Preparation and validation of WEC time corrections for year 2002

Keith Yearby, 22 September 2006

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 2002. Like the 2001 TCOR datasets, the 2002 data is organised in periods of 3 calendar months.

2 Data and references

Source data:

ESOC DIFF measurements for 2002.
WBD data DVDs for 2002.
Cluster RDM for 2002.

Documents:

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

Software:

wbddiff, version 1.0, 2004-06-11
maketcor, version 3.4, 2006-03-03
apptcor, version 1.4, 2006-03-10
veritcor, version 1.2, 2005-07-19
tcor2cef, version 1.6, 2006-03-02

Derived datasets

Point valid DIFF measurements

020101_1_diff.xls
020101_2_diff.xls

020101_3_diff.xls
020101_4_diff.xls
020401_1_diff.xls
020401_2_diff.xls
020401_3_diff.xls
020401_4_diff.xls
020701_1_diff.xls
020701_2_diff.xls
020701_3_diff.xls
020701_4_diff.xls
021001_1_diff.xls
021001_2_diff.xls
021001_3_diff.xls
021001_4_diff.xls

ASCII TCOR files

020101_1_tcor.txt
020101_2_tcor.txt
020101_3_tcor.txt
020101_4_tcor.txt
020401_1_tcor.txt
020401_2_tcor.txt
020401_3_tcor.txt
020401_4_tcor.txt
020701_1_tcor.txt
020701_2_tcor.txt
020701_3_tcor.txt
020701_4_tcor.txt
021001_1_tcor.txt
021001_2_tcor.txt
021001_3_tcor.txt
021001_4_tcor.txt

CEF TCOR files

C1_CP_DWP_TCOR__20020101_V01.cef
C1_CP_DWP_TCOR__20020401_V01.cef
C1_CP_DWP_TCOR__20020701_V01.cef
C1_CP_DWP_TCOR__20021001_V01.cef
C2_CP_DWP_TCOR__20020101_V01.cef
C2_CP_DWP_TCOR__20020401_V01.cef
C2_CP_DWP_TCOR__20020701_V01.cef
C2_CP_DWP_TCOR__20021002_V01.cef
C3_CP_DWP_TCOR__20020101_V01.cef
C3_CP_DWP_TCOR__20020401_V01.cef
C3_CP_DWP_TCOR__20020701_V01.cef
C3_CP_DWP_TCOR__20021001_V01.cef
C4_CP_DWP_TCOR__20020101_V01.cef
C4_CP_DWP_TCOR__20020401_V01.cef
C4_CP_DWP_TCOR__20020703_V01.cef
C4_CP_DWP_TCOR__20021001_V01.cef

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 2002 are unsigned, so the sign is determined by comparison with the WBD or TCAL DIFFs.

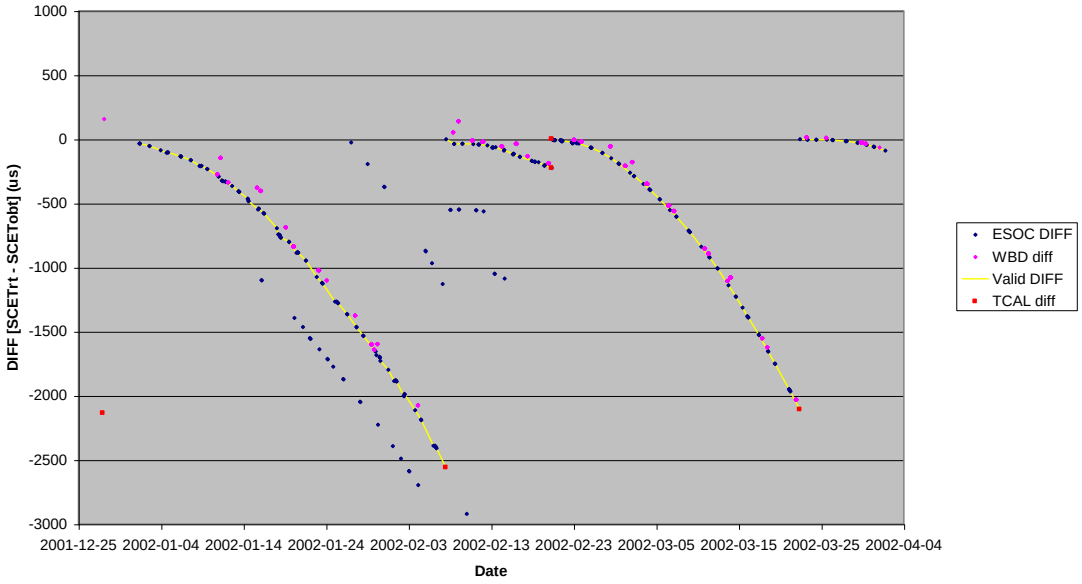
The ESOC and WBD data are copied into Excel worksheets. A duplicate is made of the ESOC data which will become the final validated data. A chart (XY scatter) is then produced, plotting points only for the raw ESOC and WBD data, and a line for the validated data.

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 period of the time correlations, and the four spacecraft. Note that the vertical scale of each figure is different. Each figure is 'Chart1' in the Excel format DIFF files listed in section 2.

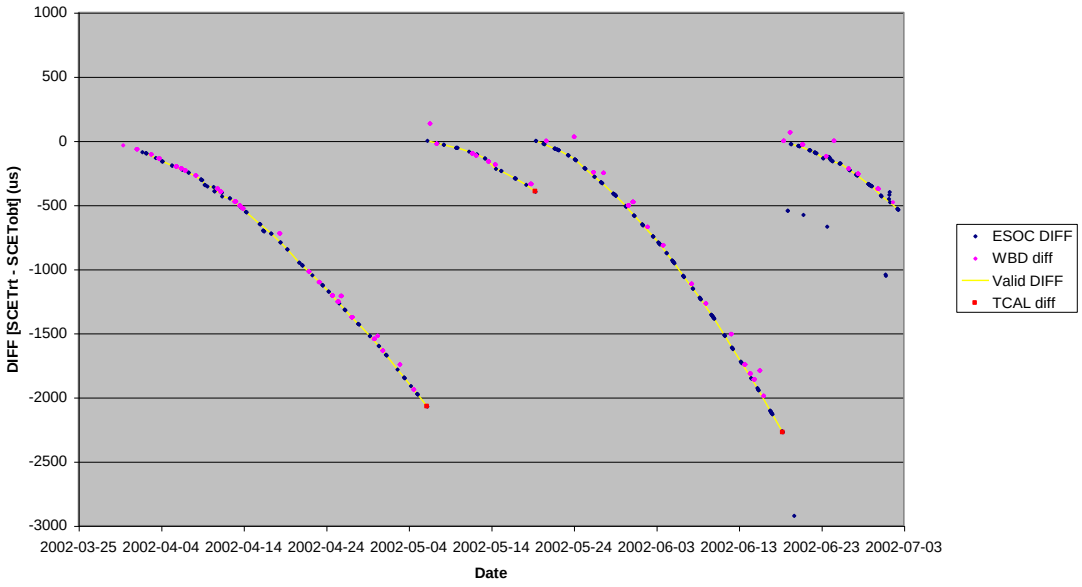
Once the valid ESOC data has been selected, its accuracy is checked by comparing each WBD measurement with a linear interpolation between the nearest ESOC measurements before and after.

The point valid DIFF files are organised in periods of 3 calendar months, the same as the ESOC DIFF measurements. Where possible, at least one point before and after the nominal 3 month period is included, so the DIFF at the boundaries of the nominal period may be obtained by interpolation. The final validated DIFF measurements are saved in Text (space delimited) format using the default .prn file name extension.

