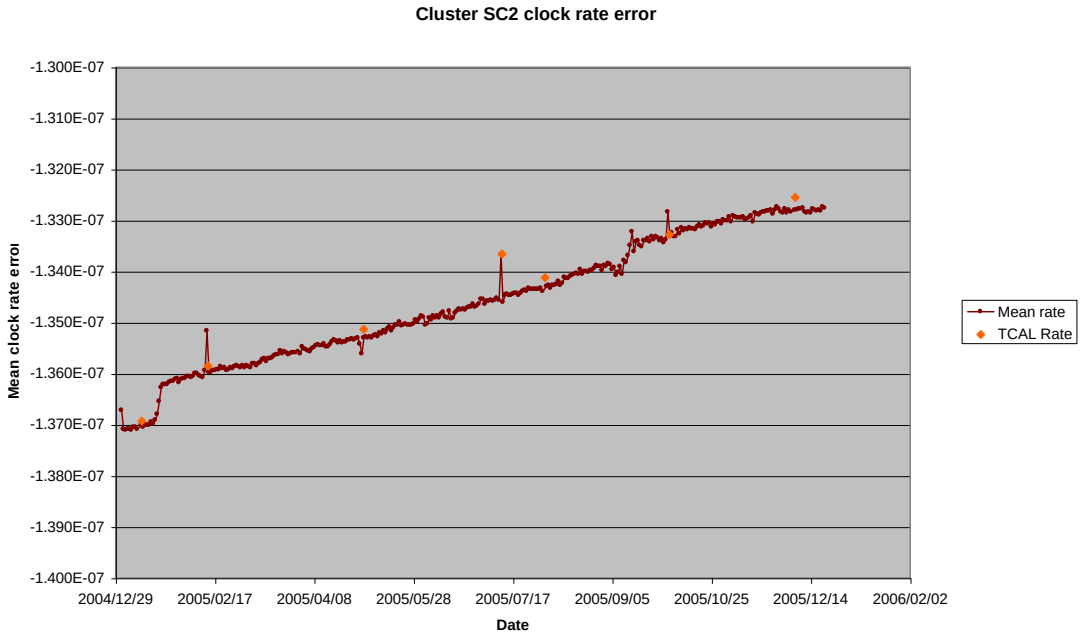
A typical 'veritcor' command is:

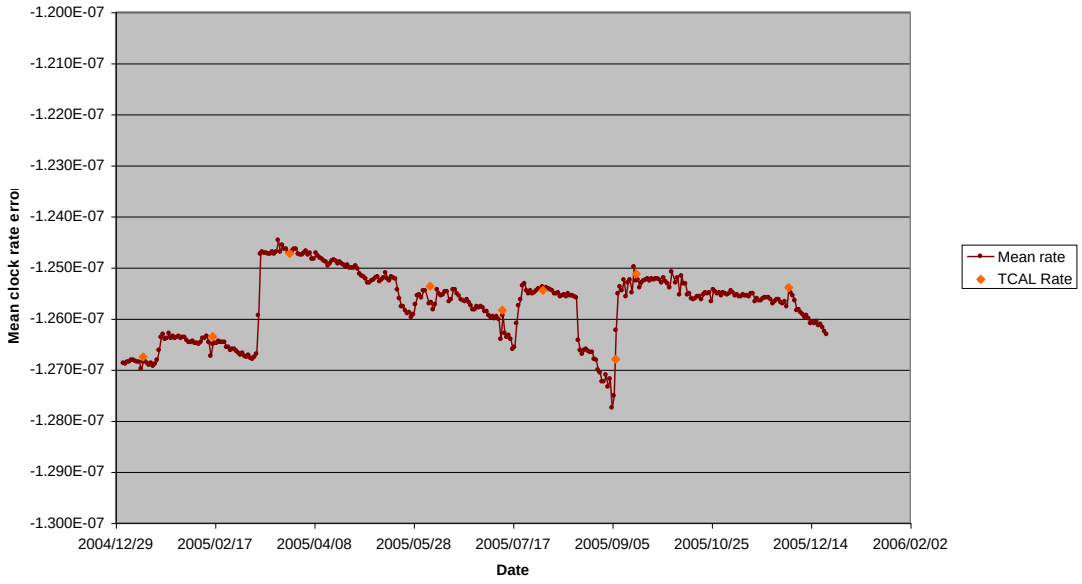
```
veritcor -f 05_1_hkla_files.txt -T . -v 4 > 05_1_veritcor.txt
```

