

Preparation and validation of WEC time corrections for year 2006

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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 ± 2 ms.

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 2006. In this case, all files were compiled in one batch for the whole year.

2 Data and references

Source data:

- ESOC DIFF measurements for 2006.
- WBD data DVDs for 2006.
- Cluster RDM for 2006.

Documents:

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

Software:

- wbddiff, version 1.0, 2004-06-11
- maketcor3, version 3.8, 2008-03-20
- 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 2006 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.

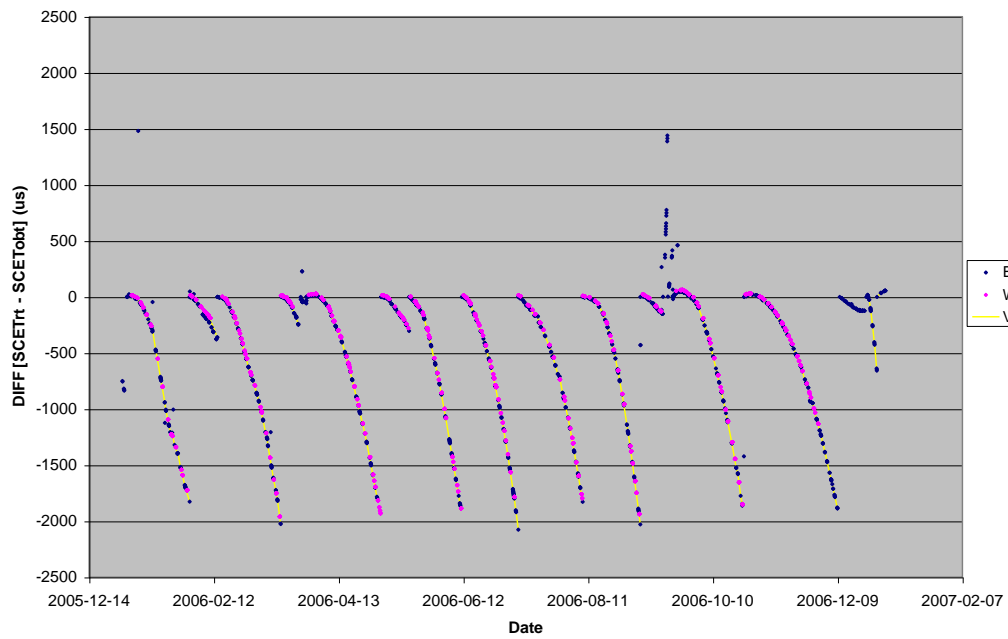
To avoid discontinuities and obtain agreement with WBD data, it was necessary to apply corrections for an apparent offset of the reference clock at the ESA ground station.

SC1	2006-02-06 15:00 to 2006-02-13 05:00	+40 μ s
SC2	2006-02-06 10:00 to 2006-02-13 09:00	+40 μ s
SC3	2006-01-01 15:00 to 2006-02-04 19:00	+40 μ s
SC4	2006-01-01 19:00 to 2006-02-04 14:00	+40 μ s