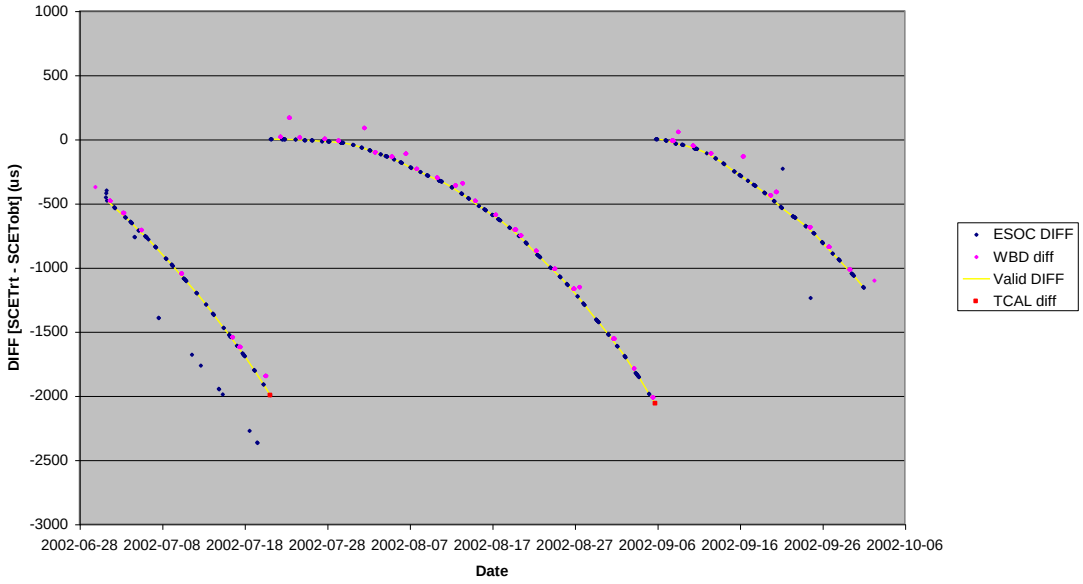
Cluster SC1 ESOC & WBD DIFF for 2002/01..03



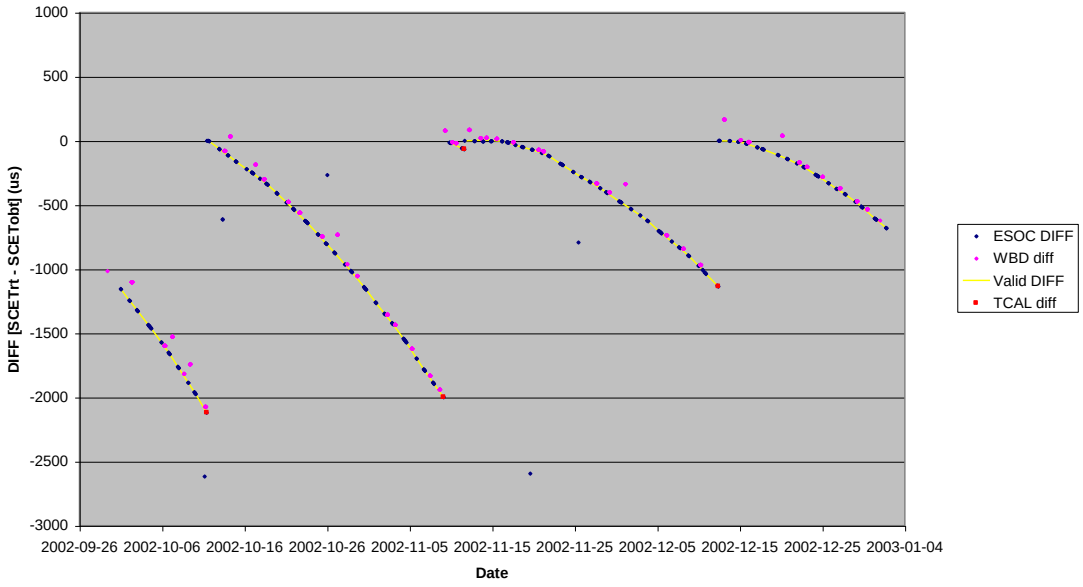
Cluster SC1 ESOC & WBD DIFF for 2002/01..03



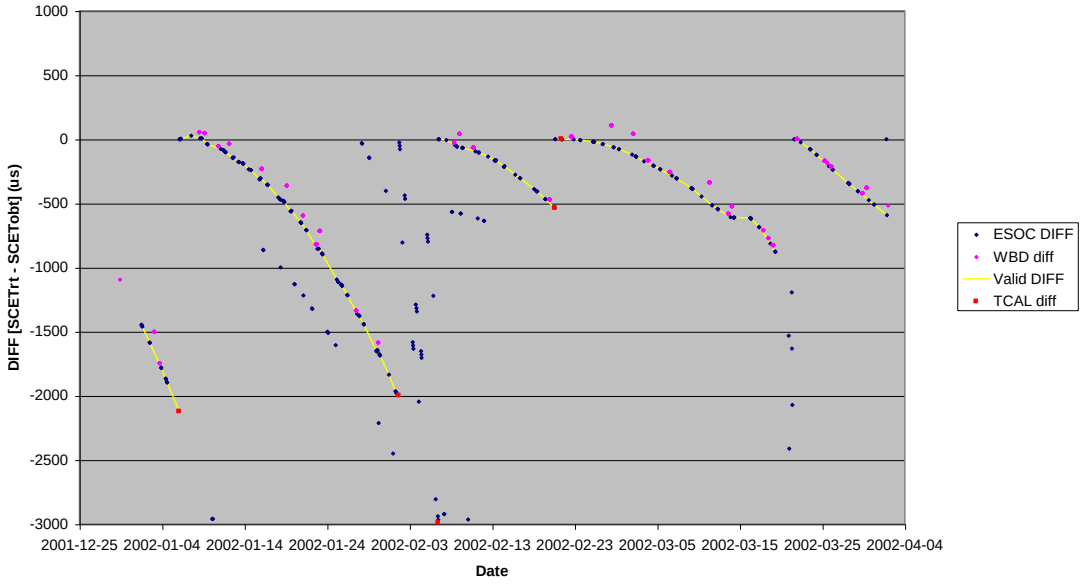
Cluster SC1 ESOC & WBD DIFF for 2002/07..09



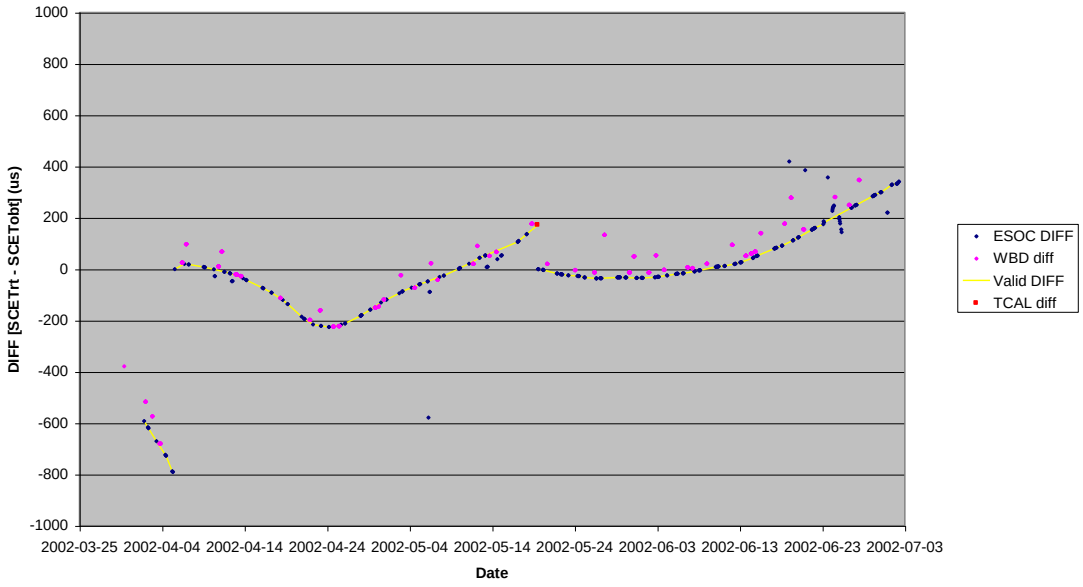
Cluster SC1 ESOC & WBD DIFF for 2002/10..12