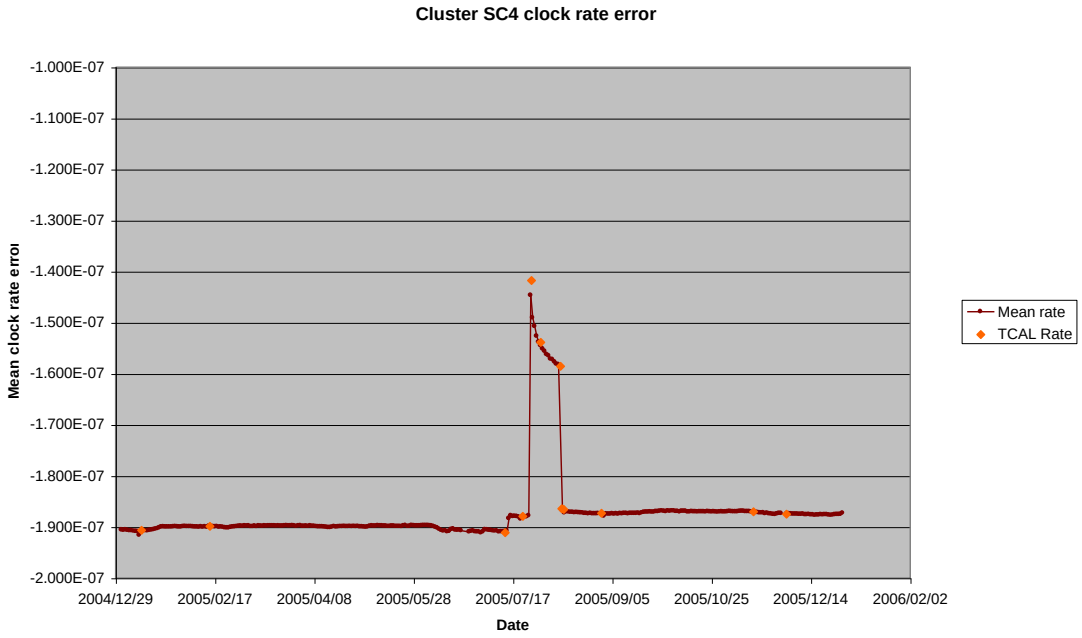
It uses the same HK+TCAL file list file as 'maketcor3', although only the HK files are used. 'veritcor' includes the same code module used by TED to apply the TCOR corrections, and requires CEF TCOR files to be installed with the same index files. The '-T .' option specifies that the TCOR files (and 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.




Cluster SC2 clock rate error
-1.300E-07
-1.310E-07
-1.320E-07
-1.330E-07
-1.340E-07
-1.350E-07
-1.360E-07
-1.370E-07
-1.380E-07
-1.390E-07
-1.400E-07
Mean clock rate erroi
2004/12/29
2005/02/17
2005/04/08
2005/05/28
2005/07/17
2005/09/05
2005/10/25
2005/12/14
2006/02/02
Date
Mean rate
TCAL Rate


Cluster SC3 clock rate error
-1.200E-07
-1.210E-07
-1.220E-07
-1.230E-07
-1.240E-07
-1.250E-07
-1.260E-07
-1.270E-07
-1.280E-07
-1.290E-07
-1.300E-07
Mean clock rate erroi
2004/12/29
2005/02/17
2005/04/08
2005/05/28
2005/07/17
2005/09/05
2005/10/25
2005/12/14
2006/02/02
Date
Mean rate
TCAL Rate


