# Preparation and validation of WEC time corrections for year 2003

Keith Yearby, 27 April 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 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 2003.
WBD data DVDs for 2003.
Cluster RDM for 2003.

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

## 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.

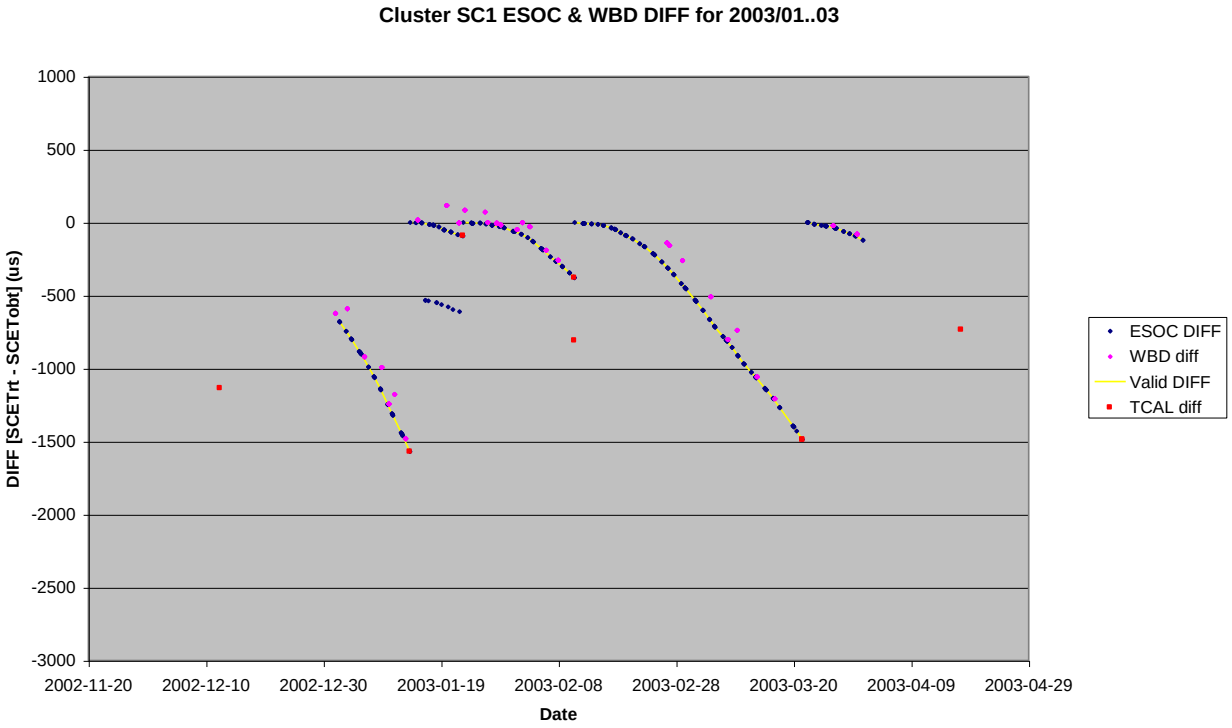
The DIFF measurements received from ESOC for 2003 are unsigned, so the sign is determined by comparison with the WBD or TCAL DIFFs.

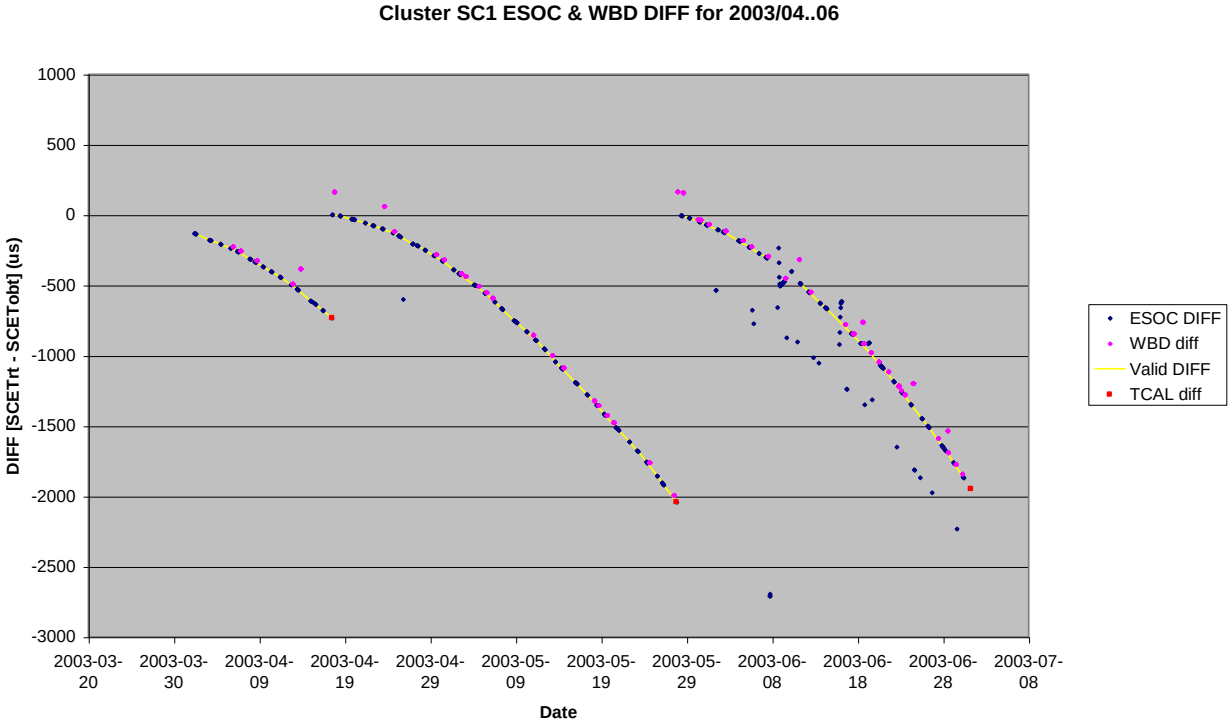
The ESOC and WBD data are copied into Excel worksheets. A duplicate is made of the ESOC data which will become the final validated data. A chart (XY scatter) is then produced, plotting points only for the raw ESOC and WBD data, and a line for the validated data.

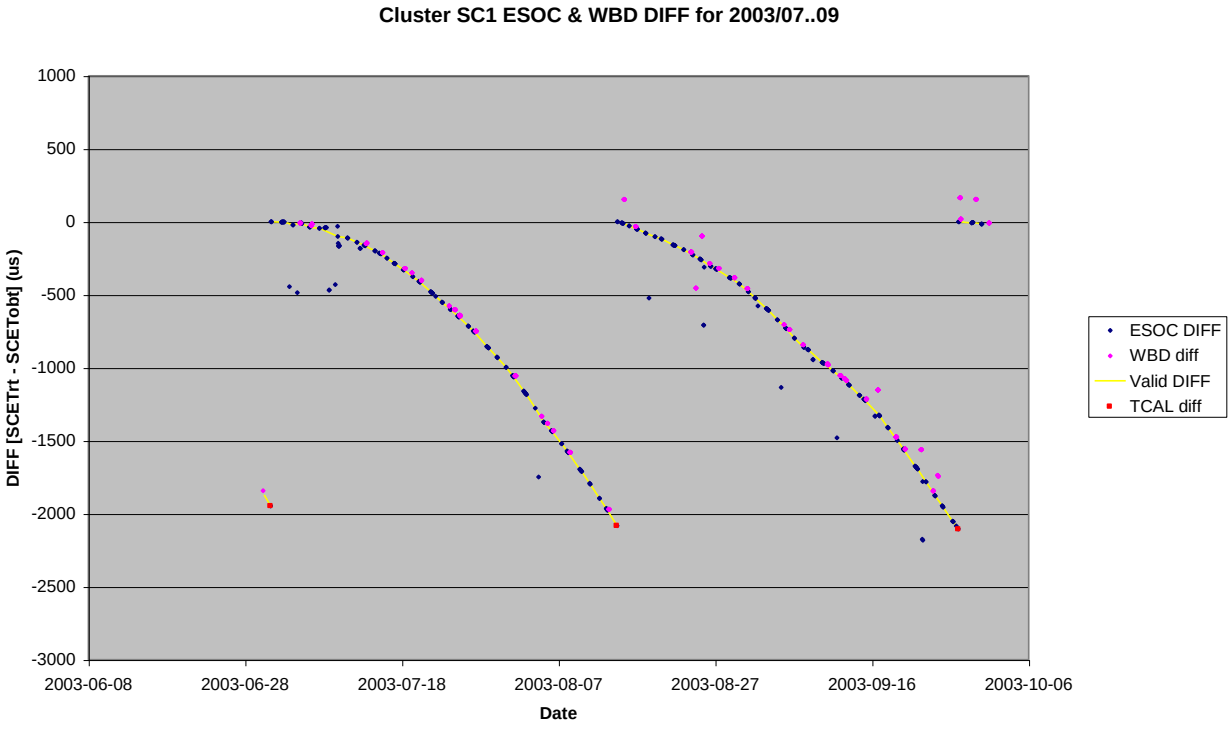
It is fairly clear which points have large errors and these are simply deleted from the validated data worksheet. The following charts show the data for the period of the time correlations, and the four spacecraft. Note that the vertical scale of each figure is different. Each figure is 'Chart1' in the Excel format DIFF files listed in section 2.