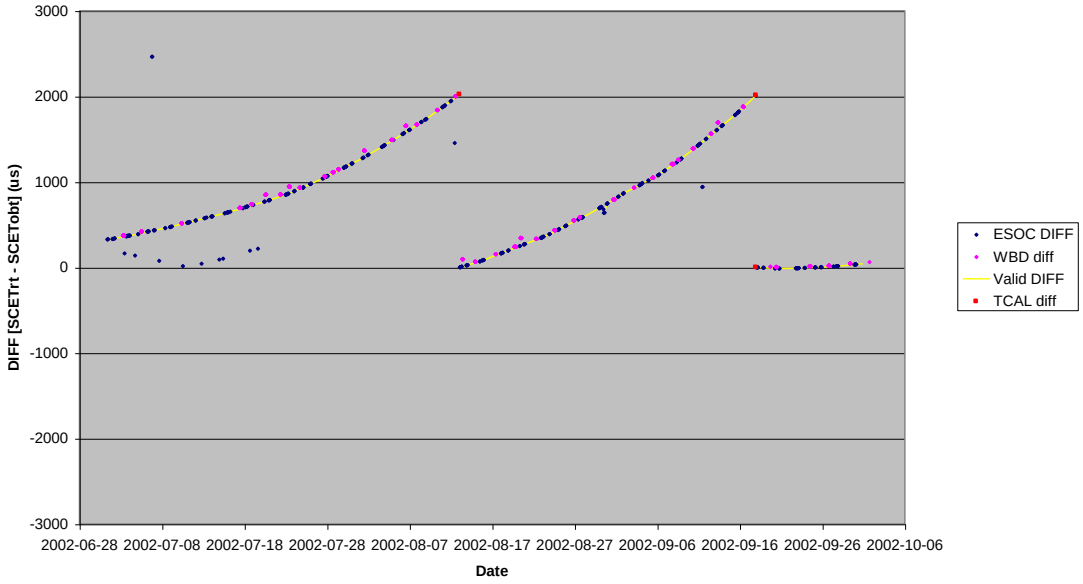
Cluster SC2 ESOC & WBD DIFF for 2002/01..03



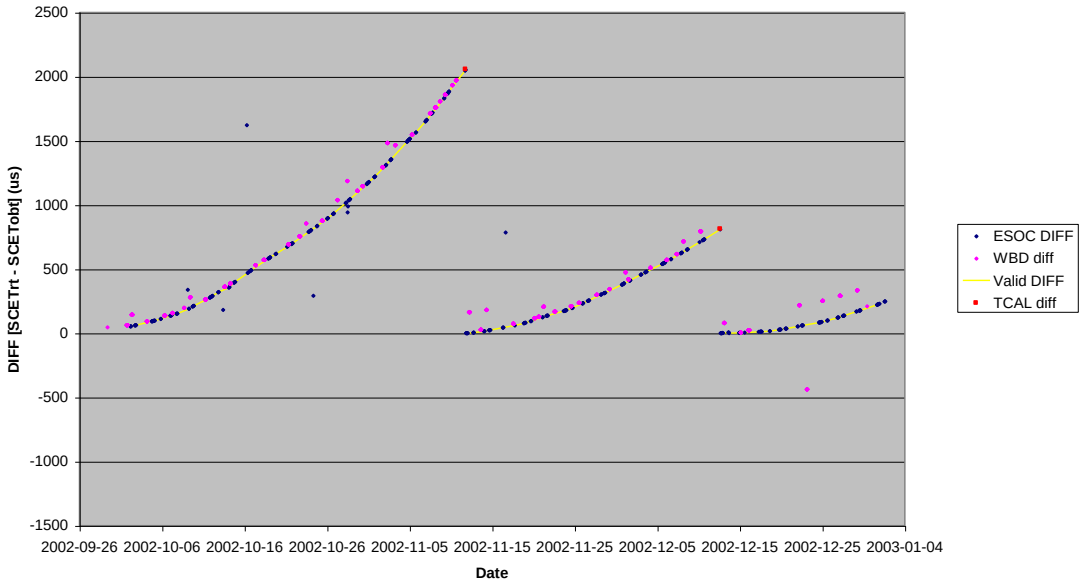
Cluster SC2 ESOC & WBD DIFF for 2002/04..06