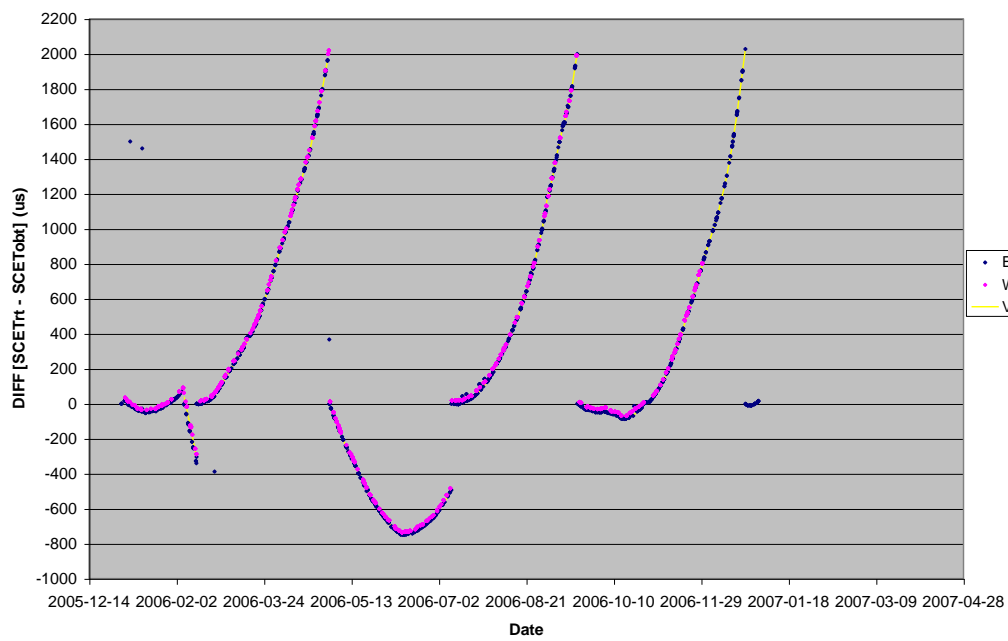
Once the valid ESOC data is selected, its accuracy is checked by comparing each WBD measurement with a linear interpolation between the nearest validated ESOC measurements before and after. Unlike previous years, for 2006 this comparison identifies no anomalous WBD measurements. The average and standard deviation of all measurements were calculated. For SC1 and SC4 the standard deviation is somewhat higher than in previous years - this is probably due to the relatively high rate of change of DIFF and frequent time correlations at times during 2006.

SC	Average wbd-esoc (micro-sec)	St Dev wbd-esoc (micro-sec)
1	14.7	6.0
2	14.5	4.3
3	12.4	4.5
4	14.6	7.0