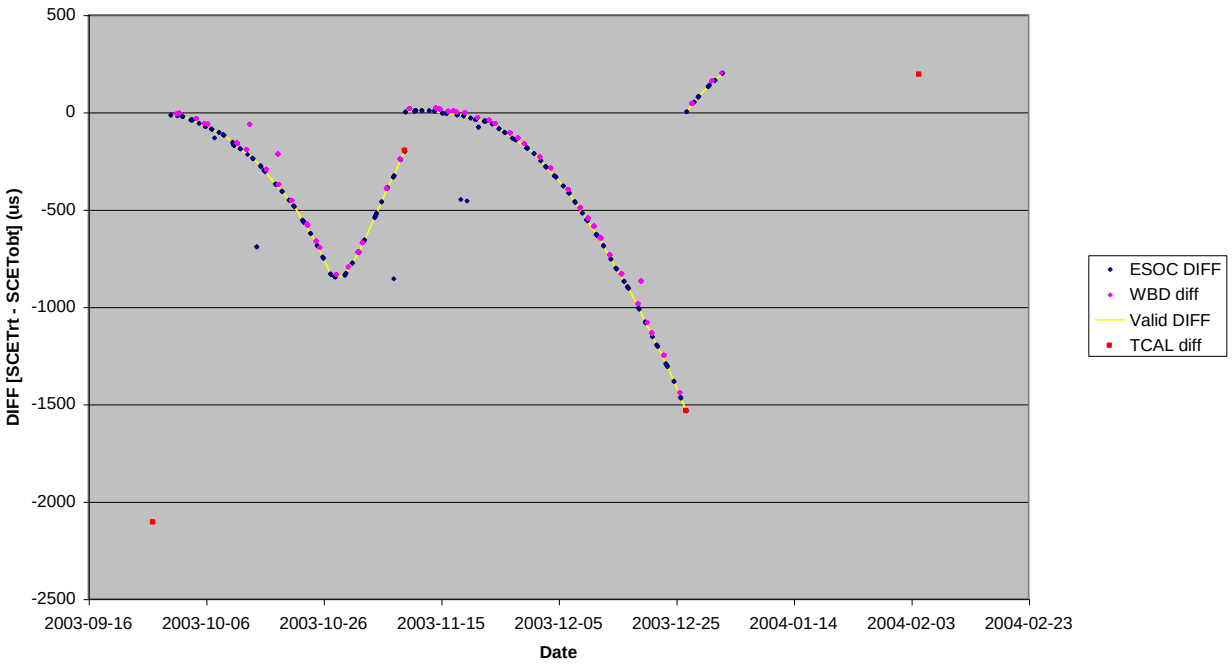
Once the valid ESOC data has been selected, its accuracy is checked by comparing each WBD measurement with a linear interpolation between the nearest ESOC measurements before and after.

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.

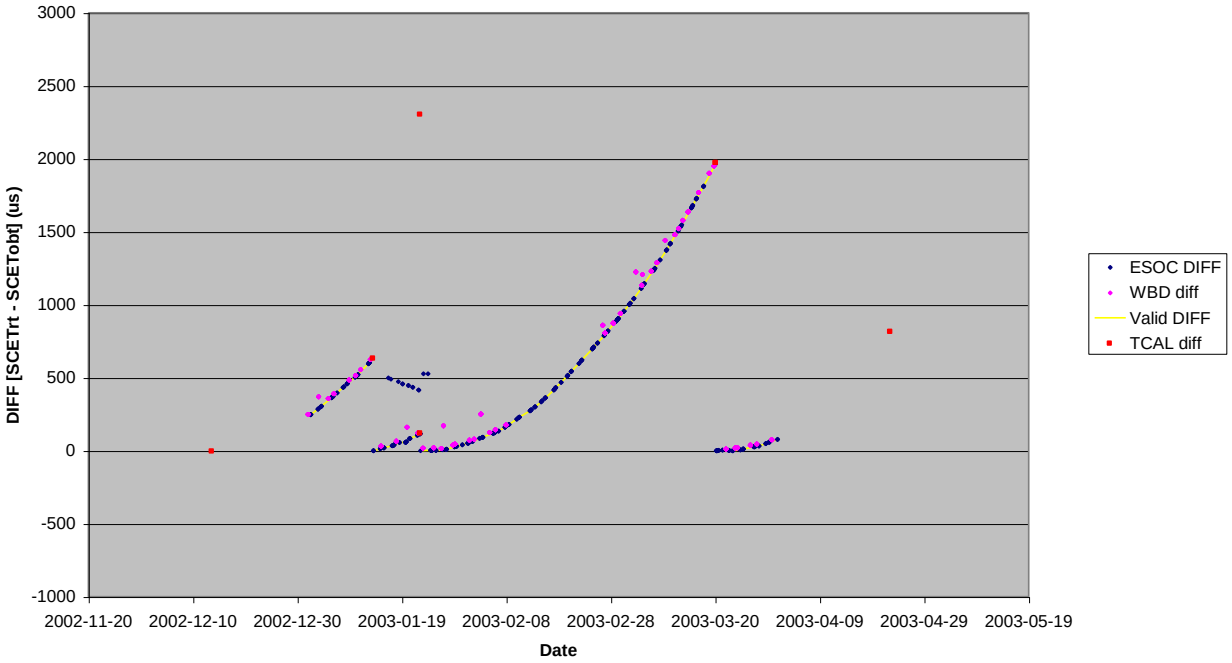

Cluster SC1 ESOC & WBD DIFF for 2003/01..03
DIFF [SCETrt - SCETobt] (us)
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
2002-11-20
2002-12-10
2002-12-30
2003-01-19
2003-02-08
2003-02-28
2003-03-20
2003-04-09
2003-04-29
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff


Cluster SC1 ESOC & WBD DIFF for 2003/04..06
DIFF [SCETrt - SCETobt] (us)
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
2003-03-20
2003-03-30
2003-04-09
2003-04-19
2003-04-29
2003-05-09
2003-05-19
2003-05-29
2003-06-08
2003-06-18
2003-06-28
2003-07-08
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff

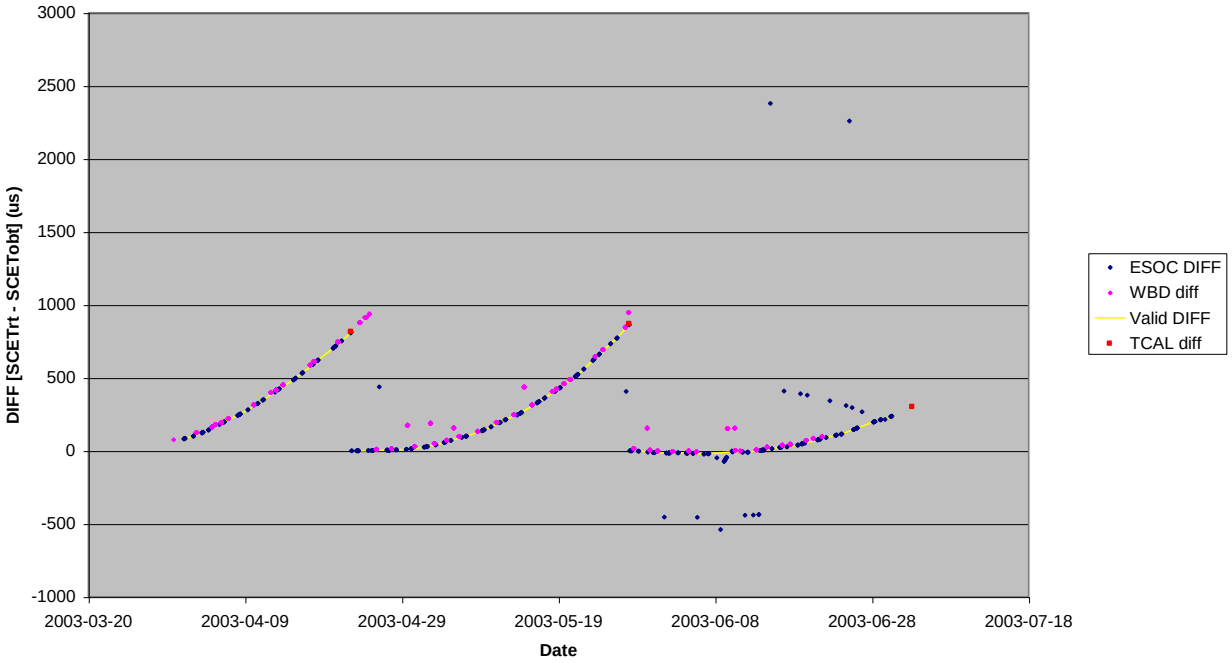

Cluster SC1 ESOC & WBD DIFF for 2003/07..09
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
DIFF [SCETrt - SCETobt] (us)
2003-06-08
2003-06-28
2003-07-18
2003-08-07
2003-08-27
2003-09-16
2003-10-06
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff

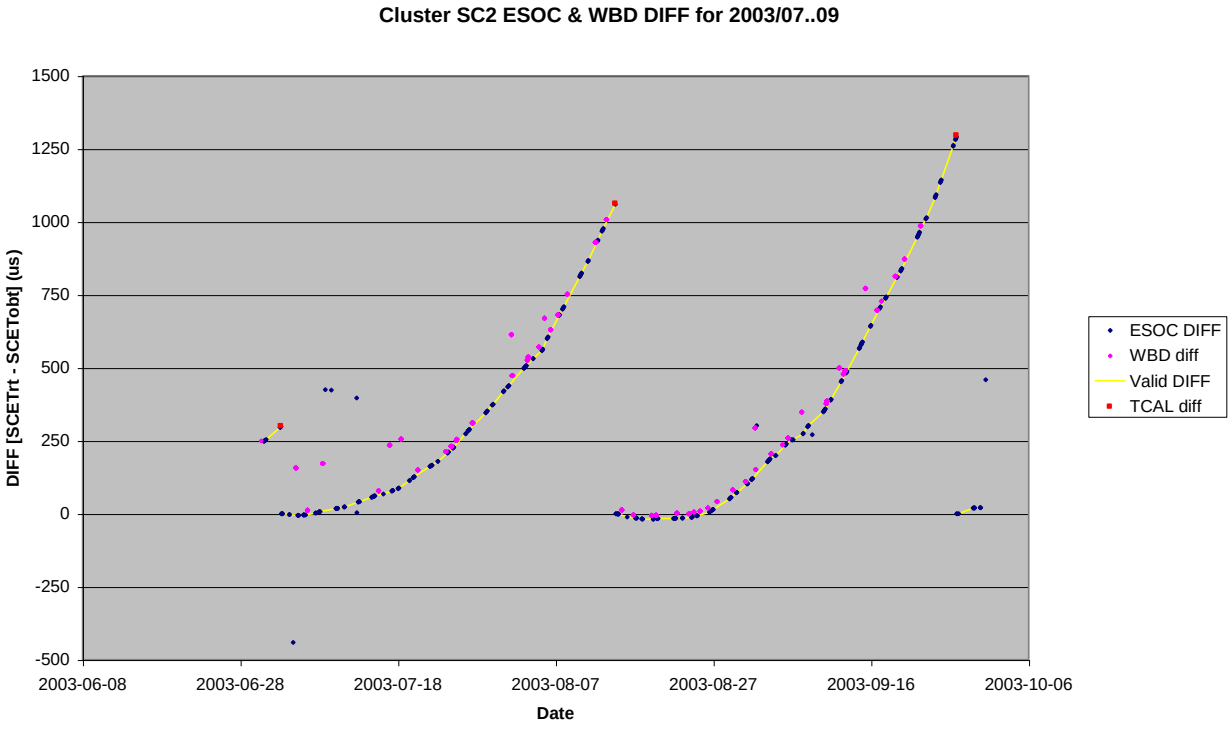

Cluster SC1 ESOC & WBD DIFF for 2003/10..12
500
0
-500
-1000
-1500
-2000
-2500
DIFF [SCETrt - SCETobt] (us)
2003-09-16
2003-10-06
2003-10-26
2003-11-15
2003-12-05
2003-12-25
2004-01-14
2004-02-03
2004-02-23
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff

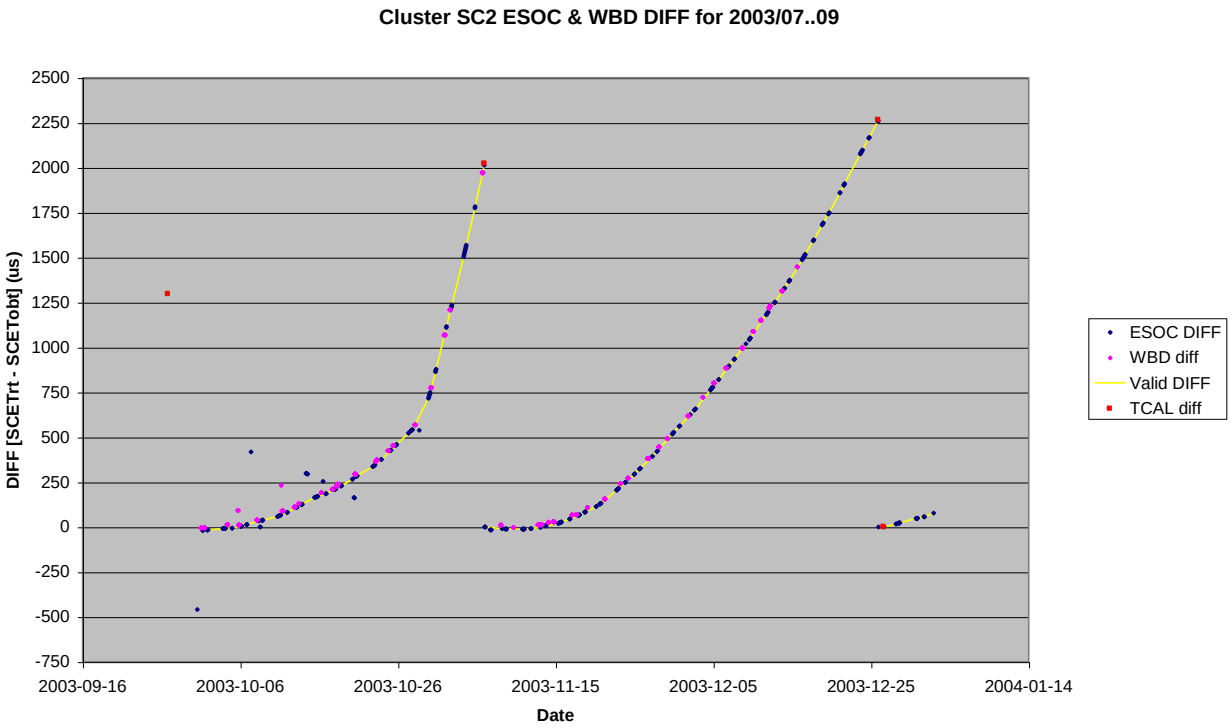
**Cluster SC2 ESOC & WBD DIFF for 2003/01..03**