Cluster SC2 ESOC & WBD DIFF for 2002/07..09

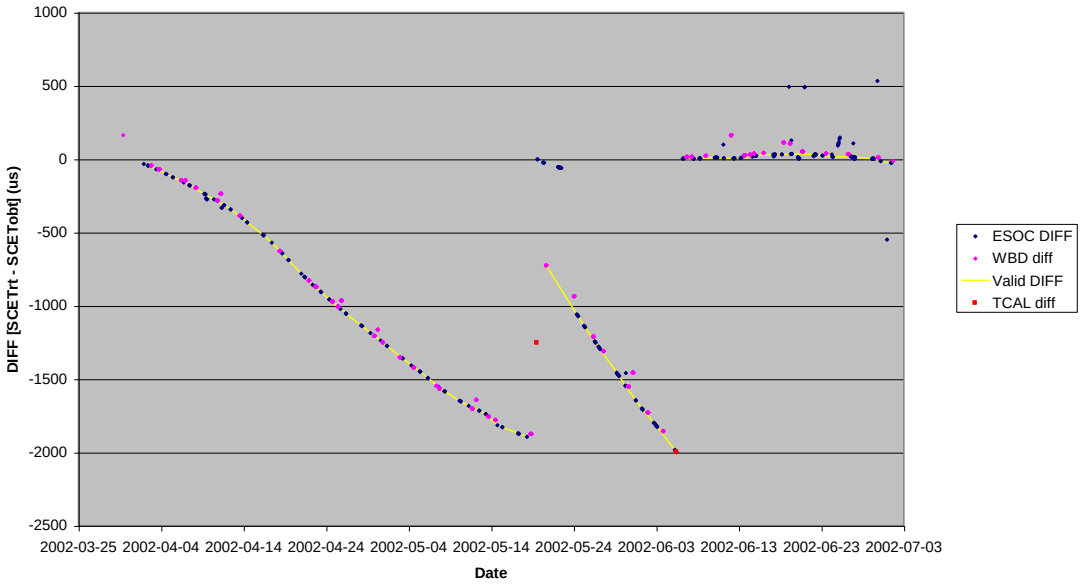


Cluster SC1 ESOC & WBD DIFF for 2002/10..12



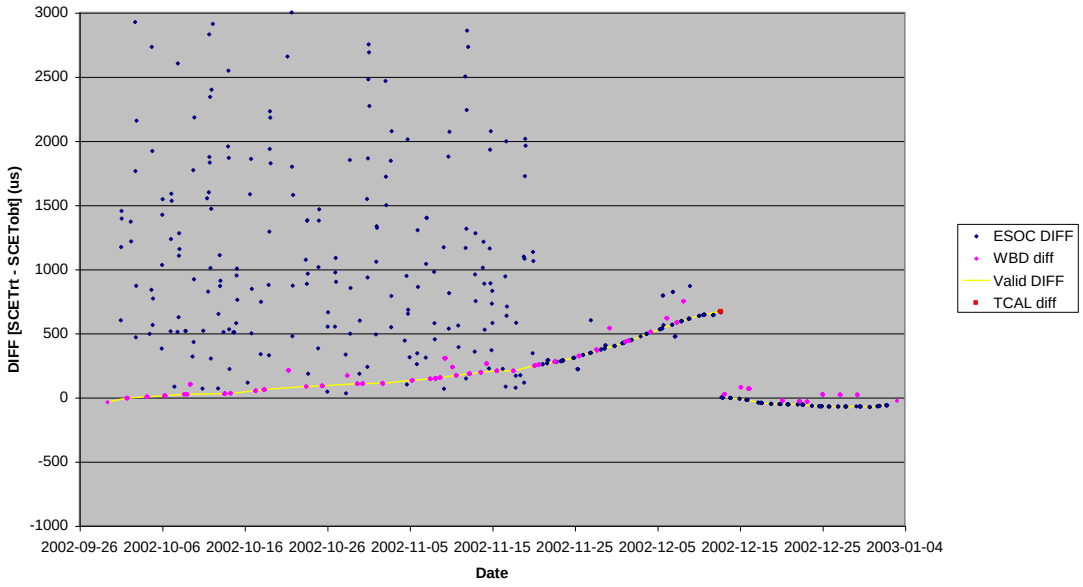
Cluster SC3 ESOC & WBD DIFF for 2002/01..03

Cluster SC3 ESOC & WBD DIFF for 2002/04..06

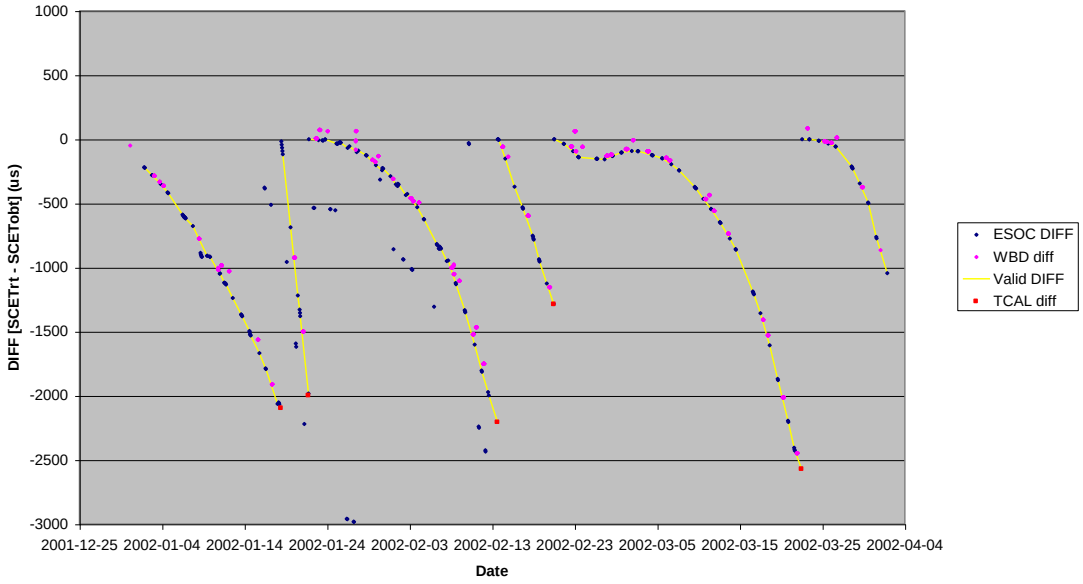


Cluster SC3 ESOC & WBD DIFF for 2002/07..09

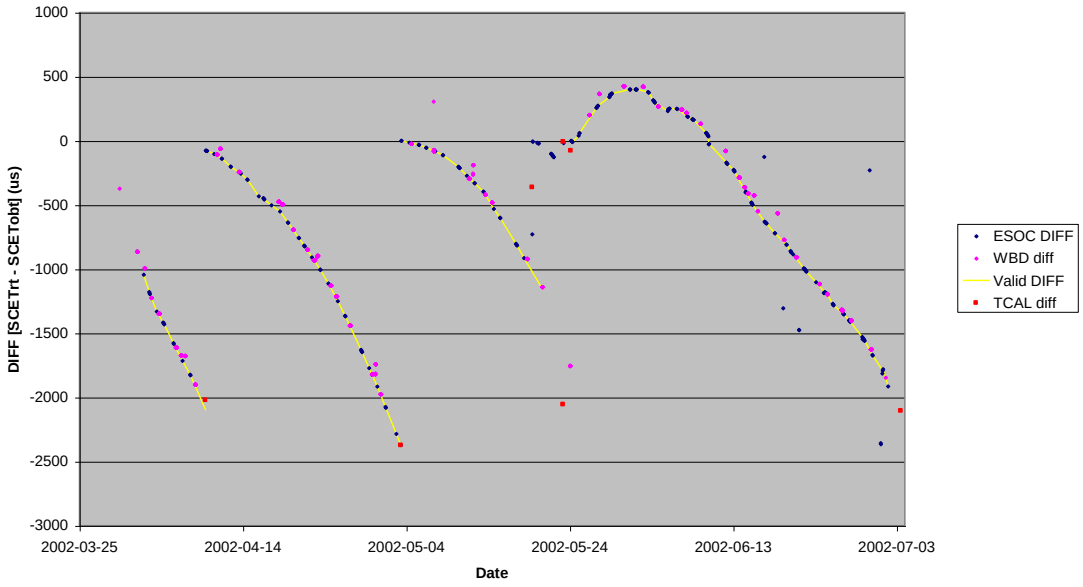
Cluster SC3 ESOC & WBD DIFF for 2002/10..12



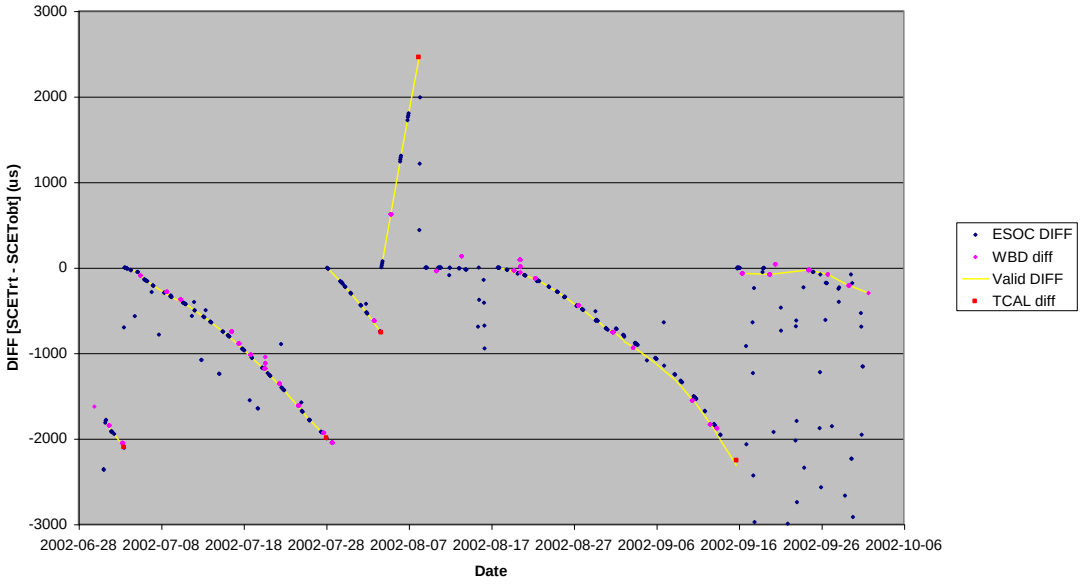
Cluster SC4 ESOC & WBD DIFF for 2002/01..03