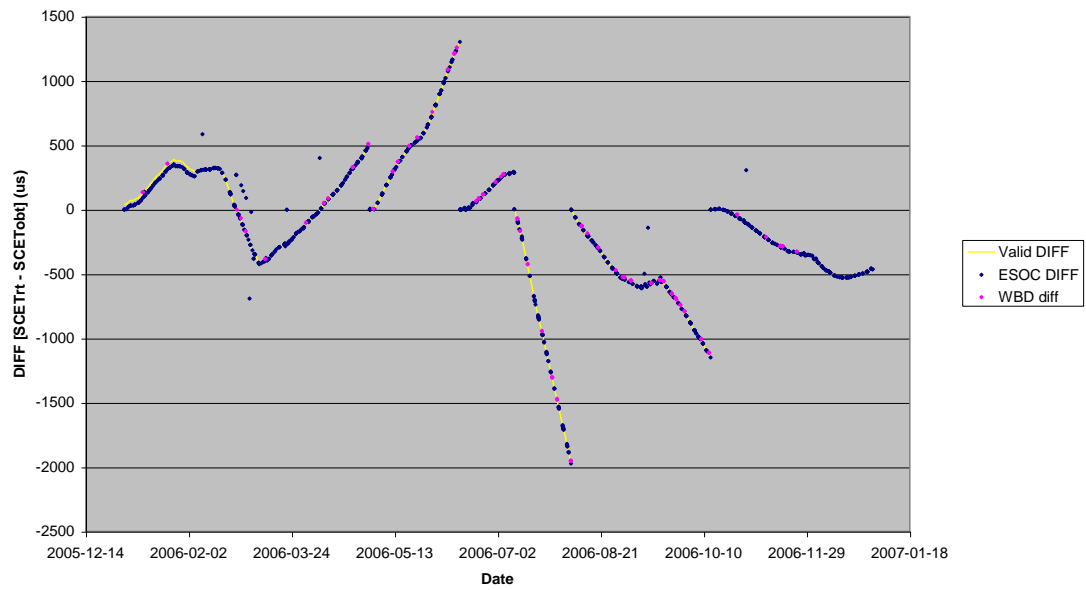
Cluster SC1 ESOC & WBD DIFF for 2006



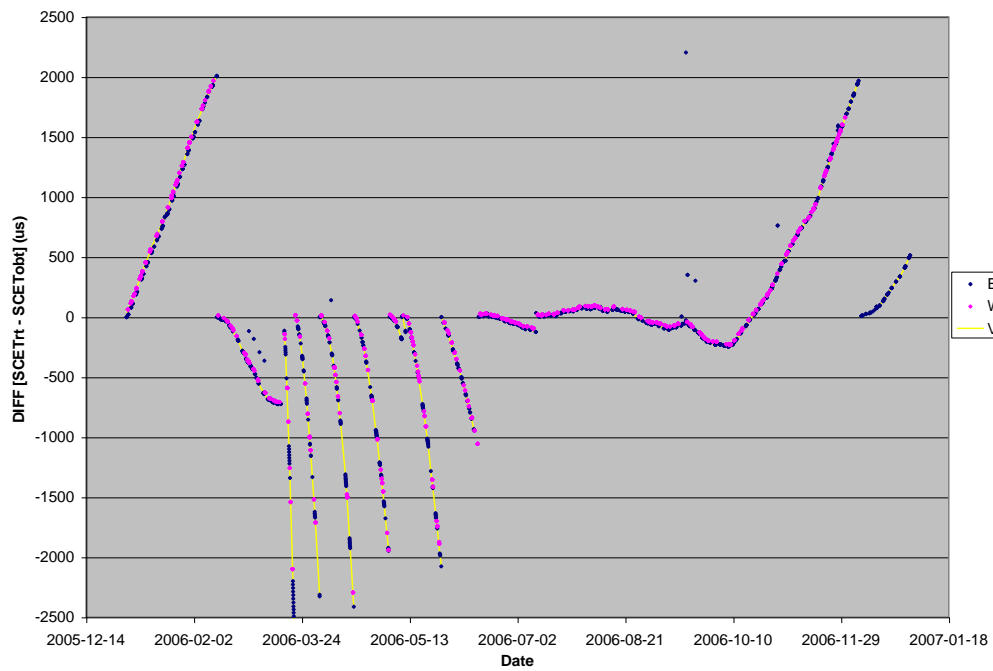
Cluster SC2 ESOC & WBD DIFF for 2006



Cluster SC3 ESOC & WBD DIFF for 2006



Cluster SC4 ESOC & WBD DIFF for 2006



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, and sorts. The individual lists must be in chronological order. They are written to files named like 06_s_hkla_files.txt.

The following commands were used:

```
find /data/disk2/cluster/RDM/06* -name '*wh*' >> scr.scr
find /data/disk2/cluster/RDM/06* -name '*la*' >> scr.scr
~/CAA/weclog/purgedup scr.scr 06_hkla_files.txt
grep cluster1 06_hkla_files.txt | sort > 06_1_hkla_files.txt
grep cluster2 06_hkla_files.txt | sort > 06_2_hkla_files.txt
grep cluster3 06_hkla_files.txt | sort > 06_3_hkla_files.txt
grep cluster4 06_hkla_files.txt | sort > 06_4_hkla_files.txt
```

Then maketcor3 is used to generate the ASCII TCOR files. For SC1 and SC4 an updated version of maketcor (3.8) was used. This includes use of OBTM values from WBD data to help track the real time OBTM, and reduces the amount of data lost due to frequent time correlations.

```
../maketcor3.8 -d 06_1_diff.prn -f 06_1_hkla_files.txt \
-s 060101 -e 061231 -w ../wbd/wbd_all_c1_ncd.txt > 06_1_tcor_w.txt
../maketcor3 -d 06_2_diff.prn -f 06_2_hkla_files.txt \
-s 060101 -e 061231 > 06_2_tcor.txt
../maketcor3 -d 06_3_diff.prn -f 06_3_hkla_files.txt \
-s 060101 -e 061231 > 06_3_tcor.txt
../maketcor3.8 -d 06_4_diff.prn -f 06_4_hkla_files.txt \
-s 060101 -e 061231 -w ../wbd/wbd_all_c4_ncd.txt > 06_4_tcor_w.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.

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.