Cluster SC4 clock rate error
-1.000E-07
-1.100E-07
-1.200E-07
-1.300E-07
-1.400E-07
-1.500E-07
-1.600E-07
-1.700E-07
-1.800E-07
-1.900E-07
-2.000E-07
Mean clock rate error
2004/12/29
2005/02/17
2005/04/08
2005/05/28
2005/07/17
2005/09/05
2005/10/25
2005/12/14
2006/02/02
Date
Mean rate
TCAL Rate

## 6 Production of the CEF files

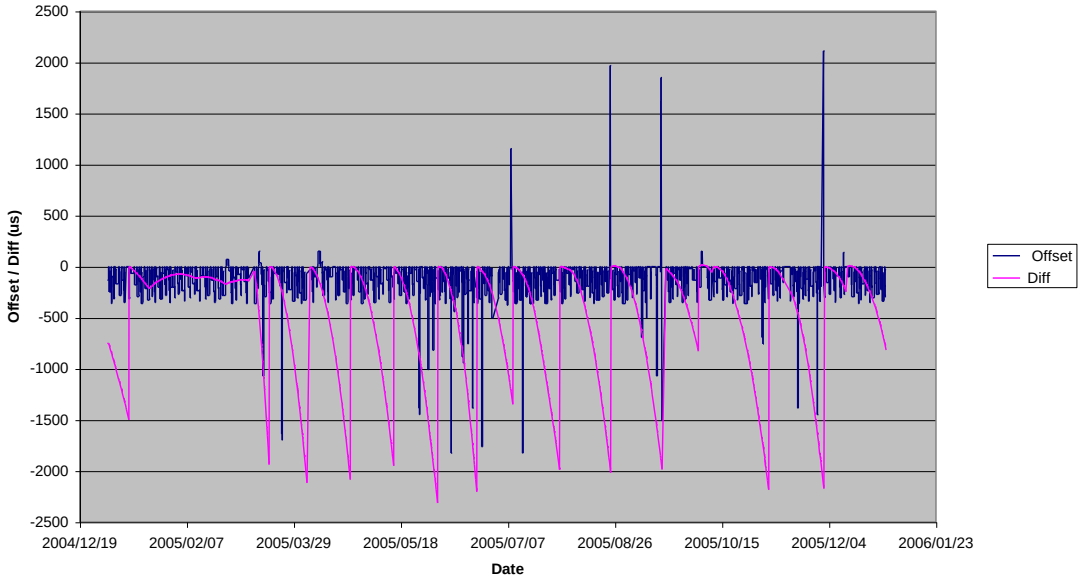
The final CEF files were produced by running TCOR2CEF on the validated ASCII format TCOR files, with version number 1 specified. The file comparison utility (diff) was used to check that the only changes between the version 0 files used for validation, and the final version, are in the filenames, version 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.