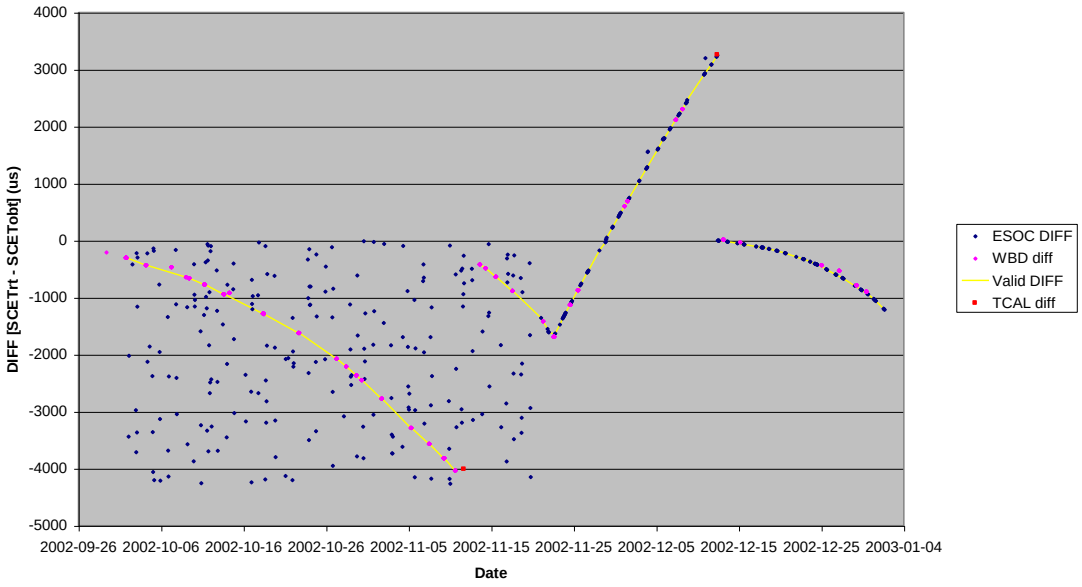
Cluster SC4 ESOC & WBD DIFF for 2002/04..06



Cluster SC4 ESOC & WBD DIFF for 2002/07..09



Cluster SC4 ESOC & WBD DIFF for 2002/10..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. The individual lists must be in chronological order. They should be written to files named like *yy_s*_hkla_files.txt.