```
../tcor2cef -t 06_1_tcor_w.txt
TCOR2CEF, version 1.6
TCOR file:          06_1_tcor_w.txt, s/c: 1, records: 1819
Generated CEF name: C1_CP_DWP_TCOR_20060101_V00
Time range:         2006-01-01T05:04:25Z/2006-12-31T23:00:25Z
Finished, CEF size: 207372 bytes
Total duration:     31514160 seconds
Corrected:          25698132 seconds (81.5 %)

hoodie% ../tcor2cef -t 06_2_tcor.txt
TCOR2CEF, version 1.6
TCOR file:          06_2_tcor.txt, s/c: 2, records: 1990
Generated CEF name: C2_CP_DWP_TCOR_20060103_V00
Time range:         2006-01-03T07:00:30Z/2006-12-31T17:00:23Z
Finished, CEF size: 222623 bytes
Total duration:     31312793 seconds
Corrected:          30060914 seconds (96.0 %)

hoodie% ../tcor2cef -t 06_3_tcor.txt
TCOR2CEF, version 1.6
TCOR file:          06_3_tcor.txt, s/c: 3, records: 1586
Generated CEF name: C3_CP_DWP_TCOR_20060101_V00
Time range:         2006-01-01T15:00:28Z/2006-12-30T23:00:21Z
Finished, CEF size: 177151 bytes
Total duration:     31391993 seconds
Corrected:          29344940 seconds (93.5 %)

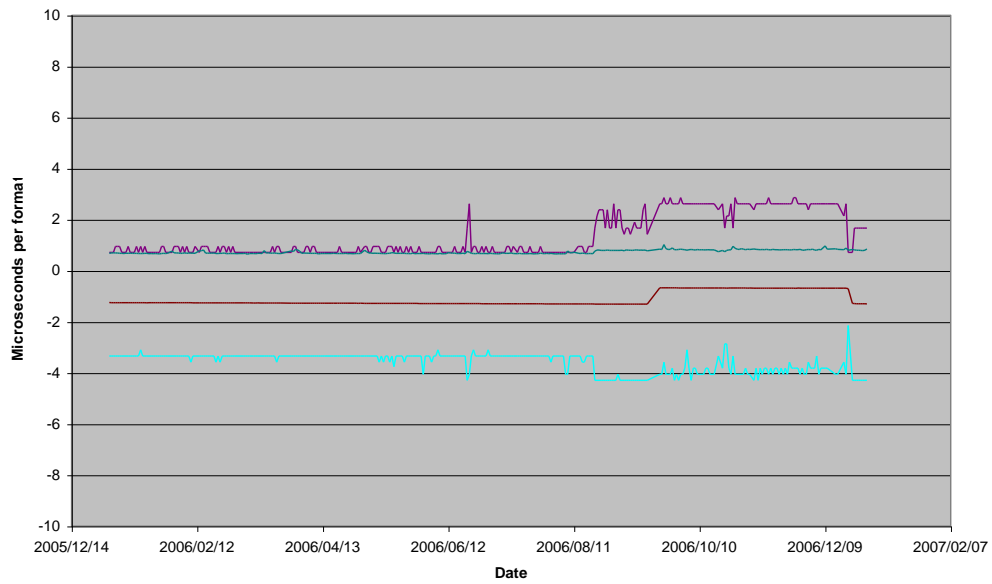
../tcor2cef -t 06_4_tcor_w.txt
TCOR2CEF, version 1.6
TCOR file:          06_4_tcor_w.txt, s/c: 4, records: 2030
Generated CEF name: C4_CP_DWP_TCOR_20060101_V00
Time range:         2006-01-01T19:00:30Z/2006-12-31T02:00:21Z
Finished, CEF size: 228142 bytes
Total duration:     31388391 seconds
Corrected:          29041633 seconds (92.5 %)
```