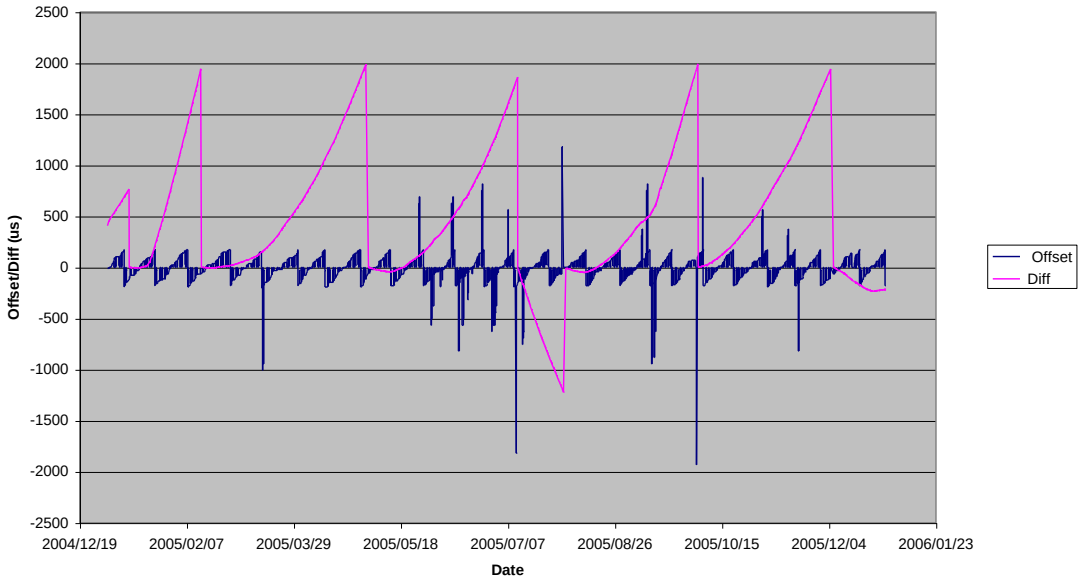
```
hoodie% ../tcor2cef -t 05_1_tcor.txt -v 01
TCOR2CEF, version 1.6

TCOR file:          05_1_tcor.txt, s/c: 1, records: 1705
Generated CEF name: C1_CP_DWP_TCOR__20050101_V01
Time range:         2005-01-01T00:00:00Z/2005-12-30T16:38:26Z
Finished, CEF size: 195123 bytes
Total duration:     31423106 seconds
Corrected:          28450268 seconds (90.5 %)
hoodie% ../tcor2cef -t 05_2_tcor.txt -v 01
TCOR2CEF, version 1.6

TCOR file:          05_2_tcor.txt, s/c: 2, records: 1839
Generated CEF name: C2_CP_DWP_TCOR__20050101_V01
Time range:         2005-01-01T00:00:00Z/2005-12-30T11:45:20Z
Finished, CEF size: 205773 bytes
Total duration:     31405520 seconds
Corrected:          30444975 seconds (96.9 %)
hoodie% ../tcor2cef -t 05_3_tcor.txt -v 01
TCOR2CEF, version 1.6

TCOR file:          05_3_tcor.txt, s/c: 3, records: 1527
Generated CEF name: C3_CP_DWP_TCOR__20050101_V01
Time range:         2005-01-01T17:58:11Z/2005-12-30T17:20:26Z
Finished, CEF size: 172485 bytes
Total duration:     31360935 seconds
Corrected:          29615333 seconds (94.4 %)
hoodie% ../tcor2cef -t 05_4_tcor.txt -v 01
TCOR2CEF, version 1.6

TCOR file:          05_4_tcor.txt, s/c: 4, records: 1845
Generated CEF name: C4_CP_DWP_TCOR__20050101_V01
Time range:         2005-01-01T12:34:17Z/2005-12-30T12:23:16Z
Finished, CEF size: 206688 bytes
Total duration:     31362539 seconds
Corrected:          29008814 seconds (92.5 %)
hoodie%
```

A final validation of the CEF files was performed by importing them to Excel and plotting charts of the data.