Then maketcor3 is used to generate the ASCII TCOR files for each 3 month period using a series of commands like:

```
maketcor3 -d 020101_1_diff.prn -f 02_1_hkla_files.txt \
          -s 020101 -e 020331 > 020101_1_tcor.txt
maketcor3 -d 020401_1_diff.prn -f 02_1_hkla_files.txt \
          -s 020401 -e 020630 > 020401_1_tcor.txt
maketcor3 -d 020701_1_diff.prn -f 02_1_hkla_files.txt \
          -s 020701 -e 020930 > 020701_1_tcor.txt
maketcor3 -d 021001_1_diff.prn -f 02_1_hkla_files.txt \
          -s 021001 -e 021231 > 021001_1_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.

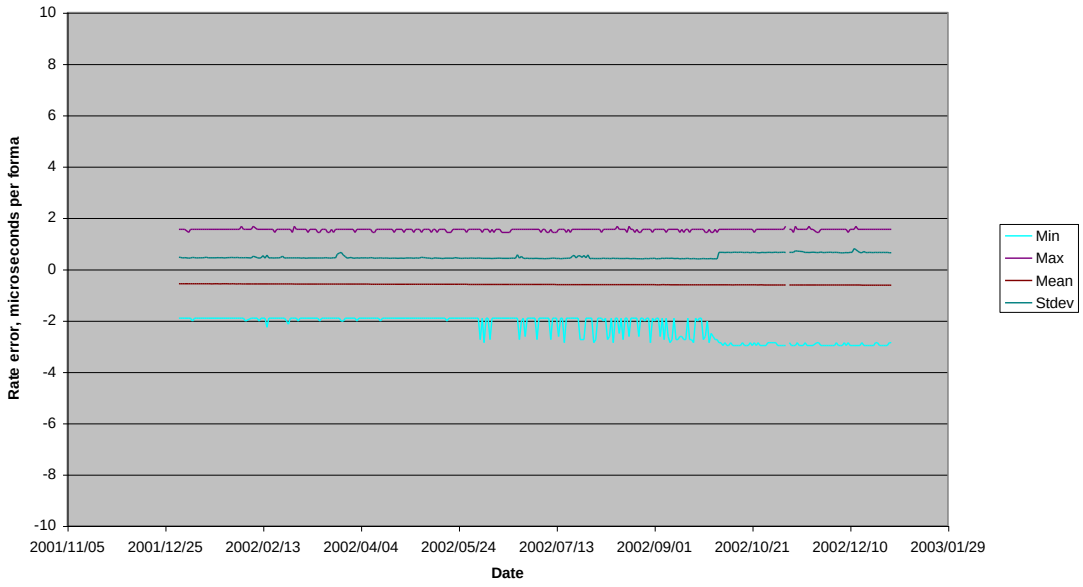
A typical 'veritcor' command is:

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

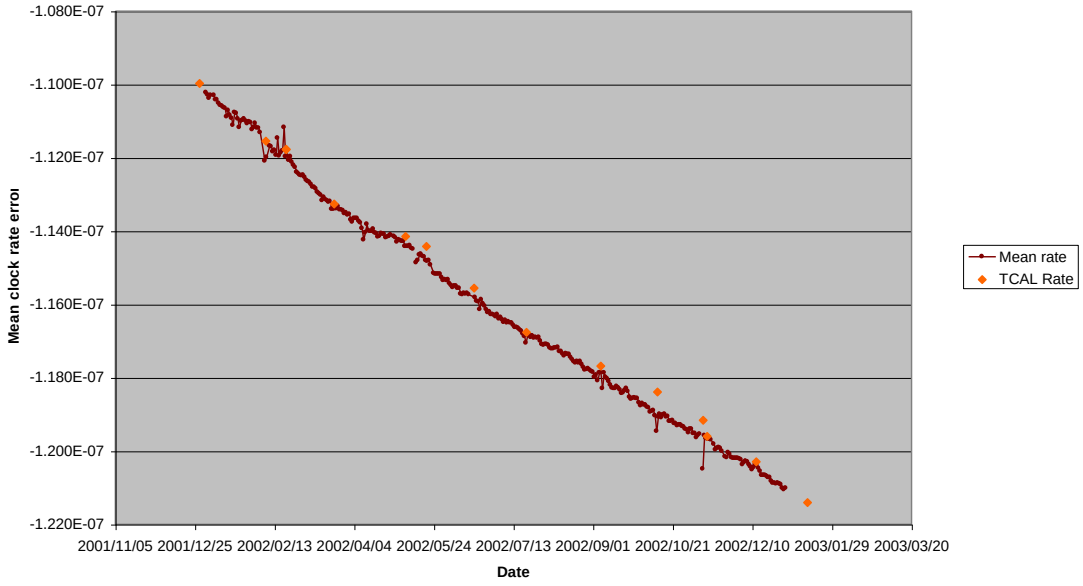
It uses the same HK+TCAL file list file as 'maketcor3', although only the HK files as used. 'veritcor' includes the same code module used by TED to apply the TCOR corrections, and requires CEF TCOR files to be installed with the same index files. The '-T .' option specifies that the TCOR files (and the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