```

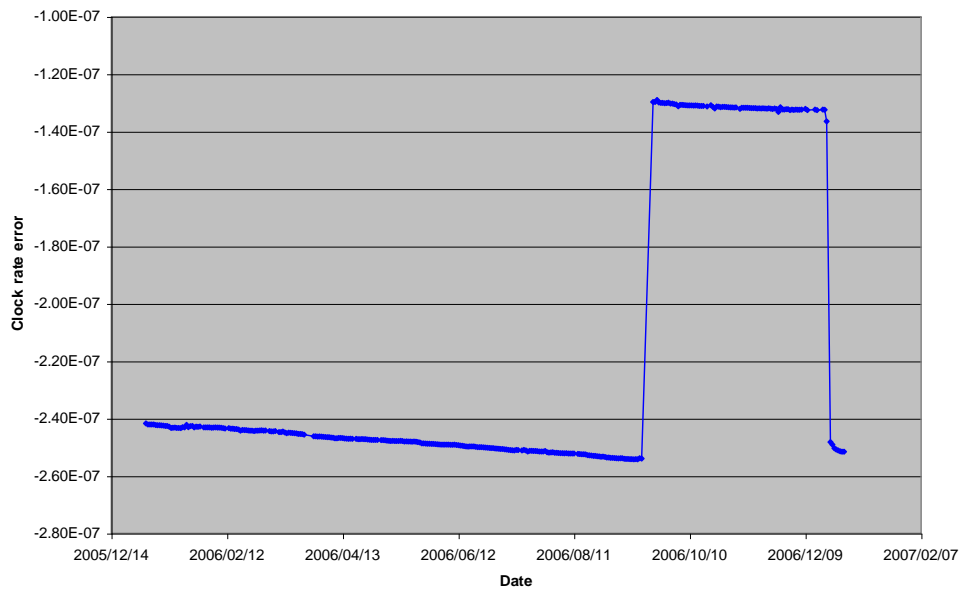
../veritcor -f 06_1_hkla_files.txt -T . -v 4 > 06_1_veritcor.txt
../veritcor -f 06_2_hkla_files.txt -T . -v 4 > 06_2_veritcor.txt
../veritcor -f 06_3_hkla_files.txt -T . -v 4 > 06_3_veritcor.txt
../veritcor -f 06_4_hkla_files.txt -T . -v 4 > 06_4_veritcor.txt