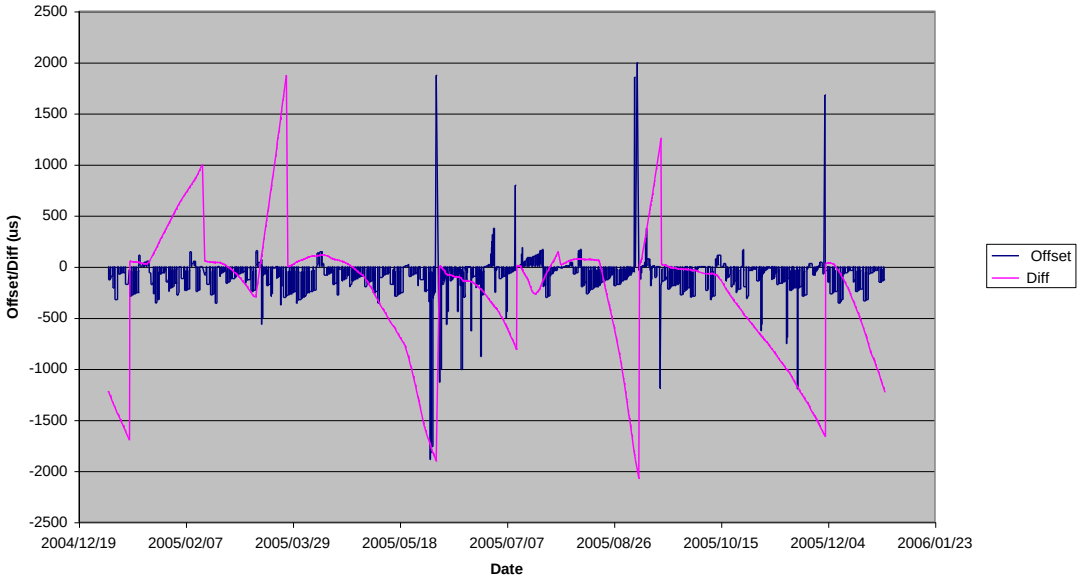
C1_CP_DWP_TCOR__20050101_V01



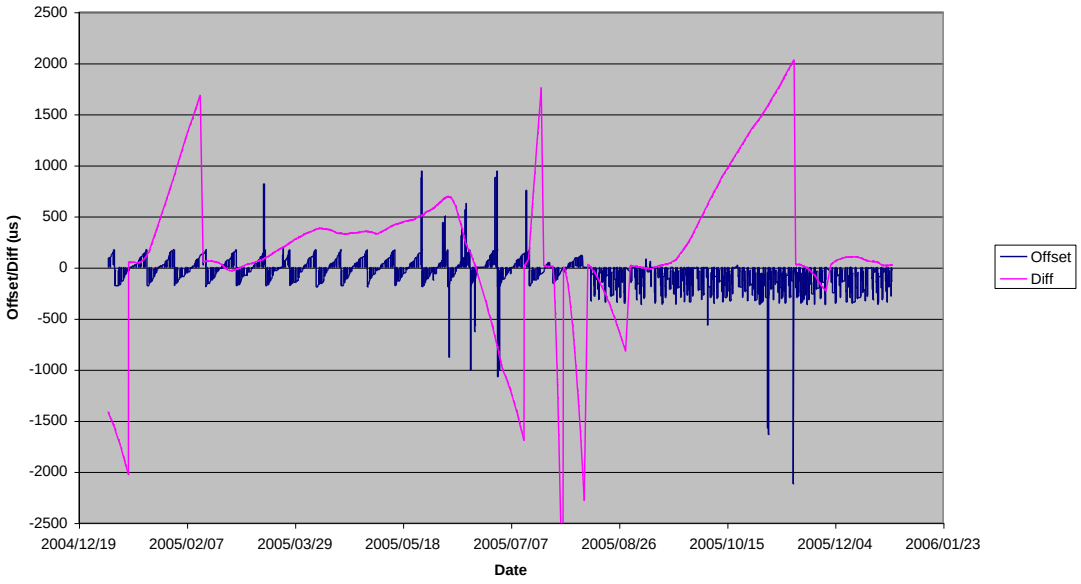

C2_CP_DWP_TCOR__20050101_V01



C3_CP_DWP_TCOR__20050101_V01




C4_CP_DWP_TCOR__20050101_V01



## 7 Caveats

The following general caveats apply to year 2005 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 2005, TCOR coverage is typically around 90 to 97%. Gaps are mainly around the times when a new time correlation is performed.

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.