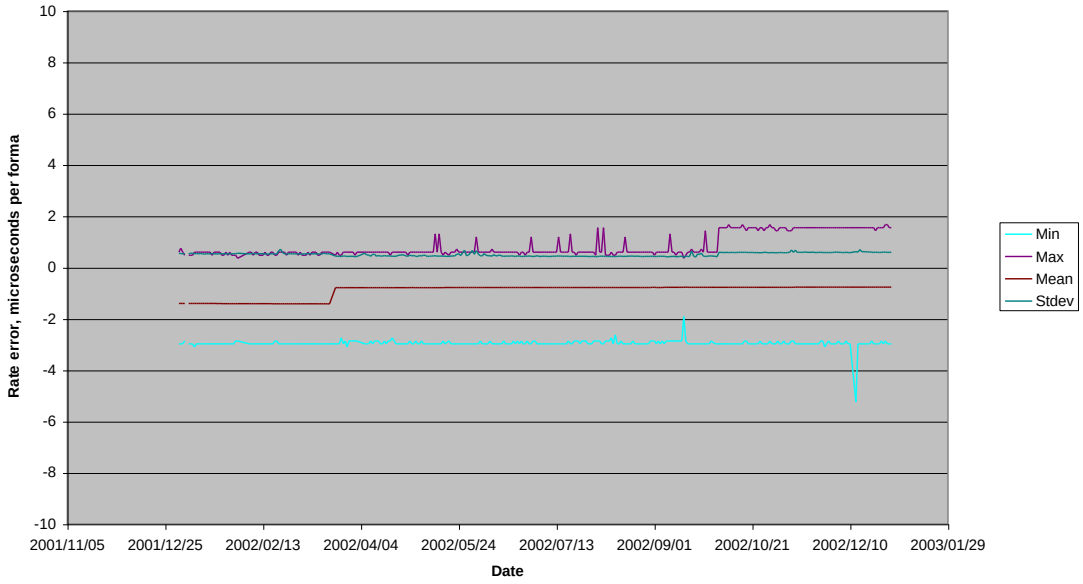
Cluster SC1 timing analysis, year 2002



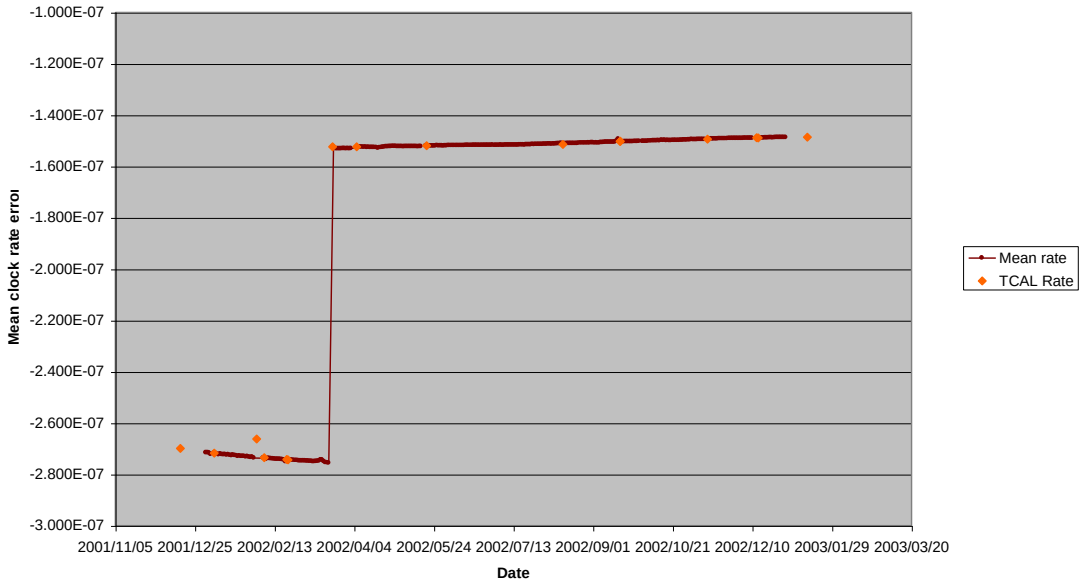
Cluster SC1 clock rate error, year 2002



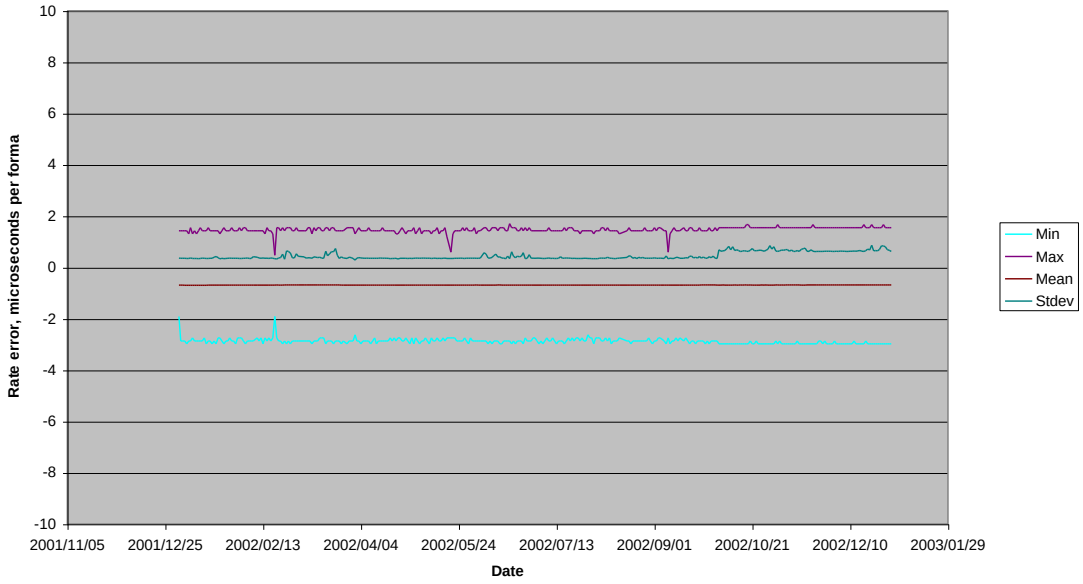
Cluster SC2 timing analysis, year 2002



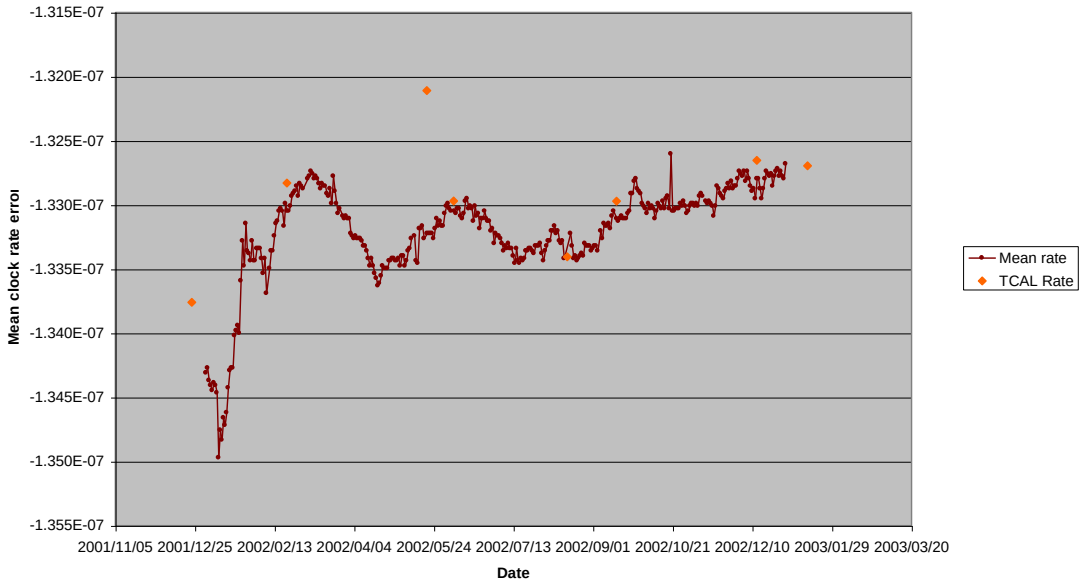
Cluster SC2 clock rate error, year 2002



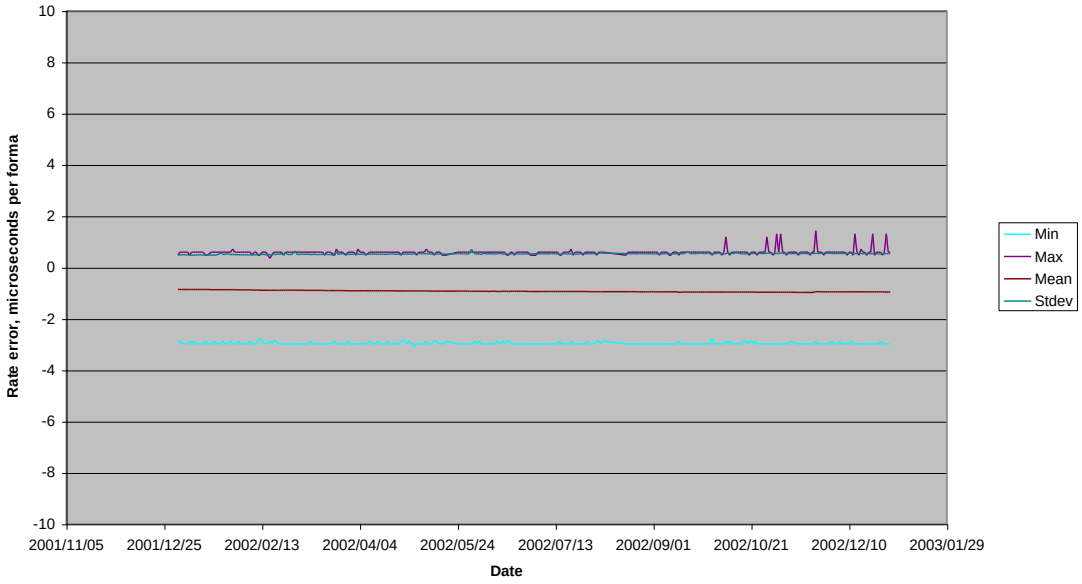
Cluster SC3 timing analysis, year 2002



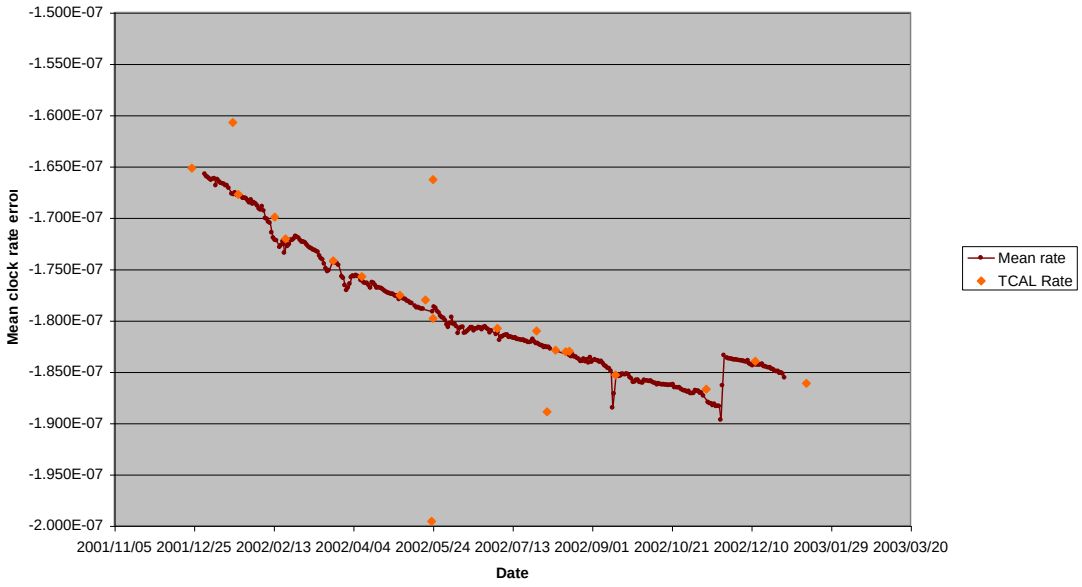
Cluster SC3 clock rate error, year 2002



Cluster SC4 timing analysis, year 2002



Cluster SC4 clock rate error, year 2002



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 (fc) was used to check that the only changes between the version 0 files used for validation, and the final version, are in the 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 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.

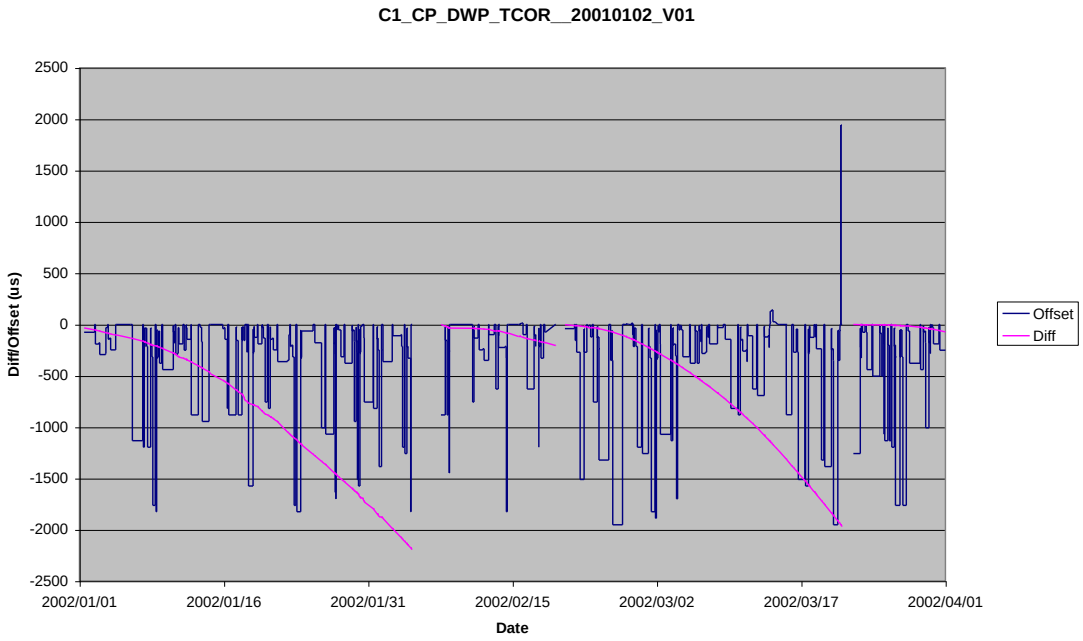
The standard output from TCOR2CEF is listed below. This includes a measure of what proportion of the time corrections are available.