```

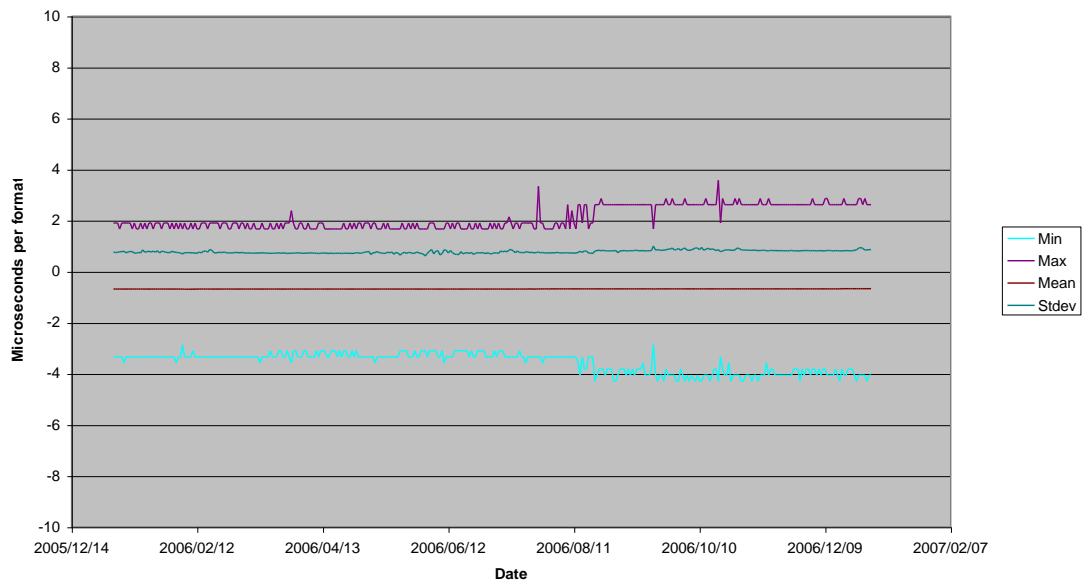
Cluster SC1 timing analysis, 2006



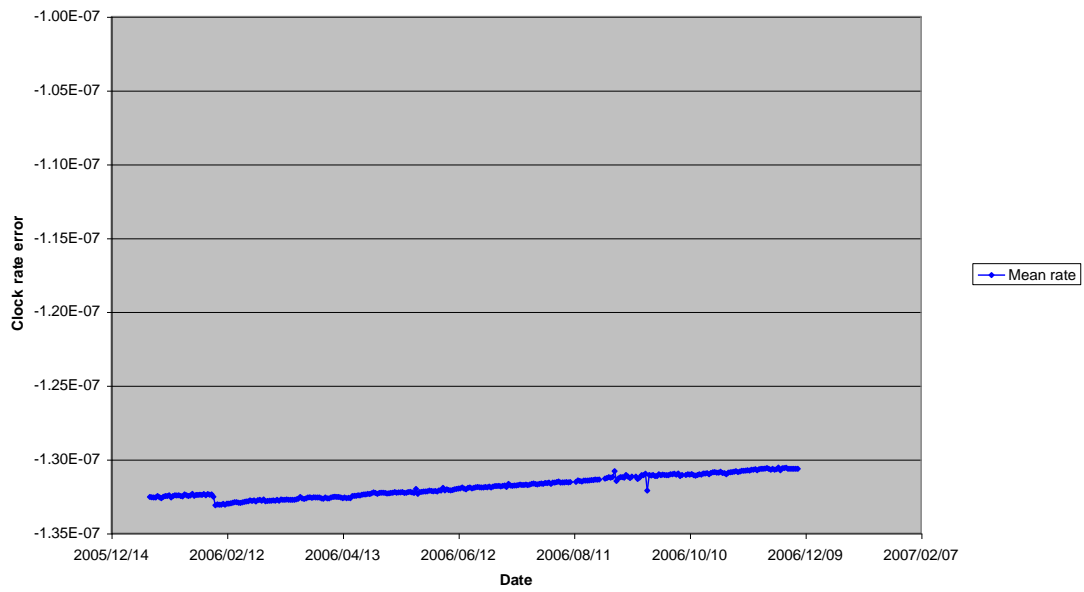
Cluster SC1 clock rate error, 2006



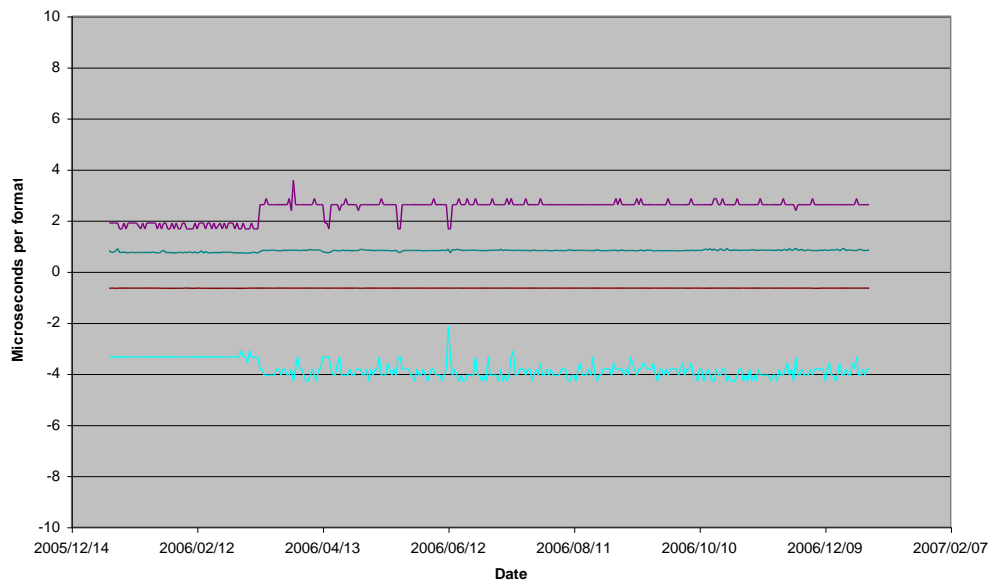
Cluster SC2 timing analysis, 2006



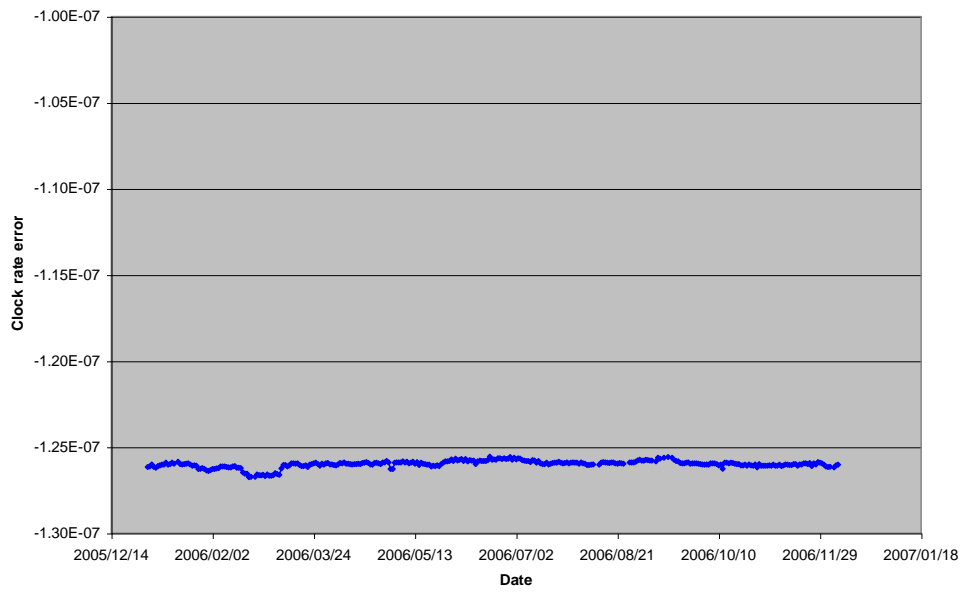
Cluster SC2 clock rate error, 2006