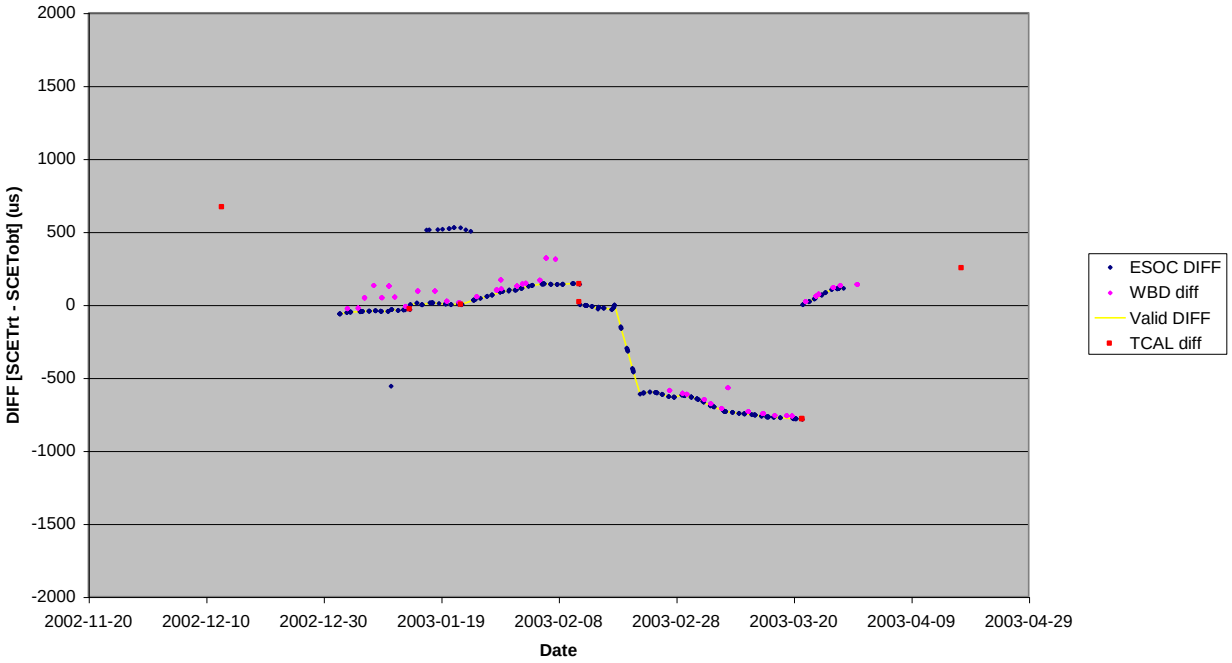

**Cluster SC2 ESOC & WBD DIFF for 2003/04..06**



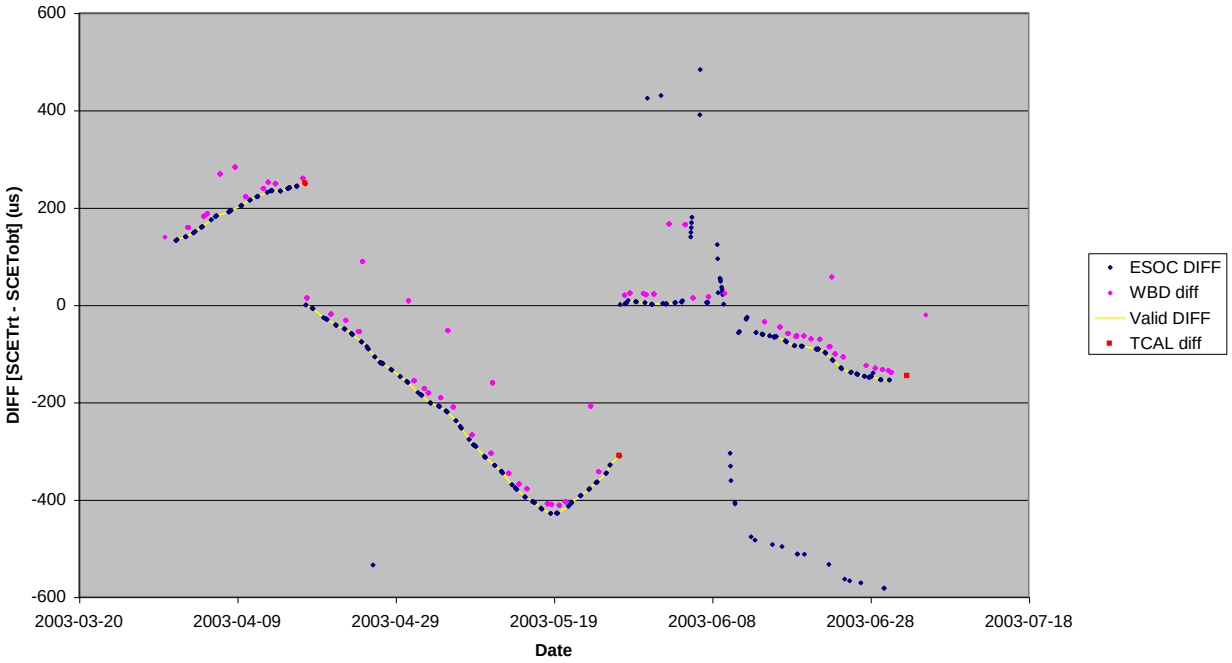

Cluster SC2 ESOC & WBD DIFF for 2003/07..09
DIFF [SCETrt - SCETobt] (us)
1500
1250
1000
750
500
250
0
-250
-500
2003-06-08
2003-06-28
2003-07-18
2003-08-07
2003-08-27
2003-09-16
2003-10-06
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff

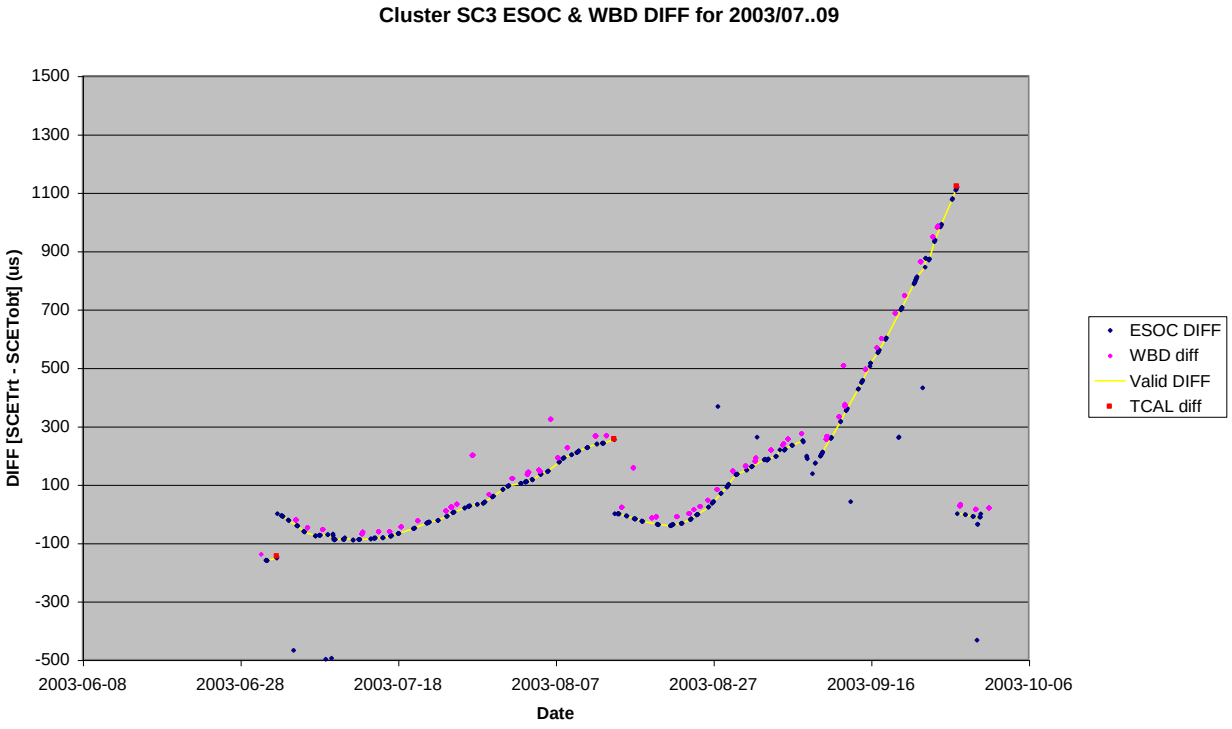

Cluster SC2 ESOC & WBD DIFF for 2003/07..09
DIFF [SCETrt - SCETobt] (us)
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
-250
-500
-750
2003-09-16
2003-10-06
2003-10-26
2003-11-15
2003-12-05
2003-12-25
2004-01-14
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff

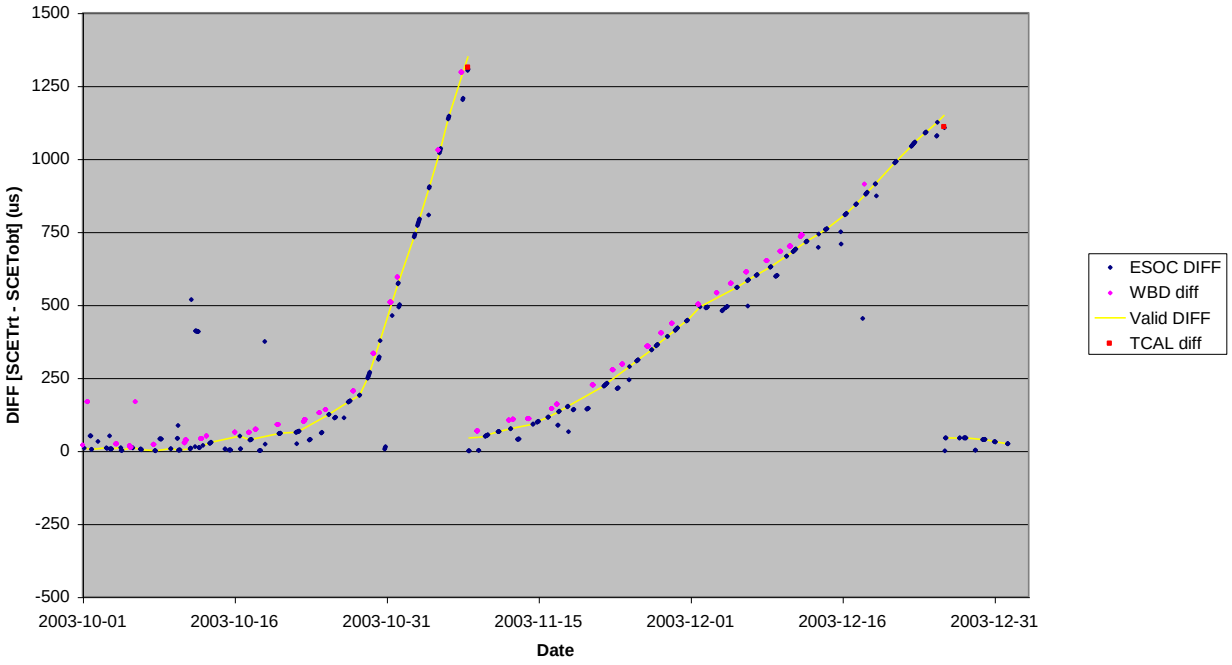
**Cluster SC3 ESOC & WBD DIFF for 2003/01..03**