```
TCOR2CEF, version 1.6
TCOR file:          020101_1_tcor.txt, s/c: 1, records: 475
Generated CEF name: C1_CP_DWP_TCOR__20020101_V01
Time range:         2002-01-01T11:43:18Z/2002-03-31T23:59:59Z
Finished, CEF size: 56872 bytes
Total duration:     7733801 seconds
Corrected:          6580873 seconds (85.1 %)

TCOR2CEF, version 1.6
TCOR file:          020101_2_tcor.txt, s/c: 2, records: 425
Generated CEF name: C2_CP_DWP_TCOR__20020101_V01
Time range:         2002-01-01T15:22:23Z/2002-03-31T23:59:59Z
Finished, CEF size: 50427 bytes
Total duration:     7720656 seconds
Corrected:          5999866 seconds (77.7 %)

TCOR2CEF, version 1.6
TCOR file:          020101_3_tcor.txt, s/c: 3, records: 481
Generated CEF name: C3_CP_DWP_TCOR__20020101_V01
Time range:         2002-01-01T19:01:30Z/2002-03-31T23:59:59Z
Finished, CEF size: 56555 bytes
Total duration:     7707509 seconds
Corrected:          6615859 seconds (85.8 %)

TCOR2CEF, version 1.6
TCOR file:          020101_4_tcor.txt, s/c: 4, records: 498
Generated CEF name: C4_CP_DWP_TCOR__20020101_V01
Time range:         2002-01-01T22:40:36Z/2002-03-31T23:59:59Z
Finished, CEF size: 59077 bytes
Total duration:     7694363 seconds
Corrected:          6700009 seconds (87.1 %)

TCOR2CEF, version 1.6
TCOR file:          020401_1_tcor.txt, s/c: 1, records: 469
Generated CEF name: C1_CP_DWP_TCOR__20020401_V01
Time range:         2002-04-01T18:54:48Z/2002-06-30T23:59:59Z
Finished, CEF size: 56360 bytes
Total duration:     7794311 seconds
Corrected:          6707365 seconds (86.1 %)

TCOR2CEF, version 1.6
TCOR file:          020401_2_tcor.txt, s/c: 2, records: 454
Generated CEF name: C2_CP_DWP_TCOR__20020401_V01
```

```
Time range:          2002-04-01T20:16:15Z/2002-06-30T23:59:59Z
Finished, CEF size: 53032 bytes
Total duration:     7789424 seconds
Corrected:          6735446 seconds (86.5 %)

TCOR2CEF, version 1.6
TCOR file:          020401_3_tcor.txt, s/c: 3, records: 495
Generated CEF name: C3_CP_DWP_TCOR__20020401_V01
Time range:          2002-04-01T22:59:16Z/2002-06-30T23:59:59Z
Finished, CEF size: 58633 bytes
Total duration:     7779643 seconds
Corrected:          7365215 seconds (94.7 %)

TCOR2CEF, version 1.6
TCOR file:          020401_4_tcor.txt, s/c: 4, records: 477
Generated CEF name: C4_CP_DWP_TCOR__20020401_V01
Time range:          2002-04-01T21:37:44Z/2002-06-30T23:59:59Z
Finished, CEF size: 56598 bytes
Total duration:     7784535 seconds
Corrected:          6899367 seconds (88.6 %)

TCOR2CEF, version 1.6
TCOR file:          020701_1_tcor.txt, s/c: 1, records: 440
Generated CEF name: C1_CP_DWP_TCOR__20020701_V01
Time range:          2002-07-01T08:13:50Z/2002-09-30T23:59:59Z
Finished, CEF size: 52675 bytes
Total duration:     7919169 seconds
Corrected:          7530800 seconds (95.1 %)

TCOR2CEF, version 1.6
TCOR file:          020701_2_tcor.txt, s/c: 2, records: 405
Generated CEF name: C2_CP_DWP_TCOR__20020701_V01
Time range:          2002-07-01T11:57:41Z/2002-09-30T04:34:18Z
Finished, CEF size: 47723 bytes
Total duration:     7835797 seconds
Corrected:          7437045 seconds (94.9 %)

TCOR2CEF, version 1.6
TCOR file:          020701_3_tcor.txt, s/c: 3, records: 416
Generated CEF name: C3_CP_DWP_TCOR__20020701_V01
Time range:          2002-07-01T12:04:23Z/2002-09-30T23:59:59Z
Finished, CEF size: 49344 bytes
Total duration:     7905336 seconds
Corrected:          7314492 seconds (92.5 %)

TCOR2CEF, version 1.6
TCOR file:          020701_4_tcor.txt, s/c: 4, records: 349
Generated CEF name: C4_CP_DWP_TCOR__20020703_V01
Time range:          2002-07-03T22:36:41Z/2002-09-30T23:59:59Z
Finished, CEF size: 41589 bytes
Total duration:     7694598 seconds
Corrected:          6119970 seconds (79.5 %)

TCOR2CEF, version 1.6
TCOR file:          021001_1_tcor.txt, s/c: 1, records: 367
Generated CEF name: C1_CP_DWP_TCOR__20021001_V01
Time range:          2002-10-01T01:41:35Z/2002-12-31T20:20:00Z
Finished, CEF size: 44059 bytes
Total duration:     7929505 seconds
Corrected:          7166574 seconds (90.4 %)
```

```
TCOR2CEF, version 1.6
TCOR file:          021001_2_tcor.txt, s/c: 2, records: 421
Generated CEF name: C2_CP_DWP_TCOR__20021002_V01
Time range:         2002-10-02T06:13:19Z/2002-12-31T22:31:43Z
Finished, CEF size: 49030 bytes
Total duration:     7834704 seconds
Corrected:          7252108 seconds (92.6 %)

TCOR2CEF, version 1.6
TCOR file:          021001_3_tcor.txt, s/c: 3, records: 499
Generated CEF name: C3_CP_DWP_TCOR__20021001_V01
Time range:         2002-10-01T00:00:00Z/2002-12-31T23:03:18Z
Finished, CEF size: 57733 bytes
Total duration:     7945398 seconds
Corrected:          7777769 seconds (97.9 %)

TCOR2CEF, version 1.6
TCOR file:          021001_4_tcor.txt, s/c: 4, records: 444
Generated CEF name: C4_CP_DWP_TCOR__20021001_V01
Time range:         2002-10-01T20:16:06Z/2002-12-31T20:19:55Z
Finished, CEF size: 52895 bytes
Total duration:     7862629 seconds
Corrected:          7464478 seconds (94.9 %)
```

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.



7 Caveats

The following general caveats apply to all year 2002 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 the version 1 files, any data that fails validation is simply deleted from the files. For 2002, TCOR coverage is typically around 90%.

The DIFF measurements received from ESOC for 2002 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). Usually DIFF is set to zero in such periods to minimise any possible error.

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.