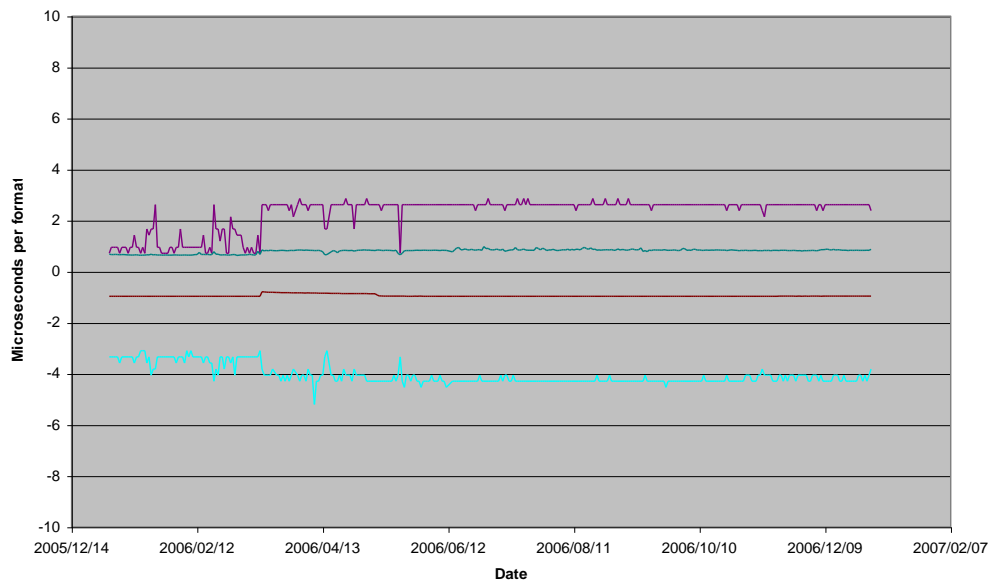
Cluster SC3 timing analysis, 2006



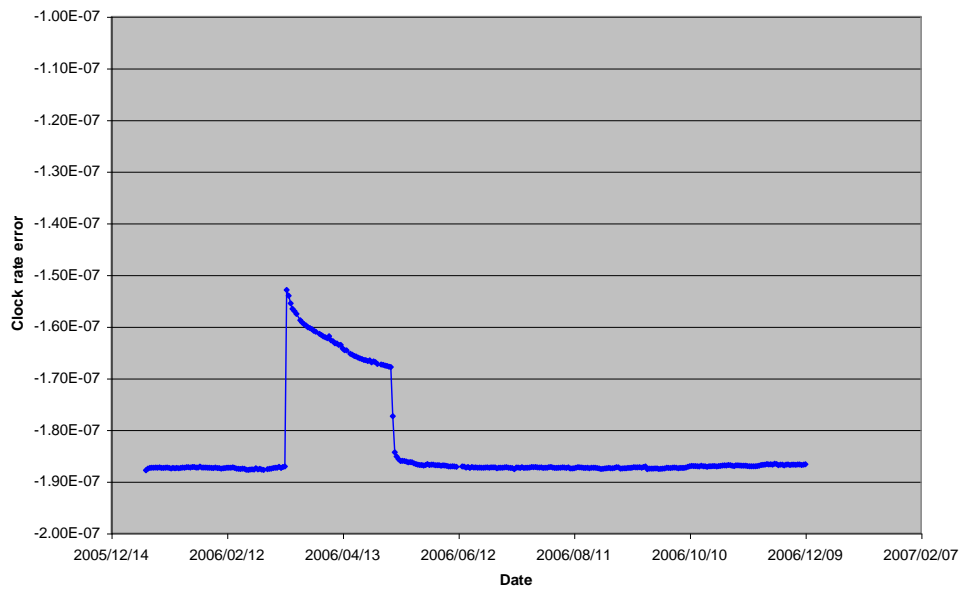
Cluster SC3 clock rate error, 2006



Cluster SC4 timing analysis, 2006



Cluster SC4 clock rate error, 2006



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.