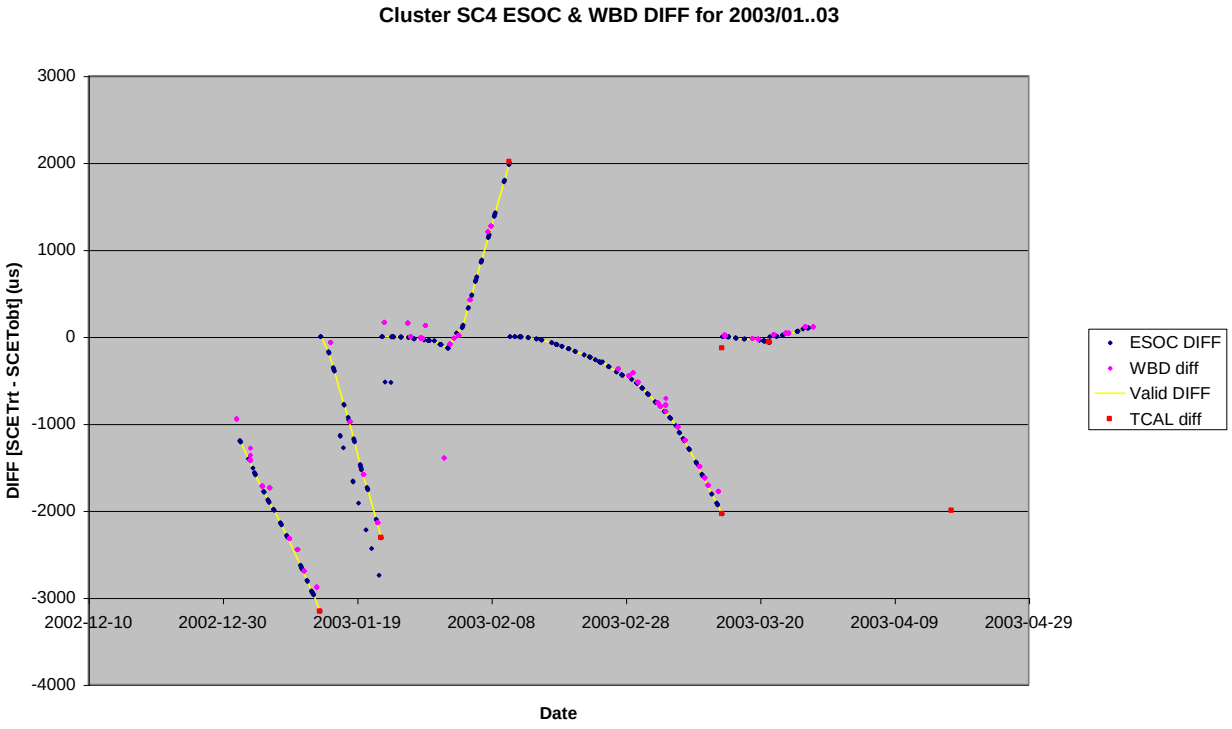


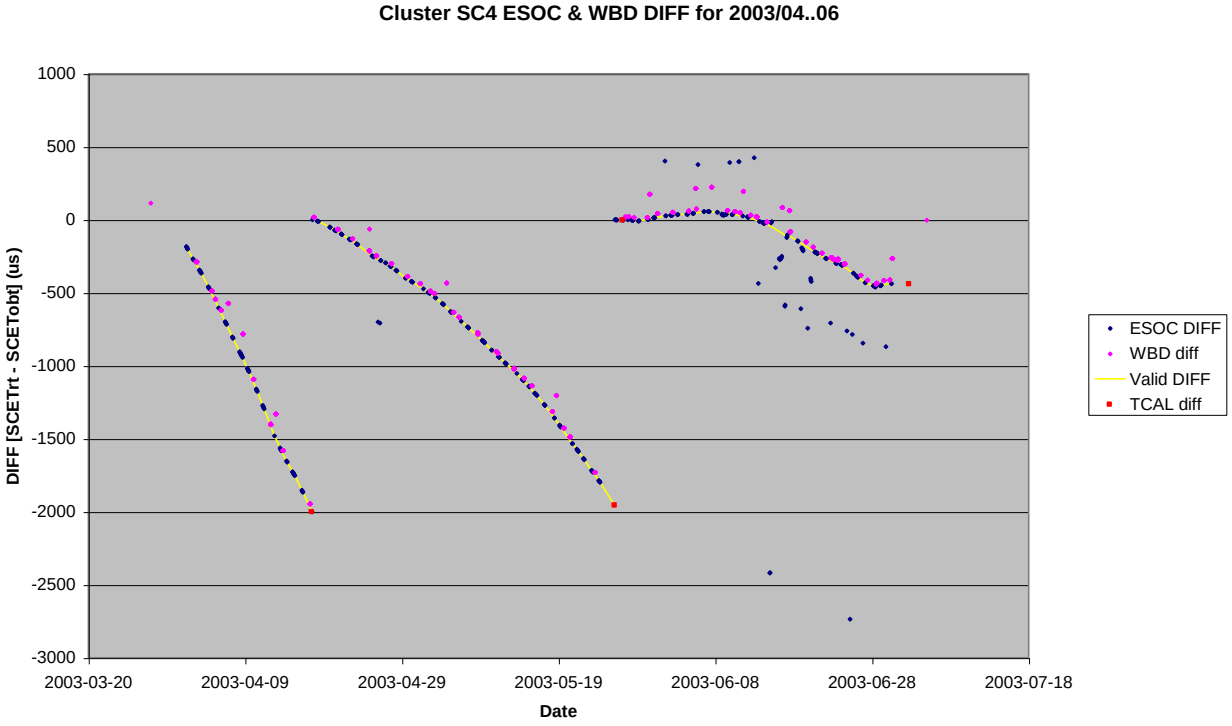

**Cluster SC3 ESOC & WBD DIFF for 2003/04..06**

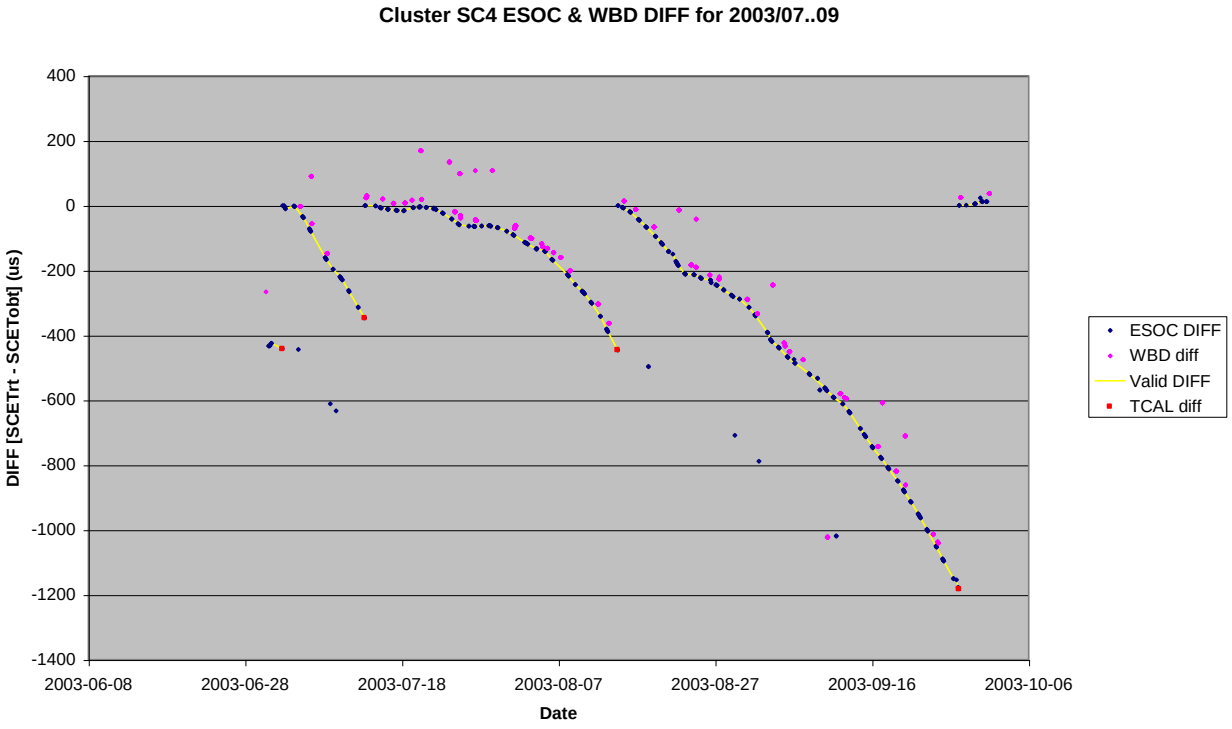


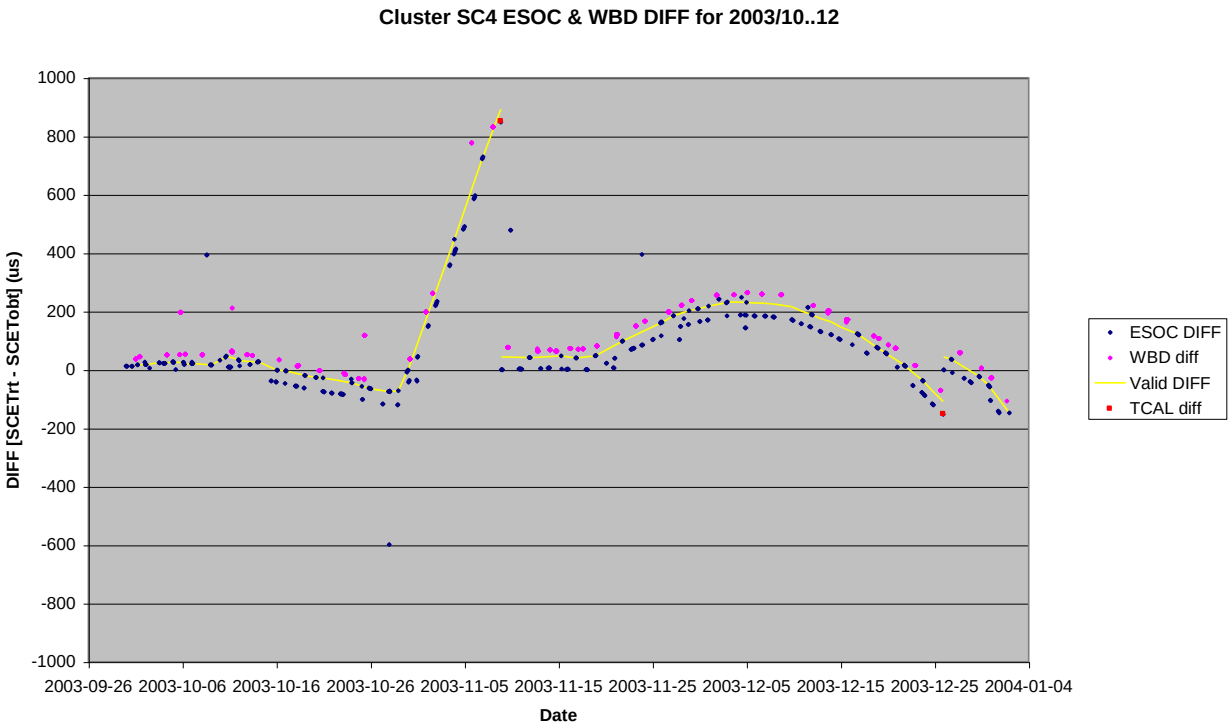

Cluster SC3 ESOC & WBD DIFF for 2003/07..09
DIFF [SCETrt - SCETobt] (us)
1500
1300
1100
900
700
500
300
100
-100
-300
-500
2003-06-08
2003-06-28
2003-07-18
2003-08-07
2003-08-27
2003-09-16
2003-10-06
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff


Cluster SC3 ESOC & WBD DIFF for 2003/10..12
DIFF [SCETrt - SCETobt] (us)
1500
1250
1000
750
500
250
0
-250
-500
2003-10-01
2003-10-16
2003-10-31
2003-11-15
2003-12-01
2003-12-16
2003-12-31
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff


Cluster SC4 ESOC & WBD DIFF for 2003/01..03
DIFF [SCETrt - SCETobt] (us)
3000
2000
1000
0
-1000
-2000
-3000
-4000
2002-12-10
2002-12-30
2003-01-19
2003-02-08
2003-02-28
2003-03-20
2003-04-09
2003-04-29
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff


Cluster SC4 ESOC & WBD DIFF for 2003/04..06
DIFF [SCETrt - SCETobt] (us)
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
2003-03-20
2003-04-09
2003-04-29
2003-05-19
2003-06-08
2003-06-28
2003-07-18
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff


Cluster SC4 ESOC & WBD DIFF for 2003/07..09
DIFF [SCETrt - SCETobt] (us)
400
200
0
-200
-400
-600
-800
-1000
-1200
-1400
2003-06-08
2003-06-28
2003-07-18
2003-08-07
2003-08-27
2003-09-16
2003-10-06
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff


Cluster SC4 ESOC & WBD DIFF for 2003/10..12
DIFF [SCETrt - SCETobt] (us)
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
2003-09-26
2003-10-06
2003-10-16
2003-10-26
2003-11-05
2003-11-15
2003-11-25
2003-12-05
2003-12-15
2003-12-25
2004-01-04
Date
ESOC DIFF
WBD diff
Valid DIFF
TCAL diff