```
../tcor2cef -t 06_1_tcor_w.txt -v 1
TCOR2CEF, version 1.6
TCOR file:          06_1_tcor_w.txt, s/c: 1, records: 1819
Generated CEF name: C1_CP_DWP_TCOR_20060101_V01
Time range:         2006-01-01T05:04:25Z/2006-12-31T23:00:25Z
Finished, CEF size: 207372 bytes
Total duration:     31514160 seconds
Corrected:          25698132 seconds (81.5 %)

../tcor2cef -t 06_2_tcor.txt -v 1
TCOR file:          06_2_tcor.txt, s/c: 2, records: 1986
Generated CEF name: C2_CP_DWP_TCOR_20060103_V01
Time range:         2006-01-03T07:00:30Z/2006-12-31T17:00:23Z
Finished, CEF size: 222189 bytes
Total duration:     31312793 seconds
Corrected:          30060254 seconds (96.0 %)

../tcor2cef -t 06_3_tcor.txt -v 1
TCOR2CEF, version 1.6
TCOR file:          06_3_tcor.txt, s/c: 3, records: 1422
Generated CEF name: C3_CP_DWP_TCOR_20060101_V01
Time range:         2006-01-01T15:00:28Z/2006-12-30T23:00:21Z
Finished, CEF size: 160065 bytes
Total duration:     31391993 seconds
Corrected:          29342705 seconds (93.5 %)

../tcor2cef -t 06_4_tcor_w.txt -v 1
TCOR2CEF, version 1.6
TCOR file:          06_4_tcor_w.txt, s/c: 4, records: 2030
Generated CEF name: C4_CP_DWP_TCOR_20060101_V01
Time range:         2006-01-01T19:00:30Z/2006-12-31T02:00:21Z
Finished, CEF size: 228142 bytes
Total duration:     31388391 seconds
Corrected:          29041633 seconds (92.5 %)

diff C1_CP_DWP_TCOR_20060101_V01.cef \
    C1_CP_DWP_TCOR_20060101_V00.cef
diff C2_CP_DWP_TCOR_20060103_V01.cef \
    C2_CP_DWP_TCOR_20060103_V00.cef
diff C3_CP_DWP_TCOR_20060101_V01.cef \
    C3_CP_DWP_TCOR_20060101_V00.cef
diff C4_CP_DWP_TCOR_20060101_V01.cef \
    C4_CP_DWP_TCOR_20060101_V00.cef
```

7 Caveats

The following general caveats apply to year 2006 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 2006, TCOR coverage is typically around 81 to 96%. 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.