## 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*_whla_files.txt.

This can be done using the following commands:

```
find /data/disk1/cluster/RDM/03* -name '*wh*' > scr.scr
~/CAA/weclog/purgedup scr.scr 03_hk_files.txt
find /data/disk1/cluster/RDM/03* -name '*la*' > scr.scr
~/CAA/weclog/purgedup scr.scr 03_la_files.txt
cat 03_hk_files.txt 03_la_files.txt | sort | \
    grep cluster1 > 03_1_whla_files.txt
cat 03_hk_files.txt 03_la_files.txt | sort | \
    grep cluster2 > 03_2_whla_files.txt
cat 03_hk_files.txt 03_la_files.txt | sort | \
    grep cluster3 > 03_3_whla_files.txt
cat 03_hk_files.txt 03_la_files.txt | sort | \
    grep cluster4 > 03_4_whla_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 030101_1_diff.prn -f 03_1_hkla_files.txt \
          -s 030101 -e 030331 > 030101_1_tcor.txt
maketcor3 -d 030401_1_diff.prn -f 03_1_hkla_files.txt \
          -s 030401 -e 030630 > 030401_1_tcor.txt
maketcor3 -d 030701_1_diff.prn -f 03_1_hkla_files.txt \
          -s 030701 -e 030930 > 030701_1_tcor.txt
maketcor3 -d 031001_1_diff.prn -f 03_1_hkla_files.txt \
          -s 031001 -e 031231 > 031001_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.

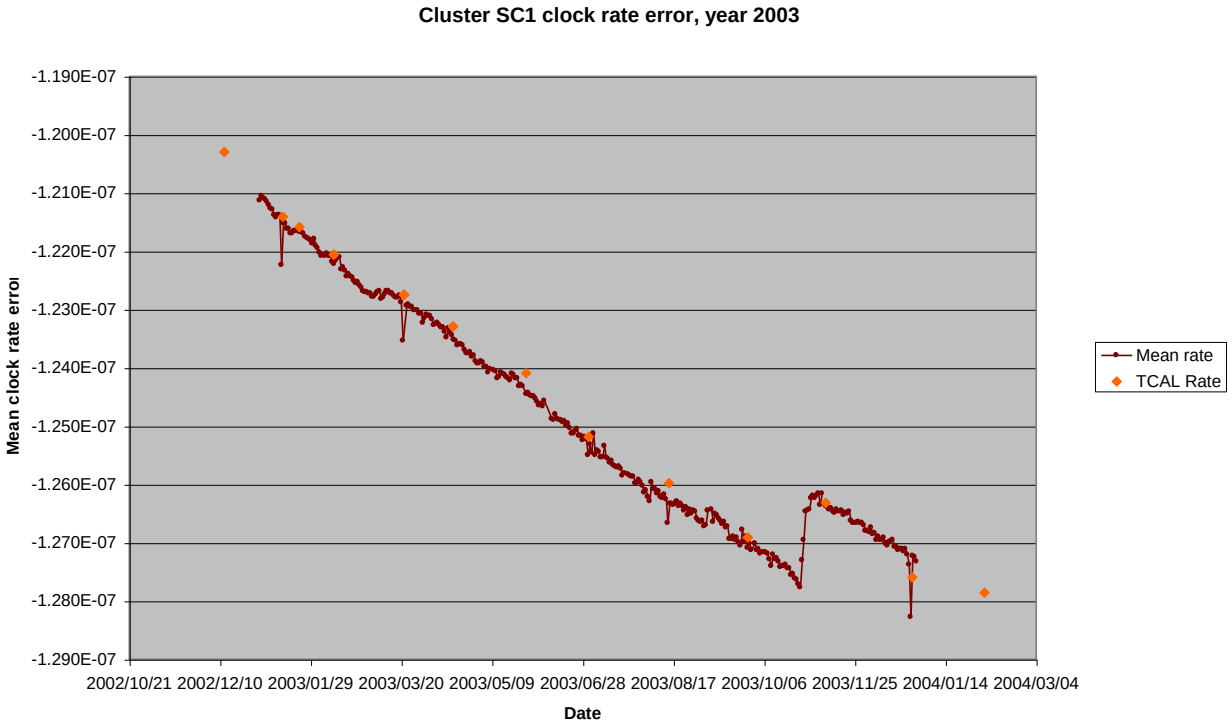
A typical 'veritcor' command is:

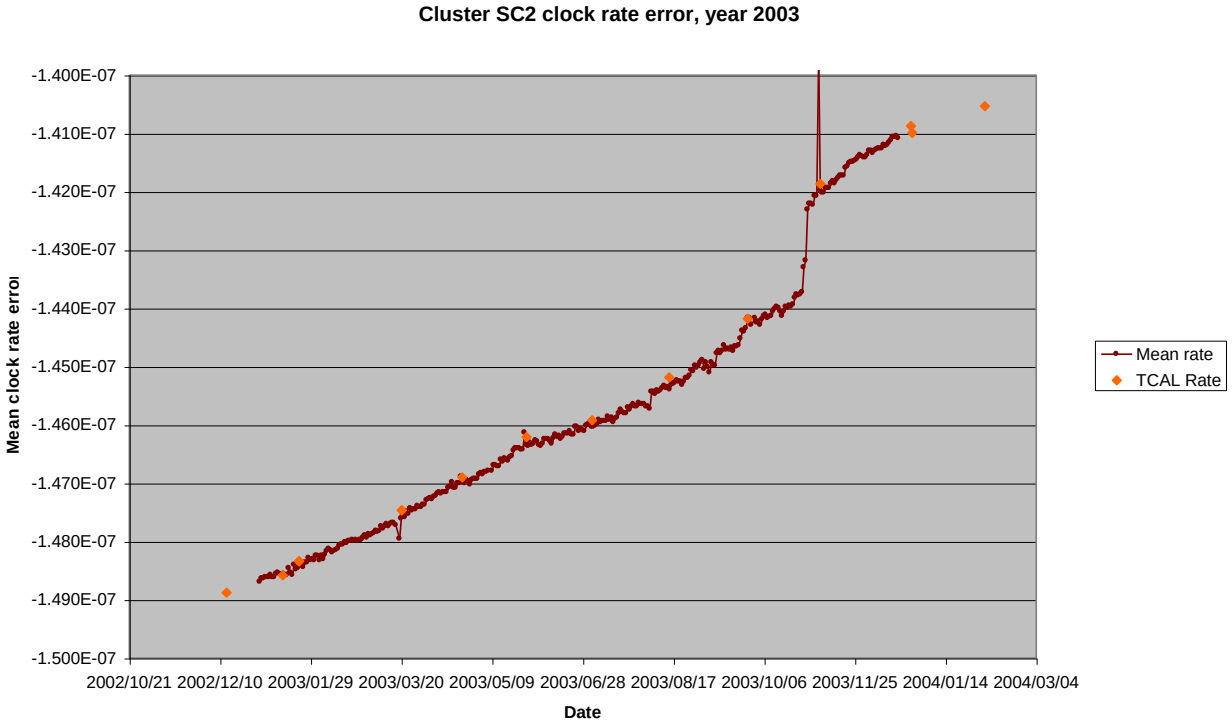
```
veritcor -f 03_1_hkla_files.txt -T . -v 4 > 03_1_veritcor.txt
```

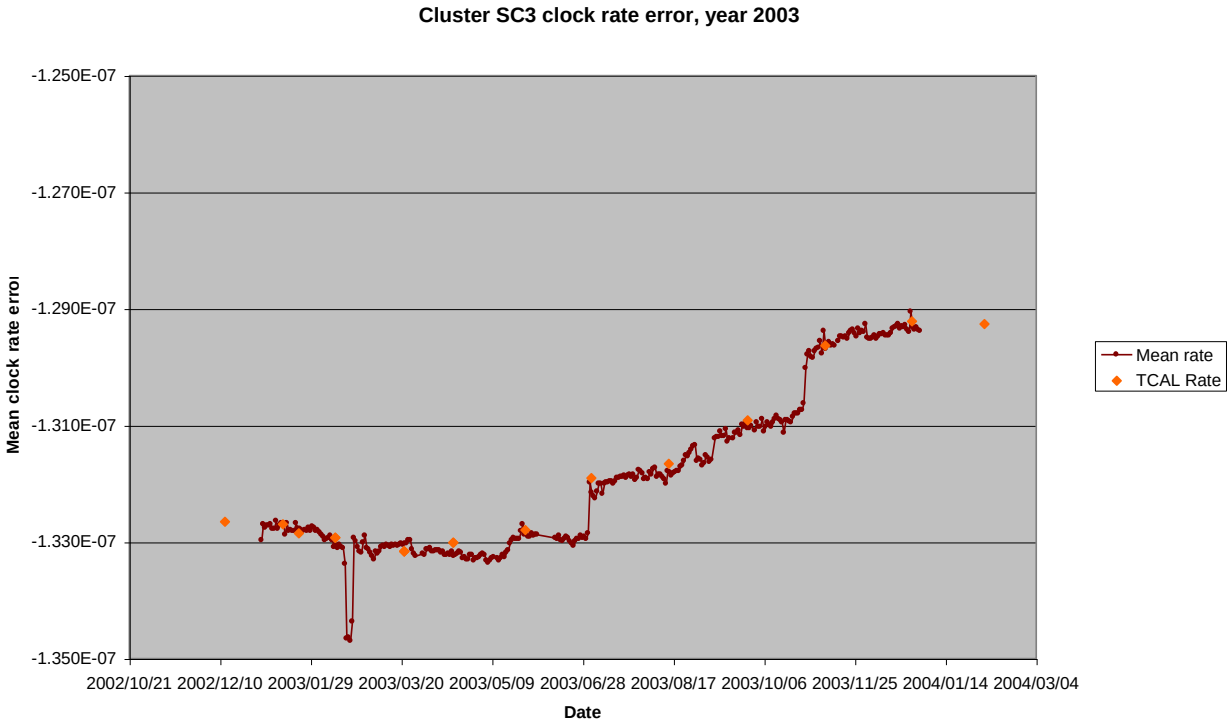
It uses the same HK+TCAL file list file as 'maketcor3', although only the HK files are used. 'veritcor' includes the same code module used by TED to apply the TCOR corrections, and requires CEF TCOR

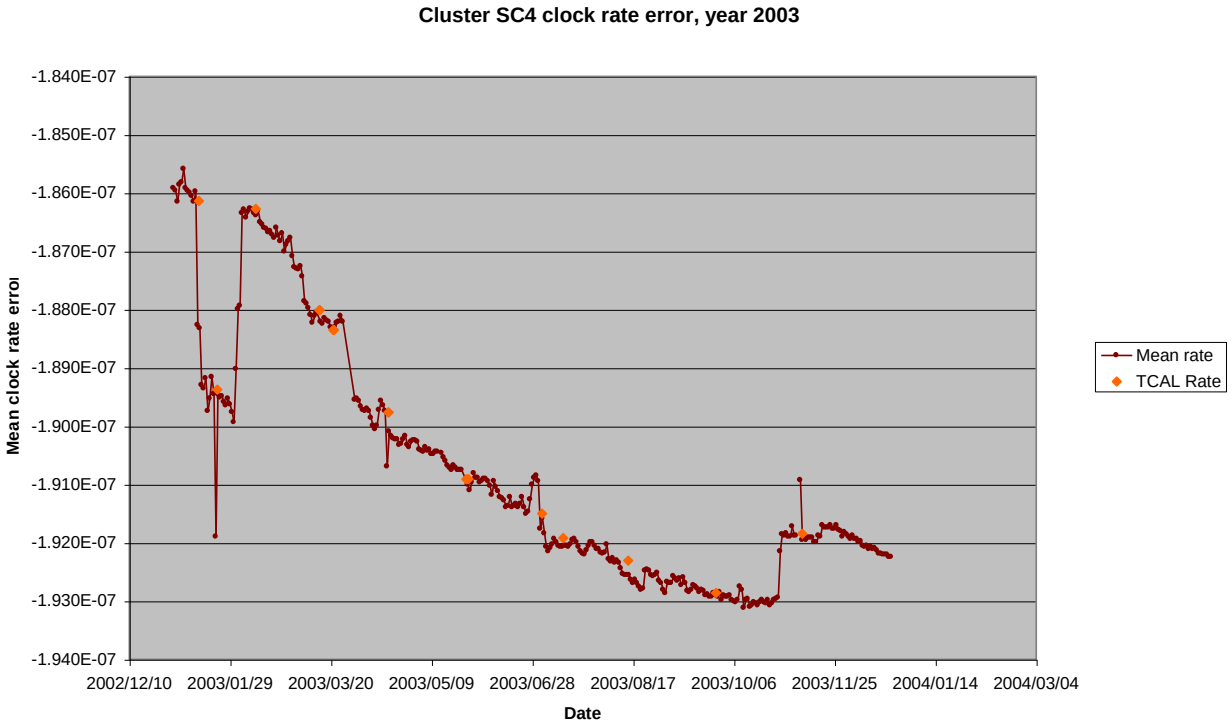
files to be installed with the same index files. The '-T .' option specifies that the TCOR files (and the index files) are located in the default directory.

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 SC3 clock rate error, year 2003
-1.250E-07
-1.270E-07
-1.290E-07
-1.310E-07
-1.330E-07
-1.350E-07
Mean clock rate erroı
2002/10/21 2002/12/10 2003/01/29 2003/03/20 2003/05/09 2003/06/28 2003/08/17 2003/10/06 2003/11/25 2004/01/14 2004/03/04
Date
Mean rate
TCAL Rate


Cluster SC4 clock rate error, year 2003
-1.840E-07
-1.850E-07
-1.860E-07
-1.870E-07
-1.880E-07
-1.890E-07
-1.900E-07
-1.910E-07
-1.920E-07
-1.930E-07
-1.940E-07
Mean clock rate erroı
2002/12/10 2003/01/29 2003/03/20 2003/05/09 2003/06/28 2003/08/17 2003/10/06 2003/11/25 2004/01/14 2004/03/04
Date
Mean rate
TCAL Rate

## 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 for January to September are version 1, whereas those for October to December are version 2 (to avoid conflict with previously submitted 2004 files, which actually start in December 2003).

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:          030101_1_tcor.txt, s/c: 1, records: 320
Generated CEF name: C1_CP_DWP_TCOR__20030101_V01
Time range:         2003-01-01T19:42:52Z/2003-03-31T18:22:16Z
Finished, CEF size: 37302 bytes
Total duration:     7684764 seconds
Corrected:          7159599 seconds (93.2 %)

TCOR2CEF, version 1.6

TCOR file:          030401_1_tcor.txt, s/c: 1, records: 373
Generated CEF name: C1_CP_DWP_TCOR__20030401_V01
Time range:         2003-04-01T15:45:26Z/2003-06-30T07:52:32Z
Finished, CEF size: 43844 bytes
Total duration:     7747626 seconds
Corrected:          7032192 seconds (90.8 %)

TCOR2CEF, version 1.6

TCOR file:          030701_1_tcor.txt, s/c: 1, records: 423
Generated CEF name: C1_CP_DWP_TCOR__20030701_V01
Time range:         2003-07-01T00:00:00Z/2003-09-29T22:31:28Z
Finished, CEF size: 49387 bytes
Total duration:     7857088 seconds
Corrected:          7136431 seconds (90.8 %)

TCOR2CEF, version 1.6

TCOR file:          031001_1_tcor.txt, s/c: 1, records: 416
Generated CEF name: C1_CP_DWP_TCOR__20031001_V02
Time range:         2003-10-01T00:00:00Z/2003-12-31T16:18:35Z
Finished, CEF size: 48201 bytes
Total duration:     7921115 seconds
Corrected:          7738772 seconds (97.7 %)

TCOR2CEF, version 1.6

TCOR file:          030101_2_tcor.txt, s/c: 2, records: 389
```

```
Generated CEF name: C2_CP_DWP_TCOR__20030101_V01
Time range:         2003-01-01T16:00:17Z/2003-03-31T21:02:45Z
Finished, CEF size: 44037 bytes
Total duration:     7707748 seconds
Corrected:          7231581 seconds (93.8 %)

TCOR2CEF, version 1.6

TCOR file:          030401_2_tcor.txt, s/c: 2, records: 452
Generated CEF name: C2_CP_DWP_TCOR__20030401_V01
Time range:         2003-04-01T09:45:07Z/2003-06-30T10:32:15Z
Finished, CEF size: 50879 bytes
Total duration:     7778828 seconds
Corrected:          7549987 seconds (97.1 %)

TCOR2CEF, version 1.6

TCOR file:          030701_2_tcor.txt, s/c: 2, records: 449
Generated CEF name: C2_CP_DWP_TCOR__20030701_V01
Time range:         2003-07-01T04:11:07Z/2003-09-29T19:03:08Z
Finished, CEF size: 50682 bytes
Total duration:     7829521 seconds
Corrected:          7548444 seconds (96.4 %)

TCOR2CEF, version 1.6

TCOR file:          031001_2_tcor.txt, s/c: 2, records: 426
Generated CEF name: C2_CP_DWP_TCOR__20031001_V02
Time range:         2003-10-01T06:58:23Z/2003-12-31T19:40:22Z
Finished, CEF size: 48251 bytes
Total duration:     7908119 seconds
Corrected:          7652101 seconds (96.8 %)

TCOR2CEF, version 1.6

TCOR file:          030101_3_tcor.txt, s/c: 3, records: 367
Generated CEF name: C3_CP_DWP_TCOR__20030102_V01
Time range:         2003-01-02T22:03:07Z/2003-03-28T11:14:18Z
Finished, CEF size: 41979 bytes
Total duration:     7305071 seconds
Corrected:          6820077 seconds (93.4 %)

TCOR2CEF, version 1.6

TCOR file:          030401_3_tcor.txt, s/c: 3, records: 385
Generated CEF name: C3_CP_DWP_TCOR__20030401_V01
Time range:         2003-04-01T10:50:58Z/2003-06-30T08:26:21Z
Finished, CEF size: 44272 bytes
Total duration:     7767323 seconds
Corrected:          6508264 seconds (83.8 %)

TCOR2CEF, version 1.6

TCOR file:          030701_3_tcor.txt, s/c: 3, records: 474
Generated CEF name: C3_CP_DWP_TCOR__20030701_V01
Time range:         2003-07-01T06:53:34Z/2003-09-29T20:47:58Z
Finished, CEF size: 53720 bytes
Total duration:     7826064 seconds
Corrected:          7217245 seconds (92.2 %)

TCOR2CEF, version 1.6
```

```
TCOR file:          031001_3_tcor.txt, s/c: 3, records: 442
Generated CEF name: C3_CP_DWP_TCOR__20031001_V02
Time range:         2003-10-01T04:45:22Z/2003-12-31T16:57:28Z
Finished, CEF size: 50051 bytes
Total duration:     7906326 seconds
Corrected:          7737896 seconds (97.9 %)

TCOR2CEF, version 1.6

TCOR file:          030101_4_tcor.txt, s/c: 4, records: 359
Generated CEF name: C4_CP_DWP_TCOR__20030101_V01
Time range:         2003-01-01T16:45:38Z/2003-03-26T23:53:40Z
Finished, CEF size: 41438 bytes
Total duration:     7283282 seconds
Corrected:          6697230 seconds (92.0 %)

TCOR2CEF, version 1.6

TCOR file:          030401_4_tcor.txt, s/c: 4, records: 483
Generated CEF name: C4_CP_DWP_TCOR__20030401_V01
Time range:         2003-04-01T16:36:26Z/2003-06-30T10:35:31Z
Finished, CEF size: 55265 bytes
Total duration:     7754345 seconds
Corrected:          7427973 seconds (95.8 %)

TCOR2CEF, version 1.6

TCOR file:          030701_4_tcor.txt, s/c: 4, records: 490
Generated CEF name: C4_CP_DWP_TCOR__20030701_V01
Time range:         2003-07-01T04:58:00Z/2003-09-30T13:24:15Z
Finished, CEF size: 56029 bytes
Total duration:     7892775 seconds
Corrected:          7671468 seconds (97.2 %)

TCOR2CEF, version 1.6

TCOR file:          031001_4_tcor.txt, s/c: 4, records: 493
Generated CEF name: C4_CP_DWP_TCOR__20031001_V02
Time range:         2003-10-01T00:00:00Z/2003-12-31T21:17:23Z
Finished, CEF size: 55280 bytes
Total duration:     7939043 seconds
Corrected:          7716314 seconds (97.2 %)
```

## 7 Caveats

The following general caveats apply to all year 2003 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 or 2 files, any data that fails validation is simply deleted from the files. For 2003, TCOR coverage is typically around 95%.

The DIFF measurements received from ESOC for 2003 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.